The Geology and Development of Northern Granular Resources

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EXECUTIVE SUMMARY

The Northwest Territories and Yukon fall within two geologically and physiographically distinct parts of Canada, the Canadian Shield and the Borderlands. Each of these areas have been affected by slightly different geologic events that have resulted in distinctive bedrock, Quaternary deposits and unique landforms. Part 1 of this report summarizes the geological events or geologic history which has occurred within the Canadian Shield and Borderlands and was responsible for forming bedrock and Quaternary deposits that are the sources of granular resources in these two areas.

Granular resources derived from naturally occurring Quaternary deposits and bedrock are necessary for private and public development projects in northern Canada. Part 2 of this report describes the detailed studies that have taken place along major transportation corridors and near existing communities to delineate and describe the principal sources of granular material.

The high per capita consumption of granular resources, shortages of specific types of material in certain geologic settings, and construction problems in northern Canada has made it is necessary to carry out both regional geological and detailed multidisciplinary studies to delineate and describe principal granular sources and their development issues. Multidisciplinary studies encompass geology, engineering, socio-economic, and environmental fields.

PREFACE

Construction material requirements for public needs and private resource development projects have led to the involvement of both federal and local government organizations and their consultants in the study and management of granular resources. The following government organizations have been engaged in granular resource projects in the north since the 1970's:

- Department of Indian and Northern Affairs (DIAND);
- Federal Department of Public Works (DPW);
- Government of the Northwest Territories (GNWT) Highways;
- GNWT Government Services and Public Works;
- Government of the Yukon Transportation Engineering Branch;
- Government of the Yukon Municipal Engineering and Lands Branch.

During that time the Geological Survey of Canada and DIAND geologists have provided these organizations with maps and reports on bedrock and Quaternary (surficial) geology. These maps and reports describe the geologic history, distribution, and general characteristics of bedrock and unconsolidated surficial sediments which constitute the primary sources of northern construction materials.

Part 1 of the present study will summarize key regional geological events, outlined in these baseline government geological publications, which affected the distribution and properties of granular sources in northern Canada. Part 2 will discuss the more site specific multidisciplinary granular studies that have further defined development issues related to the primary granular sources.

1.0 INTRODUCTION

1.1 Study Description

In 1993-1994, GVM Geological Consultants Ltd., Calgary, Alberta carried out this study which (1) summarizes the significant influences of local geology and geological processes on the existence, type, and variability of granular resources and (2) describes the multidisciplinary site specific studies which have been carried out since the 1970's to delineate and characterize these resources in areas of the north.

The study was funded by the Department of Indian and Northern Affairs (DIAND) as Contract Number 92-0173, File Number A-1632-92-0173. The Scientific Authority for the project was Mr. Robert J. Gowan, Geotechnical Advisor, Natural Resources Directorate, Department of Indian and Northern Affairs.

1.2 Location of the Study Area

The study area encompasses the Northwest Territories and Yukon Territory and covers 3.7 million sq km or approximately 40% of the land mass of Canada (Figure 1). The Northwest Territories (NWT) extends from Baffin Island at Longitude 62° West to the Yukon Territory border at Longitude 124° West. Latitude 60° North forms the southern boundary of the NWT and the coastline of Ellesmere Island at Latitude 83° North is the most northerly land area. The Yukon Territory lies between Longitudes 124° and 140° West and Latitudes 60° and 70° North. The study area is 3500 kilometres from east to west and 2500 kilometres from north to south.

The study area has a small total population of 94,400 people (Corpus Almanac, 1995). The population of the Northwest Territories (64,300 people) is concentrated in one city (Yellowknife), several towns, and numerous hamlets, villages, and settlements. Most of these communities are located on the mainland around Great Slave Lake and along the Mackenzie River Valley. Other settlements are scattered along the coastlines of the mainland and Arctic Islands. In the Yukon Territory, more than half of the population of 30,100 residents lives in the City of Whitehorse. Other towns and settlements are located along the Alaska, Klondike, Dempster, and Robert Campbell Highways.

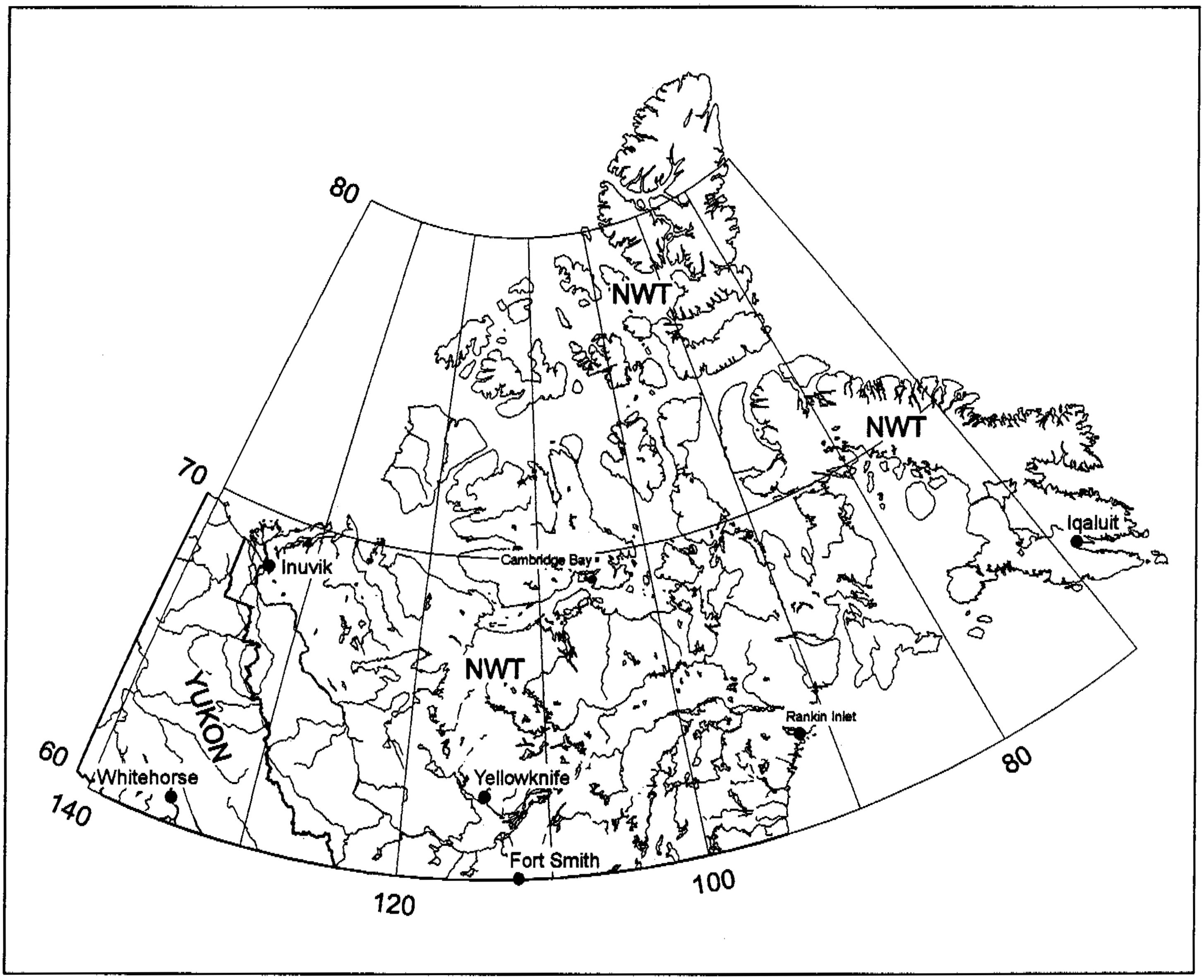


Figure 1: Study Area

1.3 Definitions

Numerous terms have been used to describe naturally occurring unconsolidated earth materials and bedrock that are used in construction. These terms are not precisely defined or widely used and they are often used interchangeably.

"Construction materials" and "borrow materials" are two general terms that include a wide range of material types and grain sizes. "Construction materials" include fine grained material (silt, clay or till) that can be used for fill, granular material (mostly sand and gravel), crushed bedrock, and specialized material (e.g., clay, rip-rap and building stone). The term "borrow" infers that unconsolidated earth materials (sand, gravel, till, etc.) are taken from one location (borrow pit) and used for fill at another location. This contrasts to construction material that is used on site in a cut and fill operation (AGI Glossary, 1973; Territorial Quarry Regulations, 1978).

"Granular deposits" and "granular materials" are more specific terms. "Granular deposits" include all naturally occurring accumulations of sand, gravel or other unconsolidated mixtures with a major proportion of the particles in the sand or gravel grain-size range. The term "granular materials" is commonly used to refer to the gravel and sand-sized materials which are the primary constituents of the granular deposits. "Granular aggregate" usually refers to gravel and sand-sized products produced by processing naturally occurring unconsolidated mixtures, or crushing bedrock.

The terms "granular materials" and "granular aggregate" are sometimes used synonymously. However, in its strictest definition, the term "granular aggregate" describes hard construction materials both naturally occurring and man-made such as sand, gravel, crushed stone or slag, which can be used for mixing in various size fragments to manufacture concrete, asphalt, mortar, plaster or used alone in railroad ballast or in manufacturing processes (AGI Glossary, 1973). Aggregate materials are generally defined by a precise gradational specification, and inherent to the definition is the mechanical processing of the original material.

In this report, the term "granular resources" includes all "sources" of northern granular construction materials, whether naturally occurring granular deposits or bedrock used for the production of granular aggregates.

2.0 PART 1 - THE GEOLOGY OF NORTHERN GRANULAR RESOURCES

2.1 Baseline Geology Studies

Baseline information on the geological history, setting, and properties of bedrock and unconsolidated surficial materials in northern Canada comes directly from geological studies undertaken by the Geological Survey of Canada (GSC) and more recently by the Geology Divisions of Indian and Northern Affairs in the Northwest Territories and Yukon.

The GSC has prepared maps and reports on the geology of the Northwest Territories and Yukon since the late 1880's. Early reconnaissance surveys along major waterways were undertaken in the 1880's to 1900's by famous geologists like McConnell, Dawson, Bell, Camsell, Tyrrell, Dowling, and Low (Zaslow, 1975).

Systematic regional geological mapping of Canada's bedrock began in 1863 in eastern Canada and in western and northern Canada after 1950. Mapping in the less accessible Northwest Territories and Yukon was assisted by the advent of air travel in the 1920's, the adaptation of stereoscopic airphotos to geological mapping in the 1940's, and the use of helicopter support for geological mapping in the 1950's.

Surfical or Quaternary geology was studied by the Geological Survey of Canada since its founding in 1842. Earliest observations were included as part of a holistic approach to geology and natural sciences, but by the 1880's separate regional maps were prepared to meet the needs of agriculture, forestry, settlement and development (Fulton, 1993).

Mapping of surficial of Quaternary geology in association with systematic mapping of bedrock began in the 1930's and 1940's. A surficial geology mapping component was part of most of the northern mapping projects in the Northwest Territories and Yukon during the 1950's and 1960's (e.g. Operation Norman in the Mackenzie Valley). From 1970 to the present systematic Quaternary geology mapping projects have been run by the GSC in remote areas of northern Canada (Fulton, 1989a).

Since the 1970's, the Northwest Territories (NWT) Region, Geology Division of DIAND in Yellowknife and the Exploration and Geology Services Division, Northern Affairs Program of DIAND in Whitehorse have also produced bedrock and surficial geology maps, in areas of special interest to the minerals industry (List of Publications Available for the NWT Geology Division, Northern Affairs Program, 1993; List of Publications Available from the Exploration and Geology Services Division DIAND for the Yukon).

These mapping activities are similar to those undertaken by the provincial surveys in southern Canada.

2.2 Bedrock and Surficial Geology Mapping

Bedrock and surficial geology maps along with accompanying reports are primary sources of information that should be reviewed at the beginning of granular resource inventory work. This published information, in combination with a stereoscopic examination of airphoto pairs, identifies typical landforms and bedrock in a specific geologic region and locates bedrock and surficial materials that might be suitable for construction purposes.

Bedrock maps of various scales cover most of the Northwest Territories and Yukon (see Figure 2 and 2A). For example, In Figure 2 and 2A from the Root River, District of Mackenzie, areas with surface limestone exposures of Cambrian to Upper Devonian age would be good locations for limestone quarries. Examination of airphoto pairs to indicate locations with no overburden and field investigations of rock properties in outcrop would indicate the best quarry locations in the map area.

Surficial or Quaternary geology maps (see Figure 3 and 3A) show the distribution and properties of unconsolidated nonglacial and glacial deposits lying on bedrock. These surficial deposits are the most recent geological deposits which were developed in the latest geological period known as the Quaternary. The surficial or Quaternary deposits occur in landforms which have distinct geological origins related to glacial and postglacial processes. For example on Figure 3, proglacial outwash terrace landforms made up of sand and gravel would be good sources of granular material.

In summary, the bedrock geology maps provide:

- an understanding of the bedrock geology of an area;
- the location of areas with specific types of bedrock that might be suitable for quarrying;
- an indication of areas where thick Quaternary overburden overlies the bedrock.

The surficial or Quaternary geology maps which cover most of the Northwest Territories and Yukon at several scales (see Figure 4) show:

Figure 2: Example Bedrock Geology Map After GSC Map 1376A by Douglas and Norris (1974).

ROOT RIVER

DISTRICT OF MACKENZIE

Scale 1:250,000

Kilometres 6 0 6 12 18 Kilometres

Miles 4 0 4 8 Miles

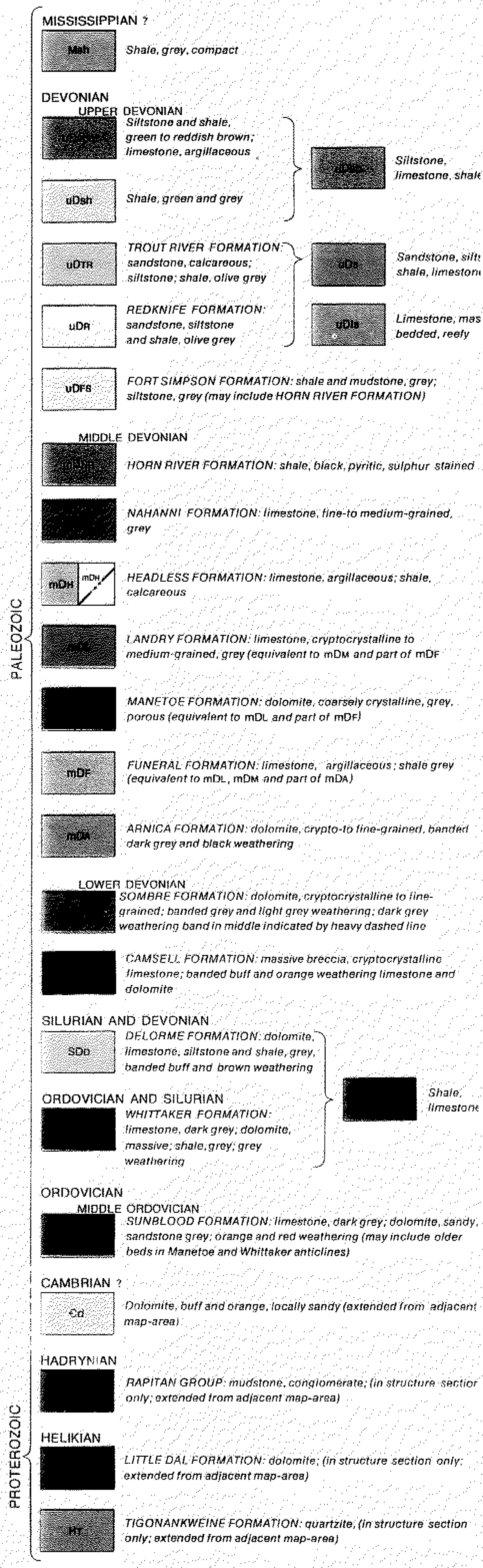


Figure 2A: Example Legend for Bedrock Geology Map After GSC Map 1376A by Douglas and Norris (1974).

Figure 3: Example Quaternary Geology Map After GSC Map 1677A by Dyke (1990).

LITTLE HYLAND RIVER

YUKON TERRITORY - NORTHWEST TERRITORIES

Scale 1:100 000 - Échelle 1/100 000

Kilomètres 2 0 2 4 6 8 Kilomètres

LEGEND

This legend is common to maps 1674A, 1675A, 1676A, 1677A; coloured legend blocks indicate map units that appear on this map

SURFICIAL DEPOSITS
QUATERNARY

POST LAST GLACIATION

NEOGLACIATION

GLACIAL ENVIRONMENT

ICE AND SNOW

TILL: nonsorted debris, commonly bouldery, 0.5-20 m thick, forming discontinuous veneers, fluted, hummocky, or channelled blankets, and lateral and end moraine ridges; distinguished from older till by its general lack of vegetation; includes deposits of six advances, oldest of which postdates White River tephra (ca. 1200 years old)

NONGLACIAL ENVIRONMENT

COLLUVIAL DEPOSITS: block accumulations and landslide debris, 1-50 m thick

Ca — *Talus (scree): accumulations of blocks, commonly exceeding 3 m in diameter, as much as 50 m thick, forming aprons and fans below cliffs; commonly crossed by debris flow channels and levees. Most slopes active*

Rock glacier debris: accumulations of talus deformed by flow of interstitial ice to form rock (talus) glaciers, generally 10-50 m thick, with pronounced transverse and longitudinal ridges and furrows, steep sides and fronts; includes deposits of several ages, at least three older and six younger than White River tephra (ca. 1200 years old)

Landslide debris: rock avalanches more than 10 m thick and slumped and slid till incorporating organic detritus, 1-10 m thick, with hummocky or rolling surfaces and steep fronts

ALLUVIAL DEPOSITS: gravel, sand, and organic detritus 2-20 m thick

Af — *Alluvial fan deposits: poorly sorted gravel and sand with organic detritus and buried organic soils; fans commonly laterally amalgamated, commonly crossed by debris flow channels and levees and subject to shifting stream courses*

Ap,t — *Alluvial plain and terrace deposits: well sorted gravel and sand with detrital organic beds, including concentrations of logs, forming meander scrolled plains* Ap, *and terraces* At

Er — *EOLIAN DEPOSITS: sand, 1-5 m thick, forming sharp crested dunes, now stable; probably formed immediately after deglaciation and prior to establishment of a vegetation cover*

LAST GLACIATION

PROGLACIAL AND GLACIAL ENVIRONMENT

Lt,p — *GLACIOLACUSTRINE DEPOSITS: fine sand, silt, and clay, 10-30 m thick, forming terraces deeply dissected by postglacial erosion where thick or plains where thin; deposited in glacier dammed lakes*

GLACIOFLUVIAL DEPOSITS: gravel and sand, 2-30 m thick, deposited on, beneath, and in front of the marginal zone of a glacier

Gt, p,f | Gtk Gpk — *Proglacial outwash: gravel and sand forming distal outwash terraces* Gt, *plains* Gp, *and fans* Gf, *and proximal kettled outwash terraces* Gtk, *and plains* Gpk; *characterized by abandoned braided channel patterns*

Ice contact stratified drift: gravel and sand, with clasts commonly 10-100 cm across, commonly faulted, forming lateral kame terraces and delta terraces It, *with ice contact escarpments and kettle holes* Ik, *hummocky moulin kame fields, or ice block disintegration terrain* Ih, *and eskers or crevasse fillings* Ir

GLACIAL ENVIRONMENT

TILL: nonsorted debris, 0.5-20 m thick, ranging widely in grain size and petrological composition but including deposits locally derived almost entirely from black shale, red shale, serpentine, marble, limestone, granite, and schist

Tv — *Till veneer: 0.5-2 m thick; surface mimics underlying rock surface, fluted in places, commonly channelled by meltwater*

Tb | Tbh — *Till blanket: 2-20 m thick; much of surface lineated by flutings and drumlins or channelled by meltwater* Tb, *distinctly hummocky* Tbh, *where composed mostly or entirely of shale*

ROCK
PRE-QUATERNARY

R1 | R2 — *ROCK: rock of various lithologies and ages forming alpine valley walls and ridges extensively modified by glacial erosion* R1, *and high plateau remnants of restricted extent showing little or no sign of glacial erosion* R2, *high plateaus and other low to moderate slopes commonly mantled by felsenmeer; patches of till and glacial erratics occur throughout*

Figure 3A: Example Legend for Quaternary Geology Map After GSC Map 1677A by Dyke (1990).

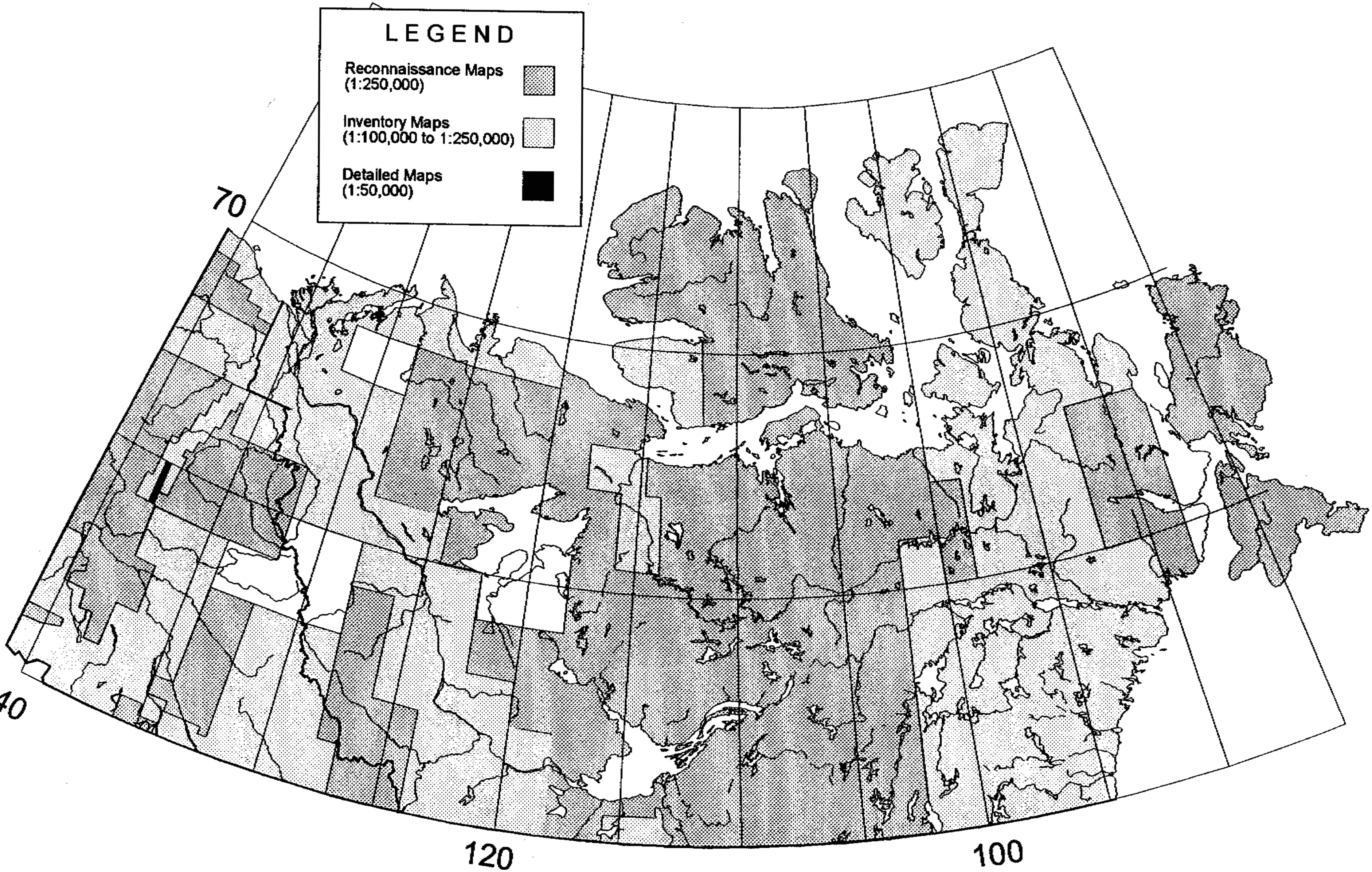


Figure 4: Status of Quaternary Mapping Geology in Yukon Territory and Northwest Territories

Source: Maurice, L. (1988)

- the Quaternary geologic history of an area;

- the location of specific surficial materials and landforms;

- the properties and geological constraints to development for specific landforms and their sediments.

