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Beaufort Sea Energy Production and Environmental Protection

Richard A. W. Hoos

Dome Petroleum Limited
Calgary

Abstract

Exploration permits in the Beaufort Sea-Mackenzie Delta Region were issued to the petroleum industry by the Federal Government beginning in 1965. The purpose of these permits was to encourage exploration for hydrocarbons in this region. To retain the permits, industry was obliged to carry out a certain minimum level of exploration-related activity. Since that time, almost $ 2 billion has been spent on exploration. Drilling results to date, and particularly the recent oil discoveries at Kopanoar, Tarsiut, Issungnak and Koakoak has led the major operators to commence the design of systems to extract the hydrocarbons and deliver them to market.

Permanent islands built of sand, concrete and steel in waters up to 200 feet deep will provide the offshore platforms for producing and processing the hydrocarbons. Initially oil will be of primary interest, with the plan being to transport it via Arctic icebreaker tankers and/or pipeline(s) to markets. As the demand for gas develops, it will also be transported to market, most likely by pipeline. A significant shorebase infrastructure complete with quarries, roads, harbours, airports, maintenance facilities and other services will be required to support the impending development.

All of the foregoing activities must be carried out in an environmentally and socially responsible manner. The proposed developments are presently being examined under the auspices of Canada's Federal Environmental Assessment and Review Process. This process is assisting by involving the public in the early identification of the major environmental and socio-economic concerns respecting proposed developments. The outcome of this effort, along with more specific reviews to be conducted by the appropriate regulatory agencies, should ensure that the final developments which take place will conform to the high environmental protection and socio-economic standards expected by all Canadians and the international community.

Background

Petroleum activity in the Beaufort Sea and Mackenzie Delta area began in the early 1960's with seismic exploration and the drilling of exploration wells by a number of operators. The prelude to offshore exploratory drilling occurred in 1971 when Imperial Oil Ltd. applied for permission to drill in shallow water from man-made islands. Approval was granted for the first such island, Immerk, in 1972, from which a well was drilled soon afterwards. Since then 18 man-made, or artificial islands have been built in waters off the Mackenzie Delta (Figure 1). Industry has gained valuable operating experience both on land in the Delta and offshore in the Beaufort Sea and more than 130 exploration wells have been drilled.

Dome, through its subsidiary Canadian Marine Drilling Ltd. («Canmar») began its exploratory drilling program in the Beaufort Sea during 1976 with three ice-reinforced drillships (Figure 2). A fourth drill ship was added in 1979. In addition to the drillships, the present drilling fleet includes eight supply vessels four of which

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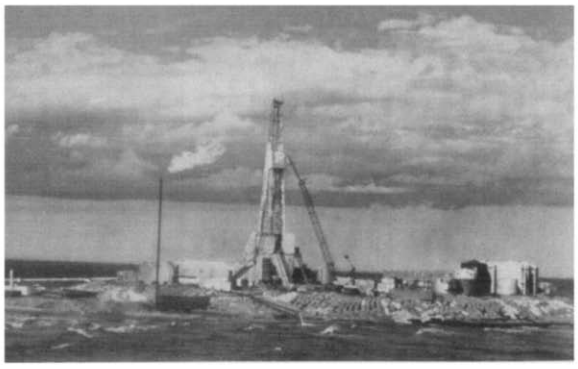

FIGURE 1. *Issungnak, site of one of the more recent offshore oil and gas discoveries, was built by Esso Resources Canada Limited. It is located about 30 kilometres north of the nearest Arctic coastline in 60 feet of water. Issungnak required the dredging of five million cubic metres of sand from the sea floor.*

are ice class, one Class 4 icebreaker, four ice class support tugs, an ice reinforced fuel tanker, an offshore crane barge, a floating drydock and six specialty barges.

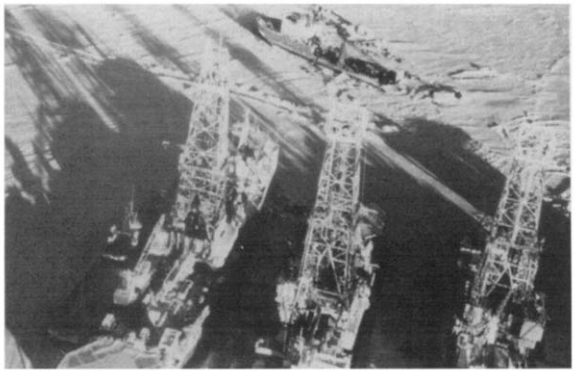

FIGURE 2. *Three of the ice-reinforced drillships, several supply ships and at the top of the photo, the icebreaker Kigoriak, while moored in McKinley Bay during the winter of 1979-80.*

To increase the pace of offshore drilling activity, in 1980 Dome commenced the construction of exploration drilling islands in the offshore Beaufort at the Kaglulik and Tarsiut sites. The Tarsiut island, operated by Gulf, was completed in 1981 and drilling at this site is presently underway (Figure 3). Tarsiut is the world's first caisson retained island built in Arctic waters.

