North of 60 Engineering Ltd.

Granular Resource Requirements for Potential Hydrocarbon Development in the Western Region of NWT

Prepared for
Department of Indian Affairs
and Northern Development

James C. McDougall
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Contents

List of Tables

List of Figures

Executive Summary

NORTH OF 60 ENGINEERING LTD. has identified, in collaboration with industry, granular resource requirements for a number of oil and gas development scenarios in the Beaufort / Mackenzie Delta region. These scenarios have the potential to be economic under current price outlooks, given plausible technological and fiscal uplift. This report summarizes the potential development scenarios, their possible timing, and granular resource requirements.

The motivation for this work is driven by the ongoing need of the Department of Indian Affairs and Northern Development (DIAND) to assess granular resource requirements in the region. This work has been sponsored under the Northern Oil and Gas Action Program (NOGAP) Project A4: "Granular Resources Inventory and Management".

Granular resources, such as gravel, sand, and rock suitable for construction are essential to northern development. High quality granular resources are in short supply in many regions of the Territories and new sources are being sought.

Hydrocarbon exploration and development in the region has in the past, and will in the future, require granular resources. Historically, onshore granular resources have been used to construct drilling pads and temporary offshore exploration structures in the shallow waters of the near shore Beaufort Sea.

Exploration in the Northwest Territories started in the early 1920s, when the investigation of oil seeps into the Mackenzie River led to the discovery of the Norman Wells Oil field. Over 1000 wells have been drilled in the Northwest Territories since 1921, which has resulted in a number of discoveries in the Mainland region of the Territories and in the Mackenzie Delta Beaufort Sea area. An assessment completed in mid-1988 by the Geological Survey of Canada, estimates undiscovered resources in this area at 5.25 billion barrels of oil and 55 Tcf of gas.

Production from Mackenzie Delta - Beaufort Sea region has yet to occur despite the considerable investment by industry into development planning, engineering studies, as well as regulatory

and environmental reviews. In fact, exploration drilling in the area has dropped to a twenty year low and there has been little interest shown in obtaining new leases.

A major factor in this low activity is the current price of oil which has fluctuated in recent years around $20 US per barrel. The prevailing industry view is that the existing oil reserve base in the Mackenzie delta is not large enough to support a costly transportation system to southern markets.

Industry's efforts are, therefore, focused on identifying and discovering onshore oil prospects.

Frontier natural gas discoveries, while significant in size, are currently not competitive with the existing reserves in southern Canada, due to the costly transportation system that is required to move the gas to market. Given current low gas prices and the unexpected near term growth in those prices, it is unlikely that the discovered reserve base will be developed within the next decade, although significant changes in fuel use could alter this outlook.

The key to future development in the current economy is to find innovative ways of reducing the high costs associated with oil and gas development and transportation.

Towards that end, NORTH OF 60 ENGINEERING LTD. in association with K.R. Croasdale and Associates Ltd. recently completed a study to identify key research and development thrusts, which, if successful, would significantly improve the potential of oil and gas development in the region. A number of generic oil and gas development scenarios were considered. The study identified the cost, economic viability, and economic sensitivities associated with each of the scenarios. In addition, it outlined a number of potential research initiatives which could reduce costs and, thus, improve the economics.

One of the important conclusions from the study was that small scale oil development, using either an extension of the Norman Wells pipeline or tanker transportation, could be economically attractive without additional reserves, if technology advancements could achieve lower costs.

The development scenarios considered for this study built on that knowledge base. They included:

- the development of a small onshore oil or gas field to provide a fuel source to meet local energy demands.
- the potential for seasonal production from the Amauligak reservoir.
- a generic 200 million barrel onshore field, and
- the processing of onshore gas for sale to southern markets.

The timing of these scenarios has been phased to reflect the ongoing level of exploration, the time frame required to develop a particular scenario, and the current economic outlook.

The general scope of each scenario was established in order to identify the associated granular resource requirements. Generally, the scope was based on inputs from a variety of sources including industry, the experience of the author, and a computer model (NORCOST©), which establishes the scope and cost of facilities necessary to produce and transport oil and gas from the Frontier regions to southern markets. As a subset of the output, it also quantifies the granular resources required for the development.

Table 1 summarizes the granular resource requirements for both oil and gas. Onshore oil development will require an estimated 2 million m^3 of granular material, while gas development will require an estimated 8 million m^3. Offshore oil development is estimated to require 3 million m^3 from offshore sources.

Year	Onshore Oil	Offshore Oil	Onshore Gas
1993-1995	716,275		0
1996-2000	625,447	650,000	40,000
2001-2005	6,250		0
2006-2010	6,250		7,819,054
2011-2015	388,525	2,700,000	573,413
2016-2020	235,615		0
Total	1,978,362	3,350,000	8,432,467

Granular Material Required for Oil & Gas Development (m^3)
Table 1

This study has concluded that while the granular resources requirements for the development scenarios considered are significant, they are considerably lower than historical estimates based on much larger development plans.

Introduction

Study Goals

The goals of this study were to:

- identify, in collaboration with industry, oil and gas developments in the Beaufort / Mackenzie Delta region, which have the potential to be economic under current price outlooks, given plausible technological and fiscal uplift, and
- to determine the associated granular resource requirements and their timing, for these developments.

Early identification of granular requirements would not only identify the potential impact that hydrocarbon development would have on this resource, but, would also assist those groups entrusted with the current management of the resource in the future planning and ongoing management of the resource.

The motivation for the study is driven by the ongoing need of the Department of Indian Affairs and Northern Development (DIAND) to assess granular resource requirements in the region. This study has, therefore, been sponsored under the Northern Oil and Gas Action Program (NOGAP) Project A4: "Granular Resources Inventory and Management".

Background

Granular resources, such as gravel, sand, and rock suitable for construction are essential to northern development. High quality granular resources are in short supply in many regions of the Territories and new sources are being sought.

Management of this valuable and finite resource is necessary to ensure that known sources are effectively used and that remaining materials are conserved for future development. Managing granular resources effectively requires detailed assessments of the

existing supply, up-to-date forecasts of potential demands, management planning and appropriate legislation.

An inventory of granular resources is kept for roads and highways, artificial islands for offshore oil and gas production, and for community and other industrial needs. Past and present programs related to inventory management include the Mackenzie Highway Study Group, the Northern Oil and Gas Action Program and the Inuvialuit Final Agreement Implementation. The inventory must occasionally be updated in response to new initiatives and revised demand forecasts. In addition, the inventory must be current to provide useful information to the territorial governments and native organizations as part of transferring responsibility and implementation of land claim settlements.

