THE IMPACTS OF ENVIRONMENTAL AND SOCIO-ECONOMIC COSTS ON BEAUFORT SEA - MACKENZIE DELTA HYDROCARBON DEVELOPMENT VIABILITY

By

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ABSTRACT

Cost data from different marine and pipeline scenarios were analyzed under changing world oil price and discount assumptions to determine a minimum economic scale for Beaufort Sea - Mackenzie Delta hydrocarbon development. Environmental and socio-economic impacts were included to supplement the purely economic analysis.

The minimum economic scale project, a sixteen-inch pipeline through the Mackenzie Valley, was found to be marginally economic. When environmental and social costs were assumed to be internalized by the companies involved, and federal government exploration and development incentives disregarded, the minimum scale project was found to yield a negative internal rate of return.

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CHAPTER 1 INTRODUCTION

1.1 Introduction

Canada has been a net exporter of energy since 1969, one of only five developed countries in the world. Export revenues from natural gas, electricity and other energy forms have greatly and consistently exceeded payments for imported oil. The trend throughout the 1970's and early 1980's, however, towards ever-increasing oil imports led to the designation of oil as "Canada's energy problem" (Energy, Mines and Resources, 1982, p. 13). This latter tendency, coupled with several major leaps in world oil prices, created a situation of almost crisis proportions.

In response the Federal government developed the first explicit national energy policy - the (1980) National Energy Program (NEP). The main objective of this measure was to achieve independence from the world oil market by 1990. Since conventional oil reserves in western Canada are dwindling, the NEP places great emphasis on the discovery and development of new domestic sources of supply.

The Beaufort Sea - Mackenzie Delta area is one of three frontier areas in Canada which appear to contain significant commercial accumulations of oil and gas. The offshore East Coast area and the Arctic Islands are also regions with such promise. It was originally anticipated that frontier production would increasingly contribute to future Canadian petroleum production (Path Economics Ltd., 1983), and that there existed a long-term need to continue concurrent exploration and development of all commercially viable reservoirs in order to meet projected demand (Dome et al., 1982a).

The current situation, however, one of worldwide economic recession and falling world oil prices linked with reduced consumption, has led to the questioning of the need and economic feasibility of frontier development; in particular, that of the Beaufort Sea - Mackenzie Delta region. Such energy development may be viable only when oil prices rise consistently in real terms. Since the outlook for international oil prices is uncertain, 'megaprojects' which require large, long-term investments and may be only marginally economic warrant extensive scrutiny.

It is important to note that at such times, when a project is only marginally beneficial (that is, economic returns only slightly exceed cost outlays), there arises the possibility that the decision should be based on alternative criteria. For instance, environmental or socio-economic disadvantages could far outweigh a small economic gain. It is, however, up to the decision-maker to determine the relative weightings of all impacts.

1.2 Objective of the Study

This study seeks to provide estimates of environmental and socio-economic impacts as a supplement to a purely economic analysis, of Beaufort Sea - Mackenzie Delta hydrocarbon development. The concern is whether non-economic impacts reinforce or negate the economic analysis. An attempt is made to predict the outcome considering these additional impacts.

1.3 The Beaufort Sea - Mackenzie Delta Project: An Overview

Approximately fifty companies hold exploration permits for the Beaufort region. The area's three major operators are Esso Resources Canada Limited, Dome Petroleum Limited and Gulf Canada Resources Inc. An estimated 2.6 billion dollars spent on exploration in the Beaufort Sea - Mackenzie Delta since the early 1950's has led to the discovery of both on- and offshore oil and gas reservoirs (Dome et al., 1980)(see Figure 1.1).

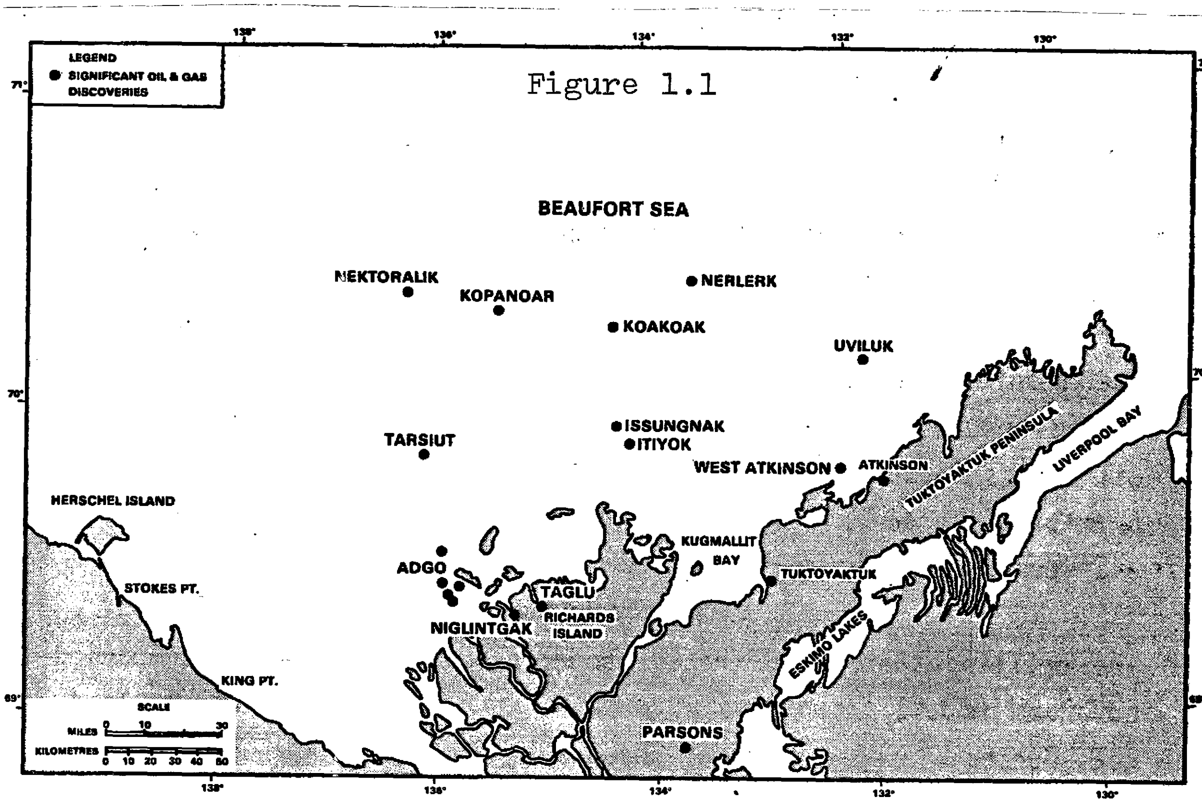


Figure 1.1

Several significant oil and gas discoveries have been made in the Mackenzie Delta and offshore in the Beaufort Sea. The dots on this map show some of the main locations.

Source: Dome et al., 1982a, p.1.27

Oil was first discovered at Atkinson Point in 1970. The first offshore well, at Immerk, was drilled in three metres of water (not shown in Figure 1.1: it was a "dry hole" and therefore would not be considered a discovery). Offshore drilling currently takes place from drillships and from exploration (caisson-retained) islands. Twenty-one of these year-round islands have been built to date.

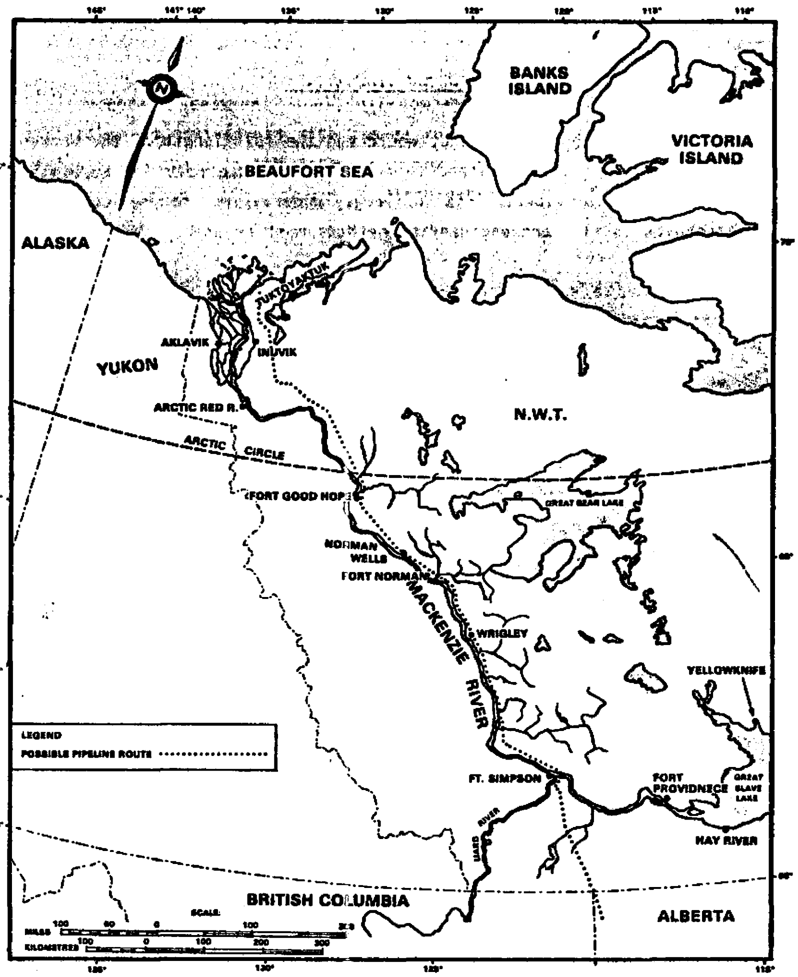
Estimates of the ultimately recoverable oil in the area range from 0.9 billion cubic metres (6.3 billion barrels) to 5.1 billion cubic metres (32 billion barrels)(Dome et al., 1983e). The Ministry of Energy, Mines and Resources estimated in the 1982 NEP Update that the combined area of the Beaufort Sea and Mackenzie Delta contained 1.5 billion cubic metres (9.4 billion barrels) of oil (Energy, Mines and Resources, 1982). Although estimates of future output differ, it is generally believed within the oil industry that the first production (and delivery to southern markets) could occur by 1990 (Maier, July 1984).

Not one of the fields yet discovered has been found to be commercially viable. This is likely due to the fact that a much greater quantity of threshold reserves is required to develop an offshore field than one that is onshore because associated costs for exploration and development are much less for the latter. However, this does not mean that several fields produced in combination would not be commercially viable; it is quite probable that such associated production will be essential to initial development in the Beaufort Sea - Mackenzie Delta area.

