SUMMARY OF GRANULAR RESOURCE DATA FOR THE UPPER MACKENZIE VALLEY (FORT PROVIDENCE TO NORMAN WELLS)

Prepared for:
INDIAN AND NORTHERN AFFAIRS CANADA

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EXECUTIVE SUMMARY

EBA Engineering Consultants Ltd. and its subconsultant GVM Geological Consultants Ltd. have compiled a summary of over 50 granular resource studies that were conducted in the Upper Mackenzie Valley prior to 1988. The summary covers an area of approximately 100,000 square kilometres south of Norman Wells, including both sides of the Mackenzie River and adjacent regions outside the narrow pipeline and highway corridor. This work was completed under contract to Indian and Northern Affairs Canada, Land Resources Division in Yellowknife (INAC).

Geographic, geologic and engineering characteristics for 762 sites are summarized and an assessment of the potential value of each site is provided. Quantitative information has been interpreted from site investigation data or original estimates, if available. Quantities removed by Public Works Canada for the Mackenzie Highway and by Interprovincial Pipelines for the Norman Wells Oil Pipeline are included, if applicable.

The site data is presented on 1:250,000 scale maps and in a tabular format (in a separate volume) compatible with INAC's dBase III data management programs. A copy of it on 5 1/4 inch floppy diskettes also has been submitted separately.

Five new Borrow Management Areas are proposed herein to be continuous with ones previously developed for the Lower Mackenzie Valley. These areas generally encompass similar geologic materials and resource availability. Regional requirements and shortages of granular materials are broadly addressed by considering future community, highway, pipeline and airstrip demands relative to the distribution of the previously identified deposits. Recommendations are presented to address concerns raised in the Fort Providence, Fort Simpson and Fort Norman areas, and south of River-Between-Two Mountains.

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1.0 INTRODUCTION

1.1 PROJECT AUTHORIZATION

EBA Engineering Consultants Ltd. (EBA) was retained by Indian and Northern Affairs Canada (Yellowknife) (INAC) to review and summarize the results of the many granular resource assessment studies done for government agencies and industry in the upper Mackenzie Valley between 1970 and 1988. Formal authorization to proceed with the study, as outlined in EBA's unsolicited proposal (P-4016) submitted in 1986 December, was received in 1987 October. This work was conducted under INAC Contract No. YK-87-88-047. Mr. E. Hornby was the departmental representative.

1.2 PROJECT ORGANIZATION

EBA's project team included Ms. Gretchen Minning of GVM Geological Consultants Ltd. (GVM) as a subconsultant. Her previous experience in the area as a direct participant in quite a few of the studies being referenced provided a valuable level of reliability whenever it was necessary to interpret ambiguous or incomplete data from the references.

This study developed as a by-product of another EBA project with which Ms. Minning was significantly involved. In 1987 EBA completed a study of the feasibility of developing granular borrow resources from the bed of the Mackenzie River. As part of that work, it was necessary to review some of the data referenced herein and to consider some of the same regional supply concerns. Riverine borrow prospects identified in EBA (1987) have not been included in this report, which focuses on conventional terrestrial deposits, unless they have been previously referenced or are being exploited.

The work of Hardy and Associates (1978) Ltd. in a report of the granular borrow deposits in the Lower Mackenzie Valley is acknowledged. Wherever it has been reasonable to do so, EBA's report for the Upper Mackenzie Valley has adopted a format similar to Hardy (1986) for the lower valley so that these studies can be used together with the least amount of confusion. Almost 1100 deposits have been catalogued as a result of these two studies.

1.3 STUDY OBJECTIVES

The purpose of this study was to summarize in one report, data pertaining to the granular resource potential of the Upper Mackenzie Valley. This data was available in a variety of studies compiled by government, pipeline and highway agencies. In order to accomplish this, the following objectives were initially set out:

a) Identify, locate and review published and unpublished reports relating to surficial geology and granular materials of the Upper Mackenzie Valley.

b) Locate on a series of 1:250,000 maps granular deposits, potential quarry sites and existing pits described in these reports.

c) Condense into one entry data from various reports that are related to a single deposit.

d) Assign each deposit a unique identification number.

e) Summarize the previously documented characteristics of each deposit including quantity of material information.

f) Summarize the previously documented development history and/or development constraints (environmental) that have been identified for each deposit.

g) Provide additional geologic and geomorphic data which can be readily interpreted from the reports and maps.

h) Assess the level and reliability for the existing data.

i) Assign a priority for further study to each deposit.

j) Identify local and regional supply and demand balances for granular materials with specific attention to the communities.

k) Develop a dBase III database file for the summarized information and provide diskettes.

l) Prepare this project overview report including recommendations arising from the study.

2.0 THE STUDY AREA

2.1 THE UPPER MACKENZIE VALLEY

The study area which is approximately 780 km long and 130 km, covers the Upper Mackenzie River Valley and adjacent terrain between Norman Wells in the north and Fort Providence in the south. In the northern portion of the study area, the western boundary is formed by the Mackenzie Mountains and the eastern boundary is situated slightly east of the Franklin Mountains. In the south and east, beginning at Camsell Bend, the study area broadens and is bounded on the north by the Ebbutt Hills and Horn Plateau and on the south by the Alberta Plateau.

The geologic setting of the study corridor is described below relative to the physiographic regions and subdivisions which occur within the study area. Physiographic subdivisions are areas of similar geomorphic and geologic features which are distinct from the adjacent region. The types of granular deposits and bedrock borrow sources within each physiographic subdivision are directly related to the surficial and bedrock geology.

Figure 1 shows the physiographic subdivisions and the outline of the study area. The 1:250,000 scale maps which are presented in Appendix C, (in pockets with this volume) show in more detail some of the geographic features which are referred to in the discussion of the physiographic subdivisions below.

2.2 GEOLOGIC SETTING

2.1.1 Mackenzie Plain

The Mackenzie Plain is a physiographic subdivision of the Cordilleran Region. It lies west and south of the Franklin Mountains and east of the Canyon Ranges of the Mackenzie Mountains. The Mackenzie River is located toward the eastern side of Mackenzie Plain near the Franklin Mountains. The western portion of the Mackenzie Plain adjacent to the Mackenzie Mountains is a dissected piedmont while the area near the river has the characteristics of a flat plain before an abrupt slope change east of Norman Wells at the base of the Franklin Mountains. Local relief throughout Mackenzie Plain varies but a difference of 915 m to 1219 m between the river and the mountains over a distance of 6.5 km to 8 km is not uncommon.

Mackenzie Plain is underlain by soft mudstone, shale, and sandstone of Upper Devonian and Lower Cretaceous age. Locally Devonian carbonates form resistant benches parallel to the Franklin Mountains. Bedrock outcrops are found near the Franklin and Mackenzie Mountains, in deeply dissected piedmont areas, and along major rivers. Along the Mackenzie River outcrops are more common in the northern portion of Mackenzie Plain. In a small basin near Great Bear River, there are Tertiary sand and gravel deposits lying unconformably on Lower Cretaceous to Middle Devonian strata.

Bedrock is overlain by a covering of glacial and postglacial deposits. Fine-grained morainal and glaciolacustrine deposits are the most common surficial materials in lowland areas. Glaciolacustrine silts, fine sands, and clays are most commonly at ground surface below 150 m a.s.l. and are 10 m to 60 m thick. At some localities in southern Mackenzie Plain these thick glaciolacustrine materials can be found up to elevations of 300 m. Beach ridges formed at the shorelines of the glacial lake that occupied the Mackenzie Valley and occur at 150 m a.s.l. near Norman Wells.

Morainal deposits of silty clay till (<20 percent gravel) underlie glaciolacustrine materials and are at ground surface above the glaciolacustrine plain inland from the Mackenzie River Valley.

Glaciofluvial deposits overlie morainal deposits upslope of the glacial lake deposits. These deposits consist mostly of sand and gravel and form plains, terraces, eskers, kames, and abandoned meltwater channel landforms.

Postglacial activity of the Mackenzie River and its tributaries have reworked some of the glacial deposits into alluvial plains and terraces. Winds have reworked fine-grained glaciolacustrine deposits and formed dunes. Postglacial erosion has formed colluvial deposits on steeper slopes.

