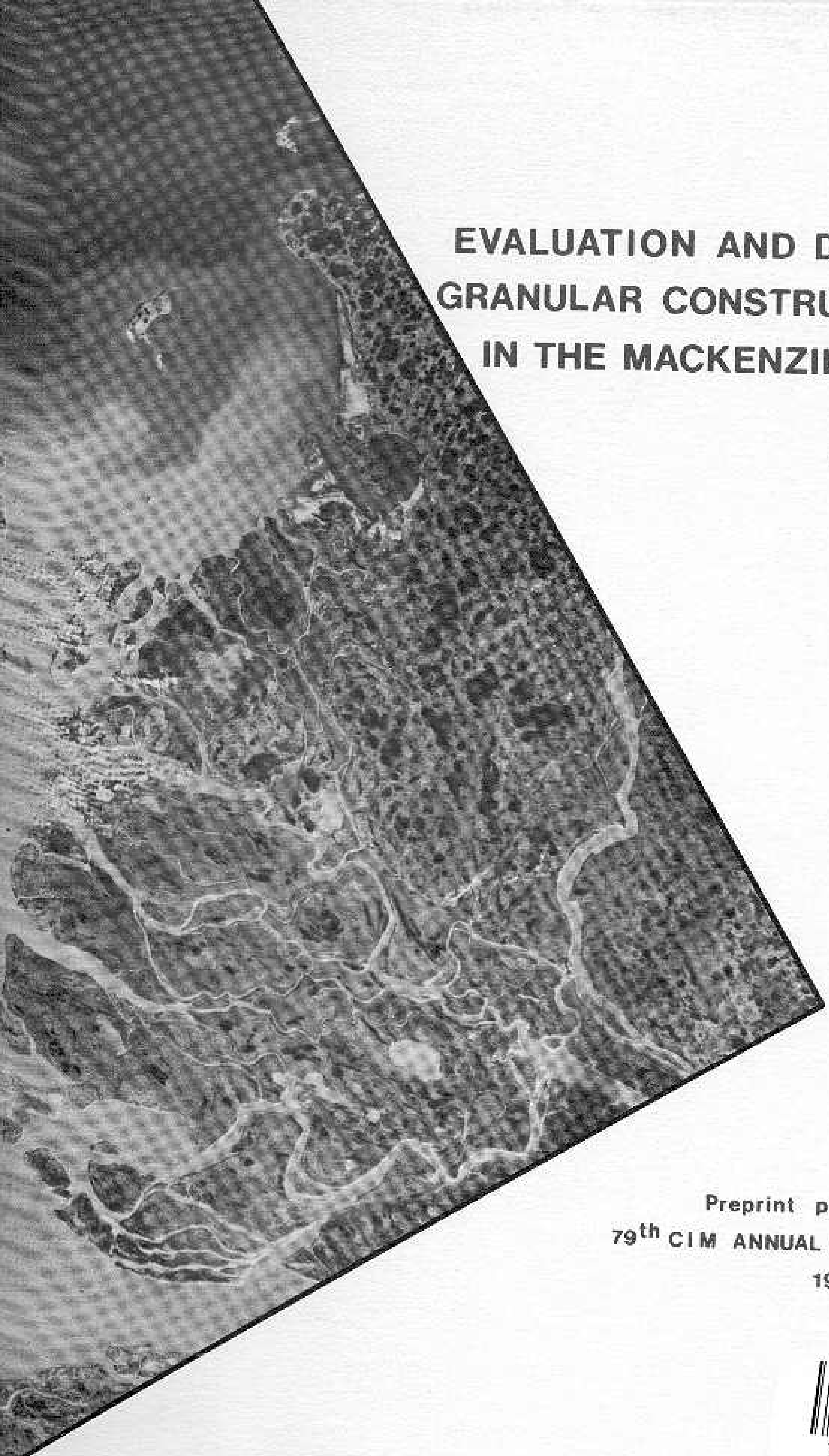

EVALUATION AND DEVELOPMENT OF GRANULAR CONSTRUCTION MATERIALS IN THE MACKENZIE DELTA REGION

Preprint prepared for
79th CIM ANNUAL GENERAL MEETING
1977

EBA Engineering Consultants Ltd.
Arctic Geotechnical Group

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ATTENTION: Mr. J. T. Inglis
Acting Head of
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Dear Julian:

I am enclosing for your general information two copies of a paper presented at the Annual CIM Meeting in Ottawa last week. I had hoped to drop these off personally when I was in Ottawa, but your secretary advised us you were in Whitehorse.

I hope our paths will cross again in the not too distant future.

Yours truly,

EBA Engineering Consultants Ltd.

D. W. Hayley, P. Eng.

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EVALUATION AND DEVELOPMENT OF GRANULAR CONSTRUCTION MATERIALS IN THE MACKENZIE DELTA REGION

By

D. W. Hayley and N. R. MacLeod

of

EBA Engineering Consultants Ltd.

