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Ontario

Aggregate Resources Inventory of the

County of Lanark

Southern Ontario

Ontario Geological Survey
Aggregate Resources Inventory
Paper 189

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Paper 189

By V.L. Lee

2013

Users of OGS products are encouraged to contact those Aboriginal communities whose traditional territories may be located in the mineral exploration area to discuss their project.

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***Map 1 and Map 2 accompanying this report are simplified to depict information critical to the majority of users. Enhanced information on the aggregate resources for this area is provided in a compressed (*.zip*) file available for download from GeologyOntario (www.ontario.ca/geology). Additional documents in the *.zip* file provide further details on the vector ESRI® ArcGIS® files for Maps 1 and 2, Microsoft® Excel® versions of Tables 1 to 11, and other files that enhance this report.**

Abstract

The purpose of this study is to delineate, inventory and evaluate the aggregate resources within the County of Lanark. This information is required for infrastructure development and renewal, general construction application, land use planning purposes and to help ensure that sufficient aggregate resources are available for future use. This report is based on a detailed field assessment undertaken in the summer of 2010 and on previous studies of the area.

Four sand and gravel resource areas have been selected at the primary resource level in the County of Lanark. These selected resource areas have a total unlicenced area of 810 ha with a possible resource area of 281 ha after considering physical, cultural and environmental constraints. These resource areas have approximately 30 million tonnes of aggregate material. Deposits are not evenly distributed throughout the county and these primary selected resources are concentrated in the western half of the county. It should be noted that the sand and gravel deposits of the county are complex. Drilling and extensive testing should be completed prior to the development of a resource. The stone quality of these deposits potentially limits the use of this granular material for high-specification aggregate products.

A number of sand and gravel deposits have been selected at the secondary level of significance. These deposits add to the overall granular resource of the County of Lanark. Deposit size, variability of material, lower coarse aggregate content and the concern over stone quality of these deposits lowers their aggregate potential. Although the development of these deposits is less desirable for development than the primary deposits, they are still a valuable resource.

The March, Oxford, Gull River and Bobcaygeon formations frequently crop out, or are within 8 m of the surface, in the eastern portion of the study area. These rock units are thick, consistent and recognized as a significant aggregate resource with the potential to produce a wide range of aggregate products. Areas underlain by these formations and with less than 8 m of overburden have been chosen as selected bedrock resource areas. These selected resource areas have a total unlicenced area of 67 693 ha with a possible resource area of 59 514 ha after considering physical, cultural and environmental constraints. These resource areas have approximately 23 648 million tonnes of aggregate material.

Selected Resource Areas are not intended to be permanent, single land use units that must be incorporateed into 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.

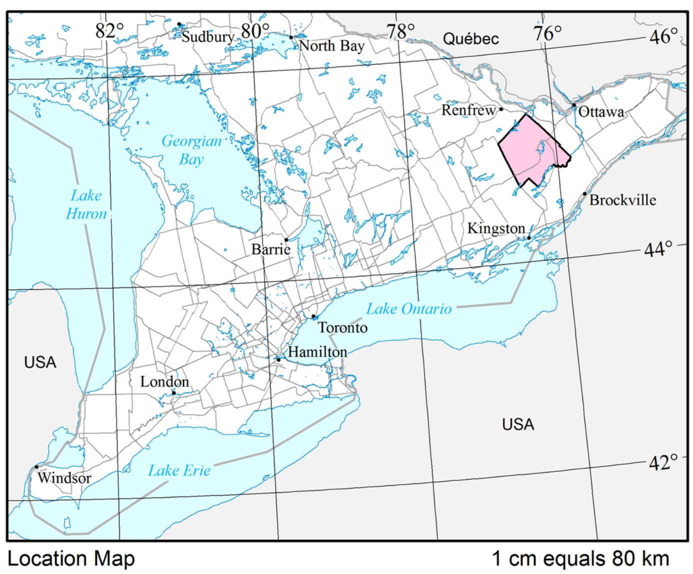

Figure 1. Map of southern Ontario showing the location of the County of Lanark.

Aggregate Resources Inventory of the County of Lanark

By V.L. Lee[1]

Field work, map production and report by V.L. Lee[1].

Report reviewed and approved by R.I. Kelly[1].

Manuscript accepted for publication in 2012 by R.I. Kelly, Senior Manager (Acting), Sedimentary Geoscience Section (now Earth Resources and Geoscience Mapping Section), Ontario Geological Survey. This report is published with the permission of the Director, Ontario Geological Survey.

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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. Large quantities of these materials are used each year throughout the Province. For example, in 2010, the total tonnage of mineral aggregates extracted in Ontario was 166 million tonnes, greater than that of any other metallic or nonmetallic commodity mined in the Province (The Ontario Aggregate Resources Corporation 2010).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, non-renewable resources that 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 areas where land use competition is extreme. For these reasons, the availability of adequate resources for future development is now being threatened in many areas, especially urban areas where demand is the greatest.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Unfortunately, in some cases, the best aggregate resources are found in or near areas of environmental sensitivity, resulting in the requirement to balance the need for the different natural resources. Therefore, planning 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 Program is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies. 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 an area's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential for bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Inventory Methods, Data Presentation and Interpretation

FIELD AND OFFICE METHODS

The methods used to prepare the report involved the interpretation of published geological data such as bedrock and surficial geology maps and reports, as well as field examination of possible resource areas. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located by field surveys and from records held by the Ministry of Transportation of Ontario (MTO), the Ontario Geological Survey (OGS), and by Regional, District and Area Offices of the Ministry of Natural Resources (MNR) of Ontario. Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-sized materials in the deposit. Observations regarding the shape and lithology of the particles were also made. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering, test pitting and drilling.

Deposits with potential for extractive development, or those where existing data are scarce, were studied in greater detail. In instances, representative sites in these deposits are evaluated by taking 11 to 45 kg samples from existing pit or quarry faces, roadcuts or other exposures. The samples may be subjected to some or all of the following tests: absorption capacity, magnesium sulphate soundness test, micro-Deval abrasion test, unconfined freeze–thaw test, and accelerated mortar bar expansion test.

The field data were supplemented by pit information on file with the Soils and Aggregates Section of the Ministry of Transportation of Ontario. 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 suitability of the aggregate. Information concerning the development history of the pit and acceptable uses of the aggregate is also recorded. The locations of additional aggregate sources were obtained from records held by Regional, District and Area Offices of the Ministry of Natural Resources. In addition, testing data for type, quantity and quality of aggregates were also obtained from aggregate licence applications where these reports are on file with the Ministry of Natural Resources, and from individuals and companies.

Aerial photographs and remotely sensed imagery at various scales were used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ministry of the Environment (MOE), were used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records were used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a base map, also at a scale of 1:50 000. These base maps were prepared using digital information taken from the Ontario Land Information Warehouse, Land Information Ontario, Ministry of Natural Resources, with modifications by staff of the Ministry of Northern Development and Mines.

Units and Definitions

The measurements and other primary data available for resource tonnage calculations are presented in metric units in the text and on the tables that accompany the report. Data are generally rounded off in accordance with the *Metric Practice Guide* (Ontario Interministerial Committee on National Standards and Specifications 1975).

The tonnage estimates for aggregate deposits are termed possible resources (*see* Appendix B – Glossary) in accordance with terminology used by the Ontario Resource Classification Scheme (Robertson 1975, p.7) and the Association of Professional Engineers of Ontario (1976).

DATA PRESENTATION AND INTERPRETATION

Two maps, each portraying a different aspect of the aggregate resources in the report area, accompany the report. Map 1, "Sand and Gravel Resources", provides an inventory and evaluation of the sand and gravel resources in the report area. Map 2, "Bedrock Resources", shows the distribution of bedrock formations and the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

The hard-copy versions of Map 1 and Map 2 (back pocket of the report) are simplified to depict information critical to the majority of users.

Enhanced information on the aggregate resources for this area (e.g., complete deposit information for Map 1) is provided in vector ESRI® ArcGIS® files available for download as a compressed (*.zip*) file from GeologyOntario (www.ontario.ca/geology). A "readme" file included in the *.zip* file provides further details regarding the contents of these vector files. In addition, cross-references to data provided in the *.zip* file are provided for clients who wish to access digital data that does not require opening the vector ArcGIS® files. The file that contains the tables for sand and gravel resources and bedrock resources data is found in the root data folder. The tables are in a database (*.mdb*) format file that can be opened using other software, for example, Microsoft® Access® (however, it is recommended the file be copied before opening to avoid creating problems with the vector ArcGIS® files). The cross-references include the table and the field name separated by a short vertical line; the field name is indicated by bold, small capital letters (e.g., | D rift_Thick | **AABBCC**).

Map 1: Sand and Gravel Resources

Map 1 shows the extent and quality of sand and gravel deposits within the study area and an evaluation of the aggregate resources. The map is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete.

The present level of extractive activity is also indicated on Map 1. Those areas licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number that refers to the pit descriptions in Table 2. Each description notes the owner/operator and licenced hectarage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or pits operating on demand under authority of a wayside permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, any test locations appear on Map 1 as a point symbol and the results of the test material are provided in Table 9.

SELECTED SAND AND GRAVEL RESOURCE AREAS

All the sand and gravel deposits are first delineated by geological boundaries and then classified into one of 3 levels of significance: primary, secondary or tertiary. The deposit's significance is also recorded in | Sand_Gravel | **SIGNIF**.

Areas of primary significance are coloured red on Map 1 and identified by a deposit number that corresponds to numbers in Table 3. The deposit number is also recorded in | Sand_Gravel | **SELECT_AREA**.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units. They represent areas in which a major resource is known to exist, and may be reserved wholly or partially for extractive development and/or resource protection. In many of the recently approved municipal Official Plans, all or portions of resources of primary significance, and in some cases resources of secondary significance, are identified and protected.

Deposits of secondary significance are coloured orange on Map 1. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the best resources in the report area, they may contain large quantities of sand and gravel and should be considered as part of the overall aggregate supply of the area.

Deposits of tertiary significance are coloured yellow on Map 1. They are not 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 or extraction under a wayside permit, but are unlikely to support large-scale development.

SELECTION CRITERIA

The process by which deposits are evaluated and selected involves the consideration of 2 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 report area 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 AND THICKNESS

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 resources in the rest of the project area.

The "thickness class" indicates a depth range, which is related to the potential resource tonnage for each deposit (*see* Table 1, Column 1: "Class Number"). Four thickness class divisions have been established: Class 1 deposits are greater than 6 m thick; Class 2 sand and gravel deposits are from 3 to 6 m thick; Class 3 represents a deposit that is from 1.5 to 3 m thick; and Class 4 represents a sand and gravel deposit that is less than 1.5 m thick. The thickness class for each deposit is also recorded in | Sand_Gravel | **DEP_THICK**.

Generally, deposits in Class 1 and containing more than 35% gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in areas with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregates for various uses result from variations in the lithology of the particles comprising the deposit and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit information: gravel content (G or S), fines (C), oversize (O) and lithology (L). Three of the quality 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% gravel ("G") in addition to a minimum of 20% 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. In "sandy" deposits ("S"), the gravel-sized aggregate (greater than 4.75 mm) makes up less than 35% of the whole deposit making it difficult to produce coarse aggregate products. The gravel content is also recorded in | Sand_Gravel | **MATERIAL**.

Excess fines (high silt and clay content) ("C") may severely limit the potential use of a deposit. Fines content in excess of 10% may impede drainage in road subbase aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles.

Deposits containing more than 20% oversize material (greater than 10 cm in diameter) ("O") may also have use limitations. The oversize component is unacceptable for uncrushed road base, so it must be either crushed or removed during processing.

Another indicator of the quality of an aggregate is lithology ("L"). Just as the unique physical and chemical properties of bedrock types 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 and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate.

If the deposit information shows either "C", "O" or "L", or any combination of these indicators, the quality of the deposit is considered to be reduced for some aggregate uses. The deposit quality, if applicable, is recorded in | Sand_Gravel | **LIMITATION**. No attempt is made to quantify the degree of limitation imposed. Assessment of the 4 indicators is made from published data, from data contained in files of both the Ministry of Transportation of Ontario (MTO) and the Earth Resources and Geoscience Mapping Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendixes B and E, respectively.

Deposit Information

The deposit information coding is similar to that used in soil mapping and land classification systems commonly in use in North America and indicates the gravel content, thickness of material, origin (type) and quality limitations, if applicable. The "gravel content" and "thickness class", as described above, are basic criteria for distinguishing different deposits. The geologic deposit type is also reported (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C of the report). The geologic deposit type is recorded in | Sand_Gravel | **DEP_ORIGIN**.

In the following example of a deposit information code,

"G / 1 / OW / C",

where G represents gravel content, 1 represents thickness class, OW represents geological type and C represents aggregate quality, the deposit information code is interpreted as an outwash deposit greater than 6 m thick containing more than 35% gravel with excess silt and clay.

The deposit information is recorded in | Sand_Gravel | **LABEL**.

Texture Symbol

The texture symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves that, if available, are included with the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the texture symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 60% gravel, 30% sand and 10% silt and clay ("fines").

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural, environmental and man-made features that 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).

In addition to man-made and cultural features, certain natural features, such as provincially significant wetlands, may prove to be constraints. In this report, such constraints have not been outlined and the reader is advised to consult with municipal planning staff and the local office of the MNR for information on these matters. Depending on the number and type of constraint applicable, anywhere from 15 to 85% of the total resources in a municipality may be unavailable for development (Planning Initiatives Limited 1993).

The assessment of sand and gravel deposits with respect to local land use and private land ownership is an important component of the general evaluation process. Since the approval of the Provincial Policy Statement (PPS) under the authority of the *Planning Act* in 2005, recently approved Official Plans now contain detailed policies regarding the location and operation of aggregate extraction activities. These official plans should be consulted at an early stage with regard to the establishment of an aggregate extraction operation. 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 office of the Ministry of Natural Resources, Ministry of Municipal Affairs and Housing staff, and/or regional and local planning officials.

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 or "market share" of an area will remain roughly at the same level.

The availability of aggregate resources in the region surrounding a project area should be considered in order to properly evaluate specific resource areas and to develop optimum resource management plans. For example, an area that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Areas with large resources in proximity to high-demand centres, such as metropolitan areas, are special cases as the demand for aggregate may be greater than the amount of production in the areas close to the urban boundary.

Although an appreciation of the multitude of factors affecting aggregate availability (e.g., environmental and planning constraints) is required to develop comprehensive resource management strategies, 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 the preceding sections.

SAND AND GRAVEL RESOURCE TONNAGE CALCULATIONS

Once the interpretative boundaries of the aggregate units have been established, 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 hectares (ha). The deposit area is also recorded in | Sand_Gravel | AREA. 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 records. Tonnage values can then be calculated by multiplying the volume of the deposit by 0.01770 (the density factor). This factor is approximately the number of tonnes in a 1 m thick layer of sand and gravel, 1 ha in extent, assuming an average density of 1770 kg/m^3.

Tonnage = Area × Thickness × Density Factor

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

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of hectares unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g., wayside, unlicenced and abandoned 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 × Column 6 × 0.01770), to give an estimate of the sand and gravel tonnage (Column 7) possibly available for extractive development and/or resource protection. It should be noted, however, that studies (Planning Initiatives Limited 1993) have shown that substantial proportions of the resources in an area may be constrained due to environmental considerations (e.g., floodplains, environmentally sensitive areas). Lack of landowner interest in development, a range of planning considerations or other matters may also reduce the available resources.

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

Map 2: Bedrock Resources

Map 2 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ministry of the Environment (MOE), oil and gas well data from the Ministry of Natural Resources (MNR), and from geotechnical test hole data from various sources. Map 2 is based on concepts similar to those outlined for Map 1.

Inventory information presented on Map 2 is designed to give an indication of the present level of extractive activity in the report area. Those areas licenced for extraction under the *Aggregate Resources Act* are shown by a solid outline and identified by a number that refers to the quarry descriptions in Table 5. Each description notes the owner/operator, licenced hectarage 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 2 and described in Table 5. Drill hole locations or other descriptive stratigraphic sections appear as a point symbol on Map 2. Table 7 provides these descriptions. These descriptions are also recorded in | Bedrock | Add_Info table.

The geological boundaries of the Paleozoic bedrock units are shown by black dashed lines. Isolated Paleozoic and Precambrian outcrops are indicated by an "×". Three sets of contour lines delineate areas of less than 1 m of drift, areas of 1 to 8 m of drift, and areas of 8 to 15 m of drift. The extents of these areas of thin drift are indicated on Map 2 and are indicated in Table 4 (Column 1). The deposit's significance is also recorded in | Drift_Thick | **CONTOUR**. The darkest shade of blue indicates where bedrock crops out or is within 1 m of the ground surface. These areas constitute potential resource areas because of their easy access. The medium shade of blue indicates areas where drift cover is up to 8 m thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade of blue indicates bedrock areas overlain by 8 to 15 m of overburden.

Outside of these delineated areas, the bedrock can be assumed to be covered by more than 15 m of overburden, a depth generally considered to be too great to allow economic extraction. However, areas in which the bedrock is covered with greater than 8 m of overburden may constitute resources that have extractive value in specific circumstances. These circumstances include the resource being located adjacent to existing industrial infrastructure (e.g., a quarry operation or processing plant); speciality industrial mineral products (e.g., chemical lime and metallurgical rock) that can be produced from the resources; or part or all of the overburden being composed of an economically attractive deposit.

SELECTED BEDROCK 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 within a specific geological formation 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, if present, are shown on Map 2 by a line pattern and the calculated available tonnages are given in Table 6. The selected bedrock resource areas are also recorded in | Drift_Thick | **SELECT_AREA**.

Selected Bedrock Resource Areas shown on Map 2 are not permanent, single land use units. They represent areas in which a major bedrock resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection, within an Official Plan.

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 Ministry of Transportation of Ontario. The main characteristics and uses of the bedrock units 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. The deposit size is recorded in | Drift_Thick | **AREA**; the favourable bedrock formations are reported in | Drift_Thick | **FORMATION**. 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 are 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.

BEDROCK RESOURCE TONNAGE CALCULATIONS

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above for sand and gravel resources. The areal extent of bedrock formations overlain by less than 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 (Table 4). The measured extent of such areas is then multiplied by the estimated quarriable 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 18 m is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tonnes of a 1 m thick section of rock, 1 ha in extent). The areal extent of bedrock formations is also recorded in | Drift_Thick | **AREA**.

Resources of limestone and dolostone are calculated using a density factor of 2649 kg/m^3; sandstone resources are calculated using a density estimate of 2344 kg/m^3; and shale resources are calculated with a factor of 2408 kg/m^3 (Telford et al. 1980).

Assessment of Aggregate Resources in the County of Lanark

LOCATION AND POPULATION

The County of Lanark (herein referred to as "Lanark County") is located west of the City of Ottawa and occupies an area of approximately 303 381 ha. It is bounded to the west by the County of Frontenac; to the north by the County of Renfrew; to the east by the City of Ottawa; and to the south by the United Counties of Leeds and Grenville (Figure 2). The study area is covered by all or parts of 10, 1:50 000 scale map sheets of the National Topographic System (NTS). These map sheets include Merrickville (31 B/13), Westport (31 C/9), Tichborne (31 C/10), Sharbot Lake (31 C/15), Perth (31 C/16), Carleton Place (31 F/1), Clyde Forks (31 F/2), Renfrew (31 F/7), Arnprior (31 F/8) and Kemptville (31 G/4).

Lanark County consists of 5 townships and the towns of Carleton Place, Mississippi Mills, Perth and Smiths Falls (Table A). In 1998, the municipal structure of Lanark County was restructured. The Town of Carleton Place was annexed from the Township of Beckwith; the townships of South Sherbrooke, Bathurst and North Burgess amalgamated to form the new Tay Valley Township; the townships of Drummond and North Elmsley amalgamated to form the new Township of Drummond / North Elmsley; the Town of Almonte and the townships of Pakenham and Ramsay amalgamated to form the new Town of Mississippi Mills; parts of the Township of North Elmsley were annexed to the Town of Perth; and the Village and Township of Lanark, and the townships of Darling, Lavant, Dalhousie and North Sherbrooke amalgamated into one municipality: the Township of Lanark Highlands. In addition, the Town of Smiths Falls was annexed from Lanark County. Although politically independent, physically the area of the Town of Smiths Falls is included as part of the study area as it falls within the boundaries of the county.

In 2011, the population of Lanark County was 65 667 (Statistics Canada 2012), which represents a 2.95% increase from the 2006 census data (Statistics Canada 2007). Lanark County is largely rural in character and the majority of the county is either farmed or forested. There are 3 main urban centres: Carleton Place, Perth and Smith Falls, which, respectively, comprise 14.9%, 8.9% and 13.7% of the overall population of the county (*see* Table A). Almonte and Lanark are small urban centres in the county with a smaller proportion of the population.

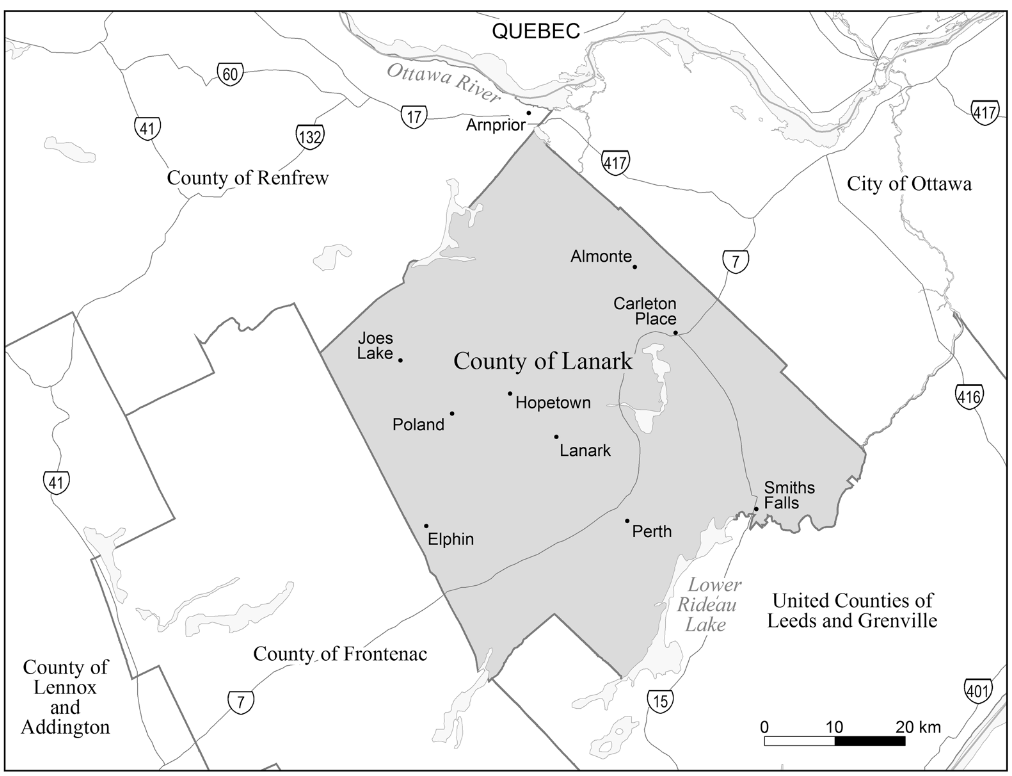

Figure 2. Detailed location map for the County of Lanark.

Major road access to Lanark County is provided by Provincial Highway 7. Access to Toronto and Ottawa is via Highway 7. Travel throughout the county is provided by a well-developed network of county and township roads. Highway 29 in the east connects Smiths Falls, Carleton Place and Almonte with Brockville in the south and Arnprior in the north. Highway 15 connects Perth and Smiths Falls.

Table A – Area and Population, County of Lanark

Municipality (Listed Alphabetically)	Land Area (Hectares)	2006 Population	2011 Population
Township of Beckwith	24 051	6387	6986
Town of Carleton Place	883	9453	9809
Township of Drummond / North Elmsley	36 603	7118	7487
Township of Lanark Highlands	104 819	5180	5128
Town of Mississippi Mills	51 953	11 734	12 385
Township of Montague	27 974	3209	3483
Town of Perth	1225	5907	5840
Town of Smiths Falls	961	9163	8978
Tay Valley Township	54 912	5634	5571
TOTAL	**303 381**	**63 785**	**65 667**

SURFICIAL GEOLOGY AND PHYSIOGRAPHY

The physiography and distribution of surficial materials in Lanark County, including the sand and gravel deposits illustrated on Map 1, were deposited primarily by glacial activity that occurred during the Late Wisconsinan (Barnett 1992). This period, approximately 23 000 to 10 000 years ago, was marked by the repeated advance and retreat of the Laurentide Ice Sheet across southern Ontario (Barnett 1992). The advance of the ice sheet across the study area was in a predominantly west to southwest direction as evidenced by the orientation of glacial ice-flow indicators such as striae and drumlins (Kettles 1992a).

Locally, the direction of ice flow appears to have been strongly influenced by local topography. In the northeast portion of the county, ice flow was influenced by the Mount St. Patrick escarpment. Glacial ice flowed south to southeast on the north side of the escarpment and south-southwest on the south side of the escarpment across the remainder of the county (Kettles 1992a). As the ice advanced, it scoured the underlying soil and bedrock, accumulating debris within and beneath the ice sheet. This entrained debris consisted of a mixture of boulders, stone, sand, silt and clay. Retreat of the ice sheet resulted in the deposition of till and drumlins over parts of the county (Barnett 1992).

Lanark County is covered by 4 physiographic regions as defined by Chapman and Putnam (1984). From west to east, these include the Algonquin highlands, Georgian Bay fringe, Smiths Falls limestone plain and the Ottawa Valley clay flats (Figure 3).

Algonquin Highlands and Georgian Bay Fringe

In the western and central portions of the county, erosion-resistant Precambrian bedrock provided little soil and weathered material to the advancing Laurentide Ice Sheet. As the ice advanced from the northeast, accumulated debris within and beneath the ice sheet was deposited as a thin and discontinuous blanket of till. The Algonquin highlands and Georgian Bay fringe are characterized by Precambrian rock knobs and ridges covered by a layer of till approximately 1.5 m thick. Locally, thicker till deposits are found, often in bedrock depressions, and commonly take the form of drumlins. Drumlins occur north of Smiths Falls and in the areas of Carleton Place and the Village of Lanark, their orientation is generally in a southwest direction (Kettles 1992a).

As the margin of the Laurentide Ice Sheet receded northward from these physiographic regions, large volumes of meltwater flowed from the ice margin. Isostatic depression of the Earth's crust caused by the weight of the ice sheet, along with blockage of drainage ways (e.g., St. Lawrence River) during retreat of the ice margin, resulted in large portions of the study area being flooded by glaciolacustrine waters. Glacial Lake Iroquois (precursor to Lake Ontario) formed with the flooding of the Lake Ontario basin 12 500 years ago. Retreating glacial ice blocked the St. Lawrence River outlet allowing the basin to flood. The extent of glacial Lake Iroquois has been inferred through the occurrence of specific freshwater species (molluscs) found in laminated sediments located throughout southeastern Ontario and deposits that are associated with ice margin and proglacial lakes. At its most northern limit, glacial

Lake Iroquois extended to at least the Joes Lake area in the northwest part of Lanark County (Kettles 1992a). This glacial lake and later stage glacial lakes abutted the ice margin and expanded with continued ice margin retreat.

As the Laurentide Ice Sheet continued to melt and retreat, sediment-laden meltwater flowed southward from the ice margin leaving behind a number of relatively large glaciofluvial and glaciolacustrine deposits including outwash, ice-contact and deltaic sediments. Regionally, these deposits can be related to similar deposits across eastern Ontario. When these systems are traced west to east, they indicate the south-to-north regression of the glacier and represent possible ice margins where retreat of the glacier was temporarily stalled (Gorrell 1991).

The glaciofluvial ice-contact deposits occur locally as discontinuous, linear accumulations of sediment. These deposits are complex and consist of facies ranging from large boulders to fine-textured sand being deposited in subglacial, proglacial and shoreline environments (Gorrell 1991). Detailed study of these deposits have been completed by Gorrell (1991) and Gorrell and Shaw (1991). They are typically described as an esker core and subaqueous fan deposit con-

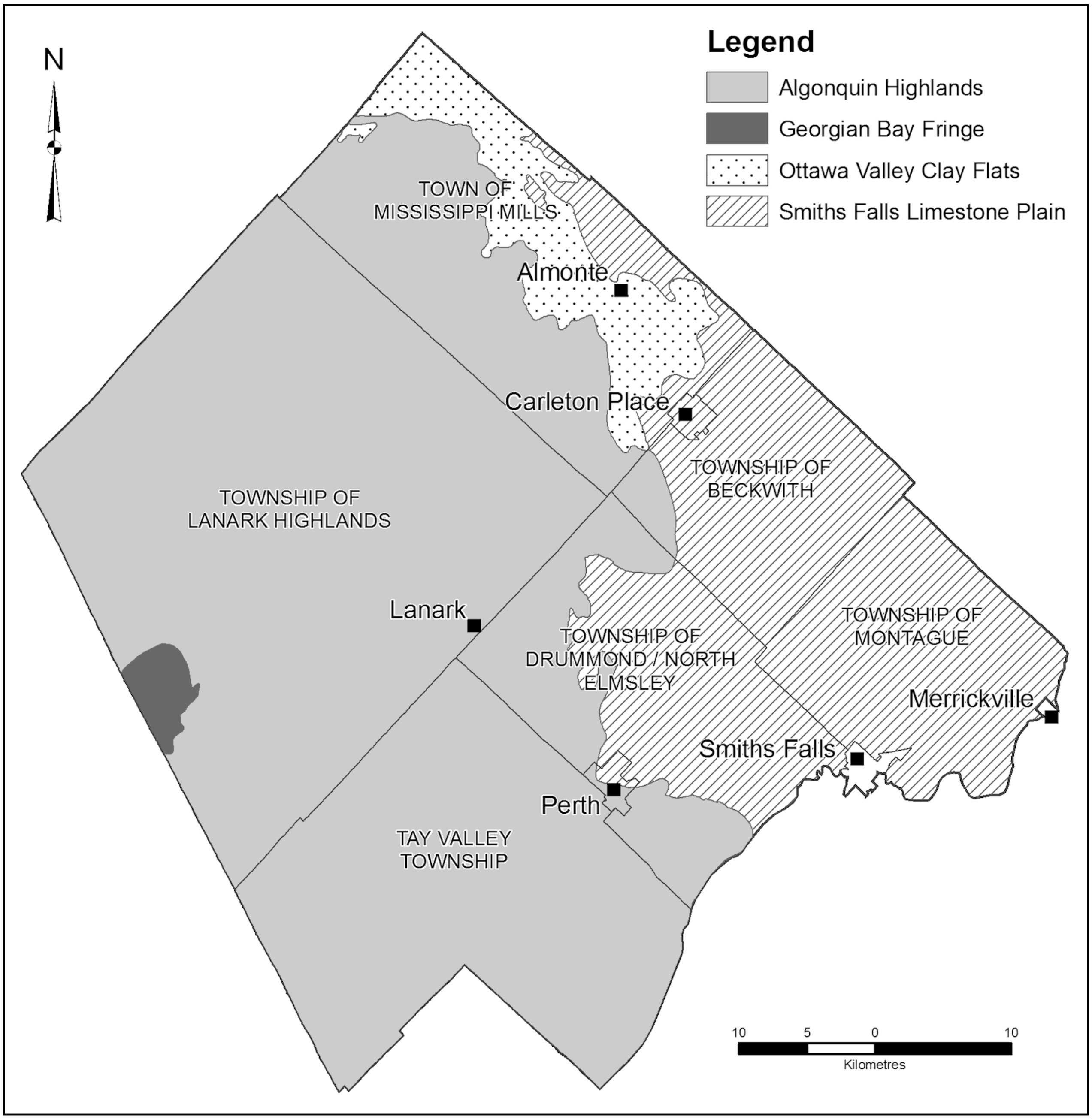

Figure 3. Physiographic regions of the County of Lanark (*modified from* Chapman and Putnam 2007).

sisting of a boulder core overlain by layers of sand and gravel. These deposits are generally oriented perpendicular to the direction of ice flow and were deposited subglacially at or near the ice margin as water in subglacial meltwater channels flowed into proglacial lakes (Kettles 1992a). A number of such deposits occur in the study area. In addition to these large deposits, there are a number of smaller discontinues pockets of ice-contact deposits that occur and are predominantly concentrated in the western and central portions of the study area (townships of Lanark Highlands and Drummond / North Elmsley, and Tay Valley Township).

Often found adjacent to or in close proximity to these ice-contact deposits are glaciolacustrine deltaic deposits. One such deposit is located in the northern portion of Lanark County (Township of Lanark Highlands area) at Joes Lake. The deposit is a large delta deposited at the ice margin in a proglacial lake environment. The surface of this deposit is also marked by well-developed kettle hole and terraces indicating deposition close to the ice margin (Kettles 1992a). The deposit contains a large quantity of coarse material because of its proximity to the ice margin.

Ottawa Valley Clay Plain

Approximately 11 700 to 11 500 years ago, with further retreat of the Laurentide Ice Sheet, the St. Lawrence River Valley became ice free. This opened drainage outlets for the Great Lakes and allowed water levels in glacial Lake Iroquois to drop and permitted seawater to inundate the isostatically depressed Ottawa and upper St. Lawrence River valleys. This led to the creation of the Champlain Sea that, at its most westerly extent, inundated the eastern portion of the area now designated as Lanark County (Barnett 1992). The western limit of the Champlain Sea is hard to define because of the rocky terrain of the study area. Glaciomarine beaches and stratified clay are present as indicators of the presence of the sea (Chapman and Putnam 1984). The western extent of the Champlain Sea is also approximated through paleontological evidence, mainly the presence of marine shells and whale bones found at sites near the towns of Carleton Place, Perth and Smiths Falls (Kettles 1992a).

An alternative theory to the development of the Champlain Sea suggests that the area was undergoing deglaciation and inundated by marine waters as early as 12 200 years ago. This conflicts with the above reasoning that glacial Lake Iroquois was present in the area until after 12 000 years ago and that the Champlain Sea did not form until after glacial Lake Iroquois was fully established (Fulton and Richard 1987). This theory of the development of the Champlain Sea proposed by Gadd (1980, 1987) evolved out of radiocarbon ages obtained on marine shells from beach deposits near the western marine limit of the sea. Tests on these shells consistently resulted in ages a number of years older than those in the St. Lawrence and Gatineau valleys to the east. It is suggested that a calving bay allowed marine waters to invade the Ottawa Valley area while ice remaining in the upper St. Lawrence Valley confined fresh waters of glacial Lake Iroquois to the Lake Ontario basin (Gadd 1980, 1987).

The majority of deposits associated with the Champlain Sea are located in the eastern portions of the study area (townships of Beckwith, Montague, Drummond / North Elmsley and the Town of Mississippi Mills). Confined to the areas within the Town of Mississippi Mills are thick deposits of clays that characterize the Ottawa Valley clay plain. The clay plains are flat lying with local ridges of rock or sand. In the study area, the clay plains are juxtaposed against the rocky and highly varied Precambrian rocks of the Algonquin highlands to the west. The clay is grey in colour, noncalcareous and commonly referred to as the “Leda clay” (Chapman and Putnam 1984). The clay was deposited in deep basins and can be as thick as 100 m locally. Glaciomarine deltas and beaches deposited with the later retreat of the sea were sporadically deposited over the clay plain.

Smiths Falls Limestone Plain

With the retreat of the ice sheet and removal of the weight of the thick ice sheet, the Earth’s crust was able to rebound. This increase in elevation caused the recession of marine waters from the study area. The Champlain Sea is thought to have started receding from its western limit in the study area by about 10 000 years ago, receding from west to east as the isostatically depressed region began uplifting (Fulton and Richard 1987).

As the marine waters receded, the southeast portions of the county (townships of Beckwith, Montague and Drummond / North Elmsley) were left with a thin covering of soil overlying relatively flat-lying limestone bedrock. Glaciomarine plains, deltas and beaches, as previously discussed, are common deposits overlying the thin soil of the Smiths Falls limestone plain. Ridges caused by bedrock faulting and shallow depressions in the bedrock provide the area with what little relief is observed. The low-relief areas are, in general, poorly drained and, with the accumulation of organic matter, support abundant bogs. Bogs are common in the southeast where the Paleozoic rock abuts the knobby Precambrian bedrock that characterizes the Algonquin highlands.

SEDIMENTS

Till

The geology and geochemistry of the till in the study area has been studied in detail by Kettles (1992a) and Kettles and Shilts (1987). Although till is usually not well suited for aggregate use because it often contains excess fines and oversized clasts, it is the most widespread glacial deposit in Lanark County and, in some cases, till may be suitable for fill and other lower quality aggregate products. The thin and discontinuous nature of the till in the study area contributes to the fact that no identification of till facies has been done. Due to the coarsely crystalline nature of the Precambrian source rocks, the till is primarily stony with a sand-rich matrix. The average texture of the till has been identified as 67% sand, 26% silt and 7% clay with these values ranging from 34 to 97%, 2 to 55% and 1 to 29%, respectively (Kettles and Shilts 1987). Exposure of till in pit sections reveals indicators of well-sorted and water-saturated sediment. This suggests that local deposition of till was carried out, in part, by meltwater.

North of the Town of Perth, thicker deposits of till overlying the Paleozoic bedrock are present. Kettles (1992a) attributes this thickening to the low erosion resistance of the underlying Paleozoic bedrock. As the area is surrounded on the north, west and south by harder Precambrian lithologies, debris entrained by the ice sheet would be composed in part from these lithologies. These harder lithologies would be capable of grinding and eroding the softer lithologies of the Paleozoic bedrock thereby creating a greater amount of entrained debris.

Glaciofluvial Deposits

Ice-contact deposits are most common in the western half of the study area. These deposits represent the most important sand and gravel deposits in the study area. The larger of these deposits occur as discontinuous linear ridges in the townships of Lanark Highlands, Tay Valley and Drummond / North Elmsley. One ridge extends 75 km south-southwest from the Poland area into the adjacent County of Frontenac, and a second ridge extends 25 km southwest from the south of Elphin to north of the Town of Lanark. These deposits have the greatest potential as an aggregate resource. Smaller and scattered ice-contact deposits also occur throughout this area and the rest of the county. In some cases, the stone quality (i.e., excess shale clasts), the presence of excess fines (silt and clay) or oversized material and the small size of the deposits may limit the potential of the resource.

