GRANULAR MATERIAL SOURCES

INVESTIGATION

LAKE HARBOUR, N.W.T.

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EXECUTIVE SUMMARY

The Hamlet of Lake Harbour, which was incorporated on April 1, 1982, is a mature and growing community of approximately 350 people that needs a reliable and convenient source of all types of granular material.

This report presents the results of a geotechnical study, conducted under the objectives and guidelines of the Community Granular Program, to determine the 20-year demand for granular materials and the best means of satisfying that demand.

In summary, the 20-year demand for granular materials in the community is nearly 139,000 cubic meters. This demand is primarily for local capital projects and maintenance of community facilities.

In general, pit-run granular materials of sufficient quality and quantity to meet the 5-year forecast demand are <u>NOT</u> available in the vicinity of Lake Harbour. A review of existing sources indicates that deficiencies of select granular material will exist by 1992, and of embankment and subbase granular materials by 1993. Development of potential sources will satisfy the community's foreseen needs to 1994/95 and beyond through 'drill and blast' quarry operations. A quarry and stockpile operation should be implemented during the 1993/94 fiscal year and then continue on an 'as and when needed' basis.

Implementation of a Granular Source Management Plan by the Hamlet of Lake Harbour, based on the technical recommendations of this report and local concerns, is recommended at the earliest possible date.

1. INTRODUCTION

The geotechnical studies undertaken by the Community Granular Section are an integral part of the Community Granular Program. The goals, principles, definitions and methodology of these reports are discussed in this section.

1.1 Purpose

The Community Granular Program, Engineering Division, D.P.W., provides the capital resources for identifying, laboratory testing, developing, and restoring granular sources for all non-taxed based communities in the N.W.T. The objective is to process, stockpile, and manage granular supplies to ensure materials are available for planned community development projects, ongoing maintenance, and private use, at a reasonable cost.

To meet this objective, geotechnical investigations are planned for various communities throughout the N.W.T. and are priorized on the basis of the granular needs in the communities. These needs are derived through an analysis of the 5 year capital plans and the 20 year capital needs assessment of every GNWT Department, the N.W.T. Housing Corporation, the Federal Government and where available, the private sector, as of November, 1989. Highly speculative needs such as resource development projects (i.e. oil and gas) are beyond the scope of these studies.

The intent of this report is to precisely define the community's available granular resources and its granular needs over a 20 year horizon and develop options for the management of those resources that ensure the community's long term needs are met. The report and recommendations will enable the community, through the consultative process, to develop a comprehensive Granular Resource Development and Management Plan that will provide control of the extraction, development, use and restoration of granular resource areas.

1.2 Geotechnical Investigation Procedure

This granular materials study is a multi-phased investigative and assessment process that may be broken down as follows:

Terrain Analysis
- regional setting
- geology and geomorphology
- drainage
- permafrost distribution

Resource Description and Assessment
- review of pertinent information
- air photograph interpretation
- ground reconnaissance and sampling
- material quantity assessment
- material quality assessment
- ground ice and permafrost assessment
- evaluation of all sources
- access routes
- source summary

Granular Needs Assessment
- granular material breakdown
- 5 year needs assessment
- 20 year needs projections
- needs summary

Recommendations
- comparison of resources and needs
- development of options
- development of estimates
- selection of options

1.3 Specifications and Terminology

A number of systems have been devised for classifying granular materials that are based on soil characteristics and engineering properties of the material. The Community Granular Section uses the following standards, criteria and specifications to describe the material in the granular sources discussed in this report. In addition, a Glossary of Terms is to be found following Section 8.

1.3.1 Classification of Soils

The Unified Soil Classification System (USC) is used to identify various types of soils through visual description in situ and in the laboratory and through tests such as Atterburgh Limits and sieve analysis. The USC system is shown on the following page.

1.3.2 Engineering Properties of Materials

Granular materials have been separated into various "types" for the purposes of this report. Each type is based on the intended end use of the material and conforms to the American Association of State Highways and Transportation Officials (AASHTO) specifications, as follows:

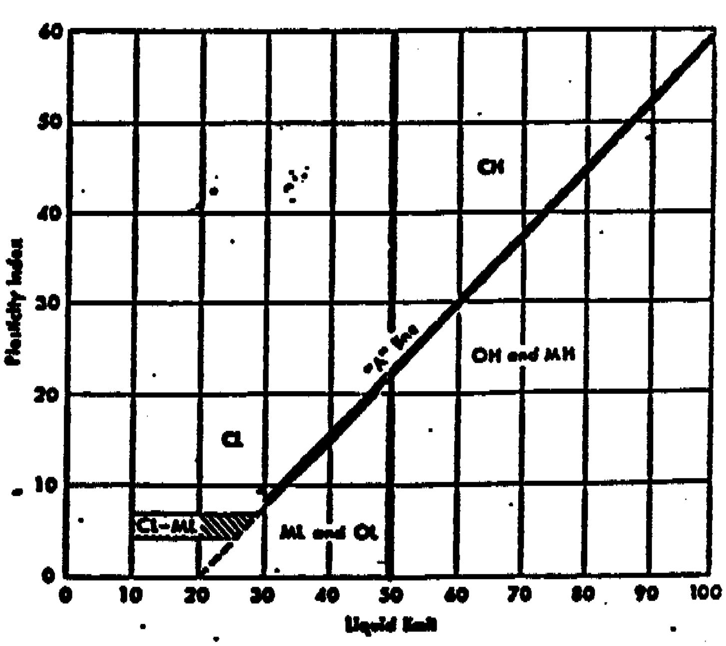
Type		Specification
Embankment		AASHTO M 57-80
Sub-base		AASHTO M 57-80
Base		AASHTO M 147-65(80)
Surface		AASHTO M 147-65(80)
Concrete Aggregate	- fine	AASHTO M 6-81
	- coarse	AASHTO M 80-77(92)

All granular material samples are subjected to standard laboratory tests to ensure conformance with these specifications. The tests are:

- **Washed Sieve Analysis: AASHTO T11-82:**
  Report grain size analysis on standard form showing all calculations, eg. original dry, dry after washing amount retained per sieve and percent error. Use following sieve nest.

100 mm	4 in.	4.75 mm	No. 4
75 mm	3 in.	2.36 mm	No. 8
67.5 mm	2 1/2 in.	2.00 mm	No. 10
50 mm	2 in.	1.18 mm	No. 16
37.5 m	1 1/2 in.	0.60 mm	No. 30
25 mm	1 in.	0.425 mm	No. 40
19 mm	3/4 in.	0.300 mm	No. 50
16.5 mm	5/8 in.	0.150 mm	No. 100
12.5 mm	1/2 in.	0.075 mm	No. 200
9.5 mm	3.8 in.		

Major divisions			Group symbols		Typical names	Laboratory classification criteria		
Coarse-grained soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW		Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5 per cent.....GW, GP, SW, SP; More than 12 per cent.....GM, GC, SM, SC; 5 to 12 per cent.....Borderline cases requiring dual symbols**	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP		Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM*	d	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
				u				
			GC		Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above "A" line with P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW		Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP		Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM*	d	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Limits plotting in hatched zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
				u				
			SC		Clayey sands, sand-clay mixtures		Atterberg limits above "A" line with P.I. greater than 7	
Fine-grained soils (More than half of material is smaller than No. 200 sieve)	Silts and clays (Liquid limit less than 50)		ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity			
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL		Organic silts and organic silty clays of low plasticity			
	Silts and clays (Liquid limit greater than 50)		MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH		Inorganic clays of high plasticity, fat clays			
			OH		Organic clays of medium to high plasticity, organic silts			
	Highly organic soils		Pt		Peat and other highly organic soils			



Plasticity Chart

- **Dry Sieve Analysis: AASHTO T27-82:**
  Sieve down to No. 4 (4.75 mm) using sieve nest indicated in specification. Prepare grain size curve on standard form.

- **Lab Crushing:**
  Crush to required maximum size using laboratory jaw crusher. Size will be given on sample information.

- **Atterberg Limits: AASHTO T89-81 Method A. T90-81:**
  Report summary list of sample numbers with liquid limit, plastic limit, and plasticity index. Report on standard form.

- **Visual Description and Classification:**
  Give a brief visual description of sample content as per example. Classify the material as per Unified Soils system and AASHTO system including group index. Report on standard form.

- **Natural Moisture Content: AASHTO T265-79:**
  Supply summary list showing sample number and moisture content. Also complete lab data copies.

- **Magnesium Sulphate Soundness, AASHTO T104-77 (1982):**
  Report the loss on each coarse fraction and the total loss by the weighted average based on the grading of the original sample.

- **Los Angeles Abrasion, AASHTO T96-77:**
  Depending on the sample, use the appropriate grading, and report the loss as a percentage.

- **Modified Proctor Standard Proctor, AASHTO T99-81:**
  Report results of five (5) points and prepare proctor curve on standard form.

- **Petrographic Analysis, MTC LS-609:**
  Using coarse aggregate report PN number and flakiness index.

- **Fractured Face Count, MTC LS-607:**
  Report as percentage of original sample mass.
  Refer to AASHTO T4-35, Section 2.

- **Flat and Elongated Particle Count, MTC LS 608:**
  Report as percentage of original sample mass.

- **Hydrometer Analysis: AASHTO T88-81:**
  Supply all lab data and grain size curve. Plot results of grain size on Contractor's standard grain size distribution curve.

- **Washed Sieve Analysis:**
  Minus 0.075 mm: AASHTO T11-82.
  Organic Content: AASHTO T267.

It is important to note that all samples may not have to be subjected to the full range of test procedures.

It should be noted also that ground thermal analysis and the engineering properties of permafrost unique to northern periglacial environments are taken into consideration in all situations.

1.3.3 Environments of Deposition

The properties of any granular material vary with its gradation, moisture content, vertical position in relation to the surface of the ground, and geographic location. Time and climate influence the weathering process of mechanical and chemical disintegration that breaks the material down into progressively smaller particles. The term gradation refers to the relative size of these particles in a deposit.

Size distribution is related to environments of deposition that indicate the texture and composition of a granular deposit. The amount of each size grouping in a deposit is one of the major tools used in judging, analyzing, and classifying a source for use as a construction material. Granular deposits contain particles ranging in size from boulders through clay, as indicated below.

203.2 mm (8 in.) | 71.6 mm (3 in.) | 19 mm (0.75 in.) | 4 mm (0.16 in.) | 2 mm (0.08 in.) | 0.42 mm (0.02 in.) | 0.074 mm (0.003 in.)

Boulders	Cobbles	Coarse Gravel	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt & Clay (Fines)

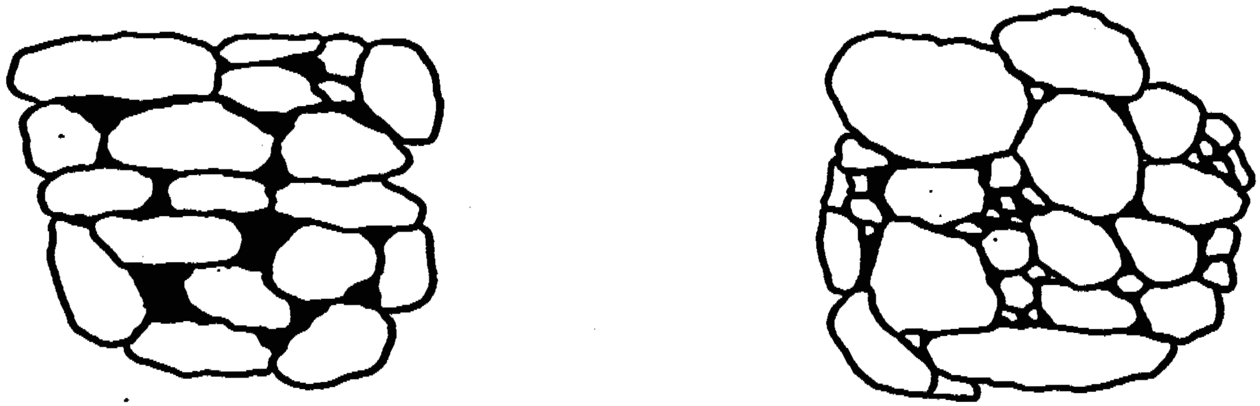
Gravel and sand particles are the most desireable and are found in glacio-fluvial deposits and post glacial beaches. Silt and clay particles, called 'fines', are undesirable over 15 percent because they tend to hold water which in periglacial environments, as in the N.W.T., results in high ice content and greater frost susceptibility. However, a lower limit of 5% is often acceptable to aid in compaction. Fines are often found in deltaic and lacrustine deposits, some fluvial sediments, and tidal flats. Post glacial/fluvial processes during the Quarternary period have also influenced the type of gradation in granular sources in the N.W.T.

Mechanical weathering is the dominant process acting on the rock strata of the precambrian outcrops throughout the N.W.T. Since the regolith produced from the weathering process occur "in situ", most granular deposits in the N.W.T. are "poorly graded" with a high percentage of "oversized" particles.

The suitability of a deposit for construction purposes is directly related to the particle distribution or grain-size curve. This curve indicates if a deposit is "well-graded" or "poorly graded", two terms that are used extensively in this report.

A "well graded" granular deposit has an equal amount of each gravel and sand size and little or no fines. These deposits are referred to as "clean" and are excellent quality materials for "pitrun" construction purposes. Eskers and raised beaches are prime examples of "clean" deposits.

A "poorly graded" granular source has an excess of some particle sizes, a shortage or lack of others, or has nearly all particles the same size. These sources need processing to improve and upgrade their quality. Screening and washing can be used to remove undesirable particle sizes. Talus slopes, alluvial fans, and varved clays are prime examples of this type of deposit found in the N.W.T.



Poorly-graded materials with all particles the same size or with a lack of certain particle sizes (left drawing) have more voids and are less stable than well-graded materials where the voids are filled by the smaller particle (right drawing).

1.4 Volume Estimates

Volumes of granular material sources as described in this study are classified as being proven, probable, or prospective.

A **proven** volume is one where existence, extent, thickness and quality is supported by ground truth information such as a test-pitting, exposed stratigraphic sections, bore hole drilling, and aggressive sampling and ground truth reconnaissance.

A **probable** volume is one whose existence, extent, thickness and quality is inferred on the basis of direct and indirect evidence such as airphoto interpretation, geophysical data, terrain analysis, and limited sampling and ground thruth reconnaissance.

A **prospective** volume is one whose existence, extent, thickness and quality is suspected on the basis of limited direct evidence, such as airphoto interpretation, remote sensing information, or imaging radar techniques. There is no sampling or ground truth reconnaissance.

1.5 Restoration and Regulations

Pit planning, design, and restoration are important aspects of granular resource development. Environmentally, the development of any granular sources offers the potential for drainage and erosion problems, habitat destruction, and the disturbance of wildlife. In many communities in the N.W.T., excessive scarring of the surrounding terrain is a major concern. These reports take into account the economic and environmental factors of pit abandonment and reclamation. Guidelines to minimize the impact of pit development and quarry operations are available in the INAC (1982) publication "Environmental Guidelines Pits and Quarries". At all stages of pit planning, design and operation, methods that ensure final pit restoration are stressed.

Permafrost can be expected throughout the N.W.T. and results in a variety of environmentally sensitive problems related to pit abandonment and restoration; thus pit development in permafrost environments must be planned well in advance and special techniques used during the extraction of material.

Territorial land use regulations are to be followed in all development plans, without exception, especially in the areas of land use permits, explosives, and pit abandonment.

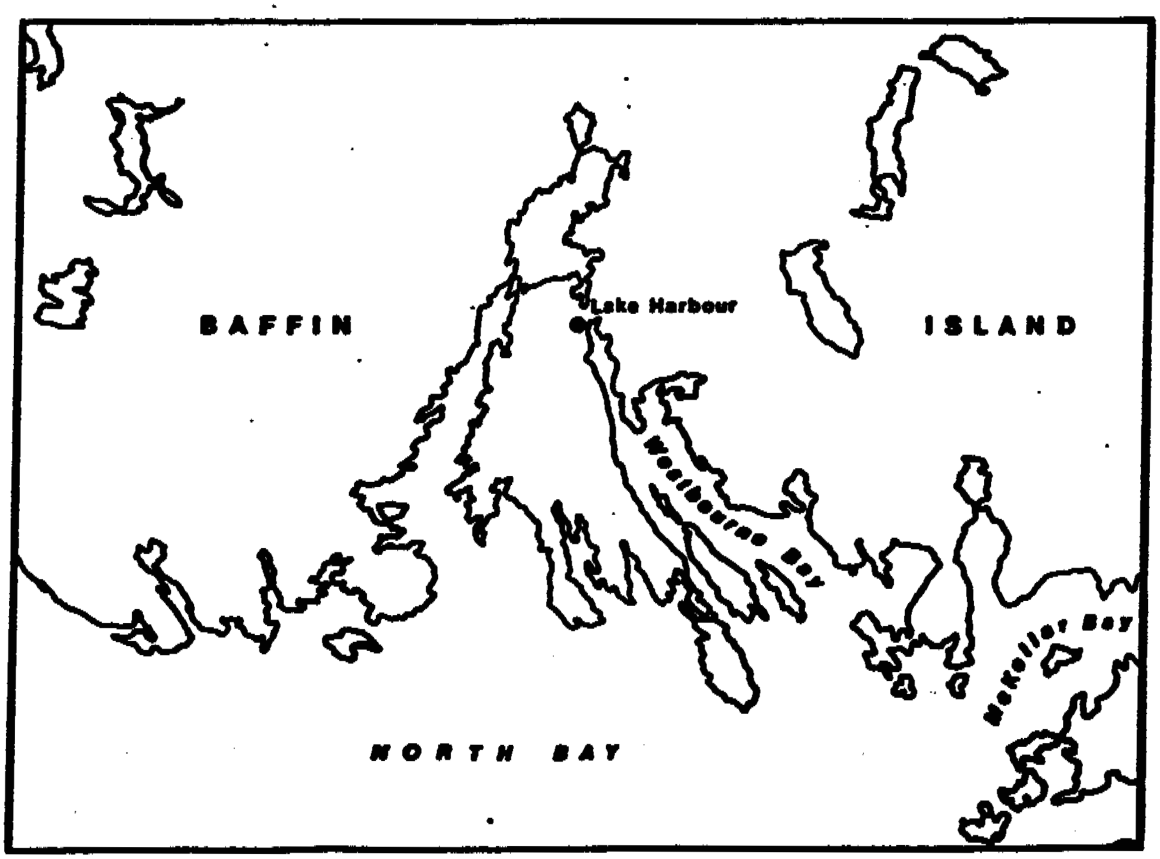
2. TERRAIN ANALYSIS

2.1 Regional Setting

The community of Lake Harbour is located within the Baffin Region of the N.W.T. Lake Harbour is an isolated settlement situated on the S.W. corner of Baffin Island on the western shore of Westbourne Bay. The geographical co-ordinates of the community are 62 degrees 51 minutes north latitude and 69 degrees 53 minutes west longitude. A site location map is viewed below. The N.T.S. map references are:

LAKE HARBOUR	.... 25K/13		
UTMS	.... 450000 - 550000	meters	EAST
	.... 6880000 - 698000	meters	NORTH

The community of 350 people is approximately 50 minutes flying time southwest of Iqaluit on the Meta Incognita Peninsula.