Edmonton, Alberta

PREPRINT

Prepared for the

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Industrial Minerals Division

Paper No. 100

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EVALUATION AND DEVELOPMENT OF GRANULAR CONSTRUCTION MATERIALS IN THE MACKENZIE DELTA REGION

BY

D. W. Hayley and N. R. MacLeod[1]

ABSTRACT

The rapid expansion of exploration drilling with anticipated production facilities for oil and gas in the Mackenzie Delta region of the Northwest Territories has created a demand for granular construction materials. This paper discusses the techniques adopted and experiences gained by the authors from several major resource evaluation programs in this remote area. The first part of the paper describes a methodology for deposit identification, logistics of helicopter and ground based drilling operations and the sampling difficulties which are unique to permafrost soils. The second part of the paper describes the exploitation of a large glaciofluvial deposit at Ya Ya Lake on Richards Island.

Granular construction material is sparse in the delta region when compared with projected demands. Exploitable sources of granular materials for aggregates or construction borrow are found in glaciofluvial deposits of Pleistocene age or in outcrops of Paleozoic bedrock. Glaciofluvial landforms can be located by reference to published surficial geology maps coupled with airphoto interpretation. Preliminary assessment of these features in a large region is most economically carried out during the summer months with a helicopter transportable drill. Once prospective borrow pit sites are identified, a detailed ground based winter drilling program must be undertaken to establish aggregate quality, quantity and to provide information on natural features affecting development.

The glaciofluvial terrain has been highly modified by the formation of massive ground ice within the gravel deposits. This presents some unique pit development problems which are not encountered in a normal bedrock quarry operations.

Some of the difficulties associated with excavation and stockpiling of thawing granular soil at the Ya Ya Lake esker-kame complex are discussed. The most noteable is trafficability in the pits where thermokarst depressions are caused by rapidly melting bodies of ground ice.

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INTRODUCTION

The current and potential demand for granular construction material in the Mackenzie Delta area severely taxes the known reserves. The requirements of the petroleum exploration companies for drilling and production platforms plus the proposed Mackenzie Valley Pipeline and other transportation facilities will consume the sources of good quality, readily accessible granular materials. As the need to utilize less desireable deposits increases the problems of access and the occurence of permafrost become as significant to the overall evaluation of any deposit as does the material quality.

The first part of this paper will be directed toward the general concepts of location, identification, and sampling of potential sources of granular construction materials. The examples presented herein refer specifically to the lower Mackenzie Valley and the Delta area shown in Figure 1. However, the general principles of exploration and development of granular construction materials apply throughout Canada's north. The unique aspects of pit development in a region of continuous permafrost are discussed in the latter part of the paper. These development problems are related to experience gained from exploitation of a large glaciofluvial deposit on Richards Island in the Mackenzie Delta.

The authors have been involved with the evaluation and development of potential granular deposits at several sites representing very different conditions within the region of interest. The materials which have been considered range from Paleozoic carbonate and shale bedrock in the Inuvik area (Ref. 1), to granular deposits of glaciofluvial origin to submarine sand deposits off the coast of the Tuktoyaktuk Peninsula. The