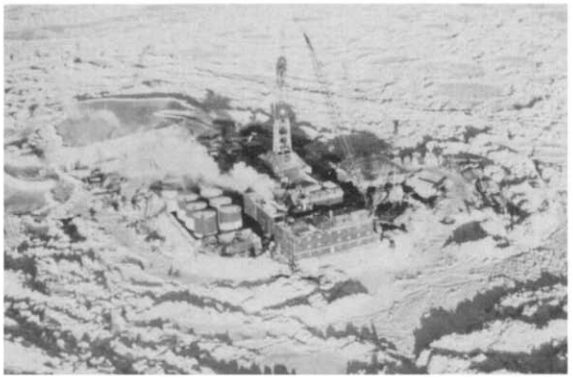

FIGURE 3. *Tarsiut, the first caisson-retained island in the Beaufort Sea, was completed during 1981. A successful delineation well was drilled from the island during the winter of 1981-82, and further wells are planned including one currently underway.*

This type of island construction represents a significant step forward in the design and construction of future Arctic offshore platforms. Unlike the more conventional sacrificial beach islands built in the shallower waters of the Beaufort, Tarsiut required much less gravel and sand to complete the structure. It was built with a more steeply sloped berm foundation, with a 1 in 5 slope, compared to the more conventional 1 in 15 for previous islands. In addition, because of the use of caissons to break through the water-air interface, the subsea berms end approximately 6 metres (20 ft.) below the waterline.

Tarsiut also serves as a research laboratory, having been equipped with more than a million dollars worth of instrumentation to measure ice and other forces throughout the life of the island. This preliminary experience, together with the research data generated, are being directed into the design of other exploration islands projected for the Uviluk and Koakoak areas, and will make a major contribution to the design of future production facilities.

To support the exploratory drilling effort, sizeable shorebases are operated by Dome, Esso and Gulf (being built) at Tuktoyaktuk. The base facilities include docks, staging areas, accommodation facilities, administration complexes, warehouses, light steel fabrication and machine shops.

The bases are serviced by air from the Tuktoyaktuk airport, and a small strip at the Esso base. These facilities accommodate the variety

of aircraft including Boeing 737's, Hercules transporters, helicopters and STOL planes needed to transport personnel and equipment.

During the first three years of operation in the Beaufort, the drillships were anchored through the winter at natural harbour sites located at Herschel Island and at Cape Parry. This posed various operational difficulties and in 1979 permission was received to create a new winter anchorage at McKinley Bay on the Tuktoyaktuk Peninsula. A large cutter suction dredge known as the Aquarius was brought in, and by the end of the 1979 open water season, had dredged a navigation channel and basin in McKinley Bay (Figure 4).

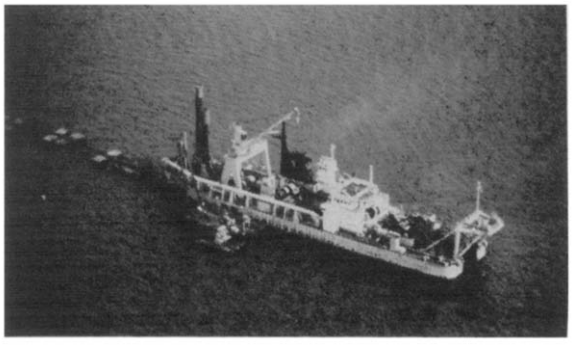

FIGURE 4. *The cutter suction dredge Aquarius was brought to the Beaufort in 1979 to dredge an overwintering harbour at McKinley Bay. Since then it has been used to perform a variety of jobs including enlarging the McKinley Bay harbour, providing sand for the Tuktoyaktuk water reservoir, and to help with the building of Tarsiut.*

During 1980 and 1981 the McKinley Bay harbour was enlarged to accommodate the expanding drilling fleet. In the process, an island was built on the north side of the mooring basin. This island, which serves to protect the ships anchored in the basin, has grown to 63 hectares in size. Geotechnical studies conducted on the island have shown it to be very adequate as a foundation for future support base facilities and activities.

Plans are presently being developed to use the island as a major support base to service year-round exploration drilling and the initial future production development activities.

