Engineering and Construction

Transportation and Construction in the Northwest

THE EARLY YEARS

Fur-traders of the Montreal-based North West Company followed the water routes explored by the French to the western plains, then extended them north to Lake Athabasca, where they built Fort Chipewyan in 1788. A year later, Alexander Mackenzie set out across Great Slave Lake and down the long northern river that now bears his name. It proved to extend just over a thousand miles through rich new fur territory, and soon the North West Company had established trading posts along its banks at Trout River in 1796, and at sites near the present settlements of Fort Simpson, Fort Norman and Fort Good Hope in the following decade.

In the last century, the traders travelled by York boat from Methy Portage to the 16-mile stretch of rapids on Slave River above present-day Fort Smith, around which they had to portage. (This river route was shortened by the extension of rail from Edmonton to Waterways early in this century, and York boats were replaced by steamboats.) They then continued down the Slave River to Fort Resolution, across Great Slave Lake to the head of the Mackenzie, and down the Mackenzie as far as the Delta. Today, the Mackenzie River is still the principal means of transporting supplies to settlements along the Mackenzie Valley and in the Western Arctic. And it is this fleet of tugs and barges on the Mackenzie River that will have to be expanded to carry the equipment, material and supplies for the proposed pipeline.

In 1888, a Select Committee of the Senate was appointed "to inquire into the resources of the Great Mackenzie Basin and the country eastward to Hudson's Bay," but Northern Canada first came to international notice in the late 1890s, when gold was discovered in the Yukon Territory. An estimated 100,000 men and women sought the gold fields, and almost overnight Dawson City became the largest city in Canada west of Winnipeg, with a population of over 30,000.

The city was built on difficult permafrost soils. Most of its early foundations were simple mud sills of local timbers laid in gravel or sand and levelled with the same material. Wood was the primary building material for the banks, post office, hotels and dance halls and the many homes that were built. The city acquired such urban services as running water, electric lighting and telephones. On the gold fields themselves, the Yukon Gold Company built a 70-mile ditch system to provide water for a large-scale dredging operation on the Klondike River and its tributaries. This project, which included 13 miles of 42- to 54-inch-diameter wood-stave and steel pipe, was a remarkable engineering feat on an isolated frontier.

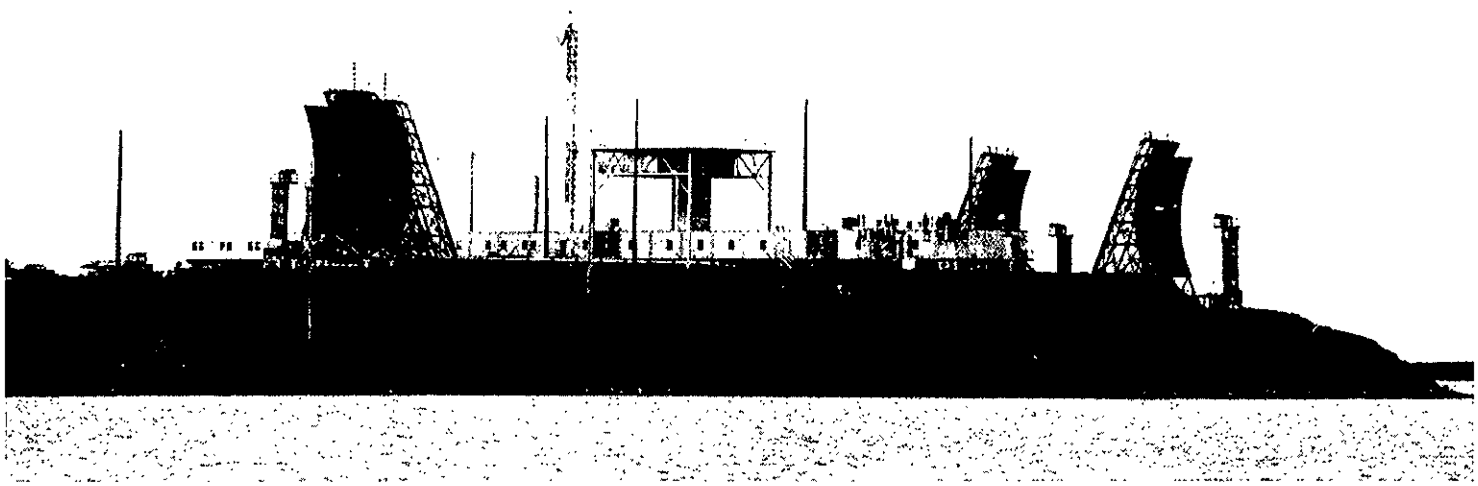
The 1920s witnessed the development of the petroleum reserves at Norman Wells. Mackenzie himself had reported oil seepages on the river bank, but it was only in 1914 that a geologist, T.O. Bosworth, staked three claims near these seepages. Imperial Oil acquired these claims in 1919, and by 1924 six wells had been drilled, three of which were producers. A small refinery was built, but the market was so small that in the same year the wells were capped and the refinery shut down. During the development of the petroleum reserves at Norman Wells, the detrimental results of thawing perennially frozen water-bearing silts and clays soon made themselves evident, and experimentation began with the installation of foundations on gravel pads.

In the early 1930s, after rich mineral deposits had been discovered at Yellowknife and at Port Radium on Great Bear Lake, the refinery at Norman Wells was reopened to supply gasoline and fuel oil for riverboats and mine machinery. Between 1937 and 1972, heavy fuel oil was barged from Norman Wells to the rapids on Great Bear River, transported by a 2-inch 8.5-mile pipeline around the rapids, then barged the remainder of the way to the Eldorado uranium mine on Great Bear Lake.

DEFENCE PROJECTS DURING AND AFTER THE SECOND WORLD WAR

During the Second World War the United States Army undertook two major construction projects in the Canadian North: the Northwest Staging Route and an associated highway, now called the Alaska Highway; and the Canol Project to transport men, materials, equipment and oil to defend Alaska against the Japanese.

The Alaska Highway connected Dawson Creek, B.C., to Fairbanks, Alaska, following the Northwest Staging Route airports at Fort St. John and Fort Nelson, B.C., Watson Lake and Whitehorse, Y.T., and Big Delta, Alaska. The construction began in March 1942, and it involved a force that totalled some 11,000 officers and men over the construction period. By the end of October 1942, a passable pioneer road, 1,428 miles long and 26 feet wide, linked Dawson Creek to Big Delta. Permafrost conditions were ignored during construction, which resulted in road failures and severe icings at many locations. During most of 1943, 81 contractors under the United States Public Roads Administration worked on an all-weather gravel road with a civilian



force that totalled some 15,950 men over the construction period. The total cost of the project was $147 million. When the war ended, the United States handed over the Canadian section of the Alaska Highway to Canada.

In 1942, also, the United States Army undertook the Canol project to transport oil from Norman Wells across the Mackenzie Mountains to Whitehorse. The oil was to be refined there, then delivered to Alaska to aid the war effort. The labour force over the construction period of the pipeline involved 2,500 military personnel and approximately 22,550 civilians. A pioneer road preceded pipelaying and the building of pumping stations. Except at its southern end, the road was laid entirely over permafrost. The road performed satisfactorily during its short period of use, April 1944 to May 1945, except for icings on some stretches. The pipeline, consisting of 100 miles of 6-inch pipe and 500 miles of 4-inch pipe, was laid on the ground beside the road, and pumping stations were spaced about 50 miles apart. This project was completed in 1944 and cost $134 million. Very little oil reached Whitehorse by the pipeline, and when the war ended, the Canol road was closed and the pipeline dismantled.

Between 1955 and 1957, Canada and the United States built the Distant Early Warning Line (DEW Line), a chain of radar stations intended to detect foreign aircraft in polar regions and to relay the warning to North American Air Defence Command units. The line stretches 5,000 miles along the Arctic coast from Point Barrow, Alaska, to Cape Dyer, Baffin Island. The construction of the DEW Line involved airlifting a total of about 25,000 men and one-half million tons of equipment by commercial aircraft. Approximately 45,000 flights averaging 720 miles each were made.

POST-WAR PERIOD

In 1954, construction began on Inuvik, a new regional administrative centre for the Western Arctic at a site on the east side of the Mackenzie Delta. All major buildings, including serviced housing, are elevated on piles. The air space between the buildings and the ground dissipates heat losses from the buildings, thus reducing the possibility of permafrost degradation and associated shifting of foundations. These buildings have performed satisfactorily; only a few of the 14,000 piles installed have shown any significant movement owing to thaw settlement.

Other new towns have been built farther south, but they did not encounter the same formidable permafrost problems. In the 1960s, Cominco's development of the rich lead-zinc deposits on the south shore of Great Slave Lake led to the construction of a large mill and the associated mining town of Pine Point. Edzo, another new town, was built at the head of the North Arm of Great Slave Lake in 1971. At Yellowknife and Hay River, there are suburbs and high-rises that would have been difficult to imagine in such settings only a few years ago. The development of the Northern Transportation Company Limited (NTCL) dry-dock and transshipment facilities at Hay River is representative of the recent growth in transportation.

TRANSPORTATION

Barge and boat transporation on the Athabasca, Slave and Mackenzie Rivers has served the transportation needs of the Northwest for more than a century. Today, water transport northward from Hay River continues to be important, particularly for construction materials, heavy equipment and fuels. Although freight traffic on the Mackenzie River has had intermittent periods of rapid growth, its long-term annual growth rate is about nine percent. This growth peaked in 1972 at 477,000 tons; since then annual traffic has averaged around 400,000 tons.

Northern Transportation Company Limited, a crown corporation, is the largest common carrier in the Mackenzie River system, and it also serves the Arctic coast from Alaska to Spence Bay. KAPS Transport Limited, the second largest operator, is licensed to transport goods to and from exploration and drilling sites, and building and construction sites in the Mackenzie watershed.

In recent years, there have also been major air, rail and road developments in the Western Arctic. Northern air services began in the region in 1920, with float-equipped aircraft. During and shortly after the Second World War, airfields were built at several settlements on Great Slave Lake and along the Mackenzie River, including Hay River, Yellowknife, Fort Resolution, Fort Providence, Fort Simpson and Norman Wells, and both scheduled and charter flights in the Western Arctic increased steadily.

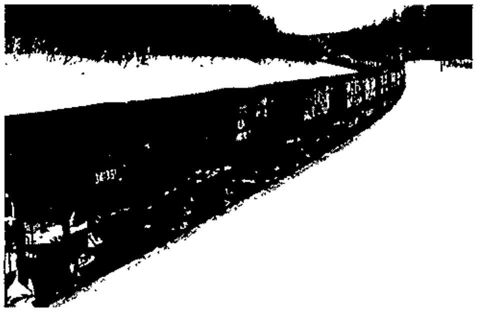
Today, there is air service to all of the Mackenzie River settlements, although its frequency varies. Pacific Western Airlines, the largest carrier operating in the Northwest Territories, has the most extensive network of routes; and chartered aircraft serve the smaller and remoter settlements. These carriers, commercial and private, are essential to the communities in the Mackenzie Valley and the Western Arctic, the territorial and federal governments, tourist

Distant Early Warning (DEW) Line site, Tuktoyaktuk. (GNWT)

Great Slave Lake Railway near Pine Point. (Canadian National)

Judge Berger at pipe stockpile in Alaska. (I. Waddell)

Inquiry staff viewing TransCanada pipeline under construction in Ontario. (G. Milne)



lodges, and construction companies, and they play a vital role in the activities related to oil and gas exploration.