The varied development plans for the region, submitted jointly by Dome, Gulf and Esso, list initial production as early as 1986 (Dome et al., 1982b). The Beaufort Sea Environmental Assessment Panel predicts that the earliest commercial shipments from the Beaufort Sea could be in 1988 (Hamilton Spectator, July 31, 1984). The predicted outputs range from a rate, bounded only by technical constraints (not economic or regulatory) of 60,000 m^3 per day (380,000 bbl per day) by 1990 and 200,000 m^3 per day (1,260,000 bbl per day) by the year 2000 (Dome et al., 1982b), to an offshore minimum economically feasible rate that does not exceed 32,000 m^3 per day (200,000 bbl per day) (Dome, 1982f).

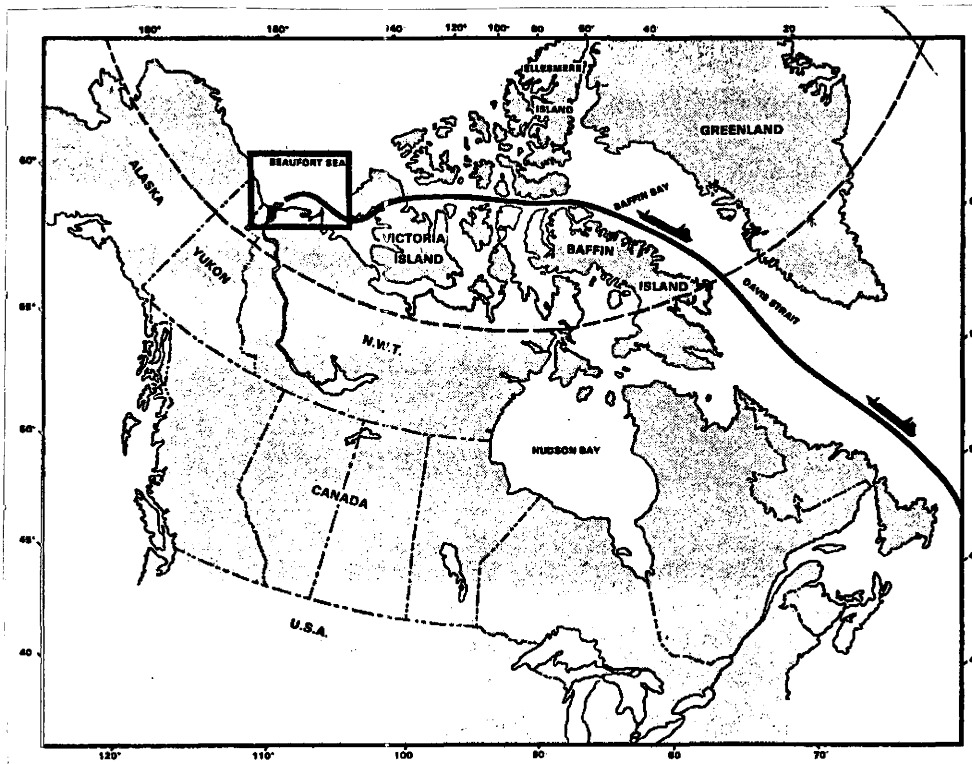
Development of the oil reserves must include some combination of land and offshore production facilities connected either to a main transmission pipeline (see Figure 1.2) or to an offshore storage and loading terminal for ocean-going tankers (see tanker route, Figure 1.3). If enough reserves could be discovered to justify the magnitude of investment, it is possible that both modes of transport might be utilized.

The technology required for the two transport modes differs. The Alaska oil pipeline provides an excellent example of the proven technology that exists for building in the harsh Northern environment. Alternatively, the tanker mode presents a great many technological hurdles. Members of the oil industry are, however, quite confident that none of these problems is insurmountable, and that an icebreaking tanker or a



Mackenzie Valley pipeline route.

Figure 1.2
Source: Dome et al., 1983e, p. 10



If Arctic tankers were used to carry oil from the Beaufort Sea they would likely travel through the Northwest Passage as shown here.

Figure 1.3
Source: Dome et al., 1983f, p. 9

buried pipeline can operate independently and safely year-round in the Arctic.

Government officials and Northern natives, however, are rather apprehensive about the possible negative and unmitigated impacts of the project on the Arctic land and its peoples. Traditionally, social and environmental concerns have been neglected when decisions regarding feasibility of projects have been made. In this case, those who will be impacted upon fear that great emphasis will be placed on potential monetary benefits to be gained by the companies involved, while noneconomic, indirect or intangible costs - which they feel are considerable - will be ignored.

Community and government concerns cover a wide spectrum: they range from the need for this type and size of project, to the risk and impact of an oil spill, to the potential increase in drinking and violence among natives that could result from accelerated or large-scale development. Attempts by the federal government to allay fears such as this led to the institution of an environmental and socio-economic review process (1973). The preparation of an Environmental Impact Statement (EIS) by the proponents of the project is an integral part of this formal review. This occurs, however, only when significant environmental effects are anticipated, and the Federal Environmental Assessment Review Office (FEARO) establishes a panel to review the project.

No energy project proposal has ever been rejected on the basis of its environmental impact assessment, a procedure which is mandated by law (Lonergan, 1984 in press). In a project where there is obviously a very high internal rate of return, the environmental and social impacts - particularly in frontier areas - may not be very relevant. Where economic returns are marginal, however, and are very much a function of discount rate and future price, environmental and social impacts can be very important, and possibly be large enough to overturn the economic decision.

The Environmental Impact Statement for Hydrocarbon Development in the Beaufort Sea - Mackenzie Delta Region was submitted to FEARO in 1982. The Beaufort Sea Environmental Assessment Panel (March 1983) produced a statement of deficiencies for the EIS. The criticisms were such that several supplementary documents had to be provided by the proponents (Dome et al., 1983) in order to determine more accurately the potential environmental and socio-economic impacts of hydrocarbon development in the Beaufort Sea region.

CHAPTER 2 LITERATURE REVIEW

Both economic, and environmental and social analyses have been copiously studied and reviewed in current literature. The form of economic assessment utilized in this study, minimum economic scale, entails a comparison of monetized costs and benefits similar to that of cost-benefit analysis (CBA). The form of levelized supply and selling prices used herein corresponds to time-discounted CBA costs and benefits. Although CBA is possibly the most frequently used systematic method of evaluation, Hill (1967, as cited in McAllister, 1982) has major criticisms, several of which apply equally well to levelized price evaluations.

Firstly, intangibles cannot be incorporated into the analysis, and secondly, the results ignore equity effects. From a social perspective, proper evaluation of an investment project must encompass all costs and benefits: those directly pertaining to the project, and those imposed on other segments of society (Path Economics Ltd., 1983).

It is essential, therefore, that environmental interactions be explicitly incorporated into economic decision-making (Costanza, 1984). Until recently, the social costs of consumption of environmental resources had been excluded from economic consideration. Several authors, however, have proposed biophysical models which provide estimates of the magnitudes of environmental interactions and impacts (Odum 1971, Ayres 1978, Costanza et al. 1983; in Costanza, 1984). Costanza (1984) contends that this is not sufficient: these models must be linked to economic analyses through some form of market valuation, such as energy analysis. This, however, is beyond the limited scope of the present study.

Scaling checklists, although they fail to provide exact, quantitative valuations, permit the ranking of impacts in order of magnitude or severity (Shopley and Fuggle, 1982). Where an impact cannot be physically quantified, it is assigned a subjective value rating. A major shortcoming of such checklists is that they fail to distinguish between severity and importance; that is, while the impact on two different species may be equally severe, it may not be of equal importance. Therefore, it is necessary that judgements be made with reference to some framework of social values. Once a context has been established for environmental impact analysis, the interpretation of data becomes objective (Shopley and Fuggle, 1982).

A number of studies have utilized a checklist approach to identify the potential environmental impacts of Arctic hydrocarbon development on various biophysical resources (Environmental Sciences Ltd. 1982, Cowles et al. 1981). The Beaufort Sea-Mackenzie Delta Environmental Impact Statement (Dome et al., 1982), and its follow-up Supplementary Information volumes (Dome et al., 1983), estimated impacts and their degree of significance on birds, animals, fish and lower trophic levels. Socio-economic impacts upon the human population, where they are not numerically quantifiable, are also scaled in order of severity.

While such scales are suitable for rating most intangibles, they cannot be used to evaluate risk. For instance, although transportation of crude oil entails the possibility of major oil spills, the risks and their consequences can only be predicted with a limited degree of confidence (U.S. Department of the Interior, 1979). Beyer and Painter (1977) summarized historical oil spill statistics and attempted to forecast the future oil spill potential of marine tankers, offshore development facilities and onshore pipelines using probability estimates. However, they were unable to predict future reductions in spill volume of frequency due to technological, environmental and safety improvements, and thus their analysis has been accepted only as a worst case estimate.

CHAPTER 3 METHODOLOGY

3.1 Economic Analysis

3.1.1 Minimum Versus Optimum Economic Scale

Several methods may be used to estimate the desirability of investment in a large, long-term project. One involves the estimation of an optimum scale of output, which is achieved through the minimization of per unit average costs of production. This implies the realization of all economies of scale. An alternative method, which has been applied to this particular economic analysis, entails determining the minimum economic scale. An explanation of the important differences between these methods will indicate why the latter is more appropriate to the present study.

The optimum scale deals solely with minimizing average costs and therefore is not affected by the price of the final output. Conversely, the minimum economic scale is inversely related to the final value of the good. For example, the minimum economic scale will decrease as the value of the good increases. The value of the good will then support the higher per unit costs that will be associated with smaller scales of output. Only changes in the technical cost structure will alter the optimum scale.

Estimating the optimum scale was beyond the scope of this analysis firstly, because such an evaluation would require the analysis of all alternatives on a scale larger than that of the minimum economic scale.

3.1.2 Minimum Economic Scale

It is important to determine the minimum economic scale at which Beaufort Sea - Mackenzie Delta oil reserves can be developed and delivered to Southern Canada. By estimating the minimum reserves that will be required to proceed with development, it can be determined whether the required levels of reserves are available. Also, a minimum scale would suggest either the appropriate scale for initial development, or, should a larger project be attempted, the upper economic bound for per unit costs, beyond which the development would become uneconomic. In addition, it can be determined whether smaller scale options, which possibly reduce environmental and social impacts, remain economically viable (Path Economics Ltd., 1983). With respect to this study, since no particular alternative has yet been confirmed, one is unable to perform the customary cost-benefit analysis. Therefore, a minimum scale analysis provides a likely project from which to choose estimates of costs and benefits.