2.3 The Geology of Northern Canada

2.3.1 Physiographic Regions and Subdivisions

Physiographically and geologically Canada is composed of two large parts known as the Canadian Shield and the Borderlands (Bostock, 1970a). The Borderlands are further subdivided into the Inner and Outer Borderlands Regions (see Figure 5). The Northwest Territories and Yukon encompass subdivisions of these two principal parts. The Inner Borderlands, which cover mostly the Northwest Territories and the coastal part of the Yukon, consist of the Interior Plains, Arctic Coastal Plain, and Arctic Lowlands Subdivisions. The Outer Borderlands cover mostly the Yukon Territory, the Queen Elizabeth Islands and a small area in the western Northwest Territories. Geological events from Precambrian to Quaternary time have resulted in the evolution of bedrock and unconsolidated Quaternary deposits which occur within the Canadian Shield and Borderlands Regions (see Figure 6).

2.3.2 The Geology of the Canadian Shield

The Canadian Shield consists of a core of old, massive Precambrian crystalline rocks. These rocks formed by many geological processes including igneous intrusion, volcanism, sedimentation, and metamorphism which was associated with several periods of mountain building that were followed by long erosional intervals (Stockwell et al., 1970). The major areas or geologic subdivisions of the Canadian Shield, e.g. Kazan, Hudson, were formed during these different orogenies.

During the latest geologic time period known as the Quaternary, glacial and postglacial processes eroded and deposited sediments derived from the bedrock and older unconsolidated materials. Four continental glaciers advanced and retreated across the Canadian Shield of northern Canada and produced morainal, glaciofluvial, and glaciolacustrine deposits and landforms of unconsolidated sediments which range in grain size from clay to boulders. Drainage patterns changed as a result of the glaciations and there was some tilting of the land surface.

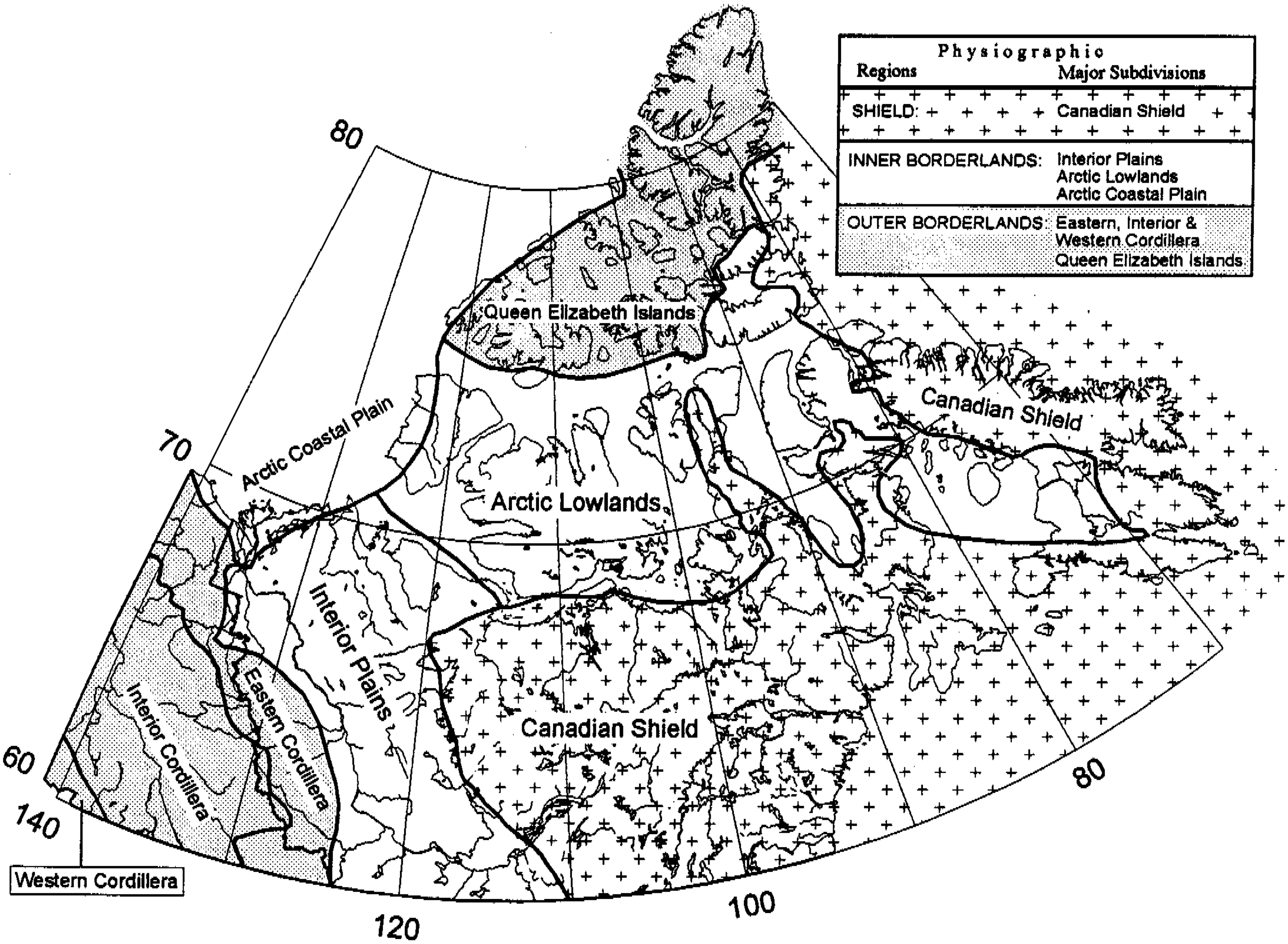


Figure 5: Major Physiographic Subdivisions of Northern Canada

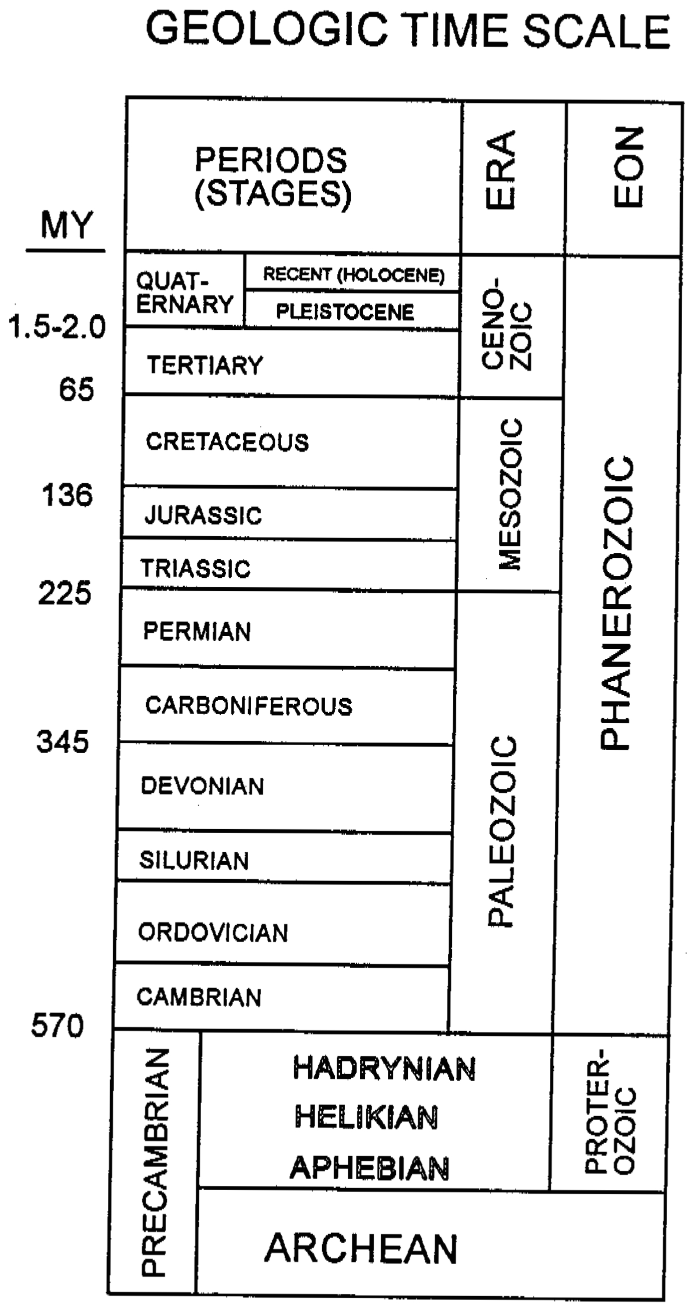


Figure 6: Geologic Time Scale (After Douglas et al., 1970)

The continental ice sheet that was responsible for the four glacial advances across the Canadian Shield was known as the Laurentide Ice Sheet (Fulton, 1989). The Laurentide Ice Sheet consisted of a large complex of ice domes, divides, saddles, and lobes. Elements of the complex acted semi-independently and were affected by a variety of regional and local physiographic, climatic, and glacier bed conditions. The Laurentide Ice Sheet had several subdivisions known as the Labrador, Keewatin, and Baffin sectors.

The last glacial advance known as the Wisconsinan left the most widespread landforms and deposits during its advance and retreat because it reworked and buried deposits of previous glaciations. Centers of final glacial retreat of the Wisconsinan Laurentide Ice Sheet in the central District of Keewatin in the Canadian Shield are characterized by large fields of ribbed moraine formed in association with drumlins and flutings. Beyond these areas are broad zones of thick and nearly continuous drift consisting of streamlined till and large, long eskers.

In the Canadian Shield, a few thick exposures of Quaternary sediments in the Hudson Bay Lowlands and Baffin Island show glacial deposits related to older glacial and interglacial times. There are also extensive areas of residuum (weathered rock) and colluvium which developed prior to the last glaciation (e.g. Somerset and Prince of Wales Island and parts of Keewatin) (Dyke and Dredge, 1989).

Postglacial fluvial, lacustrine, and eolian processes acting during the Holocene or Recent portion of the Quaternary (see Figure 6) reworked the pre-existing glacial sediments and weathered bedrock and formed fluvial, lacustrine, and eolian deposits which overlie the older glacial deposits.

2.3.3 <u>The Geology of the Borderlands</u>

The Borderlands form an arcuate region of stratified Phanerozoic (e.g. post-Precambrian) rocks bordering the Canadian Shield in two concentric bands. The inner band (Inner Borderlands) consists of lowlands, plains, and plateaux of generally flat-lying sedimentary rocks rimming and "shelving up" onto the Canadian Shield. The Inner Borderlands include the Interior Plains, the Arctic Lowlands, and the Arctic Coastal Plain (see Figure 5). The outer band (Outer Borderlands) is formed of discontinuous mountains and plateaux where the younger rocks have been deformed. The Outer Borderlands comprise the Eastern, Interior, and Western Cordillera and the Queen Elizabeth Islands. On the northeast edge where the Borderlands are absent, the Canadian Shield is tilted upward and drops abruptly into the sea. The

Borderlands were glaciated more than once during the Quaternary.

Inner Borderlands - The Inner Borderlands are underlain by flat-lying poorly consolidated shales, siltstones, and sandstones. The Interior Plains subdivision of the Inner Borderlands Region north of Latitude 60° is further divided into nine parts including Anderson Plain, Horton Plain, Peel Plain, Peel Plateau, Mackenzie Plain, Collville Hills, Great Bear Plain, Great Slave Plain, Alberta Plateau, and Fort Nelson Lowland. Each of these nine parts are characterized by the type of sedimentary bedrock which underlies them, the cover of Quaternary deposits, and present drainage patterns.

The Arctic Lowlands includes small portions of the mainland and most of the Arctic Islands south of Viscount Melville Sound. These lowlands are formed on the mostly flat-lying Paleozoic and late Precambrian sedimentary rocks lying between the Canadian Shield and the Queen Elizabeth Islands. Subdivisions of the Arctic Lowlands include Lancaster Plateau, Foxe Plain, Boothia Plain, Victoria Lowland, and Shaler Mountains. The smooth undulating ancient erosional surface of the lowlands is covered by a variety of glacial deposits including drumlinoid ridges and moraine belts.

The Arctic Coastal Plain includes the coastal terrain along the shores of the Arctic Ocean. This area is underlain by the Beaufort Formation of unconsolidated Tertiary or Early Pleistocene sands and gravels. On the mainland, the Arctic Coastal Plain is represented by the Mackenzie Delta and the Yukon Coastal Plain subdivisions. The island portions of the Arctic Coastal Plain extends from Meighen Island to Banks Island. Surficial deposits of the Arctic Coastal Plain are commonly alluvial, deltaic, and eolian in origin.

The Inner Borderlands, like the Canadian Shield, were also covered by glacier ice several times during the Quaternary. The Laurentide ice advanced into the borderlands from a center in Keewatin. Ice sheet dynamics were different in the Inner Borderlands than on the Canadian Shield because of the composition of the glacial bed. The beds of poorly consolidated sedimentary rock were deformable and glaciers were extremely mobile and had low gradient surface profiles. Morphological features such as hummocky moraine and ice-thrust sheets of bedrock and Quaternary material are well developed. Thick successions of Quaternary deposits representing three or four glaciations are often preserved (Vincent and Klassen, 1989).

On mainland portions of the Inner Borderlands subdivisions, Quaternary deposits vary somewhat with topographic position. For example, in the low areas of the Mackenzie and Liard Rivers in the Interior Plains, glaciofluvial floodplain, terrace, and delta deposits and large glaciolacustrine silt and sand plains are present (Vincent, 1989). Somewhat higher, in the low-lying interfluve areas, peat mantled moraine plains, commonly drumlinized and fluted occur. On higher ground, hummocky moraine with some glaciofluvial deposits cover plateaus and hills. In the highest areas adjacent to the glaciated edge of the Eastern Cordillera, Quaternary deposits are typically thin and bedrock derived colluvium is at ground surface.

The Arctic Lowlands has a variety of Quaternary deposits. In the low-lying part of Banks Island, till plain deposits are broken by outwash deposits. Eastern Banks Island has many lakes of glacial and thermokarst origin. Higher portions of Banks Island consist of dissected bedrock with sparse Quaternary cover because Quaternary materials were never deposited or they were obliterated by wave action in glacial lakes or the sea. Victoria Island in the Arctic Lowlands, except for the Shaler Mountains, is also low-lying and has drumlinized till plain or scoured and felsenmeer-covered bedrock. Postglacial seas covered much of the southern and eastern parts of Victoria Island. Till plains with well developed ice contact landforms and outwash plains cover most of Wollaston, southern Diamond Jenness, and Prince Albert peninsulas.

Outer Borderlands - The outer band of the Borderlands lies to the north and west of the Inner Borderlands. It is a region underlain by moderately to highly deformed strata and is characterized by moderate to very high topographic relief such as the Mackenzie and Richardson Mountains on the mainland (District of Mackenzie) and the Grantland, Victoria, and Axel Heiberg Mountains of the Queen Elizabeth Islands (District of Franklin). Typically mountainous physiographic subdivisions are interspersed with subdivisions of moderate relief. Areas of moderate relief include the Hyland Plateau, Richardson Plateau, Porcupine Plateau and Peel Plateau on the mainland and Parry Plateau and Eureka Upland in the Queen Elizabeth Islands. The Outer Borderlands are not geographically continuous (see Figure 5). The mainland part, or the Cordillera, is separated from the Queen Elizabeth Islands physiographic subdivision by the Arctic Coastal Plain.

Two major periods of mountain building (orogenies) have influenced the topography of the Outer Borderlands (Thorsteinsson and Tozer, 1970). The first of these deformed pre-Devonian strata of the Arctic Islands and contributed strongly to present-day relief of the Parry Plateau and Eureka Upland in the Queen Elizabeth Islands subdivision. The second period of mountain building, in Cretaceous to Tertiary time, caused the development of the north-south trending mountain belt of the Eastern Cordillera and contributed to the present-day relief of the mountains of the northern parts of Ellesmere and Axel Heiberg Islands.

During glacial times, the moderate to extreme topography of the Outer Borderlands meant that no specific area acted as a main accumulation centre for the Cordilleran glacier. At the beginning of glacial periods, local glaciers and ice caps expanded and coalesced to form more major ice sheets. On the west side of the Cordillera (coastal B.C.) where glacier accumulation was greatest, ice was funnelled into fiords and ablated by calving into the Pacific Ocean. Ice moving toward the east accumulated in the low interior of the Cordillera and coalesced with glacier complexes flowing from local centres to form a major Cordilleran ice sheet. Some areas of the Cordillera, like the upland plateaux regions of the northern Yukon, stood above the ice sheet and remained unglaciated. In some areas, Cordilleran and Laurentide (continental) ice sheets were in close proximity. This is evidence that the Cordilleran ice reached its maximum limit and was retreating as the Laurentide ice reached its maximum or that the two ice sheets coalesced.

The Cordillera is subdivided into the Eastern, Interior, and Western subdivisions (see Figure 5). Quaternary deposits in the Cordillera are varied and have a complex distribution (Clague, 1989). Most surficial sediments were deposited during the last glaciation and in postglacial time. Some older deposits are exposed in the Yukon and along the Eastern Cordillera. During nonglacial periods sedimentation was concentrated in valleys, lakes, and the sea. Mountains were eroded and plateaus and lowlands experienced little erosion or deposition at these times. At the beginning of each Pleistocene glaciation ice spread from the mountains into low lying areas and streams aggraded their valleys with outwash. Advancing glaciers impounded large lakes into which fine sediments were deposited and till was deposited at the base of the ice sheet. Some areas were intensely scoured and older valley fills were removed. Deglacial intervals saw rapid valley aggradation and drainage changes. Glaciolacustrine sediments were deposited in lakes in front of the decaying ice sheet. Valleys became choked with glaciofluvial and fluvial sediments which were eroded from drift deposits on upper slopes. Marine sediments were deposited on the continental shelf and in isostatically depressed coastal lowlands that were flooded by the sea after the retreat of the ice.

The Queen Elizabeth Islands subdivision of the Outer Borderlands were at one time covered by a major extension of Laurentide ice and a limited extension of Greenland ice. Another ice sheet, the

Innuitian ice sheet may also have been involved (Fulton, 1989a). The pattern of fiords and inter-island channels leading away from topographic basins suggests former existence of lowland ice centres. However, difficulties is delineating a moisture source capable of nourishing regional ice sheets at high latitude exists.

2.4 Principal Granular Resources by Physiographic Region

The two large geologically distinct parts of northern Canada, the Canadian Shield and the Borderlands, have specific bedrock and Quaternary deposits which are can be exploited to provide construction materials. Granular materials are obtained mostly from surficial sediments of glacial, proglacial, and nonglacial origin deposited during the Quaternary period. In locations where surficial sediments are lacking or where granular surficial deposits have been depleted, resistant bedrock is sometimes crushed as a source for granular material. Tertiary sediments (poorly consolidated sands and gravels) can also provide granular material at specific localities where they have been identified, e.g. the Caribou Hills.

2.4.1 Principal Granular Resources in the Canadian Shield

Glacial sediments (primarily composed of till) are deposited directly from glacier ice. These are contained in morainal landforms which are of several distinct types including moraine plain, moraine veneer and blanket deposits, drumlins and fluted till, hummocky and ribbed moraine (interlobate moraine), and moraine ridges (terminal and kame). Morainal deposits are generally less than 4 m thick in the Canadian Shield, but in some localities they can be up to 100 m thick. The thicker deposits are generally found in the vicinity of late centres of glacier outflow (Dyke and Dredge, 1989).

On the Canadian Shield, till in morainal landforms is usually of two basic types. The most common is sandy, gravelly till that is derived from igneous and metamorphic rock of the Shield. Sandy till is also derived from loosely-cemented Proterozoic sandstones (Dyke and Dredge, 1989). Carbonate-rich, silty and clayey till is produced by the ice sheet in localities, e.g.the Hudson Bay Lowlands, where Paleozoic carbonate rock has contributed to the till composition. Bouldery till, produced from areas of felsenmeer are also present in some localities, e.g. central Boothia Peninsula. Sandy, gravelly till, particularly from hummocky and ribbed moraine (interlobate moraine) and moraine ridges (terminal and kame), is sometimes used as a granular resource (see discussion of these deposits under glaciofluvial origin below).

Proglacial and glacial deposits of glaciofluvial origin usually provide the best sources of granular material. These deposits include eskers, crevasse fillings, interlobate moraines, and radial (kame) moraine deposits, glaciofluvial plains, and glaciofluvial terrace and channel deposits. Distribution of glaciofluvial deposits on the Canadian Shield is not uniform.

Eskers consist mostly of sand and gravel, but can have short segments that are mostly boulders. Eskers, typically long sinuous, steep sided ridges, are relatively rare and short on Somerset, Prince of Wales, and King William islands and on Boothia Peninsula. However, over much of Keewatin and eastern Mackenzie, longer eskers and esker complexes describe a radial glacier flow pattern emanating from the Keewatin Ice Divide (Dyke and Dredge, 1989).

Interlobate moraines consist of broad, ridged segments of stratified sand, gravelly sand, and till. Each segment of an interlobate moraine can be of a different length and quite high (e.g. 60 m high). Kame moraines are bulky, esker-like features similar to interlobate moraines which developed in zones of sluggish flow between ice streams. Ice flow patterns are convergent toward these features. These features can be 20-30 m high and in some cases have been identified as terminal moraines.

Outwash plain deposits with minor esker ridges are also located on the Canadian Shield. Sediments in these deposits were laid down in ice-walled channels, open to the sky, in a stagnant marginal zone of the ice sheet. These deposits can be up to 60 m thick.

Elongate belts of smaller ridged moraine landforms composed primarily of gravel and sand with some till lie between larger moraine belts. These features are crevasse fillings which formed where ice became stagnant.

Glaciofluvial channels were cut in both till and bedrock. Lateral meltwater channels are common on Somerset and Prince of Wales islands and on central Boothia Peninsula. These channels may be filled with sand and gravel deposits. Glaciofluvial terraces of sand and gravel many also be present adjacent to these channels.

Glaciolacustrine deposits were formed at numerous locations on the Canadian Shield during deglaciation. For the most part, these deposits are fairly thin as the lakes were short lived. However, in several locations, e.g. the Coppermine River, thicker deltaic and deep water sediments accumulated. Some beach deposits are found adjacent to the glacial lake basin deposits.

Glaciolacustrine deposits can be used as a source for granular material where finer grain sizes are acceptable.

Glaciomarine deposits of stratified silt, clay, and sand are located along Hudson Bay and the northern Mainland and along the shorelines of many of the Arctic Islands (Prest, 1970). In some localities the deposits are thin and discontinuous and in some localities they are thick enough to have developed badlands topography and large thermokarst features (Dyke and Dredge, 1989). Coarser ice contact sediment of glaciomarine origin occurs mostly in the form of deltas which are common at the marine limit in northern Keewatin, on northeastern Boothia Peninsula, and in the western Coronation Gulf region. Esker nodes, a related ice contact glaciomarine sediment, is common is areas of marine submergence of Keewatin and Mackenzie. The coarse grained glaciomarine deposits of delta and esker-node origin are often used as a source of granular material in the Canadian Shield. In northern Keewatin, nodes are at regular intervals and in the space between nodes, DeGeer moraines are developed on the adjacent till sheet. These moraines are closely spaced ridges which are only several metres high and wide. They can only be traced laterally for a few hundred metres. A few of the ridges can be up to 10 metres high and traced for tens of kilometres. The larger ridges were deposited at the ice margin during deglaciation.