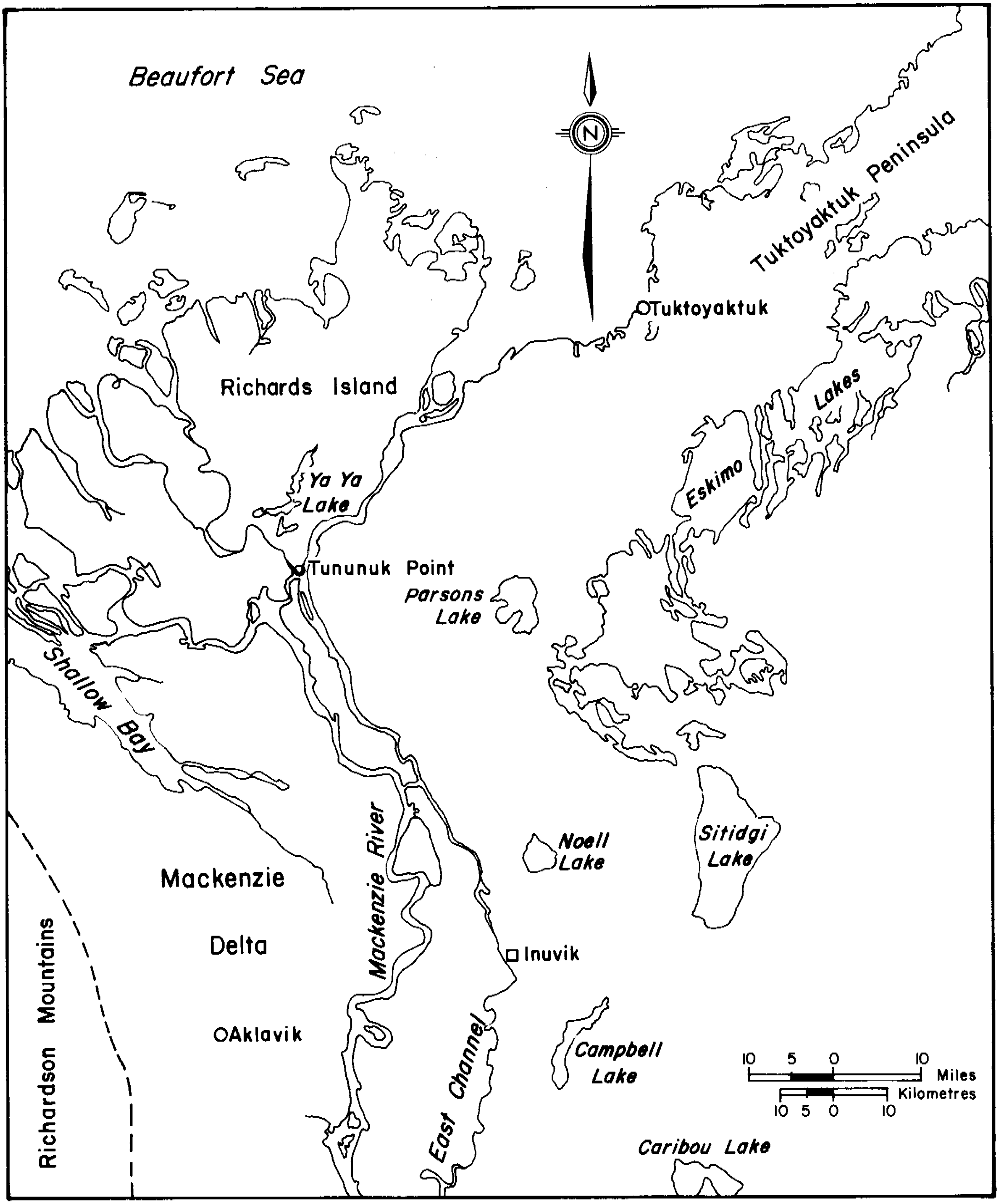

FIGURE 1 THE MACKENZIE DELTA AREA

significant exploration programs which will be emphasized herein are those involving glaciofluvial deposits along the East Channel of the Mackenzie River north of Inuvik, Northwest Territories and on Richards Island. The locations of these deposits are shown on Figure 2 as Source 222, Source 303 and Source 326 and the Ya Ya Lake esker, respectively.

REGIONAL SETTING

The Mackenzie Delta, like any large delta, is a poor setting in which to find granular construction materals. The silt and clay sediments of the river have buried most of the coarse deposits in the recent delta areas and in the present offshore areas. The target of most exploration for material is therefore the bedrock on the margins of the delta, and the exposed Pleistocene granular deposits in the old delta area.

Bedrock exposed in most of the eastern Mackenzie Delta area is a poorly indurated shale of Cretaceous age (Ref. 2). Generally, its use as an engineered fill is avoided because the shale rapidly decomposes into very frost susceptible silt and clay. An uplift area south of Inuvik exposes Paleozoic carbonates which are far superior in quality to quarried shale. Several operators have developed quarries in the bedrock to obtain rock fill and road surfacing material. The high cliffs associated with the Paleozoic uplift offer unique scenery, and environmental habitats so are being protected in a wilderness preserve. Limited expansion of the existing quarrying operations are contemplated under strict governmental control (Ref. 1).