Drilling Results to Date

The exploration effort has been very successful in corroborating the expectations of geologists who have long predicted that the Mackenzie Delta-Beaufort Sea area would be a major oil and gas producting province (Figure 5). On-land in the Delta, over 100 wells have been drilled and three major gas fields have been confirmed at Taglu, Parsons Lake and Niglintgak. Proven gas reserves are estimated at 6 trillion cubic feet. Offshore, the drillship operations have completed 15 wells and are credited with four of the offshore oil discoveries and two gas discoveries. Likewise oil has been discovered at several offshore island sites with the most promising locations being Issungnak in 19 metres of water and Adgo, in very shallow water.

Delineation drilling is required to establish the commerciality of the offshore discoveries. One successful delineation well was drilled in 1981 offsetting the Kopanoar discovery, and a successful delineation well was completed from the Tarsiut island during the winter of 1981-82. Two further delineation wells (1 from island, 1 by drillship) are presently being drilled at Tarsiut; delineation drilling of the Koakoak discovery is planned for 1983; and further drilling at Kopanoar for 1983 and 1984. The Tarsiut discovery is located in the shallowest water and therefore has the greatest potential for early production from the Beaufort.

Estimates for Beaufort hydrocarbon potential vary over a range from 6.9 to 34 billion barrels of oil and up to 60 trillion cubic feet of gas. However, the precise potential of the Beaufort should not be an issue at this stage of evaluation since only a few fields would be fully developed by the end of this century. The industry expects to confirm 4.5 to 7.5 billion barrels of oil in the Beaufort by 1990.

Consultants estimates for recoverable oil reserves at Kopanoar range from 270 million barrels to 1.8 billion barrels and at Koakoak from 300 million barrels to 2.0 billion barrels. Estimates have not been released for other discoveries.

The Development Objective

The Beaufort Sea-Mackenzie Delta region has the potential to help Canada become self-sufficient in oil production within this decade and in the process could stimulate considerable economic and employment activity in Canada.

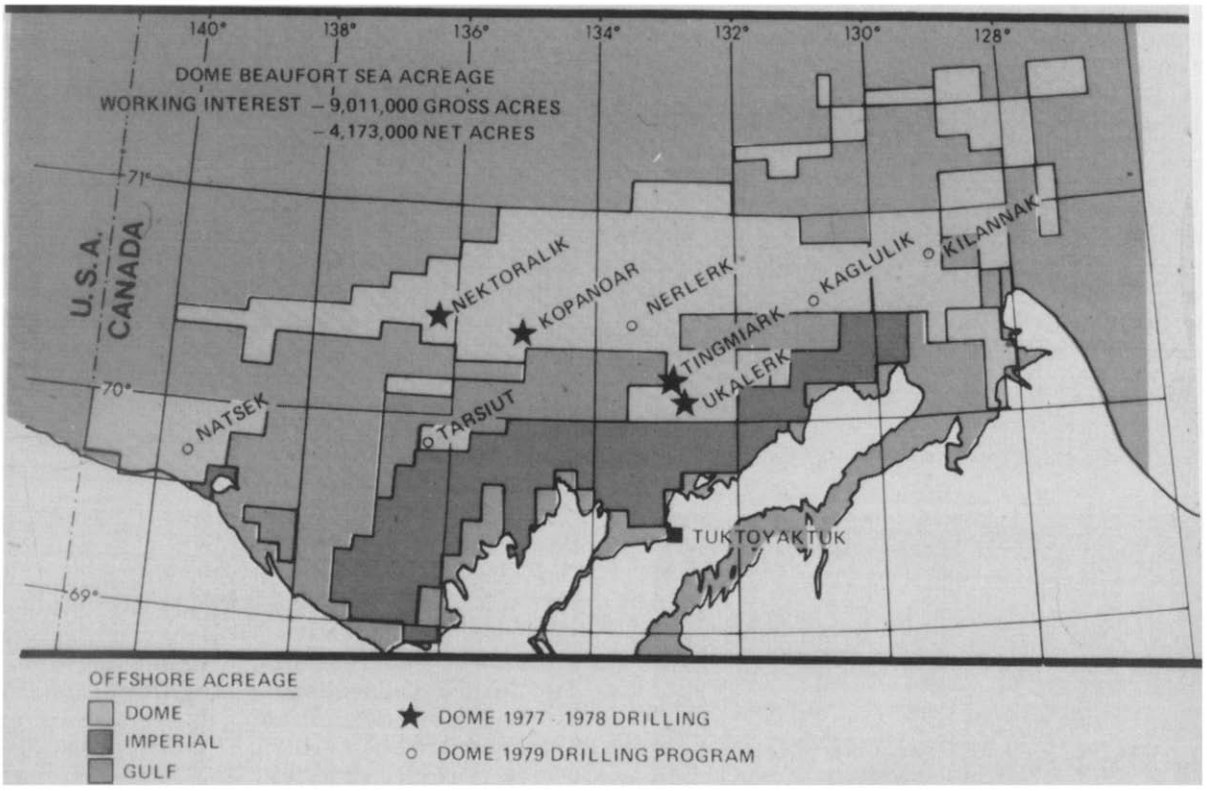

FIGURE 5. *Acreage holdings of Dome, Esso and Gulf in the offshore Beaufort Sea region.*