Nonglacial deposits of two ages exist on the Canadian Shield. Deposits which predate the last glaciation include extensive areas of residuum (weathered bedrock) and associated colluvium. These occur locally on Prince of Wales and Somerset islands and in parts of Keewatin. Residuum consists of large blocks with substantial quantities of interstitial grus (angular coarse grained fragments derived from the weathering of crystalline rocks) and fine weathering residues developed on Precambrian rock. Diamicton (mixtures of stony, sandy, clay silt) form residuum on Paleozoic rocks. Landforms in residuum formed on Precambrian rock consist of cryoplanation terraces and tors. On Paleozoic rocks, except in sandstone and conglomerate on Somerset Island, minor landforms are absent and terrain consists of smooth, graded hillslopes interrupted by a few low cuestas. These residual deposits have limited use as a source for granular material, but can supply general fill in some instances.

The other nonglacial deposits are postglacial or interglacial in origin. These include blockfield, marine, fluvial, eolian, and organic deposits (Dyke and Dredge, 1989). Blockfields can be either interglacial or postglacial and consist of frost heaved rock. Marine, fluvial, eolian, and organic deposits were formed postglacially. Postglacial deposits on the northwestern Canadian

Shield consist of raised beaches of gravel and sand, terraced and active alluvium, terraced and active delta sediments, and eolian sands. Organic deposits cover small areas and are thin. Raised gravel beaches form continuous flights of ridges along Boothia Peninsula (west coast), north and southeast coasts of Somerset Island, steeper sloping segments of Prince of Wales, Simpson, and Rasmussen lowlands. These beaches developed from wave erosion of highly calcareous stony till and are generally less than 1 m thick because the till became armoured as the fines were washed away. Continuous flights of raised beaches are uncommon except along the flanks of glaciofluvial deposits (e.g. Hudson Bay Coast). Postglacial alluvium and delta deposits are small and scattered. Eolian deposits occur on outwash deposits and on sandy raised marine beaches. The coarse grained marine and alluvial deposits are often exploited for granular material. The fine grained deposits can provide lesser quality material for general fill purposes.

Quaternary deposits are not evenly distributed on the Canadian Shield. In some localities where granular material is required, Quaternary deposits either do not exist within close proximity to the community or have been depleted because of previous exploitation (see Appendix B). In these areas (e.g. Rankin Inlet and Yellowknife), resistant bedrock (either Precambrian or Paleozoic) is crushed or will be crushed in future to supply granular material.

2.4.2 Principal Granular Resources in the Borderlands

Quaternary deposits and rock are both sources of granular material in the Inner and Outer Borderlands. Quaternary deposits include glacial material of morainal, glaciofluvial, glaciolacustrine, and glaciomarine origin. These materials supply granular and fill material as do nonglacial deposits of postglacial and interglacial origin (including those of colluvial, marine, fluvial, and eolian origin). Bedrock of sedimentary, metamorphic, and igneous origin also provides a source for construction materials in the Borderlands.

Granular Resources of the Inner Borderlands - Glacial sediments composed primarily of till deposited directly from glacier ice form moraine veneer, moraine blanket, moraine plain, drumlinoid moraine, hummocky moraine, and ridged moraine deposits throughout the Inner Borderlands. These deposits, for the most part, consist of silty clay till (5 to 10% coarse fraction; almost equal parts of sand, silt, clay in matrix) with local differences related to the rocks and sediments from which they were derived (Hughes et al., 1973; Rutter et al., 1973). For example, bouldery till is found locally where thin till overlies resistant bedrock. Morainal deposits are generally greater than 5 m thick. In some locations, they can be thicker than 30 m (Hughes et al., 1973). For the most part till lies directly on bedrock, except where it overlies interglacial sediments and other tills.

Evidence of three or more advances of the continental glacier is recorded in exposures along rivers and coastlines of the Inner Borderlands where till alternates in layers with interglacial sediments. Moraine veneer and blanket deposits overlie areas where bedrock is near the surface. Rolling to hummocky moraine, drumlinoid moraine, and moraine ridge deposits are fairly thick. Rolling to hummocky moraine and moraine ridges are found in irregular belts which mark former positions of the Laurentide ice sheet, e.g. Fort McPherson area (Hughes et al., 1973). Morainal deposits in low lying areas can be covered with thick organic deposits. For the most part, morainal deposits are not exploited for granular material. However, in locations where they are unfrozen they have been used as a source of fill material for construction projects (e.g. roadbed of the Mackenzie Highway south of Fort Simpson, NWT).

Proglacial deposits of glaciofluvial origin usually provide the best sources of granular material in the Inner Borderlands. These deposits are found as plains, terraces, meltwater channel deposits, outwash fans and trains, esker ridges or irregular kames of sand and gravel (see Appendix A - Photographs 1A, 1B, 3A, 4A) (Hughes et al., 1973; Rutter et al., 1973; Rampton, 1974;). Glaciofluvial delta plain and delta fan deposits are often in close proximity to glaciolacustrine deposits because they were formed at glacial lake margins. There is a textural gradation from glaciofluvial sand and gravel of the deltas through sand and silt to silt and clay which was deposited in deeper water. Glaciofluvial sand and gravel may often overlie ice-rich fine grained glaciolacustrine material in the vicinity of delta deposits. Glaciofluvial terrace deposits are found in areas of transition where a glacial lake became a river, e.g. along the Mackenzie River valley in the area of former Glacial Lake McConnell east of Fort Simpson, NWT. Some glaciofluvial terrace deposits of gravel and sand are 15 m thick. Glaciofluvial fan and valley train deposits are common along the Yukon Coastal Plain subdivision of the Arctic Coastal Plain (see Appendix A - Photograph 4A). Hummocky ice contact glaciofluvial deposits or kames are found overlying till at various locations in the Interior Plains of the Inner Borderlands (see Appendix A - Photograph 3A).

In southern and central portions of the Inner Borderlands (e.g. the southern Mackenzie Valley) glaciofluvial deposits are unfrozen, have a thick active layer, or contain only pore ice

(Hughes et al., 1973). However, in the far northern areas glaciofluvial deposits with flat surfaces can have ice wedges and thermokarst features (Hughes et al., 1973; Rampton, 1974).

Glaciolacustrine plain deposits consist mostly of fine grained sediments deposited in glacial lakes which were adjacent to the margin of an ice sheet (see Appendix A - Photograph 2B). Turbid meltwater flowed off the ice sheet through channels into the lakes. Glaciolacustrine silt, clay, and sand overlie till and less commonly glaciofluvial sand and gravel (Hughes et al., 1973). At some localities, glaciolacustrine deposits can be up to 50 m thick, e.g. along the Mackenzie River valley. The glaciolacustrine sediments usually grade upwards from silt and clay, through silt and sand to fine gravel. Locally the sand can be up to 25 m thick. The sand has a disconformable contact with the underlying silt and clay. Glaciolacustrine beach deposits of sand and gravel can be found at the margin of glacial lakes, particularly where bedrock or outwash deposits have been reworked by the glacial lake (see Appendix A - Photograph 5A) (Thurber Consultants Ltd., 1987).

Typically, the glaciolacustrine sand has pore ice only or lacks ice altogether. The silt contains pore ice and segregated ice as lenses, veins, or a reticulate network. Massive clay contains segregated ice as a reticulate network that encloses unfrozen, very stiff plastic clay. Because of ice contents, slopes developed on glaciolacustrine plains can be subject to active layer detachment slides, retrogressive thaw flow slides, and rotational slides. Thermokarst lakes, ponds, and depressions are common on glaciolacustrine plains. Glaciolacustrine silt and clay deposits are generally unsuitable sources for construction material because of their high ice contents. However, low ice content or unfrozen sand and silt can be used for general fill purposes. Sand and gravel glaciolacustrine sediment, particularly beach deposits, may supply granular material for construction purposes (e.g. beach deposits north of Enterprise, NWT.).

Nonglacial deposits of colluvial, marine, fluvial (alluvial), eolian, and organic origin overlie bedrock and glacial deposits in the Inner Borderlands. Colluvial sediments are formed from weathered bedrock and/or glacial deposits. Colluvial materials form veneer and blanket deposits on exposed bedrock and along slopes adjacent to bedrock highs where they are mixed with morainal and other deposits. Colluvial deposits also exist along steep-walled river and stream valleys. Marine deposits along coastlines in the Inner Borderlands are generally fine grained and sandy only in lagoons and tidal flats (Rampton, 1974). These recent marine deposits are subject to flooding and because of the short time since deposition they may contain permafrost. At some locations older marine deposits are interbedded with fluvial sands and gravels, e.g. Eskimo Lakes area.

Fluvial (alluvial) deposits are generally of two types: high energy stream deposits of sand and gravel and low energy stream deposits of sand and silt (Hughes et al., 1973). High energy streams have braided or locally divided shifting channels (see Appendix A - Photograph 4B). Low energy streams are relatively straight or meandering. Each river and stream can have segments of high and low energy deposits (e.g. the Mackenzie River). All but the most high energy streams have a silt cover beneath vegetated parts of the floodplain. The thickness of the silt cover is related to the size of the stream. Ground ice lenses are present in floodplain deposits, but layers of segregated ground ice are rare. Wedge ice in polygonal patterns occurs where silt cover is greater than several metres. Most recent floodplains (lowest level) are subject to flooding seasonally. Older (higher level) floodplains are sometimes flooded when water levels are high. Fluvial or alluvial terraces (highest level fluvial deposits) are never flooded, except under severe conditions (see Appendix A -Photograph 4B).

Eolian deposits of fine sand are developed on glaciolacustrine plain and delta deposits. For the most part these deposits are not used for construction materials because they are too fine grained. If unfrozen, they can be used for general fill if no other good material is available.

Bedrock can also be used as a source of granular material. Quarries have been developed in limestone near Inuvik, limestone and shale near Norman Wells, and limestone along Highway 2 near Enterprise, NWT (see Appendix A - Photograph 5B). In these areas there is a shortage of Quaternary sediments consisting of good quality sand and gravel and quarries have been developed to fulfil needs for good quality construction material.

Granular Resources of the Outer Borderlands - Glacial sediments deposited directly from glacier ice in subglacial and supraglacial settings typically are poorly sorted, massive to weakly stratified, and very stony (Clague, 1989). Morainal deposits made up of these sediments have sand, silt, and clay matrices. Morainal sediments vary in character locally and regionally because of differences in source of materials and depositional environments, complexities in the pattern of glacier flow, and the effects of water and gravity during deposition. Tills derived from volcanic rocks, carbonates, mudstone, shale, and slate have a matrix rich in silt and clay. However, tills derived from granitic and metamorphic rock, sandstone and conglomerate have a sandy matrix. Also, tills formed from older glacial sediments tend to resemble those sediments in both texture and composition. Tills in areas of greater relief are more gravelly and have less silt and clay than tills in lowland and plateau areas. Tills on mountain slopes are similar to poorly sorted glaciofluvial sediments and colluvial sediments. Till in morainal landforms is generally used as a source of fill or impermeable borrow for construction purposes. However, the sandy gravelly till derived from crystalline rock, sandstone and conglomerate can be used as a source of granular material, particularly if better quality material is not readily available.

Glaciofluvial sediments include both ice contact and outwash deposits deposited subaerially, in lakes and the sea. Ice contact sediments consist of gravel and sand with some sorting and stratification. Ice contact sediments are found in the Cordillera in kames, kame terraces, knob and kettle topography, eskers, discontinuous sheets of gravel and sand overlying till (see Appendix A - Photograph 3B). Ice contact deposits are widely distributed and often are associated with large meltwater channels such as those on the Yukon Plateau (Clague, 1989). Outwash deposits consisting of stratified, well-sorted gravel and sand occurs as valley trains, plains, terraces, and deltas (see Appendix A - Photograph 2A). These materials lack the deformation structures associated with ice contact deposits. In the Cordillera, large amounts of outwash were deposited at the end of the last glaciation on proglacial floodplains and deltas and in subaqueous fans that prograded outward from glaciers terminating in lakes or the sea. In contrast, active outwash trains extending downvalley from large glaciers in the high mountains are graded to existing streams. Glaciofluvial sediments which predate the Late Wisconsinan glacial maximum underlie other Quaternary sediments. Glaciofluvial deposits of ice contact and outwash origin are the most common deposits which are exploited for granular material in glaciated portions of the Outer Borderlands (Cordillera and Queen Elizabeth Islands).

Glaciolacustrine deposits consist mostly of fine sand, silt, and clay which has been carried into glacier-dammed lakes by meltwater streams. Coarser sediments are found mostly in outwash fans, deltas, and beaches. Most glaciolacustrine sediments are fairly thick and may exhibit kettled topography. Some are well stratified, laminated, or varved and others have disturbed stratification. Glaciolacustrine deposits are common in the southern Yukon and in the unglaciated northern Yukon. In the northern Yukon, the Laurentide Ice Sheet advanced to the front of the Richardson Mountains and dammed east-flowing streams. Glaciolacustrine sediments are found in some locations beneath till. These deposits represent proglacial sediments which accumulated in lakes impounded by advancing Late Wisconsinan glaciers. Glaciomarine deposits consisting of fine to coarse grained deposits were formed at the continental margins during glacial times when sea level was higher. These deposits can consist of massive to stratified mud which resembles till or they can be stratified sand and gravel. Glaciomarine deposits are most common the west side of the Cordillera and on the Queen Elizabeth Islands. For the most part, glaciolacustrine and fine grained glaciomarine deposits are not exploited for construction materials except where fill or fine grained impermeable material may be required (e.g. construction of the core of dams).

Nonglacial deposits of colluvial, marine, fluvial (alluvial), lacustrine, eolian, volcanic and organic origin overlie bedrock and glacial deposits in the Outer Borderlands (Clague, 1989). Older nonglacial fluvial, lacustrine, and deltaic sediments are at the surface in the unglaciated parts of the Yukon. Colluvial deposits were formed by mass movement processes and are found at the surface and beneath glacial deposits in the Cordillera. There are four types of colluvium including landslide deposits, talus, colluviated drift, and solifluction deposits.

Modern marine deposits resemble glaciomarine deposits in composition and can consist of both coarse and fine grained material. Stratified sand and gravel are restricted to deltas, outwash fans, and beaches.

Nonglacial fluvial (alluvial) deposits consist of stratified sediments deposited by streams associated with Holocene and contemporary channels, floodplains, terraces, fans, and deltas. They also occur as nonglacial gravels beneath Late Wisconsinan drift. Streams with steep gradients and high sediment loads, which are common in the mountains, have shallow braided channels and gravelly floodplains. Streams with lower gradient are floored by sand and/or fine gravel with floodplains underlain by sand and silt deposited during floods. These streams occur in broad, low valleys outside mountain ranges. Fluvial terraces are underlain by gravel similar to that found on floodplains. These formed during the Holocene when streams incised Pleistocene valley fills. Alluvial fans consist of gravel, sand, and minor amounts of other material. Many of these formed at the end of the Pleistocene, but some are active today. Fluvial deltas are built into lakes or seas by streams and rivers.

Lacustrine deposits resemble glaciolacustrine deposits except they accumulated in environments free of glacier ice. These deposits are thickest in lakes with high sediment influx, (e.g. Kluane Lake, Yukon Territory).

Floodplain deposits were reworked locally into eolian deposits.

Holocene volcanic deposits of lavas and pyroclastics are also found in numerous localities in the Cordillera. Organic deposits accumulated in poorly drained areas.

Of the nonglacial deposits, Holocene fluvial floodplain, terrace, and fan deposits are the most commonly exploited for granular material. In some cases, beach deposits, and rubbly colluvium are also mined for granular material.

In the unglaciated part of the Yukon, older nonglacial fluvial sediments are at the surface (Hughes et al., 1989). These deposits are the best source of granular material in the area.

At some localities in the Outer Borderlands (Cordillera and Queen Elizabeth Islands) there is a shortage of naturally occurring granular material and bedrock is crushed to provide granular material for construction purposes. For example, crushed sandstone and shale is used as a source of granular material and fill along the Dempster Highway in the Richardson Mountains of the northern Yukon.

3.0 PART 2 - DEVELOPMENT OF NORTHERN GRANULAR RESOURCES

3.1 Previous Granular Resource Studies in the North

3.1.1 Introduction

The Department of Indian Affairs and Northern Development (DIAND) first attempted to establish a comprehensive inventory of Mackenzie Valley granular resources in the 1970's because hydrocarbon exploration activity, Mackenzie Highway construction, and planning for large diameter gas pipeline construction were expected to increase the demand for granular materials in this region where good quality sources are unevenly distributed and sometimes in short supply (Gowan, 1993). Government and anticipated users were involved in locating and planning for the development of the existing resources (see reports in Arctic Institute Northern Granular Resources Bibliography, 1993).

Expansion of hydrocarbon exploration in the Beaufort Sea during the 1980's and associated growth of support facilities at Tuktoyaktuk resulted in a second phase of granular resource work sponsored by DIAND and NOGAP (Northern Oil and Gas Action Program). This work was concentrated in the Beaufort Sea-Mackenzie Delta-Tuktoyaktuk Peninsula (Gowan, 1993).

Since the late 1980's, the Engineering Division of the GNWT Services and Public Works Department has undertaken granular resource studies in the non-tax based communities of the Northwest Territories. Tax-based communities (Inuvik, Yellowknife, etc.) have also compiled information on the granular resources available to them.

During the 1990's, DIAND granular resource assessment work has focused on updating and expanding the existing granular resource information base in the western Northwest Territories and the Yukon, and on carrying out projects in communities where there are critical shortages of granular materials. Also community land use concerns and land claims settlements have put pressure on public supplies of granular material and have led to local studies in communities with known shortages of material.

3.1.2 Granular Resource Inventories

Granular Resource Inventories 1970 - 1980 - Since the 1970's, granular resource inventory studies have been carried out along northern transportation corridors and near communities where proposed major engineering projects were expected to deplete the supply of good quality construction materials. Many of these studies were carried out by engineering consulting companies working for government (DIAND; DPW; GNWT) or industry, including pipeline companies (Canadian Arctic Gas Pipeline, Foothills Gas Pipeline, Mapleleaf Gas Pipeline, Beaufort-Delta Gas Pipeline, Polar Gas Pipeline, Norman Wells Oil Pipeline) and hydrocarbon companies exploring the Mackenzie Delta-Beaufort Sea (primarily Esso, Shell, Gulf, and Dome)).

Granular inventory studies began in the Mackenzie Corridor in 1972 when Mackenzie Highway construction, hydrocarbon exploration, and gas pipeline expansion began (PemCan Services, 1972a to 1972j; Ripley, Klohn Leonoff International Ltd., 1973 and 1972a to 1972i; EBA Engineering Consultants Ltd., 1974; Minning et al., 1973; Lawrence et al., 1972; Northern Engineering Services, 1973; 1974; 1976a; 1976b; 1977; Foothills Pipelines Ltd, 1975a; 1975b; other references in Arctic Institute Northern Granular Resources Bibliography, 1993).

Granular Resource Inventory Work 1980 to 1995 - In 1983, DIAND adopted a materials classification system which is similar to the system presented in the Territorial Pits and Quarries Regulations. Under this system material quality is divided into five classes related to the suitable end use of the material and the Unified Soil Classification of the material.

In 1986 and 1988, the information from earlier granular resource inventories, were summarized, correlated, standardized, and compiled in two reports (Hardy Associates (1978) Ltd., 1986; EBA Engineering Consultants Ltd., 1988). These reports for the Lower and Upper Mackenzie Valley presented the granular resource potential relative to projected future pipeline and community needs. As a result of these two studies, the Mackenzie Corridor was divided into "twelve borrow management zones" and all previously identified deposits were located on maps and described in tables. New information on supply and demand issues was also included. Based on the classification system accepted by DIAND in 1983, material quality in the deposits was divided into five classes.

In 1992, information on the granular sources contained in the two Mackenzie Valley summary reports were reproduced in (dBase III format) database files (EBA Engineering Consultants Ltd., 1992). In the Upper Mackenzie Valley, the volumes of material which were removed for construction of the Mackenzie Highway and the Interprovincial Pipeline were also subtracted from material totals (EBA Engineering Consultants Ltd., 1988).

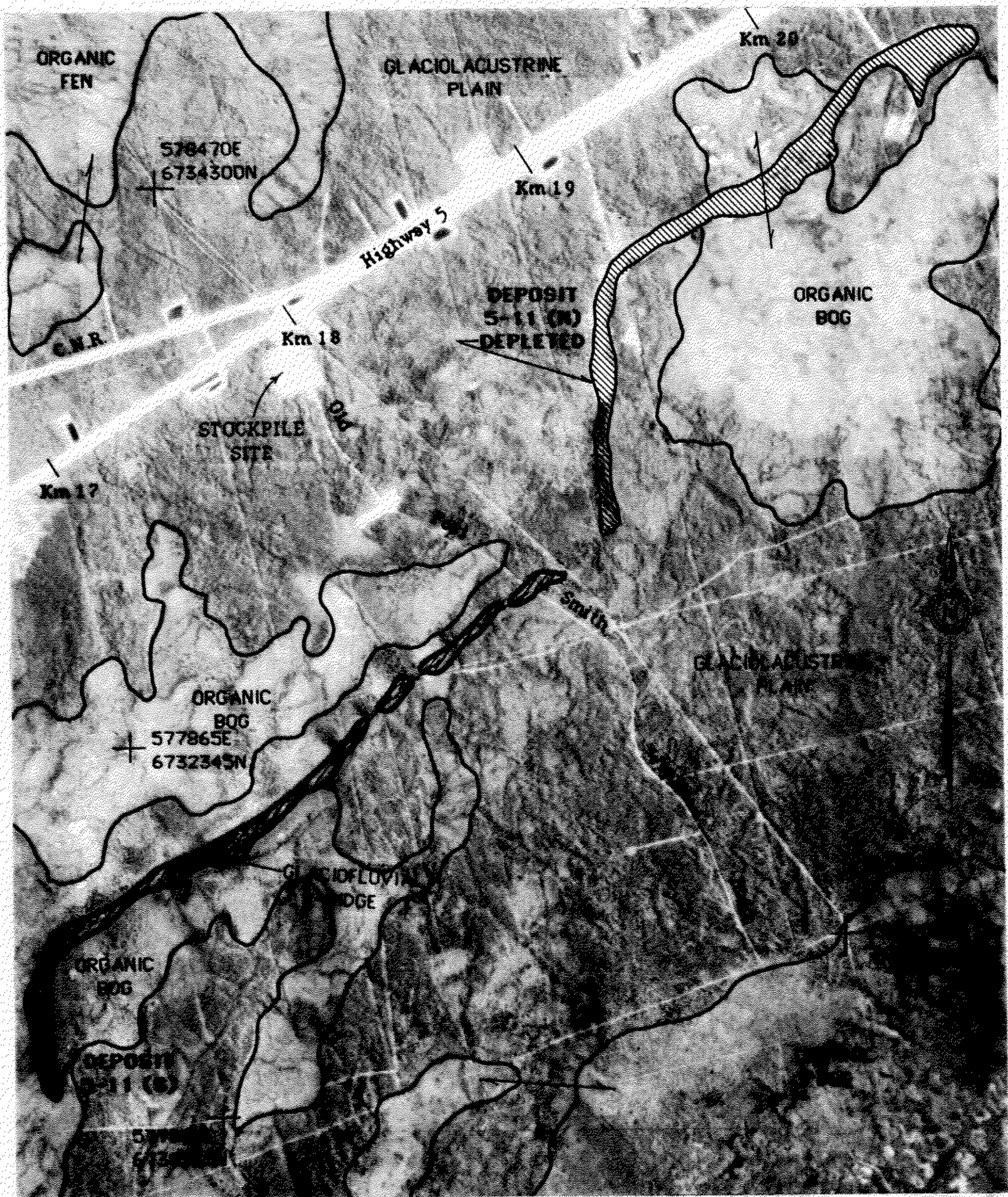
In 1987, DIAND retained Thurber Consultants to investigate granular aggregate supply and demand and a management strategy for the South Slave Region, NWT (Thurber Consultants Ltd., 1987). The area covered is located south of Great Slave Lake, between Slave River and the Mackenzie Highway. The communities of Fort Smith, Hay River, Enterprise, Pine Point, and Fort Resolution were included in this study. Supply and demand issues were analyzed and five borrow management areas were identified. Reserves of different classes of material in the categories of "proven", "probable", and "prospective" were identified in each management area. Depleted resources were also identified and rehabilitation of these resources was addressed.

DIAND has developed another database (dbase III format) similar to the Mackenzie Valley database files for existing known deposits in the Yukon. Because some of these deposits were partially or totally depleted by past users, the database for the Yukon includes confirmation of the field condition of many of the deposits.

