Ontario Geological Survey

Aggregate Resources Inventory Paper 92

AGGREGATE RESOURCES INVENTORY OF THE FORT FRANCES AREA

Rainy River District

NORTHERN ONTARIO

by

Staff of the Engineering and Terrain Geology Section

Ontario Geological Survey

1983

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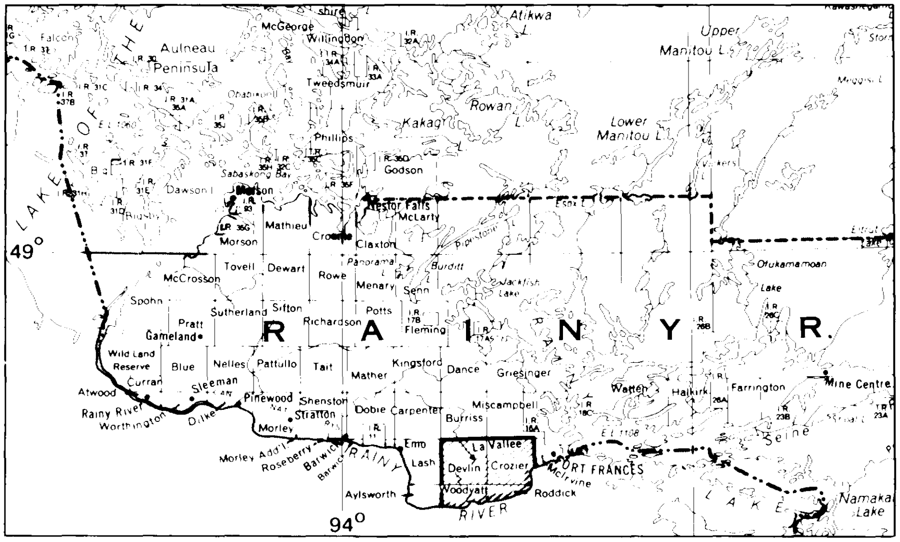
ABSTRACT



LOCATION MAP   Scale: 1:1 584 000 or 1 inch to 25 miles

Figure 1 - Key Map Showing the Location of the Fort Frances Area, Scale 1:584 000.

This report includes an inventory and evaluation of sand and gravel, as well as bedrock resources in the Fort Frances Area, focusing on the geographic townships of Crozier, Devlin, Roddick and Woodyatt (Figure 1). The report is based on previous studies in the area and on detailed field assessment undertaken by a two-man field party funded by the Ontario Ministry of Northern Affairs. The aggregate resources in the townships have been assessed according to standards developed for the Aggregate Resources Inventory Program by the Aggregate Resources Assessment Office of the Ontario Geological Survey (see Parts I and II).

The remaining reserves of surficial sand and gravel in the project area are limited. All surficial deposits of glaciolacustrine beach origin have been selected at a tertiary level of significance because of their quantity and quality limitations. Assessment of the subsurface aggregate potential of the townships did not reveal extensive buried deposits of sand and gravel close enough to the surface to be economic, consequently, selected deposits of primary and secondary significance have not been outlined.

The project area is underlain by complex, folded metasedimentary, metavolcanic, felsic and mafic intrusive crystalline rocks of Precambrian age. The latter two bedrock types are the most suitable for extractive development. Several areas of these rocks have been selected for possible resource protection based on drift thickness and location. Total possible resources of crushable rock in the Selected Bedrock Resource Areas are 1500 million tons (1360 million tonnes) based on an assumed quarriable thickness of 60 feet (18 m). Detailed petrographic evaluation is recommended before extractive activities commence.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCES INVENTORY OF THE FORT FRANCES AREA[1]

BY
STAFF OF THE ENGINEERING
AND TERRAIN GEOLOGY SECTION

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1980, the total tonnage of mineral aggregate extracted was 171 million tons (155 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1981).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where the deposits occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area, as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons, the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipalty's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

[1] Manuscript accepted for publication by Chief, Engineering and Terrain Geology Section, December 24, 1982.

This paper is published with the permission of E.G. Pye, Director, Ontario Geological Survey.

PART I - INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report involved the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References), as well as field examination of potential resource areas. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications (M.T.C.), the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel and sand-sized fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Airphotos at various scales were used to determine the continuity of deposits, especially in areas of limited information.

Deposits with potential for further extractive development or those where existing data are scarce, were studied in greater detail. Representative layers in these deposits were sampled in 25- to 100-pound (11- to 45-kg) units from existing pit faces. The samples were analysed for grain size distribution and in some cases for petrographic assemblage. Analyses were performed in the laboratories of the Engineering Materials Office, Ontario Ministry of Transportation and Communications. In areas of limited subsurface exposure, geophysical surveys and subsurface drilling were undertaken. The geophysical survey consisted of the use of an EM-31 portable conductivity unit with an effective exploration depth of approximately 20 feet (6 m). Subsurface drilling was carried out by a CME 45 auger drilling machine equipped with 3-inch (7.5-cm) hollow stem augers. Samples were recovered by means of a 2-inch (5-cm) standard split spoon sampler, in order to better assess the potential of the subsurface for buried aggregate. The location of test holes and geophysical traverse lines are shown on Map 1. Test hole logs with stratigraphic descriptions of test holes and conductivity plots summarizing geophysical data are enclosed in Part III.

In the office, the field data were supplemented by pit information on file with the Engineering Materials Office of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits, as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The locations of additional sources were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were referred to at the preliminary assessment stage to identify areas of possible buried granular material. These records were used in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows: First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3-m) thick layer of sand and gravel, one acre (0.4 ha) in extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however, the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 25 feet (8 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the rock unit. In most cases, a standardized estimate of a quarriable thickness of 60 feet (18 m) is used. Although the thickness of the Precambrian bedrock units in northern Ontario are all probably considerably greater, the 60-foot (18-m) value is considered an appropriate estimate of the maximum thickness of material that can be economically and technologically extracted from a given quarry face. Volume estimates are then multiplied by 3700 (the estimated weight, in Imperial tons, of a one-foot (0.3-m) thick section of Precambrian rock one acre (0.4 ha) in extent, assuming a bulk density of 170 pounds per cubic foot (2729 kg per cubic metre)).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel, as well as bedrock-derived aggregate, are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976) (see Appendix B).

PART II - DATA PRESENTATION AND INTERPRETATION

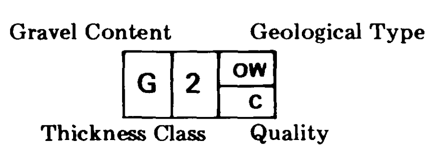
There are three maps, each portraying a different aspect of the aggregate resources in the report area. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of bedrock formations, the distribution of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Map 1 is derived directly from existing surficial geology maps or from airphoto interpretation in areas where mapping is incomplete. The map represents a comprehensive inventory of sand and gravel deposits within the project area and serves as a base for the calculation of total sand and gravel resources. All known deposits are delineated by a dashed line and given a brown or beige tone. The map also represents a summary of all available information related to the quality of aggregate in the mapped deposits. Much of this information is contained in two symbols which appear on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:



This symbol identifies a lacustrine beach deposit 5 to 10 feet (1.5 to 3 m) thick containing more than 35 percent unprocessed gravel. Excess fines may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate makes up less than 35 percent of the whole deposit. The "G" indicates that the deposit probably contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken during field study. The data from which these symbols are derived has been plotted on grain size distribution graphs. The relative amounts of gravel, sand, and fines in the sampled material are shown graphically by the subdivision of a circle into proportional segments.

Test hole locations are shown on Map 1 by a solid drillhole symbol. All known sand and gravel pits, whether presently active or inactive, are shown by a dot symbol and a number which refers to the pit descriptions given in Table 2. Each description notes the location and owner of the pit and the estimated face height and gravel content.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary and tertiary. These areas are identified on Map 2 by different shading patterns.

Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order in that municipality. All such deposits are shown by a red tone on Map 2.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single, land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically, but are indicated by a light red tone on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resource areas, they may contain large quantities of sand and gravel and should be considered as part of the aggregate supply of the municipality.

Areas of tertiary significance are outlined on the map by a solid line, but have no tone. They are neither rated nor considered to be important resource areas, because of their low available resources or because of possible difficulties in extraction. Such areas may be useful for local needs, but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the municipality is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

DEPOSIT SIZE

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6 m) and containing more than 35 percent coarse aggregate larger than the No. 4 (4.75 mm) sieve are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregate for various uses result from variations in the lithology of the particles making up the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S), fines (C), oversize (0) and lithology (L).

Three of the indicators deal with grain size distribution. The "gravel content", (G or S), indicates the suitability of aggregate for various uses. Deposits containing more than 35 percent coarse aggregate larger than the No. 4 (4.75 mm) sieve, and also a minimum of 20 percent larger than the 1 inch (25 mm) sieve, are considered to be favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess "fines" (high silt and clay content) may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent "oversize" material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete and road-building aggregate, so must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is "lithology". Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high-quality uses. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Analyses of unprocessed samples obtained from test holes or pits are plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course (G.B.C.) A, B, and C; and Hot-Laid (H.L.) Asphaltic Sand Nos. 1, 2, 3, 4, 5, 6 and 8. By plotting the grading curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product.

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas, because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3.

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the Ontario Ministry of Natural Resources' District Office.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology maps, water well data from the Ontario Ministry of the Environment, drilling assessment data from the Ontario Ministry of Natural Resources and from the Northern Ontario Engineering Geology Terrain Studies produced for the Ontario Geological Survey. The geological boundaries of the bedrock units are shown by a dashed line. Drift-covered bedrock is indicated by two blue tones and is delineated by drift thickness contour lines. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

Areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface are indicated by dark blue tone. Isolated bedrock outcrops which lie outside these areas are indicated by a black "X" symbol. These areas constitute potential resource areas of primary significance, because of their easy access. Areas where the bedrock is covered by 3 to 25 feet (1 to 8 m) of drift are indicated by medium blue tone. Quarrying is possible in this depth of overburden and these also represent potential resource areas. Outside the delineated areas of thin drift cover, the bedrock can be assumed to be overlain by more than 25 feet (8 m) of drift. These areas constitute resources which have extractive value only in specific circumstances and will not likely be of economic significance.

Scattered bedrock outcrops and areas of thin drift may occur outside the drift thickness boundaries, but may not be delineated on Map 3 because of the lack of sufficient subsurface data.

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. All known quarries are shown by a dot symbol and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, bedrock lithology and an estimate of face height. Two additional symbols appear on the map: an open dot indicates the location of a selected well which penetrates bedrock; a closed dot with crossed lines indicates a test hole location. The overburden thickness is shown in feet beside the dot in both cases.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics of the bedrock units found in the study area are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of bedrock resource areas has been restricted to a single level of significance. Two factors support this approach: (1) the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and (2) crushed bedrock has a higher unit value than sand and gravel, therefore, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The wide range of possible resource areas allows greater flexibility in locating quarry operations away from areas of intensive land use competition. The selected areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

The Precambrian Shield rocks in northern Ontario are generally more complex and variable than the Paleozoic rocks of southern Ontario. The bedrock in northern Ontario often shows wide variations in mineralogy, texture (grain size) and degree of weathering, even within specific rock types and over relatively short distances. As these factors are considered important in determining the suitability of the bedrock for use as aggregate, the aggregate potential may also vary considerably from location to location.