Drainage on the flat lying Mackenzie Plain is generally poor and as a result recent organic materials have accumulated in some areas. Permafrost is discontinuous in the fine-grained materials south of Willowlake River and fairly continuous in poorly drained fine-grained material north of this river. There is little evidence of permafrost in well drained granular deposits in this area.

A dense, well integrated drainage network is present in Mackenzie Plain. Some streams flow, into the Mackenzie, off the adjacent piedmont, uplands, and Mackenzie Mountains to the west and others cut across the Franklin Mountains from plains to the east. Many of these rivers have sand and gravel beds and during glaciation they carried coarse-grained glaciofluvial materials.

2.2.2 Franklin Mountains And Mackenzie Mountains

The Franklin Mountains and Mackenzie Mountains (Canyon and Backbone Ranges) are subdivisions of the Cordilleran physiographic region. These mountains consist of thrusted and folded ridges of cliff forming Middle and Upper Devonian limestone and dolomite. Some Devonian shale and anhydrite are also present. Ordovician and Silurian carbonates are exposed in the crest of the Franklin and Mackenzie Mountains. At some locations within the mountain ranges older bedrock units including Cambrian shales and evaporites are also present.

A thin veneer of morainal and/or colluvial material covers the bedrock in the Franklin Mountains and Canyon Ranges of the Mackenzie Mountains which are just west of the study area. Alluvial fans of coarse and fine-grained material occur where streams flow out of bedrock gorges. Talus slopes often occur at the base of cliffs and in some cases where ice contents are high rock glaciers form. In less rugged portions of the mountains morainal deposits are thicker and are often overlain by organic deposits.

Surface drainage in the Canyon Ranges and Franklin Mountains is variable. In rugged and ridged areas, drainage is good to excellent and small streams and larger rivers flow toward the Mackenzie basin. Some poorly drained flatter areas are also present between the major ridge areas within the mountains. Recent lacustrine soils have accumulated in some of these lower areas and thicker organic deposits are common where poorly drained fine-grained morainal and/or glaciolacustrine materials are present.

2.2.3 Great Slave Plain

The Great Slave Plain physiographic subdivision occurs within the Interior Plains physiographic region. In the study area it begins just east of the Mackenzie River in the vicinity of River-Between-Two Mountains. This flat to rolling plain is underlain primarily by Upper Devonian shale, mudstone, siltstone, and sandstone of the Fort Simpson Formation. Shallow gently dipping Upper Devonian limestone is also present on the south side of the Mackenzie River in the vicinity of the Mackenzie Highway. Upland plateau within Great Slave Plain, including Ebbutt Hills and Horn Plateau, are comprised of Upper Cretaceous shale and sandstone which lies unconformably on Devonian formations.

Bedrock in the Great Slave Plain is covered primarily by surficial deposits of morainal and glaciolacustrine origin. Morainal deposits of silty clay till (<20 percent gravel) covers much of the area between River-Between-Two Mountains and the Mackenzie River. These are also the most common deposits south of the Mackenzie Highway where it trends east-west just east of its junction with the Liard Highway. Till in morainal deposits is from 3 m to 25 m thick and sometimes contains concentrations of boulders. Locally, thick organic deposits have formed in depressions on the surface of the till plain.

In the vicinity of the Mackenzie River Valley, glaciolacustrine silts, clays, and sands deposited in Glacial Lake McConnell cover the morainal deposits particularly below elevation 240 m. Most of the glaciolacustrine plain is poorly drained and covered with thick organic deposits. Glaciolacustrine materials range in thickness from 6 m to 24 m. In some localities (eg; east of Fort Simpson), glaciolacustrine materials have been reworked by the wind into sand dunes that are 6 m to 9 m high. Coarse granular beach deposits which marked the edge of Glacial Lake McConnell are present between elevation 215 m and 240 m both north and south of the Mackenzie River.

Alluvial and glaciofluvial deposits containing silt, sand, and gravel are located in terraces along the banks of the Mackenzie, Liard, and Trout Rivers and Jean Marie Creek. Glaciofluvial deposits overlying morainal materials are scattered throughout the Great Slave Plain and are fairly extensive between Willowlake River and River-Between-Two Mountains. Large glaciofluvial deposits are also common along the east-west trending escarpment southeast of Fort Simpson.

Much of the Great Slave Plain is poorly drained because the terrain is flat and surficial materials are fine-grained. Thick organic cover has developed on the fine-grained materials and in many areas, water flows along fen filled shallow drainageways. Major rivers include the Mackenzie, the Liard, the Trout, the Willowlake, the Redknife, the Harris, and Jean Marie Creek.

2.2.4 Great Bear Plain

The Great Bear Plain touches a small portion of the east side of the study area just east of the Franklin Mountains. Sedimentary bedrock of Mesozoic age forms the rolling surface that is generally under 300 m in elevation. A few subcircular plateau and hills rise above this to elevations of 450 m. The south facing escarpment of the Cartridge Mountains forms the southern boundary of the Great Bear Plain.

Surficial materials on Great Bear Plain are similar to those of Great Slave Plain. Morainal materials are most common at ground surface. Scattered glaciolacustrine, glaciofluvial, and alluvial deposits are also present. Organic deposits have formed where poorly drained fine-grained materials are present.

2.3 PERMAFROST

The study area lies entirely within the discontinuous permafrost zone. South of Ebbutt Hills permafrost is not widespread and its occurrence is related to the presence of organic cover, poor drainage, elevation, and fine-grained material. North of and including Ebbutt Hills permafrost is widespread and unfrozen areas are associated with old burns, well drained terrain, water courses and springs. Some types of granular deposits are higher, well drained and permafrost free; whereas others, such as alluvial plains and channel deposits are poorly drained and permafrost is a concern.

Mackenzie Plain, Great Bear Plain, Franklin Mountains, Mackenzie Mountains, and northern Great Slave Plain are within the zone of widespread discontinuous permafrost. Permafrost is present in fine-grained materials and may occur at variable depths in coarse, granular deposits. Ice contents for permafrost in these granular deposits is low. The active layer ranges of 0.3 m to 1 m but may reach 3.5 m in coarse-grained materials.

South of Wrigley the active layer is substantially thicker on south facing slopes than in surrounding terrain. Ground ice is common in fine-grained till (morainal deposits) and glaciolacustrine sediments, especially if they are insulated by organic material and are poorly drained. Till may contain ground ice as irregular seams with up to 25 percent ice by volume in the top 1.5 m to 3 m. Ice contents in till generally decrease with depth. South of Wrigley permafrost may be sporadic in areas overlain by less than 1.2 m of organic cover. Glaciolacustrine sediments are generally ice rich and are very sensitive to thermal degradation, especially where the surface organic cover is thin or has been disturbed.

Outcropping bedrock in the Norman Wells and McConnell Ranges of the Franklin Mountains and the Canyon Ranges of the Mackenzie Mountains has minimal ice content while debris overlying bedrock may exhibit low to medium ice content. Permafrost is also present in talus slopes, alluvial fans, and rock glaciers found at the base of mountain slopes.

The Great Slave Plain, south of Ebbutt Hills, lies in that part of the discontinuous permafrost zone where unfrozen areas are more widespread. Permafrost is generally restricted to morainal and glaciolacustrine areas that are poorly drained and underlie boglands, although ground ice has been found in well drained glaciolacustrine sediments. Boglands include elevated organic terrain that contains ground ice in contrast to fenlands which are unfrozen. South of Ebbutt Hills many areas of bogland are undergoing thermokarst erosion and becoming fenland. Throughout this area, material in till ridges and hummocks is generally free of permafrost.

3.0 DATA EVALUATION AND PRESENTATION

3.1 INFORMATION SOURCES

The study began with an extensive review of existing published and unpublished information. Approximately 50 references were reviewed. Many of the reports prepared for DIAND and various pipeline consortiums were obtained through EBA Engineering Consultants Ltd. and GVM Geological Consultants Ltd. or at the library of the Institute of Sedimentary and Petroleum Geology of the Geological Survey of Canada in Calgary. Information on granular materials used in regard to construction of the Mackenzie Highway was collected at the offices of Public Works Canada (PWC) in Edmonton, Alberta and from the Government of the Northwest Territories, Department of Public Works and Highways (GNWT, DPW&H). Information regarding granular deposits exploited for the Norman Wells Oil Pipeline was obtained from Interprovincial Pipelines Ltd. (IPL), Edmonton, Alberta.