The Great Slave Lake Railway, built in the early 1960s, extends from Grimshaw, Alberta, to Hay River, Northwest Territories. The railway, which closely parallels the Mackenzie Highway, was constructed primarily to ship concentrates from Cominco's mine at Pine Point, to which it is connected by a branch line. Heavy goods are shipped by rail to Hay River, then trans-shipped to barges for the voyage down the Mackenzie River.

The Mackenzie Highway between Grimshaw and Hay River was built between 1946 and 1948. In 1960, as part of the federal Roads to Resources program, it was extended 280 miles around the north end of Great Slave Lake to Yellowknife; in 1970, the highway reached Fort Simpson, and it is planned to reach Wrigley by 1979. There has been road construction between Arctic Red River and Inuvik, but it is not complete.

A second major highway project, the Dempster Highway, was begun in 1959 and is scheduled for completion in the late 1970s. It will link Dawson City to Inuvik and will connect with the Mackenzie Highway.

Recent gas and oil exploration activity in the Mackenzie Valley and Western Arctic used existing transportation systems in the region, which has helped these systems to expand to their present capacities. The nature and level of future petroleum development will clearly have an important influence on the future development of these transportation systems. Implementation of either pipeline proposal will involve major expansion in existing transportation capabilities.

The Pipeline Project: Its Scope and Scale

Two companies, Canadian Arctic Gas Pipeline Limited and Foothills Pipe Lines Ltd., are competing for the right to build a pipeline to bring natural gas through the Mackenzie Valley to markets in the South. Arctic Gas propose to build a pipeline from the Prudhoe Bay field in Alaska across the Northern Yukon to the Mackenzie Delta, to join with their pipeline extending south from the Mackenzie Delta gas fields. The Foothills proposal is for a pipeline southward from the Mackenzie Delta only.

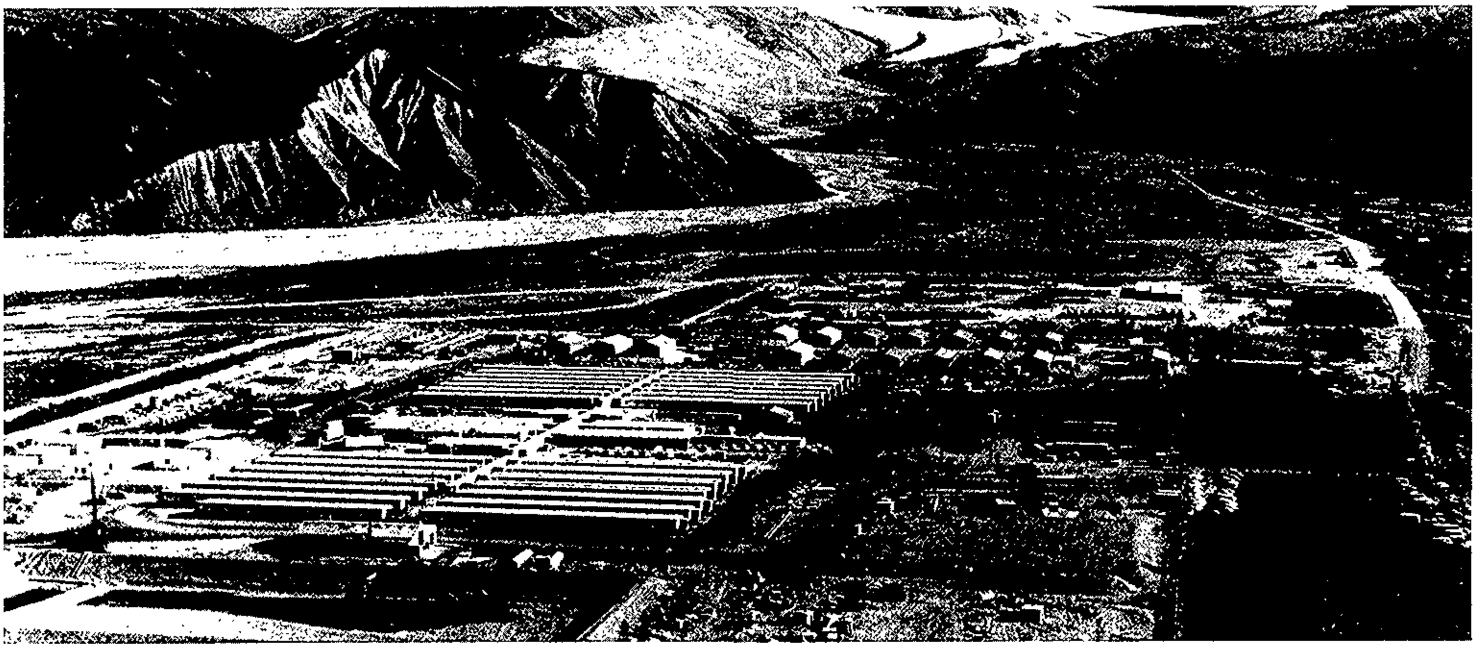
The Arctic Gas group is a consortium of Canadian and American producers and gas transmission and distribution companies. Imperial, Gulf and Shell, the three principal gas producers in the Mackenzie Delta, are members of the consortium, as well as TransCanada Pipe Lines, Canada's largest gas transmission company. The Foothills Pipe Lines group is made up of two companies, Alberta Gas Trunk Line and West Coast Transmission, the largest gas transmission companies in Alberta and British Columbia.

The pipeline that Arctic Gas and Foothills propose to build presents quite novel problems of science, engineering and logistics. Either pipeline will be very long, and will carry enormous volumes of gas. But these are not unique characteristics: what makes either pipeline unique from an engineering point of view is that it will be buried in ice-rich, permanently frozen soil – permafrost – and the gas transported in the pipe will be refrigerated. The pipeline is to be built across our northern territories, a land that is cold and dark throughout the long winter, a land that is at present largely inaccessible by road or rail, and through which a large infrastructure of roads, wharves, airstrips and other work sites must be built. The pipeline's impact will not, therefore, be confined to its right-of-way.

Unique Aspects of the Project

The pipeline that Arctic Gas propose to build would be longer than any pipeline in the world: it is 2,400 miles from Prudhoe Bay to the Lower 48. Pipelines have, of course, been built over great distances in the past. The 31-inch trans-Arabian pipeline (now abandoned) from Abaiq Field in Arabia to Sidon in Lebanon is 1,047 miles long; the 36-inch Colonial pipeline from Houston to New Jersey is 1,531 miles long. And pipelines have been built and are being built today across difficult terrain and in northern latitudes. The trans-Andean pipeline crosses one of the most rugged mountain ranges in the world, and the trans-Alaska pipeline crosses three mountain ranges. Some of the biggest pipelines in the world have been built in Siberia, and both these and the trans-Alpine pipelines were constructed in severe climatic conditions. But, as we shall see, there is not a great deal we can learn from the experience of the Soviet Union, the United States and other nations that is directly relevant to the design and operation of a buried refrigerated pipeline.

Normally, gas flows through a pipeline at temperatures above freezing. Compressors drive the gas through the pipe, and the process of compressing gas makes it hot. If the pipeline is buried in permafrost, heat from the gas will thaw the ground around the pipe. Such thawing could lead to severe and costly engineering and environmental problems where the soil contains any appreciable quantity of ice. Problems arising from



progressive sinking of the ground, blocking of drainage, erosion or slope failure could damage or rupture the pipe. To avoid these problems, both Arctic Gas and Foothills propose to chill the gas passing through the pipeline so there will be no heat loss to melt the permafrost. Chillers will, therefore, be needed to extract the heat generated by compression before the gas goes into the pipeline and through the permafrost.

A pipeline running south from the Mackenzie Delta along the Mackenzie Valley must cross about 250 miles of continuous and about 550 miles of discontinuous permafrost. It cannot avoid long stretches of ice-rich soil in both zones of permafrost. A pipeline across the Northern Yukon would lie entirely within the zone of continuous permafrost. Thus, neither the Arctic Gas nor the Foothills proposal can avoid the problem. They must either refrigerate a pipeline through the permafrost or, at much greater cost, lay a pipeline on the ground or elevated above it. Now, if a chilled and buried pipeline passes through ground that is not frozen, it will freeze the ground around it. This change may lead to a build-up of ice in the ground around the pipe and may cause the pipe to move upward. This is known as frost heave.

Magnitude of the Project

A pipeline through the Canadian North has been likened to a string across a football field. This simile is misleading and is indicative of a utopian view of pipeline construction. Of course, the area required for the right-of-way, compressor stations, and ancillary facilities is miniscule when measured against the great mass of the Canadian North. Although Arctic Gas propose to lay 1,100 miles of pipeline across the Yukon and Northwest Territories, their total land requirement for the right-of-way and related facilities is only about 40 square miles. Such a figure gives a mistaken impression of the magnitude of the construction project. It is not just a 120-foot right-of-way.

The estimated cost of the Arctic Gas project within Canada now stands at about $8 billion. A network of roads largely of snow and ice must be built. The capacity of the fleet of tugs and barges on the Mackenzie River must be greatly increased. Nine construction spreads and 6,000 construction workers will be required North of 60 to build the pipeline. Imperial, Gulf and Shell will need 1,200 more workers to build the gas plants and gas gathering systems in the Mackenzie Delta. There will be about 130 gravel mining and borrow operations, and about 600 water crossings. There will be about 700 crawler tractors, 400 earth movers, 350 tractor trucks, 350 trailers and 1,500 trucks. There will be almost one million tons of pipe. There will be aircraft, helicopters, and airstrips. Arctic Gas propose to use about 20 wharf sites; and plan to build about 15 STOL airstrips of 2,900 feet each and five airstrips of 6,000 feet each. Carson Templeton, Chairman of the Environment Protection Board, has likened the building of a pipeline in the North in winter to the logistics of landing the Allied forces on the beaches of Normandy. The pipeline's effects will be felt far beyond the area of land across which it is built.

I have visited the trans-Alaska pipeline project, and it has given me some idea of the scale of activity that construction of a pipeline in Northern Canada would entail. Construction of the trans-Alaska oil pipeline began officially in April 1974. To transport oil from Prudhoe Bay on the northern coast of Alaska to the southern Alaskan port of Valdez has required, in addition to the construction of an 800-mile-long, 48-inch diameter pipe, the construction of a 360-mile-long gravel road, bridges over 20 major streams, a 2,300-foot bridge over the Yukon River, three permanent airfields, eight temporary airfields, 15 permanent access roads, numerous temporary access roads, 19 construction camps, 12 pump stations, and oil-storage and tanker-loading facilities. The project is expected to cost approximately $8 billion, and the estimated completion date is mid-1977.

Flying low along the route of the trans-Alaska pipeline, south from Prudhoe Bay, you can see the extent of activity: construction spreads, pump station sites, hovercraft on the Yukon River, trucks on the haul road, the right-of-way itself. At Prudhoe Bay, the oil wells and gathering facilities stretch outward for miles, and they give you some idea of how similar facilities would alter the landscape of the Mackenzie Delta.