The objective of commencing oil production from the Beaufort Sea is consistent with the national interests and goals of all Canadians; oil self-sufficiency by 1990, regional benefits where possible and increased technological infrastructure to ensure employment opportunities. However, the total potential of the Beaufort Sea-Mackenzie Delta region for oil and Canadian benefits cannot be realized unless production is allowed to begin. Basic building blocks must be put in place now to achieve results in the future.

Recognizing the difficulty of forecasting demand, the long lead times required to develop the supply alternatives, and the potential of sudden interruptions in foreign supplies, the only prudent direction that the country can follow at this juncture is the development of all alternative energy sources. Once production has commenced from frontier areas such as the East Coast and the Arctic the government will be in a much better position to match supply and demand by controlling the pace of further development in these areas.

Development Schedule

The development schedule leading to future production from the Beaufort Sea is dependent on numerous factors. They include: the time taken to delineate a discovery; water depth and location of the field; the transportation mode employed, particularly in the early stages of development; the complexity of the production scheme selected; and government approvals.

Shallow water developments (less than 25 m) will be simpler to bring on production than deep water developments (30-60 m). This is because much less dredged material will be required to build the necessary islands, and the islands themselves can be designed for lower levels of ice forces, since most of the larger ice features will be prevented from moving into this area due to draft considerations. Likewise, finding the oil in shallow zones (less than 2,000 m) will make such fields easier to develop than those with deeper reservoirs because the well pressures will be lower and drilling time will be reduced.

For this presentation, I will examine in fair detail the current plan for developing the Tarsiut field although similar plans have been developed for other fields such as Kopanoar, Koakoak and Issungnak. The Tarsiut discovery holds great promise for early production from the Beaufort because the water is relatively shallow, ranging from 17 — 22 metres deep, and the oil discovery zone is at roughly 1,500 metres. Furthermore, the Tarsiut structure (like most structures in the Beaufort) is relatively simple so only a few delineation wells will be required around each prospective island location to justify proceeding with development. As an example, Prudhoe Bay, 300 miles to the west, was evaluated with only 2 wells. The Tarsiut structure, illustrated in Figure 6, is approximately 20 miles long, by two miles wide. It indicates the potential ultimate development scheme with five development islands including one Artificial Production and Loading Atoll (APLA). The present island could be modified to accommodate an early production scheme.

Early production systems were first used in the North Sea where there was a long construction time for permanent production platforms. Wells drilled from semi-submersible rigs (frequently delineation wells) were completed with subsea wellheads and connected to a semi-submersible floating rig with flexible riser pipes. A storage tanker equipped with a production process system was moved to a single point mooring system and wells were placed on production. Tankers loaded directly at the storage tanker. Similar systems are being employed in other parts of the world including the Philippines (Figure 7).

At Tarsiut, by the end of 1982 there could conceivably be four or five wells capable of production and more wells could easily be drilled from the existing island. Thus, if a floating production and storage system was available along with suitable transportation, this island could theoretically be capable of producing in the summer of 1984. Recognizing this possibility, conceptual plans have been developed for an

