INDIAN AND NORTHERN
AFFAIRS CANADA

# GRANULAR RESOURCE DEVELOPMENT AND MANAGEMENT PLAN

## TUKTOYAKTUK, N.W.T.

DECEMBER 1983



EBA Engineering Consultants Ltd.

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS
OF ALBERTA
PERMIT NUMBER
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E B A ENGINEERING
CONSULTANTS LTD.

# GRANULAR RESOURCE DEVELOPMENT
# AND MANAGEMENT PLAN
# FOR
# TUKTOYAKTUK, N.W.T.

Submitted to:

INDIAN AND NORTHERN AFFAIRS CANADA
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# EXECUTIVE SUMMARY

Granular construction materials have historically been in short supply in the Tuktoyaktuk area. Recent borrow demands created by oil and gas related activities in the northern Mackenzie region have severely strained the existing resources, due in part to the actual demand and in part to the generally ad hoc manner of resource recovery and removal. In order to facilitate future orderly borrow development, a study has been conducted to assess various factors controlling borrow management.

An examination of existing borrow resource evaluations allowed the compilation of a group of pits suitable for producing any of four types of granular material. These material types are specified as Type I (high quality structural aggregate), Type II (structural fill), Type III (general fill), and Type IV (rip-rap and armour stone). Unit granular material costs, predicted for each of the next 5 years, have been assigned to each type of material recoverable from suitable borrow pits. Borrow demand, by both the public and private sectors, has been assessed concurrent with an evaluation of the economic supply of material from the various inventoried pits.

Two development scenarios are identified. Scenario 1 considers normal average material utilization around Tuktoyaktuk while Scenario 2 considers the effects of possible large-scale airport expansion in addition to normal requirements. It is concluded that sources currently under development (160/161 and Ya Ya Lake) would most economically satisfy Scenario 1 requirements while Scenario 2 will require development of alternative sources (162 and possibly 168) to economically meet with the increase in demand. Scenario 2 will also see Source 160/161 restricted to use by the Hamlet of Tuktoyaktuk.

Detailed pit development plans for each of the pits recommended for development are appended to the report. General recommendations regarding pit development, monitoring, and inspection are contained in the body of the report.

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# 1.0 INTRODUCTION

## 1.1 Background

Significant volumes of high quality granular construction materials have historically been in short supply in and around the Hamlet of Tuktoyaktuk, N.W.T. Studies conducted over the past 10 years have located a number of small sources of marginal quality sand and gravel in the surrounding area. Development of these deposits has been on an ad hoc basis. Commonly, projects necessitated removal of granular borrow from the most convenient location with the most convenient technique.

Methodical development of granular resources has been hampered by the lack of information on current and future demand for granular construction materials. In this regard, the Department of Indian Affairs and Northern Development (DIAND) retained EBA Engineering Consultants Ltd. (EBA) to develop a 5 year management plan to promote efficient use of granular resources, based on an assessment of availability and requirements.

## 1.2 Project Scope

The scope of the project described in this report included the following:

a) Examination of reports describing granular material desposits near Tuktoyaktuk.

b) Development of a granular resource supply model.

c) Consultation with local private and public sector granular material users.

d) Development of a granular resource demand model.

e) Development of a recommended resource development scenario.

f) Preparation of pit management plans for those sources with the best development prospects.

The next three sections of this report (Sections 2.0 to 4.0) address the background considerations involved in preparation of the supply-demand model, which is presented in Sections 5.0 and 6.0. Recommended development scenarios and management plans are included as Sections 7.0 and 8.0, respectively.

## 2.0 INVENTORY OF GRANULAR MATERIALS

Several inventory and assessment studies have been undertaken since 1970 to determine granular material potential in the Tuktoyaktuk area. These studies were prompted by a period of unusually high material demands associated with oil and gas activity in the area. Most studies have included airphoto interpretation, field reconnaissance, geophysical surveys, and drilling programs to identify, delineate, and evaluate granular material sources.

The first inventory (Ripley, Klohn & Leonoff International, 1973), commissioned by DIAND, identified 14 sources within a 16 km radius of Tuktoyaktuk, and two sources located 27 km from the community. A total volume of approximately 1.5 million cubic metres of suitable granular material was estimated for the 10 sources (mainly spits, bars, and beaches), considered suitable for development. Another inventory (Mollard, 1972) conducted for the Arctic Petroleum Operators Association, although centred on Richards Island, also identifed several sources within a reasonable distance of Tuktoyaktuk.

Rapid depletion of the sources proximal to the community and anticipated high granular material requirements towards the end of the 1970's necessitated a second major inventory study of the Tuktoyaktuk area (Hardy, 1977). The study, commissioned by DIAND, included airphoto interpretation, reconnaissance, test-pitting and water-jetting operations. The objective was to identify a minimum of 7.6 million cubic metres of granular material within a 48 km radius of Tuktoyaktuk. A total of 22 sites were investigated, and detailed evaluation of the four most accessible sites was recommended. Eight additional sites were recommended for detailed evaluation after construction of the proposed Inuvik-Tuktoyaktuk Highway, depending on future borrow requirements.

Detailed borrow evaluation programs have since been undertaken at several of the sites identified in the previous inventories. Geophysical surveys (Hardy, 1978), and test drilling (Hardy, 1979), were undertaken for DIAND at Source 162 in Tuktoyaktuk Harbour. DIAND also commissioned studies at Source 160/161, on the east side of the harbour (Hardy, 1980), and at Sources 168 and 211, south of Tuktoyaktuk (BBT, 1983). Other pertinent detailed investigations include the evaluation of the Ya Ya Lake esker-kame complex (EBA, 1975), and the geotechnical investigation of granular sources adjacent to the proposed Inuvik-Tuktoyaktuk Highway (DPW, 1981). References for the inventory and detailed investigation programs are included in Appendix B-1.

# 3.0 CLASSIFICATION OF GRANULAR BORROW MATERIALS

## 3.1 Type I Borrow Material

Type I borrow has been classified as granular material suitable for use as high quality surfacing material (i.e. for airport runway use) or asphalt and concrete aggregate. This type of material consists of a structurally sound aggregate that adheres to a relatively narrow gradational range. Processing (crushing, washing and blending) is usually necessary to produce the required gradation.

## 3.2. Type II Borrow Material

Quality gravel will be required for a stable surface course on roads and for fills supporting structural loads. This type of material should possess the gradational characteristics shown in Figures A-1 and A-2, Appendix A, and have moisture contents (ice contents) below 10 percent. With this gradation and moisture content, the Type II borrow material will be relatively frost stable, will place and compact with reasonable effort, and will have good load bearing characteristics.

## 3.3 Type III Borrow Material

Type III granular borrow has been classified as material suitable for use as general fill for roads, airstrips, flexible foundation pads, and lay-down yards. Gradational limits of this material are similar to those for the Type II material (Section 3.2) however, a fines content of up to 15 percent is considered acceptable.

Moisture contents should be limited to less than 10 percent since most of the moisture (ice) will be located in the fines. If the moisture content is too high, the backfill will be unstable upon thaw, resulting in poor trafficability, potential sloughing, and settlement of the fill during warm weather.

### 3.4 Type IV Borrow Material

Type IV granular borrow material has been classified as material suitable for use in erosion control measures. This type of material commonly consists of cobbles, boulders, or rock fragments.

## 4.0 COST OF GRANULAR BORROW MATERIALS

### 4.1 General

The cost of granular borrow materials is controlled primarily by pit development and transportation costs, and annual volume requirements. A certain minimum volume is required to offset the costs of access upgrading, site preparation work, and initial set-up costs for each borrow source. The unit cost of borrow materials from a particular source will be substantially higher if volumes smaller than the minimum amount are extracted.

Once the initial site development work is completed, the cost of materials from established borrow sources is largely controlled by haulage costs, which are generally independent of annual volume requirements. In most cases, these costs reflect travel time, rather than distance, due to difficulties associated with northern surface transportation, where most roads are useable only during winter conditions. If site access can be made via an ice road on a river, travel times, and consequently haulage costs will be relatively low, in comparison with the cost of transportation to the same site via an overland winter only, route of similar distance.

A certain minimum annual volume is also required to offset annual start-up costs at each source. For sources accessible only by an overland route, higher road maintenance costs tend to increase the unit price of borrow materials, by an amount dependent on annual volume requirements.

## 4.2 Basis of Material Costs

The estimated costs of materials from the various borrow sources in the study area are based on discussions with local contractors. The unit prices for materials from existing pits are based on actual production costs and volumes of material extracted during the winter of 1983. Costs of materials from other borrow sources have been estimated, with consideration of the factors outlined in Section 4.1, and discussions with local contractors. An annual cost increase of 8 percent has been assumed for years subsequent to 1983.

Delivery-to-site costs of materials that have been previously stockpiled in Tuktoyaktuk are based on the 1983 unit price of $\$6.50/m^3$($\$5.00/yd^3$) and an 8 percent annual increment. The costs for windrowing deposits during the summer period are estimated on the basis of a 1983 cost of $\$1.25/m^3$ ($\$1/yd^3$) and the assumed 8 percent annual increment.

The 1983 prices were provided by one contractor, E. Gruben Transport Ltd. (Gruben, 1983b,c), except as noted. While this approach may limit the validity of the economic considerations somewhat, it can not be avoided since there are no other experienced contractors resident in the area. Consultations with granular resource users and other contractors in the Tuktoyaktuk area indicate that the current prices are realistic. The values presented do, however, provide at least a means of comparing costs between the various borrow sources.

# 5.0 DEMAND FOR GRANULAR BORROW MATERIALS

## 5.1 General

The information gathering process was initiated by distributing a letter and questionnaire to potential granular resource users and contractors in the Tuktoyaktuk area. The questionnaire recipient was asked to estimate their highest likely and lowest likely demand for the various types of granular material over a 5 year period starting in 1984. Examples of uses of each of the material types were given.

Information from the distributed questionnaire was received through a combination of mailed responses, telephone follow-up, and personal consultation. A field visit was made by an EBA representative and Mr. A. Cronk, of DIAND, during the week of February 28, 1983 to consult with granular material users and governmental agencies in Tuktoyaktuk, Inuvik, and Yellowknife. References for the above personal communications are included in Appendix B-2.

The demands presented in the following sub-sections are the aggregate of reported demands and form the current best estimate of the 5-year granular requirements in and around Tuktoyaktuk.

## 5.2 Public Sector Demand

Public sector granular borrow demand is primarily comprised of Hamlet use for road construction, land development, and maintenance; and Ministry of

Transport (MOT) use for airport expansion and maintenance. The proposed Inuvik-Tuktoyaktuk highway would require large amounts of fill material, which would have a significant effect on granular supply in the area. Public Works Canada have previously conducted their own granular borrow material programs, thus DIAND requested that granular demands presented by the highway be excluded from this study. It is noted, however, that construction of the highway might result in an overall improvement in the granular supply situation by providing access to, and opening up of sources in the Parson's Lake area.

Large-scale use of borrow material by the public sector has occurred infrequently. In 1981, 750 000 $m^3$ of sand was dredged from Tuktoyaktuk Harbour for use in the construction of a freshwater reservoir. No projects of this scale, with the exception of the possible airport expansion, are planned for the next few years.

Projected public sector granular borrow material demands are summarized in Table 1. Estimates of the 20-year borrow demand for Hamlet use, based on the recently approved town plan, were provided by Ferguson, Simek, Clark Limited (1983). The 5-year demand data was estimated inconjunction with the 20-year plan and discussions with the Government of the Northwest Territories, Department of Local Government (1983c). Estimates for airport expansion were provided by Acres (1983). The quantities include material required for upgrading the present runway, expansion of the runway and aircraft parking areas, and possible future developments such as apron areas, commerical lots and oil company terminals. The actual material requirements are very dependant on the rate of development in the area of oil company facilities.

TABLE 1 PUBLIC SECTOR GRANULAR BORROW DEMAND

| PROJECT | MATERIAL | VOLUME (low/high) ($m^3$) | | | | | TOTAL ($m^3$) |
|---|---|---|---|---|---|---|---|
| HAMLET USE[1] | | 1984 | 1985 | 1986 | 1987 | 1988 | |
| Misc. Projects | Type III | 6100 | 6100 | 6100 | 6100 | 6100 | 30500 |
| | Type I | 63 | 63 | 63 | 63 | 63 | 315 |
| Engineering Projects | Type III | 20300 | 20300 | 20300 | 20300 | 20300 | 101500 |
| | Type II | 3300 | 3300 | 3300 | 3300 | 3300 | 16500 |
| | Type I | 1250 | 1250 | 1250 | 1250 | 1250 | 6250 |
| Road Construction and Maintenance | Type III | 4000 | 4000 | 4000 | 4000 | 4000 | 20000 |
| | Type II | 1000 | 1000 | 1000 | 1000 | 1000 | 5000 |
| Erosion Control Maintenance | Type IV | 3000 | 3000 | 3000 | 3000 | 3000 | 15000 |
| SUB-TOTALS | Type IV | 3000 | 3000 | 3000 | 3000 | 3000 | 15000 |
| | Type III | 30400 | 30400 | 30400 | 30400 | 30400 | 152000 |
| | Type II | 4300 | 4300 | 4300 | 4300 | 4300 | 21500 |
| | Type I | 1313 | 1313 | 1313 | 1313 | 1313 | 6565 |
| AIRPORT EXPANSION[2] | Type III | 100000/150000 | 100000/150000 | 100000/150000 | 25000 | 25000 | 350000/500000 |
| | Type II | 32000 | 32000 | 16000 | 16000 | 16000 | 112000 |
| TOTALS | Type IV | 3000 | 3000 | 3000 | 3000 | 3000 | 152000 |
| | Type III | 130400/180400 | 130400/180400 | 130400/180400 | 55400 | 55400 | 502000/652000 |
| | Type II | 36300 | 36300 | 20300 | 20300 | 20300 | 133500 |
| | Type I | 1313 | 1313 | 1313 | 1313 | 1313 | 6565 |

NOTE: 1. Borrow demand data for Hamlet provided by GNWT, Dept. Local Gov't (1983c), and Ferguson, Simek, Clark Limited (1983).
2. Airport expansion may or may not occur during the next 5 years.

## 5.3 Private Sector Demands

The Tuktoyaktuk area private sector consists primarily of three resource development companies, (Esso Resources Canada Limited, Dome Petroleum Limited, and Gulf Canada Resources Inc.), two transportation companies, (Arctic Transportation Ltd. and Northern Transportation Co. Ltd.), and a marine construction company (Beau-Tuk Marine Services Ltd). Large volumes of granular fill have been used in the past, primarily for campsite and yard construction. In 1980, Dome Petroleum dredged 400 000 $m^3$ from Tuktoyaktuk Harbour for construction of a lay-down yard, an airport taxiway, and general fill. In 1981, Esso dredged 273 700 $m^3$ of sand from the bay for a lay-down yard adjacent to their camp.