A complete list of all references is presented in the bibliography in Appendix A, in two formats. Appendix A.1 lists the reference by number according to the cross-referencing system used on the table in Appendix B. Appendix A.2 presents the references in a more conventional bibliographic format.

3.2 PROPOSED BORROW MANAGEMENT AREAS

In the Hardy (1986) report for the Lower Mackenzie Valley, seven borrow management areas (BMA) were proposed. Borrow management areas were defined on the basis of physiographic and geologic features, and supply and demand information. In this present report, following the format of

Hardy (1986), five new borrow management areas (BMA 8 through BMA 12) are proposed for the Upper Mackenzie Valley (see Figure 2). The northernmost borrow management region in the Upper Mackenzie Valley is a continuation of BMA 7 of the Hardy study. Table 1 describes the characteristics of each borrow management area.

Prior to defining the boundaries for these borrow management areas, contact was made with territorial and federal officials to obtain information on established resource management regions for the upper part of the valley. Although the Environmental Guidelines for Pits and Quarries (MacLaren Plansearch, 1982) suggests the DIAND had established Resource Management Areas, these do not seem to be in effect for granular resources, although there is some local jurisdiction for each of the communities. The proposed borrow management areas, therefore are not in conflict with any known jurisdictional boundaries.

3.3 DEPOSIT IDENTIFICATION

The summary table presented in Appendix B lists and describes each of 762 deposits that have previously been identified within the study area. The deposits are presented numerically for each proposed management area. The site number, in Appendix B, includes a prefix for the borrow management area in which the deposit lies and a suffix for the individual source number. On the maps in Appendix C, an additional piece of information describing the class of material which occurs in the deposit is also included.

The source numbers generally increase from north to south on the east side of the Mackenzie River then north to south on the west side of the Mackenzie River. The classes of material, as described on the Legend with the 1:250,000 maps range from Class (1) to Class (4) for excellent to poor granular borrow. Class (5) identifies bedrock suitable for quarry development and Class (NG) describes fine-grained and cohesive (nongranular) soils which have limited potential for development.

Wherever possible, the outlines of these deposits were transferred from the original topographic or photomosaic base maps to the 1:250,000 scale maps presented in Appendix C. In some reports, particularly in-house reports of PWC or pipeline borrow studies, deposits were indicated as a pit at a specific kilometre post along the right-of-way. These deposits are indicated as a dot on the 1:250,000 maps.

As noted above, Borrow Management Area 7 is a continuation of one proposed in Hardy (1986). In that report, 52 deposits were described in BMA 7. There is a small zone of overlap with this report. Deposits 7.043 to 7.052, presented herein, correspond to Deposits 7.43 to 7.52 in Hardy (1986). There are some changes in the details for these deposits.

3.4 DEPOSIT DESCRIPTION

The physical and developmental characteristics of individual granular deposits and bedrock borrow sources are compiled in a summary table which comprises Appendix B and is presented in a second volume. A comprehensive legend preceeding the table provides a description of the type of information in each column. The comparison of geographic, geologic, geotechnical, and developmental information from various sources was used to evaluate the data reliability, to develop an overall assessment of the deposit, and to determine further study priorities. These observations are recorded for each deposit on the table.

It should be recognized that these interpretations are based on data from several of the original reports, if possible. A cross-reference list is provided to identify the site numbers used in the various studies which previously reported on the deposit.

4.0 REGIONAL ASSESSMENT

4.1 BORROW MANAGEMENT AREA NO. 7

Borrow Management Area 7 extends northward beyond the area addressed in this report. In Hardy (1986) 52 deposits were identified in BMA 7. With this present report, the number of deposits in BMA 7 has been expanded to 175. There is an overlap between the two reports for Deposits 7.043 and 7.052.

From Norman Wells southward, along the pipeline and proposed highway corridor, BMA 7 extends approximately 70 km. To the north it extends approximately 110 km. Along the southward leg of the corridor, between the river and the mountains, 82 potential granular deposits have been mapped and several of those are composite ones (separate deposits of common geologic origin that are grouped together under one site number). Outside of that segment of the main corridor, only 37 deposits have been mapped. Clearly, the distribution of deposits is proportional to the level of exploration effort. Only the largest and most obvious deposits outside the main valley have been identified.

Norman Wells is the only community in EBA's portion of BMA 7. Hardy (1986) reports that the community has requirements for about 200,000 m^3 of granular borrow over the next few years and Transport Canada will require an additional 100,000 m^3 during 1988/89 for airport work. It is also anticipated that there will be local oilfield related requirements which have not been defined.

Most of the material supplied to Norman Wells comes from the quarry (Source 7.057) and nearby gravel pits (Source 7.058). Both of these were exploited during the Norman Wells Expansion Project by ESSO and its contractors, in the early 1980's. Although the quantities for material removed were not available for inclusion in this study, it is known that a large portion (1.8 million m^3) of the borrow used on the project was obtained by dredging the riverbed (EBA, 1987). Therefore it is expected that a considerable volume of material remains in these sources and they will adequately meet future local requirements.

4.2 BORROW MANAGEMENT AREA NO. 8

This relatively small region has been separated because of its unique physiographic and geologic nature. It is an area in the Mackenzie Valley where the mountains are not close to the river. Therefore the depositional energy of fluvial and glaciofluvial processes has been less; consequently the granular materials are finer.

Sixty-six deposits have been identified within the region, although the level of study is obviously much greater along the pipeline and proposed highway corridors than elsewhere. There are several good prospects in this area for development. With the exception of Deposits 8.002 (3) and Deposit 8.009 (2), however, the others are quite far from the main Mackenzie corridor and on either side of the river. The former is an important local source for Fort Norman and although Deposit 8.009 has been previously developed, there was no data available to indicate its quantity status.

Fort Norman is the only community in BMA 8. It is located just south of the boundary with BMA 7 which has been set to coincide with the Great Bear River. In EBA (1987) it was identified that Fort Norman would require approximately 10,700 m^3 of granular borrow over the five year period of 1987-91. Deposits 8.001 and 8.002 appear to be the primary sources developed for the town. Source 8.001 which contains poor Class 3 material, has been identified as the airport borrow deposit. Apparently the high water table and low quality restrict the potential of the source.

Deposit 8.002 appears to be the community's main source of coarse granular materials. The information available for this study suggests that only 5,000 m^3 of material are available from this source and that it is accessible only during periods of low water level on the Mackenzie River. If these comments are correct, the security and quality of long term supply is doubtful.

There are several alternate source areas in BMA 7 that could be developed to supply Fort Norman. Deposits 7.154 and 7.155 on the west side of the Mackenzie River are both reported to have excellent quality material (Class 1 and Class 1-2, respectively). Also, Deposit 7.101 (Bennett Field Deposits at St. Charles Rapids) is an unproven prospect with a highly rated potential. Although it is quite a distance away, the site probably could be serviced by barge at a competitive cost (see EBA, 1987).

4.3 BORROW MANAGEMENT AREA NO. 9

BMA 9 is comprised literally of three separate regions. There is one concentration of potential deposits along the heavily mapped pipeline/highway corridor. There is a second large area with widespread deposits on the eastern margin of the mapped area. The third region includes the three major alluvial trains along the Keele River (Deposits 9.72-9.73), Redstone River (Deposits 9.76-9.83) and Dahadinni

River (Deposit 9.86) on the west side of the Mackenzie River. Overall 98 deposits were mapped in BMA 9.

Generally there appears to be an acceptable distribution of better quality deposits along the pipeline/highway corridor. Most of those deposits to the east of the valley are also thought to be of good to excellent quality. West of the river the best deposits are found near the mountains. The Keele River alluvium does not seem to be as good as the Redstone or Dahadinni alluvium.

In BMA 9 there are no communities for which local supply is an issue.

4.4 BORROW MANAGEMENT AREA NO. 10

A total of 175 potential sources of granular material have been identified in BMA 10. Approximately 85 of these are in the pipeline/highway corridor, down the east side of the Mackenzie River and west of the Franklin Mountains. For the northern-most 45 km extending south from Blackwater River almost to the Ochre River, the quality of material is generally poor and bedrock sources might be feasible if Class 1 or 2 granular is needed. Otherwise there would seem to be plenty of granular prospects located at a reasonable spacing.