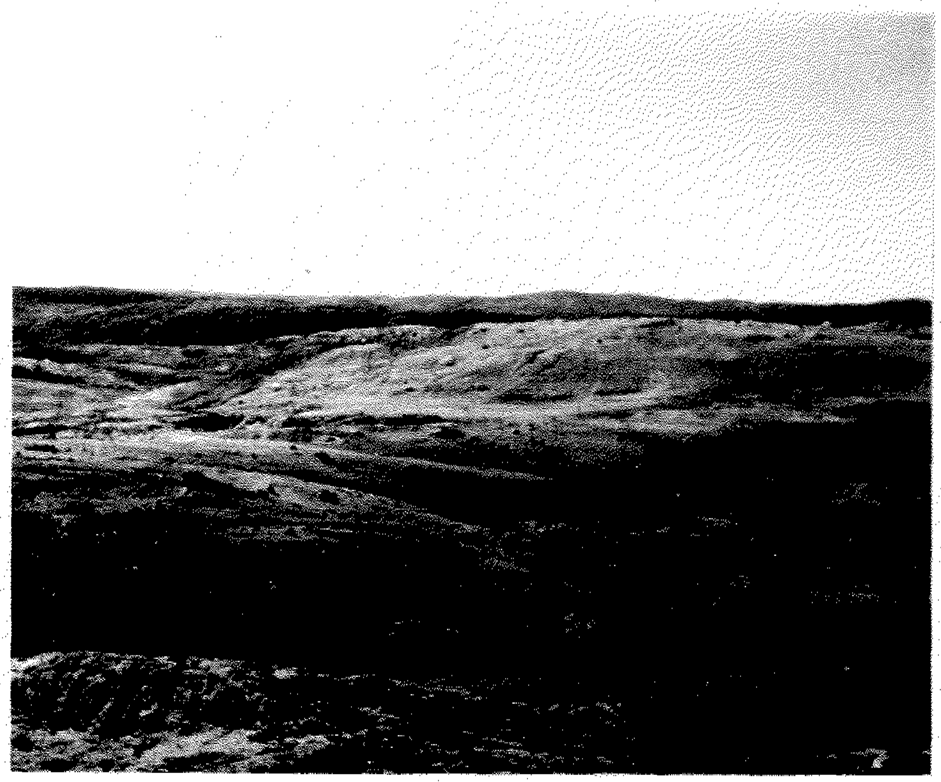
LATITUDE: 62° 51' LONGITUDE: 69° 53' NTS MAP REFERENCE NO.: 25K

2.2 Geology and Geomorphology

Lake Harbour is located within the Frobisher Upland physiographic region. The terrain is rocky and extremely rugged, elevations range from 150 - 215 meters in the vicinity of the community. The uplands rise abruptly from the sea to 1000 meters then slopes southward into Hudson Straight; they are actually a highly eroded, ancient, mountain range comprising the S.W. portion of Baffin Island.

The main part of the village is close to the head of Lake Harbour on the western shore of Westbourne Bay. The community is situated at the end of a long fiord.and occupies the only relatively flat terrain in the vicinity. A hanging valley between these ridges contains a small lake. The settlement airstrip was constructed by placing fill into the lake.

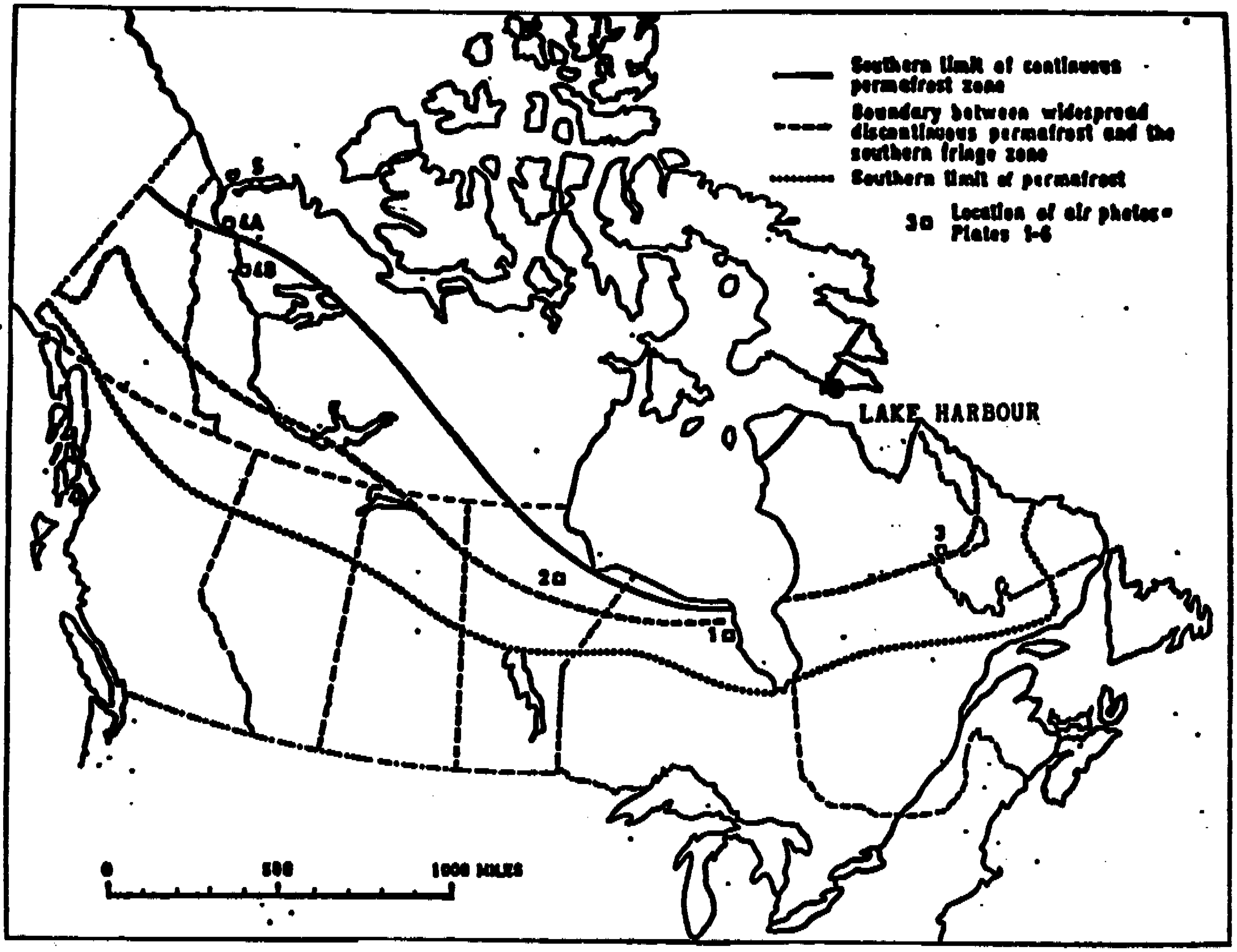
The bedrock of the study area is situated within the Churchill structural province and is very old belonging to the Archean period of the Precambrian Era. The area was completely folded during the Kenoran orogeny. As seen below, extensive bedrock outcrops are exposed throughout the region in parallel linear ridges that trend in a northwesterly direction. The view is to the northwest. Note the continuous nature of the ridges and the rugged terrain.



Southern Baffin Island is primarily composed of medium to high grade gneiss. At Lake Harbour, these biotite-quartz feldspar gneiss are associated with bands of carbonate limestone that vary greatly in thickness and lateral extent. These rock types are intricately mixed and the structure highly convoluted. The crystalline limestone is compose of medium-to-coarse grained, white, grey, or orange calcite crystals. Metamorphism of the original sediments that were complex and impure themselves, has produced a great diversity of minerals: serpentine, muscovite, diopside (soapstone), pyrite, and graphite.

The geomorphology of the area is extremely rugged and access inland is difficult. The terrain is rounded with scree and talus deposits below steep bedrock slopes. The topography has been affected by two major N.W. trending faults and numerous smaller faults that have resulted in a typically blocky and broken surface. A large syncline exists between Soper Lake and the head of Lake Harbour.

Mechanical weathering of the rock and talus development are the major geomorphic processes responsible for the existing accumulations of surface deposits. Repeated freeze-thaw cycles acting on the friable crystalline limestone, as viewed above, has resulted in the breakdown of this large rock outcrop in situ; the detritus formed in this manner can accumulate in topographic lows to a depth



PERMAFROST DISTRIBUTION

of one to three meters. Mass movement by gravity of this material on steep slopes form talus fans and scree deposits. The weathered material tends to be angular, friable, and poorly graded with a large percentage of oversize. The study area lies almost on a line separating the continuous and discontinuous permafrost zones (see map on previous page). Aggradation of the permafrost has resulted in the formation of large palsa bogs especially in the long narrow valleys.

2.3 Drainage

The drainage pattern is bedrock controlled. Fluvial processes are limited to small ponds that are formed in closed bedrock depressions. In general, runoff and river flow in periglacial environments is characterized by irregularity and sudden fluctuations in spring and early summer and a complete cessation of flow and therefore of all fluvial activity in winter. Most rivers within the region originate from large glaciers and as they approach Hudson Straight their valleys become well defined and more deeply incised.

The photo above was taken just north of the community. Typically linear ridges separate small narrow valleys that consists of small ponds surrounded by wet pulsa bogs; yet other valleys will contain numerous ponds and small lakes in bedrock controlled depressions with no organic mat or vegetation.

2.4 Environments of Deposition

To explain the existing borrow and potential sources of granular material in the vicinity of Lake Harbour, or lack of it as is the case, the processes that have resulted in the accumulation of surfical deposits in the region need to be addressed. With respect to Lake Harbour, there are three ways in which surfical granular materials are formed.

The most widespread type of granular source found in the region is related to scree and talus deposits associated with the mechanical weathering of limestone. Although numerous, these deposits tend to be shallow, poorly graded, and contain permafrost and ground ice. They are mostly composed of a limy gravel and silt. Collectively this type of deposit is often referred to as 'colluvium'.

Another type of deposit widespread in the region is related to the mechanical breakdown of large rock masses in situ. The resulting material (referred to as detritus) contain large angular cobbles and gravels, are seldom more than one meter in depth and often cover a large land area. Field observations indicate that these deposits are limited to topographic lows and, as a result, are mostly poorly drained with large amounts of ground ice. As they develop slowly over years due to the periglacial nature of the climate, these sources often contain well developed permafrost. These deposits consist mostly of angular quartzite and gneiss fragments.

The third manner in which granular deposits are formed within the Lake Harbour region is through fluvial deposition. Sands and gravels are found over valley bottoms near the present beach level and along fast flowing streams that drain the uplands. The Soper valley directly north of the community, across Soper Lake, contains large volumes of frozen gravels and sands formed within a deltaic complex by the Soper River. This particular deposit contains a large volume of granular material but is frozen with well developed ice lensing.

Another form of these deposits are the post glacial beaches that are located as terraces at higher elevations. Site 1 is such a deposit, a remanent marine beach terrace (or strand) related to a time when existing ocean levels were much higher. The ocean level has since receded leaving a series of terraced , wave washed sand deposits behind.

3. GRANULAR SOURCES AND ASSESSMENT

This section provides an overview of the various existing and potential granular sources within the study area. Each source is described in terms of location, genesis, volume, engineering properties, development considerations. Test results are found in **Appendix I.** Note Granular Source Location Map in **Appendix 3.**

3.1 Existing Sources

There are two borrow sources presently in use in the vicinity of Lake Harbour. Site 1 is a natural sand pit just north of the fuel storage area and the present dump site. Site 2 is a combination of weathered limestone and blasted rock. The blast was carried out by Canadrill Ltd in September 1986 and produced 6500 cubic meters of base and surfacing material. Locally Site 2 is known as the Soper Lake deposit. The estimated quantity of granular material from both sources is in the order of 19,000 m^3.

3.1.1 Site 1 (Sand Pit)

Description/Genesis: The sand pit is located approximately 0.7 kms along the road to the southwest of the existing community on a height of land overlooking Westbourne Bay. It is located in close proximity to the tank farm, the communications facility and the garbage dump. A panorama of Site 1 can be seen on the following page. The deposit represents a large remanent beach that was formed at a time when ocean levels were much higher. Isostatic rebound of the lowering mass and the global lowering of ocean levels have created a series of raised beaches, one above the other. These beaches have been eroded throughout most of the study area, but at this location, large remanent beach terraces still exist. Subsequent excavation has resulted in the destruction of individual terraces so that, at present, the deposit appears as one large sand pit. The site is well drained with a distinct northwest - southeast slope. There was no evidence of permafrost.

Quantity:

Numerous small stockpiles are spread randomly over the entire site. The deposit covers an area of 200 m x 50 m to an average depth of 1.5 meters. An estimated 15,000 m^3 of coarse sand can still be extracted from this site.

SITE 1 (Sand Pit)

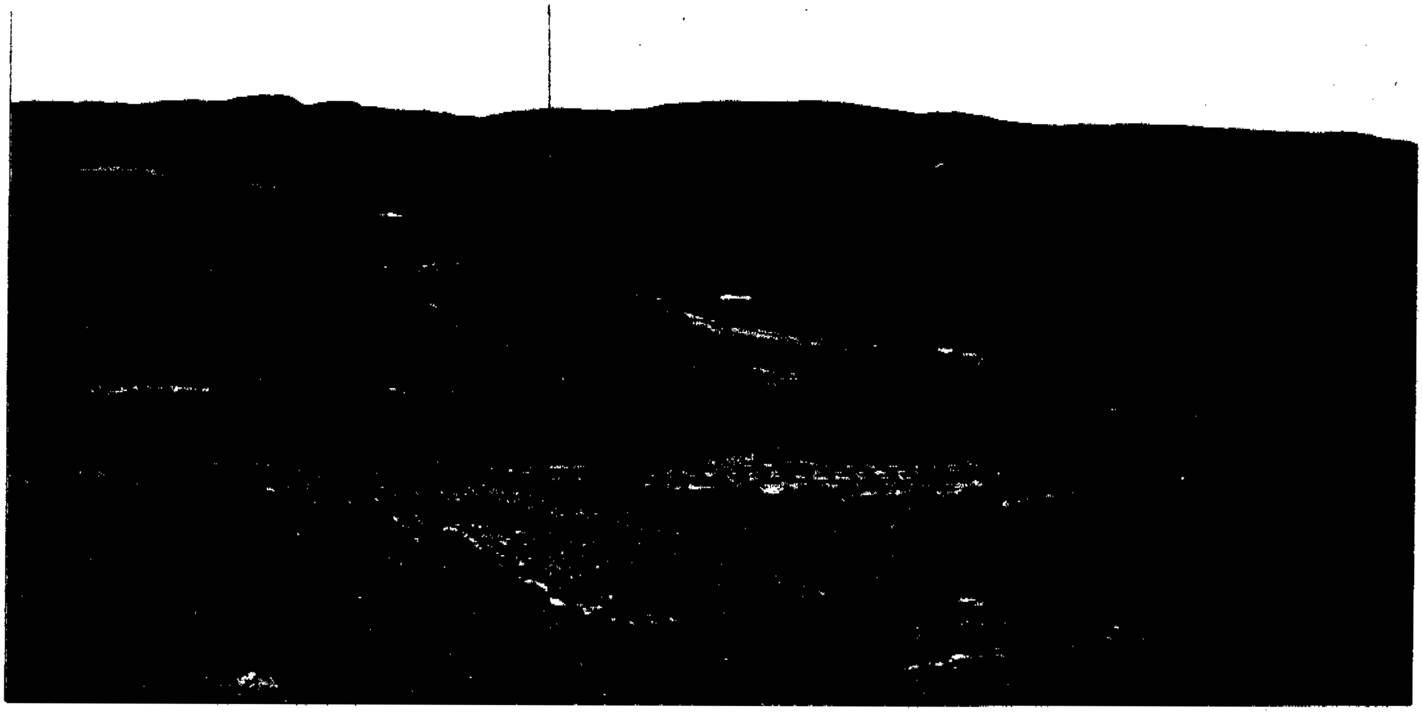


Photo above is a view directly west from eastern edge of source.

