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Aggregate Resources Inventory
Paper 65

Aggregate Resources Inventory of

Oro Township

Simcoe County

Southern Ontario

By Staff of the Engineering and
Terrain Geology Section
Ontario Geological Survey

1984

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Project Supervisor: Dale W. Scott
Field Work and Report by: R. Gorman
Compilation and Drafting by: Staff of the Aggregate Assessment Office

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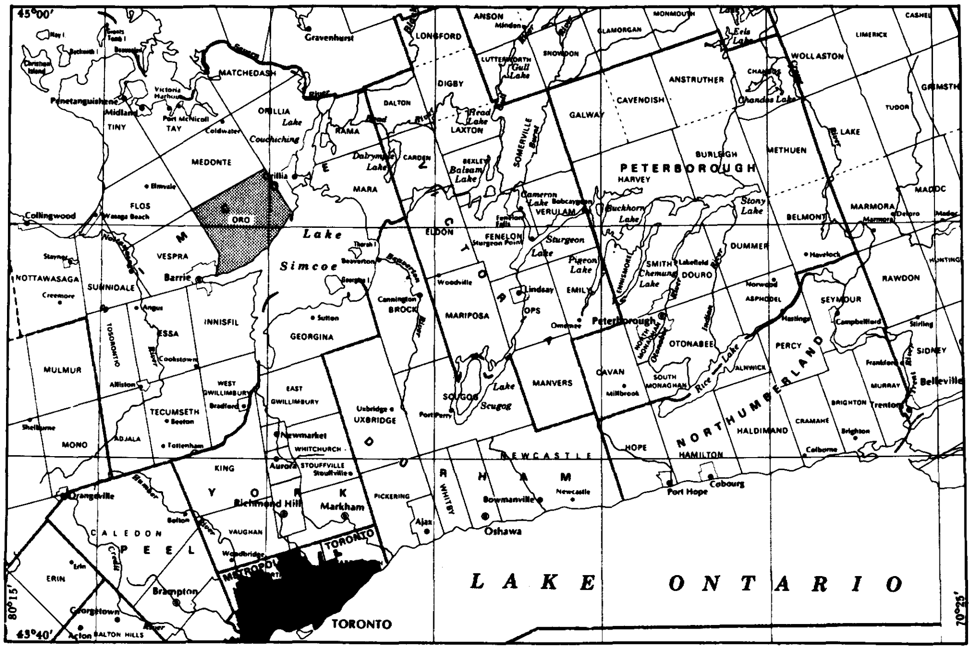

Figure 1 - Key Map Showing Location of Oro Township, Scale 1:1 800 000.

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in Oro Township. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under The Pits and Quarries Control Act, 1971.

In Oro Township, five areas containing significant amounts of sand and gravel have been selected as Resource Areas of Primary Significance. The Selected Areas occupy an available area of 3150 acres (1280 ha), containing resources of 215 million tons (195 million tonnes). The resource areas represent 10 percent of the total area occupied by sand and gravel deposits in the township, and 15 percent of the total resource tonnage.

Oro Township is underlain by bedrock of the Bobcaygeon and Verulam Formations. Since both formations are covered by more than 50 feet (15 m) of drift throughout most of the township, no areas have been selected for possible resource protection.

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 wholly or partially reserved for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCES INVENTORY OF ORO TOWNSHIP[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 1979, the total tonnage of mineral aggregates extracted was 144 million tons (131 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1980).

Although mineral aggregate deposits are plentiful in southern Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they 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 municipality's resources.

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

[1] Manuscript accepted for publication by Chief, Engineering and Terrain Geology Section, December 31, 1983.

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PART I - INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References). 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, 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 subsurface 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 either from existing pit faces or from test pits dug by backhoe. The samples were analysed for grain size distribution and in some cases for petrographic assemblage. Analyses were performed by the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications. In areas of limited subsurface exposure, drilling using a powered hollow stem auger was undertaken. The stratigraphic sections in these test holes are described in drill logs included in the report as Table 7. In some cases samples taken during the course of the drilling were analysed to determine grain size distribution. The symbols for and locations of test hole sites are noted on Map 1.

In the office, the pit and field sample data were supplemented by information on file with the Soils and Aggregates Section 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 location, size, and depth of extraction of pits licenced under The Pits and Quarries Control Act, 1971 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 used in some areas to corroborate thickness estimates, or to indicate the presence of buried granular material. These records were used only in conjunction with other evidence. Soil reports published by the Ontario Ministry of Agriculture and Food were also consulted in order to supply additional information in areas with limited data. 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 test holes and 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 represent only those parts of the deposit lying outside licenced areas (Column 2). Two successive subtractions are made from the unlicenced 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 lying outside of licenced properties 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 (Column 7) presently available for extractive development and/or resource protection.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of favorable bedrock formations overlain by less than 50 feet (15 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 workable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of a workable thickness of 60 feet (18 m) is used. Volume estimates are then multiplied by 3600 (the estimated weight in tons of a one-foot (0.3 m) thick section of dolostone, one acre (0.4 ha) in extent, assuming a bulk density of 165 pounds per cubic foot (2649 kg per cubic metre)).

Resources of sandstone are calculated using a bulk density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) or approximately 3200 tons per acre (7173 tonnes per hectare). Shale resources are calculated on the basis of a bulk density estimate of 150 pounds per cubic foot (2408 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 aggregates 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 Glossary, Appendix B).

PART II - DATA PRESENTATION AND INTERPRETATION

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. 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 thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

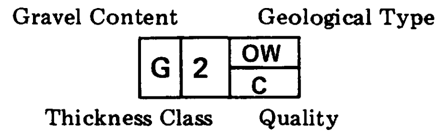
Map 1 is derived directly from the existing surficial geology maps of the area or from airphoto and field interpretation where surficial mapping is incomplete. It shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

The present level of extractive activity in the study area is indicated as follows. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are also identified and numbered on Map 1 and described in Table 2.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found 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 a given deposit. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay 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 (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate 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 identify 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 identify 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 for analysis 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, silt, and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

Test hole locations are shown on Map 1 by a solid drill hole symbol.

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. All such deposits are shown by a dark shading 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 in this report, but are indicated by a light shading 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 in a municipality, they may contain large quantities of sand and gravel and should be considered an integral component of the aggregate supply of the municipality.

Areas of tertiary significance are indicated on the map by a dashed line but have no shading. 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 (6m) and containing more than 35 percent crushable gravel 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 aggregates for various uses result from variations in the lithology of the particles composing 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 (O); 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 at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (or 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 asphaltic 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 aggregate and for road-building aggregate, so it 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 such as concrete or structures. 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", or "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. The Engineering Materials Office of the Ontario Ministry of Transportation and Communications has recently compiled a detailed assessment of aggregate suitability for selected areas in southern Ontario. This material has been consulted extensively in preparation of the inventory reports.

Analyses of unprocessed samples obtained from test holes and pits have been 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 A,B, and C; and Hot-Laid Asphaltic Sand Nos. 1, 2, 3, 4, 5, 6 and 8. By plotting the gradation 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 those 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, power lines, 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 (Column 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 pertinent District Office of the Ontario Ministry of Natural Resources.

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 at roughly 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, bedrock topography, drift thickness maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources), and from geotechnical test hole data from various sources. 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.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of the areas of thin drift are shown by three shades. The darkest shade indicates areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas of primary significance because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive sand and gravel deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, and licenced acreage of the quarry and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

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 and uses of the bedrock formations found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations of sufficient thickness to support quarry operations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource is usually consistent over large areas.

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. Three factors support this approach. First, quality and quantity variations are gradual. Second, 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 third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

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 ORO TOWNSHIP

LOCATION AND POPULATION

Oro Township occupies an area of 78,698 acres (31 849 ha) in central Simcoe County. The township is shown on portions of the Barrie (31 D/5), Beaverton (31 D/6), Elmvale (31 D/12) and Orillia (31 D/11) map sheets of the National Topographic System at a scale of 1:50 000. Oro Township is bounded by Lake Simcoe to the south, Vespra Township to the west, Medonte Township to the north and Orillia Township to the east.

The total population of Oro Township was 6919 in 1982 and figures from previous years indicate that the population has increased by approximately 40 percent between 1972 and 1982 (Ontario Ministry of Municipal Affairs and Housing 1983; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). Communities in the township include Shanty Bay, Hawkestone, East Oro and Rugby. The remainder of the population in Oro Township is rural-farm or rural-residential.

The cities of Barrie and Orillia are the two main regional trade and retail centres that serve Oro Township, but both cities lie outside the township boundary. The City of Barrie is located just outside the southwestern boundary of the township, and the City of Orillia lies east of the township. The populations of Barrie and Orillia, in 1982, were 44,111 and 23,854 respectively (Ontario Ministry of Municipal Affairs and Housing 1983). Figures from previous years indicate that between 1972 and 1982 the populations of the cities of Barrie and Orillia increased by approximately 55 and 8 percent, respectively (Ontario Ministry of Municipal Affairs and Housing 1983; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974).

If the present growth rates for Barrie and Orillia continue in the near future, additional pressure will be placed upon the extractive industry in Oro Township.

Access to sand and gravel resource areas within the township is provided by King's Highways 11 and 93, and by a network of paved and gravel-surfaced roads. A single line track of the Canadian National Railways is located between Barrie and Orillia.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography of Oro Township can be divided into the Simcoe uplands, located in the northern half of the township, and the Simcoe lowlands, which occupy parts of the southern half of the township and an area adjacent to Bass Lake (Chapman and Putnam 1966). The upland areas are characterized by thick glacial deposits such as the Bass Lake kame moraine. The lowlands are generally characterized by fine-grained lacustrine silts and clays as well as abundant swampy bottom lands.

The physiography and distribution of surficial materials in Oro Township, including the sand and gravel deposits shown on Map 1, are the result of glacial activity that took place approximately 23 000 to 10 000 years ago in the latter part of the 'Great Ice Age'. This period of time was marked by the repeated advance and melting back of extensive, continental ice sheets. Oro Township was affected by a sub-lobe of the main ice sheet, known as the Lake Simcoe lobe, which is believed to have advanced from the northeast.

Large amounts of till were deposited at the base of this ice sheet to form the Lake Simcoe Till Plains (Deane 1950). The gritty loam texture of the till resembles the Newmarket Till of Gwyn (1972). The till becomes sandier as well as more bouldery towards the north but is of little value as an aggregate source because of its excessive fines content.

After the main ice advance, warmer climatic conditions caused the ice margin to melt back. During the melting, large volumes of meltwater ponded in front of the ice margin forming glacial Lake Algonquin.

During a relatively long halt in the retreat of the margin of the glacier, the Bass Lake kame moraine was formed. This upland area rises above the level of Lake Algonquin and may have formed as a kame-delta as meltwater flowed off the ice margin. Large volumes of sand and gravel were deposited at this time. The material from the moraine is suitable for a wide range of road-building products, but locating good-quality coarse aggregate is difficult because of the variable and unpredictable nature of the materials in the moraine.

Along the main Algonquin shoreline, prominent beach deposits of sand and gravel are common, especially southeast of the community of Rugby. Aggregate from such deposits can be used for a range of road-building and construction activities. Lacustrine deposits of sand, silt and clay form the relatively flat bed of the Algonquin Lake Plain (Simcoe lowlands) at an approximate elevation of 800 feet (244 m) above sea level (a.s.l.). The lack of crushable material and the presence of fine-grained silts and clays restrict the use of lacustrine sediments to mainly fill-related purposes.

The draining of Lake Algonquin marked the end of glacial activity in the area. Postglacial erosional and depositional processes have been of minor importance in modifying the physiography in Oro Township. The only major Recent deposit in the township consists of black muck that occupies a large area west of Bass Lake (Deane 1950).

EXTRACTIVE ACTIVITY

Oro Township has large resources of high-quality sand and gravel mainly located in the Bass Lake kame moraine. Numerous sand and gravel pits have been established in Oro Township in the past. Most pits are concentrated within the Bass Lake kame moraine in the northern portion of the township, however, other pits have been opened in glaciolacustrine deposits in the eastern portion of the township.

Since the designation of the township in 1973 under The Pits and Quarries Control Act, 1971, many of the pits have become inactive. At the time of writing, eleven sources are licenced for extraction. The total area licenced for extraction in the township is 538.4 acres (217.9 ha).