Careful selection is especially important if the bedrock is to be used as concrete aggregate. Deleterious chemical reactions may develop in the concrete which can lead to its eventual deterioration. Fortunately, these chemical reactions should not influence the use of bedrock-derived aggregate for hot-laid asphaltic and road-base material. However, highly weathered, very porous and friable rock should be avoided for all uses.

For these reasons, the entire area selected as a bedrock resource should not be considered acceptable for aggregate use. The resource areas are, however, areas in which the probability of finding a supply of acceptable aggregate is considered most likely.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such a Resource Area may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

PART III - ASSESSMENT OF AGGREGATE RESOURCES IN THE FORT FRANCES AREA

LOCATION AND POPULATION

The project area is located west of the Town of Fort Frances and north of the Rainy River. The area consists of the geographic townships of Crozier, Devlin, Roddick and Woodyatt, which belong to the incorporated townships of Alberton and La Vallee. The location and extent of the project area are shown on Figure 1. The four townships occupy a combined area of approximately 60,900 acres (24 650 ha) in the District of Rainy River. They are shown on portions of the Fort Frances (52 C/11) and Emo (52 C/12) map sheets of the National Topographic System, at a scale of 1:50 000.

The Town of Fort Frances, located near the eastern boundary of the project area, is the largest centre, providing trade and retail facilities for the surrounding population. Several very small settlements, such as Devlin, Crozier, La Vallee, Box Alder and Big Fork, are scattered within the townships. In 1980, the combined population of these areas including Burris Township was 1746 (Ontario Ministry of Intergovernmental Affairs 1981). Figures from previous years indicate that the population has increased by approximately 17 percent since 1973 (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). Population projections made by the Regional Planning Branch of the Ontario Ministry of Treasury, Economics and Intergovernmental Affairs (1976, p. 151) for the District of Rainy River indicate a probable trend of population decrease for the time period of 1981-2001. However, within the townships included in this report, there is intense land use competition for rural-residential development, because of the relatively short commuting distance to the developing Town of Fort Frances. The intensification of local rural-residential development will likely result in increased future demand for sand and gravel and crushed stone supplies for road-building and construction aggregate.

Good road access in the townships is provided by a rectangular grid of gravel-surfaced and paved township roads, as well as by the Trans-Canada Highway and Secondary Highways 602, 611 and 613. Rail access is provided by a line of the Canadian National Railways, which runs east-west through the northern portions of Crozier and Devlin Townships.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The townships of Crozier, Devlin, Roddick and Woodyatt lie within the Rainy Lake Physiographic Region. It is an extensive, flat to undulating plain interspersed with large peat bogs and poorly drained areas. Elevations of the ground surface range from 1100 feet (335 m) to 1250 feet (381 m) above sea level (a.s.l.). The southern and eastern margins of the project area are bounded by the Rainy River which serves as the International Boundary between Canada and the United States of America.

Local bedrock consists of complex, folded metasedimentary, metavolcanic, felsic and mafic intrusive, crystalline rocks of Precambrian age (Davies 1973). Glacial drift covers most of the project area, however, outcrops also occur in the form of rock knobs, representing the highest bedrock peaks. Drift thickness is variable and, in general, exceeds 100 feet (30 m) in areas south of the Trans-Canada Highway.

The distribution and thickness of unconsolidated sediments, including sand and gravel, are the result of extensive glacial activity which took place during the Wisconsinan Stage of the Pleistocene Epoch. This period of time, which lasted from approximately 100 000 to 7000 years ago, was marked by the repeated advance and retreat of extensive, continental ice sheets.

Johnston (1915) carried out the first systematic study of the glacial history and unconsolidated sediments of the Rainy River area. Additional work was carried out by Zoltai (1961; 1965). The following is a brief summary of the major glacial movements and their associated materials based on the findings of these authors.

Four significant glacial ice advances and two major glacial lake stages were recognized during the Great Ice Age. The oldest known ice movement to affect the area came from the north-northwest. The extent of this advance is uncertain, but this glacial activity is evidenced by calcareous rusty coloured till and striae in the western half of northwestern Ontario. This till is not found at the surface in the project area. The degree of oxidation of the till suggests a prolonged interglacial period.

The next ice advance was from the northeast, spreading noncalcareous till over the area. This till consists of fragments of granitic rock of all sizes up to several feet in diameter and set in a matrix of sand and silt or rock flour with a minimum amount of clay-sized particles. The significance of this till is amplified by its association with irregularly bedded sands and gravels of glaciofluvial origin during this same period of time. The till and the sand and gravel are concealed by an overlying thick mantle of calcareous drift (attributed to the third glacial advance). These materials were observed in the large Armstrong Pit located outside the eastern margin of the project area. About 30 feet (9 m) of sand and gravel are exposed in the pit face. The pit floor is made up of southwesterly striated Precambrian bedrock. The granular material is well rounded, crystalline, and appears to contain no limestone. Much of the material is fine aggregate, but many, well rounded boulders also occur. This aggregate is processed to supply high-quality sand and gravel.

Complete or partial deglaciation followed the second ice advance. The ice-free period was probably short, because no weathering is evident in the till deposited by the second glacier. Following the short interglacial period, a glacier advanced from the west and extended as far east as Fort Frances. This glacier did not build distinguishable end moraines, but the extent of its advance is marked by a distinctive calcareous till. This bluish gray (yellowish gray when weathered or exposed at surface), stiff silty clay till consists of unstratified silty and clayey material with some angular to subrounded clasts and occasional medium gravel-sized stones. About half of the stones are Precambrian, while the other half consists mainly of buff coloured Paleozoic limestone of Ordovician age, outcropping in Manitoba (Johnston 1915). The till is not suitable for aggregate use because of an excessively high 'fines' content.

The retreat of this glacier gave rise to a large ice-marginal lake called Lake Agassiz I. Gritty glaciolacustrine clays closely associated with the calcareous till were deposited in this glacial lake. The glaciolacustrine clays are also not suitable for aggregate use because of the high silt and clay content.

Following the draining of Lake Agassiz I, ice transgressed from the northeast depositing granitic till. The ice stopped just short of the project area leaving the calcareous till and lacustrine materials as the uppermost surficial deposits.

This final glacial stage was a period of intermittent retreat during which Lake Agassiz II was initiated. During the life of this lake, wave action further denuded bedrock outcrop areas and varved clays were deposited in depressions. Near topographic highs, shallow beach ridges and bars of sand and gravel were formed. These deposits, ranging in thickness from 3 feet (1 m) to 9 feet (3 m), have been traditional local sources of low-specification aggregate. Because of poor quality and limited remaining reserves, these deposits will not be able to meet future demand for road-building and construction aggregate.

The eventual draining of Lake Agassiz II marked the end of glacial activity in the project area. Postglacial erosional and depositional processes have been of minor importance in modifying the physiography. Poor drainage in several large depressions has led to the development of extensive peat bogs and swampy terrain, which has limited the availability of land for agricultural and other economic and cultural development.

EXTRACTIVE ACTIVITY

Numerous small borrow pits have been opened in Crozier, Devlin, Roddick and Woodyatt Townships. The pits are all located in shallow, wave-worked beach ridges or nearshore bars of previous stages of Lake Agassiz. Many of the pits have been depleted to the extent of being completely excavated to the underlying clayey till surface. These old pits are difficult to locate and are not shown on Map 1, because of the limited extent and very flat geometry of the deposits in which the pits were situated. At the time of writing, six small pits were documented (Table 2) based on Ontario Ministry of Transportation and Communications (M.T.C.) or Ontario Ministry of Natural Resources (M.N.R.) data files and field checking. These pits are borrow and low-specification aggregate sources operating on a local demand basis. The remaining reserves in these sources are very limited and nearing depletion.

Records of annual production of sand and gravel from the pits have been maintained by the Fort Frances District Office of the Ontario Ministry of Natural Resources. Total production from local sources over a four-year period from 1975 to 1979 has been 16,450 tons (14 920 tonnes) for Crozier and Woodyatt Townships, and 18,530 tons (16 810 tonnes) for Devlin and Roddick Townships. Future demand for sand and gravel is expected to increase in these municipalities. However, local supply may not be able to meet this demand.

SURFICIAL SAND AND GRAVEL DEPOSITS

Sand and gravel deposits exposed at the surface in Crozier, Devlin, Roddick and Woodyatt Townships are the shallow beach ridges and their associated nearshore bars and spits of previous stages of glacial Lake Agassiz (see Map 1). The material found in these relatively narrow beach ridges contains fine limestone gravel and quartzose and feldspathic sand derived from the erosion of the underlying calcareous till. Silt and clay lenses also occur in these deposits decreasing their value as aggregate material. The average thickness of the deposits ranges from 3 feet (1 m) to 9 feet (3 m) with approximate widths extending from 50 feet (15 m) to 500 feet (152 m).

At the time of writing, six pits were documented in the beach deposits. The aggregate suitability of the sand and gravel extracted from these deposits is limited to low-specification, noncrushable uses. For example, data obtained from the Ontario Ministry of Transportation and Communications' aggregate information files for Pits 1 and 5 in Crozier Township indicate that the material in these pits is acceptable for Granular and Subbase C, as well as borrow material use, but does not meet the requirements for higher quality uses such as 1/2 inch (13 mm), 5/8 inch (16 mm) Type A crushed stone or Hot-Laid (H.L.) 4 sand. Selection is frequently required to obtain Granular C material because of the presence of silt and clay seams and lenses in objectionable quantities. Lack of sufficient stone content, excess fines and fineness of gradation are the major quality limitations of these deposits (These conclusions can be drawn from Figures 3a and 3b which show the typical gradation characteristics of the glaciolacustrine material in the project area, based on samples analysed by the Engineering Materials Office of the Ontario Ministry of Transportation and Communications).

All glaciolacustrine beach deposits outlined on Map 1 have been selected at the tertiary level of significance, based on their inherent quality and quantity limitations. These deposits have limited local importance and will not be able to supply the high-quality aggregate necessary to meet future demand.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 shows that there are no Selected Sand and Gravel Resource Areas at the level of primary and secondary significance in the project area. All deposits have been selected at the tertiary level of significance for reasons discussed previously. These deposits cover approximately 440 acres (178 ha), having an original resource tonnage of 3 million tons (3 million tonnes) (Table 1). The remaining available tonnage is considerably less.

SUBSURFACE SAND AND GRAVEL DEPOSITS

Preliminary work by Sado (1976), Springer (1978) and Roed (1980) suggested the possibility of locating buried deposits of high-quality, glaciofluvial sand and gravel, similar to the deposit exposed under the silty clay till in the Armstrong Pit, near the eastern boundary of the project area. The location of these deposits was suspected to range from 3 feet (1 m) to 50 feet (15 m) below ground surface. In order to find and delineate these deposits, a detailed subsurface exploration program of geophysics and drilling was carried out in accessible areas.

First the geophysical program was completed in order to locate possible anomalous areas of buried aggregate. Survey was undertaken by the use of an EM-31 portable conductivity unit, effective to an approximate working depth of 20 feet (6 m). Based on water well information obtained from the Ontario Ministry of the Environment and geological data, a total of eighteen geophysical traverse lines were run in the project area. The approximate locations of these traverses are shown on Map 1. Summary plots of the conductivity readings are portrayed on Figures 4a and 4b. The conductivity of the clayey till was found to fluctuate within a range of 60 to 100 millimhos, while the conductivity of surficial aggregate (beach material) ranged from 30 to 60 millimhos. The wide range of readings obtained is attributed to factors such as variability of moisture content, degree of weathering of the subsurface and effect of vegetation. The conductivity survey did not reveal any significant areas of thin drift underlain by sand and gravel. The survey was, however, very effective in the detection of surface aggregate deposit boundaries.