In evaluating the minimum economic scale of the Beaufort Sea - Mackenzie Delta project, the general approach taken follows the Path Economics Ltd. (1983) Analysis of the Minimum Ecomonic (sic) Scale of Developing Beaufort Sea Oil Reserves. The evaluation considers only alternatives that are technically feasible; that is, those modes that are being considered as potential alternatives by the oil industry. In order to identify the minimum economic scale, the alternatives examined represent low-scale production options. Using estimates of fixed and variable costs, economic evaluations of the alternatives are performed to test the viability of each alternative under various oil pricing assumptions. These identify minimum scales of development by indicating the economic feasibility of alternatives under changing economic conditions. Such minimum scales will be highly dependent upon the estimations of capital costs and forecasted oil prices.

Because the choice of a transportation mode is currently uncertain, two separate evaluations will be undertaken: one will determine the minimum economic scale of a project with a marine (tanker) base; the other will evaluate the minimum scale of a pipeline mode.

Economic viability will be determined solely by a comparison of revenue to costs. Revenue is defined as the value received for oil in the market (and is in this study equal to the world price for oil). Costs are those incurred in the development of the oil fields, and in the transport of oil to market, which will herein be considered to be Montreal, Quebec. Thus, only the actual costs directly incurred to produce and deliver the oil will be of consequence, while external environmental, social, and economic costs will be excluded.

3.1.2.1 Levelized Costs

A standard approach to economic comparison of several projects is to undertake a cash flow analysis in order to determine which project has the highest internal rate of return. However, the rate of return fails to indicate the extent to which a project realizes cost savings due to scale economies. It also requires an accurate knowledge of future revenues - something that is highly uncertain.

> Ideally, then, for comparative analysis, one requires a measure which is sensitive to project scale, timing, production, and costs, and which allows one to infer whether economies of scale are being realized. Further, the measure should not depend on an accurate revenue forecast. (Path Economics Ltd., 1983, p. 49).

Bradley (1967) has developed a useful measure: levelized cost. Levelization is used to calculate per unit cost by converting a stream of costs into a single per unit cost measure. Generally, levelization involves the calculation of a tariff which is applied to every unit of oil produced. The levelized costs are based upon development, production and transportation costs, and therefore can be compared to the delivered price (selling price of oil at the market). If the levelized cost (supply price) is less than this selling price, the project is economically viable; if the cost is greater than the return the alternative is uneconomic. The economic impacts of Beaufort Sea drilling are reported below and estimated using this measure of levelized cost.

Levelized costs are aggregated into two categories: field costs and transport costs. The former include the capital and operating costs of all development, production and gathering facilities. For the purposes of this study, only oil production is considered since oil recovery is the primary objective of companies drilling in the Beaufort region, and most information on the proposed projects is available on oil. Natural gas production would entail separate facilities and is not considered at this time. Transport costs include capital, operating and delivery costs of the transportation systems. With respect to the marine mode, this necessitates the calculation of costs of developing and operating the APLA, the tankers, and supporting marine equipment, as well as the shipping tariff from Point Tupper to Montreal. Transport costs for the pipeline scenarios include the capital and operating costs of the main trunk line and its supporting facilities, and the costs of delivering the oil to northern Alberta, and then to Montreal.

3.2 Environmental Impacts

A number of studies have attempted to identify the existing and potential impacts of Arctic hydrocarbon development upon various biophysical resources. The Environmental Sciences Ltd (1982) report detailed the effects of Beaufort exploration and production on marine flora and fauna, while Cowles et al. (1981) concentrated on marine mammals potentially impacted by offshore oil and gas development. The Beaufort Sea - Mackenzie Delta Environmental Impact Statement (1982), and its follow-up

Supplementary Information volumes (1983), estimated impacts, and their degree of significance, on birds, animals, and fish.

The present study attempts to present a synthesis of such environmental effects. Since there are two possible modes of oil transport, which would impact upon disparate regions, results are presented separately for each area affected. Both transport scenarios have similar impacts upon the Beaufort Sea - Mackenzie Delta exploration and production region, while the small-diameter pipeline impacts solely upon the Mackenzie Valley region, and the tanker mode upon the Northwest Passage region.

3.2.1 Definition of Impacts

The analysis is limited in its ability to accurately predict quantifiable impacts, and therefore a set of definitions of degrees of potential impacts is utilized to categorize effects that cannot be explicitly measured. These definitions focus on the regional populations of specific resources rather than on local groups of individuals, and lack any reference to resource use since such socio-economic factors are discussed in section 3.4. Due to the great size of the geographic area being considered, the emphasis is primarily regional. Definitions used for determining the degree of impact on biological resources (excluding terrestrial vegetation), as found in the EIS Mackenzie Valley Zone Summary (Dome et al., 1983), are categorized as follows, and explained in further detail in Appendix B: major, moderate, minor, and negligible.

Possible impacts of various development components on physical resources and vegetation have been evaluated using a different set of criteria. These involve spatial and temporal considerations rather than magnitude (proportion of the population affected). Spatial impacts are categorized as either local or regional, while temporal impacts can be short-, medium- or long-term. Detailed definitions are found in Appendix C.

Where possible, attempts are made to calculate numerical values. This is extremely difficult in all but a few cases, since there has been a dearth of comprehensive study in this area until very recently. Oilspills, however, are an anomaly. Although it is difficult to determine beforehand which impact definitions will best describe a spill, it is relatively straightforward to calculate discharge and oil spill predictions based upon historical statistics, and future production estimates.

It should be noted that in most cases it is assumed that mitigative measures, to prevent or minimize impacts, are an integral part of the development and would be applied when feasible. Therefore, most predicted impacts will be considered residual. However, in those cases where an adequate data base is lacking, a "worst case" approach ensures that estimates are conservative (Dome et al., 1982c).

There are important data deficiencies regarding Arctic resources. There is a current dearth of information about, for instance, marine life populations and movements, and accurate measurement of marine flora and fauna, and how they are impacted, is often difficult. No attempt has been made in this study to explicitly value natural resources; impact estimates are subjective, following the above scales, with few exceptions. Only one prior study attempted to value the marine wildlife in the southern Beaufort Sea (Brackel, 1977). Explicit, quantitative valuation of natural resources has taken two forms, "willingness-to-pay" and energy analysis, both of which are fraught with difficulty (Costanza, 1984).

3.3 Socio-Economic Issues

A socio-economic assessment forecasts the various impacts which may be experienced by the residents of the communities within the three regions affected by the Beaufort project. Analysis will focus on nine topics considered to be of greatest importance: population impacts, government and influence systems, economic impacts, effects on community physical infrastructures, family and community solidarity, social problems, health conditions, service delivery systems and community culture patterns.

As noted above, the consequences will differ for the two delivery modes and therefore the pipeline and tanker impact scenarios have been assessed independently, as has the Beaufort Sea - Mackenzie Delta production region.

"Manpower and population implications are key determinants of the social impact of developments of this nature but their estimation is fraught with difficulty" (Dome et al., 1983c). The bases for the EIS population projections and analysis were the Beaufort Sea Planning Model, Census Canada returns and the Northwest Territories' population and sectoral growth projections. Statistical projections made from this data cannot be considered wholly accurate, as the level of uncertainty regarding the future of the Canadian economy is very high. However, the results are expressed in ranges and are of sufficient accuracy for this study.

The resulting projections have in many cases been compared with a 'base case' analysis of the area economies (with zero migration over time), to compare potential Beaufort development demands with the level expected to occur if only current levels of exploration activity continue (Dome et al., 1983c). Both the direct and indirect population impacts resulting from each delivery mode have been incorporated into the projections.

3.3.1 Impact Assessment: Definitions

As with environmental concerns, definitions will be used to determine the significance of projected impacts, which will be labelled as negligible, minor, moderate or severe. Since the Beaufort EIS results are utilized in this study, the definitions of impacts must coincide, and are as found in Appendix C.

3.3.2 Impact Assessment: Limitations

These definitions have severe usage limitations, however, because of the inherent subjectivity of rating categories. There is no decisive level, for instance, which enables one to discern between impacts which are acceptable and ones which are not.

Corley (1984), in particular, has been critical of the validity of many of the socio-economic measures used in the Beaufort analysis. While he agrees that often such indicators are the best possible under less-than-perfect conditions he feels that many potential measures have been disregarded due to difficulties in deriving accurate statistics. For instance, renewable resource harvesting (hunting, fishing or trapping for money and/or as a source of 'country food') has been greatly underestimated because estimates exclude the number of pelts, seals or migratory birds kept for personal use, and the large amount of furs sent for auction to southern markets (Corley, 1984). Also, many statistics are sensitive to "human discretion". For instance, alcohol-related crime statistics depend on the willingness of a police officer to make a formal arrest (versus, say, giving the offender a warning, or failing to associate the crime with alcohol). Different crime reporting and charging practices can greatly influence statistical crime rates (Corley, 1984).

One must also bear in mind, however, that there have been a great number of impact studies similar to the Beaufort EIS completed for northern development projects (such as the Alyeska Pipeline and the James Bay Hydro project), and increasing amounts of literature written on social change in the north.

Therefore, although there is in some cases a large degree of inexactness, and ambiguous terminology, the level of information available for the study zones, and knowledge that can be gained from similar projects, suggest that one may be reasonably confident that Beaufort Sea - Mackenzie Delta impact assessments are valid at the general level required by this study.

CHAPTER 4 ANALYSIS AND RESULTS

4.1 Minimum Economic Scale

4.1.1 Marine Alternative

4.1.1.1 Marine Analysis

The marine alternative requires an offshore loading and storage facility built in shallow water (less than 20 metres in depth) to serve as a terminal for tankers transporting oil to southern Canada. Each tanker would have a capacity of 8000 m^3 per day (50,000 barrels per day). The oil would be transported to Point Tupper, Nova Scotia, where it would be transferred to smaller carriers. After reaching Portland, Maine the oil would be shipped via pipeline to Montreal for refinement (Dome et al., 1982b).

Path Economics (1983) analyzed six different marine scenarios, which had output capacities ranging from 8000 m^3 (50,000 barrels) per day (considered to be the minimum technically feasible scale) to 32,000 m^3 (200,000 barrels) per day (see Appendix A for detailed explanation of scenarios). This study analyzes the same six scenarios to determine a minimum scale project.

Dome Petroleum's Beaufort Sea Planning Model (1982) was the source of most of the cost and output data used in the Path Economics estimate of marine transportation and offshore development costs. Esso Resources Canada supplied cost and output data relevant to onshore development. The Environmental Impact Statement (1982), submitted jointly by Dome, Esso and Gulf, also provided much pertinent information.

Output and cost profiles previously determined by the Path Economics (1983) study will not be derived herein. Specific profiles for each scenario can be found in that document and in the Environmental Impact Statement (1982). As well, these documents contain more detailed information about the components of each scenario.

Based upon Path Economics' original cost data, current estimates were derived by escalating the 1982 costs by the rate of inflation: by 10.8% (Department of Finance, April 1983) to bring them into constant 1983 dollars and by 5.8% (Statistics Canada, 1984) to equal constant 1984 dollars (see Table 4.1).