Photo above is a view of the sand pit looking directly north from the fuel storage facility; note the terracing.

Test Results:

The estimated volume of 15,000 m^3 was based in part on the numerous test pits that were dug using a D6 dozer. Sample LH-01 was obtained from the middle of the deposit.; LH-05 from one of the stockpiles. LH-01 contained 77 % sand and LH-05 83 %. Both samples indicate that the material is a well to poorly graded, subrounded, well drained, reddish brown medium sand with a non-plastic soil binder of approximately 7 % silt. The deposit can be classified under the AASHTO system within the A-1-b subgroup.

Development Considerations:

This site should be used until depletion as a source of embankment and subbase material owing to its proximity to the community, available access, and proven volume. At present the granular material extracted from this site is being removed on an irregular basis. There are no processing facilities located on the site. The community has used this site for a number of years and it would seem logical to continue to excavate this source till depletion. The primary development constraint is the cemetery located just to the north and west of the site.

3.1.2 Site 2 (Soper Lake Deposit)

The Soper Lake deposit consists of light brown to grey, angular, poorly graded, quartzite and weathered limestone. A view of the deposit is seen on the preceding page. The view is looking directly north from the Soper Lake access road. The road actually traverses the site. The site is located approximately 1.7 kms north of the community. Easy access is provided by an all season 2 km road (Soper Lake access road) that stretches northeast between the community airport and Soper Lake. The road terminates at the lake.

The source is well drained with no evidence of permafrost. The south end of the site consists of the post blast material whereas the north terminus is more representative of the weathered limestone. The weathered detritus is the result of the severe mechanical weathering of the soft carbonate limestone producing medium to coarse grained calcite crystals.

Quantity:

Since the 1986 blast, the site has been continually excavated with little planning of pit development. At present there are two stockpiles that contain approximately 2500 m^3 of base and surfacing material. Another 1500 m^3 remain as residual material between the two stockpiles with an average depth of 1.5 - 2.0 meters. In total there is in the order of 4000 m^3 remaining.

Test Results: Sample LH-03 was extracted from the north end of the deposit. A view of the sample area is below. This area of the site is a mixture of post blast material and residual weathered limestone. The sample contained approximately 49% gravel and 44% sand sizes with 7% 'fines'. Samples were obtained by hand shovel from the existing stockpiles. Test pits were dug in the residual material between the two stockpiles. No permafrost or ice lensing was encountered .

Sample LH-04 was obtained from the south end of the site and as seen below is more representative of the post blast material. The sample contained approximately 72% gravel and 24% sand sizes with 4% 'fines'.

Development Consideration:

The source was developed from blasting a limestone ridge which produced approximately 6500 m^3 of 'select' material. Approximately 4000 m^3 of material remain within easy access to the community. Select grades of material can be obtained from the two stockpiles without any required processing. The material is ideal for base and surfacing although it does have a high rate of loss through abrasion and therefore continual replacement will be necessary when used for road re-surfacing; however, the community is a low-traffic settlement with all terrain vehicles being the main mode of transportation.

3.2 Potential Sources

Potential sources of granular material in the vicinity of Lake Harbour are limited in volume, poor quality, and inaccessible. The physiographic setting of the community is such that large volumes of quality granular material simply do not exist in close proximity to the community.

3.2.1 Site 3 (Valley Bottom Deposits)

Description/Genesis:

Site 3 is a representative location for all the numerous valley bottom deposits observed within the study area. These small sources of coarse granular material are confined to low lying isolated areas in the bedrock. The actual Site 3 is seen below but as mentioned it is typical of many such valleys located in and around the community. The small valley below is located just 0.8 kms south of the community.

Often glacial till covers these valley bottoms as seen above. Field observations indicate that these deposits are shallow, poorly drained,and frost susceptible. Palsa bogs and thick sphagnum peat cover a large number of these valleys.

Quantity:

A proven quantity estimate is not available. A perspective combined volume of valley bottom granular is estimated upwards of 12,000 m^3 within the study area. Individual deposits contain from 300 - 800 m^3.

Test Results:

Sample LH-07 is typical of valley bottom sediments. The SM classification indicates a silty sand with a high moisture content. The high silt content results in low compressibility and a high liquid limit and medium plasticity. The A-2-4 subgroup indicates that borrow from this source would not be suitable as construction material.

Development Considerations:

These sources of potential borrow are only mentioned because they are so numerous throughout the study area and are highly visual. However, collectively these deposits are of poor quality, are poorly drained, and difficult to access. The small quantities associated with individual deposits are not cost-effective to develop.

3.2.2 Site 4 (Talus Deposits)

Site 4, as viewed below, is a representative source related to the numerous talus and scree deposits found throughout the study area.. This site is located 0.7 kms. north of the community adjacent to the Soper Lake access road. The view is looking northwest approximately 200 meters from the road.

These deposits are widespread and are associated with numerous limestone and gneiss ridges that exit between Soper Lake and the head of Lake Harbour. The deposits range from silt to gravel sizes and have an average depth of one to three meters. Permafrost and ground ice is prevalent within most of these deposits especially on north facing slopes. The material is grey to light brown, poorly graded , angular, friable and non-plastic.

Quantity:

Individual talus slopes such as Site 4 can contain between 400 - 800 m3 of coarse granular material. Collectively these deposit represent a total probable volume of 15,000 m^3 within the study area.

Test Results:

Sample LH-02 is typical of these ridge deposits. The sample contains approximately 59% sand sizes and 36% gravels with 5% silt. Tests indicate the talus material to be highly friable with a high abrasion rate.

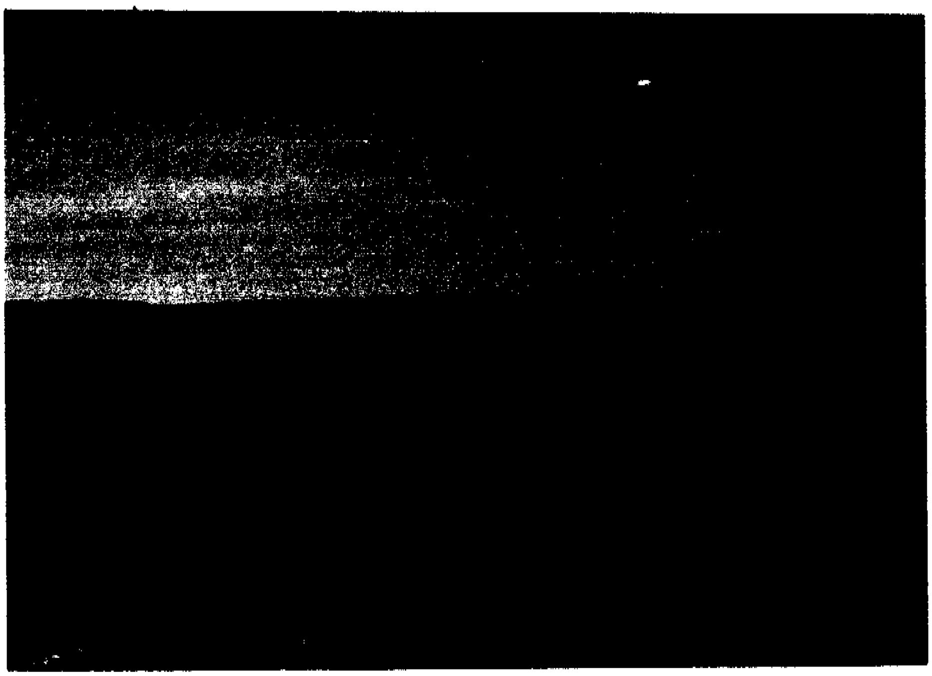
Development Considerations:

Site 4 is accessible to the community so it could be developed if a small volume of material is required; however, in general these deposits are difficult to access and do not contain sufficient high quality materials for community project.

3.2.3 Site 5 (Soper Lake Delta)

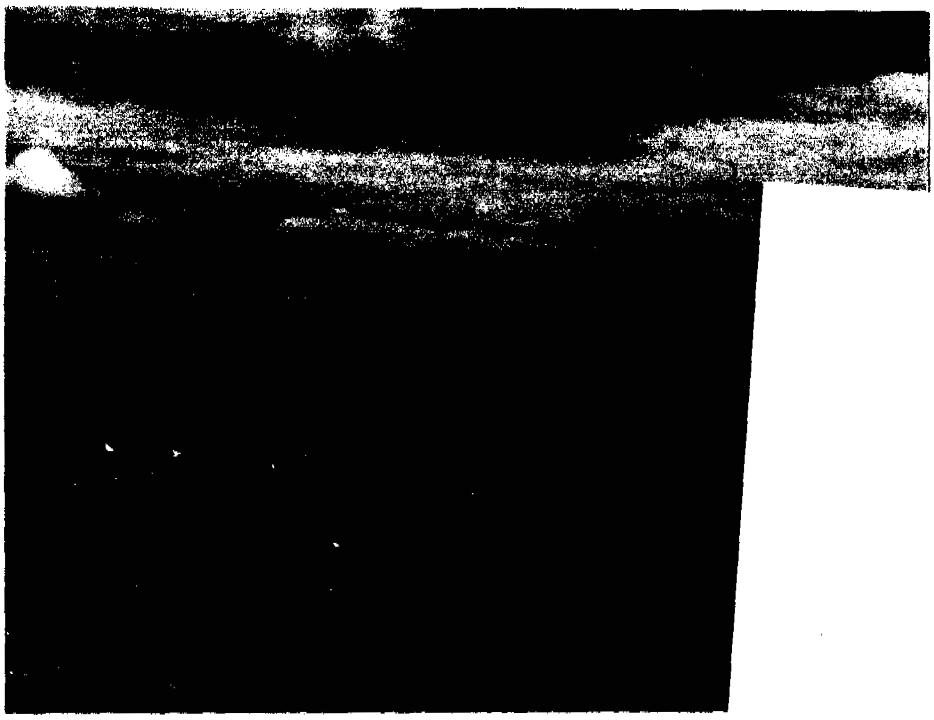
The largest potential source of granular materials within the study are the fluvial deposits along the northeastern edge of Soper Lake. These deposits parallel the Soper River which empties into Soper Lake. Additional granular material has been deposited along the delta that has built into the lake over many years. Site 5 is a test pit within the river-delta complex.

The source is located approximately 7.5 kms north of the community. During the investigation a small boat was used to cross the lake as there are no land access routes to this site. A view of Soper Lake is seen below looking directly north from the terminus of the Soper lake access road across the lake towards the Soper River Valley.



A strong current exists at the confluence of the river and the lake. As the flow velocity increases during spring runoff, fine sands and silts are carried far into the lake. Due to the high energy condition of the river and the low energy status of the lake, only the coarse sands and gravels are deposited and accumulate without serious erosion. This active deposition has occurred outward from the mouth of the river forming the delta frontal complex.

The granular material is composed primarily of coarse sand and gravel. There is a great deal of oversize material that cover the surface of this massive deposit in the cobble to boulder range. The sample area is seen below. The view is towards the south with the Soper River and Soper Lake in the distant background. The community ia located approximately 7.5 kms across the lake directly south. Large cobbles to boulders (20 cm - 100 cm) cover the site area.



PERENNIALLY

Quantity:

A probable estimate would be upward of 100,000 m^3 of embankment and subbase material; further processing would be required to obtain select grade. The deposit covers a large area but it was extremely difficult to obtain an average thickness of the material as most of the deposit was frozen below 0.7 meters.

Test Results:

Normally delta deposits are characterized by well developed cross bedding of fine sand and silts but due to the high energy nature of the Soper River and the predominance of mechanical weathering in periglacial environments, the Soper Lake delta contains very coarse, angular, gravels and cobbles intermixed with coarse clean sands. Sample LH-06 was obtained from an exposed section of the river channel approximately 200 meters from the confluence of the river and lake. The active layer thickness varies from only 0.4 m to 0.7 m thus test pits were shallow. The thawed granular materials within the active layer were often wet and are underlain by frozen, well bonded medium to coarse gravel and sand. The sample contained approximately 53% gravel and 44% sand with little or no 'fines'.

Development Considerations:

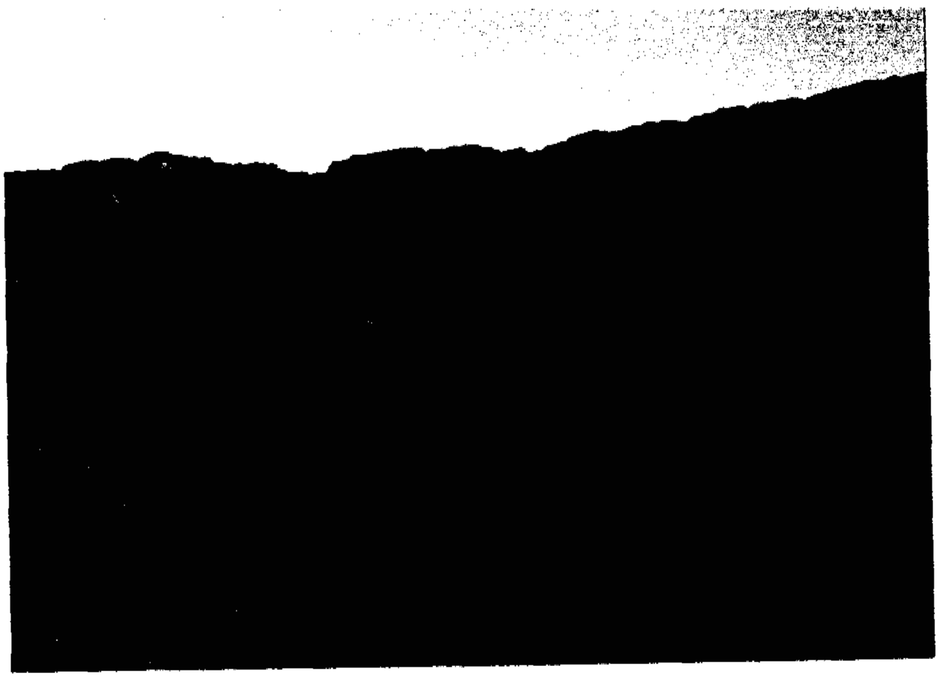
Although the deposit covers a large area, most of it appeared frozen below 0.7 meters. Owing to the frozen nature of the material the stratigraphic thickness and lateral continuity of the deposit is difficult to assess. The only practical means of access would be a 6 kilometer ice road across Soper Lake and another kilometer up the river. The material would have to be blasted and hauled to the community a distance of 8 kms. Exploitation of this deposit would be difficult and costly involving both a blasting operation and a winter haul.

Another consideration is that there exists an advanced plan for the designation of Soper River Valley as a Heritage River and as a Territorial Park. A large borrow excavation would be incompatible with the resource protection objectives of such a designation.

3.3 Quarries/Ridge Complex

There are a number of excellent quarry locations within the vicinity of Lake Harbour due to a series of long narrow, ridges that are aligned in a N.W. - S.E.direction throughout the study area. Two distinct types of ridge-rock assemblages exist within easy access of the community.

As was mentioned, the bedrock of the study area consists of exposed, parallel, linear ridges that never exceed 60 meters in height in the immediate area. These ridges are composed of medium to high grade gneiss and limestone. Gneissic rock is very hard, dense, and foliated and in the Lake Harbour region is composed of quartz and feldspar with bands of pyrite and graphite (from field observation). The oxidation of the pyrite has produced a rusty colouring to the bedrock outcrops. The most common mafic mineral present in the rock assemblage is pyroxene which is resistant to weathering. The 'blasting' properties of gneiss are such the cost per meter is higher than that of limestone as the hardness and compressive strength coefficients are much higher. As a result a much tighter blasting pattern is needed (more holes are needed), bore hole drilling takes longer, and a much higher energy explosive is necessary. A gneissic ridge is shown below. This particular ridge face is located approximately 0.6 kms. north of the community.



Associated with these gneissic ridges are numerous bands of carbonate limestone ridges that vary greatly in height and lateral extent. A typical limestone ridge is shown below.

This outcrop is part of a long narrow ridge that continues south of the community. The location of the ridge-face in the photo is approximately 0.8 kms. south of the settlement near the present dump site. It is similar in appearance to the ridge that Canadrill Ltd. 'blasted' in 1986. These limestone outcrops virtually surround the community and are especially found exposed along and adjacent to the Soper Lake access road. A major recommendation will be to produce granular material for the community through a blast and quarry operation of these limestone ridges.

4. SITE INFORMATION SUMMARY

The following table is an inventory of all existing and potential granular resources in the vicinity of Lake Harbour. Associated with each site is the U.S.C., description, volume, grade, and processing required. Samples were taken when and where possible; test results are available for viewing in Appendix 1.

4.0 TABLE 1: GRANULAR INVENTORY, LAKE HARBOUR 1989

SOURCE	USC	DESCRIPTION	VOLUME (m3)	GRADE	PROCESSING
Site 1	SP-SW	Poorly to Well-Graded Coarse Sand	15,000 (proven)	Embankment & Subbase	Pitrun
Site 2	GP	Poorly graded fine to coarse gravel	4,000 (proven)	Subbase Base Surfacing	Pitrun/Screen
Site 3 (representative)	SM	Silty Sands	12,000 prospective	Not Recommended	Not Recommended
Site 4 (representative)	SP-GP	Poorly graded sands & gravels	15,000 prospective	Not Recommended	Pitrun/Embankment
Site 5	GW	Well-graded gravel	100,000 probable	Embankment & Subbase Base	Pitrun/Screen
Soft Rock Blasting	SP-GW	Poorly to well-graded sands & gravels	50,000+	All Grades	Quarry / Blast Operation

5. GRANULAR NEEDS ASSESSMENT

As previously indicated, the granular requirements for Lake Harbour have been developed from each G.N.W.T. Department's 5 year capital plan and 20 year capital needs assessment, as well as information from the NWTHC, Federal Agencies and the private sector. The various projects were analyzed for their granular requirements and this information was used as the basis for establishing a 20 year granular needs projection by the type of materials required.