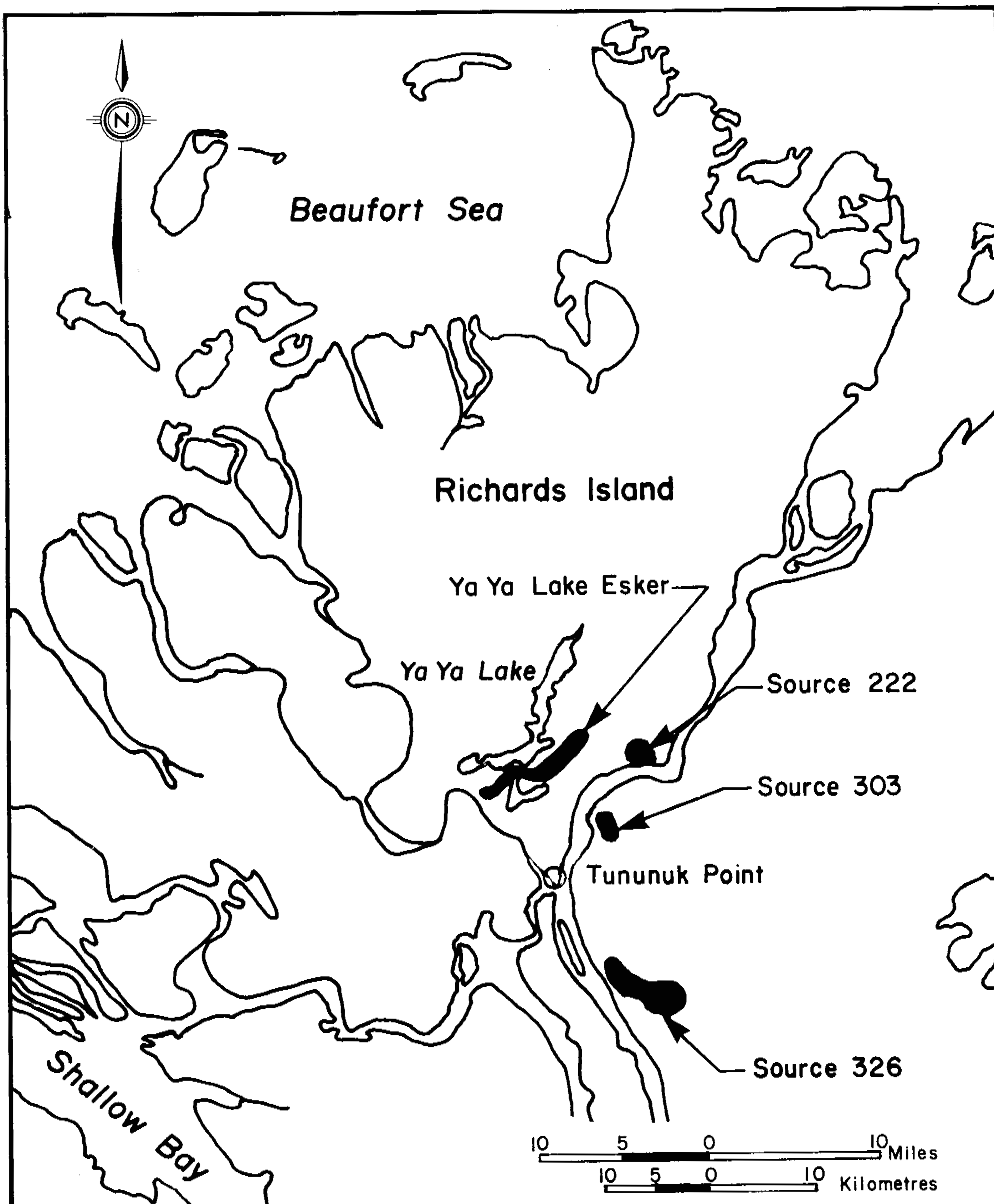

FIGURE 2 GLACIOFLUVIAL DEPOSITS OF THE NORTHERN MACKENZIE DELTA (REF. 4)

The Mackenzie Delta is within the zone of continuous permafrost. Only the seasonally thawed active layer and those deposits lying below deep lakes, river channels and offshore in the Beaufort Sea are unfrozen. Regardless of the material present, excavation in perennially frozen ground poses a challenge which is not a concern in the southern provinces. Ground temperatures and ground ice conditions combine to create exploitation problems which can be as significant to the economics of pit development as the quantity and quality of the material.

EVALUATION

The evaluation or assessment of potential pit or quarry sites proceeds through three separate levels. Once a need for granular construction materials has been identified, the first stage involves the cataloguing of all potential deposits in the area of interest. This stage of the exploration program for materials in remote areas is normally conducted in the office and library. Excellent maps and reports on the surficial geology of much of Canada's remote northern areas have been produced by the Geological Survey of Canada and others. In addition to published maps and reports, a detailed examination of airphotos can help identify granular deposits and provide a general review of the area. A preliminary assessment of the nature of the potential deposit, the environmental setting and access routes can be made by interpreting terrain features from airphotos.

The second level of a planned search for granular construction materials is the first level field reconnaissance. Generally hand excavated test pits, preliminary drilling and site inspection of all potential sources are conducted quickly by a helicopter-borne crew and drill rig. In most cases, this work can only be done in the summer when the surface is free of snow and thaw has progressed to a point where it is feasible to dig test pits. A typical helocipter transportable auger drill in operation at a site south of Inuvik is shown in Photo 1.

The purpose of the field reconnaissance program is to confirm airphoto interpretation and to assess the size, and distribution of natural deposits, the nature, texture, and variability of the material within these deposists, and to examine potential access routes to those deposits which appear favourable. Sites of unfavourable setting or quality can be identified and eliminated. Ideally geological conditions which are favourable for suitable granular deposits can be identified. The environmental setting and associated land use restrictions can be identified and evaluated as part of the overall evaluation of the pit location.

Photo l - Evaluation of potential gravel source with a heliportable auger drill.

The area between Fort Good Hope and Inuvik, shown in Figure 3, covers 6250 square miles. Initial air photo reconnaissance of this area identified 156 potential source areas. Some of the sources contained 2 or 3 individual deposits. All of the sites were visited during a ground reconnaissance study. At least 245 test pits were excavated and 104 boreholes drilled in the reconnaissance stage program. It was concluded that only about 25 of the sites investigated appeared to be suitable for large scale development and as many as 75 of the sites appeared to be suitable or desireable for any level of development. These 25 to 75 sites were judged suitable for a third level detailed examination program (Ref. 3).

The objectives of the third level of a granular material study should be to obtain sufficient information on each specific source area to allow a pit development plan to be formulated. A development plan requires a detailed analysis of the properties and physical characteristics of the granular material which will be excavated and the overburden which must be removed. The positioning of material stockpiles, surface drainage ditches and roadways within the pit must be considered relative to the distribution of granular materials and ground ice features. The total development plan must include consideration of the means of coping with land use regulations particularly with respect to proposed access routes, pit drainage and surface restoration requirements.

The formation of a pit development plan requires much more specific detail, in a smaller area than is practical to obtain with light weight drilling equipment. Generally, the use of a larger track or sleigh