Table 4.1 shows production and cost data for the six marine transportation scenarios. The levelized supply prices, calculated at differing real discount rates, are crucial for the identification of the minimum economic scale. The supply price can be defined in this particular study as that price that must be received (in Montreal) for each cubic metre of oil produced in order to enable all field and transportation costs incurred to be recovered. This includes a real return on capital investment.

A minimum scale project earns just enough revenue to recover all costs including a ten percent return on capital investment. The minimum real return on capital that is assumed

Table 4.1
Results of Cost Analysis *
Marine Scenarios (4)

	M-1	M-2	M-3	M-4	M-5	M-6
Number of Producing Fields:						
Offshore (1)	1s	1s, 1d	1s, 2d	2s, 2d	1s	1s
onshore					5	5
Number of Ships	1	2	4	4	2	2
Production Life (2)	4-28	4-28	4-28	4-28	4-28	4-28
Total Production [10^6 m^3; 10^6 bbls]	47; 296	103; 649	155; 977	198; 1247	81; 510	62; 391
Peak Production [10^3 m^3/d; 10^3 bbls/d]	7; 44	16; 101	29; 183	32; 202	16; 101	16; 101
Total Cost [Billion 1984 $]	14	27	37	40	21	16
Levelized Supply Price (r=10%):						
Field Costs per m^3; per bbl	265.18; 42.14	266.06; 42.28	247.31; 39.30	239.07; 37.99	222.01; 35.28	182.12; 28.94
Transportation Costs per m^3; per bbl	189.16; 30.06	119.63; 19.01	104.71; 16.64	96.97; 15.41	115.98; 18.43	123.09; 19.56
Supply Price $/$m^3$; $/bbl (3)	454.34; 72.20	385.69; 61.29	352.02; 55.94	336.04; 53.40	337.99; 53.71	305.21; 48.50
Levelized Supply Price ($/$m^3$; $/bbl) r=8%	412.75; 65.79	346.80; 55.11	316.22; 50.25	299.73; 47.63	312.44; 49.65	286.77; 45.57
Levelized Supply Price ($/$m^3$; $/bbl) r=5%	349.88; 55.60	294.95; 46.87	269.40; 42.82	252.53; 40.13	277.01; 44.02	261.59; 41.57

1. s = shallow water field (less than 20-25 metres)
   d = deep water field (greater than 25 metres)
2. Expressed as year of initial production to final year of production. 1982 equals year 0.
3. Levelized supply price equals sum of field costs (development plus operating) and transportation costs, both calculated on a levelized basis.
4. This table is based upon a combination of similar charts found in Path Economics Ltd (1983 pp 29, 61); in order to change to 1984 constant dollars costs have been escalated by 10.8 and 5.8 percent respectively.

* all cost are in 1984 dollars
r = real discount rate

to be required by oil companies is five percent. Any return above this level allows the excess to be taxed by the government without the project becoming uneconomic. The ten percent discount rate ensures a minimum return on private capital and permits normal levels of taxation by the government. The eight percent real return reduces taxes, and the five percent discount rate eliminates government taxation and a margin for cost overruns or price decreases.

4.1.1.2 Marine Minimum Economic Scale

In order to determine which scenarios are economic, the supply prices as shown in Table 4.1 must be compared to the selling price in Montreal. And, to enable comparison, the selling price must also be levelized.

The current world price for oil (landed in Montreal) is approximately \$261.45 per m^3 or \$41.50 per barrel (Globe and Mail, July 17, 1984). This can be converted to an estimate of levelized selling price by utilizing the following formula:

$$p = \frac{d}{d-r} \cdot P_o \qquad (1)$$

where

p = levelized price
r = real price growth
d = real discount rate
P_o = current price

According to this formula, if the world oil price escalated in real terms equal to two percent per year and the real discount rate was ten percent, the levelized equivalent of the current world oil price (\$261.45 per m^3 or

\$41.50 per barrel) would be \$326.84 per m^3 (\$51.88 per barrel).

Table 4.2 represents the levelized price for world oil per cubic metre and per barrel under a range of different real discount rates and price growth rates. Until recently, world oil prices were forecasted to increase by two percent per annum in real terms. Should this occur, the levelized selling price would range from \$326.84 per m^3 (\$51.88 per barrel) to \$348.58 per m^3 (55.33 per barrel) with a discount rate of ten or eight percent, allowing a return to both industry and government. However, current economic trends indicate that it is doubtful that world oil prices will grow in such a manner (Statistics Canada, 1984). It is quite probable that growth rates will on the average be considerably less over the next two decades.

Because of the uncertainty regarding future world oil prices, a zero real growth rate has been suggested (Griffin et al., 1982) and has been employed in this study. At this growth rate, the levelized price is independent of the real discount rate (see Table 4.2). Therefore, the levelized price used to identify the minimum scale is that price corresponding to a zero rate of real growth in world oil prices, and equals \$261.45 per m^3 or \$41.50 per barrel.

M-4 is the only scenario that is economically viable under these circumstances, and it is only economic at a five percent real discount rate. Thus, scenario M-4 is the minimum economic marine scenario.

Table 4.2

Levelized Selling Prices for Different Real Discount Rates and Price Increases

$\$/m^3$; \$/bbl

Real Discount Rate (d) (%)	Real Oil Price Growth (r) (%) -2	-1	0	-1	-2
10	326.84 51.88	290.49 46.11	261.45 41.50	237.69 37.73	217.85 34.58
8	348.58 55.33	298.81 47.43	261.45 41.50	232.41 36.89	209.16 33.20
5	435.77 69.17	326.84 51.88	261.45 41.50	217.85 34.58	186.73 29.64

It should be noted that this is in sharp contrast to the findings of the Path Economics report. At a zero rate of real price growth, and at a world oil price of \$44, M-6, the lowest output scenario (see Figure 4.1), was discovered to be the most economically viable at a five percent real discount rate. At the existing world oil price, this scenario is no longer feasible.

It has also been suggested that, given the current situation, the near future holds a \$4.30 to \$5.75 absolute drop in the real world oil price. Shell oil is using a \$20 to \$25 U.S. (\$28.62 to \$35.78 Canadian) per barrel price of oil as one of their twenty-year planning price scenarios (Brummel, 1984). Assuming that the price of oil will stabilize at \$35.78 per barrel (\$225 per cubic metre) until 1990, all marine scenarios will become uneconomical, even at the five percent discount rate.

4.1.2 Pipeline Alternative

4.1.2.1 Pipeline Analysis

The major alternative to the marine mode is the utilization of an overland pipeline. The pipeline envisioned would have access to both the on- and nearshore reserves in the Mackenzie Delta region. If required, it could also be used to gain access to deeper reserves in the Beaufort Sea through connection to a buried submarine pipeline. Although a number of pipeline alternatives have been considered, there is a consensus on the general route to be taken: future construction will follow the Mackenzie River corridor through Norman Wells to Zama, Alberta, where the new pipeline will tie into existing oil delivery systems (see Figure 1.3).

Although serious speculation has centred on two specific alternatives, a 300-millimetre (12-inch) pipeline and a 400-millimetre (16-inch) pipeline, this study investigates only the latter for several reasons. Firstly, a recent study by the Beaufort Sea Environmental Assessment Panel (July, 1984) recommended that a 400-millimetre diameter buried pipeline be considered "the most acceptable alternative" for transporting oil to the southern facilities (Hamilton Spectator, July 31, 1984). Secondly, Path Economics Ltd. (1983) determined that the 300-millimetre configuration was highly susceptible to sustained real declines in the world oil price, and could easily become uneconomic. Thus, due to the degree of downside risk involved, and the negative reaction of the Environmental Assessment Panel, this option has been discounted.

Cost data was again obtained from the Path Economics study, and, after the requisite price escalations, has been reproduced in Appendix A. Esso Resources Canada Ltd. provided estimates of amount and costs of pipeline construction and operation, and near- and onshore field development. Island construction and development costs for Tarsiut were based on Dome Petroleum's estimates; Esso estimations for Issungnak (Esso, 1982b) are similar.

4.1.2.2 Pipeline Minimum Economic Scale

As previously stated, a comparison of the supply price to the selling price of oil in Montreal is necessary to determine profitability of a project. The current value of oil, $261.45 per cubic metre ($41.50 per barrel), is taken as a benchmark of economic viability, and it is assumed that real oil price growth equals zero over the applicable time period.

Configuration P-1 is quite noticeably the more costly of the two alternatives (see Tables A.1 and A.2). That is, not one scenario can generate a supply price less than or equal to the selling price at an eight or ten percent real discount rate. This configuration is therefore also subject to downside risk. The most feasible scenario, P-1(6), under a total tax exemption, would result in a supply price of $232.27 per m^3 ($36.87 per barrel). This supply price provides the five percent minimum real return on private capital. However, it should be noted (see Table 4.2) that at a five percent real discount rate, a one percent sustained annual decline in oil prices corresponds to a levelized selling price of \$217.84 per m^3 (34.58 per barrel). The marginal project becomes uneconomic; thus, the downside risk is considerable.

Conversely, all scenarios save one, P-2(1) at a ten percent discount rate, under the P-2 configuration are economically viable at the current world oil price. Supply prices for this configuration are consistently lower than those for the P-1 configuration. The highest economically feasible supply price calculated corresponds to scenario P-2(1) where the delivered supply price for oil to Montreal is \$253.79 per cubic metre (\$40.28 per barrel). Only the one offshore field would operate in this scenario, and would result in expenditures of approximately six and one-half billion dollars over a twenty year project life.

This configuration is advantageous, however, in that downside risk can be mitigated by expanding the production base to include more onshore fields. If, for instance, production is expanded to full scale - that is, scenario P-2(6) - at a ten percent real discount rate the levelized supply price would be \$229.81 per cubic metre (\$36.48 per barrel). At this rate of discount the project could remain economic at anything less than a 1.4 percent per year sustained decline in the world oil price. Additionally, in the event of a total collapse in the world oil price, the project can still be ensured viability through selective tax decreases (Path Economics Ltd., 1983): the minimum supply price for this configuration under total tax exemption (at a five percent real discount rate) is $198.35 per cubic metre ($31.48 per barrel). Thus, even under the Shell pricing forecasts (Brummel, 1984), this configuration remains economic for all scenarios except the first at a five percent discount rate. Economies of scale may also be realized, as transport costs decline to almost half their former amount as the project expands from scenario P-2(1) to P-2(6).

