# LEGISLATIVE ASSEMBLY OF THE NORTHWEST TERRITORIES

## 8TH ASSEMBLY, 67TH SESSION

## TABLED DOCUMENT NO. 23-67

## TABLED ON Feb.12, 1979

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Tabled Document No. 23-67
Tabled Feb 12, 1979

# NORTHEAST MACKENZIE DISTRICT

# TRANSPORTATION STUDY

# PHASE I

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OCTOBER, 1978

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# NORTHEAST MACKENZIE DISTRICT TRANSPORTATION STUDY

## INTRODUCTION

The region lying to the east of Great Bear Lake in the Northwest Territories is considered to be a potentially mineral rich area, and, in fact, a number of rich ore bodies have been discovered. One of the major problems facing the resource industry in the Northwest Territories in general, and in the exploitation of these known ore bodies, is that of transportation. The Minister of Indian Affairs and Northern Development in his speech of January 20, 1978, to the Northwest Territories Council Opening Session announced that the Department would be undertaking a study of alternative means and routes for the transportation of base metal concentrates from the area east of Great Bear Lake.

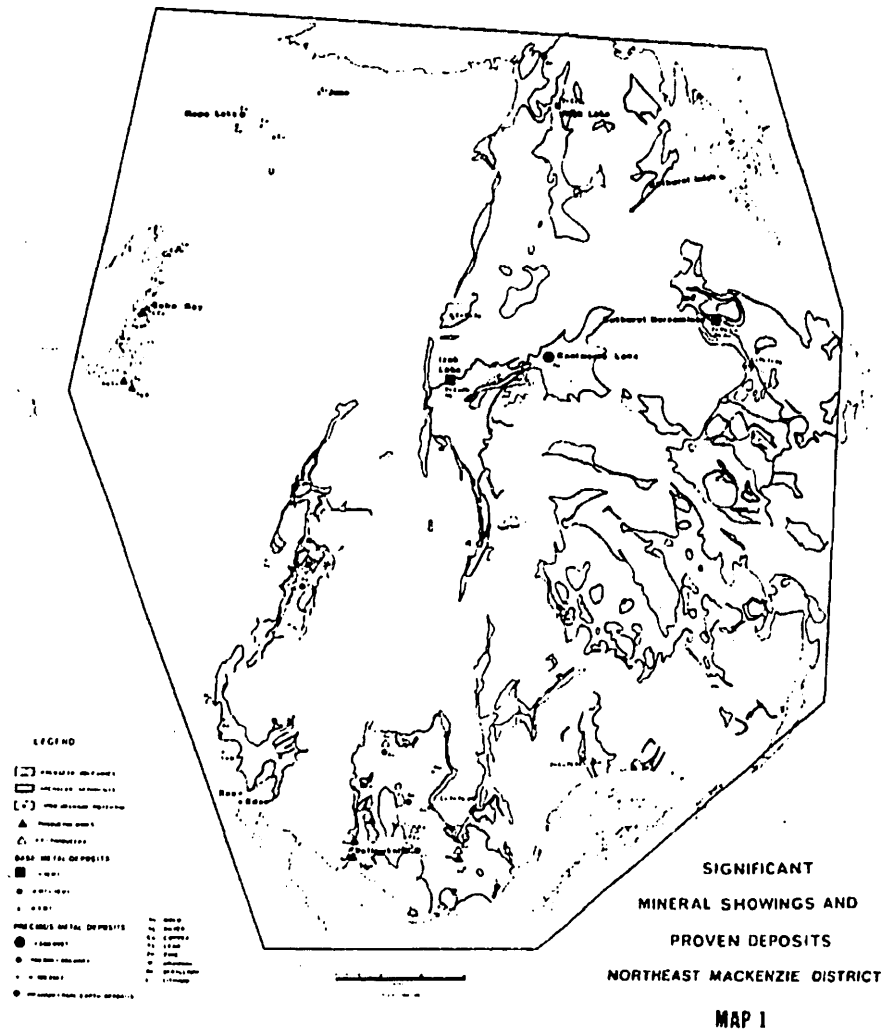
## OBJECTIVE

The objective of the study is to determine the transportation system required within the next decade, 1980-1990, in the area lying to the east of Great Bear Lake in the Northwest Territories. This report contains Phase I of the study. It describes the existing producing mines and transportation systems, the known and potential mineral deposits, an analysis of the transportation alternatives and recommendations of further in-depth study required of those alternatives which are most economical and technically feasible given the present state of development of the various transportation modes.

## STUDY AREA

The area selected for study generally encompasses the region bounded by the following points (refer to Map 1):

> Coppermine, Bathurst Inlet, Fort Reliance, Simpson Islands on Great Slave Lake, Rae-Edzo and Sawmill Bay on Great Bear Lake.



SIGNIFICANT

MINERAL SHOWINGS AND

PROVEN DEPOSITS

NORTHEAST MACKENZIE DISTRICT

**MAP 1**

## PRESENT SITUATION - PRODUCING MINES AND TRANSPORTATION SYSTEMS

At the present time there are five producing mines in the study area:

| | | |
|---|---|---|
| Yellowknife: | Giant Yellowknife Mines Ltd. | - gold |
| | Cominco's Con Mine | - gold |
| Great Bear Lake: | Echo Bay Mines Ltd. | - silver/copper |
| | Terra Mining & Exploration Limited | - silver/copper |
| | Northrim Mines Ltd. | - silver/copper |

The two mines located in the Yellowknife Area have year-round road access, except during the periods of freeze-up and break-up. The Great Bear Lake mines are restricted to a short two season surface transportation system in addition to air. Northern Transportation Company Limited operates a barge service on the Great Bear River and Lake during the July-September period, and a winter road connects the mines to Highway 3 at Rae-Edzo from January to March.

With the exception of the Yellowknife area, transportation facilities are virtually non-existent within the study area.

Following is a summary of existing transportation infrastructure:

Roads:
- Highway 3 connects Yellowknife to the Mackenzie Highway (Highway 1) near Fort Providence, a total distance of 215 miles.
- Highway 4 (Ingraham Trail) extends east of Yellowknife for 40 miles to Tibbitt Lake.

Airstrips:

| Location | Length/Surface |
|---|---|
| Yellowknife | 7500' asphalt |
| Coppermine | 5000' sand |

| | |
|---|---|
| Bathurst Inlet | 4000' sand |
| Port Radium | 4000' gravel |
| Camsell River | 4000' gravel |

Marine: NTCL barge service on Great Bear Lake.

## MINERAL POTENTIAL AND TRAFFIC

The study area is considered to have a high mineral potential. A number of ore bodies have been discovered but their exploitation is not possible at this time because of the lack of a viable transportation system. Details of known deposits are shown in Appendix I, along with comments regarding potential ore tonnage. The table below summarizes the potential annual concentrate production. It is considered that this would be a minimum demand for transportation in that, with the development of a transportation system, exploration would increase, with a very high probability of new discoveries.

## MINERAL FORECAST

| DEPOSIT | POTENTIAL CONCENTRATE PRODUCTION (s.t./year) |
|---|---|
| Izok Lake | 258,526 |
| Bathurst Norsemines | 103,183 |
| High Lake | 73,037 |
| TOTAL | 434,746 |
| Hope Lake/June * | 105,235 |

*Because of distance from Izok Lake deposits, additional discoveries would be required in the vicinity of these deposits to make them economically viable.

Of the above indicated potential concentrate production from the Izok Lake, Bathurst Norsemines and High Lake deposits, approximately 64.8 per cent of the concentrate produced would be zinc with copper and lead accounting for 29.4 per cent and 5.8 per cent respectively.

## DESCRIPTION OF TRANSPORTATION ALTERNATIVES

Future development of the vast mineral potential located in the Northeast Mackenzie District is dependent upon the provision of an economically viable transportation system. The purpose of this study is to identify the possible alternate routes and means of transporting the concentrate and then to specify which of the alternatives are the most economically and technically attractive. Following a brief outline of the modal requirements for each alternative is an in-depth analysis of each of the possibilities.

Contwoyto Lake has been specified as the common origin in the following discussion as it is fairly central to the major Izok Lake and Bathurst Norsemines deposits. Domestic smelters which could be used for refining the concentrate extracted from this region are located at Trail, Timmins and Flin Flon. Foreign markets are assumed to be Japan and Europe.

Winter roads have been ruled out as a viable modal alternative because capital requirements for equipment and storage facilities combined with annual inventory holding costs would result in exorbitant costs per ton.

For each of the following thirteen alternatives, the required infrastructure and resultant annual operating costs have been indicated. Actual costs will not be identified immediately but are discussed later in the evaluation of each alternative.

### AIR

#### Alternative One: Air Freighter Direct to Domestic Smelter

An airport would be required at a location central to the mine sites. Existing infrastructure and facilities at the airports servicing the towns where the domestic smelters are located would also require extensive capital outlay for upgrading. Capital costs would

be incurred for containers and it has been assumed that the capital cost of the air freighters would also be charged to the mines.

Annual operating costs would include charges for airport maintenance, aircraft operations and trucking charges from the airport to the smelter.

Transportation charges then, would be assessed on annual operating costs and capital recovery requirements for the air freighters, airport infrastructure and containers.

Alternative Two: Airship Direct to Domestic Smelter

Capital outlay would be necessary for the airships as well as for the infrastructure required for landing and servicing the structures which would be required at both the origin and destination.

Annual operating charges would be assessed on the operating costs of the airships and landing infrastructure .

Total transportation charges would be based on the total of operating costs and annual recovery requirements for capital expenditures.

AIR/RAIL

Alternative Three: Air Freighter to Pine Point, Rail to Smelter

As in Alternative One capital outlay for the construction of landing sites at both Pine Point and the site selected to service the mines would be necessary. Containers would have to be acquired and additional rail rolling stock would be necessary.

Annual operating charges would include air freighter operating costs, rail charges from Pine Point to the smelter and intermodal transfer costs.

The total cost for transporting the concentrate would be based on the identified operating charges and annual capital charges incurred from expenditures on the air freighters, containers and landing facilities. It has been assumed that the capital cost of the rail rolling stock would be included in the tariff charged by the CNR.

RAIL

Alternative Four: Rail Direct to Domestic Smelter

Capital expenditures would be required to extend the existing Great Slave Lake Railway from Enterprise via Rae-Edzo to the Contwoyto Lake region, a distance of about 550 miles. Additional ore hopper cars, locomotives and cabooses would be required for the transporting of annual tonnage requirements and it is assumed that this capital cost would be charged to the mines through the tariff charged by the railroad for the hauling of the concentrate.

Annual operating costs would include charges assessed by the railroads in their tariff to haul the concentrate to the smelter.

Total annual charges attributable to the transporting of the concentrate in the all rail alternative include rail charges reflecting actual operating costs of haulage, capital costs for equipment and capital recovery requirements to recoup the capital cost of construction of the new rail line.

ROAD/RAIL

Alternative Five: Road to Enterprise, Transfer to Rail for Delivery to Smelter

The construction of a permanent road about 335 miles long from the mine sites to the existing Yellowknife Highway, possibly linking at Rae-Edzo or Yellowknife, would be necessary. Capital costs would also be generated in the purchasing of a fleet of trucks and containers. Additional rail rolling stock would also have to be purchased.

Annual operating costs would include operating charges assessed for road transport to Enterprise and rail transport to the smelter, road maintenance and intermodal transfer charges.

Total transportation costs would include charges to recover the capital costs of road construction, rail equipment, trucking and container equipment, if purchased, combined with the aforementioned operating costs.

Alternative Six: Hovercraft to Pine Point, Transfer to Rail for Delivery to Smelter

Capital expenditures would be necessary for the acquisition of the hovercraft, the construction of two hoverports, at the origin and Pine Point, the cost of building a hoverway, i.e. - a pathway for the hovercraft, at least 200 miles long and additional rail rolling stock.