Methodology Followed in Granular Resource Inventory Studies - Granular resource inventory studies were carried out using existing geological mapping and airphoto interpretation to delineate bedrock and surficial deposits which could serve as "sources" for construction materials (R.M. Hardy and Associates and Terrain Analysis and Mapping Services, 1977; EBA Engineering Consultants, 1978; Thurber Consultants Ltd., 1987).

Deposits were outlined on airphotos (see example in Figure 7) and described on the basis of both geological and engineering field investigations and laboratory testing. Field investigations involved test pitting, drilling, some geophysics and analysis of existing pits and natural exposures to obtain information on the geological setting, extent and thicknesses of the deposits. Test pit, drillhole logs and laboratory testing of representative samples produced information on engineering properties and geological characteristics of materials within each deposit,(e.g. grain size, ice contents, overburden thicknesses). Observations on the biologic setting, drainage, access, and other development constraints were also made during field investigations. Field and laboratory information were combined to calculate volumes of material within the deposits.

Several types of volume calculations were made depending on the year of the inventory and the number of subsurface boreholes available for volume calculations. "Total estimated volume" in earlier studies was calculated from the areal extent of the deposits multiplied by the estimated thickness of useable good quality granular material (PemCan Services, 1972a). These estimated volume calculations took into account the estimated thickness of useable good quality granular material, the recovery depth, and characteristics of the deposits. Total estimated



NOTE: AFTER AIRPHOTO A25787-54

	DEPARTMENT OF SUPPLY AND SERVICES	DRAWN IGJ/JAB
	Figure 7: Example of Interpreted Airphoto Map of Granular Resources. (Deposit 5-11)	DATE APRIL, 1987
		APPROVED
		SCALE 1:20,000
	SOUTH SLAVE GRANULAR STUDY	FILE No. 16-5-38
THURBER	CONSULTANTS LTD., Geotechnical Engineers	DRAWING No. C4

volume calculations did not differentiate between total estimated volumes and recoverable volumes.

In later inventory studies "recoverable volumes", were calculated separately from total estimated volumes (R.M. Hardy and Associates and Terrain Analysis and Mapping Services, 1977). Total estimated volumes were calculated only from the geometry of the deposit so that new information on deposit properties, excavation depth, etc. could be used with the original total estimated volume to produce recoverable volume estimates at any future date. Recoverable volumes based on the inventory studies were then calculated recognizing the current "known" properties of the deposits e.g. ground ice contents, permafrost, and groundwater, combined with excavation depths in effect at the time. For the most part, recoverable volumes were somewhat less than the total estimated volumes.

After 1983, when DIAND accepted the five classes of material based on the suitable end use of the material and the Unified Soil Classification, total estimated volume information was subdivided into three major categories: "proven", "probable", and "prospective" (EBA Engineering Consultants Ltd., 1988).

"Proven" resources consist of material whose occurrence, distribution, thickness, and quality is supported by extensive ground truth information such as test pitting, drilling, and/or exposed sections. The volume is calculated assuming an average thickness of sampled material which is extrapolated over an area of 50 m radius around a drillhole/test pit with adjustments for landform type and general stratigraphic complexity. "Probable" resources include material whose existence and extent have been inferred on the basis of several types of direct or indirect evidence including topography, geophysics, airphoto interpretation, and limited test pits or boreholes. "Prospective" resources are deposits whose volumes are based on limited indirect evidence such as airphoto interpretation and general geological considerations. By convention, "probable" resources extend to and include "proven" resources, and "prospective" resources include "probable" resources.

3.1.3 Detailed Granular Resource Studies

Detailed granular resource studies have also been undertaken in certain localities to expand on information obtained during granular resource inventories. These more detailed studies covered (1) specific sources in the Mackenzie Valley, the Beaufort Sea and northern Yukon where shortages of certain classes of granular material exist, and (2) community sources throughout the Northwest Territories and Yukon which had not been previously identified and studied.

Good quality granular material is in short supply in the Lower Mackenzie Valley near Tuktoyaktuk and Inuvik. In the late 1970's and 1980's, hydrocarbon exploration onshore near Inuvik and offshore in the Beaufort Sea, and development of Tuktoyaktuk as a support base for exploration placed demands on the existing granular sources in this region. Proposals for further hydrocarbon exploration facilities in the Beaufort Sea, north of the Yukon Coastal Plain, led to further delineation of construction materials in the region immediately west of the Lower Mackenzie Valley. Construction of the Norman Wells oil pipeline in the Upper Mackenzie Valley also resulted in site specific granular materials studies along that portion of the Mackenzie Corridor.

Studies near Inuvik focused on analysis of the granular deposits in the Mackenzie Delta area and Richards Island (EBA Engineering Consultants Ltd., 1976a; 1986), evaluation of three granular sources #326 (Devil's Lake), #303 (Lucas Point), and #222 (Swimming Point) (EBA Engineering Consultants Ltd., 1976b) the Ya-Ya esker (EBA Engineering Consultants Ltd., 1975) and investigation of potential quarries in the Inuvik Area (EBA Engineering Consultants Ltd., 1976c).

At Tuktoyaktuk, a granular materials inventory and a geophysical evaluation of granular materials resources in the harbour were carried out (R.M. Hardy and Associates, 1977; 1978). Detailed evaluation of deposits 168 and 211 near Tuktoyaktuk were also undertaken (BBT Geotechnical Consultants Ltd., GVM Geological Consultants Ltd., and Terrain Analysis and Mapping Services Ltd., 1983).

In the Beaufort Sea and along the Yukon Coastal Plain, offshore and onshore deposits were investigated. In addition to the onshore granular materials inventory (R.M. Hardy Associates and Terrain Analysis and Mapping Services Ltd., 1977), an overview of granular resource potential for the western Beaufort (Yukon) continental shelf was done (Earth and Ocean Research Ltd, 1986; 1988). The characteristics of granular deposits offshore at the Herschel Sills Site was investigated (EBA Engineering Consultants Ltd., 1984) and potential rock quarries in the Beaufort Region were evaluated (Peter Kiewitt Sons Co., 1983; Golder Associates 1988a; 1988b). Sources for concrete aggregate in the western Beaufort region were also assessed in laboratory experiments (Klohn Leonoff Ltd., 1988; 1989).

Construction of the Norman Wells oil pipeline in the Upper (South) Mackenzie Valley led to environmental studies of borrow sources required for pipeline construction (Hardy Associates (1978) Ltd. and Interprovincial Pipeline, 1982a; 1982b). During construction of artificial islands in the Mackenzie River at wellsites that supply hydrocarbons to this pipeline, gravel reserves were discovered in the Mackenzie River at Norman Wells. This discovery led to a special study to determine the feasibility of developing granular borrow from the bed of the Mackenzie River (EBA Engineering Consultants Ltd., 1987a).

In the late 1980's and 1990's, granular resources near specific communities were documented and assessed in some detail by other government agencies. The Engineering Division of the GNWT compiled information on granular resources which could be developed within a reasonable distance of the non-tax based communities in the Northwest Territories. Fifty-five communities are covered by this program including 36 hamlets, 5 towns, 2 villages, and 12 settlements (Fred Collins, GNWT Engineering Division, personal communication). Detailed reports on both sources of granular material and community demand issues have been completed for 12 of these communities, 4 reports are in progress, and 5 studies were planned for 1993-1994.

Similar compilations have been done for tax-based communities like Yellowknife as part of their land use planning activities (Howard Madill, DIAND Land Resources, personal communication).

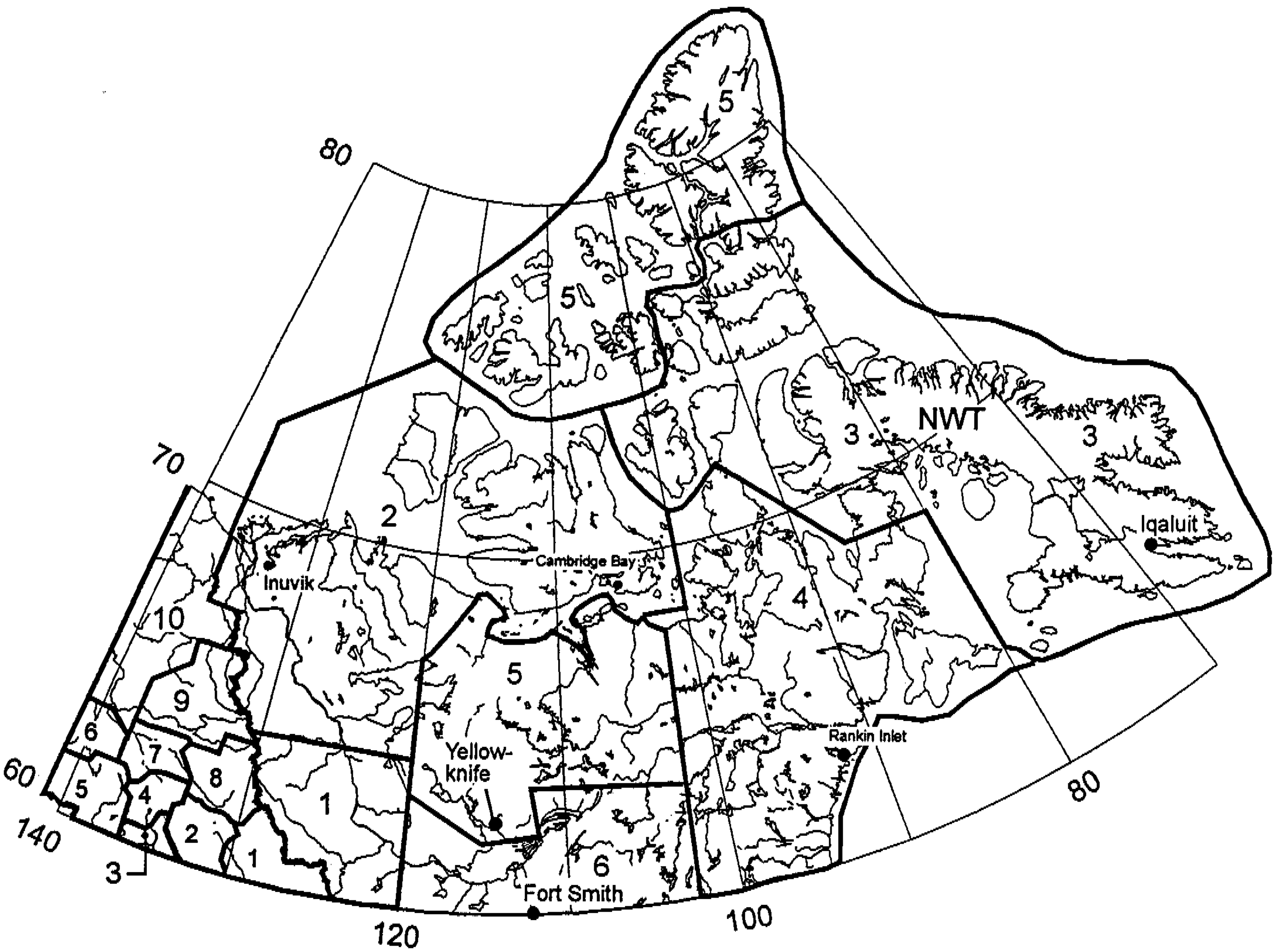
Highways departments in both the NWT and Yukon have ongoing programs to evaluate the status of specific deposits which are designated for highway maintenance and construction (Sandy Murray, GNWT Highways Department, personal communication; Peterson, 1993).

Local issues related to granular resource development are handled by personnel attached to local DIAND Management Districts and Regional Offices in the north (see Figure 8).

As a result of land claims settlements, various native groups have become involved as the administrators for granular materials issues on their lands (EBA Engineering Consultants Ltd., 1987b; Klengenberg, 1993). Future inventories may tend to be organized more on the basis of land claims settlement regions than on the present DIAND Management Districts.

3.1.4 Granular Resource Development Studies

From the late 1970's to the 1990's, studies which focused on planning for an orderly and environmentally acceptable development of northern granular resources have also been undertaken. DIAND implemented guidelines for the development and



LEGEND

NORTHWEST TERRITORIES	YUKON TERRITORIES
1. Ft. Simpson	1. Watson Lake
2. Inuvik	2. Teslin
3. Baffin	3. Tagish
4. Keewatin	4. Laberge
5. Yellowknife/Arctic Islands	5. Haines Junction
6. Ft. Smith	6. Beaver Creek
	7. Carmacks
	8. Ross River
	9. Mayo
	10. Dawson

Figure 8: DIAND Management Districts

restoration of pits and quarries in the Northwest Territories and Yukon (DIAND, 1982). Some other studies done for DIAND and GNWT investigated granular resource management strategies by region, community, or land claim area (Thurber, 1987; Hardy BBT Ltd., 1986; Collins, 1987 to 1993c; EBA Engineering Consultants Ltd., 1987a and 1987b).

Other studies were more site specific and discuss the development and restoration of an individual source like the Ya-Ya esker complex or the Norman Wells pits and quarries (Terrain Analysis and Mapping Services Ltd., 1976; Thurber, 1986). Industry also conducted studies on pits and quarries proposed for specific projects (see Appendix A - Photograph 9A) (Northern Engineering Services Company Ltd. 1976a, 1976b, 1977; Hardy Associates (1978) Ltd. and Interprovincial Pipelines 1982a, 1982b).

3.2 Current Status of Granular Resource Supply and Demand Information

3.2.1 Production Information for the Yukon and Northwest Territories

Construction materials are produced at many locations throughout the Northwest Territories and Yukon. Hundreds of sand and gravel pits which provide both good quality granular material and general fill are located near highways and communities (see Appendix A - Photographs 5A, 6A, 6B, 7A, 7B, 10A). In the vicinity of major resource development projects, e.g. Beaufort Sea and Norman Wells, pits and quarries have been developed to supply the need for all grades of construction material (see Appendix A - Photographs 5B, 8A, 8B).

Granular material is produced by two distinct sectors: commercial and public. In the commercial sector, individuals or companies produce material for sale to other parties. In the public sector, a level of government produces material for public works. In some cases, commercial operations produce material that is sold to the public sector. Most commercial sector production in the north is carried out in the vicinity of cities (Yellowknife and Whitehorse).

Production figures for granular resources throughout Canada are published by Energy, Mines, and Resources (EMR), Ottawa, Ontario. Accumulation of granular resource statistics for the Yukon and Northwest Territories began in 1982 (EMR Statistics, see Underwood Bibliography, 1992). These reports give the amounts of granular resources (aggregate resources is synonymous with granular resources in these reports) in terms of weight and/or volumes. Weights are given in tonnes and volumes in cubic yards or cubic metres.

Granular resource production in the Yukon was 19.0 Megatonnes (average of 1.9 Megatonnes/year) for 1982 to 1991 (see Figure 9). All other minerals produced during this time equalled 1.6 Megatonnes. In the Northwest Territories, total production for granular material (aggregates) between 1982 and 1991 was 46.8 Megatonnes (average of 4.68 Megatonnes/year) (see Figure 10). All other minerals produced during this time equalled 3.9 Megatonnes. Figures for production of quarry rock (stone) are also reported separately by EMR (see Figures 9 and 10). In the north, most of this quarry rock is crushed to provide aggregate material rather than to provide material for cement or building stone.

On a per capita basis, production of granular material in the north is greater than in Canada as a whole. Between 1982 and 1991 the national average was 13.4 tonnes/person/year while in the Yukon and Northwest Territories it was 77.8 tonnes and 92.2 tonnes respectively (Underwood, 1992). Also, great fluctuations were seen in the territorial production, while Canada's total remained stable. These fluctuations may result from the impact of aggregate demand booms from megaprojects, and their subsequent busts, or statistical variations within the small total aggregate production.

Processing of granular material in the north is less common than in the south. In 1990, 62% of territorial aggregate material was unprocessed. Most of the processed aggregate (35%) was gravel that had been crushed and screened only. Several reasons exist for less processing of material in the north including: (1) less industrial diversification and less demand for processed products than in the south; and (2) less mechanization in aggregate processing in the north because of the cost of moving and operating equipment, particularly in winter.

3.2.2 Demand Information for the Yukon and Northwest Territories

The demand for construction materials in the north comes from the public sector and from industrial users. The public sector requires construction material for transportation and community uses. In the north, road, airport, and harbour construction depend on significant quantities of granular material. Community needs include the use of bedding and padding under buildings and trailers placed on permafrost, concrete aggregate for construction of buildings, and sand, gravel, and fill for community roads, pervious and impervious material for dams, etc. (see Appendix A - Photograph 10B).

TABLE AGGREGATE PRODUCTION FOR YUKON, IN VOLUME, WEIGHT, AND DOLLAR VALUE, 1982 - 1991.

Material		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991(P)
sand & gravel	$'000	550	1,438	5,105	2,995	13,355	1,502	5,184	5,675	9,833	6,883
	kt	463	480	3,074	1,185	4,902	352	2,246	2,367	2,113	1,542
	m^3 '000	262	271	1,737	669	2,769	199	1,269	1,337	1,194	871
	$/t	1.19	3.00	1.66	2.53	2.72	4.27	2.31	2.40	4.65	4.46
	% total geol. t	79.69	99.59	99.93	99.66	95.72	42.62	89.16	89.12	88.56	86.63
stone	$'000					405	679				
	kt					116	206				
	m^3 '000					66	116				
	$/t					3.49	3.30				
	% total geol. t					2.27	24.94				
total aggregates	$'000	550	1,438	5,105	2,995	13,760	2,181	5,184	5,675	9,833	6,883
	kt	463	480	3,074	1,185	5,018	558	2,246	2,367	2,113	1,542
	m^3 '000	262	271	1,737	669	2,835	315	1,269	1,337	1,194	871
total geological resources production	$'000	169,120	62,987	70,143	60,069	176,715	426,027	492,299	532,330	541,814	346,216
	kt	581	482	3,076	1,189	5,121	826	2,519	2,656	2,386	1,780

P = preliminary figures, kt = kilotonnes, t = tonnes, m^3 = cubic metres

sources: Canadian Transport Commission. 1978. The Canadian Aggregate Industry.
Ministry of Indian Affairs and Northern Development. 1985-1990. Mines and Mineral Activities.
Statistics Canada. 1988-1991. Canada's Mineral Production. Industry Div., Census of Manufactures Section. Annual.

(Underwood, 1992): yukagpro.wq1

Figure 9: Aggregate Production Information for the Yukon 1982-1991

TABLE AGGREGATE PRODUCTION FOR THE NORTHWEST TERRITORIES, IN VOLUME, WEIGHT AND DOLLAR VALUE, 1982 -1991.

Material		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991(P)
sand & gravel	$'000	41,482	32,479	36,323	8,981	3,281	8,132	10,966	11,813	13,856	8,160
	kt	6,625	5,905	7,249	6,803	986	2,183	2,443	2,203	3,274	1,853
	m^3 '000	3,743	3,336	4,095	3,844	557	1,233	1,380	1,245	1,850	1,047
	$/t	6.26	5.50	5.01	1.32	3.33	3.73	4.49	5.36	4.23	4.40
	% total geol. t	91.63	68.41	85.80	90.92	54.33	71.55	81.41	65.45	64.82	70.32
stone	$'000	1,268	14,601	4,617	434	1,011	1,486	232	4,344	9,079	3,735
	kt	323	2,409	729	163	368	472	108	727	1,495	508
	m^3 '000	210	1,564	473	106	239	306	70	472	971	330
	$/t	3.93	6.06	6.33	2.66	2.75	3.15	2.15	5.98	6.07	7.35
	% total geol. t	4.47	27.91	8.63	2.18	20.28	15.47	3.60	21.60	29.60	19.28
total aggregates	$'000	42,750	47,080	40,940	9,415	4,292	9,618	11,198	16,157	22,935	11,895
	kt	6,948	8,314	7,978	6,966	1,354	2,655	2,551	2,930	4,769	2,361
	m^3 '000	3,953	4,900	4,569	3,949	796	1,540	1,450	1,717	2,820	1,377
total geological resources production	$'000	468,349	557,198	746,451	649,732	668,452	713,310	826,487	960,771	729,675	544,681
	kt	7,230	8,632	8,449	7,482	1,815	3,051	3,001	3,366	5,051	2,635

P = preliminary figures, kt = kilotonnes, t = tonnes, m^3 = cubic metres

sources: Canadian Transport Commission. 1978. The Canadian Aggregate Industry.
Ministry of Indian Affairs and Northern Development. 1985-1990. Mines and Mineral Activities.
Statistics Canada. 1988-1991. Canada's Mineral Production. Industry Div., Census of Manufactures Section. Annual.

(Underwood, 1992): nwtagpro.wq1

Figure 10:Aggregate Production Information for the Northwest Territories

Industrial demand comes principally from the development of hydrocarbons and minerals. Development of hydrocarbons requires granular material and fill for artificial islands and land based facilities. Armour stone is also required for offshore production facilities. Pipelines require granular material for construction of facilities (e.g. staging areas, compressor stations, stockpile sites, wharfs, communications towers, roads, airstrips, meter stations and operations and maintenance areas), bedding and padding under the pipeline, concrete weights, and other miscellaneous uses (see Appendix A - Photographs 9A and 9B; Photograph 8A) (Northern Engineering Services Company Ltd., 1974). Mining requires granular material for mine backfill and for construction of roads and other facilities.

Historical territorial usage patterns show that roads account for 46% of the demand for granular material between 1982 and 1990 (see Figure 11) (Underwood, 1992; DIAND Report, in prep.). Other uses (artificial island building, etc.) account for 27%, fill 23%, concrete aggregate 2%, mine backfill 1%, ice control on roads, asphalt aggregate, and mortar sand 1%. It is anticipated that future demands for granular resources and other construction material (see Figures 11 and 12) will follow historical usage patterns with routine maintenance and upgrading of infrastructure, e.g., road building, accounting for a large part of the demand. Political decisions, like the creation of a new town or expansion of an existing community, may increase demand in a certain area. Increased population growth also affects the need for more construction materials. Major northern development projects, such as pipelines and oil and gas production facilities, while less certain in their timing will result in increased demand for construction materials if they are built (McDougall, 1993). However, it should be noted that changes in technology and engineering design could result in lower demand than previously predicted for construction materials in both the public and private sectors.

By linking population forecasts to average per capita production of granular material over the past 10 years, it is estimated that 2.2 million m^3 (3.89 Megatonnes) would be required per year in the Yukon and over 5.2 million m^3 (9.2 Megatonnes) in the Northwest Territories (Underwood, 1992).

TABLE USES OF SAND AND GRAVEL IN TERRITORIES AND CANADA, IN KILOTONNES, USING AVAILABLE DATA, 1982 - 1990.

	1982		1983		1984		1985		1986		1987		1988		1989		1990		9 Year Average	
Use	Terrs	Canada	Terrs	Canada	Terrs	Canada	Terrs	Canada	Terrs	Canada	Terrs	Canada	Terrs	Canada	Terrs	Canada	Terrs	Canada	Terrs	Canada
road bed, surface	843	130,455	893	152,908	4,229	145,962	2,454	159,892	3,144	154,917	2,228	192,019	3,823	178,512	3,815	164,513	3,788	147,193	2,802	158,486
other uses	23	18,340	5,404	24,491	5,197	25,748	178	20,812	2,369	26,651	326	3,696	353	11,747	163	15,716	640	14,636	1,628	17,982
fill	6,218	29,327	77	20,358	160	20,271	5,156	27,726	283	27,130	222	31,430	129	27,491	59	25,783	41	22,787	1,372	25,811
concrete aggregate	3	22,437	9	24,214	16	27,425	34	33,619	56	34,803	110	39,304	333	38,149	329	36,881	275	32,652	129	32,165
mine backfill		1,182		971		1,551	165	1,761	25	2,599	11	1,615	9	1,562		806	603	1,268	90	1,479
roads, ice control	1	6,233	2	4,620	--	5,577	1	5,208	10	6,228	7	5,122	21	6,048	16	5,063	18	4,981	8	5,453
asphalt aggregate													13	18,681	5	21,498	20	17,080	4	6,362
mortar sand		1,563		3,223		2,361		2,073	1	2,294	1	3,165	2	3,227	2	2,680	1	2,321	1	2,545
railroad ballast		2,796		2,623		4,864		5,092		3,055		2,565		2,234		1,961		1,493	0	2,965
total	7,088	212,333	6,385	233,408	9,602	233,759	7,988	256,183	5,888	257,677	2,905	278,916	4,683	287,651	4,389	274,901	5,386	244,411	6,035	253,249

source: Statistics Canada. 1982 - 1990. Quarries and Sand Pits. Manufacturing and Primary Industries. Catalogue 26-225.