The information upon which this report is based is as accurate as could be found in November, 1989. To revise it and the conclusions drawn from it to keep them up to date has been impossible. Therefore, comparison with the approved capital plan for 90/91 will certainly show differences. However, the objective has been to make a reasonable assessment of needs for granular materials in Lake Harbour for the period noted. Since the changes brought about each year by the capital planning process will tend to reduce the quantities required and, to some extent the substitution of one project for another will probably have a relatively small effect on the totals, this approach is considered fair and reasonable. Furthermore, continual surveillance of the sources and the quantities extracted will show when additional sources must be developed.

The analysis shows that Lake Harbour requires approximately 87,000 m^3 of granular materials for fiscal years 1990/91 through 1998/99. This information is shown in part on the following pages, as is a summary of the projected requirements for fiscal years 1998/99 through 2000/2009. Detailed information for this later period is available from office files. If consulted, the data should be considered rather speculative at best.

For the purpose of this report, granular materials have been separated into five major types: embankment, subbase, base, surfacing and concrete aggregate. However, base, surfacing, and concrete aggregate are often referred to collectively as "select grades". The reason for this is that embankment and subbase materials are often used directly from a source as "pitrun" while select grades are obtained through the processing of the material by washing, screening or crushing.

Table 2 represents the granular material breakdown of capital projects that was used to develop this section of the report. This information was then used to derive the granular needs assessment tables for individual fiscal years displayed in Table 3.

5.1 TABLE 2: CAPITAL PROJECTS

Granular Material Breakdown
(in cubic metres)

Description	Embankment	Sub Base	Base	Surface Material	Concrete Aggregate	Riprap
Warehouse		900	450	300		
Group Home		500	175	300		
Solid Waste Facility	9000		3750	2250		
Solid Waste Facility/ Access (1 km.)	13900		1300	200		10
Solid Waste Improvements	6000		2500	1500		
Water Supply Improvements	6000		2500	1500		
Water Supply - Reservoir	30000	10000	10000			
WS-Facility Access	10000		5000	3000		
R/S/L - Lot Development (1 lot)		180	80	100		
R/S/L - New Road (1 km.)	4900		1300	1200		100
R/S/L - Resurfacing (l km.)	600		200	1200		50
R/S/L - Road Upgrade (l km.)				1000		
Staff Housing		400	175	200		
Single Unit (Satellite base)		300	100	200		
Duplex		500	175	200		
4-plex		675	225	200		

Description	Embankment	Sub Base	Base	Surface Material	Concrete Aggregate	Riprap
In town gas station		600	200	200	50	
Garage x 2 Bay x 3 Bay		600	200	200	50	
Firehall		350	100	200	50	
New School		400	100	200	200	
School Addition		200	50	100	100	
Museum - Low$		200	50	100	100	
Small Community Hall ($250m^2$)		300	100	200		
Medium Community Hall ($390m^2$)		500	175	200		
Large Community Hall ($440m^2$)		675	225	200		
Hamlet Office		500	175	200		
Small Gym ($250m^2$)		300	100	200		
Medium Gym ($390m^2$)		500	175	200		
Large Gym ($440m^2$)		675	225	200		
Medium Arena		675	225	200		
Trade Shop		300	100	200		
Small Arena		500	175	200	100	
Skating Rink		500	175	200	100	
Airstrip - New 60 x 900	81000		16200	5400		
Airstrip - Upgrade Maint/year				1700		
Airstrip - Resurface 60 x 900				5400		

Description	Embankment	Sub Base	Base	Surface Material	Concrete Aggregate	Riprap
Tankfarm - new facility	3000		2000	3000		
Tankfarm - upgrade	300	300	300			
Tankfarm - facility & access	6000		2000	6000		
Increase capacities	6000		2000	6000		
Shoreline Protection				600		4000
Sewage Lagoon	100,000m³					
Office - small	Duplex	500	175	200	(visitor centre)	
Office - large	4-plex	675	225	200		
Arena - large		850	275	200		
Park Development (Low$)	600		200	1200		50
(High$)	4900		1300	1200		100

5.2 GRANULAR NEEDS ASSESSMENT TABLES

TABLE 3:
GRANULAR NEEDS ASSESSMENT
LAKE HARBOUR CAPITAL PROJECTS ESTIMATED MATERIAL REQUIREMENTS
SUMMARY
(Volumes in cubic metres)

FISCAL YEAR	EMBANKMENT	SUBBASE	BASE	SURFACING MATERIAL	CONCRETE AGG.	RIPRAP	ANNUAL TOTAL
1990 - 1991	2,600	1,560	1,800	1,800			7,760
1991 - 1992	2,000	360	1,160	1,700			5,220
1992 - 1993	2,364	3,600	3,100	2,500	200	36	11,800
1993 - 1994	9,600	12,400	8,800	14,200	200	75	45,275
1994 - 1995	5,200	855	2,005	2,845			10,905
1995 - 1999	7,727	4,050	4,150	9,476	10	50	25,463
1999 - 2009	10,470	9,100	7,675	5,610	150	15	33,020
20-YEAR TOTAL	**39,961**	**31,925**	**28,690**	**38,131**	**560**	**176**	**139,443**

TABLE 4:
GRANULAR NEEDS ASSESSMENT
LAKE HARBOUR CAPITAL PROJECTS ESTIMATED MATERIAL REQUIREMENTS
1990 - 1991
(Volumes in cubic metres)

PROJECT	EMBANKMENT	SUBBASE	BASE	SURFACING MATERIAL	CONCRETE AGG.	RIPRAP
MACA						
Warehouse		900	450	300		
Small Gymnasium		300	100	200		
Reduce Grade	600		100	600		
Residential Subdivision		360	150	200		
Sewage Pond	2,000		1,000	500		
TOTAL REQUIREMENTS	**2,600**	**1,560**	**1,800**	**1,800**		

TABLE 5:
GRANULAR NEEDS ASSESSMENT
LAKE HARBOUR CAPITAL PROJECTS ESTIMATED MATERIAL REQUIREMENTS
1991 - 1992
(Volumes in cubic metres)

PROJECT	EMBANKMENT	SUBBASE	BASE	SURFACING MATERIAL	CONCRETE AGG.	RIPRAP
MACA						
Residential Subdivision		360	160	200		
Water Supply Improvements	2,000		1,000	1,500		
TOTAL REQUIREMENTS	**2,000**	**360**	**1,160**	**1,700**		

TABLE 6:
GRANULAR NEEDS ASSESSMENT
LAKE HARBOUR CAPITAL PROJECTS ESTIMATED MATERIAL REQUIREMENTS
1992 - 1993
(Volumes in cubic metres)

PROJECT	EMBANKMENT	SUBBASE	BASE	SURFACING MATERIAL	CONCRETE AGG.	RIPRAP
MACA						
Residential Subdivision	1,764	3,000	2,000	2,500		36
EDUCATION						
New School		400	100		200	
ECONOMIC DEVELOPMENT						
Kimmirut Park / Super R	600	200	1,200			
TOTAL REQUIREMENTS	**2,364**	**3,600**	**3,300**	**2,500**	**200**	**36**

TABLE 7:
GRANULAR NEEDS ASSESSMENT
LAKE HARBOUR CAPITAL PROJECTS ESTIMATED MATERIAL REQUIREMENTS
1993 - 1994
(Volumes in cubic metres)

PROJECT	EMBANKMENT	SUBBASE	BASE	SURFACING MATERIAL	CONCRETE AGG.	RIPRAP
GOVERNMENT SERVICES						
Increase Fuel Capacities	4000		1500	4000		
MACA						
Residential Subdivision	5000	12,000	7,000	9,000		75
ECONOMIC/TOURISM						
Kimmirut Park / Super R	600		200	1,200		
EDUCATION						
New School		400	100		200	
TOTAL REQUIREMENTS	**9600**	**12,400**	**8,800**	**14,220**	**200**	**75**

TABLE 8:
GRANULAR NEEDS ASSESSMENT
LAKE HARBOUR CAPITAL PROJECTS ESTIMATED MATERIAL REQUIREMENTS
1994 - 1995
(Volumes in cubic metres)

PROJECT	EMBANKMENT	SUBBASE	BASE	SURFACING MATERIAL	CONCRETE AGG.	RIPRAP
MACA						
Medium Arena		675	225	200		
Residential Subdivision		180	80	100		
Sewage Disposal	4,000		1,500	1,000		
ECONOMIC/TOURISM						
Kimmirut Park / Super R	1,200		400	1,500		
TOTAL REQUIREMENTS	**5,200**	**855**	**2,005**	**2,845**		

TABLE 9:
GRANULAR NEEDS ASSESSMENT
LAKE HARBOUR CAPITAL PROJECTS ESTIMATED MATERIAL REQUIREMENTS
1995 - 1996
(Volumes in cubic metres)

PROJECT	EMBANKMENT	SUBBASE	BASE	SURFACING MATERIAL	CONCRETE AGG.	RIPRAP
MACA						
Medium Arena		675	225	200		
Residential Subdivision		3,125	641	1,500		
TOTAL REQUIREMENTS		**3,800**	**866**	**1,700**		

6. COST ESTIMATES

The following preliminary cost estimates outline the cost to supply the community of Lake Harbour with approximately 20,000 m^3 of granular material past the depletion of identified local sources.

6.1 Winter Load, Haul, and Stockpile

A preliminary cost estimate to winter haul and stockpile 20,000 m^3 of embankment and subbase material from the Soper Lake source (Site 5) is approximately **$609,350** or **$30.46 m^3**. This cost estimate is based on a round trip distance for haul of 15 kilometers, a loading factor of 0.89 between bank and loose measure, and the use of available community equipment.

6.2 Drill, Blast, and Stockpile

A preliminary cost estimate to drill and blast the soft rock ridges in the vicinity of Lake Harbour to produce 20,000 m^3 of all grades of granular material (six inch minus) is approximately **$483,800** or **$24.19 m^3**. The contractor would supply all labour, equipment, and material. The work would involve drilling and blasting the bedrock in a 6 ft. x 6 ft. x 10 ft. deep pattern (1.82m. x 1.82m. x 3m.). The local contractor would then muck and stockpile the spoil which is included in the unit price.

6.3 Cost Summary

The cost difference is considerable but another consideration is that the hauled material would still have to be processed to produce select material. This would increase the unit price by at least 25 percent.

A drill and blast operation would produce all grades of material immediately depending on the hole pattern and type of explosive used. A similar blast in 1986 created the present stockpile at Site 2 (Soper Lake) that is still used for surfacing and base material. A minimum amount of mucking will produce separate stockpiles for embankment and select grades on site and close to the community.

7. GRANULAR RESOURCE EVALUATION

7.1 Supply and Demand

As shown in Table 10, the total amount of granular material from all existing sources is approximately 19,000 m^3, of which 15,000 m^3 is considered embankment and subbase and 4,000 m^3 select. The select grades can be obtained directly from the Soper Lake source (Site 2) with little or no processing required. Embankment and subbase material can be obtained from Site 1 although compaction will be a problem as the material is mostly sand.

TABLE 10

AVAILABLE MATERIAL / EXISTING SOURCES

Existing Sources	Grades		Totals (m^3)
	Embankment/Subbase	Select	
Site 1	15,000		15,000
Site 2		4,000	4,000
Total cu. m.	**15,000**	**4,000**	**19,000**

Of a total ten year forecast demand of approximately 106,000 m^3 of granular material between 1990 and 1999 there is available approximately 19,000 m^3 of material within the vicinity of Lake Harbour for use in local capital projects.

Table 11 is a summary of the material requirements (from needs assessment tables) for all proposed capital projects from 1990 through 1999.

TABLE 11

MATERIAL REQUIREMENTS (m^3)

YEAR	EMBANKMENT/SUBBASE		SELECT	
	Increment	Cumulative	Increment	Cumulative
1990/91	4,160	4,160	3,600	3,600
1991/92	2,360	6,520	2,860	**6,460**
1992/93	5,964	12,484	5,936	12,396
1993/94	22,000	**34,484**	23,275	35,671
1994/95	5,200	39,684	5,705	41,376
1995/96	11,777	51,461	13,686	55,062

An examination of supply and demand will indicate that during the 1993/94 fiscal year, there will be a deficit of embankment and subbase material from existing sources. However, the table indicates that even before the present supply of embankment and subbase is depleted the community will deplete their present reserves of select grades before the end of 1991/92.

91/92 Select Grades(m^3)	93/94 Embankment/Subbase
4,000(existing) - **6,460**(required)	**15,000**(existing) - **34,484**(required)
= **-2,460**	= **-19,484**

It is obvious that even if the material needs for select are not 100 percent realized, there will exist a major deficit of select material by the beginning of the 92/93 fiscal year. The existing source of embankment and subbase (Site 1) will also be depleted during the 92/93 construction season. Future requirements of all grades of granular material beyond 92/93 will certainly have to be met by the development of potential sources. These sources will have to be adequate to provide for over 24,000 m^3 of embankment and subbase and 37,000 m^3 of select material between the years 1992 and 1995 just to satisfy the short term granular needs of the community, if the total material needs are 100 percent realized.

7.2 Land Development Study

The G.N.W.T. Five Year Capital Plan identifies the development of a residential subdivision, primarily during the 93/94 fiscal year. Six options for the expansion of the community were identified in the call for proposals (note Appendix 2 - from J. L. Richards & Associates Limited prepared for M.A.C.A.). It was recommended that the existing airfield be considered as the site for future residential development in the community and that a new airfield be constructed. Although the other options have been rejected, decisions on land development in the community have not been finalized.

The location of this subdivision and/or the construction of a new airport will strongly influence the development and management of granular resources in the community more so than any other capital project. The volume demand for all grades of granular material is extremely high for this project. For this reason, the land development study has been singled out for special attention. Site access and location of any potential granular source will be dependent on the direction of land development in the community. It is recommended that the development of any source related to the production of granular material be deferred until decisions related to the expansion of the community and/or the construction of a new airport are finalized.

7.3 Assessment

Development of identified potential sources will be required to satisfy the long term granular needs of the community. Unfortunately the study indicates that potential sources of 'pitrun' within the vicinity of Lake Harbour are limited in volume and quality. As well, identified sources lack the quantity and quality necessary for the cost-effective production of select grades.

The present study concludes that a 'drill and blast' quarry operation is necessary to produce and stockpile the required grades of granular material for use in local capital projects. A quarry operation similar to the 1986 'blast' can easily be implemented and confined to the soft rock ridges in the vicinity of the community.

Approximately 20,000 m^3 of material should be produced and stockpiled to satisfy the immediate needs of the community (note recommendations). A 'quarry blast' operation can then be continued on an as-needed basis.

The location of the quarry should be deferred until final decisions on land development are finalized. Obviously the location of a major quarry operation should coincide with the direction of community expansion. It should be noted that it may require two or more site locations to produce the required amount of material. Although the soft rock ridges are numerous, access roads to these ridges maybe required. The direction in which the community is expanding will become an important factor in determining the location of a quarry. Present information indicates that quarry operations should be confined to an area west and north of the community dump and Site 1.

Finally, an assessment of a winter haul from the Soper Lake delta area should be mentioned. First, the status of the area as a proposed Territorial Park must be clarified. Second, the 15 - 16 kilometer return haul distance and lack of equipment in the community will result in higher unit prices. Third, a 'drill and blast' operation will be necessary, as opposed to 'stripping', as the source is permanently frozen; the thawed layer was less than 1.0 meters thick even in August. Finally, the excavated material will still have to be processed to produce select grades. For these reasons, this source is not attractive (see also Section 6).

8. RECOMMENDATIONS

It is recommended that, as soon as possible, the Hamlet of Lake Harbour, implement a Granular Source Management Plan based on this report and modified as is appropriate by legitimate local concerns that are beyond the scope of this report. Also, not all capital projects will be 100 percent realized so any plan must be flexible to changing granular needs and fiscal restraints.

The specific technical recommendations of this report are:

1. Continue to use the existing sources until depletion which is expected to be in 1991/92 for select grades and 1992/93 for embankment and subbase.

2. Develop a 'drill and blast' quarry operation during the 1992/93 fiscal year to produce approximately 20,000 m^3 of all grades of granular material. A quarry location should be localized and restricted to the soft rock (limestone) ridges that surround the community.

3. Once a stockpile of material has been established, a quarrying operation should be continued on an as-and-when needed basis to supply the long term granular needs of the community for embankment and select grades of material.

4. The need for large volumes of granular material during 1993/94 (note Table 11) is directly attributed to future land development decisions as to the direction of community expansion and the proposed construction of a new airport. Final decisions were not available for consideration at the completion of this report. The location of a major quarry operation should coincide with future decisions on the direction of residential land development within the community.

5. Since the requirements beyond 1995/96 are uncertain, review and reconsider source potential and requirements in 1994/95.

REFERENCES

Annual Book of Standards, American Society for Testing and Materials,(ASTM), various rock and foundation tests and standards.

Department of Indian and Northern Affairs, 1988, Plan for the Reservation and Development of Granular Materials in the vicinity of Inuvik, N.W.T., CE00992T. Prepared by Hardy BBT Limited.

Department of Indian and Northern Affairs, 1982, Environmental Guidelines Pits and Quarries.

Department of Energy, Mines and Resources, 1970, Geology and Economic Minerals of Canada, Ottawa, Canada.

Department of Public Works and Highways, 1987, Lake Harbour Granular Study, Yellowknife.