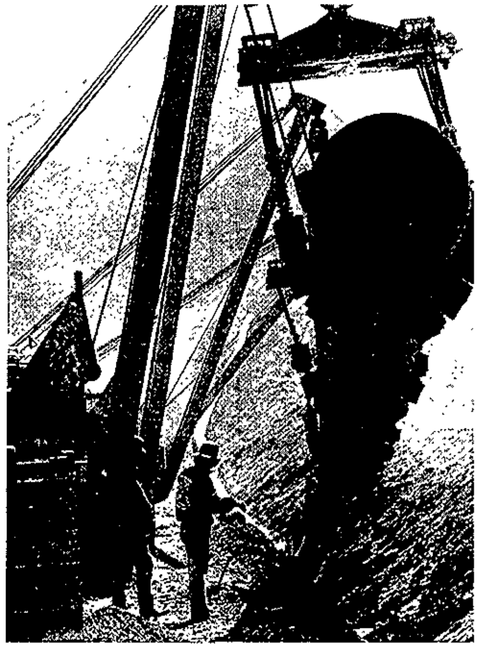
The Mackenzie Valley pipeline, according to the proposal of Arctic Gas, would be the greatest construction project, in terms of capital expenditure, that private enterprise has ever undertaken, anywhere. We have been told by Vern Horte, President of Arctic Gas, that if the pipeline is built, it is likely that it will be fully looped over time – that is, by building loops between compressor stations, a second gas pipeline would ultimately parallel the original one. But looping would not begin until the original system is fully loaded, and that, we were told, will not happen until its fifth year of operation.

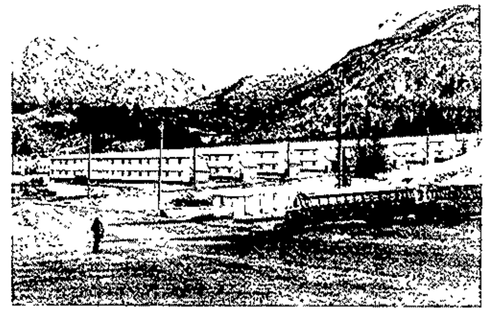
Twelve-hundred man construction camp on the trans-Alaska pipeline. (Alyeska)

Welding pipe on the trans-Alaska pipeline. (E. Weick)

Pipe being laid in ditch, trans-Alaska pipeline. (Alyeska)

Bunkhouses for workers at the Valdez terminal of trans-Alaska pipeline. (E. Weick)





Pipe Size and Pressure

The Arctic Gas pipeline, by tapping both the Prudhoe Bay and Mackenzie Delta gas fields, would carry much more gas than the Foothills pipeline. The Arctic Gas proposal is, therefore, for a larger pipe than that proposed by Foothills, and it will be operated at a higher pressure.

To carry very large quantities of gas, Arctic Gas propose to use 48-inch diameter pipe made of steel 0.720 inches thick and operated at a maximum pressure of 1,680 pounds per square inch. At this pressure, the pipe can carry 4.5 billion cubic feet of gas per day, which is more gas than Canada at present consumes each day. This pipe is bigger in diameter than any existing gas pipeline in North America, although there are 48-inch and 56-inch gas pipelines in the Soviet Union. There are oil pipelines of this size in North America: both the Alyeska oil pipeline and loops on the Interprovincial oil pipeline are 48 inches in diameter. The pressure of 1,680 pounds per square inch is substantially higher than that of ordinary gas pipelines in Canada, and even the 48-inch and 56-inch gas pipelines in the Soviet Arctic reach pressures of only about 1,000 pounds per square inch. Of course, the pipe to be used by Arctic Gas is designed to withstand this high pressure, and the pressure complies with Canadian standards for the maximum operating pressure in such pipe. Nonetheless, Arctic Gas are sufficiently concerned by the possibility that the pipe might crack under pressure, that they plan to surround the pipe with steel reinforcing bands or "crack arrestors" at intervals of about 300 feet.

Foothills say that the system proposed by Arctic Gas is novel and untried, whereas the system they propose will use conventional techniques. Foothills propose to use 42-inch diameter pipe made of steel 0.520 inches thick and operated at a pressure of 1,220 pounds per square inch, although that pressure can (and might) be raised to 1,440 pounds per square inch. The higher pressure is the maximum operating pressure for this 42-inch pipe, according to Canadian standards, and Foothills say they will use the lower pressure for safety. Pipe of the size chosen by Foothills is already used by TransCanada Pipe Lines and Alberta Gas Trunk Line in sections of their gas pipelines, but at pressures lower than that proposed by Foothills.

Existing Pipelines in Permafrost Areas

Pipelines have been built across permafrost areas of Alaska and the Soviet Union, and short sections of the Pointed Mountain pipeline on the British Columbia-Yukon-Northwest Territories boundary cross permafrost. Although we can learn about permafrost and northern construction from these projects, they are of little help in assessing the proposals before this Inquiry to bury a refrigerated gas pipeline in ice-rich permafrost soils.

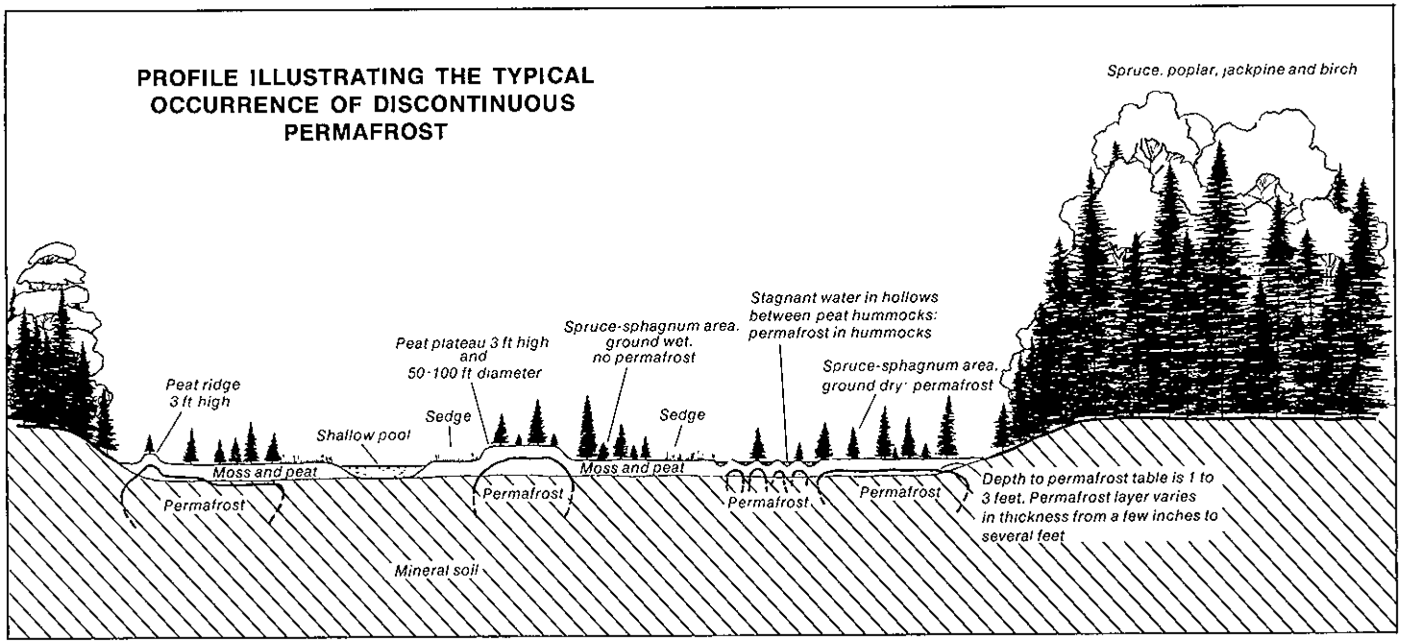
Let us look first at the Soviet experience. Gas pipelines in the Soviet Union are usually buried, but in permafrost regions they may also be elevated on piles or placed on the ground surface in a sand mound or berm. Elevated-pile construction is used across ice-rich permafrost terrain, berm construction is used where the permafrost terrain has moderate-to-low ice content, and burial is used only where the soil is sandy and dry or unfrozen.

There are three pipeline systems in the Soviet sub-Arctic, but none has yet been built north of the tree line. The oldest of these pipelines was built between 1966 and 1968 from Tas Tumus to Yakutsk in Eastern Siberia; it is 300 km (190 miles) long and 500 mm (20 inches) in diameter. The northern half of it crosses what appears to be ice-rich permafrost terrain and is built on piles; the southern half is buried. The line was later extended about 100 km south to Bestyakh and Pokrovsk; this section is apparently almost entirely elevated.

The Messoyakha-Norilsk system in the north part of West Siberia comprises two 730-mm (29 inches) lines, each 265 km (165 miles) long. The first was built between 1968 and 1970, the second between 1971 and 1973. The system crosses an area of discontinuous permafrost and is elevated on piles. In 1972, a 730-mm (29-inch), 35-km (22-mile) extension was built on piles from the Soleninskoye to Messoyakha gas fields.

The most recently built trunk pipeline system in the Soviet Union – the line between Medvezhye and Punga in northwestern West Siberia – is the largest in the Soviet Union in terms of pipe size. It comprises 670 km (420 miles) of 1,420-mm (56-inch) and 1,220-mm (48-inch) diameter pipe. The northern part of this pipeline passes through a region of discontinuous permafrost, where it is partly on the ground in a berm and partly buried. In many places the route of this pipeline avoids potentially troublesome areas of ice-rich permafrost by crossing dry sand plains, where the pipeline is buried. The Medvezhye pipeline, like the others, is operated at temperatures above freezing, but it is planned to refrigerate a short section of it as an experiment.

There is not a great deal that we can learn from the Russian experience. The Yakutsk and the Messoyakha-Norilsk systems are



built on piles above ground, and they are not large-diameter pipelines. Where the Medvezhye pipeline has been buried, it has been routed to avoid permafrost. The Soviet Union, so far, has been able to avoid the vital questions that we must consider in Northern Canada: How can the permafrost be kept from melting? And how can we overcome the problem of frost heave?

What about the trans-Alaska oil pipeline? Alaska, after all, has a permafrost distribution very similar to Canada's, and the problems to be overcome would seem to be similar. But, once again, the experience is of limited usefulness for us. The Alyeska pipeline will carry oil, and oil can be transported in a pipeline only when it is hot. Obviously, such a pipe cannot be buried in permafrost without melting the ice in it, and therefore the trans-Alaska pipeline is elevated wherever it crosses ice-rich permafrost terrain. Elsewhere it is either bermed or buried, depending upon the ground conditions.

The proposed Mackenzie Valley pipeline is a new kind of pipelining venture that will entail innovations in engineering design, construction and operation. Canadian engineers and pipeline contractors have as much northern experience and expertise as their counterparts in any country. Nevertheless, the proposed pipeline will confront engineers and builders with major challenges of engineering and logistics.

Buried Refrigerated Pipeline: Frost Heave

Where the pipeline crosses permafrost, both Arctic Gas and Foothills propose to refrigerate their buried pipeline by chilling the gas to a temperature below freezing. Unfortunately, because permafrost is discontinuous along parts of the route, this ingenious solution to the problem of thawing of frozen ground would create other problems in previously unfrozen ground. The creation of artificial permafrost around the refrigerated pipe could cause upward movement of the ground by a process called frost heave. This movement, if it exceeded certain limits, would damage the pipe.