(Underwood, 1992): consns&g.wq1

Figure 11: Uses of Sand and Gravel in the Territories and Canada 1982-1990

TABLE USES OF STONE IN TERRITORIES AND PROVINCES, IN KILOTONNES AND DOLLARS, 1982 - 1990.

Use		Yuk & NWT 1982	Cdn Provs 1982	Yuk & NWT 1983	Cdn Provs 1983	Yuk & NWT 1984	Cdn Provs 1984	Yuk & NWT 1985	Cdn Provs 1985	Yuk & NWT 1986	Cdn Provs 1986	Yuk & NWT 1987	Cdn Provs 1987	Yuk & NWT 1988	Cdn Provs 1988	Yuk & NWT 1989	Cdn Provs 1989	Yuk & NWT 1990	Cdn Provs 1990
dimensional stone	kt		314		266		318		363		256		278		329		360		390
	$'000		9,695		12,079		15,726		18,446		22,150		24,867		33,786		34,845		44,610
chemical process	kt		2,622		2,909		2,734		16,680		18,161		19,531		19,133		20,256		18,660
stone	$'000		15,224		17,517		17,617		59,362		59,956		62,858		65,872		71,448		67,606
pulverised stone	kt		1,223		1,426		1,461		1,741		1,512		1,839	79	1,660		1,627		1,535
	$'000		14,699		18,962		21,674		29,479		26,202		31,128	62	30,298		33,436		32,145
misc. stone	kt	--	1,985	6	2,393	1	2,054	38	5,463	111	3,883	266	4,724	13	4,647	101	4,488	203	3,476
	$'000	1	24,452	35	30,478	5	31,775	104	20,680	289	27,587	381	30,240	216	31,444	208	28,044	364	29,921
crushed stone	kt		46,642		51,296	38	64,448	125	75,826	373	88,397	412	101,919	24	109,124	625	107,940	1,292	101,158
	$'000		168,354		187,262	262	248,433	330	317,221	1,127	392,948	1,784	474,355	95	515,984	4,137	540,250	8,715	527,241
total	kt	--	52,786	6	58,290	39	71,015	163	100,073	484	112,209	678	128,291	116	134,893	726	134,671	1,495	125,219
	$'000	1	232,424	35	266,298	267	335,225	434	445,188	1,416	528,843	2,165	623,448	373	677,384	4,345	708,023	9,079	701,523

kt = kilotonnes

source: Statistics Canada. 1982-1990. Quarries and Sand Pits. Manufacturing and Primary Industries Division. Cat. 26-225.

(Underwood, 1992): shipston.wq1

Figure 12: Uses of Stone in the Territories and Provinces 1982–1990

3.3 Issues Affecting the Supply and Development of Northern Granular Resources

3.3.1 Supply Issues Related to Northern Granular Resources

Increased future demand for construction materials in the north, discussed in Section 3.2 of this report, will require both the expansion of existing borrow pits and quarries and the development of new granular and bedrock sources. Granular deposits and near surface resistant quarry rock are not evenly distributed because their location is related to the regional geologic history and setting. The sporadic occurrence of sources and the depletion of existing sources may result in localized shortages of specific types of material, particularly naturally occurring good quality granular materials in Quaternary deposits.

3.3.2 Shortages of Granular Material in the Canadian Shield

Quaternary deposits which are most commonly used as a source for granular material on the Canadian Shield include deposits of glacial, proglacial, and nonglacial origin. Glacial and proglacial deposits (morainal, glaciofluvial, and nearshore glaciolacustrine and glaciomarine deposits) are concentrated in areas of late glacier advance and retreat. Postglacial nonglacial deposits of marine and fluvial origin exist near the sea and along present day rivers and streams. Interglacial (nonglacial) deposits of fluvial origin are found beneath glacial deposits in areas of thicker drift. In some localities, granular material may be covered by fine grained sediment (overburden) of marine or lacustrine origin.

Despite the general abundance of granular deposits in the Canadian Shield, materials of suitable grading and quality are not always available where there is a requirement for the material (Dyke et al., 1989). The dominant by-products of glacier action on Precambrian rocks are fine sand and boulders. As a result, many landforms that would appear suitable for granular material (eskers or moraines) have a short fall of medium and coarse sand and fine pebbles, and an excess of fine sand. Glacial and postglacial beach deposits locally cover extensive areas and consist of coarse sand and fine pebbles. However, large areas of these deposits have to be scraped to obtain appreciable volumes of material. In most areas, coarse textured till is a source of low grade granular material. Processing is required to make higher grade material from the till. Precambrian rock is often crushed in to provide sound, nonreactive materials but in some areas this rock may contain biotite-rich lithologies which are subject to disintegration. Also limonitic rocks, siltstones, and slates may not be sound when processed.

Recently completed granular resource studies by GNWT Government Services and Public Works Department near twelve communities in the Canadian Shield, indicate that eight of these communities will face shortages of good quality granular material at reasonable haul distances from the communities in the not too distant future (Collins, 1987, 1989a, 1989b, 1990, 1991a, 1991b, 1992a, 1992b, 1992c, 1993a, 1993b, 1993c). These communities (Rankin Inlet, Baker Lake, Rae/Edzo, Cape Dorset, Repulse Bay, Lake Harbour, Whale Cove, and Snare Lakes) currently use granular deposits from morainal, marine (primarily beaches), colluvial, glaciofluvial, and alluvial deposits, but will eventually depend on quarried rock to provide granular material (see Appendix B).

3.3.3 Shortages of Granular Material in the Borderlands

In the Inner Borderlands (Interior Plains, Arctic Lowlands, and Arctic Coastal Plain), granular material is found primarily in Quaternary glaciofluvial deposits (outwash and ice contact deposits), in Tertiary and Quaternary alluvium (floodplains and terraces), in Tertiary gravels on plateau surfaces, and in nearshore marine and glacial lake deposits (primarily beaches). At some localities, resistant sedimentary rock is crushed to provide granular material (e.g. limestone at Norman Wells and Inuvik). In the northern part of the Inner Borderlands, Quaternary deposits can have high ice contents which affect the amount of material available for development and the methods employed to develop the deposits.

Previous studies of granular deposits in the Inner Borderlands have indicated potential local shortages (see Appendix B). During planning for pipeline projects through the Mackenzie Valley of the Interior Plains and the Arctic Coastal Plain, areas with shortages of good quality granular material were identified (a) south and east of Travaillant Lake, (b) immediately south of Fort Good Hope, (c) south of Great Bear River, (d) north of Wrigley, and in some localities on the Arctic Coastal Plain (Pipeline Assessment Group, 1974). Some of these same areas were also identified in later reports which summarized and described granular resource studies from the Lower and Upper Mackenzie Valley, the Mackenzie Delta Region, and Inuvialuit Lands respectively (Hardy Associates (1978) Ltd., 1986; EBA Engineering Consultants Ltd., 1988; Hardy BBT, 1991 Limited; EBA Engineering Consultants Ltd., 1987b).

In the Lower Mackenzie Valley and Mackenzie Delta, areas with potential for shortages of certain types of material were identified in Borrow Management Area 1A near Tuktoyaktuk, in Borrow

Management Borrow Management Area No. 2 centered on Inuvik, Borrow Management Area No. 3 (east of Arctic Red River), and Borrow Management Area No.6 south of Fort Good Hope (Hardy Associates (1978) Ltd., 1986). An overall 20 year supply-demand comparison prepared in 1991, indicated that there is adequate supply of granular material (based on proven volumes of good prospects) for Inuvik and Aklavik, but a shortage of 9.0 x 10^6 m^3 exists for Tuktoyaktuk unless resources are allocated from Borrow Management Area 1B (Hardy BBT Limited, 1991). Borrow Management 1B has 35.5 x 10^6 m^3 of Class 1, 2, and 3 material which is more than adequate to meet Tuktoyaktuk's projected needs.

In the Upper Mackenzie Valley, potential granular resource shortages were identified south of River-Between-Two Mountains (Borrow Management Area 10) and near the communities of Fort Norman (Borrow Management Area 8), Fort Simpson and Jean Marie (Borrow Management Area 11), and Fort Providence (Borrow Management Area 12 (EBA Engineering Consultants Ltd., 1988).

In the South Slave Region (partly Interior Plains and partly Shield), the 5 year demand is considerably less than the 5 year supply (Thurber Consultants Ltd., 1987). Some demand concerns exist in some areas (e.g. shortages of naturally occurring Class 2 material in Borrow Management Area 1, and Class 1 and 2 materials in Borrow Management 4.

In the Outer Borderlands, most granular materials are produced from glaciofluvial deposits (outwash and ice contact deposits), from Quaternary alluvium, from Pleistocene beach deposits, from sandy, gravelly till, from colluvium, and from nonglacial deltaic and fluvial sediments in unglaciated areas. At some localities, resistant rock is crushed and substituted for gravel. The Outer Borderlands have significant reserves of granular materials, but local shortages of certain classes of material may occur, particularly where there is development, e.g. along highways and near towns. In northern parts of the Outer Borderlands surficial deposits may have high ice contents, making their exploitation difficult. In some of these locations, e.g. along the Dempster Highway, shallow bedrock is used instead of these materials to provide good quality, ice-free granular and nongranular material. Also in the Outer Borderlands, where there is significant sand and gravel-sized material, there is a shortage of fine grained material (silt and clay) which may be needed for construction purposes (e.g. liners for land fills and cores for dams).

3.3.4 Land Use Planning and Granular Resources

In northern Canada, federal and territorial governments and native organizations have the responsibility for planning the use and development of the land. Planning agencies and/or departments within the governments and members of native organizations are involved in preparing land use plans which outline development requirements. The availability of construction materials is affected by the land-use planning process because land may be zoned to include or exclude the extraction of these materials. Granular resource inventory and quarrying study information can be important to those involved in the planning process because it is useful in comparing the merits of extracting construction materials to other land uses (Edwards et al., 1985). In the past, this information was not always available and planning decisions were made without considering the resource base or the effects of planning decisions on future use.

DIAND is involved in administering land use planning issues on territorial land of northern Canada. Six districts (including several subdistricts) of DIAND exist in the Northwest Territories. The Yukon is considered one district with ten subdistricts (DIAND, 1982; see Figure 8). In addition to territorial land, there is also community land around many of the communities in the Northwest Territories and Yukon. These lands, known as "Commissioner's Lands," have been transferred from the Federal Government to the Territorial Government. Commissioner's Lands were set up to protect community interests, and usually include the local source of granular material (DIAND, 1982). The Territorial Government and/or the community initially opens the community pit and then the administration of the pit is the responsibility of the community council.

Recent land claim settlements have changed land ownership and resource development procedures within settlement regions (Klengenberg, 1993). For example, in the Inuvialuit Settlement Region the Inuvialuit Land Administration (ILA), a division of the Inuvialuit Regional Corporation, has the mandate to administer access to and across Inuvialuit Lands. These lands are tracts of land, within the Inuvialuit Settlement Region, that are privately owned by the Inuvialuit. The ILA has established a land management system, whereby all access and developmental activities on Inuvialuit Lands are subject to ILA Rules and Procedures. It is the responsibility of the ILA to reserve and make available adequate granular resources to meet public and community needs in the Western Arctic based on 20 year forecasts. The forecasts are jointly prepared between the Inuvialuit and appropriate levels of government on the basis of community estimate requirements.

Future land use plans developed by all planning departments of local and regional government and land claim settlement regions should be aware of the location, geology and engineering properties of available granular resources and quarries and planning issues related to the developing these resources within their jurisdictions.

3.3.5 Resource "Sterilization"

Granular resources and other construction materials may be permanently removed from available supplies because the land may be committed to purposes other than the development of these resources. This loss of availability is called "sterilization" (Edwards, et al., 1985). Most cases of "sterilization" of granular resources results from placing permanent structures over the deposits or from potential conflicts with adjacent land users. As a result, a valuable resource may never be used, often because insufficient information was available to the people making land use decisions. "Sterilization" of construction material resources is most common near more populated areas where population pressures have required large-scale land development, e.g. Yellowknife. Away from settled areas, highways, pipelines and transmission lines and the buffer zones around them can also cause resources to be "sterilized".

To prevent resource "sterilization" it is important that land administrators and planners recognize the influence of geological conditions on the availability of granular resources within their area and identify the types of land-use that might permanently remove these resources from production. Land use plans should include measures to protect these resources.

4.0 SUMMARY AND RECOMMENDATIONS

4.1 Summary

Good quality granular material (sand and gravel, crushed resistant bedrock) and lesser quality material (till, silt, and clay) are needed for economic development in the Canadian north. The special construction requirements related to permafrost and the long distances between population centres makes per capita consumption of granular resources significantly higher in the north than in the south.

Naturally occurring granular resources and other construction materials are distributed according to their geological origin and the geological history of the region in which they occur. The Northwest Territories and Yukon Territory encompass several geological regions and subdivisions of the Canadian Shield and Borderlands, each with unique bedrock and Quaternary deposits that supply the sources for granular and other construction materials.

High demand in certain locations may result in shortages of some types of material because the geological processes which affected these areas did not always result in the development of suitable sources which are evenly distributed.

In order to conserve granular resources, and ensure their orderly future development, resource management programs should take into account background geological information on the key sources of granular material.

4.2 Recommendations

Future granular resource planning programs would:

1) have granular resource management personnel be aware of newly produced federal and territorial government surficial and bedrock geology maps in the Northwest Territories and Yukon and maintain an up-to-date catalogue of these maps. These maps give a preliminary indication of the construction material resources within a specific area;

2) ensure that any future construction materials inventories and studies should incorporate background information on the geological setting in order to understand the distribution of material sources and their physical characteristics (e.g. lithology, grain size, permafrost content);

3) have granular material personnel and planners in local and federal government and industry be aware of the geological history and setting of areas with shortages of material so that planning for development of resources in these areas is done to conserve and protect the remaining resources;

4) make sure that community reserves of granular material are maintained and that key sources for future granular material development are not sterilized by becoming the sites for other types of development;

5) see that granular deposits and other construction material sources are developed with environmental issues addressed in development and reclamation plans;

6) encourage engineering designs to use lower quality material and new procedures (e.g. geotextiles) whenever

possible to conserve better quality resources for specific uses (e.g. concrete aggregate);

7) upgrade format for reporting material usage from existing pits and quarries so that more accurate information on remaining quantities in these sources can be made;

8) upgrade demand forecasting procedures encompassing historical demand factors and population forecasts for use in the planning process (Underwood, 1992);

9) prepare for future development by adding new information on existing and newly investigated deposits to the DIAND database (e.g. add information from GNWT community granular materials investigations, South Slave granular materials investigations, information gathered in advance of road construction in any new transportation corridors (e.g. Izok Lake));

10) make borrow database information on the location and characteristics of available deposits, ownership, costing, etc. readily available to construction project planners so there is minimal delay and duplication of effort related to development of construction material resources.

PERMIT TO PRACTICE
GVM GEOLOGICAL CONSULTANTS LTD.
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Date February, 1995
PERMIT NUMBER: P 3184
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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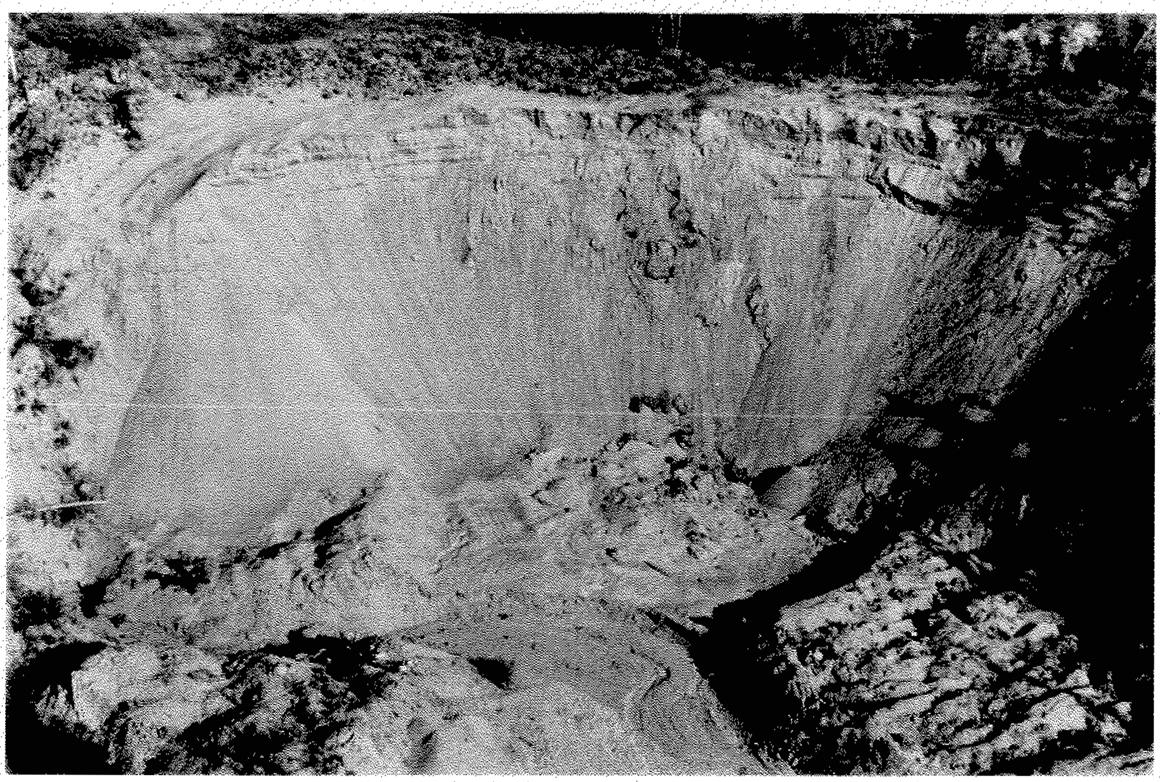
APPENDIX A - PHOTOGRAPHS

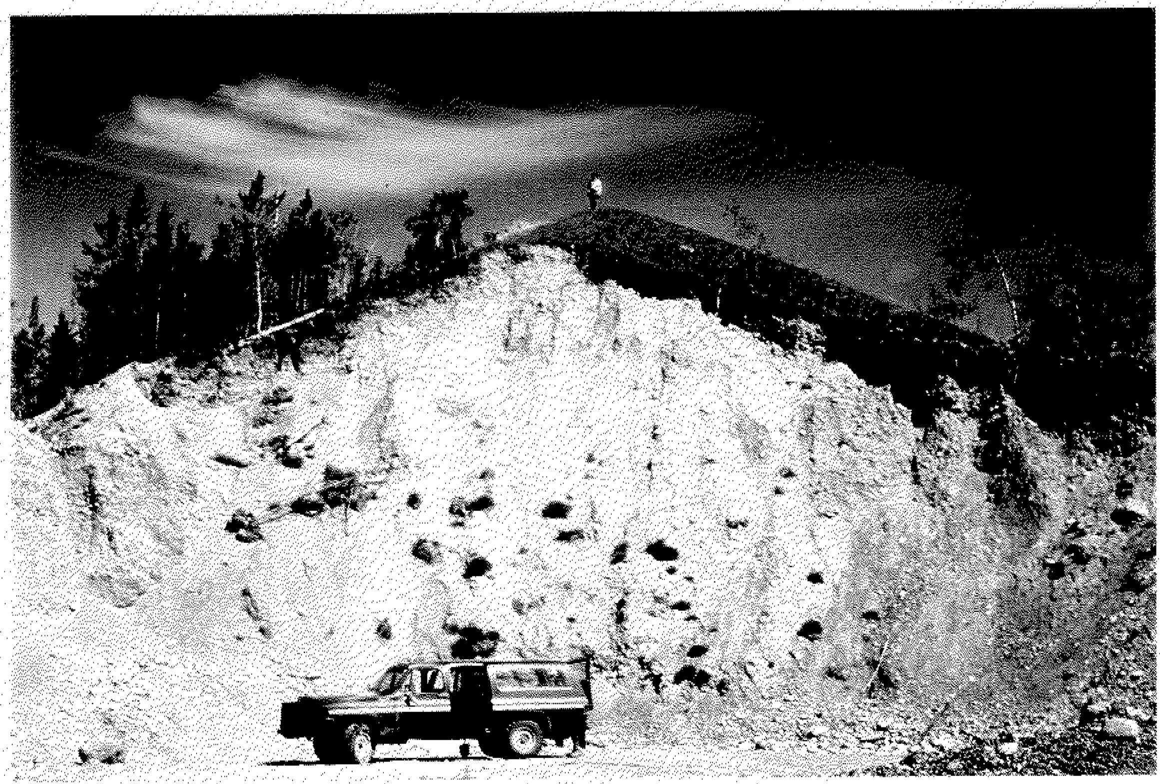
Photograph 1A: Glaciofluvial terrace of sand and gravel above Hay River near the Mackenzie Highway, N.W.T. Photo by Ian Jones, in Thurber Consultants Ltd. report Granular Resources Management Strategy - South Slave Region.

Photograph 1B: Glaciofluvial terrace of sand and gravel, upper Mackenzie Valley, N.W.T. Photo by Gretchen Minning, GVM Geological Consultants Ltd.



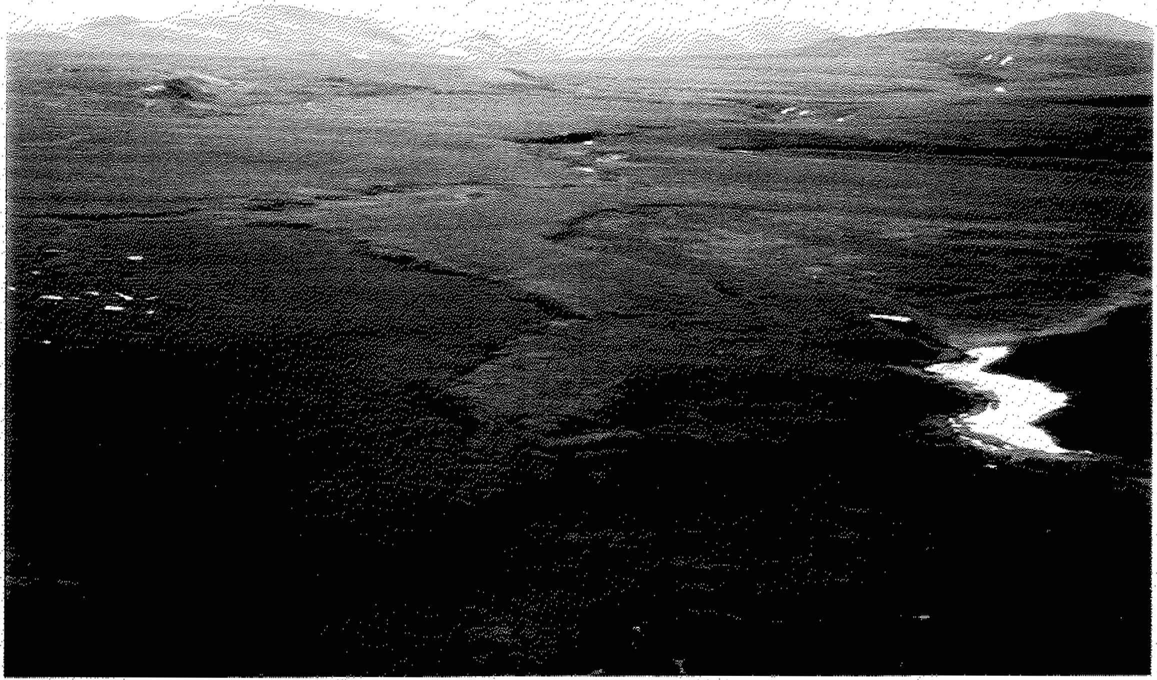
Photograph 2A: Glaciofluvial terrace of sand and gravel in Tatchun Creek valley, Yukon Territory. Photo by: Rudy Klassen, Geological Survey of Canada.