Annual operating charges would be assessed on hovercraft operating expenses, maintenance expenses for the Hoverway and equipment, rail charges from Pine Point to the smelter and intermodal transfer charges.

Total transportation costs then, would include the capital recovery requirements of the hovercraft, hoverports and rail equipment combined with the annual operating and maintenance costs.

RAIL/ROAD/RAIL

Alternative Seven: Rail to Yellowknife Highway, Road to Enterprise, Rail to Smelter

In order for this alternative to be operative a railroad would have to be constructed from the Yellowknife Highway to the Contwoyto Lake region, a distance of about 270-300 miles. Additional rail rolling stock would be required and the purchase of containers would be necessary.

Total operating costs would include charges incurred from rail transport for the two segments of the route, as well as from the road transport of the concentrate around Great Slave Lake and intermodal transfer costs.

For this intermodal alternative, total transportation charges would be assessed on the annual capital requirements necessary to cover construction costs of the new railroad, acquisition costs of containers and rail rolling stock and on annual operating expenses incurred from rail and road charges.

ROAD/MARINE

Alternative Eight: Road to Bathurst Inlet, Ocean Shipment to Foreign Markets

Capital outlay would be necessary for the construction of a permanent road from each of the mine access roads to the Inlet. Port facilities and a sizeable storage building would have to be constructed at a suitable site on Bathurst Inlet.

Annual operating charges would be assessed on the cost of trucking the concentrate to the port, storing it for a period of up to one year and shipping it to foreign markets. Road maintenance costs and intermodal transfer charges would also be incurred.

Total transportation charges then, would include the capital costs of constructing the permanent road, storage building and port requirements, inventory holding costs and annual operating charges as specified previously.

Alternative Nine: Road to Hudson Bay, Ocean Shipment to Foreign Markets

A permanent road approximately 600 miles in length would be required to be constructed from the mine sites to port facilities at Chesterfield Inlet or Rankin Inlet. The road could be shortened by about 125 miles if it were extended only as far as Baker Lake

but barges would then be required to transport the concentrate to either of the Bay ports for subsequent ocean shipment. Storage requirements with a capacity to house up to one year of concentrate would also be necessary at the port site.

Operating costs would be based on road maintenance costs, trucking charges and marine charges.

Combined capital and operating expenditures would result in total transportation charges assessed on the annual capital recovery requirements of the permanent road and port facilities and on operating charges resulting from inventory holding charges, road maintenance and carrier charges.

ROAD/MARINE/RAIL

Alternative Ten: Road to Great Slave Lake, Barge to Hay River, Rail to Smelter

Capital outlay for this alternative would be incurred by the construction of a road from the Contwoyto Lake region to Yellowknife or Rae-Edzo where storage facilities would be required to house the concentrate for up to eight months. The acquisition of containers, additional rail rolling stock and barge equipment would be necessary.

Operating costs would include road maintenance costs, freight charges as assessed by the truck, barge and rail companies and intermodal transfer charges.

Total costs generated annually that would be attributable to transportation would include capital recovery costs for road infrastructure, rail equipment and storage, inventory handling charges and operating costs as indicated earlier.

Alternative Eleven: Road to Port Radium, Barge to Fort Franklin, Road to Fort Norman, Barge to Hay River, Rail to Smelter

Capital outlay would be necessary for the construction of a permanent road approximately

270 miles in length and for storage facilities at Great Bear Lake capable of storing concentrate for about 9 months. Additional capital expenditures would be required for the purchase of a trucking fleet and additional rail rolling stock and barges would have to be acquired.

Total operating expenses would be generated by road maintenance costs, truck rates from the mines to Port Radium and from Fort Franklin to Fort Norman, providing that a permanent road were constructed, barge rates on both Great Bear Lake and the Mackenzie River, rail rates from Enterprise to the smelter and intermodal transfer costs.

Charges assessed in determining the total transportation cost would include annual capital costs required to recover capital expenditures on the road and equipment, inventory holding charges and the aforementioned operating costs.

Alternative Twelve: Road to Bathurst Inlet, Barge via Tuktoyaktuk to Hay River, Rail to Smelter

A permanent road constructed from the mine sites to port facilities at Bathurst Inlet would be necessary as would storage facilities capable of storing up to one year of concentrate. Extensive capital outlay for barges and tugs would be necessary. Containers and additional rail rolling stock would have to be acquired.

Annual operating costs would consist of freight charges assessed on the concentrate moved via road, barge and rail, intermodal transfer charges and road maintenance costs.

Total annual transportation charges then would include annual operating costs as specified previously and capital costs required to recoup the initial capital outlay

and interest charges for the permanent road, port facilities, storage shed and rail and barge equipment. Inventory holding costs would also be included in the determination of the total cost.

## ROAD/MARINE/ROAD

### Alternative Thirteen: Road to Baker Lake, Barge to Fort George, Truck to Smelter

As in Alternative nine, a permanent road about 475 miles in length would be required to be constructed from the mines to Baker Lake. As shipping on Hudson Bay is restricted to a three month season, a large storage shed would be required at Baker Lake.

Operating costs would be based on freight charges (assessed on the truck movements from Contwoyto Lake to Baker Lake and Fort George to the Texasgulf smelter at Timmins and the barge movement out of Chesterfield Inlet and across Hudson Bay), intermodal transfer charges and road maintenance costs.

Total charges attributable to the transportation segment of the mines total cost breakdown then include the annual capital cost requirements of the road and storage infrastructure, the preceeding operating costs and inventory holding charges.

## EVALUATION OF TRANSPORTATION ALTERNATIVES

In order to analyze the viability of each of the Alternatives specified previously, several criteria have been selected to form the basis of the evaluation. Economic viability has been assessed by the derivation of total charges directly attributable to the transporting of the lead/zinc/copper concentrate. Total long term capital requirements have been identified along with annual operating costs and the annual recovery requirements necessary to recoup total capital outlay during the life of the mines. Inventory holding charges have also been included in the total transportation charge. Technical viability has been assessed basically by the determination of the existing 'state of the art'. That is, recent developments have been assessed and conclusions derived from those developments.

Several assumptions are implicit to the following analysis and should be noted at this point. Although total estimates of concentrate production for the deposits outlined previously amount to 546 thousand tons annually, 400 thousand tons has been used as the average annual concentrate production level. Limited reserves at both the Hope Lake and June deposits combined with their geographical isolation from the larger deposits render their inclusion impractical at this time. Should copper become increasingly in demand these two deposits may in fact be developed. The discount rate at which capital may be borrowed has been assumed to be 10 per cent. The Izok Lake and Bathurst Norsemines deposits are assumed to have a twenty year life, and the concentrate value used in the determination of inventory holding charges was $350 per ton. Transportation charges for most of the domestic routes have been based on modal rates to the Trail smelter. If the Flin Flon or Timmins smelters were determined to be the ultimate destination for the ore concentrate the analysis would largely have to be re-evaluated.

Alternative One: Air Freighter Direct to Smelter

The only type of air freighter with sufficient capacity to render the air mode a viable alternative in this analysis is the Boeing 747 model. The payload in each shipment would be approximately 130 tons. NASA expects a 300 ton payload freighter to be available by 1990 but until then the 747's offer the largest capacity. Although costs specified in the following evaluation are in terms of 1977 dollars, there would be a 3-5 year time lag, between ordering of the freighters and delivery to the purchasing company. As there is not sufficient slack in the air industry to transfer a fleet of 747 freighters to the Northeast Mackenzie district, should this alternative be shown to be the most advantageous and economically feasible, it is assumed that all freighters would have to be ordered.

Given the following assumptions seven freighters (see Appendix II for derivation) would be required annually to transport the concentrate to the smelter;

- cruising speed of 550 miles per hour;
- average one-way distance to the smelter of 2,000 miles;
- 4 hours of flying time per load to smelter, 4 hours for return flight and 4 hours for loading, unloading and servicing of aircraft;
- maximum feasible operational level of 4,000 hours per annum per aircraft.

The current purchase price for a 747 is $45-50 million in U.S. dollars. Assuming a Canadian dollar equivalent of $.90 per U.S. dollar, total charges for the fleet would be $346.5 million.

To enable the landing of the 747's, Transport Canada has recommended that the runway length be 12,000 feet. Assuming ready accessibility to eskers for construction inputs to the airstrip, the total cost for the completion of a Class A Arctic airport located

in the Contwoyto Lake region has been estimated at $12 million. This total includes the provision of asphalt pavement for the runway, visual and landing aids and some refueling facilities. It does not provide for extensive terminal facilities.

For comparative purposes, the recently constructed airport at Nanisivik has cost $4.1 million to date and it is estimated that final costs, upon completion next fall, will be about $4.7 million. Major reasons for the large difference in projected costs for an airport in the Contwoyto Lake region compared to actual construction costs at Nanisivik include extremely difficult access for airport construction and unfavourable permafrost and other subterranean conditions. Also, the runway length required for landing the 747 aircraft is almost double the 6,400 foot runway at Nanisivik.

The capital cost required to upgrade the airports at any of the smelter locations has also been estimated at $10-12 million. As expansion of facilities at Trail would be impossible due to its mountainous location, Cranbrook has been identified as the alternate landing site. The concentrate could then be delivered to the Trail smelter via truck or rail.

Capital costs for the purchase of 485 containers (4 ton flexible type - see Appendix II for derivation of quantity required), at a price of $235 per container would amount to $114 thousand. Each container has about a six year life and it has been assumed that approximately 32 containers could be carried per trip by each freighter. Each of the 747's could make two return trips per day from the mine to the smelter and about 4.3 freighters would be operative per day on an annual basis.

While operating costs for the 747 freighters have been specified as low as 4 cents per ton mile, both the Boeing Company and a spokesman for the Department of Energy, Mines and Resources have indicated that 14 cents per ton mile is more in line with actual direct operating costs in the north. In order to allow for higher fuel costs

in the north, corporate overhead and the profit requirements of the carrier, the minimum rate for the recovery of operating costs would be 25 cents per ton-mile. A compensatory rate for both the operating costs and capital costs of the 747 fleet would be 30 cents per ton-mile. With fuel costs accounting for almost 50 per cent of these direct charges, it is obvious that any increase in fuel prices would alter the rate significantly. Total operating costs for the seven freighters then, would be about $200 million annually, assuming a 25¢/ton-mile tariff for the return trip. However, this tariff does not reflect a backhaul and is therefore overstated somewhat.

As mining operations would be on a scale comparable to those at the Cyprus-Anvil mine, it can be deduced that approximately 400 men would be required to operate the mines. Based on annual resupply requirements of 12 tons per capita,[1] approximately 5,000 tons of inbound traffic would be necessary. It is assumed that these resupply requirements would be flown into the mines as a backhaul and effectively reduce the doubled tariff. Because of the tonnage imbalance the reduction would be small however. If arrangements were made such that the 747 freighters could deliver resupply requirements for other companies operating in the north to one common point, the tariff could be significantly reduced. If the tariff were reduced to 24¢ per ton-mile given the 5,000 ton backhaul, operating costs for the freighters would be reduced to $192 million annually.

Given that annual maintenance costs for the Contwoyto Lake airport were chargeable to the mines, additional operating expenses of $100 thousand per annum would be generated.

In summary, total capital costs at minimum would be; $346.5 million for the 747 fleet, $22 million for airport construction and container acquistion costs of $114 thousand for a total of $368.6 million. Assuming a twenty year life for each of the capital

1. The Yukon Railway Study, p. 35. A range of 8.0 - 15.7 tons per capita was specified as annual inbound commodity requirements for mines operative in the Yukon.

expenditures and a discount rate of 10 per cent, annual capital costs would amount to $43.3 million.