Limited large-scale private sector granular material use is reported for the next 5 years. The only large project identified through the study is the potential construction of a base camp by Arctic Transportation Ltd.

A summary of anticipated private sector granular borrow demand is presented in Table 2. The demand data was obtained from the written or verbal responses to the circulated questionnaire by each of the companies, as referenced in Appendix B-2.

## 5.4 Granular Resource Demand Summary

A summary of the total five-year granular resource demand, for both the public and private sectors, is contained in Table 3. Of note is the effect of a single project, airport expansion, on overall granular borrow demand. Assumptions regarding the likelihood and timing of such a projct have a disproportionate effect on the estimated required volumes.

TABLE 2 PRIVATE SECTOR GRANULAR BORROW DEMAND[1]

| FIRM | MATERIAL | VOLUME (low/high) ($m^3$) | | | | | TOTAL ($m^3$) |
|---|---|---|---|---|---|---|---|
| | | 1984 | 1985 | 1986 | 1987 | 1988 | |
| Arctic Transportation | Type III | 5500/7700 | 3800/6100 | 10500/14000 | 1500/2300 | 1500/2300 | 22800/32400 |
| | Type I | 150/300 | | 450/600 | | | 600/900 |
| Beau-Tuk Marine | Type III | 7600 | 7600 | 7600 | 7600 | 7600 | 38000 |
| Dome Petroleum | Type III | | | 5000 | | | 5000 |
| | Type II | | 5000 | 10000 | | 5000 | 20000 |
| | Type I | | 3500 | | | | 3500 |
| Esso Resources | Type III | 5000 | 5000 | 5000 | 5000 | 5000 | 25000 |
| Gulf Canada | Type III | 3000 | 3000 | 3000 | 3000 | 3000 | 15000 |
| | Type II | 1000 | 1000 | 1000 | 1000 | 1000 | 5000 |
| Northern Transportation | Type III | 0/300 | 0/300 | 0/300 | 0/300 | 0/300 | 1000[2] |
| | Type II | 0/10000 | 0/10000 | 0/10000 | 0/10000 | 0/10000 | 25000[3] |
| | Type I | 0/300 | 0/300 | 0/300 | 0/300 | 0/300 | |
| TOTALS | Type III | 21100/23600 | 19400/22000 | 31100/34900 | 17100/18200 | 17100/18200 | 106800/116400 |
| | Type II | 1000/11000 | 9000/19000 | 11000/21000 | 1000/11000 | 6000/16000 | 50000 |
| | Type I | 150/600 | 3500/3800 | 450/900 | 0/300 | 0/300 | 5100/5400 |

NOTES: 1. Demand data was obtained from responses to questionnaires by each of private companies, as referenced in Appendix B-2.
2. Total volume is for both general and selected fill materials.
3. Total volume is representative of 5 year demand.

TABLE 3 GRANULAR BORROW DEMAND SUMMARY[1]

| SECTOR | MATERIAL | VOLUME (low/high) ($m^3$) | | | | | TOTAL ($m^3$) |
|---|---|---|---|---|---|---|---|
| | | 1984 | 1985 | 1986 | 1987 | 1988 | |
| Public-without airport expansion | Type IV | 3000 | 3000 | 3000 | 3000 | 3000 | 15000 |
| | Type III | 30400 | 30400 | 30400 | 30400 | 30400 | 152000 |
| | Type II | 300 | 4300 | 4300 | 4300 | 4300 | 21500 |
| | Type I | 1313 | 1313 | 1313 | 1313 | 1313 | 6565 |
| Private | Type III | 21100/23600 | 19400/22000 | 31100/34900 | 17100/18200 | 17100/18200 | 106800/116400 |
| | Type II | 1000/11000 | 9000/1900 | 11000/21000 | 1000/11000 | 6000/16000 | 50000[2] |
| | Type I | 150/600 | 3500/3800 | 450/900 | 0/300 | 0/300 | 5100/5400 |
| TOTALS - without airport expansion | Type IV | 3000 | 3000 | 3000 | 3000 | 3000 | 15000 |
| | Type III | 51500/54000 | 49800/52400 | 61500/65300 | 47500/48600 | 47500/48600 | 258800/268400 |
| | Type II | 5300/15300 | 13300/23300 | 15300/25300 | 5300/15300 | 10300/20300 | 71500[2] |
| | Type I | 1463/1913 | 4813/5113 | 1763/2213 | 1313/1613 | 1313/1613 | 11665/11965 |
| TOTALS - with airport expansion | Type IV | 3000 | 3000 | 3000 | 3000 | 3000 | 15000 |
| | Type III | 151500/20400 | 149800/202400 | 161500/215300 | 72500/73600 | 72500/73600 | 608800/768400 |
| | Type II | 37300/47300 | 45300/55300 | 31300/41300 | 21300/31300 | 26300/36300 | 183500[2] |
| | Type I | 1463/1913 | 4813/5113 | 1763/2213 | 1313/1613 | 1313/1613 | 11665/11965 |

NOTES: 1. Data summarizes public and private demands from Tables 1 and 2, respectively.
2. Total volume requirements are based upon estimated 5 year demand rather than yearly estimates

# 6.0 SUPPLY OF GRANULAR MATERIALS

## 6.1 General

Previous studes have identified approximately 7 material sources within 8 km of Tuktoyaktuk, 11 sites within 29 km, and over 40 sites within the remainder of the Tuktoyaktuk-Mackenzie Delta area. Evaluations of these potential pits may be found in the reports listed in the general references in Appendix B-1. Table 4 contains an evaluation of various granular deposits currently under consideration for development.

A substantial number of these potential borrow sources are not suitable for development at this time, primarily because of transportation costs. Other potential borrow pits can be excluded from development consideration due to restrictions placed on them by various levels of government. For instance, the Northern Affairs Program, in consultation with the Tuktoyaktuk Hunters and Trappers Association and Hamlet Council, has a general policy of not granting permission for the extraction of material from granular beach deposits on either side of Tuktoyaktuk, except under special circumstances.

Four prominent granular sources exist in the study area. Material properties are well known, access is good and adequate volumes are available. Source 160/161 (east of Tuktoyaktuk Harbour) contain a good quality Type III borrow material at a relatively low cost. Source 162 (Tuktoyaktuk Harbour) contains a lower quality of Type III borrow. This material can be extracted efficiently if large volumes of borrow are dredged and stockpiled at a given time. The Ya Ya Lake deposit is the most prominent source of Type II material in the Mackenzie Delta area. Although

TABLE 4 EVALUATION OF SELECTED GRANULAR SOURCES[1, 2.]

| SOURCE | MATERIAL | QUANTITY $m^3$ | DEVELOPMENT CONSIDERATIONS | 1983 COST $\$/m^3$ |
|---|---|---|---|---|
| 156 | Type III | 230 000 | Deposit consists of ocean spits and beach deposits, thereby excluding it from development. | |
| 157 | Type III | 1 000 000 | Deposit consists of ocean spits and beach deposits, thereby excluding it from development | |
| 158 | Type III | 3 800 000 | Deposit consists of a reef and a shoal located 5 km north of Tuktoyaktuk. Material would need to be dredged, stockpiled on the shoreline, and re-excavated and hauled to Tuktoyaktuk before use. Development may have adverse impact on biota. | 12.00-18.00 |
| 159 | Type III | 3 500 000 | Deposit is located near Tuktoyaktuk however, is similar and adjacent to the already developed 160 and 161 sources. Is covered by up to 2 m of overburden. | 11.75 |
| 160/161 | Type III | 750 000 | Deposit is located across the harbour from Tuktoyaktuk and is currently under development. | 11.75 |
| 162 | Type III | 630 000 | Deposit consists of sand on the bottom of Tuktoyaktuk Harbour. Has previously been a source of borrow material and is suitable for development when large quantities of material are required. | 6.50-12.50[3.] |
| 167 | Type III | 1 750 000 | Deposit is a kame located 27 km south-east of Tuktoyaktuk. Feasible for development only if the Inuvik-Tuktoyaktuk highway is constructed. | 32.00[3.] |
| 168 | Type II | 350 000 | Deposit consists of a kame-esker complex, located adjacent to Source 167. Relatively inaccessible, may be feasible source of Type II borrow material, if sufficient quantity excavated in single season | 30.00[3.] |
| 169 | Type III | 750 000 | Deposit consists of an outwash plain located 16 km southeast of Tuktoyaktuk. Has extensive overburden cover and is very discontinuous, thus making it unsuitable for development. Relatively inaccessible. | |
| 177 | Type II-Type III | 1 900 000 | Deposit consists of an outwash plain located 22 km south of Tuktoyaktuk. Fairly discontinuous, making development difficult. Relatively inaccessible. | 30.00[3.] |
| 211 | Type III | 380 000 | Deposit consists of an esker located on the shore of Willow Lake. Distance from Tuktoyaktuk makes development of this source unfeasible until closer sources are depleted. | 36.00[3.] |
| Ya Ya Lake | Type II | 7 600 000 | Deposit is a kame-esker complex on the shore of Ya Ya Lake. Is currently under development and is a good source of Type II material. | 36.00 |

NOTES: 1. Data based on consultants reports on individual pits.

2. Costs based on discussions with E. Gruben Transport (1983)and include delivery to site of volumes in the order of typical annual requirements.

3. Costs based on a minimum annual volume, as discussed in text.

the gravel is relatively expensive, very large and easily recoverable quantities are available (EBA, 1975). Slightly less expensive Type II borrow material may be available from Source 168, located 26 km overland from Tuktoyaktuk, if large quantities are extracted in a single season.

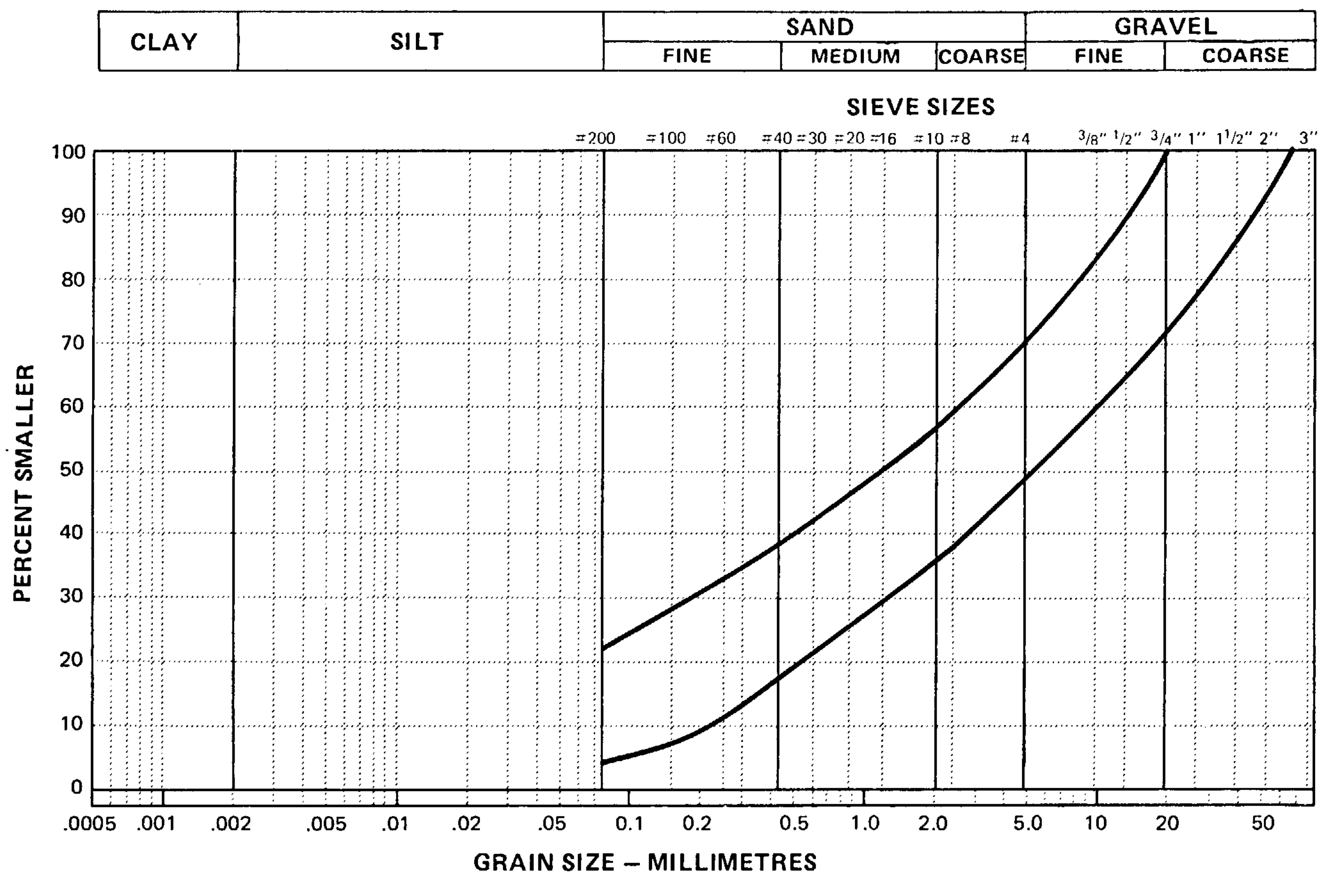
The following sub-sections contain more detailed comments on these borrow areas.

## 6.2 Source 160/161

Hardy Associates (1978) Ltd. under contract to DIAND, evaluated granular Source 160/161, located on the east side of Tuktoyaktuk Harbour. This project included two field programs, conducted in 1977 and 1980. Portions of the area had previously been explored by EBA in 1973, for Imperial Oil Limited, and by Ripley, Klohn, & Leonoff International Ltd., representing DIAND, in 1972.

The deposit landform was described as being a glaciofluvial terrace, locally covered with a thin veneer of peat and/or lacustrine silt. Thicker lacustrine deposits occurred in thermokarst depressions. Sand and gravel were found near-surface; visible ice contents were between 5 percent and 20 percent by volume, with 10 percent being about average. A total of 36 grain size analyses were performed on recovered samples; a summary of the testing is presented in Figure 1. This figure shows that the borrow material at Source 160/161 ranges from a gravelly sand to a sand and gravel mixture with a fines (silt and clay) content between 5 percent and 22 percent. This material is classified as Type III borrow material.