Photograph 2B: Glaciolacustrine sand near Norman Wells, N.W.T. Photo by Ian Jones, Geo-Engineering (M.S.T.) Ltd.



Photograph 3A: Hummocky glaciofluvial kame deposit at Lost Reindeer Lakes, lower Mackenzie Valley, N.W.T. Photo by: Vern Rampton, Terrain Analysis and Mapping Services Ltd.

Photograph 3B: Kame ridge of sand and gravel, Yukon Territory. Photo by: Rudy Klassen, Geological Survey of Canada.

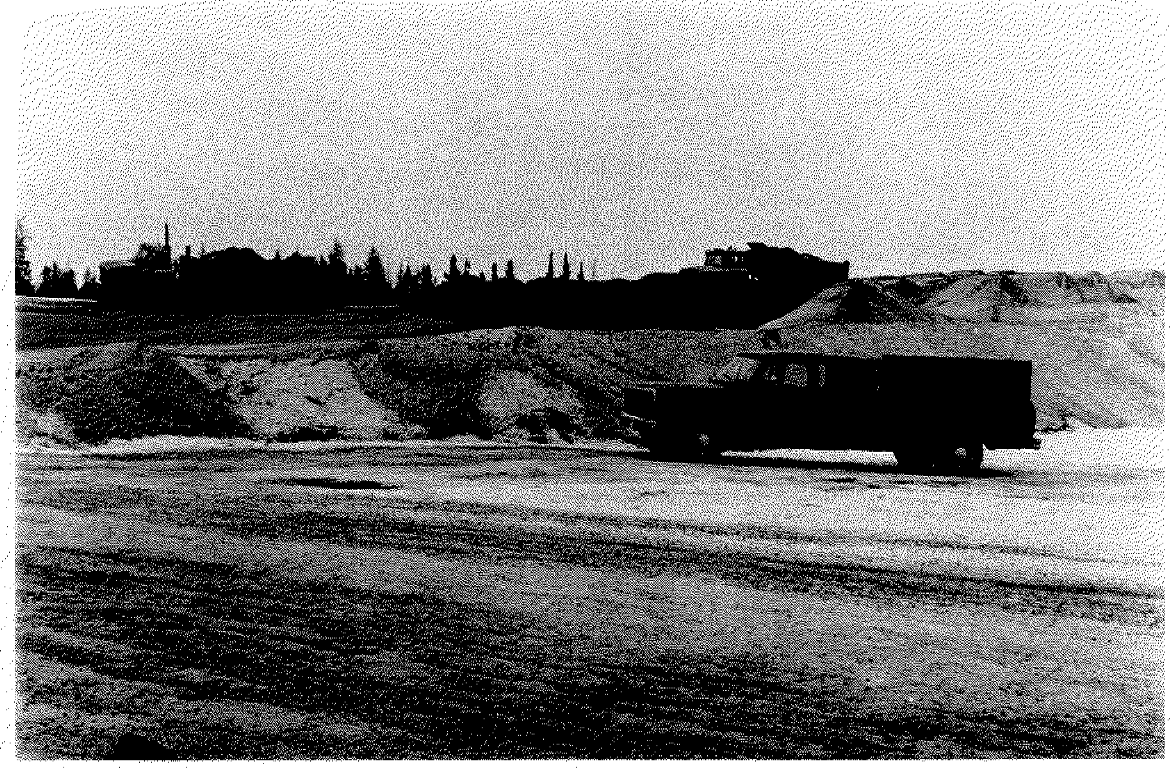


Photograph 4A: Glaciofluvial plain and terrace complex, Yukon Coastal Plain, Yukon Territory. Photo by: Vern Rampton, Terrain Analysis and Mapping Services Ltd.

Photograph 4B: Alluvial terrace and floodplain deposits along Firth River, Yukon Coastal Plain, Yukon Territory. Photo by: Vern Rampton, Terrain Analysis and Mapping Services Ltd.

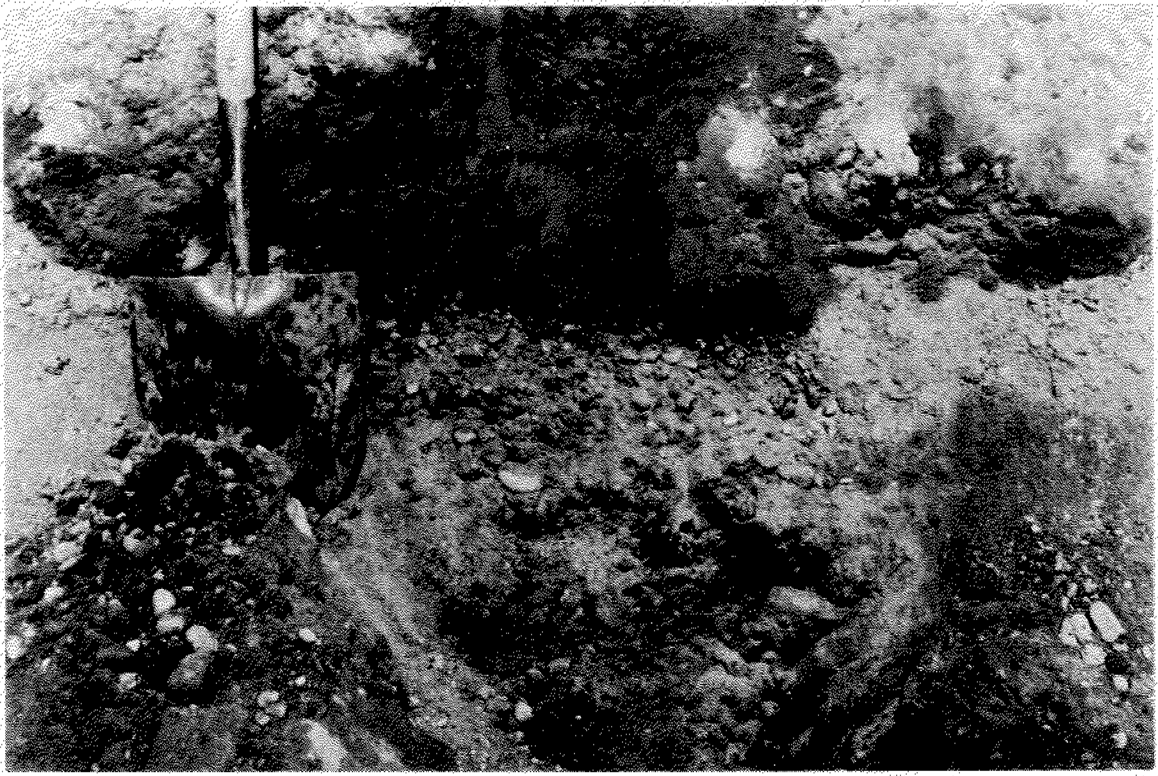
Photograph 5A: Glaciolacustrine beach deposits, N.W.T. Deposit 5-19 in Granular Resources Management Strategy South Slave Region, 1987. Photo by: Ian Jones, Geo-Engineering (M.S.T.) Ltd.

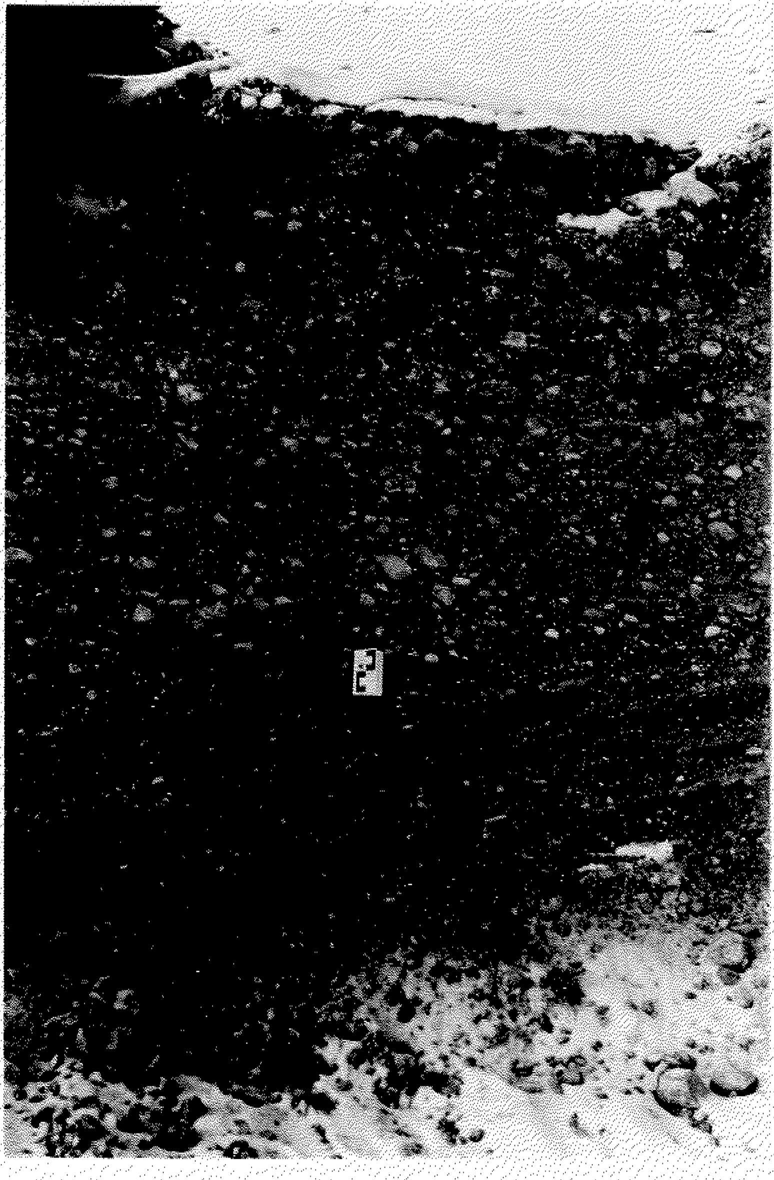
Photograph 5B: Limestone and shale quarries at Norman Wells, N.W.T. in Thurber Consultants Ltd. report on Norman Wells quarries. Photo by: Ian Jones, Geo-Engineering (M.S.T.) Ltd.



Photograph 6A: Granular material stockpile, pit at km. 64.5 on Highway 1 north of Alberta/N.W.T. border. Photo in Thurber Consultant's Ltd. report Granular Resources Management Strategy, South Slave Region. Photo by: Ian Jones, Geo-Engineering (M.S.T.) Ltd.

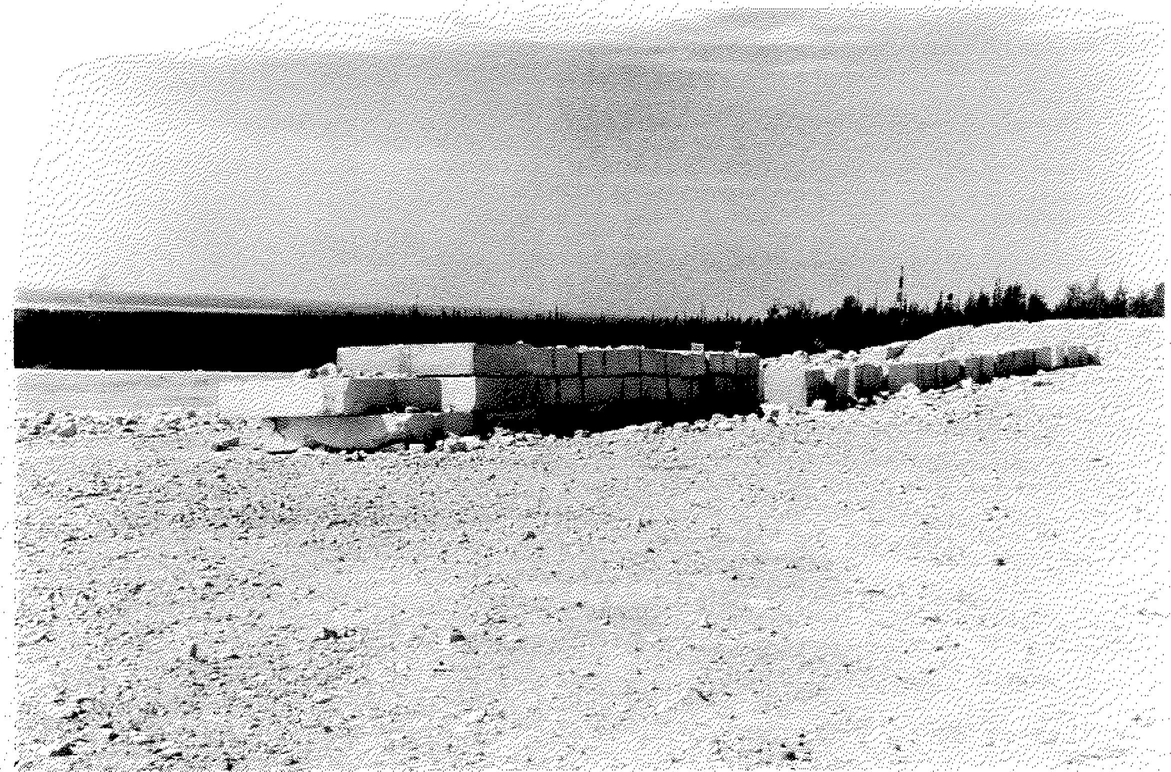
Photograph 6B: Salt Mountain borrow pit near Fort Smith, N.W.T. Photo by: Ian Jones, Geo-Engineering (M.S.T.) Ltd.

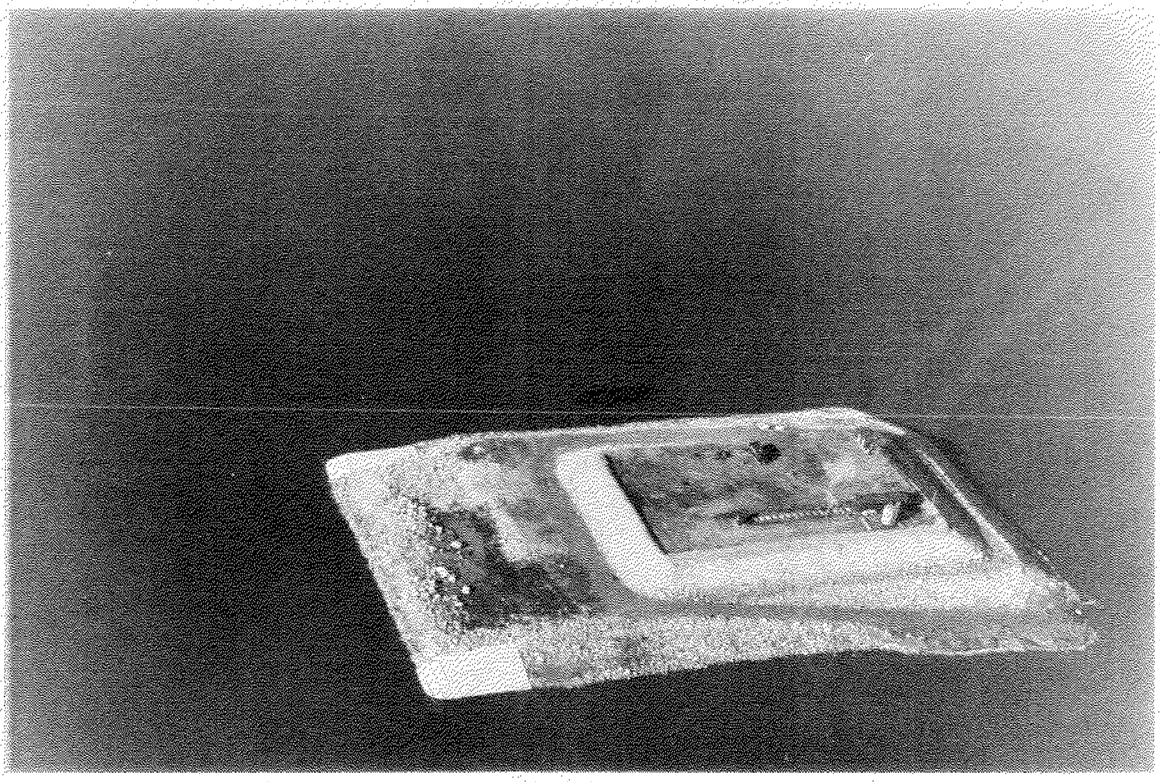




Photograph 7A: Silt and sand veneer overlying sandy gravel in pit near Norman Wells, N.W.T. Photo by: Ian Jones, Geo-Engineering (M.S.T.) Ltd.

Photograph 7B: Well graded gravel with fine sand beds. Deposit 5-6 near Fort Smith, N.W.T., described in Thurber Consultants Ltd. report Granular Resources Management Strategy - South Slave Region. Photo by: Ian Jones.



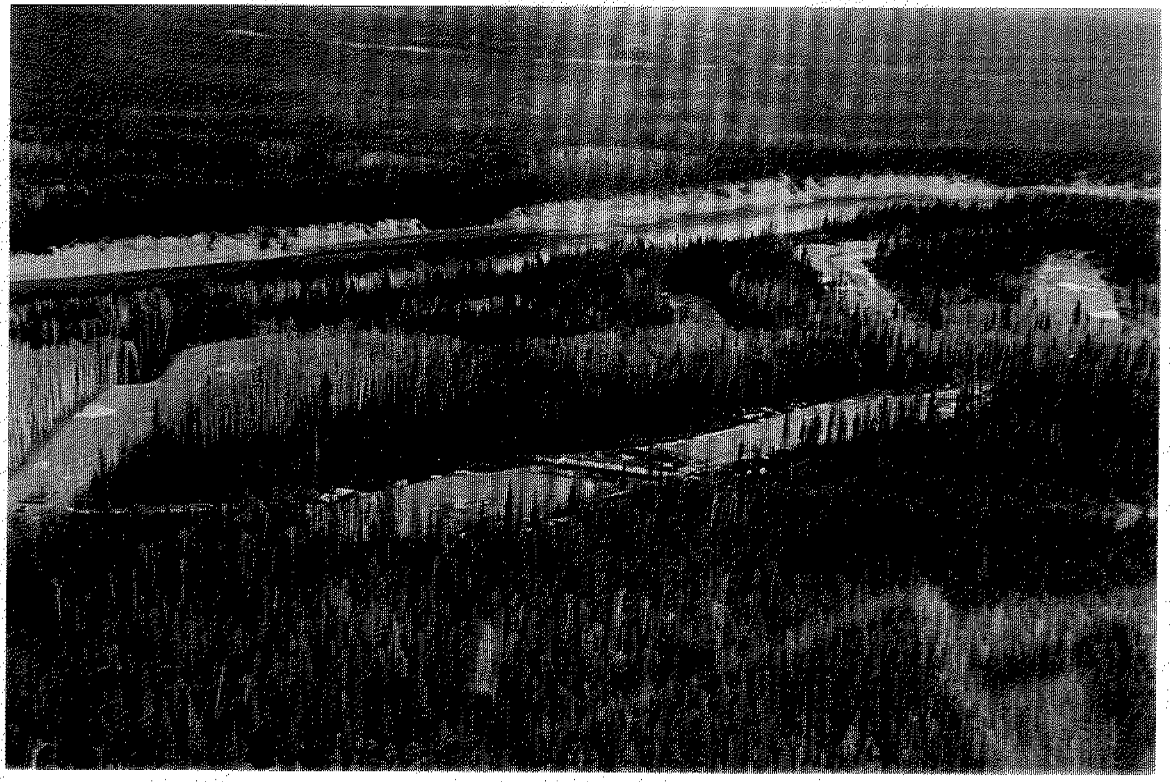


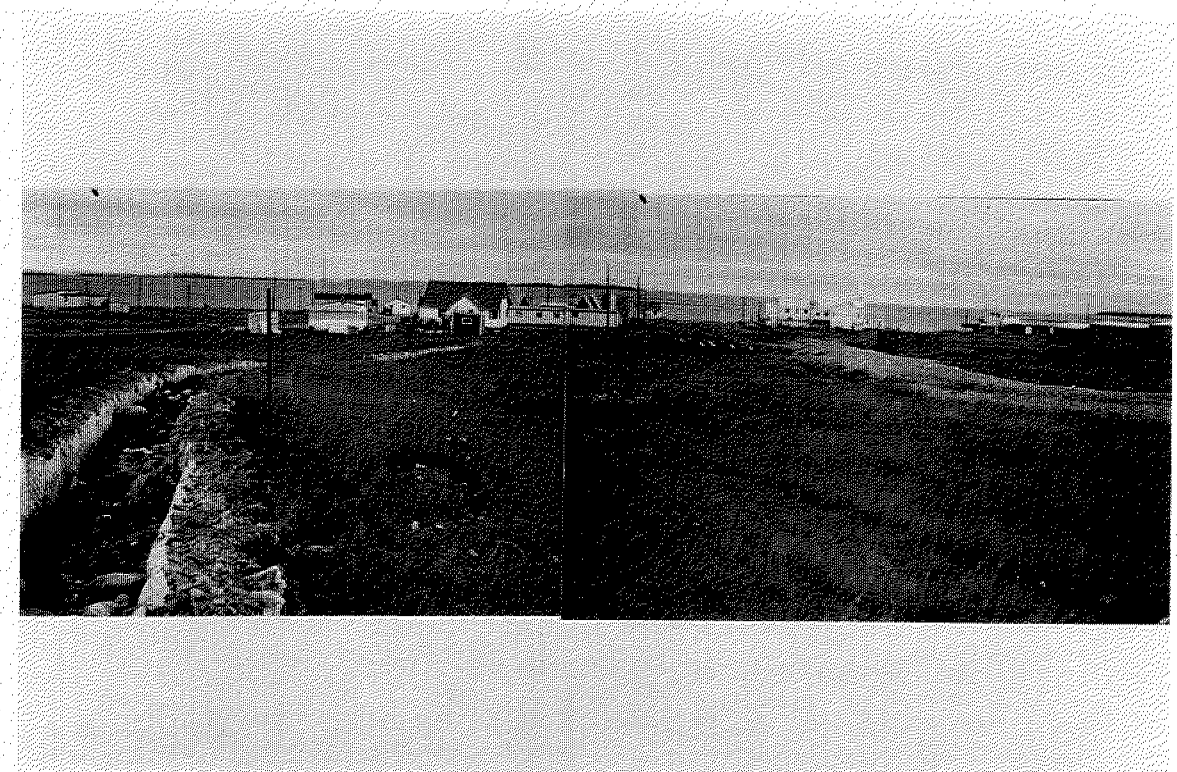
Photograph 8A: Concrete weights made from good quality granular material, stockpiled near Norman Wells, N.W.T. Photo by: Ian Jones, Geo-Engineering (M.S.T.).

Photograph 8B: Artificial island for oil development at Norman Wells. Island is made of sand and gravel excavated from the bed of the Mackenzie River. Photo by: Ian Jones, Geo-Engineering (M.S.T.) Ltd.

Photograph 9A: Granular material exploration program for pipeline purposes using helicopter portable drill rig. Exploration program was undertaken by Northern Engineering Services Company Ltd. for Canadian Arctic Gas Study Ltd in the Mackenzie Valley, N.W.T. Photo by: Stan Munn.

Photograph 9B: Pipeline ditcher test in permafrost near Norman Wells, N.W.T. The pipeline ditch requires sandy material for protection of the pipe. Test was undertaken by Canadian Arctic Gas Study. Photo by: Stan Munn.





Photograph 10A: Reclaimed granular deposit 2-8 near Hay River, N.W.T. The reclaimed area is a golf course for Hay River. Photo is from Thurber Consultants Ltd. report Granular Resources Management Strategy - South Slave Region. Photo by: Ian Jones.

Photograph 10B: Granular material used for bedding and padding in roadways and under buildings in permafrost terrain at Coppermine, N.W.T. Photo by: Thurber Consultants Ltd.