Annual operating expenses for the freighters, given a tariff of 24 cents per ton-mile, would amount to $192 million and maintenance charges for operating the Northeast Mackenzie airport would amount to about $100,000 annually. Road charges from Cranbrook to Trail at a cost of 6 cents per ton-mile and a distance of 151 miles would amount to $3.6 million annually and total operating expenses would amount to $195.7 million.

Total annual transportation charges for the air alternative would amount to $239 million or $597.50 per ton. Although the environmental impact of transferring the concentrate to the smelter via freighter would be minimal, the immense transportation charges, weighted especially by the exorbitant operating costs of the 747's, render this option economically infeasible.

COST BREAKDOWN
ALTERNATIVE ONE

| | CAPITAL COST | | | OPERATING COST | | ANNUAL COST | |
|---|---|---|---|---|---|---|---|
| | TOTAL | PER ANNUM[1] | PER TON | TOTAL | PER TON | TOTAL | PER TON |
| | $millions | | $ | $millions | $ | $millions | $ |
| 747's | 346.5 | 40.7 | 101.75 | 192.0 | 480.00 | 232.7 | 581.75 |
| Airports | 22.0 | 2.6 | 6.50 | .1 | .25 | 2.7 | 6.75 |
| Containers | .11 | .01 | .03 | - | - | .01 | .03 |
| Truck[2] | - | - | - | 3.6 | 9.00 | 3.6 | 9.00 |
| Total | 368.6 | 43.3 | 108.28 | 195.7 | 489.25 | 239.01 | 597.53 |

1. assumes 10 percent annual rate of recovery and 20 year life.
2. capital cost of equipment included in operating cost.

Alternative Two: Airship Direct to Smelter

The foreseeable benefits in utilizing airships in the movement of concentrates from the mine site to the smelter would include; low haul operating costs, direct routing, large tonnage capacity, minimal environmental impact and fuel efficiency. Preliminary vehicle operating costs range from $8-16/mile with infrastructure acquisition costs ranging from $20,000 - $100,000 per site. The capacity of each airship would be dependant upon the type used with current estimates ranging from 100-400 tons per trip. Given the following assumptions, a minimum of 12 airships (see Appendix II) would be required; maximum level of utilization of 3,500 hours/year per airship, average one way trip length 2,000 miles, average speed of 100 miles/hour and a payload of 400 tons per trip. [1]

Current estimates of initial capital outlay for airships range from $20-56 million per unit. Thus, a minimal requirement of 12 airships would cost $240-672 million. Assuming a discount rate of 10 per cent and an average capital outlay of $38 million per airship, total fleet costs would amount to $456 million and annual capital requirements would be $53.6 million. The two landing sites would require an additional $120 thousand outlay.

Annual operating expenses for the fleet would amount to an additional $50.4 million, based on a vehicle operating cost of $12 per mile and 87.5 shipments per vehicle per annum. Infrastructure maintenance costs would amount to about $20 thousand annually.

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1. Data obtained from Izok Lake Transportation Assessment; Vol. 1, August 1977, pp. 38-39.

Total annual transportation costs then would consist of $53.6 million in capital charges and $50.4 million in operating expenses for a combined total of $104 million or $260 per ton, which renders this alternative unlikely, at least given the current selling prices of the base metals found at the Izok Lake and Bathurst Norseminés deposits.

Of more importance is the fact that the airship structures have not been developed technologically to the point where costs have been finalized nor have the stated qualities been proven. Goodyear has indicated that it could have their Heavy Lift airship capable of transporting up to 400 tons operational by 1981. The company has still however, to perform an actual flight test on any of its models. Consequently, despite the several advantages that make this alternative attractive, it is too early in the developmental period to consider airships as a viable alternative for the immediate future.

COST BREAKDOWN
ALTERNATIVE TWO

| | CAPITAL COST | | | OPERATING COST | | ANNUAL COST | |
|---|---|---|---|---|---|---|---|
| | TOTAL | PER ANNUM[1] | PER TON | TOTAL | PER TON | TOTAL | PER TON |
| | $millions | | $ | $millions | $ | $millions | $ |
| Airships | 456.0 | 53.6 | 134.00 | 50.4 | 126.0 | 104.0 | 260.00 |
| Landing Sites | .12 | .01 | .04 | .02 | .05 | .03 | .08 |
| Total | 456.12 | 53.61 | 134.04 | 50.42 | 126.05 | 104.03 | 260.08 |

1. Assumes 10% annual rate of recovery and 20 year life.

Alternative Three: Air to Pine Point, Rail to Smelter

Capital and operating costs for the air mode, as applicable to 747 freighters, were indicated in Alternative One. Given a distance of about 400 miles from the mines to Pine Point, three freighters (see Appendix II) would be required annually to transport

the concentrate to the rail transfer point. Hay River was ruled out as the location for the intermodal transfer because the existing island airport could not be expanded to service the 747's.

Capital construction costs for the three freighters would be $148.5 million and for the two landing sites $22 million. Approximately 240 of the 4 ton flexible containers would be required and at a unit cost of $235 total outlay required would be $56.4 thousand.

Approximately 580 ore concentrate hopper cars would be necessary (includes 10 percent for contingency) in order for the Great Slave Lake Railway to move the annual concentrate to the smelter. These hoppers would cost $21.5 million or about $37 thousand a piece. It is assumed that a 30 day car cycle to transport the concentrate to Trail and ship the empty car back to Enterprise would be required.

Given an air rate of 26 cents per ton-mile (slightly higher than rate in Alternative One due to shorter distance - hence higher costs per mile), air charges for the three freighters would amount to $36.4 million annually. Assuming an intermodal transfer cost of $3 per ton, annual charges would be $1.2 million. Although the $3 charge is significantly higher than $.50 intermodal charge currently incurred by Cyprus-Anvil for its truck to rail transfer of the concentrate, expensive capital equipment for the air to rail transfer would be necessary. The $3 charge then, includes capital expenses for the heavy equipment. Based on CN's current rail rate of $40 per ton for Cominco's concentrate shipped from Pine Point to Trail, rail charges would amount to $16 million annually at minimum. Obviously, if the Flin Flon or Timmons smelters were the ultimate destination for the concentrate rail charges would be higher.

There is the possibility that the mines may prefer a higher valuation on the concentrate shipped by rail. However, Canadian National Railways indicated that a higher valuation merely implies payment of a higher insurance premium through the higher rate. They recommended that the lowest possible valuation be stated for rate purposes and then the company could further insure the concentrate for the higher value with a private company.

As in Alternative One, annual maintenance costs for the Contwoyto Lake region airport would be $100 thousand.

Total capital requirements for the air/rail route would be $192.1 million or $22.6 million annually assuming a 10 per cent rate of discount. Annual operating charges would total $53.7 million for a combined total annual cost of $76.3 million. The cost per ton would be $190.75.

COST BREAKDOWN
ALTERNATIVE THREE

| | CAPITAL COST | | | OPERATING COST | | ANNUAL COST | |
|---|---|---|---|---|---|---|---|
| | TOTAL | PER ANNUM[1] | PER TON | TOTAL | PER TON | TOTAL | PER TON |
| | $million | | $ | $million | $ | $million | $ |
| Contwoyto/ Pine Point | | | | | | | |
| 747's | 148.5 | 17.4 | 43.61 | 36.4 | 91.00 | 53.8 | 134.50 |
| Airports | 22.0 | 2.6 | 6.46 | .1 | .25 | 2.7 | 6.97 |
| Containers | .06 | .01 | .02 | - | - | .01 | .03 |
| Intermodal Transfer | - | - | - | 1.2 | 3.00 | 1.2 | 3.00 |
| Sub-total | 170.6 | 20.01 | 50.09 | 37.7 | 94.25 | 57.8 | 144.50 |
| Pine Point/ Trail | | | | | | | |
| Rail[2] | 21.5 | 2.5 | 6.31 | 16.0 | 40.00 | 18.5 | 46.25 |
| Total | 192.1 | 22.6 | 56.40 | 53.7 | 134.25 | 76.3 | 190.75 |

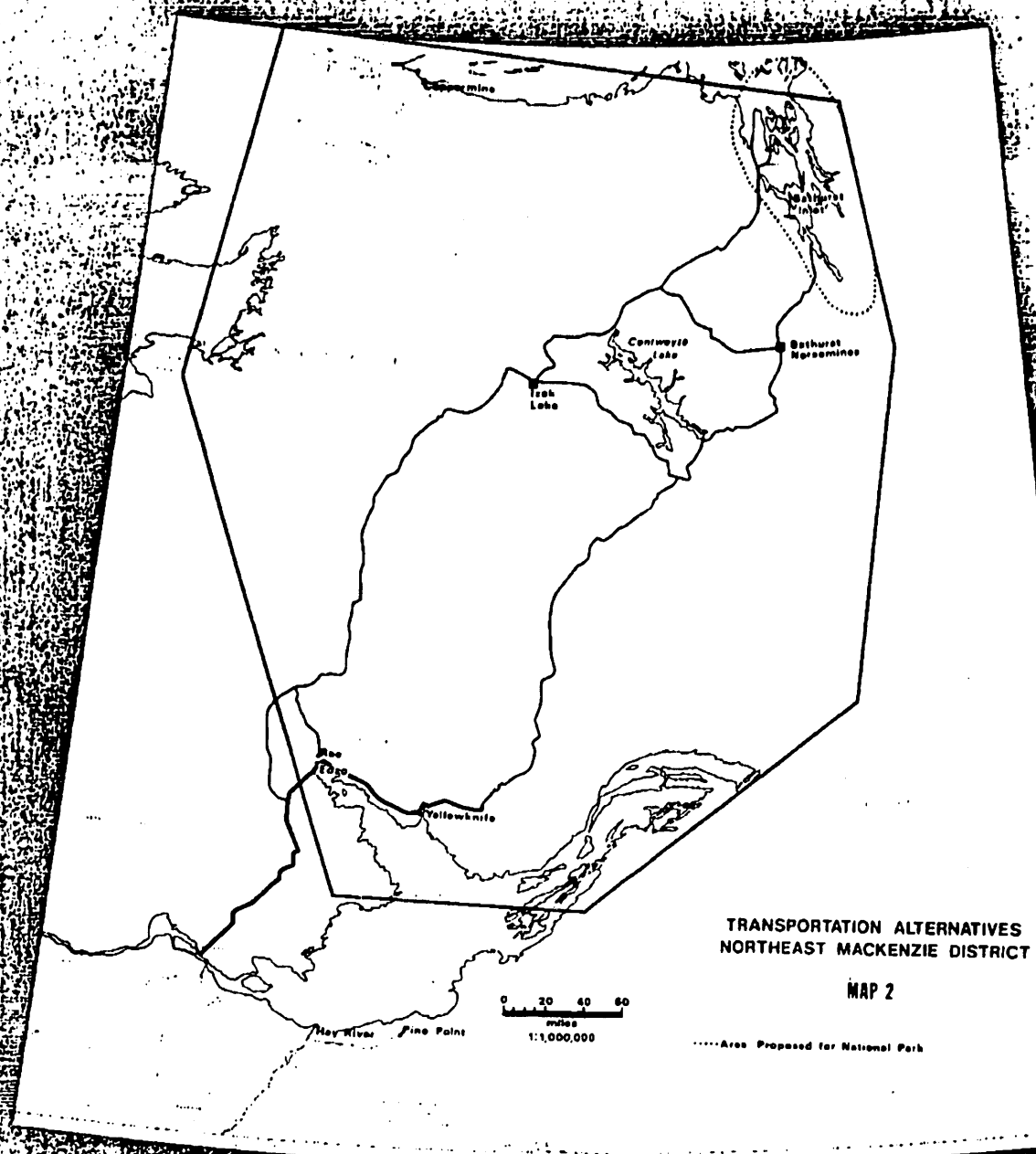
1. Assumes 10 percent annual rate of discount and twenty year life.
2. Operating cost includes rail charges only.