Most of the pits have a "moderate to high" use rating according to criteria established by the Ontario Ministry of Transportation and Communications (M.T.C.) (Deike 1981). Most of the pits in the Bass Lake kame moraine are capable of producing high-quality coarse aggregate suitable for hot-mix asphalt paving mixes (Deike 1981). Pits 3 to 7, and 15 to 18 are all able to supply materials for Granular Base Course (G.B.C.) A and other lesser uses, however, in some cases sand control is required (Deike 1981). Licenced pits 9, 10 and 11 are located in glaciolacustrine deposits in the eastern portion of the township and are of value in supplying hot-mix paving coarse aggregate as well as aggregate for lesser uses (Deike 1981).

Records of the total annual production of sand and gravel from all licenced sources have been maintained by the Huronia District Office of the Ontario Ministry of Natural Resources since the designation of the township under The Pits and Quarries Control Act, 1971. The average annual production over the six-year period from 1975 to 1980 has been approximately 340,000 tons (310 000 tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 illustrates the occurrence of sand and gravel deposits in Oro Township. The total area occupied by these deposits is approximately 31,500 acres (12 700 ha), containing a total tonnage of 1470 million tons (1330 million tonnes). However, much of this material has low potential for use as road-building or construction aggregate.

Map 2 illustrates the Selected Sand and Gravel Resource Areas. Three of the five primary areas are located within the Bass Lake kame moraine complex, however, deposits of glaciolacustrine origin located in the eastern portion of the township have also been selected. The five Selected Areas of Primary Significance have a total area of 3700 acres (1500 ha), exclusive of licenced properties. Cultural constraints and previous extraction reduce the area presently available for resource protection to 3150 acres (1280 ha). Utilizing an average deposit thickness estimate for each resource area, the total available sand and gravel resources are estimated to be 215 million tons (195 million tonnes). The resource areas represent 10 percent of the total area occupied by sand and gravel deposits in the township, and they contain 15 percent of the total resource tonnage. The remainder of the Bass Lake kame moraine, the sand outwash deposit located along the southern border of the moraine and several glaciolacustrine beach deposits have been selected at the secondary level of significance.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 is an ice-contact stratified drift deposit located in the northeastern portion of the township and constitutes part of the Bass Lake kame moraine (Map 2). The Bass Lake kame moraine is a complex glaciofluvial deposit where meltwater streams have carried and deposited glacial drift in close contact with the ice (Deane 1950, p. 31). Test hole data (OR-TH-1 to OR-TH-13) indicate that this highly variable deposit is primarily composed of sand and gravel with minor occurrences of a sandy till. The gravels generally become coarser towards the south-central and eastern portion of the moraine (pit nos. 3, 4, 7 and 8) thus allowing a greater range of crushed products to be produced. In the north-central and western parts of the moraine the material becomes more variable and therefore poses a limitation on the number of crushed products that can be produced. Subsurface testing indicates that lenses of silt exist throughout the entire extent of the moraine, but generally at depths greater than 20 feet (6 m).

There are two licenced properties (pit nos. 7 and 8) located in Area 1. Faces in pit no. 7 exhibit 40 to 50 feet (12 to 15 m) of gravelly fine to medium sand with a 30 to 40 percent stone content. The western face of the property exposes rounded and well sorted medium to coarse gravel in a matrix of fine to medium sand. As with most sand and gravel pits in the kame moraine, pit no. 7 has been given a moderate to high pit use rating by Deike (1981) and is capable of producing a full range of products. The oversize material has to be either crushed or removed to produce Granular Base Course B (Deike 1981). The other licenced property (pit no. 8) is not yet opened but, a small 10-foot (3 m) excavation reveals similar materials as found in pit 7.

A bore hole in the western edge of the Selected Area (OR-TH-13) indicated 40 feet (12 m) of gravel with 1- to 2-inch (2.5 to 5.0 cm) diameter pebbles with a 10-foot (3 m) lens of fine sand at a depth of 30 feet (9 m) (Table 7). Water well information in the immediate vicinity north of the Selected Area indicates a considerable depth of gravelly fine to medium sand. The licenced properties, subsurface drilling and water well information all suggest that the eastern portion of the moraine has a very high potential for good-quality coarse aggregate.

Resource Area 1 occupies 315 acres (128 ha), exclusive of the licenced properties. Cultural constraints reduce the area presently available to 270 acres (109 ha). Assuming an average deposit thickness of 30 feet (9 m), sand and gravel resources are estimated to be 20 million tons (18 million tonnes). Road access to the Selected Area is good.

SELECTED SAND AND GRAVEL RESOURCE AREAS 2 AND 3

Selected Sand and Gravel Resource Areas 2 and 3 also represent ice-contact stratified drift deposits located in the central to south-central portion of the Bass Lake moraine.

The eight pits in the area (except pit 2) have been given a moderate to high pit use rating (Deike 1981). The two unlicenced pits in the central portion of the deposit (pit nos. 15 and 16) have faces ranging in height from 5 to 10 feet (1.5 to 3 m) and expose fine to medium sand and gravel with a gravel content of approximately 20 percent. Aggregate from both pits has been used for a full range of products. Oversize material must be removed or crushed for the production of either G.B.C. B or C. The sand grades dirty for hot-laid asphalt and blending is required (Deike 1981). A road cut located north of the two pits reveals a 10-foot (3 m) face of fine to medium sand on the north-central boundary of the Area.

The sand and gravel pits in the eastern section of the deposit exhibit partially slumped faces that expose fine to medium sand and poorly stratified medium to coarse gravel. Faces in these properties range in height from 10 to 30 feet (3 to 9 m) and expose stone contents ranging from 40 to 60 percent. The aggregate from the pits is suitable for G.B.C. B and blending is necessary because the sand grades fine and dirty for hot-laid products (pit no. 6) (Deike 1981).

The two licenced pits (pit nos. 3 and 4) in the south-central portion of the deposit exhibit faces ranging from 10 to 40 feet (3 to 12 m) in height and expose stratified silty fine sand and medium to coarse gravel. The stone content of both pits ranges from 40 to 60 percent. The aggregate from both pits is utilized for a full range of products, although blending is required and oversize material must be crushed or removed for G.B.C. B (Deike 1981).

Of the four test holes (OR-TH-7, 8, 9 and 11) drilled in Area 2, two test holes (OR-TH-7 and OR-TH-11) revealed 10 to 15 feet (3 to 4 m) of coarse sand and medium gravel (Figures 3a and 5a). Test hole OR-TH-9 revealed 50 feet (15 m) of well rounded gravel, suitable for crushing, below the floor of pit 4 (Figure 4a). Silt layers were discovered in test holes 7, 9 and 11. Water well data in the Area indicate a considerable depth of sandy gravel.

There are no sand and gravel pits in Resource Area 3, but the material in the deposit is expected to be similar to Area 2. One water well in the central portion of the Selected Area indicates a considerable depth of sandy gravel.

Selected Resource Areas 2 and 3 occupy available areas of 2170 acres (880 ha) and 365 acres (148 ha), respectively. Assuming an average deposit thickness of 30 feet (9 m) for Area 2 and 20 feet (6 m) for Area 3, sand and gravel resources are estimated to be 163 million tons (148 million tonnes) and 18 million tons (16 million tonnes), respectively. The Resource Areas are accessible by several gravel-surfaced roads as well as a county road.

SELECTED SAND AND GRAVEL RESOURCE AREA 4

Selected Sand and Gravel Resource Area 4 consists of three glaciolacustrine beach deposits of sand and gravel related to the abandoned shorelines of Lake Algonquin. A very prominent abandoned Algonquin shoreline can be traced continuously from Barrie to Orillia.

There is one licenced property situated in Resource Area 4 (pit no. 10). Faces in the pit are 15 feet (5 m) high and expose well sorted and well stratified fine to medium sand and gravel with a stone content ranging from 20 to 40 percent. Generally the gravel is rounded to well rounded. The property exhibits a coarse gravel layer underlain by fine to medium sand. The material from the pit is generally of value in supplying coarse aggregate for hot-mix paving and aggregate for lesser uses (Deike 1981). The sand grades dirty for hot-laid asphalt and blending is required. Road cuts in Selected Area 4 also reveal rounded medium to coarse gravels.

Selected Resource Area 4 occupies 440 acres (178 ha), exclusive of licenced properties, of which 340 acres (138 ha) are available for resource protection. Assuming an average deposit thickness of 15 feet (5 m), sand and gravel resources are estimated to total 13 million tons (12 million tonnes). Road access to the Area is good.

SELECTED SAND AND GRAVEL RESOURCE AREA 5

Selected Resource Area 5 is an ice-contact stratified drift deposit located east of Dalston. There are two pits (pit nos. 1 and 12) in the Area. Both pits have been given a moderate to high use rating by Deike (1981). Faces in the pits range in height from 10 to 15 feet (3 to 5 m) and expose a stone content of 25 to 50 percent. The aggregate in both pits is suitable for a full range of products, but sand control is required for the production of G.B.C. A (Deike 1981). Faces in the pits reveal clean, fine to medium sand and gravel as well as oversize boulders.

Selected Area 5 occupies 30 acres (12 ha), exclusive of the licenced area, of which 15 acres (6 ha) are available. Assuming an average depth of 15 feet (5 m), total sand and gravel resources are estimated to be 1 million tons (1 million tonnes). The Resource Area is accessible by gravel-surfaced roads and King's Highway 93 which is located west of the Area.

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

The remainder of the Bass Lake kame moraine has been selected as the most important Sand and Gravel Resource Area of Secondary Significance in Oro Township. Glaciolacustrine beach deposits and a substantial deposit of outwash sand constitute the township's remaining secondary resources. Protection measures should be considered for these deposits since they provide alternate extractive sites to supplement those provided by the Primary Resource Areas.

The secondary area in the Bass Lake kame moraine contains three licenced properties (pits 5, 7 and 8) and two unlicenced pits (pits 13 and (14). Pit 5 exhibits a 10- to 15-foot (3 to 5 m) face of fine sand and fine to medium gravel. The stone content ranges from 30 to 50 percent. This pit is capable of supplying materials for both G.B.C. A and other uses, as well as producing high-quality coarse aggregate that is suitable for hot-mix asphalt (Deike 1981). Pit 14 exhibits a 10-foot (3 m) face of medium to coarse sand and pebbly gravel lenses. The stone content ranges from 10 to 15 percent. Seven test holes (OR-TH-1 to 6 and 10) were drilled in the deposit, revealing varying depths of fine to coarse sand. Test hole OR-TH-1 revealed a 5-foot (1.5 m) seam of coarse gravel at an approximate depth of 45 to 50 feet (14 to 15 m). Water well data throughout this portion of the kame moraine indicate substantial depths of sand and gravel. This information also indicates that layers of loose sandy till with a minor clay content are incorporated into ice-contact sand in the northwest part of the moraine.

The glaciolacustrine beach deposits located in the Carthew Bay area also have been selected as Secondary Resource Areas. One property (pit no. 11) northeast of Hawkestone has a face ranging in height from 5 to 10 feet (1.5 to 3 m) and a stone content of approximately 25 percent. Aggregate from this pit is suitable for hot-mix paving uses but the oversize material must be removed or crushed for the production of G.B.C. C (Deike 1981).

The flat outwash deposit along the southern border of the Bass Lake kame moraine has also been selected at the secondary level of significance. The material of this deposit probably is composed of well sorted and stratified sand. One test hole (OR-TH-12) drilled in the deposit revealed 25 feet (8 m) of clean fine to medium sand. The thickness of the outwash deposit is probably affected by the undulating surface of the underlying ground moraine. This ground moraine projects through the outwash deposit as gentle rises of loose sandy till (Deane 1950).

BEDROCK GEOLOGY

Glacial deposits in Oro Township are underlain by Middle Ordovician limestones and shales of the Bobcaygeon and Verulam Formations. The distribution of the formations is shown on Map 3 (after Liberty 1969). The flat-lying bedrock surface is covered by more than 50 feet (15 m) of unconsolidated sediments.