APPENDIX B - TABLES OF GRANULAR RESOURCE SUMMARIES FOR 25 COMMUNITIES

Summaries indicate deposits nearest to communities (generally less than 10 km)

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TABLE 1: RANKIN INLET GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1 - Nipissar Pit	N/A	Blend	< 800	Active - Depleted	Minimal
2 - Site B	Moraine/ Rock	Embankment Fair-Poor	4,000	Active	Minimal
3 - Diana R.	Beach/ Moraine	All Grades Good-Excellent	65,000	Active	Moderate
4 - Meliadine South	Esker Complex	Poor - Sand Only	300,000	Active	Minimal
5 - Site A	Moraine/ Beach Veneer over Rock	Embankment Poor-Fair	11,000	Potential	Minimal
6 - Meliadine Esker	Esker	All Grades Good-Excellent	1,200,000	Potential	Severe (Proposed Park)
7 - Q1	Rock	All Grades Blasted Rock	Unlimited	Potential	Significant
8 - Q2	Rock	All Grades Blasted Rock	Unlimited	Potential	Significant (Poor Access)

* Represents Total Volume Unless Specified

TABLE 1 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR RESOURCE EVALUATION RANKIN INLET, NWT, 1992.**

PROJECTED DEMAND INFORMATION FOR RANKIN INLET:

Rankin Inlet is the administrative centre for Keewatin and is a rapidly growing community that has been affected by several major projects demanding granular material. When the Diana River pit is depleted, large scale quarry and processing from sources Q1 or Q2 will be required to meet future needs of the community.

TABLE 2: BAKER LAKE GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1	Beach/ Moraine	Sand/ Gravel (Fines, Oversize)	10,000	Abandoned	Minimal (Needs Reclam.)
2	Beach	Sand/ Some Oversize	100,000	Abandoned	Moderate
3	Beach	Gravelly Sand- Good to Excellent	50,000	Active	Severe (Needs Reclam. & Pit Mgt.)
4	Beach/ Terrace	Gravelly Sand; Poorly Graded	10,000	Active	Minimal
5 North	Beach	Sandy Gravel/ Coarse Sand	25,800	Active	Moderate (Needs Reclam.)
5 South	Beach/ Rock	Sand/ Some Oversize	15,000	Active	Severe (Needs Drainage & Erosion Control)
6	Beaches	Sandy Gravel/ Some Oversize	60,000	Potential	Moderate
7	Beach/ Rock	Gravelly Sand	15,000	Potential	Minimal (Needs Haul Road)
8	Beach	Cobbles & Gravel	200,000	Potential	Minimal
9	Moraine/ Lacust-rine Plain	Silty Sand/ Some Gravel	24,000	Potential	Moderate (Needs Drainage & Erosion Control)

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
10	Beach	Gravelly Sand	10,000	Potential	Minimal
11	Beach	Cobbles to Gravel/ Some Sand	30,000	Potential	Minimal
Q1	Rock	Blasted Rock	100,000+	Potential	Moderate (Needs Access Road)
Q2	Rock	Blasted Rock	40,000+	Potential	Moderate (Needs Access Road)

* Represents Total Volume Unless Specified

TABLE 2 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR RESOURCE EVALUATION BAKER LAKE, NWT, 1993.**

PROJECTED DEMAND INFORMATION FOR BAKER LAKE:

Baker Lake is the only inland Inuit settlement in the NWT and has recently been impacted by several projects requiring granular material. The community will be self sufficient in all grades of ganular material provided that adequate management of existing sources is maintained.

TABLE 3: POND INLET GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1	Outwash Terrace/ Colluvium	Gravelly Sand/ Some Oversize	15,000	Active (75% depleted)	Moderate (Needs Drainage & Erosion Control)
2	Moraine/ Kame Complex	Sand/ Some Cobbles, Gravel	29,000	Active	Access Restricted Because of Water Lake
3	Meltwater Channel	Sand	1,500	Active	N/A
4	Alluvial Delta/ Moraine	Gravelly Sand	300,000	Active	Access Requires Creek Crossing
5	Marine Plain	Sand/ Some Gravel	15,000	Active	Drainage Problems
6	N/A	Gravel/ Oversize	2,000	Abandoned	Needs Reclam.
7	N/A	Sandy Gravel/ Oversize	3,000	Abandoned	Needs Reclam.
8	Marine Delta	Sand	100,000	Potential	Needs Access
9	Alluvial/ Moraine	Sandy Gravel/ Oversize	> 102,000	Potential	Needs Access
10	Alluvial Delta	Sand/ Some Gravel & Oversize	125,000	Potential	N/A
11	Moraine	Gravelly Sand/ Some Oversize	15,000	Potential	Needs Access; Organics

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
12	Moraine/ Kame Complex	Gravelly Sand/ Some Oversize	40,000	Potential	N/A
13	Alluvial Fans	Sandy Gravel/ Some Oversize	8,000	Potential	Needs Access
14	Rock	Blasted Rock	100,000+	Potential	N/A
15	Alluvial Delta	Sand/ Gravel/ Oversize	>1,000,000	Potential	N/A

* Represents Total Volume Unless Specified

TABLE 3 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR RESOURCE EVALUATION POND INLET, NWT, 1992.**

PROJECTED DEMAND INFORMATION FOR POND INLET:

Pond Inlet is a hamlet located on the north coast of Baffin Island. Anticipated demands for granular resources for the next 20 years can be met from existing and potential sources located within a four kilometre radius of the community.

TABLE 4: IGLOOLIK GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1	Beach/ Colluvium	Silty Gravel/ Common Grade	10,000	Active	Moderate (Drainage & Erosion Control)
2	Beach Ridge	Sandy Gravel	7,000	Active	Minimal
3	Beach Ridge	Gravel/ Some Cobbles	3,000	Active	Minimal
4	Beach/ Colluvium	Gravel/ Rip Rap Boulders	5,000	Active	Moderate (Needs Drainage & Erosion Control)
5	Beach Ridges	Cobbles to Sandy Gravels	400,000	Potential	Minimal
6	Beach Ridges	Cobbles & Gravels	1,000,000	Potential	Minimal
7	Beach	Gravel & Sand	165,000	Potential	Minimal
8	Beach	Cobbles to Sandy Gravel	8,000	Potential	Severe (Modern Storm beach)

* Represents Total Volume Unless Specified

TABLE 4 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR RESOURCE EVALUATION IGLOOLIK, NWT, 1993.**

PROJECTED DEMAND INFORMATION FOR IGLOOLIK:

Igloolik is a hamlet of over 900 people located on island near Melville Pennisula in the District of Keewatin. It is one of the oldest Inuit settlements. With proper management, existing and potential sources of granular materials should be adequate to meet future needs for the community.

TABLE 5: RAE/EDZO GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1 - Frank Channel	Crushed Stockpile	Crushed to 19mm	4,500	Active (1990)	None
2 - Russell Lake	Glaciolacustrine	Gravels & Sand	8,000	Active	N/A
3 - Edzo Sand Pit	Glaciolacustrine	Sand	6,000	Active	N/A
4 - Site 1	Moraine	Sandy Till	30,000	Potential	N/A
5 - Site 2	Moraine	Sandy Till/ Oversize	35,000	Potential	Winter Access
6 - Mosquito Creek	Moraine/ Glacio-fluvial Ridges	Sand & Gravel/ Oversize	11,400	Abandoned and has Potential For Further Develop.	N/A
7 - Q1	Rock	Blasted Rock	100,000+	Potential	N/A
8 - Q2 & Q3	Rock	Blasted Rock	113,000+	Previous Quarry, Future Potential	N/A

* Represents Total Volume Unless Specified

TABLE 5 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR RESOURCE EVALUATION RAE/EDZO, NWT, 1990.**

PROJECTED DEMAND INFORMATION FOR RAE/EDZO:

Rae/Edzo is a growing community on the north arm of Great Slave Lake. In 1990 the 20 year demand for granular materials was estimated to be 360,000 m^3. Development of quarrying operations will be required to meet these needs.

TABLE 6: CAPE DORSET GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1 - Site A (Tank Farm)	Beach	Gravel & Sand/ Oversize	15,000	Active	N/A
2 - Site B (Ice Lake)	Beach/ Colluvium	Sands/ Gravel	2,100	Active	Proximity to Ice Lake
3 - Site 14 (Airport)	N/A	Sands & Gravels	9,000+	Active	N/A
4	Rock/ Colluvium	Weathered Shale	6,500	Active	N/A
5 - Site 13	N/A	Gravel/ Oversize	8,500	Active	N/A
6 - Site 3	Colluvium	Weathered Rock	----	Depleted	Needs Reclam.
7 - Site 6	N/A	N/A	----	Depleted	Needs Reclam.
8 - Site 15	N/A	Sand/ Some Gravel	----	Depleted	Needs Reclam.
9 - Site 2	Colluvium	Sand/ Some Gravel	33,000	Potential	N/A
10 - Site 10	Beach/ Colluvium	Gravel	8,000	Potential	Access Problems
11 - Site 4	N/A	Sand	1,000	Abandoned & Depleted Stockpile Site	N/A
12 - Tidal Flats	Marine Tidal Flats	Sand/ Fines	4,000	Potential	Moderate to Severe
13 - Mallik Island	Moraine	Sand/ Oversize	10,000	Potential	Access Problems
14 - Q1	Rock	Blasted Rock	10,000+	Potential	Near Resid. Subdivision

Source	**Landform**	**Quality**	**Quantity* m^3**	**Status of Source**	**Development Constraints**
15- Q2	Rock	Blasted Rock	10,000	Potential	Land Use Problems
16 - Q3	Rock	Blasted Rock	Unlimited	Potential	Minimal
17- Blend Sources	Marine Tidal Flats	Sand	N/A	Potential	Stockpile & Drain before use

* Represents Total Volume Unless Specified

TABLE 6 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR MATERIAL SOURCES INVESTIGATION CAPE DORSET, NWT, 1989**

PROJECTED DEMAND INFORMATION FOR CAPE DORSET:

Cape Dorset is a growing community on Foxe Peninsula, Baffin Island. In 1989 the 20 year demand for granular materials was estimated to be 161,000 m^3. Development of quarrying operations will be required to meet these needs sometime after 1994.

TABLE 7: REPULSE BAY GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1 - Talun Bay	Beach	Gravel/ Sand	300,000	Potential	Access Problems
2 - Site 1	Beach Ridge/ Moraine	Gravel & Sand	1,200	Abandoned & Depleted	Needs Reclam.
3 - Esker Deposits	Several Esker Ridges	Sand & Gravel	700,000	Potential	Long Haul
4 - Quarry Ridges	Rock	Blasted Rock	Unlimited	Potential	Quarry Impacts

* Represents Total Volume Unless Specified

TABLE 7 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR MATERIAL SOURCES INVESTIGATION REPULSE BAY, NWT, 1991**

PROJECTED DEMAND INFORMATION FOR REPULSE BAY:

Repulse Bay is a growing community on the south shore of Melville Peninsula. In 1991 the 20 year demand for granular materials was estimated to be 78,000 m^3. Development of quarrying operations will be required to meet these needs because all naturally occurring granular sources in close proximity to the community have been depleted.

TABLE 8: LAKE HARBOUR GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1 - Site 1 (Sand Pit)	Beach	Sand	15,000	Active	Needs Reclam.
2 - Site 2 (Soper Lake)	Rock/ Colluvium	Weathered Rock	4,000	Active	N/A
3 - Site 3	Moraine	Sand & Gravel/ Oversize & Fines	12,000	Potential	Poor Drainage & Access
4 - Site 4	Colluvium	Sands & Gravels	15,000	Potential	Difficult Access
5 - Site 5 (Soper Lake Delta)	Alluvial Delta	Gravel/ Sand & Oversize	100,000	Potential	Permafrost & Access Problems; Also Proposed Park
6 - Quarry Ridges	Rock	Blasted Rock	50,000+	Potential	N/A

* Represents Total Volume Unless Specified

TABLE 8 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR MATERIAL SOURCES INVESTIGATION LAKE HARBOUR, NWT, 1989**

PROJECTED DEMAND INFORMATION FOR LAKE HARBOUR:

Lake Harbour is a hamlet of 366 people (1990) on the Meta Incognita Peninsula on the south side of Baffin Island. In 1989 the 20 year demand for granular materials was estimated to be 139,000 m^3. Development of quarrying operations will be required in 1993-1994 to meet community needs.

TABLE 9: WHALE COVE GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1	Beach Ridge	Silty Sand; High in Fines	2,000	Active	Moderate; Drainage & Erosion Control Needed
2 - Tank Farm	Storm Beaches; Some Moraine & Rock	Cobbles to Coarse Gravel	1,500 to 2,000	Active	Minimal
3	Moraine; Beaches	Till; Gravelly Sand	3,000	Active	Minimal; Present Pit Design Poor
4	Beaches	Silty Sand; Some Gravel	2,000	Semi-Active	Severe; Needs Mgmt. & Reclam.
5	N/A (Sand Pits)	Clean Sand	1,000	Active	Minimal
6 - Arctic Airports Crushed Stockpile	Crushed Gravel	Crushed 19 mm	4,800	Stockpile	Minimal
7 - Airport	Beach; Moraine	Gravelly Sand; Some Oversize	5,000 Probable; 10,000 Prospect.	Potential	Severe Unless Environ-mental Guidelines Followed
8 - Island	Beaches & Esker-Delta Complex	All Grades; Cobbles to Coarse Sand	15,000 Probable; 20,000 Prospect.	Potential	Severe; Wildlife Habitat & Denning Area
9 - Q1	Rock	Blasted Rock	60,000+	Potential	Minimal
10 - Q2	Rock	Blasted Rock	50,000+	Potential	Moderate; Near Lake

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
11 - Q3	Rock	Blasted Rock	35,000+	Potential	Minimal

* Represents Total Volume Unless Specified

TABLE 9 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR RESOURCE EVALUATION WHALE COVE, NWT, 1993**

PROJECTED DEMAND INFORMATION FOR WHALE COVE:

Whale Cove is a small Inuit settlement in the Keewatin Region on the northwest coast of Hudson Bay. There are insufficient quantities of all grades of granular materials within close proximity, to supply the long term needs of the hamlet. Development of large scale quarrying operations will be required to meet future community needs.

TABLE 10: SNARE LAKE GRANULAR RESOURCES

Source	**Landform**	**Quality**	**Quantity* m^3**	**Status of Source**	**Development Constraints**
1A/1B	Beach	Sand	8,000 to 10,000	Potential	Minimal; Winter Access
2	Beach	Med. to Coarse Sand; Some Gravel	>100,000	Potential	Moderate
3 - New Location Community Airport	Glacio-fluvial Plain	Poorly Graded Gravelly Sand	30,000+	Potential	Moderate
4	Esker	Poorly Graded Gravelly Sand	>500,000	Potential	Moderate
5	Esker Complex	Gravelly Sand	Unlimited	Potential	Moderate
6 - Q1	Rock	Blasted Rock	100,000+	Potential	Minimal
7 - Q2	Rock	Blasted Rock	N/A	Potential	Minimal

* Represents Total Volume Unless Specified

TABLE 10 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR RESOURCE EVALUATION SNARE LAKE, NWT, 1992**

PROJECTED DEMAND INFORMATION FOR SNARE LAKE:

Snare Lake is a traditional native settlement with a population of 126 (1988). It is located 200 km north of Yellowknife. As of 1992 the community lacked a land-based airport, and the equipment necessary to exploit potential granular sources. Airport construction is planned for 1994-1995 and a drill/blast/crush operation should be implemented concurrently to satisfy the long-term community needs for granular materials.

TABLE 11: ENTERPRISE GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
2A (Deposit 2-1 Thurber)	Beach Ridge Complex	Sand & Gravel	40,000	Active - Depleted	Old pit development does not follow environmental guidelines; Reclamation Recommended
2B (Deposit 2-2 Thurber)	Beach Ridges	Sandy Gravel	100,000+ (610,000 Thurber Estimate)	Potential	Best used for embankment material
2C (Deposit 2-3 Thurber)	Beach Ridges	Sand; Some Gravel	100,000+ (340,000 Thurber Estimate)	Active	Poor pit design; Drainage Problems
2D (Deposit 2-5 Thurber)	Alluvial Terraces	Sandy Gravel	25,000	Active-Depleted	Only adequate for embankment material
2E (Deposit 1-17 Thurber)	Beach Ridges	Sandy Gravel	100,000+ (1,500,000 Prospective - Thurber Estimate)	Potential	No good existing access
KM. 7.0 Pit (Deposit 1-18 Thurber)	Beach Deposits overlying Rock	Sandy Gravel; Limestone	7,000	Active	Extract remaining material in one season; Reclaim pit
KM. 1.1 Pit	Alluvial Terrace/ Moraine	Sandy Gravel	6,000	Abandoned	Reclaim existing pit
Enterprise Pit	Beach Ridge	Gravelly Sand	2,500	Abandoned	No further development recommended

* Represents Total Volume Unless Specified

TABLE 11 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **GRANULAR MATERIAL SOURCES INVESTIGATION ENTERPRISE, NWT, 1991.** Information has also been obtained from a report prepared by Thurber Consultants Ltd. (1987) for DIAND entitled: Granular Resources Management Strategy - South Slave Region.

PROJECTED DEMAND INFORMATION FOR ENTERPRISE:

Enterprise is a settlement of approximately 56 people on Highway 1, 100 km north of the Alberta/NWT border. In general, pit run granular materials of sufficient quality to meet the 20 year demand of 20,000 m^3 are available in close proximity to Enterprise.

TABLE 12: SNOWDRIFT (LUTSEL'KE) GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
1 - Existing Source (Near Airstrip)	N/A	Gravel; Few Fines; Oversize	30,000	Active	Poor Pit Design
2 - Source A	Moraine Complex	Coarse Gravel; Few Fines	N/A	Potential	Needs Access
3 - Source B	Sand Dunes	Sand; Some Silt	100,000+	Active	Near Snow-drift River; Winter Access
4 - Source C	Beach & Alluvial	Sand & Gravel	N/A	Potential	Winter Access, Drainage Problems

* Represents Total Volume Unless Specified

TABLE 12 is adapted from a report by the Department of Government Services and Public Works, Government of the Northwest Territories titled: **COMMUNITY GRANULAR STUDY SNOWDRIFT, NWT, 1987**

PROJECTED DEMAND INFORMATION FOR SNOWDRIFT:

Snowdrift is a settlement on Christie Bay of Great Slave Lake. The existing source has sufficient material to supply the short term embankment needs of the community. Source A was recommended for development in 1990 when the existing source was depleted. Source C is to remain the long term potential source of granular material. Source B was developed recently.

TABLE 13: TUKTOYAKTUK GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
T-112 (RKL) 156 (Hardy)	Ocean Spit	Gravel; Some Sand	25,000	Undevel-oped	Waterfowl Habitat; Beluga Whale
T-113 (RKL) 167 (Hardy)	Kames (17.0 Km SE of Tuk)	Gravel; Some Sand	1,500,000	Active	Difficult Access
T-114 (RKL)	Esker Ridge (26.0 Km SE of Tuk)	Gravel; Some Sand	300,000	Undevel-oped	Difficult Access; Winter Waterfowl Nesting Area
T-115 (RKL)	Glacial Outwash (5.6 Km SE of Tuk)	Gravel & Sand	100,000	Undevel-oped	Minimal; Waterfowl Nesting
T-108A (RKL) 156 (Hardy)	Ocean Spit (1.6 Km S of Tuk)	Sand; Some Gravel	25,000	Some Develop-ment	Erosion Problem; Area Used By Local Inhabit-ants
T-109 (RKL) 156 (Hardy)	Ocean Spit (1.6 to 4.8 Km SW of Tuk)	Gravel; Some Sand	75,000	Active	Proximity to Water; Needs En-vironmen-tal Assessment
T-110A (RKL) 156 (Hardy)	Ocean Beach (6.4 Km SW of Tuk)	Sand	45,000	Undevel-oped	Poor Quality; Environ-mental Concerns
T-111A (RKL) 156 (Hardy)	Ocean Spit	Gravel; Some Sand	20,000	Undevel-oped	Low Quality; Environ-mental Concerns

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
T-104A (RKL) 158 (Hardy)	Ocean Beach (2.4 Km E of Tuk)	Sand; Some Gravel	25,000	Undevel-oped	Erosion Problems; Low Quality & Quantity
T-105 (RKL)	Ocean Beach (3.2 Km SW of Tuk	Gravel; Some Sand	30,000	Undevel-oped	Fishing Area; Waterfowl Nesting
T-106 (RKL) 158 (Hardy)	Island	Gravel; Some Sand	50,000	Active	Offshore Fishing Area
T-107 (RKL) 158 (Hardy)	Ocean Spit on Island	Gravel; Some Sand	20,000	Undevel-oped	Beach Used Locally; Environ-mental Concerns
T-100 (RKL) 157 (Hardy)	Ocean Spit (Tibjak Point)	Sand	80,000	Undevel-oped	Beach Erosion & Wildlife Concerns
T-101 (RKL) 157 (Hardy)	Ocean Spit (Topkak Point)	Sand	100,000	Undevel-oped	Beach Erosion & Wildlife Concerns
T-102A (RKL) 157 (Hardy)	Beach (Beluga Point)	Sand	90,000	Undevel-oped	Beach Erosion & Wildlife Concerns
T-103A (RKL) 157 (Hardy)	Ocean Beach	Sand; Some Gravel	100,000	Undevel-oped	Beach Erosion & Wildlife Concerns

* Represents Total Volume Unless Specified

TABLE 13 is adapted from a report by Ripley, Klohn, Leonoff Ltd. (RKL), 1973: Community Granular Materials Inventory. The report was prepared for the Federal Department of Indian and Northern Affairs. Information on supply and demand is contained in Preliminary Granular Resources Demand Mackenzie Delta Region prepared by Hardy-BBT Ltd. for DIAND in 1991.

PROJECTED DEMAND INFORMATION FOR TUKTOYAKTUK :

Tuktoyaktuk is a community of 995 people on the Tuk Peninsula of the Beaufort Sea. It has been a supply centre for offshore oil and gas exploration activities in the Mackenzie Delta Region. Based on proven volumes of good granular prospects there will be a shortage of 9,000,000 m^3 over the 20 year period starting in 1991. If probable volumes of granular material in borrow mapping Area 1-B (Hardy, 1991) are included in the supply figures there is adequate supply of Class 1, 2 and 3 material to meet Tuktoyaktuk's projected needs.

TABLE 14: INUVIK GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
I-400 (RKL) (Hardy Source 2.48)	Glacio-fluvial	Sand; Some Gravel & Silt	250,000	Active	Minimal; Needs Management & Some Reclamation
I-401A (RKL) (Hardy Source 2.47)	Small Kames	Sand & Silt; Some Gravel	250,000	Undevel-oped	Poor Quality & High Ice Content
I-402 (RKL) (Hardy Source 2.50)	Bedrock	Shale	6,000,000	Active	Minimal
I-403 (RKL) (Hardy Source 2.52)	Bedrock	Limestone	2,500,000	Active	Source Is 20 km From Inuvik On Hwy; Long Haul, But Good Access
Unknown No. 68°12'04.6"N 133°20'34.4"W on Dempster Highway (R.Cockney, pers. comm.)	Bedrock	Limestone ?	?	Active	Source Is at Km. 235.3 of the Dempster Highway
I-404 (RKL) (Hardy Source 2.51)	Bedrock	Sandstone	100,000+	Active	Source Is 22 km From Inuvik On Hwy; Poor Quality
I-407 (RKL) (Hardy Source 2.13)	Glacio-fluvial; Delta	Gravel & Sand	6,000,000	Active; Inuvial-luit Land	Wildlife Area; Impact Assessment Needed

* Represents Total Volume Unless Specified

TABLE 14 is adapted from a report by Ripley, Klohn, Leonoff Ltd. (RKL), 1973: Community Granular Materials Inventory and additional information was extracted from reports prepared by Hardy Associates (1978) Ltd. (1986) and by EBA Engineering Consultants Ltd. (1987). All these reports were prepared for Indian and Northern Affairs.

PROJECTED DEMAND INFORMATION FOR INUVIK :

Inuvik falls within Borrow Management Area 2. The Inuvialuit Lands Selections occupy part of Area 2 and any granular deposits within these lands are controlled by the native peoples. Borrow sources presently used by the town of Inuvik include 2.48, 2.50, and 2.52 (Hardy source numbers). As of 1987, the 20-yr demand is nearly 7.6 million m^3. Ninety eight percent of the demand is for speculative projects (e.g. construction of the Inuvik-Tuktoyaktuk highway and production of armour stone for offshore petroleum facilities). The remainder of the demand is for local capital projects (70,200 m^3) and maintenance of community facilities (107,000 m^3). Inuvik is a mature community that is able to meet its projected requirements for granular materials from existing sources.