Glaciolacustrine Deposits

Glacial and postglacial lacustrine deposits are common throughout the western portion of the study area in the townships of Lanark Highlands, Tay Valley and Drummond / North Elmsley, which represent areas not inundated by the Champlain Sea. Glaciolacustrine delta deposits are the most abundant type. They are often deposited in topographic lows and in association with ice-contact deposits as discussed previously. In general, these deposits are thick and comprise well-sorted fine-textured sediments (sands, silts and clays) with lesser amounts of gravels. These deposits have a low potential as significant aggregate sources due to the abundance of fine-textured sediments. Some deltaic deposits with a higher proportion of, or sections with greater amounts of, coarse material (gravel) have a higher potential.

One such glaciolacustrine deltaic deposit located at Joes Lake in the Township of Lanark Highlands is the largest and best exposed. The deposit at Joes Lake is characterized by cementation and encrustation (Photo 01, ArcGIS® version only) that causes the sand and gravel material to stick together. This deposit is well sorted and generally contains significant amounts of coarse-textured material, which is ideal for aggregate production.

Glaciomarine Deposits

Glaciomarine deposits are common in the eastern portion of the study area in the townships of Beckwith, Montague, Drummond / North Elmsley and the Town of Mississippi Mills, which represent areas inundated by the Champlain Sea. Glaciomarine beaches and deltas are present with beaches being the most common. The beaches tend to be small, thin linear deposits. Larger and more irregularly shaped deposits are located along the eastern border of the study area. Where beach deposits were derived from the reworking of till or glaciofluvial deposits, the deposit tends to be composed of boulders, gravel and sand. When beach deposits are derived from underlying limestone bedrock, the deposit tends to be composed of slabs or “shingles” of sedimentary rock. These deposits, being relatively small, are suitable for use to supply local needs.

Alluvial Deposits, Glaciomarine Plains and Organic Deposits

Alluvial and organic sediments within the study area have very limited potential as aggregate resources. Clays deposited as glaciomarine plains also have very limited potential as an aggregate resource; however, there is potential to use the clay as liner material for waste disposal sites. Site-specific testing is required to evaluate a clay’s compatibility as a liner (e.g., Theriault and Mitchell 1997).

In addition to the references already cited, more detailed information on the Quaternary geology of Lanark County is provided in the following maps and publications: Barnett and Clarke (1980), Bélanger, Moore and Prégent (1997a, 1997b), Bélanger et al. (1995), Henderson (1973), Henderson and Kettles (1992), Kettles (1992b, 1992c), Kettles, Henderson and Henderson (1992) and Sharpe (1979).

PREVIOUS WORK

A previous aggregate resources inventory of Lanark County was completed by Gorrell, van Haaften and Fletcher (1985). This report does not follow the “traditional” *Aggregate Resources Inventory Paper* format currently in use. Extensive borehole data were collected as part of this earlier project; these data are provided in Table 7 (and in the ArcGIS® files) of the current study.

SAND AND GRAVEL EXTRACTIVE ACTIVITY

The sand and gravel deposits of Lanark County are shown on Map 1 accompanying this report. Sand and gravel deposits occupy approximately 9648.4 ha with a possible aggregate resource of 574.9 million tonnes (Table 1). **These figures represent a comprehensive inventory of all the granular material in Lanark County, although much of the material included in the estimate has no potential for use in aggregate products.**

At the time of writing, there were 137 sand and gravel pits identified in Lanark County (Table 2). The majority of these have been developed in glaciofluvial ice-contact and ice-contact esker deposits, in glaciolacustrine beach and deltaic deposits and in glaciomarine beach deposits. At the time of writing, 88 pits were licenced for operation under the *Aggregate Resource Act* (*see* Table 2). Ten of the operations are licenced for both sand and gravel and bedrock extraction. This information was provided by the Ministry of Natural Resources, Land and Information Ontario (LIO) current to the fall of 2010. Tables B and C provide statistics on aggregate production from 2000 to 2009 for Lanark County and lower tier municipalities, respectively. Pit locations are shown on Map 1 and individual descriptions are provided in Table 2.

Most of the unlicenced pits have been abandoned and many are overgrown. Many unlicenced pits are difficult to identify and only the very obvious unlicenced pits are shown on Map 1. This happens for a variety of reasons, including 1) many of the unlicenced pits were small to begin with and have left a small "footprint"; 2) many have been fully or partially rehabilitated following extractive activities; 3) many pit faces have been sloped and revegetated naturally; 4) many pits may be hard to identify from the natural rolling topography of the area; and 5) the *Pits and Quarries Control Act* (1971) and the *Aggregate Resources Act* (1989) have been effective in preventing the establishment of new unlicenced pits.

The majority of sand and gravel extractive activity occurs in a number of glaciofluvial ice-contact and ice-contact esker deposits located primarily in the Township of Lanark Highlands. There are approximately 1280 ha of licenced property in the Township of Lanark Highlands, which represents 61% of the total licenced area in the county.

A greater dependence on crushed bedrock for use as coarse aggregate is expected over the next decade as sand and gravel supplies near depletion and the demand for higher quality products increases. This trend can already be seen. The aggregate production in sand and gravel–dominated municipalities (i.e., Township of Lanark Highlands) has decreased, whereas production in Paleozoic bedrock–dominated municipalities (i.e., Township of Montague) has increased significantly (*see* Table C). This trend

Table B – Aggregate Production (2000–2009), County of Lanark

Year	Production (×10^6 tonnes)
2000	1.6
2001	1.7
2002	2.0
2003	2.4
2004	2.3
2005	2.3
2006	2.3
2007	2.3
2008	1.9
2009	2.5

Source: The Ontario Aggregate Resources Corporation (2010)

Table C – Aggregate Production (2000 and 2009) by Municipality, County of Lanark

Municipality	2000 Production * (tonnes)	2009 Production ** (tonnes)
Township of Beckwith	47 281.77	728 942.01
Town of Carleton Place	–	–
Township of Drummond / North Elmsley	130 689.87	83 995.50
Township of Lanark Highlands	1 271 406.79	885 241.59
Town of Mississippi Mills	13 154.10	497 436.69
Township of Montague	96 061.38	270 214.17
Town of Perth	–	–
Town of Smiths Falls	–	–
Tay Valley Township	34 874.90	20 121.10
TOTAL	**1 593 468.81**	**2 485 951.06**

Sources: *The Ontario Aggregate Resources Corporation (2001); **The Ontario Aggregate Resources Corporation (2010) can also be attributed to the proximity of bedrock-dominated townships to the City of Ottawa where demand for aggregate is high. Historically, aggregate production in Lanark County has supplied the local market, providing basic aggregate products for local construction projects. Many of the small pits throughout the county produce pit-run sand products to meet local construction needs. This type of production will likely continue at current levels into the foreseeable future.

SAND AND GRAVEL AGGREGATE QUALITY

Test data from the Ministry of Transportation (MTO) files have been used extensively in the assessment of the resources of the county. However, significant changes have occurred in the testing and specifications applied to aggregates over the years. The Los Angeles abrasion test (LS-603) is no longer used in the Ontario Provincial Standard Specifications (OPSS) and the magnesium sulphate soundness test (LS-606) has been reduced to an alternate test. Two newer tests, the micro-Deval abrasion test (LS-618 and LS-619) and the unconfined freeze–thaw test (LS-614) have been added. The accelerated mortar bar expansion bar test (LS-620) has also become a standard test for the determination of potential alkali–silica reactivity in concrete aggregate.

The MTO files for Lanark County commonly contain test results for the Los Angeles abrasion and magnesium sulphate soundness tests. These data are extensive and they are still useful in assessing the general quality of the material, so they have been included in the current assessment. For example, a Los Angeles abrasion test loss of 35% or less generally indicates good physical quality in an aggregate.

Many former sources of sand and gravel are now depleted; however, the data compiled when they were operating is useful in indicating the potential of adjacent properties within the same deposit.

Care should be exercised in extrapolating the quality test data for individual samples contained in this report to the entire deposit due to the inherent variability of sand and gravel deposits, particularly large and extensive deposits. Where possible, a range of test results have been provided, which represent a number of sample locations distributed throughout the deposit from samples collected over a long period of time. Where aggregate test results and photos (vector ArcGIS® version only) have been included for the selected deposit, the location of these photos and test results have been re-positioned to ensure the privacy of property owners. These photos and results are often placed near the centre of the deposit.

Discussion on what specifications the granular material within a deposit or selected resource area may be suitable for relate only to aggregate products that are generally used by the MTO. Other aggregate products, such as winter road sand, fill, septic and mortar sand, to name a few, are not discussed; therefore, many licenced operations are economically viable and are successfully producing these other valuable aggregate products.

It is highly recommended, therefore, that, where sand and gravel extraction and development is contemplated, extensive testing be conducted to verify aggregate quality and quantity. Site-specific investigations provide greater detail on the nature of the local deposit.

SELECTED SAND AND GRAVEL RESOURCES AREAS

Map 1 shows the geographic distribution of sand and gravel in Lanark County. Four areas have been chosen as Selected Sand and Gravel Resource Areas of primary significance and are indicated on Map 1 in red. These areas occupy an unlicenced area of approximately 809.7 ha that is reduced to 280.6 ha after considering extracted area and cultural, physical and environmental constraints. These areas represent a possible aggregate resource of 29.8 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 is located at Joes Lake in the northwest part of the study area in the Township of Lanark Highlands. The deposit is a large glaciolacustrine deltaic deposit.

The delta deposit is inferred to have been deposited close to the ice margin. There is a well-developed kettle hole on the surface and the deposit material is cobbly in nature (Kettles 1992a). The deposit material, ranging from cobble-sized to silt, is well sorted with distinct layers of cobbles, gravel, sand and silt-rich layers (Photo 02, ArcGIS® version only). The silt layers and certain sections dominated by fines pose a problem as they contain enough silt as to limit the usefulness of the deposit and should be avoided during extraction. Well-defined terraces mark the boundaries of the deposit.

One licenced pit (Pit No. 3) and one unlicenced pit (Pit No. 55) have been developed in this resource area. Face heights in the pits range from 4 to 10 m; however, available borehole records indicate the potential for more than 15 m of sand and gravel locally. Calcite cementation within the deposit holds material 30° off the vertical and can cause potential problems during extraction (Gorrell, van Haaften and Fletcher 1985). The cementation also lowers the quality of the aggregate material.

The aggregate test results for sample 10-VLL-004, collected as part of this study, are provided in Table 9, and shown in Figure 6. The gradation results show 43.7% coarse aggregate with 14.5% of the coarse aggregate fraction being crushable. Magnesium sulphate soundness test results were

6.0% for coarse aggregate. The micro-Deval abrasion value for coarse aggregate was 13.2%. The sample had an absorption of 1.20% and a bulk relative density of 2.724. The Petrographic Number value for Hot-Laid (HL) and concrete products was 277.5 in part because of the encrustation and cementation of the granular material as previously mentioned.

Previous aggregate test results provided the following information and are provided in Table 9 and Figure 7. The aggregate content varies from 68.2 to 69.7% coarse, 20.3 to 23.5% sand and 0.7 to 1.2% fine-grained aggregate. Petrographic Number values range from 129.5 to 135.5 for Granular and 16 mm and from 164.5 to 178.8 for HL and concrete stone products. A magnesium sulphate soundness test result from one sample was 10.3% for coarse aggregate. Based on the test results discussed above material from this deposit is suitable for the production of Granular B and SSM products. The material is not suitable for production of HL and concrete products in part because of the high Petrographic Number values.

Selected Sand and Gravel Resource Area 1 has a total unlicenced area of 100.0 ha. After considering physical, cultural and environmental constraints, the area available for possible resource protection and development is approximately 51.6 ha. Assuming an average thickness of 6 m, the area is estimated to contain a possible aggregate resource of 5.5 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 is located along the southern border of the Township of Lanark Highlands. The selected area consists of an east-trending glaciofluvial ice-contact–esker ridge approximately 6 km long and 300 m wide.

The main feature of the deposit is the coarse-textured esker core. The core consists of medium to coarse sand and gravel with numerous cobbles and boulders. With the removal or crushing of oversized material, the material in this deposit is suitable for manufacturing a range of sand and gravel products. Because of this, the coarse material in the centre of the deposit has been largely extracted (Photo 03, ArcGIS® version only). However, it is likely that this coarse material continues beneath the roads that have been built along the length of the deposit. Pit face heights range from 3 to 10 m. Borehole data indicate local deposit thickness as great as 21 m.

The aggregate test results for sample 10-VLL-005, collected within this selected resource area as a part of this study, are provided in Table 9 and shown in Figures 8A and 8B. The gradation results for this sample indicate 54.0% coarse aggregate, 45.6% sand and 0.4% fine-grained aggregate, with 4.1% of the coarse aggregate fraction being crushable. Magnesium sulphate soundness test results were 5.0% for coarse aggregate. The micro-Deval abrasion value was 14.3% for the coarse aggregate and 7.8% for fine-grained aggregate. The sample had absorption of 0.620% and a bulk relative density of 2.735.

Previous aggregate test results provided the following information. The aggregate content varies from 16.0 to 82.1% coarse, 17.1 to 80.1% sand and 0.8 to 3.9% fine-textured aggregate. Petrographic Number values range from 100.5 to 123.7 for Granular and 16 mm and from 112.8 to 174.8 for hot mix and concrete products. Magnesium sulphate soundness test results vary from 2.9 to 12.1% for coarse aggregate and from 9.2 to 19.7% for fine-grained aggregate. Los Angeles abrasion test results range from 32.3 to 47.0%. Absorption capacity results vary from 0.502 to 2.110% and bulk relative density values range from 2.589 to 2.792 (*see* Table 9). Gradation results for chosen representative samples are shown in Figures 9A to 10B.

Granular material from this selected area is capable of meeting the grain-size specification for Granular A, Granular B and SSM aggregate products. The material grades coarse for concrete and HL products. With proper blending, material from these deposits may have the potential to be used in the production of HL aggregate products. The stone quality (high Petrographic Number values) present in some samples is a concern for the production of HL and concrete products.

Six licenced pits (Pit Nos. 37 to 42) have been developed along the length of Selected Sand and Gravel Resource Area 2. Selected Sand and Gravel Resource Area 2 has a total unlicenced area of 109.7 ha. After considering physical, cultural and environmental constraints, the area available for possible resource protection and development is reduced to 43.2 ha. Assuming an average deposit thickness of 6 m, there are approximately 4.6 million tonnes of possible aggregate resources available (*see* Table 3).

Selected Sand and Gravel Resource Area 3

Selected Sand and Gravel Resource Area 3 is located in the southern portion of the Township of Lanark Highlands adjacent to Selected Sand and Gravel Resource Area 2. The selected area consists of 2 glaciofluvial ice-contact deposits.

Three licenced pits (Pit Nos. 34 to 36) have been developed in the deposit and one land parcel was in the licencing process during the field investigations. Face heights range from 3 to 7 m with borehole data indicating depths of up to 18 m locally. These deposits exhibit esker-like characteristics in the most easterly sections that are proximal to Selected Sand and Gravel Resource Area 2. Oversize material is common in these sections and will have to be removed or crushed. The deposit fines to the west and, in general, the deposit consists of beds of medium-textured sand with varying amounts of gravel. There are also sections of the deposit that contain high amounts of silt; these sections should be avoided during extraction.

Previous aggregate test results provided the following information. Gradation varies from 26.9 to 67.9% coarse aggregate, 31.0 to 64.6% sand and 1.9 to 8.5% fines. Petrographic Number values range from 101 to 109 for Granular and 16 mm and 113 to 141 for hot mix and concrete products. Magnesium sulphate soundness test results for coarse aggregate vary from 5.9 to 12.1% and from 5.6 to 22.5% for fine-grained aggregate (*see* Table 9). Gradation results for chosen representative samples are shown in Figures 11A and 11B.

With processing and the avoidance of silty sections, the material in these deposits are capable of meeting the grain-size specification for Granular A, Granular B and SSM products. The stone quality of the deposit is relatively good. Few test results had values over the accepted range. With appropriate blending and screening, there is the potential to use the material for HL products.

Selected Sand and Gravel Resource Area 3 has a total unlicenced area of 207.3 ha. After considering physical, cultural and environmental constraints, the area available for possible resource protection and development is reduced to 79.0 ha. Assuming an average deposit thickness of 6 m, there are approximately 8.4 million tonnes of possible aggregate resources available (*see* Table 3).

Selected Sand and Gravel Resource Area 4

Selected Sand and Gravel Resource Area 4 is a glaciofluvial complex located northeast of the Town of Lanark. The deposit is a combination of various depositional environments, including eskers, esker beads, deltas and fans.

There are currently 7 licenced pits (Pit Nos. 44 to 50) located in the deposit with face heights ranging from 3 to 12 m. Previous borehole records indicate that the deposit can be up to 18 m thick locally. The sediment succession, sedimentary structure and grain size of the deposits has been detailed by Gorrell and Shaw (1991). The esker complex, including the eskers and esker beads, were created by subglacial drainage that developed into interconnecting channel networks. When these subglacial drainage paths emerged from the ice front, subaqueous fans and deltas were developed.

Aggregate test results from 2 samples, 10-VLL-007 and 10-VLL-008, collected within this selected resource area as a part of this study, are provided in Table 9 and are shown in Figures 12A and 12B. Sample 10-VLL-007, from a fan located south of the main esker ridge, was collected from graded and massive silt to medium-textured sand. The gradation results for this sample were 85.1% sand and 14.9% fine-textured aggregate. Magnesium sulphate soundness test results were 13.0% and the micro-Deval abrasion value was 8.7% for the fine-textured aggregate fraction. The sample had absorption of 0.510% and a bulk relative density of 2.711.

Sample 10-VLL-008 was collected from a subaqueous fan located west of the main esker ridge. The gradation results for this sample were 7.5% coarse aggregate, 89.9% sand and 2.7% fine-textured aggregate; with 1.9% of the coarse aggregate fraction being crushable. The micro-Deval abrasion value for fine aggregate was 9.1%. The sample had an absorption value of 0.530% and a bulk relative density of 2.690. The Petrographic Number value for HL and concrete was 138.0 and the accelerated mortar bar value was 0.051% indicating that the material can be used in Portland cement. Stone quality may be a concern since the Petrographic Number values from other samples within this deposit are far outside the acceptable range (*see* below).

Previous aggregate test results provided the following information. Gradation varies from 24.4 to 71.3% coarse aggregate, 27.6 to 70.1% sand and 0 to 5.5% fine-textured aggregate. The percentage of crushable material ranges from 0 to 27.3%. Magnesium sulphate soundness test results vary from 8.9 to 37.0% for coarse aggregate and from 8.9 to 26.5% for fine-textured aggregate. Gradations from chosen representative samples are shown in Figures 13A to 14B. Los Angeles abrasion test results range from 9.3 to 51.4%. Bulk relative density varies from 2.482 to 2.721 and absorption capacity ranges from 0.510 to 2.970%. Petrographic Number values range from 109.1 to 371.4 for Granular and 16 mm and from 131.5 to 419.2 for hot mix and concrete (*see* Table 9). The high Petrographic Number values are attributed to a variety of poor rock types including shale, shaly limestone and friable gneisses. The amount of shale is thought to be the largest contributor of deleterious material. It is believed to be local in origin with the average shale content ranging from relatively low values of 4.8% to as high as 36.2%.

The esker and esker beads have been largely extracted. Remaining material in the subaqueous fans is variable in part because of rapid changes in paleocurrent strength and direction. A general fining-upward sequence has been observed in the fans (Gorrell and Shaw 1991). The granular material of this deposit is able to meet the gradational requirements for Granular A, Granular B, SSM, HL and concrete products. Stone quality is an obvious problem that will limit usefulness for the production of granular material as mentioned above.

Selected Sand and Gravel Resource Area 4 has a total unlicenced area of 392.7 ha. After considering physical, cultural and environmental constraints, the area available for possible resource protection and development is reduced to 106.8 ha. Assuming an average deposit thickness of 6 m, there are approximately 11.3 million tonnes of possible aggregate resources available (*see* Table 3).

Resource Areas of Secondary Significance

There are relatively few resource areas of secondary significance in Lanark County. Areas of secondary significance do not have the best aggregate, specifically a blend of crushable gravel and sand-sized material; however, they may contain large quantities of material suitable for some applications. In some cases, resource areas of secondary significance are classed as secondary due to the lack of reliable geological data. This lack of data may not allow an accurate assessment of either the quality or quantity of sand and gravel within a deposit. Resource areas of secondary significance serve as important alternative extraction sites and should be considered as part of a region's total aggregate supply. Secondary aggregate resources can also be used for wayside pit operations, which are generally related to specific, time-restricted projects. The secondary deposits are not labelled individually on the accompanying maps and only selected descriptions are provided herein.

There are a number of smaller deposits that would normally be selected at the secondary level, but the deposits often lie completely within a licenced operation. Therefore, there is no more aggregate potential within the deposit beyond the licence boundary.

A number of ice-contact deposits located in the western part of Lanark County have been identified as aggregate resource areas of secondary significance. These areas have been selected because they tend to occur along transportation corridors or they host existing aggregate licences. A few glaciolacustrine delta deposits have also been selected as resource areas of secondary significance because of existing aggregate licences and their proximity to areas selected as a primary resource.

TOWNSHIP OF LANARK HIGHLANDS

There are a series of ice-contact deposits located in the north-central portion of the Township of Lanark Highlands along Highway 511 that have been selected at the secondary level. There are currently no licenced pits located in the deposits, and only 1 unlicenced pit (Pit No. 57). Face heights range from 3 to 5 m and borehole records indicate that locally over 10 m of material is potentially available. Previous gradation results indicate an aggregate content of 26.1 to 75.8% coarse, 24.0 to 68.1% sand and 0.2 to 5.8% fines. The amount of crushable material from the coarse aggregate fraction ranges from 0 to 54.3%. Gradation results from chosen representative samples are shown in Figures 15A to 15B. Previous Petrographic Number test results for Granular and 16 mm range from 100.3 to 177.9 and from 105.3 to 184.5 for hot mix and concrete products. Previous magnesium sulphate soundness test results range from 3.0 to 6.4% for coarse aggregate and from 10.4 to 18.8% to fine-grained aggregate. Los Angeles abrasion test values varied from 23.4 to 29.8%. Bulk relative density results varied from 2.739 to 2.774 and absorption capacity values ranged from 0.830 to 1.169% (*see* Table 9). The material in the deposit meets the gradational requirements for Granular A, Granular B and SSM products. The material generally grades coarse for HL products and would require blending to meet product specifications. Overall, the material of the deposit is of reasonable quality. The discontinuous nature of the deposit and the difficulty in determining the amount of past extraction makes it difficult to determine the amount of desirable material remaining. The deposit is potentially a source for wayside pit operations for road improvement and construction activity along the Highway 511 corridor.

Located in the central portion of the Township of Lanark Highlands, northwest of Hopetown, is a series of ice-contact deposits. There are currently 3 operating licenced pits (Pit Nos. 10 to 12) with face heights ranging from 2 to 9 m. Borehole data indicate depths of up to 18 m locally. Previous gradation results indicate an aggregate content of 31.1 to 61.5% coarse, 36.5 to 65.7% sand and 2.0 to 3.2% fine-textured aggregate. Gradation results for chosen representative samples are shown in Figures 16A to 16B. Previous test results indicate Petrographic Number values ranging from 109.2 to 130.8 for Granular and 16 mm and from 138.9 to 173.9 for hot mix and concrete products. Magnesium sulphate soundness test results range from 6.0 to 11.4% for coarse aggregate and from 12.7 to 23.0% for fine-grained aggregate (*see* Table 9). Although stone quality is a concern, material in these deposits meet the gradational requirements for Granular A, Granular B and SSM aggregate products. With processing, material can be used for HL 4 coarse aggregate and HL 4 fine-grained aggregate products, with HL 4 coarse aggregate potentially requiring the use of an anti-stripping agent.

Along the western border of the Township of Lanark Highlands, a series of ice-contact deposits have been selected as a resource area of secondary significance. One licenced pit (Pit No. 17) is operating in the resources area. Face height ranges from 2 to 5 m and borehole data indicate a potential deposit thickness of up to 7 m. The deposits consist of layers of medium- to medium-fine-textured sand with differing amounts of gravel. Layers composed predominantly of gravel can be over a metre thick. Limited information is available on the deposit, but the deposit does exhibit esker-like characteristics. It is recommended that further testing be completed on the deposit to confirm the potential of the deposit.

Located in the southwestern corner of the Township of Lanark Highlands, northeast of Elphin, a glaciolacustrine delta deposit has been selected at the secondary level of significance. There is 1 licenced pit (Pit No. 33) and 1 unlicenced pit (Pit No. 64) located in the deposit. Face heights range from 2 to 6 m. Previous gradation results indicate an aggregate content of 7.8 to 57.5% coarse, 40.7 to 77.6 % sand and 1.8 to 14.6 % fine-textured aggregate. Gradation results for chosen representative samples are shown in Figure 17A and 17B. Previous aggregate test results provide the following information. Petrographic Number values range from 102 to 113 for Granular and 16 mm and from 125 to 160 for hot mix and concrete products. Magnesium sulphate soundness test results vary from 4.2 to 12.6% for coarse aggregate and from 4.0 to 12.1% for fine-grained aggregate (*see* Table 9). Ministry of Transportation (MTO) records indicate that the material from the deposit is acceptable for the production of Granular A and B with the removal or crushing of oversize material. The material can also meet specifications for HL products with sand control and avoidance of silty sections.

Located in the southwest corner of the Township of Lanark Highlands, west of Selected Sand and Gravel Resource Area 3, a pair of ice-contact deposits have been selected as having secondary significance. There are no licenced pits in the deposits and only 1 unlicenced pit (Pit No. 63) with a face height of 3 to 8 m. Borehole data indicate that, locally, the deposit is up to 17 m thick and is composed of layers of medium-textured sand and gravel with sections containing quantities of fine-grained sand and silt. Limited data are available for the deposit, but the aerial extent, deposit type and proximity to known sand and gravel resources indicate that there is potential. Further testing is recommended to determine material acceptability.

Also located in the southwest corner of the Township of Lanark Highlands is a series of ice-contact deposits. There are 2 licenced operations (Pit Nos. 31 and 32) in the deposit with face heights ranging from 3 to 12 m. Borehole data indicate a thickness of up to 15 m locally. Previous gradation results indicate a coarse aggregate content from 0.5 to 25.6%. Field observations suggest that the deposit is composed mainly of sand but with sections and layers of gravel material. These gravel sections also contain quantities of crushable material.

Located in the southern portion of the Township of Lanark Highlands, surrounding Selected Sand and Gravel Resource Area 2, are glaciolacustrine deltas that have been selected at the secondary level of significance. There are currently 5 licenced operations (Pit Nos. 37 to 41) in these deposits, which also extend into Selected Sand and Gravel Resource Area 2. Face heights range from 2 to 12 m with sand being the primary material of the deposit. Test results from a sand sample collected within this selected resource area, 10-VLL-006, is provided in Table 9 and Figures 18A and 18B. These gradation results indicate that the material can potentially be used for HL asphalt mix. Previous MTO test results indicate that Petrographic Number values range from 100.0 to 106.8 for Granular and 16 mm and from 112.9 to 127.8 for hot mix and concrete products. Magnesium sulphate soundness test results range from 3.7 to 7.2% for coarse aggregate and from 8.9 to 16.0% for fine aggregate. Los Angeles abrasion test results vary from 38.9 to 44.7%. Bulk relative density varies from 2.721 to 2.726 and absorption capacity ranges from 0.800 to 0.860%. These deposits have been selected as aggregate resource areas of secondary significance in part because the material in these deposits adds to the overall quantity of material available in Selected Sand and Gravel Resource Area 2. The material is potentially acceptable for HL products, although blending may be required due to fines.

TAY VALLEY TOWNSHIP

Located along the northeast border of Tay Valley Township, a pair of ice-contact deposits has been selected as having secondary significance. These deposits are associated with the eastern limit of Selected Sand and Gravel Resource Area 2. There are no licenced operations in the deposits and 1 unlicenced pit (Pit No. 99) with a face height ranging from 3 to 5 m. Previous gradation test results indicate a coarse aggregate content ranging from 5.9 to 48.4%. Previous test results indicate Petrographic Number values ranging from 102.5 to 150.6 for Granular and 16 mm and from 127.4 to 163.9 for hot mix and concrete products. Magnesium sulphate soundness test results range from 3.1 to 4.9% for coarse aggregate and from 2.4 to 16.3% for fine-grained aggregate. Absorption values vary from 0.800 to 1.030%. With proper processing, material in these deposits can be used for Granular B and HL products.

Located in the northwestern portion of Tay Valley Township north of Highway 7, a series of ice-contact deposits have been identified as being of secondary significance. There is 1 licenced pit (Pit No. 84) and 1 unlicenced pit (Pit No. 94) located in these deposits. Limited data are available, but field observations suggest that the coarse aggregate content ranges from 5 to 25%. Crushable and oversize material was observed in the deposit, but it is difficult to determine the extent of these materials. The deposits are bordered by glaciolacustrine deltaic sediments that, although predominantly sand, add to the total amount of material available. It is suggested that further testing be carried out to determine the acceptability of the material.

Located in the western portion of Tay Valley Township just south of Highway 7, an ice-contact deposit has been identified as being of secondary significance. There is 1 licenced pit (Pit No. 85) developed in the deposit with a face height ranging from 3 to 6 m. The deposit is predominantly a sand source with previous gradation test results indicating a coarse aggregate content ranging from 1 to 25%. The material in the deposit is not acceptable for Granular A, but can meet the specification for Granular B and HL products with proper processing. More testing is recommended to determine the exact potential of the deposit. The deposit has the potential to provide aggregate to an area that is relatively void of the resource.

Located in the southwest corner of Tay Valley Township, an ice-contact deposit has been identified as being of secondary significance. There are no licenced pits in the deposit and 1 unlicenced pit (Pit No. 102). Face heights range from 2 to 10 m. The deposit is bordered by glaciolacustrine deltaic sediments that contain significant amounts of sand and add to the overall quantity of material available in the ice-contact deposit. More testing on the deposit would be required to determine the specific aggregate products the material is able to produce.

TOWNSHIP OF DRUMMOND / NORTH ELMSLEY

Located in the northwest part of the Township of Drummond / North Elmsley, an ice-contact deposit has been selected as being of secondary significance. There is 1 licenced (Pit No. 109) and 1 unlicenced pit (Pit No. 117) that have been developed in the deposit. Face height in these pits range from 2 to 4 m and borehole data indicate local thicknesses of up to 6 m. Previous aggregate test results provided the following information. Coarse aggregate content ranges from 1.7 to 41.3%. Petrographic Number values range from 120.2 to 162.5 for Granular and 16 mm and from 140.7 to 185.7 for hot mix and concrete. Magnesium sulphate soundness test results vary from 9.9 to 15.7% for coarse aggregate and from 4.4 to 9.1% for fine-grained aggregate. Material of this deposit will meet the specifications for Granular B and HL products with proper processing.

Resource Areas of Tertiary Significance

Deposits of tertiary significance are abundant in the eastern portions of the county within the Town of Mississippi Mills and the townships of Beckwith and Montague. Glaciomarine delta and beach deposits in the survey area are commonly small, thin deposits of fine-textured sand and gravelly sand that are found in the lee of rock knobs and in bedrock depressions. They are generally of very limited area and thickness, and do not contain significant amounts of granular material.

BEDROCK GEOLOGY

The western and central portions of Lanark County are underlain by rocks of Precambrian age belonging to the Grenville Province. The eastern and southeast portions of the county are underlain by a succession of relatively flat-lying Paleozoic strata consisting of sandstones, limestones, dolostones and shales. The Paleozoic strata are cut by a number of faults creating escarpments.

The Precambrian rocks found in the study area are part of the Central Metasedimentary Belt of the Grenville Province. The bedrock is generally characterized as marble, volcanic rocks and clastic metasedimentary rocks. The metasedimentary rocks include crystalline limestone, quartzite, amphibolite and paragneiss (Easton 1992). The Central Metasedimentary Belt is known for mineral deposits. In the past, mica, apatite and feldspar, among other minerals, have been mined in Lanark County. Calcite continues to be extensively mined in the county. Detailed mapping and discussion of the Precambrian rocks of Lanark County are provided by Easton (1988, 1990, 2001a, 2001b, 2001c), Hewitt (1964) and Lumbers (1982).

In the central part of the Township of Lanark Highlands, calcite is being extracted for use as an industrial extender and filler. The deposit is one of the highest-grade sources in North America and plays a significant role in the local economy. Portions of the deposit contain impurities making the marble blue or salmon in colour. These areas cannot be used as a high-purity industrial mineral, but have been quarried in the past for use as dimension and decorative stone. As these operations are generally producing non-aggregate products, the resource has not been identified in the report.

Unconformably overlying the Precambrian basement rocks are a succession of Paleozoic (Cambrian to Ordovician) sedimentary strata. Regional correlation of the Paleozoic strata in the study area is difficult due to abrupt sedimentary facies changes and faulting. The lithostratigraphic nomenclature of the Paleozoic rocks used for this study follows that of Williams (1991). However, it is important to note that other researchers have been working on redefining the stratigraphy and related nomenclature in eastern Ontario (e.g., Bernstein 1992; Dix and Al Rodhan 2006; Salad Hersi and Dix 1997, 1999; Salad Hersi, Lavoie and Nowlan 2003; Sanford and Arnott 2010). Figure 4 illustrates the nomenclature proposed by these researchers.

In addition to the references listed above, more detailed mapping and discussion of the Paleozoic rock in the study area are provided by Carson (1982a, 1982b), Russell and Williams (1985), Williams and Wolf (1984a, 1984b, 1984c) and Williams, Wolf and Rae (1984).

The oldest Paleozoic formations, and those that unconformably overlie the Precambrian basement, are conglomerates and sandstones of the Potsdam Group. In the study area, these Cambrian strata are the Covey Hill Formation and the overlying Nepean Formation. The Covey Hill Formation consists of interbedded, noncalcareous feldspathic conglomerate and sandstone, with conglomerate intervals dominating. The sandstone and the matrix of the conglomerate are composed of fine- to coarse-grained quartz and feldspar. The conglomerate consists of pebble- to boulder-size clasts derived from a variety of bedrock sources. The thickness of the formation is highly varied, being affected by Precambrian topography, ranging from 0 to 8.8 m (Williams 1991). Outcrops of the Covey Hill Formation have been identified in the St. Lawrence Lowland, although no occurrences of the formation are present in the study area. This formation has limited aggregate potential and, for that reason, has not been selected for possible resource protection.

The Nepean Formation overlies the Precambrian basement and, when present, the Covey Hill Formation. The Nepean Formation consists of quartz sandstone with some conglomerate interbeds and rare shaly partings. The matrix of the conglomerate and the sandstone consists of fine- to coarse-grained quartz sand. Fine-textured sandstone predominates in the upper part of the formation, whereas the conglomerate beds are confined to the lower part of the formation (Williams 1991). The sandstone can be quite varied with some beds being calcareous and argillaceous. Historically, sandstones of the formation have been extracted in the Perth area for use as building stone. The potential to use the Nepean Formation as a source of silica has been researched in the past. Although geochemical analyses repeatedly returned results of greater than 95% silica, the Nepean Formation is not considered to be a source of high-grade silica for use by industry. More information on the use of the Nepean Formation for silica production is provided in Hewitt (1963) and Klugman and Yen (1980). This formation is quite friable and has limited potential as an aggregate resource. For that reason, it has not been selected for possible resource protection.

A sequence of Lower Ordovician strata disconformably overlies the Potsdam Group (Dix, Salad Hersi and Nowlan 2004). In ascending order, these formations include the March and Oxford formations. The March and Oxford formations form the Beekmantown Group.

The March Formation (equivalent to the Theresa Formation; *see* Figure 4) consists of interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone (Williams 1991). The sandstone beds of the March Formation are similar in lithology to those of the Nepean Formation. They can be up to 10 m thick and generally consist of fine- to medium-grained quartz and include both quartz- and calcite-cemented type. Colour varies from white to light grey, brown to reddish brown and green where glauconite is present. The sandy dolostone and dolostone beds are fine- to medium-crystalline weathering light grey to brownish grey (Williams 1991). These beds of the formation are able to meet the rigid specifications for HL 1 and Dense Friction Course (DFC) aggregate products that are used in surfacing Ontario highways requiring these high specification products. The March Formation is considered to be an aggregate resource of provincial significance for these products. Outcrops of the formation occur throughout the southeast portion of the study area.

Conformably overlying the March Formation is the Oxford Formation (= Carillon Formation and Beauharnois Formation; *see* Figure 4). The formation consists of light- to dark-grey, light- to medium-brown and grey blue, fine- to coarse-crystalline dolostone. Pink calcite-filled vugs are common throughout the formation along with white and black chert occurring locally (Williams 1991). This formation crops out in the southeast portion of the study area and is quarried for crushed stone for use in a variety of aggregate applications. The formation is generally well suited for a wide range of aggregate uses making it an important bedrock resource available in the study area. The Oxford Formation is considered to be an aggregate resource of provincial significance for these products.