4.1.3 A Comparison: Overall Minimum Economic Scale

Since there are lower levels of output in the P-2 pipeline configuration than in the M-4 marine alternative which are economically viable, and since the pipeline is economic at a higher real discount rate (and thus less susceptible to downside risk), the P-2 pipeline alternative is identified as the minimum economic scale project. It has been suggested by the Beaufort Sea Environmental Assessment Panel that oil production and transportation be carried out in a small-scale and phased manner (Hamilton Spectator, August 1, 1984). Therefore, it is assumed that scenario P-2(1) represents the initial pilot project for Beaufort Sea - Mackenzie Delta production, and that scenario P-2(6) will embody the final result should full-scale development proceed.

Given everything considered, there are few economically viable options. Yet the cost analysis does not even include sunk costs, which are exploration and development costs incurred prior to physical development. This implies that the minimum scale of production estimated will provide a return only on the additional investment necessary for production. If sunk costs are included in the economic analysis, the aforementioned projects will become only very slightly marginally economic, or uneconomic.

4.2 Environmental Impacts*

4.2.1 Oil Spills

Gulf (1981) and Lanfear and Amstutz (1983) used historical data from the North Sea, Gulf of Mexico, and Alaska State to derive a probability estimate of Beaufort-produced oil being released from spills and chronic discharges of less than 0.001%. Although the actual occurrences from all three aforementioned operations are considerably higher, it was felt that the Beaufort project would be operating under similar but much improved circumstances.

More recently, Dome et al. (1983), having incorporated the above study into their analysis, predicted that the spillage from Beaufort offshore facilities would release 8 barrels per

* This synthesis of potential environmental impacts is based upon assessments by the industry proponents, which are found in Dome et al. (1982 volume 1 and volume 5; 1983 Environmental and Technical Issues) unless otherwise cited.

million barrels produced into the environment (Dome et al., 1983a). Beyer and Painter's (1977) worst case scenario estimated a spill rate of approximately 85 barrels per million barrels transported through the Northwest Passage, while Bercha (1981) predicted that technological and safety improvements would reduce the Arctic tanker spill rate to between 4.25 and 10.6 barrels per million produced. Although the Alyeska pipeline has released about 25 barrels per million barrels transported since its start-up (Dome et al., 1983a) the average release from Canadian, United States' and European onshore pipelines is 4 barrels per million barrels produced (Dome et al., 1983a); this latter average is used for this study. All of the above spill rate predictions include an estimation of the volume of unreported spills.

It is not possible to put an exact dollar value on the cost of spills, because they vary greatly in size, timing and frequency (all factors which affect the clean-up cost) and because it is nearly impossible to evaluate accurately costs of losses to the natural environment. The cost of spills may well be inestimable; millions or even billions of dollars cannot totally mitigate the impact of spills on the natural environment (Meikle, 1984).

4.2.1.1 Spill Impacts Under a Marine Scenario

Using Dome et al.'s (1983) estimates of potential spill rates, multiplied by the expected total production of the marine scenario, it can be predicted that total spillage from Beaufort Sea - Mackenzie Delta production will exceed 1580 cubic metres (9976 barrels), and that spillage from tankers plying the Northwest Passage will range from 841 cubic metres (5300 barrels) to 2098 cubic metres (13,218 barrels). These figures seem low because they mask the costs associated with spills, and are based upon probability estimates. In reality, it is likely that either no spill will occur, or a massive one will. Although the probability is low, according to Pimlott et al. (1976), the potential consequences of spillage of this magnitude (released over the lifetime of the project) could mean significant damage to marine life and migrant birds, disruption of the Beaufort Sea ecosystem, melting of large portions of the ice pack due to the spreading of the oil, and even climatic changes.

Although the impact of an oil spill on birds, marine mammals and fish is highly dependent on the time of the event, the areas contaminated and the species present (Dome et al., 1982a), Dome et al. (1983b, 1982e) have estimated - but not quantified - the general impacts that would occur from a production or transportation spill under the marine scenario. Within the Beaufort - Mackenzie region, especially from April to September, birds would be the most severely affected by a spill, with impacts ranging from moderate for the majority of species annually migrating to the Beaufort Sea, to major for the others. Bowhead whales (suffering minor impacts) and white whales (moderately affected) are most vulnerable during their spring migration as they follow leads (open water) in the ice. Ringed and bearded seals would suffer moderate impacts, especially if oil reached their primary pupping grounds. Fish resources could be moderately affected by the potential disruption of spawning migration and of fresh water drainages and adjoining coastal areas (such as the Mackenzie River Delta). Short term degradation of marine water quality would also occur (U.S. Department of the Interior, 1979).

A tanker spill would be far-reaching in its damage to the Northwest Passage. Although there would only be negligible to minor impacts of the loss of nearshore and bottom fauna on higher life forms, such as marine mammals (with the exception of polar bears, which would suffer moderate impacts because badly oiled furs cause death), birds and nearshore fauna would face major impacts for several years should the oil not be recovered quickly.

Since a prediction of the spill response effectiveness would be unrealistic (Dome et al., 1982a) the potential effects mentioned here have been estimated assuming that no countermeasures are applied. Preventative or corrective mitigation would be applied, however, and is assumed to reduce the overall impact on biological resources. Thus, the above presents a worst case scenario rather than events which are likely to occur.

4.2.1.2 Spill Impacts Under a Pipeline Scenario

Assuming that the aforementioned 4 barrels per million barrels produced (section 4.2.1) is a correct prediction of the potential spillage rate for the Mackenzie Valley pipeline, it can be expected that there will be a release of between 224 cubic metres (1411 barrels) and 472 cubic metres (2974 barrels) over the life of the project.

Should a spill occur at a crossing on the Mackenzie River, according to Dome et al. (1982e), mechanical containment and recovery during the summer would ensure that no greater than moderate impacts would occur to most flora and fauna. Aquatic birds would probably suffer moderately from coming in contact with the oil, while furbearing animals (such as beaver, muskrat and mink) would be subject to minor to moderate effects, depending on the extent of oil on their fur. Negligible to minor impacts would be experienced by freshwater aquatic organisms because of rapid oil dilution in the flowing water, evaporation of lighter fractions, and the self-cleaning capacity of streams (Dome et al., 1982a).

Impacts on terrestrial vegetation would be limited to the areas covered by oil, and would range from minor impacts (where lichens and mosses would regrow within a few weeks) to moderate (where vascular plants would require several growing seasons before seedling establishment). Impacts upon large animals would be negligible to non-existent because spill areas would be fenced in some locations to prevent intrusion (Dome et al., 1982a). Possible long-term degradation of groundwater could also occur in major terrestrial oil spills (U.S. Department of the Interior, 1979). (?)

Impacts on the Beaufort Sea - Mackenzie Delta region would be similar to those discussed in section 4.2.1.1.

4.2.2 Environmental Impacts - Marine Mode

The marine scenario will impact upon two areas: the Beaufort Sea - Mackenzie Delta region, and the Northwest Passage. Because the marine scenario determined to be the most economically feasible (M-4) consists solely of offshore producing fields, the environmental impacts considered will deal only with the impacts of offshore production.

4.2.2.1 Development and Production: Impacts on Beaufort Sea-Mackenzie Delta

According to the supplement to the EIS (Dome et al., 1983b), offshore production could result in a long-term reduction in local water quality from produced-water discharges; the impact would be confined to areas surrounding drilling platforms and vessels. Dredging activities and construction of artificial islands will have local impacts on water quality as a result of short-term increases in suspended sediment concentrations, and could possibly produce long-term local changes in the Beaufort Sea continental shelf floor. Icebreakers will be restricted to certain corridors so that their impact will remain limited and local. Impacts upon air quality should be negligible.

Potential impacts upon marine mammals are for the greatest part negligible or minor, with the few exceptions being moderate. There are regional concerns about the possible effects of underwater noise (during construction and operation) on white and bowhead whales, but these are assumed to be negligible, as are the possible cumulative or synergistic effects from common waste water discharges. This latter assumption is based upon the facts that most discharges are biodegradable, that the sea has a tremendous dilution and buffering capacity, and that a relatively small number of individuals would be affected. The impact upon bearded and ringed seals is expected to be minor. Seals may suffer some mortalities due to icebreakers and to exposure to trace metals and hydrocarbons in formation water for extended periods. The possible cumulative impacts of multiple waste discharges and sources of disturbance on seals should not exceed minor. Human presence, waste disposal, stationary noise and artificial islands are expected to have minor impacts on the regional bear population, as is the killing of animals destroyed for human safety. Since normal industrial activity should not cause significant changes to the regional seal population, indirect impacts on the bears, who prey on seals, are not expected. The impact on Arctic foxes due to the presence of offshore industrial activities is expected to be negligible because the number of individuals affected would be regionally insignificant, and because foxes are rarely killed.

Although over one hundred species of birds migrate to or through the Beaufort Sea region annually, potential impacts are expected to be minor at most. Negligible regional effects will occur from common wastes and disturbances including dredging, icebreaking and vessel activities. Minor impacts may include sickness or mortality from gas flaring and from routine discharges of formation and oily waste water. Possible impacts from airborne noise (helicopters and STOL aircraft) will be negligible or minor on all regional populations due to aircraft route and altitude restrictions. Cumulative effects of all waste discharges and disturbances associated with the construction and operation of offshore structures could have a minor regional impact on several marine birds (such as eiders, glaucous gulls and loons) but will have a negligible effect on most other species.

Offshore development in the Beaufort Sea is expected to have negligible to minor impacts on fish. Waste discharge will alter water quality only close to exploration and production platforms and vessels, and dredging, vessel traffic and icebreaking will be temporary and only affect fish close to the sources of disturbance. Near the shore, however, large numbers of important fish species feed and spawn, and minor to moderate impacts could occur from dredging if such feeding and rearing areas are not avoided.

Organisms living on or in the sea bottom will be directly disturbed by dredging, pipeline installations, and exposure to discharges from exploration or production platforms. This will have minor to moderate impacts on the regional population, depending on the number of generations necessary for the benthic communities to recover. Even with moderate impacts the proposed dredging is unlikely to create a regionally signigicant disturbance of the benthic habitat or have many indirect impacts on higher trophic levels, although there may be cumulative moderate impacts in local areas. There will also be negligible to minor impacts as phytoplankton and zooplankton are exposed to dredging, oily and formation water discharges and ballast water. Only local increases in primary production or organic loading are expected to occur.

4.2.2.2 Marine Transport: Impacts on Northwest Passage

A number of geographical areas along the eastern shipping corridor are expected to be impacted by normal tanker activities. Icebreaker operations in the Amundsen Gulf (see Figure 4.1) are likely to have a minor impact on ringed seals, whose birth lairs will be crushed, and a negligible effect on bearded seals disturbed by the tankers. Tanker noise causing disturbance and interfering with communications is likely to have negligible impacts upon white and bowhead whales, although the latter could suffer minor effects from increased traffic by the year 2000. Temporary disturbance to birds from reconnaissance aircraft is expected to be negligible.