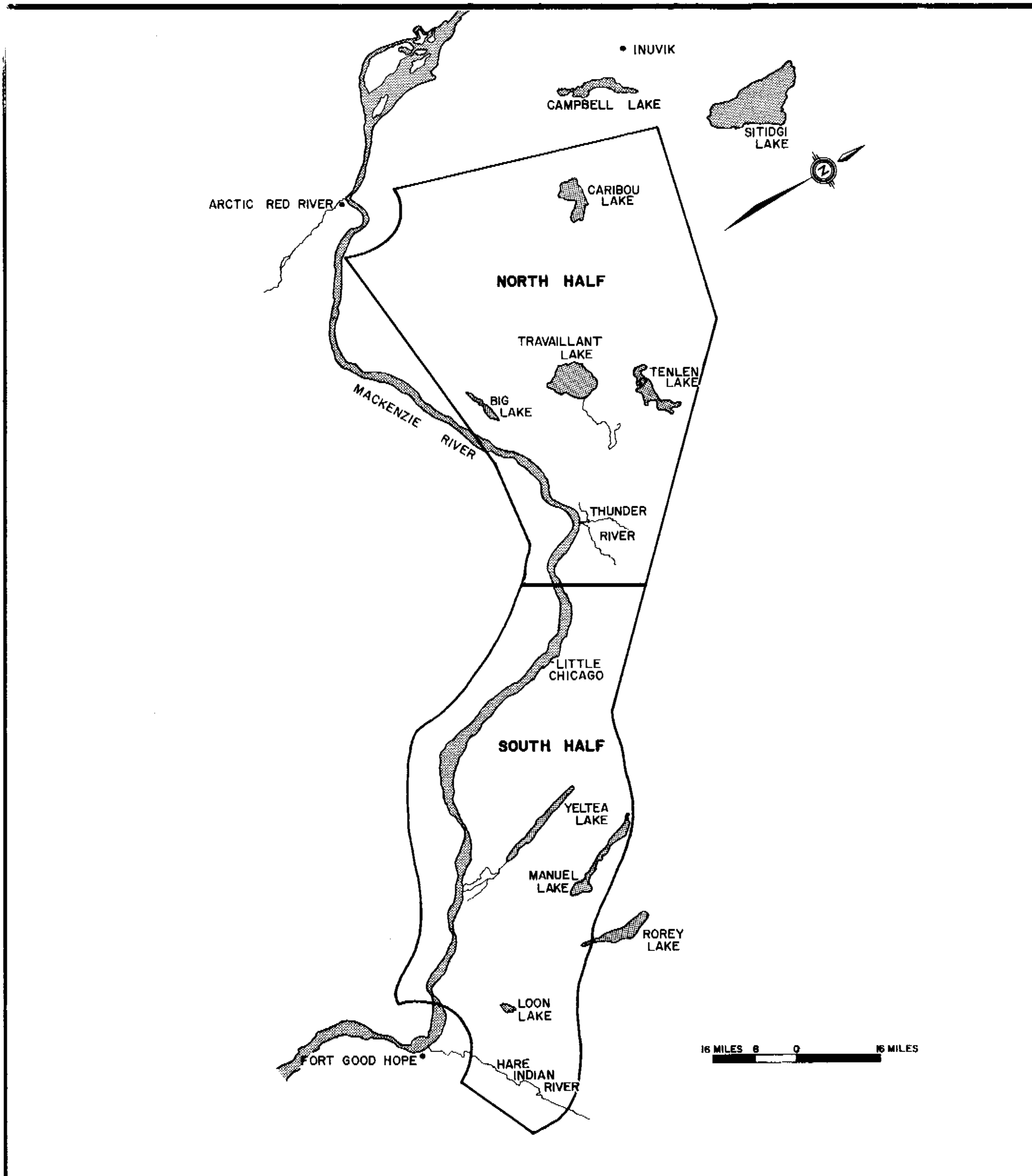

FIGURE 3 GRANULAR MATERIAL INVENTORY STUDY AREA (REF. 3)

mounted drill rig wi'h capabilities of coring the granular material produces the most reliable engineering and gradational information. Present land use regulation for the Mackenzie Delta area, and generally throughout the Canadian Arctic restrict such operations to the winter months. The snow cover and frozen ground surface prevent serious disturbance of the sensitive tundra landscape. Photo 2 shows a typical winter drilling and surveying operation at the Ya Ya Lake esker which is discussed later.