Disconformably overlying the Oxford Formation is the Rockcliffe Formation. This formation consists mainly of interbedded light grey to light greenish grey quartz sandstone,

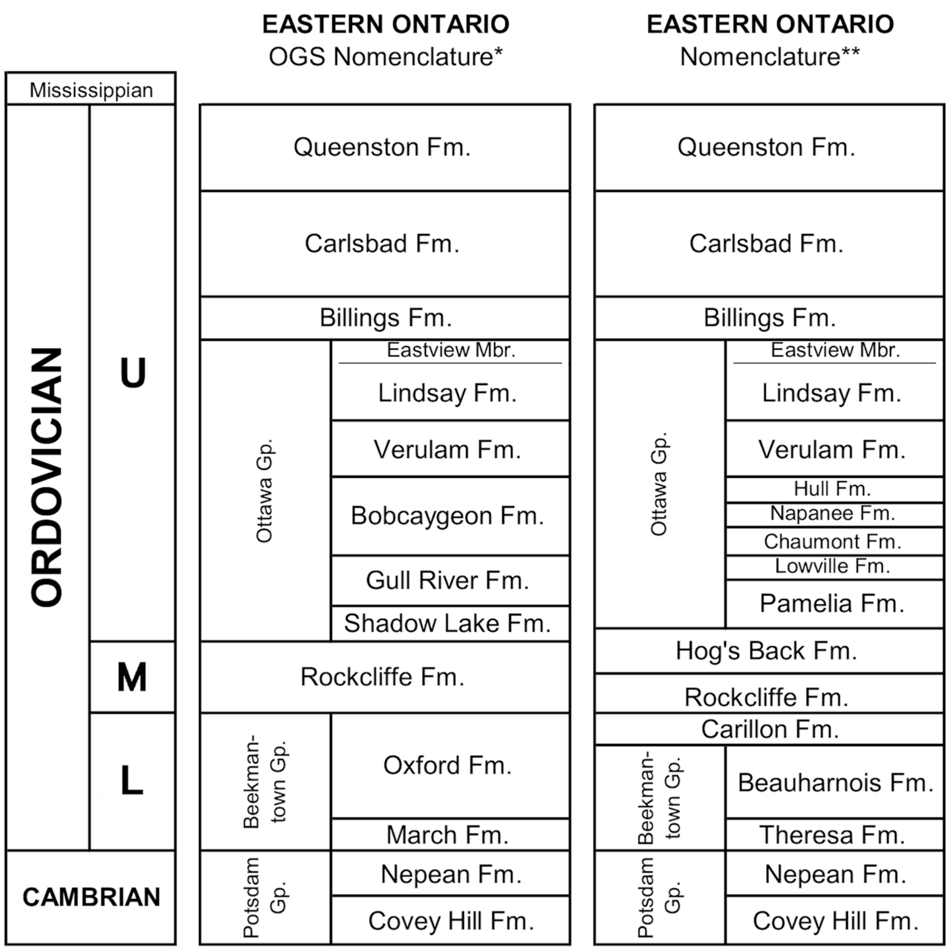

Figure 4. Exposed Paleozoic stratigraphic sequence in eastern Ontario (**adapted from* Williams (1991) and Armstrong and Dodge (2007); ***adapted from* Bernstein (1992), Salad Hersi and Dix (1997, 1999) and Salad Hersi, Lavoie and Nowlan (2003)).

and dark grey to dark green to maroon shale. The formation is subdivided into lower (= Rockcliffe Formation) and upper (= lower portion of Hog's Back Formation) members (*see* Figure 4). In the study area, interbeds of bioclastic limestone and shale predominate in the upper member of the formation (Williams 1991). The upper member of this formation has been intermittently quarried for use as aggregate east of the study area, due to its higher calcium content and greater thickness (Derry Michener Booth and Wahl and Ontario Geological Survey 1989). In general, this formation has limited potential as an aggregate resource. For that reason, it has not been selected for possible resource protection.

Overlying the Rockcliffe Formation is a sequence of Upper Ordovician limestones of the Ottawa Group. In ascending order, the formations include the Shadow Lake, Gull River, Bobcaygeon, Verulam and Lindsay formations. Only the oldest 4 (Shadow Lake, Gull River, Bobcaygeon and Verulam) formations occur in the study area and will be discussed.

The Shadow Lake Formation (= upper portion of Hog's Back Formation and lower portion of Pamelia Formation; *see* Figure 4) consists of silty to sandy dolostone, with shaly parting and thin interbeds of calcareous quartz sandstone. The formation is relatively thin with thicknesses ranging from approximately 2.5 to 2.8 m (Williams 1991). The formation is not extensively quarried and no outcrops of the Shadow Lake Formation are present in the study area. This formation has limited potential as an aggregate resource. For that reason, it has not been selected for possible resource protection.

The Gull River Formation conformably overlies the Shadow Lake Formation and is subdivided into lower and upper members. The lower member of the Gull River Formation (= upper portion of Pamelia Formation; *see* Figure 4) consists of interbedded limestone and silty dolostone with shaly partings. The limestone beds are thin to thick bedded, medium- to dark-grey to brownish grey, weathering light- to medium-bluish grey to brown. Dolomitic beds are thin to thick bedded, light grey to light greenish grey, weathering greenish grey. The upper member of the Gull River Formation (= Lowville Formation; *see* Figure 4) consists of thin- to thick-bedded lithographic to finely crystalline limestone with shaly partings. Beds are medium- to dark-grey to brownish grey in colour, weathering light- to medium-bluish grey to brown (Williams 1991). Fossils and burrows are common throughout the formation. This formation also contains a "bird's-eye" texture consisting of white calcite lenses scattered throughout some of the beds (Williams 1991). Outcrops of the formation are concentrated in the eastern and northern portions of the study area. Crushed stone from the Gull River Formation is extracted for a variety of aggregate uses in southern Ontario, including concrete, asphalt and granular base. There are quality concerns when using certain beds of the formation as concrete aggregate, which are discussed in "Bedrock Aggregate Quality and Suitability". Despite these quality concerns, the Gull River Formation is considered to be an aggregate resource of provincial significance for these products.

Conformably overlying the Gull River Formation is the Bobcaygeon Formation (= Chaumont, Napanee and Hull formations; *see* Figure 4). The contact between the Gull River and Bobcaygeon formations is identified by the presence of massively bedded, high-purity limestone at the base of the Bobcaygeon Formation. The formation is subdivided into 3 members. The lower member consists of interbedded lithographic to coarse crystalline limestone with shaly partings. The middle member consists of interbedded, lithographic to coarse crystalline limestone with interbeds containing numerous undulating shaly partings. The middle member contains a higher amount of shale than the lower and upper members and is easily identified in geophysical records by an increase in natural gamma radiation. Certain beds of the middle member have also been shown to be alkali–silica reactive due to small amounts of chert and microscopic chalcedony. As a result, these beds should not be used as concrete aggregate in Portland cement (Rogers 1985). The upper member consists of interbedded lithographic to coarse limestone with subordinate shale partings and dolomitized zones up to 20 cm thick. Numerous fossil types are common throughout the formation. Selective extraction may be required to eliminate silica-rich and shaly beds if the formation is to be used for the production of concrete aggregate. As with the Gull River Formation discussed previously, there are quality concerns when using certain beds of the Bobcaygeon Formation as concrete aggregate. These concerns are discussed in "Bedrock Aggregate Quality and Suitability". The formation crops out along the northeast border of Lanark County and is actively quarried in the study area.

Conformably overlying the Bobcaygeon Formation is the Verulam Formation. The formation consists of thin- to medium-bedded, sublithographic to coarse-crystalline, fossiliferous limestone with interbeds of dark grey calcareous shale. Beds are light- to dark-grey to brownish grey in colour, weathering brown to bluish grey (Williams 1991). In the study area, the Verulam Formation is unsuitable for high-quality aggregate production because of its high shale content; however, elsewhere in eastern Ontario, the Verulam Formation is used for the production of Portland cement and crushed stone products (Derry Michener Booth and Wahl and Ontario Geological Survey 1989). The different acceptable uses of the Verulam Formation reflect regional differences in the unit's composition. No significant outcrops of the formation occur in the study area. Only a small amount of the Verulam Formation possibly exists along the eastern border of the study area. The possibility of commercial extraction and of aggregate product from the study area is highly unlikely.

Structural Concerns

Lanark County lies within the Ottawa Valley rift zone, which includes the Ottawa–Bonnechere Graben, where numerous faults transect the area. These faults and associated features increase the complexity of the Paleozoic geology in the area. Known faults in the area include the Pakenham, Shamrock, Mount St. Patrick, Madawaska and Plevna faults that often define the boundary between Precambrian and Paleozoic rock types (Figure 5) (Williams 1991).

The formation of many faults with significant vertical displacements has resulted in rapid changes in bedrock geology over short distances. This, in turn, can result in significant changes in stone quality within rock formations. Large regional faults that have been previously mapped are indicated on Map 2 that accompanies this report. These faults, where one block is down dropped relative to another, often result in fault-controlled formational changes that are easy to identify. The changes in stone quality that results from these faults are relatively easy to determine and mitigate. Smaller local faults will often not result in a formational change, but will result in a change of the position in a sequence of the formation. The result can be significant changes to the stone quality properties. The displacements of these faults are too small to be mapped on a regional scale and are not indicated on Map 2. Site-specific investigations will be required to determine the extent that faulting will have on stone quality.

The faults indicated on Map 2 are from Armstrong and Dodge (2007), which is based on interpretations by Carson (1982a, 1982b), Williams, Rae and Wolf (1984, 1985), Williams and Wolf (1984), Williams, Wolf and Carson (1985) and Williams, Wolf and Rae (1984). Caution is advised when using this interpretation because a more recent interpretation completed by the Geological Survey of Canada (1994; and Bélanger 1994) differs from the one provided. The region would benefit from a new survey to resolve these differences.

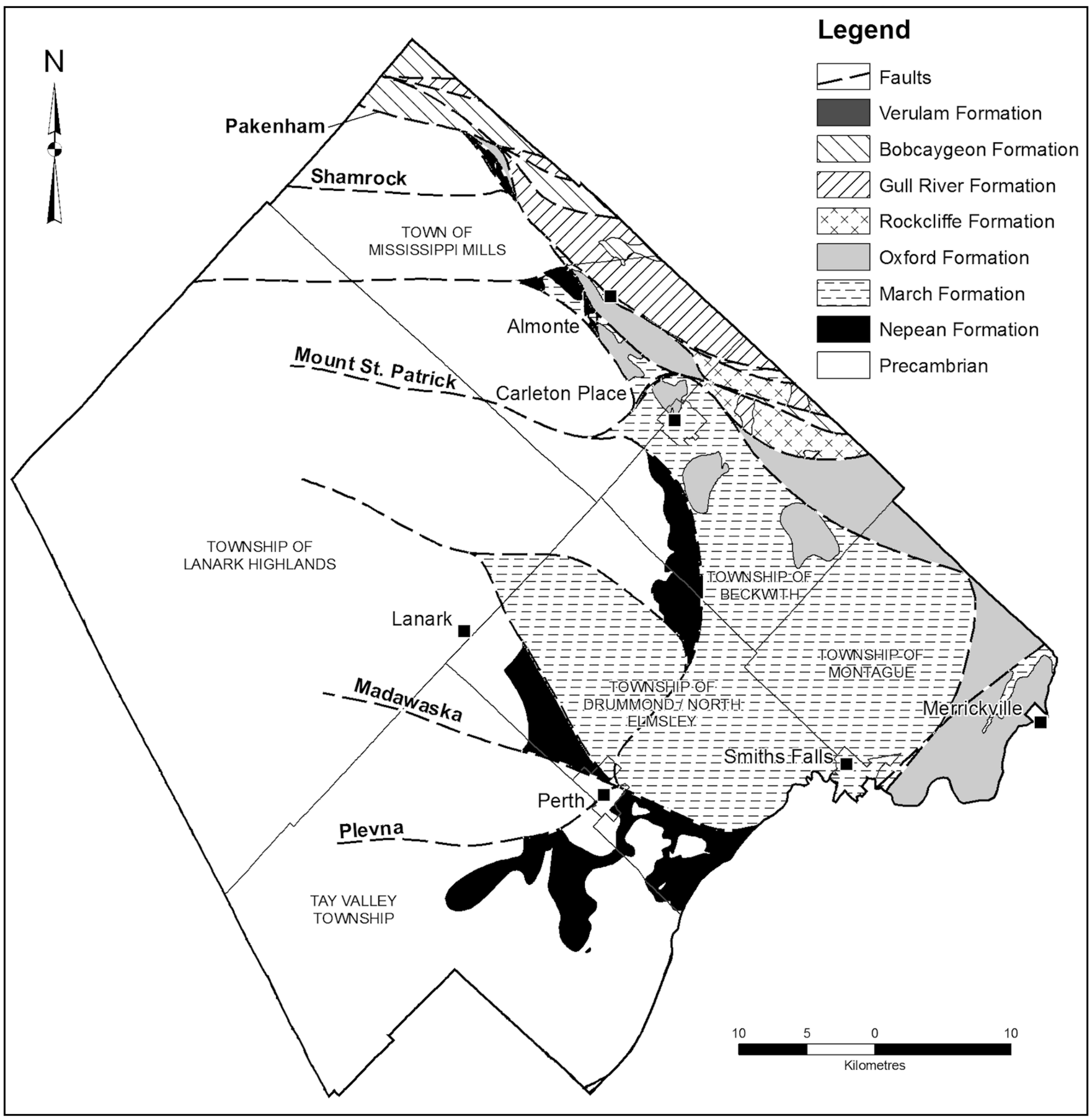

Figure 5. Bedrock geology of the County of Lanark (*modified from* Armstrong and Dodge 2007). *See* text for more information about the faults depicted.

BEDROCK AGGREGATE QUALITY AND SUITABILITY

Precambrian bedrock may exhibit wide variations with respect to aggregate quality over relatively short distances. Consequently, any site proposed for quarry development should be tested in detail before extraction occurs. Highly weathered, brittle and friable Precambrian bedrock, which is unacceptable for aggregate use, may occur in the study area. There are also areas underlain by more massive, hard and durable rock that appears suitable for a variety of aggregate applications. However, some of the massive, coarse-grained felsic igneous rocks and gneisses with high mica, feldspar and quartz content may have bonding problems because the smooth cleavage and fracture surfaces of these minerals hinder the adhesion of asphalt and cement mixes. This problem may be circumvented by weathering the rocks for a period of time in stockpiles or by adding chemicals (anti-stripping agents) that erode the smooth surfaces and allow better adhesion. Rogers (1985) reports that some granitic rocks can react slowly with alkalis from Portland cement resulting in premature concrete deterioration.

No specific areas of Precambrian bedrock have been selected for possible resource protection because Paleozoic bedrock is considered the preferred source of bedrock-derived aggregates in the area. Having stated this, there are areas where the Precambrian rock is acceptable for the production of high-specification aggregate.

Of the Paleozoic rock formations that underlie the county, the March, Oxford, Gull River and Bobcaygeon formations are best suited for aggregate extraction and production. The Verulam Formation can be used in the production of some aggregate products, although the high shale content of this formation limits its use and specialized production methods would be required. As stated earlier, the Verulam Formation may be used to produce Portland cement, but it is not present in any amount that would warrant its extraction in the study area.

The March Formation is quarried extensively throughout southeast Ontario for a variety of aggregate products. As noted in “Bedrock Geology and Resource Potential”, the sandy dolostone beds of the March Formation were originally found to be a good source of skid-resistant aggregate for highway surfacing by Rogers (1980) through laboratory testing. *In situ* testing has continued to show that these beds are one of the best sources of skid-resistant aggregate available in southern Ontario (Rogers, Gorman and Lane 2003). These beds are the only Paleozoic rock type approved for use as a skid-resistant aggregate for application of HL 1 and DFC surfacing on Ontario highways. A number of operations extracting the March Formation in the Ottawa area have been added to the MTO’s Designated Sources of Materials Lists (DSM) allowing those operations to supply aggregate for Superpave™ projects on major Ontario highways (Rogers, Gorman and Lane 2003). There may be quality concerns with other beds of the March Formation when trying to meet specifications of a variety of aggregate products. For example, certain beds of the March Formation can be alkali–silica reactive when used in Portland cement concrete. Previous MTO test results provide the following information. Petrographic Number values range from 100 to 117 for Granular and 16 mm and from 103 to 149 for hot mix and concrete products. Magnesium sulphate soundness test results vary from 1.4 to 12.9% for coarse aggregate. Los Angeles abrasion test results range from 19.3 to 24.8%. Absorption results vary from 0.469 to 1.3% and the bulk relative density varies from 2.66 to 2.74.

As noted in “Bedrock Geology and Resource Potential”, the Oxford Formation is used for the production of a variety of both low- and high-end aggregate products and is quarried extensively throughout southeast Ontario. The shaly interbeds of the formation, which can be up to 30 cm thick, have been characterized as low in quality and durability. Having stated this, the Oxford Formation is still able to meet specifications for the majority of, if not all, aggregate-products. Previous MTO test results provide the following information. Petrographic Number values range from 100 to 118 for Granular and 16 mm and from 100.4 to 124.3 for hot mix and concrete products. Magnesium sulphate soundness test results vary from 5.0 to 9.7% for coarse aggregate and from 15.5 to 22.7% for fine aggregate. Los Angeles abrasion test results range from 19.3 to 24.8%. Absorption values vary from 0.963 to 1.760%.

As noted in “Bedrock Geology and Resource Potential”, crushed stone from the Gull River Formation is extracted for a variety of aggregate uses in southern Ontario. Detailed site-specific testing of the rock is necessary because certain beds within the formation are chemically reactive with Portland cement mixes (Rogers 1985; Ryell et al. 1974). In particular, the dolomitic beds of the lower member have been shown to be alkali–carbonate reactive (Rogers 1985). The alkali–carbonate reaction can result in the premature deterioration of concrete structures particularly those surfaces that are subject to weathering and road salt. Alkali–carbonate reactive beds cannot be readily identified through visual examination in the field. Subjecting the rock to concrete expansion testing, microscopic examination and/or chemical analysis can identify the problematic beds (Rogers 1985; Ryell et al. 1974). Selective extraction of the nonreactive beds may be required for production of concrete aggregates. Ryell et al. (1974) suggest that a dilution ratio of 4:1 (competent rock to alkali-reactive rock) may also provide an acceptable solution. The Gull River Formation is generally well suited for use as hot-laid asphalt, but polishing of the stone may be a problem if the rock is used for asphaltic surface course. Beds of shaly, silty to sandy dolostone may require blend ing with the surrounding, more competent bedrock units for production of granular base. Similarly, beds of calcitic dolostone at the base of the formation may only be suitable for granular base.

As noted in “Bedrock Geology and Resource Potential”, certain beds within the Bobcaygeon Formation may also be alkali reactive. In this case, an alkali–silicate reaction occurs between Portland cement and the silica-bearing rock strata. Reactive beds within the Bobcaygeon Formation usually contain less than 3% black chert along with microscopic chalcedony. In particular, these beds have been shown to occur in the middle member of the formation (Rogers 1985). In addition, the shaly middle portions of the formation may not be as suitable for the production of concrete aggregate as are the surrounding strata. Previous MTO test results from samples collected from the Bobcaygeon Formation were collected as a part of this study and provide the following results (*see* Table 9). Petrographic Number values range from 100.0 to 149.6 for Granular and 16 mm and from 100.8 to 176.9 for hot mix and concrete products. Magnesium sulphate soundness test results vary from 1.8 to 3.2% for coarse aggregate and from 9.9 to 12.2% for fine aggregate. Los Angeles abrasion test results range from 22.8 to 27.2%. Absorption results vary from 0.460 to 0.96%. Results indicate that the Bobcaygeon Formation in Lanark County is generally well suited for most aggregate uses including asphalt stone and granular base. Selective extraction measures may be required for the production of concrete and high-quality aggregate within the formation.

Samples from various formations were collected as part of this study. The results for samples 10-VLL-001 to 10-VLL-003 are presented in Table 9. The results from 3 formations, the March, Oxford and Bobcaygeon, indicate that the material would pass specifications for a variety of aggregate products. The March Formation sample had high results for absorption, micro-Deval abrasion and freeze–thaw tests. Once again, these test results are applicable to these samples only and should not be interpreted across the formations. Samples were also collected for geochemical analyses; the results for samples are 10-VLL-001 to 10-VLL-003 presented in Table 11.

BEDROCK EXTRACTIVE ACTIVITY

At the time of writing, there were 25 licenced quarries located throughout Lanark County occupying 984 ha (Table 5). A number of operations are licenced for both bedrock and sand and gravel extraction. The majority of the quarries are producing bedrock-derived crushed stone for use in road building and construction industries. This information was provided by the Ministry of Natural Resources in the fall of 2009. MNDM staff gratefully acknowledge the co-operation of MNR staff in providing this information.

SELECTED BEDROCK RESOURCE AREAS

Based on the quality of the aggregate produced, areas of the March, Oxford, Gull River and Bobcaygeon formations that are covered by less than 8 m of overburden have been identified as Selected Bedrock Resource Areas and are identified on Map 2. These areas occupy a possible resources area of 59 514.1 ha in the study area and have a possible aggregate resource of 23 647.9 million tonnes (Table 6).

The above figures represent a comprehensive inventory of all areas with less than 8 m of overburden overlying these formations. Other planning issues and constraints may prevent site development in these Selected Bedrock Resource Areas. Further site investigation and aggregate testing is highly recommended before the development of any potential property.

Selected Bedrock Resource Area 1

Areas with less than 8 m of overburden overlying the March Formation have been chosen as Selected Bedrock Resource Area 1. These areas occur throughout the eastern portion of the county (Town of Mississippi Mills and townships of Lanark Highlands, Drummond / North Elmsley, Beckwith and Montague). The most extensive portion of the formation occurs in the southeast corner of the county. The March Formation is best known as a source of skid-resistant aggregate, but can be used in the production of a variety of other aggregate products. The total unlicenced area of Selected Bedrock Resource Area 1 is 47 398.1 ha. After consideration of physical, cultural and environmental setbacks, this unlicenced area is reduced to 41 726.9 ha with possible bedrock-derived aggregate resources of 16 580.2 million tonnes (*see* Table 6).

Selected Bedrock Resource Area 2

Areas with less than 8 m of overburden overlying the Oxford Formation have been chosen as Selected Bedrock Resource Area 2. These areas occur along the eastern boundary of the county (Town of Mississippi Mills and the townships of Beckwith and Montague) in segmented sections that are often delineated by faults. The Oxford Formation is a significant aggregate resource and is used to manufacture a wide variety of aggregate products. The total unlicenced area of Selected Bedrock Resource Area 2 is 9887.9 ha. After consideration of physical, cultural and environmental setbacks, this unlicenced area is reduced to 8357.8 ha with possible bedrock-derived aggregate resources of 3321.0 million tonnes (*see* Table 6).

Selected Bedrock Resource Area 3

Areas with less than 8 m of overburden overlying the Gull River Formation have been chosen as Selected Bedrock Resource Area 3. These areas occur along the eastern boundary of the county (Town of Mississippi Mills and the Township of Beckwith). Although there are no operations in the study area currently extracting the formation, the Gull River Formation is a significant source of aggregate in adjacent municipalities (i.e., City of Ottawa) and throughout southern Ontario. The total unlicenced area of Selected Bedrock Resource Area 3 is 7177.2 ha. After consideration of physical, cultural and environmental setbacks, this unlicenced area is reduced to 6526.4 ha with possible bedrock-derived aggregate resources of 2593.3 million tonnes (*see* Table 6).

Selected Bedrock Resource Area 4

Areas with less than 8 m of overburden overlying the Bobcaygeon Formation have been chosen as Selected Bedrock Resource Area 4. These areas occur along the eastern boundary of the county (Town of Mississippi Mills and the Township of Beckwith) in segmented sections that are delineated by faults. The formation is a significant source of aggregate resources and has been used in the manufacturing of a variety of aggregate products throughout eastern and southern Ontario. The total unlicenced area of Selected Bedrock Resource Area 4 is 3230.6 ha. After consideration of physical, cultural and environmental setbacks, this unlicenced area is reduced to 2903.0 ha with possible bedrock-derived aggregate resources of 1153.5 million tonnes (*see* Table 6).

SUMMARY

Four areas have been identified as sand gravel resources area of primary significance within the County of Lanark. These Selected Sand and Gravel Resource Areas occupy a total unlicenced area of 810 ha, which is reduced to 281 ha after applying cultural constraints and considering previous extractive activity. Combined, these selected sand and gravel resource areas have possible aggregate resources of 30 million tonnes. Reserves of sand and gravel are becoming short in supply in the county and it will be necessary to use crushed bedrock to meet the demand for most aggregate products in the near future.

A thin overburden cover over the March, Oxford, Gull River and Bobcaygeon formations means that there is a large potential to quarry these rock units. Total unlicenced area is 67 694 ha with a possible resources area of 59 514 ha after physical, cultural and environmental constraints have been considered. This represents a bedrock resource of 23 648 million tonnes. Since sand and gravel material is not plentiful in the county, bedrock-derived aggregate material will play an important role in the region.

Care should be taken to ensure the continued availability of as much as possible of these selected resource areas.

Enquiries regarding the Aggregate Resources Inventory of the County of Lanark may be directed to the Earth Resources and Geoscience Mapping Section, Ontario Geological Survey, Mines and Minerals Division, Ministry of Northern Development and Mines, 933 Ramsey Lake Road, Sudbury, Ontario P3E 6B5 [Tel: (705) 670-5758]; or to the Kemptville District Office, Ministry of Natural Resources, Kemptville, Ontario [Tel: (613) 258-8204].

Table 1 - Total Identified Sand and Gravel Resources, County of Lanark

1 Class Number	2 Deposit Type	3 Areal Extent (Hectares)	4 Original Tonnage (Million Tonnes)
Township of Lanark Highlands			
1	G-IC	956.0	101.5
	G-LD	100.0	10.6
	S-IC	113.9	12.1
	S-LD	265.3	28.2
2	G-IC	15.7	1.2
	S-IC	879.3	70.0
	S-LD	774.1	61.7
	S-MB	40.2	3.2
3	G-OW	37.2	1.3
	S-AL	9.9	0.4
	S-IC	446.9	15.8
	S-LD	630.0	22.3
4	S-LD	10.1	0.2
Subtotal		**4278.6**	**328.5**
Town of Mississippi Mills			
2	S-MB	314.2	25.0
3	S-IC	150.1	5.3
	S-MB	415.6	14.7
4	S-IC	0.8	0.0
	S-MB	51.0	0.9
Subtotal		**931.5**	**46.0**
Tay Valley Township			
1	G-IC	8.6	0.9
	S-IC	31.9	3.4
	S-LD	84.6	9.0
2	G-IC	67.2	5.4
	S-IC	80.9	6.4
	S-LD	509.0	40.5
3	S-IC	159.9	5.7
	S-LB	2.8	0.1
	S-LD	774.2	27.4
4	S-IC	17.1	0.3
	S-LD	101.9	1.8
Subtotal		**1838.1**	**100.9**

Table 1 - Total Identified Sand and Gravel Resources, County of Lanark

1 Class Number	2 Deposit Type	3 Areal Extent (Hectares)	4 Original Tonnage (Million Tonnes)
Township of Drummond / North Elmsley			
2	G-IC	116.9	9.3
	S-MB	30.7	2.4
3	S-IC	127.1	4.5
	S-LD	18.9	0.7
	S-MB	69.6	2.5
	S-MD	137.0	4.8
4	S-IC	9.1	0.2
	S-LD	8.4	0.1
	S-MB	11.2	0.2
	S-MD	11.6	0.2
Subtotal		**540.4**	**24.9**
Town of Perth			
3	S-MD	16.3	0.6
4	S-IC	2.1	0.0
Subtotal		**18.3**	**0.6**
Township of Beckwith			
3	S-MB	1092.8	38.7
4	S-MB	69.5	1.2
Subtotal		**1162.3**	**39.9**
Township of Montague			
2	S-IC	76.2	6.1
3	S-IC	10.2	0.4
	S-MB	747.4	26.5
	S-MD	17.8	0.6
4	S-IC	2.7	0.0
	S-LD	3.4	0.1
	S-MB	3.9	0.1
	S-MD	17.5	0.3
Subtotal		**879.1**	**34.0**
TOTAL		**9648.4**	**574.9**

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

* The above figures represent a comprehensive inventory of all granular materials in the map area. Some of the material included in the estimate has no aggregate potential and some is unavailable for extraction due to land use restrictions.

Explanation of Deposit Type:

First letter denotes gravel content:
G = >35% gravel; S = generally "sandy", gravel-size (>4.75 mm) aggregate <35% gravel.

Letters after hyphen denote the geologic deposit type (*see also* Appendix C):
AL = alluvium; IC = undifferentiated ice-contact stratified drift; LB = glaciolacustrine beach deposits;
LD = glaciolacustrine deltas; MB = glaciomarine beach deposits; MD = glaciomarine deltas; OW = outwash.

Table 2 - Sand and Gravel Pits, County of Lanark

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Township of Lanark Highlands					
Licenced/Permitted					
1	Percy J. Crosbie	2.30	2 - 4	-	Pit has been developed in till material
2	Percy J. Crosbie	2.00	2 - 4	-	Pit has been developed in till material
3	Thomas Cavanagh Construction Ltd.	27.80	4 - 6	30 - 80	Pit has been developed in an outwash deposit
4	Jeff Madden	31.30	2 - 10	10 - 40	Licenced as both a pit and quarry. Sand and gravel pit has been developed in till material
5	H & B McLachlan Construction Ltd.	36.60	1 - 4.5	5 - 15	Pit has been developed largely in till material
6	George Carpenter	3.40	4 - 10	-	Pit has been developed in till material
7	William H. Paul	8.20	3 - 10	-	Pit has been developed in till material
8	Robert Bourdeau	13.40	2 - 5	0 - 10	Pit has been developed in a glaciolacustrine delta deposit
9	Lyall and Brian Bingley	39.30	1 - 4	5 - 15	Pit has been developed in an ice-contact deposit and till material
10	Thomas Cavanagh Construction Ltd.	25.20	2 - 9	15 - 25	Pit has been developed in an ice-contact deposit surrounded by till material
11	Annie Gibson	4.50	2 - 6	15 - 25	Pit has been developed in till material
12	Douglas Ranger	9.30	2 - 5	0 - 25	Pit has been developed in an ice-contact and glaciolacustrine delta deposit
13	OMYA (Canada) Inc.	47.90	2 - 4	-	Pit has been developed in till material
14	County of Lanark	15.20	3 - 6	-	Pit has been developed in till material
15	Joan Pretty	61.30	Variable	10 - 30	Pit has been developed in an ice-contact deposit surrounded by till material
16	442649 Ontario Ltd.	6.50	1 - 10	15 - 25	Pit has been developed in an ice-contact deposit
17	Elaine Plumridge	51.10	2 - 5	25 - 35	Pit has been developed in an ice-contact deposit surrounded by till material
18	WFIPERTH ULC, 4148	8.70	2 - 5	15 - 40	Pit has been developed in an ice-contact deposit and till material
19	Malcolm Clegg	10.60	3 - 7	0 - 15	Pit has been developed in an glaciolacustrine delta deposit
20	Rhodena H. Bell	8.10	1.5 - 5	5 - 20	Pit has been developed in an glaciolacustrine delta deposit
21	Perry and Jeffrey James Stansel	21.60	3 - 5	-	Pit has been developed in till material
22	Township of Lanark Highlands	4.70	1 - 2.5	0 - 15	Pit has been developed in an ice-contact deposit
23	Harold Stead	10.60	1 - 5	-	Pit has been developed in till material
24	Township of Lanark Highlands	5.72	1 - 6	10 - 30	Pit has been developed in an ice-contact deposit and till material
25	Randy F. Mitchell	13.90	1 - 3	-	Pit has been developed in till material
26	Thomas Cavanagh Construction Ltd.	71.50	2 - 12	0 - 25	Pit has been developed in an ice-contact deposit and till material
27	Annie Gibson	8.60	2 - 4	10 - 25	Pit has been developed in an ice-contact deposit and till material
28	Mary Thompson	17.90	2 - 7	0 - 30	Pit has been developed in an ice-contact deposit and till material
29	Bessie M. Parks	9.40	1 - 3	10 - 20	Pit has been developed in an ice-contact and glaciolacustrine delta deposits
30	Crains' Construction Ltd.	3.48	-	-	Pit was unopened at time of field investigation
31	Crain Valley Farms	16.30	5 - 12	10 - 30	Pit has been developed in an ice-contact and glaciolacustrine delta deposits

Table 2 - Sand and Gravel Pits, County of Lanark					
Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
32	L.N. and A. Crain	36.50	3 - 12	10 - 30	Licenced as both a pit and quarry. Pit has been developed in an ice-contact deposit
33	Norman Crain	24.00	2 - 6	20 - 35	Pit has been developed in a glaciolacustrine delta
34	Tackaberry Sand and Stone Ltd.	63.50	3 - 7	0 - 35	Pit has been developed in an ice-contact deposit
35	Thomas Cavanagh Construction Ltd.	4.60	3 - 6	0 - 35	Pit has been developed in an ice-contact deposit
36	Robert Anderson	41.70	-	-	Pit was unopened at time of field investigation
37	G. Tackaberry & Sons Construction Co.	69.40	1 - 12	0 - 15	Pit has been developed in an ice-contact esker and glaciolacustrine deposit. Coarse aggregate core has been removed - predominantly a source of sand
38	County of Lanark	15.90	2 - 7	0 - 15	Pit has been developed in an ice-contact esker and glaciolacustrine deposit. Coarse aggregate core has been removed - predominantly a source of sand
39	Thomas Cavanagh Construction Ltd.	39.60	3 - 6	0 - 15	Pit has been developed in an ice-contact esker and glaciolacustrine deposit. Coarse aggregate core has been removed - predominantly a source of sand
40	Crains' Construction Ltd.	6.50	3 - 12	0 - 15	Pit has been developed in an ice-contact esker and glaciolacustrine deposit
41	Dorothy B. Poole	9.50	3 - 12	0 - 20	Pit has been developed in an ice-contact esker and glaciolacustrine deposit
42	Jay K. and M. Elaine Playfair	6.10	3 - 5	0 - 35	Pit has been developed in an ice-contact esker deposit
43	George Carpenter	13.20	4 - 10	-	Pit has been developed in till material
44	Allen and Joyce Stewart	40.14	6 - 12	10 - 35	Pit has been developed in an ice-contact deposit
45	Thomas Cavanagh Construction Ltd.	16.90	3 - 10	15 - 30	Pit has been developed in an ice-contact deposit
46	Tackaberry Sand and Stone Ltd.	20.60	3 - 9	10 - 25	Pit has been developed in an ice-contact deposit
47	Thomas Cavanagh Construction Ltd.	47.80	5 - 9	0 - 15	Pit has been developed in an ice-contact deposit. Predominantly a source of sand
48	Thomas Cavanagh Construction Ltd.	40.50	-	-	Pit was unopened at time of field investigation
49	Thomas Cavanagh Construction Ltd.	177.10	2 - 5	10 - 25	Licenced as both a pit and quarry. Pit has been developed in an ice-contact esker deposit. Coarse aggregate core has largely been removed
50	803836 Ontario Inc.	10.50	-	-	Pit has been developed in till material. Pit was in the process of rehabilitation at the time of field investigation
Unlicenced					
51	-	-	4 - 5	15 - 25	Pit has been developed in an ice-contact deposit. Pit is largely overgrown
52	-	-	2 - 10	-	Pit has been developed in till material
53	-	-	1 - 6	15 - 25	Pit has been developed in an ice-contact deposit
54	-	-	2 - 3	0 - 10	Pit has been developed in a glaciolacustrine delta
55	-	-	6 - 10	20 - 35	Pit has been developed in an outwash deposit. Pit has been partially rehabilitated by The Ontario Aggregate Resources Corporation
56	-	-	4 - 5	0 - 25	Pit has been developed in an ice-contact deposit and till material
57	-	-	2.5 - 8	15 - 25	Pit has been developed in an ice-contact deposit. Pit is predominantly overgrown
58	-	-	2 - 3	10 - 20	Pit has been developed in an ice-contact deposit. Pit is predominantly overgrown
59	-	-	1 - 3	-	Pit has been developed in till material

Table 2 - Sand and Gravel Pits, County of Lanark

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
60	-	-	1 - 4	0 - 15	Pit has been developed in an ice-contact deposit and till material
61	-	-	1 - 5	0 - 15	Pit has been developed in a glaciolacustrine delta deposit. Pit is predominantly overgrown
62	-	-	1 - 2.5	-	Pit has been developed in till material
63	-	-	3 - 8	0 - 25	Pit has been developed in an ice-contact deposit
64	-	-	1 - 2	5 - 20	Pit has been developed in a glaciolacustrine delta deposit
65	-	-	1.5 - 4	20 - 30	Pit has been developed in an ice-contact deposit
66	-	-	2 - 5	-	Pit has been developed in till material
67	-	-	1.5 - 7	-	Pit has been developed in till material
68	-	-	1 - 3	-	Pit has been developed in till material
69	-	-	2 - 4	-	Pit has been developed in till material
70	-	-	2 - 4	10 - 20	Pit has been developed in an ice-contact deposit. The pit is largely overgrown and used for farm storage
71	-	-	1 - 3	5 - 15	Pit has been developed in an ice-contact deposit. The pit is overgrown in parts and water is present in the deepest part of pit
72	-	-	2 - 5	5 - 20	Pit has been developed in an ice-contact deposit. Formerly a licenced pit - predominantly overgrown
73	-	-	-	-	Rehabilitated
74	-	-	-	-	Rehabilitated
Town of Mississippi Mills					
Licenced					
75	Peter Stanley	11.80	1 - 3	0 - 10	Pit has developed in a glaciomarine beach deposit
76	George Deugo	44.50	1 - 3	10 - 25	Pit has developed in a glaciomarine beach deposit
77	Charles Rath	16.80	1 - 4.5	10- 25	Pit has developed in an ice-contact deposit
78	Ralph Monette	9.00	1 - 3	0 - 20	Pit has developed in an ice-contact deposit and till material
79	Thomas Cavanagh Construction Ltd.	22.40	1 - 5	0 - 15	Pit has developed in an ice-contact deposit. Predominantly a sand source
80	John S. Neilson	40.50			Licenced as both a pit and quarry. No pit developed at time of field visit
81	Robert Charles Lyle	84.90			Licenced as both a pit and quarry. Quarry operation is the main focus
Unlicenced					
82	-	-	1 - 2	-	Formerly a licenced pit developed in till material. Pit is overgrown
83	-	-	1 - 2.5	-	Formerly a licenced pit developed in till material. Pit is overgrown
Tay Valley Township					
Licenced					
84	Steven E. Rayfield	4.10	2 - 5	15 - 25	Pit has been developed in an ice-contact deposit. The pit is largely overgrown
85	Malcolm Campbell	47.60	3 - 6	10 - 20	Pit has been developed in an ice-contact deposit and till material
86	Corp. of the Township of Bathurst North Burgess	24.00	1 - 3	-	Pit has been developed in till material