On the basis of the 1980 study, six potential borrow areas were identified within the confines of the site. Total recoverable volumes were estimated




*NOTES:*
*1) Envelope constructed from 25 grain size analyses.*
*2) Adapted from Hardy Associates (1978) Ltd., 1980.*

FIGURE 1 GRADATIONAL RANGE– GRANULAR BORROW AT SOURCES 160 AND 161 at 746 000 $m^3$, with yearly recoverable volumes being estimated at 67 000 $m^3$.

This source is currently being exploited, with borrow being excavated and transported to Tuktoyaktuk during the winter season. The cost of this material delivered in Tuktoyaktuk is currently $11.75/$m^3$ ($9.00/$yd^3$) (Gruben, 1983b).

Some difficulties in working with this material have been reported, primarily related to high ice content and consequent instability when thawed. Usually, several summer seasons are required for the placed gravel to drain and acquire sufficient strength to support traffic loads. If drainage was enhanced in the pit during periods of thaw, the winter excavated and placed gravel would likely be stable during the first thaw period. The cost of leaving a dozer in the borrow pit over the summer, to maintain site drainage and windrow gravel, would add approximately $1.25/$m^3$ ($1.00/$yd^3$) (Gruben, 1983b) to the current cost of granular borrow from this source.

## 6.3 Source 162

Granular materials Source 162 is located in the northern half of Tuktoyaktuk Harbour. It was originally sampled by EBA, for Imperial Oil Limited, in 1973 and more fully explored through geophysical surveys and a drilling program conducted for DIAND by Hardy Associates in 1978 and 1979. A portion of the southern half of the harbour was explored by EBA in 1981 for Esso Resources Canada Limited.

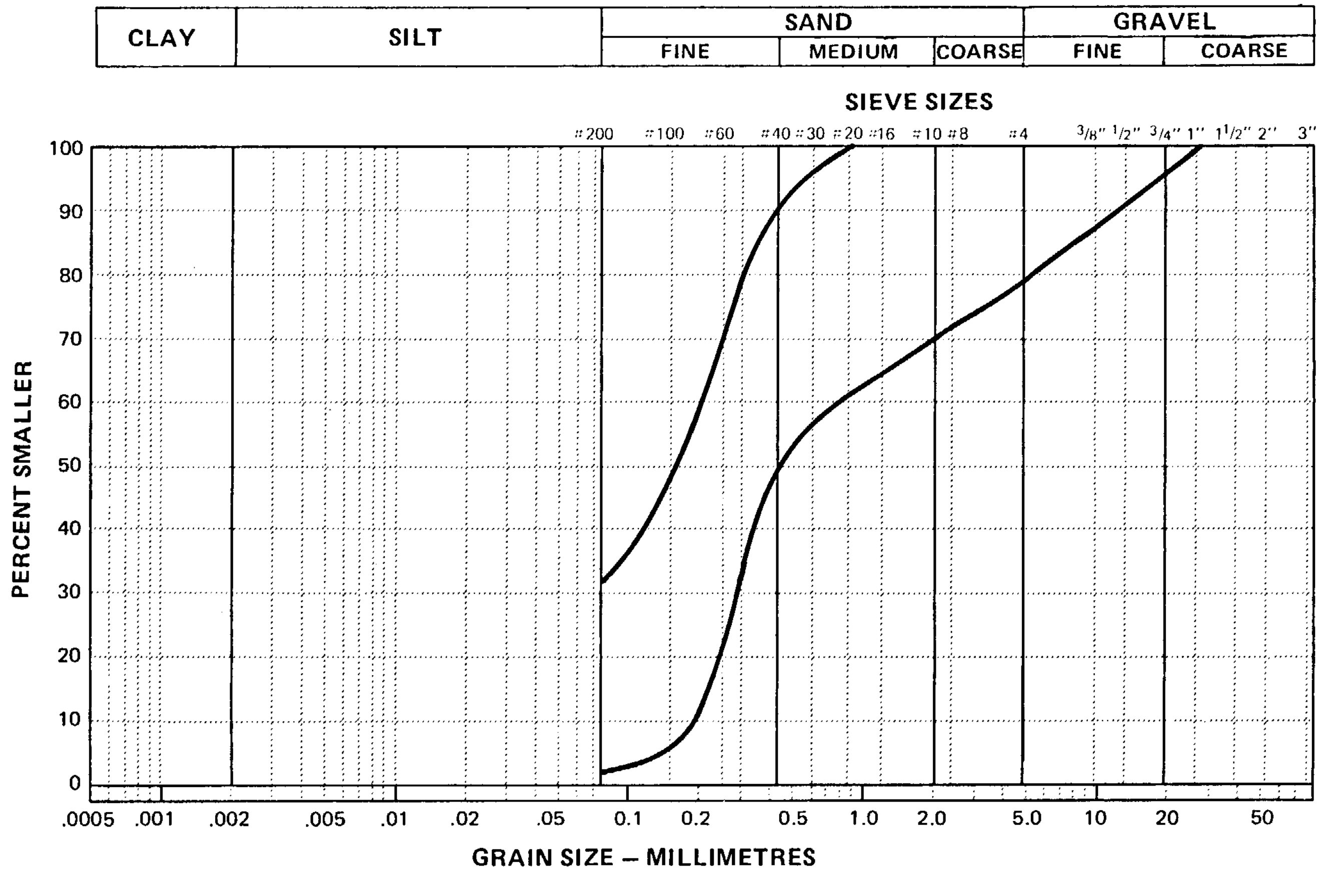
Field investigations determined that sand, with some gravel, exists under an average overburden thickness of 1.0 m. Gradational limits of this sand, determined from 32 grain size analyses, are presented in Figure 2.

Hardy Associates (1979) determined that approximately 630 000 $m^3$ of Type III borrow material could be extracted from the harbour, assuming an average dredging depth of 3.5 m to 4.0 m below the mudline.

Preliminary evaluation of potential harbour-bottom resources in the vicinity of Esso's base camp (located on the east side of Tuktoyaktuk harbour) indicated that approximately 500 000 $m^3$ of Type III borrow could be obtained in this area alone, if dredging was conducted to -20 m seabed penetration (EBA, 1981).

Dredged harbour sand has been used in the past for general fill for land development, construction of water reservoir embankments, airport construction, and as general fill for both the Dome and Esso yards. This sand is not a popular fill material in Tuktoyaktuk. Local inhabitants complain about frequent sand storms in the area, since most of the sand fills have not been capped or stabilized, while contractors are concerned about excessive equipment wear caused by the fine grained sand when it penetrates equipment seals.

The current cost of dredged sand stockpiled on the beach is reported to be in the range of \$6.50/$m^3$ to \$7.80/$m^3$ (\$5.00/$yd^3$ to \$6.00/$yd^3$) (Northern Construction Company, 1983), if a Northern Construction Company cutter-suction dredge is used. These costs are based on volumes in the order of 400 000 $m^3$ to 500 000 $m^3$. A larger dredge, such as the Zanen Verstoep Aquarius may achieve a higher production rate, but, the cost of stockpiled material will be approximately \$11.00/$m^3$ to \$12.50 $m^3$ (\$8.50/$yd^3$ to \$9.50




*NOTES:*

*1) Envelope constructed from 24 grain size analyses.*

*2) Adapted from Hardy Associates (1978) Ltd., 1979.*

EBA Engineering Consultants Ltd.

FIGURE 2 GRADATIONAL RANGE– GRANULAR BORROW AT SOURCE 162 (TUKTOYAKTUK HARBOUR)

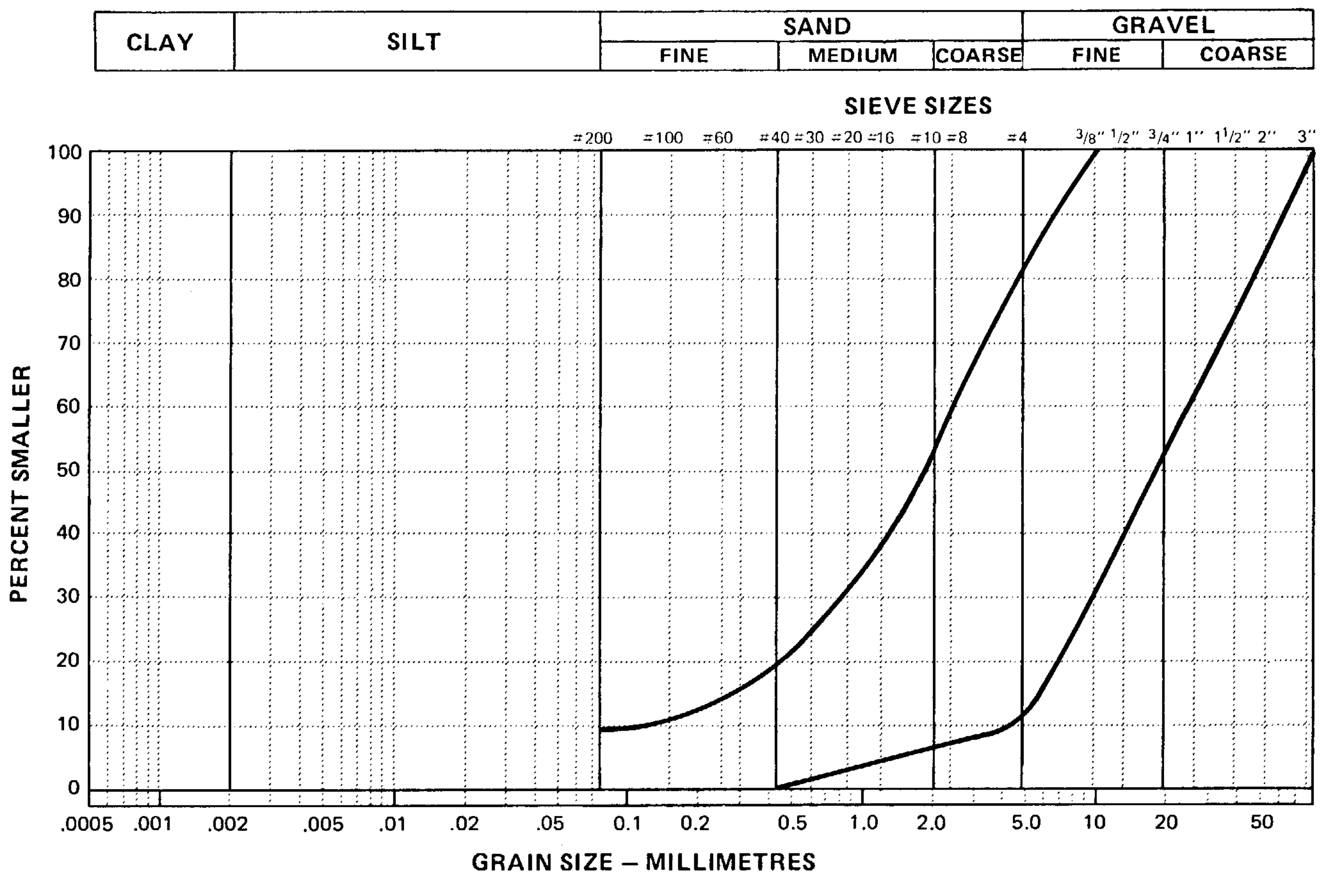
$yd^3$) (Canadian Marine Drilling, 1983). These prices assume that a dredge is available when the borrow material is required.

## 6.4 Ya Ya Lake

The Ya Ya Lake kame-esker complex, located on Richards Island, has been extensively explored and evaluated. Large scale extraction and stockpiling operations have been conducted at the source for nearly 10 years. In 1975, EBA conducted a detailed evaluation of the deposit for the Arctic Petroleum Operators Association. A total of 299 boreholes were drilled and sampled. Grain size curves summarizing the testing program are presented in Figure 3. Generally, the material, which ranges from a gravelly sand to a gravel with some sand, is fairly well-graded and has less than 10 percent fines. This material is generally of Type II quality. Moisture (ice) contents were generally in the range of 5 percent to 10 percent. Deposits of massive ground ice up to 16 m in thickness were encountered during the drilling program. A description of the deposit and certain development problems has been provided by Hayley and MacLeod (1977).

Exploitable volumes of gravel are substantial. Over 7.6 million $m^3$ (10.0 million $yd^3$) of gravel have been inventoried. Due to the areal extent of the deposit, yearly recovery rates are not a limiting factor. The Ya Ya Lake gravel is generally considered to be the best deposit of granular construction material in the Mackenzie Delta area. Gravel from this deposit has been used as Type I, Type II and Type III borrow material for projects ranging from roads to artificial islands.

Ya Ya Lake gravel currently costs \$36.00/$m^3$ (\$27.50/$yd^3$) (Gruben, 1983c) delivered to Tuktoyaktuk. Although located 70 km from Tuktoyaktuk, the site is readily accessible from the Inuvik-Tuktoyaktuk winter ice road. The




*NOTES:*

*1) Envelope constructed from 297 grain size analyses.*

*2) Adapted from EBA Engineering Consultants Ltd., 1975.*

**FIGURE 3 GRADATIONAL RANGE– GRANULAR BORROW AT YA YA LAKE**

EBA Engineering Consultants Ltd.

price of Ya Ya gravel would be adversely affected by closure of the Inuvik-Tuktoyaktuk ice road, if the proposed land road is constructed.