Alternative Four: Rail to Smelter

Currently the Great Slave Lake Railway extends to Hay River on Great Slave Lake. In order for a railroad to service the Contwoyto Lake region an extension of a minimal 550 miles of roadbed from Enterprise would be required. Preliminary estimates of construction costs for a roadbed in an area such as the Contwoyto Lake region, which is characterized by an abundance of lakes and rivers, indicate that a minimum of $1.0-1.2 million per mile would be necessary to build a standard gauge roadbed. Assuming a cost of $1.2 million per mile, total capital costs for the roadbed would be $660 million. Since the mines would not be the sole users of the railroad it has been assumed that 70 percent of this cost would be chargeable to the mines, for a total cost of $462 million - refer to Map 2 for possible routes.

For comparative purposes, costs specified in the Yukon Railway Study for the proposed Watson Lake - Dawson rail extension ranged from $473.6 thousand to $651.3 thousand per mile in 1974 dollars. These costs escalate to $625.3 thousand and $860.0 thousand per mile in 1977 dollars based on the 32.04 per cent increase in costs of non-residential construction during this same period. Although costs for the BCR rail extension have not been finalized, preliminary costs, in 1977 dollars, range from $600.0 thousand to $850.0 thousand per mile of track. Also, Canalog Consultants has suggested a cost of $1-1.2 million per mile for a railroad built in the northern wilderness.

Although capital costs for rail equipment are not readily available, the Yukon Railway Study and information received from Canadian National Railways can be used as source for developing capital costs. Assuming rolling stock required would include 5 diesel units, 3 cabooses and 580 ore hopper cars as well as loading equipment at the rail terminal serving the mine and a freight shed, capital outlay for equipment would be $26.2 million - see Appendix II for cost breadown.


Coppermine
Bathurst Inlet
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TRANSPORTATION ALTERNATIVES
NORTHEAST MACKENZIE DISTRICT
MAP 2
Area Proposed for National Park

Given that each of the three southbound trains per week from Enterprise would transport about 43 ore hopper cars from the Contwoyto region at 65 tons per car, and assuming a one month turnaround for the cars from Enterprise to the smelter at Trail, approximately 515 cars per month would be required. It has been assumed that 580 ore hopper cars would be necessary however, in order to allow for contingencies.

In order for the railway to be operative year round, a rail bridge at the Fort Providence-Mackenzie River crossing would be necessary. Costs for a bridge have been estimated in recent years as falling in the $12-30 million range. A cost of $7-10 thousand per lineal foot has also been given as an estimate and this cost is in line with recently evaluated bridge costs in the Yukon Rail Study. This cost however would be borne partially by other users. Assuming the mines also bore 70 percent of this cost and given that the bridge would cost $30 million to construct, additional capital outlay of $21.0 million would be necessary.

Assuming operating costs of 6 cents per return ton-mile, which again are in-line with costs developed for the Minto/Alaska sector in the Yukon Railway Study, total annual operating costs for the rail extension would be $13.2 million. Additional charges of $40 per ton for the Enterprise to Trail haul would total $16 million annually.

Total capital charges then would amount to $509.2 million with the annual recoverable costs totalling $59.8 million assuming a 10 percent rate of discount on capital costs.

Operating charges would amount to $29.2 million including $13.2 million for the haul on the extended portion of the railroad and $16 million on the southern portion of the haul. A cost-compensating tariff including coverage for total capital and operating requirements on the extended Enterprise/Contwoyto portion would amount to 32 cents per ton-mile.

Total annual transportation charges for all-rail route would amount to $89.0 million or $222.50 per ton. In order to be competitive with the road haul cost from Contwoyto to Enterprise, the compensatory rail rate (including capital recovery requirements) would need to be a minimum of 10 cents per ton-mile lower (see Appendix II) i.e. reduced from 32 cents per ton-mile to 22 cents per ton-mile. A very cursory sensitivity analysis (Appendix II) indicates that approximately 650,000 tons of concentrate must be shipped annually in order for the rail route to be competitive with the road/rail route. It becomes evident then, that if additional production of concentrates or other commodities were slated to come on-stream in this region in the near future, the all-rail route could indeed become an economically attractive transportation alternative.

COST BREAKDOWN
ALTERNATIVE FOUR

| | CAPITAL COST | | | OPERATING COST | | ANNUAL COST | |
|---|---|---|---|---|---|---|---|
| | TOTAL | PER[1] ANNUM | PER TON | TOTAL | PER TON | TOTAL | PER TON |
| | $million | | $ | $million | $ | $million | $ |
| Contwoyto/Enterprise | | | | | | | |
| RR | 462.0 | 54.3 | 135.75 | - | - | 54.3 | 135.75 |
| Equipment[2] | 4.7 | .5 | 1.38 | 13.2 | 33.00 | 13.7 | 34.25 |
| Bridge | 21.0 | 2.5 | 6.25 | - | - | 2.5 | 6.25 |
| Sub-Total | 487.7 | 57.3 | 143.38 | 13.2 | 33.00 | 70.5 | 176.25 |
| Enterprise/Trail | | | | | | | |
| Equipment[3] | 21.5 | 2.5 | 6.31 | 16.0 | 40.00 | 18.5 | 46.25 |
| Total | 509.2 | 59.8 | 150.19 | 29.2 | 73.00 | 89.0 | 222.50 |

1. Assumes 10 percent annual rate of discount and 20 year life.
2. Capital cost includes cost of diesels, cabooses, mine loading equipment and freight shed. Operating cost includes freight charges.
3. Capital cost includes cost of ore hopper cars. Operating cost includes rail charges.

Alternative Five: Road to Enterprise, Rail to Smelter

Any of a number of possible road routes could be constructed from the Yellowknife Highway or Ingraham Trail to the Contwoyto Lake region. Construction costs for a permanent road approximately 335 miles long would be in the proximity of $174 million, based on average road construction costs of $520 thousand per mile. This estimate reflects an assessment of Texasgulf's costing of potential roads by the Transportation Division of the Engineering and Architecture Branch, Department of Indian Affairs and Northern Development who concluded that total costs, including engineering and contract administration, on a per mile basis would fall in the $476-562 thousand range. Maintenance costs of about $4,000 per mile would accrue to $1.3 million annually. Assuming a twenty year life and cost of capital at 10 percent, annual capital charges for the road would total $20.4 million.

The balance of the road haul to the railhead at Enterprise would be over 215 miles of the existing Yellowknife Highway. Assuming that the mines bore 70 percent of the cost of construction of a Mackenzie River bridge at Fort Providence, estimated at $30 million, capital costs for the bridge would total $21.0 million.

As in Alternative Four, it is assumed that 580 hopper cars for the lead/zinc/copper concentrate rail haul would be required, at a total capital cost of $21.5 million. Discounted at 10 per cent over 20 years the annual charge to the mines would be $2.5 million or $6.30 per ton.

Current estimates of road haul rates are available from the recently completed Izok Lake Transportation Assessment prepared for Texasgulf by Underwood McLellan (1977) Ltd. Return truck rates were quoted at 10.7 cents per ton-mile for a 550 mile haul. Road charges then would total $23.5 million. It is assumed that the aforementioned rate includes coverage of the trucking company's capital requirements for equipment

and that the mines therefore would not be required to expend additional monies for trucking equipment. The above rate is in line with the 1974 operating cost for trucking, at about 7 cents per ton-mile, determined in the Yukon Railway Study. This rate provided for depreciation, licence fees and insurance premiums, driver costs, fuel costs, maintenance costs, overhead and administrative costs. Rail charges from Enterprise to the Trail smelter would total $16 million, based on a $40 per ton rate and intermodal transfer charges would amount to $1.2 million given a rate of $3.00 per ton. The higher transfer charge has been specified here because the truck/rail haul does not assume the use of containers, as was the case in the analysis of some alternatives.

Total capital costs incurred for the road/rail route amount to $216.5 million or $25.4 million annually assuming a 10 percent rate of interest charged on required capital recovery.

Operating charges would amount to $42.0 million based on road haul charges of $23.5 million, rail charges of $16 million, maintenance expenses for the 335 miles of new road at $1.3 million and intermodal transfer charges of $1.2 million.

Total transportation charges would amount to $67.4 million annually or $168.50 per ton. In view of the limited additional capital requirements and low operating charges, at least relative to the other alternatives assessed thus far, this transportation alternative appears to be economically favorable.

## COST BREAKDOWN
## ALTERNATIVE FIVE

| | CAPITAL COST | | | OPERATING COST | | ANNUAL COST | |
|---|---|---|---|---|---|---|---|
| | TOTAL | PER ANNUM[1] | PER TON | TOTAL | PER TON | TOTAL | PER TON |
| | $million | | $ | $million | $ | $million | $ |
| **Contwoyto/Enterprise** | | | | | | | |
| Road | 174.0 | 20.4 | 51.09 | 1.3 | 3.35 | 21.7 | 54.25 |
| Bridge | 21.0 | 2.5 | 6.25 | - | - | 2.5 | 6.25 |
| Trucking[2] | - | - | - | 23.5 | 58.75 | 23.5 | 58.75 |
| Intermodal Transfer | - | - | - | 1.2 | 3.00 | 1.2 | 3.00 |
| Sub-Total | 195.0 | 22.9 | 57.34 | 26.0 | 65.10 | 48.9 | 122.25 |
| **Enterprise/Trail** | | | | | | | |
| Rail[3] | 21.5 | 2.5 | 6.30 | 16.0 | 40.00 | 18.5 | 46.25 |
| Total | 216.5 | 25.4 | 63.64 | 42.0 | 105.10 | 67.4 | 168.50 |

1. Assumes 10 percent annual rate of discount and 20 year life.
2. Capital cost included in operating charges.
3. Operating cost includes rail charges only.

Alternative Six: Hovercraft to Pine Point, Rail to Smelter

Hovercraft service has already been considered as a viable transportation service in Labrador. N.D. Lea and Associates[1] determined in 1967 that hovercraft service would best suit the needs of Labrador communities. However, capacity limitations of 115 tons per trip combined with speed and distance factors would necessitate a requirement for eight hovercraft to transfer the concentrate extracted from the Contwoyto region to Pine Point (see Appendix II).

Costs indicated in the Labrador Highway study were not specific enough to apply to the evaluation of this transportation alternative. One recurring problem in attempting to analyze hovercraft viability is the lack of sufficient cost data. Unfortunately, even the hovercraft currently being utilized by the Alberta government in the Peace River District cannot be used to derive operating costs; it has experienced so many breakdowns that 'average' operating costs have yet to be determined. Until the technology of hovercraft operations has been proven successful, cost estimates will continue to be subjective, and likely vary significantly. When both the technology and costing of the hovercraft is sound, an evaluation of this alternative would be in order.

Alternative Seven: Rail to Yellowknife Highway, Road to Enterprise, Rail to Smelter

As was discussed in Alternative Four, construction costs for a railbed in the Contwoyto Lake region would be $1.2 million per mile at minimum. Given a minimal track requirement of 335 miles, from Edzo to the proximity of the mines, the lowest estimate of total construction costs for a railroad would be $402 million. Since the mines would likely be the sole users of this railroad it has been assumed that 100 percent of construction costs would be charged to the mines. Capital costs for the acquisition of 3 diesels, 2 cabooses and 20 ore hopper cars for the Northeast Mackenzie railroad would amount to $4.18 million while the 580 hopper cars required for the movement of the concentrate

1. Labrador Highway Study, April 1967.

from Enterprise to Trail would cost $21.5 million (see Appendix II). As was assumed in previous analysis, bridge costs at Fort Providence would require a further capital outlay of $21 million.