Table 2 - Sand and Gravel Pits, County of Lanark					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
87	Alvin Dobbie	57.30	1 - 2.5	0 - 10	Pit has been developed in glaciolacustrine plain deposit and till material. Licence also includes ice-contact deposit. Silt and clay material being extracted at time of field investigation
88	Gerald and David Deacon	14.90	2 - 7	0 - 10	Pit has been developed in a glaciolacustrine delta deposit. Predominantly a source of sand
89	772698 Ontario Ltd.	5.70	2 - 3	0 - 15	Pit has been developed in a glaciolacustrine delta deposit and till material
90	Howard Burns Equipment Rentals Ltd.	5.50	2 - 4	10 - 25	Pit has been developed in an ice-contact deposit
91	772698 Ontario Ltd.	4.00	0.5 - 3	0 - 15	Pit has been developed in a glaciolacustrine delta deposit
92	Donald and Sally McRae	14.10	2 - 4	5 - 15	Pit has been developed in a glaciolacustrine delta deposit
Unlicenced					
93	-	-	3 - 8	-	Pit has been developed in till material
94	-	-	3 - 5	15 - 25	Pit has been developed in an ice-contact deposit. Pit was being used as a pasture field at the time of field investigation
95	-	-	3 - 8	-	Pit has been developed in till material
96	-	-	1 - 4.5	-	Pit has been developed in till material
97	-	-	2 - 4.5	-	Pit has been developed in till material
98	-	-	1 - 4		Pit has been developed in till material
99	-	-	3 - 5	10 - 20	Pit has been developed in an ice-contact deposit
100	-	-	-	-	Pit has been largely rehabilitated at the time of field investigation
101	-	-	4 - 6	0 - 15	Pit has been developed in a glaciolacustrine plain deposit. The pit was largely overgrown at the time of field investigation
102	-	-	1 - 10	5 - 25	Pit has been develop in an ice-contact deposit. Pit was predominantly overgrown with exposed bedrock and water present at the time of field investigation
103	-	-	1 - 4	0 - 10	Pit has been developed in a glaciolacustrine delta deposit. Pit was predominantly overgrown
104	-	-	1 - 5		Pit has been developed in a glaciolacustrine delta and ice-contact deposits. Pit was partially overgrown with exposed bedrock
105	-	-	2 - 10	-	Pit has been developed in till material
106	-	-	1 - 4	-	Pit has been developed in till material
Township of Drummond / North Elmsley					
Licenced					
107	Thomas Cavanagh Construction Ltd.	8.00	2 - 4	10 - 25	Pit has been developed in an ice-contact deposit
108	Donald Wilson Cartage Ltd.	36.90	-	-	Pit is undergoing rehabilitation
109	Steven R. Bothwell	13.00	2 - 4	10 - 30	Pit has been developed in an ice-contact deposit
110	Robbie Robertson	6.20	1 - 3	0 - 10	Pit has been developed in a glaciomarine beach deposit
111	Tackaberry Sand and Stone Ltd.	16.50	1 - 2	-	Licenced as both a pit and quarry - predominantly a quarry operation
112	Tackaberry Sand and Stone Ltd.	27.00	1 - 2	-	Licenced as both a pit and quarry - predominantly a quarry operation
113	Gordon McConnell	11.80	-	-	Pit is undergoing rehabilitation
114	Michael H. McGuire	27.70	1 - 2.5	-	Pit has been developed in till material

Table 2 - Sand and Gravel Pits, County of Lanark					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
115	Wm. Lyle Armstrong	14.90	1 - 3	10 - 20	Pit has been developed in an ice-contact deposit and till material
116	Malcolm Campbell	9.70	1 - 5		Pit has been developed in till material
Unlicenced					
117	-	-	2 - 4	10 -25	Pit has been developed in an ice-contact deposit
118	-	-	1 - 4	-	Pit has been developed in a glaciomarine beach deposit
119	-	-	1.5	-	Pit has been developed in a glaciomarine plain deposit
Township of Beckwith					
Licenced					
120	Dechan Construction Limited	32.60	1 - 2	-	Licenced as both a pit and quarry. Quarry operation is the main focus
121	Thomas Cavanagh Construction Ltd.	25.70	1 - 2	-	Licenced as both a pit and quarry. Quarry operation is the main focus
122	Thomas Cavanagh Construction Ltd.	7.50	1 - 3	0 - 10	Pit has been developed in a glaciomarine beach
123	Lyle Nolan	14.40	1 - 3	-	Pit has been developed in till material
124	Thomas Cavanagh Construction Ltd.	18.60	1 - 3	0 - 10	Pit has been developed in a glaciomarine beach
125	Roderick and Mark Rabb	13.20	1 - 3.5	0 - 10	Pit has been developed in a glaciomarine beach
Unlicenced					
126	-	-	1 - 3	5 - 15	Pit has been developed in a glaciomarine beach
127	-	-	-	-	Pit has been developed in a glaciomarine beach. Pit was largely rehabilitated at time of field investigation
128	-	-	1 - 2	-	Pit has been developed in a glaciomarine beach. Pit was largely overgrown at time of field investigation
129	-	-	1 - 2	0 - 10	Pit has been developed in a glaciomarine beach
Township of Montague					
Licenced					
130	J.A. Calipeau Construction Limited	13.60	1 - 3	-	Pit has been developed in till material
131	Donald McConnell	7.60	2 - 3	0 - 10	Pit has been developed in a glaciomarine beach
132	Rideau Bulk Terminals Inc.	30.72	1 - 2	-	Licenced as both a pit and quarry - predominantly a quarry operation
133	Malcolm Campbell	16.60	2 - 6	20 - 30	Pit has been developed in an ice-contact deposit
134	Roy Durant	12.90	1 - 3	0 - 10	Pit has been developed in a glaciomarine plain deposit
135	Donald McConnell	12.70	2 - 3	-	Pit has been developed in till material
136	Tony Brownrigg	8.10	1 - 1.5	-	Pit has been developed in silt and clay material
137	Donald McConnell	19.80	1 - 3	-	Pit has been developed in till material

Table 3 - Selected Sand and Gravel Resource Areas, County of Lanark

1 Deposit No.	2 Unlicenced Area* (Hectares)	3 Cultural Setbacks** (Hectares)	4 Extracted Area*** (Hectares)	5 Possible Resource Area (Hectares)	6 Estimated Deposit Thickness (Metres)	7 Possible Aggregate Resources**** (Million Tonnes)
1	100.0	20.6	27.8	51.6	6	5.5
2	109.7	29.3	37.2	43.2	6	4.6
3	207.3	18.5	109.8	79.0	6	8.4
4	392.7	63.6	222.3	106.8	6	11.3
TOTAL	**809.7**	**132.0**	**397.1**	**280.6**		**29.8**

Minor variations in the tables are caused by the rounding of the data.

* Excludes areas licenced under the *Aggregate Resources Act.*

** Cultural setbacks include heavily populated urban areas, roads (including a 100 m wide strip centred on each road), water features (e.g., lakes, streams), 1 ha for individual houses. NOTE: This provides a preliminary and generalized constraint application only. Additional environmental and social constraints will further reduce the deposit area.

*** Extracted area is a rough estimate of areas that are not licenced, but, due to previous extractive activity, are largely depleted.

**** Further environmental, resource, social and economic constraints will greatly reduce the selected resource quantity realistically available for potential extraction.

Table 4 - Total Identified Bedrock Resources, County of Lanark				
1 Drift Thickness (Metres)	**2 Formation**	**3 Estimated Deposit Thickness (Metres)**	**4 Areal Extent (Hectares)**	**5 Original Tonnage (Million Tonnes)**
Township of Lanark Highlands				
<1	March	15	0.51	0.2
1-8	March	15	879.69	349.5
8-15	March	15	71.69	28.5
Subtotal			**951.88**	**378.2**
Town of Mississippi Mills				
<1	Nepean	15	127.96	45.0
1-8	Nepean	15	522.65	183.8
8-15	Nepean	15	24.98	8.8
<1	March	15	1031.08	409.7
1-8	March	15	1245.08	494.7
8-15	March	15	3.26	1.3
<1	Oxford	15	1123.81	446.5
1-8	Oxford	15	1647.76	654.7
8-15	Oxford	15	42.33	16.8
<1	Rockcliffe	15	59.79	21.0
1-8	Rockcliffe	15	246.34	86.6
<1	Gull River	15	2684.93	1066.9
1-8	Gull River	15	3545.04	1408.6
8-15	Gull River	15	271.82	108.0
<1	Bobcaygeon	15	1515.46	602.2
1-8	Bobcaygeon	15	1268.52	504.0
8-15	Bobcaygeon	15	375.98	149.4
>1	Verulam	10	9.98	2.6
Subtotal			**15 746.77**	**6210.7**
Tay Valley Township				
<1	Nepean	15	1013.25	356.3
1-8	Nepean	15	2815.41	989.9
8-15	Nepean	15	77.85	27.4
<1	March	15	53.39	21.2
Subtotal			**3959.90**	**1394.7**
Township of Drummond / North Elmsley				
<1	Nepean	15	1584.22	557.0
1-8	Nepean	15	3864.50	1358.8
8-15	Nepean	15	499.80	175.7
<1	March	15	9866.90	3920.6
1-8	March	15	14 456.98	5744.5
8-15	March	15	118.53	47.1
Subtotal			**30 390.93**	**11 803.7**

Table 4 - Total Identified Bedrock Resources, County of Lanark

1 Drift Thickness (Metres)	2 Formation	3 Estimated Deposit Thickness (Metres)	4 Areal Extent (Hectares)	5 Original Tonnage (Million Tonnes)
Town of Perth				
<1	Nepean	15	17.64	6.2
1-8	Nepean	15	109.71	38.6
<1	March	15	7.26	2.9
1-8	March	15	170.32	67.7
Subtotal			**304.94**	**115.3**
Town of Carleton Place				
<1	March	15	274.51	109.1
1-8	March	15	343.37	136.4
<1	Oxford	5	65.13	8.6
1-8	Oxford	15	8.72	3.5
Subtotal			**691.74**	**257.6**
Township of Beckwith				
<1	Nepean	15	514.03	180.7
1-8	Nepean	15	792.04	278.5
8-15	Nepean	15	1.34	0.5
<1	March	15	3310.92	1315.6
1-8	March	15	7432.33	2953.2
8-15	March	15	8.11	3.2
<1	Oxford	15	2466.16	979.9
1-8	Oxford	15	3541.65	1407.3
<1	Rockcliffe	15	168.77	59.3
1-8	Rockcliffe	15	3084.10	1084.4
8-15	Rockcliffe	15	2.39	0.8
<1	Gull River	15	275.89	109.6
1-8	Gull River	15	700.58	278.4
<1	Bobcaygeon	15	91.80	36.5
1-8	Bobcaygeon	15	399.36	158.7
Subtotal			**22 789.49**	**8846.7**
Township of Montague				
<1	March	15	10 925.77	4341.4
1-8	March	15	7852.06	3120.0
8-15	March	15	313.19	124.4
<1	Oxford	15	6256.69	2486.1
1-8	Oxford	15	2418.55	961.0
8-15	Oxford	15	461.64	183.4
Subtotal			**28 227.90**	**11 216.4**
TOTAL			**103 063.54**	**40 223.4**

Minor variations in the tables are caused by the rounding of data.

The above figures represent a comprehensive inventory of all bedrock resources in the map area. Some of the material included in the estimate has no aggregate potential and some is unavailable for extraction due to land use restrictions.

Table 5 - Quarries, County of Lanark				
Quarry No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**Remarks**
Township of Lanark Highlands				
Licenced				
1	Jeff Madden	31.30	-	Licenced as both a pit and quarry aggregate operation
2	Arriscraft International Limited	1.10	-	Licenced under the *Aggregate Resources Act*, but the main focus of this operation is for its non-aggregate products
3	OMYA (Canada) Inc.	280.70	85	Licenced under the *Aggregate Resources Act*, but the main focus of this operation is for its non-aggregate industrial mineral potential
4	L.N. and A. Crain	36.50	6 - 8	Licenced as both a pit and quarry aggregate operation. Quarry has been developed in Precambrian rock
5	Thomas Cavanagh Construction Ltd.	162.80	4 - 8	Licenced as both a pit and quarry aggregate operation. Quarry has been developed in Precambrian rock
Town of Mississippi Mills				
Licenced				
6	Thomas Cavanagh Construction Ltd.	36.90	8 - 10	Quarry has been developed in the Bobcaygeon Formation, producing a variety of aggregate products
7	Robert Charles Lyle	84.90	5 - 7	Licenced as both a pit and quarry aggregate operation. Quarry has been developed in the Bobcaygeon Formation, producing a variety of aggregate products
8	John S. Neilson	40.50	3 - 5	Quarry has been developed in Precambrian rock
9	Duffy Road Oiling Limited	11.20	8.5 - 12	Licenced as both a pit and quarry aggregate operation. Quarry has been developed in the Oxford and March formations
Unlicenced				
10	-	-	-	Old, overgrown quarry, Gull River Formation
11	-	-	2 - 4	Old, overgrown quarry, Nepean Formation
Tay Valley Township				
Licenced				
Unlicenced				
12	-	-	2 - 3	Old, filled with water; feldspar mineral extraction quarry
Township of Drummond / North Elmsley				
Licenced				
13	Tackaberry Sand and Stone Ltd.	16.50	3 - 6	Quarry has been developed in the March Formation, producing a variety of aggregate products
14	Tackaberry Sand and Stone Ltd.	27.00	4 - 8	Quarry has been developed in the March Formation, producing a variety of aggregate products
Unlicenced				
15	-	-	1 - 1.5	Old, overgrown quarry developed in the March Formation
16	-	-	3 - 5.5	Old, filled with water, developed in the Nepean Formation
17	-	-	3 - 4.5	Old quarry developed in the March Formation
18	-	-	2 - 3	Old, overgrown quarry developed in the March Formation

Table 5 - Quarries, County of Lanark

Quarry No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	Remarks
Township of Beckwith				
Licenced				
19	Thomas Cavanagh Construction Ltd.	25.70	8 - 10	Licenced as both a pit and quarry aggregate operation. Quarry has been developed in the Bobcaygeon Formation, produces a variety of aggregate products
20	Dechan Construction Limited	32.60	4 - 8	Licenced as both a pit and quarry aggregate operation. Quarry has been developed in the March Formation, produces a variety of aggregate products
21	Thomas Cavanagh Construction Ltd.	20.40	5 - 10	Quarry has been developed in the Oxford Formation, produces a variety of aggregate products
Township of Montague				
Licenced				
22	Rideau Bulk Terminals Inc.	30.72	3 - 10	Licenced as both a pit and quarry aggregate operation. Quarry has been developed in the Oxford Formation, produces a variety of aggregate products
23	The Warren Paving & Materials Group Ltd.	85.50	2 - 10	Quarry has been developed in the March Formation, produces a variety of aggregate products
24	G. Tackaberry & Sons Construction Co.	18.40	4 - 6	Quarry has been developed in the March Formation, produces a variety of aggregate products
25	G. Tackaberry & Sons Construction Co.	41.70	4 - 7	Quarry has been developed in the Oxford Formation, produces a variety of aggregate products

Table 6 - Selected Bedrock Resource Areas, County of Lanark

1 Area Number	2 Depth of Overburden (Metres)	3 Unlicenced Area* (Hectares)	4 Cultural Setbacks** (Hectares)	5 Extracted Area*** (Hectares)	6 Possible Resource Area (Hectares)	7 Estimated Workable Thickness (Metres)	8 Possible Bedrock Resources**** (Million Tonnes)
1	< 8	47 527.5	5404.5	277.1	41 845.9	15.0	16 627.5
2	< 8	9887.9	1426.1	104.0	8357.8	15.0	3321.0
3	< 8	7206.5	640.1	14.6	6551.8	15.0	2603.4
4	< 8	3230.6	230.3	97.3	2903.0	15.0	1153.5
TOTAL		**67 852.5**	**7701.0**	**493.0**	**59 658.5**		**23 705.3**

Minor variations in the tables are caused by the rounding of the data.

* Excludes areas licenced under the *Aggregate Resources Act* (1989).

** Cultural setbacks include heavily populated urban areas, roads (including a 100 m wide strip centred on each road), water features (e.g., lakes, streams), 1 ha for individual houses. NOTE: This provides a preliminary and generalized constraint application only. Additional environmental and social constraints will further reduce the deposit area.

*** Extracted area is a rough estimate of areas that are not licenced, but, due to previous extractive activity, are largely depleted.

**** Further environmental, resource, social and economic constraints will greatly reduce the selected resource quantity realistically available for potential extraction.

Table 7 - Borehole Data, County of Lanark

Borehole Number *	Depth (m)	Description
Township of Lanark Highlands		
1	13.1	gravel boulders 13.1
2	3.7	topsoil 0.31, fsand silt 1.5, silt 2.4, till 3.7, bedrock
3	2.4	topsoil 0.31, fsand 2.1, till 2.4, bedrock
4	9.5	topsoil 0.31, mfsand 1.5, msand gravel 4.6, gravel msand 6.l, msand gravel 8.23, till 9.5, bedrock
5	9.5	topsoil 0.31, fsand 1.5, msand 1.4, msand stones 3.1, msand gravel 4.6, mfsand stones 8.5, mfsand silt gravel 8.5, till 9.5
6	9.5	topsoil 0.31, fsand 3.1, mfsand 8.8, till 9.5, bedrock
7	9.5	topsoil 0.31, fsand 4.0, msand 9.5, bedrock
8	5.9	mfsand 5.2, till 5.9, bedrock
9	3.8	cmsand 1.8, msand stones 3.8, bedrock
10	5.0	msand 3.4, boulders till 5, bedrock
11	3.8	fsand 2.7, boulders 3.8, bedrock
12	3.8	msand 2.7, boulders 3.8
13	4.1	fsand 1.4, boulders till 4.1
14	2.6	msand gravel 3.7, bedrock
15	16.8	fmsand 6.4, mfsand 10.7, fsand 16.8
16	14.5	fmsand 12.8, till 14.5, bedrock
17	6.7	gravel 6.7, bedrock
18	13.7	mfsand 2.7, mfsand stones 6.9, msand stones 7.5, msand gravel 8.5, gravel 13.7
19	10.7	silt fsand 1.2, silt 10.7
20	12.8	msand gravel 2.7, till 4.4, silt mfsand stones 6.4, mfsand gravel 12.8
21	5.6	msand stones 2.4, msand gravel 4.7, gravel 5.3, boulders 5.6
22	16.8	fsand 9.1, fmsand 11.3, msand stones 16.8
23	16.8	gravel 3.8, fmsand 6.4, fmsand 9.1, fsand 16.8
24	11.0	mfsand 3.4, mfsand stones 7.0, msand gravel 7.3, gravel 10, till 11.0
25	13.7	topsoil 0.3, msand stones 9.5, msand gravel 11.0, gravel boulders 13.7
26	16.8	topsoil 0.3, fsand 16.8
27	25.0	mfsand 15.6, mfsand stones 18.4, till 25.0
28	17.1	fsand 3.7, msand 4.6, msand stones 7.9, cmsand stones 8.8, cmsand gravel 16.1, boulders gravel 17.1, bedrock
29	2.6	mfsand 2.6, bedrock
30	10.1	mfsand 1.5, msand stones 4.6, msand gravel 8.8, gravel boulders 10.1, bedrock
31	9.9	topsoil 0.3, gravel 4.9, msand gravel 6.3, gravel 9.3, gravel boulders 9.9
32	7.0	topsoil 0.3, mfsand 3.4, mfsand stones 7.0
33	6.4	topsoil 0.2, silt 6.4
34	8.4	topsoil 0.2, silt 1.1, msand 7.6, msand gravel 7.8, gravel boulders 8.4, bedrock
35	9.5	gravel msand 9.5
36	4.3	gravel 3.8, boulders 4.3, bedrock
37	12.8	gravel 11.6, till 12.8
38	4.3	fsand 4.3, bedrock
39	7.0	fsand 4.1, silt fsand 7.0
40	12.5	mfsand 4.6, msand stones 7.0, gravel 10.4, till 12.5, bedrock
42	5.0	topsoil 0.3, mfsand 3.4, mfsand stones 5, bedrock
43	17.1	topsoil 0.3, msand stones 1.5, cmsand stones 2.7, mfsand 3.4, msand stones 4.3, fmsand stones 16.0, till 17.1, bedrock

Table 7 - Borehole Data, County of Lanark		
Borehole Number *	**Depth (m)**	**Description**
44	13.7	topsoil cmsand 4.0, msand 4.4, fmcsand 9.1, gravel 13.7
45	1.4	msand 1.4, bedrock
46	10.1	topsoil 0.3, mfsand 7.2, mfsand gravel 8.5, mfsand stones 10.1, bedrock
47	7.3	topsoil 0.3, msand 0.8, gravel 2.3, msand stones 27, gravel 3.5, msand 3.8, msand gravel 4.4, msand stones 4.9, gravel 7.3, bedrock
48	3.8	topsoil fsand 0.8, msand stones 1.5, gravel 2.6, msand 3.1, gravel 3.8
49	5.5	topsoil fsand 0.6, mfsand 1.5, gravel 2.1, cmsand 3.5, gravel 4.6, gmsand 5.3, boulders gravel 5.5
50	2.7	topsoil fsand 1.2, silt fsand 3.1
51	21.3	topsoil 0.2, mfsand 7.6, fmsand 8.2, fmsand 9.8, silt 9.9, mfsand stones 12.2, mfsand 21.3
52	1.4	till 1.4, bedrock
53	2.7	topsoil 0.2, silt fsand 1.5, silt 2.7, silt fsand 4.6
54	11.7	topsoil 0.2, mfsand 1.5, mfsand stones 4.6, msand 11.7
55	10.7	topsoil 0.2, silt mfsand 10.7
56	18.3	topsoil 0.2, msand 2.7, msand stones 3.1, msand gravel 7.6, gravel 14.9, msand 15.9, gravel 18.3
57	8.8	msand 4.3, cmsand 5.6, mfsand 8.5, msand boulders 8.8
58	17.1	msand 8.8, msand gravel 13.6, till 17.1, bedrock
59	6.4	topsoil 0.2, msand gravel 4.6, gravel 5.8, boulders till 6.4
60	17.1	topsoil 0.2, msand 2.1, msand gravel 3.1, msand 3.7, gravel 4.3, msand 5.2, gravel 5.8, msand 5.9, gravel 13.1, msand 13.7, msand stones 15.9, msand 17.1
61	8.5	topsoil 0.2, msand gravel 1.5, gravel 7.9, boulders gravel 8.5
62a	4.9	topsoil 0.2, mfsand stones 1.5, silt fsand stones 3.7, silt 4.0, fsand 4.9
62b	14.5	topsoil 0.2, mfsand 4.9, mfsand stones 6.1, till 6.4, mfsand 8.5, mfsand stones 13.4, till 14.5, bedrock
63	11.3	topsoil 0.2, mfsand 1.8, mfsand stones 2.4, msand 3.1, msand gravel 5.2, mfsand 7.2, mfsand stones 10.8, till 11.3, bedrock
64	4.6	topsoil 0.2, mfsand 3.1, silt fsand 4.6
65	9.1	fsand 0.8, gravel 1.8, msand 2.1, gravel 13.7, msand gravel 4.6, gravel 5.2, msand 7.0, gravel 8.0, msand 9.1, msand gravel 12.2, mfsand 15.24
66	16.2	msand stones 2.4, msand 5.2, gravel 6.1, msand stones gravel 12.8, silt msand stones gravel 15.24, till 16.2
67	9.1	topsoil 0.2, msand 4.6, msand stones 7.8, till 8.5, silt fmsand 9.1
68	9.1	topsoil 0.2, mfsand 1.5, mfsand 9.1
69	12.0	topsoil 0.2, msand 4.9, fmsand stones 6.1, mfsand gravel 8.2, mfsand stones 11.3, till 12
70	4.7	msand gravel 12.2, msand 13.4, msand gravel 14.6, msand 15.2, till 16.2
71	10.7	gravel 0.8, silt 0.9, gravel 4.3, msand 5.5, gravel 6.4, msand stones 7.0, silt 7.5, msand gravel 10.7
72	4.9	msand 1.5, silt 3.1, silt mfsand 4.9
73	4.9	mfsand 1.5, silt msand 3.1, silt fsand 4.9
74	2.7	fsand 1.8, silt 2.7
75	1.5	silt fsand stones 1.5
76	1.5	silt 1.5
77	3.7	msand 2.4, till 3.7
78	2.7	msand 2.3, till 2.7, bedrock
79	3.7	fmsand 2.1, fsand gravel 3.1, fsand 3.7, bedrock
80	9.8	msand 2.1, silt 3.7, gravel 4.1, fsand 9.8, refusal
81	8.5	topsoil 0.2, msand 0.6, msand gravel 1.5, mfsand stones 2.1, mfsand gravel 3.7, mfsand 6.0, mfsand stones 7.0, till 8.5
82a	11.6	topsoil fsand 0.8, stones 1.1, cmsand 1.5, cmsand gravel 1.8, cmsand 2.3, cmsand gravel 3.0, cmsand stones 7.0, msand stones 7.6, mfsand stones 9.1, mfsand 10.2, till 11.6, bedrock
82b	16.5	topsoil 0.2, msand stones 2.7, msand 4.3, stones 4, cmsand 7.0, cmsand stones 7.3, cmsand 10.4, fsand 14.3, silt gravel 15.9, till 16.5

Table 7 - Borehole Data, County of Lanark

Borehole Number *	Depth (m)	Description
83	18.3	topsoil 0.2, cmsand gravel 4.7, gravel 9.5, msand 14.3, silt fsand stones 15.2, mfsand 18.3
84	4.6	fsand 4.6, water table 2.3
85	9.1	topsoil 0.2, msand stones 4.7, gravel 5.5, msand gravel 6.4, msand 6.7, gravel 8.2, msand 9.1
86	15.2	topsoil 0.2, msand stones 10.1, fmsand 15.2
87	9.1	msand stones 7.9, silt fsand 9.1
88	2.7	topsoil 0.2, msand stones 1.2, msand gravel 1.5, fmsand 2.7, bedrock
89	4.6	mfsand 1.4, silt fsand 3.7, boulders till 4.6
90	6.1	mfsand 3.6, till 3.8, silt 4.0, till 6.1
91	4.6	topsoil 0.2, fsand 1.4, silt 1.5, till 4.6
92	7.9	mcsand gravel 7.9
93a	6.7	topsoil 0.2, fsand 1.5, silt fsand 5.5, fmsand stones 6.7
93b	6.1	topsoil 0.2, silt fsand 6.1
94	4.6	topsoil 0.2, fsand 1.8, till 4.6
95	6.1	topsoil 0.2, fsand 1.8, till 6.1
96	4.6	topsoil 0.2, fsand 1.8, till 4.6
97	9.1	topsoil 0.2, fsand stones 2.4, till 6.4, mfsand 7.0, till 9.1
98	10.7	topsoil 0.2, fsand stones 8.5, boulders till 10.7
99	11.3	fsand 8.8, fsand stones 9.5, fsand 11.3
100	7.9	topsoil 0.2, silt fsand 3.4, fsand 6.4, silt fsand 7.2, till. 7. 9
101	3.8	topsoil 0.2, fsand 3.2, till 3.8
102	4.9	topsoil 0.2, till mfsand 4.1, boulders till 4.9
103	5.2	topsoil 0.1, msand 5.2, bedrock
104	5.6	gravel 1.8, cmsand 2.1, gravel 3.1, fmsand 5.2, till 5.6, bedrock
105	4.7	topsoil 0.2, msand stones 3.4, mfsand 4.7
106	7.6	topsoil 0.2, mfsand stones 3.8, mfsand gravel 6.9, till 7.6
107	7.6	msand gravel 3.1, fmsand stones 6.1, till 7.6
108	6.1	topsoil 0.2, mfsand stones 5.6, till 6.1
109	3.7	topsoil 0.2, gravel 3.7
110	7.6	gravel 2.1, mfsand gravel 7.6
111	1.5	topsoil 0.15, msand boulders 1.5, bedrock
112	16.8	topsoil 0.15, msand 1.2, msand stones 3.1, fmsand stones 4.3, gravel 4.6, msand gravel 5.2, gravel 5.8, mfsand stones 10.4, gravel 10.7, mfsand stones 16.8
113	10.7	topsoil 0.2, msand 2.1, gravel 3.4, cmsand 3.8, gravel 5.9, silt mfsand 10.7
114	12.2	topsoil 0.2, msand 3.4, mfsand 12.2
115	4.9	mfsand stones 4.9, silt 5.3, fsand 5.8
116	13.7	cmsand stones 4.3, msand stones 5.8, mfsand 7.6, fsand 12.2, silt fsand 13.7
117a	5.8	topsoil 0.2, mfsand 1.1, gravel 5.8
117b	4.6	topsoil 0.3, msand gravel 2.9, gravel 3.6, fmsand 4.6
118	4.9	topsoil 0.3, gravel 4.9
119	3.7	gravel 2.1, mfsand 3.7
120	3.1	topsoil 0.3, gravel 2.1, gravel boulders 3.1
121	5.8	topsoil 0.2, msand 5.8
122	16.8	topsoil 0.2, mfsand 16.8
123	15.2	topsoil 0.2, msand 2.4, fmsand 15.2
124	11.3	topsoil 0.2, mfsand 11.3, water table 5.2
125	3.4	topsoil 0.2, msand 2.9, boulders 3.4, bedrock

Table 7 - Borehole Data, County of Lanark

Borehole Number *	Depth (m)	Description
126	7.7	topsoil 0.2, mfsand 5.5, cmsand gravel 7.6, gravel 7.7
127	7.6	topsoil 0.2, silt fsand 3.4, fmsand 7.6
128	7.6	topsoil 0.2, mfsand 5.2, gravel 7.6
129	2.1	fmsand gravel 2.1, bedrock
130	2.6	msand 2.1, gravel boulders 2.6, bedrock
131	2.1	msand gravel 2.1
132	4.3	msand gravel 1.2, msand stones 4.3
133	3.1	msand stones 1.7, gravel boulders 3.1
134	13.4	topsoil 0.2, gravel 4.6, msand 5.2, msand gravel 9.1, mfsand 10.7, mfsand stones 12.3, till 13.4, bedrock
135	1.7	topsoil 0.2, mfsand 1.7
136	9.1	topsoil 0.3, msand stones 1.6, fmsand 2.2, fmsand stones 3.1, fmsand 4.6, mfsand stones 6.4, silt fsand 7.0, msand 7.4, msand stones 7.9, fmsand 8.3, msand stones 9.1
137	3.7	topsoil 0.3, msand boulders 1.6, mfsand stones 3.7, bedrock
138	7.3	topsoil 0.3, msand stones 1.5, msand 1.9, fmsand stones 2.4, msand gravel 2.9, fmsand gravel 3.4, msand 4.2, mfsand gravel 4.8, mfsand 5.4, fsand 5.8, mfsand 6.4, fmsand 7.2, fsand 7.3
139	3.7	topsoil 0.3, fmsand 1.8, msand gravel 2.4, till 3.7
140	5.5	topsoil 0.3, mfsand 1.5, mfsand stones 3.1, fsand gravel 5.0, till 5.5
141	3.0	topsoil 0.3, mfsand 2.0, till 3.0
142	2.5	topsoil 0.3, fsand 1.1, till 2.5
143	1.8	fmsand 1.8, bedrock
144	3.4	topsoil 0.3, msand stones 1.9, silt fsand 3.0, till 3.4
145	17.2	topsoil 0.3, msand stones 0.9, cmsand stones 3.2, cmsand gravel 4.2, msand stones 4.8, msand 5.0, cmsand gravel 5.5, msand gravel 6.1, cmsand 10.7, msand gravel 14.8, msand 17.2
Tay Valley Township		
41	2.4	mfsand 1.8, mfsand stones 2.4

* For source of borehole data, *see* "References": Gorrell, van Haaften and Fletcher (1985).

Table 8 - Summary of Geophysical Data, County of Lanark

— NONE —

Table 9 - Aggregate Quality Test Data, County of Lanark

		COARSE AGGREGATE									FINE AGGREGATE	
Sample Number	Sample Information	Petrographic Number: Granular and 16 mm	Petrographic Number: Hot Mix and Concrete	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)	Los Angeles Abrasion Test (% Loss)	Freeze–Thaw (% Loss)	Absorption (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<0.150%*	*<25%*	*<15–25%*
Township of Lanark Highlands												
Secondary ice-contact deposit (Highway 511)												
	Sand & gravel	118.9	155.4	3.7	-	23.9	-	0.870	2.810	-	19.0	-
	Sand & gravel	100.3	105.3	3.0	-	23.4	-	-	-	-	10.4	-
	Sand & gravel	101.2	118.7	3.8	-	25.1	-	0.680	2.748	-	19.7	-
	Sand & gravel	110.5	142.3	5.3	-	23.6	-	0.988	2.786	-	13.9	-
	Sand & gravel	120.0	163.9	4.6	-	25.5	-	0.830	2.768	-	15.7	-
	Sand & gravel	109.0	131.0	7.6	-	29.5	-	1.169	2.739	-	18.9	-
	Sand & gravel	126.3	184.5	6.2	-	23.8	-	0.970	2.785	-	22.6	-
Selected Sand and Gravel Resource Area 1												
10-VLL-004	Sand & gravel	-	277.0	6.0	13.2	-	-	1.200	2.724	0.120	-	-
	Sand & gravel	135.5	178.8	10.3	-	-	-	-	-	-	-	-
	Sand & gravel	129.5	164.5	-	-	-	-	-	-	-	-	-
Secondary ice-contact deposit, northwest of Hopetown												
	Sand & gravel	114.0	173.9	8.4	-	36.0	-	0.860	2.690	-	21.8	-
	Sand & gravel	123.1	170.8	6.5	-	35.3	-	0.900	2.668	-	22.2	-
	Sand & gravel	114.9	148.5	7.2	-	32.3	-	0.830	2.698	-	19.2	-
	Sand & gravel	110.5	140.0	9.7	-	34.4	-	0.830	2.679	-	23.0	-
Secondary glaciolacustrine deposit, northeast of Elphin												
	Sand & gravel	102.0	125.0	10.6	-	37.9	-	-	-	-	12.1	-
	Sand & gravel	107.0	160.0	4.2	-	21.4	-	-	-	-	7.1	-
Selected Sand and Gravel Resource Area 2												
10-VLL-005	Sand & gravel	-	132.0	5.0	14.3	-	-	0.620	2.735	0.026	-	7.8
	Sand & gravel	111.5	149.0	6.0	-	-	-	1.100	2.703	-	9.2	-
	Sand & gravel	101.1	112.2	3.8	-	14.1	-	0.630	2.734	-	14.7	-
	Sand & gravel	102.8	116.3	2.9	-	41.9	-	0.860	2.705	-	11.9	-
	Sand & gravel	107.8	123.7	3.6	-	37.7	-	0.760	2.724	-	-	-
	Sand & gravel	102.3	117.3	3.7	-	39.3	-	0.830	2.724	-	8.9	-
	Sand & gravel	105.9	174.4	4.5	-	43.6	-	1.000	2.704	-	21.3	-
	Sand & gravel	104.3	146.6	7.2	-	39.7	-	1.230	2.672	-	13.2	-
Secondary resources surrounding Selected Sand and Gravel Resource Area 2												
10-VLL-006	Sand	-	-	-	-	-	-	0.660	2.716	0.007	-	11.5
Selected Sand and Gravel Resource Area 3												
	Sand & gravel	105.0	141.0	10.9	-	39.1	-	-	-	-	22.5	-
	Sand & gravel	101.0	127.0	11.7	-	-	-	0.502	2.772	-	19.1	-
	Sand & gravel	101.0	113.0	6.9	-	40.6	-	0.703	2.732	-	12.5	-
	Sand & gravel	101.0	125.0	6.1	-	36.8	-	1.082	2.714	-	14.4	-
	Sand & gravel	104.0	128.0	5.9	-	32.3	-	1.051	2.708	-	10.3	-
	Sand & gravel	102.0	131.0	6.5	-	38.9	-	1.163	2.713	-	12.7	-

Table 9 - Aggregate Quality Test Data, County of Lanark

Sample Number	Sample Information	COARSE AGGREGATE: Petrographic Number: Granular and 16 mm	Petrographic Number: Hot Mix and Concrete	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)	Los Angeles Abrasion Test (% Loss)	Freeze–Thaw (% Loss)	Absorp-tion (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	FINE AGGREGATE: $MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<0.150%*	*<25%*	*<15–25%*
Selected Sand and Gravel Resources Area 4												
10-VLL-007	Sand	-	-	-	-	-	-	0.510	2.711	-	13.0	8.7
10-VLL-008	Sand & gravel	-	138.0	-	-	-	-	0.530	2.690	0.051	-	9.1
	Sand & gravel	371.4	411.7	32.2	-	46.3	-	2.150	2.648	-	19.8	-
	Sand & gravel	292.0	319.6	27.4	-	51.4	-	2.500	2.624	-	23.7	-
	Sand & gravel	204.2	224.5	15.9	-	41.5	-	1.610	2.721	-	21.3	-
	Sand & gravel	240.4	270.4	21.9	-	36.5	-	1.640	2.644	-	19.8	-
	Sand & gravel	390.4	419.2	37.0	-	37.8	-	2.170	2.632	-	23.1	-
	Sand & gravel	371.4	393.7	36.0	-	39.1	-	1.020	2.639	-	26.5	-
	Sand & gravel	171.9	216.1	8.9	-	46.9	-	0.990	2.702	-	17.8	-
Bedrock Samples												
Town of Mississippi Mills												
10-VLL-003	Bobcaygeon Fm.	-	100.0	3.0	12.3	-	-	0.320	2.693	0.102	-	-
	Bobcaygeon Fm.	109.7	116.1	6.6	-	24.9	-	0.560	2.686	-	13.3	-
	Bobcaygeon Fm.	109.1	113.7	5.2	-	24.3	-	0.530	2.690	-	-	-
	Bobcaygeon Fm.	133.3	144.6	6.9	-	23.6	-	0.670	2.669	-	-	-
	Bobcaygeon Fm.	130.4	140.9	5.6	-	25.0	-	0.630	2.670	-	-	-
	Bobcaygeon Fm.	122.3	133.8	6.8	-	-	-	0.730	2.666	-	-	-
	Bobcaygeon Fm.	122.3	123.9	4.5	-	24.0	-	0.500	2.678	-	-	-
	Bobcaygeon Fm.	122.3	12.7	10.0	-	24.6	-	0.552	2.670	-	-	-
	Bobcaygeon Fm.	126.6	138.8	11.0	-	-	-	0.688	2.661	-	21.5	-
	Bobcaygeon Fm.	134.6	176.2	23.0	-	25.2	-	0.960	2.663	-	31.8	-
	Bobcaygeon Fm.	149.6	176.9	-	-	27.2	-	-	-	-	-	-
	Bobcaygeon Fm.	101.4	104.1	2.6	-	23.5	-	0.460	2.681	-	-	-
	Bobcaygeon Fm.	102.1	104.8	3.2	-	22.8	-	0.500	2.684	-	-	-
	Bobcaygeon Fm.	100.0	100.8	1.8	-	22.8	-	-	-	-	-	-