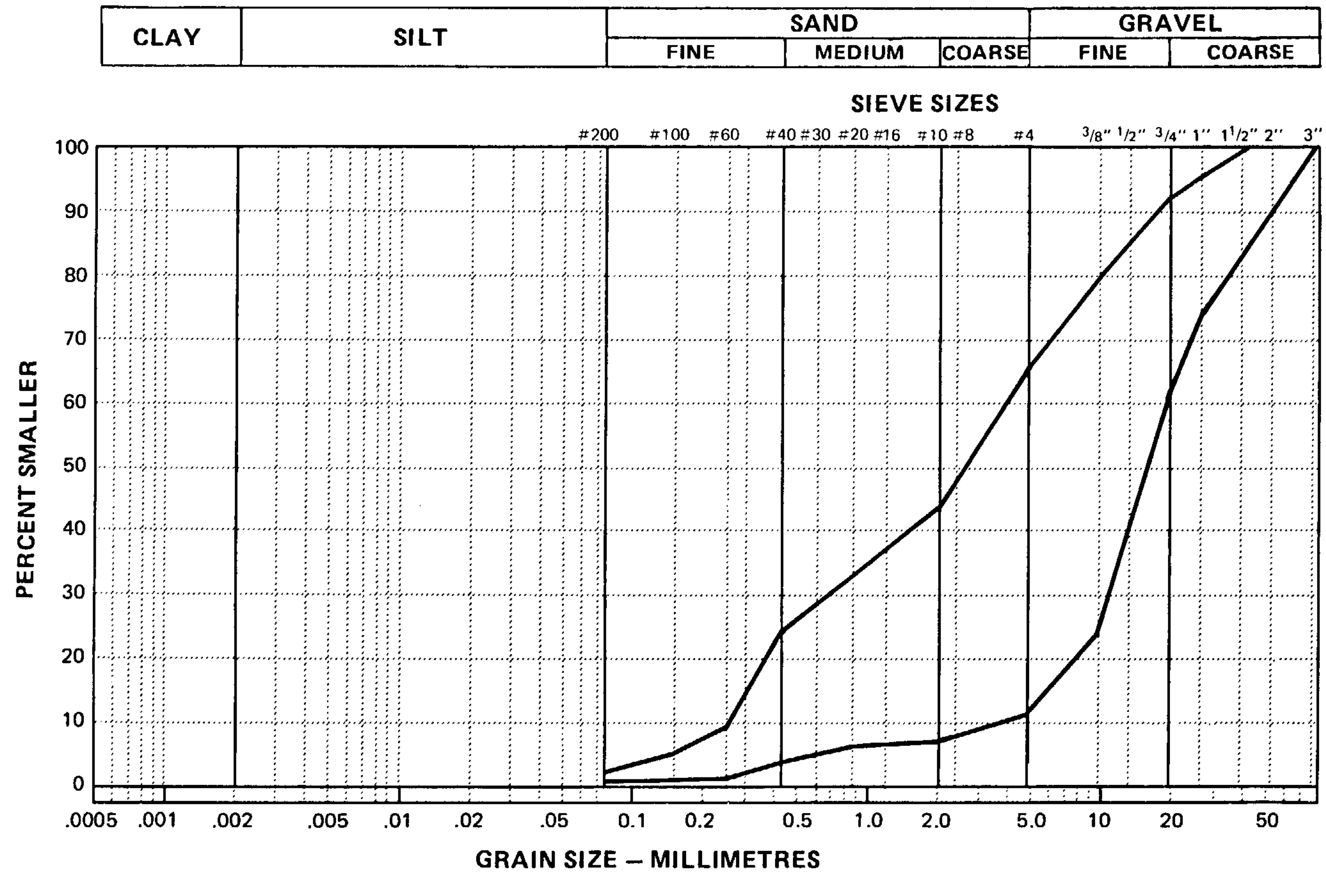
## 6.5 Source 168

Source 168, located on the north shore of Eskimo Lakes, was initially identified and sampled as source T-114 (Ripley, Klohn & Leonoff, 1973). It was renamed in the 1977 DIAND granular resources inventory (Hardy, 1977). A more detailed study of the source, summarized below, was completed recently by BBT Geotechnical Consultants Ltd., (1983), under contract to DIAND.

The granular deposits at this site consist of an esker and several small kames. A 1.5 m-thick layer of lacustrine clay was encountered at surface in one borehole, but generally overburden is absent, or thin, ranging from 50 mm to about 1.0 m (on the flanks of the ridge). The granular materials are generally classified as a gravel and sand mixture, sandy gravels, or gravelly sand. A total of 39 grain size analyses were conducted on samples recovered during the field programs; a summary of the gradational analysis is presented in Figure 4. The fines content is typically one to two percent. This material is suitable as a Type II borrow material, however, compaction may be difficult due to the very low fines content.

The upper 1.8 m to 2.5 m of the granular materials was typically dry and friable. Below this, the gravels were ice bonded, with visible ice contents typically five percent to fifteen percent; however, none of the samples contained excess moisture on thawing. While no massive ice was encountered, it was anticipated that ice bodies may be present in the underlying clay.

On the basis of the drilling program, it was estimated that the esker and kames contained a total of 600 000 $m^3$ of good quality granular material, of which 350 000 $m^3$ is recoverable. It was determined that the top 1.5 m to




*NOTES:*

*1) Envelope constructed from 32 grain-size analyses.*

*2) Adapted from BBT Geotechnical Consultants Ltd., 1983.*

**FIGURE 4 GRADATIONAL RANGE – GRANULAR BORROW AT SOURCE 168**

2.0 m would be easily excavated, but subsequently, annual production would be limited to the estimated 1.0 m to 1.5 m seasonal depth of thaw. While granular deposits extend several metres below the level of the surrounding terrain, the recoverable volumes are based on a maximum depth or recovery to about 1.5 m above the level of the surrounding area (BBT, 1983). Drainage is considered the limiting factor.

Development of the source would require construction and maintenance of an overland winter haul road. Due to the orientation of the access road relative to the direction of the prevailing winds, the yearly access costs would be extremely high and unpredictable, but probably in the order of $100,000 (Gruben, 1983c). This necessitates that large quantities, perhaps in the order of 150 000 $m^3$ (BBT, 1983), of material be removed in a single excavation season to reduce unit costs to a reasonable level. Under ideal conditions, it is estimated that material could be delivered in Tuktoyaktuk for a unit cost of $30/$m^3$ in 1984, provided at least 50 000 $m^3$ were excavated from the upper portions of the deposit in a single effort (Gruben, 1983c).

## 6.6 Granular Supply Summary

Although numerous granular deposits have been identified in the Tuktoyaktuk area, only 4 sources are regarded as economically feasible for development. The suitability of the individual sources is strongly dependent on the five-year material requirements of the different development scenarios.

No other deposits have been identified which contain material that can be obtained at reduced cost. Many of the previously identified granular sources either contain very small amounts of desirable material, have large amounts of overburden, or are very discontinuous. Access to other, larger, potential sources is difficult and transportation costs are relatively high.

A summary of the volumes of granular material available for each of the 4 recommended areas is presented in Table 5.

## 7.0 DEVELOPMENT SCENARIO

### 7.1 Without Airport Expansion

The total estimated maximum granular borrow demand for the next 5 years is 367 000 $m^3$, while the estimated minimum granular borrow demand is 357 000 $m^3$ (Table 3, Section 5.4). Approximately 73 percent of this demand is for Type III material. Type II fill accounts for 20 percent of the total fill requirements, while Types IV and I only account for 4 and 3 percent, respectively. Yearly requirements are 3 000 $m^3$ for Type IV borrow material and range from 47 500 $m^3$ to 65 300 $m^3$, 5 300 $m^3$ to 25 300 $m^3$, and 1 313 $m^3$ to 5 113 $m^3$ for Types III, II, and I borrow, respectively.

The most cost-effective scheme appears to involve extracting the Type III fill from Source 160/161. The borrow material is of reasonable quality, relatively inexpensive and the yearly supply exceeds requirements. Material quality could be further improved by leaving a dozer in the pit area over the summer period to windrow borrow material to reduce moisture contents

Estimated costs for various combinations of excavating, stockpiling, and placing material from Source 160/161 are presented in Table 6. While the least expensive granular material results from winter excavation and placement, thaw instability is likely, due to the high ice content of the

TABLE 5 GRANULAR SUPPLY SUMMARY

| SOURCE[1.] | MATERIAL | YEARLY RECOVERABLE VOLUME ($m^3$) | TOTAL RECOVERABLE VOLUME ($m^3$) |
|---|---|---|---|
| 160/161 | Type III | 67 000 | 750 000 |
| 162 | Type III | Unknown | Unknown |
| Ya Ya Lake | Type II | Unknown | 7 500 000 |
| 168 | Type II | 90 000 - 135 000 | 350 000 |

NOTE: 1. Data from detailed geotechnical evaluations of sources:

160/161 (Hardy, 1980)
162 (Hardy, 1979)
Ya Ya Lake (EBA, 1975)
168 (BBT, 1983)

TABLE 6 ESTIMATED YEARLY COSTS OF GRANULAR BORROW-SOURCE 160/161[1]

| YEAR | WINTER EXCAVATE, WINTER DELIVER | | WINTER EXCAVATE, WINTER STOCKPILE, SUMMER DELIVER | | SUMMER WINDROW, WINTER EXCAVATE, WINTER DELIVER | | SUMMER WINDROW, WINTER EXCAVATE, WINTER STOCKPILE, SUMMER DELIVER | |
|---|---|---|---|---|---|---|---|---|
| | $\$/m^3$ | $\$/yd^3$ | $\$/m^3$ | $\$/yd^3$ | $\$/m^3$ | $\$/yd^3$ | $\$/m^3$ | $\$/yd^3$ |
| 1984 | 12.75 | 9.75 | 19.75 | 15.00 | 14.25 | 10.75 | 21.25 | 16.25 |
| 1985 | 13.75 | 10.50 | 21.25 | 16.25 | 15.25 | 11.50 | 22.75 | 17.50 |
| 1986 | 14.75 | 11.25 | 22.75 | 17.50 | 16.50 | 12.50 | 24.50 | 18.75 |
| 1987 | 16.00 | 12.25 | 24.75 | 19.00 | 18.00 | 13.75 | 26.75 | 20.50 |
| 1988 | 17.25 | 13.25 | 26.75 | 20.50 | 19.50 | 15.00 | 28.75 | 22.00 |

NOTE: 1. Based on discussions with E. Gruben Transport Ltd (Gruben, 1983b).
An annual price increase of 8 percent has been assumed.

fill. Summer windrowing will increase the price of the borrow slightly, but thaw stability of the gravel will be substantially improved.

If granular material from Source 160/161 is stockpiled in Tuktoyaktuk during the winter, the material should be allowed to thaw and drain before fill is removed for placement. Stockpiling gravel in Tuktoyaktuk will add approximately \$6.75/$m^3$ (\$5.25/$yd^3$) to the cost of gravel delivered to site.

Type II granular borrow should come from the Ya Ya Lake source. Visible ice-free granular material from this pit will have moisture contents low enough to allow winter placement, making it unnecessary to allow the material to thaw and drain before use. It may be desirable to stockpile Ya Ya gravel in Tuktoyaktuk for future use, rather than haul gravel every year. Since the yearly demand for Type II material is in the order of 15 000 $m^3$ to 20 000 $m^3$, stockpiling a 2 year supply in Tuktoyaktuk would likely be more practical. Estimated yearly prices for Ya Ya Lake granular borrow are presented in Table 7.

Evidently, unless a Tuktoyaktuk stockpile is created, Ya Ya gravel should be excavated, hauled, and placed under winter conditions, as this operation would result in the lowest-cost Type II granular borrow. An alternative source of Type II borrow has recently been proven at Source 168, considerably closer to Tuktoyaktuk; however, the high and unpredictable costs of constructing and maintaining an overland winter access road may limit development of this source to the airport expansion scenario (Section 7.2). Under ideal conditions, the stockpiling of a four or five-year supply may reduce unit costs sufficiently for use of this source as an alternative to Ya Ya Lake gravel.

Type IV and Type I granular borrow should continue to be obtained from the Campbell Quarry, located south of Inuvik, since no suitable alternative sites have been located to date. It is very unlikely that alternate sources

TABLE 7 ESTIMATED YEARLY COSTS OF GRANULAR BORROW-YA YA LAKE SOURCE[1].

| YEAR | WINTER EXCAVATE, WINTER DELIVER | | WINTER EXCAVATE, WINTER STOCKPILE, SUMMER DELIVER | |
|---|---|---|---|---|
| | $\$/m^3$ | $\$/yd^3$ | $\$/m^3$ | $\$/yd^3$ |
| 1984 | 39.00 | 29.75 | 46.00 | 35.00 |
| 1985 | 42.00 | 32.00 | 49.50 | 37.75 |
| 1986 | 45.25 | 34.50 | 53.25 | 40.75 |
| 1987 | 49.00 | 37.50 | 56.75 | 43.25 |
| 1988 | 53.00 | 40.50 | 62.50 | 47.75 |

NOTE: 1. Based on discussions with E. Gruben Transport Ltd. (Gruben, 1983c).
A yearly price increase of 8 percent has been assumed.
Assumes existence of government-built and maintained ice road between Tuktoyaktuk and Ya Ya Lake.

could be developed for less cost than the existing sources, given the small volumes required. Processing facilities required to crush and blend Type I material are currently in place at the Campbell Quarry.

## 7.2 With Airport Expansion

If airport expansion occurs, the demand for granular borrow, and particularly Type II fill, increases twofold. The project will require between 350 000 $m^3$ and 500 000 $m^3$ of Type III fill and approximately 112 000 $m^3$ of Type II fill. Maximum Type III fill useage rates of 150 000 $m^3$/year would greatly exceed the yearly production of 70 000 $m^3$/year at Source 160/161 as well as restrict the availability of Type III granular material to the public sector (i.e. Hamlet use). In order to ensure that an inexpensive source of granular material for community use exists, the 160/161 deposit should be excluded from large-scale use for purposes other than Hamlet development.

Alternate sources of fill will have to be exploited in order to meet the demand of airport expansion. Dredged sand appears to be the most viable option at this time. A dredge could be positioned in the harbour, with a land-line running to the airport expansion site. If desired, all Type III fill required for the project could be dredged in one season, thereby reducing yearly start-up problems.

Dredged sand could be placed on-site for between \$6.50/$m^3$ and \$12.00/$m^3$, (Section 6.3) depending upon the dredging equipment. In this regard, the Aquarius may be available for contract dredging during the 1983 summer season. Northern Construction will not have a dredge in the area until 1984.

Annual requirements for Type II material could continue to be satisfied by the Ya Ya Lake deposits. Source 168 appears to provide an economical alternative to Ya Ya Lake provided sufficient quantitites are extracted during a single season. A comparison of the estimated unit and total costs of Type II material from the two sources is given in Table 8. The costs for Source 168 are based on stockpiling a two-year supply in 1984 and a three-year supply in 1986.

No Type IV and Type I material requirements were indicated for the airport expansion; Type IV and Type I material will still need to be imported from the Campbell Quarries, near Inuvik for the reasons indicated in Section 7.1

# 8.0 BORROW SOURCE MANAGEMENT PLANS

## 8.1 General

Borrow source plans have been prepared on the basis of the supply-demand analysis and the recommended development scenarios for the next five years. These plans have taken into consideration information presented in the Environmental Guidelines: Pits and Quarries Handbook (Indian and Northern Affairs Canada, 1982), and the draft Territorial Lands and Public Lands Pits and Quarries Regulations. The following sections present the objectives of the management plans, their limitations, general considerations regarding pit development and restoration which pertain to all borrow sources, and recommendations for refining the site-specific plans. The detailed site-specific management plans are presented in Appendix C, D, E, and F, for Sources 160/161, 162, Ya Ya Lake, and 168, respectively.