TABLE 15: FORT McPHERSON GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
FM-500 (RKL)	Rock	Shale; Sandstone	1,000,000	Active	Minimal
FM-501A (RKL)	Hillocks or Kames on Peel Plain	Sand & Silt	25,000	Undevel-oped	Poor Access; Low Quality & Quantity of Material
FM-502 (RKL)	Inactive flood plain - Stoney Cr.	Gravel	200,000	Undevel-oped	Minimal
FM-503 (RKL)	Eskers	Gravel; Some Sand	50,000	Undevel-oped	Environ-mental Concerns; Low Priority For Devel-opment
FM-504 (RKL)	Talus Slope	Sandstone	200,000	Undevel-oped	Minimal
FM-505 (RKL)	Rock	Shale	6,000	Active; Depleted For Dempster Hwy.	Source Depleted
Unknown No. 67°10'43.3"N 135°49'20.5"W on Dempster Highway; R.A. Cockney (pers. comm.)	Rock	Sand-stone, Shale	?	Active for Dempster Highway	Source is at Km. 24.0 of Dempster Highway; On a south face with a steep slope near Rat Pass
650 (RKL) Frog Creek	GF Outwash Plain	Gravel & Sand	2,500,000	Developed	Distance From Community; on Gwich'in Private Land

* Represents Total Volume Unless Specified

TABLE 15 is adapted from a report by Ripley, Klohn, Leonoff Ltd. (RKL), 1973: Community Granular Materials Inventory. The report was prepared for the Federal Department of Indian and Northern Affairs.

PROJECTED DEMAND INFORMATION FOR FORT McPHERSON :

Fort McPherson is located just west of Borrow Management Area 3 and Arctic Red River. No good or excellent prospects have been identified in Area 3, but rock from the Richardson Mountains and scattered granular deposits on Peel Plain will be used to meet future requirements for the community of Fort McPherson. Source 650 is fully developed and is the best source of pit run gravel in this district.

TABLE 16: ARCTIC RED RIVER GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
A-0103-1 AR-602 (RKL)	Glacio-fluvial Kame	Gravel; Some Sand & Fines	100,000	Developed	Permafrost Below 1.2 m; Winter Access
A-0103-1 AR-603 (RKL)	Glacio-fluvial Esker	Sand; Some Silt & Fine	400,000	Undevel-oped	Winter Access Only
A-0103-1 AR-604 (RKL)	Glacio-fluvial Kames & Eskers	Sand & Silt	750,000	Undevel-oped	Sensitive Terrain, Requires Access Road
A-0103-1 AR-605 (RKL)	Glacio-fluvial Esker	Sand; Some Gravel & Silt	60,000	Undevel-oped	Sensitive Terrain, Winter Access Only
A-0103-1 AR-606 (RKL)	Weathered Rock	Shale; gravel & sand overburd.	85,000	Developed	Minimal
A-0103-1 AR-607 (RKL)	Rock	Shale & Sandstone	150,000+	Developed	Minimal
A-0103-1 AR-609 (RKL)	Glacio-fluvial Kame	Sand & Gravel	50,000 to 80,000	Undevel-oped	Minimal; Winter Access

* Represents Total Volume Unless Specified

TABLE 16 is adapted from the DIAND Granular Resources Databases, Mackenzie Valley Transportation Corridor, 1992. Deposits were discussed in Ripley, Klohn Leonoff International Ltd. (RKL), 1973: Community Granular Materials Inventory. Supply/Demand was obtained from Hardy Associates (1978) Ltd. report prepared for DIAND and entitled Granular Resource Potential Lower Mackenzie Valley, 1986.

PROJECTED DEMAND INFORMATION FOR ARCTIC RED RIVER :

Arctic Red River is a community of 107 people on the Mackenzie River 100 km south of Inuvik. In the past the community has used borrow sources AR-607 and AR-606 which provided crushed rock and Class 3 material respectively. Borrow sources AR-605 and AR-609 will be developed to meet future general fill requirements, particularly for future airport development. There are shortages of good quality granular material east and south of Arctic Red River.

TABLE 17: FORT GOOD HOPE GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
A-0102-1 FGH-1 (PemCan)	Glacio-fluvial Esker	Gravel; Some Sand	5,500,000	Undevel-oped	Winter Road
A-0102-1 FGH-2 (PemCan)	Glacio-fluvial Esker Complex	Gravel; Some Sand	25,000,000	Active	Minimal; Some Comm-unity Concerns
A-0102-1 FGH-3 (PemCan)	Glacio-fluvial Outwash Terrace	Gravel; Some Sand	10,000,000	Undevel-oped	No Access at Present
A-0102-1 FGH-4 (PemCan)	Glacio-fluvial Outwash Plain	Gravel	7,500,000	Undevel-oped	Near Air-port; N/A
A-0102-1 FGH-8 (PemCan)	Glacio-fluvial Outwash Plain	Sand & Gravel	750,000	Undevel-oped	Winter Access
A-105-01 BD7-51 (TEC)	Glacio-fluvial Outwash Plain	Sand	200 million	Undevel-oped	Low Qual.; Winter Access
A-105-01 BD7-56 (TEC)	Alluvial Fan	Sand & Gravel	1,000,000	Undevel-oped	Severe; Thermally sensitive terrain & stream relocation
A-105-01 BD7-49 (TEC)	Aeolian Plain	Sand	25,000,000	Undevel-oped	Low Qual.; Winter Access

* Represents Total Volume Unless Specified

TABLE 17 is adapted from the DIAND Granular Resources Databases, Mackenzie Valley Transportation Corridor, 1992. Original investigations of deposits were covered in PemCan, GSC, TEC, and NES reports 1973-1976 (see Northern Granular Resources Bibliography, 1993. Information on supply and demand was obtained from Hardy Associates (1978) Ltd. report prepared for DIAND and entitled Granular Resource Potential Lower Mackenzie Valley, 1986.

PROJECTED DEMAND INFORMATION FOR FORT GOOD HOPE :

Fort Good Hope is a community of 597 people on the east bank of the Mackenzie River. Class 2 granular material is currently supplied from source FGH-2. Airport expansion scheduled for 1987-1988 would draw from FGH-4. Adequate reserves for long term demands exist in deposits near Fort Good Hope, but there is a shortage of good quality granular material south of the community. However, community concerns related to development of the Fort Good Hope esker complex may affect reserve figures.

TABLE 18: NORMAN WELLS GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
A-0102-1 NW-1 (PemCan)	Alluvial Terrace	Gravel; Some Sand	150,000	Developed	Minimal
A-0102-1 NW-2 (PemCan)	Alluvial Plain	Sand & Gravel	250,000	Undevel-oped	Local Water Supply in Bosworth Creek; Active Floodplain
A-0102-1 NW-3 (PemCan)	Alluvial Bars	Sandy Gravel	500,000	Undevel-oped	Winter Access; Local Water Supply
A-0102-1 NW-4 (PemCan)	Rock	Limestone Sandstone & Shale	N/A	Developed	Minimal
A-0102-1 NW-6 (PemCan)	Aeolian Dunes	Sand	1,125,000	Undevel-oped	Winter Access
A-0102-1 NW-10 (PemCan)	Alluvial Fan	Gravel; Trace Silt	750,000	Undevel-oped	Needs Access Road
A-0102-1 NW-14 (PemCan)	Glacio-fluvial Esker Ridges	Sand & Gravel	1,100,000	Developed	Difficult Access
A-0102-1 NW-15 (PemCan)	Glacio-fluvial Eskers & Kames	Gravel; Some Sand & Silt	2,500,000	Undevel-oped	Major Stream Crossing & Winter Access
A-0102-1 NW-20 (PemCan)	Alluvial Fan	Gravel; Some Sand & Silt	4,000	Developed	Low Volume
A-0102-1 NW-21 (PemCan)	Talus Slopes	Limestone	1,500,000	Undevel-oped	Needs Access; Ice Problems

* Represents Total Volume Unless Specified

TABLE 18 is adapted from the DIAND Granular Resources Databases, Mackenzie Valley Transportation Corridor, 1992. Original investigations of deposits were covered in PemCan, GSC, TEC, and NES reports 1973 to 1976. Information on supply and demand was obtained from a Hardy Associates (1978) Ltd. report done for DIAND entitled Granular Resource Potential Lower Mackenzie Valley, 1986.

PROJECTED DEMAND INFORMATION FOR NORMAN WELLS :

Norman Wells is a community of 482 people on the east bank of the Mackenzie River. The community developed as a result of oil production from the Norman Wells field. Current community demands for granular material are met from sources NW-4, NW-1, NW-14, and 7.48 on the Canol Road on the west side of the Mackenzie River. Granular material for artificial island building in the Mackenzie River has been dredged from the river. Norman Wells has adequate available volume of granular material to satisfy long term community demands.

TABLE 19: FORT NORMAN GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
FN 1 EBA 7.112	Bedrock	Limestone	Unlimited	Potential	Some Water-fowl Considera-tions
FN 4 EBA 7.119	Alluvial Fan	Limestone	1,000,000	Potential	Proximity to River
FN 8 EBA 8.010	Tertiary Sand & Gravel Overlain by GL deposits	Gravel	N/A	Undevel-oped	Extensive Overburden Depth; Uneconomic Deposit
FN 10 EBA 8.004	River Terrace	Sand; Some Silty Gravel	400,000	Potential	Adjacent to River; Difficult Access
FN 13 EBA 8.006	River Terrace	Sand; Some Silty Gravel	1,000,000	Potential	Sensitive Terrain
FN 14 EBA 8.001	Existing Borrow Pit GL	Sand	300,000	Active	Minimal
FN 16 EBA 8.011	Eolian Dunes	Sand	1,000,000	Potential	Sensitive Terrain
FN 19 EBA 7.155	Outwash Plain	Gravel	Unlimited	Potential	Minimal; Recommended For Development
FN 22 EBA 7.113	Outwash Remnant	Sand; Some Gravel	100,000	Potential	Minimal
FN 23 EBA 8.002	Gravel Bar or Terrace	Sand & Gravel	5,000	Active	Minimal
FN 25 EBA 7.109	Bedrock	Limestone	Unlimited	Potential	Minimal
FN 26 EBA 7.110	Esker Ridge	Sand & Gravel	2,000,000	Potential	Minimal

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
FN 27 EBA 7.107	Terrace Mackenzie River	Silty Sand	700,000	Potential	Sensitive Terrain
FN 29 EBA 7.108	Glacial Outwash	Gravel & Sand	300,000	Potential	Minimal
FN 31 EBA 7.116	Fluvial Fan	Sand; Some Gravel	75,000	Potential	Minimal

* Represents Total Volume Unless Specified

TABLE 19 is adapted from the PemCan report completed in 1972 for Canada. Dept. of Indian Affairs and Northern Development titled: Granular Materials Inventory: Fort Norman, N.W.T.: Community Study Area, and from EBA Engineering Consultants Report titled: Summary of Granular Resource Data for the Upper Mackenzie Valley completed in 1988 for DIAND.

PROJECTED DEMAND INFORMATION FOR FORT NORMAN:

Good quality material is not abundant near Fort Norman. Some of the deposits shown on this table are greater than 8.0 km from Fort Norman. Deposits 8.001 and 8.002 are primary sources for the town. From 1987 to 1991 Fort Norman required 10,700 m^3. These deposits have probably been depleted. Alternate sources 7.154 and 7.155, on the west side of Mackenzie River, have excellent quality material and deposit 7.101 is an unproven prospect with good potential. These deposits, which have more difficult access, could serve to meet increased demand.

TABLE 20: WRIGLEY GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
BP65 (PWC-Public Works Canada)	Glaciolacustrine	Sand & Silt; Overlying Till	N/A	Undeveloped	N/A
10.035 439-1 (PWC)	Alluvial Terrace	Sand & Gravel	N/A	Undeveloped	N/A
10.036 W-12 (PemCan)	Alluvial Terrace	Sandy Gravel	500,000	Undeveloped	May be winter operation because of Hodgson Creek fisheries
10.037 W-13 (PemCan)	Glacio-fluvial Outwash	Sandy Gravel	750,000	Undeveloped	Must Cross Hodgson Cr. Winter Op. only
10.038 W-7 (PemCan)	Alluvial Terrace	Sand & Gravel	200,000	Undeveloped	Access Required
10.039 W-10X (PemCan)	Alluvial Terrace	Sandy Gravel	230,000	Undeveloped	Difficult Access; Creek Cross.; Thick Overb.
10.040 W-8X (PemCan)	Alluvial Plain	Sand & Gravel	N/A	Undeveloped	Deposit in Active Stream Channel - Hodgson Cr.
10.041 W-6 (PemCan)	Alluvial Terrace	Gravel & Sand	750,000	Undeveloped; Recomm. for town expansion	Minimal

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
10.042 W-5 (PemCan)	Alluvial Terrace	Sandy Gravel	7,600,000	Undevel- oped;	Adjacent to townsite & airport; Also close to Mack. R.
10.043 95-O-B2 (NES)	Glacio- fluvial Terrace	Gravel; Some Sand & Silt	24,600,000	Undevel- oped	Moderate; Highway & Creek buffer zones
10.124 W-17X (PemCan)	Rock	Sandstone & Shale	N/A	Undevel- oped	Caribou Range; Difficult Access
10.125 W-18X (PemCan)	Alluvial Plain	Sand	N/A	Undevel- oped	Caribou Range; Difficult Access
10.126 W-11 (PemCan)	Alluvial Terrace	Gravel	110,000	Undevel- oped	Winter Op.because of Hodgson Cr.
10.127 W-19X (PemCan)	Alluvial Terrace	Sand & Silt	N/A	Undevel- oped	No Access
10.128 W-20X (PemCan)	Alluvial Terrace	Gravel	150,000	Undevel- oped	No Land Access
10.173 BP64 (PWC)	Glaciola- custrine	Sand & Silt	N/A	Undevel- oped	N/A
10.174 BP62 (PWC)	Glaciola- custrine	Sand & Silt	N/A	Undevel- oped	N/A

* Represents Total Volume Unless Specified

TABLE 20 is adapted from the DIAND Granular Resources Databases, Mackenzie Valley Transportation Corridor, 1992. Original investigations of deposits were covered in PWC, PemCan, GSC, and NES reports 1973 to 1975 (see Northern Granular Resources Bibliography, 1993). Deposits were summarized in EBA report titled: <u>Summary of Granular Resource Data for the Upper Mackenzie Valley</u> (prepared for DIAND).

PROJECTED DEMAND INFORMATION FOR WRIGLEY:

Good quality granular material is available within 8.0 km of Wrigley. The townsite is located within the boundaries of deposit 10.042 (Class 1 material). As of 1988, three pits have been developed in the deposit and the one at the west end of town has been depleted. Quantity data suggest 7,500,000 m^3 remain in the deposit. EBA (1987) reported the community will need a total 22,900 m^3 between 1987 and 1992. The Wrigley deposit has supplied this demand. Town planning at Wrigley should take into consideration the boundaries of deposit 10.042.

TABLE 21: FORT SIMPSON GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
11.070 FS-12 (PemCan)	Glacio-fluvial Outwash Terrace	Gravel	5,100,000	Undevel-oped	Protect N bank of Mackenzie River from disturb.; River Crossing
11.071 FS-13 (PemCan)	Glacio-fluvial Outwash Terrace	Sand & Gravel	1,000,000	Developed	Access Problems; River Crossing
11.168 FS-3 (PemCan)	Glaciola-custrine Plain	Sand; Some Silt	N/A	Undevel-oped; Serves as Dump; Reserved for Comm-unity Use	Sensitive Terrain
11.169 FS-4X (PemCan)	Glaciola-custrine	Sand; Some Silt	N/A	Develop.; 3 Old Pits	Adjacent to Liard R; In Area of Future Town Develop.
11.170 FS-1 (PemCan)	Alluvial Terrace	Gravel & Sand	380,000	Develop., Active Pit in 1973	Adjacent to Liard R.; Thick overb.
11.171 FS-11 (PemCan)	Alluvial Terrace	Sand & Silt	N/A	Undevel-oped	Access Difficult
11.172 FS-5X (PemCan)	Glaciola-custrine Plain	Silty Sand	N/A	Develop.; 4 Old Pits	Minimal; Material is poor Qual.

* Represents Total Volume Unless Specified

TABLE 21: is adapted from the DIAND Granular Resources Databases, Mackenzie Valley Transportation Corridor, 1992. Original investigations of deposits were covered in PemCan, GSC, and NES reports 1973 to 1975 (see Northern Granular Resources Bibliography, 1993). Summarized in EBA Report titled: <u>Summary of Granular Resource Data for the Upper Mackenzie Valley</u> (prepared for DIAND).

PROJECTED DEMAND INFORMATION FOR FORT SIMPSON:

Fort Simpson lacks good source of Class 1 granular material. Source 11.168 (Class 4) has been specified for community use but it consists of a very fine sand. Source 11.169 (Class 4) has three abandoned pits and is an area of town development. Source 11.170 (Class 2) is the town's main source for quality material. Deposit 11.188 (45.0 km south of Fort Simpson) is a developed source for Class 2 materials. In 1987 borrow use for the settlement was estimated to be 10,000 m^3 to 20,000 m^3 per year. EBA (1988) recommends the supply/demand situation for Fort Simpson may indicate that reserves of material should be closely monitered.

TABLE 22: FORT SMITH GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
5-68 (Hill 2)	Beach Ridge Complex	Class 3 Sand; Some Gravel & Silt	1,750,000 (Prospec-tive)	Potential	Not Recommended For Development Until Salt Mtn. Depleted; 45 km West of Fort Smith
5-69 (Hill 1)	Beach Ridge Complex	Class 3 Sand; Some Gravel & Silt	9,000,000 (Probable)	Active; Primary Source For Fort Smith	None Identified; 34 km West of Fort Smith
5-70 (Salt Mtn.)	Beach Ridge Complex	Class 3 Sand; Some Gravel & Silt	2,000,000 (Probable)	Active; Hwys Mainten-ance Pit	None Identified; 32 km West of Fort Smith
Myers Lake Pit	Esker	Class 1 Gravel; Some Sand	N/A	Active	Deposit East of Slave River in Alberta; Access In Winter Only Across Slave River

* Represents Total Volume Unless Specified

TABLE 22: is adapted from a report prepared by Thurber Consultants Ltd. (1987) for DIAND entitled: Granular Resources Management Strategy - South Slave Region.

PROJECTED DEMAND INFORMATION FOR FORT SMITH:

Fort Smith is a town of 2487 people (1990) near the Alberta-NWT border. The town is adjacent to Wood Buffalo Park. Some small deposits are located near the townsite, but most granular resources are obtained from pits (see Table above) which are west and east of Fort Smith. Enough Class 3 and 4 material is available in existing deposits to satisfy long term needs of the community. Class 1 and 2 materials will continue to be imported from the Myers Lake deposit.

TABLE 23: FORT RESOLUTION GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
6-21	Beach Ridge	Class 4 Sand	19,000 (Probable)	Active	Poor Quality; Further Development Not Recommended
6-22	Beach Ridge & Lag Material	Class 3 Sand; Some Gravel & Silt	380,000 (Probable)	Active	Main Source of Class 3 Material for Community
6-23	Beach Ridge & Lag Material	Class 3 & 4 Sand; Some Gravel	1,000,000	Potential	Recreation Area for Community; Development not Recommended
6-24	Beach Ridge	Class 4 Sand	50,000 (Probable)	Active; Several Small Pits	Minimal

* Represents Total Volume Unless Specified

TABLE 23: is adapted from a report prepared by Thurber Consultants Ltd. (1987) for DIAND entitled: Granular Resources Management Strategy - South Slave Region.

PROJECTED DEMAND INFORMATION FOR FORT RESOLUTION:

Fort Resolution is community of 502 people (1990) on the south shore of Great Slave Lake. Class 3 and 4 material is available in existing deposits to satisfy long term needs of the community. Class 1 materials for concrete aggregate will continue to be obtained from Dawson Landing Area at Kilometre 52 on Highway 6 as required. Other material is obtained from a local quarry adjacent to the airport, and from two quarry sites south of Fort Resolution near Little Buffalo River.

TABLE 24: PINE POINT GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
6-3	Glacio-fluvial Outwash	Most Classes; Sand to Gravel	7,500,000 (Prospect-ive)	Potential	Not Needed Currently; 12 to 20 km SW of Pine Point
6-4	Beach Ridge & Lag Deposit	Class 4 Gravelly Sand	400,000 (Prospect-ive)	Inactive	Was Mine Borrow Pit; Closed 1991
6-5	Glacio-fluvial	Class 3 Sandy Gravel	375,000 (Probable)	Inactive	Was Borrow Source for Mine; Closed 1991
6-6	Beach Ridges & Spit Deposits	Class 3 Sandy Gravel	650,000 (Prospect-ive)	Potential	Minimal
6-7	Glacio-fluvial Ridges	Class 3 Sandy Gravel	225,000 (Prospect-ive)	Potential	Minimal
6-8	Glacio-fluvial Ridges	Class 3 Sandy Gravel	400,000 (Prospect-ive)	Potential	Minimal
6-9	Beach Ridge Complex	Class 2 Gravel	450,000 (Prospect-ive)	Inactive	Closed
6-10	Beach Ridge	Class 3 Gravel	Depleted	Abandoned	Some Clean-up Needed
6-11	Beach Ridges	Class 2 & 3 Gravel	340,000 (Probable)	Inactive	Source Closed
6-12	Glacio-fluvial	Class 3 Sandy Gravel	2,700,000 (Prospect-ive)	Potential	Not Recom-mended For Development At This Time

* Represents Total Volume Unless Specified

TABLE 24: is adapted from a report prepared by Thurber Consultants Ltd. (1987) for DIAND entitled: Granular Resources Management Strategy - South Slave Region.

PROJECTED DEMAND INFORMATION FOR PINE POINT:

Pine Point is located halfway between Hay River and Fort Resolution on Highway 6. Primary demand for material in this area was for road building related to Pine Point Mines which was closed in 1989. Class 1 material for concrete aggregate will continue to be obtained from source 6-9 west of Pine Point as required.

TABLE 25: HAY RIVER GRANULAR RESOURCES

Source	Landform	Quality	Quantity* m^3	Status of Source	Development Constraints
2-9	Beach Ridges	Class 4 Silty Sand	225,000	Potential	Low Qual; High Water Table; Not Recommended (GNWT Block Land Transfer)
2-10	Beach Ridges	Class 4 Silty Sand	300,000 (Probable)	Potential	Suitable for General Fill; Recreation Area (GNWT Block Land Transfer)
2-11	Beach Ridges	Class 4 Silty Sand	1,000,000 (Probable)	Active	Primary Source for Sand/Fill at Hay River (GNWT Block Land Transfer)
5-1	Beach Ridge	Class 3 Gravelly Sand	Depleted	Abandoned	Natural Revegetat-ion in Progress
5-2	Beach Ridges	Class 4 Gravelly to Silty Sand)	35,000 (Prospect-ive)	Potential	Near Sandy River Channel
5-3	Beach Ridges	Class 4 Fine Sand	1,000,000 (Prospect-ive	Potential	Low Qual. Material; On Hay River Reserve

* Represents Total Volume Unless Specified

TABLE 25: is adapted from a report prepared by Thurber Consultants Ltd. (1987) for DIAND entitled: Granular Resources Management Strategy - South Slave Region.

PROJECTED DEMAND INFORMATION FOR HAY RIVER:

Hay River is a town of 2891 people (1990) on the south shore of Great Slave Lake. Class 1 material for Hay River is obtained from sources 5-6, 5-19, 5-27, and 5-33 between Pine Point and Hay River on Highway 5. Class 2 and 3 material will continue to be extracted from sources 5-19, 5-27, and 5-29, 30 to 35 km southeast of town on Highway 5. Class 4 material will continue to be obtained from source 2-11, 3 to 5 km west of Hay River.