As with the other borrow management areas, there is a scarcity of detailed data for areas west of the Mackenzie River and east of the Franklin Mountains. Both these areas appear to have several large, high quality deposits and it is likely that detailed work would identify many smaller useable deposits for local projects.

In BMA 10, Wrigley is the major community. It is located within the boundaries of Deposit No. 10.042 which provides Class 1 material. Three pits have been previously developed within the deposit, although the one at the west end of town has been depleted. The quantity data suggests that there should be over 7.5 million m^3 remaining in the deposit.

Transport Canada have not indicated that they will need any material at Wrigley; whereas, PWC have a stockpile of 50,000 m^3 to 60,000 m^3 nearby. EBA (1987) reported that the community will need a total of 22,900 m^3 of granular material over the next five years. It would seem that Wrigley is well off in this regard.

4.5 BORROW MANAGEMENT AREA NO. 11

In this rather large area, 238 potential borrow sources have been compiled. Unfortunately it is a region where Class 1 and 2 materials are at a premium. Most deposits have a very high sand to gravel ratio and many of those with significant gravel are noted to be in environmentally sensitive settings, such as active alluvial channels.

The pipeline and highway corridors split up where the highway crosses the river, approximately 70 km northwest of Fort Simpson. The IPL pipeline remains on the right bank of the river; whereas, the highway parallels the left bank. On the highway side of the river, Deposit 11.022 (Class 2) should be checked out as a potential source in an area critically deficient in gravels. Similarly, Deposit 11.188 (Class 2) would appear to be more valuable than most. In between these two, over a distance of 135 km, there is not much from which to choose for gravel. Deposit 11.157 (Class 2-3) Deposit 11.141 (Class 2-3) and Deposit 11.164 (Class 2-3) have potential but all are subject to environmental restrictions. On the right (north) bank across from Fort Simpson, Deposits 11.71 and 11.72 (Class 2-3) should be considered for gravel sources.

The use of nongranular soils for general fill and roadway embankment construction in BMA 11 has been successful and necessary. The lack of permafrost in areas of higher, well drained mineral soil has been fortuitous. Approximately 70 nongranular sources are included in the potential sources listed.

Within BMA 11, Fort Simpson is the main community. Anticipated granular borrow use for that settlement was estimated to be 10,000 m^3 to 20,000 m^3 per year (EBA, 1987). PWC identified, a year ago, that 63,000 m^3 were stockpiled in the area for the highway and that an additional 10,000 m^3 to 60,000 m^3 were required.

Around Fort Simpson there are few sources of Class 2 or better material. Source 11.168 (Class 4) has been specified for community use although the quality appears poor (very fine sand) and it is on sensitive terrain. No quantity and very little test data was available to substantiate its worth. Source 11.169 (Class 4) contains three abandoned pits and has become an area of new town development. Source 11.170 (Class 2) appears to be the town's main borrow source for quality material, although its development may pose some risk to fish populations in the mouth of the Liard River. As an alternate, Deposit 11.188, located approximately 45 km south of Fort Simpson, on the highway is a developed source for Class 2 materials. None of the other nearby sources appear suitable for major development although several have been previously worked for local borrow supply..

The quantity of material in Source 11.170 may be as high as 380,000 m^3 (all grades) however only 75,000 m^3 are listed as Proven Reserves. If the previous estimate of annual consumption is correct, there are less than four years of Proven Reserves remaining. It is therefore recommended that the supply-demand situation for Fort Simpson be examined more closely.

The community of Jean Marie River, located approximately 53 km southeast of Fort Simpson, also is situated in BMA 11. EBA (1987) reported that the community would require as much as 12,900 m^3 of granular borrow between 1987 and 1989. The nearest mapped deposit is 11.202 (Class 4-NG) which contains the community's stockpile. As a source, however, it is reported to be depleted. The stockpiled granular is apparently brought in each winter, probably from Deposit 11.188 on the Mackenzie Highway. There are two other possible sources nearby. Deposit 11.072 (Class 2-3) is located 4 km north of the community on the opposite side of the Mackenzie River and Deposit 11.203 (Class 2-3) is located 11.5 km inland, to the south - southwest. The latter is reported to contain about 1.2 million m^3 of good material, however it is located within the active channel of Jean Marie Creek and is an environmentally sensitive area.

4.6 BORROW MANAGEMENT AREA NO. 12

The references available for this study indicated that the most southerly area in the Mackenzie Valley includes 52 deposits of potential borrow materials. Many of these were identified for the highway by PWC, however drawings to show their precise location were unavailable. The map (Sheet C-4, Appendix C) indicates that there is an irregular distribution of potential borrow sources in this area. Along the Mackenzie Highway there are some large sources of good quality material which have been delineated but otherwise there are large tracts with no borrow sources. This may be misleading because the region east of 118° Longitude was not included in previous major granular materials explorations. For example, the bedrock escarpment south of Kakisa Lake has not been identified as a granular or bedrock source but it is clearly an extension of Deposit 12.46.

Fort Providence is the main community in the region. There are four potential deposits within 15 km of Fort Providence. Deposits 12.07, 12.09, 12.10 and 12.11 are on the same side of the Mackenzie River and another Deposit 12.08 is nearby but across the main channel of the river. Deposit 12.09 is reported to have been depleted and another Deposit 12.10 is nearly depleted.

Deposit 12.11 (Bluefish Creek Pit) is apparently the main local source, although it has been used to supply material to PWC for the highway, as well. The available data suggests that its volume was 56,000 m^3 with no indication of how much has been removed. No borehole, test pit or testing data could be found to justify the quantity or quality estimates. Similarly, it was not possible to confirm the potential of Sources 12.07 and 12.08 which may be required in the future.

Information collected by EBA (1987) indicated that the community of Fort Providence would require 18,300 m^3 of granular borrow between 1987 and 1991. It was also indicated that Transport Canada would need 8,000 m^3 for airport work. There was no indication of potential borrow demand for highway construction from local deposits.

It appears likely that there are sufficient reserves available in the Fort Providence area to meet short to moderate term requirements. The data which was used to prepare this report however, may be somewhat incomplete. It is recommended, therefore, that a specific review be completed by obtaining borehole and/or test pit data, laboratory test data and quantity information from local authorities or pit operators. Further efforts to quantify future highway construction and maintenance requirements are also needed.

5.0 SUGGESTIONS FOR FUTURE WORK

5.1 SUMMARY OF MAJOR USERS

5.1.1 Mackenzie Highway

Maintenance of the Mackenzie Highway up to Wrigley will continue to require a large volume of granular borrow materials. Prior to 1988, PWC had their own inventory of prospective and actual pit sites along the road. Now that responsibility for the highway has become a matter of territorial jurisdiction, it is evident that the inventory must be reviewed and updated. Likely one of the first intensive uses of this report will be for that purpose.

In EBA (1987) a summary was presented from PWC sources of the overall highway requirements. It is repeated here.

1) Fort Providence to Fort Simpson - no information available

2) Fort Simpson Area - 63,000 m^3 in stockpiles
   - 10,000 m^3 to 60,000 m^3 more required

3) Hardie River to River-Between-Two Mountains - PWC were (winter '87) searching for additional gravel

4) Willowlake River Area - 69,000 m^3 in stockpiles
   - 10,000 m^3 more required

5) Wrigley Area - 48,000 m^3 in stockpiles
   - 10,000 m^3 more required
   - a new pit was under development

The scale of this study is inappropriate for looking at specific sections of the highway to determine if there are sufficient reserves of the quality required. Generally it appears that the highway needs are being met from local sources except in the area south of the River-Between-Two Mountains.

5.1.2 Pipeline Requirements

The existing Normal Wells (IPL) pipeline was built using a relatively small volume of granular borrow in proportion to native nongranular borrow. Hardy (1986) indicated that Interprovincial Pipelines used only 450 m^3/km. It is understood, however, that remedial works since construction have required considerably more material than was forecast. The distribution of sites needing granular soils for repairs is not known.