Department of Public Works, G.N.W.T., Soil Classification System, Yellowknife.

Embleton and King, 1971, Glacial and Periglacial Geomorphology, London.

Krynine and Judd, 1957, Principles of Engineering Geology and Geotechnics, McGraw-Hill Civil Engineering Series, Toronto.

J. L. Richards & Associates Limited, 1989, Lake Harbour Future Land Development Study, for M.A.C.A., Yellowknife, N.W.T.

Nasa, Jet Propulsion Laboratory, 1986, Imaging Radar-C Science Plan, Pasadena.

GLOSSARY OF TERMS

Active layer:	the layer of ground in permafrost which thaws each summer and refreezes each fall.
Alluvial fan:	fan shaped mass of alluvial deposits shed by fluvial activity from mountain streams.
AASHTO:	American Association of State Highways and Transportation Officials, used almost exclusively by the several state Departments of Transportation and the Federal Highway Administration in earthwork specifications for transportation lines.
Colluvial sediments:	sediments transported and deposited through the process of mass wasting (i.e. by gravity).
Continuous permafrost zone:	an area underlain by permanently frozen subsoil.
Deltaic deposits:	deposition of sediments by rivers in low energy environments, characterized by well-developed cross-bedding and sands, silts and clays.
Detritus:	the accumulation of non-stratified rock fragments through the weathering of large rock outcrops in situ.
Environment of deposition:	the lithology, composition, and diversity of all granular deposits are directly related to part and modern depositional and erosional environments.
Eskers:	a long narrow, winding ridge composed of stratified accumulations of sand and gravel produced from subglacial streams; eskers are aligned with the flow of retreating glaciers or ice sheets.

Frost Susceptible Soil:	soil in which significant ice-segregation will occur, resulting in frost heave, or heaving pressures, when requisite and freezing conditions exist.
Frost wedging:	water expanding as it freezes widens crevices in well-bedded or well-jointed rock and shatters it.
Glacial Till:	unstratified glacial drift deposited directly by the ice.
Ground-truth reconnaissance:	the physical act of acquiring data on the ground to prove geological assumptions.
In-situ:	the natural undisturbed soil or strata of weathered material in place.
Isostatic Rebound:	the upward movement of the earth's crust to achieve a general equilibrium as the great weight of the continental ice sheets decrease.
Kame Terrace:	a steep-side, constructional terrace consisting of stratified sand and gravel formed as a glacio-fluvial deposit between a melting glacier or a stagnant ice lobe and a higher valley wall or lateral moraine.
Lacrustine deposits:	silts and clays deposited in lake water and later exposed either by the lowering of the water level or by the elevation of the land.
Mass Movement:	surface movements of earth materials caused primarily by gravity; known also as Mass Wasting.
Mechanical weathering:	relates to the physical breakdown of rocks, at or near the earth's surface, by external processes (such as wind and water).

Metamorphism:	extensive change of rocks or mineral due to great changes in temperature, pressure, and chemical environment.
Outwash Plan:	a broad, gently sloping sheet of outwash deposited by melt water streams flowing in front of or beyond a glacier.
Oversize Material:	this refers to rock particle size as gravel particles larger than 75 mm (3") in diameter are usually considered to be too large to be used for most geotechnical uses.
Periglacial environment:	depositional and erosional environments modified by cold climates (subglacial).
Permafrost:	the thermal condition in soil or rock where temperatures below 0° C persist over at least two consecutive winters and the intervening summer.
Permafrost Table:	the interface between the active layer and permafrost zone.
Raised beaches:	beaches formed during times of high water level and then stranded by the lowering of the water level or by the elevation of the land.
Regolith:	unconsolidated mantle of weathered rock and soil material on the earth's surface.
Solifluction:	in subarctic regions, fine rock fragments when saturated with water, spread slowly down slope and along valley floors.
Syncline:	a trough or downfold in the rocks.

Talus slope:	the accumulation of small fragments (scree) in the millimeter-to-meter range from cliffs or steep walls that maintain a uniform slope (commonly about 30°) as it grows.
Territory Land Use Regulations:	provides regulatory control for maintaining sound environmental practice for any land use activity on all lands under Federal control in the territories.
USC:	United Soil Classification System, used for foundation engineering such as dams, buildings, road earthwork specifications, and airfield design.
Varved sediments:	distinct band representing the annual deposit in sedimentary materials.

APPENDIX 1

Geotechnical Data 1989

Laboratory Test Results
Grain Size Curves
Cross Sections

Northwest Territories Public Works

SAMPLE DATA SHEET

PROJECT	LAKE HARBOUR GRANULAR INVESTIGATION	PROJECT NUMBER	89-9170-801

PART 1 - COMPLETED IN THE FIELD

SAMPLE IDENTIFICATION	LH-01-FC	METHOD OF SAMPLING	Shovel
LOCATION	Site '1' - existing borrow source		
TEST HOLE NUMBER	LH-01	DEPTH	1.7 meters — no permafrost
FIELD DESCRIPTION	Sample extracted from middle of large sand pit - Site '1'		
LAB TESTS REQUIRED	visual / wash sieve / AASHTO / U.S.C.		
SAMPLED BY		DATE D/M/Y	25/08/89
SAMPLE DISCARDED		RETAINED	

PART 2 - COMPLETED IN THE LABORATORY

DATE RECEIVED		RECEIVED BY	
REQUESTED COMPLETION DATE D/M/Y		RESULTS SUBMITTED TO	E.B.A. ENGINEERING

PART 3 - LABORATORY TEST RESULTS AND COMMENTS

Visual Description

Reddish Coarse Sand, Well drained, Well graded, 5 - 8% 'fines'.

Wash Sieve

Gravel	>	16%
Sand	>	77%
Silt	>	7%

U.S.C. = SW

AASHTO = M145 - 82 is A - 1 - a (ô)

(a well graded sand with a non-plastic soil binder)

COMPILED BY	EBA Consultants	DATE D/M/Y	29/09/89
REVIEWED BY	Fred Collins	DATE D/M/Y	
ATTACHMENTS		PAGES	

NWT 2601/0886

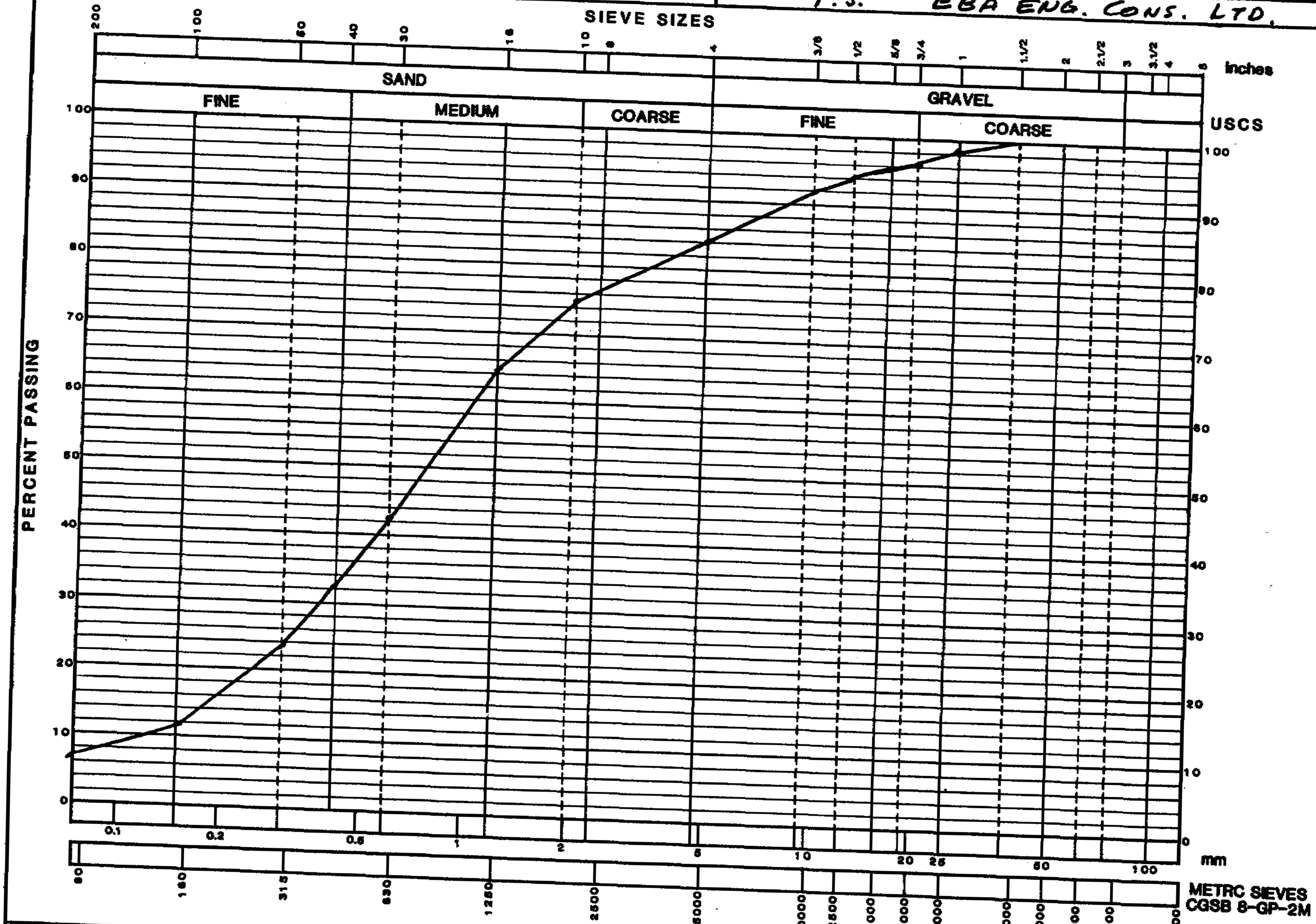
Northwest Territories Canada

LAKE HARBOUR

GRAIN SIZE CURVES

SAMPLE IDENTIFICATION: LH-01-FC

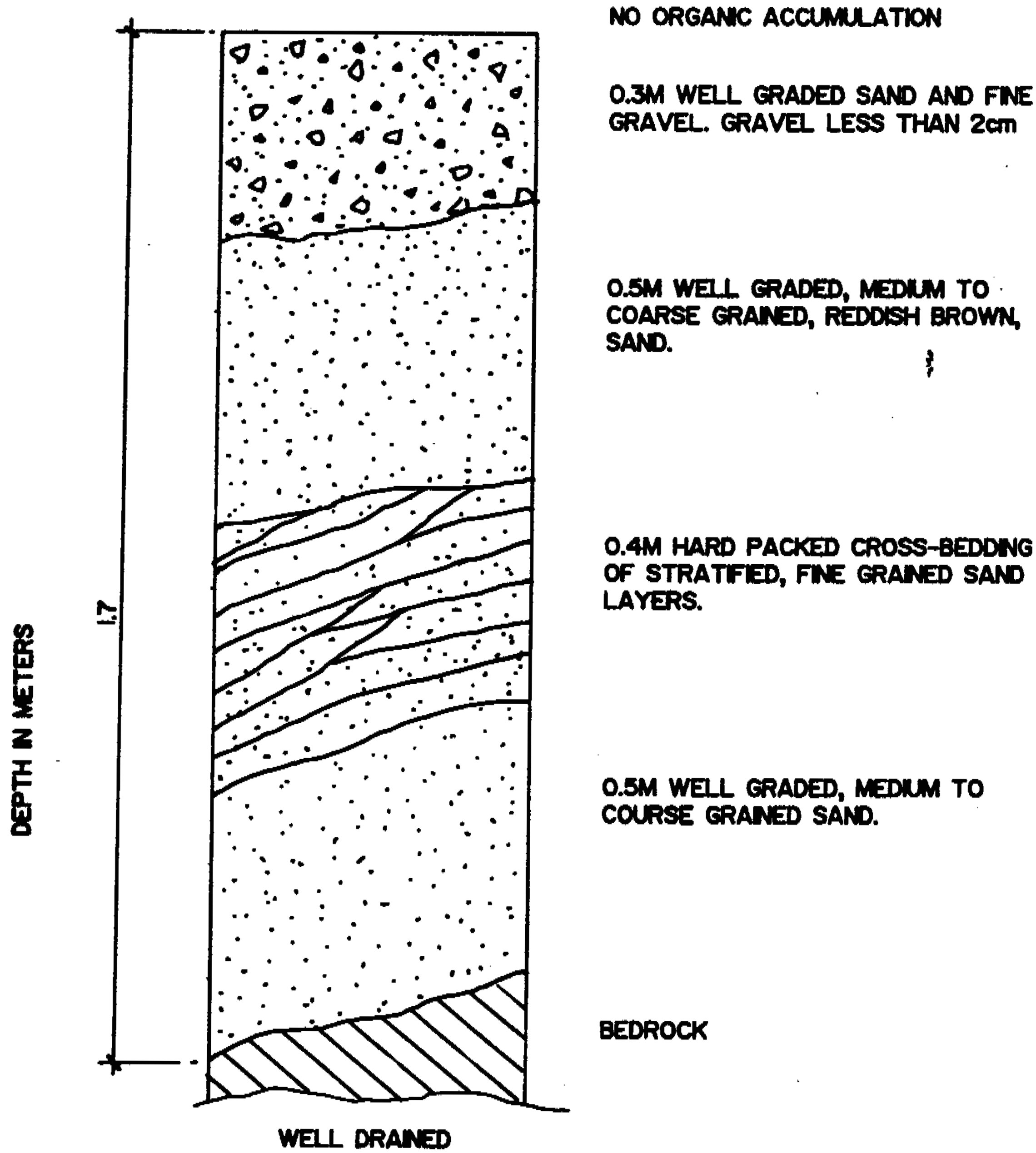
TESTED BY: T.J. EBA ENG. CONS. LTD.



D_{10}	D_{30}	D_{60}	C_u	C_c
0.12	0.39	1.02	8.8	1.3

TED-101/01 88;IJ

TEST HOLE PROFILE LH-01



Northwest Territories Public Works

Checked by		COMMUNITY PROGRAMS SECTION ENGINEERING DIVISION
Approved by		
REVISIONS		LAKE HARBOUR SITE I SAMPLE LH-01 CROSS SECTION
Date	By	

Drawn by	Date	Scale	Dwg. No.
BR	JAN/90	N.T.S.	

Northwest Territories Public Works

SAMPLE DATA SHEET

PROJECT LAKE HARBOUR GRANULAR INVESTIGATION	PROJECT NUMBER 89-9170-801

PART 1 - COMPLETED IN THE FIELD

SAMPLE IDENTIFICATION LH-02-FC	METHOD OF SAMPLING Shovel	
LOCATION Ridge S.E. of sand pit - refer to site '4'		
TEST HOLE NUMBER LH - 02	DEPTH 1.0 meters	dry / no permafrost
FIELD DESCRIPTION Layers of weathered material "in situ" on large ridge.		
LAB TESTS REQUIRED Visual/W.S.A.		
SAMPLED BY	DATE D/M/Y 28/08/09	SAMPLE DISCARDED RETAINED

PART 2 - COMPLETED IN THE LABORATORY

DATE RECEIVED	RECEIVED BY
REQUESTED COMPLETION DATE D/M/Y	RESULTS SUBMITTED TO EBA Consultants

PART 3 - LABORATORY TEST RESULTS AND COMMENTS

Visual Description

Light grey gravels with a high percentage of 'fines'.
Angular, weathered, fragile, non-durable.
Poorly graded.

Wash Sieve Analysis

Gravel	>	36%
Sand	>	59%
Silt	>	5%

U.S.C.