Table 9 - Aggregate Quality Test Data, County of Lanark

Sample Number	Sample Information	COARSE AGGREGATE: Petrographic Number: Granular and 16 mm	COARSE AGGREGATE: Petrographic Number: Hot Mix and Concrete	COARSE AGGREGATE: $MgSO_4$ (%)	COARSE AGGREGATE: Micro-Deval Abrasion (% Loss)	COARSE AGGREGATE: Los Angeles Abrasion Test (% Loss)	COARSE AGGREGATE: Freeze–Thaw (% Loss)	COARSE AGGREGATE: Absorption (%)	COARSE AGGREGATE: Bulk Relative Density	COARSE AGGREGATE: Accelerated Mortar Bar (14 days) (% Loss)	FINE AGGREGATE: $MgSO_4$ (%)	FINE AGGREGATE: Micro-Deval Abrasion (% Loss)
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<0.150%*	*<25%*	*<15–25%*
Township of Drummond / North Elmsley												
10-VLL-001	March Fm.	-	100.0	12.0	13.9	-	-	0.990	2.604	0.041	-	-
	March Fm.	122.0	135.0	20.0	-		-	1.008	2.624	-	3.4	-
	March Fm.	111.6	113.1	21.0	-	24.8	-	1.070	2.671	-	32.6	-
	March Fm.	114.3	121.1	19.2	-	24.2	-	1.230	2.660	-	31.7	-
	March Fm.	144.0	122.0	17.6	-	25.7	-	1.270	2.610	-	-	-
	March Fm.	109.9	130.8	-	22.4	37.7	-	-	-	-	-	12.1
	March Fm.	108.5	131.5	30.0	23.1	38.0	-	-	-	-	-	13.0
	March Fm.	118.0	147.6	31.0	-		-	-	-	-	25.0	13.1
	March Fm.	118.3	147.2	33.0	-	35.0	-	-	-	-	29.0	-
	March Fm.	108.6	122.7	-	20.1	44.8	-	-	-	-	-	11.5
	March Fm.	107.0	163.0	18.1	-		-	-	-	-	-	-
	March Fm.	128.0	133.0	15.5	-	43.2	-	-	-	-	31.4	-
	March Fm.	131.0	145.0	23.3	-	40.6	-	-	-	-	35.7	-
	March Fm.	104.4	132.3	18.0	-	45.6	-	-	-	-	22.0	12.4
Township of Beckwith												
	Oxford Fm.	102.9	106.2	6.4	-	22.0	-	-	-	-	-	-
	Oxford Fm.	104.0	111.0	5.4	-	-	-	1.000	2.725	-	-	-
	Oxford Fm.	106.5	109.0	5.0	-	21.5	-	1.210	2.708	-	-	-
	Oxford Fm.	110.0	120.9	8.2	-	22.8	-	1.100	2.719	-	-	-
	Oxford Fm.	105.0	110.2	9.7	-	22.8	-	0.970	2.725	-	-	-
	Oxford Fm.	100.0	100.4	8.9	-	20.8	-	1.070	2.720	-	-	-
	Oxford Fm.	101.0	103.0	12.9	-	20.0	-	1.300	2.700	-	-	-
	Oxford Fm.	-	108.1	10.8	10.5	-	-	1.000	-	-	-	-
	March Fm.	103.0	109.0	1.4	-	18.7	-	0.600	2.740	-	-	-
	March Fm.	117.0	110.0	1.9	-	23.9	-	0.660	2.660	-	-	-
	March Fm.	108.5	121.3	4.7	-	37.7	-	0.660	2.650	-	-	-
	March Fm.	108.3	120.9	9.4	-	37.0	-	0.830	2.652	-	-	-
	March Fm.	105.0	110.0	3.9	-	22.1	-	-	-	-	17.8	-
	March Fm.	108.0	114.0	4.1	-	-	-	-	-	-	16.0	-
	March Fm.	105.0	125.0	-	-	29.0	-	-	-	-	17.3	-
	March Fm.	101.0	112.0	5.3	-	27.0	-	0.633	2.707	-	-	-
	March Fm.	104.0	141.0	-	10.6	-	4.0	0.469	2.697	-	-	-

Table 9 - Aggregate Quality Test Data, County of Lanark

		COARSE AGGREGATE									FINE AGGREGATE	
Sample Number	Sample Information	Petrographic Number: Granular and 16 mm	Petrographic Number: Hot Mix and Concrete	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)	Los Angeles Abrasion Test (% Loss)	Freeze–Thaw (% Loss)	Absorption (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<0.150%*	*<25%*	*<15–25%*
Township of Montague												
10-VLL-002	Oxford Fm.	-	100.0	1.0	7.8	-	-	0.680	2.754	-	-	-
	Oxford Fm.	107.0	112.8	5.7	-	24.3	-	1.300	2.709	-	16.0	-
	Oxford Fm.	102.6	107.1	5.6	-	24.7	-	1.100	2.726	-	-	-
	Oxford Fm.	103.2	106.6	8.4	-	24.8	-	1.760	2.706	-	15.5	-
	Oxford Fm.	104.2	104.2	3.2	-	21.3	-	1.300	2.705	-	-	-
	Oxford Fm.	112.0	-	15.5	7.8	-	-	0.871	-	0.013	-	-
	Oxford Fm.	-	-	7.1	8.1	-	-	-	-	0.028	-	-
	Oxford Fm.	114.0	-	2.2	8.0	-	-	1.060	-	0.029	-	-
	Oxford Fm.	108.0	-	16.0	7.9	-	-	1.050	-	-	-	-
	March Fm.	116.5	-	2.9	-	23.0	-	1.420	-	-	-	-
	March Fm.	103.8	-	8.7	-	28.7	-	1.050	-	-	-	-
	March Fm.	122.0	-	5.6	-	22.8	-	0.934	-	-	-	-
	March Fm.	140.0	-	-	13.8	-	5.1	0.879	-	-	-	-
	March Fm.	105.0	105.0	7.3	-	27.6	-	1.000	2.709	-	-	-
	March Fm.	112.9	123.6	16.7	-	26.1	-	1.190	2.659	-	-	-
	March Fm.	108.0	111.0	6.9	-	24.9	-	-	-	-	-	-
	March Fm.	142.0	146.0	16.4	-	34.0	-	-	-	-	20.6	-
	March Fm.	101.2	103.6	4.7	-	32.2	-	0.970	2.706	-	-	-
	March Fm.	107.0	110.5	7.4	-	26.6	-	1.000	2.674	-	-	-
	March Fm.	100.0	101.0	2.6	-	25.4	-	0.860	2.709	-	-	-
	March Fm.	106.1	113.2	9.5	-	26.1	-	1.030	2.660	-	26.3	-
	March Fm.	100.0	110.5	-	-	-	-	-	-	-	17.0	27.6

Note - The quality test data refer strictly to a specific sample. Because of the inherent variability of sand and gravel deposits, care should be exercised in extrapolating such information to the rest of the deposit, particularly where some of the deposits may be quite large.

Table 10 - Previous Drill-Hole Data, County of Lanark

Drill-Hole Station Number *	Generalized Description
CA-1	*UTM: 410600m E 5001762m N, NAD83, Zone 18* 1.80 m of Oxford Formation 6.90 m of March Formation 31.1 m of Nepean Formation
CA-2	*UTM: 403638m E 5010310m N, NAD83, Zone 18* 20.1 m of Nepean Formation
CA-3	*UTM: 413086m E 4994636m N, NAD83, Zone 18* 9.2 m of March Formation 1.2 m of Nepean Formation
CA-4	*UTM: 410361m E 5001675m N, NAD83, Zone 18* 2.3 m of Oxford Formation 6.6 m of March Formation 5.1 m of Nepean Formation
PE-1	*UTM: 395404m E 4969059m N, NAD83, Zone 18* 4.0 m of Nepean Formation
PE-2	*UTM: 397395m E 4969469m N, NAD83, Zone 18* 13.7 m of Nepean Formation
PE-3	*UTM: 414071m E 4972691m N, NAD83, Zone 18* 34.4 m of March Formation 34.4 m of Nepean Formation

* For source of drill-hole data and more information, *see* “References”: Williams (1991).

Table 11 - Results of Geochemical Analyses of Bedrock Samples, County of Lanark

Sample No.	10VLL-001	10VLL-002	10VLL-003
Formation	March	Oxford	Bobcaygeon
Major Oxides Analyses			
SiO_2 (%)	68.39	9.10	5.14
Al_2O_3	3.03	1.89	0.90
MnO	0.09	0.10	0.03
MgO	1.59	15.72	0.91
CaO	12.15	27.51	50.47
Na_2O	<0.01	<0.01	<0.01
K_2O	2.05	1.50	0.34
P_2O_5	0.04	0.03	0.01
TiO_2	0.12	0.11	0.05
$Fe_2O_3^{total}$	0.63	0.56	0.39
LOI	12.31	43.29	43.00
Total	100.34	99.70	101.11
CO_2	10.50	40.40	40.20
S	0.04	0.03	0.18
H_2O^+	0.30	0.40	0.40
H_2O^-	0.42	0.43	0.44
Atomic Absorption (Flame) Spectroscopy Analyses			
Cd (ppm)	<5	<5	<5
Co	<30	<30	32.00
Cu	5.00	3.00	4.00
Li	10.00	17.00	28.00
Ni	<6	<6	<6
Pb	<12	<12	<12
Zn	<6	12.00	9.00
Inductively Coupled Plasma Mass Spectroscopy Analyses			
Ba (ppm)	1387.8	63.4	31.3
Be	0.42	0.34	0.06
Bi	<0.15	<0.15	<0.15
Cd	0.041	0.038	0.133
Ce	25.85	5.51	1.08
Co	1.73	2.10	1.56
Cr	69	20	7
Cs	0.46	0.54	0.60
Cu	4.5	1.5	11.8

Sample No.	10VLL-001	10VLL-002	10VLL-003
Formation	March	Oxford	Bobcaygeon
Inductively Coupled Plasma Mass Spectroscopy Analyses (cont'd)			
Dy (ppm)	1.658	0.304	0.055
Er	0.935	0.160	0.033
Eu	0.61	0.11	0.03
Ga	3.51	2.75	0.69
Gd	2.018	0.377	0.100
Hf	3.78	0.62	<0.14
Ho	0.3270	0.0590	0.0110
In	0.0140	0.0080	0.0030
La	11.61	3.05	0.69
Li	4.4	3.7	4.2
Lu	0.1290	0.0190	0.0030
Mo	3.49	0.40	0.16
Nb	2.526	1.821	0.689
Nd	11.90	3.22	0.70
Ni	6.6	12.6	7.5
Pb	2.6	2.9	3.5
Pr	3.070	0.811	0.197
Rb	31.21	18.97	10.50
Sb	0.04	0.08	0.04
Sc	2.8	2.4	1.5
Sm	2.278	0.526	0.128
Sn	0.30	0.26	<0.16
Sr	131.7	102.1	281.6
Ta	0.110	0.078	<0.023
Tb	0.2810	0.0530	0.0130
Th	1.269	0.069	0.024
Ti	735	525	151
Tl	0.108	0.080	0.047
Tm	0.1320	0.0210	0.0050
U	0.861	1.103	0.224
V	12.0	19.8	3.1
W	0.13	0.12	0.09
Y	9.89	0.70	0.12
Yb	0.86	0.13	0.03
Zn	<7	7	9
Zr	155	21	<6