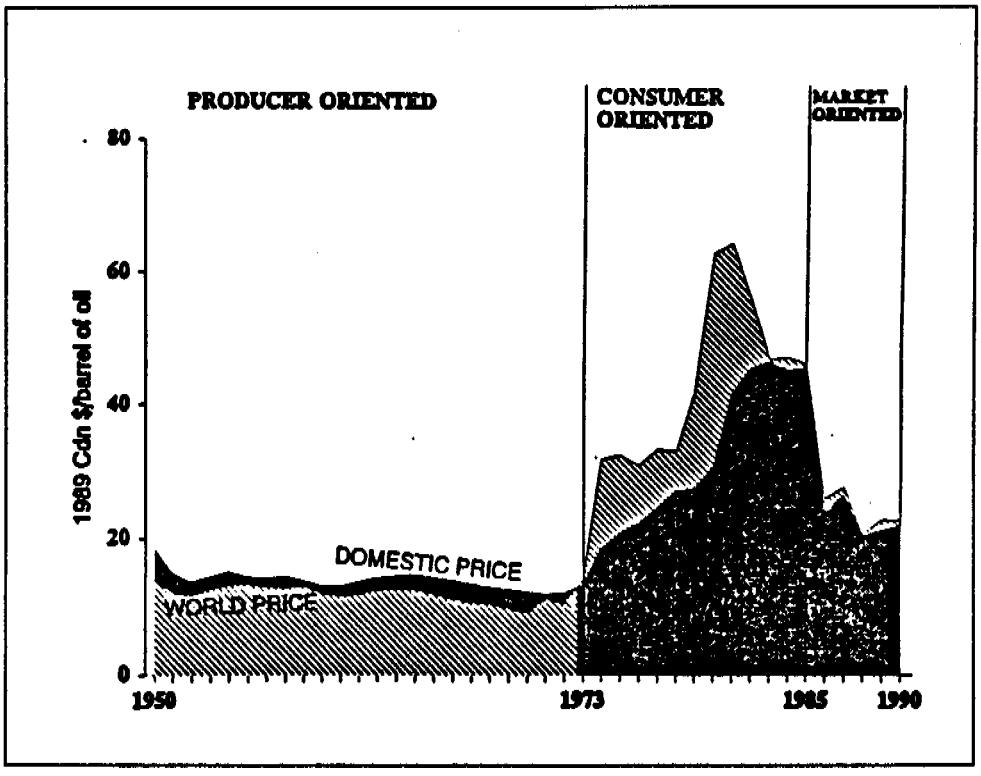
It is also intended that granular resource management plans will be implemented in several priority areas in co-operation with local planning groups. These plans would ensure the resource is equitably shared between the public and private interests in an environmentally sensitive manner.

Current Realities and Rationale for the Study

Hydrocarbon exploration and development in the region has in the past, and will in the future, require granular resources. Historically, onshore granular resources have been used to construct drilling pads and temporary offshore exploration structures in the shallow waters of the Mackenzie Delta.

Development planning and exploration in the area have been influenced to a great degree by oil prices. As shown in Figure 1, the price of oil has varied considerably during the past quarter century. During the period 1973 to 1985, the price reached well over $40/barrel, driven largely by OPEC policies. During this period, exploration activity in the region was high, based on the expected potential of the area and support from the Petroleum Incentives Program (PIP). Over 200 wells have been drilled in the region and significant discoveries have been made, but, well below initial expectations.

To compound the problem of lower than expected discoveries, the prospects for Beaufort Development have been hit by the dramatic drop in oil prices after 1986. Today, the oil price fluctuates around $20/barrel and the current view is that no real growth in price (other than inflation) can be counted on.



Oil Price: 1950-1990 (EMR,1990)
Figure 1

This lower oil price, together with depressed natural gas prices, has also led to significantly lower profits (and in some cases, losses) for the industry. This has also reduced the appetite of the industry to get involved in high-cost Frontier activities.

These are the new realities which have resulted in a dramatic drop in Frontier activities and plans. This change leads one to question what the potential granular resource needs might be for future exploration and development in the region. This is the question which this study will address.

Scope of Work

As outlined earlier, the overall objective of this study was:

- to identify, in collaboration with industry, oil and gas developments in the Beaufort / Mackenzie Delta region, which have potential to be economic under current price outlooks, given plausible technological and fiscal uplift, and
- to determine the associated granular resource requirements and their timing, for these developments.

Specific components of the study include:

1. identifying, using existing experience and input from current and former contacts within industry, the various potential development scenarios for the western Northwest Territories, based on presently known discoveries, and considering the impact of future discoveries.

2. outlining in greater detail, two or three of the scenarios identified in part 1, which are close to being economic, using conventional approaches and current price outlooks, and

3. determining, using existing experience, computer models and input from industry contacts where possible, the categories (types) and quantities and timing of granular resources required for each of the main scenarios identified above.

General Approach

A significant component of the study was focused on obtaining input from industry related to granular resource requirements for current and future needs.

Definitive short term requirements for granular resources were identified from information supplied by the current operators in the region. These requirements reflect anticipated needs to support ongoing operations, exploration drilling, or potential projects identified for the near future.

The third step in the analysis was to identify realistic development scenarios for the region. These scenarios were based on the current and potential reserve base, the experience of the author and input from industry.

The general scope of each scenario was established in order to identify the associated granular resource requirements. Generally, the scope was based on inputs from a variety of sources including industry, and the experience of the author. In some cases, where data was unavailable for a particular scenario, the scope and associated capital costs were established using NORCOST©, a Northern Regions Venture Cost Model developed by NORTH OF 60 ENGINEERING LTD.. The NORCOST© model establishes the scope and cost of facilities necessary to produce and transport oil and gas from the Frontier regions to southern markets. As a subset of the output, it also quantifies the granular resources required for the development.

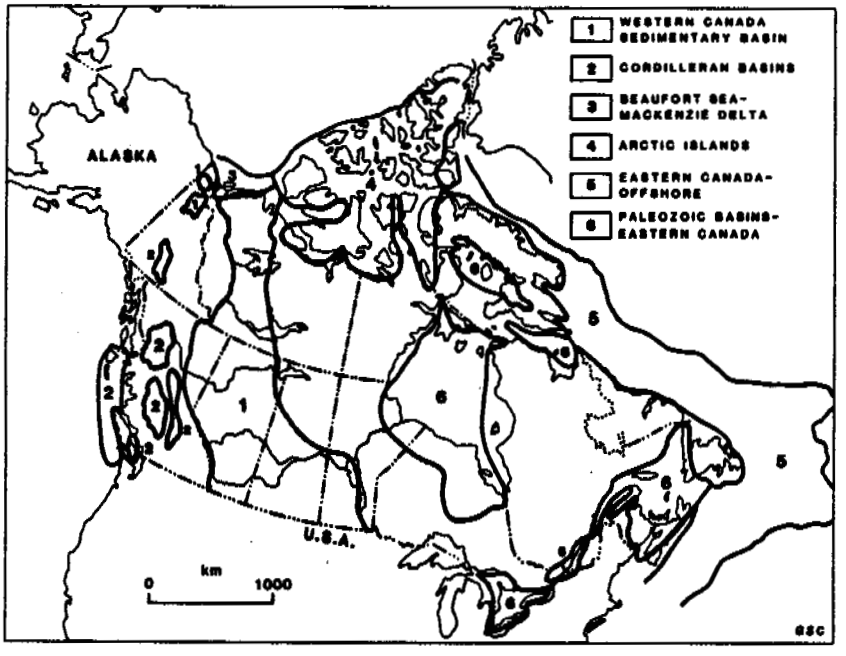
Transportation systems were sized for each of the development scenarios. Pipelines were sized based on hydraulic considerations. Associated granular resource requirements are based on input from industry.