TABLE 8 COST COMPARISON OF TYPE II MATERIAL SOURCES

| YEAR | ESTIMATED ANNUAL VOLUME[1] | | ANNUAL COST OF MATERIAL BY SOURCE | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | YA YA LAKE[2] | | | SOURCE 168[3] | | |
| | LOW | HIGH | $/m^3$ | LOW | HIGH | $/m^3$ | LOW | HIGH |
| | | | | ($x10^6$) | | | ($x10^6$) | |
| 1984 | 37 300 | 47 300 | 39.00 | 1.46 | 1.85 | 33.50 | 1.25 | 1.59 |
| 1985 | 45 300 | 55 300 | 42.00 | 1.90 | 2.33 | 41.00 | 1.86 | 2.27 |
| 1986 | 31 300 | 41 300 | 45.50 | 1.43 | 1.88 | 39.00 | 1.23 | 1.61 |
| 1987 | 21 300 | 31 300 | 49.00 | 1.05 | 1.54 | 47.75 | 1.02 | 1.50 |
| 1988 | 26 300 | 36 300 | 53.00 | 1.40 | 1.93 | 48.50 | 1.28 | 1.77 |
| TOTAL | 183 500 | | 44.85[4] | 8.23 | | 41.05[4] | 7.54 | |

NOTES:
1. Volumes based on totals for Airport Expansion Scenario, Table 3.
2. Ya Ya Lake costs based on annual winter excavation and delivery.
3. Source 168 costs based on winter excavation and delivery for 1984 and 1986, and delivery from stockpile for other years.
4. Weighted average unit cost.

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## 8.2 Plan Objectives

Site-specific management plans must consider the requirements and constraints of regional borrow demand and availability. Each plan should ensure that economical recovery of quality granular materials is achieved at each pit without causing excessive adverse environmental impact. The environmental impact on the region can be minimized by restricting granular recovery operations to a select number of pits, realizing that maximum extraction from a pit will likely cause a slight rise in material cost. This cost increase must be weighed against the environmental costs of having numerous smaller pits, containing less expensive material, open simultaneously or sequentially. In this light, the pit management plans have been developed to minimize primarily the regional environmental disturbance and secondly pit-specific environmental disturbance.

Actual borrow requirements for the Tuktoyaktuk area will be significantly influenced by major projects, such as the proposed airport expansion or the Inuvik-Tuktoyaktuk Highway. Uncertainty regarding the scheduling of these and oil and gas industry activities, prevents determination of an accurate schedule of extraction from the individual sources. The management plans therefore attempt to achieve orderly and economical development and restoration such that if a source is abandoned from time to time, future extraction of remaining resources may be achieved with minimal effort and cost.

## 8.3 Limitations

The pit management plans have been prepared based on all available data for the individual borrow sources. This generally consists of observations and results from reconnaissance and drilling programs designed to identify borrow sources, and determine preliminary development guidelines. Detailed site survey and borrow delineation, and test-pitting programs have generally not be undertaken. Thus, factors such as total recoverable borrow quantities, excavation costs, and anticipated environmental disturbance are difficult to assess.

In those sources which have already been developed to some extent, little inspection or monitoring has been undertaken. Thus, verification of original material quantity estimates, and determination of remaining borrow reserves are not available. Information on the general performance of the existing pits, and assessment of environmental impact is also lacking.

The pit management plans necessarily rely on the recommendations presented in previous reports, as well as limited information obtained during the winter site visit, and previous experience with pit development in northern regions.

## 8.4 Pit Access

Winter haulage is recommended for all onshore sources to minimize environmental disturbance. Winter access to Source 160/161 and Ya Ya Lake is available over short snow/ice roads from the sources to main ice roads. Construction and maintenance costs for these access roads are insignificant in comparison to excavation and haulage costs.

Access to Source 168 would require construction of a long overland snow/ice road, with and estimated cost in the order of $100,000 (Gruben, 1983c). Maintenance costs would be high, and unpredictable, due to the orientation of the access route with respect to prevailing winds.

Summer operations would require construction of temporary access roads from the sources and docking facilities for barges. These facilities would require large quantities of granular materials, and therefore would significantly reduce the recoverable volumes. Appropriate consideration of controlling surface drainage would also be required. Costs of hauling material by barges are probably higher than winter trucking costs due to the amount of rehandling. Additional costs of construction of access roads and docking facilities, and reclamation following abandonment probably prohibit this alternative.

## 8.5 Pit Development

### 8.5.1 Site Preparation Work

Site preparation work should be conducted sufficiently in advance of excavation to prevent contamination of granular materials, and preferably in winter to minimize disturbance to the surrounding terrain. Snow should be cleared from the area to be excavated and yard areas and placed so as to minimize subsequent pit infilling by drifting snow. Topsoil consisting of peat and organic soils, while typically scarce, should be stripped where possible and stockpiled or windrowed at the edges of the pit area. Windrows should be placed parallel to slope direction to prevent ponding of surface water during spring, or contamination of granular materials. Inorganic overburden materials should be stripped and placed in separate stockpiles or windrows, with similar consideration of drainage considerations. The stripped materials are to be reserved for reclamation purposes. Disturbed areas must be kept to a practical minimum.

### 8.5.2 Extraction Methods

Winter recovery operations will normally consist of ripping of friable frozen granular material and pushing it into temporary windrows or stockpiles for loading. This type of extraction can be conducted with conventional equipment including bulldozers with rippers, loaders, and trucks. Poorly-bonded granular material will usually be located near the surface of deposits that exhibit positive relief. It will represent the material that has thawed and drained over the summer season. If an insufficient volume of material can be obtained through ripping, or ripping is not possible, blasting will be necessary.

Summer operations will typically consist of stripping and windrowing or stockpiling thawed layers of granular material with bulldozers, commencing when thaw has progressed about 0.5 m into the deposit. The cycle of operation is largely dependant on the rate of thawing, and drainage considerations. This method allows potentially greater annual recovery by progressively increasing the amount of thawed material, and permits rapid drainage of the material in stockpiles or windrows. The stockpiled material may be easily loaded with front-end loaders and removed at any time of the year.

Excavation costs are largely dependant on the depth of recovery possible and ease of excavation, and are therefore difficult to estimate. Annual recovery depths in undeveloped areas will be initially dependent on natural moisture contents and the corresponding degree of ice-bonding. Subsequent to initial development, the annual depth of recovery will depend largely upon seasonal depth of thaw and pit drainage. Poorly-bonded granular materials, with moisture contents less than five percent, will generally be easily ripped. Moderately ice-bonded material will be rippable, but with some difficulty. Where moisture (ice) contents exceed approximately 10 percent, depending on material type, and the granular materials are well-bonded, slow production rates, and consequently high excavation costs will result. Blasting will be necessary if the material is unrippable.

Large annual requirements from a particular borrow source may warrant comparison of the economics of ripping and drill and blast operations. The latter operation proved successful for development of a gravel source near Fort MacPherson, NWT, during construction of the Dempster Highway. Crushing of frozen blasted blocks may be required to reduce material to an acceptable size.

### 8.5.3 Treatment of Massive Ice

The pervious nature of granular materials tends to encourage the growth of bodies of tabular ground ice where abundant water is available. Massive ice presents both environmental and construction-related problems to pit development. Where practical, the extent of massive ice in a prospective deposit should be defined prior to pit development. The development plans should include methodology for coping with ice bodies as they are encountered.

Where practical, large bodies of massive ice should be avoided. Thin, or less extensive massive ice within the granular material at higher elevations should be excavated and wasted, or exposed to permit thawing during the summer. Drainage must be considered with either method of disposal.

Relatively thin layers of massive ice at depth may be permitted to thaw provided all overlying recoverable granular materials are removed during one extraction season. Formation of thaw ponds as ice melts during the summer is inevitable in this situation. Appropriate measures must be taken to control drainage and to protect, and ensure access to, adjacent recoverable granular materials.

Thicker ice bodies at depth, frequently at the base of the deposit, should be preserved, if thawed it is likely to prevent recovery of adjacent materials, or result in major disturbance of the surrounding areas. A minimum cover of 1.5 m of granular material should be left as insulation over massive ice to prevent excessive thawing. Criteria for establishing the minimum thickness of massive ice beds which should be preserved should be influenced by topographic relief, thickness and extent of granular materials, and the anticipated effect of thaw ponds on surrounding terrain.

### 8.5.4 Drainage Considerations

Adequate drainage of pit areas must be maintained to ensure availability of recoverable granular material and to attain required annual extraction rates, since higher moisture contents inhibit thawing, increase excavation costs and reduce material quality. Small amounts of meltwater runoff from ice bonded and thinly ice-lensed granular materials could be allowed to seep into the surrounding terrain, but larger amounts of runoff, from thawing of large massive ice bodies, should be directed to retention ponds or sumps excavated in the pit floor. Where gravity drainage is possible, natural ponds or drainage ditches may be effective at removing water from the site. However, excavated ditches are generally ineffective in regions of high ground ice content soils.

It is essential that pit drainage facilities be maintained and updated frequently to ensure that moisture drains away from the working face, and that ponded runoff does not accumulate on recoverable granular material. Where thaw ponds are allowed to form by exposing buried massive ice, or collection ponds are created, care should be taken to preserve, and maintain access to, adjacent recoverable granular materials. A development plan to adequately account for pit drainage is particularly important where summer extraction operations are employed.

#### 8.5.5 Waste Material

All lenses of fine-grained material (silts and clays) found within the granular deposit, should be stripped and wasted. Waste material should be stockpiled near the wasted overburden for use in pit reclamation. Fine-grained waste material at depth will undoubtedly have high excess ice contents, hence it may be advisable to construct a dyke of drier overburden around waste piles to prevent flow of thawed waste onto surrounding terrain or into pit areas.

### 8.6 Utilization of Borrow Sources

High quality granular materials are scarce and costly in the Tuktoyaktuk area, therefore, full utilization of material from each source must be achieved. Maximum recovery from existing sources may require more costly extraction and drainage control measures, but these should be encouraged before new sources are contemplated. Material from any particular source must be used only for the purposes for which it is best suited; high-grading, the practice of using any readily-available material where lower quality material would suffice, should be discouraged, possibly through stockpiling of various material types in the immediate Tuktoyaktuk area.

As indicated previously, in Section 6.2, the limited reserves of Type III material at Source 160/161 should be reserved primarily for Hamlet use. If major volumes of general fill material are needed, as for the airport expansion, dredging from Source 162 is recommended, and consideration should be given to stockpiling additional dredged material for Hamlet use.

Similar, good quality Type II material is available at Source 168, and Ya Ya Lake; however, minimum volume requirements required to deliver material to Tuktoyaktuk at reasonable cost will likely limit development of Source 168 to a high-use scenario, such as completion of the airport expansion in the next five years.

Wherever practical, development of any individual source should be awarded to a single contractor, either on a negotiated or competetive-bid basis. The contractor should be responsible for construction and maintenance of any overland access, site preparation work, extraction delivery and stockpiling, if required, of all granular materials from the source, and restoration measures. When sources are abandoned temporarily, and remaining granular materials are to be recovered at a later date, some allowance should be made for conducting restoration following depletion and permanent abandonment.

## 8.7 Environmental Considerations

### 8.7.1 Terrain Disturbance

Terrain disturbance is significantly less where winter operations are undertaken, and access is obtained by following ice roads. Overland travel involving considerable maintenance of access trails, should be minimized where possible and totally restricted to winter. Summer operations normally require that at least 1.5 m of fill be used in construction of roads, access trails and working areas. Regardless of season, areas which are particularly environmentally sensitive, such as steep banks, vegetated lowlands and major wildlife habitats, should be avoided.

Areas required for staging, and for stockpiling organics, overburden, and borrow materials should be kept to a minimum and located on drier, poorly vegetated areas, or where possible, confined to previously disturbed areas.

### 8.7.2 Thermokarst

Thaw ponds resulting from melting of massive ice at the floor of worked areas are generally considered to be environmentally acceptable in areas with numerous natural ponds and small lakes. Initially, melting of ice will be accompanied by collapse along the shorelines, but these are expected to stabilize over a few years. Where summer operations are undertaken, it should be noted that these open bodies of water may attract wild fowl during pit development.

Existing thaw ponds bordering granular sources may also be environmentally sensitive. Smaller, shallow ponds which freeze to the bottom, and do not support permanent aquatic populations, may be considered expendable. Larger and deeper ponds must be avoided.

The other major concerns where large bodies of massive ice are encountered, are related to drainage control, as discussed in the next section, and restoration of thermokarst areas, as discussed in Section 8.8.

8.7.3 Drainage Control

Small amounts of meltwater from ice-bonded granular materials may be disposed of by draining onto the surrounding terrain; however, where massive ice is present, the large quantities of silty water may result in some environmental damage, thus retention ponds should be used. Retention time will vary with the characteristics of individual sites.

Existing drainage courses must be maintained and protected. Disposal of silt-laden meltwater in clean streams supporting aquatic life is generally not acceptable. A positive pit floor slope to direct meltwater to adjacent lakes is considered an acceptable alternative to flooding of large areas of the pit floor or surrounding terrain. Ditches, although practical in low ice-content soils, may soften from thermal erosion and collapse. Pumping of water to a suitable location is preferable.

Disposal of meltwater in adjacent ponds will result in siltation, therefore, this should be limited to non-productive or already turbid bodies of water. Use of temporary settling ponds will reduce siltation. Workings below the level of adjacent lakes will likely result in flooding of portions of the pit floor. Dykes of in situ frozen soil or constructed of saturated frozen fill may be used to reduce the area of flooding. Pumping of water to adjacent lakes after settling may be necessary in summer operations.

## 8.8 Restoration

Restoration measures are required whether the pit is being abandoned temporarily or permanently. All worked areas should be cleaned of all debris, and graded to remove all topographic irregularities. Where abandonment is temporary, positive drainage away from existing faces and access routes must be provided by grading or ditches to ensure future recovery of remaining materials. Berms should be constructed at the top of pit faces, if necessary, to prevent surface runoff from entering the pit area.

Prior to permanent abandonment, the edges of worked areas, or pit walls, if any, should be recontoured to blend as much as possible into the surrounding terrain. All obstructions to natural drainage should be removed and any slopes graded to prevent runoff from channelling and downcutting. Since thaw ponds and lakes and massive ground ice are common in the Tuktoyaktuk area, flooding of pits is an acceptable, and frequently inevitable, method of restoration. Areas which are not likely to become flooded should be smoothly graded and covered with stockpiled overburden and organics.