The middle and upper members of the Bobcaygeon Formation underlie most of Oro Township. The Bobcaygeon is composed of homogeneous, thin-bedded, fine-grained limestone with some shaly partings (Liberty 1969). The two members are hard and compact and are erosion and abrasion resistant (Dolar-Mantuani 1975). The Bobcaygeon Formation has been quarried in Victoria County for road-building and construction aggregate.

The Bobcaygeon Formation is overlain by the Verulam Formation in the southwest corner of the township. The formation consists of approximately 200 feet (61 m) of fossiliferous pure to impure limestone with interbedded shale (Liberty 1969, p. 52). This formation has been quarried in other parts of southern Ontario to produce cement. It is not well suited for the production of road-building and construction aggregates because of its low abrasion resistance.

No areas in either of the two formations have been selected for possible resource protection because of the excessive thickness of drift overlying the formations.

SUMMARY

Oro Township has possible resources of sand and gravel which should be able to meet local requirements for a considerable period of time. Four ice-contact stratified drift deposits and several glaciolacustrine beach deposits have been selected for possible resource protection at the primary level of significance. These resource areas contain high-quality coarse aggregate that is suitable for most road-building and construction products. In addition, several deposits have been selected at the secondary level for possible resource protection. The secondary areas contain resources which should be considered as part of the township's aggregate supply.

The township is underlain by flat-lying bedrock of the Bobcaygeon and Verulam Formations. Neither formation has been selected for possible resource protection because of the thick drift cover overlying them.

Enquiries regarding the Aggregate Resources Inventory of Oro Township should be directed to the Ontario Ministry of Natural Resources, either at the Huronia District Office, Midhurst, Ontario, L0L 1X0 (Tel. (705) 728-2900) or at the Central Region Office, 10670 Yonge Street, Richmond Hill, Ontario, L4C 3C9 (Tel. (416) 884-9203).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, ORO TOWNSHIP

1 **CLASS NO.**	2 **DEPOSIT TYPE** (see Appendix C)	3 **AREAL EXTENT** Acres (Hectares)	4 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
1	G-IC	315 (128)	24 (22)
	G-IC	2900 (1170)	145 (132)
	S-IC	20,600 (8300)	1030 (930)
	S-OW	2600 (1050)	130 (118)
2	S-IC	30 (12)	1 (1)
	G-LB	560 (227)	21 (19)
	S-LP	2450 (990)	92 (84)
3	S-IC	630 (255)	13 (12)
	G-LB	80 (32)	2 (2)
4	S-IC	1000 (405)	10 (9)
	G-LB	175 (71)	2 (2)
		31,500 (12 700)	1470 (1330)

N.B. Minor variations in all tables are due to rounding of data.

TABLE 2 | SAND AND GRAVEL PITS, ORO TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS							
1	B03-112	Disher Farrand	23	2	22.3 (9.0)	10-15 (3-5)	25-50
2	E03-166	E.R. Alexander Const.	8	7	109.0 (44.1)	unopened	
3	E03-167	York Sand & Gravel	11	7	124.7 (50.5)	40 (12)	40-60
4	E03-42	Twp. of Oro	11	8	61.8 (25.0)	10-30 (3-9)	40-60
5	E03-165	Buck's Sand & Gravel	7	10	20.2 (8.2)	10-15 (3-5)	30-50
6	E03-152	McLeod	9	11	10.0 (4.0)	30 (9)	40
7	O11-87	Oro Sand & Stone Ltd. (Blake Uren)	9	13	25.0 (10.1)	40-50 (12-15)	30-40
8	–	Stewart Const.	9	14	117.5 (47.6)	unopened	
9	O11-41	D.A. Davis	12	13	13.6 (5.5)	20 (6)	30-40
10	O11-39	Alroy Gravel & Const. Ltd.	13	14	23.0 (9.3)	15 (5)	20-40
11	O11-34	H. Wrigley	21	13	11.3 (4.6)	5-10 (1.5-3)	25
					538.4 (217.9)		
UNLICENCED PITS*							
12	B03-112	Keyes	24	2		10 (3)	40-50
13	E03-98	Hutchinson	7	5		7-10 (2-3)	30-40

TABLE 2 | SAND AND GRAVEL PITS, ORO TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
14	E03-140	Unknown	1	5		10 (3)	10-15
15	E03-72	Cook Const.	7	8		5-10 (1.5-3)	20
16	E03-75	Middleton	8	8		5-10 (1.5-3)	20
17	E03-158	Hodgkinson	7	10		10-20 (3-6)	60
18	E03-106	Copeland	8	10		10-15 (3-5)	55

* Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREAS, ORO TOWNSHIP

1 DEPOSIT NO.	2 UNLICENCED 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)
1	315 (128)	45 (18)	0 (0)	270 (109)	30 (9)	20 (18)
2	2500 (1010)	320 (130)	10 (4)	2170 (880)	30 (9)	163 (148)
3	420 (170)	55 (22)	0 (0)	365 (148)	20 (6)	18 (16)
4	440 (178)	90 (36)	10 (4)	340 (138)	15 (5)	13 (12)
5	30 (12)	12 (5)	3 (1)	15 (6)	15 (5)	1 (1)
	3700 (1500)	520 (210)	23 (9)	3150 (1280)		215 (195)

TABLE 4 | TOTAL IDENTIFIED BEDROCK RESOURCES, ORO TOWNSHIP

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)

– NONE –

TABLE 5 | QUARRIES, ORO TOWNSHIP

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

– NONE –

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, ORO TOWNSHIP

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)

– NONE –

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-1

LOCATION: Lot 3, Con. 2

ELEVATION: Approximately 1150 feet (350 m) a.s.l.

DATE: November 4, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	light topsoil layer; very coarse sand (0.5 to 2 mm); gravel hit at 5 feet (1.5 m)
5-10 (1.5-3)	coarse gravel and fine sand (0.074 to 0.25 mm)
10-15 (3-5)	silty fine sand (0.074 to 0.25 mm)
15-20 (5-6)	silty very fine sand
20-25 (6-8)	coarse sand (0.5 to 2 mm); fine gravel mixed in possible transition zone
25-30 (8-9)	boulder; coarse sand
30-35 (9-11)	very fine sand
35-40 (11-12)	silty fine sand terminated on boulder
40-45 (12-14)	fine sand
45-50 (14-15)	medium sand (0.25 to 0.50 mm) 5-foot (1.5 m) coarse gravel seam

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-2

LOCATION: Lot 7, Con. 3

ELEVATION: Approximately 1125 feet (343 m) a.s.l.

DATE: November 5, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	very coarse sand; some fine gravel present
5-10 (1.5-3)	coarse gravel medium to coarse sand; gravels 1 to 1.5 inch (2.5 to 3.8 cm) diameter
10-15 (3-5)	sand; clayballs present
15-20 (5-6)	medium sand with large stones
20-25 (6-8)	medium to coarse sand with few stones
25-30 (8-9)	uniform fine sand; some stones present
30-35 (9-11)	medium to coarse sand with small amounts of stone present
35-40 (11-12)	coarse deposit; very well rounded large gravel
40-50 (12-15)	no sample recovered; terminated on boulder

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-3

LOCATION: (Bidwell Hill) Lot 9, Con. 5

ELEVATION: Approximately 1200 feet (366 m) a.s.l.

DATE: November 5, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	cohesive clay present in top layer; some stone present
5-10 (1.5-3)	transition to fine sand; no clay
10-15 (3-5)	clean fine sand
15-20 (5-6)	transition to coarser sand
20-30 (6-9)	coarse sand
30-35 (9-11)	coarse sand with layers of fine silt present
35-50 (11-15)	fine to medium sand

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-4

LOCATION: Lot 6, Con. 5

ELEVATION: Approximately 1200 feet (366 m) a.s.l.

DATE: November 6, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	medium to coarse sand with occasional pebbles present
5-10 (1.5-3)	medium sand with medium to coarse gravel at base (1 to 1.5 inch (2.5 to 3.8 cm) diameter)
10-20 (3-6)	medium to coarse sand with occasional gravel present
20-25 (6-8)	clean fine to medium sand
25-30 (8-9)	medium sand
30-40 (9-12)	fine to medium sand
40-45 (12-14)	compact fine to medium sand trace of gravel
45-50 (14-15)	fine to medium sand

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-5

LOCATION: Lot 3, Con. 6

ELEVATION: Approximately 1150 feet (350 m) a.s.l.

DATE: November 6, 1981

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	topsoil; gravelly medium to coarse sand present
5-15 (1.5-5)	fine to medium sand with trace of gravel present
15-20 (5-6)	very clean fine to medium sand
20-25 (6-8)	fine to medium sand with occasional pebbles
25-30 (8-9)	fine to medium sand
30-35 (9-11)	fine to medium sand with 3-inch (8 cm) layer of silt at base of sample
35-40 (11-12)	sample lost
40-45 (12-14)	augers grinding; possibly gravel seam; no sample — hit large boulder
45-50 (14-15)	silty sand mixed with broken rocks

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-6

LOCATION: Lot 5, Con. 7

ELEVATION: Approximately 1100 feet (335 m) a.s.l.

DATE: November 7, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	silty topsoil to 3 feet (1 m); underlain by silty fine to medium sand
5-10 (1.5-3)	fine to medium sand with occasional pebbles; auger intermittently grinding; trace of gravel present
10-15 (3-5)	silty sand with some find to medium gravel present; augers grinding occasionally
15-20 (5-6)	silty fine to medium sand; silt appears in occasional thin veneers
20-35 (6-11)	clean fine sand
35-40 (11-12)	no sample; water found in hole; suspect material same as above
40-45 (12-14)	no sample; wet sand; augers sinking

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-7

LOCATION: Lot 10, Con. 7

ELEVATION: Approximately 1200 feet (366 m) a.s.l.

DATE: November 10, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	already 15 feet (5 m) of coarse gravel above test hole; hit gravel at 5 feet (1.5 m); medium sand above 5 feet (1.5 m)
5-10 (1.5-3)	gravel to 10 feet (3 m); medium sand also present
10-15 (3-5)	medium to coarse sand; few pebbles
15-20 (5-6)	fine to medium sand
20-25 (6-8)	medium to fine sand with small pebbles
25-30 (8-9)	fine to medium sand; pebbly
30-40 (9-12)	silty medium sand
40-45 (12-14)	coarse sand
45-50 (14-15)	silty medium sand

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-8

LOCATION: (Timber Lot) Lot 9, Con. 8

ELEVATION: Approximately 1100 feet (335 m) a.s.l.

DATE: November 11, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	topsoil present; fine to medium sand
5-15 (1.5-5)	fine to medium sand
15-20 (5-6)	no sample available
20-30 (6-9)	coarse sand; few pebbles present
30-35 (9-11)	gravel
35-40 (11-12)	medium to coarse sand
40-45 (12-14)	fine sand
45-50 (14-15)	fine to medium sand

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-9

LOCATION: Lot 11, Con. 8

ELEVATION: Approximately 1050 feet (320 m) a.s.l.

DATE: November 11, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	coarse sand and gravel; 3 inch (8 cm) diameter gravel
5-10 (1.5-3)	coarse sand and excellent crushable gravel
10-15 (3-5)	finer gravel with higher sand content
15-20 (5-6)	silt seam; medium to coarse sand
20-25 (6-8)	no sample; likely gravel present
25-30 (8-9)	well rounded gravel; trace of medium sand present
30-50 (9-15)	crushable gravel

Note:
Sieve analysis (Map 1) for OR-TH-9a was from sample at 15 feet (5 m)
Sieve analysis (Map 1) for OR-TH-9b was from sample at 30 feet (9 m)

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-10

LOCATION: Lot 7, Con. 8

ELEVATION: Approximately 1100 feet (335 m) a.s.l.

DATE: November 12, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	gravel with medium sand
5-10 (1.5-3)	transition into fine to medium sand; some gravel but less than above sample
10-20 (3-6)	medium sand
20-30 (6-9)	medium to coarse sand; occasional fine pebbles
30-35 (9-11)	medium sand
35-50 (11-15)	silty sand

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-11

LOCATION: Lot 8, Con. 10

ELEVATION: Approximately 1050 feet (320 m) a.s.l.