The final step in the process was to summarize the granular resource quantities by type and timing, and to present the basis for the estimates.

Hydrocarbon Exploration & Development in the Western Region of the Northwest Territories

The Region and Geography

The western region of the Northwest Territories is one of the five petroleum regions in Canada's Frontiers. A map of Canada's petroleum regions is shown in Figure 2. This region represents one of the major undeveloped Frontiers in Canada

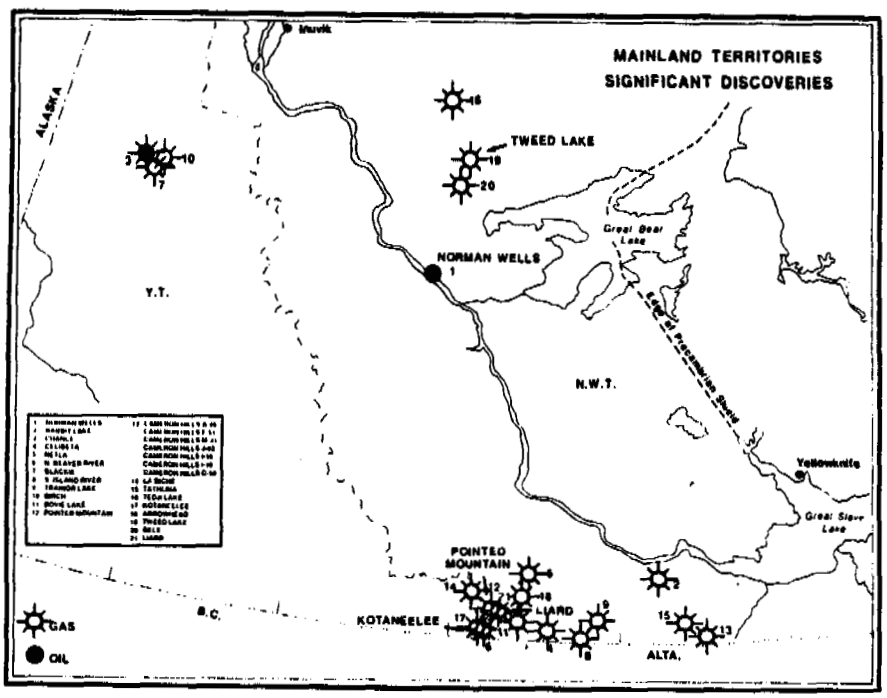


Canada's Petroleum Regions (GSC, 1983)
Figure 2

The term "Frontier" has been used for a good reason. The region north of 60°, is characterized by a harsh climate, sensitive environment and lack of infrastructure. Special engineering and operational procedures are required to avoid subsidence in permanently frozen ground (permafrost), which often contains large quantities of ice. It is this severe environment and the remoteness, which significantly affect not only the cost of oil and gas operations in the Frontier Regions but, also requires large quantities and creates a high demand for granular resources.

Exploration History

The exploration activity in the Western region of the Northwest Territories has been divided into two areas for purposes of discussion. They are the mainland region, which extends from the Alberta - British Columbia border to the area north of Norman Wells (Figure 3) and the northern region, which encompasses the Mackenzie Delta - Beaufort Sea (Figure 4).



Northwest Territories Mainland (DIAND, 1990)
Figure 3

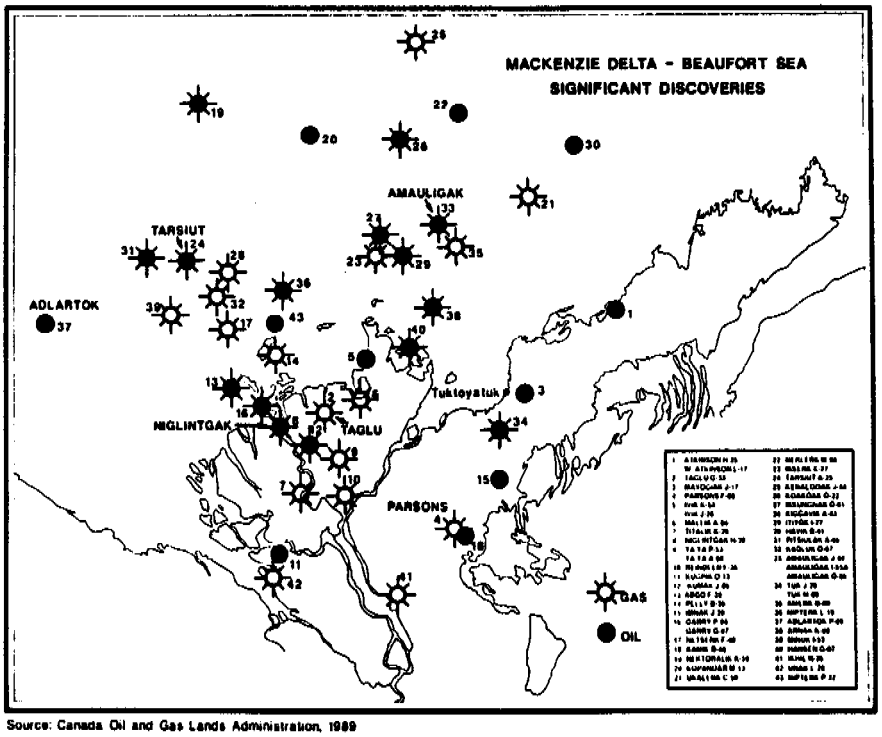
Exploration in the Northwest Territories started in the early 1920s, when the investigation of oil seeps into the Mackenzie River led to the discovery of the Norman Wells oil field.

Over 1000 wells have been drilled in the Northwest Territories Mainland since 1921, which has resulted in a meager 27 significant discoveries. A number of small gas pools have been discovered in the Great Slave Plain just north of the British Columbia - Alberta border. Several medium-sized pools were found in the Liard Plateau, including the currently producing Pointed Mountain gas field, and in the Great Bear Plain, north of Norman Wells. The Geological Survey of Canada indicates an average expectation of undiscovered resource potential in the mainland territories of 590 million barrels of oil and 10.2 Tcf of gas.