Gulf Canada and others recently have been examining the concept of an oil pipeline down the Mackenzie Valley from the Beaufort Sea. A gas pipeline has also been proposed by Polar Gas from Taglu and the Parsons Lake area in the Mackenzie Delta. Likely these would follow the previously examined corridor on the east side of the Mackenzie River through the Lower Mackenzie Valley and would parallel the Norman Wells (IPL) pipeline in the Upper Mackenzie Valley.

There are a wide range of estimates for the quantities of granular materials required to construct a pipeline. On the low end is the history of IPL's Norman Wells line which required only 450 m^3/km to construct (Hardy, 1986) and an estimated 50 - 100 m^3/km to date for remedial works. Gulf Canada estimated a need for about 2,000 m^3/km for an oil pipeline (EBA, 1987) and Canadian Arctic Gas estimated requirements of 4,000 m^3/km (EBA, 1980) for a large (1,220 mm) diameter gas pipeline. It is reasonable to expect each pipeline (if both oil and gas lines are constructed) will use between 1,000 m^3 and 3,000 m^3/km of borrow material.

5.1.3 Communities

As discussed above, a five year (1987-91) demand forecast for the main communities was presented in EBA (1987). Assuming that it is generally indicative of annual requirements, a summary is presented below, for the Upper Mackenzie Valley. The differences in requirements indicated for the communities suggests that these quantities are not too reliable.

1) Norman Wells - 40,000 m^3/year (average local use)
   -100,000 m^3 1988-89 airport development (from Hardy, 1986)

2) Fort Norman - 2,140 m^3/year (average local use)

3) Wrigley - 4,580 m^3/year (average local use)
   - 10,000 m^3 (required for highway use)

4) Fort Simpson - 10 to 20,000 m^3/year (average local use)
   - 10 to 60,000 m^3 (required for highway construction)

5) Jean Marie River - 4,300 m^3/year (between 1987 and 1989)

6) Fort Providence - 3,660 m^3/year (average local use)
   - 8,000 m^3 (required for airport modifications)

5.2 GRANULAR RESOURCE SUPPLY

It is difficult to predict where the pipeline, or highway demands will outstrip supply, based on this broad overview. In total, the Mackenzie Valley has plentiful supplies, however, the practical consideration of haul distance, alternate route, and separate right-of-ways greatly influences regional supply and demand balances. This is further complicated by environmental (fish and wildlife) constraints and access over sensitive terrain.

PWC have identified for the Mackenzie Highway that a major supply deficiency exists south of River-Between-Two Mountains. Additionally there are locations near Fort Simpson where coarse granular material for road surfacing must be transported some distance. In other regions it appears that supply adequately meets the highway requirements.

For the communities it is easier to assess the supply versus demand prospects. Norman Wells and Wrigley appear to be well supplied. Fort Norman and Jean Marie River do not have adequate local sources. Fort Simpson and Fort Providence appear to have adequate short term supplies but may be deficient in the long term supply situation. A more detailed study would appear to be warranted in each of the last four cases.

5.3 RECOMMENDATION

The following recommendations are based on the findings of this study. It is suspected that some of the concerns identified herein could be resolved with data believed to exist but which was not available for this overview. It is a failing of the present granular resource management practices that specific details concerning many existing pits and critical supplies for the communities could not be located.

1) The data available from PWC regarding the highway has been largely prepared for in-house use. As such it is widely variable in quality and documentation. The authors are aware that because of the change in jurisdictional responsibility for the Mackenzie Highway from PWC to GNWT, DPW&H, some data has been transmitted to Yellowknife, but not yet sorted and collated. It is not inconceivable that significant data could exist that was unavailable for this study.

   It is recommended that a thorough review of all related information is required to accurately locate suggested borrow sources, identify the borehole, test pit and laboratory data upon which the sites have been rated and to examine the quantity assessments that have been made. It is suspected that the level of effort that has gone into identifying borrow prospects, for in-house uses, is much lower than the level of assessment that would be necessary to prepare a definitive report.

2) It appears that PWC undertook in 1987 to identify new borrow prospects between Hardie River and River-Between-Two Mountains. The results of that work have not been made available. The database should be updated to include this new information.

3) It is suggested that highway and community demands may conflict around Fort Providence and Fort Simpson. A review of these situations is necessary.

4) In evaluating regional supply and demand, the scale of this report may be too broad. The Mackenzie pipeline-highway corridor is very narrowly confined in the Upper Mackenzie Valley north of Camsell Bend. To reliably assess the supply and demand balance for future pipelines, a narrow (say 20 km wide) strip along the valley should be

examined. This could be addressed for variable requirement rates of 1,000 m^3/km, 3,000 m^3/km and 5,000 m^3/km (for two pipelines).

5) From the work done to produce this report and EBA (1987), it is evident that pipeline and highway granular borrow evaluation data and pit withdrawal data (both during construction and for maintenance) have not been recorded in detail sufficient for the broad management of a nonrenewable resource. Resource managers should have site specific data on each deposit (Borehole, Test Pit and Lab Data) and on nearby alternate pits so that priorities can be determined and high-grading prevented. It is recommended that a system of pit management could be developed using the information presented herein as a master inventory listing and by adding more detail as it becomes available.

6) In preparing this report, the format of Borrow Management Areas proposed by Hardy (1986) was extended to Great Slave Lake. These areas were developed for physiographic and geologic reasons. The authors were unable to establish that there were any other defined jurisdictional boundaries. This apparent lack of responsibility and control could lead to wasteful or environmentally damaging resource development. It is recommended that a more formal resource management scheme be instituted.

7) There are many promising deposits mapped in the Upper Mackenzie Valley for which quantity and quality data is largely speculative (ie; prospective reserves). Within many of these the relative amounts of high quality versus lower quality material is unknown. Clearly detailed evaluation of all 762 deposits identified in the upper valley cannot be justified. However, a more reliable evaluation is required of deposits in critical or deficient areas. From comments appearing elsewhere in this report some of these are listed below.

a) Deposit 8.009 (Class 2) - previous pits but no borehole or quantity data.

b) Deposit 8.002 (Class 3) - determine security of supply for Fort Norman.

c) Deposits 7.154 and 7.155 on west side of Mackenzie and Deposit 7.101 are possible alternate sources for Fort Norman if nearby supply is inadequate.

d) Source deposits for Classes 1 and 2 material are not evident between Blackwater River and Ochre River in BMA 10. Further testing of selected deposits might demonstrate a reliable supply. Otherwise bedrock source areas should be mapped.

e) Deposit 11.022 (Class 2) - potential source of gravel in an area generally deficient in it.

f) Deposit 11.188 (Class 2) - a large deposit that appears to be critical to a regional supply. This resource should therefore be carefully managed to prevent over developing or high-grading.

g) Deposits 11.071 and 11.073 (Class 2-3) may be critical to regional supply if cross-river transport is cost effective.

h) Deposits 11.157, 11.141 and 11.164 (all Class 2-3) are subject to environmental constraints because they are located in active alluvial channels. Some baseline environmental work might be prudent, if these are ever to be developed.

i) Deposits 11.168 (Class 4) - test data to establish quantities and quality should be found or developed for this Fort Simpson supply.

j) Deposit 11.170 (Class 2) - unless there is an environmental concern for development of this deposit, further work to extend Proven Reserves should be completed.

k) BMA 12 - further mapping and testing appears to be needed to identify surficial deposits and potential bedrock sources in this region and in particular the area to the east of Kakisa Lake.

l) Deposit 12.010 - this Fort Providence source is reported to be nearly depleted. This should be confirmed.

m) Deposit 12.011 - this source is under development but data was not available to indicate volumes and/or long term supply potential.

n) Deposits 12.07 and 12.08 - no quality or quantity data was available.

8) The level of evaluation must be consistent with the extent, geology and class of material as well as a reasonable projection of the quantity of granular borrow that would be needed. It is unreasonable to create a blanket requirement for borehole, test pit and laboratory testing work for each deposit. Therefore recommendations for additional work as was included in Hardy (1986) have not been provided herein. If such information is required, geotechnical consultants, such as EBA and GVM, can provide recommendations appropriate for the specific deposit or area of concern.