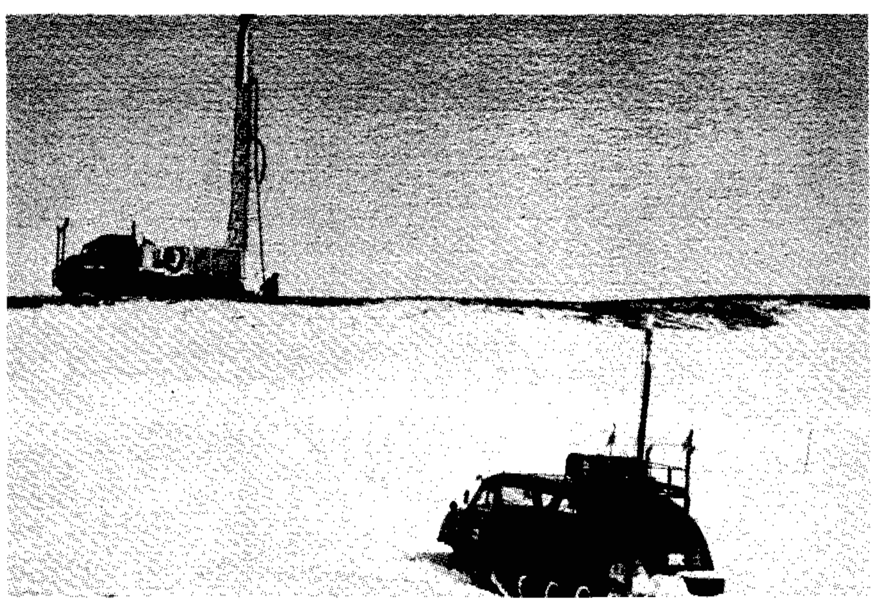

Photo 2 - Winter drilling and surveying at Ya Ya Lake esker, 1975

A typical third level program was conducted on three source areas near Tununuk Point. Figure 2 shows the location of these deposits together with the Ya Ya Lake esker. The detailed analysis of these three deposits included drilling approximately 185 boreholes. The exploration program was conducted during January and February utilizing a fully enclosed, sleigh mounted Mayhew 200, "Heli-drill" with compressed air. Access to the three sites was made directly from roadways maintained on the river ice by the petroleum exploration companies working in the delta area. Approximately every third hole was cored with a VTM-3, carbide tipped corebarrel to obtain 3 inch, undisturbed samples of the frozen granular soils. Coring of frozen granular soils was possible during the winter at these sites because the circulating air was cooled with a simple heat exchanger before it was discharged down the borehole.

A maximum 38 million cubic yards of potentially suitable material were identified at the three source areas (Ref. 4). However, pit development will be complicated by the presence of bodies of massive ice at the base of the deposits, by undesireable overburden thicknesses, and by the occurrence of shallow lakes within the deposit boundaries. These features may reduce the total recoverable volume to less than 20 million cubic yards.

YA YA LAKE GRAVEL DEPOSIT

The esker complex at Ya Ya Lake on Richards Island is probably the largest active gravel quarrying site within the zone of continuous permafrost. Industry has been extracting granular construction materials from this source since the late 1960's primarily for construction of drilling platforms and their associated camps and access roads on the arctic tundra. An upswing in activity associated with major gas strikes coupled with the application by Canadian Arctic Gas Pipeline Ltd. to construct a gas transmission line with one northern terminal on Richards Island recently rekindled interest in methods of gravel production from this source.

The sand and gravel occurs in a complex of esker ridges, some kames and small outwash plains. The deposits cover an area in excess of 650 acres and have a local relief up to 75 feet. The sand and gravel is underlain by preglacial silt and fine sand of the ancestral Mackenzie River Delta. The surface and flanks of the esker are marked by lakes and many small thermokarst ponds.

The first detailed survey of granular resources within the deposit was conducted by the authors during the spring of 1975 (Ref. 5). This study, commissioned by the Arctic Petroleum Operators Association (APOA), included the drilling of some 300 boreholes from which thickness contours of recoverable granular materials could be determined. Coupled with this was an evaluation of soil texture and other engineering properties of the granular material.

The study confirmed that in excess of 17 million cubic yards of sand and gravel is present within the broad development zone contemplated. However, approximately 7 million cubic yards of the deposit lie below the level of adjacent lakes where the method of exploitation requires considerable study. The sand and gravel was found to be remarkably uniform throughout the deposit. It is well graded with a 3 inch top size and generally less than 10% passing a No. 200 sieve. Although it is considered very suitable for fill material, its suitability as a concrete aggregate is questionable because of a high chert-chalcedony content.

The most significant find of the drilling program was that large bodies of massive ground ice prevail throughout the deposit. The ice bodies could often be correlated between boreholes and were described as "clean white bubbly ice". Where ice was encountered, most boreholes were terminated after penetrating approximately 10 feet into the ice. On several occasions, however, the entire ice body was drilled. Clear ice in excess of fifty feet thick was logged within the gravel. Large accumulations of ground ice were found more frequently on the flanks and at the base of the esker. It is postulated that the ice grew in place in a closed system during permafrost aggradation according to the mechanism described by Mackay (Ref. 6). Figure 4 shows a cross-section in which large zones of massive ice are interpreted.

PIT DEVELOPMENT

Early in the 1976 summer season, the senior author was requested by Imperial Oil Limited to examine its current workings in order to recommend operational improvements that would maximize the amount of gravel that could be recovered from their limited pit area during the short summer