A great deal was said at the Inquiry about the plans of Arctic Gas and Foothills to prevent, avoid, reduce or control frost heave and its effects, and the two companies were not in agreement on the problem nor on its treatment. I have, as well, heard a great deal of criticism of their plans to control frost heave and I have heard many expressions of concern about the environmental consequences likely to result from inadequate control of this problem. Moreover, in the last weeks that the Inquiry heard evidence, Arctic Gas revealed that, through a laboratory error, they had underestimated the magnitude of the forces causing frost heave, and I learned that they will have to modify the procedures proposed for controlling frost heave.

How important is this specific problem of engineering, a problem that involves concepts of physics about which the experts do not agree? From the beginning, refrigeration of the gas has been regarded as the key to design of the Mackenzie Valley pipeline. This technique, it was claimed, would solve the problems created by the thawing of permafrost and the settling of ground that had forced Alyeska to adopt the expensive elevated construction mode. But the refrigerated buried gas pipeline is an innovation that lacks engineering precedent. Arctic Gas and their engineering consultants have discussed their plan to refrigerate and bury the pipeline with optimism and assurance. I think, however, my own approach should be conservative. I must consider the impacts that can be expected to arise from the construction, operation, maintenance and repair of a buried refrigerated pipeline that must be protected from frost heave.

In my view, the controversy and uncertainty that surround the subject of frost heave and its control reflect adversely on the proposals brought before this Inquiry by both companies. I recognize, of course, that these proposals were in a preliminary, conceptual stage, not in their final design stage. I recognize, too, that important improvements will appear in the final design. Arctic Gas filed their application for a right-of-way in March 1974. They insisted then, that it was essential that the right-of-way be granted within the year. Yet now, three years later, we are still faced with basic uncertainty about this fundamental aspect of their design.

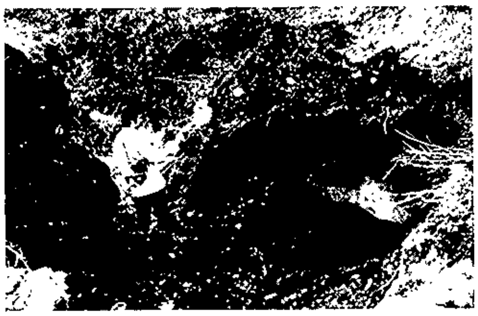
Frost Heave and the Frost Bulb

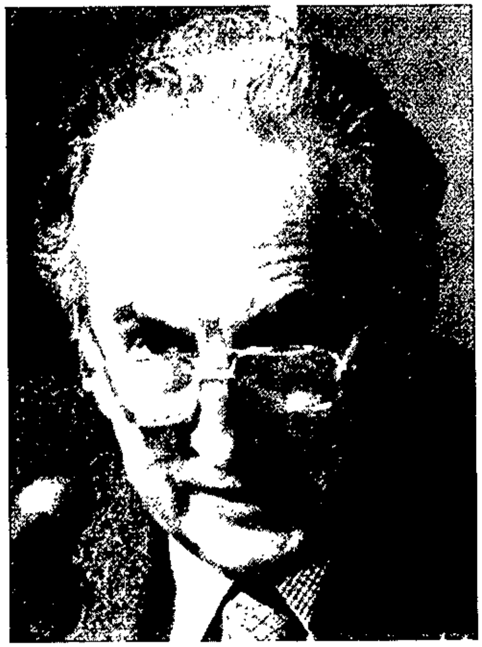
A refrigerated pipeline will experience frost heave and related effects principally in the zone of discontinuous permafrost, which extends southward from Fort Good Hope to the general vicinity of the Alberta border, a distance of about 550 miles. In this zone, the pipeline will repeatedly pass through sections of unfrozen ground that alternate with

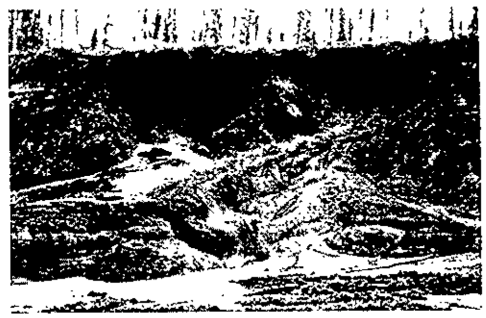
Ice in soil in permafrost area, Inuvik. (R. Read)

Carson Templeton. (Native Press)

Thawing of permafrost caused the soil to liquify and flow, Dempster Highway near Fort McPherson. (GSC–A. Heginbottom)







sections of permafrost. Heave may occur wherever the pipe passes through unfrozen wet ground and the gas in it is kept at a temperature below the freezing point of water. Foothills argued at the Inquiry that the "southern limit of chilling" should be in the neighbourhood of Fort Simpson, but Arctic Gas argued that it should be near the Alberta border. North of Fort Good Hope, in the zone of continuous permafrost, the pipeline would pass through unfrozen ground in relatively few places, principally beneath river channels. The problem of frost heave is not, therefore, widespread in this zone, but it may be serious at river crossings: Arctic Gas say that their present proposed route passes through 17 miles of unfrozen ground beneath the channels of the Mackenzie Delta.

Where the refrigerated pipe passes through unfrozen ground, it will surround itself with a frost bulb, a zone of frozen soil, that will grow outward at first rapidly, then more slowly, over a period of years. It could extend 20 feet or more below the pipe. The frost bulb will cause frost heave in varying degrees, depending on local conditions in the ground, including the nature of the soil, temperature, pressure and availability of water. When soil freezes, two things happen that cause it to expand and the ground to heave. First, water in the soil expands by about ten percent in changing to ice. Second and more important, water in fine and fairly fine soils such as silt or clay may move progressively to the freezing soil, so that the amount of water, as ice, increases in the frozen soil generally in layers. The expanding soil would heave the pipe upward by a distance approximately equal to the sum of all the ice layers that have grown beneath it. If this heave should be uniform all along the pipe, it would raise both the pipe and the ground surface, but it would not buckle the pipe. However, where the amount of heave varies within a short distance, the pipe could buckle or even rupture.

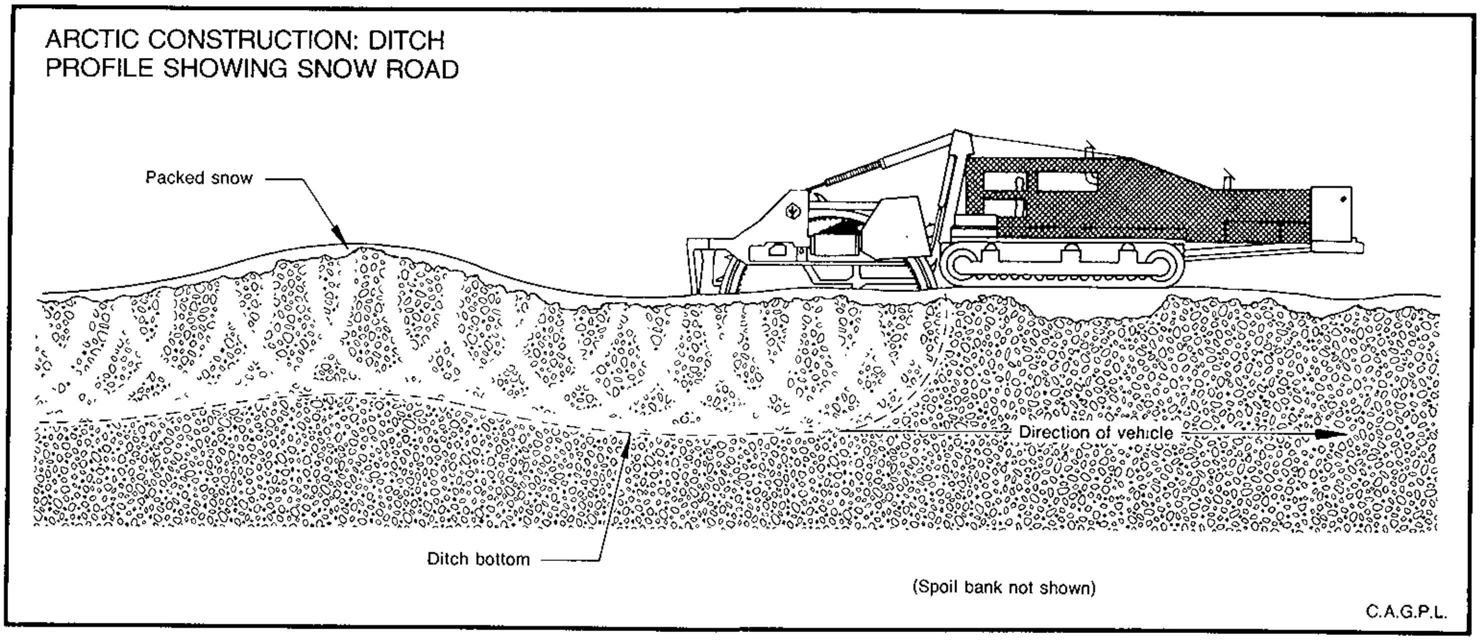
The effects of the growing frost bulb are not limited to frost heave. Carson Templeton of the Environment Protection Board referred to the frost bulb as a wall. It would be a continuous frozen underground barrier that would be created along the length of each section of refrigerated pipe that passes through unfrozen ground. This barrier would block movement of groundwater across the pipeline's route. Ponds or surface icings might be created, or water might begin to move along the pipe or parallel to it. This movement of groundwater on sloping terrain could lead to erosion or slope instability. Also, many river and stream beds are not frozen in winter: when a buried chilled pipeline crosses under a stream that has only a little water flowing in it, the frost bulb could block or divert that flow or create icings.

Controversy over Heave Forces and Control

The processes that cause frost heave are understood in general terms, and so are the soil types, temperature, pressure, and water availability that are conducive to frost heave. Moreover, highway engineers and others have had practical experience in reducing the amount and rate of frost heave by putting a load – gravel perhaps – on the surface to counteract the upward heaving force. Experience in controlling frost heave, however, is limited to situations in which frost builds up during the winter months and then melts in spring and summer. This experience is no precedent for a situation in which frost will build up continuously from year to year. Moreover, there is no unanimity about details of the frost heave process, the magnitude of the forces that are generated, the range of situations in which the problem may be encountered, and – especially – the magnitude of the differential forces to which the pipe might be subjected. Finally, the engineering procedures to reduce or avoid the heaving of a buried refrigerated pipeline over the years are still in a conceptual stage. There has been no practical demonstration of these procedures under the conditions that will prevail in this project.

Arctic Gas have given much attention to frost heave and its related effects on a buried refrigerated pipeline. More than $1 million has been spent on their Calgary test site and on associated experiments. The impressive panel of geotechnical experts brought before the Inquiry in the spring of 1975 by Arctic Gas indicated that they fully understood the frost heave phenomenon and its effect on the pipeline, and that they had complete confidence in the methods they proposed for its control. They gave assurances that frost heave could be reduced to an acceptable level by loading – either by deep burial or by a built-up berm or by both – without substantial environmental impact. Dr. Ken Adam, on behalf of the Environment Protection Board, and Dr. Peter Williams, of Carleton University, who was called by Commission Counsel, disagreed with the opinion of the Arctic Gas panel. Williams in particular disputed the theoretical and experimental basis of the analysis made by the Arctic Gas experts, and he indicated that the magnitude of the heave forces had been underestimated:

> In my opinion, the maximum shut-off pressures that would be required to prevent deleterious heaving during the life of the pipe are greater than those that have been stated. Correspondingly, at problem sites, such as



transitions between different types of materials where the possibilities of differential heave damaging the pipe are greatest, conditions will be more difficult than that described by the Applicant's witnesses. Particularly in the region of discontinuous permafrost, it appears that freezing induced by the cold pipeline could give rise to pipe deformations greater than the Applicant's maximum permissible curvature of the pipe. [Summary of evidence, filed July 8, 1975, p. 2]

Arctic Gas disagreed fundamentally with the position taken by Williams, which their counsel summarized as follows:

> Dr. Williams' thesis is that a chilled pipeline, such as that proposed by Arctic Gas, is going to produce many times more heave than our evidence predicts, and that we will not be able to suppress this heave with types of burial or surcharging that we propose. [F10825]

Arctic Gas then brought forward another panel that strongly challenged Williams' thesis and emphasized that the position of Arctic Gas remained unchanged. Williams in turn maintained his position.