Exploration in the Mackenzie Delta - Beaufort Sea region of the Territories began in the early 1960's. The first well was drilled at Winter Harbour on Melville Island in 1962 and this was followed by wells in the Mackenzie Delta/Tuk peninsula region. Oil was first discovered at Atkinson point on the Tuktoyaktuk peninsula in 1969 by Imperial Oil Limited. In 1971, large gas deposits were in the Taglu area of Richards Island by Imperial Oil Ltd. and in 1972 in the Parson Lake area by Gulf Canada Ltd. In 1973 Shell Canada Ltd. made several oil and gas discoveries in the Niglintgak and Kugpik areas of the delta. The cancellation of the Mackenzie Valley Pipeline Project in 1977 virtually ended onshore drilling. However, activity increased between 1982 and 1986 with more exploration in the Tuktoyaktuk peninsula area.

The first offshore well in the Mackenzie Delta - Beaufort Sea was drilled from an artificial island in 1973. Drilling from artificial islands, Esso discovered oil at Adgo in 1974, at Issungnak in 1980, West Atkinson in 1982, Itiyok in 1983 and Nipterk in 1985. In the deeper waters, Dome Petroleum undertook an ambitious exploration program using drill ships. Between 1976 and 1980, Dome encountered oil at the Nektoralik, Koakoak, Kopanoar, Ukalerk and Tarsuit locations. In intermediate waters, Gulf found oil at Pitsiulak and Amauligak. These wells were drilled from a mobile arctic caisson, which was placed on the sea floor or a berm, depending on the water depth and then filled with a sand core to provide sliding resistance against moving ice in the winter. Several gas discoveries were also made in the offshore regions.

In total, over 200 wells have been drilled in the Mackenzie Delta - Beaufort sea area including about 90 wells offshore. The significant discoveries to date are shown in Figure 4. Estimated discovered reserves to date and potential for the region are given in Table 2.



Source: Canada Oil and Gas Lands Administration, 1989

Beaufort Sea - Mackenzie Delta (DIAND, 1990)
Figure 4

The largest oil field discovered is Amauligak, which lies offshore in about 30 m of water. It is estimated to contain about 350 million barrels of recoverable oil and about 2.0 Tcf of gas.

The largest discovered gas field is Taglu in the Mackenzie Delta. It is estimated to contain about 3.0 Tcf of gas and about 30 million barrels of liquids. Other onshore and offshore gas fields give a development potential of about 12 Tcf.

An assessment completed in mid-1988 by the Geological Survey of Canada, estimates undiscovered resources in this area at 5.25 billion barrels of oil and 55 Tcf of gas.

REGION	Oil (billion Barrels)		Gas (Tcf)	
	Discovered	Potential	Discovered	Potential
Onshore - Shallow Offshore	0.22 - 0.26	0.82 - 1.18	6.6 - 8.3	9.4 - 19.7
Offshore Delta	0.8 - 1.0	1.0 - 1.3	3.0 - 4.0	12 - 15
West Beaufort	0.05 - 0.35	1.35 - 2.15	-	12
Deep Offshore	0.2 - 0.4	0.9 - 1.3	0.4 - 0.8	13 - 19
Total	1.27 - 2.01	4.07 - 5.93	10.0 - 13.1	46.4 - 65.7

Mackenzie Delta / Beaufort Sea
Discovered and Potential Reserves (GSC,1988)
Table 2

Historical Development Activities

It took sixty-five years after oil was discovered at Norman Wells, before oil production finally flowed to southern markets (although the oil field had been tapped to produce refined product for the region for several decades). At the commencement of production in 1985, the Norman Wells reservoir was estimated to contain about 200 million barrels of oil. Norman Wells is Canada's most northerly oil field with sustained year round production. It currently produces about 35,000 barrels/day.

Although the Mackenzie Delta - Beaufort Sea region has oil discoveries totaling 1.0 to 1.5 billion barrels and gas discoveries of 12 trillion cu. ft., development has not yet occurred. Considerable effort, though, has gone into development planning, engineering, as well as regulatory and environmental reviews for future development.

The first significant initiative took place in the mid 70's when a consortium of producers and pipeliners proposed to produce the newly discovered gas reserves in the Mackenzie Delta. At that time, the outlook for gas prices was bullish, shortages in the U.S. were predicted, and the project was predicted to be very economic. Extensive public reviews and regulatory screening took place culminating in the Berger Report (1977), which recommended a ten year moratorium on the construction of a large diameter pipeline up the Mackenzie Valley.

A second attempt to develop the gas took place in the late 1980's, when the producer reapplied for a license to export the gas to the US. Unfortunately, however, natural gas prices started to fall rather than rise, and the marketplace didn't seem ready for Arctic gas. Once again, gas development was put on the shelf.

The possibility of oil development from the Beaufort Sea was scrutinized very closely in conjunction with the above activity, during the late 1970's and early 1980's. At that time Dome Petroleum was very active exploring and promoting development (even though the actual major discoveries had not yet been made). But, there was a sense of urgency for Canada to develop new oil supplies. This is not surprising, when it is remembered that world oil price reached $60/barrel in 1980 and was expected to go higher, and Western Canada oil production was expected to decline.

In order to shorten lead times and prepare the way for Beaufort oil development, the industry partners prepared a very comprehensive Environmental Impact Statement (Dome Petroleum et al, 1982), that encompassed production rates up to 700 thousand barrels per day. The companies conducted an extensive public consultation process, which was directed by a federally appointed panel, who reviewed the industry's proposals and public input, and made recommendations. Even though this came only six years after the Berger report, the Panel did report that Beaufort Sea development could proceed without significant adverse environmental and socio-economic effects. However, they did recommend that initial development be on a small-scale, and preferable by pipeline in order to minimize impacts and prepare communities for the larger developments which would follow (FEARO, 1984).

Subsequent to the Beaufort EIS in 1982, companies continued to explore as discussed in the previous section, and Gulf Canada Ltd. discovered the Amauligak reservoir in 1985 with an initial assessment of recoverable reserves of 700 million barrels. This initial assessment triggered a sizable development planning effort. Subsequent delineation, however, lowered the initial reserve estimate to 400 million barrels, which, when combined with falling oil prices, led to the project being shelved as being uneconomic without price increases or innovations to lower costs.

Current Outlook

Hydrocarbon resource exploration and development activity in the region is at an all-time low. Exploration drilling has dropped to a twenty year low and there has been little interest shown in obtaining new leases.

A major factor in this low activity is the current drive within the industry to reduce costs and to only invest in projects which yield short-term returns. This strategy is driven by the general financial weakness of the industry.

At the same time, the major oil companies in Canada do see the need to replenish their current production and reserves, which are in decline. But, the current attitude is that, this will only be done if the economics are in-line with shareholders expectations. A major hurdle, even for those companies with financial strength, is to make the new Canadian supplies competitive, whether they be from the Frontiers, the Oil Sands, or from enhanced recovery.