9) New pits should be allowed only where or when there is a local demand that cannot be met from existing pits. Applications for new pits should be evaluated relative to alternatives in the area on a step-wise basis. Only when critical environmental, aesthetic, quality and quantity data for all deposits in the area are considered should the responsible authorities permit the development of one site rather than another. It is therefore recommended that the GNWT develop a resource management and conservation review process which outlines the expected level of effort that resource developers should satisfy prior to issuing new pits or quarries operating permits.

These recommendations are not intended to replace those in the publication Environmental Guidelines for Pits and Quarries (Macharen-Plansearch, 1982). Rather, they should compliment it, in aspects relating to pre-development assessment of a deposit and local alternates.

6.0 ACKNOWLEDGEMENTS

EBA and those responsible for this report wish to thank several individuals who have contributed to the quality of this report. First, Ms. G. Minning of GVM Geological Consultants has been instrumental in tracking down government reports and pipeline studies from the early detailed work in the corridor. Her direct knowledge of some deposits and the regional geology contributed to the accuracy of the data presented herein. Second, there is Mr. G. Prest who compiled much of the data summarized in the tables and on the maps.

We must acknowledge the help of Mr. S. Murray from the GNWT who seems to have the best understanding of recent developments in the valley's borrow requirements.

We also wish to express our appreciation to Mr. C. Yurchak of PWC in Edmonton. He was very helpful in providing in-house data relating to the Mackenzie Highway.

Finally, we wish to thank Mr. R. Gowan of INAC in Hull, Quebec for the development of the database system and general assistance on the subject of resource development and management.

7.0 CLOSURE

Most of the objectives, outlined in EBA's 1986 proposal have been met within the budget and timeframe available. A few of the original objectives have been sacrificed, however, because there were many more references and potential source areas to catalogue than was initially anticipated. With agreement from INAC, more effort was diverted into fully compiling all available data while some of the interpretive work was cut back.

This report presents the compilation of data from 762 sites in an area of slightly more than 100,000 square kilometres. The data has been compiled geographically (on maps in Appendix C) in tabular format (Appendix B, Volume 2) and on computer discs in a format suitable for dBase III retrieval and manipulation. Unfortunately the scale of the mapping and number of entries precluded all but very broad interpretation of the data. It should be possible however to use the information, presented herein, as a major resource management tool. Future studies of the granular resources of the Upper Mackenzie Valley will be much more efficient now that the diverse data from more than 50 references has been summarized.

Prepared by:

EBA ENGINEERING CONSULTANTS LTD.

REGISTERED PROFESSIONAL ENGINEER
NEIL R. MacLEOD
LICENSEE
N.W.T.

88-4-21

N.R. MacLeod, P.Eng.,
Project Director

GVM GEOLOGICAL CONSULTANT LTD.

PROFESSIONAL GEOLOGIST ALBERTA
GRETCHEN V. MINNING

Gretchen V. Minning

G.V. Minning, P.Geol.

NRM:GVM:jms

LIST OF TABLES

TABLE 1
DESCRIPTION OF BORROW MANAGEMENT REGIONS

MANAGEMENT REGION	DESCRIPTION
7) Norman Wells to Great Bear Rv.	The Franklin Mountains/Mackenzie Plain region with Norman Wells as the main community near the southern boundary of the area. This area includes portions of the Franklin Mountains, foothills of the Canyon Ranges of the Mackenzie Mountains, and the Mackenzie Plain physiographic subdivisions.
8) Great Bear Rv. to Little Smith Cr.	The Mackenzie Plain region with Fort Norman as the main community. This area includes portions of the Mackenzie and Great Bear Plains, foothills of the Canyon Ranges of the Mackenzie Mountains, and a small portion of the Franklin Mountains physiographic subdivisions.
9) Little Smith Cr. to Blackwater Rv.	The McConnell Range/Mackenzie Plain North region has no communities. This area contains elements of the McConnell Range of the Franklin Mountains, the Mackenzie Plain, and the Great Bear Plain.
10) Blackwater Rv. to Willowlake Rv.	The McConnell Range/Mackenzie Plain South region has Wrigley as the main community. This area has elements of the McConnell Range of the Franklin Mountains, the Mackenzie Plain, and the Great Bear Plain.
11) Willowlake Rv. to Trout Rv.	The Great Slave Plain West region has Fort Simpson as the main community. This area contains elements of the Camsell and Nahanni Ranges of the Franklin and Mackenzie Mountains as well as the Great Slave Plain.
12) Trout Rv. to Great Slave Lake	The Great Slave Plain East region has Fort Providence as the main community. This area lies entirely within the Great Slave Plain. To the south of both this region and Region 11 lies the Alberta Plateau.