About a year later, in October 1976, Arctic Gas informed the Inquiry that there had been a continuing malfunction in the test apparatus they were using to determine frost heave. This discovery, which had been made by the Division of Building Research of the National Research Council, indicated that the measurements of frost heave pressures upon which Arctic Gas had relied were erroneous: the pressures that had been measured were, in fact, less than the correct pressures. At that date, Arctic Gas did not know the magnitude of the heave forces that the refrigerated pipeline would encounter under severe conditions, and they admitted that, in some situations, burial or surcharge would not be able to suppress heave. Counsel for the company stated:

> Arctic Gas believe that there are some soils in which the heave pressure is larger than can be controlled by deep burial and/or surcharge. [F31491]

Counsel went on to list five other methods that are available to control the problem: insulation of the pipe, insulation of the pipe with heat trace (heating cable), operation of the pipe at temperatures close to 32° Farenheit, replacement of frost-susceptible soil, and placement of the pipe with insulation in a berm on the ground surface.

Thus, at the end of the hearings, Arctic Gas had withdrawn from the position they had held so strongly regarding frost heave and its control. The surcharge method they had relied on as the principal means of controlling frost heave was admitted to be inadequate in severe conditions. The five alternative methods of frost heave control were not described in any detail.

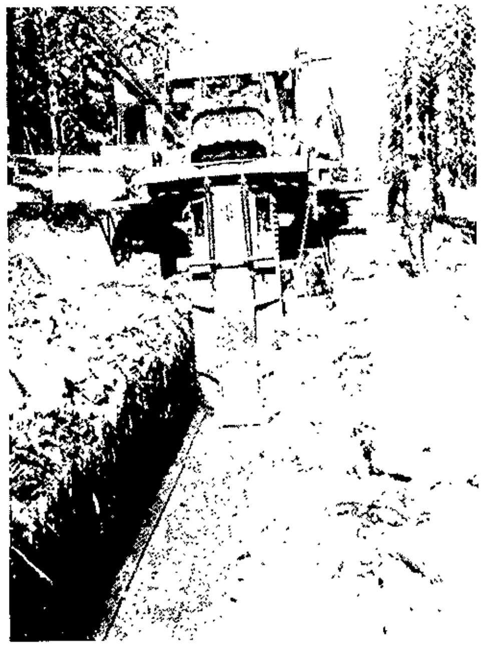
The evolution of the plans of Arctic Gas to control frost heave of the refrigerated twin pipes they propose to bury beneath Shallow Bay, a four-mile crossing in the Mackenzie Delta, provides a graphic illustration of the uncertainties in frost heave control. At Shallow Bay, and at river crossings in general, it is obvious that a berm cannot be used to control heave. In March 1976, the design proposed for the Shallow Bay crossing indicated that burial of the pipeline 10 feet below the bottom would satisfy frost heave requirements. But further studies led to an increase in the depth of burial: 35 feet was then thought to be required to achieve the necessary overburden pressure. Arctic Gas presented this information to the National Energy Board in June 1976. After the fault in the test equipment was discovered, Arctic Gas told this Inquiry in November 1976 of yet further changes to their plans for Shallow Bay:

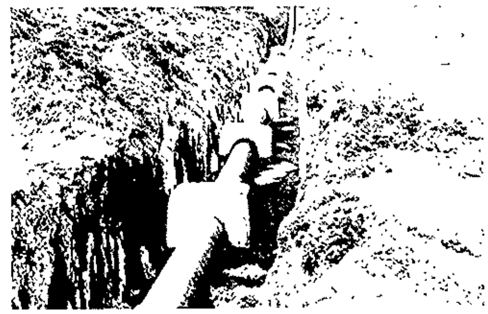
> This [fault] indicated a need for even greater burial depths and gravel borrow if the surcharge method were employed. Further assessment of the data is required to determine the feasibility of this technique. If the surcharge method of design proves to be not feasible, alternative designs as put before the Berger Commission on October 15, 1976, will be applied. Two alternatives are feasible: one involving the use of insulation and replacement of frost-susceptible soil ... and the other ... insulation of the pipe with heat trace. [Exhibit F891, p. B-13]

In view of these uncertainties, it is not surprising that counsel for Arctic Gas said that this Inquiry is not in a position to offer any specific findings in this regard.

In February 1977, Arctic Gas filed with the National Energy Board further evidence regarding their plans for controlling frost heave in which they conceded that, for virtually all soils to be crossed by the refrigerated buried pipe, the depth of burial and the height of the berm required to control frost heave would exceed practical limits. They had found that they could not, as a practical matter, bury the pipe deep enough nor build a berm high enough to control frost heave. Moreover, Arctic Gas indicated, for the first time, that frost heave would be a problem wherever the refrigerated pipe passes through shallow permafrost. According to their new plans, presented with this evidence, insulated pipe with heat trace would be used in all of the overland sections where the ground is unfrozen or where permafrost is less than 15 feet deep. Heat probes would be used to prevent the build-up of ice lenses where permafrost is 15 feet or more thick. At river crossings, in frost-susceptible soils, a heavy casing would be placed around the insulated pipe and heating cables would also be used.

To reduce the length of pipe requiring frost heave control, the southern limit of





Above-ground section of trans-Alaska pipeline. (Alyeska)
Pipeline ditching machine. (E. Owen)
Pipe in ditch with saddle weights to prevent it from floating. Pointed Mountain. (E. Owen)

refrigeration of the pipe would, according to this modified plan, be moved northward about 160 miles to a point north of Fort Simpson. This 160-mile section would be kept above rather than below freezing, and it would thaw any permafrost that it encounters. To maintain pipe stability when such a thaw occurs, Arctic Gas now propose deep burial of the pipe and, in critical locations, support of the buried pipe on piles fixed in stable material beneath the thawed zone.

Throughout the uncertainties and changes associated with frost heave, Arctic Gas have strongly opposed the use of above-ground pipeline construction. In 1975, Dr. Hoyt Purcell, a witness for Arctic Gas, summarized the company's position as follows:

> After reviewing the pros and cons of above-ground versus buried construction, the Arctic Gas engineers continued to use the buried mode as their prime design technique, and put the above-ground mode on the shelf to be used only in the event insuperable problems with the buried mode emerged. [F3764]

Purcell also said that the cost of a section of pipeline would be increased by 60 percent if two-thirds of its length were built above ground on piles instead of being buried. Arctic Gas told the Inquiry in November 1976 that they do not consider above-ground construction a viable alternative. In February 1977, they still maintained that above-ground construction is greatly inferior to an insulated, heat-traced pipeline buried in frost-susceptible terrain.

Despite the strength of their statements against above-ground construction of the pipeline, Arctic Gas have admitted the possibility of placing short sections of insulated pipe on the ground within a berm to avoid frost heave. Counsel for Arctic Gas referred to this possibility in October 1976; it was raised again before the Inquiry in November 1976, and again before the National Energy Board in February 1977.

Implications

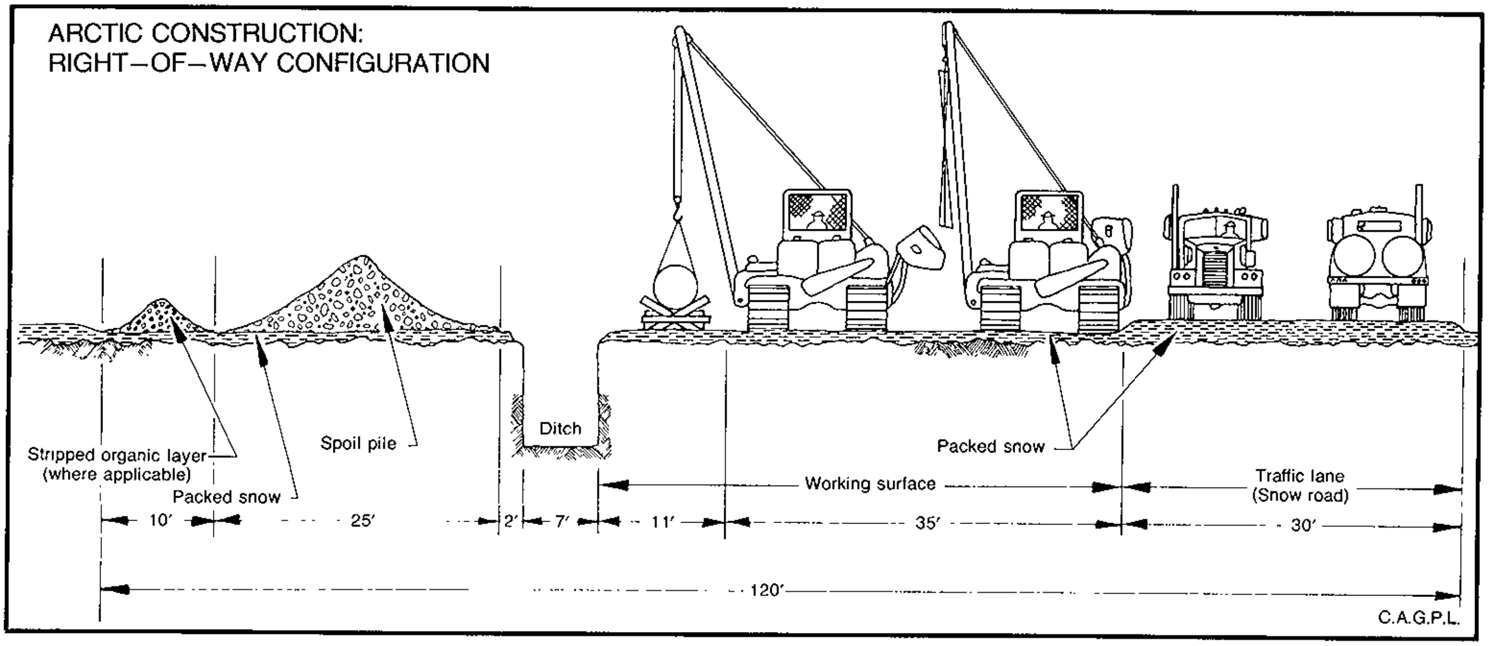
I have reviewed the problem of frost heave in some detail to illustrate two problems: first, the inadequacies in some aspects of the pipeline proposals; and second, inadequacies in the knowledge that is available to the Inquiry and to the government on which an assessment of precedent-setting or innovative aspects of the pipeline engineering must be based.