In the Mackenzie Delta/Beaufort Region, the prevailing industry view is that there are insufficient reserves discovered for an economically attractive development. This is mainly because any developments are viewed as requiring an expensive transportation system, resulting in high pipeline tariffs, unless sufficient reserves can be developed economically to maintain pipeline throughput. The current industry strategy would appear to be one of preparing for additional exploration to start, when the financial state of the industry will allow it. It appears that industry would start with onshore exploration first, in the hope of finding economic reserves based on lower-cost onshore fields.

Frontier natural gas discoveries, while significant in size, are currently not competitive with the existing reserves in southern Canada due to the costly transportation system that is required to move the gas to market. Given current low gas prices and the unexpected near term growth in those prices, it is unlikely that the discovered reserve base will be developed within the next decade although significant changes in fuel use could alter this outlook.

Current Granular Resource Requirements

Despite the pessimistic outlook, Industry has identified a number of ongoing or potential projects that will require granular material in the near term. They are:

- Shell Canada will potentially require 15,225m^3 to support their ongoing exploration actives in the Mackenzie Delta in the 93/94 period, however, they will attempt to utilize surplus material currently stockpiled in the area.

- An annual requirement of 500m^3 rock, and 750m^3 sand to support ongoing operations by Imperial Oil Limited at Norman Wells.

- Imperial has planned a number of small projects for 1993 that will require 3,000m^3 rock, 10,000m^3 gravel and 1,300m^3 sand.

- A new well pad a Norman Wells in 1994, which would require 40,000m^3 of rock and 53,000m^3 of gravel.

- An estimated 500,000m^3 for a 40 to 50 km access road into the Cameron Hills area to support potential resource development in the area.

- An estimated 90,000m^3 for a potential refinery and access road in the Jean Marie area.

The above quantities are summarized along with possible future requirements based on plausible development scenarios in the following sections.

Development Scenarios

Recent Studies

In recent years, industry has usually considered two distinct scenarios for Beaufort Oil.

One has been an offshore development based on Amauligak, producing about 80,000 barrels/day transported via a 16 inch (or bigger) pipeline up the Mackenzie Valley to Alberta. As indicated in the previous section though, the current reserve base at Amauligak is not sufficient to achieve this level of throughput for a significant period of time. Even when some of the smaller fields are added, there is still a shortfall. The conventional wisdom for Amauligak is that it is stalled until more reserves are discovered.

The other scenario for Beaufort Oil has considered only the onshore (and very shallow offshore). Current onshore discoveries total about 120 million barrels, but, in a number of relatively small fields. A scenario often looked at is an extension of the Norman Wells pipeline to the Mackenzie Delta to produce onshore oil at about 25,000 BPD from a yet-to-be discovered onshore field of 100 - 200 million barrels. As will be discussed shortly, this scenario can be economic, if certain cost savings are achieved and the pipeline extension can be kept running full for a 20 - 25 year period. Currently, there are insufficient onshore reserves discovered to achieve this sustained production.

As discussed earlier, the usual development scenario for Beaufort Gas has focused on the currently discovered large reserve base onshore, with additional reserves offshore being developed to maintain contracted volumes.

Certainly, the key to development in today's economy is to find innovative ways of reducing the high costs associated with oil and gas development and transportation.

Towards that end, NORTH OF 60 ENGINEERING LTD. in association with K.R. Croasdale and Associates Ltd. recently completed a study for the Federal Panel on Energy R & D (PERD) to identify

key research and development thrusts, which, if successful, would significantly improve the potential of oil and gas development in the region. A number of generic oil and gas development scenarios were considered. They included:

- A 100 million barrel (recoverable reserves) onshore field, utilizing a 12" extension of the Interprovincial Pipeline from northern Alberta to Norman Wells.

- A 350 million barrel offshore pool, producing at a rate of 80,000 barrels per day into a 16" pipeline from the offshore location to northern Alberta.

- A 350 million barrel offshore pool, producing at a rate of 80,000 barrels per day, utilizing year round ice breaking tankers to transport the product to market.

- A 350 million barrel offshore pool, producing at a rate of 35,000 barrels per day, utilizing a 12" extension of the Interprovincial Pipeline from northern Alberta to Norman Wells.

- A 350 million barrel offshore pool, producing seasonally into a tanker, which would transport the product to market.

- A gas scenario to produce only the onshore reserves at a rate of 800 Mcf/day through a 30 inch pipeline, constructed from Taglu to northern Alberta.

The study identified the cost, economic viability, and economic sensitivities associated with each of the scenarios. In addition, it outlined a number of potential research initiatives, which could reduce costs and, thus, improve the economics.

One of the important conclusions from the study was that small scale oil development, using either an extension of the Norman Wells pipeline or tanker transportation, could be economically attractive without additional reserves, if technology advancements could achieve lower costs. The study also recommended a framework to focus future research into areas that could potentially make development a reality.

Oil and Gas Scenarios

Based on the results of the previous work by the author, a number of potential development scenarios have been considered for this study. They include:

- the development of a small onshore oil or gas field to provide a fuel source to meet local energy demands.
- the potential for seasonal production from the Amauligak reservoir.
- a generic 200 million barrel onshore field, and
- the processing of onshore gas for sale to southern markets.

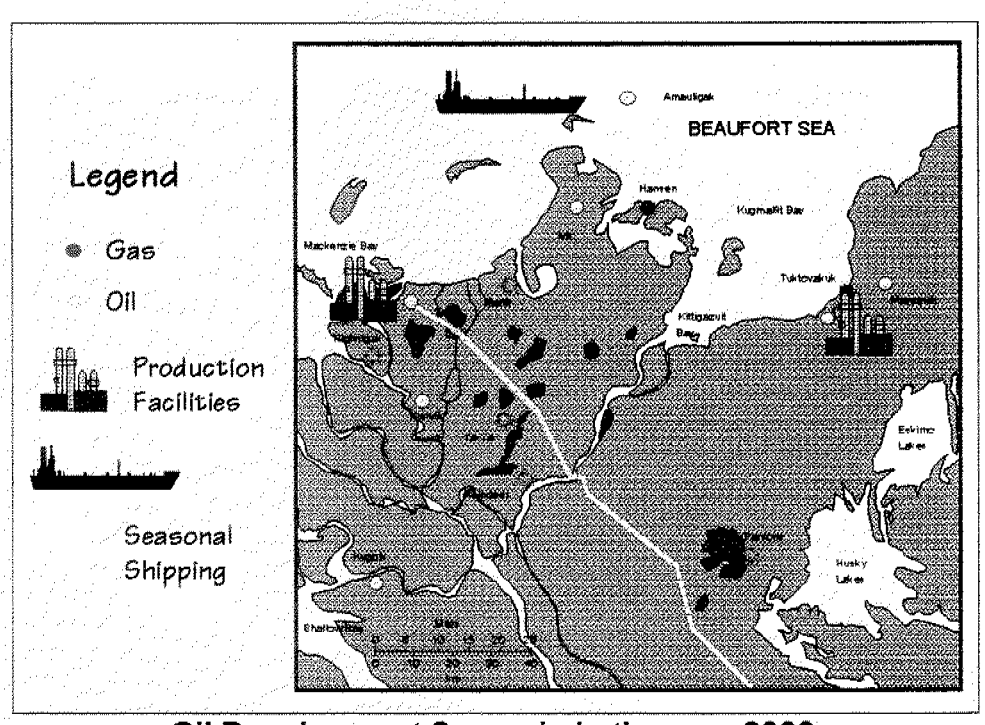
The timing of these scenarios has been phased to reflect the ongoing level of exploration, the time frame required to develop a particular scenario and the current economic outlook.