LIST OF FIGURES

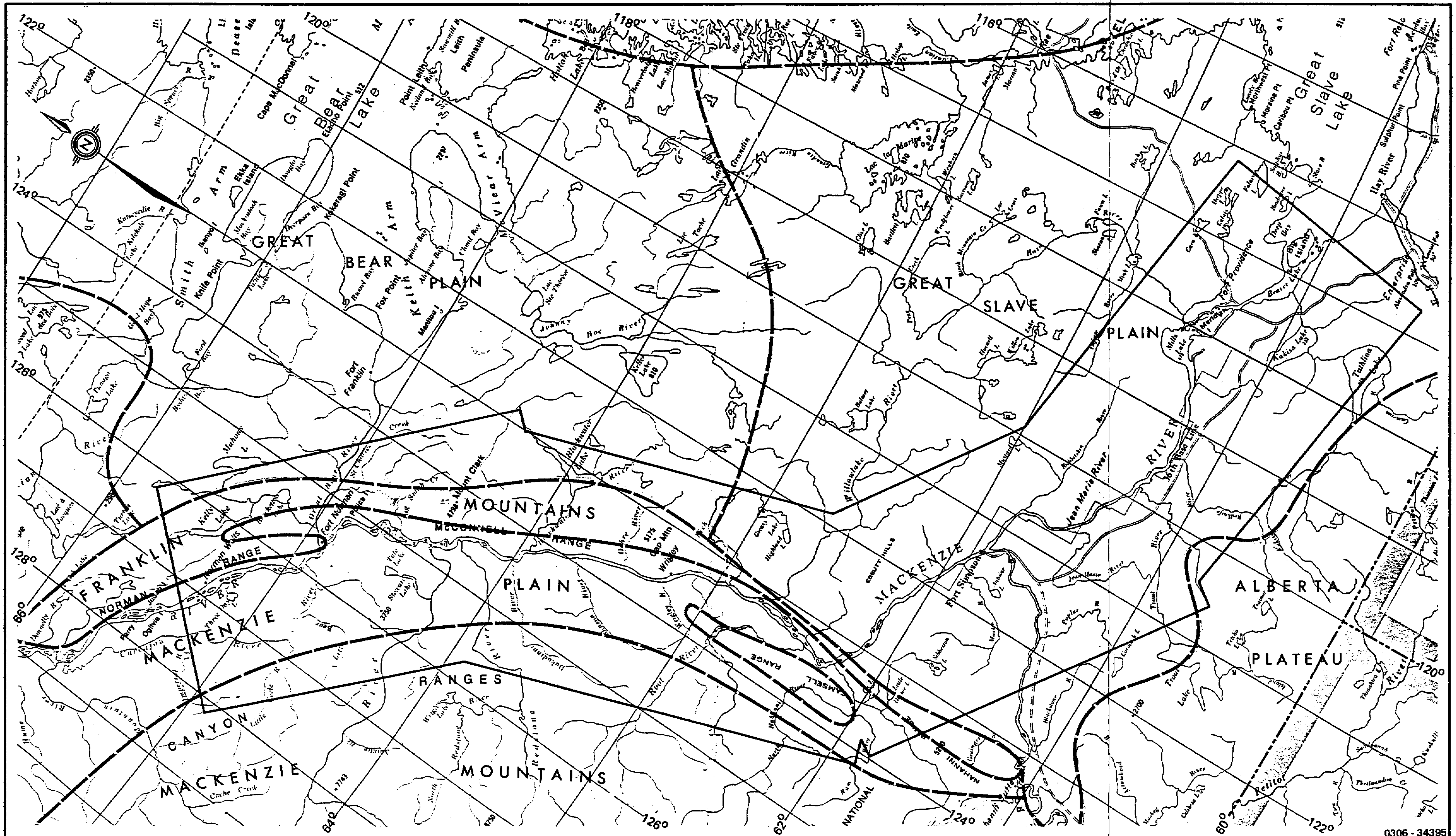

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FIGURE 1 **PHYSIOGRAPHIC REGIONS OF STUDY AREA**

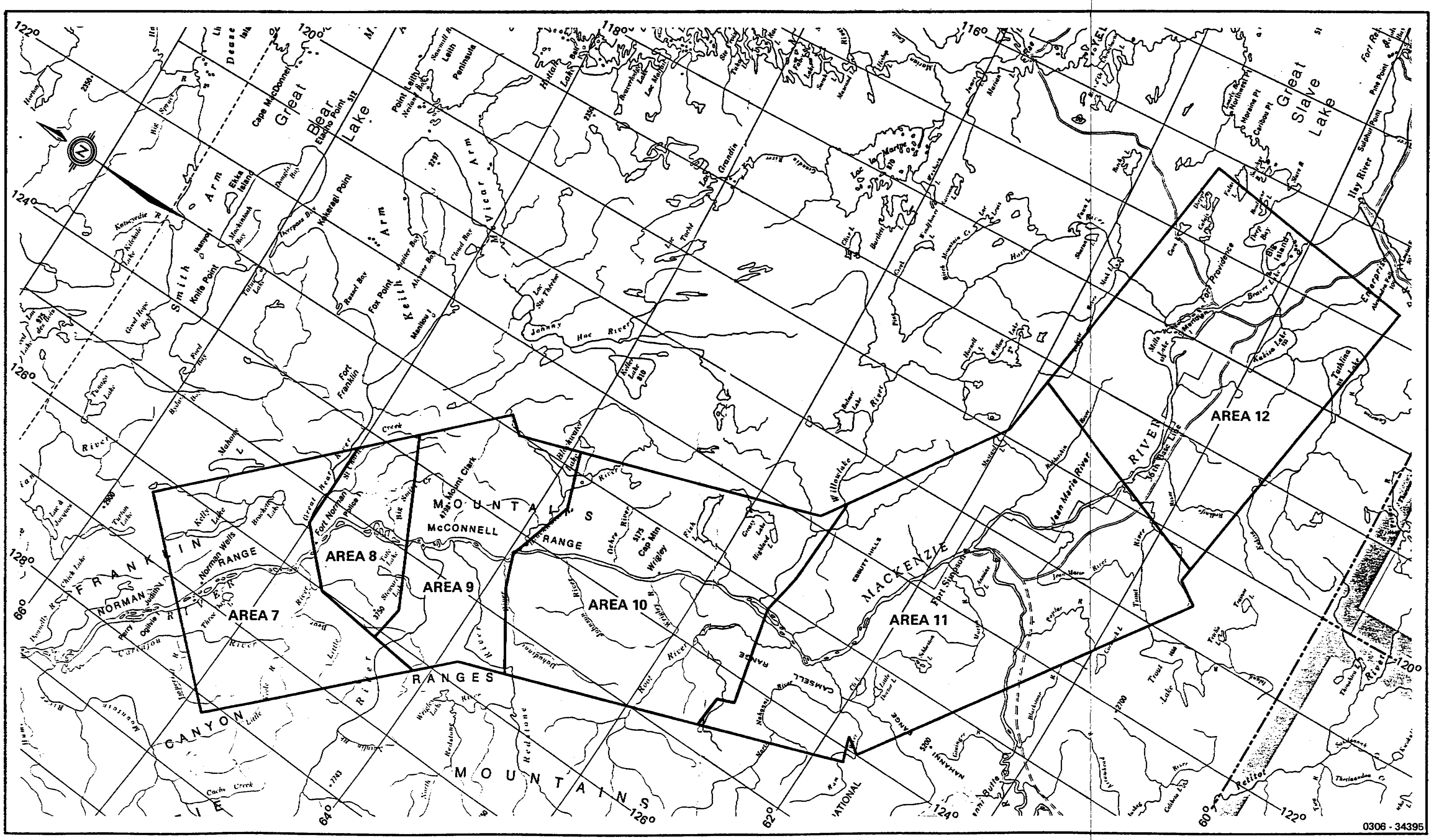

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FIGURE 2 BORROW MANAGEMENT AREAS

APPENDIX A
REFERENCE LIST AND BIBLIOGRAPHY

A.1 Listed by Cross-Reference Number

A.2 Listed in Alphabetical Format

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16 - Wrigley 95-O
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b) Red Shading - Camsell Bend to River-Between-Two Mountains (hand dug test holes, 1982 September).

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- M.P. 395 - 425
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29 - Camsell Bend 95-J
30 - Norman Wells 96-E
31 - Norman Wells - Addendum 96-E
32 - Blackwater Lake 96-B
33 - Fort Norman 96-C
34 - Mahony Lake 96-F
35 - Carcajou Canyon 96-D
36 - Grain Size Analysis from (95-N,O,K,J,G,H,I,B,A, 85-D,E)

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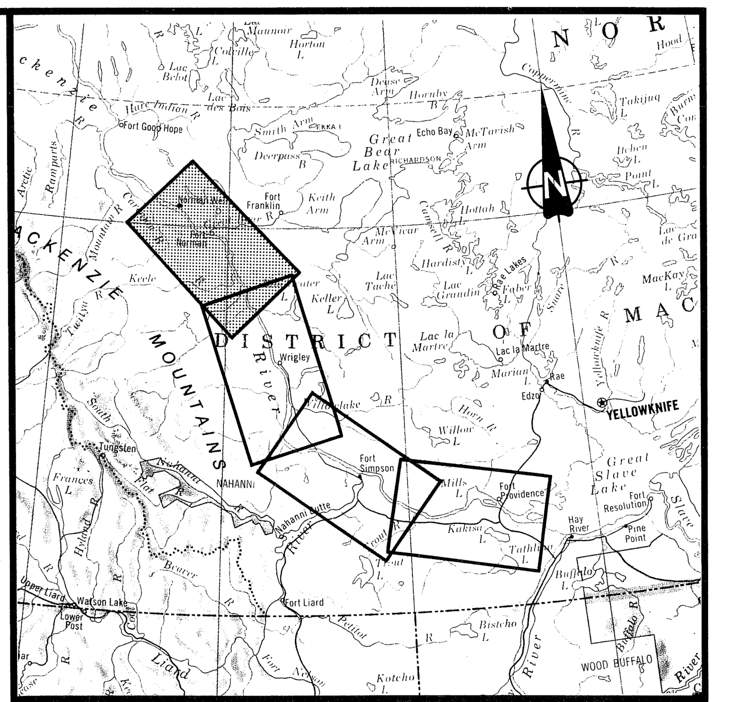
43 - Volume II - Soil Data Mile 347 to 440.
44 - Volume III - Soil Data Mile 440 to 510.
45 - Volume IV - Soil Data Mile 510 to 583.
46 - Volume V - Soil Data Mile 583 to 690.

APPENDIX B
TABULAR SUMMARY OF
PROSPECTIVE SOURCE DATA
(Refer to Report Volume II)

B.1 Legend

B.2 Summary Tables

APPENDIX C
LOCATION MAPS



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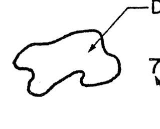
Index Map

LEGEND

BORROW SOURCE DESIGNATION



EXPLANATION OF MATERIAL CLASSIFICATION

(1) CLASS 1 - Clean, well graded, structurally sound granular material. Suitable for high quality surfacing materials or asphalt and concrete aggregate with minimal processing.

(2) CLASS 2 - Good quality granular material composed of well graded sands and gravels with limited fines. Suitable for base and surface course aggregates, embankments, or structural fill. Requires processing for concrete aggregate.

(3) CLASS 3 - Fair quality granular material composed of poorly graded sands and gravels with or without silt. Suitable for general fill.

(4) CLASS 4 - Poor quality granular material composed of poorly graded, fine sands with moderate to high silt content. Sometimes contains minor amounts of gravel. Suitable for general fill purposes only.

(5) CLASS 5 - Fair to excellent quality bedrock which is suitable for quarrying and processing into required grades of granular material.