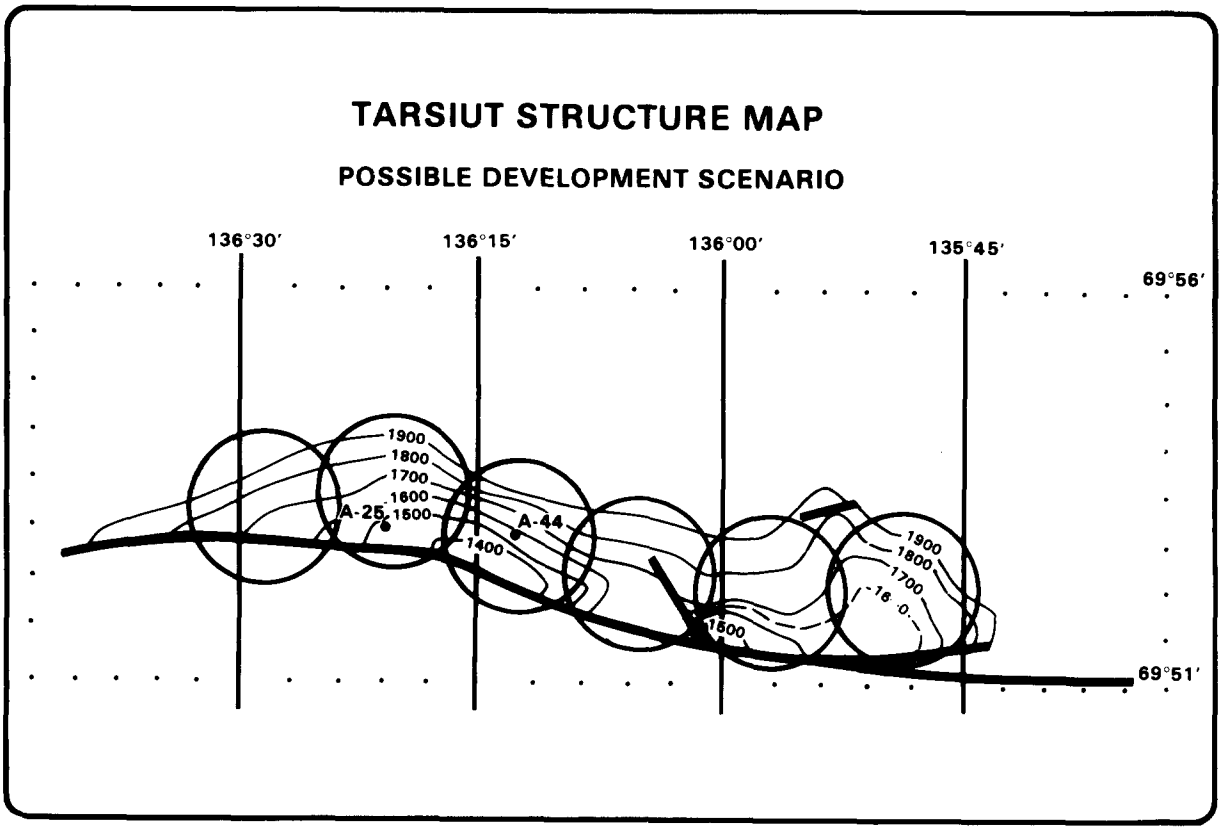

FIGURE 6. *The structure map for the Tarsiut field. The structure is 20 miles long by 2 miles wide and would require up to 5 development islands to efficiently produce the recoverable oil.*

early production system for Tarsiut. This system would be portable so after permanent systems had taken over at Tarsiut, it could be moved to another site such as Koakoak. It also provides a technique for bringing the Beaufort on production slowly.

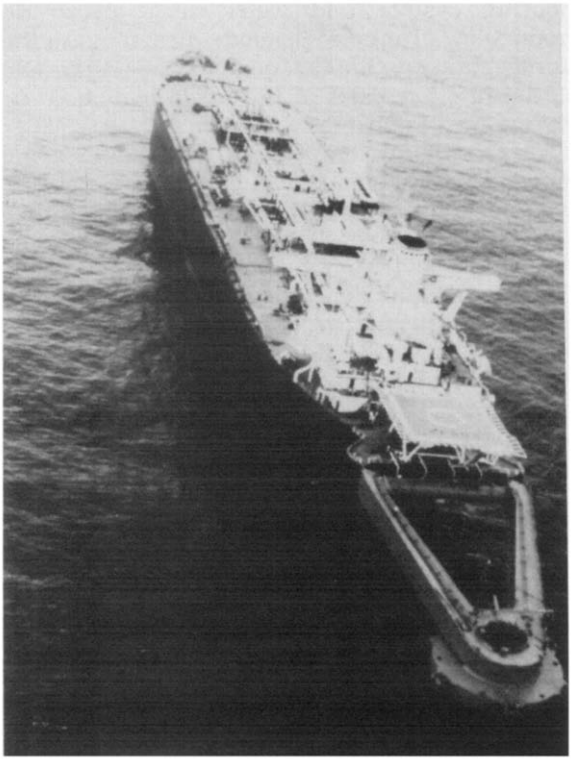

FIGURE 7. *This photo shows one of the newest early production systems (EPS) presently in use in the Philippines. An EPS is a crude oil processing and handling system which allows the earliest possible delivery of oil, before the permanent production system comes on line. Subject to approval, a similar system using an ice-reinforced tanker, could be used in the Beaufort as early as 1985.*

Figure 8 shows how Tarsiut could be produced during open water and moderate ice conditions. The island would be connected to a single point mooring system located a few kilometres away. The processing and storage tanker would be similar to that used in the Philippines example except the vessel would be ice-strengthened and all of the facilities will be enclosed.