Assuming rail operating costs of 6 cents per return ton-mile on the northern railroad, annual charges for the 335 mile movement would total $8 million. A cost-compensatory charge, including both capital and operating charges, would increase from 6 cents per ton-mile to 42 cents per ton-mile. Additional operating costs on the northern route would include road haul charges of $9.2 million from the Yellowknife Highway to Enterprise, at a rate of 10.7 cents per ton-mile, and intermodal transfer charges of $2.4 million. This charge would provide for the rail/road and road/rail interchanges at a rate of $3.00 per ton. The higher charge has been specified in this alternative because transfer operations from the bulk ore carriers to truck and vice versa would not be as streamlined as the transfer of Cyprus Anvil's containers on the White Pass system. The use of containers and rail flat cars is another option that could be further investigated. Finally, based on Cominco's current charge on the transporting of concentrate from the Pine Point mine to Trail, rail charges on the Great Slave Lake Railway movement from Enterprise to Trail at a distance of 1,338 miles would be $16 million or 2.99 cents per ton-mile. Compensatory rates, including coverage for the annual capital costs of the hopper cars would increase from 2.99 cents per ton-mile to 3.46 cents per ton-mile.

Total capital charges would amount to $448.7 million or $52.7 million annually, assuming that annual recovery requirements were based on a 10 percent annual rate of discount and a 20 year life. Operating costs would amount to $35.6 million including $24 million for rail operating charges, $2.4 million for intermodal transfer charges and $9.2 million for road haul costs. Total annual costs for this rail/road/rail alternative would amount to $88.3 million or $220.65 per ton.

In order to be competitive with the road/rail haul, as discussed in Alternative Five, total annual costs on the Contwoyto/Enterprise segment of the haul would have to be reduced from the derived $174.40 per ton or 31.7 cents per ton-mile to 22 cents per ton-mile. If the rail traffic level could be increased from 400,000 tons per annum to about 650,000 tons per annum, as was earlier indicated in Alternative Four, this rail/road/rail route would become as economically viable as the road/rail route.

COST BREAKDOWN
ALTERNATIVE SEVEN

| | CAPITAL COST | | | OPERATING COST | | ANNUAL COST | |
|---|---|---|---|---|---|---|---|
| | TOTAL $million | PER[1] ANNUM | PER TON $ | TOTAL $million | PER TON $ | TOTAL $million | PER TON $ |
| Contwoyto/Enterprise | | | | | | | |
| Rail | 402.0 | 47.2 | 118.05 | - | - | 47.2 | 118.05 |
| Equipment[3] | 4.2 | .5 | 1.23 | 8.0 | 20.10 | 8.5 | 21.33 |
| Bridge | 21.0 | 2.5 | 6.02 | - | - | 2.5 | 6.02 |
| Intermodal Transfer | - | - | - | 2.4 | 6.00 | 2.4 | 6.00 |
| Road[2] | - | - | - | 9.2 | 23.00 | 9.2 | 23.00 |
| Sub-Total | 427.2 | 50.2 | 125.45 | 19.6 | 49.10 | 69.8 | 174.40 |
| Enterprise/Trail | | | | | | | |
| Rail[3] | 21.5 | 2.5 | 6.31 | 16.0 | 40.00 | 18.5 | 46.25 |
| Total | 448.7 | 52.7 | 131.76 | 35.6 | 89.10 | 88.3 | 220.65 |

1. Assumes 10 percent annual rate of discount and twenty year life.
2. Capital cost of equipment included in operating charges.
3. Operating cost includes rail charges only.

Alternative Eight: Road to Bathurst Inlet, Marine for Export

The road distance from the Bathurst Norsemines and Izok Lake deposits north to an Arctic port at Bathurst Inlet would be considerably shorter than a southbound route to the Yellowknife Highway. The Bathurst Norsemines site is located about 60 miles

south of the Inlet whereas the Izok Lake site is approximately 150 miles southwest of the Inlet. The Transportation Division of the Department of Indian Affairs and Northern Development has analysed costs for three possible road routes up to Bathurst Inlet, based on a preliminary assessment of existing maps and aerial survey photos. They determined that the length of road required would be 246 miles if originating at Izok Lake and terminating at the southern arm of Bathurst Inlet, passing via Bathurst Norsemines, or 295 or 297 miles if extending northward from the two mine sites and terminating at either Brown Sound or Arctic Sound repectively - see Map 2. Total construction costs ranged from $142.3 million to $177.6 million and included allowances for contingencies, engineering design and temporary winter roads, necessary for equipment access for the constructing of the permanent road, port facilities and for mine development. Averaging these estimates results in a total capital construction cost of $160 million. Annual maintenance costs would be in the order of $1.1 million, assuming an average cost of $4,000 per mile and an average distance of 272 miles to the port.

Given that each truck could transport 30 tons per trip and make 1.5 return trips per day, a fleet of thirty trucks would be necessary. According to the Proposed Yukon Minerals Act, the expected life for these ore trucks would be 3 years, so that in total, over the 20 years, 200 trucks would be required. Basing tractor/trailor costs at $50 thousand per unit and trailer costs at $17 thousand per unit, total required capital outlay for the fleet would be $13.4 million - see Appendix II for detailed calculation.

As the shipping season for ocean-going vessels is restricted to about three months in the Bathurst Inlet/northern Arctic region, storage facilities with a capacity for storing up to 400,000 tons of concentrate would be necessary. Based on construction costs of storage facilities at Nanisivik, which totalled $3.3 million and have a capacity for storing 150 thousand tons of concentrate, the capital requirement for a shed would be in the $5-5.5 million range.

Although detailed estimates of capital requirements necessary to build a dock are not available, the recently constructed dock at Nanisivik can be used as a basis for capital costs. The dock was constructed between 1975-1977 at a cost of $2.8 million. Inflating the cost entirely to 1977 dollars would result in minimal capital outlay of $3.5 million, based on the 32 percent price increase of the Non-residential Building Construction Input Price Index. Estimates of dock costs in a submission to Cominco entitled "Waterbourne Transportation Systems for the Bathurst Norsemine Project" fell within the $2.3-2.8 million range (1974 dollars). Again, by applying the industrial price index, these costs escalate to the $3.0-3.7 million range so that the required $3.5 million capital construction outlay appears to be in line.

Operating costs including allowances for depreciation, license fees, insurance, driver costs, fuel, maintenance and overhead for Cyprus Anvil trucks were shown to be approximately 6.4 cents per ton-mile in the Yukon Railway Study. Since these costs were in terms of 1974 dollars, the 32.04 percent increase in the non-residential construction price index between 1974 and 1977 would increase those costs to about 8.5 cents per ton-mile.

Truck operating expenses then would amount to $9.2 million based on 108.8 million ton-miles at a cost of 8.5 cents per ton-mile. A cost compensatory charge, including both operating and capital charges would amount to 20.8 cents per ton-mile. Intermodal transfer charges for the truck to rail interphase in Cyprus Anvil's operations is currently 50 cents per ton. Assuming streamlined operations in the Northeast Mackenzie District a rate of 50 cents per ton would amount to $200,000 in annual charges.

Although it is difficult to assess what the ocean charter rate for the marine shipments would be due to volatility of charter rates and severe ice conditions in the central Arctic region, current rates (1978) paid by Nanisivik Mines Ltd. to Salen Shipping

Company for transporting the concentrate to Antwerp or Rotterdam are $20.50 per metric tonne (U.S. dollars). Assuming a Canadian dollar equivalent of $.90 per U.S. dollar this rate amounts to $24.85 per short ton (Can. dollars). By prorating Salen's rate strictly on a distance basis and by allowing for more severe ice conditions, a rate of $35 per short ton would be reasonable. Seven vessels similar in size to the M.V. Arctic would be required to transport the total concentrate to the smelter location in the three month shipping season. It is assumed that only two shipments per season would be possible per vessel. Assuming sufficient slack in the world charter market for the provision of seven Class B vessels, the charges developed for this analysis are based on the $35 rate per short ton, so that total annual marine shipping costs would be $14 million.

Federal Commerce and Navigation has indicated that marine charges, based on capital and operating costs of the M.V. Arctic, would be about $80 CDN per metric tonne or $88.16 CDN per short ton. This cost however, is heavily weighted by high capital charges, as it was assumed that seven vessels similar to the M.V. Arctic would have to be constructed.

Inventory interest charges incurred in holding the concentrate for an average 12 month period would amount to $14 million or $35 per ton based on an ore value of $350 per ton and annual rate of discount of 10 percent - see Appendix II. Nanisivik Mines Ltd., incurred interest charges amounting to $2.4 million or $16.56 per ton during the February 1977 - January 1978 period if one assumes that the average cost of capital for the mines was 8.4 percent, that inventory was stored for an average 9 month period and that concentrate production totalled 147,646 short tons.

Total capital costs then would amount to $181.9 million given required average capital outlays of $160.0 million for road construction, $13.4 million for trucking equipment,

$5.0 million for storage facilities and $3.5 million for port facilities. Amortized over a twenty year period at a cost of capital of 10 percent, annual capital costs would amount to 21.4 million.

Annual operating costs would average $24.5 million or $61.25 per ton. This charge would be based on road maintenance costs of $1.1 million, truck operating expenses of $9.2 million, intermodal transfer charges of $200 thousand and marine shipping charges of $14 million.

Total charges assessed on capital, operating and inventory holding costs and as relating to transportation would amount to $59.9 million or $149.75 per ton. Hence, this alternative also appears to be attractive economically given the above considerations. However, its comparative advantages will be discussed in the final assessment of costs found in the Summary of this report.

It should be noted that the technical viability of this Alternative is subject to some degree of risk. While it has been assumed that two shipments of concentrate per vessel each shipping season would be possible, severe ice conditions in the central Arctic region could considerably delay or even prevent sailings to or from the Bathurst Inlet port. Thus, provision for ice-breaker support through perhaps the shipping charge and/or the possibility of an alternate transportation system, in anticipation of such a condition, should carefully be assessed in any further evaluation of this alternative.

COST BREAKDOWN
ALTERNATIVE EIGHT

| | CAPITAL COST | | | INTEREST CHARGES AND OPERATING COST | | ANNUAL COST | |
|---|---|---|---|---|---|---|---|
| | TOTAL | PER[1] AN-NUM | PER TON | TOTAL | PER TON | TOTAL | PER TON |
| | $million | | $ | $million | $ | $million | $ |
| Road | 160.0 | 18.8 | 46.98 | 1.1 | 2.75 | 19.9 | 49.75 |
| Truck | 13.4 | 1.6 | 3.93 | 9.2 | 23.00 | 10.8 | 27.00 |
| Port | 3.5 | .4 | 1.03 | - | - | .4 | 1.03 |
| Marine | - | - | - | 14.0 | 35.00 | 14.0 | 35.00 |
| Storage | 5.0 | .6 | 1.47 | - | - | .6 | 1.47 |
| Intermodal Transfer | - | - | - | .2 | .50 | .2 | .50 |
| Interest Charges | - | - | - | 14.0 | 35.00 | 14.0 | 35.00 |
| Total | 181.9 | 21.4 | 53.41 | 38.5 | 96.25 | 59.9 | 149.75 |

Alternative Nine: Road to Hudson Bay, Marine to Foreign Smelter

The minimum road distance from the Contwoyto Lake region to port facilities at either Chesterfield Inlet or Rankin Inlet would be about 600 miles. If, for environmental reasons the road was not allowed to be constructed through the Thelon Game Sanctuary the road distance would increase significantly. Another option would be to construct the road only as far as Baker Lake and then transfer the concentrate to barges for transit down Chesterfield Inlet to the port. However, currently only one NTCL tug operates in the Keewatin area and total capacity is used in resupplying the several communities on the west shore of Hudson Bay. Therefore, significant capital outlay for barges and tugs would be necessary. More importantly though, timing of the barge shipments conflicts with timing of the export shipments from the Hudson Bay port, thus rendering this option unlikely.