The initial development scenario is shown in Figure 5. It assumes that development of local energy sources to supply the town of Tuktoyaktuk, or seasonal oil production from an offshore discovery such as Amauligak could take place in the 1995 - 2000 time frame. It also assumes a discovery, and the development of an onshore 200 million barrel pool in Richards Island area by the year 2000. Production from the field would be transported to southern markets through a 12 inch extension of the pipeline that currently runs from Zama, Alberta to Norman Wells.

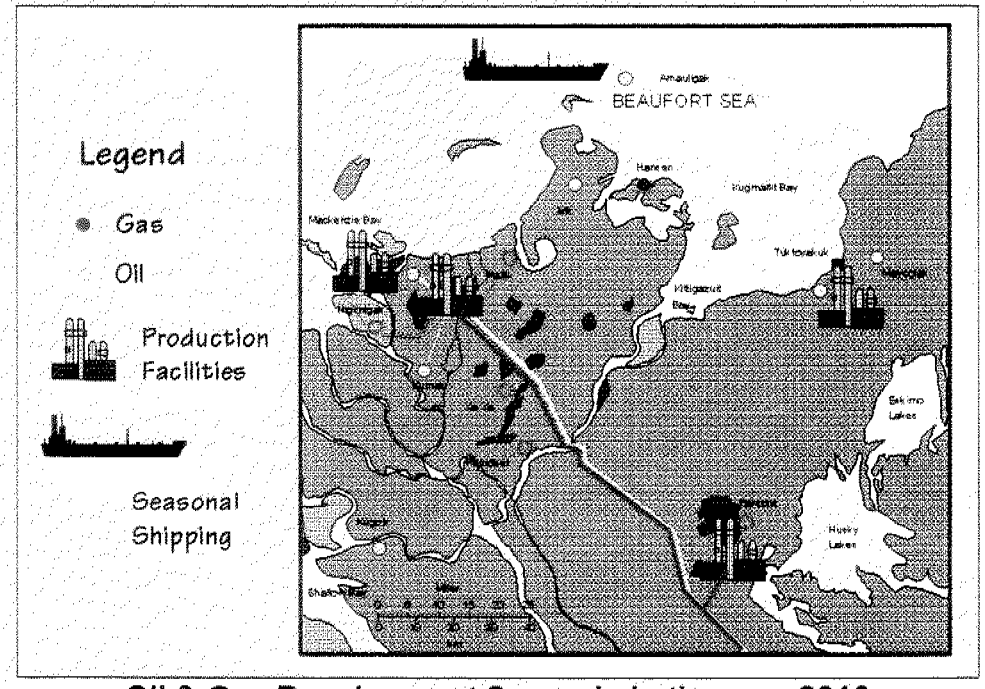
As initial production starts to decline, additional onshore fields would be brought on stream. The timing of these additional developments would depend on available pipeline capacity and the actual timing of gas development.

The author has assumed that sufficient demand and growth in gas prices will occur by the year 2005 to justify development of the three major onshore fields (Taglu, Parsons Lake and Niglintgak). This would trigger the construction of a gas pipeline, development drilling and production facilities which would come on stream in the year 2010. A possible development scenario for the year 2010 is presented in Figure 6.

And finally, as additional capacity in the transportation system is established, additional onshore fields would be added.



Oil Development Scenario in the year 2000
Figure 5



Oil & Gas Development Scenario in the year 2010
Figure 6

Granular Resource Requirements

Future Granular Requirements by Scenario

Local Opportunities

A number of small gas pools are located in close proximity to the town of Tuktoyaktuk. The Inuvialuit Petroleum Corporation has, on a number of occasions, considered developing these reserves as a fuel source to meet local energy needs. The development scenario that has been considered in the past includes the drilling of two wells from gravel pads which would be tied into a small gas treating facility also located on a gravel pad. This process facility would remove water and any other liquids from the gas, so that it could be transported in a small buried line to the town of Tuktoyaktuk, where it would be used as a fuel source for heat, power generation, and potential commercial development. Based on previous engineering studies, the IPC has estimated that approximately 40,000 m^3 of granular material would be required for this development.

Seasonal Offshore Production

Another small scale scenario that appears attractive, given the current economic outlook, is the development of one of the offshore prospects, using an existing platform and then producing the field on a seasonal basis in a similar manner to the Panarctic operation at Bent Horn.

A number of exploration drilling structures, such as the Molikpaq, could be upgraded for seasonal production. Many of the offshore discoveries could easily sustain production rates of about 30 - 35,000 Bbl/day during the 90 day summer season into existing ice reinforced tankers, which would shuttle the oil for transshipment in the Bering Sea. This production scenario would require a potential offshore berm or, depending on the structure used, sand fill for stability against moving ice in the winter months, when production would be suspended. These requirements have been estimated to be in the order of 650,000 m^3. An offshore source would be used for these volumes.

As indicated in the PERD sponsored study, this scenario could ultimately be expanded to include year round transportation of the crude using ice breaking tankers, or through a subsea pipeline to connect with a small onshore extension of the Interprovincial pipeline to Norman Wells. Full development of the field would likely require and additional 2,700,000 m^3 of granular fill for a berm to support the permanent structure.

Onshore Oil Development

A generic case of a 200 million barrel (recoverable) oil field has been chosen based on the results of the recent PERD sponsored study. No such oil field has yet been discovered, but the Geological Survey of Canada report suggests that fields of this size (and larger) are a possibility onshore. Clearly, future onshore drilling will be aimed at such targets.

The development plan for this scenario was generated using the NORCOST model developed by NORTH OF 60 ENGINEERING LTD. A summary of the development plan is presented in Appendix A. In summary, the field would produce at a rate of approximately 36 kBbl/day into a 12" extension of the Interprovincial Pipeline to Norman Wells. The development would require 90 wells (60 producers) drilled from 2 pads based on an assumed aerial size of 15 sq. miles and a reservoir depth of 8000 ft. Granular resource requirements for the field development as estimated by the model are summarized in Table 3. These volumes are based on 6 miles of road, a dock and staging area, drilling and plant pads.