The passage of up to two tankers per day through the Prince of Wales Strait is expected to have a measurable effect

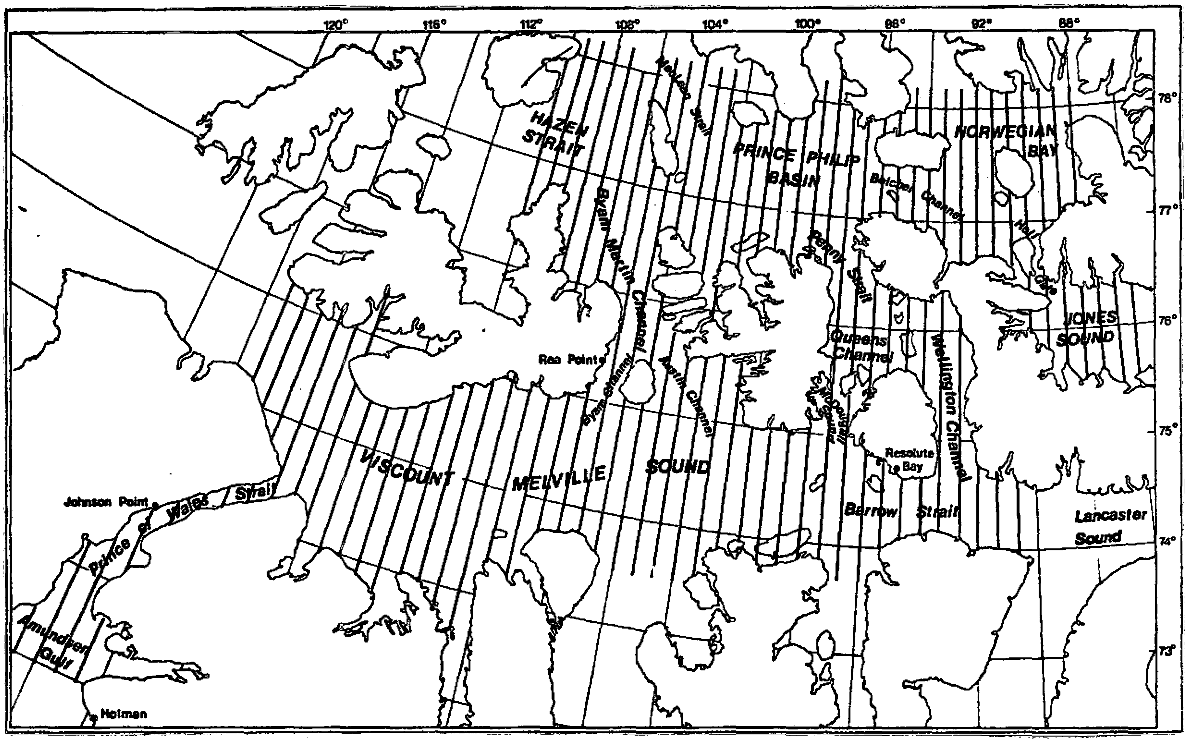


Figure 4.1
Northwest Passage Impact Area
Source: Stirling et al., 1981

only on ringed seals. Moderate impacts will result when seven to ten percent of the ringed seal habitat (approximately twenty-five to thirty-five seals)(Stirling et al., 1981) is destroyed each year.

The impacts of icebreaking on ringed seals in Viscount Melville Sound would be minor, with approximately three percent (thirty seals) (Stirling et al., 1981) of breeding habitat lost each year. Impacts on whales, birds, fish and lower trophic levels would be negligible.

There is concern that the destruction of between two and four percent of the high density Barrow Strait ringed seal habitat (fourteen to twenty-eight seals) will lead to moderate impacts (Stirling et al., 1981). White whales, narwhals and bowheads are expected to be affected only during migration, and therefore should suffer negligible consequences.

Possible impacts upon the ringed seal population of Lancaster Sound could be minor to moderate. White whales, narwhals and bowheads could suffer negligible effects during migration, while seabird colonies along the shores could face similar impacts from both reconnaissance aircraft and tanker disturbances.

A larger number of marine species live in Baffin Bay and Davis Strait during both summer and winter than in other portions of the eastern shipping route. Bowhead whales migrate both along the coast and in the offshore region. Since shipping noise levels are significantly disturbing only at relatively short ranges, effects upon bowheads range from negligible to minor, depending on the proportion of the population migrating offshore. Narwhals and white whales suffer the same range of impacts during the six to seven month period of ice cover. Baleen and odontocete whales, conversely, are negligibly impacted upon during summer off western Greenland. Winter impacts upon bearded seals and walruses from shipping are expected to be minor, while those upon ringed seals should be minor to moderate. Harp and hooded seals, as well as seabirds, should generally face negligible effects.

4.2.3 Environmental Impacts - Pipeline Mode

The pipeline scenario will impact upon the Beaufort Sea - Mackenzie Delta onshore production region, and the Mackenzie Valley.

4.2.3.1 Development and Production: Impacts on Beaufort Sea - Mackenzie Delta

Impacts upon geology and soils resulting from production, gathering pipelines, and support facilities should be localized and short-term, and include the possibility of stream bank and slope erosion, thermal effects (from thawing permafrost) and terrain damage from emergency repairs for pipeline failures. Alterations in drainage patterns should also be localized and short-term. Atmospheric impacts from noise, particulate and geseous emissions, and ice fogs are expected to be limited and localized. Disturbances to vegetation (which will be re egetated if removed) should be localized and short-term.

Wildlife can be affected by habitat alteration, disruption of movements, disturbances, and mortality. Onshore oil development could impact upon reindeer on the Tuktoyaktuk Peninsula and in the western Mackenzie Reindeer Grazing Reserve. Short-term habitat loss would result from construction of gathering and production facilities, and from construction camps, while longer term habitat loss would occur at well sites, processing plants, storage areas and along permanent access roads. The total habitat loss will, however, be very small compared to land available. Roads and buried pipelines should not restrict reindeer movements, and disturbances from human activities should be limited to facility sites and pipeline corridors. Improved road access and increased human population could result in more poaching, but herds are very intensive, and overall impacts of development upon reindeer should be minor.

Bluenose caribou remain east of the proposed development and would be negligibly impacted.

The types of disruptions and disturbances affecting the small moose population are similar to those described for reindeer. However, because increased hunting would strongly impact upon the very low and therefore vulnerable population, development impacts are considered to be minor.

Grizzly bears will suffer minor effects from the loss of denning areas, human disturbance, increased hunting, and the killing of problem bears attracted to project facilities.

Future development is expected to have minor impacts upon beaver and muskrat only if an oil spill or leak pollutes their waterways. The widespread distribution of both animals would ensure that the majority of the population would remain unaffected.

The impact upon foxes and wolves is expected to be minor, with the greatest concerns being increased hunting and trapping, and overdependency upon camp garbage for food.

Increased trapping could lead to local depletion of mink, weasel, wolverines and other Mackenzie Delta furbearers, but impacts on regional populations would be negligible to minor.

Impacts upon smaller mammals, such as shrews, small rodents and hares, are expected to be negligible.

In spring, summer and fall (few birds are present in winter) impacts on birds on the eastern outer Delta and Tuktoyaktuk Peninsula range from minor to moderate, and may involve a general reduction of breeding range and a decrease in productivity. A major spill in the western outer Delta, an important nesting, rearing and moulting area, could have impacts ranging from negligible to major, depending on the location, size, timing and clean-up of the spill.

Freshwater fish are expected to experience minor local reductions in fish populations due to increased stream sedimentation from the construction of pipeline stream crossings, road bridges, and other in or near stream activities. Small areas of short-term habitat modifications, resulting from toxic spills, channel alteration, increased sediment and stream crossings, are expected to have only negligible effects. Short-term declines (mortality) in local fish populations would have only minor impacts, while the effects of increased recreational fishing and increased water withdrawal would be negligible. Disturbances to the lower trophic levles upon which fish feed (for instance, from sedimentation or toxic spills) would be local and short-term, and would be expected to range from negligible to minor.

4.2.3.2 Pipeline Transport: Impacts on Mackenzie Valley

Most anticipated impacts of normal pipeline-related activities will occur during construction of the pipeline and its associated facilities. Once construction is completed, fewer impacts are expected to arise from operations and maintenance activities. Removal of vegetation, soil and gravel is expected to cause localized short-term drainage alterations and erosion problems, while the latter are expected to lead to short-term local reductions in water quality and altered stream flow. Local noise, air emissions and ice fog will locally reduce air quality.

Many species of animals are found in the Mackenzie Valley for at least part of the year, and all would suffer some form of habitat alteration, disruption of movements, disturbance or direct mortality from pipeline-related activities. These activities will have short-term local minor impacts upon reindeer and bluenose caribou from increased poaching, temporary barriers to movement, and disturbance from human activity. Woodland caribou would have less exposure to the pipeline and therefore would be negligibly affected.

Currently overharvested moose in the Mackenzie Valley would suffer locally moderate impacts from increased hunting and temporary barriers to movement. Of lower density and less migratory than moose, deer populations would be only negligibly affected by the same impacts.

Grizzly bears along the northernmost section of the pipeline route would suffer moderate impacts from increased hunting pressure, illegal harvest, and human disturbances leading to local displacement and sometimes mortality. Both grizzly and black bears would have minor impacts throughout forested areas of the Mackenzie Valley.

Aquatic furbearers, such as beaver, muskrat and mink, are widely distributed and will be affected only in areas of minor short-term habitat loss due to alterations in vegetation or water levels, or where there is local overharvesting.

Although both Arctic and Red fox are widely dispersed and would have few interactions with the pipeline, minor impacts are expected from destruction of den sites, attraction to camps, and some increased hunting and trapping. Marten and lynx are sensitive to overharvesting and could suffer minor impacts, as could wolves which are dependent upon overharvested caribou and moose for food. Other furbearing mammals in the Mackenzie Valley corridor, such as weasels, squirrel, otter and coyote, are generally widely dispersed and would suffer negligible habitat alteration and disturbance, as well as minor impacts from overharvesting.

The Mackenzie Valley has great importance continentally as a migration corridor, and for the nesting and breeding of birds. Concentrated in flocks at certain seasons, birds are vulnerable to human disturbances, long-term habitat loss or modification, increased hunting pressure and the possibility of oil spills. Overall impacts to waterfowl are generally expected to be negligible, but could approach minor or moderate in some local areas.

Fisheries resources may be impacted upon in several ways by pipeline construction and operation. Increased stream sedimentation will lead to a few localized reductions in fish populations, which may have minor impacts upon the regional population. Spills of toxic materials, stream crossings and modifications, and sediment introductions reduce habitat quality and lead to short-term habitat alteration. The small amount of habitat affected, however, will lead to only negligible cumulative effects on fish habitat. Expanded recreational fishing and increasing water withdrawals should not endanger local fish populations and therefore will have a negligible impact. Sedimentation, nutrient enrichment, and toxic spills can alter the local community structure of lower trophic levels, thus changing the feeding distribution of local fish populations. Effects are limited, however, by widespread distribution and overall impacts are expected to be minor.