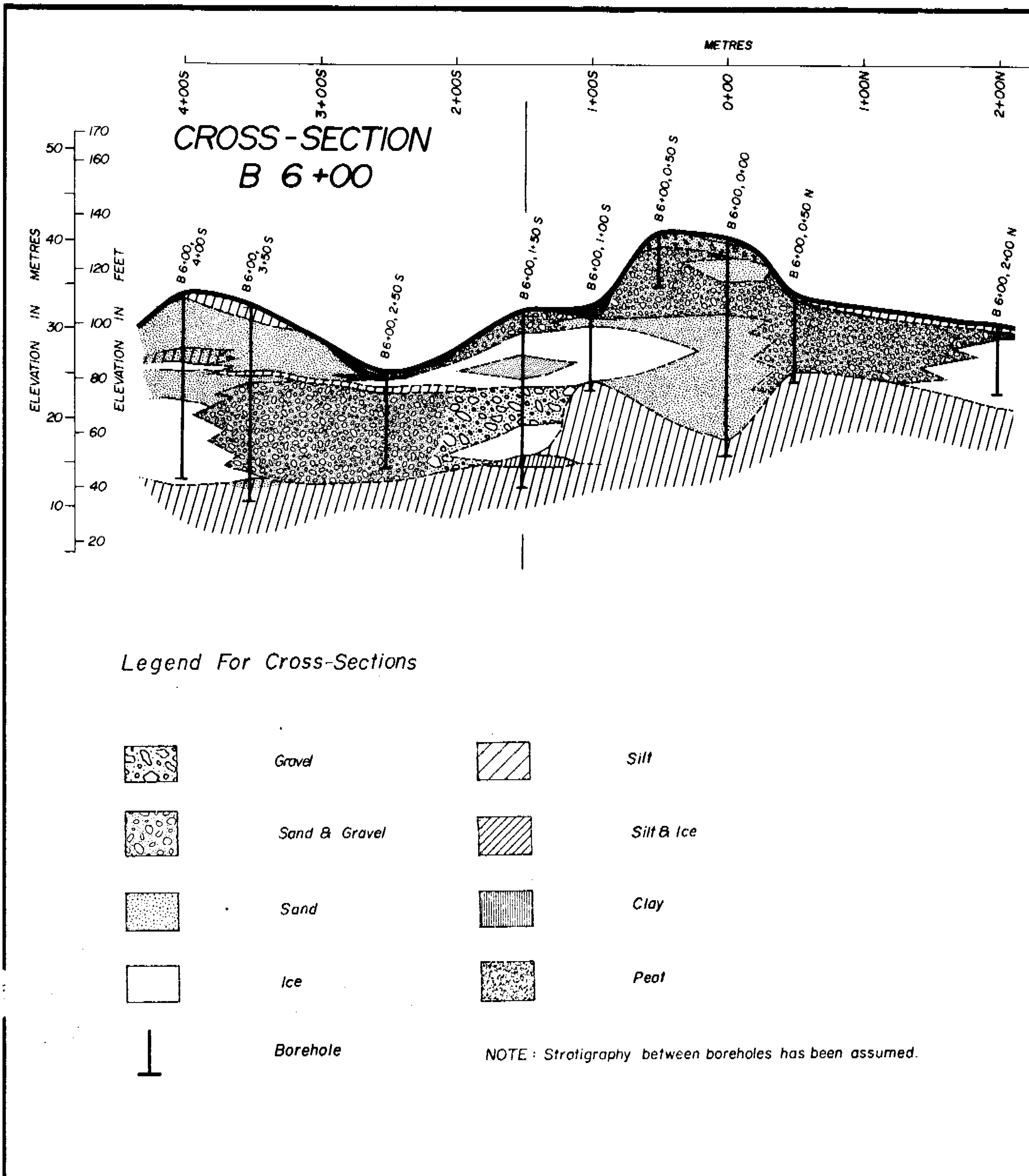

FIGURE 4 TYPICAL SECTION THROUGH Ya Ya LAKE ESKER (REF. 5)

work season. The common development procedure with all industry working in the pit at that time was to scrape the material off the surface as it thawed during the long warm summer days and to push it into long windrow piles to drain. During the following winter the material was loaded and trucked away over ice roads. This procedure was entirely satisfactory during the early years of pit exploitation when volume requirements were low and the pit floor was well above the surrounding tundra. However, serious logistic problems developed during the 1975 summer and winter operations.

It was clear that melting of massive ground ice exposed in the pit floor was continually liberating water and forming thermokarst ponds. Such a pond is shown in Photo 3. Attempts at gravity drainage by conventional open ditches failed because a ditch grade cannot be maintained where massive ice is so abundant in the soils. Thus, the ditches would rapidly expand and deepen locally to form larger thaw ponds which simply aggravated the problem. These pit mobility problems coupled with the random location of the windrowed stockpiles was clearly interfering with orderly pit development.

A second problem developed as a result of the more advanced state of pit development. As the pit floor was lowered each year more ice, similar to that shown in Photo 4, was uncovered. Consequently the natural moisture content of the stockpiled gravel increased to typical values of 8 to 12 percent. Also, in the stockpiling procedure the gravel was being packed or densified by the action of the caterpiller tractors. It was obvious to the operators that ripping the frozen stockpiles the following winter was becoming more difficult. During the 1976 winter construction season the condition of the stockpiles deteriorated until only about one-half of the gravel stockpiled the previous summer was actually recoverable.

Photo 3 - Thermokarst pond approximately 10 feet by 25 feet, developed in pit floor at Ya Ya Pit in summer 1976.

Photo 4 - Exposure of massive ice in Ya Ya Pit during stripping operation in summer 1976.

During the 1976 summer season, a new approach to gravel exploitation was adopted. The gravel was stripped with bulldozer drawn scrapers and brought to a central location. It was then stockpiled with a conveyor system consisting of a feeder and a stacker which had a capacity of approximately 5500 cubic yards per day. Photo 5 shows the conveyor and stockpiling operation which was adopted. Although there was a risk of particle segregation, stockpiling with the conveyor resulted in a reduction in the moisture content typically from 8 percent to 4 percent. Moreover, it ensured that gravel density in the stockpile was the minimum achievable.