SP

COMPILED BY EBA Consultants	DATE D/M/Y 29/09/89	
REVIEWED BY Fred Collins	DATE D/M/Y	ATTACHMENTS ______ PAGES

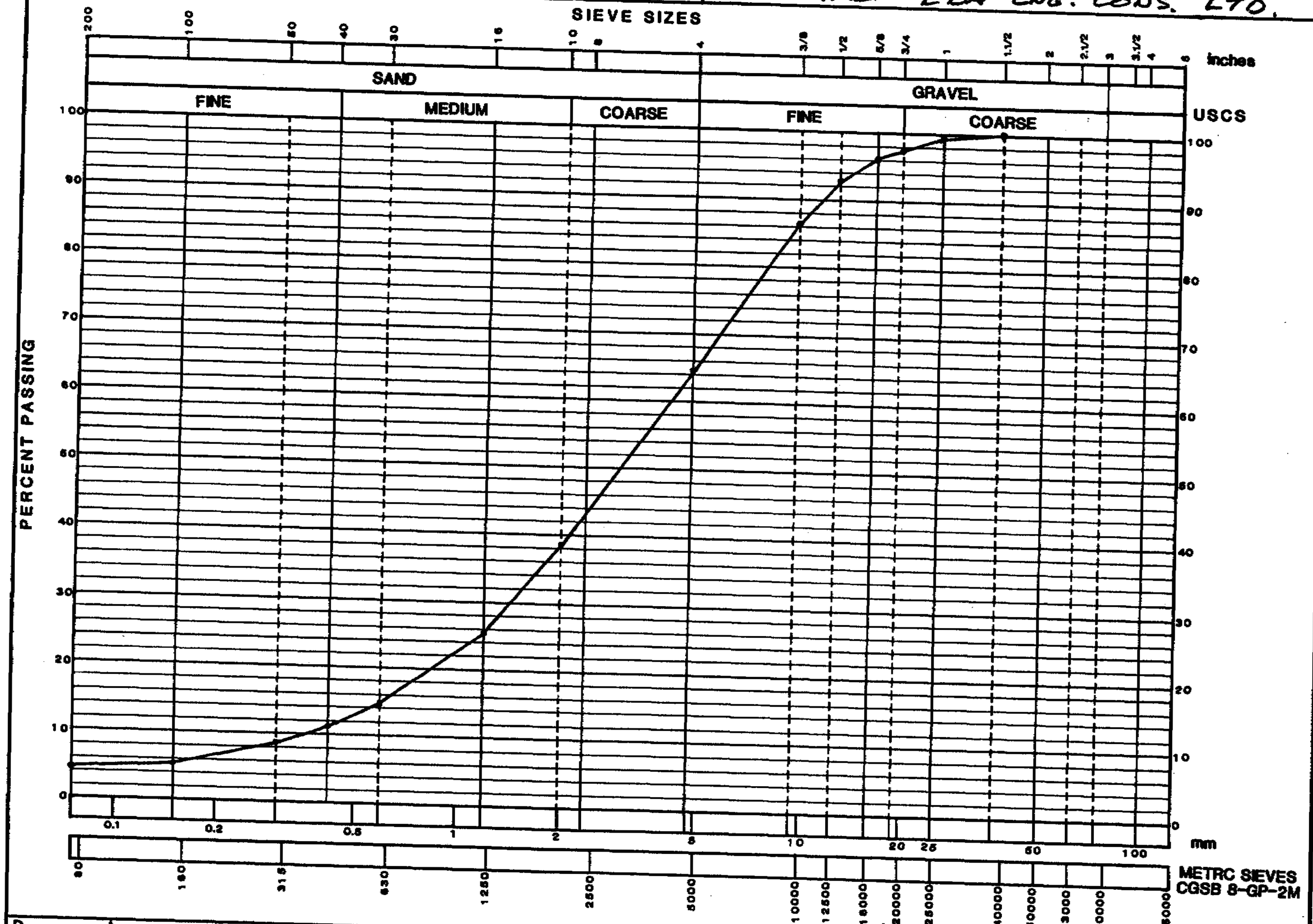
NWT 2601/0886

F-0486 - 016

Northwest Territories Canada LAKE HARBOUR

GRAIN SIZE CURVES

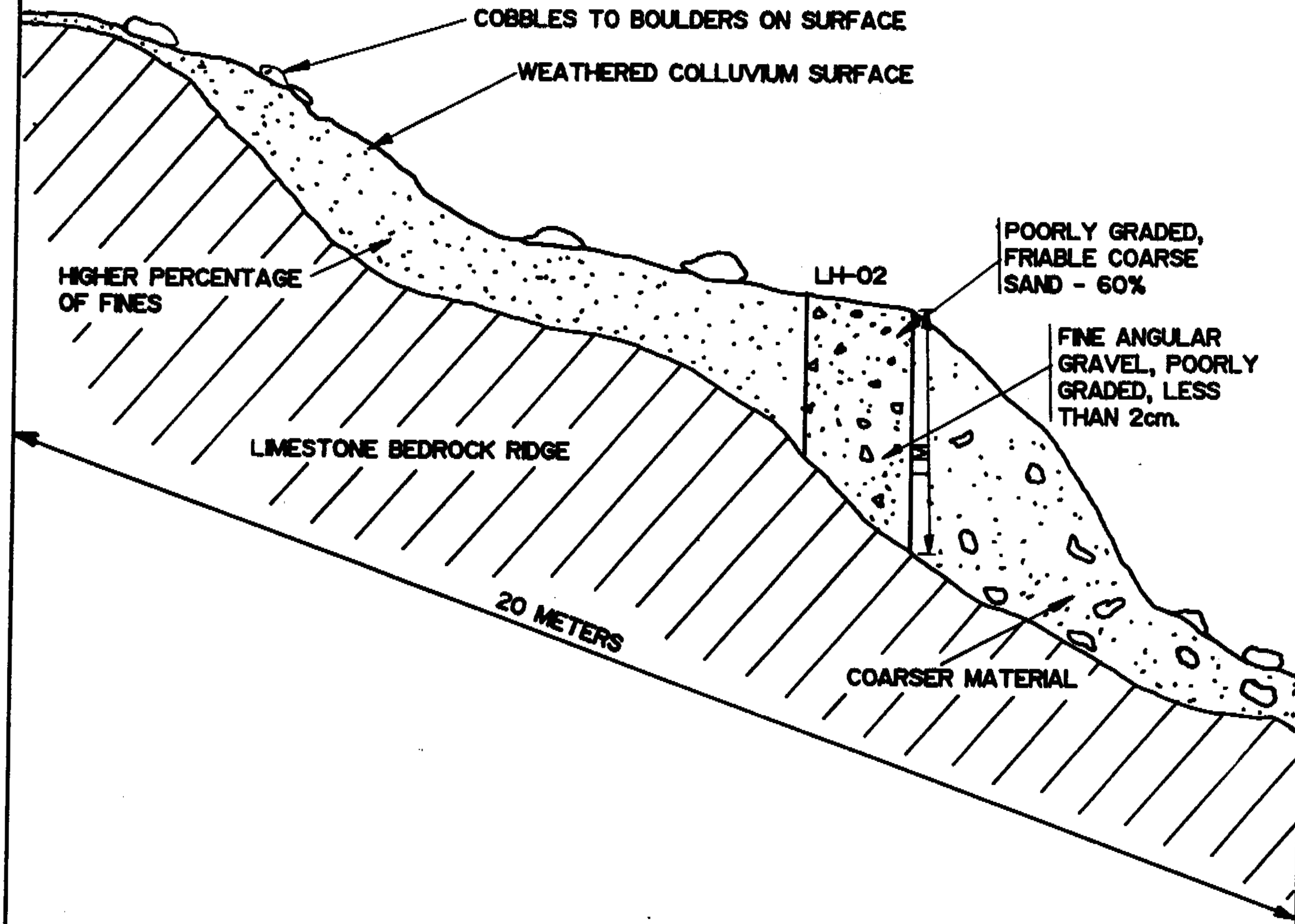
SAMPLE IDENTIFICATION	LH - 02 - FC	TESTED BY	WRB. EBA ENG. CONS. LTD.



D_{10} 0.4 mm	D_{30} 1.5mm	D_{60} 4 mm	C_u 10.0	C_c 1.4

TED-1 01/01 88;U

TEST HOLE PROFILE LH-02



Northwest Territories Public Works	Checked by	COMMUNITY PROGRAMS SECTION ENGINEERING DIVISION
	Approved by	
	REVISIONS	LAKE HARBOUR SITE 4 REPRESENTATIVE CROSS SECTION
	Date / By	
		Drawn by BR · Date JAN/90 · Scale N.T.S. · Dwg. No.

Northwest Territories Public Works

SAMPLE DATA SHEET

PROJECT	LAKE HARBOUR GRANULAR	PROJECT NUMBER	89-9170-801

PART 1 - COMPLETED IN THE FIELD

SAMPLE IDENTIFICATION	LH-03-FC	METHOD OF SAMPLING	Shovel
LOCATION	Soper Lake Source - Site '2'		
TEST HOLE NUMBER	LH-03	DEPTH	1.2 meters — permafrost at 1.2m
FIELD DESCRIPTION	North end of Site '2' - fine sand gravel mixture of quartzite and sand		
LAB TESTS REQUIRED	visual/ wash sieve/ U.S.C./ AASHTO		
SAMPLED BY	DATE D/M/Y 27/08/89	SAMPLE DISCARDED	RETAINED

PART 2 - COMPLETED IN THE LABORATORY

DATE RECEIVED		RECEIVED BY	
REQUESTED COMPLETION DATE D/M/Y		RESULTS SUBMITTED TO	E.B.A. Consultants

PART 3 - LABORATORY TEST RESULTS AND COMMENTS

Visual Description

Light brown and grey, angular, friable,
fragile, coarse gravels to pebbles.

Wash Sieve Analysis

Gravel	>	49%
Sand	>	44%
Silt	>	7%

U.S.C.

GP - SP, non-plastic

AASHTO

M145 - 82/A - 1 - a (o)

COMPILED BY	E.B.A. Consultants	DATE D/M/Y	29/09/89		
REVIEWED BY	Fred Collins	DATE D/M/Y		ATTACHMENTS ______	PAGES

NWT 2601/0686

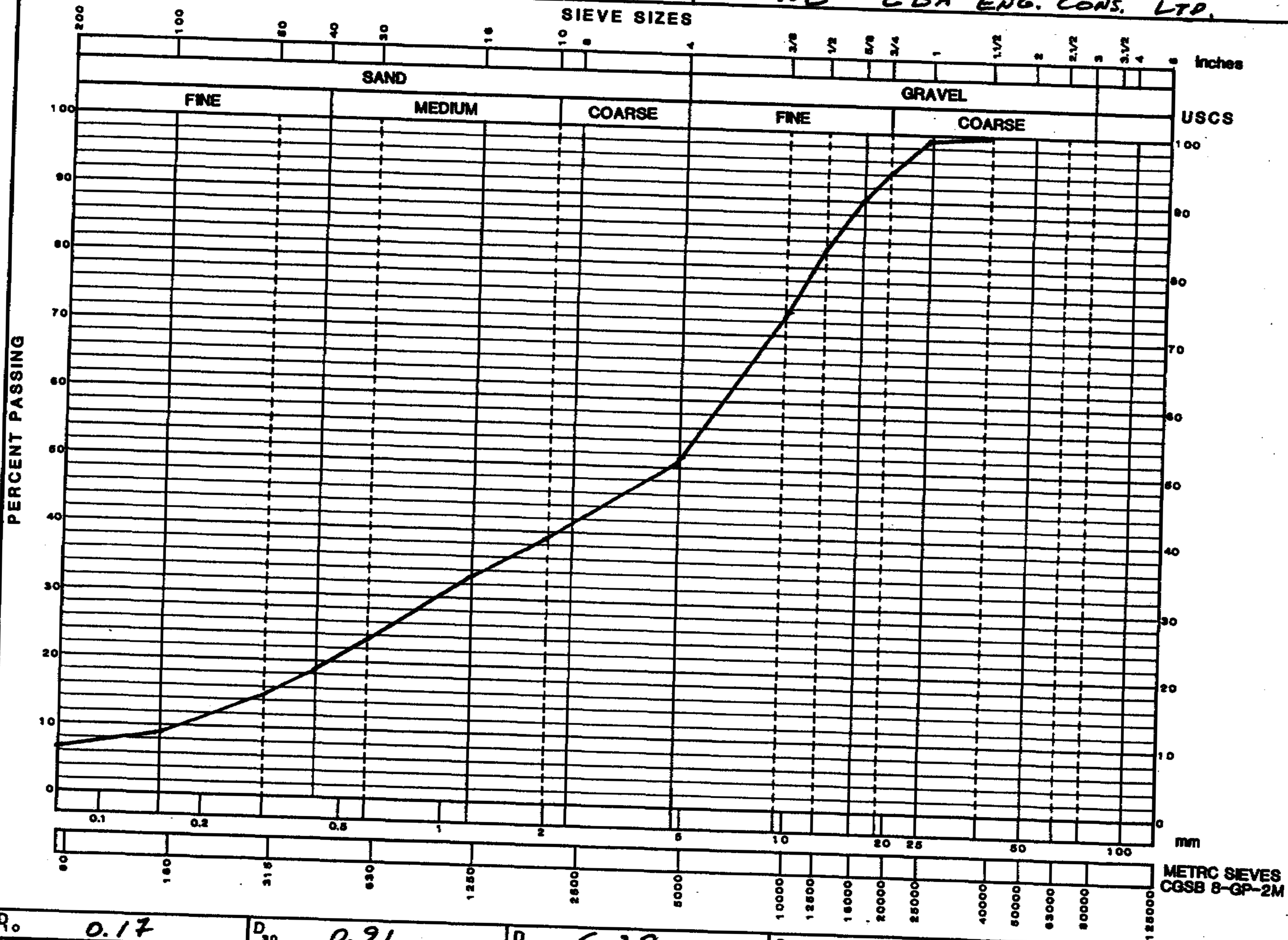
F-0486-0

Northwest Territories Canada LAKE HARBOUR

GRAIN SIZE CURVES

SAMPLE IDENTIFICATION LH-03-FC

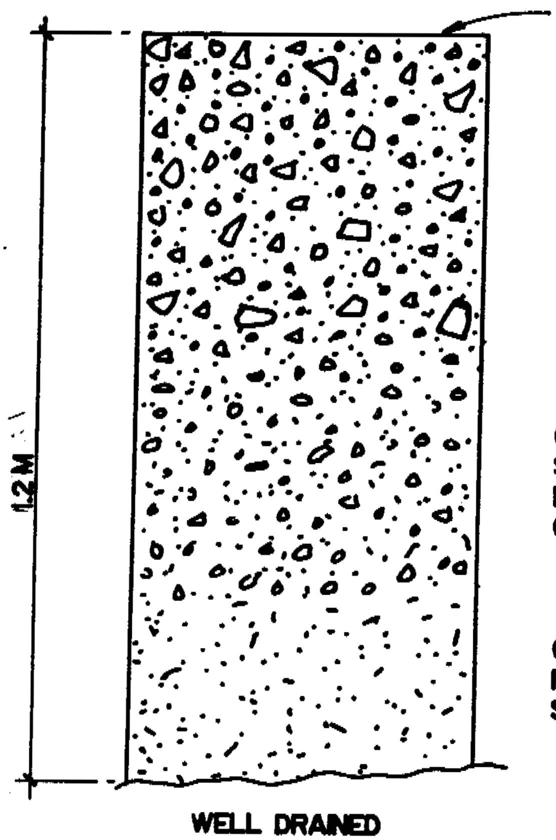
TESTED BY WB EBA ENG. CONS. LTD.



D_{10} 0.17	D_{30} 0.91	D_{60} 6.29	C_u 37.2	C_c 0.8

TED-1 01/01 88;IJ

TEST HOLE PROFILE LH-03



0.5M COARSE GRAVELS AND PEBBLES, LESS THAN 3cm, ANGULAR TO SUBROUNDED, CRYSTALLINE, FRIABLE, NON-STRATIFIED.

0.4M GRAVEL AND COARSE SAND, GRAVEL LESS THAN 1cm, SUBROUNDED, WELL GRADED, NON-STRATIFIED.

0.3M COARSE SAND WITH 'FINES', POORLY GRADED, NON-STRATIFIED.

Northwest Territories Public Works	Checked by	COMMUNITY PROGRAMS SECTION ENGINEERING DIVISION
	Approved by	
	REVISIONS	LAKE HARBOUR SITE 2 SAMPLE LH-03 CROSS SECTION
	Date / By	
		Drawn by BR / Date JAN/90 / Scale N.T.S. / Dwg. No.

Northwest Territories Public Works

SAMPLE DATA SHEET

PROJECT: LAKE HARBOUR INVESTIGATION	PROJECT NUMBER: 89-9170-801

PART 1 - COMPLETED IN THE FIELD

SAMPLE IDENTIFICATION: LH-04-FC	METHOD OF SAMPLING: Shovel

LOCATION: Sand/gravel stockpile at Soper Lake - Site '2'

TEST HOLE NUMBER: LH - 04	DEPTH: stockpile site	

FIELD DESCRIPTION: South end of Site '2' at old blast site of 1986.

LAB TESTS REQUIRED: Visual/Wash Siee Analysis/L.A. Abrasion

SAMPLED BY	DATE D/M/Y 28/08/09	SAMPLE DISCARDED	RETAINED

PART 2 - COMPLETED IN THE LABORATORY

DATE RECEIVED	RECEIVED BY
REQUESTED COMPLETION DATE D/M/Y	RESULTS SUBMITTED TO EBA Consultants

PART 3 - LABORATORY TEST RESULTS AND COMMENTS

Visual Description

Light brown and weathered, clean, angular, maximum size 40 mm.
Poorly graded and coarse.

Wash Sieve Analysis

Gravel	>	72%
Sand	>	24%
Silt	>	4%

U.S.C.

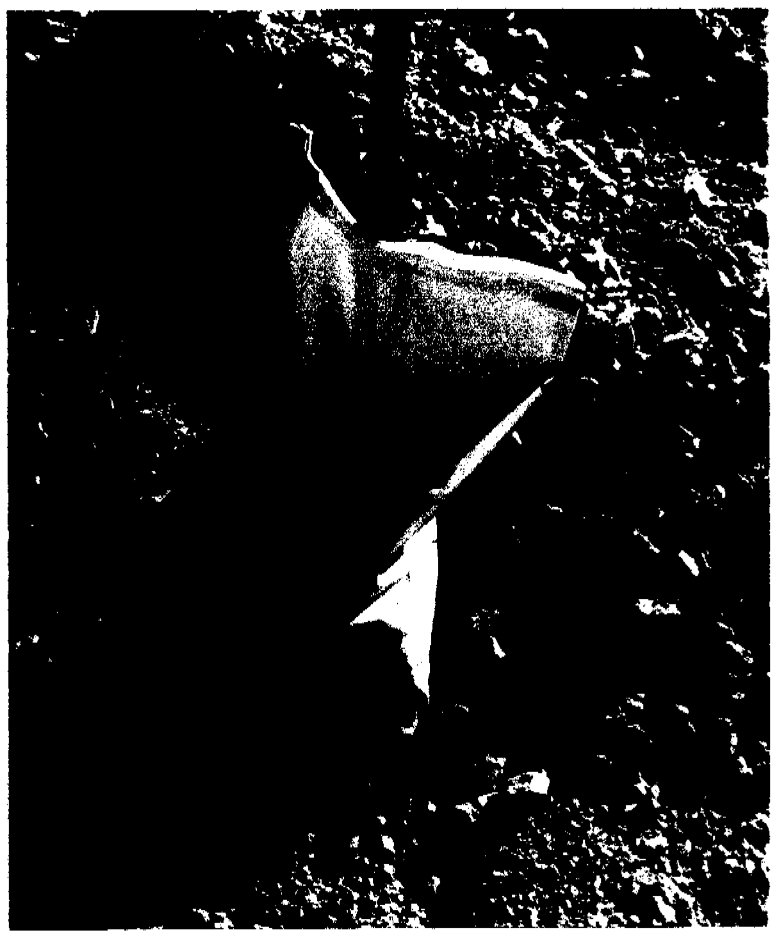
G.P.