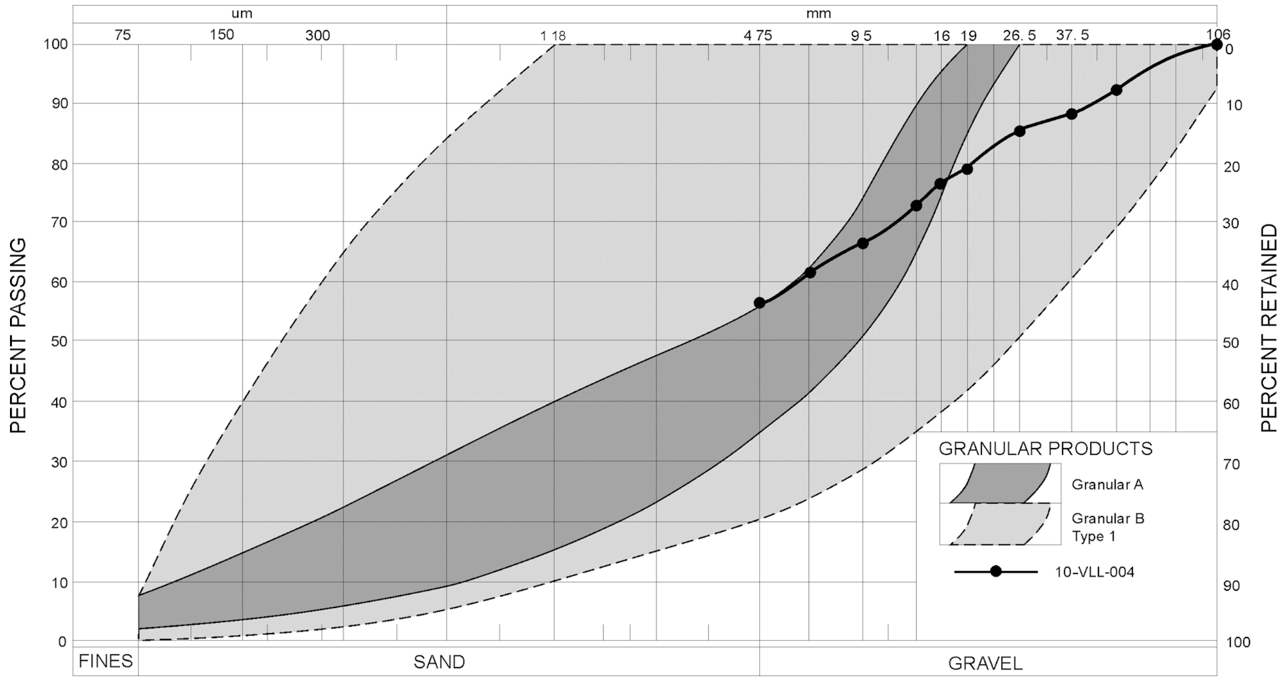

Figure 6. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

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

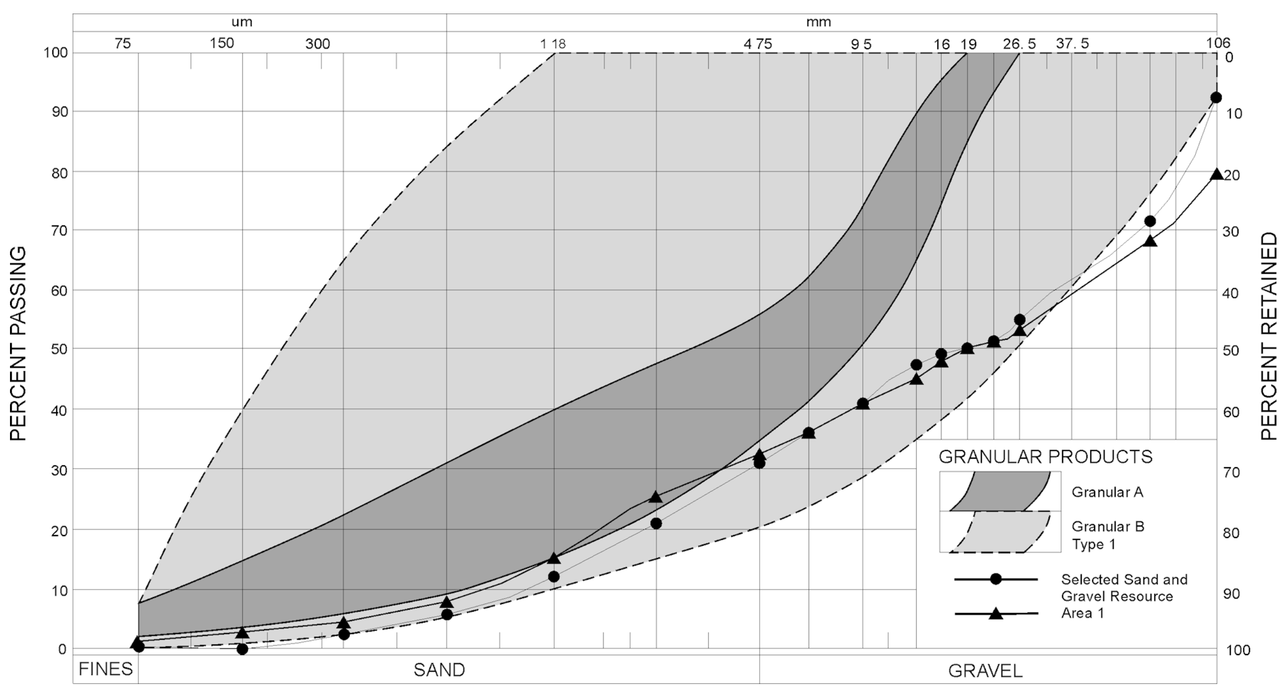

Figure 7. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

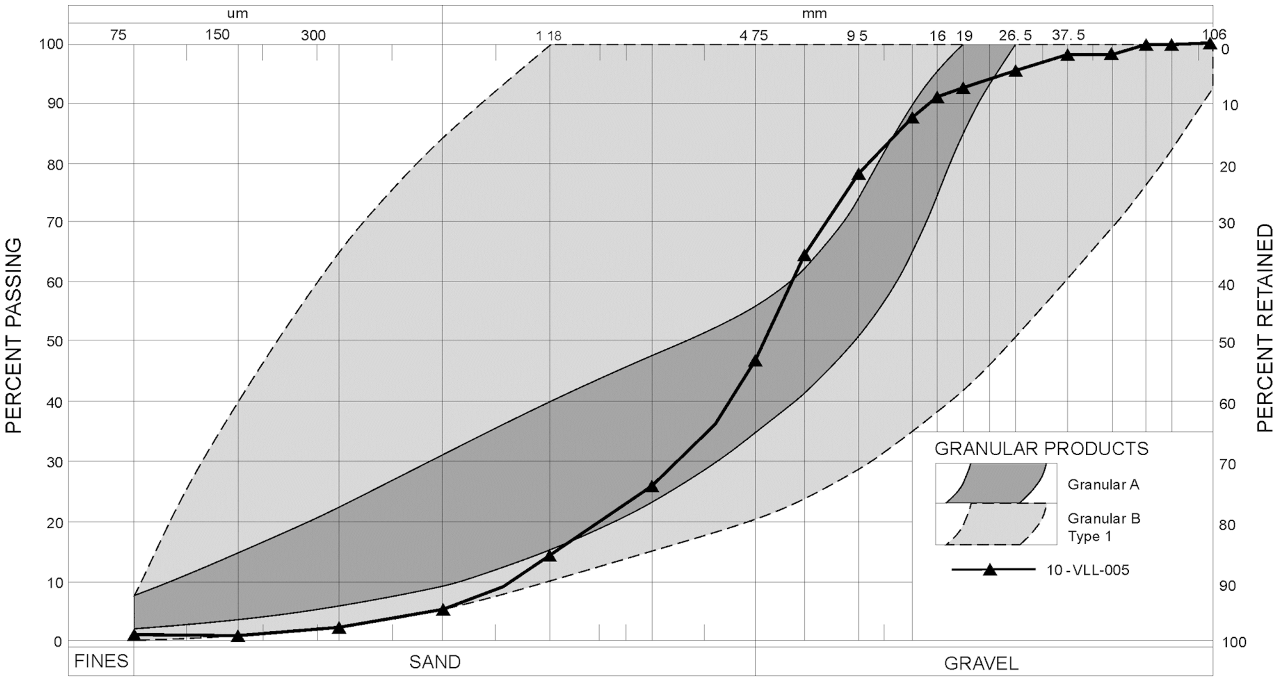

Figure 8A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

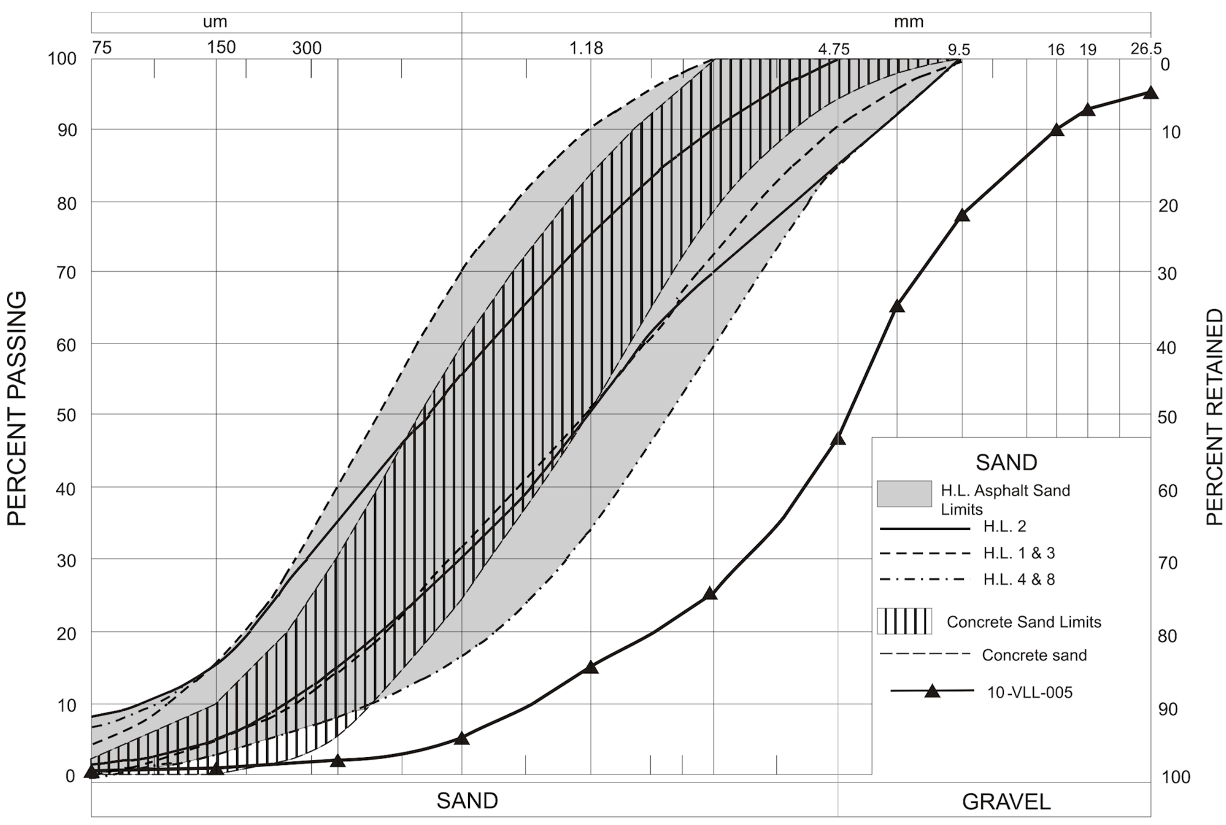

Figure 8B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

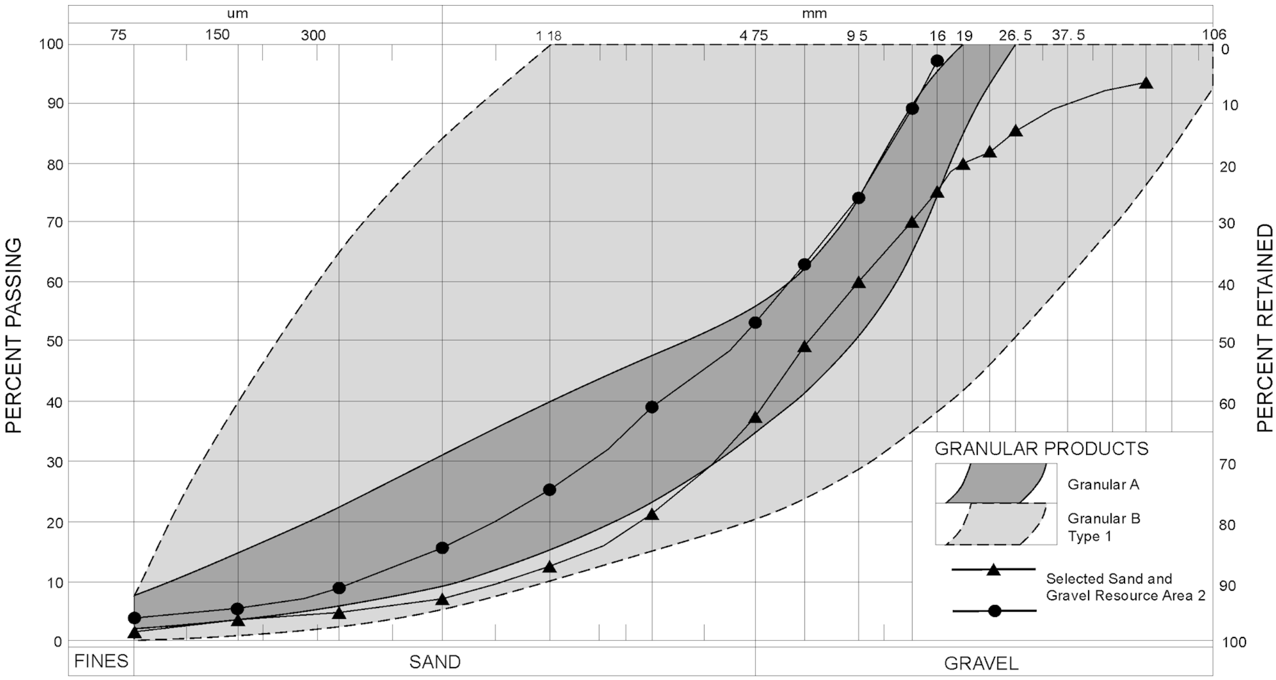

Figure 9A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

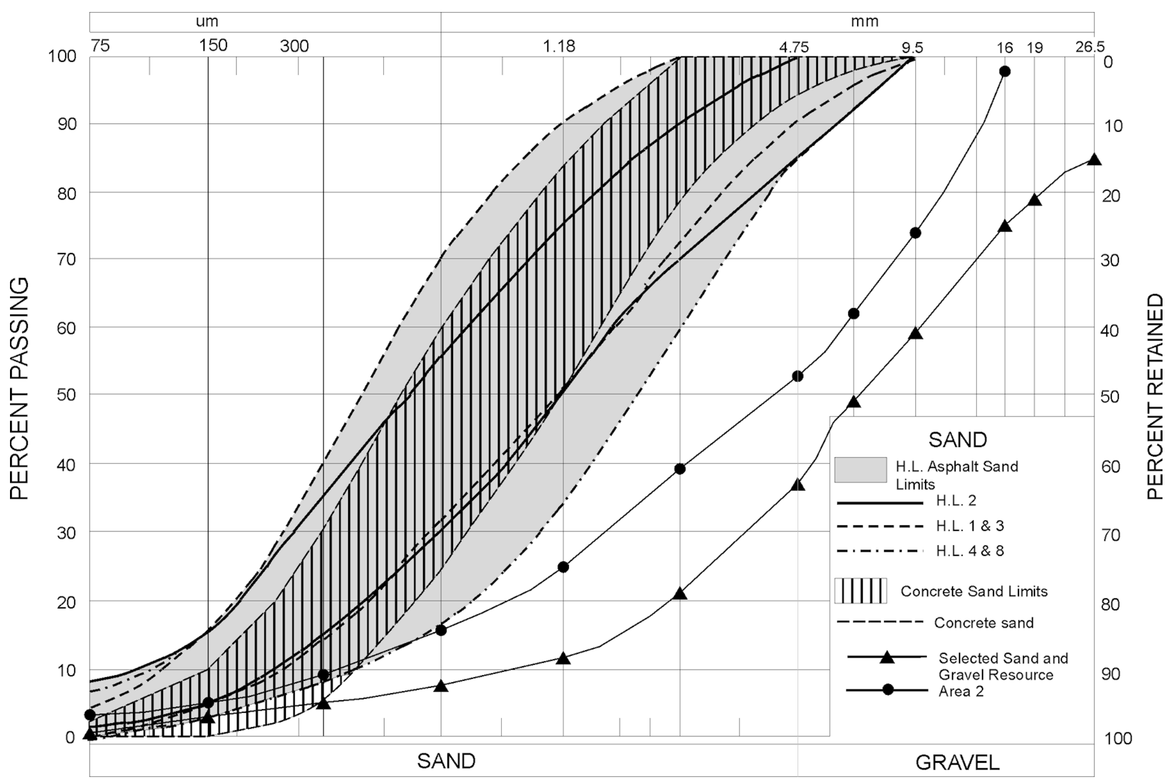

Figure 9B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

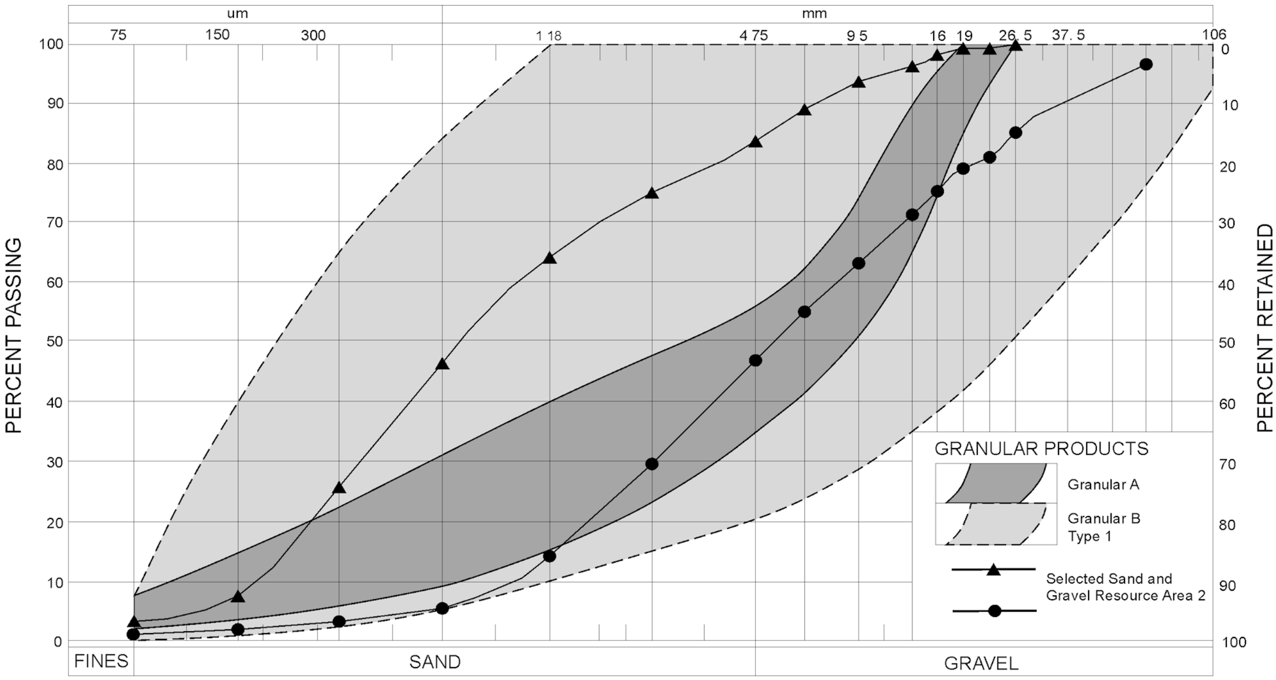

Figure 10A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

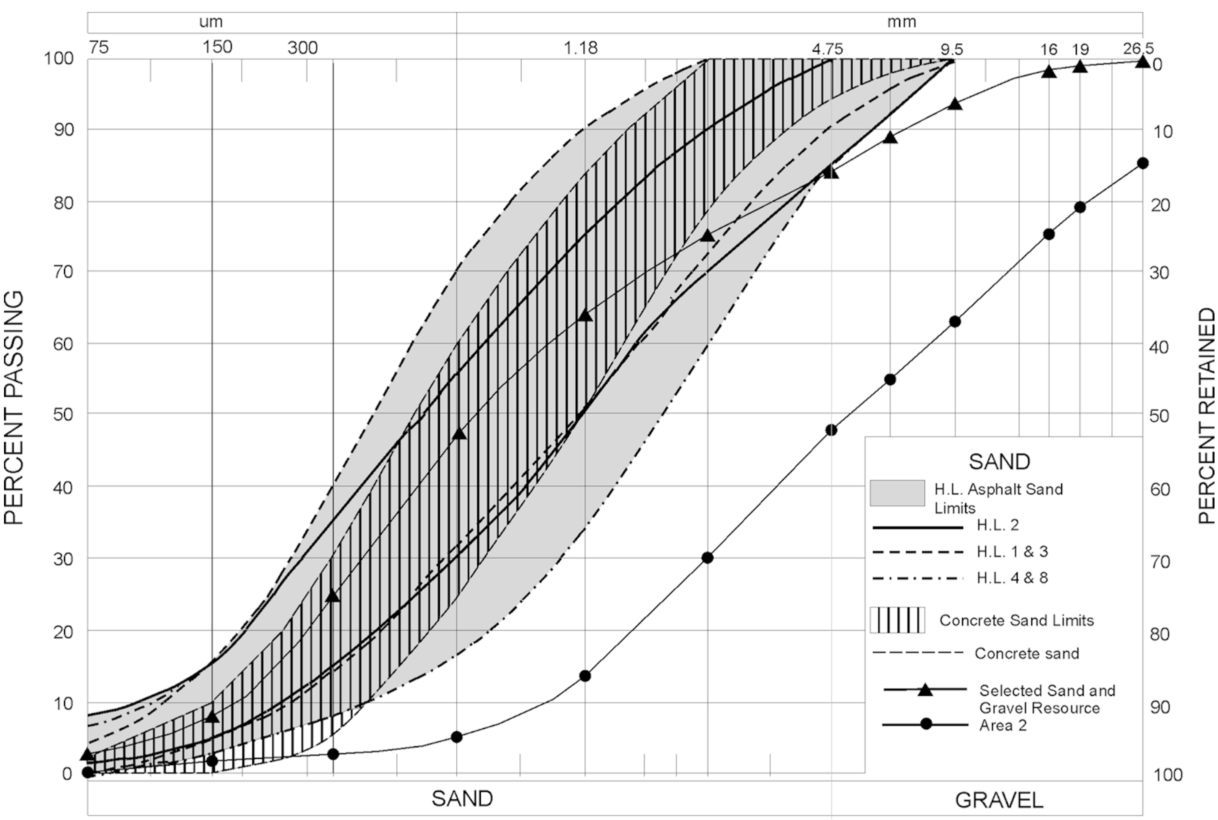

Figure 10B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

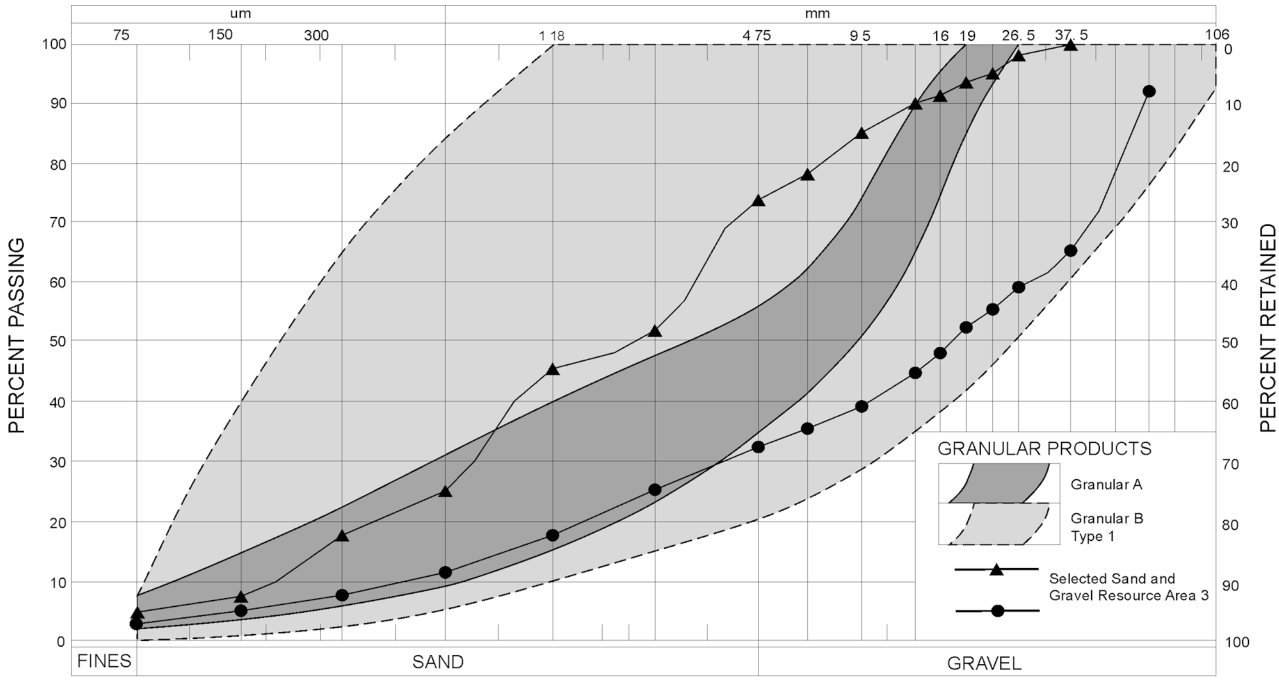

Figure 11A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

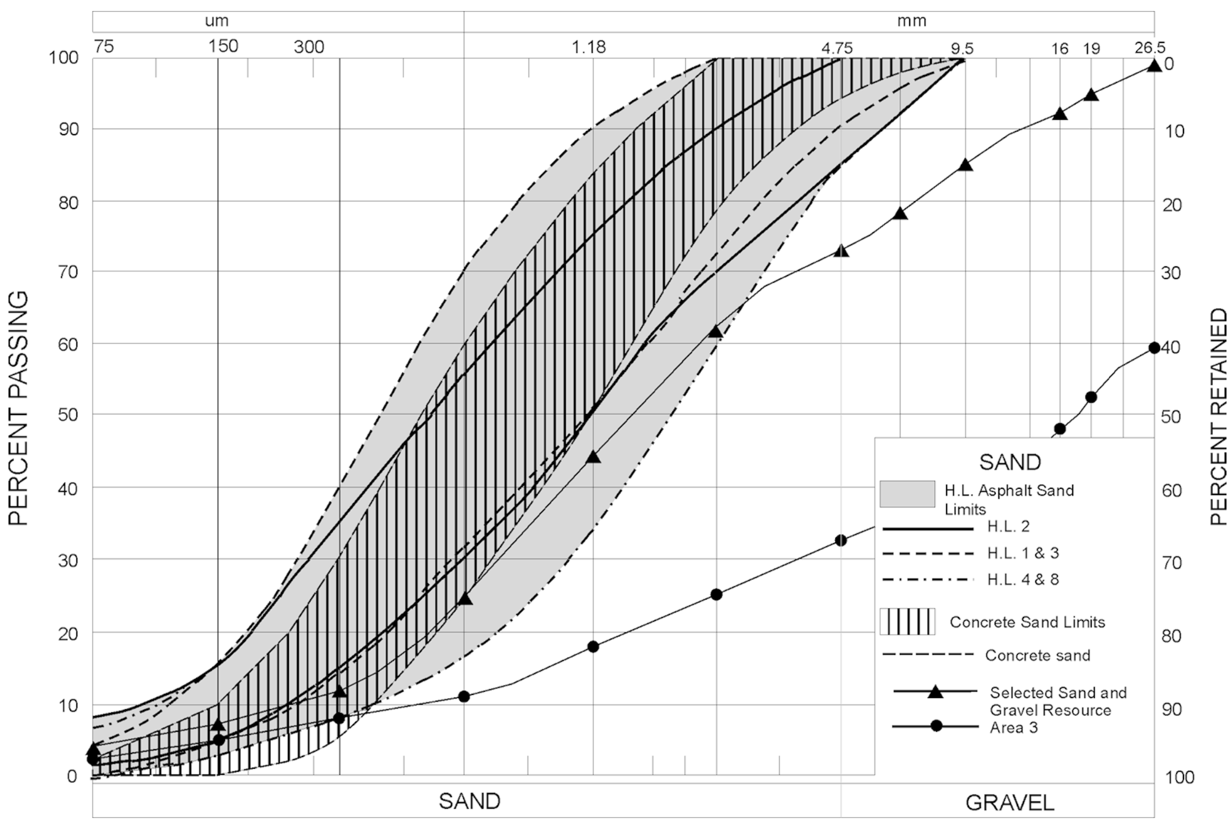

Figure 11B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

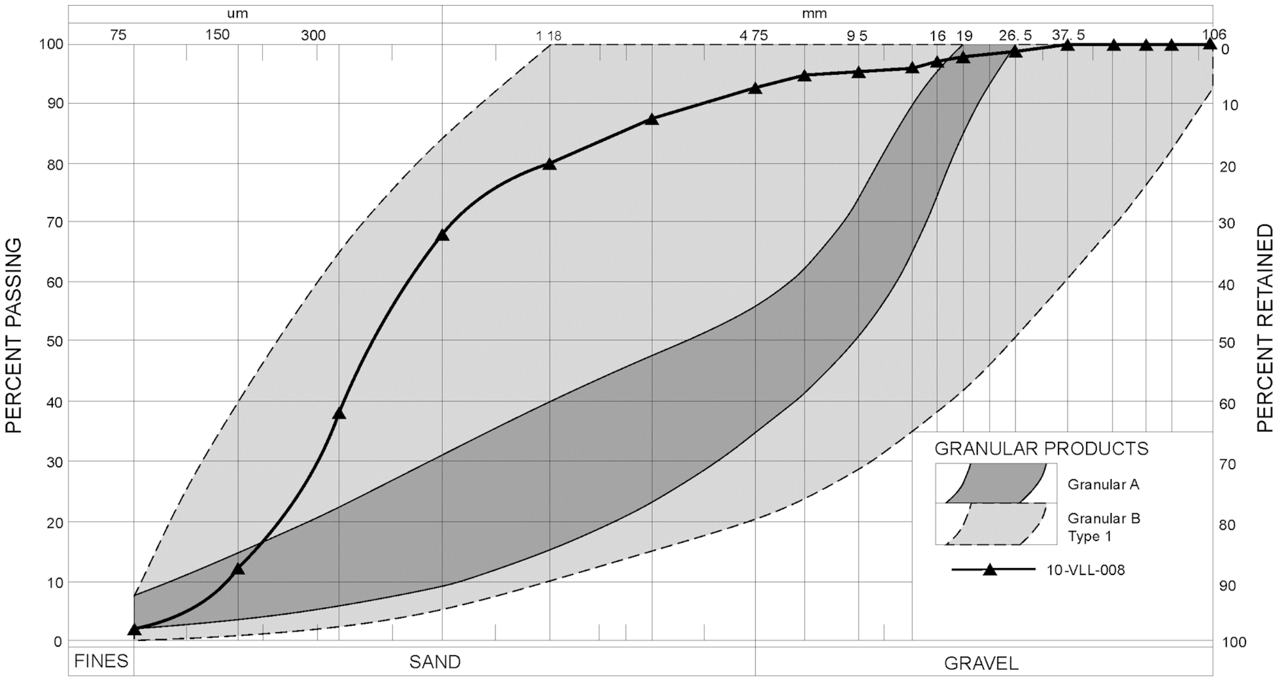

Figure 12A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

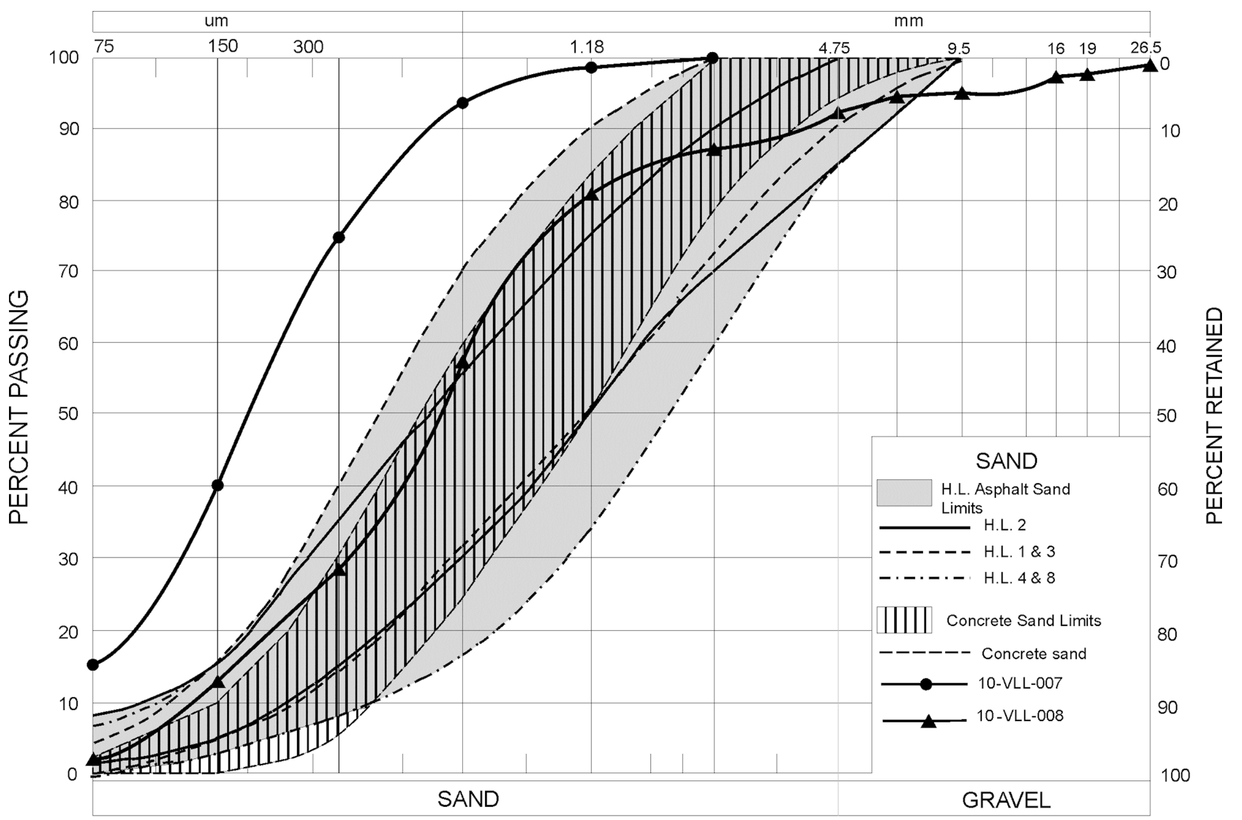

Figure 12B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

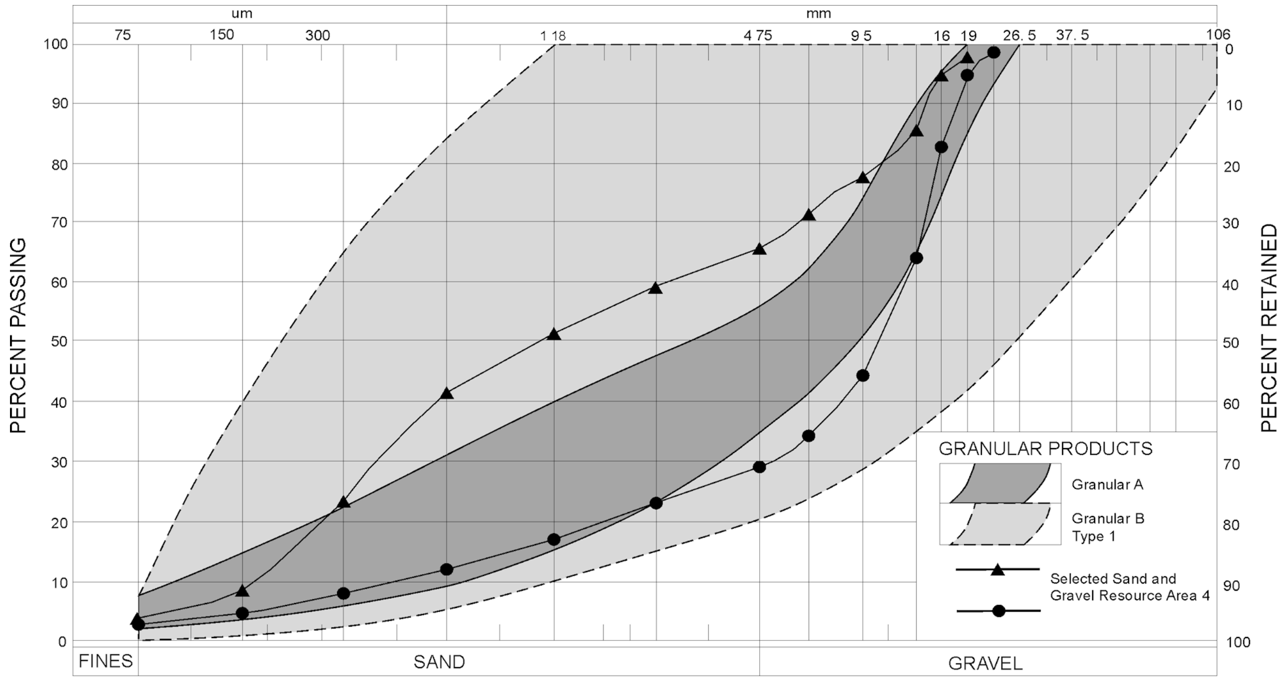

Figure 13A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

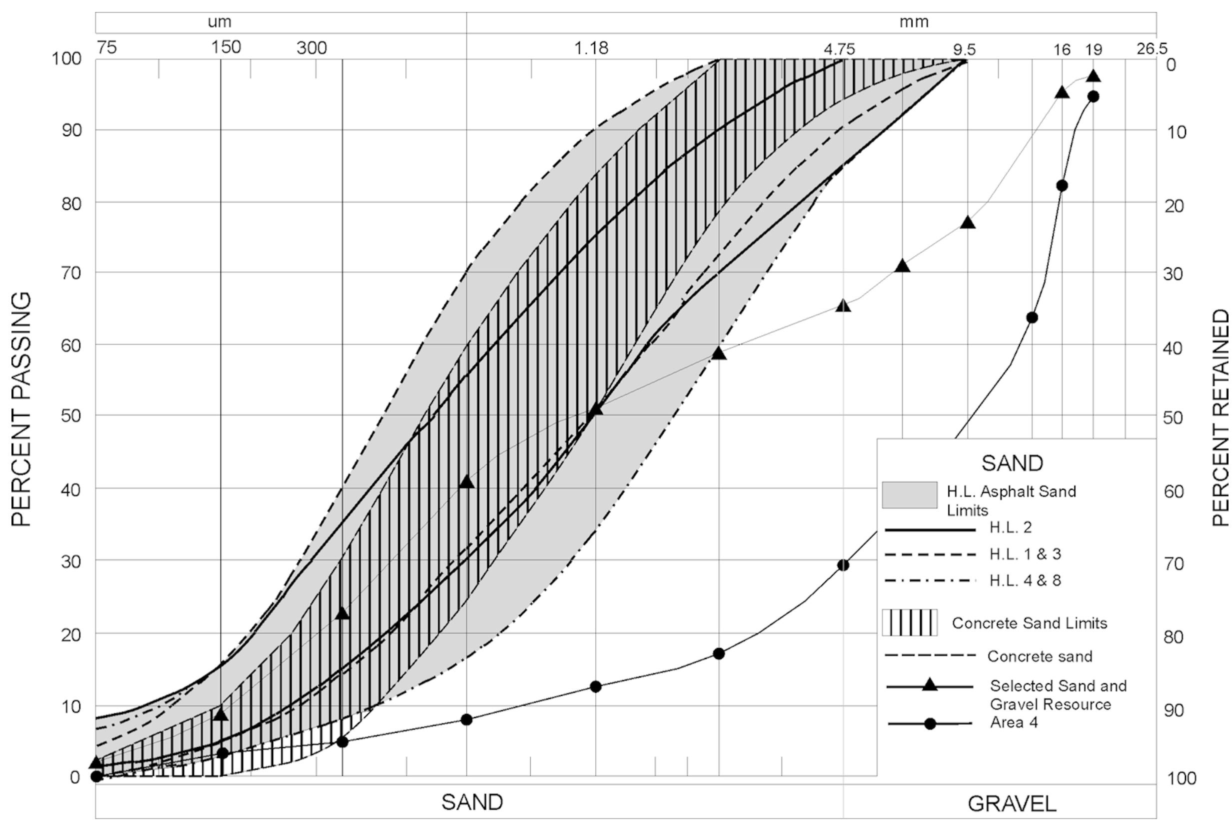

Figure 13B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

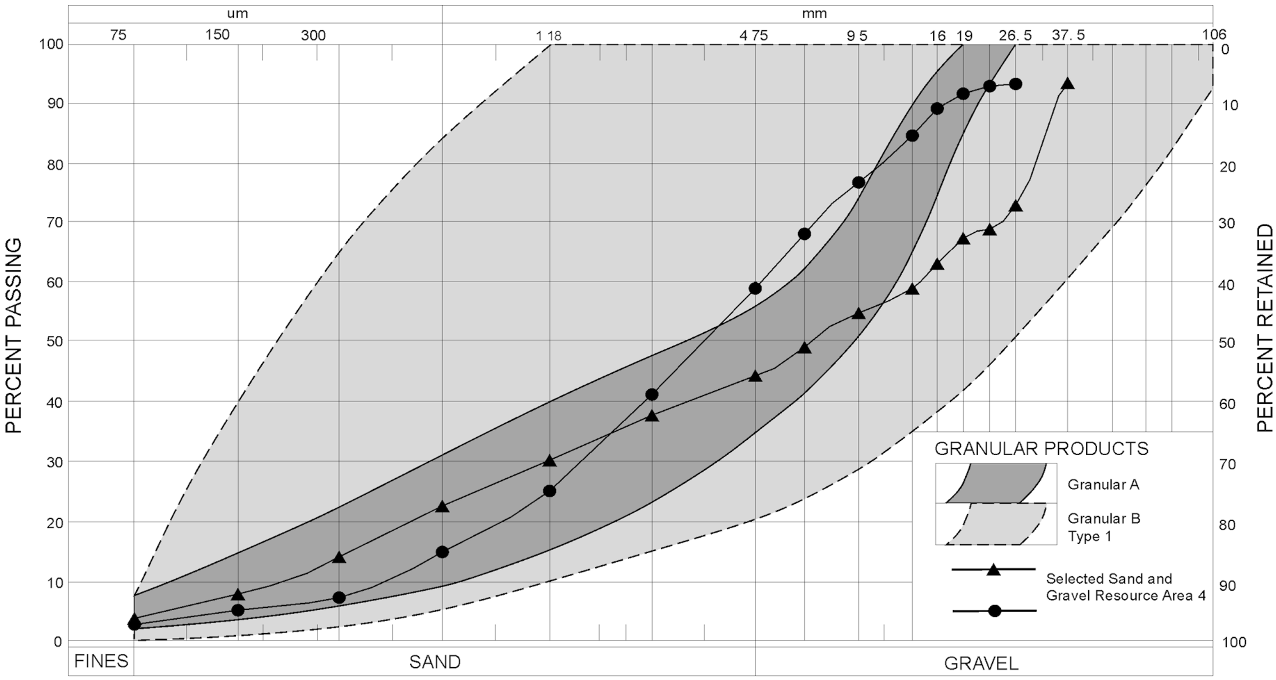

Figure 14A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

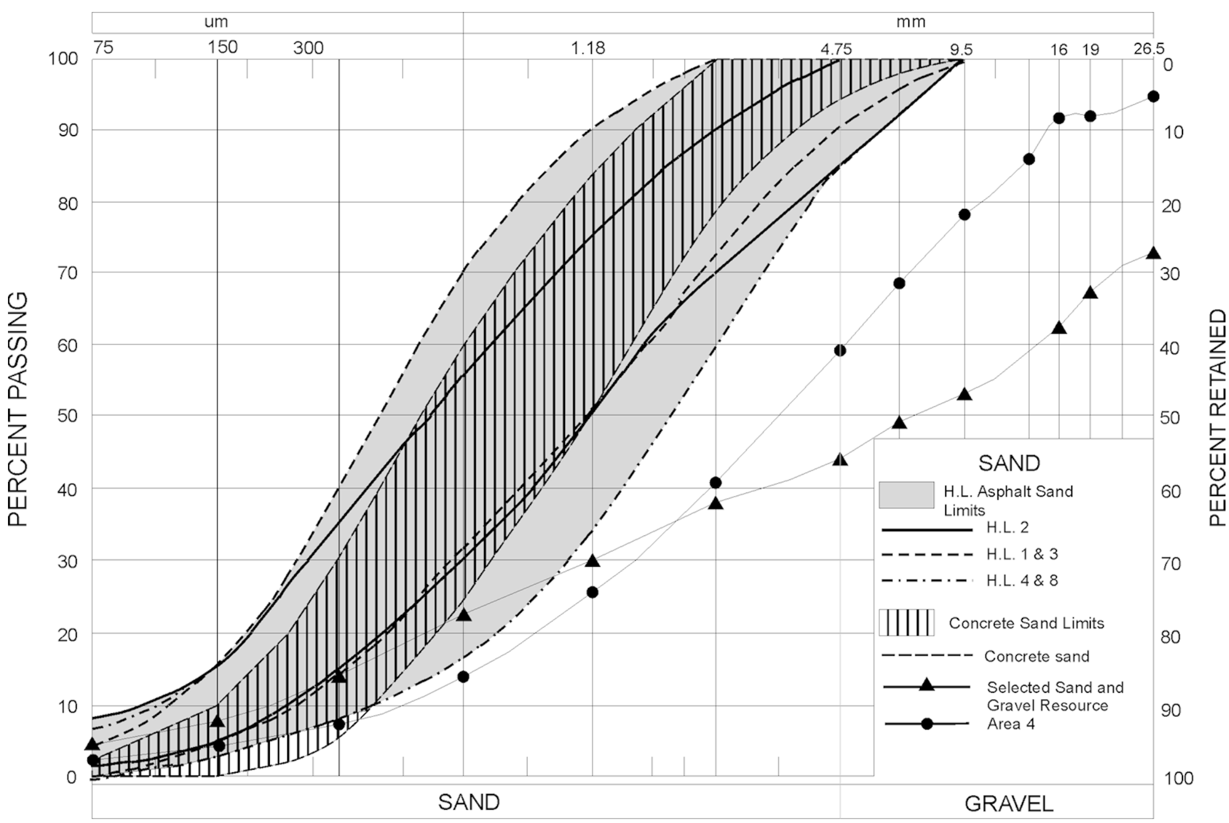

Figure 14B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

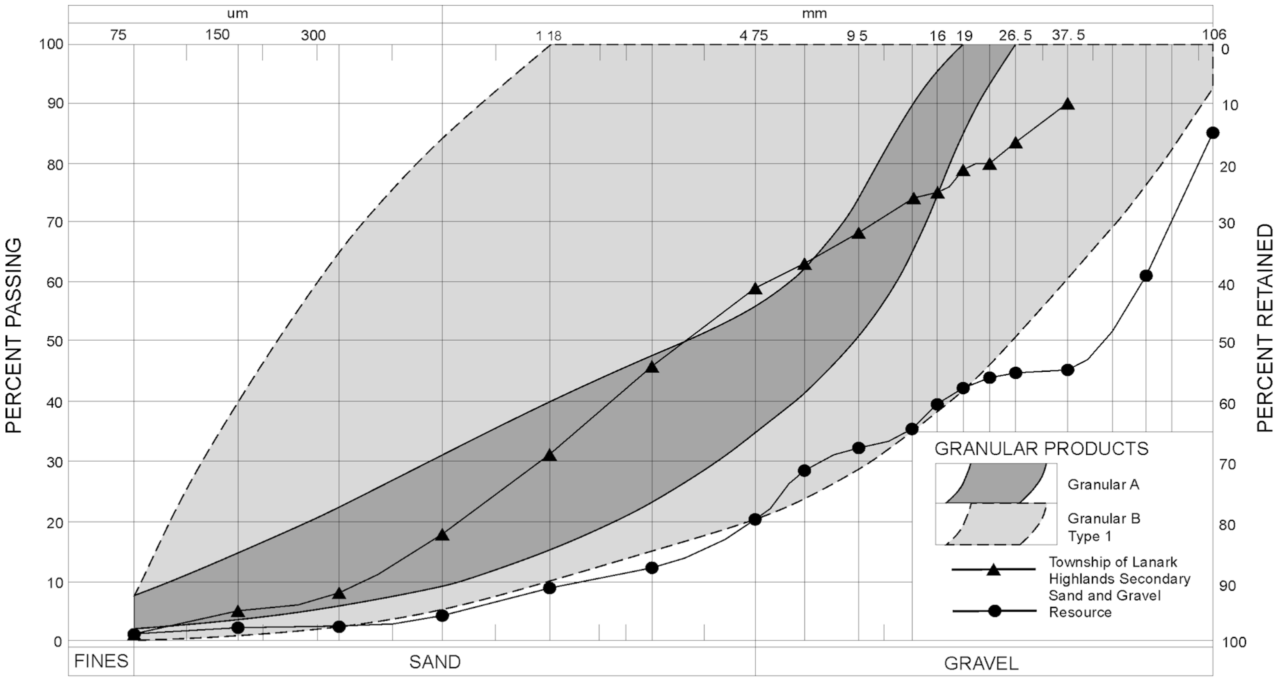

Figure 15A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

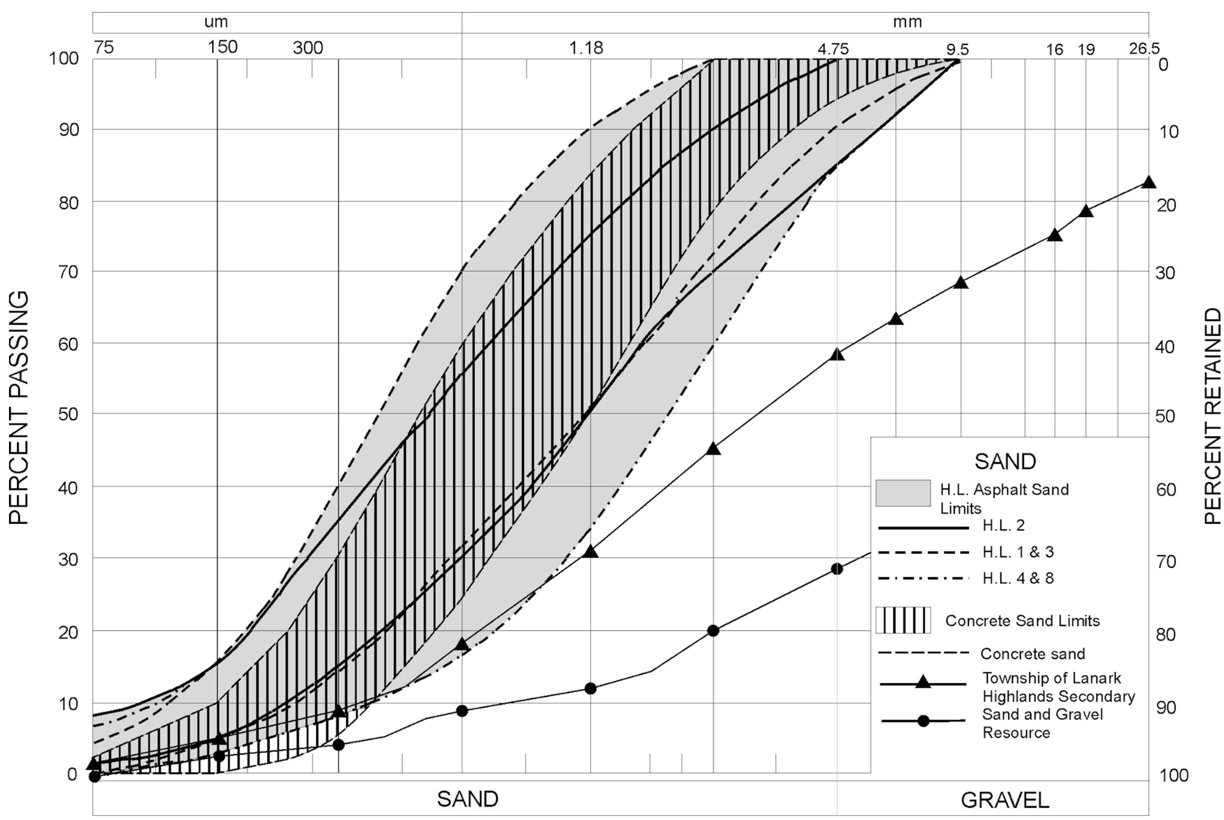

Figure 15B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

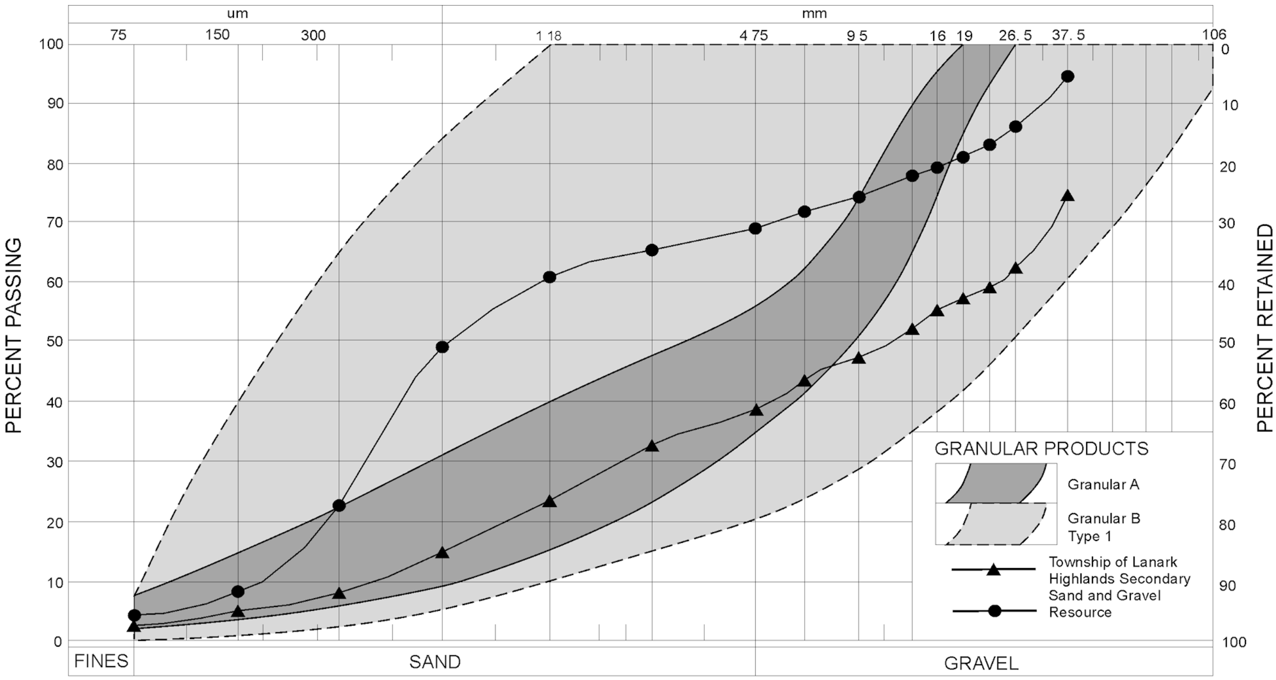

Figure 16A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

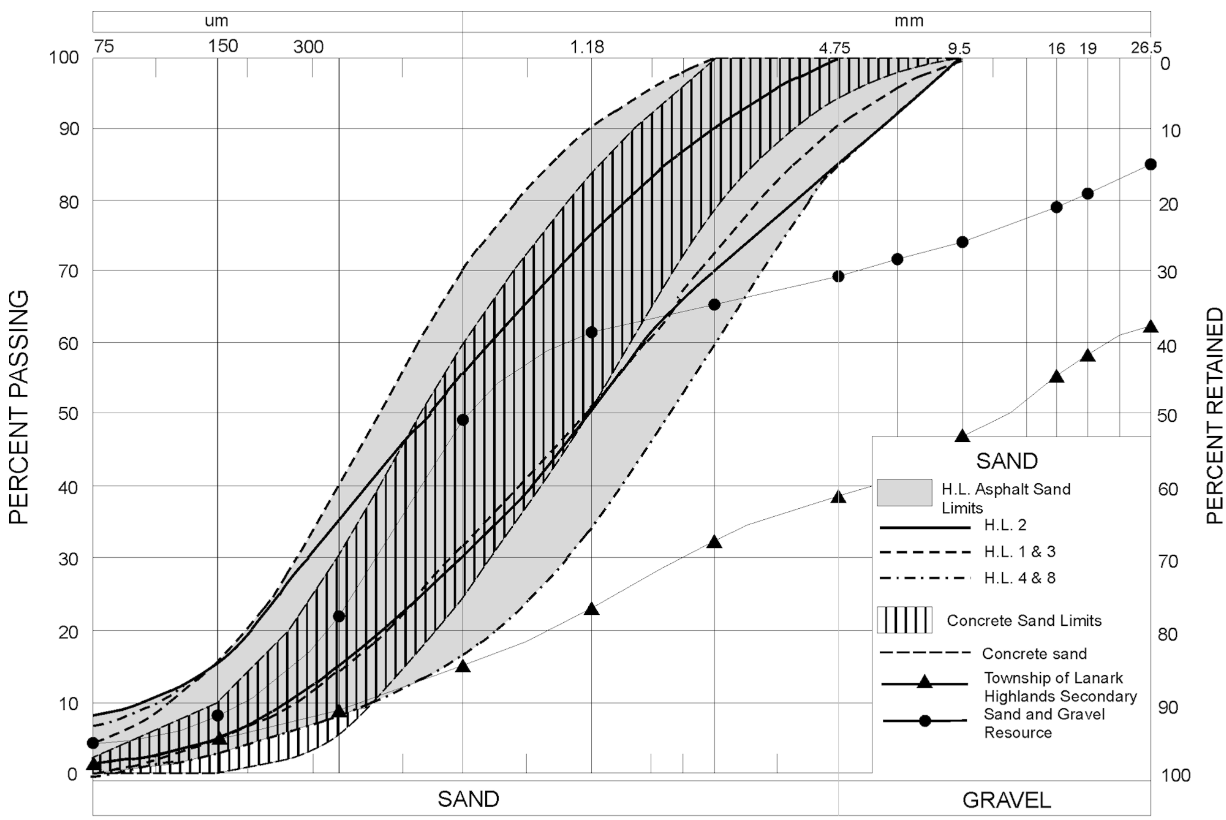

Figure 16B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

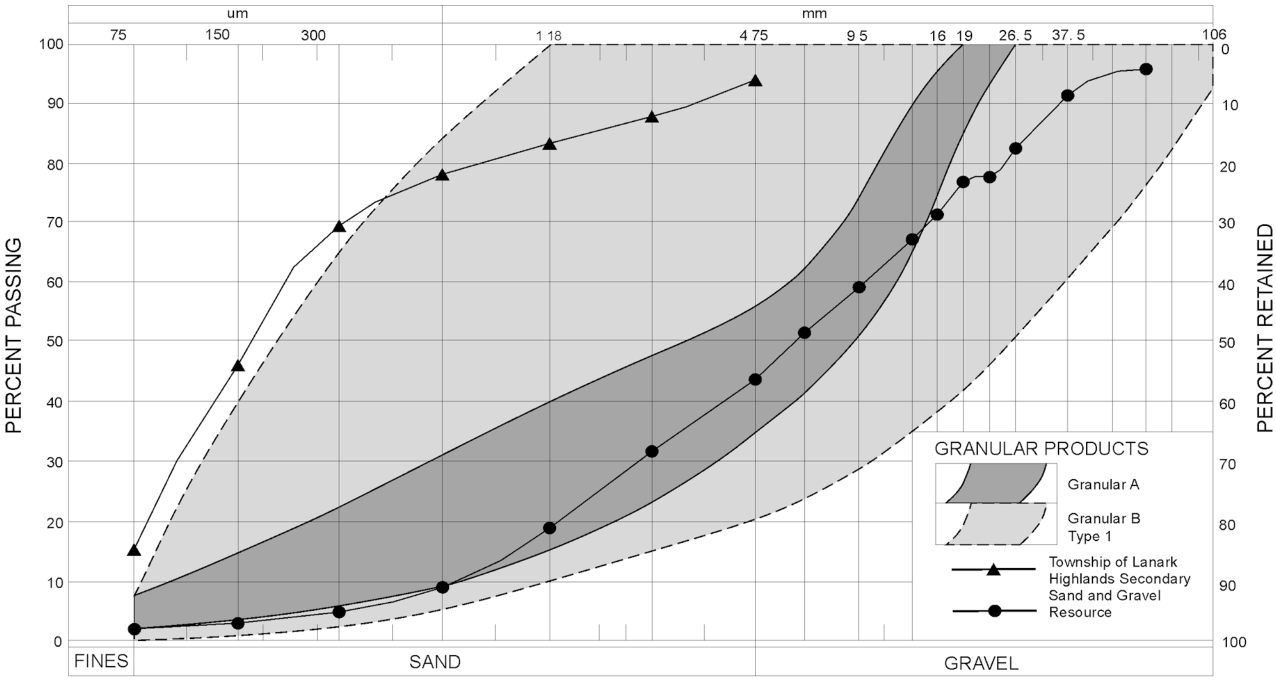

Figure 17A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

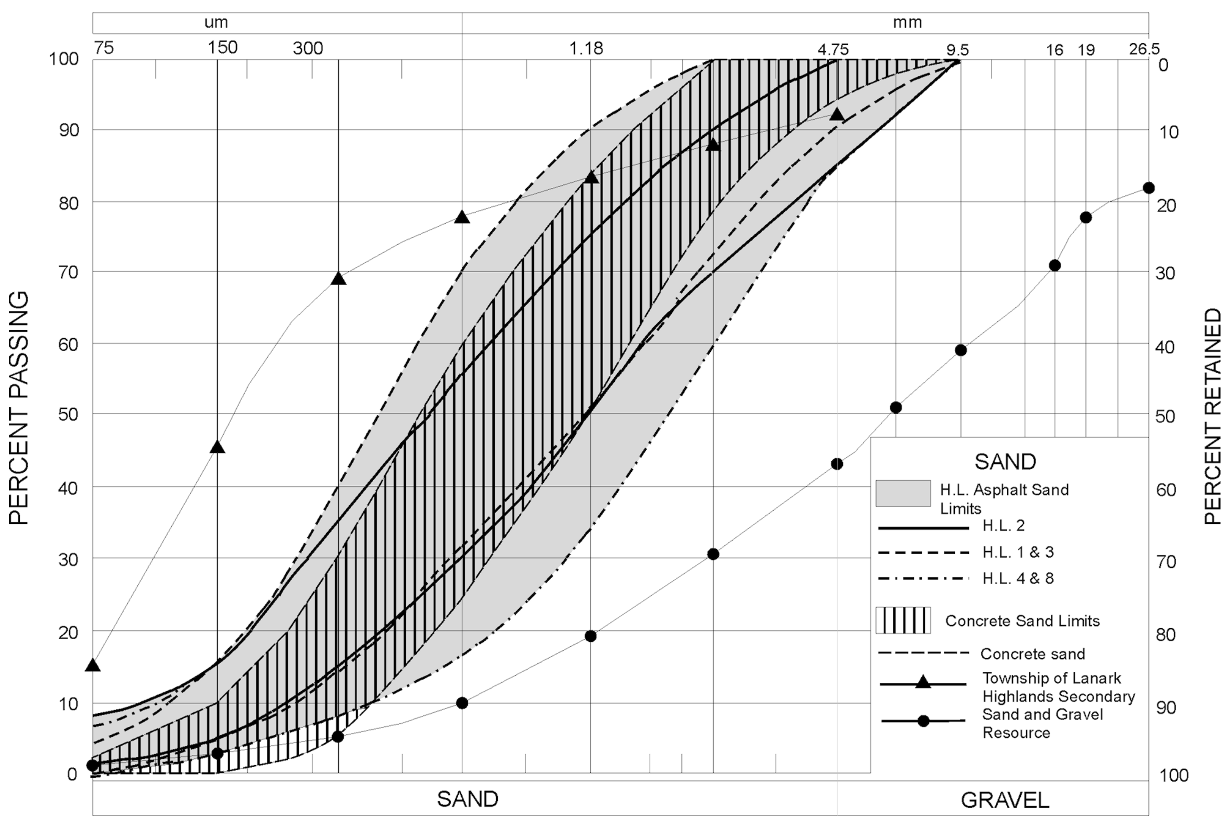

Figure 17B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

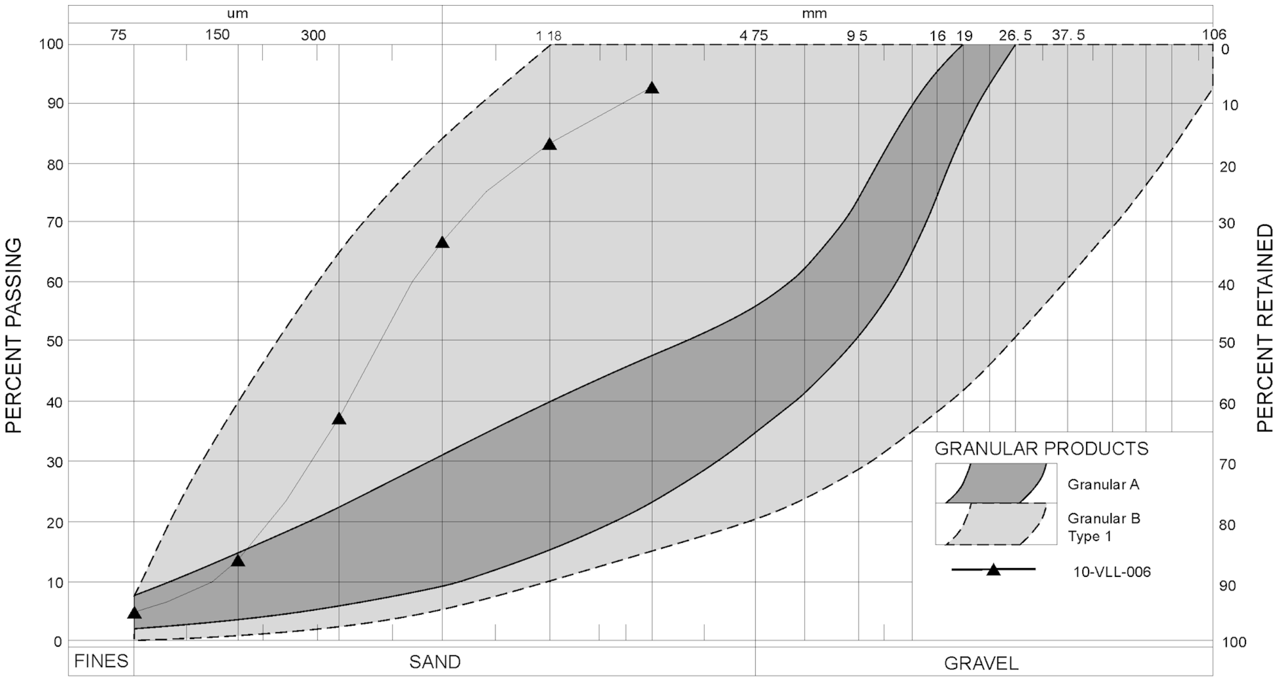

Figure 18A. Aggregate Grading Curves, County of Lanark – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