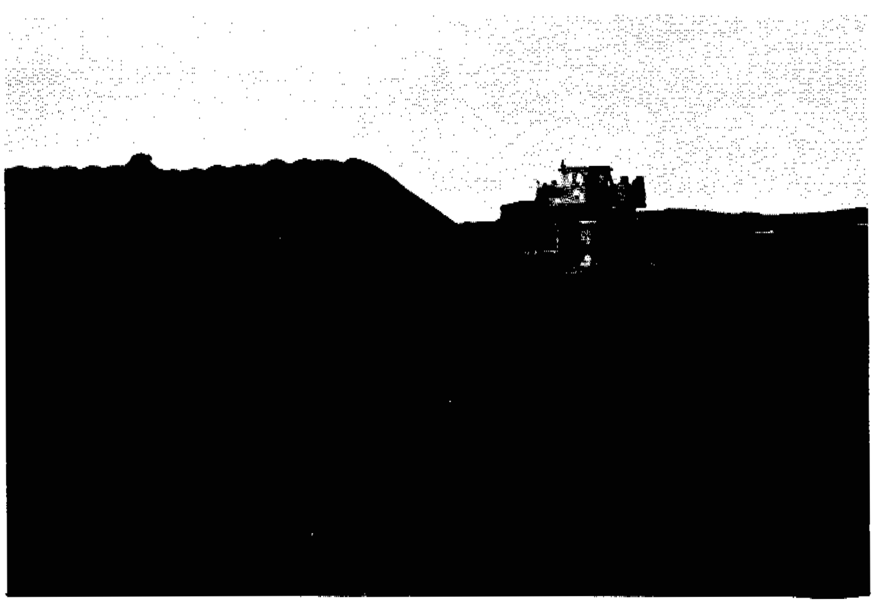

Photo 5 - Gravel stockpile constructed with conveyor at Ya Ya Pit. (Photo courtesy of Imperial Oil Ltd.)

Pit mobility was improved by pumping water from ponds created by the melting of massive ice, by the use of short term ditches and by removal of windrows from the pit floor. Experience has shown, as described earlier, that open ditches cannot be left for extensive periods. Drainage of the area around the melt ponds was improved by using ditches with wide banks to prevent sloughing. However, frequent maintenance was required. The ditches were backfilled with gravel, once they had achieved their purpose, to prevent further thermal erosion.

The thaw rate experienced in gravel without excess ice was approximately 1 foot per day. However, if the gravel was progressively stripped during the day, up to three feet per day could be recovered under ideal conditions.

A limited recovery operation conducted this winter has demonstrated that the stockpiled gravel is readily workable by front end loaders during subfreezing conditions.

FUTURE DEVELOPMENT REQUIREMENTS

The ever increasing requests for quarry permits for the Ya Ya Lake esker prompted the government to examine the balance of supply versus projected demands for granular material in the pit area. Gravel has been trucked from the Ya Ya Lake pits to sites as far away as Tuktoyaktuk, a distance of some 60 miles. During the summer of 1976 requests to the Department of Indian and Northern Affairs for expansion of quarrying operations into virgin portions of the esker were denied pending confirmation that all gravel had been removed from existing workings. The Department then commissioned a study by Dr. V. Rampton (Ref. 7) to determine an orderly development and restoration plan. The report submitted by Dr. Rampton will probably form the basis for future regulation. The concept puts the onus on the operator to present a logical plan for development of specific designated blocks, before a quarry permit will be issued. The boundaries of gravel reserves, massive ice and topographic features must be identified by an extensive survey and geotechnical drilling program. This would be submitted at the beginning of the quarrying operation each year.

The development philosophy is one of maximum utilization of the resources while minimizing adverse environmental side effects. It is proposed that certain ponds or small lakes be drained and others preserved. Excavation of gravel from below the level of adjacent lakes is encouraged by leaving a dyke of frozen ground adjacent to the lakes. It is envisaged that ultimate restoration of the pits will involve breaching the dykes and flooding the mined out pit areas.

The pit development concepts proposed by Dr. Rampton are for the most part accepted by industry. Excavation below the level of adjacent lakes within the confines of a dyke which must stay frozen in order to remain impervious, will require detailed study before such a scheme can be considered either feasible or safe.

SUMMARY AND CONCLUSIONS

Within the Mackenzie River Delta region, sources of granular construction materials are very scarce. Materials which have been used for engineered fills are either crushed carbonate rock or gravel of glaciofluvial origin. Gravel deposits located within this region where permafrost is continuous have been found to contain massive bodies of ground ice at surprisingly frequent intervals. The ground ice coupled with a high natural moisture content of the gravel when thawed leads to unique problems during pit development.

Experience gained at the large Ya Ya Lake esker on Richards Island has shown that stripping and thawing operations must be planned a full year in advance of the winter when the gravel is actually needed. Detailed geotechnical evaluation must be undertaken to locate the granular borrow and subsurface massive ice before a rational development plan can be formulated. The material must be removed from the pit floor as it thaws and be stockpiled in a manner that keeps it in a loose condition and with a moisture content of less than 5% if it is to be workable during the following winter. The entire stripping operation is highly dependant upon the rate of thaw which requires long warm summer days. Due to variations in the weather and the distribution of ice in the deposit, careful planning of the equipment and areas of development are required if stockpile objectives are to be met within any given year.

ACKNOWLEDGEMENTS

The resource evaluation projects referenced in this paper were carried out for the Department of Indian and Northern Affairs and the Arctic Petroleum Operators Association. Special thanks is extended to Imperial Oil Ltd. for permission to publish their experience gained at Ya Ya Lake esker. Assistance of the staff at EBA, particularly Mr. K. O. Stangl who supervised the field drilling activities for the various projects and Dr. D. W. Devenny who reviewed the manuscript, is greatly appreciated.

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