(NG) NON - GRANULAR - Non-granular material including sands, silts, and cohesive soils. It is unsuitable for most construction purposes, except non-structural fills.

Borrow Management Area Boundary

Pipeline Route

Mackenzie Highway (proposed extension)

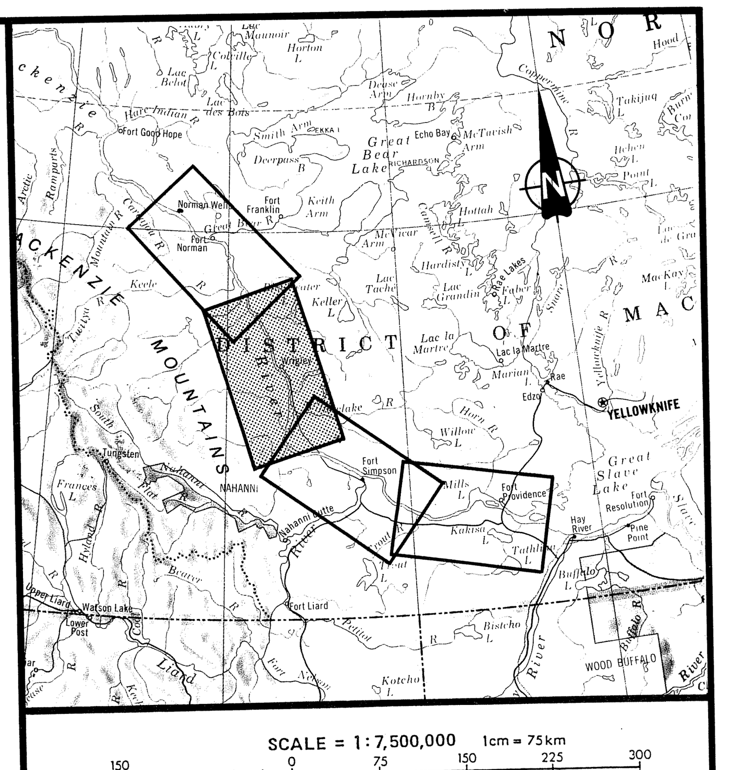
SCALE (kilometers)

Indian and Northern Affairs Canada

GRANULAR RESOURCE POTENTIAL
UPPER MACKENZIE VALLEY

Drawn GP/KV	Check GM/NM	Date Feb./88	Sheet C-1
Scale 1 : 250,000		Proj. No. 0306-34395	

EBA Engineering Consultants Ltd.
Civil, Geotechnical and Materials Engineers



SCALE = 1:7,500,000 1cm = 75km

Miles 150 0 75 150 225 300

Kilometres 150 0 75 150 225 300 375 450

Index Map

LEGEND

BORROW SOURCE DESIGNATION

7.25 (3)

- Deposit Outline
- Material Classification
- Deposit Number
- Borrow Management Area

EXPLANATION OF MATERIAL CLASSIFICATION

(1) CLASS 1 - Clean, well graded, structurally sound granular material. Suitable for high quality surfacing materials or asphalt and concrete aggregate with minimal processing.

(2) CLASS 2 - Good quality granular material composed of well graded sands and gravels with limited fines. Suitable for base and surface course aggregates, embankments, or structural fill. Requires processing for concrete aggregate.

(3) CLASS 3 - Fair quality granular material composed of poorly graded sands and gravels with or without silt. Suitable for general fill.

(4) CLASS 4 - Poor quality granular material composed of poorly graded, fine sands with moderate to high silt content. Sometimes contains minor amounts of gravel. Suitable for general fill purposes only.

(5) CLASS 5 - Fair to excellent quality bedrock which is suitable for quarrying and processing into required grades of granular material.

(NG) NON - GRANULAR - Non-granular material including sands, silts, and cohesive soils. It is unsuitable for most construction purposes, except non-structural fills.

Borrow Management Area Boundary

Pipeline Route

Mackenzie Highway
(proposed extension)

5 0 5 10 15
SCALE (kilometers)

Indian and Northern Affairs Canada

GRANULAR RESOURCE POTENTIAL
UPPER MACKENZIE VALLEY

Drawn GP/KV	Check GM/NM	Date FEB/88	Sheet C-2
Scale 1: 250,000		Proj. No. 0306-34395	

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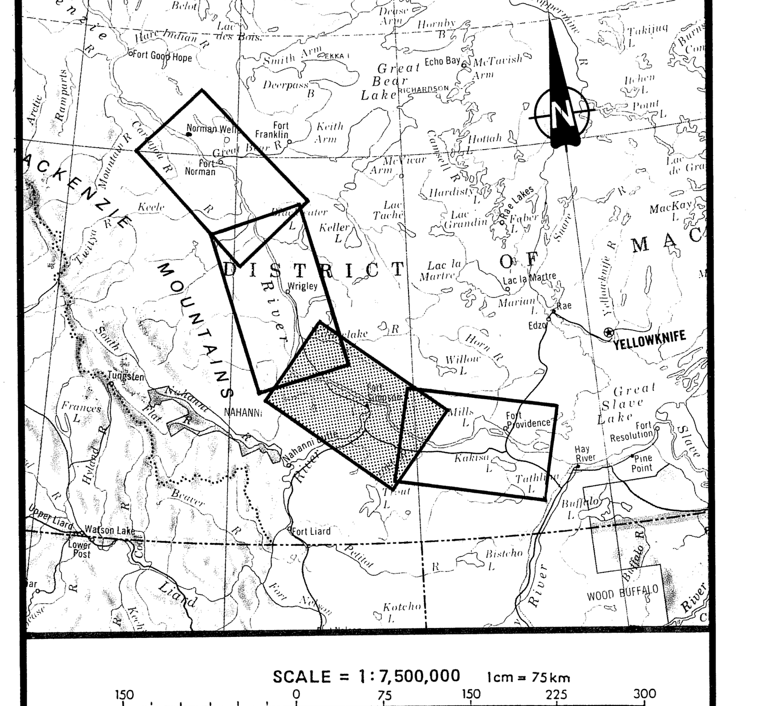

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UPPER MACKENZIE VALLEY

Drawn GP/KV	Check GM/NM	Date Feb/88	Sheet C-3
Scale 1: 250,000		Proj. No. 0306-34395	

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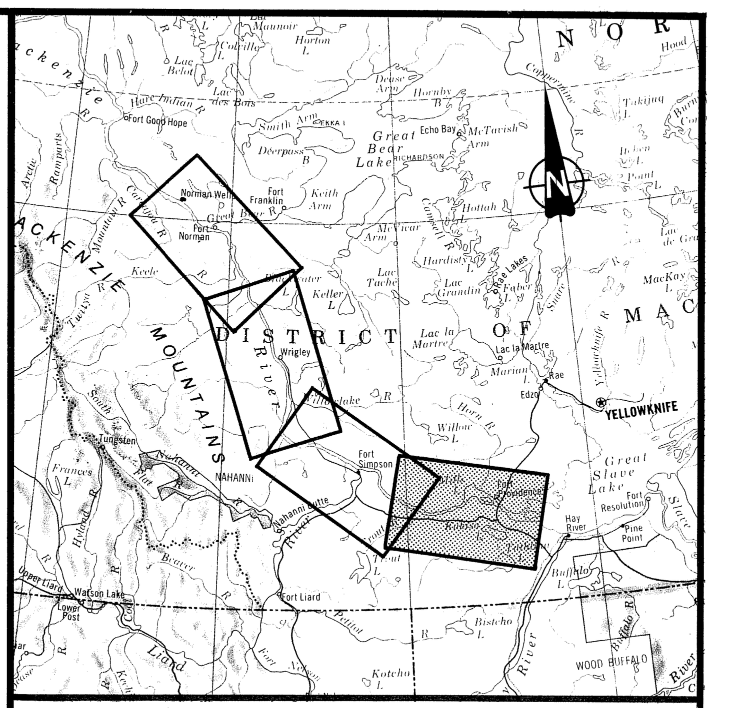

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Indian and Northern Affairs Canada

GRANULAR RESOURCE POTENTIAL
UPPER MACKENZIE VALLEY

Drawn GP/KV	Check GM/NM	Date Feb/88	Sheet C-4
Scale 1: 250,000		Proj. No. 0306-34395	

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