Revegetation may be feasible in certain areas by redistributing stockpiled organic topsoil and peat over the graded slopes of areas unlikely to be flooded, and seeding or allowing reinvasion of natural vegetation, depending on the nature of the site and the quality of the topsoil. Fine-grained overburden soils are generally adequate for surface reclamation, however, the amount of naturally-occurring topsoil is very limited at some sites. The fertility of these soils may require enrichment for revegetation.

The surface of areas to be revegetated should be broken up with a caterpillar ripper tooth in the fall after frost has penetrated to a depth of about 150 mm. The resulting roughened surface serves to reduce potential wind erosion, and provide sheltered sites for re-establishment of vegetation.

## 8.9 Monitoring and Inspection

Field monitoring and inspection are required to ensure that each source is developed according to the management plan in order to maximize recoverable volume and minimize environmental damage.

Field inspection during operations, should involve regular checking of:

1) the area under development,
2) removal and stockpiling of organic topsoil and inorganic overburden,
3) drainage control measures,
4) excavation rates and volumes, and
5) disposal of waste material.

Occasional monitoring during operations by qualified geotechnical personnel is also recommended to verify recoverable reserves and development guidelines. This monitoring should include:

1) mapping subsurface soil stratigraphy, ground ice conditions, and depth of thaw,
2) delineation of waste soil and ice bodies,
3) observation of excavation, including extraction methods, ease of excavation, and depth of excavation possible,
4) evaluation of drainage and erosion control measures,
5) observation of thermokarst development, and
6) assessment of required restoration measures.

Field inspection following temporary abandonment should include checking of:

1) pit area and excavated volumes,
2) clean-up measures, and
3) drainage and erosion control measures.

Inspection and monitoring following permanent or long-term abandonment and restoration should be undertaken for a period of at least two years and include, in addition to the above,

1) checking site grading,
2) monitoring extent of flooding, and thermokarst development,
3) evaluation of progress of revegetation, and
4) identification of potential problem areas.

## 9.0 SUMMARY AND RECOMMENDATIONS

Based on reported 5-year granular borrow demands, it appears that sufficient granular borrow resources exist in the Tuktoyaktuk area. Development of

Source 160/161 should continue, as it is the most convenient and least expensive source of Type III fill material. Dredged sand is the most cost-effective Type III fill for large scale projects if it can be placed directly. If the airport is expanded, dredging of harbour sand from Source 162 will likely be required.

The Ya Ya Lake deposit is the most suitable source of Type II construction material unless the airport expansion scenario occurs. Although the gravel is relatively expensive, the deposit is well proven and extensive. Source 168, shows potential for supplying more economical Type II borrow, provided sufficient quantities are excavated during a single season to offset the costs and risks of constructing and maintaining an overland winter access road.

Preparation of site-specific borrow source management plans is necessary to ensure the maximum availability of economical granular material of all required types, with a minimum of environmental disturbance. This process is hindered by a lack of detailed information on the existing borrow sources, including the actual distribution of materials encountered in the pits, the performance of materials on placement, ease of excavation, annual depth of recovery, and overall performance of the disturbed areas. The lack of information on the extent and distribution of massive ice is of particular concern, as it significantly affects pit development and restoration. Identification of regions and probable extent of massive ice within pits where it is known to occur is feasible by drilling and geophysical methods.

Pit development and restoration plans and estimated costs for each borrow source can be refined as detailed site-specific information is obtained. Monitoring and inspection of borrow sources currently under development is essential.

Respectfully submitted,

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APPENDIX A

GRADATION SPECIFICATIONS

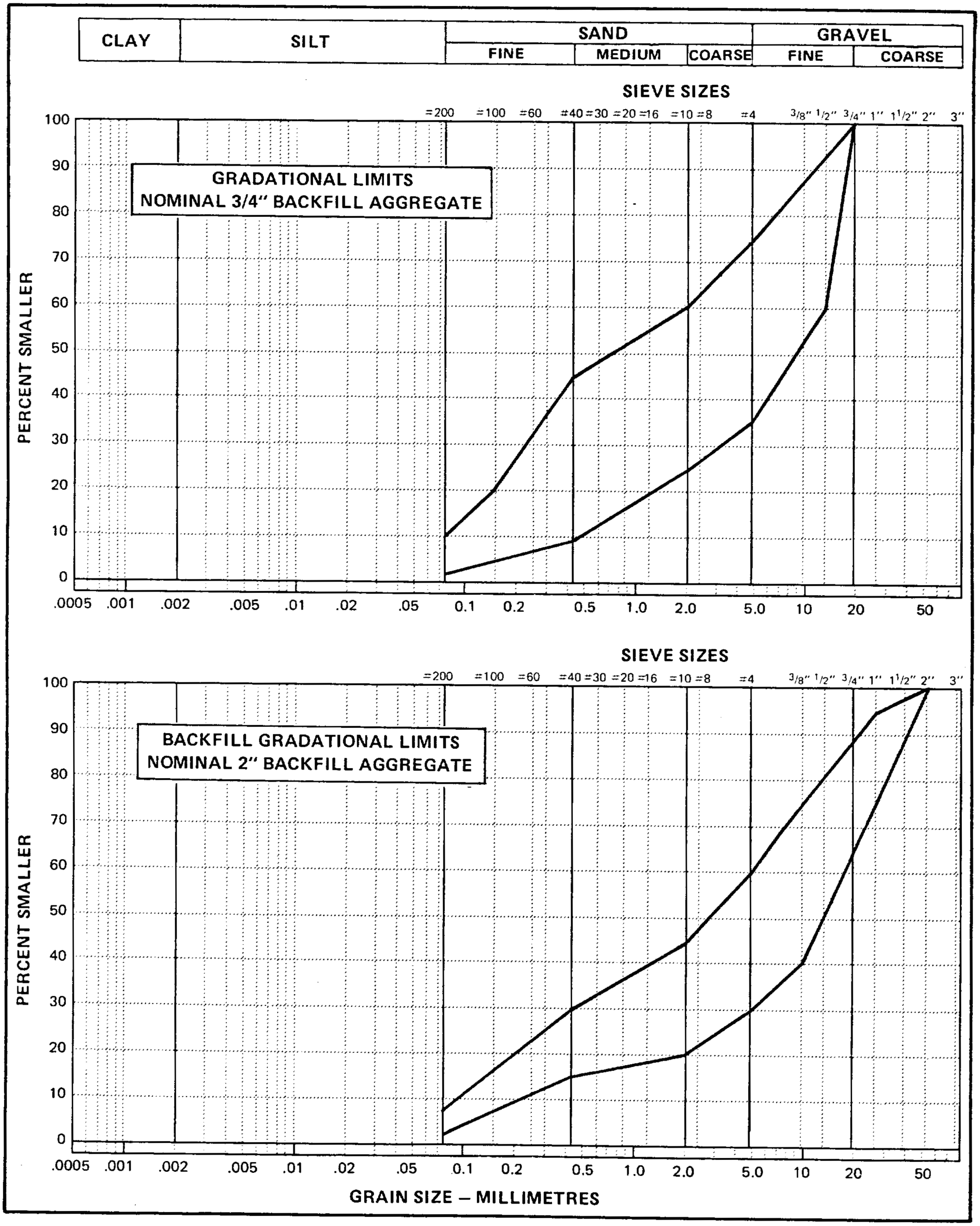
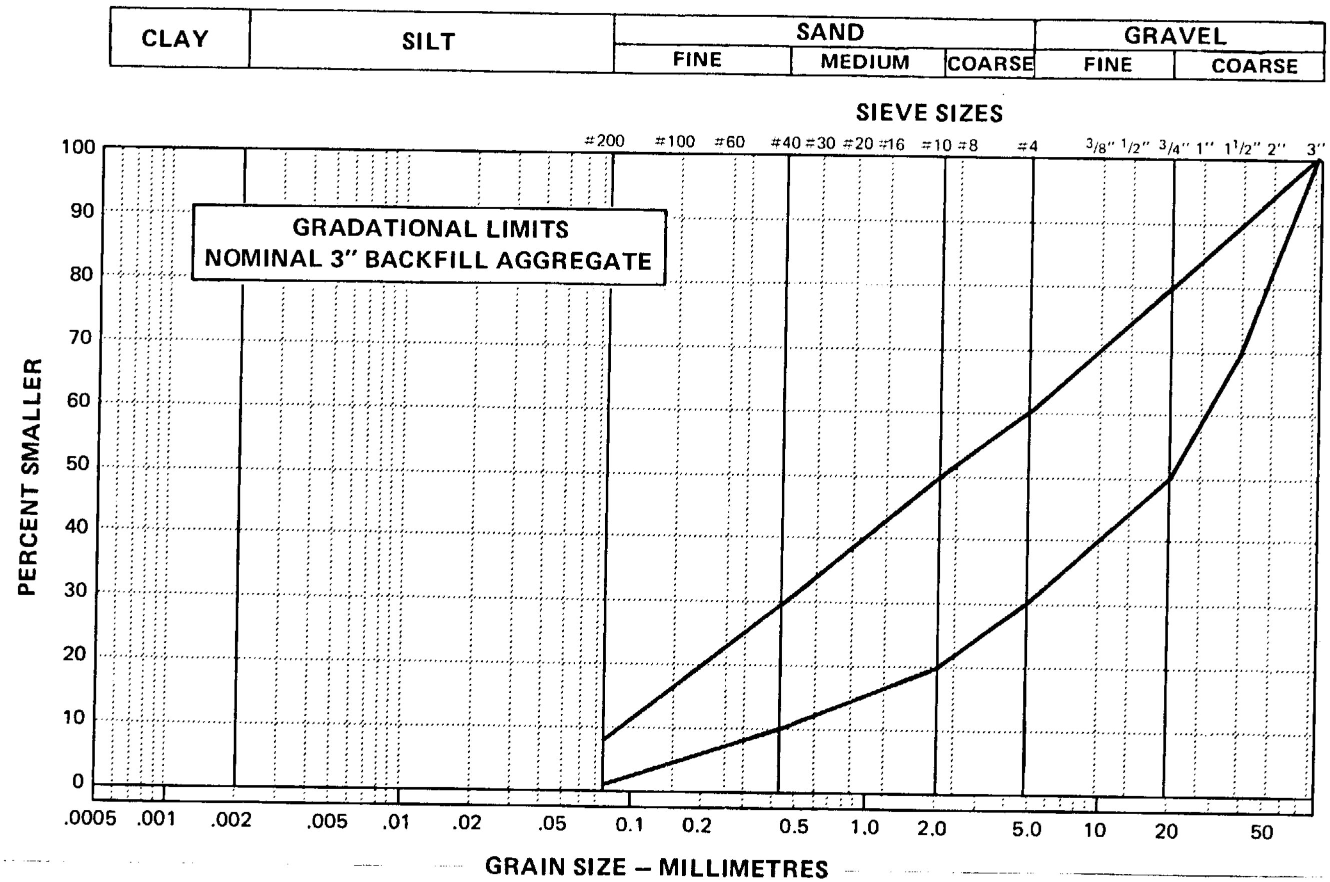



FIGURE A - 1 TYPICAL GRADATIONAL LIMITS– NOMINAL 3/4" AND 2" AGGREGATE

EBA Engineering Consultants Ltd.




EBA Engineering Consultants ltd.

FIGURE A - 2 TYPICAL GRADATIONAL LIMITS– NOMINAL 3" AGGREGATE

APPENDIX B

REFERENCES

APPENDIX B

REFERENCES

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APPENDIX C

BORROW SOURCE MANAGEMENT PLAN

SOURCE 160/161

BORROW SOURCE MANAGEMENT PLAN

SOURCE 160/161

**LOCATION:** East Side of Tuktoyaktuk Harbour

**DISTANCE TO TUKTOYAKTUK:** 2-3 km W

**LANDFORM:** Glaciofluvial Terraces

**RECOVERABLE VOLUME ($m^3$):**
**Total :** 750,000
**Annual:** 67,000

**MATERIAL TYPE:** Type III

**UNIT COST (1983):** $11.75/$m^3$

**REFERENCES:** Ripley, Klohn & Leonoff International, 1972a
Hardy Associates, 1977
Hardy Associates, 1980

**PIT PLAN REFERENCE:** Hardy Associates, 1980

**SITE DESCRIPTION:**

Source 160/161 consists of six glaciofluvial terrace deposits in a region of flat to gently rolling terrain with relief generally less than 15 m. The rolling to hummocky surfaces of the terraces are probably a result of thermokarst subsidence that has occurred since deposition. The deposits, which are generally bounded by the 8 m or 10 m contour, range in area from 1.7 ha to 10.0 ha, and total 25.0 ha.

The predominant vegetation complex is birch-heath tundra. Overburden, consisting of peat and thin silt layers, ranges in thickness from 0 m to 2.5 m, averaging about 300 mm over the six areas. Granular materials consist of fine to coarse sands, with discontinuous gravel layers. While both the fines (silt and clay) and gravel contents are generally low, they vary considerably locally.

The deposits are moderately to well-drained. Much of the granular material is ice-bonded and visible ice contents are generally low to moderate, but ice-rich zones are present. Massive ice underlying the deposit, was encountered in many of the boreholes, at depths as shallow as 2.0 m, but averaging 4.3 m. Most of the boreholes were terminated in the massive ice bodies.

Source 160/161 is currently being developed. While no detailed records have been kept to date, it is estimated that approximately 150,000 $m^3$ of material has been excavated and removed.

ACCESS:

Winter access is available via a short snow road from the source to an ice road across Tuktoyaktuk Harbour. The cost of the short access road does not significantly effect minimum annual volumes, or unit costs of granular materials delivered to Tuktoyaktuk.

Summer access is not practical due to the costs of rehandling material for barging, and the need for construction of onshore facilities.

PIT DEVELOPMENT:

Site Preparation Work:

Development during a single season should be restricted to as small an area as possible to ensure maximum recovery of the limited amount of granular material available. Site preparation work should be conducted during winter to minimize terrain disturbances. Overburden should be ripped and stockpiled with separate piles for organic and inorganic materials. The overburden should be retained for reclamation purposes.

Extraction Methods:

Winter recovery operations currently consist of ripping and pushing frozen granular material into temporary stockpiles for loading onto trucks. Although the average thickness of granular material averages 3.7 m over the six deposits, the recoverable depth may be reduced as a result of the variability in the depth to massive ice, and difficulty in excavating well-bonded granular materials. Some additional excavation costs (i.e. drilling and blasting) may be justified to maximize recoverable volumes.

Partial summer extraction at Source 160/161 may be feasible due to its proximity to Tuktoyaktuk. Summer operations would consist of progressive stripping and windrowing, or stockpiling thawed layers of material with a bulldozer, commencing when the depth of thaw has reached about 500 mm. This method would maximize recoverable volumes by allowing potentially greater annual excavation depth while permitting drainage of the relatively ice-rich Source 160/161 materials. The 1983 unit cost of leaving a bulldozer in the pit for summer windrowing purposes is estimated to be about $\$1.25/m^3$ based on typical annual volume requirements.