4.3 Socio-Economic Impacts*

4.3.1 Socio-Economic Impacts - Marine Mode

The tanker mode of delivery would impact most heavily upon Tuktoyaktuk and Inuvik, but there would also be significant effects on other Beaufort Sea - Mackenzie Delta Communities.

The major impacts of marine delivery on Tuktoyaktuk and Inuvik derive from the projected increase inpopulation, as much as fifty percent of which will be young, non-native, single men. Although population-added will fluctuate, it is expected to add up to 520 and 1630 to "Tuk" and Inuvik populations respectively by the year 2000. This will change the ethnic balance of the communities and impact greatly upon all social and physical structures. Other Beaufort - Delta communities will experience little impact; their cumulative population increase is expected to be 186 by 2000, comprised totally of young people retained or older people drawn back to the area by the availability of rotational employment related to oil production.

Total wage income accruing to Northern residents is expected to increase significantly over the next twenty years, although it is probable that there will be large differentials in wages among categories of labour. By 2000, wage increases may equal as much as one quarter of total wage income. Payments of this level have significant multiplier effects. With the anticipated diversification and growth of the economy, it is possible that induced income effects will rise to 25 percent of direct northern wages and salaries by 1990 (equalling $20 to $25 million) (Outcrop Ltd., 1981). Increased multiplier effects will also be realized in the northern economy through purchases of goods and services.

Increased income will lead to local price inflation in Tuk and Inuvik as local business labour costs rise under competition with oil companies for workers. The higher population will put minor strain in Inuvik and moderate in Tuk on the availability of wild foods, while moderately increased dependence on social assistance will occur in both communities, as well as others.

Significant impacts on local government and influence structures are expected only in Tuk, where drastic shifts in the size and composition of the population would result in severe changes in the power structure and substantial inter-racial conflict.

Inuvik and the smaller communities would experience only minor impacts upon physical infrastructures because they either have sufficient capacity to meet new demand, or can acquire it quickly. Tuk, conversely, although it too would suffer only minor impacts, would require costly expansion of housing, sewage, recreation facilities, schools and hospitals because its facilities are currently near or at capacity.

The large influx of young, single non-native males - comprising approximately 40 percent of the expected normal population in 2000 - will have major adverse impacts upon family solidarity in Tuk. Increased competition for women and interracial tension would likely escalate into severe intro-family conflict and greater violence. Severe impacts from increased alcohol and drug abuse and illegal and violent behaviour would accompany this. Inuvik and the other communities anticipate at most minor impacts on community solidarity, although there exists a possibility of moderate impacts on the family solidarity of inmigrants. Small communities are expected to suffer negligible impacts, while Inuvik will pro - bably face moderate increases in alcoholism, minor impacts from drug abuse, and minor to moderately increased crime rates.

In terms of health conditions, all three areas expect minor to moderate (with greater emphasis on the latter) increases in accidents, violence and diseases, especially with inmigrants. Minor demands will be made on education, medical, social service and police systems and staff due to this and population increases in Inuvik and smaller communities. Tuk may suffer moderate impacts if the required personnel cannot be provided to meet the forecasted overload.

Since no significant increase in non-native residents is expected in communities other than Tuk or Inuvik, the impacts on community cultural patterns are predicted to be negligible; that is, there is no threat to the subsistence resource base which is crucial to the survival of traditional lifestyles. In Tuk and Inuvik, however, development implies a severe threat to the survival of native cultures. While Tuktoyaktuk is threat- ened by the probability of non-natives acquiring an increasingly powerful voice in local decision-making, Inuvik could lose its cultural retention due to a substantial increase in the native population. That is, if oil production increases the native population artificially to the point where the people are less able to depend heavily upon resource harvesting, the survival of native cultures is threatened.

No more than minor impacts are expected in any Parry Channel community from the marine delivery mode. Potential population impacts are negligible; direct and indirect employment opportunities will be minor at most (with a slight chance for rotational employment in Beaufort Sea operations or on ships plying the Northwest Passage). It is possible that increased employment in a community could exacerbate income disparities and cause a minor increase in dependency on social assistance. There are negligible impacts at most on local government or infrastructure. It is possible that minor, mitigable impacts on social problem rates could occur, but this would have no effect on health, social services, or culture.

Industry is confident that the year-round passage of tankers through the Baffin Bay - Davis Strait route will have virtually no effect on the communities of eastern and southern Baffin Island, and will not interfere with Inuit hunting or with migration of marine mammals.

4.3.2 Socio-Economic Impacts - Pipeline Mode

The predicted population impacts of the sixteen-inch pipeline delivery mode on all of the Beaufort - Delta communities are marginally smaller in every year than are the projected population impacts under the tanker delivery mode. Since social impacts are assumed to be related to changes in employment or local population, and both of these are similar to those under the marine scenario, it can be assumed that the nature and magnitude of impacts on the Beaufort - Delta communities are essentially the same under the two modes.

It is expected that Norman Wells and Fort Simpson would serve as district offices, with operations and maintenance staff stationed there, under the pipeline mode. Therefore, these will be the areas of greatest impact. In both communities the added population will not arrive until 1987, and will rapidly increase from 9 people to a peak of approximately 115 people in 1989. After 1990, the population will level off at about 50 people (the operating staff) and remain at this level throughout the production life. At peak, the added population represents only 10 percent (Fort Simpson) to 20 percent (Norman Wells) of the permanent population.

Since the population added is relatively small, there will be at most a minor impact on the availability of fish or game, and no change in the levels of social assistance payments or wage-price inflation.

While the impacts on local government and influence structures will be negligible in Fort Simpson because of the large majority of natives, there will be minor to moderate impacts in Norman Wells due to the increased workload of the Hamlet Council. Effects on the physical infrastructure of the communities will be negligible.

While threats to community solidarity will be negligible, minor problems relating to family solidarity may reflect difficulties of adjustment and integration among inmigrants. This could conceivably explain the minor possible increases in alcohol and drug abuse and crime rates in Fort Simpson.

No more than minor, mitigable impacts on health conditions are expected in either community. Thus, increased pressure on health and social service systems should be negligible. The same applies to education and police systems.

Negligible impacts are expected on existing community cultural patterns in Norman Wells because the non-native inmigrants and the existing non-native population have similar social backgrounds and characteristics. Only minor impacts are expected on community cultural patterns in Fort Simpson, but they will induce no significant cultural change.

Other Mackenzie River Zone Communities will experience no impacts, except where residents are involved in rotation employment. These impacts are not expected to be significant.

4.3.3 Canadian Benefits

Dome et al. (1982a) purport that the long-term development of Beaufort Sea - Mackenzie Delta hydrocarbon resources will have a positive impact on the economic and industrial base of Canada. There are a number of national economic and industrial benefits, which are as follows. Firstly, new investment will range from 65 to 100 billion (1981) dollars. Canadian industrial demand will greatly increase if Canadian contentof expenditures on materials, supplies and services is targetted at 75 to 90 percent of all procurement. 11,000 to 13,000 new direct jobs can be created by 1990, and 17,000 to 24,000 by the year 2000. Rotational employment would provide a broad base of Canadian employment opportunities. The total employment impact in Canada, including direct, indirect and induced jobs, would be 200,000 to 240,000 jobs during the highest production year. Beaufort development would add $210 to $220 billion (1981) dollars to Gross National Product, thus encouraging real economic growth. There would also be a cumulative impact on the Federal account of approximately 120 billion (1981) dollars by the year 2000.

Beaufort development would also afford a number of regional economic and industrial benefits. Total northern employment-added would reach 4,500 to 7,000 jobs by 1990 and 12,000 jobs by the year 2000. Improvements would occur in northern infrastructure and services. Territorial governments would have the opportunity to become more financially independent due to a higher tax base from a growing population, and from a broader industrial base. Multiplier effects - on regional expenditures and on Beaufort personnel incomes - would result in stronger economies in all regions of Canada.

Canada as a whole would gain a number of intangible benefits, including the development of new technology, improved northern transportation, a better skilled labour force in energy technology, and self-sufficiency in crude oil supply.

CHAPTER 5 SUMMARY AND DISCUSSION

The foregoing analysis indicates that, under the forecasted world oil price scenarios, few economically viable options exist for hydrocarbon production in the Beaufort Sea - Mackenzie Delta Region. Furthermore, those options that are feasible are marginal at best. With the addition of excluded sunk costs, the above projects would become very marginally economic, or uneconomic. If it is assumed that companies involved in the projects internalize environmental and social costs, they will receive a negative rate of return. This implies that opportunity costs of investment are very high, and that the internal rate of return is less than what companies could receive investing elsewhere. Thus, the projects would not be commercially profitable and companies should not invest.

Oil companies are, however, investing heavily in Beaufort Sea hydrocarbon exploration for two reasons. Firstly, the federal government offers tremendous tax concessions and incentive payments to encourage development and production activity in Canada's frontier areas (see Table A.3). Although they are excluded from minimum economic scale analysis, these subsidies are very important when evaluating commercial profitability. The levelized supply prices in Tables 4.1, A.1 and A.2 are relatively low; with incentive payments added they would be even lower. The federal and provincial governments together pay twenty percent of development costs, and most sunk costs.

Thus, the internal rate of return is much higher when subsidies are incorporated into the cost analysis.

Secondly, oil companies invest because they do not have to internalize negative externalities. Not only do the people of Canada pay for incentives, but they also are forced to absorb the environmental and social costs incurred by the projects. This is in return for the intangible 'social benefit' of Canadian oil self-sufficiency, a strong objective of the government.

One of the main components of Canada's goal of self-sufficiency has been frontier oil development, as is clearly indicated by government incentives offered for development and exploration. Achievement of this goal does not, however, come without social costs, as has been mentioned above. The economic costs of achieving self-sufficiency may also be great since energy production is less efficient, and there are greater intra- and interregional inequalities (Wilbanks, 1981).

Estimations of social and environmental costs associated with Beaufort production, as discussed above and elsewhere, are not without problems. An important limiting factor is the inherent subjectivity of most analyses. Impact definitions that are deliberately vague to allow a large degree of flexibility in application also allow divergent interpretations. Many statistics, such as those on criminal justice, are sensitive to "human discretion" (Carley, 1984). For instance, different crime reporting and charging practices can greatly influence statistical crime rates, especially where populations are low, as in the Beaufort region.