DATE: November 12, 1980

DEPTH feet (metres)	DESCRIPTION
0-10 (0-3)	very coarse sand; few large pebbles
10-15 (3-5)	coarse sand with good crushable gravel
15-20 (5-6)	coarse sand; less gravel than above sample
20-25 (6-8)	no sample
25-30 (8-9)	fine sand above a silt layer
30-35 (9-11)	silty fine sand
35-40 (11-12)	hit fine gravel at 39 feet (12 m)
40-45 (12-14)	silty fine sand
45-50 (14-15)	silt with fine sand pockets

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-12

LOCATION: Lot 12, Con. 10

ELEVATION: Approximately 1000 feet (305 m) a.s.l.

DATE: November 12, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	medium sand
5-10 (1.5-3)	clean find sand
10-15 (3-5)	fine to medium sand
15-25 (5-8)	clean fine sand

TEST HOLE NUMBER: OR-TH-13a

LOCATION: Lot 9, Con. 12

ELEVATION: Approximately 1000 feet (305 m) a.s.l.

DATE: November 13, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	dense clay and boulder; terminated hole at 5 feet (1.5 m) and moved to back of land owner's lot to potential gravel ridge.

TABLE 7 | SUMMARY OF TEST HOLE DATA, ORO TOWNSHIP

TEST HOLE NUMBER: OR-TH-13b

LOCATION: Lot 9, Con. 12

ELEVATION: Approximately 1000 feet (305 m) a.s.l.

DATE: November 13, 1980

DEPTH feet (metres)	DESCRIPTION
0-5 (0-1.5)	medium sand with gravel 1 inch (2.5 cm) in diameter
5-10 (1.5-3)	good gravel with some medium sand
10-15 (3-5)	excellent gravel with medium sand; at 12 feet (4 m) finer gravels but same concentrations
15-20 (5-6)	excellent gravel with medium sand
20-25 (6-8)	gravel 1 to 2 inch (2.5 to 5 cm) in diameter
25-30 (8-9)	hit fine to medium sand layer at 30 feet (9 m)
30-35 (9-11)	fine to medium sand
35-40 (11-12)	fine to medium sand with some gravel
40-45 (12-14)	coarse gravel with fine sand
45-50 (14-15)	good 1 to 2 inch (2.5 to 5 cm) gravel with medium to coarse sand present; at 50 feet (15 m) fist-size rocks

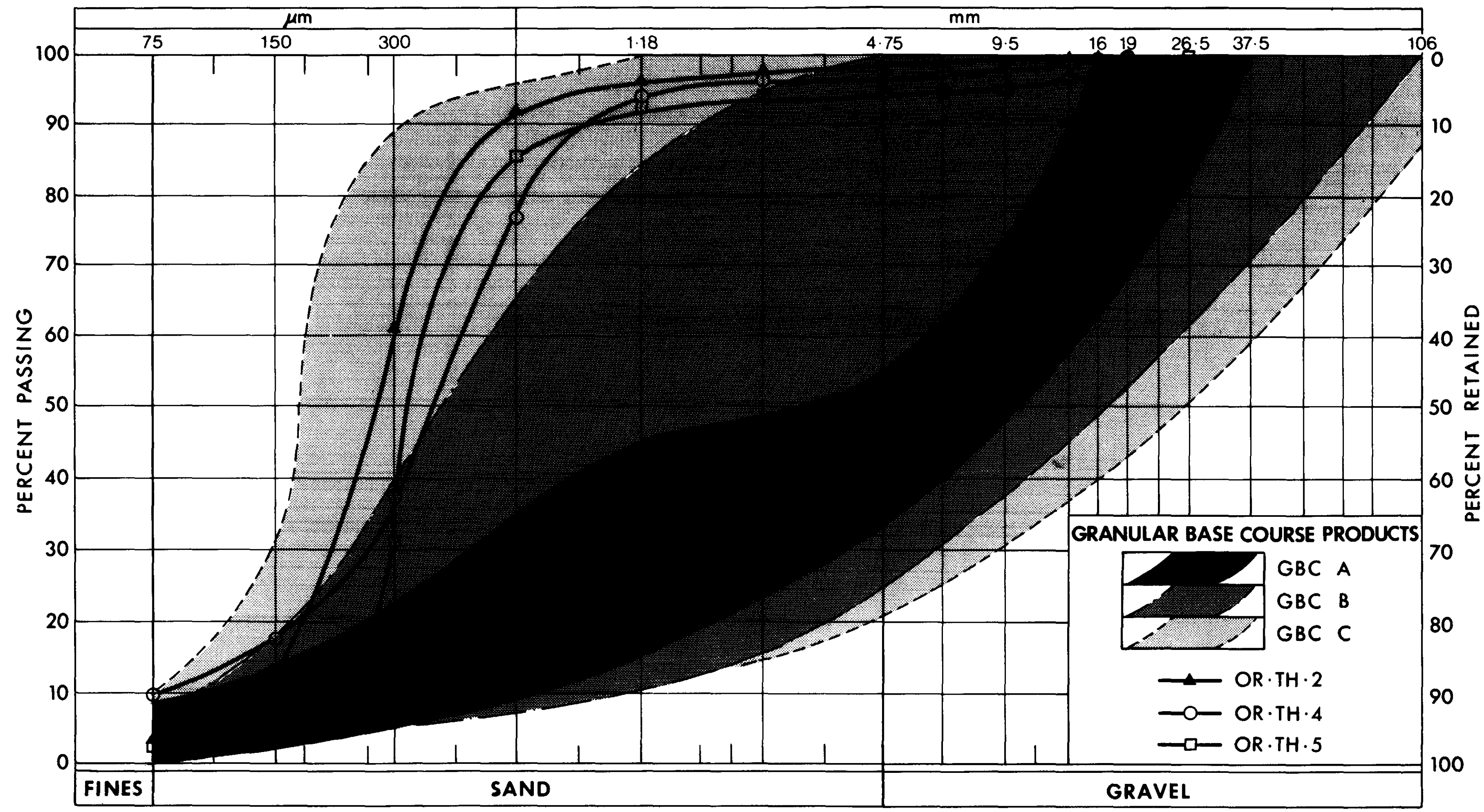


FIGURE 2a: AGGREGATE GRADING CURVES, ORO TOWNSHIP;

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.

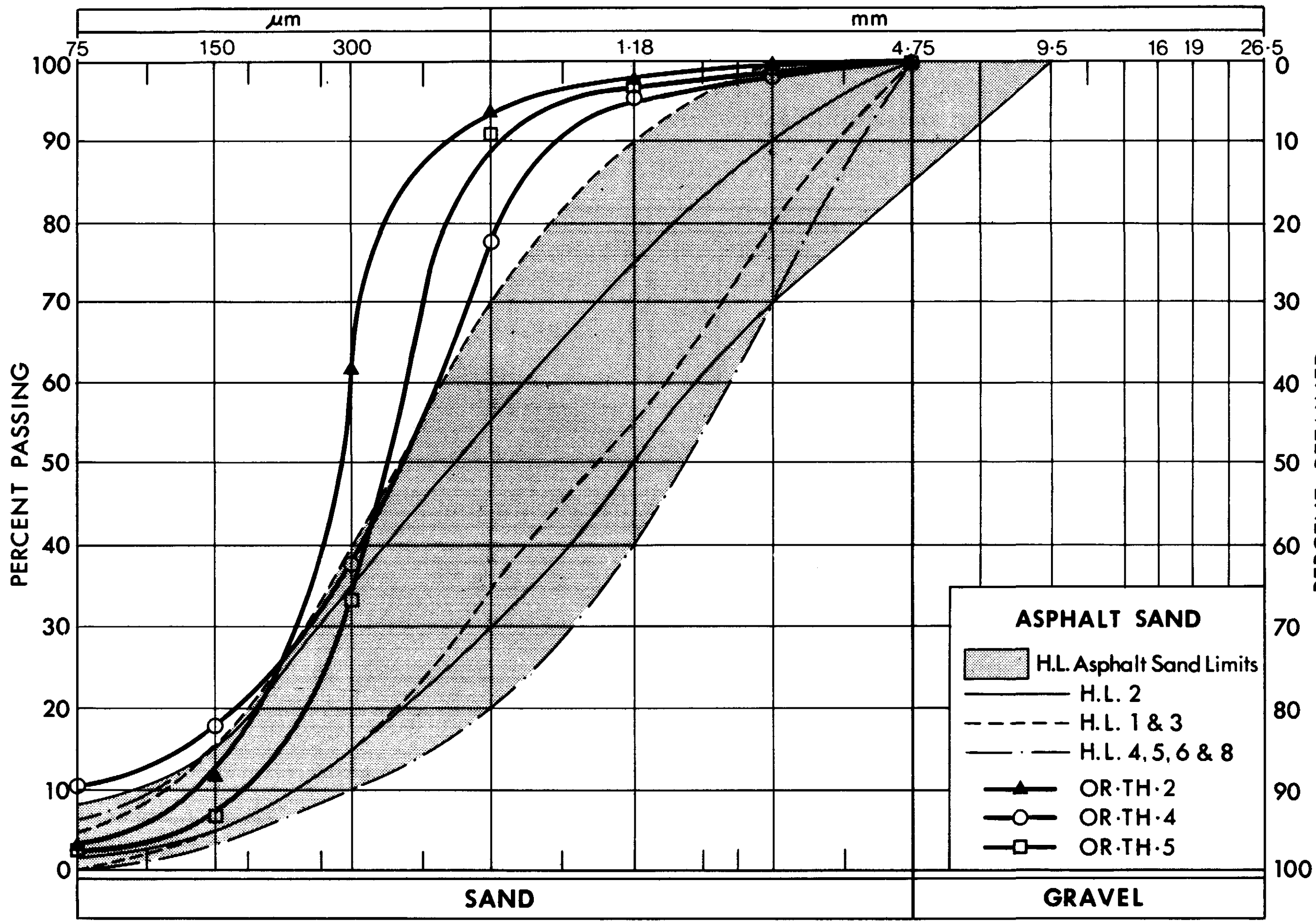


FIGURE 2b: AGGREGATE GRADING CURVES, ORO TOWNSHIP;

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.

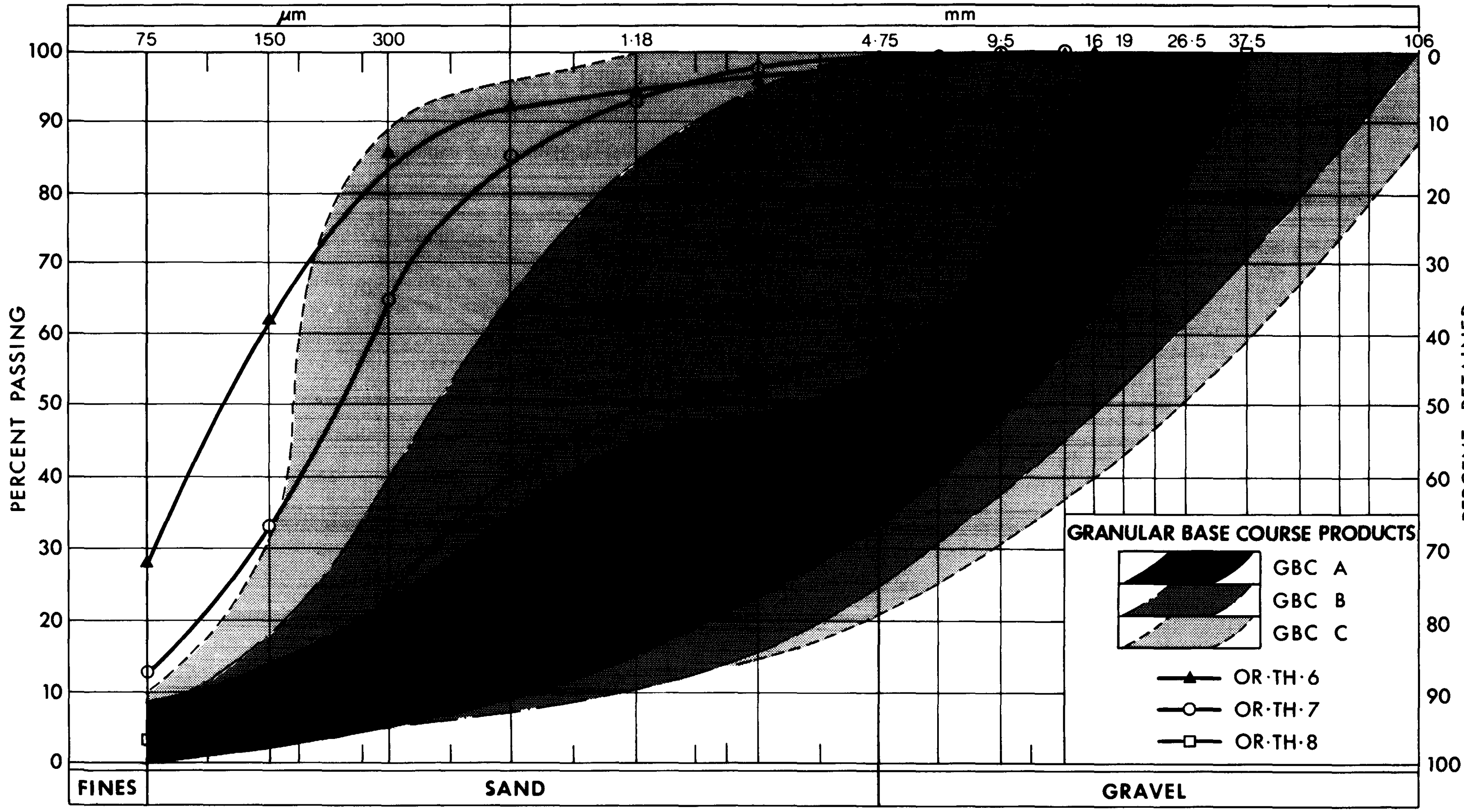


FIGURE 3a: AGGREGATE GRADING CURVES, ORO TOWNSHIP;

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.