AASHTO

A - 1 - a

L.A. Abrasion

% wear = 97%



COMPILED BY		DATE D/M/Y	
REVIEWED BY	DATE D/M/Y	ATTACHMENTS ______ PAGES	

NWT 2601/0886

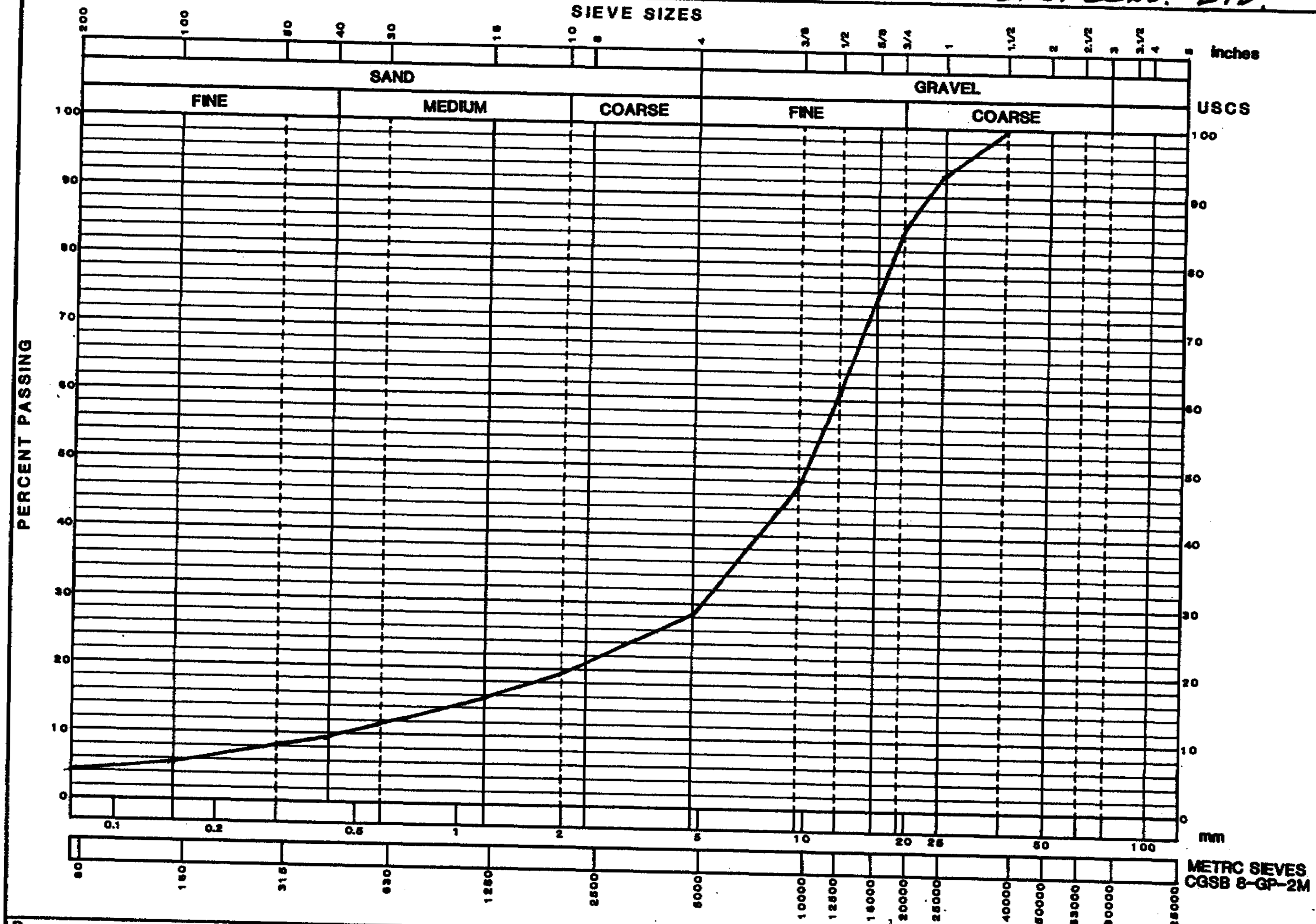
F-0486 - 0

Northwest Territories Canada

LAKE HARBOUR

GRAIN SIZE CURVES

SAMPLE IDENTIFICATION	TESTED BY
LH-04-FC	WB EBA ENG. CONS. LTD.



D_{10} 0.44	D_{30} 5.02	D_{60} 12.16	C_u 27.5	C_c 4.7

TED-1 01/01 88;IJ

Northwest Territories Public Works

SAMPLE DATA SHEET

PROJECT: LAKE HARBOUR GRANULAR INVESTIGATION	PROJECT NUMBER: 89-9170-801

PART 1 - COMPLETED IN THE FIELD

SAMPLE IDENTIFICATION: LH-05-FC	METHOD OF SAMPLING: Shovel	
LOCATION: Site '1' - existing borrow source		
TEST HOLE NUMBER: LH-05	DEPTH: 1.8 meters	no permafrost
FIELD DESCRIPTION: Sample dug from test pit in large stockpile.		
LAB TESTS REQUIRED: Visual / Wash Sieve / AASHTO / U.S.C.		
SAMPLED BY: F. Collins	DATE D/M/Y: 25/08/89	~~SAMPLE DISCARDED~~ RETAINED

PART 2 - COMPLETED IN THE LABORATORY

DATE RECEIVED	RECEIVED BY
REQUESTED COMPLETION DATE D/M/Y	RESULTS SUBMITTED TO: Thurber Consultants

PART 3 - LABORATORY TEST RESULTS AND COMMENTS

Visual Description

Reddish brown sandy gravel with angular aggregates (sandstone) and little or no 'fines'.

Wash Sieve Analysis

Gravel	>	11%
Sand	>	83%
Silt	>	6%

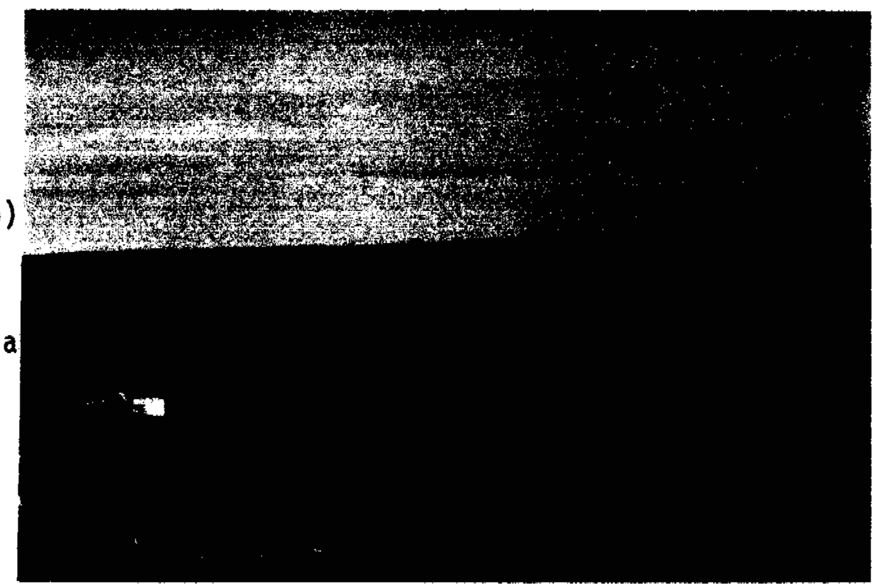
U.S.C.

SP

AASHTO

M145 - 82 is A - 1 - a (o)

(a poorly graded sand with a non-plastic soil binder).



COMPILED BY: Thurber Consultants	DATE D/M/Y: 29/09/89	
REVIEWED BY: Fred Collins	DATE D/M/Y	ATTACHMENTS ______ PAGES

NWT 2001/0886

F-0486-C

Northwest Territories Public Works

SAMPLE DATA SHEET

PROJECT LAKE HARBOUR GRANULAR INVESTIGATION	PROJECT NUMBER 89-9170-801

PART 1 – COMPLETED IN THE FIELD

SAMPLE IDENTIFICATION LH-06-FC	METHOD OF SAMPLING Hand Shovel

LOCATION Soper Lake Delta NE of Soper Lake - Site '5'

TEST HOLE NUMBER LH-06	DEPTH 1.1 meters	no permafrost

FIELD DESCRIPTION Delta area of Soper River NE of community, wet, coarse, sands and gravels

LAB TESTS REQUIRED Visual, W.S.A., L.A. Abrasion

SAMPLED BY	DATE D/M/Y 27/08/89	SAMPLE DISCARDED	RETAINED

PART 2 – COMPLETED IN THE LABORATORY

DATE RECEIVED	RECEIVED BY
REQUESTED COMPLETION DATE D/M/Y	RESULTS SUBMITTED TO Thurber Consultants

PART 3 – LABORATORY TEST RESULTS AND COMMENTS

Visual Description

Light brown-yellow and grey gravels with angular aggregates. Material is a mixture of quartz, pyrite, and carbonates.

> 90% are flat visually

Wash Sieve Analysis

Gravel	>	53%
Sand	>	44%
Silt	>	3%

U.S.C.

G.W.

AASHTO

M145 - 82 / A - 1 - a (o) - a
Well graded mixture of stone fragments and gravel and coarse sand

L. A. Abrasion

% wear by abrasion = 97%

COMPILED BY Thurber Consultants	DATE D/M/Y 29/09/89	
REVIEWED BY Fred Collins	DATE D/M/Y	ATTACHMENTS ____ PAGES

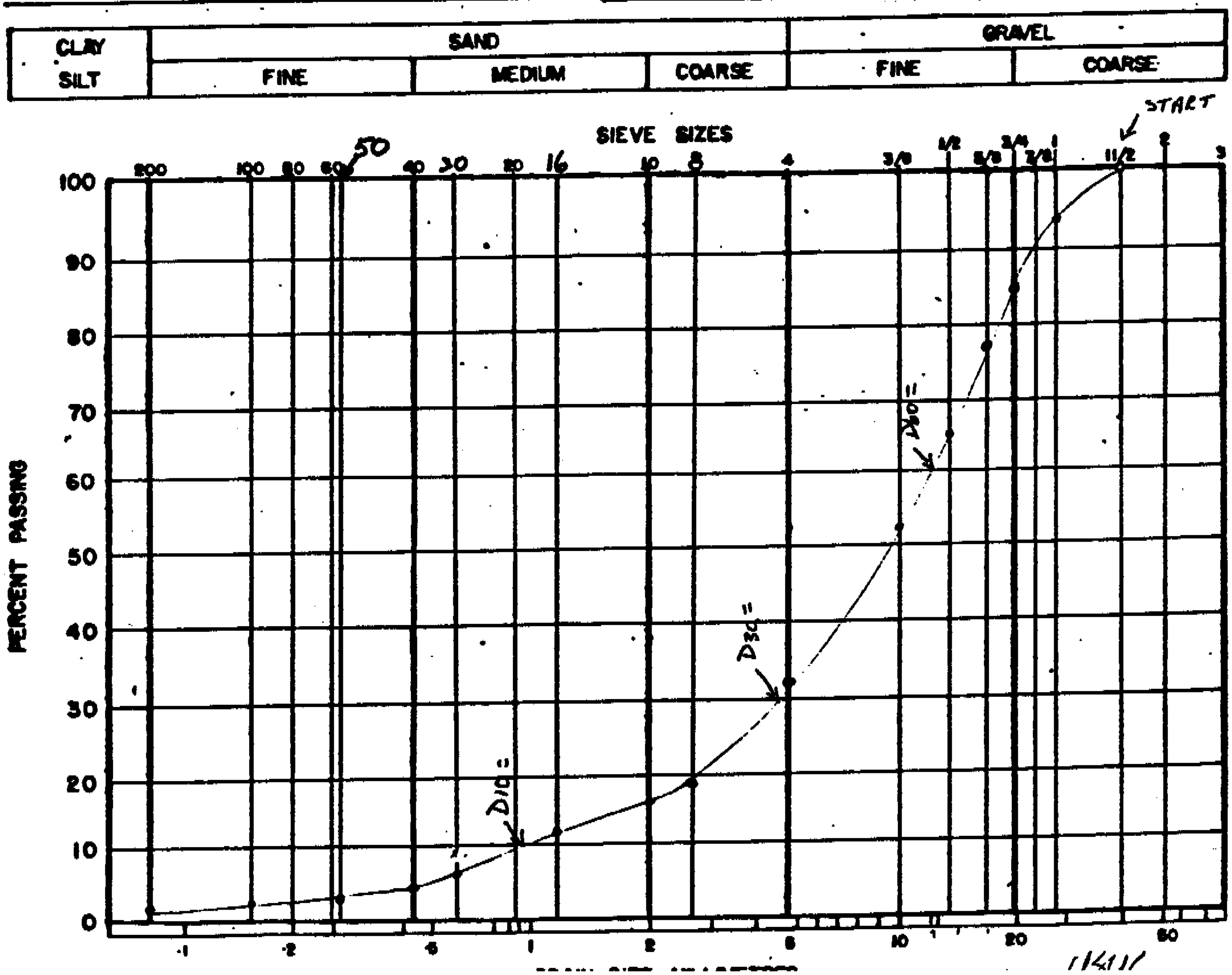
NWT 2601/0686

Northwest Territories Public Works
Design and Construction

GRAIN SIZE ANALYSIS

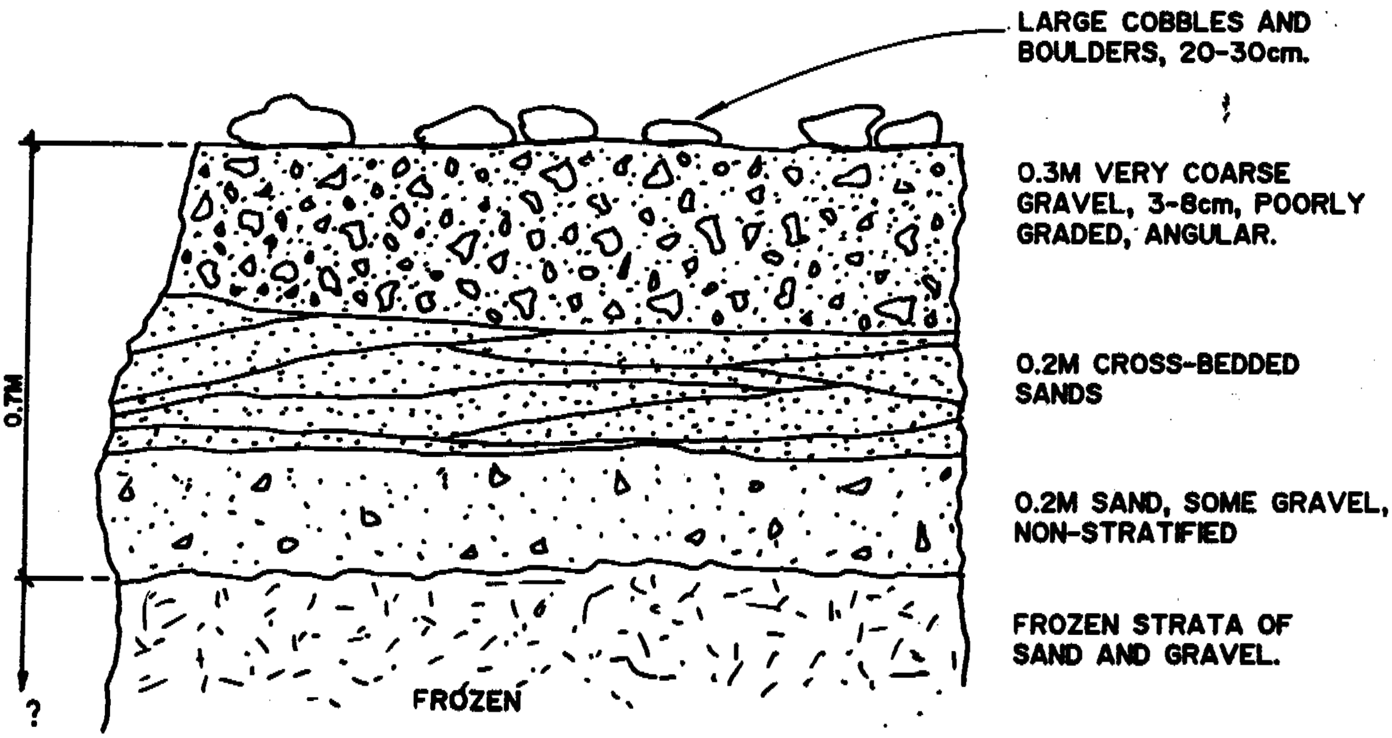
Project: Lake Harbour, 89-9120
Lab. Sample No.: LH-06-FC
Sample Description: U.S.C. is GW
AASHTO M145-82 is A-1-a(a)
Comments: WSA
D_{10} = 0.98
D_{30} = 4.9
D_{60} = 12.5
Cu = 12.75
Cc = 1.96
According to AASHTO
T27-82

SIEVE SIZES U.S. Standard	SIEVE SIZES Metric (mm)	% Retained Per Sieve	% Passing
1½"			100
1"		6	94
¾"		9	85
5/8"		7	78
½"		14	64
3/8"		12	52
NO. 4		20	32
NO. 8		13	19
NO. 10		2	17
NO. 16		6	11
No. 30		4	7
No. 40		2	5
No. 50		1	4
No.100	0.150	1	3
No.200	0.075	0	3



11411

SOPER RIVER EMBANKMENT PROFILE



Northwest Territories Public Works	Checked by	COMMUNITY PROGRAMS SECTION ENGINEERING DIVISION
	Approved by	
	REVISIONS — Date / By	LAKE HARBOUR SITE 5 REPRESENTATIVE CROSS SECTION
		Drawn by BR / Date JAN/90 / Scale N.T.S. / Dwg. No.