To convert the first island from an early production system to a full scale year-round operation, the island would be expanded over a period of approximately two years, and during the process, transformed into an Artificial Production and Loading Atoll (APLA) (Figure 9). The APLA provides a berth for the floating processing and

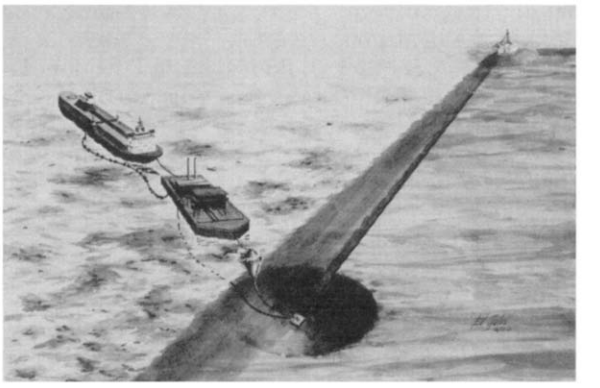

FIGURE 8. *Earliest production from the Beaufort could be carried out as illustrated in this artist's rendering. Oil from a drilling island (eg. Tarsiut) would be pipelined into deeper water where a marine riser would bring it into an EPS, much as the Phillippines example, for processing, prior to loading it into a tanker.*

FIGURE 9. *The most recent artist's rendering of the Arctic Production and Loading Atoll (APLA) being designed for the Tarsiut field is illustrated here. It will contain permanent production, crude oil storage and processing, and loading facilities to transfer oil to Arctic tankers.*

storage facilities as well as providing protection for tankers during loading operations.

The additional production islands in this field can be constructed using conventional dredging equipment at a rate of one per year. Because of the shape of the Tarsiut field all production locations will be connected to the APLA by a subsea pipeline. This will be carried out in phases with islands being connected when they become completed.

Dome proposes to transport at least the first Beaufort oil to market with double-hulled class 10 icebreaking oil tankers (Figure 10). The first ship of this new generation is likely to be fairly small, in the order of 80,000 DWT (Figure 10). It will serve to demonstrate the technical feasibility of the plan as well as continue the process of evaluating the environmental and other implications associated with year-round shipping. Subsequent vessels will range to 200,000 DWT, with an oil carrying capacity of 1.5 million barrels. These ships will combine the best features of both icebreakers and tankers with the final product being the strongest, safest tankers that may ever be built. Eventually, when much greater oil reserves have been delineated in the Beaufort and daily oil throughput approaches 1.0 million barrels, we believe the use of a pipeline becomes a much more viable option and could become realized.

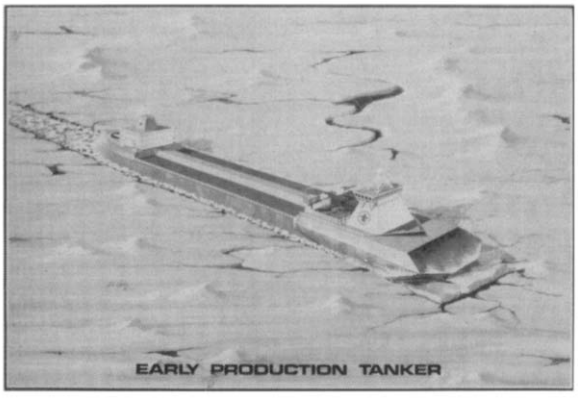

FIGURE 10. *The tankers being proposed to transport oil through the Arctic seas will be ice Class 10 double-hulled ships. The first ship of this new generation will be fairly small, at approximately 80.000 DWT. Subsequent ships will range to 200.000 DWT with an oil carrying capacity of 1.5 million barrels.*

Beaufort Production and the Environment

The preceding discussion examined some of the plans and engineering hardware that will form part of the Beaufort development picture. However we believe it is the view of all Canadians, that whatever activities take place in the region, they should do so with preferably no, or at most minimal impacts to the Arctic environment. This as you will recognize, is also quite a challenge, but we believe firmly, can be met.

Many of the answers to technical problems have gone hand in hand with environmental and socio-economic solutions. Most of these solutions have been developed through the course of lengthy and diligent research, stepwise and cautious development, and the sensible application of real world experience. The oil industry's expertise, built up over more than 15 years, has given it invaluable insight into both the technical and the environmental concerns. A sensible approach to these concerns is reflected in the excellent safety record achieved in the Beaufort Sea and Mackenzie Delta. There have been few serious mistakes, no well blowouts, and little ecological damage caused by exploration.

Scientists in general have become acutely aware of the sometimes delicate balance between climate, geography, and nature. Since some of the interactions between living things in the Delta and the Beaufort Sea may be disrupted by exploration and development, the industry has been especially cautious in applying new technology to the region.