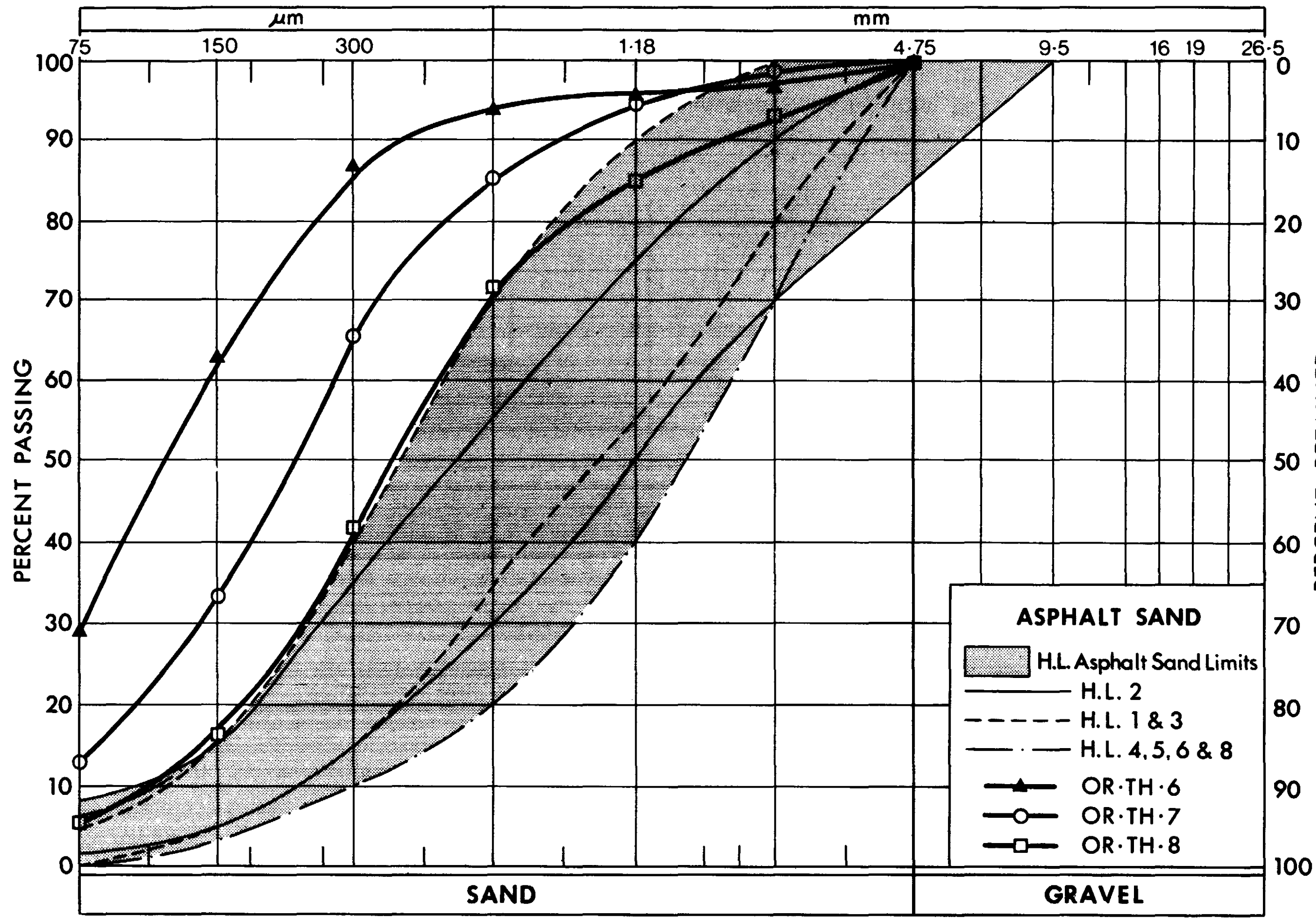


FIGURE 3b: AGGREGATE GRADING CURVES, ORO TOWNSHIP;

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.

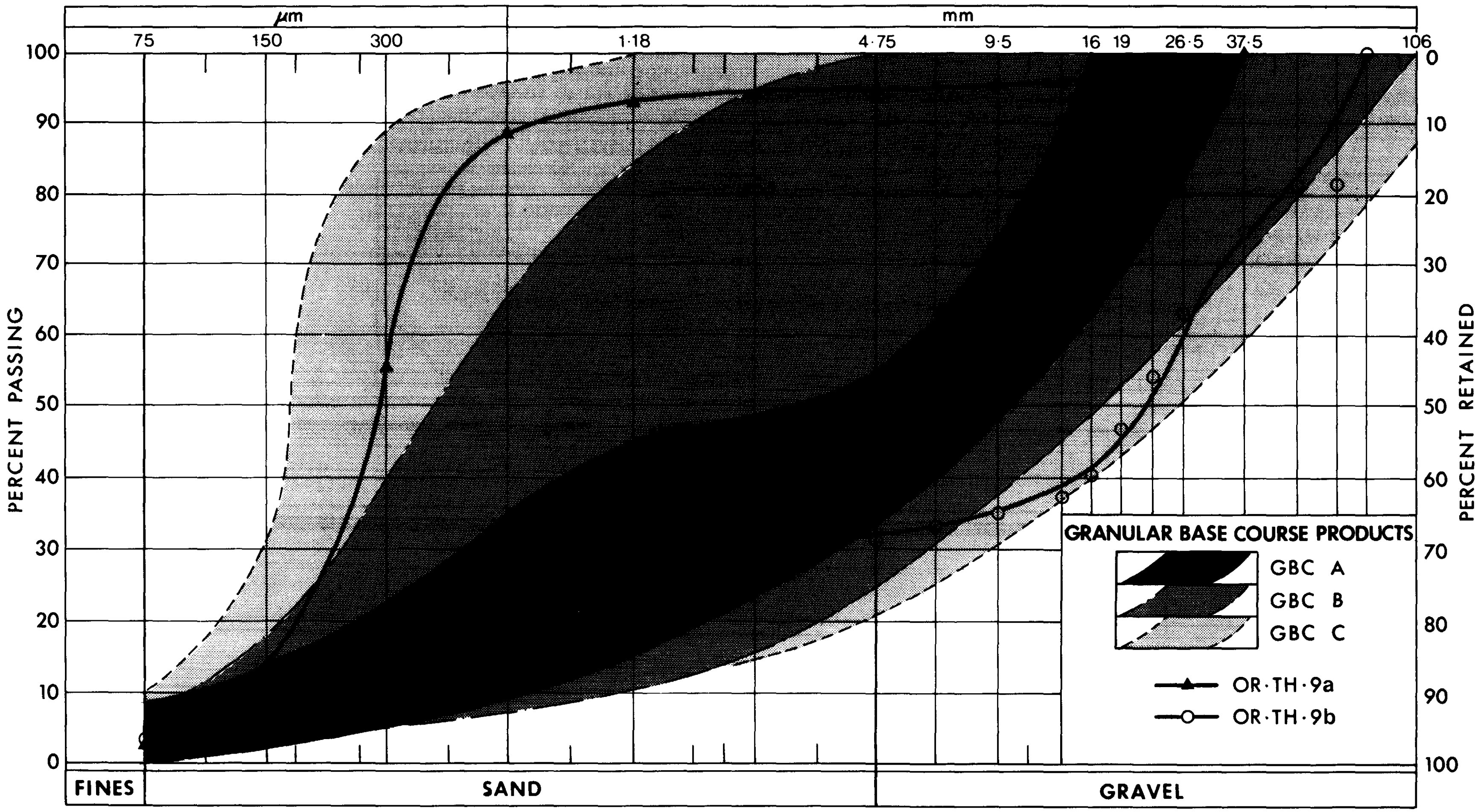


FIGURE 4a: AGGREGATE GRADING CURVES, ORO TOWNSHIP;

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.

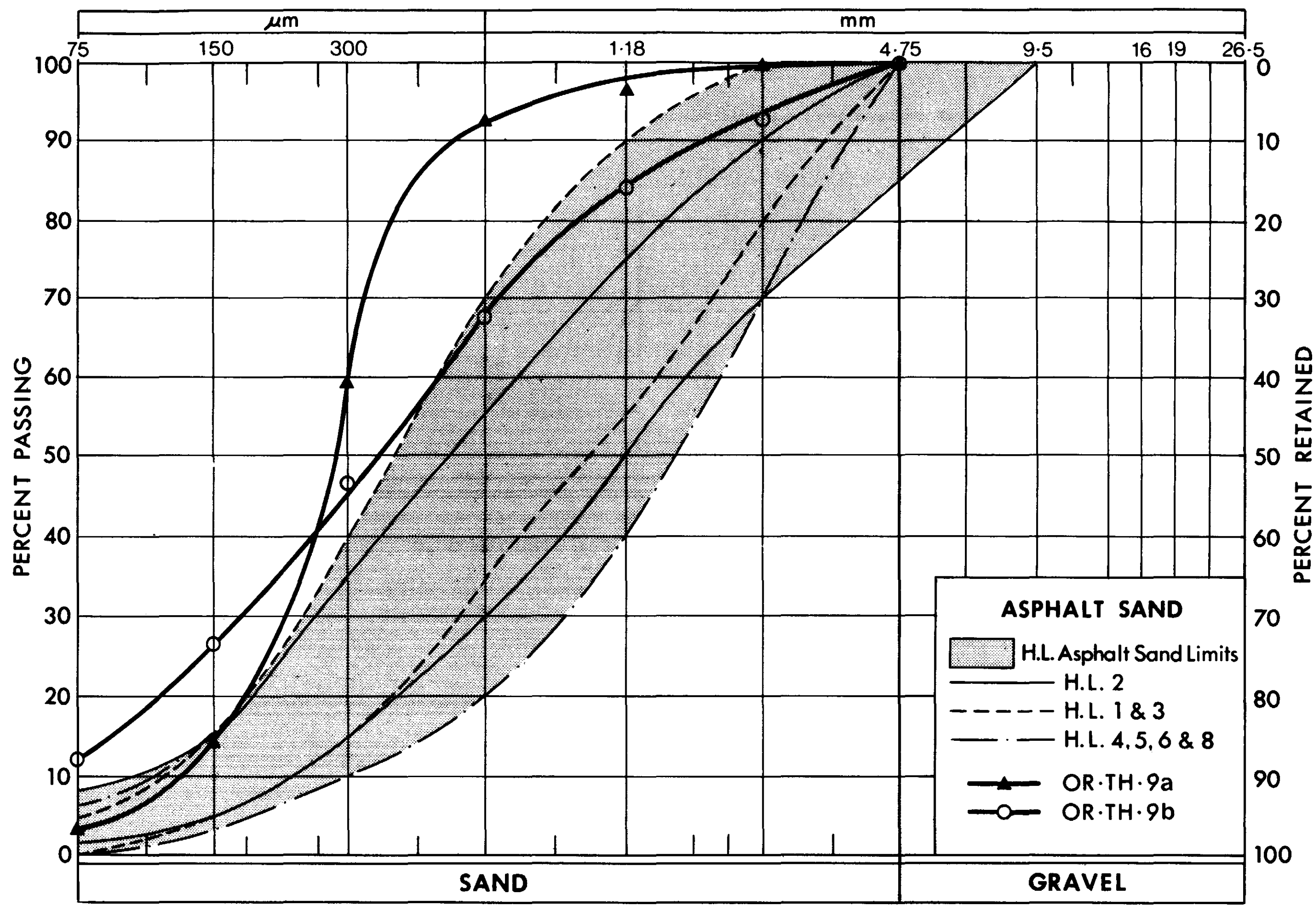


FIGURE 4b: AGGREGATE GRADING CURVES, ORO TOWNSHIP;

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.