Project Component	Class 2 Volume m^3	Class 3 Volume m^3	Total Volume m^3
Roads	15,000	282,109	297,109
Runway & Helipads	1,954	0	1,954
Plant & Staging Area	12,000	67,428	79,428
Drill Sites	0	160,704	160,704
Total	28,954	510,241	539,195

Granular Requirements for a 200 Million Barrel Onshore Pool
Table 3

Norman Wells to Mackenzie Delta Oil Pipeline

A 12 inch extension from Norman Wells to the Mackenzie Delta would be roughly 350 miles in length requiring 3 to 4 pump stations. Two configurations for the line are possible depending on the rheology of the crude oil. If the crude oil to be transported has a pour point below 0°C, the pipeline would likely be buried and the crude oil refrigerated to prevent thawing of the ice rich permafrost. A pour point significantly above 0° would require that the line be elevated on vertical support members. The final configuration will ultimately depend on the crude properties of the reservoir that leads the development.

According to Interprovincial Pipe Line Inc. approximately 50,000 m^3 of granular resource material would be required for construction of the extension north of Norman Wells. This small volume (when compared to the gas pipeline requirements discussed below) can likely be attributed to the small diameter of the line.

Onshore Gas Development

In the Mackenzie Delta - Beaufort Sea region, natural gas discoveries total about 12 Tcf of which 4.5 Tcf is located offshore. The largest onshore gas field is Taglu with 3 Tcf, followed by Parsons Lake field with 1.9 Tcf and Niglintgak field with 1 Tcf. The most recent study of gas development was conducted during the period 1987 - 1991 by the producers, who applied for an export license for the gas. This was approved by NEB in 1989, but, since then, the initiative has stalled due to poor economics based on the latest outlook for gas prices.

The development plan assumed for this study is based on a 36 inch pipeline up the Mackenzie Valley to Caroline, Alberta. Initially, only the three major onshore reserves would be produced at an estimated initial capital investment of about $2 billion for facilities and over $5 billion for the pipeline. The gas would be produced at 1.2 billion cu. ft./day. Production facilities at Taglu and Parsons Lake would dehydrate the gas, remove hydrocarbon liquids and, then, chill the gas to avoid permafrost thawing and subsequent subsidence. Ultimately, the development scenario would require additional onshore reserves to maintain the 1.2 billion cu. ft/day rate. For the basis of this study, it has been assumed that existing discoveries in the Mallik and Tuk areas

would be developed and tied into the system to maintain production.

Development plans for Taglu, Parsons Lake, and Niglintgak were prepared using the NORCOST model. A summary of these plans is contained in Appendix A. The granular resource requirements for each field are summarized in Table 4.

Development plans for the Mallik and Tuk fields were not prepared. Granular resource requirements for these fields were assumed based on the size of the fields, to be 250,000 yd^3 and 500,000 yd^3 respectively.

Field	Class 2 Volume m^3	Class 3 Volume m^3	Total Volume m^3
Taglu	105,890	953,012	1,058,902
Niglintgak	38,870	349,830	388,700
Parsons	60,138	541,247	601,385
Mallik	19,114	172,024	191,138
Tuk Cretaceous	38,228	344,047	382,275
Total	262,240	2,360,160	2,622,400

Granular Requirements for Onshore Gas Development
Table 4

Gas Pipeline - 36" - Mackenzie Delta to Edson

A 914 mm diameter, 2,330 km long, pipeline would be required to transport the gas from the Mackenzie Delta to Edson, Alberta for distribution to markets in Southern Canada and the United States. Gas in the line would be refrigerated to prevent thawing of the permafrost.

General fill (similar to Class 3) would be required for work pads, access roads, airstrips and other associated pipeline facilities. Select fill (Class 2) would be required to improve the durability of subgrade surfaces and for bedding and packing around the pipe. Finally, a limited quantity of aggregates (Class 1) would be required for concrete pipe weights and structural foundations.

Granular resource requirements for the pipeline, by type, and construction spread, are summarized in Table 5. Operating and maintenance facilities to support the pipeline would require an additional 244,073 m^3 of general and select material.

Spread #	Length km	General Fill m^3	Pipe Protection m^3	Aggregate m^3	Total m^3
1	210	432,840	345,585	948	794,845
2	245	674,806	331,207	1,228	1,054,443
3	250	539,338	321,863	32,780	931,002
4	260	571,607	342,556	62,025	1,020,739
5	275	278,318	318,104	47,956	662,904
6	395	262,217	216,467	44,740	566,105
7	485	237,263	184,610	35,464	495,957
Total	2,120	2,996,389	2,060,392	225,141	5,525,995

Granular Requirements for a 36" Pipeline Source: Kaustinen
Table 5

Total Granular Resource Requirements

Total granular resource requirements for the various onshore and offshore development scenarios discussed in the previous section are summarized in Tables 6 and 7. Table 6 represents a breakdown of the requirements for oil development, while Table 7 summarizes the requirements for gas development.

Year	Onshore	Offshore
1993-1995	716,275	0
1996-2000	625,447	650,000
2001-2005	6,250	0
2006-2010	6,250	0
2011-2015	388,525	2,700,000
2016-2020	235,615	0
Total	1,978,362	3,350,000

Granular Material Required for Oil Development (m^3)
Table 6

Year	Onshore	Offshore
1993-1995	0	0
1996-2000	40,000	0
2001-2005	0	0
2006-2010	7,819,054	0
2011-2015	573,413	0
2016-2020	0	0
Total	8,432,467	0

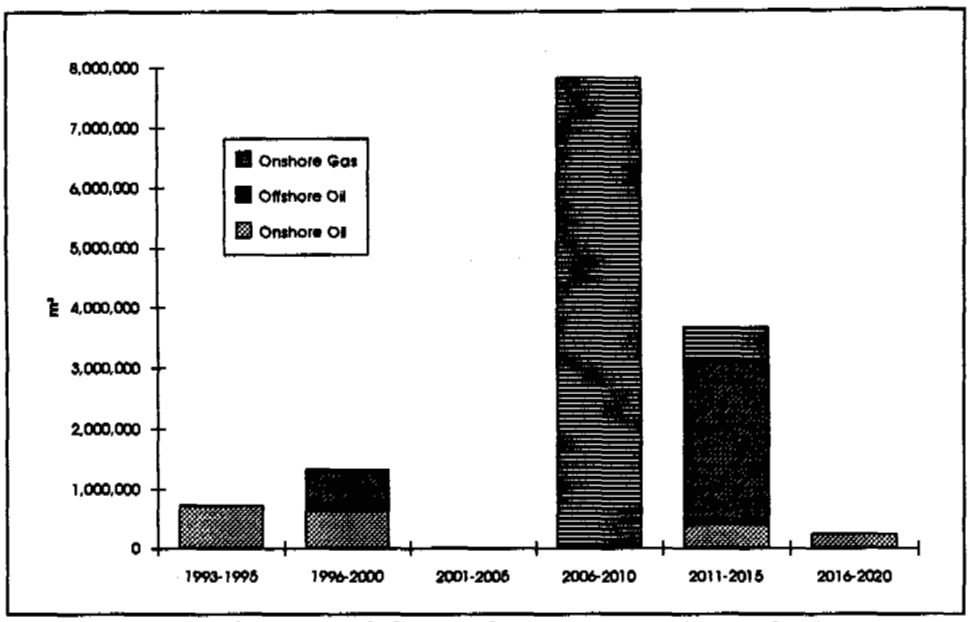
Granular Material Required for Gas Development (m^3)
Table 7

Table 8 summarizes the onshore and offshore granular resource requirements for both oil and gas. Onshore oil development will require an estimated 2 million m^3 of granular material, while onshore gas development will require an estimated 8 million m^3. Six million m^3 of the 8 million estimate is associated with the construction of a pipeline that would be required to deliver the gas to southern markets The granular material for offshore oil development would likely be dredged from offshore sources that have been identified in the Beaufort Sea.