Treatment of Massive Ice:

Massive ice is present throughout the source, as thin layers within and large bodies below the recoverable granular materials. As the massive ice occurrs at relatively shallow depths, it cannot practically be preserved. Thin layers of ice should be excavated and wasted, with consideration given to drainage control. All overlying recoverable granular material should be excavated until the underlying large ice bodies are exposed.

Drainage Considerations:

Adequate drainage must be maintained to ensure availability of recoverable gravel. Pit drainage facilities must be updated frequently to ensure that water liberated by thaw drains away from the pit. Where thaw ponds are allowed to form by exposing massive ice, or collection ponds are created, access to adjacent recoverable deposits must be preserved. Maintenance of proper drainage and collection ponds is particularly important where summer extraction is employed.

Waste Material:

If possible, lenses of silt within the granular materials should be stockpiled with the inorganic overburden materials for use in pit reclamation. Dykes constructed of drier stockpiled overburden should be utilized to prevent flow of thawed ice-rich waste into working areas or onto the surrounding terrain.

**UTILIZATION OF BORROW MATERIAL:**

Limited reserves of easily accessible Type III material dictate that maximum potential recovery be achieved at Source 160/161, and that the source be reserved primarily for Hamlet use.

The in-place performance problems associated with the high ice content of this material, as discussed in the text of this report, could be greatly reduced by leaving a bulldozer in the pit for partial summer excavation, and for promoting drainage away from remaining recoverable materials.

The schedule for development of the six areas within Source 160/161 should proceed as previously recommended (Hardy, 1980).

## ENVIRONMENTAL CONSIDERATIONS:

### Terrain Disturbance:

Previous development at Source 160/161 has resulted in environmental disturbance, to the extent that is normally associated with borrow extraction. Future disturbance should may be minimized by ensuring that activities are restricted as much as possible to pit areas, and to winter operations when work must be undertaken outside of previously disturbed areas.

### Thermokarst:

Naturally-occurring thermokarst is common in the areas surrounding the deposits. Thaw ponds resulting from melting of massive ice exposed during recovery operations are generally considered environmentally acceptable in the area. The likely extent of thermokarst development is difficult to assess with the available information. The thickness of the massive ice at depth is not known since most boreholes were terminated in the massive ice. Monitoring of the extent and distribution of massive ice and thermokarst formation in the existing pit areas has not been undertaken. It is anticipated that melting of ice will be accompanied by collapse along pond shorelines. These slumps are expected to stabilize after a few years.

### Drainage Control:

Significant amounts of silt-laden runoff from thawing of massive ice bodies are anticipated. Existing drainage courses and deeper ponds supporting aquatic life must be maintained and protected from siltation by runoff.

Grading or ditching to collect and direct meltwater to collection ponds in exploited areas is recommended. Dykes constructed of saturated frozen fill may be used to reduce the area of flooding. Pumping of water, after settling of the fines, to Tuktoyaktuk Harbour may be necessary during summer operations.

**RESTORATION:**

All worked areas should be cleaned of debris and graded to remove any topographic irregularities that might obstruct drainage at the end of each excavation season. Where abandonment of the source is temporary, positive drainage away from existing working surfaces and access routes must be provided. Where necessary, berms should be constructed at the top of working surfaces to prevent surface runoff, from adjacent higher elevations, from entering the pit area.

Staged restoration can be planned and implemented as granular materials are removed from areas under development. Prior to abandonment, following depletion of each of the developed areas, the edge of the deposit should be recontoured to blend as much as possible into the surrounding terrain. Formation of thaw ponds, and flooding of significant portions of the worked areas is an inevitable and acceptable method of restoration. Areas which are not likely to become flooded should be graded and covered wth stockpiled overburden in preparation for revegetation.

Revegetation is accomplished by redistributing stockpiled organic topsoil and peat over the graded slopes, fertilizing, and seeding. To roughen the surface and trap moisture prior to seeding, the surface should be broken up with a bulldozer ripper tooth in the fall after frost has penetrated to a depth of about 150 mm.

Fertilizer and seed should be applied by broadcasting following surface preparation. The recommended fertilizer mix (14-28-14) should be applied at a rate of 440 kg/ha (Hardy, 1980) at seeding, and possibly again the next summer. A seed mixture of Boreal creeping red fescue, Nugget Kentucky bluegrass, Fairway crested wheatgrass, and Engmo timothy in the ratio by weight of 2:2:1:1 (Hardy, 1980) should be applied at a rate of 55 kg/ha. Re-fertilization and re-seeding requirements should be assessed during annual inspections.

**MONITORING AND INSPECTION:**

Monitoring and inspection services should follow the general guidelines presented in the text. Areas of particular concern in Source 160/161 include area of development, extent and distribution of exposed massive ice, ease of excavation and practical depth of recovery, thermokarst development and extent of flooding, and revegetation progress.

APPENDIX D

BORROW SOURCE MANAGEMENT PLAN

SOURCE 162

# BORROW SOURCE MANAGEMENT PLAN
# SOURCE 162

**LOCATION:** Northern Half of Tuktoyaktuk Harbour

**DISTANCE TO TUKTOYAKTUK:** 0.5 to 2.0 km W

**LANDFORM:** Underwater, marine- and thermokarst-modified glaciofluvial complex

**RECOVERABLE VOLUME ($m^3$):**
**Total** :Unknown
**Annual**:Unknown

**MATERIAL TYPE:** Type III

**UNIT COST (1983):** \$6.50/$m^3$-\$12.50/$m^3$

**REFERENCES:** EBA Enginnering Consultants, 1973
Hardy Associates, 1978
Hardy Associates, 1979
Hardy Assoicates, 1979
Pit Plan Reference

**PIT PLAN REFERENCE:** Hardy Associates, 1979

**SITE DESCRIPTION:**

Source 162 consists of a modified glaciofluvial complex forming the bottom of Tuktoyaktuk Harbour. Water depths vary greatly throughout the harbour, from less than 3 m in the vicinity of the islands to over 33 m in the numerous, irregular depressions. The harbour itself, and the depressions are thought to have formed from melting of massive ice and icy glaciofluvial sediments.

Granular materials, consisting of fine to medium-grained sands, with some gravel, are overlain by a variable thickness of soft clayey silt. The overburden is thickest (up to 10 m) in the depressions, and is frequently absent in shallower waters. In the four areas recommended for development in previous studies, the overburden thickness averaged about 1.0 m. The better quality materials lie within the top 3.0 m of the granular deposits. The total thickness of the granular materials has not been determined to date.

**PIT DEVELOPMENT:**

General:

Development of Source 162 offers several advantages, including its proximity to Tuktoyaktuk, the large quantity of material available, its unfrozen state, and the limited terrain disturbance resulting from development. The deposit it has utilized in the past as a source of general fill for large-scale projects (the water reservoir and land assembly).

The major disadvantages include dredge availability, location of stockpiling sites, removal of overburden, impact on aquatic life, and difficulties in stabilizing the obtained sand.

Site-specific studies of, stockpiling sites and environmental impact are necessary prior to development of any portion of Source 162. Additional site investigation is recommended when extraction depths in the order of 20 m are planned.

Extraction Methods:

Cutter suction dredging is best suited for selective removal of overburden and recovery of the highest quality granular material from the surface of the granular deposit. The dredge employs a cutter head and suction unit mounted on a swinging ladder, which permits accurate control of dredging depth. The cutter head loosens sediments, which are then drawn up through the suction hose and discharged through a floating pipeline to shore.

Overburden should be stripped and disposed of prior to recovery of granular materials. Overburden should be disposed of in the Beaufort Sea, preferably at the time of peak flows of the Mackenzie River. Disposal into the deeper waters of Tuktoyaktuk Harbour will have a negative impact on aquatic life.

Granular materials are then extracted in a second pass and discharged to an onshore stockpiling site. The depth of recovery is dependent upon the equipment used. Where overburden is thin, and the depth of recovery is greater, say 20 m, overburden stripping may possibly be avoided by mixing the two materials when dredging.

Drainage Considerations:

Stockpiling sites must be located where disposal of large quantities of dredge effluent can be controlled. Drainage may require construction of dykes and ditches to direct effluent either temporarily to lakes for settling or directly back into the harbour depending on the amount of fines (silt and clay) in the effluent.

The dredged granular materials are expected to drain rapidly.

## UTILIZATION OF BORROW MATERIALS:

Developmelnt of Source 162 is recommended when large quantities of Type III material are required for major projects, such as the proposed airport expansion. However, utilization of the deposit is dependent on dredge availability. If the airport expansion occurs, it is recommended that all the airport requirements for Type III material be dredged in a single season.

**ENVIRONMENTAL CONSIDERATIONS:**

General:

Environmental concerns in the dredging of Tuktoyaktuk Harbour include the impact on shoreline erosion, impact on aquatic life, and terrain disturbance at stockpiling sites. Detailed site specific studies are required prior to development of any underwater source.

Impact on Shoreline Erosion:

Shallow dredging (4 m to 5 m ) is not likely to significantly affect shoreline erosion. The harbour is relatively deep, and currents are generally weak. However, it is recommended that dredging be restricted to areas at least 30 m from shore.

Impact on Aquatic Life:

Dredging will result in removal or burial of substrates and organisms, and increased turbidity and sedimentation. Measures to reduce the impact of dredging include minimizing the time period, area of extraction, and minimizing sedimentation. As discussed previously, disposal of overburden into the Beaufort Sea, and use of settling ponds for effluent, will greatly reduce the impact upon aquatic life in Tuktoyaktuk Harbour.

Impact on Stockpiling Site:

Siltation is likely to destroy vegetation on stockpile sites and the adjacent areas and thermokarst may be initiated. Stockpiling sites should therefore be chosen carefully with particular attention to drainage and ground ice conditions in order to minimize the area of disturbance, and to avoid particularly sensitive areas. Restoration measures are required at stockpiling sites.

**RESTORATION:**

Restoration should proceed as soon as possible after removal of granular materials from stockpile sites, and in the immediate autumn following dredging in adjacent areas where vegetation has been destroyed by siltation. The disturbed areas should be ripped to mix in the underlying native organic soils, during later autumn after frost has penetrated about 150 mm. Seed and fertilizer should then be broadcast at rates of 55 kg/ha, and 440 kg/ha, respectively. Boreal creeping red fescue, Nugget Kentucky bluegrass, Fairway crested wheatgrass and Engmo timothy in a 2:2:1:1 mixture, and 14:28:14 fertilizer are recommended (Hardy, 1979).

**MONITORING AND INSPECTION:**

Monitoring and inspection services are required during dredging operations, and for a period of at least two years following reclamation of stockpiling sites. Borrow material quality should be monitored continuously during dredging operations. Inspection of stockpiling sites and drainage control measures should also be undertaken during dredge operations. The impact of stockpiling operations should be monitored immediately following completion of dredging to determine the restoration measures required. The progress of revegetation should be monitored for at least two years after restoration.

APPENDIX E

BORROW SOURCE MANAGEMENT PLAN

YA YA LAKE SOURCE

# BORROW SOURCE MANAGEMENT PLAN
## YA YA LAKE SOURCE

**LOCATION:** Southern End of Richards Island

**DISTANCE TO TUKTOYAKTUK:** 82 km NE

**LANDFORM:** Esker-kame complex

**RECOVERABLE VOLUME ($m^3$):**
**Total :** 7,500,000
**Annual:** Unknown

**MATERIAL TYPE:** Type III

**UNIT COST (1983):** $36/m$^3$

**REFERENCES:** Mollard and Assoicates, 1973
EBA Engineering Consultants, 1975
Terrain Analysis and Mapping Services, 1976

**PIT PLAN REFERENCE:** Terrain Analysis and Mapping Services, 1976

SITE DESCRIPTION:

The Ya Ya Lake source consists of a glaciofluvial esker-kame complex with outwash-, wave-, and thermokarst-modified features. The main esker, which reaches to a maximum height of 41 m above Ya Ya Lake, is composed of a series of single and multiple, steep-sided ridges, dissected in several locations by drainage courses. Several minor eskers form the main ridge at the eastern end. The separate esker ridges merge in several locations to form kame features, most of which are 25 m to 30 m in diameter, and about 8 m in height. Glaciolacustrine-modified terraces and small areas of outwash are present on the edges of the complex. Much of the local relief over the deposit is attributed to aggradation and subsequent localized melting of massive ice.

Vegetation is generally sparse on the ridge tops and consists of lichens and grasses and an assortment of shrubs and bushes (willows, labrador tea, berries). More dense vegetation is encountered on the flanks of the ridges. Overburden is absent, or consists of very thin layers of organics and silt on the eskers, but thickens away from the main ridges to about 600 mm to 3.0 m. Granular materials range from medium-grained sandy gravels to medium and coarse sands. The eskers contain mainly well-graded sands and gravel, while the kames are more variable, with lenses of silt and fine sand within well-graded sand and gravel.

The surfaces of the eskers are dry and well-drained. Small randomly-oriented veins of visible ice were observed within the granular materials at depth, and moisture contents were typically five percent to ten percent. Bodies of massive ice were encountered throughout the Ya Ya area, usually between the bottom of the granular material and the underlying preglacial silts. The exact extent and configuration of the ice bodies is not known, but 17 m of ice was encountered in one borehole.

Extraction from the deposit has occurred since the early 1970's. No estimate of the total volume extracted is available.

ACCESS:

Access to Ya Ya Lake is available in winter via a short haul road from the Inuvik-Tuktoyaktuk ice road. Due to previous work at the source, the annual cost of opening the short onshore haul road is insignificant. Access to the site would be seriously affected if the main ice road is no longer built and maintained after construction of the Inuvik to Tuktoyaktuk Highway. Alternative access would be by barging in summer.

## PIT DEVELOPMENT

General:

A detailed site development and restoration plan for the Ya Ya Esker Complex was prepared for DIAND by Terrain Analysis and Mapping Services Ltd. (1976). The complex was subdivided into a series of extraction blocks, which were to be assigned to the major users, including reserve blocks for use by the Hamlet of Tuktoyaktuk. No detailed monitoring or inspection has been ongoing to date, hence, it is not certain to what extent the 1976 plans have been implemented. The management plan presented herein refers only to the area being utilized as a source of Type II granular material for use in Tuktoyaktuk.