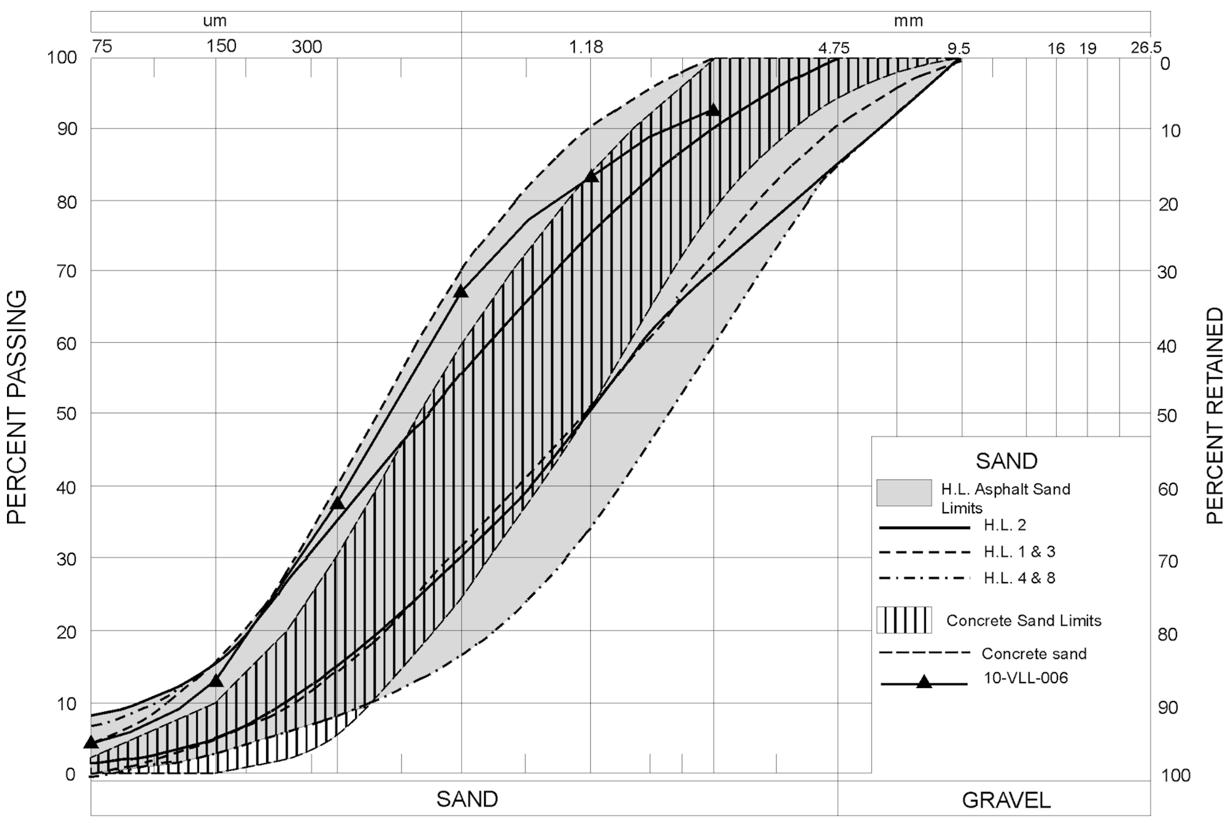

Figure 18B. Aggregate Grading Curves, County of Lanark – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

Note: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Because of 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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Appendix B – Glossary

Abrasion Resistance: Tests such as the Los Angeles abrasion test (*see* Appendix E) 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.

Acid-Soluble Chloride Ion Content: This test measures total chloride ion content in concrete and is used to judge the likelihood of re-bar corrosion and susceptibility to deterioration by freeze–thaw in concrete structures. There is a strong positive correlation between chloride ion content and depassivation of reinforcing steel in concrete. Depassivation permits corrosion of the steel in the presence of oxygen and moisture. Chloride ions are contributed mainly by the application of de-icing salts.

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 alkalis 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.

Beneficiation: Beneficiation of aggregates is a process or combination of processes that improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing, or classification. Heavy media separation, jigging, or application of special crushers (e.g., "cage mill") are usually considered processes of beneficiation.

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 540 and 500 million years age. The Cambrian precedes the Ordovician Period.

Chert: Amorphous silica, generally associated with limestone. Often occur as irregular masses or lenses, but can also occur finely disseminated through limestones. It may be very hard in unleached form. In leached form, it is white and "chalky" and is very absorptive. It has deleterious effect for aggregates to be used in Portland cement concrete due to reactivity with alkalis in Portland cement.

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

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

Deleterious Lithology: A general term used to designate those rock types that 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 Paleozoic Era thought to have covered the span of time between 410 and 355 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest Paleozoic rocks 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 formed beneath an advancing ice sheet and were shaped by its flow.

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

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

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 then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in Ontario.

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

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes, which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The 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

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

Granular Base and Subbase: Components of a 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. Granular A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular B, which is usually pit-run or other unprocessed aggregate. Granular M is a shouldering and surface dressing material with quality requirements similar to Granular A. Select Subgrade Material (SSM) has similar quality requirements to Granular B and it provides a stable platform for the overlying pavement structure. (For more specific information, the reader is referred to Ontario Provincial Standard Specification (OPSS) 1010 and Appendix E).

Heavy Duty Binder: Second layer from the top of hot mix asphalt pavements used on heavily travelled (especially by trucks) expressways, such as Highway 401. Coarse and fine aggregates are to be produced from high-quality bedrock quarries, except when gravel is permitted by special provisions.

Hot-Laid (or Asphaltic) Paving Aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course or as binder course used to bind the surface course to the underlying granular base.

Limestone: A carbonate sedimentary rock consisting chiefly of the mineral calcite. It may contain the mineral dolomite up to about 40%.

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

Medium Duty Binder: Second layer from the top of hot mix asphalt pavements used on heavily travelled, usually four-lane, highways and municipal arterial roads. It may be constructed with high-quality quarried rock or high-quality gravel with a high percentage of fractured faces or polymer modified asphalt cements.

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: One of the major divisions of the geologic time scale thought to have covered the time period between 540 and 250 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into 6 geologic periods, of which only 4 (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Pleistocene: An epoch of the recent geological past including the time from approximately 1.75 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, but do not take into account many site-specific natural and environmental constraints that could render the resource inaccessible.

Precambrian: The earliest geological period extending from the consolidation of the Earth’s crust to the beginning of the Cambrian Period.

Sandstone: A clastic sedimentary rock consisting chiefly of sand-sized particles of quartz and minor feldspar, cemented together by calcareous minerals (calcite or dolomite) or by silica.

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.

Siltstone: A clastic sedimentary rock consisting chiefly of silt-sized particles, cemented together by calcareous minerals (calcite and dolomite) or by silica.

Silurian: An early period of the Paleozoic Era thought to have covered the time between 435 and 410 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 Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C – Geology of Sand and Gravel Deposits

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

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into 2 broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice–Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but, in most cases, the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of 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 cross-bedded, 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 Ontario, and are significant components of the total resources of many areas.

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

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. 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.

Subaqueous Fans (SF): Subaqueous fans are formed within or near the mouths of meltwater conduits when sediment-laden meltwaters are discharged into a standing body of water. The geometry of the resulting deposit is fan or lobe shaped. Several of these lobes may be joined together to form a larger, continuous sedimentary body. Internally, subaqueous fans consist of stratified sands and gravels that may exhibit wide variations in grain size distribution. As these features were deposited under glacial lake waters, silt and clay that settled out of these lakes may be associated in varying amounts with these deposits. The variability of the sediments and presence of fines are the main extractive problems associated with these deposits.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are 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 Ontario. Well-developed lacustrine beaches are usually less than 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 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 is called a glaciolacustrine plain. The sediments that form the plain are predominantly fine to medium sand, silt and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular subbase aggregate.

GLACIOMARINE DEPOSITS

Glaciomarine Beach Deposits (MB): Similar to glaciolacustrine beach deposits, glaciomarine beach deposits are formed in a glaciomarine environment (i.e., ocean rather than lake environment).

Glaciomarine Deltas (MD): Similar to glaciolacustrine deltas, glaciomarine deltas are the result of a glaciomarine environment.

Glaciomarine Plains (MP): Similar to glaciolacustrine plains, glaciomarine plains are the result of a glaciomarine environment.

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 2 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 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 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

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure D1) and, where known, the potential uses of the various bedrock formations. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure D2) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey (e.g., Johnson et al. 1992 and Armstrong and Carter 2010) and the Geological Survey of Canada should be referred to for more detailed information. The lithology, thickness and general use of rocks from these formations are noted. If a formation may be suitable for use as aggregate and aggregate suitability test data are available, the data have been included in the form of ranges.

The following short forms have been used in presenting these data:

AAV = aggregate abrasion value,
Absn = absorption (percent),
BRD = bulk relative density,
LA = Los Angeles abrasion and impact test (loss in percent),
$MgSO_4$ = magnesium sulphate soundness test (loss in percent),
PN (A-C) = PN (Asphalt & Concrete) = petrographic number for asphalt (“A”) and concrete (“C”) use,
PSV = polished stone value.

The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data have been provided by the Ministry of Transportation of Ontario. Aggregate suitability tests are defined in Appendix E. Aggregate product specifications are also provided in Appendix E.

Covey Hill Formation (Cambrian)

STRATIGRAPHY and/or OCCURRENCE: Lower formation of the Potsdam Group.
LITHOLOGY: Interbedded noncalcareous feldspathic conglomerate and sandstone.
THICKNESS: 0 to 14 m.
USES: Has been quarried for aggregate in the United Counties of Leeds and Grenville.

Nepean Formation (Cambrian)

STRATIGRAPHY and/or OCCURRENCE: Upper formation of the Potsdam Group.
LITHOLOGY: Thin- to massive-bedded quartz sandstone with some conglomerate interbeds and rare shaly partings.
THICKNESS: 0 to 30 m.
USES: Suitable as dimension stone; quarried at Philipsville and Forfar for silica sand; alkali–silica reactive in Portland cement concrete.
AGGREGATE SUITABILITY TESTING: PSV = 54-68, AAV = 4-15, $MgSO_4$ = 9-32, LA = 44-90, Absn = 1.6-2.6, BRD = 2.38-2.50, PN (A-C) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY and/or OCCURRENCE: Lower formation of the Beekmantown Group.
LITHOLOGY: Interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone.
THICKNESS: 6 to 64 m.
USES: Quarried extensively for aggregate in areas of outcrop and subcrop; alkali–silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate. The formation is suitable for use as facing stone and paving stone.
AGGREGATE SUITABILITY TESTING: PSV = 55-60, AAV = 4-6, $MgSO_4$ = 1-17, LA = 15-38, Absn = 0.5-0.9, BRD = 2.61-2.65, PN (A-C) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY and/or OCCURRENCE: Upper formation of the Beekmantown Group.
LITHOLOGY: Thin- to thick-bedded, microcrystalline to medium-crystalline, grey dolostone with thin shaly interbeds.
THICKNESS: 61 to 102 m.
USES: Quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate.
AGGREGATE SUITABILITY TESTING: PSV = 47-48, AAV = 7-8, $MgSO_4$ = 1-4, LA = 18-23, Absn = 0.7-0.9, BRD = 2.74-2.78, PN (A-C) = 105-120.

Rockcliffe Formation (Lower Ordovician)

STRATIGRAPHY and/or OCCURRENCE: Divided into a lower member and an upper (St. Martin) member.
LITHOLOGY: Interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominate in the upper member.
THICKNESS: 0 to 125 m.
USES: Upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high-purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production.

AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, $MgSO_4$ = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (A-C) = 122-440.

Shadow Lake Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: The basal unit of the Black River Group. Informally, the formation is known as the basal unit of the Ottawa Group in eastern Ontario and the basal unit of the Simcoe Group in central Ontario.

LITHOLOGY: Poorly sorted, red and green sandy shales; argillaceous and arkosic sandstones; minor sandy argillaceous dolostones and rare basal arkosic conglomerate.

THICKNESS: 0 to 15 m.

USES: Potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: Part of the Black River Group. Informally, the formation is part of the Simcoe Group in central Ontario and the Ottawa Group in eastern Ontario. In eastern Ontario, the formation is subdivided into upper and lower members; in central Ontario, it is presently subdivided into upper, middle and lower members.

LITHOLOGY: In central and eastern Ontario, the lower member consists of alternating units of limestone, dolomitic limestone and dolostone. West of Lake Simcoe, the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone. The upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. The upper member also consists of thin-bedded limestones with thin shale partings.

THICKNESS: 7.5 to 135 m.

USES: Quarried in the Lake Simcoe, Kingston, Ottawa and Cornwall areas for crushed stone. Rock from certain layers has proven to be alkali reactive when used in Portland cement concrete (alkali–carbonate reaction).

AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-17, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (A-C) = 100-153, micro-Deval (C) = 8.8-18.7, mortar bar (14 days) = 0.004-0.030.

Bobcaygeon Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: Informally, the formation is part of the Simcoe Group in central Ontario and the Ottawa Group in eastern Ontario. The formation is subdivided into upper, middle and lower members. Formally, some researchers refer to the lower member as the Coboconk Formation of the Black River Group. The upper and middle members are sometimes referred to as the Kirkfield Formation, a part of the Trenton Group.

LITHOLOGY: The lower member is light grey-tan to brown-grey, medium- to very thick-bedded, fine- to medium-grained, bioturbated to current-laminated, bioclastic limestones, wackestones, packstones and grainstones. The middle member is thin- to medium-bedded, tabular-bedded, bioclastic, very fine- to fine-grained limestones with green shale interbeds and partings. The upper member is similar to the middle member, but also includes fine- to medium-grained, dark grey to light brown, thin- to medium-bedded, irregular to tabular bedded, bioturbated, horizontal to low-angle cross-laminated, bioclastic, fossiliferous limestones, wackestones, packstones and grainstones.

THICKNESS: 7 to 87 m.

USES: Quarried at Brechin, Marysville and in the Ottawa area for crushed stone. Generally suitable for use as granular base course aggregate. Rock from certain layers has been found to be alkali reactive when used in Portland cement concrete (alkali–silica reaction).

AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (A-C) = 100-320.

Verulam Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: The Verulam Formation is often referred to as the Sherman Fall Formation of the Trenton Group. Informally, the formation is part of the Simcoe and Ottawa groups.

LITHOLOGY: The Verulam Formation is informally subdivided into 2 members. The lower member consists of interbedded with limestone and calcareous shale. The limestone beds are very fine to coarse grained, thin to thick bedded, nodular to tabular bedded, light to dark grey-brown and fossiliferous. The upper member is thin- to thick-bedded, medium- to coarse-grained, cross-stratified, tan to light grey, fossiliferous, bioclastic limestone.

THICKNESS: 32 to 67 m.

USES: Quarried at Picton and Bath for use in cement manufacture. Quarried for aggregate in Ramara Township, Simcoe County and in the Belleville–Kingston area. The formation may be unsuitable for use as aggregate in some areas because of its high shale content.

AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (A-C) = 120-255.

Lindsay Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: The Lindsay Formation is divided into 2 members. The lower member is often referred to as the Cobourg Formation of the Trenton Group. The upper member is referred to as the Collingwood Member of the Trenton Group. In eastern Ontario, the Collingwood Member is often referred to as the Eastview Member. Informally, the Lindsay Formation is part of the Simcoe and Ottawa groups.

LITHOLOGY: The lower member is interbedded, very fine- to coarse-grained, bluish-grey to grey-brown limestone with undulating shale partings and interbeds of dark grey calcareous shale. The Collingwood Member is a black, organic-rich, petroliferous, calcareous shale with very thin, fossiliferous, bioclastic limestone interbeds.

THICKNESS: The upper member is up to 10 m thick, whereas the lower member can be up to 60 m thick.

USES: In eastern Ontario, the lower member is used extensively for aggregate production; in central Ontario, it is quarried at Picton, Ogden Point and Bowmanville for cement. The formation may be suitable or unsuitable for use as concrete and asphalt aggregate.

AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2-47, LA = 20-28, Absn = 0.4-1.3, BRD = 2.64-2.70, PN (A-C) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: The Blue Mountain Formation includes the upper and middle members of the former Whitby Formation. In eastern Ontario, the Billings Formation is equivalent to part of the Blue Mountain Formation.

LITHOLOGY: Blue-grey to grey-brown, noncalcareous shales with thin, minor interbeds of limestone and siltstone. The Billings Formation is dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds.

THICKNESS: Blue Mountain Formation - 43 to 60 m; Billings Formation - 0 to 62 m.

USES: The Billings Formation may be a suitable source for structural clay products and lightweight expanded aggregate. The Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: The Georgian Bay Formation trends in a northwest direction from Lake Ontario toward Georgian Bay. The Carlsbad Formation is the equivalent of the Georgian Bay Formation in eastern Ontario.

LITHOLOGY: The Georgian Bay Formation consists of greenish to bluish-green shale interbedded with limestone, siltstone and sandstone. The Carlsbad Formation consists of interbedded shale, siltstone and bioclastic limestone.

THICKNESS: Georgian Bay Formation - 125 to 200 m; Carlsbad Formation - 0 to 186 m.

USES: Georgian Bay Formation was previously used by several producers in the Metropolitan Toronto area to produce brick and structural tile, as well as for making Portland cement. At Streetsville, expanded shale was used in the past to produce lightweight aggregate. These operations are no longer in production. The Carlsbad Formation may be used as a source material for brick and tile manufacturing and has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: The Queenston Formation conformably overlies the Georgian Bay Formation and crops out along the base of the Niagara Escarpment.

LITHOLOGY: Red-maroon, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding.

THICKNESS: 45 to 335 m.

USES: There are several quarries developed in the Queenston Formation along the base of the Niagara Escarpment and one at Russell, near Ottawa. All extract shale for brick manufacturing. The Queenston Formation is the most important source of material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Lower formation of the Cataract Group, generally located in the Niagara Peninsula and along the Niagara Escarpment as far north as Duntroon.

LITHOLOGY: White to grey to maroon, fine-grained, orthoquartzitic sandstone with thin grey shale partings.

THICKNESS: 0 to 9 m.

USES: Building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Cataract Group. The formation generally occurs north of Stoney Creek.

LITHOLOGY: Thin- to medium-bedded, moderately fossiliferous, fine- to medium-crystalline dolostone with minor grey-green shale. Chert nodules or lenses, and silicified fossils have also been reported within the formation.

THICKNESS: 0 to 25 m.

USES: Extracted for crushed stone in Grey County, and for decorative stone on Manitoulin Island.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Cataract Group. The formation occurs in the subsurface throughout southwestern Ontario and crops out along the length of the Niagara Escarpment.

LITHOLOGY: Grey to green to red-maroon, noncalcareous shales with subordinate sandstone and carbonate interbeds.

THICKNESS: 12 to 40 m.

USES: Potential source of lightweight aggregate. Extraction opportunities are limited by the lack of suitable exposures.

Grimsby Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Upper formation of the Cataract Group. The formation has been identified along the Niagara Peninsula as far north as Clappison's Corners.
LITHOLOGY: Interbedded sandstone, dolomitic sandstone and red shale. The lower part of the Grimsby Formation becomes greener and shalier as it grades into the upper Cabot Head Formation.
THICKNESS: 0 to 15 m.
USES: No present uses.

Thorold Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Lower formation in the Clinton Group.
LITHOLOGY: Grey-green to white, fine- to coarse-grained, quartzose sandstone with minor thin grey to green shale or siltstone partings.
THICKNESS: 2 to 7 m.
USES: No present uses.

Neagha Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Clinton Group.
LITHOLOGY: Dark to greenish grey shale, sparsely fossiliferous, fissile shale, with minor thin limestone interbeds. The base of the Neagha Formation consists of a phosphatic pebble lag that indicates an unconformable contact with the underlying Thorold Formation.
THICKNESS: 0 to 2 m.
USES: No present uses.

Dyer Bay Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Cataract Group. Crops out on Manitoulin Island and along the east side of the Bruce Peninsula as far south as Owen Sound. In the subsurface, it underlies the Bruce Peninsula and most of Essex and Kent counties.
LITHOLOGY: Thin- to medium-bedded, fine- to medium-grained, blue-grey to brown, argillaceous, fossiliferous dolostone with green-grey shaly partings.
THICKNESS: 0 to 8 m.
USES: No present uses.

Wingfield Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Cataract Group. Occurs on Manitoulin Island and the northernmost part of the Bruce Peninsula.
LITHOLOGY: Interbedded brown, fine- to medium-grained, argillaceous dolostone and olive-green, noncalcareous, sparsely fossiliferous shale.
THICKNESS: 0 to 15 m.
USES: No present uses.

St. Edmund Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Cataract Group. Occurs on Manitoulin Island and the northernmost part of the Bruce Peninsula. The upper portion of the formation was previously termed the Mindemoya Formation.
LITHOLOGY: Light creamy tan, microcrystalline, thin-bedded, sparsely fossiliferous dolostone with tan to brown, fine- to medium-crystalline, thick-bedded dolostone.
THICKNESS: 0 to 25 m.
USES: Quarried for fill and crushed stone on Manitoulin Island.
AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-2, LA = 19-21, Absn = 0.6-0.7, BRD = 2.78-2.79, PN (A-C) = 105.

Fossil Hill Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Clinton Group. Occurs on Manitoulin Island and the northern part of the Bruce Peninsula.
LITHOLOGY: Thin- to medium-bedded, very fine- to coarse-grained, very fossiliferous dolostone. The formation also contains intervals of tan-grey, very fine-crystalline, sparsely fossiliferous dolostone.
THICKNESS: 3 to 34 m.
USES: The formation is sometimes quarried along with the overlying Amabel and Lockport formations.
AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4$ = 41, LA = 29, Absn = 4.1, BRD = 2.45, PN (A-C) = 370.

Reynales Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Clinton Group. The Reynales Formation occurs on the Niagara Peninsula and along the Niagara Escarpment as far north as the Forks of the Credit.
LITHOLOGY: Light to dark grey, buff weathering, thin- to thick-bedded, very fine- to fine-grained, sparsely fossiliferous dolostone to argillaceous dolostone, with thin shaly interbeds and partings.
THICKNESS: 0 to 5 m.
USES: The formation is sometimes quarried along with overlying Amabel and Lockport formations.

Irondequoit Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Clinton Group generally along the Niagara Peninsula south of Waterdown.
LITHOLOGY: Thick- to massive-bedded, light to pinkish grey, medium- to coarse-grained, crinoidal- and brachiopod-rich limestone.
THICKNESS: 0 to 10 m.
USES: Not utilized extensively.

Rochester Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Clinton Group generally along the Niagara Peninsula.
LITHOLOGY: Dark grey to black, calcareous shale with variably abundant, thin, fine- to medium-grained calcareous to dolomitic calcisiltite to bioclastic calcarenite interbeds.
THICKNESS: 5 to 24 m.
USES: Not utilized extensively.
AGGREGATE SUITABILITY TESTING: PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Absn = 2.2, BRD = 2.67, PN (A-C) = 400.

Decew Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Clinton Group south of Waterdown along the Niagara Escarpment.
LITHOLOGY: Very fine- to fine-grained, argillaceous to arenaceous dolostone, with locally abundant shale partings and interbeds.
THICKNESS: 0 to 4 m.
USES: Too shaly for high-quality uses, but it is quarried along with the Lockport Formation in places.
AGGREGATE SUITABILITY TESTING: PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (A-C) = 255.

Lockport and Amabel Formations (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: The Lockport Formation occurs from Waterdown to Niagara Falls and is subdivided into 2 formal members: the Gasport and Goat Island members. The Amabel Formation is found from Waterdown to Cockburn Island and has been subdivided into the Lions Head and Wiarton members.
LITHOLOGY: The Gasport Member consists of thick- to massive-bedded, fine- to coarse-grained, blue-grey to white to pinkish grey dolostone and dolomitic limestone, with minor argillaceous dolostone. The Goat Island Member is dark to light grey to brown, very fine- to fine-crystalline, thin- to medium-bedded, irregularly bedded, variably argillaceous dolostone with locally abundant chert and vugs filled with gypsum, calcite or fluorite. Near Hamilton, abundant chert nodules and lenses in the Goat Island member have been informally named the Ancaster chert beds. A shaly interval, termed the Vinemount shale, occurs at the top of the Goat Island near and east of Hamilton.
The Wiarton Member consists of massive-bedded, blue-grey mottled, light grey to white, fine- to coarse-crystalline, porous crinoidal dolostone. Underlying the Wiarton Member in the Bruce Peninsula is the Colpoy Bay Member which is browner, finer grained and less fossiliferous than the Wiarton Member. The Lions Head Member consists of light grey to grey-brown, fine-crystalline, thin- to medium-bedded, sparsely fossiliferous dolostone with abundant chert nodules.
THICKNESS: (Lockport and Amabel) 3 to 40 m.
USES: Both 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.
AGGREGATE SUITABILITY TESTING: PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (A-C) = 100-105.

Guelph Formation (Lower to Upper Silurian)

STRATIGRAPHY and/or OCCURRENCE: Exposed south and west of the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula. The formation is also present in the subsurface of southwestern Ontario.
LITHOLOGY: The formation is tan- to brown-coloured, fine- to medium-crystalline, moderately to very fossiliferous, commonly biostromal to biohermal, sucrosic dolostones. In places, the formation is characterized by extensive vuggy, porous reefal facies of high chemical purity. The Eramosa Member consists of thin- to thick-bedded, tan to black, fine- to medium-crystalline, variably fossiliferous, bituminous dolostone. Locally, the Eramosa Member is argillaceous and cherty.
THICKNESS: 4 to 100 m.
USES: Some areas appear soft and unsuitable for use in the production of load-bearing aggregate. This unit requires additional testing to fully establish its aggregate suitability. The main use is for dolomitic lime for cement manufacture. The formation is quarried near Hamilton and Guelph.

Salina Formation (Group) (Upper Silurian)

STRATIGRAPHY and/or OCCURRENCE: Present in the subsurface of southwestern Ontario; only rarely exposed at surface. In southern Ontario, the succession of evaporates and evaporite-related sediments underlying the Bass Islands and Bertie formations, and overlying the reefal dolostones of the Guelph Formation, have been termed the Salina Formation. In other jurisdictions, this formation is often referred to as the Salina Group.
LITHOLOGY: Grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic-rich material with up to 8 units identifiable. The Salina Group is dominated by evaporate lithologies in the Michigan Basin and become gradually shalier into the Appalachian Basin.
THICKNESS: 113 to 420 m.
USES: Gypsum mines at Hagersville, Caledonia and Drumbo. Salt is mined at Goderich and Windsor and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY and/or OCCURRENCE: The Bertie Formation is an Appalachian Basin unit found in the Niagara Peninsula. The Bertie Formation is equivalent to the Bertie Group of New York and, therefore, consists of the Oatka, Falkirk, Scajaquada, Williamsville and Akron members in Ontario. The Bass Islands Formation is a Michigan Basin equivalent of the Bertie Formation, which rarely crops out in Ontario, but is present in the subsurface in southwestern Ontario.

LITHOLOGY: The Bertie Formation consists of a succession of dark brown to light grey-tan, very fine- to fine-grained, variably laminated and bituminous, sparsely fossiliferous dolostones with argillaceous dolostones and minor shales. The Bass Islands Formation consists of dark brown to light grey-tan, variably laminated, mottled, argillaceous and bituminous, very fine- to fine-crystalline and sucrosic dolostones with minor anhydritic and sandstone beds.

THICKNESS: 10 to 90 m.

USES: Quarried for crushed stone on the Niagara Peninsula; shaly intervals are unsuitable for use as high specification aggregate because of low freeze–thaw durability. These formations have also been extracted for the production of lime.

AGGREGATE SUITABILITY TESTING: PSV = 46-49, AAV = 8-11, $MgSO_4$ = 4-19, LA = 14-23, Absn = 0.8-2.8, BRD = 2.61-2.78, PN (A-C) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY and/or OCCURRENCE: Lower Devonian clastic unit, found in the Niagara Peninsula. The formation is equivalent to the Oriskany Formation in New York and Ohio and the Garden Island Formation of Michigan.

LITHOLOGY: Grey to yellowish white, coarse-grained, thick- to massive-bedded, calcareous quartzose sandstone.

THICKNESS: 0 to 5 m.

USES: The formation has been quarried for silica sand, building stone and armour stone. The formation may be acceptable for use as rip rap and well-cemented varieties may be acceptable for some asphaltic products.

AGGREGATE SUITABILITY TESTING: (of a well-cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (A-C) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY and/or OCCURRENCE: The formation disconformably overlies Silurian strata or, where present, the Lower Devonian Oriskany Formation. The Springvale Member forms the lower portion of formation.

LITHOLOGY: Greenish grey to grey-brown, thin- to medium-bedded, fine- to medium-grained, fossiliferous, bioturbated, cherty limestone and dolostone. The Springvale Member is a white to green-brown, commonly glauconitic, rarely argillaceous, quartzitic sandstone with minor sandy carbonates.

THICKNESS: 3 to 50 m. The Springvale Member is generally from 3 to 10 m thick; however, 30 m thickness has been reported.

USES: Quarried at Hagersville, Cayuga and Port Colborne for crushed stone. Material is generally unsuitable for concrete aggregate because of a high chert content.

AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (A-C) = 102-290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Correlated to part of the Detroit River Group. Outcrops occur on the Niagara Peninsula from Simcoe to Niagara Falls. The formation includes the Edgecliffe, Clarence and Moorehouse members.

LITHOLOGY: Medium-bedded, fine- to coarse-grained, dark grey-brown or purplish-brown, variably cherty limestone.

THICKNESS: 8 to 25 m.

USES: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. The high chert content makes much of the material unsuitable for use as concrete and asphaltic aggregate. The formation has been used as a raw material in cement manufacture.

AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliffe members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (A-C) = 190-276.

Amherstburg Formation (Lower to Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Detroit River Group. The formation correlates to the Amherstburg Formation of Michigan and the lower part of the Onondaga Formation in western New York. The Onondaga Formation terminology has been used in the outcrop belt of southern Ontario east of Norfolk County.

LITHOLOGY: Tan to grey-brown to dark brown, fine- to coarse-grained, bituminous, bioclastic, fossiliferous limestones and dolostone. Stromatoporoid-dominated bioherms are locally significant in Bruce and Huron counties and have been termed the Formosa Reef Limestone or Formosa reef facies.

THICKNESS: 0 to 60 m. The Formosa Reef Limestone is up to 26 m.

USES: Cement manufacture, agricultural lime, aggregate.

AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (A-C) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Detroit River Group in southwestern Ontario. The formation is subdivided into 3 lithological units: the Lucas Formation undifferentiated, the Anderdon Member limestone and the Anderdon Member sandy limestone.
LITHOLOGY: The undifferentiated Lucas Formation consists of thin- to medium-bedded, light to grey-brown, fine crystalline, poorly fossiliferous dolostone and limestone. Anhydrite and gypsum beds are present near Amherstburg and Goderich. The Anderdon Member consists of light to dark grey-brown, thin- to medium-bedded, fine-grained, sparsely fossiliferous limestone, alternating with coarse-grained, bioclastic limestone.
THICKNESS: 40 to 99 m.
USES: Most important source of high-purity limestone in Ontario. Used as calcium lime for metallurgical flux and for the manufacture of chemicals. Rock of lower purity is used for cement manufacture, agricultural lime and aggregate. The Anderdon Member is quarried at Amherstburg for crushed stone.
AGGREGATE SUITABILITY TESTING: PSV = 46-47, AAV = 15-16, $MgSO_4$ = 2-60, LA = 22-47, Absn = 1.1-6.5, BRD = 2.35-2.40, PN (A-C) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: The Dundee Formation occurs between the Hamilton Group or Marcellus Formation and the limestones and dolostones of the Detroit River Group. There are few outcrops and the formation is observed mostly in the subsurface of southwestern Ontario.
LITHOLOGY: Grey to tan to brown, fossiliferous, medium- to thick-bedded limestones and minor dolostones. Bituminous partings and microstylolites are common. Chert nodules are locally abundant.
THICKNESS: 35 to 45 m.
USES: Quarried near Port Dover and on Pelee Island for crushed stone. Used at St. Marys as a raw material for Portland cement.
AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-28, LA = 22-46, Absn = 0.6-6.8, PN (A-C) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Subsurface unit, mostly found below Lake Erie and extending into the eastern USA, pinches out in the Port Stanley area. The formation occurs on the southeast side of the Algonquin Arch.
LITHOLOGY: Black, organic-rich shales with interbeds of grey shale and very fine- to medium-grained, impure carbonates.
THICKNESS: 0 to 12 m.
USES: No present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Lowest formation of the Hamilton Group, not known to crop out in Ontario.
LITHOLOGY: Blue-grey, soft, calcareous shale with thin limestone and organic-rich interbeds toward the base of the formation.
THICKNESS: 0 to 14.5 m.
USES: No present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Hamilton Group; not known to crop out in Ontario.
LITHOLOGY: Grey to brown, fine-grained argillaceous limestone.
THICKNESS: 0 to 6 m.
USES: No present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Hamilton Group.
LITHOLOGY: Blue-grey, plastic, soft, calcareous shale with minor thin and laterally discontinuous argillaceous limestone beds.
THICKNESS: 5 to 37 m.
USES: Has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Hamilton Group.
LITHOLOGY: The upper part of the formation is a coral-rich, calcareous shale-dominated unit. The lower part of the formation is predominantly fossiliferous, bioclastic limestone.
THICKNESS: 0 to 2 m.
USES: Suitable for some crushed stone and fill with very selective quarrying methods.

Widder Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Hamilton Group.
LITHOLOGY: Calcareous, grey to brown-grey shale, bioturbated, fine-grained, argillaceous, nodular limestone and coarse-grained bioclastic limestone.
THICKNESS: 0 to 21 m.
USES: No present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Upper formation of the Hamilton Group; very limited distribution in Ontario.

LITHOLOGY: Grey-brown, fine- to coarse-grained, argillaceous and bioclastic limestone with shaly interbeds.
THICKNESS: 2 to 13 m.
USES: No present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY and/or OCCURRENCE: Occurs in a northwest-trending band between Sarnia and Lake Erie; small part overlain by Port Lambton Group rocks in extreme northwest.
LITHOLOGY: Dark brown to black, highly fissile, organic-rich shale with subordinate organic-poor, grey-green silty shale and siltstone interbeds.
THICKNESS: 0 to 75 m.
USES: Possible source of lightweight aggregate or fill.

Bedford Formation (Upper Devonian)

STRATIGRAPHY and/or OCCURRENCE: Lower formation of the Port Lambton Group.
LITHOLOGY: Light grey, soft, fissile shale with silty and sandy interbeds in the upper part of the formation.
THICKNESS: 0 to 30 m.
USES: No present uses.

Berea Formation (Upper Devonian)

STRATIGRAPHY and/or OCCURRENCE: Middle formation of the Port Lambton Group; not known to crop out in Ontario.
LITHOLOGY: Grey, fine- to medium-grained sandstone with grey shale and siltstone interbeds.
THICKNESS: 0 to 60 m.
USES: No present uses.

Sunbury Formation (Lower Mississippian)

STRATIGRAPHY and/or OCCURRENCE: Upper formation of the Port Lambton Group; not known to crop out in Ontario.
LITHOLOGY: Black, organic-rich shale.
THICKNESS: 0 to 20 m.
USES: No present uses.