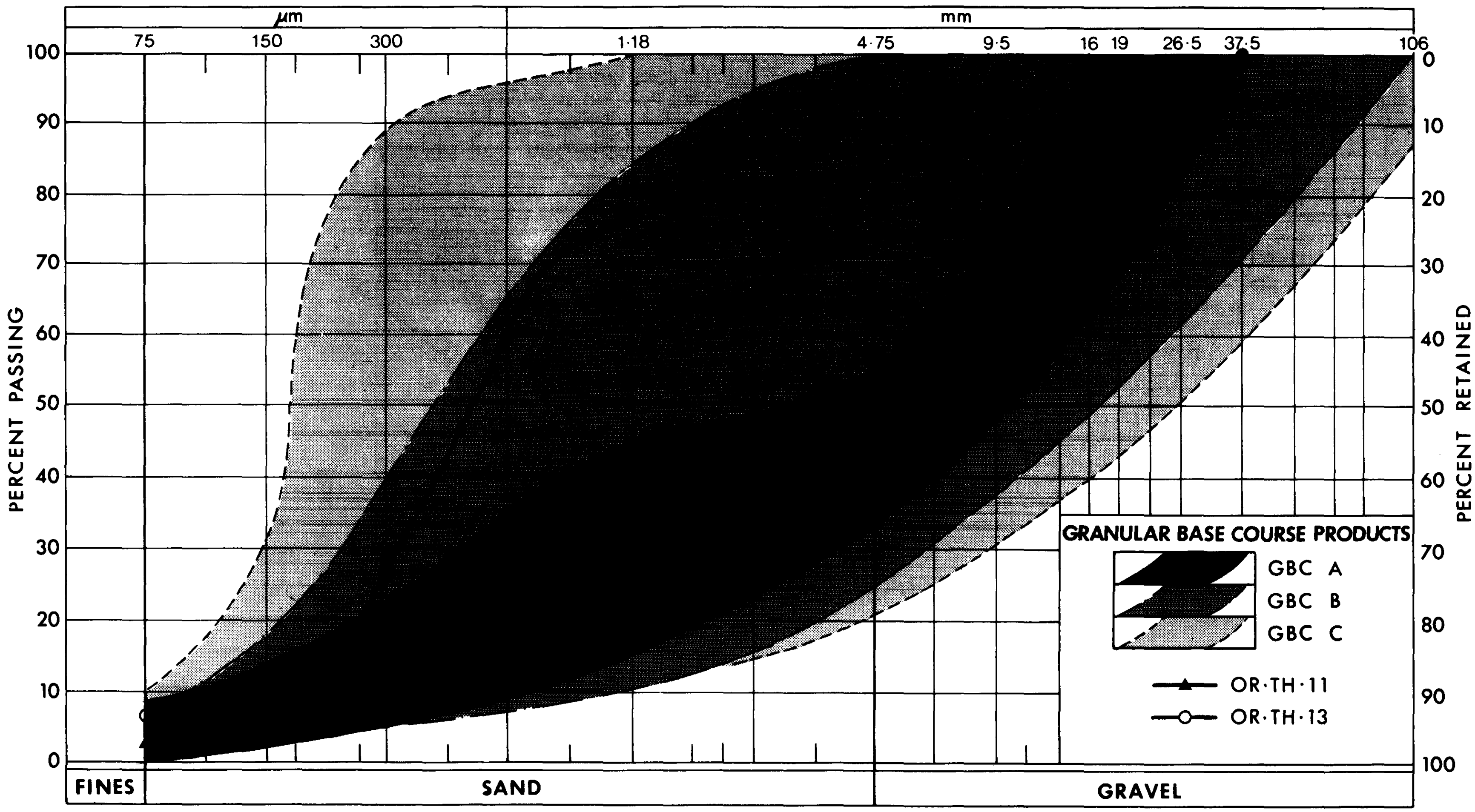


FIGURE 5a: AGGREGATE GRADING CURVES, ORO TOWNSHIP;

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.

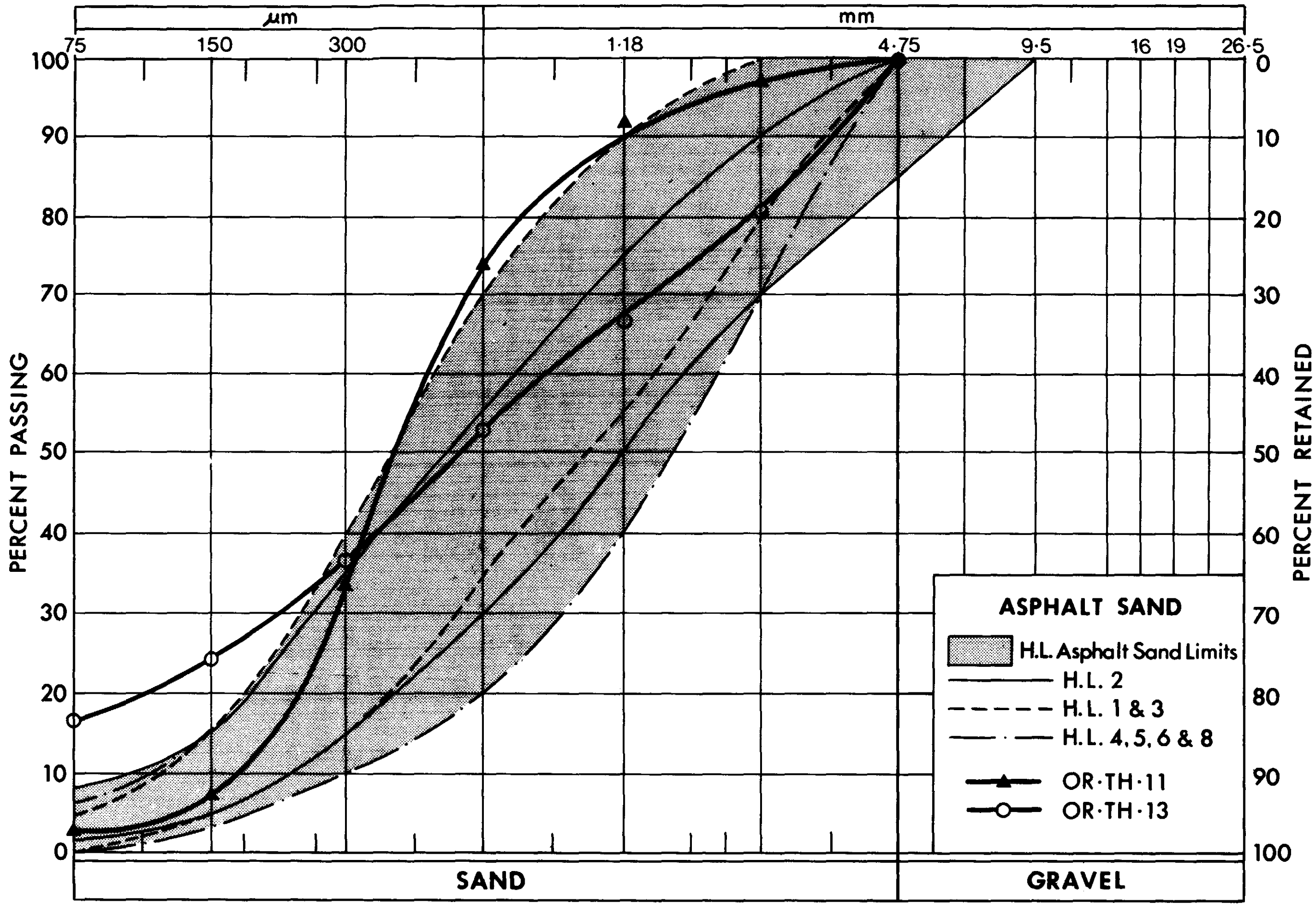


FIGURE 5b: AGGREGATE GRADING CURVES, ORO TOWNSHIP;

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.

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ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. 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.

ALKALI-AGGREGATE REACTION

A chemical reaction between the alkalies of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

BLENDING

Required in cases of extreme coarseness, fineness or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

CAMBRIAN

The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago; the Cambrian precedes the Ordovician Period.

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.

CRUSHABLE AGGREGATE

Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

DELETERIOUS LITHOLOGY

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

DEVONIAN

A period of the geological past thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

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 composed 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 (.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

GLACIAL LOBE

A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced and retreated numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

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 size limits for different particles are as follows:

Boulder	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
Silt, Clay	less than 0.075 mm

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.

HOT-LAID (OR ASPHALTIC) AGGREGATE

Bituminous, cemented aggregates 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.

MELTWATER CHANNEL

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

ORDOVICIAN

An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA

One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

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 the 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 and is popularly referred to as the "Great Ice Age".

POSSIBLE RESOURCE

Reserve estimates based largely on broad knowledge of the geological 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.

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.

SILURIAN

An early period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

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 road-building and construction aggregates.

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 period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern 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 southern 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 their 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 due to 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 rare 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 southern 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 due to their lack of continuity and grain size variability. They 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 ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are 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 aggregates 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 it has generally low value due to the presence of excess silt- and clay-sized material. There are few 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 southern 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 source 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 southern 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 due to 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 aggregates 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 DEPOSITS (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always 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

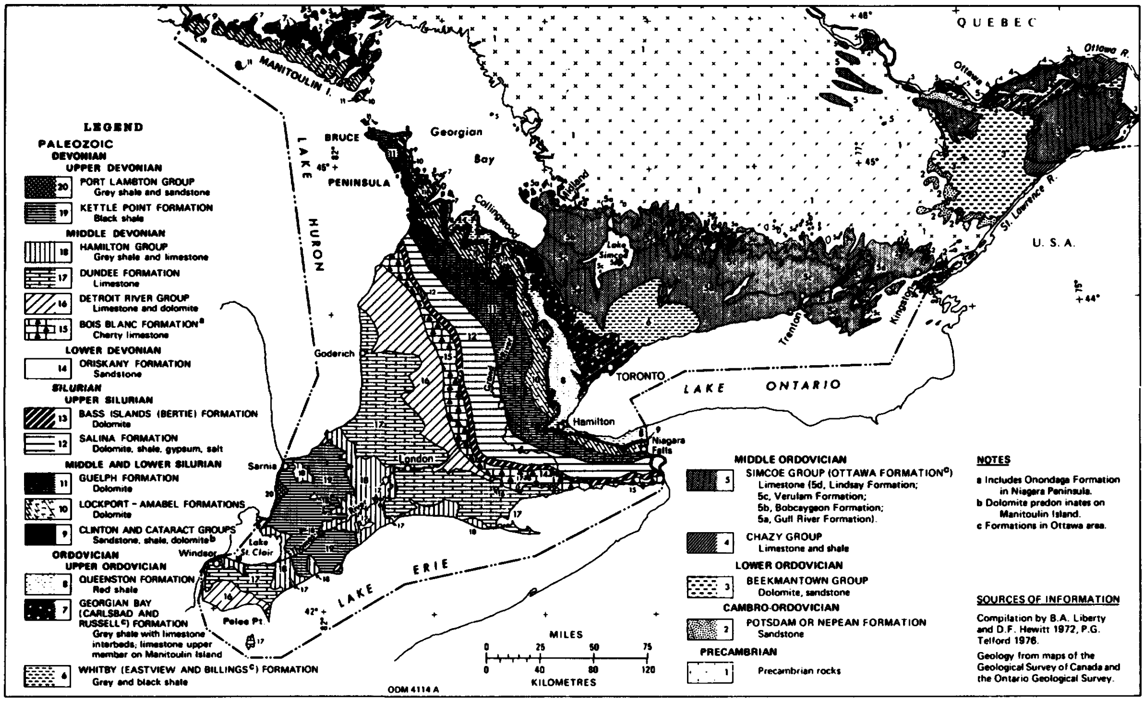


Figure 6 - Bedrock Geology of Southern Ontario

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

BASS ISLANDS FORMATION (UPPER SILURIAN)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate due to high soundness losses.