Frequently small scale experimental models are constructed and tested by the industry before any full scale activity is undertaken. For example, model islands were built first to test the impact of ice on these structures, and thereby establish safety criteria which have been demonstrated in the building of islands in progressively deeper water. The Kigoriak Class Four icebreaker is a fore-runner of a wholly new class of icebreakers including the 200,000 dead weight ton tankers.

The possible influence of year-round icebreaking through the Northwest Passage, and the building of artificial islands in coastal waters, have been examined through ongoing research and development programs. The experimental program with the John A. Macdonald icebreaker, the ongoing Kigoriak research program, the comprehensive ice tank testing, plus the cumu-

lative experience acquired by operating in the Arctic environment year after year, in all seasons, are providing a backlog of data which are showing that environmentally acceptable solutions are available.

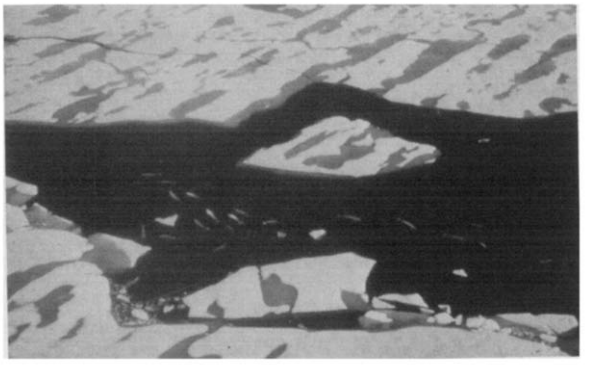

FIGURE 11. *Up to 7.000 beluga whales have been counted in the shallow waters of the Mackenzie River estuary during the summer season. Industry conducts aerial monitoring programs every year to determine where the whales are, and to redirect ship traffic if necessary to ensure that possible interference to the whales is minimized.*

Industry and government agencies have conducted research on the impact of ship traffic upon ice and the sea life that make their home on, or under that ice (Figures 11 and 12). For example, there have been noise studies conducted with Kigoriak to determine the impact, if any, of tanker passage on animal life, their habitats, and migration patterns. With this information, shipping routes can be selected to avoid ecologically vulnerable areas. Shipping corridors will be surveyed to obtain adequate bathymetric and sea ice data, and a preliminary study has been completed on the ability of hunters to cross the broken ice left in the track of an icebreaker (Figure 13).

Research and development has been conducted on a variety of other technical issues relevant to environmental protection matters and solutions are evolving to handle them. Examples include the detailed work on assessing methods to prevent oil spills, or clean them up should they occur; the effects of artificial island construction dredging and drilling operations; and the installation and operation of safe sub-sea well control systems, pipelines and other submarine hardware.

Valuable information has been obtained on the behaviour of oil under and in sea ice, and ways and means for cleaning up the oil. A study conducted in 1980 on the spread of oil under ice showed that up to 80 percent of the oil could be removed while the remaining 20 percent dispersed naturally with negligible impact on the environment. Surprisingly, ice has proven to be more of an ally than a foe when it comes to restraining and cleaning up oil spills. What we have found is that ice edges form natural booms to collect oil against, and in the case of landfast ice, which is generally the last to leave the Beaufort region, it protects the important foreshore coastline. During the lengthy winter period ice continues to grow and encapsulates oil, keeping it away from contact with marine mammals and other biota. During this process of «cold storage» ample time is available for trained people to plan an effective clean up strategy, to transport and set up equipment, and to handle the oil once it begins to be liberated from the ice in the spring. The freezing of the oil during the winter months preserves its most volatile components, which helps tremendously with burning during the spring. Although industry and government work in this important area continues, the statement «ice is nice» is becoming quite appropriate in the field of Arctic oil spill cleanup research.

FIGURE 12. Polar bears, a valuable species to the Inuit, frequent the offshore drilling area during winter and have been known to come onto offshore drilling islands.

Artificial islands constructed in the offshore Beaufort must be safe and able to withstand ice forces within the realm of probabilities. Much

experience has been gained in the construction of shallow water islands, and new innovative technologies were applied in the construction of the latest island, Tarsiut. Methods have been developed and tested to increase the slope of the subsea mound used as the base for mounting the large retaining walls. Increasing the slope means less material is required, which, of course, reduces the extremely expensive construction costs. However, it also results in reduced habitat alterations, both at the dredge sites and in the vicinity of the island. The retaining walls, or caissons, further reduce material required, and are also designed to be portable and reusable. The multi-million dollar research program which is investigating factors such as ice, erosion, and earthquake forces and their possible influence on the integrity of the island, as well as numerous other programs, will play a very important role in the design of safe future production platforms in the Beaufort region.