Assuming that the permanent road was constructed directly to the Bay port, capital costs would amount to $312 million at a cost of $520 thousand per mile. These costs may appear excessive, in that most of the route would be constructed in a region characterized by a sparse density of trees. Nevertheless, the incidence of lakes and rivers in the region is high, so that bridge costs might offset any savings gained from reduced clearing costs. Also, the very isolated nature of the region combined with its limited access would more than offset any savings resulting from clearing costs in this region relative to those north of Great Slave Lake.

Neither Chesterfield Inlet nor Rankin Inlet has port facilities capable of servicing ocean going vessels or storage facilities to stock the concentrate for summer shipment. Again basing capital costs on these experienced by Nanisivik Mines Ltd. total port construction costs would be about $3.5 million and storage facilities with capacity for storing up to 400,000 tons of concentrate would require an additional $5-5.5 million outlay.

Assuming that 387 trucks were required during the twenty year life of the mines and that capital costs for tractor trailor units averaged $50,000, with additional charges of $17,000 for the platform/flatbed unit, capital costs for the truck fleet would average $26.0 million.

Operating costs for the aforementioned capital requirements would total $26.6 million with road costs accounting for $2.4 million, truck operating expenses of $24 million, assuming a cost of 10 cents per ton-mile and intermodal transfer charges of $200 thousand. Inventory holding charges would be an additional $14 million per annum assuming a 10 per cent cost of capital and that the concentrate would be stored for up to one year.

Total annual transportation costs then, excluding the marine rate, amount to $81.3 million, including annual capital costs of $40.7 million, operating costs of $26.6 million and inventory holding charges of $14 million. On a per tonnage basis, 'land' charges would amount to $203.25. This cost already exceeds total transportation charges incurred in other alternatives discussed herein. It can be deduced then, that the total road/marine route would not be economically justifiable.

Alternative Ten: Road to Yellowknife, Barge to Hay River, Rail to Smelter

It is unlikely that this route would be utilized if $174 million were expended for a permanent road structure. With the shipping season on Great Slave Lake limited to four months, inventory holding costs and storage facilities would add significantly to annual transportation costs. Additional storage facilities would be necessary at the railhead also. Since the Yellowknife Highway is operative basically year-round, the road/rail route as in Alternative five is more likely.

Alternative Eleven: Road to Great Bear Lake, Marine/Road to the Mackenzie River, Barge to Hay River, Rail to Smelter

It would not be practical to expend approximately $172 million for construction of a minimal 330 mile highway to Great Bear Lake, where the shipping season is limited to three months, when for an additional outlay of $4 million, a year-round road linking the mines to the south could be constructed. The southbound route would also avoid expensive storage facilities and inventory holding costs, as well as the requirement for extensive capital investment for a fleet of barges.

Alternative Twelve: Road to Bathurst Inlet, Barge to Hay River via Tuktoyaktuk and Mackenzie River, Rail to Smelter

The shipping season between Bathurst Inlet and Tuktoyaktuk would be restricted to

two months due to ice conditions if the '1,500' series barges were used for transporting the concentrate. Each barge tow would be limited to three barges in the Arctic waters, with a capacity then of 4,500 tons per trip. Given a turnaround time of about one and one-half weeks between Bathurst Inlet and Tuktoyaktuk, eighteen tugs and fifty-four '1500' series barges would be necessary.

Draught restrictions on the Mackenzie River allow for only 1,350 tons per barge so that the tonnage on the '1500' series barges delivered to Tuktoyaktuk would either have to be reduced or transferred to the smaller '1350' series barges. Tugs on the Mackenzie River are capable of towing six '1350' series barges resulting in a payload of 8,100 tons per trip. Given a four month shipping season and assuming a turnaround time of two weeks from Tuktoyaktuk to Hay River 7 tugs and 42 of the '1350' series barges would be required.

Tremendous capital requirements for the necessary barging capacity combined with other factors such as time and tonnage constraints imposed by the short shipping season, ice flows and allowable barge draughts on the Mackenzie River render this alternative economically and technically infeasible. Although dredging of the Mackenzie River could be undertaken, the other constraints, as overriding factors, would still rule out this alternative as viable.

Alternative Thirteen: Road to Baker Lake, Barge to James Bay, Road to Smelter

As was indicated in the analysis of Alternative Nine, both road and truck capital and operating costs to Hudson Bay would be prohibitive. Port facilities would have to be extensive enough to store the tugs and barges for the winter and allow for drydocking of the entire fleet for shipping inspection.

Specialized deep-sea hopper barges would be necessary to transport the ore concentrate from Baker Lake to James Bay. These barges would have to be ordered as there are

none available for service in Canada at this time. Costs for 8,000 ton capacity barge would be about $1.5 million (if constructed in Japan, close to $3 million if in Canada) and for the corresponding 8,000 horsepower tugs an additional $8 million. These costs reflect the difficulty of constructing such barges which would have to be light enough to meet the more shallow draught requirements of James Bay and Chesterfield Inlet, yet strong enough to weather stormy waters on Hudson Bay. Although actual turnaround time for each barge tow is not available, it is needless to say that barge and tug requirements for the limited two and one-half month shipping season would require significant capital outlay.

Finally, although the Ontario Northland Railway is routed up to Moosonee and may appear to be an attractive alternative to the Fort George road route, extensive repair to the rail track would be necessary for the railroad to provide the required service and extensive dredging at the mouth of the Moose River would be required for the barges to land at the railhead in Moosonee. The road route from Fort George to the Timmins smelter is in fairly good condition so that, additional capital outlay for upgrading the Ontario Northland railbed would not be necessary, unless of course, they offered to transport the concentrate at a significantly lower rate than the road tariff.

Although total transportation costs have not been assessed for this alternative for lack of necessary cost data, it is evident that the construction of a 600 mile road across the Mackenzie and Keewatin Districts is not economically viable. Furthermore, the availability and order of magnitude of capital costs of large capacity barges requires further investigation. Canarctic has one ice-strengthened shallow draught barge in the Beaufort Sea which is capable of transporting 11,000 tons of freight. It requires two 9,000 horsepower tugs however to mobilize it in the Arctic waters. As total costs for several of the other alternatives are more economical than the surface portion of costs generated in this routing (i.e. ex. marine costs) it can be concluded that it would not be attractive based on economic considerations.

## SUMMARY

Several of the specified thirteen alternatives were ruled out prior to the determination of the total transportation cost on the basis of exorbitant costs or technological shortcomings. Construction costs for a 600 mile road to Hudson Bay combined with capital requirements for trucking equipment, port facilities and storage facilities would generate prohibitive costs, excluding marine charges, so that Alternative Nine was shown to be economically infeasible. Alternatives Ten, Eleven and Twelve were ruled out because the short summer shipping season would necessitate extensive barge requirements, as well as generating the requirement for substantial storage facilities. Inventory holding costs would also be high. The road/barge route via Hudson Bay in Alternative Thirteen was similarly ruled out as economically unjustifiable for the same reason as was Alternative Nine. Also barge requirements would generate exorbitant capital costs as there do not exist currently in Canada any barges of the type needed for the required type of haul.

Alternatives Two (airship direct to domestic smelter) and Six (hovercraft/rail to domestic smelter) are not technically viable for the transporting of 400,000 tons of ore concentrate. Alternative Two however, has been included for comparative purposes in the summary of total costs of alternatives which were determined as generating 'reasonable' costs - see Tables 1-3.

As is obvious from the operating charges generated by the air mode in Alternative One, 747 freighters are not a viable mode of transport when compared to other modes, given strictly economic considerations. If timeliness of delivery to the smelter was an overriding factor in this evaluation, the direct air route might then have been shown to be attractive. However, such is not the case in the transporting of lead/zinc concentrate where the lowest obtainable delivery rate is necessary. The air mode is also capital intensive which generates high annual recovery requirements and thus increases the annual transportation charges proportionately - see Tables 1, 2 and 3.

TABLE I

SUMMARY OF ANNUAL TRANSPORTATION COSTS

| ALTERNATIVE NO. | TOTAL CAPITAL COST 20 YR. LIFE | PER ANNUM | ANNUAL OPERATING COST | INVENTORY HOLDING CHARGES | TOTAL ANNUAL COST | TOTAL COST PER TON |
|---|---|---|---|---|---|---|
| | $ millions | | $ millions | $ millions | $ millions | $ |
| One - Air | 368.6 | 43.3 | 195.7 | - | 239.0 | 597.50 |
| Two - Airship | 456.1 | 53.6 | 50.4 | - | 104.0 | 260.00 |
| Three - Air/rail | 192.1 | 22.6 | 53.7 | - | 76.3 | 190.75 |
| Four - Rail | 509.2 | 59.8 | 29.2 | - | 89.0 | 222.50 |
| Five - Road/rail | 216.5 | 25.4 | 42.0 | - | 67.4 | 168.50 |
| Seven - Rail/road/ rail | 448.7 | 52.7 | 35.6 | - | 88.3 | 220.65 |
| Eight - Road/ marine | 181.9 | 21.4 | 24.5 | 14.0 | 59.9 | 149.75 |

TABLE 2

TOTAL CAPITAL CONSTRUCTION COSTS

$ MILLIONS

| Alternate No. | Vehicle Acquisition[1] | Airport Construction | Rail Roadbed[2] | Rail Equipment | Truck Equipment | Road Construction | Port Facilities | Containers | Storage Facilities | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| One | 346.5 | 22.0 | | | | | | .11 | | 368.6 |
| Two | 456.0 | .1 | | | | | | | | 456.1 |
| Three | 148.5 | 22.0 | | 21.5 | | | | .06 | | 192.1 |
| Four | | | 483.0 | 26.2 | | | | | | 509.2 |
| Five | | | | 21.5 | | 195.0 | | | | 216.5 |
| Seven | | | 423.0 | 25.7 | | | | | | 448.7 |
| Eight | | | | | 13.4 | 160.0 | 3.5 | | 5.0 | 181.9 |

Notes: 1. Includes capital cost for air freighters in Alternatives one and three, and for airships in Alternative two.
2. Includes bridge capital construction cost chargeable to mines, at $21 million.

TABLE 3

TOTAL OPERATING AND INVENTORY HOLDING COSTS

$ MILLIONS

| Alternative No. | Vehicle Operations[1] | Airport Maintenance | Rail Haul | Road Haul | Road Maintenance | Intermodal Transfer | Total Operating Cost | Interest Charges on Inventory |
|---|---|---|---|---|---|---|---|---|
| One | 192.0 | .1 | | 3.6 | | | 195.7 | |
| Two | 50.4 | | | | | | 50.4 | |
| Three | 36.4 | .1 | 16.0 | | | 1.2 | 53.7 | |
| Four | | | 29.2 | | | | 29.2 | |
| Five | | | 16.0 | 23.5 | 1.3 | 1.2 | 42.0 | |
| Seven | | | 24.0 | 9.2 | | 2.4 | 35.6 | |
| Eight | 14.0 | | | 9.2 | 1.1 | .2 | 24.5 | 14.0 |

Note: [1] Includes operating costs for the 747 freighters in Alternatives One and Three, airships in Alternative Two, and marine charges in Alternative Eight.