Year	Onshore Oil	Offshore Oil	Onshore Gas
1993-1995	716,275		0
1996-2000	625,447	650,000	40,000
2001-2005	6,250		0
2006-2010	6,250		7,819,054
2011-2015	388,525	2,700,000	573,413
2016-2020	235,615		0
Total	1,978,362	3,350,000	8,432,467

Granular Material Required for Oil & Gas Development (m^3)
Table 8

Granular material requirements have been slotted into 5 year time frames based on the assumed development scenarios. A forecast of granular resource requirements vs. time is shown in Figure 7.



Granular Material Requirements vs. Time (m^3)
Figure 7

Generally speaking granular requirements for onshore oil are spread out evenly over the forecast period. Onshore gas development will require significant volumes over a relatively short period of time (3 to 4 years), however, these requirements are distributed spatially over the length of the line, which runs from the Mackenzie Delta to Southern Alberta.

The reader is cautioned that the exact timing of these requirements is very dependent on the timing of actual development and the specific project development plans.

While the granular resources requirements for the development scenarios considered are significant, they are lower than previous estimates based on much larger development scenarios.

Conclusions

A number of conclusions can be made from the study. They are:

- **The static hydrocarbon reserves that have been discovered in the region are significant.**
- **Future oil development in the region will likely require additional reserves. Gas development will depend on the economic outlook and future demand.**
- **Technology and fiscal uplift will enhance the likelihood of development.**
- **Granular resources required to support ongoing operations at Norman Wells, the southern region of the Territories and ongoing exploration in the Mackenzie Delta - Beaufort Sea are relatively small.**
- **A number of development scenarios have been identified that are potentially viable given technology and fiscal uplift. Granular resource requirements for these development scenarios are significant (13.76 million m^3) , but lower than historical estimates for larger development scenarios.**
- **Onshore oil development requires an estimated 2 million cubic meters while onshore gas development is estimated to require 8.5 million cubic meters.**
- **The timing of future granular resource requirements for hydrocarbon development in the Mackenzie Delta / Beaufort Sea is very dependent on the actual timing of development and specific project development plans.**

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Organizations Contacted for Input to the Study

- Department of Indian Affairs and Northern Development.
- The Canadian Association of Petroleum Producers
- Amoco Canada Petroleum
- Canadian Marine Drilling
- Gulf Canada Resources
- Imperial Oil Resources
- Interprovincial Pipeline Co.
- Petro Canada
- The Inuvialuit Petroleum Corporation
- Foothills Pipeline
- Polar Gas Pipeline
- Shell Canada

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Appendix A

Input Parameters

Prospect Name:	**200 MBbl Onshore Pool**
Prospect Location:	**Mackenzie Delta**
Product:	Oil
Reservoir Depth:	8000 (ft.)
Recoverable Reserves:	200 (mBbl or BCF)
Aerial Size	15 Sq. Miles
Gas Disposition:	Re-Injected
Water Injection:	Yes
Artificial Lift:	No
Transportation System:	Pipeline
Distance to Market	15 (miles)
Site Conditions:	Permafrost
Freezing Index:	8500 °F Days
Thawing Index:	1500 °F Days

Results

Granular Resource Quantities:

Roads	388608	(c.u. yds)
Runway	0	(c.u. yds)
Hellipad	2556	(c.u. yds)
Plant Area	40000	(c.u. yds)
Staging Area	63889	(c.u. yds)
Drillsites	210194	(c.u. yds)
Total	705247	(c.u. yds)

Capital Cost: 471.0 M$

Input Parameters

Prospect Name:	**Taglu**
Prospect Location:	**Richards Island**
Product:	Gas
Reservoir Depth:	12000 (ft.)
Recoverable Reserves:	3000 (mBbl or BCF)
Aerial Size	10 Sq. Miles
Gas Disposition:	Sales
Water Injection:	No
Artificial Lift:	No
Transportation System:	Pipeline
Distance to Market	0 (miles)
Site Conditions:	Permafrost
Freezing Index:	8700 °F Days
Thawing Index:	1500 °F Days

Results

Granular Resource Quantities:

Roads	88000	(c.u. yds)
Runway	773000	(c.u. yds)
Hellipad	0	(c.u. yds)
Plant Area	364000	(c.u. yds)
Staging Area	60000	(c.u. yds)
Drillsites	100000	(c.u. yds)
Total	1385000	(c.u. yds)

Capital Cost:	510.0	M$

Input Parameters

Prospect Name:	**Nig**
Prospect Location:	**Richards Island**
Product:	Gas
Reservoir Depth:	6000 (ft.)
Recoverable Reserves:	700 (mBbl or BCF)
Aerial Size	10 Sq. Miles
Gas Disposition:	Sales
Water Injection:	No
Artificial Lift:	No
Transportation System:	Pipeline
Distance to Market	10 (miles)
Site Conditions:	Permafrost
Freezing Index:	8700 °F Days
Thawing Index:	1500 °F Days

Results

Granular Resource Quantities:

Roads	364320	(c.u. yds)
Runway	0	(c.u. yds)
Hellipad	2556	(c.u. yds)
Plant Area	100000	(c.u. yds)
Staging Area	10222	(c.u. yds)
Drillsites	31306	(c.u. yds)
Total	508403	(c.u. yds)

Capital Cost: 157.5 M$

Input Parameters

Prospect Name:	**Parsons**
Prospect Location:	**Mackenzie Delta**
Product:	Gas
Reservoir Depth:	9000 (ft.)
Recoverable Reserves:	1200 (mBbl or BCF)
Aerial Size	15 Sq. Miles
Gas Disposition:	Sales
Water Injection:	No
Artificial Lift:	No
Transportation System:	Pipeline
Distance to Market	40 (miles)
Site Conditions:	Permafrost
Freezing Index:	8700 °F Days
Thawing Index:	1500 °F Days

Results

Granular Resource Quantities:

Roads		607200	(c.u. yds)
Runway		0	(c.u. yds)
Hellipad		2130	(c.u. yds)
Plant Area		133333	(c.u. yds)
Staging Area		8519	(c.u. yds)
Drillsites		35405	(c.u. yds)
	Total	786587	(c.u. yds)

Capital Cost:	286.82	M$