Subsurface drilling served as a follow-up and ground proofing device to locate possible buried aggregate deposits at greater depth. Fifteen test holes were drilled in the study area to an average depth of 40 feet (12 m) by a CME 45 drill rig using 3-inch (7.5-cm) internal diameter hollow stem augers. Samples were retrieved by means of a 2-inch (5-cm) outside diameter standard split spoon sampler. Detailed descriptions of the stratigraphy of test holes are provided on Table 7. Locations of the test holes are shown on Maps 1 and 3.

Test holes drilled in various locations revealed the presence of an extensive 30- to 40-foot (9- to 12-m) thick, calcareous till and clay mantle with occasional, thin, wet seams of sandy material. Buried sand and gravel, similar to the material exposed in the Armstrong Pit, were encountered at a depth of 38 feet (12 m) in CR-TH-7 and 39 feet (12 m) in DN-TH-3. The thickness of these materials was only a few feet. Augering was hindered by refusal on possible bedrock or large boulders.

Three test holes in Crozier Township (CR-TH-3, 4 and 5) are particularly significant, because they were placed in order to investigate the possible continuity of the buried glaciofluvial sand and gravel of the Armstrong Pit, as outlined by Springer (1978). The discouraging results obtained (Table 7, Figures 4a and 4b) render the delineation of a buried deposit in this area infeasible. A conceptual cross-section diagram (Figure 2) through test holes 2, 4, 6 and 7 portrays a possible subsurface configuration.

The extensive thickness of the calcareous till (as found in many test holes) and its geological origin (Johnston 1915) exclude the possibility that this material contains large glaciofluvial sand and gravel deposits of economic value. Large overburden thickness, as well as the presence of a relatively high groundwater table, also make extraction of buried aggregate uneconomical in these areas. Consequently, there are no selected buried sand and gravel resource areas outlined on Map 2 for Crozier, Devlin, Roddick and Woodyatt Townships.

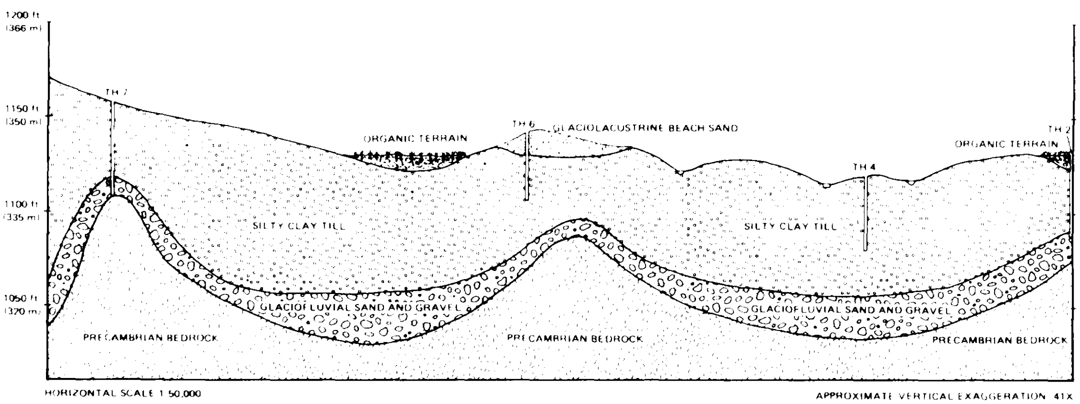


FIGURE 2: Conceptual cross-section diagram through test holes 2, 4, 6 and 7, Crozier Geographic Township

BEDROCK GEOLOGY

The bedrock underlying Crozier, Devlin, Roddick and Woodyatt Townships is of Precambrian age. The bedrock consists of complex, folded metasedimentary, metavolcanic, mafic intrusive and felsic intrusive rocks. The significant structural features are the Seine River Fault and the doubly plunging folds, the cores of which have been invaded by younger mafic and felsic intrusions (Davies 1973). The distribution of the rock units are shown on Map 3 and are described in the legend for the map, as well as in Appendix D. For a complete description of metallic and nonmetallic occurrences within the project area, the reader is referred to Davies (1973).

A relatively thick mantle of glacial drift, often exceeding 100 feet (30 m), covers most of the project area. The highest bedrock peaks are represented on the surface by scattered, isolated, bedrock outcrops. Drift thickness contours for areas covered by less than 3 feet (1 m) and less than 25 feet (8 m) of drift are shown on Map 3. These lines were derived from available subsurface drilling data and mapped bedrock outcrop locations.

Metavolcanic and metasedimentary rocks are the oldest. The volcanic rocks (Type D) include gray weathering andesite and dacite tuff, lapilli tuff breccias and hornblende schist, which in part may be metasedimentary. This rock type is found under the western half of Crozier Township and under the eastern part of Devlin Township. Metasedimentary rocks (Type E), underlying the relatively thick drift cover of Crozier, Roddick and Woodyatt Townships, are predominantly schists derived from greywacke, siltstone, and argillite with some pebble conglomerate and sandstone.

Schists, representing a large portion of rock Type E and some of rock Type D, have a foliated texture, consisting of platy minerals in which the proportion of interlocking quartz and feldspar grains is low and, therefore, these rocks tend to be susceptible to rapid mechanical weathering. The presence of large amounts of biotite as the dominant mafic mineral in the schist adds to the susceptibility to chemical and mechanical weathering. For these reasons, shists of rock Type E are not well suited for load-bearing aggregate use.

Coarse-grained quartz with deformed crystal lattice is an alkali-silica reactive mineral and may be found in metamorphosed sedimentary rocks such as greywackes and argillites belonging to rock Type E, as well as in some rocks of Type D. The quartz can react with alkalis from cement paste and may cause expansion and cracking of concrete (Rogers 1979). This characteristic reduces structural soundness.

Petrographic data for rock Types D and E are lacking, since there is no history of previous extraction of these rock types in the project area. A detailed petrographic analysis of some of the individual rocks included within rock Types D and E could prove them suitable for certain aggregate uses. However, on the basis of presently available information regarding drift thickness, mineralogy and weathering characteristics, rock Types D and E have not been selected for possible resource protection.

Younger bedrock includes the mafic and felsic intrusive rocks. Mafic intrusive rocks (Type C) consist of gabbro, diorite and syenodiorite. Type C rocks underlie a large portion of Devlin Township. They display a medium-to coarse-grained texture with mafic mineral content in excess of 25 percent.

The youngest felsic intrusive rocks have been divided into two kinds: Type A is a massive to foliated, grey granodiorite and quartz monzonite; Type B is a porphyritic granodiorite and quartz monzonite. Granodiorite consists of plagioclase grains with microcline, quartz and biotite in a typical igneous texture. Quartz monzonite has the same composition as granite, except that one-third to two-thirds of the total feldspar is oligoclase-andesine. The percentage of dark minerals is also usually higher.

Thinly drift-covered areas of rock Types A, B and C are found in the northern portions of Devlin and Crozier Townships. These rock types are considered as the most likely sources within the project area to contain rock suitable for the production of road-base, hot-laid asphaltic and possibly concrete aggregate.

A quarry in Type B granitic rock was opened in the early 1960s to supply crushed stone for the construction of the Rainy Lake causeway. The quarry is located on Indian Reservation 18B, about 1.5 miles (2.4 km) east of Fort

Frances, on the north side of the approach to the causeway. Analyses of the rock in this quarry were performed by the Ontario Ministry of Transportation and Communications and indicated that the material was suitable for production of G.B.C. A, H.L. 4 asphaltic stone and 5/8 inch (16 mm) crushed stone. Los Angeles Abrasion Tests, which measure the impact strength of the aggregate (i.e. the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed), gave acceptable results: 19.8 percent versus 35 percent, which is the maximum loss by weight permitted by M.T.C. The Magnesium Sulphate Soundness Test yielded a result of 1.3 percent, which is well below the 12 percent maximum limit, meaning that rock Type B has a very low susceptibility to freeze and thaw breakdown. The twenty-four hour absorption test result of 0.233 percent versus the allowable 2 percent maximum confirms the durability of this rock type. A derived Petrographic Number of 118 indicates that this rock is acceptable for both structural concrete and concrete paving purposes. Because of their origin and similar mineral composition, rock Types A, B and C are likely to produce similar or equivalent aggregate material to the one obtained from the causeway quarry.

Some felsic igneous rocks, referred to as "Brittle Granite" (Rogers 1979), have a high feldspar and quartz content and may have stripping and popping problems. The smooth cleavage and fracture surfaces of the minerals decrease the adhesion properties of asphalt and concrete mixes. If present, this problem can be circumvented by weathering the rock for a period of time in stockpiles or by adding chemicals which erode the smooth surfaces and allow better adhesion.

Rock hardness is an additional criteria that is an important consideration when crushing is planned. Excessive hardness makes perfectly sound rock uneconomical, because of the excessive wear and tear it would cause on the processing equipment.

A detailed petrographic analysis of the rock within selected bedrock resource areas is recommended before quarrying operations commence, to ensure successful and economic crushed stone production.

SELECTED BEDROCK RESOURCE AREAS

An inventory of rock Types A, B, C, D and E in Crozier, Devlin, Roddick and Woodyatt Townships indicates a total areal extent of approximately 13,100 acres (5300 ha) overlain by less than 25 feet (8 m) of drift. The original resource tonnage is estimated at 2900 million tons (2650 million tonnes) (Table 4).

Several thinly drift-covered areas of bedrock Types A, B and C have been selected for possible resource protection in Crozier and Devlin Townships. These resource areas occupy a total of 10,200 acres (4150 ha), of which 6700 acres (2700 ha) are available for extractive development after deletions for cultural setbacks. Assuming a quarriable depth of 60 feet (18 m), there are an estimated 1500 million tons (1360 million tonnes) of bedrock available for production of road-building and construction aggregate (This is a conservative estimate, as the bedrock units under consideration are all probably considerably thicker than 60 feet (18 m)). Quarries may be established at numerous locations within the selected bedrock resource areas, however, extensive areas of poorly drained, marshy terrain could hinder extraction.

SELECTED BEDROCK RESOURCE AREAS 1a AND 1b

Two areas of rock Type A consisting of grey granodiorite and quartz monzonite have been selected for resource protection. Area 1a lies in the northwest corner of Devlin Township, while area 1b is located immediately north of the Trans-Canada Highway in Crozier Township. The Areas are relatively flat and free of marshy terrain. Access is provided by municipal roads and the Trans-Canada Highway.

The total extent of Areas 1a and 1b is 1550 acres (630 ha). Presently, there are no quarries and no history of previous extraction. An estimated 350 acres (142 ha) are sterilized by the presence of roads, houses and other cultural features, leaving 1200 acres (485 ha) available for possible future extractive development. Assuming a workable thickness of 60 feet (18 m), possible bedrock resources are estimated to be 270 million tons (245 million tonnes) (Table 6).

SELECTED BEDROCK RESOURCE AREAS 2a, 2b, 2c AND 2d

Four areas of rock Type B, differing only in texture from rock Type A (porphyritic instead of equidimensional), have been selected as bedrock resource areas. They underlie much of the northern part of Crozier Township. The topography is flat with extensive, poorly drained swampy areas. Surface exposures of bedrock are common in Areas 2b, 2c and 2d. Good access is provided by local municipal roads.