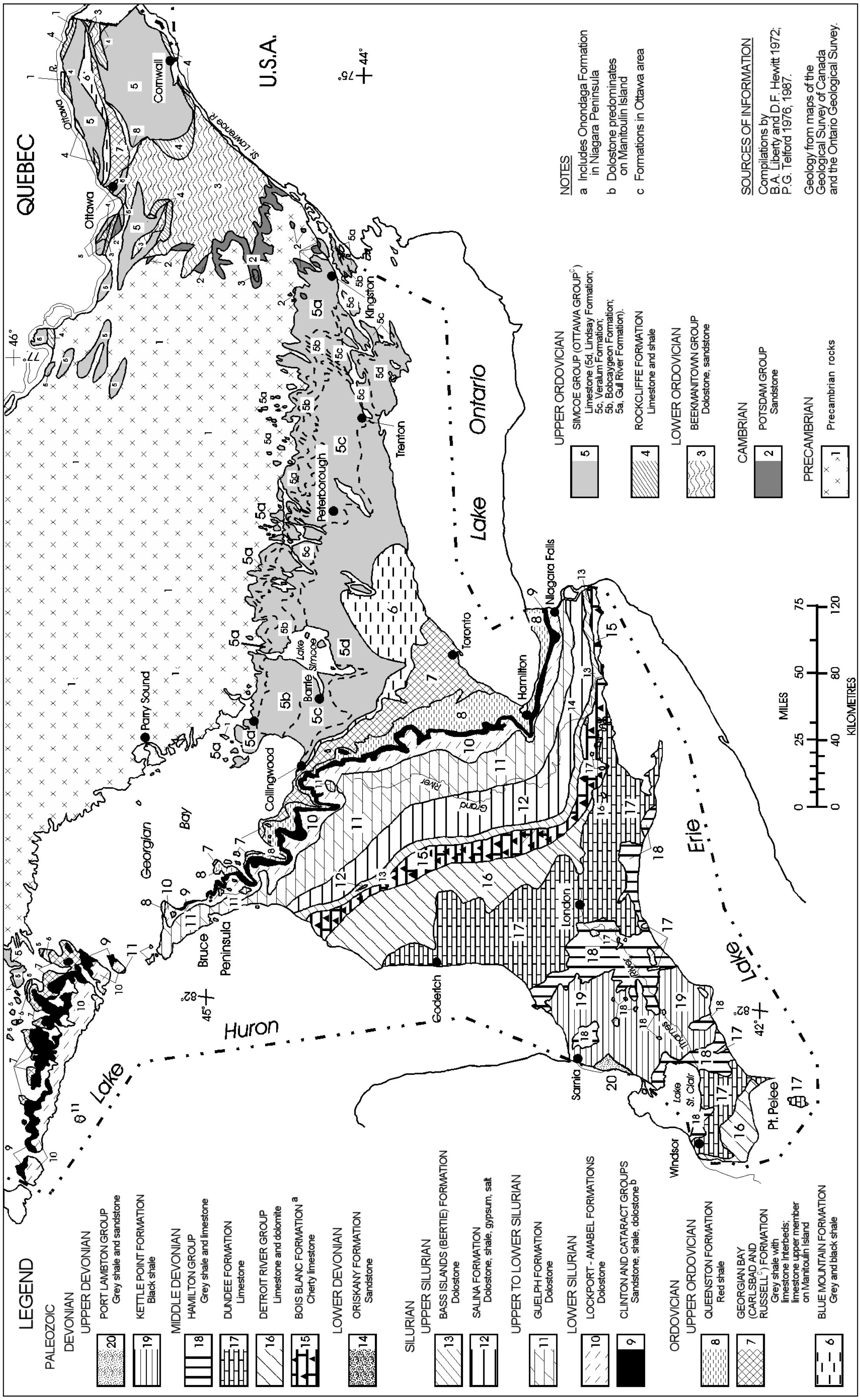

Figure D1. Bedrock geology of southern Ontario.

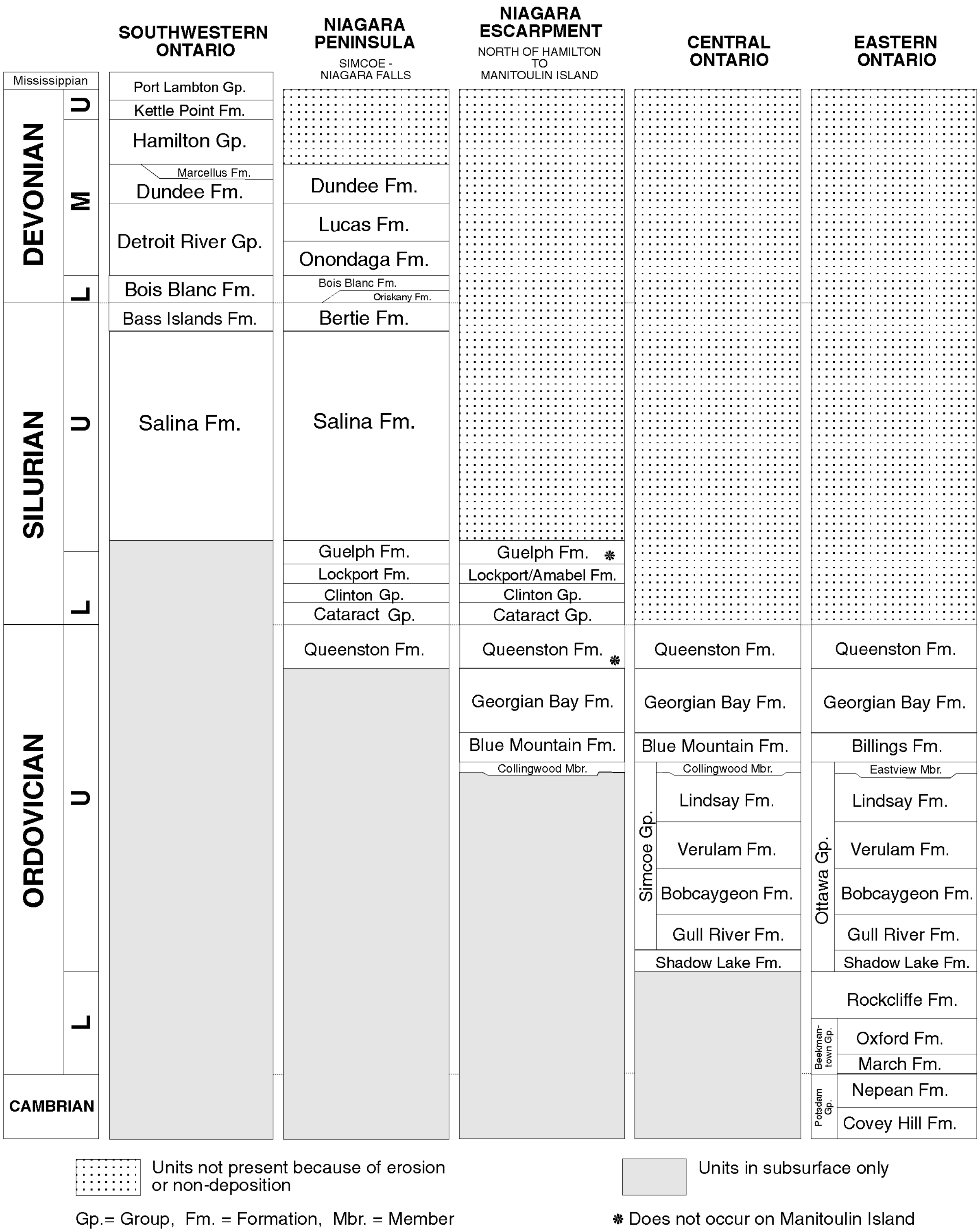

Figure D2. Exposed Paleozoic stratigraphic sequences in southern Ontario (*adapted from* Bezys and Johnson 1988 and Armstrong and Dodge 2007).

Appendix E – Aggregate Quality Test Specifications

Aggregate quality tests are performed by the Ministry of Transportation of Ontario (MTO) for the Ontario Geological Survey on sampled material. A brief description and the specification limits for each test are included in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the tests listed in this appendix can be used to determine the suitability of an aggregate. Greater detail on the tests and aggregate specifications can be obtained from the MTO.

Absorption Capacity (LS-604): This test is 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. This test is conducted in conjunction with the determination of the sample's relative density.

Accelerated Mortar Bar Expansion Test (LS-620): This is a rapid test for detecting alkali–silica reactive aggregates. It involves the crushing of the aggregate and the creation of standard mortar bars. For coarse and fine aggregates, suggested expansion limits of 0.10 to 0.15% are indicated for innocuous aggregates; greater than 0.10%, but less than 0.20%, indicates that it is unknown whether a potentially deleterious reaction will occur; and greater than 0.20% indicates that the aggregate is probably reactive and should not be used for Portland cement concrete. If the expansion limit exceeds 0.10% for coarse and fine aggregates, it is recommended that supplementary information be developed to confirm that the expansion is actually because of alkali reactivity. If confirmed deleteriously reactive, the material should not be used for Portland cement concrete unless corrective measures are undertaken such as the use of low- or reduced-alkali cement.

Aggregate Abrasion Value (AVV) (British Standard 812): The AAV is a measure of the resistance of aggregate to surface wear by abrasion using a standard silica sand. A low AVV (6 or less) implies good resistance to abrasion. An aggregate with good resistance to abrasion will usually give good macrotexture. This test is described in British Standard 812 (1975).

Bulk Relative Density (BRD) (ASTM C29): An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative-density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Los Angeles Abrasion and Impact Test (LS-603 or ASTM C131): This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing. This test has been replaced by the micro-Deval abrasion test for coarse aggregate (see below), but, because of the large number of Los Angeles abrasion analyses that exist in historical MTO records, this test can still provide an indication of the aggregate quality.

Magnesium Sulphate Soundness Test (LS-606): This test is designed to simulate the action of freezing and thawing on aggregate. Those aggregates which are susceptible will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Micro-Deval Abrasion Test (LS-618 and LS-619): The micro-Deval abrasion test for fine aggregate is an accurate measure of the amount of hard, durable materials in sand-sized particles. This abrasion test is quick, cheap and more precise than the fine aggregate magnesium sulphate soundness test that suffers from a wide multi-laboratory variation. The magnesium sulphate soundness test is still considered an alternative test as indicated in many of the accompanying tables in this appendix. The micro-Deval abrasion test for coarse aggregate has replaced the Los Angeles abrasion and impact test.

Petrographic Examination (LS-609): Individual aggregate particles in a sample are divided into categories good, fair, poor and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Polished Stone Value (PSV) (British Standard 812): The PSV is a measure of the resistance of aggregate to the polishing action of a pneumatic tire under conditions similar to those occurring on the road surface. The actual relationship between skidding resistance and PSV varies depending on the type of road surface, age, amount of traffic and other factors. Nevertheless, an aggregate with a high PSV will generally provide higher skid resistance than one with a low PSV. This test is described in British Standard 812 (1975). Values less than 45 indicate marginal frictional properties, whereas values greater than 55 indicate excellent frictional properties (average value no less than 50).

Unconfined Freeze–Thaw Test (LS-614): This test is designed to identify aggregate material that may be susceptible to excessive damage caused by freeze–thaw cycles. Aggregates that give losses greater than about 6% have a high probability of causing "popouts" on concrete and asphalt surfaces.

MATERIAL SPECIFICATIONS FOR AGGREGATES: BASE AND SUBBASE PRODUCTS

Table E1. Physical property requirements for aggregates: base, subbase, select subgrade and backfill material.

MTO Test Number	Laboratory Test	Granular O	Granular A	Granular B (Type I and Type III)	Granular B (Type II)	Granular M	Select Subgrade Material
LS-614	Unconfined Freeze–Thaw Loss (% maximum)	15	—	—	—	—	—
LS-616 LS-709	Fine Aggregate Petrographic Requirement	*[Note 1]*					
LS-618	Micro-Deval Abrasion Loss, Coarse Aggregate (% maximum loss)	21	25	30 *[Note 2]*	30	25	30 *[Note 2]*
LS-619	Micro-Deval Abrasion Loss, Fine Aggregate (% maximum loss)	25	30	35	35	30	—
LS-630	Amount of Contamination	*[Note 3]*					
LS-631	Plastic Fines	None Permitted					
LS-704	Plasticity Index (maximum)	0	0	0	0	0	0

Note 1. For materials north of the French River and Mattawa River only: for materials with >5.0% passing the 75 µm sieve, the amount of mica retained on the 75 µm sieve (passing the 150 µm sieve) shall not exceed 10% of the material in that sieve fraction unless testing (LS-709) determines permeability values >1.0×10^{-4} cm/s and/or field experience show satisfactory performance (prior data demonstrating compliance with this requirement will be acceptable provided such testing has been done within the past 5 years and field performance has been satisfactory).

Note 2. The coarse aggregate micro-Deval abrasion loss test requirement will be waived if the material has more than 80% passing the 4.75 mm sieve.

Note 3. Granular A, B Type I, B Type III, or M may contain up to 15% by mass crushed glass and/or ceramic material. Granular A, O, B Type I, B Type III and M shall not contain more than 1.0% by mass of wood, clay brick, and/or gypsum, and/or gypsum wall board or plaster. Granular B Type II and SSM shall not contain more than 0.1% by mass of wood.

Greater detail, additional specifications and other aggregate product information can be obtained from the Ministry of Transportation. Details above are derived from MTO SP-110513 (August 2007).

MATERIAL SPECIFICATIONS FOR AGGREGATES: HOT MIX ASPHALT PRODUCTS

Table E2. Physical property requirements for coarse aggregate (surface course): SMA, Superpave™ 9.5, 12.5, 12.5 FC1 and 12.5 FC2.

MTO Test Number	Laboratory Test	Superpave 9.5, 12.5	Aggregate Type				
			Gravel	Quarried Rock (SMA, Superpave 12.5 FC1 and 12.5 FC2)			
			(Superpave 12.5 FC1 only)	Dolomitic Sandstone	Traprock, Diabase, Andesite	Meta-arkose, Metagabbro, Gneiss	
LS-601	Wash Pass, 75 µm sieve (% maximum loss)	1.3 *[Note 4]*	1.0 *[Note 5]*	1.0 *[Note 5]*	1.0 *[Note 5]*	1.0 *[Note 5]*	
LS-604	Absorption (% maximum)	2.0	1.0	1.0	1.0	1.0	
LS-608	Flat and Elongated Particles (% maximum (4:1))	20	15	15	15	15	
LS-609	Petrographic Number (HL) (maximum)	*[Note 6]*	120	145	120	145	
LS-613	Insoluble Residue Retained, 75 µm sieve (% minimum)	—	—	45	—	—	
LS-614	Unconfined Freeze–Thaw Loss (% maximum loss)	6 *[Note 7]*	6	7	6	6	
LS-618	Micro-Deval Abrasion Loss (% maximum loss)	17	10	15	10	15	
Alternative Requirement for LS-614							
LS-606	Magnesium Sulphate Soundness Loss (% maximum loss)	12	—	—	—	—	

Note 4. When control charts (n >20) are used for LS-601, the average value shall not exceed the specification maximum (1.3%), with no single value greater than 1.7%. When quarried rock is used as a source of coarse aggregate, a maximum of 2.0% passing the 75 µm sieve shall be permitted. When control charts (n >20) are used from LS-601 for quarried rock, the average value shall not exceed the specification maximum (2.0%) with no single value greater than 2.4%.

Note 5. When control charts (n >20) are used for LS-601, the average value shall not exceed the specification maximum (1.0%), with no single value greater than 1.4%.

Note 6. For the locations listed below, Petrographic Number (HL) is replaced by the following Petrographic Examination requirements. When the coarse aggregate for use in a surface course mix is obtained from a gravel pit or quarry containing more than 40% carbonate rock type, e.g., limestone and dolostone, then blending with aggregate of non-carbonate rock type shall be required such as to increase the non-carbonate rock type content of the coarse aggregate to 60% minimum, as determined by LS-609. The method of blending shall be uniform and shall be subject to approval by the owner. In cases of dispute, LS-613 shall be used with a minimum of acid insoluble residue of 60%. When the aggregate for a surface course mix is obtained from a non-carbonate gravel or quarry source, blending with carbonate rock types shall not be permitted. This requirement is applicable to coarse aggregates used in surface course mixes in the area to the north and west of a boundary defined as follows: the north shore of Lake Superior, the north shore of the St. Mary's River, the south shore of St. Joseph Island, the north shore of Lake Huron easterly to the north and east shore of Georgian Bay (excluding Manitoulin Island), along the Severn River to Washago and a line easterly passing through Norland, Burnt River, Burleigh Falls, Madoc, and hence easterly along Highway 7 to Perth and northerly to Calabogie and easterly to Arnprior and the Ottawa River.

Note 7. For Superpave 12.5 only, the requirements will be waived by the owner when the aggregate meets the alternative requirements for LS-606.

Table E3. Physical property requirements for coarse aggregate (binder course): Superpave™ 9.5, 12.5, 19.0, 25.0 and 37.5.

MTO Test Number	Laboratory Test	Superpave 9.5, 12.5, 19.0, 25.0 and 37.5
LS-601	Wash Pass, 75 µm sieve (% maximum loss)	1.3 *[Note 8]*
LS-604	Absorption (% maximum)	2.0
LS-608	Flat and Elongated Particles (% maximum (4:1))	*
LS-614	Unconfined Freeze–Thaw Loss (% maximum loss) *[Note 9]*	15
LS-618	Micro-Deval Abrasion Loss (% maximum loss)	21
Alternative Requirement for LS-614		
LS-606	Magnesium Sulphate Soundness Loss (% maximum loss)	15

Note 8. When control charts (n >20) are used for LS-601, the average value shall not exceed the specification maximum (1.3%), with no single value greater than 1.7%. When quarried rock is used as a source of coarse aggregate, a maximum of 2.0% passing the 75 µm sieve shall be permitted. When control charts (n>20) are used for LS-601 for quarried rock, the average value shall not exceed the specification maximum (2.0%), with no single value greater than 2.4%.

Note 9. This requirement will be waived by the owner when the aggregate meets the requirements for LS-606.

* Designer fill-in, contact the MTO.

Table E4. Physical property requirements for fine aggregate: SMA, Superpave™ 9.5, 12.5, 12.5 FC1, 12.5 FC2, 19.0, 25.0 and 37.5.

MTO Test Number	Laboratory Test	SMA, Superpave 12.5 FC2	Superpave 12.5 FC1	Superpave 9.5, 12.5, 19.0, 25.0 and 37.5
LS-619	Micro-Deval Abrasion Loss (% maximum loss) *[Note 10]*	15	20	25
LS-704	Plasticity Index (maximum)	0	0	0

Note 10. Where the blending method has been selected for QC, the micro-Deval abrasion loss of each individual fine aggregate in the stockpile, prior to blending, shall not exceed 35%.

Greater detail, additional specifications and other aggregate product information can be obtained from the Ministry of Transportation. The above specifications are from MTO SP-110F12 (2007).

MATERIAL SPECIFICATIONS FOR AGGREGATES: CONCRETE PRODUCTS

Table E5. Physical property requirements for coarse aggregate.

MTO or CSA Test Number	Laboratory Test	Acceptance Requirements	
		Pavement	**Structures, Sidewalk, Curb and Gutter, and Concrete Base**
LS-601	Material finer than 75 μm sieve, by washing (% maximum loss) *[Note 11]* • for gravel • for crushed rock	 1.0 2.0	 1.0 2.0
LS-604 or CSA A23.2-12A	Absorption (% maximum)	2.0	2.0
LS-608	Flat and Elongated Particles (% maximum (4:1))	20	20
LS-609	Petrographic Number (Concrete) (maximum)	125	140
LS-614 or CSA A23.2-24A	Unconfined Freeze–Thaw Loss (% maximum loss) *[Note 12]*	6	6
LS-618 or CSA A23.2-29A	Micro-Deval Abrasion Loss (% maximum loss)	14	17
LS-620 or CSA A23.2-25A	Accelerated Mortar Bar Expansion (% maximum at 14 days) *[Notes 13, 14]*	0.150 *[Note 15]*	0.150 *[Note 15]*
CSA A23.2-14A	Concrete Prism Expansion (% maximum at 1 year) *[Notes 13, 16]*	0.040	0.040
CSA A23.2-26A	Potential Alkali–Carbonate Reactivity of Quarried Carbonate Rock *[Note 17]*	Chemical composition must plot in the nonexpansive field of a specific figure used with test	
Alternative Requirement for LS-614			
LS-606	Magnesium Sulphate Soundness Loss, 5 cycles (% maximum loss) *[Note 12]*	12	12

General Notes:
- Where a concrete surface is subject to vehicular traffic, the physical requirements for "Pavement" will apply to the aggregate used.
- For air-cooled blast-furnace slag aggregate, the allowable maximum value for micro-Deval shall be 21% for structures and pavements and the allowable maximum value for absorption will conform to the owner's requirements for slag aggregate.
- A coarse aggregate may be accepted or rejected by the owner based on the results of freeze–thaw testing of concrete or field performance.

Note 11. When control charts (n >20) are used for LS-601, the average value shall not exceed the specification maximum (1.3%), with no single value greater than 1.7%. When quarried rock is used as a source of coarse aggregate, a maximum of 2.0% passing the 75 μm sieve shall be permitted. When control charts (n >20) are used for LS-601 for quarried rock, the average value shall not exceed the specification maximum (2.0%), with no single value greater than 2.4%.

Note 12. The owner will waive the requirements for freeze–thaw loss when the aggregate meets the alternative magnesium sulphate soundness requirements, LS-606.

Note 13. The need to demonstrate compliance with this requirement will be waived by the Contract Administrator if the source is on the current Ministry of Transportation regional Aggregate Source List (ASL) for Structural Concrete Fine and Coarse Aggregates or the Aggregate Source List of Concrete Base/Pavement Coarse Aggregates. If the aggregate is potentially expansive due to alkali–carbonate reaction as determined by CSA A23.2-26A, the aggregate shall meet the requirements of CSA A23.2-14A, even though it may be shown as a coarse aggregate on the ASL for Structural Concrete Fine and Coarse Aggregates or the ASL for Concrete Base/Pavement Coarse Aggregates.

Note 14. An aggregate that fails to meet these requirements will be accepted by the Contract Administrator provided the requirements of CSA A23.2-14A are met.

Note 15. If the aggregate is a quarried sandstone, siltstone, granite or gneiss, the expansion shall be less than 0.080% after 14 days. For quarried aggregates of the Gull River, Bobcaygeon, Verulam and Lindsay formations, the expansion shall be less than 0.100% after 14 days.

Note 16. An aggregate needs to meet this requirement only if it fails the requirements of either CSA A23.2-25A or CSA A23.2-26A. The test data shall have been obtained within the past 18 months from aggregate from the same location within the source as that to be used in the work. If this test is conducted to show that an average deemed potentially expansive by CSA A23.2-26A does not exceed 0.040% after one year, then chemical analysis, CSA A23.2-26A, shall be provided to show that the aggregate intended for use has the same chemical composition as the material tested in CSA A23.2-14A.

Note 17. This requirement only applies to aggregate quarried from the Gull River and Bobcaygeon formations of southern and eastern Ontario. These dolomitic limestones crop out on the southern margin of the Canadian Shield from Midland to Kingston and in the Ottawa–St. Lawrence Lowlands near Cornwall.

Table E6. Physical property requirements for fine aggregate.

MTO or CSA Test Number	Laboratory Test	Acceptance Limits
LS-610	Organic Impurities, (organic plate number) *[Note 18]*	3
LS-619 or CSA A23.2-23A	Micro-Deval Abrasion Loss (% maximum loss)	20
LS-620 or CSA A23.2-25A	Accelerated Mortar Bar Expansion (% maximum at 14 days) *[Notes 19, 20]*	0.150
CSA A23.2-14A	Concrete Prism Expansion (% maximum at 1 year) *[Notes 19, 21]*	0.040

Note 18. A fine aggregate producing a colour darker than standard colour No. 3 shall be considered to have failed this requirement. A failed fine aggregate may be used if comparative mortar specimens prepared according to ASTM C87 meet the following requirements:

- Mortar specimens prepared using unwashed fine aggregate shall have a 7 day compressive strength that is a minimum of 95% of the strength of mortar specimens prepared using the same fine aggregate washed in a 3% sodium hydroxide solution. Type GU hydraulic cement shall be used.
- Setting time of the unwashed fine aggregate mortar specimens shall not differ from washed fine aggregate mortar specimens by more than 10%.

Note 19. The need for data to demonstrate compliance with this requirement shall be waived by the Contract Administrator if the aggregate source is on the current Ministry of Transportation's regional Aggregate Source List for Structural Concrete Fine and Coarse Aggregates.

Note 20. An aggregate that fails this requirement may be accepted provided the requirements of CSA A23.2-14A are met.

Note 21. An aggregate need only meet this requirement if it fails the requirements of CSA A23.2-25A. Test data shall have been obtained with the past 18 months from aggregate that is from the same source, processed in the same manner, as the material intended for use.

Greater detail, additional specifications and other aggregate product information can be obtained from the Ministry of Transportation. The above specifications are from MTO SP-110F11 (2007).

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton(short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 9**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy) / ton (short)	1 ounce (troy) / ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights / ton (short)	1 pennyweight / ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors in ***bold*** *type are exact. The conversion factors have been taken from or have been derived from factors given in the* Metric Practice Guide for the Canadian Mining and Metallurgical Industries, *published by the Mining Association of Canada in co-operation with the Coal Association of Canada.*

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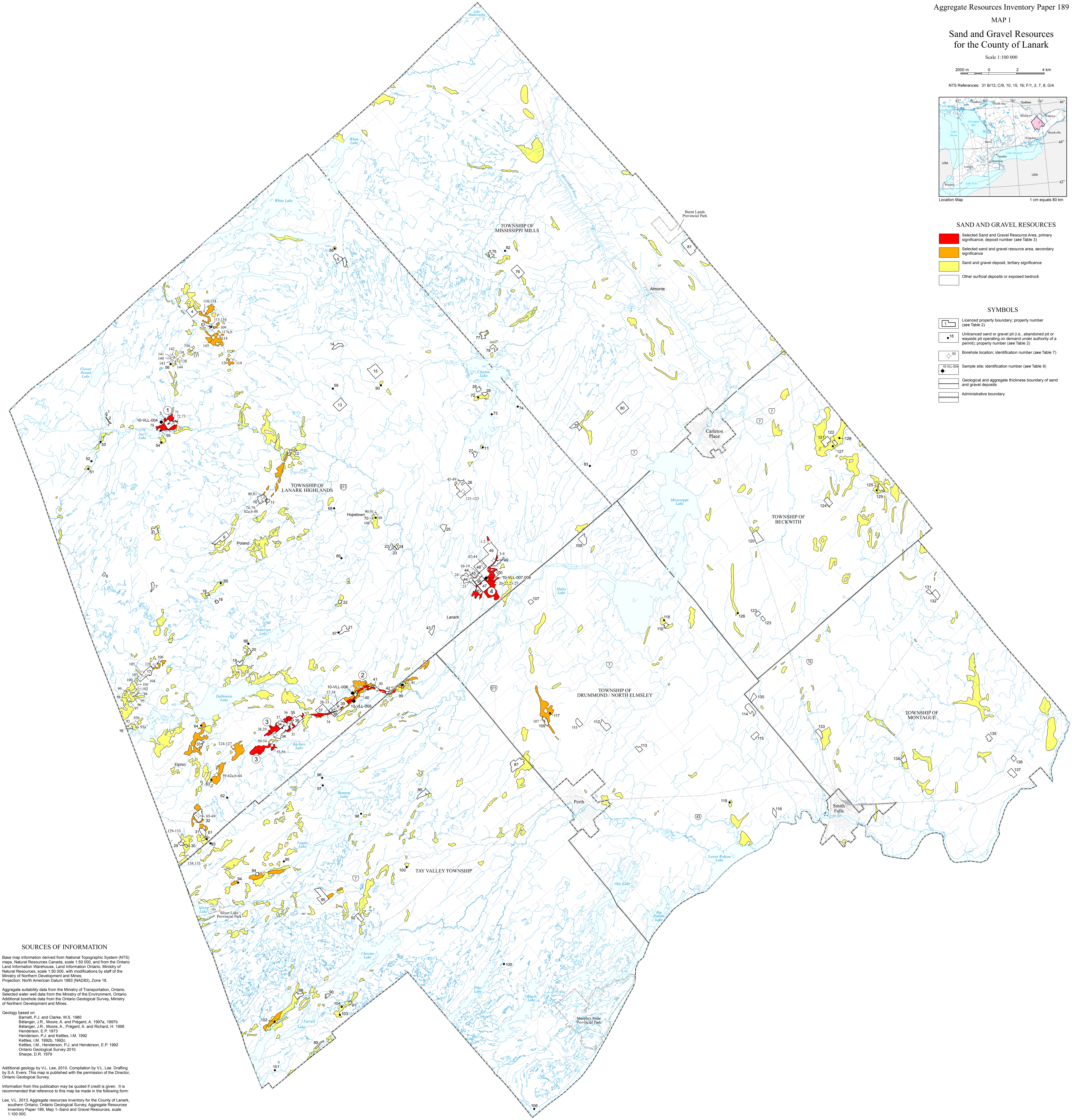

Aggregate Resources Inventory Paper 189

MAP 1

Sand and Gravel Resources for the County of Lanark

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 31 B/13; C/9, 10, 15, 16; F/1, 2, 7, 8; G/4

Location Map 1 cm equals 80 km

SAND AND GRAVEL RESOURCES

- Selected Sand and Gravel Resource Area, primary significance; deposit number (*see* Table 3)
- Selected sand and gravel resource area, secondary significance
- Sand and gravel deposit, tertiary significance
- Other surficial deposits or exposed bedrock

SYMBOLS

- Licenced property boundary; property number (*see* Table 2)
- Unlicenced sand or gravel pit (i.e., abandoned pit or wayside pit operating on demand under authority of a permit); property number (*see* Table 2)
- Borehole location; identification number (*see* Table 7)
- Sample site; identification number (*see* Table 9)
- Geological and aggregate thickness boundary of sand and gravel deposits
- Administrative boundary

SOURCES OF INFORMATION

Base map information derived from National Topographic System (NTS) maps, Natural Resources Canada, scale 1:50 000, and from the Ontario Land Information Warehouse, Land Information Ontario, Ministry of Natural Resources, scale 1:50 000, with modifications by staff of the Ministry of Northern Development and Mines.
Projection: North American Datum 1983 (NAD83), Zone 18.

Aggregate suitability data from the Ministry of Transportation, Ontario. Selected water well data from the Ministry of the Environment, Ontario. Additional borehole data from the Ontario Geological Survey, Ministry of Northern Development and Mines.

Geology based on

- Barnett, P.J. and Clarke, W.S. 1980
- Bélanger, J.R., Moore, A. and Prégent, A. 1997a, 1997b
- Bélanger, J.R., Moore, A., Prégent, A. and Richard, H. 1995
- Henderson, E.P. 1973
- Henderson, P.J. and Kettles, I.M. 1992
- Kettles, I.M. 1992b, 1992c
- Kettles, I.M., Henderson, P.J. and Henderson, E.P. 1992
- Ontario Geological Survey 2010
- Sharpe, D.R. 1979

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Information from this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form:

Lee, V.L. 2013. Aggregate resources inventory for the County of Lanark, southern Ontario; Ontario Geological Survey, Aggregate Resources Inventory Paper 189, Map 1–Sand and Gravel Resources, scale 1:100 000.

Aggregate Resources Inventory Paper 189

MAP 2

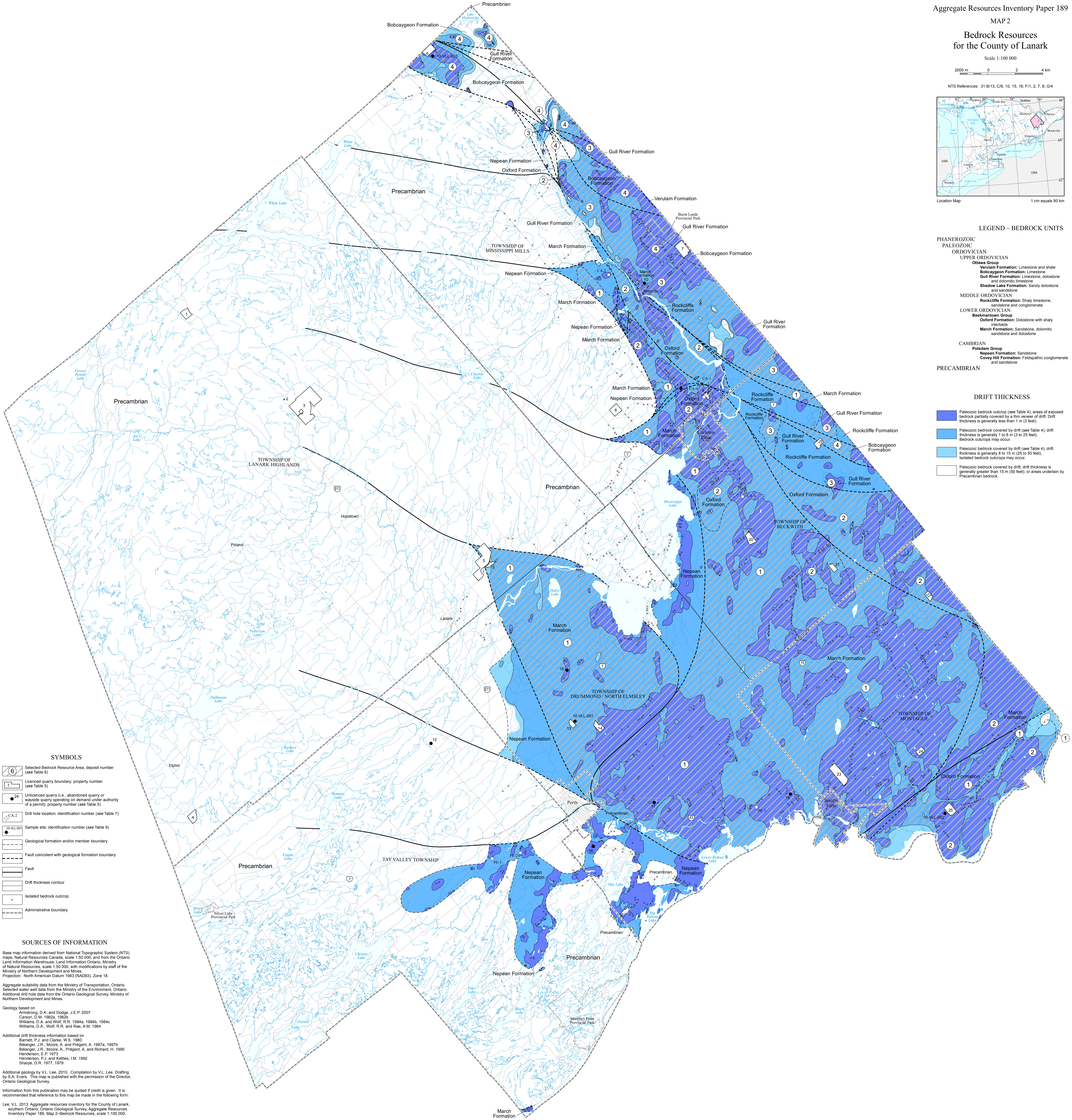
Bedrock Resources for the County of Lanark

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 31 B/13; C/9, 10, 15, 16; F/1, 2, 7, 8; G/4

Location Map — 1 cm equals 80 km



LEGEND – BEDROCK UNITS

PHANEROZOIC
PALEOZOIC
ORDOVICIAN
UPPER ORDOVICIAN
Ottawa Group
Verulam Formation: Limestone and shale
Bobcaygeon Formation: Limestone
Gull River Formation: Limestone, dolostone and dolomitic limestone
Shadow Lake Formation: Sandy dolostone and sandstone
MIDDLE ORDOVICIAN
Rockcliffe Formation: Shaly limestone, sandstone and conglomerate
LOWER ORDOVICIAN
Beekmantown Group
Oxford Formation: Dolostone with shaly interbeds
March Formation: Sandstone, dolomitic sandstone and dolostone

CAMBRIAN
Potsdam Group
Nepean Formation: Sandstone
Covey Hill Formation: Feldspathic conglomerate and sandstone

PRECAMBRIAN

DRIFT THICKNESS

Paleozoic bedrock outcrop (*see* Table 4); areas of exposed bedrock partially covered by a thin veneer of drift. Drift thickness is generally less than 1 m (3 feet).

Paleozoic bedrock covered by drift (*see* Table 4); drift thickness is generally 1 to 8 m (3 to 25 feet). Bedrock outcrops may occur.

Paleozoic bedrock covered by drift (*see* Table 4); drift thickness is generally 8 to 15 m (25 to 50 feet). Isolated bedrock outcrops may occur.

Paleozoic bedrock covered by drift; drift thickness is generally greater than 15 m (50 feet); or areas underlain by Precambrian bedrock.

SYMBOLS

Selected Bedrock Resource Area; deposit number (*see* Table 6)

Licenced quarry boundary; property number (*see* Table 5)

Unlicenced quarry (i.e., abandoned quarry or wayside quarry operating on demand under authority of a permit); property number (*see* Table 5)

Drill hole location; identification number (*see* Table 7)

Sample site; identification number (*see* Table 9)

Geological formation and/or member boundary

Fault coincident with geological formation boundary

Fault

Drift thickness contour

Isolated bedrock outcrop

Administrative boundary

SOURCES OF INFORMATION

Base map information derived from National Topographic System (NTS) maps, Natural Resources Canada, scale 1:50 000, and from the Ontario Land Information Warehouse, Land Information Ontario, Ministry of Natural Resources, scale 1:50 000, with modifications by staff of the Ministry of Northern Development and Mines.
Projection: North American Datum 1983 (NAD83), Zone 18.

Aggregate suitability data from the Ministry of Transportation, Ontario. Selected water well data from the Ministry of the Environment, Ontario. Additional drill hole data from the Ontario Geological Survey, Ministry of Northern Development and Mines.

Geology based on
Armstrong, D.K. and Dodge, J.E.P. 2007
Carson, D.M. 1982a, 1982b
Williams, D.A. and Wolf, R.R. 1984a, 1984b, 1984c
Williams, D.A., Wolf, R.R. and Rae, A.M. 1984

Additional drift thickness information based on
Barnett, P.J. and Clarke, W.S. 1980
Bélanger, J.R., Moore, A. and Prégent, A. 1997a, 1997b
Bélanger, J.R., Moore, A., Prégent, A. and Richard, H. 1995
Henderson, E.P. 1973
Henderson, P.J. and Kettles, I.M. 1992
Sharpe, D.R. 1977, 1979

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