In considering the original pipeline proposal made by Arctic Gas, the Pipeline Application Assessment Group stated in their report, published in November, 1974:

> The application provides principles and theory but in many respects lacks specifics of the *modus operandi*; it contains frequent assurances that the subject being considered is adequately understood, that designs will be developed to cope with the situations of concern, or that additional studies already planned will remove any uncertainties. [*Mackenzie Valley Pipeline Assessment*, p. 5]

Now, more than two years later, this comment is still applicable. Critical questions remain unanswered. Company officials and consultants continue to express confidence in proposed engineering designs and construction plans and to give assurances that major and precedent-setting aspects of the project are well in hand. The question of frost heave illustrates these unsatisfactory aspects of the present design proposals. The section of this chapter on construction scheduling will provide a comparable illustration. I recognize that the project proposals are still in a conceptual, and not a final, design stage. I also recognize that improvements in them will continue to be made. My concern about the engineering and scheduling aspects of construction relates to my duty to assess and judge the proposals as they now stand. Arctic Gas, at the close of the hearings, argued that the Inquiry was not in a position to make any specific finding with regard to frost heave. I agree. I am not, therefore, in a position to say that the proposals made by Arctic Gas to control frost heave are sound. But I can say something about the reasons why the Inquiry is in this position.

In dealing with frost heave and with other questions of innovative design or construction planning, it has become apparent that much of the specialized knowledge and expertise that is relevant to these matters is tied up with industry and its consultants. This situation is untenable when faced with the need to make an objective assessment of the project. Government cannot rely solely on industry's ability to judge its own case; rather, with respect to questions of fundamental design, government must have the knowledge to make an independent judgment. A contrast has been clearly apparent at the Inquiry between biological issues, where the Environmental-Social Program, the Beaufort Sea Project and related ongoing federal research have provided knowledge and expertise, and engineering issues, where the knowledge and expertise is largely confined to the industry itself. This is in no way a criticism of the advice and information that the Inquiry has received on technical matters. Indeed, it is this advice that has enabled the Inquiry to assess the magnitude and the implications of the frost heave question. But I urge the government to make itself more knowledgeable in matters involving major innovative technology, such as frost heave and other questions related to the burial of pipelines in permafrost, which are and will be involved in northern oil and



gas exploration and development proposals for years to come. Acquisition of this knowledge will necessitate ongoing research and expert scientific staff. Industry proposes, the government disposes. Without such a body of knowledge, the government will not be able to make an intelligent disposition of industry's proposals now or in the future.

The question of frost heave is basic to the theory and design of the pipeline project. If the pipe is to be buried, the gas must be chilled. If the gas is chilled, the result – frost heave – has to be overcome. The pipeline companies are obviously having trouble in designing their proposal to deal with frost heave, and they are making fundamental changes in the methods proposed for heave control. Their methods seem to be getting more complex, and the conditions for success more restrictive. There is every likelihood that the companies will make yet further changes in their proposals, changes that are likely to increase costs further and to alter substantially the environmental impacts that we have been trying to assess. The possibility that for some sections of the pipe, the buried refrigerated mode will be replaced by above-ground berm construction or above-ground pile construction brings with it a host of attendant problems. It seems to me unreasonable that the Government of Canada should give unqualified approval to a right-of-way or provide financial guarantees to the project without a convincing resolution of these concerns.

The Construction Plan and Schedule

Large-scale engineering projects are not unprecedented in the arctic and sub-arctic regions of North America. I have mentioned the large defence-oriented projects that have already been constructed in these regions, such as the Alaska Highway, the Canol Pipeline and the DEW Line. More recently, we have seen the Churchill Falls hydro-electric project in Labrador, the James Bay hydro-electric project in Quebec and, of course, the Alyeska oil pipeline in Alaska. These are all huge multimillion dollar projects in frontier settings. Now we have before us the Mackenzie Valley pipeline proposals of Arctic Gas and Foothills. Why are we so concerned by these proposals?

At the outset, we must bear in mind that the pipeline as proposed is not a simple extension of past defence- and energy-oriented frontier construction projects, nor simply an extension of tested technology to a far northern setting. In my discussion of frost heave, I have already sought to demonstrate the novel engineering aspects of the project. But the innovations – and problems – are not confined to design: the construction plans and proposed schedules for building the pipeline also involve techniques that lack precedent. Even now, before the project is underway, a number of scheduling problems can be discerned that may well compound one another in ways that have not yet been adequately considered by either Arctic Gas or Foothills. The natural and logistical constraints that the project will encounter could make the present approach to its construction optimistic and, in some respects perhaps, unrealistic.

The environmental, social and economic assessments made by the pipeline companies were carefully predicated on the assumption that the project would, in fact, be built as proposed. However, it should be plain to anyone that every substantial modification in the schedule or in the methods of construction will alter these impacts.

Let me outline some of the features of the construction plan that are novel and that may pose problems. Each of them could lead to difficulties in adhering to the construction schedule. Each of them could force changes in the project. When taken together, these changes could present us with a project that has become so different from the one originally proposed that we should question the basis of the present assessments of impact. This concern is greatest along the Arctic Gas route across the Northern Yukon where the schedule is likely to be most susceptible to upset and where the environment is highly sensitive to impact.

Snow Roads

Except for pre-construction activity, and for construction of major water crossings and compressor stations, the companies intend to build the pipeline in winter. Winter pipeline construction is not new: it is now almost standard Canadian practice because it allows heavy equipment to be moved along a right-of-way when the ground is frozen, making the construction of all-weather roads unnecessary. Such roads are expensive and could result in greater environmental and social impact than the pipeline itself.

This pipeline project is different because the continuous or discontinuous permafrost that underlies its entire route North of 60 precludes the standard approach to winter

Arctic Gas snow road test loop. (W. Sol)

Les Williams, Northern Engineering Services. (Arctic Gas)

Snow road construction at test site. (K. Adam)

grading and right-of-way preparation. Measures must be taken to protect the ground surface from damage that would lead to thermal degradation of the permafrost. To protect the ground surface, both companies propose to use snow roads and snow working surfaces, which are subtle but important variations on winter road construction practices that are common in Northern Canada. Winter roads are of snow pack or ice construction or are cleared rights-of-way along frozen waterbodies. The Denison Ice Road, which runs from the Mackenzie Highway near Rae north to Great Bear Lake, the winter road that used to run northward along the Mackenzie Valley from Fort Simpson in the early 1970s, and the roads the oil companies and their contractors have recently been using in their Delta exploration programs are examples of conventional winter roads.

The snow roads proposed for the pipeline project are a more sophisticated version of these common winter roads, and are designed to protect the vegetation, and hence the permafrost, from heavy traffic. Access roads from stockpile sites, water sources, borrow pits and camps to the pipeline right-of-way are expected to have as many as 45,000 vehicle passes in one season, and haul roads along the right-of-way will have about 29,000 passes. This volume of traffic requires a higher standard of construction than is necessary on conventional winter roads. Thus the proposed snow roads will consist of a densely compacted snow pavement over the naturally frozen but undisturbed ground surface. Adjacent to the snow road on the right-of-way there will be a snow working surface along the ditch line; it will be similar to the snow road but its pavement will be less densely packed because it will need to sustain only a few passes of slow-moving equipment.

Both Arctic Gas and Foothills propose to build hundreds of miles of snow roads, and the whole pipeline construction schedule will depend on their availability. Yet lack of experience with them has led to a number of criticisms about their potential usefulness, particularly in tundra areas.

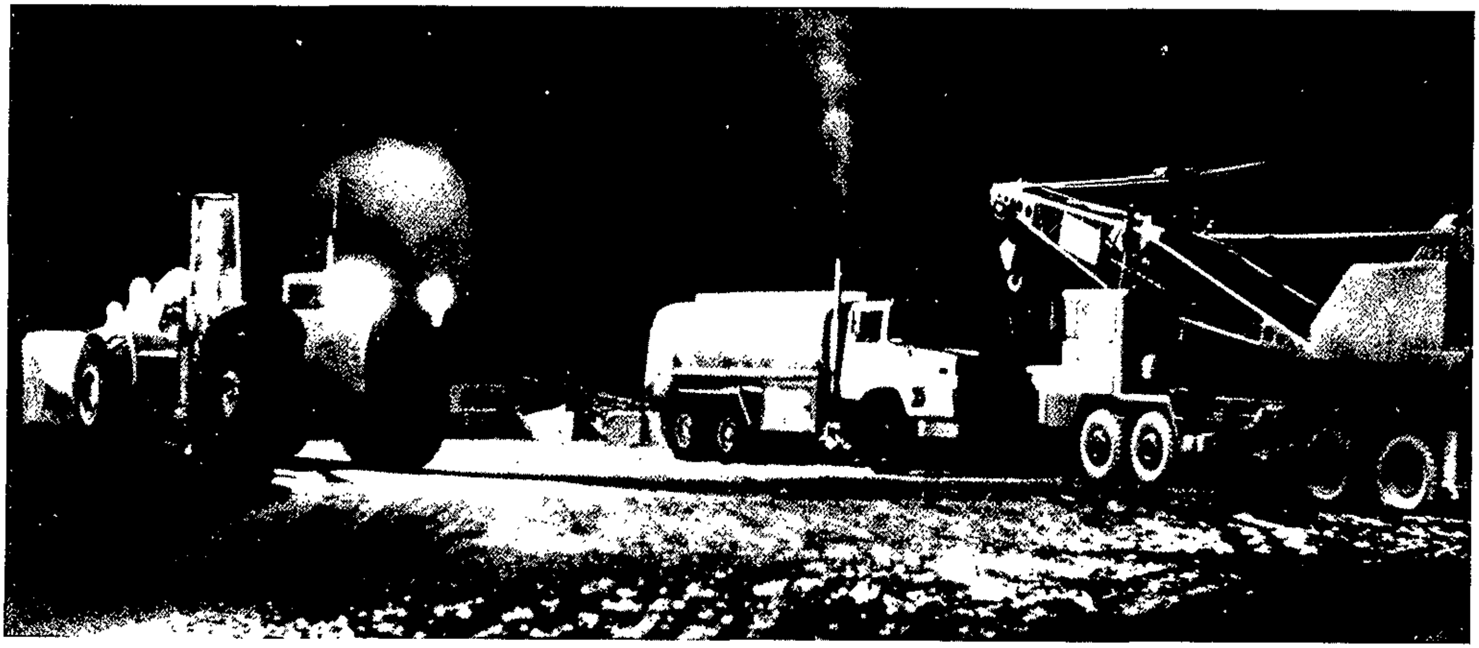
Arctic Gas undertook at an early stage to verify the practicability of the snow road concept. Preliminary tests at the Sans Sault Rapids and Norman Wells test sites were, as Les Williams, Director of Field Services for Northern Engineering Services Company Ltd., said, "not too successful" and were "not completely valid." [F4306] In 1973, Northern Engineering Services built an experimental snow road at Inuvik to verify the viability of the scheme in the more northern latitudes where the problems would be greater. A test section about three-quarters of a mile long was prepared but, because of low snowfall, snow had to be harvested from a nearby lake and hauled to the site. Snow manufacturing also was tried with some success. Once in place, the snow was compacted to achieve the necessary pavement density, and trafficability tests were conducted in winter and spring by making successive passes with a loaded truck. Follow-up observations made on the vegtation beneath the road revealed that the ground surface was relatively undisturbed.