Total extent of Areas 2a, 2b, 2c and 2d is 4100 acres (1660 ha). At the time of writing, there were no quarries. An estimated 1960 acres (795 ha), or about 49 percent of the total resource areas, are unavailable because of swampy areas and cultural features such as roads, houses, the railway line etc. This leaves approximately 2120 acres (860 ha) available for possible extractive development. Assuming a workable thickness of 60 feet (18 m), possible bedrock resources are estimated to be 470 million tons (425 million tonnes) (Table 6).

SELECTED BEDROCK RESOURCE AREAS 3a, 3b AND 3c

Three areas of rock Type C, including gabbro, diorite and syenodiorite, have also been selected for resource protection. Area 3a is the largest and is located north of the Trans-Canada Highway in Devlin Township. Areas 3b and 3c are considerably smaller in areal extent and are situated in Crozier Township, both also north of the Trans-Canada Highway. The land surface of these areas has flat to subdued relief. Area 3a is traversed by the La Vallee River and shallow creeks providing improved drainage. Surface exposures of bedrock are common near the settlement of Devlin and in the northeast portion of the resource area.

The total extent of the areas is 4500 acres (1820 ha). There are no quarries and no history of previous extractive activity. The quality and suitability of the bedrock for various aggregate uses is probably much the same as in the other selected areas outlined for rock Types A and B. An estimated 1080 acres (435 ha) are unavailable because of roads, houses and other cultural features, leaving 3400 acres (1380 ha) for possible extractive development. Using a workable thickness of 60 feet (18 m), total resources of rock Type C for production of road-building and construction aggregate are estimated to be 760 million tons (690 million tonnes) (Table 6).

SUMMARY

There is a very limited supply of known reserves of surficial sand and gravel in Crozier, Devlin, Roddick and Woodyatt Townships. Selected sand and gravel resource areas of primary and secondary significance were not outlined, because of the lack of aggregate rich deposits. The only sources of surficial sand and gravel within the area are the glaciolacustrine beach deposits. These deposits have been selected at a tertiary level of significance, based on their quality and quantity limitations. The assessment of the subsurface aggregate potential of the townships failed to confirm buried deposits of sand and gravel.

The project area is underlain by complex, folded metasedimentary, metavolcanic, felsic and mafic intrusive, crystalline rocks of Precambrian age. The latter two bedrock types are the most suitable for extractive development. Several areas of these rocks overlain by thin drift have been selected for possible resource protection. These areas may become important in the future when crushable gravel will be scarce.

For the near future, the townships of Crozier, Devlin, Roddick and Woodyatt will have to depend on nearby sources, located within economically feasible transporting distance, (e.g. the Armstrong Pit) for road-building and construction aggregate.

Enquiries regarding the Aggregate Resources Inventory of the Fort Frances Area should be directed to the Ontario Ministry of Natural Resources either at the Fort Frances District Office, 922 Scott Street, Fort Frances, Ontario, P9A 1J4 (Tel. (807) 274-5337) or at the Northwestern Region Office, 806 Robertson Street, Box 5160, Kenora, Ontario, P9N 3X9 (Tel. (807) 468-3111).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, FORT FRANCES AREA

1 CLASS NO.	2 DEPOSIT TYPE (see Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
3	S-LB	240 (97)	2 (2)
4	S-LB	200 (81)	1 (1)
		440 (178)	3 (3)

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2 | SAND AND GRAVEL PITS, FORT FRANCES AREA

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 SECTION	5 FACE HEIGHT Feet (Metres)	6 % GRAVEL	7 PIT STATUS
CROZIER TOWNSHIP						
1	E12-6	W. Weir	NE ¼, 32	5-8 (1-2)	sand with some fine gravel	nearly depleted
2	E12-7	E. Supinski	NW ½, 34	5-7 (1-2)	sand	nearly depleted
3	FF12-3	O.L. Warner	NE ¼, 25	5-7 (1-2)	sand	refuse dump
4	–	A. Spuzak	NW ½, 14	5-8 (1-2)	sand with some fine gravel	nearly depleted
5	–	Mutz	Pt. 20	4-5 (1)	sand with fine gravel	nearly depleted
WOODYATT TOWNSHIP						
6	–	Unknown	Pt. of 27, 19	2-8 (½-2)	sand	partially depleted
DEVLIN TOWNSHIP						
			– NONE –			
RODDICK TOWNSHIP						
			– NONE –			

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, FORT FRANCES AREA

1 **DEPOSIT NO.**	2 **AREA** Acres (Hectares)	3 **CULTURAL SETBACKS** Acres (Hectares)	4 **EXTRACTED AREA** Acres (Hectares)	5 **AVAILABLE AREA** Acres (Hectares)	6 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	7 **AVAILABLE AGGREGATE** Millions of Tons (Tonnes)
			– NONE –			

Note: There are no deposits selected at the primary and secondary level of significance.
All deposits are included at the tertiary level of significance.

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, FORT FRANCES AREA

1 DRIFT THICKNESS Feet (Metres)	2 BEDROCK LITHOLOGY	3 QUARRIABLE THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
0-3 (0-1)	Type A	60 (18)	100 (40)	22 (20)
3-25 (1-8)	Type A	60 (18)	1450 (585)	320 (290)
			1550 (630)	340 (310)
0-3 (0-1)	Type B	60 (18)	480 (194)	106 (96)
3-25 (1-8)	Type B	60 (18)	3600 (1460)	800 (730)
			4100 (1660)	910 (820)
0-3 (0-1)	Type C	60 (18)	480 (194)	106 (96)
3-25 (1-8)	Type C	60 (18)	4000 (1620)	890 (810)
			4500 (1820)	1000 (910)
0-3 (0-1)	Type D	60 (18)	200 (81)	44 (40)
3-25 (1-8)	Type D	60 (18)	560 (227)	124 (112)
			760 (310)	168 (152)
0-3 (0-1)	Type E	60 (18)	170 (69)	38 (34)
3-25 (1-8)	Type E	60 (18)	2050 (830)	455 (415)
			2220 (900)	495 (450)
			13,100 (5300)	2900 (2650)

TABLE 5 | QUARRIES, FORT FRANCES AREA

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 SECTION	5 FACE HEIGHT Feet (Metres)	6 QUARRY STATUS

– NONE –

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, FORT FRANCES AREA

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED QUARRIABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
Type A							
1a & 1b	0-3 (0-1)	100 (40)	40 (16)	–	60 (24)	60 (18)	13 (12)
	3-25 (1-8)	1450 (585)	310 (125)	–	1140 (460)	60 (18)	255 (231)
		1550 (630)	350 (142)		1200 (485)		270 (245)
Type B							
2a, 2b, 2c & 2d	0-3 (0-1)	480 (194)	60 (24)	–	420 (170)	60 (18)	93 (84)
	3-25 (1-8)	3600 (1460)	1900 (770)	–	1700 (690)	60 (18)	375 (340)
		4100 (1660)	1960 (795)		2120 (860)		470 (425)
Type C							
3a, 3b & 3c	0-3 (0-1)	480 (194)	80 (32)	–	400 (162)	60 (18)	89 (81)
	3-25 (1-8)	4000 (1620)	1000 (405)	–	3000 (1210)	60 (18)	670 (610)
		4500 (1820)	1080 (435)		3400 (1380)		760 (690)
		10,200 (4150)	3400 (1380)		6700 (2700)		1500 (1360)

TABLE 7 | SUMMARY OF TEST HOLE DATA, FORT FRANCES AREA

CROZIER TOWNSHIP

Test Hole Number: CR-TH-1

Location: Section 22, Crozier Township

Elevation: Approx. 1150 feet (350 m) a.s.l.

Date: August 29, 1981

Depth Feet (metres)	Description
0-25 (0-8)	very stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts.
25-30 (8-9)	stiff, moist, calcareous, bluish gray clay
	end of hole at 30 feet (9 m)

Test Hole Number: CR-TH-2

Location: Section 24, Crozier Township

Elevation: Approx. 1130 feet (344 m) a.s.l.

Date: August 25, 1981

Depth Feet (metres)	Description
0-8 (0-2)	very loose, moist, black organic material
8-30 (2-9)	stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts
30-42 (9-13)	stiff, moist, calcareous, dark gray, silty clay
42-43.5 (13-13.3)	dense, moist, very fine, bluish gray sand
	end of hole at 43.5 feet (13.3 m)

TABLE 7 | SUMMARY OF TEST HOLE DATA, FORT FRANCES AREA

Test Hole Number: CR-TH-3

Location: Section 15, Crozier Township

Elevation: Approx. 1150 feet (350 m) a.s.l.

Date: August 27, 1981

Depth Feet (metres)	Description
0-42 (0-13)	very stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts
	hole became wet at 40 feet (12 m) split spoon bouncing at 42 feet (13 m) bedrock suspected at 42 feet (13 m)
	end of hole at 42 feet (13 m)

Test Hole Number: CR-TH-4

Location: Section 13, Crozier Township

Elevation: Approx. 1120 feet (342 m) a.s.l.

Date: August 26, 1981

Depth Feet (metres)	Description
0-40 (0-12)	very stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts
	end of hole at 40 feet (12 m)

TABLE 7 | SUMMARY OF TEST HOLE DATA, FORT FRANCES AREA

Test Hole Number: CR-TH-5

Location: Section 13, Crozier Township

Elevation: Approx. 1100 feet (335 m) a.s.l.

Date: August 25, 1981

Depth Feet (metres)	Description
0-15 (0-5)	stiff, moist, calcareous, bluish gray, silty clay with ½ foot (0.15 m) of fine to medium, water bearing gravel seam at 15 feet (5 m)
15-40 (5-12)	firm, moist to wet, calcareous, bluish gray clay
	end of hole at 40 feet (12 m)

Test Hole Number: CR-TH-6

Location: Section 10, Crozier Township

Elevation: Approx. 1130 feet (344 m) a.s.l.

Date: August 26, 1981

Depth Feet (metres)	Description
0-5 (0-1.5)	loose, wet, yellowish gray, medium to coarse sand (perched water table to 5 feet (1.5 m))
5-35 (1.5-11)	very stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts
	end of hole at 35 feet (11 m)

TABLE 7 | SUMMARY OF TEST HOLE DATA, FORT FRANCES AREA

Test Hole Number: CR-TH-7

Location: Section 9, Crozier Township

Elevation: Approx. 1150 feet (350 m) a.s.l.

Date: August 27, 1981

Depth Feet (metres)	Description
0-38 (0-12)	very stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts
38-47 (12-14)	dense, dry, medium to coarse, bluish gray sand with some coarse gravel (Precambrian material) split spoon bouncing at 47 feet (14 m) bedrock or boulder suspected
	end of hole at 47 feet (14 m)

Test Hole Number: CR-TH-8

Location: Section 11, Crozier Township

Elevation: Approx. 1150 feet (350 m)

Date: August 26, 1981

Depth Feet (metres)	Description
0-35 (0-11)	very stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts
	end of hole at 35 feet (11 m)

TABLE 7 | SUMMARY OF TEST HOLE DATA, FORT FRANCES AREA

DEVLIN TOWNSHIP

Test Hole Number: DN-TH-1

Location: Section 9, Devlin Township

Elevation: Approx. 1150 feet (350 m) a.s.l.