Alternative Two would also generate extensive capital requirements and excessively high annual transportation charges. The main reason though for ruling out airships as a viable alternative is that the structures have not been developed technologically to the place where reliable service could be guaranteed. Capital costs have not yet been fully determined and any current estimates could be considerably understated.

The hovercraft alternative can be ruled out for similar reasons as the airship alternative. Hovercraft are beginning to be recognized as a viable transportation alternative. Just recently, the Canadian Coast Guard indicated that they were calling for proposals from firms interested in competing for the design and construction contract for an ice-breaking hovercraft. Petrocan has also indicated that they are investigating the construction of a 2,500 ton hovercraft capable of transporting 10,000 barrels of oil. Further consideration of this alternative must be reserved until hovercraft structures have been proven to be both economically feasible and a viable means of transportation in the north.

The air/rail route, as discussed in Alternative Three, is not as cost-efficient as some of the other routes assessed herein. Surprisingly enough at $190.75 per ton it is cheaper than the all-rail route. However, with fuel costs generating about one-half of annual operating charges and given that the alternative generates high operating charges relative to annual capital charges, this alternative would be a risky investment, especially in light of the present period of escalating fuel prices.

The total rail route, Alternative Four, is also more expensive than other of the modal combinations evaluated herein. About two-thirds of the total annual transportation charge, determined to be $222.50 per ton, is accounted for by annual capital requirements necessary to recover construction costs of the northern railroad. It was shown in

the analysis of the alternative that additional tonnage would be necessary to effectively reduce total costs. The capital costs are too excessive to be borne solely by Texasgulf and Cominco. However, if other companies were to undertake developments in the area east of Great Bear Lake, cost-sharing by all of the concerns might allow for the construction of an Arctic railroad. For similar reasons, Alternative Seven, the rail/road/rail system was not as economically efficient as the road/rail route. It was shown however, that this Alternative was slightly more economical in terms of costs than the all rail Alternative, generating total costs per ton of $220.65 compared with $222.50 for the all rail route.

The road/rail route, Alternative Five, was determined as the most cost-efficient route for domestic shipments. The $168.50 charge per ton reflects minimum charges to a Canadian smelter, as rail charges were based on the Trail smelter as the final destination for the rail haul. Operating costs for this route account for 62 percent of total annual transportation charges.

Lastly, the road/marine route, discussed in Alternative Eight, generated the least transportation charges of all potentially viable routes and systems at $149.75 per ton. This route can attribute its attractiveness to low charter shipping rates and the shorter road haul distance to the port, necessitating lower capital requirements for road construction and trucking equipment. If the marine rate was substantially higher, as could well be the case five years from now, total annual charges might render the alternative economically unattractive. For example, if the ocean rate from Bathurst Inlet to Japan or Rotterdam was $80 per short ton (Canadian $) rather than the $35 per ton used in the evaluation, operating costs would escalate by $18 million to $42.5 million with total costs per annum amounting to $77.9 million or $194.75 per ton. Nevertheless, the effectiveness or feasibility of an alternative is not determined solely by its merits relative to the other charges assessed herein, but rather to the net smelter return and mine operating costs, amongst other factors.

In summary then, if the concentrate were to be shipped to a domestic smelter, the road/rail route should be reassessed with an extensive evaluation of capital and operating requirements undertaken. Similarily, the road/marine route would require an in-depth evaluation should the demand for the concentrate come from foreign smelters.

## CONCLUSIONS

The routes identified herein as being the most cost-efficient and technologically viable were the road/rail route requiring the construction of approximately a 335 mile road south from the mines to the Yellowknife Highway and the road/marine route requiring the construction of approximately a 272 mile road north to Bathurst Inlet, storage facilities and port facilities.

It is obvious that a transportation network, in itself, is not the deciding factor in a mining company's decision as to whether or not to proceed with a new mine. Other capital requirements, mine operating costs, current markets and world supply of lead/zinc/copper concentrate are some of the other factors that must be considered in the decision-making process. Nevertheless, the intended purpose of this paper was to analyze the alternative means and routes for transporting base metal concentrates out of the area east of Great Bear Lake and to recommend which of the alternatives assessed require further study on the basis of economic and technical feasibility.

Based on the analysis and costs derived for each alternative, it is evident that further in-depth investigation of Alternatives five and eight is necessary for an accurate indication of total capital requirements and operating costs. It would also be advantageous to further examine the all rail and rail/road/rail routes to obtain more accurate information as to required traffic levels which would make the route economically attractive. Further analysis could also be used to identify possible areas where cost-sharing between the mines and government might occur.

APPENDIX I

## MINERAL RESOURCES POTENTIAL

Base metal deposits discussed herein have been considered only if the resource potential exceeds 1 million tons.

### BATHURST NORESEMINES (Hackett River)

(1) Location: 75°55'/108°22'

(2) Ownership: Bathurst Norsemines Limited, Cominco Limited

(3) Tonnage: Has been estimated to contain about 20,000,000 (1974)

(4) Grade: 4.98% Zn, 0.75% Pb, 0.41% Cu, 4.37 oz/t Ag, 0.013 oz/t Au

(5) Comments:

1974 - A preliminary transportation feasibility study commissioned by Cominco.

- Metallurgical test samples collected.
- Cominco officials speak of a potential of 100 million tons in a geologically favourable belt.

(6) Potential Concentrate Production

A 1976 feasibility study assumes production of 3,000 tons per day.

Assumptions: Ore milled: 1 million tons/year.

Recovery Rate: Zn & Pb 90%, Cu 85%

Conc. grade: Zn 55%, Pb 67%, Cu 30%

Life: 20 years

Zn: 81,491 s.t./year

Pb: 10,075 s.t./year

Cu: 11,617 s.t./year

## HIGH LAKE

(1) Location: 67° 22'45"/110° 51'19"

(2) Ownership: Kennco Exploration (Canada) Ltd.

(3) Tonnage: 5,206,856 (1967)

(4) Grade: 2.45% Zn, 3.53% Cu, 0.23 oz/t Au.

(5) Comments:

There is a good potential for more ore as the known deposit is still open at depth.

Other ore bodies are a possibility.

(6) Potential Concentrate Production

Assumptions: Life 10 years

conc. grade: same as above

Recovery grade: same as above

Zn: 20,960 s.t./year

Cu: 52,077 s.t./year

## IZOK LAKE

(1) Location: 65°38'/112°47'45"

(2) Ownership: Texasgulf Incorporated

(3) Tonnage: 12,000,000 (1976)

(4) Grade: 2.82% Cu, 13.7% Zn, 1.42% Pb, 2.05 oz/t Ag., 70.14 gm/t An

(5) Comments:

This would be an open pit operation.

Additional potential ore could be 10 to 14 million tons

(6) Potential Concentrate Production

Assumptions: Life 15 years

Cu: 63,920 s.t./year

Zn: 179,346 s.t./year

Pb: 15,260 s.t./year

HOOD RIVER

The # 10 and # 41 deposits of Texasgulf 30 miles north of Izok Lake add 970,000 tons of mineralization with various grades of copper, zinc and silver. It is expected that the company would mine these deposits during the life of Izok Lake and truck the ore to the mill at the main mine.

HOPE LAKE (Wreck Lake No. 47 Zone)

(1) Location: 67°24'25"/116°25'

(2) Ownership: Coppermine River Limited

(3) Tonnage: 4,162,433 (1968)

(4) Grade: 2.96% Cu

(5) Comments:

Open at depth and along strike

(6) Potential Concentrate Production

Assumptions: Life 5 years

others same as above

Cu: 69,818 s.t./year

JUNE

(1) Location: 67°34'25"/115°03'30"

(2) Ownership: Bernack Coppermine Exploration Limited

(3) Tonnage: 1,000,000 (1969)

(4) Grade: 2.5% Cu.

(5) Comments:

Grade and tonnage cannot be confirmed from DIAND data.

This deposit is less than 50 miles from the # 47 deposit at Hope Lake. It could be mined at the same time as the [redacted]

(6) Potential Concentrate Production

Life: 2 years

Cu: 35,417 s.t./year

APPENDIX II

## ADDITIONAL INFORMATION FOR COST DERIVATION

### Alternative One

1. Number of freighters required

$$\frac{\text{4000 hours per year maximum level of utilization per aircraft}}{\text{8 hours air time per return trip}}$$

= 500 trips maximum per aircraft per year

500 loads/year per aircraft x 130 tons per load

= 65,000 tons per aircraft per annum

$$\frac{\text{400,000 tons}}{\text{65,000 tons/aircraft}} = 6.2 = \underline{7} \text{ airfreighters required}$$

2. Number of containers required

assume: using 4 ton flexible containers with 6 year life

-dumped directly at smelter and returned to mine immediately

(i.e. no time lag)

assume: 4.3 freighters fly 2 return trips per day

4.3 freighters x 32.5 containers/flight = 140 containers

$$\frac{\text{130 tons/trip}}{\text{4 tons/container}} = 32.5 \text{ containers per freighter per trip}$$

- allowing 5 containers for contingency then, would require 145 containers every 6 year period .

- for 20 year mine life require 485 containers

Alternative Two

1. Number of airships required.

- allow 4 hours for loading and unloading

$\frac{\text{4000 miles per return trip}}{\text{100 miles per hour}}$ = 40 hours per trip

$\frac{\text{3500 hours maximum utilization per annum}}{\text{40 hours per trip}}$ = 87.5 trips/annum

87.5 trips x 400 tons/trip = 35,000 trips per airship per annum

$\frac{\text{400,000 tons}}{\text{35,000 tons/airship}}$ = 11.4 = 12 airships required

Alternative Three

1. Number of air freighters required.

assume - 550 miles per hour cruising speed

- 350 air miles from Contwoyto to Pine Point

- 4000 hours per annum maximum level of utilization per air freighter

$\frac{\text{550 miles/hour}}{\text{350 miles/trip}}$ = .64 hours = say 1 hour each way

- allow 2 hours air time and 4 hours ground time per return trip i.e. turnaround time of 6 hours.

$\frac{\text{4000 hours/year max. utilization}}{\text{2 air hours/trip}}$ = 2000 trips/annum

2000 trips x 130 tons/trip = 260,000 tons per freighter per annum

∴ 2 air freighters could carry in excess of 400,00 tons

- however 4000 air hours + 8000 ground hours = 12000 hrs/annum which exceeds 8760 calender hours.
- due to time constraint require 3 freighters per annum.

2. Number of containers required

- as determined in Alternative One require 32.5 containers per flight
- assume 2.11 freighters fly 4 return trips each day

2.11 x 32.5 = 69 containers

plus 3% for contingency ∴ require 72 containers every 6 years

$$72 \times \frac{20}{6} = \underline{240} \text{ containers}$$

Alternative Four

1. Rolling stock required

assume - average train speed 45 miles per hour
- distance from mines to Enterprise 550 miles
- 30 days turnaround for ore cars from Enterprise to Trail smelter
- three southbound trains per week out of Enterprise and car load weight restriction of 65 tons per car

$$\frac{33{,}333 \text{ tons per month}}{65 \text{ tons per car}}$$

= 513 cars per month minimal requirement in order to meet annual delivery requirements of 400,000 tons per annum.

Allowing for contingencies require about 580 ore hopper cars.

$\frac{513 \text{ cars/month}}{12 \text{ trains/month}}$ = 43 cars per train on G.S.L.R.

- for Contwoyto/Enterprise link require 5 diesels, 3 cabooses, ore hoppers for delivery to Enterprise as well as loading equipment at the mines and a freight shed.