Site Preparation Work:

No extensive site preparation work is required for the Ya Ya Lake source owing to the thin overburden, and previous development. Snow should be cleared from all working areas and placed so as to prevent subsequent pit-infilling by drifting snow. The small amounts of organic and inorganic overburden present should be stripped and placed in separate stockpiles for use in pit reclamation.

Extraction Methods:

Extraction may be achieved during winter operations with a bulldozer by ripping and pushing friable granular materials into temporary stockpiles for loading onto trucks. Typically 1.0 m to 2.0 m of granular material can be recovered annually from poorly-bonded areas. Some areas of drier, non-bonded granular material may be loaded directly from a working face onto trucks with a front-end loader. Drilling and blasting will be necessary to retrieve moderately and well-bonded granular material. Well-bonded material may require thawing and draining before placement.

Summer operations would involve stripping and stockpiling of newly-thawed material commencing when thaw has penetrated about 500 mm into the ground. The cycle of operation is dependent on initial moisture content, and consequently, rate of thawing and drainage considerations.

Treatment of Massive Ice:

Site-specific recommendations for treatment of massive ice cannot be made due to the typical variability of ice bodies. Each occurrence must, therefore, be evaluated individually as it is encountered in pit development.

Where practical, extensive bodies of massive ice, particularly near large thaw ponds adjacent to the deposit, should be avoided. Thin, or less areally extensive bodies of ice within the granular materials should be excavated and wasted, or exposed to permit thawing during the summer. Since most of the ice bodies are at the base of the granular deposits, it is considered appropriate that these be exposed at the pit floor by removal of the last 1.5 m to 2.0 m of material, during a single extraction season, and allowed to thaw during the summer.

In situations where thawing is likely to prevent recovery of adjacent materials, or result in major disturbance to the surrounding area, thicker ice bodies should be preserved by leaving a minimum cover of at least 1.5 m of granular material. Criteria for establishing the minimum thickness of massive icebeds which should be preserved are influenced by topographic relief, thickness and extent of granular materials, and the anticipated effect of thaw ponds on the surrounding terrain.

Drainage Considerations:

Adequate drainage of pit areas must be maintained to ensure availability of recoverable granular materials, and to attain the required rates of annual extraction from the designated pit area. Large amounts of meltwater from thawing of ice bodies should be directed to collection ponds in previously excavated areas, or to existing ponds, with consideration of environmental effects.

Construction of ditches to collect or direct meltwater to adjacent lakes is considered an acceptable alternative to the reduction of recoverable reserves by flooding of larger areas of the pit floor, or to flooding surrounding undisturbed terrain. However, the possibility of thermal erosion must be considered. If the ditches are unstable, a positive sloping pit floor, retention ponds, and pumping will be required to maintain pit drainage.

It is essential that pit drainage facilities be maintained and updated frequently to ensure that moisture drains away from working areas or faces, and that recoverable granular materials are not flooded. Dykes constructed of frozen fill should be used to limit the area of flooding.

Waste Material:

The kame portions of the Ya Ya Lake source are most likely to contain lenses of fine-grained material, but owing to the complex structure of the deposit, lenses or pockets of waste material are possible throughout all deposits.

All lenses of fine-grained material (silts and clays) within the granular materials should be stripped and wasted.

Waste material should be stockpiled near the overburden for use in pit reclamation. Fine-grained material obtained at depth will undoubtedly have high ice contents; therefore, waste piles should be surrounded by dykes constructed of drier stockpiled overburden to prevent flow of thawed waste into the pit, or onto the surrounding terrain.

## UTILIZATION OF BORROW MATERIALS:

Extraction facilities are already in place at the Ya Ya Lake source, and the material and its performance on placement are well-known; therefore continued development of the deposit as a source of Type II material for use in Tuktoyaktuk is recommended. Owing to the high cost of the material, it must only be utilized where Type II material is required. Stockpiling of a two-year supply in Tuktoyaktuk might be practical with current volume requirements. Development of the Ya Ya Lake source should generally follow the recommendations of the 1976 plan (Terrain Analysis and Mapping Services Ltd. 1976), with extraction from specific user-dedicated blocks.

## ENVIRONMENTAL CONSIDERATIONS:

### Terrain Distrubance:

Terrain disturbance is significantly less where winter operations are undertaken. Areas required for staging, and for stockpiling organics, overburden and borrow materials should be located on drier, poorly-vegetated areas, or where possible, confined to previously disturbed areas. Disturbed areas should be kept to a minimum.

Thermokarst:

Site-specific guidelines for the control of thermokarst cannot be prepared, since the extent and distribution of massive ice has not been accurately mapped. Melting of ice exposed at the floor of worked areas will be accompanied by collapse along the shorelines of developing thaw ponds, but these are expected to stabilize after a few years. Existing large ponds bordering the granular deposits may be particularly environmentally sensitive. Smaller, shallow ponds which freeze to the bottom, and do not support aquatic life are considered expendable; however, the larger and deeper ponds should be protected by leaving a buffer zone.

Drainage Control:

Existing drainage courses must be maintained and protected. Disposal of silt-laden meltwater into clean streams is generally not acceptable. However, if the stream is short and empties into the Mackenzie River, it may be acceptable to allow contamination of the stream.

Small amounts of meltwater from ice-bonded granular materials with low visible ice contents may be disposed of by draining onto the surrounding terrain. Large quantities of silty meltwater resulting from thawing of exposed or wasted massive ice should be directed to existing non-productive or turbid ponds, or to collection ponds constructed in worked areas. Ditches and dykes, constructed of frozen fill, may be used to direct and confine meltwater to the smallest possible area of the pit floor.

**RESTORATION:**

Restoration measures are required when the pit is abandoned temporarily or permanently. All worked areas should be cleaned of debris, and graded to remove all topographic irregularities, at the end of each exploitation season. Positive drainage away from working areas and berms on top of sloping pit faces to prevent runoff from entering the pit area should be provided where abandonment is temporary.

Prior to long-term or permanent abandonment on depletion, the pit walls, if any, or edges of worked areas should be recontoured to blend, as much as possible, into the surrounding terrain. All obstructions to natural drainage should be removed and slopes graded to prevent channelling or downcutting by runoff.

Thaw ponds and lakes and massive ice are common on Richards Island, hence, flooding of pits, and thermokarst formation are acceptable, and inevitable, methods of restoration. Areas not likely to be flooded should be smoothly graded and covered with stockpiled overburden and organics in preparation for revegetation.

Revegetation is achieved by ripping the surface after frost has penetrated to a depth of about 150 mm and broadcasting appropriate fertilizers and seed mixtures. While no studies have been conducted to determine the required fertilizer and seed mixture for the Ya Ya Lake source, it is believed that those recommended for Sources 160/161 (Hardy, 1980), and for disturbed, dredge-stockpile areas near Tuktoyaktuk (Hardy, 1979) are suitable for most tundra areas near the Mackenzie Delta underlain by granular materials.

MONITORING AND INSPECTION:

The detailed monitoring and inspection services outlined in the text of the report should be followed. Items of particular concern to the Ya Ya Lake source include the areas under development, extent and distribution of massive ice, drainage control, and thermokarst development. A detailed legal survey of the Ya Ya Lake Esker-Kame Complex, if not already completed, should be performed and survey stations placed to permit long-term monitoring of areas and volumes of excavation since proper management of this source may be particularly important in a broader regional granular materials management plan.

APPENDIX F

BORROW SOURCE MANAGEMENT PLAN

SOURCE 168

# BORROW SOURCE MANAGEMENT PLAN
## SOURCE 168

**LOCATION:** North Shore of Eskimo Lakes

**DISTANCE TO TUKTOYAKTUK:** 25 km NW

**LANDFORM:** Esker, several kames

**RECOVERABLE VOLUME ($m^3$):**
**Total:** 350,000
**Annual:** 90,000-135,000

**MATERIAL TYPE:** Type III

**UNIT COST (1983):** $30/$m^3$

**REFERENCES:** Ripley, Klohn & Leonoff International Ltd., 1972a
Hardy Associates, 1977
BBT Geotechnical Consultants, 1983

**PIT PLAN REFERENCE:** BBT Geotechnical Consultants, 1983

**SITE DESCRIPTION:**

The deposit consists of a 1000 m long esker, which varies from 80 m to 140 m in base width, and several small (about 60 m by 100 m) kames. The esker rises above the flat surrounding terrain to a maximum height of 9 m near its northern end, and to 4 m to 5 m in the southern one-third of the feature. The local relief of the kames is typically 2 m to 3 m.

Granular materials are exposed at the surface in several small, bare patches; elsewhere vegetation consisting of moss and low shrubs covers the surface. Organic topsoil beneath the vegetated areas is generally less than 50 mm thick. The overburden thickness increases on the flanks of the esker to about 1.0 m. A localized cap of clay, 1.5 m thick, was encountered in one borehole. The granular materials are classified as a mixture of sand and gravel, sandy gravel, or gravelly sand, with very low fines (silt and clay) content. Granular material was found to extend to depths of several metres below the level of the surrounding lacustrine plain.

The surface of the esker was dry during the summer site visits, but ice-bonded materials were encountered at depth. Low to moderate visible ice contents were recorded during test drilling, but no massive ice was encountered. The surrounding area is wet, and exhibits both high and low-centered frost polygons.

ACCESS:

Access is limited to a winter snow or ice road. If the source is developed prior to completion of the proposed Inuvik to Tuktoyaktuk Highway, annual construction of 25 km to 30 km of overland snow/ice road would be required. The current cost of road construction is estimated to be in the order of $100,000 (Gruben, 1983c). High and unpredictable maintenance and clearing costs are anticipated due to the orientation of the access road relative to the prevailing wind direction. The reliability of the source is also limited by potential difficulties through maintaining the long overland access during prolonged stormy periods.

If develoment of the source occurs after completion of the proposed highway, access would be available through a 10 km-long ice road over Eskimo Lakes.

PIT DEVELOPMENT:

Site Preparation Work:

Site preparation work is not anticipated to be extensive at Source 168, since organic soils and inorganic overburden are relatively thin and discontinuous. All organic topsoil and inorganic overburden should be stripped and stockpiled at the higher and better-drained edges of the deposit for subsequent use in reclamation. Stockpiles should be placed so as to prevent accumulation of drifting snow in working areas, contamination of recoverable granular materials, and ponding of surface water during summer. Care should be taken to prevent disturbance of surrounding areas containing polygonal ground.

Extraction Methods:

Extraction of the uppermost 1.5 m to 2.0 m of granular material can be achieved with a bulldozer by ripping and pushing friable frozen material into temporary stockpiles for loading onto trucks. Excavation of materials below the dry surficial layer will require considerably greater ripping efforts; the amount of which is dependent on the moisture content and degree of ice-bonding. Ripping of moderately to well-bonded material will not be possible. Recovery of well-bonded material at depth may be limited annually to a 1.0 m to 1.5 m layer which has been allowed to thaw and drain during the previous summer. If thawing and draining produce insufficient volumes of rippable material, drilling and blasting will be necessary.

The area of the esker outlined for development during the drilling program approximates the 8.0 m contour (relative elevation). The recoverable volume estimated is based on excavation to a depth about 1.5 m above the surrounding terrain. With adequate drainage control, it may be possible to recover material to the level of the surrounding terrain, and possibly, to the depth which can be excavated in a final season, below the level of the surrounding area.

Treatment of Massive Ice:

Massive ice was not encountered during the drilling program; however, all of the boreholes were located along the centreline of the esker and few penetrated the underlying sediments. Potential massive ice at the base of the granular materials is probably of little significance since it may not be possible to excavate the full depth of the granular materials. Massive ice may also be present in the kames and near the edges of the esker, in areas which were not explored. Should massive ice be encountered during pit development, the generalized guidelines presented in the text of this report should be followed.

Drainage Considerations:

The relief of the deposit will permit adequate drainage during the initial stages of development. The surface of the worked areas should be gently sloped at the end of each excavation season to ensure drainage of newly-thawed material during the following summer. When the excavation surface approaches the level of the surrounding terrain, a drainage path to a lower area southeast of the deposit may be required.

Waste Materials:

No significant beds of fine-grained material were encountered within the granular deposits. If encountered during pit development, waste materials should be stockpiled near the inorganic overburden materials.

UTILIZATION OF BORROW MATERIALS:

Source 168 contains materials similar in gradation to the Type II material from Ya Ya Lake in current useage. Owing to the high transportation costs for delivery of material from the source to Tuktoyaktuk, the deposit should be utilized only when Type II - quality material is required. The cost of constructing and maintaining access to the source may limit development of the source to a high-useage development scenario, such is the case in which the proposed airport expansion occurs within the next 5 years. Excavation and stockpiling of a several year supply in Tuktoyaktuk may be required to ensure a reasonable material cost.

## ENVIRONMENTAL CONSIDERATIONS:

### Terrain Disturbance:

Development of the site is limited to winter operations due to the length of access, hence, terrain disturbance at the source should be minimal. Worked areas should not be allowed to encroach on areas of polygonal ground. Proper construction and maintenance of snow/ice roads must be ensured to reduce the possibility of disturbance along the access route.

### Thermokarst:

Thermokarst formation is not anticipated since no massive ice was encountered. Additionally, granular material below the estimated depth of recovery will serve to insulate any massive ice at depth .

### Drainage Control:

Moisture contents and fines (silt and clay) of the recoverable granular materials are sufficiently low that drainage of meltwater onto the surrounding tundra is considered acceptable.

## RESTORATION:

Restoration measures are required whether the pit is abandoned temporarily or permanently. Worked areas should be cleaned of all debris and graded to remove all topographic irregularities, which might obstruct natural drainage, at the end of the excavation season. Positive drainage to the edges of the deposit should be provided during temporary abandonment, by grading, or ditches to ensure maximum future recovery of remaining materials.

Prior to permanent abandonment, the edges of the pit should be graded to blend, as much as possible, into the surrounding terrain, with care taken to avoid disturbance of polygonal ground in the surrounding terrain. Stockpiled inorganic overburden and organic topsoil should be spread inwards from the edges as far as possible. Flooding of lower portions of the pit is an acceptable method of restoration.

Revegetation of areas not likely to be flooded should be promoted by ripping the surface, in the fall after frost has penetrated to a depth of about 150 mm, and application of a suitable fertilizer and seed mixture. While no detailed studies were undertaken to determine the appropriate mixtures, it is believed that those recommended for Source 160/161 and disturbed areas of Source 162 stockpiles (Hardy, 1979, 1980) are suitable for most tundra areas underlain by granular deposits in the Tuktoyaktuk area.

MONITORING AND INSPECTION:

Monitoring and inspection services should follow the general guidelines presented in the text of the report. Additionally, inspection of the access routes should be undertaken both during each winter extraction season and during the following summer.