Date: August 29, 1981

Depth Feet (metres)	Description
0-40 (0-12)	stiff, moist, calcareous, dark gray, silty clay <u>till</u> with trace of angular to subangular limestone and occasional Precambrian clasts
	hole became wet below 15 feet (5 m); water bearing, medium to fine <u>sand</u> seam at 20 feet (6 m) to 22 feet (7 m)
	end of hole at 40 feet (12 m)

Test Hole Number: DN-TH-2

Location: Section 8, Devlin Township

Elevation: Approx. 1125 feet (343 m) a.s.l.

Date: August 28, 1981

Depth Feet (metres)	Description
0-20 (0-6)	very stiff, moist, calcareous, dark gray, silty clay <u>till</u> with trace of angular to subangular limestone and occasional Precambrian clasts
	end of hole at 20 feet (6 m)

TABLE 7 | SUMMARY OF TEST HOLE DATA, FORT FRANCES AREA

Test Hole Number: DN-TH-3

Location; Section 6, Devlin Township

Elevation: Approx. 1140 feet (348 m)

Date: August 28, 1981

Depth Feet (metres)	Description
0-39 (0-12)	very stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts
39-43 (12-13)	dense, wet, bluish gray, medium to coarse sand and gravel (Precambrian material)
	split spoon bouncing at 43 feet (13 m) bedrock or boulder suspected
	end of hole at 43 feet (13 m)

TABLE 7 | SUMMARY OF TEST HOLE DATA, FORT FRANCES AREA

RODDICK TOWNSHIP

Test Hole Number: RK-TH-1

Location: Section 28, Roddick Township

Elevation: Approx. 1100 feet (335 m)

Date: August 27, 1981

Depth Feet (metres)	Description
0-35 (0-11)	very stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts
	end of hole at 35 feet (11 m)

WOODYATT TOWNSHIP

Test Hole Number: WD-TH-1

Location: Section 33, Woodyatt Township

Elevation: Approx. 1150 feet (350 m)

Date: August 28, 1981

Depth Feet (metres)	Description
0-20 (0-6)	very stiff, moist, calcareous, dark gray, silty clay till with trace of angular to subangular limestone and occasional Precambrian clasts
	same material suspected with depth
	end of hole at 20 feet (6 m)

TABLE 7 | SUMMARY OF TEST HOLE DATA, FORT FRANCES AREA

Test Hole Number: WT-TH-2

Location: Section 27, Woodyatt Township

Elevation: Approx. 1115 feet (340 m)

Date: August 28, 1981

Depth Feet (metres)	Description
0-9 (0-3)	compact, wet, yellowish, medium to coarse sand (very high limestone content)
9-20 (3-6)	very stiff, moist, calcareous, silty clay till with trace angular to subangular limetone and occasional Precambrian clasts
	same material anticipated with depth
	end of hole at 20 feet (6 m)

Test Hole Number: WT-TH-3

Location: Section 21, Woodyatt Township

Elevation: Approx. 1100 feet (335 m)

Date: August 28, 1981

Depth Feet (metres)	Description
0-5 (0-1.5)	stiff, moist, calcareous, bluish gray clay
5-30 (1.5-9)	very stiff, moist, calcareous, dark gray, silty clay till with trace angular to subangular limestone and occasional Precambrian clasts
	end of hole at 30 feet (9 m)

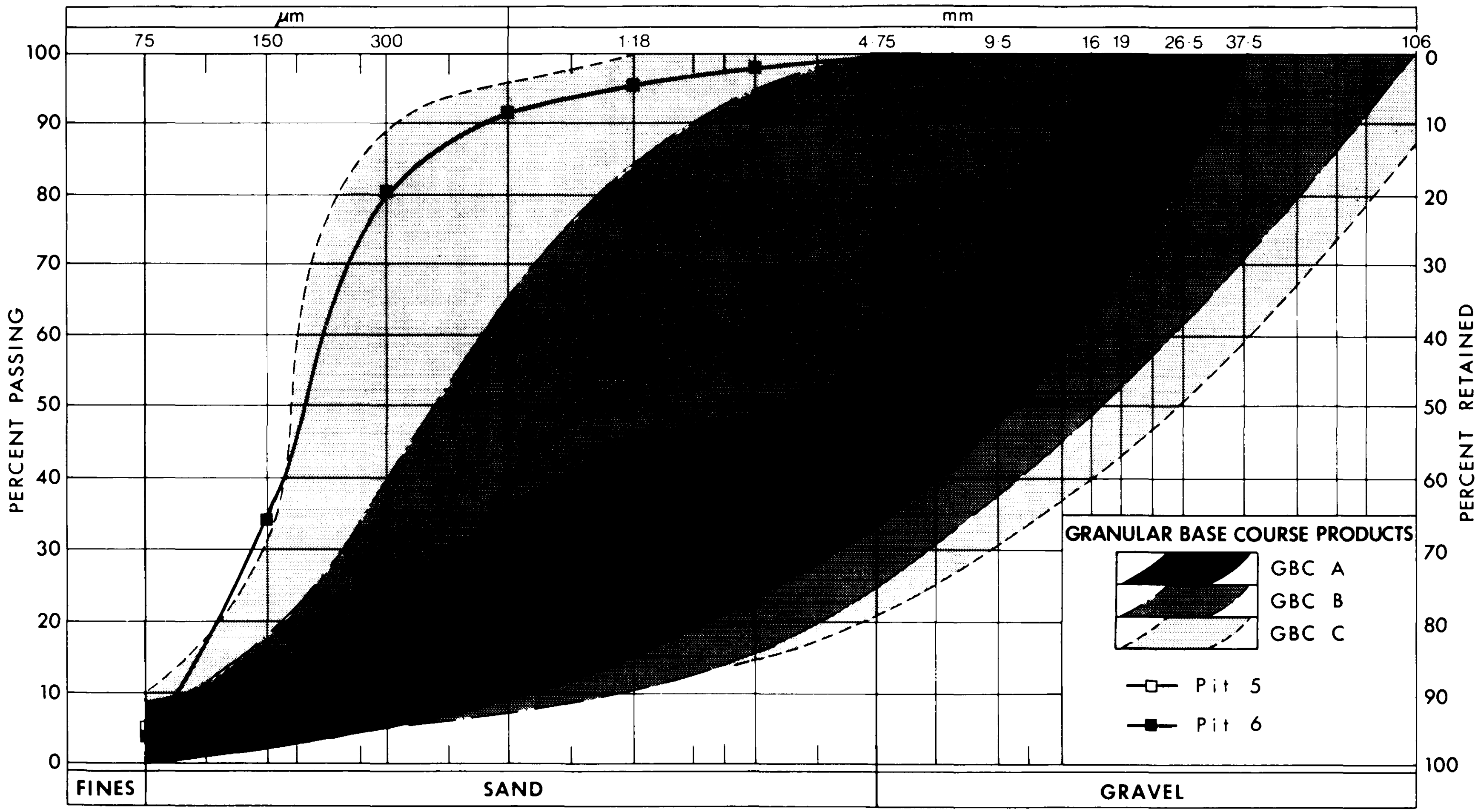


FIGURE 3a: AGGREGATE GRADING CURVES, FORT FRANCES AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

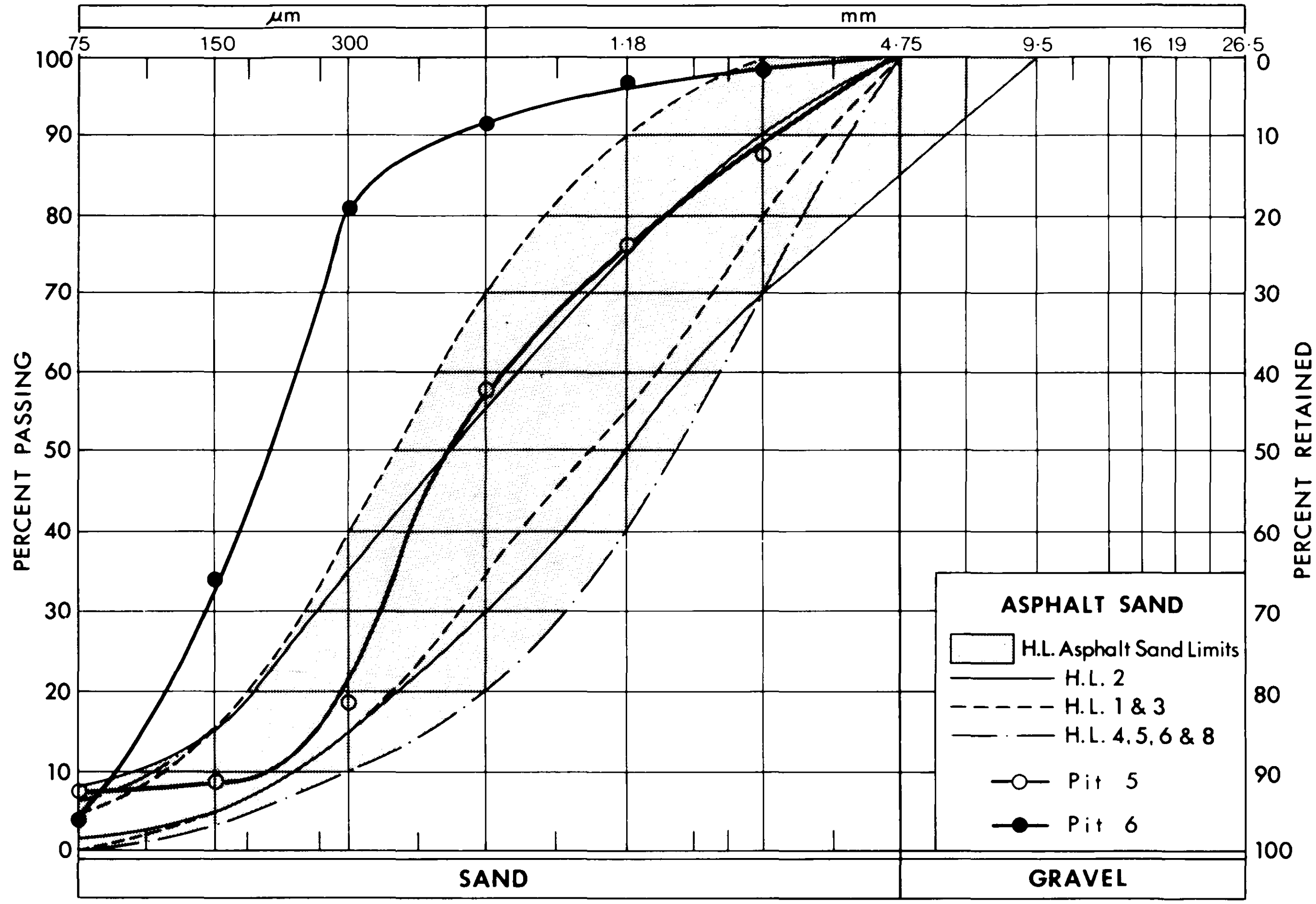


FIGURE 3b: AGGREGATE GRADING CURVES, FORT FRANCES AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1003, 1979).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