Total Cost

| | | |
|---|---|---|
| 5 diesel (1 for contingency) | @$600 thousand each | $3.0 million |
| 3 cabooses (1 for contingency) | @$65 thousand each | .195 million |
| 580 ore hoppers | @$37 thousand each | 21.46 million |
| Total rolling stock | | $24.655 million |
| mine loading equipment | | .685 |
| freight shed | | .829 |
| Total Rail Freight Capital Requirements | | $26.169 million |

2. Cost-compensating Tariff for extended railroad

Total cost per ton - Enterprise/Trail rate and capital cost per ton

= $225.50 - $46.25 = $179.25

$\therefore \frac{179.25/\text{ton}}{550 \text{ miles}}$

= 32¢ per ton-mile

3. Comparison of road to rail haul rate on Enterprise/Contwoyto segment of haul

Rail haul $\frac{\$176.25/\text{ton}}{550 \text{ miles}}$ = 32¢ per ton-mile

Road haul $\frac{\$122.25/\text{ton}}{550 \text{ miles}}$ = 22¢ per ton-mile

$\therefore$ differential of 10¢ per ton-mile

4. Sensitivity Analysis

Required traffic level to be cost competitive with trucking costs on Contwoyto/Enterprise haul.

a) assume - 800,000 tons of traffic annually
- average train speed 45 miles per hour
- distance from mine to Enterprise 550 miles
- 30 days turnaround time for ore hoppers from Enterprise to Trail smelter
- 3 southbound trains from Enterprise per week

Require

| | | |
|---|---|---|
| 580 x 2 ore hoppers | @ $ 37 thousand | $42.9 million |
| 3 x 2 cabooses | @ 65 thousand | .4 million |
| 5 x 2 diesels | @ 600 thousand | 6.0 million |
| | | $49.3 million |
| mine loading equipment | 2 x $685 thousand | 1.4 million |
| freight shed | 2 x 829 thousand | 1.7 million |
| Total Rail Freight Capital Requirements | | $52.4 million |

Operating Costs - Rail

Contwoyto/Enterprise

$.06/return ton-mile x 440 million ton-miles = $26.4 million

Enterprise/Trail

$40/ton x 800,000 ton = 32.0 million

Total rail operating costs $58.4 million

## COST BREAKDOWN
## 800,000 TONS OF CONCENTRATE

| | CAPITAL COST | | | OPERATING COST | | ANNUAL COST | |
|---|---|---|---|---|---|---|---|
| | TOTAL | PER ANNUM[1] | PER TON | TOTAL | PER TON | TOTAL | PER TON |
| | $million | | $ | $million | $ | $million | $ |
| Contwoyto/Enterprise | | | | | | | |
| RR | 462.0 | 54.3 | 67.83 | 26.4 | 33.00 | 80.7 | 100.88 |
| Equipment | 9.5 | 1.1 | 1.39 | - | - | 1.1 | 1.38 |
| Bridge | 21.0 | 2.5 | 3.08 | - | - | 2.5 | 3.13 |
| Sub-total | 72.5 | 57.9 | 72.30 | 26.4 | 33.00 | 84.3 | 105.39 |
| RR | - | - | - | 32.0 | 40.00 | 32.0 | 40.00 |
| Equipment | 42.9 | 5.0 | 6.30 | - | - | 5.0 | 6.30 |
| Total | 115.4 | 62.9 | 78.60 | 58.4 | 73.00 | 121.3 | 151.69 |

1. assumes 10 percent annual rate of discount and 20 year life

4b) if 600,000 tons were transported annually and based on same assumptions as indicated for 800,000 tons

Require

| | | |
|---|---|---|
| 580 x 1.5 | @$37 thousand | $32.2 million |
| 3 x 1.5 say 5 | @ 65 thousand | .3 million |
| 5 x 1.5 say 8 | @ 600 thousand | 4.8 million |
| | | $37.3 million |
| mine loading equipment | 2 x $685 thousand | 1.4 million |
| freight shed | 2 x 829 thousand | 1.7 million |
| | | $40.4 million |

Operating Costs - Rail

Contwoyto/Enterprise

$.06/ton-mile x 330 million ton-miles = $19.8 million

Enterprise/Trail

$40/ton x 600,000 tons = $24.0 million

Total rail operating costs $43.8 million

COST BREAKDOWN
600,000 TONS OF CONCENTRATE

| | CAPITAL COST | | | OPERATING COST | | ANNUAL COST | |
|---|---|---|---|---|---|---|---|
| | TOTAL | PER[1] ANNUM | PER TON | TOTAL | PER TON | TOTAL | PER TON |
| | $ million | | $ | $million | $ | $ million | $ |
| Contwoyto/Enterprise | | | | | | | |
| RR | 462.0 | 54.3 | 90.44 | 19.8 | 33.00 | 74.1 | 123.50 |
| Equipment | 8.2 | 2.5 | 4.16 | - | - | 2.5 | 4.16 |
| Bridge | 21.0 | 2.5 | 4.11 | - | - | 2.5 | 4.11 |
| Sub-total | 491.2 | 59.3 | 98.71 | 19.8 | 33.00 | 79.1 | 131.77 |
| RR | - | - | - | 24.0 | 40.00 | 24.0 | 40.00 |
| Equipment | 32.2 | 3.8 | 6.30 | - | - | 3.8 | 6.30 |
| Total | 523.4 | 63.1 | 105.01 | 43.8 | 73.00 | 106.9 | 178.07 |

1. assumes 10 percent annual rate of discount and 20 year life

Alternative Six

1. Number of hovercraft required

assume:
- maximum air utilization per annum of 3,500 hours
- speed of 100 miles per hours and load of 115 tons per trip
- 400 miles to Pine Point
- 8 hours air time, 4 hours ground time for total turnaround time of 12 hours

$\frac{3500 \text{ hours/year}}{8 \text{ hours/trip}}$ = 437.5 trips/annum

437.5 trips x 115 tons per trip = 50,312 tons per hovercraft per annum

$\frac{400{,}000 \text{ tons}}{50{,}312 \text{ tons/hovercraft}}$ = 8 hovercraft necessary

Alternative Seven

1. Rolling Stock Requirements for Northern Railroad

$\frac{335 \text{ miles (Contwoyto to Rae-Edzo)}}{45 \text{ miles per hour}}$ = 7.4 hours for 1 way trip

at 33,333 tons per month requiring transport assume 1 return trip per day

$\frac{33{,}333 \text{ tons/months}}{30 \text{ days}}$ = 1,111 tons/day

$\frac{1{,}111 \text{ tons/day}}{65 \text{ tons/car}}$ = 17 cars/day

- allow for 20 ore hopper cars and 1 train per day from Contwoyto to Rae-Edzo

| | |
|---|---|
| 20 hoppers x $ 37 thousand | $ 740,000 |
| 3 diesels x 600 thousand | 1,800,000 |
| 2 cabooses x 65 thousand | 130,000 |
| mine loading equipment | 685,000 |
| freight shed | 829,000 |
| Sub-Total | $ 4,184,000 |
| 580 ore hoppers x $37 thousand | 21,460,000 |
| Total capital outlay for rail equipment | $ 25,644,000 |

2. Rail and Truck operating charges

Rail 335 miles x 400,000 tons = 134 million ton-miles

$.06/ton-mile x 134 million ton-miles = $8.04 million

Truck 215 miles x 400,000 tons = 86 million ton-miles

$.107/ton-mile x 86 million ton-miles = $9.2 million

Alternative Eight

1. Capital outlay for truck fleet

$$\frac{272 \text{ miles}}{45 \text{ miles/hour}} = 6.04 \text{ hours one-way}$$

- assuming each truck carries a 30 ton load and a turnaround time of 16 hours, each truck would be capable of transporting an average 45 tons per day

$$\frac{1{,}096 \text{ tons produced/day}}{45 \text{ tons per truck/day}} = 24.4 \text{ say } 25 \text{ trucks}$$

- allow for 30 trucks including for contingencies

- say trucks have 3 year life, during 20 year mine life would require 200 trucks

200 tractors x $50,000 = $10 million

200 dump-trailers x 17,000 = 3.4 million
Total cost over 20 years $13.4 million

2. Operating costs for truck fleet

400,000 tons x 252 miles = 108.8 million ton-miles

given cost of 8.5 cents/ton-mile

$.085 x 108.8 million ton-miles = $9.2 million

trucking cost compensatory rate $9.2 million + $13.4 million = $22.6 million

$$\frac{\$22.6 \text{ million}}{108.8 \text{ million ton-miles}} = 20.8 \text{ cents/ton-mile}$$

3. Marine charges

1978 charter rate for lead/zinc concentrate shipped from Nanisivik to Antwerp/Rotterdam by SALEN

$20.50 US/tonne = $24.85 CDN/short ton
($1 US = $.90 CDN)

.. 400,000 tons x $24.85 = $9.94 million

- however Bathurst Inlet takes approximately 3 shipping days longer to reach than the Nanisivik mine
- currently return trip Nanisivik/Europe 26 days for Class 2 Arctic Vessel
- assume return trip Bathurst Inlet/Europe 33 days for Class 2 Arctic Vessel
- by prorating the SALEN rate strictly on distance and allowing for more severe ice conditions assume charter rate to be $35 per ton

$35 x 400,000 = $14 million

4. Interest Charges on Holding Inventory Northeast Mackenzie

- Ore value per annum $350 x 400,000 tons = $140 million
- At an interest rate of 10%, over 1 year interest charges would total $14 million or $35 per ton.

Nanisivik 133,980 metric tonnes x 1.102 = 147,646 short tons

3/4 x 147,646 tons x $350 = $38.8 million stored ore value

- At an interest rate of 8.4% over 9 months interest charges would total $2.4 million or $16.56 per ton.

Alternative Nine

1. Capital outlay for truck fleet

$\frac{600 \text{ miles/trip}}{45 \text{ miles/hour}}$ = 13.3 hours one way

- assume turnaround time of 34 hours and 30 tons per trip ∴ 1.42 days per trip. Therefore in 1 day each truck would move 21.1 tons

$\frac{1,096 \text{ tons produced per day}}{21.1 \text{ tons per trip}}$ = 51.9 trucks/day say 52 trucks

- allowing for contingencies, allow for 58 trucks per annum

58 trucks for 3 years
∴ 387 trucks for 20 years

387 tractors x $50,000 = $19.4 million

387 trailors x $17,000 = 6.6 million

Total capital cost $26.0 million

2. Operating charges

- Road 600 miles x $4,000/mile = $2.4 million

- Truck operations 400,000 tons x 600 miles = 240 million ton-miles

240 million ton-miles x 10¢/ton-mile = $24 million

- Intermodal transfer

400,000 tons x $.50 = $200,000

- Interest on inventory storage

- total inventory value

$350/ton x 400,000 tons = $140 million

at interest of 10 percent, to store for 12 months would cost $14 million

Alternative Twelve

1. Barge/Tug Requirements

Tuktoyaktuk/Bathurst Inlet - assume 3 barge tow

$\frac{\text{8 week shipping season}}{\text{1.5 weeks/trip}}$ = 5.3 trips/season per tow say 5

$\frac{\text{400,000 tons}}{\text{1,500 tons x 3 barges/tow}}$ = requirement 89 tows

$\frac{\text{89 tows}}{\text{5 trips/tow/season}}$ = 17.8 = 18 tows required

∴ 18 tugs and 54 of the '1500' series barges would be a minimal requirement.

Tuktoyaktuk/Hay River - assume 6 barge tow

$\frac{\text{16 week shipping season}}{\text{2 weeks per trip}}$ = 8 trips/season/tow

$\frac{\text{400,000 tons}}{\text{1,350 x 6 tons/tow}}$ = 49 tows required per shipping season

$\frac{\text{49 tows}}{\text{8 trips/season}}$ = 6.1 say 7 tows required allowing for contingencies

∴ require 7 tugs and 42 of the '1350' series barges.