Arctic Gas concluded that densely packed snow roads will be able to withstand heavy traffic and to protect sensitive terrain from disturbance. But not everyone shared their view. Walter Parker, Commissioner of Highways for the State of Alaska, and Dr. Robert Weeden of the State Governor's Office told the Inquiry that, despite the results of the test at Inuvik, they did not think the feasibility of snow roads had been demonstrated, particularly for use on the Arctic Coastal Plain. In their opinion, snow roads should be regarded as operationally unproven. Others, such as Dr. Ken Adam of the Environment Protection Board, and Paul Jarvis, a witness for Foothills, also expressed reservations, although they did not criticize the concept as severely.

In my view, the issue is not whether snow roads, once in place, will work. Canadian engineers have had ample experience with winter roads, airstrips and snow-surfaced work areas. Rather the dispute hinges on two questions. The first relates to timing, and the second to the sufficiency of snow.

The timing question is this: can the snow roads be ready early enough and can they be used long enough to enable the construction to be completed on schedule? After all, they must be prepared before pipeline construction can begin, and construction cannot continue after the roads begin to melt. There is a definite "window" for winter construction, limited on each side by freezing and thawing temperatures. The construction season cannot be extended beyond it: additional men and equipment would be of no help once the season has ended.

If the pipeline company tries to adhere to a fixed schedule in preparing snow roads, there could be considerable unnecessary damage to terrain and disruption of construction plans. Schedules must take into account regional and annual variations in climate, snowfall and frost penetration. Before snow roads can be prepared in the fall, the ground must be frozen deep enough to support heavy vehicles and there must be sufficient snow to protect the surface vegetation. Frost penetration varies from place to place and from year to year. Streams, drainage channels and wet areas will delay road



preparation because they freeze more slowly than intervening areas. If it is impossible to wait until the frost has gone deep enough in wet areas to support the movement of vehicles, temporary crossings will have to be built.

Construction activity in the spring will also be of great environmental concern. There will be compelling reasons to try to extend the use of snow roads as long as possible, particularly if the work is running behind schedule. But the shut-down date of a snow road is completely dependent on the spring weather, which varies substantially from year to year. Construction activity must be able to stop at short notice without harm to the environment.

If scheduled work cannot be accomplished in the period prescribed by nature, it will either have to be postponed until the next season or, as in Alaska, a permanent gravel road-and-working surface will have to be built to permit summer construction. Either way, the schedules and costs of construction would be changed, and the impact of the project would be increased. Arctic Gas maintain that such alterations will not be necessary. Foothills dispute that claim; late in the Inquiry, they told us they propose to build 50 miles of gravel road along the northern end of their right-of-way, to enable them to proceed whether or not temperature and snowfall allow construction of snow roads early in the season.

The second question about snow roads is this: will the snowfall early in the season be adequate for building the roads, and, if not, can sufficient snow be gathered or manufactured in an environmentally acceptable manner? The farther north you go along the proposed pipeline route, the less snow there is. The average annual snowfall of the Arctic Coastal Plain of the Yukon is less than half that of Northern Alberta. So, at the northern end of the pipeline route, the longer winter construction season is offset by lack of snow.

Thus, construction of snow roads will be most difficult in the tundra regions, mainly because of the light snowfall there. The proposed Arctic Gas Coastal Route across the Northern Yukon is the principal area of concern in this regard. Arctic Gas say that, in such regions, they will supplement natural snowfall by using snow fences to catch snow, by harvesting snow from lakes and hauling it to the road bed, and by mechanically manufacturing snow and blowing it onto the roads and work surfaces. But the winter winds sweeping across the treeless landscape will further complicate the harvesting and accumulation of snow for roads.

Along the Coastal Route snow will have to be harvested from a multitude of lakes and then hauled to where it will be used – an activity that will require extensive movements of equipment and networks of secondary snow roads (and thus even more snow). Vehicles and equipment will have to be kept in the area over summer to be available on site in the fall, and snow fences will have to be strung in the fall. Snow fences have not yet been tested on a scale and in locations similar to those proposed, nor has there been any field research on their potential effects on wildlife.

The plans for manufacturing snow also involve uncertainties. Snow making is common practice on ski slopes, and it has been used to a limited extent to make snow surfaces on airstrips, but it has never been used on the scale proposed by Arctic Gas. The experimental snow road in Inuvik used what Les Williams described as a "gerry rigged apparatus." The snow-making equipment to be used on the Arctic Gas Coastal Route does not yet exist – we were simply shown an artist's conception of a large vehicle, with a big compressor and up to six snow-making nozzles. This machine will be fed by fleets of tanker vehicles, which will in turn require an extensive network of snow roads to acceptable water sources. The snow-making machine will require up to 1,000 Imperial gallons of water per minute. Williams said that if the snow road and working surface had to be fully manufactured, about 1.75 million Imperial gallons (50,000 barrels) of water per mile of right-of-way would be needed.

This program of harvesting and manufacturing snow for roads and work surfaces is obviously a very extensive operation and Arctic Gas have tended to understate the problems involved. Quite understandably, they hope for an early and abundant snowfall during the winter they build the pipeline from Prudhoe Bay to the Mackenzie Delta. Although they have outlined techniques for harvesting and manufacturing snow, they have not presented a comprehensive plan for the whole range of activities that will be required if conditions are less than favourable.

Our greatest concern about the snow roads centres on the Northern Yukon. There the project faces the greatest environmental sensitivity; there adherence to schedules is most critical. If the snow roads across the Northern Yukon cannot be built according to plan, there could be massive disturbance that would have far-reaching geotechnical and environmental consequences.

Productivity

I began this discussion of the planning and scheduling of construction with snow roads because they determine the length of the winter construction season. Productivity

Machines in darkness of arctic winter day. (DIAND)

Alan Hollingworth and Reginald Gibbs, Q.C., counsel for Foothills. (Native Press)

Vern Horte, President of Arctic Gas. (Arctic Gas)

Pierre Genest, Q.C. and Jack Marshall, counsel for Arctic Gas. (Native Press)

within that season will dictate the success of the schedule. The duration of the construction season lengthens from south to north because of earlier freeze-up and later break-up. But other factors such as cold and dark that affect productivity are more severe farther north. Assuming that the snow roads can be built and used in the time proposed, can the amount of work that each construction spread must accomplish be done during the winter construction season?

The schedule that Arctic Gas propose is based on a winter construction season substantially longer than that proposed by Foothills. According to Arctic Gas, the preparation of snow roads and snow working surfaces across the Northern Yukon can begin in October, and pipelaying can start in early November. Foothills disagree; they say that December is the earliest starting date, but because of the cold and darkness and because the construction crews will insist on a Christmas break, it would be impractical to start work on that segment before the end of January. Arctic Gas say that darkness can be overcome by floodlighting the construction spread. In addition, they will shorten the Christmas break and pay people to stay on the job. Cold and adverse weather such as ice fog, blowing snow and whiteouts will, they agree, pose problems, but they have allowed for some delays in their schedule. They maintain, and so do the union representatives who testified, that the workers can and will work throughout the northern winter.

I heard a great deal of evidence about start-up dates, productivity, shut-down dates, downtime, the effects of cold and darkness, the practicability of lighting an entire construction spread, the working conditions the unions would insist upon, and so on. Out of it all, several main themes emerge that underline the uncertainties in planning and scheduling the pipeline project.

Winter conditions, of course, will affect productivity. Arctic Gas estimate that, along the Yukon Coastal Plain, winter productivity will be only 60 percent of what it is for summer pipeline construction on the prairies, although in the southern part of the Northwest Territories, productivity will reach about 90 percent. In preparing their construction schedules, they allowed for break-up, freeze-up, holidays, bad weather, darkness, low temperatures and downtime for environmental reasons. But, as Williams pointed out, their downtime evaluations did not include allowances for wind chill and limited visibility.

The unions and the workers will also have something to say about productivity. The labour representatives who appeared at the Inquiry said that there will be a no-strike no-lockout agreement. They said that work in severe weather can be undertaken, and specific conditions will be on a business-like basis with the contractor on the job – but unresolved and unquantified is the whole issue of downtime caused by labour disputes. Despite assurances from the company and the unions, it seems obvious that there are limits beyond which the workers will not go.

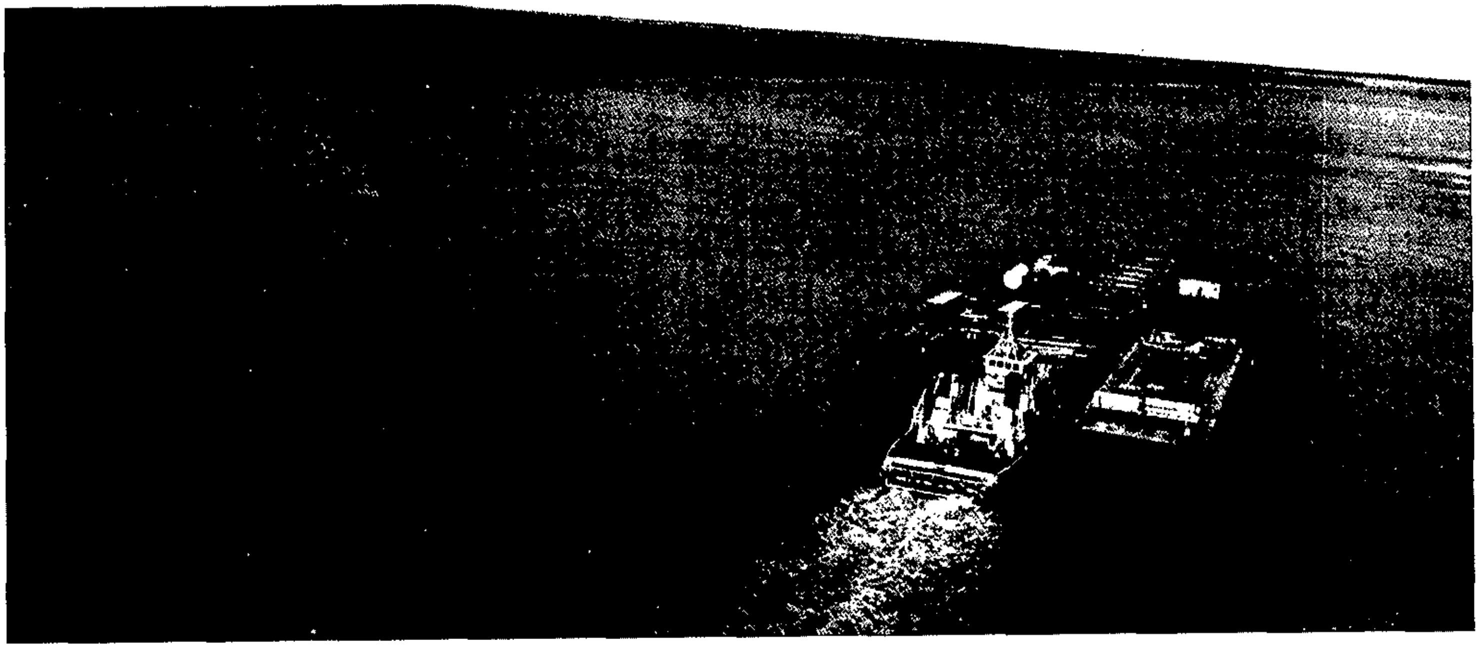
Innovations in equipment will also be required. The ditching machine, for example, is still being developed and so are some of its components such as the ditcher teeth. There is only one large ditcher in existence, the 710. Arctic Gas say that this ditcher can do 60 percent of the ditching. But this machine has not been used in permafrost, and its teeth appear to be unsuitable for permafrost work. A new ditcher, the 812, is therefore being developed, and new teeth for it are being tested to meet Arctic Gas' requirements. No prototype has yet been built.