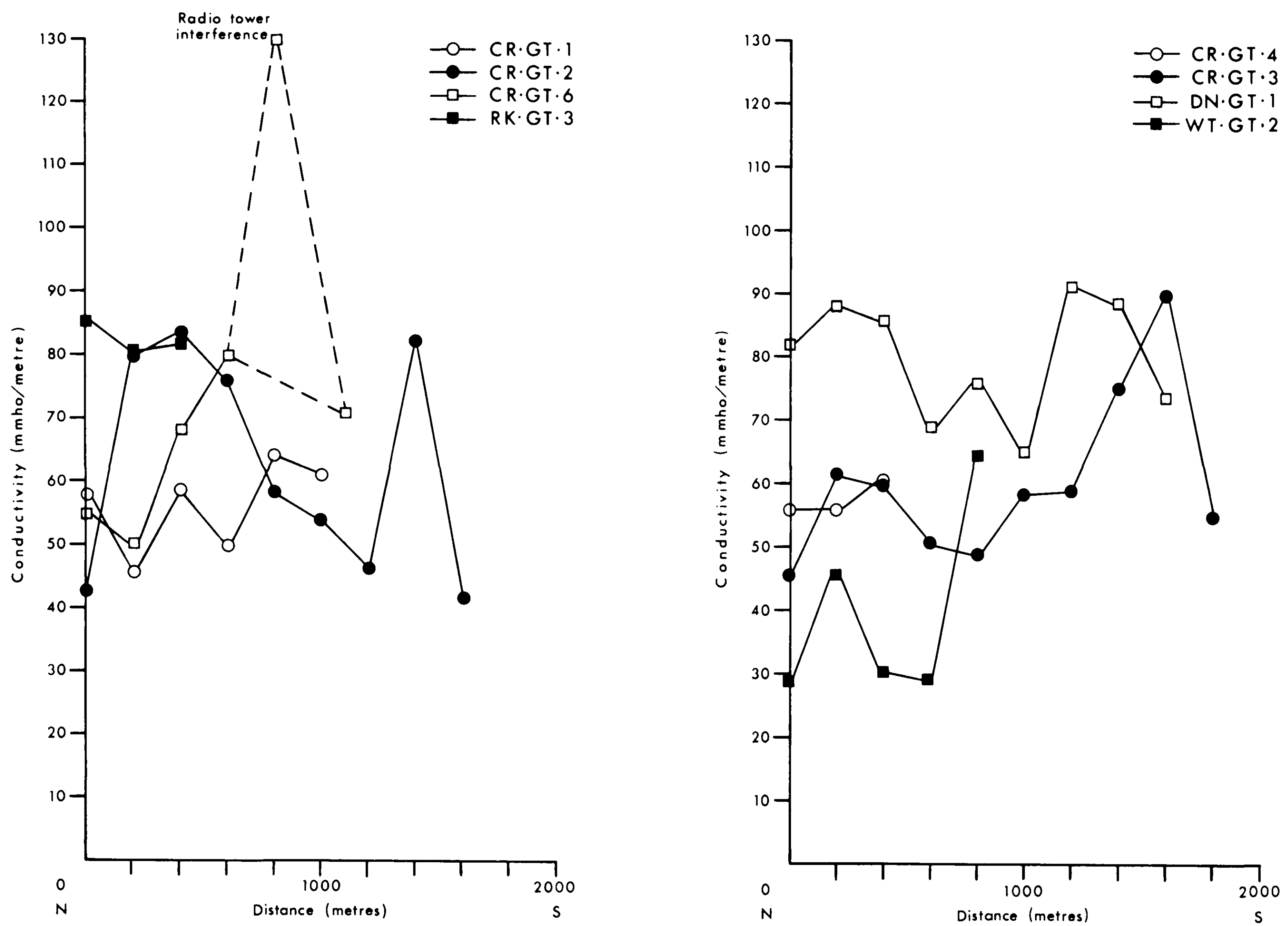


FIGURE 4a: SUMMARY OF GEOPHYSICS TRAVERSE DATA, FORT FRANCES AREA

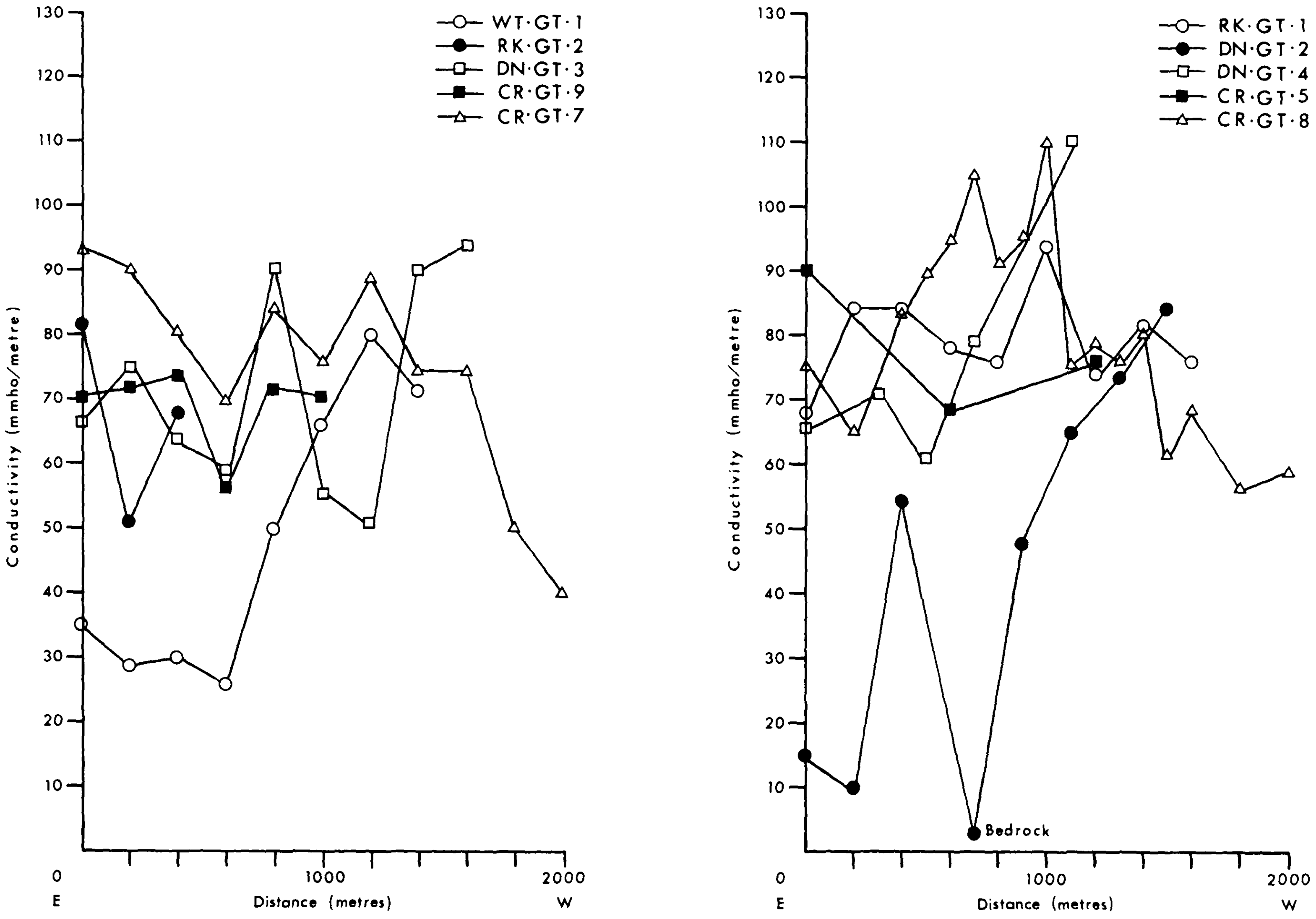


FIGURE 4b: SUMMARY OF GEOPHYSICS TRAVERSE DATA, FORT FRANCES AREA

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APPENDIX B - GLOSSARY

ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the impact strength of aggregate. This measurement gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE

Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

CLAST

An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass. Synonyms include particle and fragment.

DELETERIOUS LITHOLOGY

A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregate. Such lithologies as chert, shale, siltstone, and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DOLOSTONE

A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT

A general term for all unconsolidated rock debris transported from one place and deposited in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN

A low, smoothly rounded, elongated hill, mound, or ridge consisting of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN

Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES

A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

GNEISS

A coarse textured metamorphic rock with the minerals arranged in parallel streaks or bands, but lacking schistosity. Gneiss is relatively rich in feldspar. Other common minerals found in this rock include quartz, mica, amphibole and garnet.

GRADATION

The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The industrial gradation classification for different particles is as follows:

Boulders	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Fines: Silt, Clay	less than 0.075 mm

GRANITE

A coarse-grained, light-coloured rock that ordinarily has an even texture and consists of quartz, and feldspar with either mica, hornblende or both.

GRANULAR BASE COURSE

Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability, and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C, which are usually pit-run or other unprocessed aggregate.

H.L. (HOT-LAID OR ASPHALTIC AGGREGATE)

Bituminous, cemented aggregate used in the construction of pavements either as surface or bearing course (H.L. 1, 3, and 4), or as binder course (H.L. 2, 6, and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY

The description of rocks on the basis of such characteristics as color, structure, mineralogic composition, and grain size. Generally, the description of the physical character of a rock.

MAGNESIUM SULPHATE SOUNDNESS TEST

This test is designed to simulate the action of freezing and thawing on aggregate. Those aggregates which are susceptible will usually breakdown and give high losses in this test.

MELTWATER CHANNEL

A drainage way, usually terraced, produced by water flowing away from a melting glacier margin.

PETROGRAPHIC EXAMINATION

An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of aggregate.

PLEISTOCENE

An Epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity.

POSSIBLE RESOURCE

Estimates of mineral aggregate material based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

PRECAMBRIAN

The earliest geologic period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

SHALE

A fine-grained, sedimentary rock formed by the consolidation of clay, silt, or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

SOUNDNESS

The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of roadbuilding and construction aggregate.

TILL

Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN

Pertaining to the last glacial stage of the Pleistocene Epoch in North America. The Wisconsinan Stage began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

APPENDIX C - GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice; and those that were deposited by meltwaters carrying materials beyond the ice margin.

ICE-CONTACT TERRACES (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain size distribution.

KAMES (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good-quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the presence of excess fines (silt- and clay-sized particles).

ESKERS (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

UNDIFFERENTIATED ICE-CONTACT STRATIFIED DRIFT (IC)

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. These deposits are given a qualitative rating based on existing pit and other subsurface data.

OUTWASH (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the glacier. Outwash deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash has good horizontal bedding and is uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregate in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

ALLUVIUM (AL)

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt-and clay-sized material. There are no large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

GLACIOLACUSTRINE BEACH DEPOSITS (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the underlying material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

GLACIOLACUSTRINE DELTAS (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In Ontario, such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

GLACIOLACUSTRINE PLAINS (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

END MORAINES (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregate within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best resource areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

WINDBLOWN FORMS (WD)

Windblown deposits are those formed by the transport and deposition of sand by wind. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost invariably consist of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

APPENDIX D - GEOLOGY OF BEDROCK DEPOSITS (After Davies (1973))

FELSIC INTRUSIVE ROCKS

Rock Type A: Massive to foliated, grey granodiorite and quartz monzonite. Granodiorite consists of unzoned equidimensional plagioclase grains with microcline, quartz and biotite in typical igneous textures. Total feldspar content is about 70 percent. The quartz content is in most places close to 25 percent, with biotite, hornblende and other ferromagnesians taking up less than 5 percent of the total mineral content.

Quartz monzonite has the same minerals as granite, except that one-third to two-thirds of the total feldspar is oligoclase-andesine. The percentage of dark minerals is also usually higher. Variation towards monzonitic composition occurs in areas where this rock type has invaded the metasediments. In these areas, the rock type displays distinct foliation, higher biotite and locally increased magnetite content.