BOBCAYGEON FORMATION (MIDDLE ORDOVICIAN)

Composition: Compact, homogeneous, medium to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

BOIS BLANC FORMATION (LOWER-MIDDLE DEVONIAN)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High chert content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

DUNDEE FORMATION (MIDDLE DEVONIAN)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone.

Used at St. Marys for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

GULL RIVER FORMATION (MIDDLE ORDOVICIAN)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield, Victoria County, and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

LOCKPORT AND AMABEL FORMATIONS (MIDDLE SILURIAN)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

ONONDAGA FORMATION (MIDDLE DEVONIAN)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey brown, fine-grained, very cherty limestone having an estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for concrete aggregate.

OTTAWA FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of lime for cement production and agricultural uses.

OXFORD FORMATION (LOWER ORDOVICIAN)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

DETROIT RIVER GROUP (MIDDLE DEVONIAN)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces 80% of Ontario's cement. Its dolomitic reefal facies is also important for lime production to the north. It is generally unsuitable for crushed stone. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

GRENVILLE MARBLE (PRECAMBRIAN)

Composition: Recrystallized white limestone and dolostone, fine- to coarse-grained, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

GUELPH FORMATION (MIDDLE SILURIAN)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. The Guelph Formation and the underlying Amabel Formation have a combined thickness of 200 feet (61 m) on the Niagara Peninsula and more than 400 feet (122 m) on the Bruce Peninsula. Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

LINDSAY FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Member: fine-crystalline, rubbly, nodular-weathering limestone. Upper Member: grey calcareous claystone with shaly partings and bioclastic layers. The rock is "soft" and weathers to rubble. Both members are characterized by low dolomite content and by numerous clayey partings. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

VERULAM FORMATION (MIDDLE ORDOVICIAN)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for cement. The formation is unsuitable for crushed stone due to clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

GEORGIAN BAY FORMATION (UPPER ORDOVICIAN)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in Metro Toronto and Cooksville produce brick and structural tile. Lightweight aggregate is also produced at Streetsville by heat expansion of the shale.

HAMILTON GROUP (MIDDLE DEVONIAN)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile and brick.

QUEENSTON FORMATION (UPPER ORDOVICIAN)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

NEPEAN (POTSDAM) FORMATION (CAMBRO-ORDOVICIAN)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

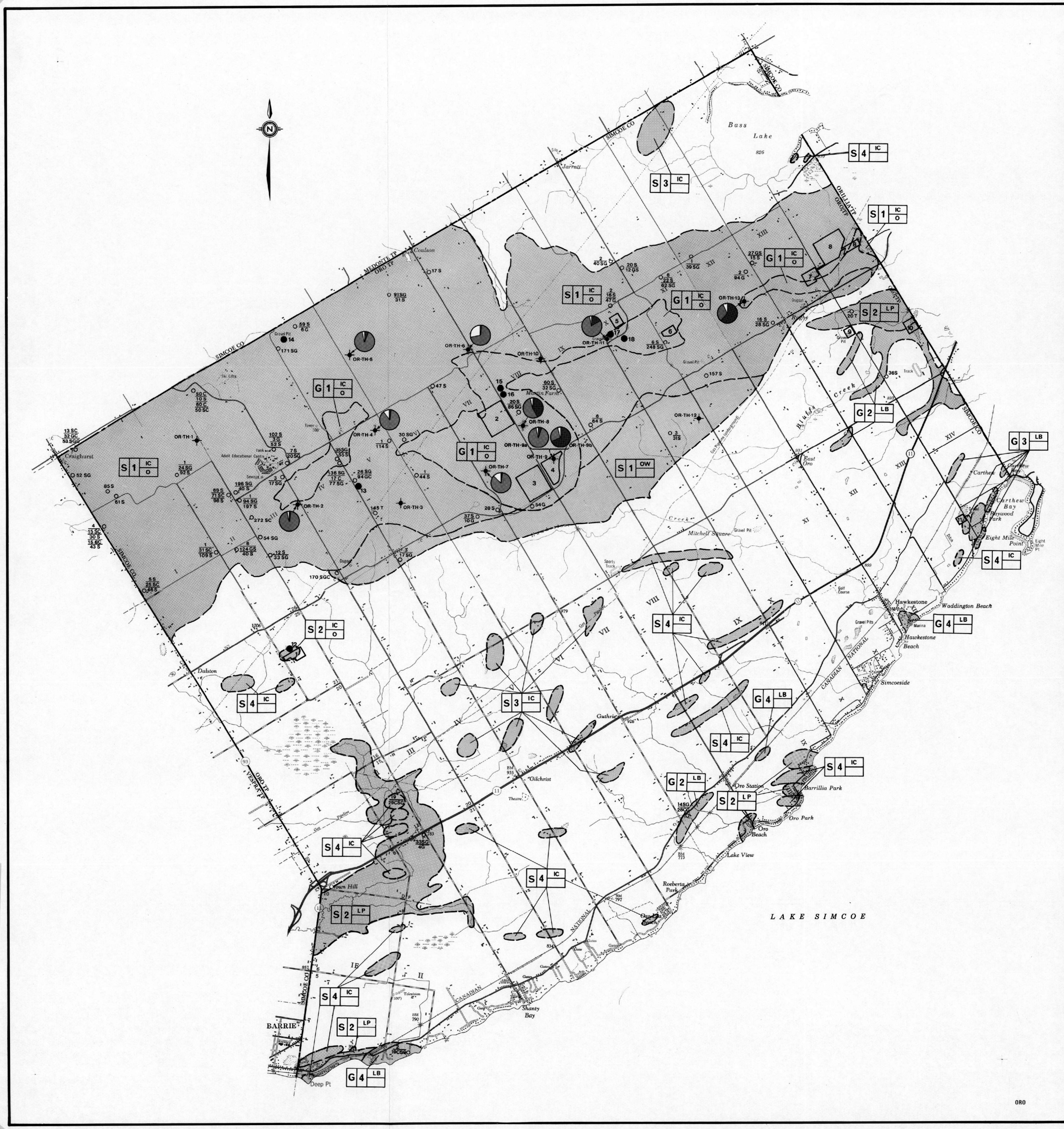
SALINA FORMATION (UPPER SILURIAN)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum.

The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

WHITBY FORMATION (UPPER ORDOVICIAN)

(Formerly known as Collingwood Shale near Toronto) Composition: Brown to black fissile shale. Uses: Quarried at Bowmanville for use in cement production. Testing indicates that the Whitby Formation may produce satisfactory lightweight expanded aggregate.



Ministry of Natural Resources

Hon. Alan W. Pope
Minister

J. R. Sloan
Deputy Minister

Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

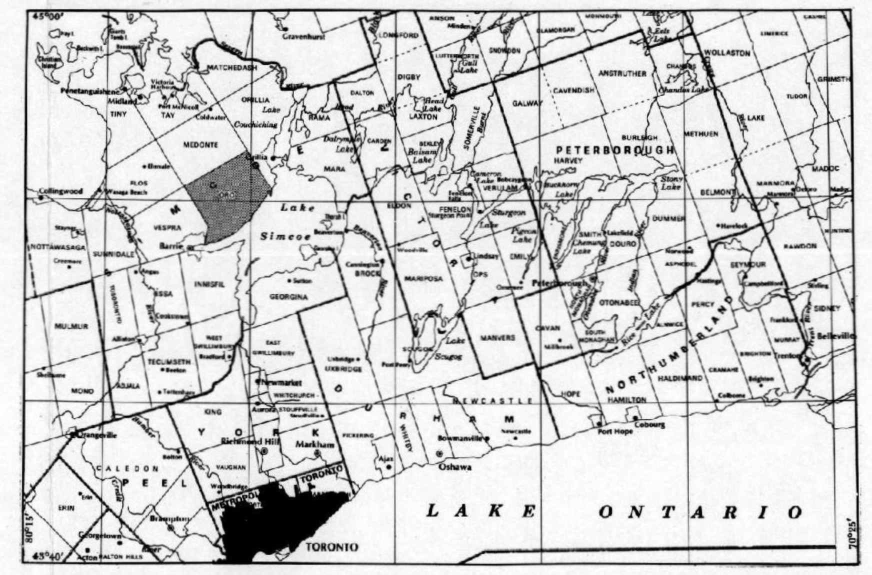
ORO TOWNSHIP
SIMCOE COUNTY

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale 1:50 000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: 31 D/5 31 D/11
31 D/6 31 D/12



SYMBOLS

(Some symbols may not apply to this map.)

Geological and aggregate thickness boundary. Shading indicates deposit area.

Buried geological and aggregate thickness boundary. Shading indicates deposit area.

Municipal boundary.

Licenced property boundary; Property number: see Table 2.

Unlicenced sand or gravel pit*; Property number: see Table 2.
*Abandoned pit or wayside pit operating on demand under authority of a permit.

OR-TH-2 Selected test hole location; Identification number: see Table 7.

Selected drilled water well location; reported thickness of material (in feet); reported type of material (number only - overburden, T - till, G - gravel, S - sand, C - clay, Bk - bedrock).

G 1 IC/C·O Deposit Symbol: see below.

Texture symbol: see below; see Figures 2 to 5.

TEXTURE SYMBOL

Fines: silt and clay (< .075 mm)
Gravel (> 4.75 mm)
Sand (.075 - 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 — G; Thickness Class — 1; Geological Type — IC; Quality Indicator — C·O

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel content is expressed as a percentage of crushable aggregate material. (Crushable aggregate material is defined as unprocessed gravel containing a minimum of 35% coarse aggregate larger than the # 4 sieve, and also a minimum of 20% larger than 1 inch sieve.) Thickness class is based on potential aggregate tonnage per acre. 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 (> 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 (< 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.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Test hole data from Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Natural Resources.
Selected drilled water well data from the Ontario Ministry of the Environment.
Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: R.E. Deane, 1950.

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 65.