Northwest Territories Public Works

SAMPLE DATA SHEET

PROJECT LAKE HARBOUR GRANULAR INVESTIGATION	PROJECT NUMBER 89-9170-801

PART 1 - COMPLETED IN THE FIELD

SAMPLE IDENTIFICATION LH-07-FC	METHOD OF SAMPLING Shovel	
LOCATION Valley Bottom Material - middle of Site '3'.		
TEST HOLE NUMBER LH-07-FC	DEPTH .8 meters	permafrost encountered
FIELD DESCRIPTION Ice crystals / very wet, silty, fine grained material.		
LAB TESTS REQUIRED Visual, moisture, Attenberg, W.S.A.		
SAMPLED BY	DATE D/M/Y 27/08/09	SAMPLE DISCARDED RETAINED

PART 2 - COMPLETED IN THE LABORATORY

DATE RECEIVED	RECEIVED BY
REQUESTED COMPLETION DATE D/M/Y	RESULTS SUBMITTED TO Thurber Consultants

PART 3 - LABORATORY TEST RESULTS AND COMMENTS

. Visual Description

Dark grey silt with flat aggregates. Material contains traces of quartz, mica, galena, and organics. Maximum particle size 2cm.

Moisture Content

8.7%

Attenberg

N/A - silt

Wash Sieve Analysis

Very difficult to obtain,
gravel/sand does not exceed 10%.
U.S.C. - SM

AASHTO

A·2·4(o) - granular material
35% or less passing #200 sieve.

COMPILED BY Thurber Consultants	DATE D/M/Y 30/09/89	
REVIEWED BY Fred Collins	DATE D/M/Y	ATTACHMENTS ______ PAGES

NWT 2001/0865

F-0486-(

Northwest Territories Public Works
Design and Construction

GRAIN SIZE ANALYSIS

Project: LAKE HARBOUR, 89-9120

Lab. Sample No.: LH-07-FC

Sample Description: U.S.C. is N/A
AASHTO M145-82 is A-2-4(0)

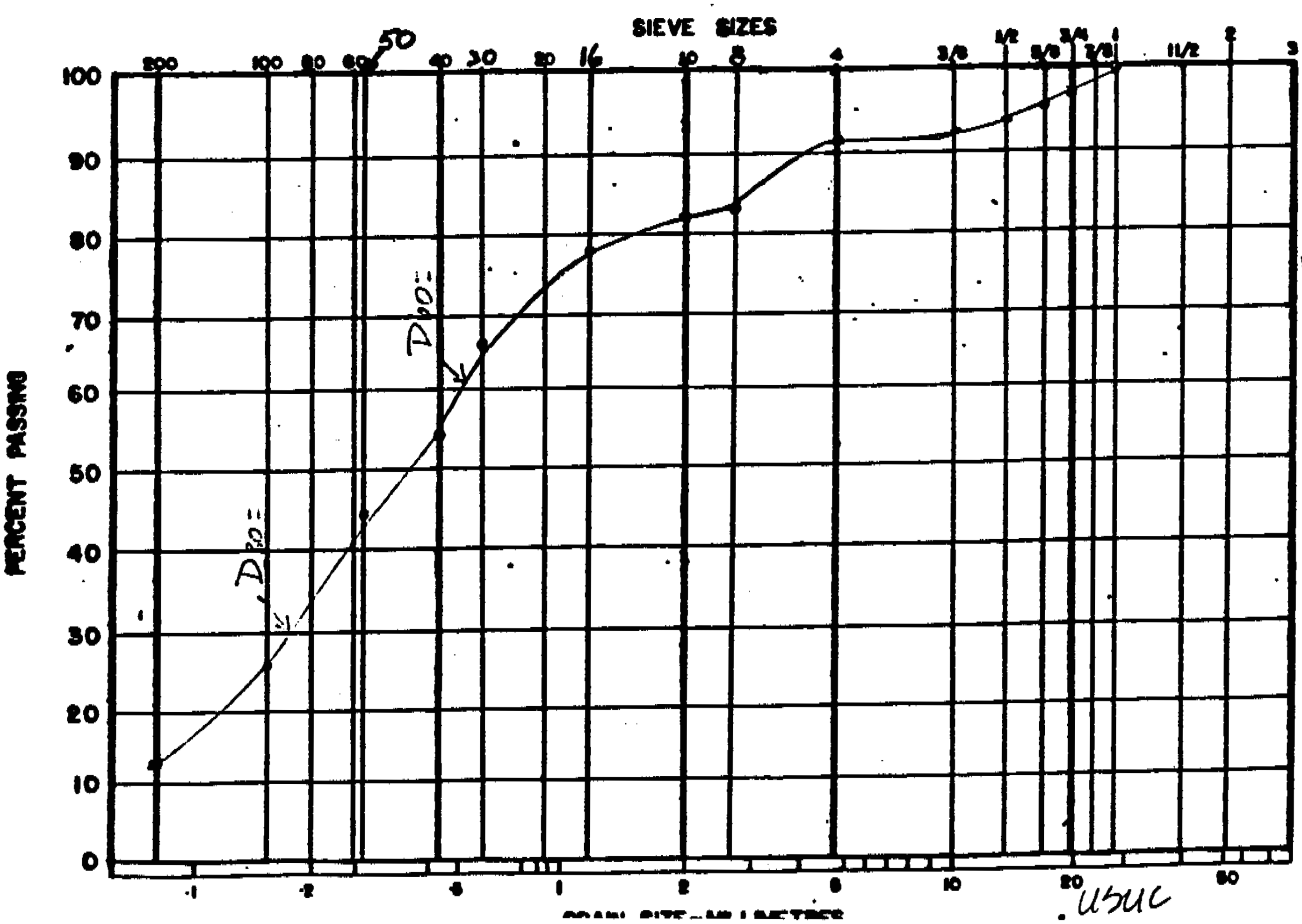
Comments:

D_{10} =
D_{30} =
D_{60} = Not Possible
C_u =
C_c =

CALCULATIONS NOT POSSIBLE AS CURVE DOESN'T CUT THROUGH D_{10}! NOT According to AASHTO T27-82 requiring 10 Kg of Sample (Received only 1.6 Kg)

SIEVE SIZES U.S. Standard	SIEVE SIZES Metric (mm)	% Retained Per Sieve	% Passing
1"			100
3/4"		3	97
5/8"		1	96
1/2"		1	95
3/8"		1	94
NO. 4		3	91
NO. 8		[illegible]	84
NO. 10		1	83
NO. 16		5	78
No. 30		[illegible]	67
No. 40		[illegible]	55
No. 50		11	44
No.100	0.150	8	26
No.200	0.075	14	12

CLAY / SILT	SAND			GRAVEL	
	FINE	MEDIUM	COARSE	FINE	COARSE



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APPENDIX 2

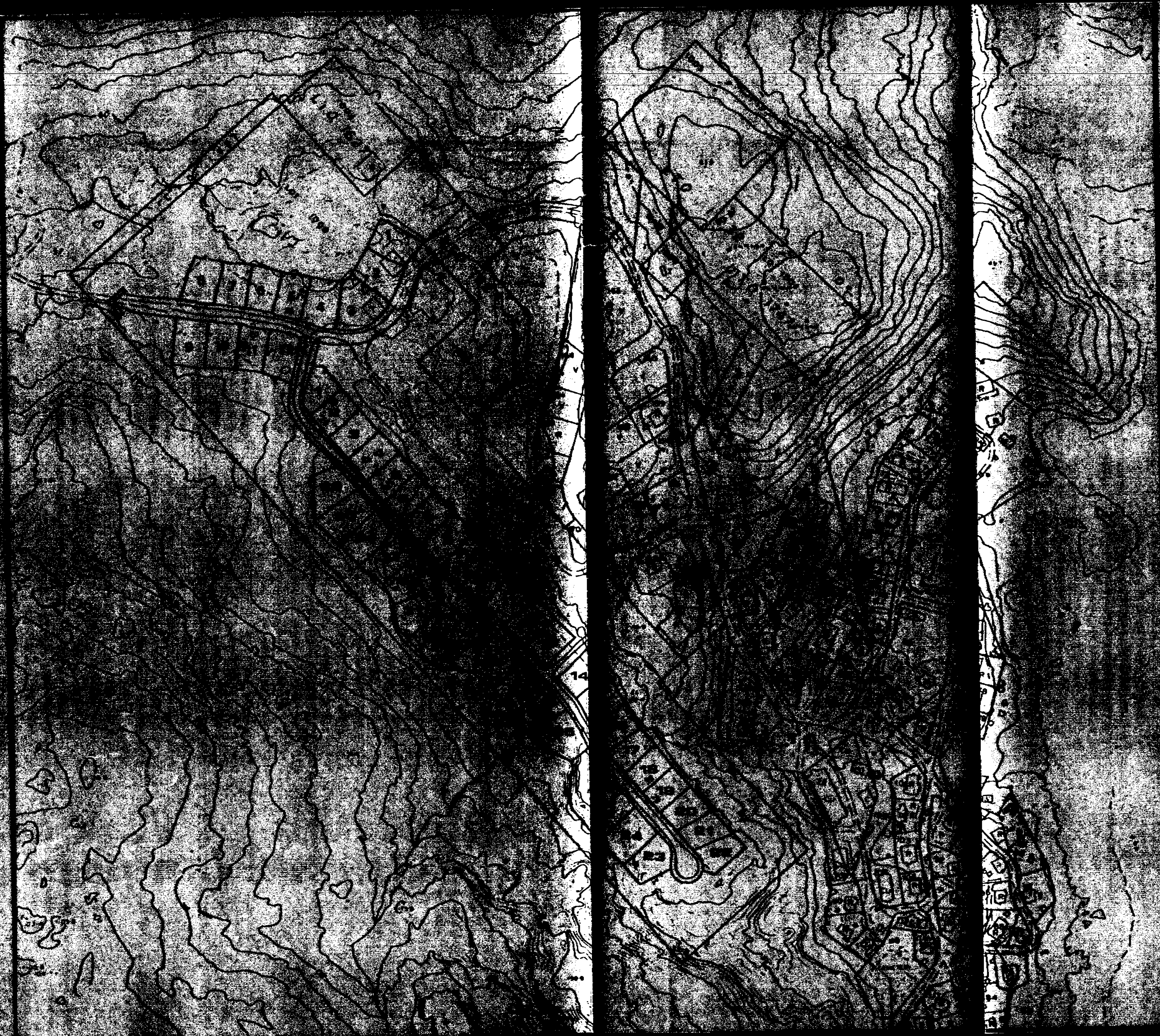
Lake Harbour Future Land Development Study

Prepared for M.A.C.A. by
J. L. Richards & Associates

APPENDIX

Summary of the Feasibility of the Development Options Identified for Lake Harbour

OPTIONS	ADVANTAGES	DISADVANTAGES	COST	RECOMMENDATION
R.C.M.P. site across Westbourne Bay	The area of this site is large enough to accommodate 74 dwelling units, which is more than enough housing to meet the 20 year demand. The topography of the site lends itself more readily to development than other areas in the vicinity	Road construction is difficult to the point of being impractical. Development at this site would have the effect of dividing the Community. Access to the municipal infrastructure located in the main community would be inconvenient.	$4,000,000.00	Rejected
The Gravel Pit	Road access to the Community is relatively easy so that construction costs will be lower.	Gravel source would have to be relocated as would the landfill site and the sewage dumping station. Development of this site would have the effect of dividing the Community.	$2,740,00.00	Rejected
West of the existing Airport	Road access to the Community is easy and housing could be developed at a relatively low cost	Development of this site would divide the Community and would place the airport in the middle of the Hamlet	$2,500,000.00	Rejected
Lots 1002 and 1003	These lots are serviced and could be rezoned to permit residential development	Lot 1002 has been developed to some extent for Industrial uses. The lots are very small and could not meet all of the housing needs	Not available	Rejected
Area to the South of the Community	Good access to the sea, southern exposure, the land is relatively flat	The Community would be divided; road construction would be expensive and difficult	$5,200,000.00	Rejected
Existing Airport	Very little site preparation needed; consolidation of the Community.	Requires relocation of the airport which is an indirect benefit (see text)	$480,000 to $720,000	Recommended



LAKE HARBOUR FUTURE LAND DEVELOPMENT STUDY

Conceptual Plan of Subdivision

[illegible] 11592
[illegible] 1, 198[illegible]
[illegible] : 2000

J.L. Richards & Associates Limited
Consulting Engineers, [illegible] and Planners

LAKE HARBOUR
FUTURE LAND DEVELOPMENT
STUDY

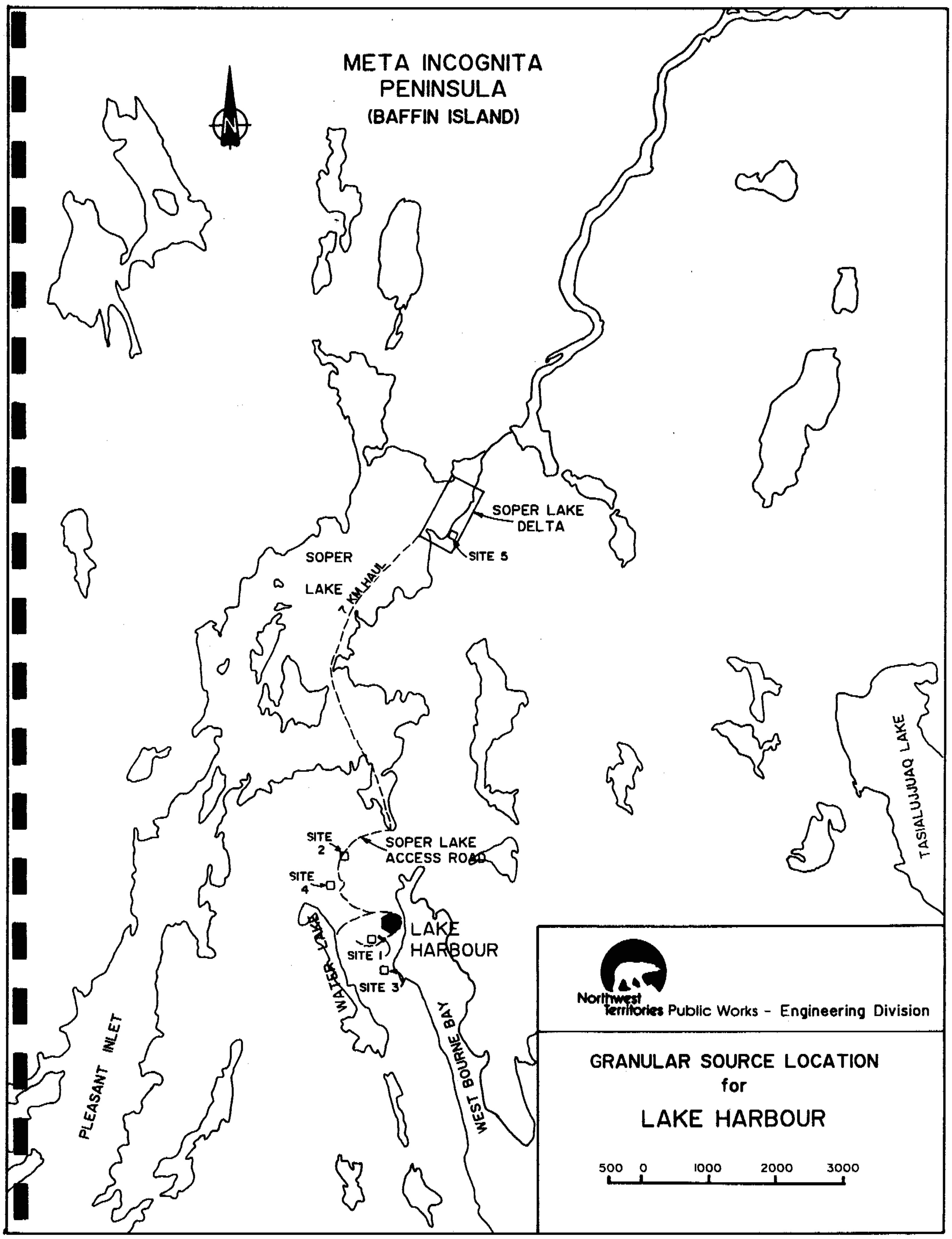
Conceptual Plan of Subdivision

JLR NO. 11592
December 1, 1989
Scale 1 : 2000

J.L.Richards & Associates Limited
Consulting Engineers, Architect and Planners

APPENDIX 3

Granular Source Location Map
July 1990


META INCOGNITA
PENINSULA
(BAFFIN ISLAND)
N
SOPER LAKE
DELTA
SITE 5
SOPER
LAKE
7 KM HAUL
TASIALUJJUAQ LAKE
SITE
2
SOPER LAKE
ACCESS ROAD
SITE
4
LAKE
HARBOUR
SITE 1
SITE 3
WATER LAKE
WEST BOURNE BAY
PLEASANT INLET
Northwest Territories Public Works - Engineering Division
GRANULAR SOURCE LOCATION
for
LAKE HARBOUR
500 0 1000 2000 3000