Rock Type B: Porphyritic granodiorite and quartz monzonite. This rock type is mineralogically very similar to rock Type A. The exception is the presence of microcline phenocrysts 5 to 35 mm in length set in a groundmass of oligoclase grains 1 to 3 mm in size. Total feldspar content is 60 to 65 percent. Quartz content is about 25 percent and the rest is made up of mafic minerals. Quartz and biotite tend to appear in elongate clusters. This rock type is found adjacent to metasedimentary and metavolcanic rocks.

MAFIC INTRUSIVE ROCKS

Rock Type C: Gabbro, diorite and syenodiorite. This rock type underlies a large portion of Devlin Township. These rocks display medium- to coarse-grained texture with mafic mineral content in excess of 25 percent. Gabbro is believed to consist of 50 to 60 percent labrodorite feldspar and the remainder is taken up by two kinds of pyroxenes.

The felsic intrusions represented by rock Type A have modified the mineralogy of rock Type C. According to Davies (1973), the original rock type was a two-pyroxene gabbro with 60 to 65 percent plagioclase, which was altered by the introduction of some quartz, altering the pyroxenes to amphibolite, which in turn was replaced by biotite. On the basis of present condition, the rock is called a diorite or a syenodiorite if microcline content is high.

MAFIC AND INTERMEDIATE METAVOLCANIC ROCKS

Rock Type D: Andesite and dacite tuff, lapilli tuff breccia and hornblende schist (which in part may be metasedimentary). In andesite, quartz occurs predominantly in the matrix in small grains mixed with feldspar. In dacite the quartz occurs in phenocrysts, as well as in the matrix. Dacites contain more silica and may be more susceptible to alkali-silica reactions.

Tuffs, in general, are ejected during volcanic explosions. Tuffs are deposited in either air or water and so share in the characteristics, structures and associations of sediments. Because of this two-fold character, many tuffs display seemingly contradictory properties and can be puzzling for field geologists.

The metavolcanic rocks underlying the western half of Crozier Township and the eastern part of Devlin Township have been interpreted as lying stratigraphically above the metasedimentary rocks of Crozier Township. The grey, weathering basaltic and andesitic rocks of this type in Crozier Township display pillow structures, indicating tops to the west. At other exposures, the presence of primary structures and bedding were not observed as noted by Davies (1973). Rock Type D may be found included with rock Type E, because of the frequent complex interlayering of metasedimentary rocks with metavolcanic rocks.

METASEDIMENTARY ROCKS

Rock Type E: Rock Type E includes sandstone, siltstone, felsic tuff, siliceous schist, greywacke, argillite, tuff, hornblende and biotite schist (which in part may be metavolcanic). They are interpreted to underly much of Crozier, Roddick and Woodyatt Townships. The origin of these metasedimentary rocks, which are predominantly schists derived from greywacke, siltstone, argillite with some pebble conglomerate and sandstone, can be explained by textural, structural, and/or mineralogical changes brought about by a change in pressure, temperature, stress or chemical environment or any combination of these four. Because of frequent interlayering, metavolcanic rocks belonging to rock Type D are often included with rock Type E.

LEGEND

(Continued from right margin)

SYMBOLS

(solid line)	Geological and aggregate thickness boundary of sand and gravel deposits.
(dash line)	Municipal, township boundary.
● 2	Sand or gravel pit; identification number; see Table 2.
(stippled area)	Extracted area of sand and gravel pits.
CR-GT-3	Geophysical traverse line; identification number; see Figures 4a & 4b.
CR-TH-2	Test hole location; identification number; see Table 7.
O 6/23 G	Selected water well location. Layers of materials are described by: reported thickness of material (in feet); reported type of material (number only - overburden, G- gravel, S - sand, C - clay, T - till, B - boulders, Bk - bedrock).
G 1 IC/C·O	Deposit symbol; see below.
(circle)	Texture symbol; see below; see Figures 3a and 3b.

TEXTURE SYMBOL

Fines: silt and clay (<.075 mm)
Sand (.075 - 4.75 mm)
Gravel (>4.75 mm)

The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

DEPOSIT SYMBOL

Gravel Content — Geological Type
G 1 IC / C·O
Thickness Class — Quality Indicator

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e. material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per acre. Geological Type refers to geologic origin. Quality Indicator describes objectionable grain size and lithology.

Gravel Content

- **G** Greater than 35% gravel.
- **S** Less than 35% gravel.

Thickness Class

Class	Average Thickness in Feet (Metres)	Tons per Acre	Tonnes per Hectare
1	greater than 20 (>6)	greater than 50,000	greater than 112 000
2	10 - 20 (3 - 6)	25,000 - 50,000	56 000 - 112 000
3	5 - 10 (1.5 - 3)	12,500 - 25,000	28 000 - 56 000
4	less than 5 (<1.5)	less than 12,500	less than 28 000

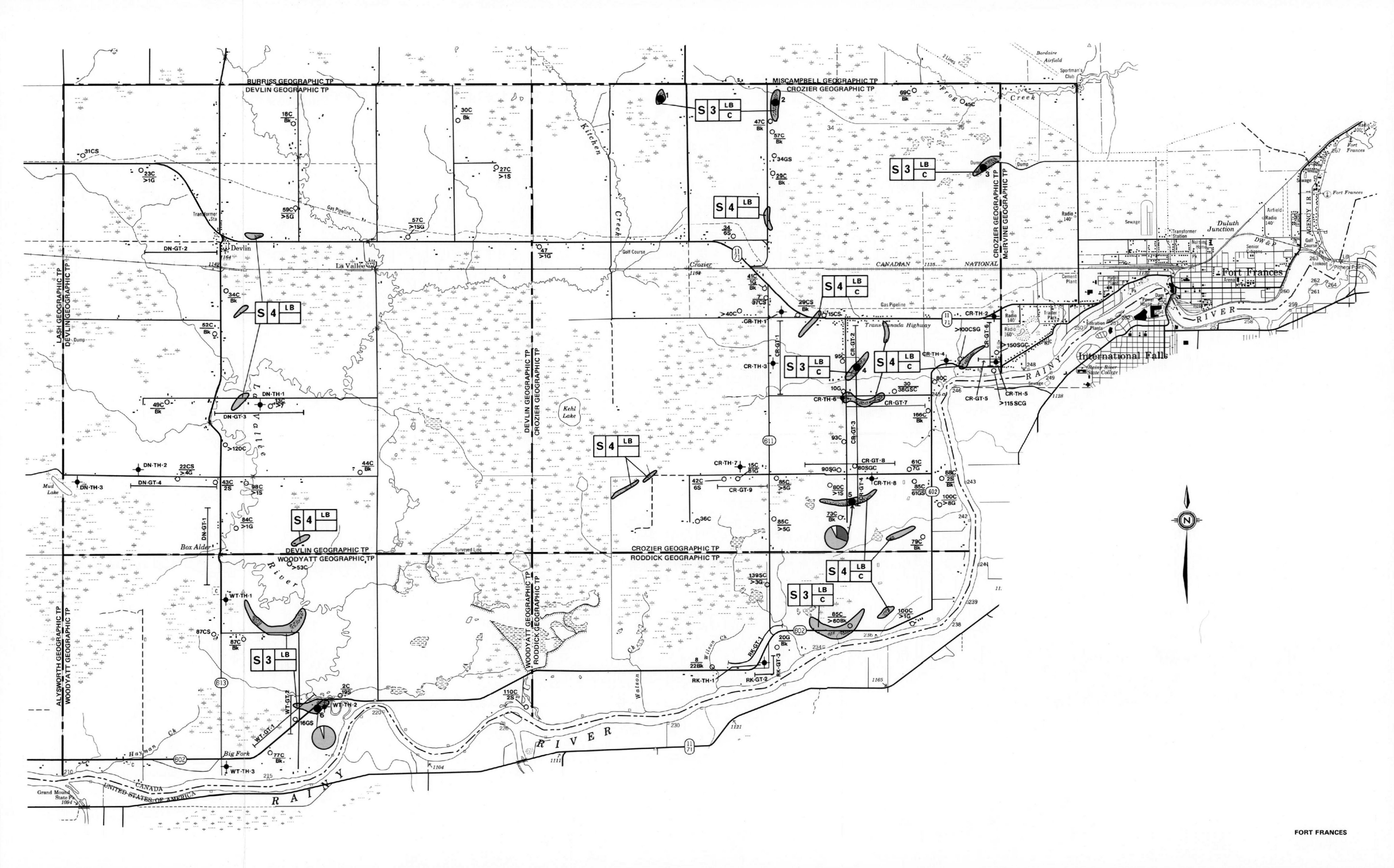
Geological Type

AL	Older Alluvium	K	Kame
E	Esker	LB	Lacustrine Beach
EM	End Moraine	LD	Lacustrine Delta
IC	Undifferentiated Ice-Contact Stratified Drift	LP	Lacustrine Plain
		OW	Outwash
ICT	Ice-Contact Terrace	WD	Windblown Forms

(see Appendix C for descriptions of Geological Types)

Quality Indicator

If blank, no known limitations present.
- **C** Clay and/or silt (fines) present in objectionable quantities.
- **L** Deleterious lithologies present.
- **O** Oversize particles or fragments present in objectionable quantities.



Ministry of Natural Resources
Ontario
Hon. Alan W. Pope, Minister
W.T. Foster, Deputy Minister

ONTARIO GEOLOGICAL SURVEY

AGGREGATE RESOURCES INVENTORY

FORT FRANCES AREA

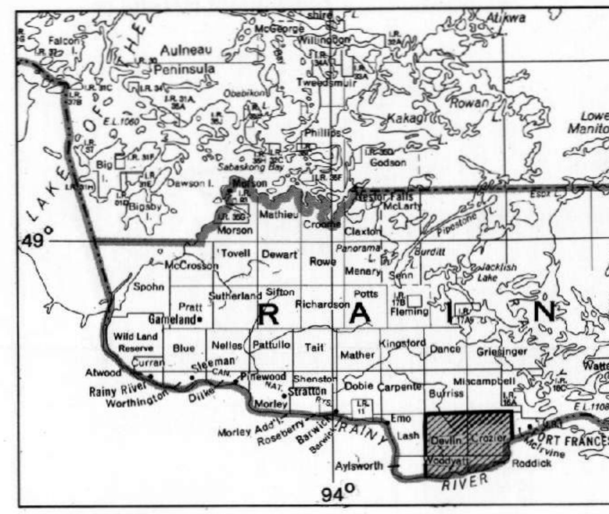
CROZIER, DEVLIN, RODDICK and WOODYATT GEOGRAPHIC TOWNSHIPS

RAINY RIVER DISTRICT

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale 1: 50 000
Mile 1 — 0 — 1 Mile
Metres 1000 — 0 — 1 Kilometre

NTS Reference: **52 C/11, 52 C/12**



Location Map — Scale: 1 inch to 25 miles

LEGEND

(Some map units and symbols may not apply to this map.)

MAP UNITS

- Gravel deposit.
- Sand deposit.
- Gravel overlain by other surficial material.
- Sand overlain by other surficial material.
- Other surficial deposits or exposed bedrock.

(Continued at left margin)

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected water well data from the Ontario Ministry of the Environment.
Test hole data from Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Natural Resources; Ontario Ministry of Transport and Communications; other sources (see Table 7).
Geology by: W. A. Johnston, 1915.
S. C. Zoltai, 1965.