FIGURE 13. The icebreaker Kigoriak sails out of the Arctic twilight during the experimental icebreaker track research program conducted at various times during the winter of 1981-82 in the Beaufort Sea.

The sub-surface well heads, manifolds, and control systems employed on the ocean floor have been designed with safety and stability as paramount ingredients. They have to function flawlessly in cold waters, be maintainable under the oceans, and be protected from moving ice. Drillships are equipped with rapid disconnecting systems which permit a shut down of exploratory drilling operations, thereby minimizing the risk of a blowout. This rapid disconnect is necessary should severe ice conditions move into the drilling area.

Further research is being conducted on the laying of sub-sea pipelines on the seafloor in areas of ice scouring. We have concluded that should pipelines be laid to shore, they will be buried beneath the depth of maximum probable ice scouring in areas where this occurs.

The Environmental and Socio-Economic Review Process

The foregoing has described our general plan for developing the hydrocarbon resources of the Beaufort Sea region as well as some of the research and monitoring programs being undertaken to evaluate and minimize impacts of present and future activities in the region. To assist in ensuring that future development takes place in a socially and environmentally acceptable manner, in July, 1980, the Minister of Indian and Northern Development referred all development proposals in the Beaufort region to the Minister of the Environment for a formal review under the Environmental Assessment and Review Process (EARP).

The Minister of Environment, in turn, established an independent panel comprised of 7 members to carry out the necessary public review. The Panel's mandate is to identify major developmental effects, both positive and negative, upon the physical, biological and human environments and recommend ways and means of dealing with them. As part of this mandate, the Panel will review and assess all relevant information associated with the physical, biological and socio-economic considerations of the proposal, amd should be prepared to address possible community changes such as effects on existing life-style and conditions. The Panel review is to include all related activities north of 60° of the proponent's proposal associated with or resulting from the commercial production and shipment of hydrocarbon resources from the Beaufort Sea area. This includes possible onshore and offshore oil and gas production facilities in the Canadian Beaufort Sea area and subsequent transportation of oil and gas to southern markets by icebreaking tankers or pipeline(s) or by both means.

The Panel's first task was to develop a set of guidelines for the Industry which would be used to prepare the necessary documentation

(Environmental Impact Statement). Following a series of public meetings held throughout the north in November-December, 1981, to solicit input, guidelines were issued to the Industry in February, 1982. Upon receipt of the guidelines, the Industry consortium, spearheaded by Dome, Esso and Gulf, began to finalize the EIS.

The Environmental Impact Statement consists of 7 primary volumes. Each volume covers specific areas of information needed to address developmental, environmental and/or socio-economic issues. The basic information needs are summarized in Figure 14. Each of the 7 volumes responds to specific information needs. The master index illustrated in Figure 15 provides the titles of these volumes.

KEY QUESTIONS THE EIS MUST ADDRESS
• WHAT IS THE DEVELOPMENT PLAN?
• WHAT ARE THE REGIONS LIKE NOW?
• WHAT WILL THE REGIONS BE LIKE IN THE FUTURE?
• WHAT IS BEING DONE ABOUT UNKNOWNS?
• WHAT IS INDUSTRIES' RESPONSE TO SPECIFIC ISSUES?

FIGURE 14. *The key types of questions that the Environmental Impact Statement must address.*

VOLUME 1	SUMMARY
VOLUME 2	DEVELOPMENT SYSTEMS
VOLUME 3A	BEAUFORT SEA-DELTA SETTING
VOLUME 3B	NORTHWEST PASSAGE SETTING
VOLUME 3C	MACKENZIE VALLEY SETTING
VOLUME 4	BIOLOGICAL & PHYSICAL EFFECTS
VOLUME 5	SOCIO-ECONOMIC EFFECTS
VOLUME 6	ACCIDENTAL SPILLS
VOLUME 7	RESEARCH AND MONITORING

FIGURE 15. The Environmental Impact Statement has been structured to provide all the necessary background information and to address the key questions in a series of 7 volumes. Information is presented in summary form, by discipline, and by geographic regions.

The EIS has now been completed and distributed to the panel, interested public and government agencies for review. Following the review period of approximately 90 days, public hearings will again be held throughout the north in communities which are mostly likely to be affected by future development of the Beaufort region's hydrocarbon resources and the transportation thereof to southern markets. More thorough technical hearings will be convened in larger southern centres. Upon completion of the hearing process, the panel will prepare a report on their findings and recommendations for consideration by the ministers of Environment and Indian and Northern Affairs.

Through this process, the views of the public and factors influencing the environmental and social well-being of the north will have been presented in a clear and thorough manner. As a result, it will make a major contribution to future decisions affecting the sound and beneficial development of the Beaufort Sea-Mackenzie Delta hydrocarbon resources.