Changes in the design of the project could also have an adverse effect on productivity. For instance, the uncertainties about frost heave referred to in the preceding section and the requirements for installing crack arrestors around the pipe have both arisen since Arctic Gas prepared their schedule.

Foothills criticized Arctic Gas' proposal to illuminate artificially a winter construction spread that will involve up to 500 men and 50 pieces of equipment deployed over a two-or-three mile stretch of confined right-of-way. They maintain that work under these conditions would be hazardous to workers – even if it were feasible. The lighting of a moving pipeline spread of this magnitude is in itself novel and quite different from the lighting of fixed and confined operations such as drilling rigs.

Although Foothills have raised important questions about the Arctic Gas proposal, they have not vindicated their own construction plan. As Arctic Gas pointed out, the most significant difference between the two plans lies in the start-up dates of fall construction, not in the productivity per spread. Recently, Foothills have modified their plans for the northern end of their pipeline to include the construction of an all-weather gravel road so that pipelaying can be carried out in the fall, too. This change in itself is of great environmental concern, and it is perhaps an indication of the way in which we might expect the construction plans of either company to evolve.

The schedules of both companies are unproven. There are no precedents by which to judge the winter construction schedule for the northern part of the line. Even if there were, the many unique elements of design would make any comparison doubtful. It has



been said that the trans-Alaska pipeline is a precedent – but that pipeline is a hot oil pipeline built in summer and is fundamentally different in design from the buried chilled gas pipeline that is proposed for the Mackenzie Valley. In fact, Arctic Gas told the Inquiry that the trans-Alaska project is so different from their proposal that any comparison between the two is meaningless.

The Schedule in the Northern Yukon

The problems of snow roads and of productivity will be especially acute on the north slope of the Yukon, and it is right to ask whether Arctic Gas can build a pipeline from Alaska across the Northern Yukon in one season. Arctic Gas have said that, if experience during the first two years of pipelaying in the Mackenzie Valley indicates that they will encounter greater difficulty on the north slope than they now envisage, and if they think the pipeline from Alaska could not be built on schedule, they will establish two additional construction spreads, one in Canada and one in Alaska. But this approach – overcoming the forces of nature with more money, more men, and more equipment – clearly has limits. The extreme environmental sensitivity of the Northern Yukon that I will describe in a subsequent chapter will impose severe limits on any *ad hoc* response to construction problems.

If the pipeline across the Northern Yukon cannot be built in one winter season, there will be great pressure to extend the work into summer and to build a gravel road rather than to postpone further construction until the following winter. Only by this means will a heavy financial penalty be avoided. But once a permanent road is in place, the likelihood is that it will be used for maintenance and repairs and will form an integral part of corridor development. This will open up the wilderness of the Northern Yukon, exposing caribou, snow geese and other species to impacts that will go well beyond the impact of pipeline construction itself.

Logistics

The Arctic Gas project will require approximately two million tons of materials to be transported from southern supply points to northern stockpile sites scattered along the pipeline route. Summer barging on the Mackenzie River and, to a lesser degree, along the Arctic coast will be relied upon to deliver the material. The deluge of construction materials – pipe, fuel, camps and equipment – will require a doubling of the capacity of the river barging system. Virtually a whole infrastructure of wharves, stockpile sites, staging areas, haul roads, camps and communication systems must be installed by the company before the pipeline can be built.

Winter construction will depend, therefore, on a short summer shipping season. If there are delays in summer transportation, the winter construction program may well be disrupted, forcing the companies to ship goods by the Dempster Highway, or by winter road from Fort Simpson to Inuvik, or by aircraft. These alternatives would be of only limited value in major freight movements, and they could involve substantial social and environmental impacts.

The vulnerability of the construction schedule goes right back to the suppliers involved. Delays in delivery caused by strikes or slowdowns by southern transportation facilities, such as railways, ports and trucking operations, could seriously impede the construction program. This dependence on suppliers and on logistics is common to all construction projects – so why the great concern here? The answer is that the construction plan and schedule of this particular project are based on a "winter-only" construction program. And its success depends on the shipment of supplies from the South during a short, inflexible "summer-only" transportation season.

All large construction projects operate according to definite schedules, and there is every reason to believe that this project would use the most sophisticated techniques of planning and management to assure success. But there are limits to what any one company or union – or even government – can do. A series of relatively small, unforeseen, and uncontrollable logistical problems could cause the break-down of the whole supply program.

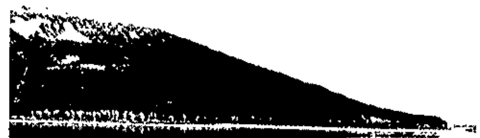
The logistics plans of both companies include the use of many non-company facilities. For example, they have made various assumptions about the Mackenzie Highway, the Dempster Highway, the Fort Simpson-to-Inuvik winter road, the use of wharf sites and airstrips near communities, and the use of trans-shipment facilities at Hay River. Also, they say that a proposal they both have made to establish a new major trans-shipment facility at Axe Point, near Mills Lake on the Mackenzie River, will extend the barging season and will relieve the pressure on the existing facilities at Hay River. Over the course of the Inquiry, there has been a steady modification of all these plans, partly in reaction to the attitudes of local people, and partly in response to specific requirements as the designs and plans have evolved. It should not be assumed that the approval of a right-of-way would

Barge on the Mackenzie River. (NTCL)

Building materials being loaded into aircraft. (N. Cooper)

Forty-eight-inch diameter pipe at Sans Sault Test Site. (Canadian Press)

Trucks passing on northern highway. (Native Press)



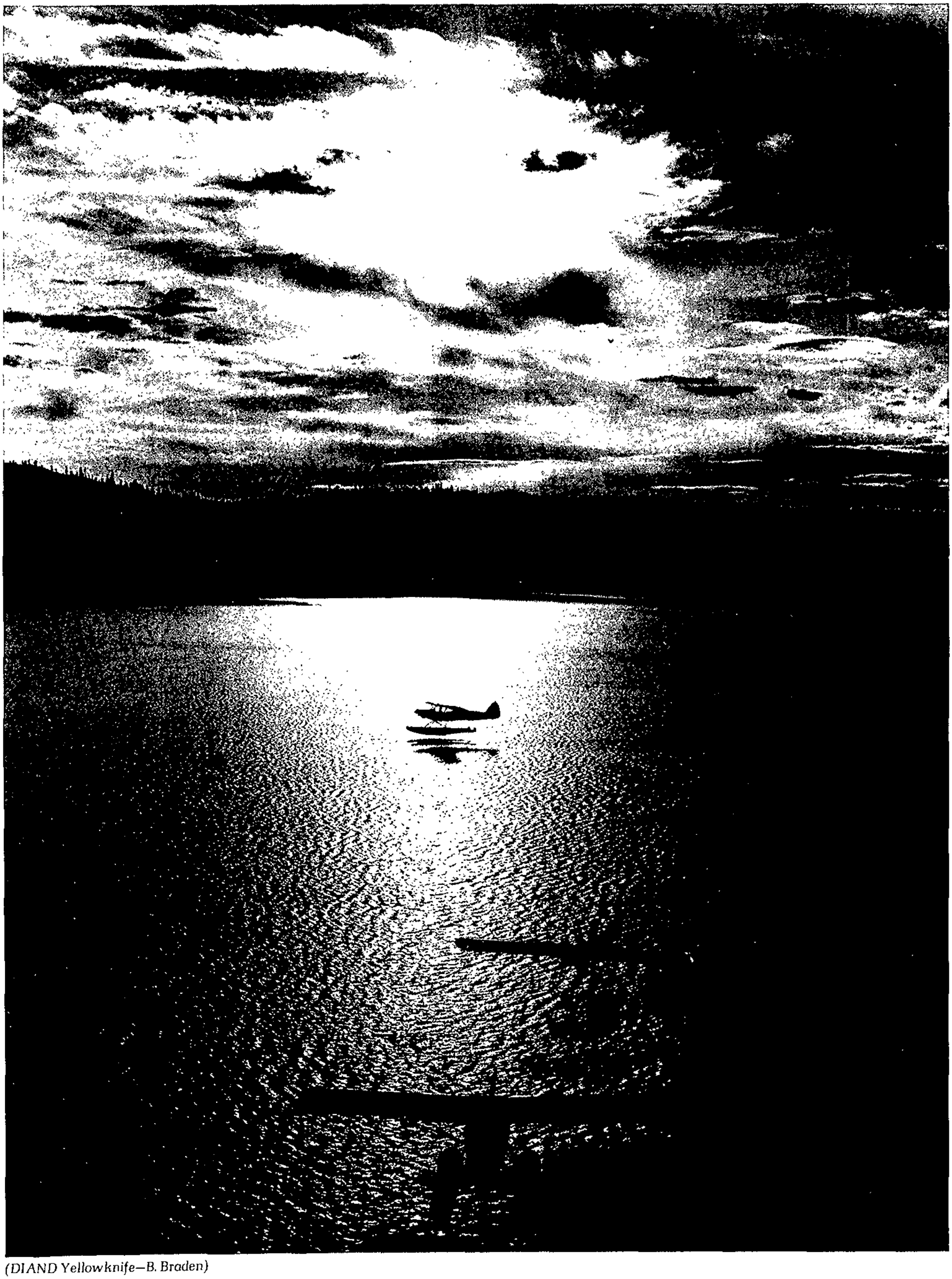
automatically carry approvals of all the logistical details advanced by the companies. For example, it will be necessary to decide if the proposed new facility at Axe Point will serve the immediate and long-term needs of the region. If the Axe Point facility is not approved, how will the limited summer shipping schedule be affected?

Implications

Throughout this Inquiry, we have heard a great deal about the ways the construction schedules could go wrong. In this section, I have reviewed at some length some criticisms of the proposals because of the consequences that a break-down in the construction plans and schedules would have. Scheduling failures will have serious financial implications for the company, its contractors, sub-contractors and workmen; for suppliers, shippers and the whole logistics infrastructure; and for local people and local communities. If the government has guaranteed cost overruns, then the government too will have an important financial stake in ensuring that the project adheres to the planned schedule. If there were a schedule failure and plans had to be changed, all of the parties concerned would react in a way dictated by their own interest. Such reaction could lead to *ad hoc* solutions, loss of quality control, an increase in accidents, and it might become impossible to protect the environment, the local people, and the local economy as originally planned.

I am not confident that the pipeline can be built in accordance with the present plans and schedules. Particularly, I am concerned that scheduling problems in the Northern Yukon could lead to a need for summer construction and a gravel road along the Coastal Route. The environmental impact of this change would be very severe. The project would then have to be completely reassessed, because the premises that were basic to all planning, environmental, social and economic assessments would have changed.

I recognize that the present stage of the companies' planning is preliminary and that, by the time final design and final plans are ready, there may be answers to the scheduling problems that concern us now. But my task is directed to assessment of the proposals in their present form and to the decision that government must make about them now. In this context, it seems unreasonable to me that Canada should give unqualified approval of the pipeline right-of-way or financial guarantees to the project without a convincing resolution of the fundamental concerns over the schedules.



(DIAND Yellowknife—B. Braden)