Terrain Evaluation by: M. A. Roed, 1980.
Additional Fieldwork by: Staff of the Aggregate Assessment Office.
Compilation and Drafting by: Staff of the Aggregate Assessment Office.
This map is to accompany O.G.S. Aggregate Resources Inventory Paper 92.
This map is published with the permission of E. G. Pye, Director, Ontario Geological Survey.
Issued 1983.

Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.

LEGEND

MAP UNITS

(1) Selected sand and gravel resource area, primary significance; deposit number; see Table 3.

Selected sand and gravel resource area, secondary significance.

Selected sand and gravel resource area, tertiary significance.

NOTE: There are no deposits selected at the primary and secondary levels of significance. All deposits are included at the tertiary level of significance.

SYMBOLS (Some symbols may not apply to this map)

Geological and aggregate thickness boundary of sand and gravel deposits.

Municipal, township boundary

● 2 Sand or gravel pit; identification number; see Table 2.

Extracted area of sand and gravel pits.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Geology by: W. A. Johnston, 1915.

S. C. Zoltai, 1965.

Terrain Evaluation by: M. A. Roed, 1980.

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FORT FRANCES AREA

CROZIER, DEVLIN, RODDICK and WOODYATT GEOGRAPHIC TOWNSHIPS

RAINY RIVER DISTRICT

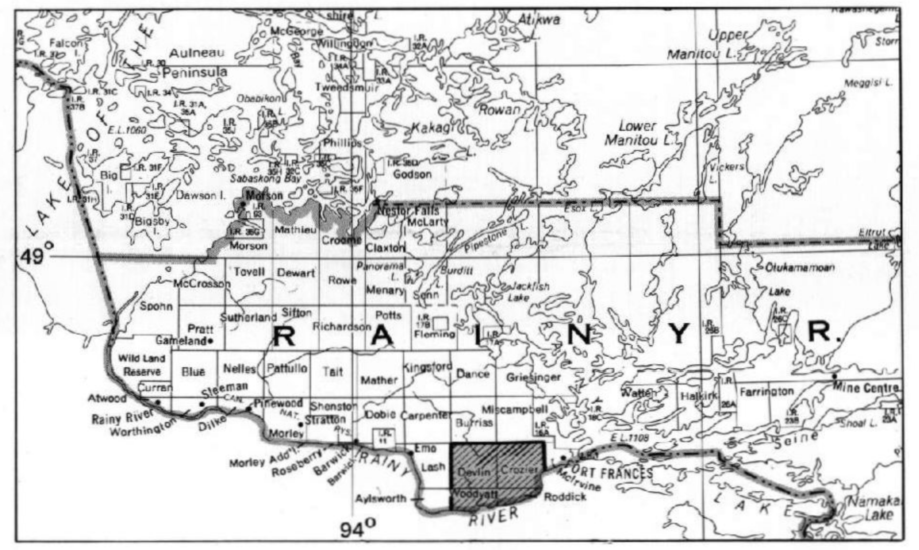
MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale 1: 50 000

Mile 1 — 0 — 1 Mile

Metres 1000 — 0 — 1 Kilometre

NTS Reference: 52 C/11, 52 C/12



Location Map

Scale: 1 inch to 25 miles

LEGEND

(Continued from right margin)

BEDROCK UNITS (Some bedrock units may not apply to this map.)

Felsic Intrusive Rocks

A Massive Gray Granodiorite and Quartz Monzonite

B Porphyritic Granodiorite and Quartz Monzonite

Mafic Intrusive Rocks

C Gabbro, Diorite, Syenodiorite

Mafic and Intermediate Metavolcanic Rocks

D Andesite and Basalt Flows; Andesite and Dacite Tuff, Lapilli Tuff Breccia; Hornblende Schist (in part may be Metasedimentary)

Metasedimentary Rocks

E Sandstone, Siltstone, Felsic Tuff, Siliceous Schist, Greywacke, Argillite Tuff, Hornblende and Biotite Schist (in part may be Metavolcanic)

SYMBOLS (Some symbols may not apply to this map)

(1) Selected bedrock resource area; deposit number; see Table 6.

Geological boundary.

25 Drift thickness contour (3-foot and 25-foot contours are shown).

Municipal, township boundary.

● Q2 Quarry; identification number.

x Isolated bedrock outcrop.

○24 Selected water well location; reported depth to bedrock (in feet).

47 OGS test hole; identification number.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Selected water well data from the Ontario Ministry of the Environment.

Geology by: J. C. Davies, 1973.

Terrain Evaluation by: M. A. Roed, 1980.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

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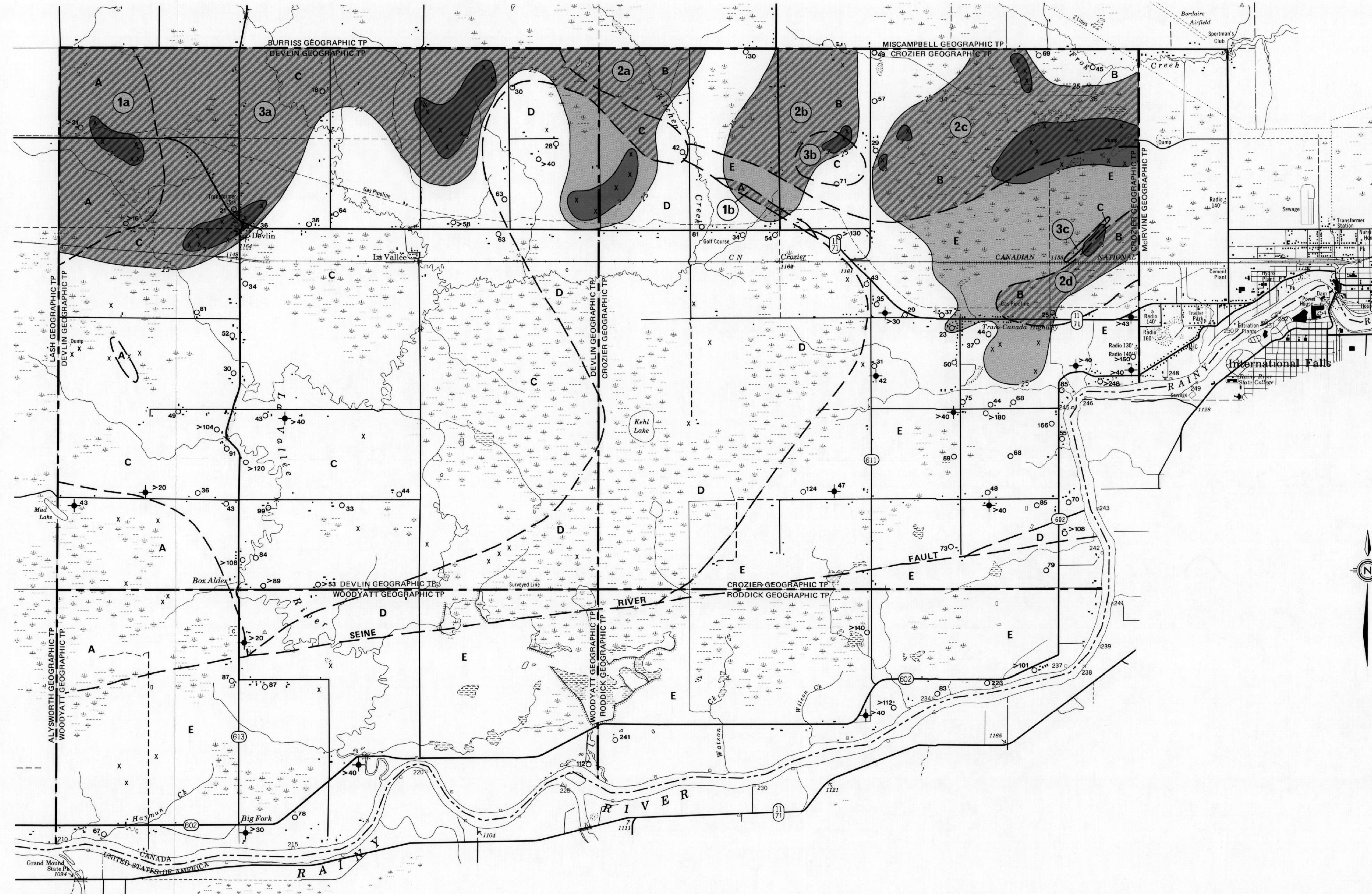
Issued 1983.



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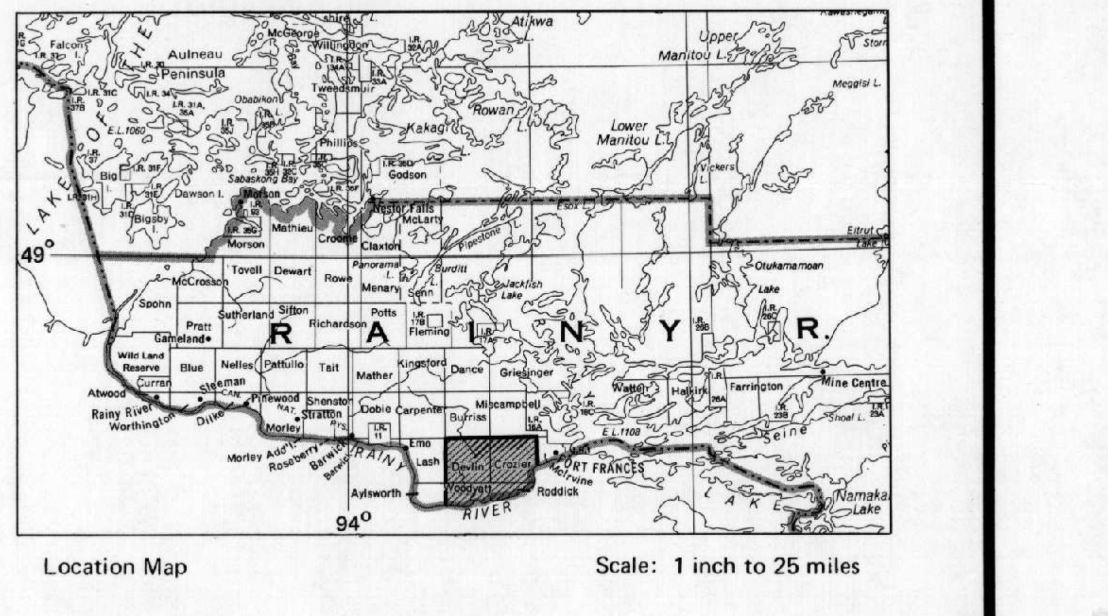
MAP 3
BEDROCK RESOURCES

Scale 1: 50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: **52 C/11, 52 C/12**



Location Map Scale: 1 inch to 25 miles

LEGEND

DRIFT THICKNESS

Bedrock outcrop: areas of exposed bedrock partially covered by an irregular veneer of drift. Drift thickness is generally less than 3 feet (1 m); see Table 4.

Bedrock drift complex: areas of bedrock covered by an irregular veneer of drift. Drift thickness is generally less than 25 feet (8 m) but may exceed 65 feet (20 m) in bedrock depressions. Isolated bedrock outcrops may occur; see Table 4.

Drift-covered bedrock: areas of bedrock generally covered by more than 25 feet (8 m) of drift. The areas contain isolated outcrops and small areas of thin drift as well as local areas of considerably thicker drift.

(Continued at left margin)