The proponents of the project - the companies involved - are responsible for assessing the anticipated environmental consequences of their own activities. The federal Environmental Assessment and Review Process (EARP), which formally reviews the Environmental Impact Statement, produces a detailed report which is not legally binding on the federal government or the proponents. Free of legal ramifications, there is no necessity for industries to introduce a high level of sophistication into their environmental and social analyses. In many cases, it would be contrary to their objectives to do so. Thus, there is no incentive for the industry to provide more than the minimal amount of information required to satisfy the criteria set by the federal government. Little independent private research has been undertaken since research is a function of the limited funds available.

Socio-economic and environmental problems notwithstanding, there is a possibility that the advent of new technology or the future discovery of tremendous new reserves in the Beaufort Sea - Mackenzie Delta region could place Canada on the road to energy self-sufficiency. In the current situation, however, production of Beaufort Sea oil appears to be a very costly objective; therefore, other alternatives should be considered at less cost.

APPENDIX A

Marine Scenarios

The "base" scenario, M-1, Dome's minimum economically feasible rate (offshore) is comprised of one tanker transporting oil from a shallow production field, assumed to be Tarsiut (see Figure 1.1). Two production islands are constructed; one is extended to accommodate storage and loading facilities. The production life is from year four to year four to year twenty-eight (years one to four are set aside for construction). 48 million m^3 (300 million barrels) of oil would be produced during the operating life, beginning with 1400 m^3 (9000 barrels) per day in year four, peaking at 7200 m^3 (45,000 barrels) per day by the eighth year, and declining from year eleven onward (Path Economics Ltd., 1983).

The other five scenarios build upon the base. Scenario M-2 adds one tanker and one deepwater field with a production island. M-3 includes another deep field and two more tankers. The addition of a shallow field to this creates scenario M-4 (operating with four production fields and four tankers). M-5 involves a combination of off- and onshore production: five onshore fields are added to scenario M-1; this latter production is connected to the Tarsiut offshore field (and therefore to the APLA terminal). Production peaks at 16,000 m^3 (100,000 barrels) per day. Marine scenarios M-1 to M-5 all share the same timing profile, having production commence in year four

Table A.1

Results of Cost Analysis*

400 mm Pipeline Configuration P-1 (Tarsiut)**

	Pipeline P-1 Scenarios (Tarsiut)					
	P-1(1)	P-1(2)	P-1(3)	P-1(4)	P-1(5)	P-1(6)
Number of Onshore Fields	0	1	2	3	4	5
Number of Offshore Fields	1	1	1	1	1	1
Production Life	4-28	4-28	4-28	4-28	4-28	4-28
Peak Throughput ($10^3 m^3/d$; 10^3 bbl/d)	7; 44.1	10; 63	12; 75.6	12; 75.6	12; 75.6	12; 75.6
Reserves ($10^6 m^3$; 10^6 bbl)	47; 296	54; 340	60; 378	67; 422	74; 466	81; 510
Total Cost (Billion 1984 $)	11.40	12.55	13.68	14.82	15.95	17.09
Levelized Supply Price (r=10%):						
Field Costs ($/$m^3$; $/bbl)	295.39; 46.89	272.17; 43.20	259.83; 41.24	253.35; 40.21	249.26; 39.57	246.43; 39.12
Transport Costs ($/$m^3$; $/bbl)	76.46; 12.14	60.98; 9.68	51.29; 8.14	46.88; 7.44	44.24; 7.02	42.41; 6.73
Supply Price ($/$m^3$; $/bbl)	371.85; 59.03	333.15; 52.88	311.12; 49.38	300.23; 47.65	293.50; 46.59	288.84; 45.85
Levelized Supply Price (r=8%)	335.22; 53.21	305.14; 48.43	287.77; 45.68	278.02; 44.13	271.54; 43.10	267.01; 42.38
Levelized Supply Price (r=5%)	281.29; 44.65	261.78; 41.55	250.33; 39.33	242.40; 38.48	236.61; 37.56	232.27; 36.87

* all costs are in 1984 dollars; r = real discount rate

** this table is based upon a combination of similar charts found in Rath Economics Ltd. (1983, pp 47, 69); costs have been escalated by 10.8 and 5.8 percent in order to change them to 1984 constant dollars from 1982 dollars.

and terminate by year twenty-eight. Scenario M-6 is identical to M-5 in configuration, with the exception that the offshore field is now Issungnak (see Figure 1.1) and production life is shortened from twenty-five to sixteen years (thus reducing total production considerably).

Pipeline Scenarios

The two 400-millimetre pipeline configurations investigated correspond to scenarios M-5 and M-6 for the marine mode. Configuration P-1 accesses the same onshore reserves, and Tarsiut production, as M-5. Similarly, configuration P-2 combines onshore and nearshore fields with production from a small offshore field such as Issungank in the same way as did M-6. Both involve the construction of a single-purpose line from the Beaufort Sea to Zama, with an estimated capacity of approximately 12,000 cubic metres per day (75,600 barrels per day) (Path Economics Ltd., 1983). Because onshore reserves might not be sufficient to fill the line, it would be connected to Tarsiut or Issungnak, which are shallow offshore fields. This offshore field would be connected first, after which near- and onshore fields would be added (to a maximum of five onshore fields) to increase the scale of production.

The Tarsiut and Issungnak configurations differ in several ways: the latter has a project life of only twenty years, while Tarsiut will be operating for twenty-nine years; and production facilities at Tarsiut will be nearly two and one half times as expensive as those at Issungnak, while pipeline

Table A.2

Results of Cost Analysis *

400 mm Pipeline Configuration P-2 **

Pipeline P-2 scenarios (Issungnak)

	P-2(1)	P-2(2)	P-2(3)	P-2(4)	P-2(5)	P-2(6)
Number of Onshore Fields	0	1	2	3	4	5
Number of Offshore Fields	1	1	1	1	1	1
Production Life	4-19	4-19	4-19	4-19	4-19	4-19
Peak Throughput (10^3 m^3/d; 10^3 bbl/d)	8; 50.4	11; 69.3	12; 75.6	12; 75.6	12; 75.6	12; 75.6
Reserves (10^6 m^3; 10^6 bbl)	28; 176.4	35; 220.5	41; 258.3	48; 302.4	54; 340.2	59; 371.7
Total Cost (Billion 1984 $)	6.33	7.47	8.61	9.75	10.70	11.61
Levelized Supply Price (r=10%):						
Field Costs ($/$m^3$; $/bbl)	182.56; 28.98	182.18; 28.92	184.07; 29.22	183.69; 29.16	183.63; 29.15	184.00; 29.21
Transport Costs ($/$m^3$; $/bbl)	86.34; 13.70	66.64; 10.58	57.58; 9.14	51.79; 8.22	48.27; 7.66	45.81; 7.27
Supply Price ($/$m^3$; $/bbl)	268.90; 42.68	248.82; 39.50	241.65; 38.36	235.48; 37.38	231.90; 36.81	229.81; 36.48
Levelized Supply Price (r=8%)	253.79; 40.28	236.49; 37.54	229.94; 36.50	224.15; 35.58	220.57; 35.01	218.49; 34.68
Levelized Supply Price (r=5%)	228.75; 36.31	215.03; 34.13	209.30; 33.22	203.95; 32.37	200.36; 31.80	198.35; 31.48

* all costs are in 1984 dollars; r= real discount rate

** this table is based upon a combination of similar charts found in Path Economics (1983, pp 48, 70); costs have been escalated by 10.8 and 5.8 percent in order to change them to 1984 constant dollars from 1982 dollars.

connections will be at least twice as costly.

The major attraction of a pipeline mode is the flexibility of connecting new fields to the system, rather than the maximum throughput of the pipeline. Therefore, both configurations have been subdivided into six scenarios, with each scenario accessing an additional field (see Tables A.1 and A.2 in the appendix). All twelve scenarios are analyzed in order to determine the minimum economic scale.

TABLE A.3

Incentive Payments as a Percent of Eligible Expenditures (as revised February 16, 1981)

	COR Level (Note 1)			
	1	2	3	4
Canada Lands				
Exploration				
1981	25%	35%	65%	80%
1982	25%	45%	65%	80%
1983	25%	45%	65%	80%
1984 seq	25%	50%	65%	80%
Development				
1981	—	—	15%	20%
1982	—	10%	15%	20%
1983	—	10%	15%	20%
1984 seq	—	10%	15%	20%
Provincial Lands				
Exploration				
1981	—	—	25%	35%
1982	—	10%	25%	35%
1983	—	10%	25%	35%
1984 seq	—	15%	25%	35%
Development (Note 2)				
1981	—	—	15%	20%
1982	—	10%	15%	20%
1983	—	10%	15%	20%
1984 seq	—	10%	15%	20%

Notes

1. *COR levels are as follows:*
   Level 1 — less than 50% COR
   Level 2 — 50% + COR
   Level 3 — 60% COR in 1981, increasing 1% per year to 65% by 1986
   Level 4 — 65% COR in 1981, increasing 2% per year to 75% by 1986
2. *These same grants are available for qualified costs in respect of non-conventional and tertiary oil projects and for crude oil upgraders.*
3. *Canadian individuals are deemed to have Level 4 COR.*

Source: Energy, Mines and Resources, 1980

APPENDIX B

Impact definitions for biological resources, based upon those found in the EIS Mackenzie Valley Zone Summary (Dome et al., 1983g) are as follows:

A major impact occurs when a regional population or species may be affected to such a degree that the population decline or change in distribution prevents that population or species, or any population dependent upon it, from returning to its former level within several generations.

A moderate impact may cause a change in abundance or distribution of a portion of the regional population or its dependents over more than one generation, but is unlikely to impact the regional population as a whole.

A minor impact exists when one group of individuals of a population in a localized area may be impacted over a short period (one generation) but the regional population is not significantly affected.

A negligible impact exists when the anticipated biological consequences are less than minor.

Spatial and temporal definitions are based upon those found in Dome et al., 1982c, and are as follows:

A local impact implies that any physical or chemical changes that occur should be detectable only within one kilometre of the proposed facilities or linear transportation corridors.

A regional impact exists when physical or chemical changes are forecasted to be detectable beyond one kilometre of either of the above.

A short-term impact should persist less than five years from the onset of the disturbance.

A medium-term impact is likely to persist for five to ten years.

A long-term impact will persist for longer than ten years.

APPENDIX C

Socio-economic impact definitions are based upon those found in Dome et al., 1983d, and are as follows:

Negligible impacts fall within the normal range without resource development (that is, the base case) and thus require no mitigation.

Minor impacts are those which can be reduced to within the normal range by appropriate mitigation (over time), although there is no guarantee that this mitigation will be applied.

Moderate impacts are inevitable effects which cannot be mitigated to normal range levels but pose only a limited threat to the social health of the community.

Severe impacts, conversely, are of such a magnitude that they would in all probability pose a serious threat to the normal social life of the community.

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