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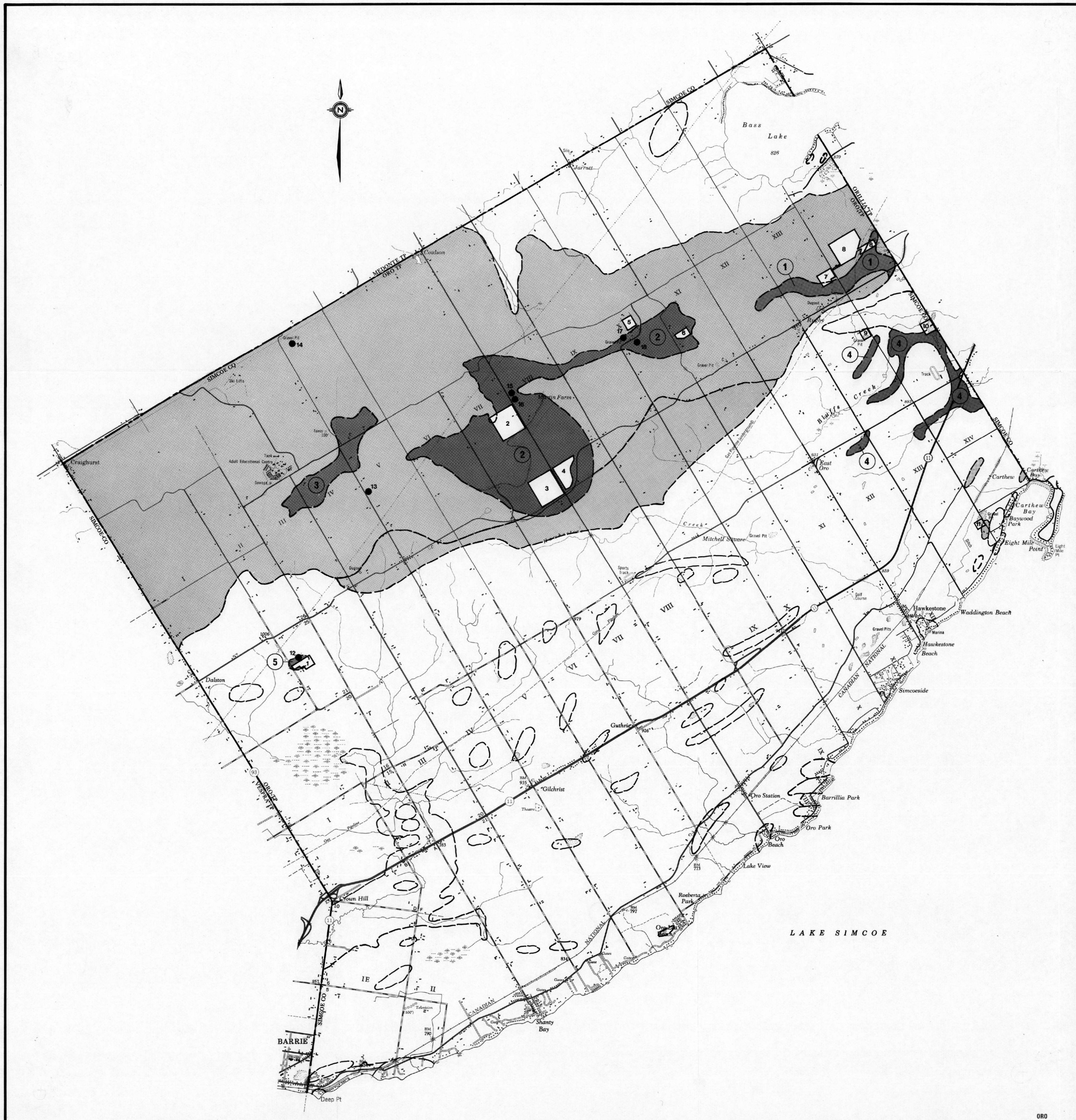
Issued 1984.

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.



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Deputy Minister

ONTARIO GEOLOGICAL SURVEY

AGGREGATE RESOURCES INVENTORY

ORO TOWNSHIP

SIMCOE COUNTY

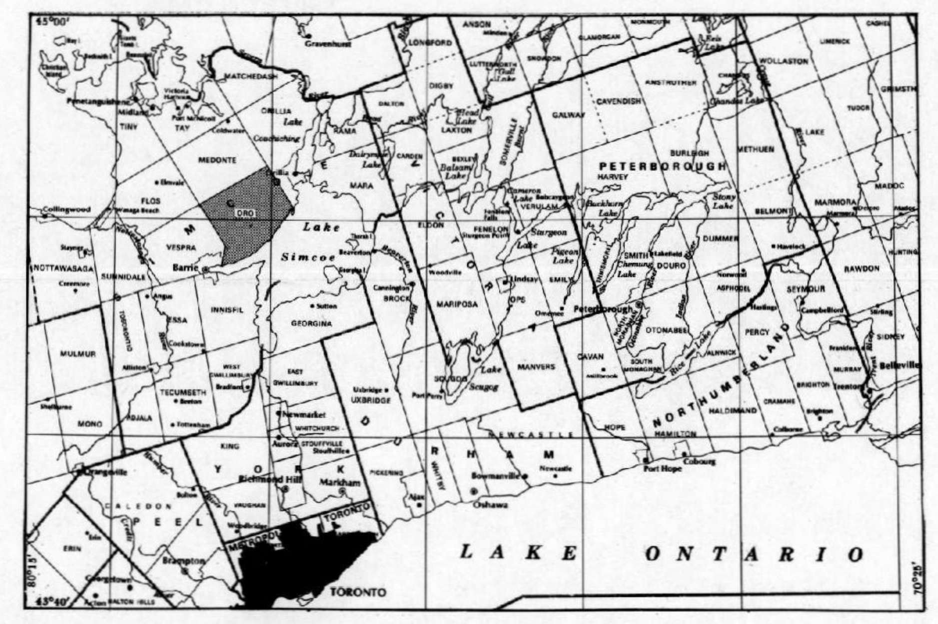
MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 31 D/5 31 D/11
31 D/6 31 D/12



SYMBOLS

(Some symbols may not apply to this map.)

Geological and aggregate thickness boundary.

Buried geological and aggregate thickness boundary.

Municipal boundary.

(2) 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.

2 Licenced property boundary; Property number: see Table 2.

● 3 Unlicenced sand or gravel pit*; Property number: see Table 2.
*Abandoned pit or wayside pit operating on demand under authority of a permit.

SOURCES OF INFORMATION

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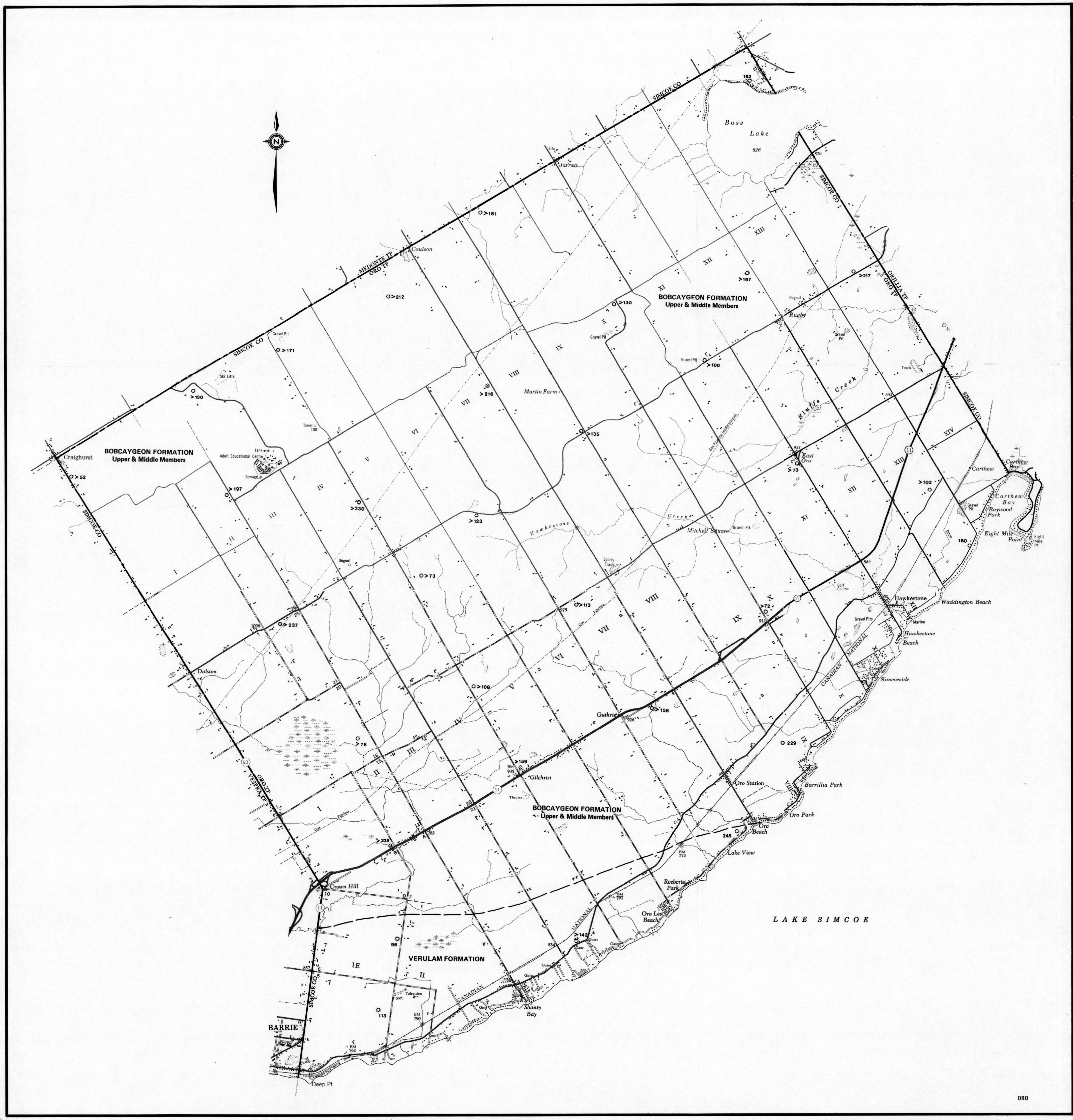

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J. R. Sloan, Deputy Minister

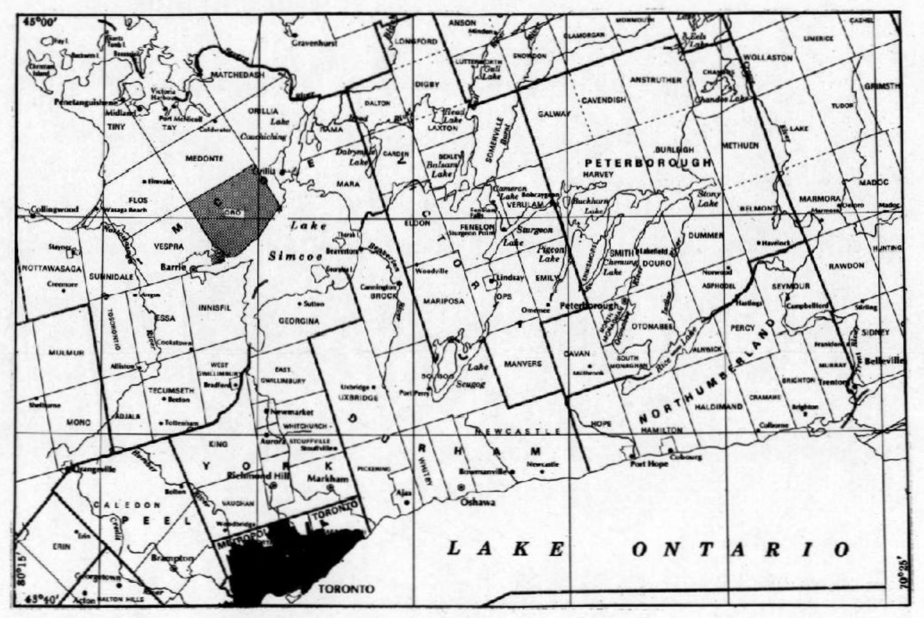
ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

ORO TOWNSHIP
SIMCOE COUNTY
MAP 3
BEDROCK RESOURCES

Scale 1:50 000

Mile 1 — 0 — 1 Mile
Metres 1000 — 0 — 1 Kilometre

NTS Reference: 31 D/5 31 D/11
31 D/6 31 D/12



LEGEND

PALEOZOIC
ORDOVICIAN
MIDDLE ORDOVICIAN
VERULAM FORMATION
Limestone, shale
BOBCAYGEON FORMATION
Limestone

SYMBOLS

(Some symbols may not apply to this map.)

- Geological formation boundary.
- Geological formation member boundary.
- Formation thickness boundary (see text).
- 25 Drift thickness contour: 25 foot (8 m) interval.
- Municipal boundary.
- (2) Selected bedrock resource area; Deposit number: see Table 6.
- Bedrock exposed or near surface; covered by less than 3 feet (1 m) of overburden: see Table 4.
- Bedrock covered by 3 to 25 feet (1 to 8 m) of overburden: see Table 4.
- Bedrock covered by 25 to 50 feet (8 to 15 m) of overburden: see Table 4.
- x Isolated bedrock outcrop.
- Q2 Licenced quarry boundary; Property number: see Table 5.
- ● Q3 Unlicenced quarry*; Property number: see Table 5. *Abandoned quarry or wayside quarry operating on demand under authority of a permit.
- o 28 Selected drilled waterwell location; reported depth to bedrock (in feet).

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected drilled water well data from the Ontario Ministry of the Environment.
Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: G. J. Burwasser and M. J. Ford, 1974a,b
B.A. Liberty, 1969.

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

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