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Ontario

Aggregate Resources Inventory of the

County of Simcoe

Southern Ontario

Ontario Geological Survey
Aggregate Resources Inventory
Paper 188

2013

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By D.J. Rowell

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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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Abstract

This report includes an inventory and evaluation of the sand and gravel, and bedrock resources for the County of Simcoe. Eleven (11) sand and gravel resource areas have been selected at the primary resource level in the County of Simcoe. These selected resource areas have a total unlicenced area of 3325 ha with a possible resource area of 2404 ha after considering physical, cultural and environmental constraints. These resource areas have approximately 283.7 million tonnes of aggregate material. The majority of these primary deposits are located in the northern portion of the County of Simcoe. Most of these deposits have been a source of aggregate extraction for a long time and many are beginning to become depleted of granular material.

The county also has considerable quantities of sand and gravel resources of secondary significance. Glaciofluvial outwash, ice-contact and glaciolacustrine beach deposits spread throughout the county add greatly to the overall aggregate resource supply. Many of the secondary deposits are nearing depletion (particularly in the southern part of the county) and may only be suitable for time-restricted, contract-specific wayside operations providing limited quantities of granular material.

The County of Simcoe has large areas of possible bedrock-derived aggregate resources. The total unlicenced area is 35 223 ha with a possible resource area of 27 503 ha after cultural, physical and environmental constraints have been considered. This represents a bedrock resource of about 10 928 million tonnes.

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

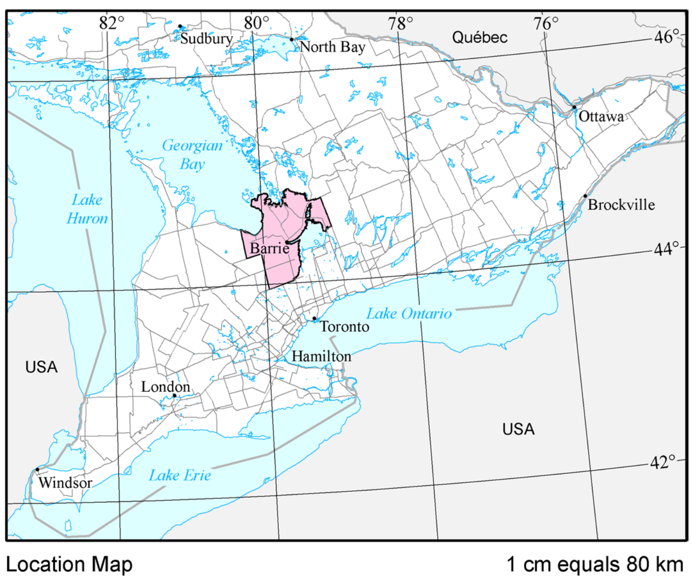

Figure 1. Map of southern Ontario showing the location of the County of Simcoe.

Aggregate Resources Inventory of the County of Simcoe

By D.J. Rowell[1]

Field work, map production and report by D.J. Rowell.

Manuscript accepted for publication in 2011 by R.I. Kelly, Senior Manager (Acting), Sedimentary Geoscience Section, Ontario Geological Survey. This report is published with the permission of the Director, Ontario Geological Survey.

[1] Earth Resources and Geoscience Mapping Section, Ontario Geological Survey

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 2011).

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 MNR, 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 1A and 1B, "Sand and Gravel Resources", provide an inventory and evaluation of the sand and gravel resources in the report area. Map 2A and 2B, "Bedrock Resources", show the distribution of bedrock formations and the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

The hard-copy versions of Maps 1A, 1B, 2A and 2B (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 Maps 1A and 1B) 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 tables for sand and gravel resources data are found in the folder "Sand_Gravel"; the data for bedrock resources data are in the folder "Bedrock". The tables are in database format (*.dbf* file) that can be opened using other software, for example Microsoft® Excel®. The cross-references include the folder, the table and the field name separated by a short vertical line; the field name is indicated by bold, small capital letters (e.g., Bedrock | Drift_Thick.dbf | **AABBCC**).

Maps 1A and 1B: Sand and Gravel Resources

Maps 1A and 1B show 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 Maps 1A and 1B. 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 Maps 1A and 1B and described in Table 2. Similarly, any test locations appear on Maps 1A and 1B 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 | Sand_Gravel.dbf | **SIGN**.

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

$$\text{Tonnage} = \text{Area} \times \text{Thickness} \times \text{Density Factor}$$

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.

Maps 2A and 2B: Bedrock Resources

Maps 2A and 2B are interpretative maps 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. Maps 2A and 2B are based on concepts similar to those outlined for Maps 1A and 1B.

Inventory information presented on Maps 2A and 2B 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 Maps 2A and 2B and described in Table 5. Drill hole locations or other descriptive stratigraphic sections appear as a point symbol on Maps 2A and 2B. Table 7 provides these descriptions. These descriptions are also recorded in Bedrock | Add_Info.dbf.

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 Maps 2A and 2B and are indicated in Table 4 (Column 1). The deposit's significance is also recorded in Bedrock | Drift_Thick.dbf | 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 Maps 2A and 2B by a line pattern and the calculated available tonnages are given in Table 6. The selected bedrock resource areas are also recorded in Bedrock | Drift_Thick.dbf | SELECT_AREA.

Selected Bedrock Resource Areas shown on Maps 2A and 2B 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 Bedrock | Drift_Thick.dbf | AREA; the favourable bedrock formations are reported in Bedrock | Drift_Thick.dbf | 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 Bedrock | Drift_Thick.dbf | **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 Simcoe

LOCATION AND POPULATION

The County of Simcoe (herein referred to as "Simcoe County") occupies 484 056 ha along the southern shore of Georgian Bay (*see* Figure 1). It is bounded to the east by the City of Kawartha Lakes (formerly Victoria County) and the District Municipality of Muskoka; to the west by the County of Grey and the County of Dufferin; and to the south by the Regional Municipalities of Peel, York and Durham. The study area is covered by all or parts of the following 1:50 000 scale map sheets of the National Topographic System (NTS): Bolton (30 M/13), Alliston (31 D/4), Barrie (31 D/5), Beaverton (31 D/6), Orillia (31 D/11), Elmvale (31 D/12), Penetanguishene (31 D/13), Gravenhurst (31 D/14), Dundalk (41 A/1), Collingwood (41 A/8), Nottawasaga (41 A/9) and Christian Island (41 A/16).

Simcoe County consists of 9 townships, 7 towns and the cities of Barrie and Orillia (Table A). The population of the county was 422 204 in 2006 (Statistics Canada 2006), which represents a 12% increase from 2001 (Statistics Canada 2006). A large proportion of this growth is occurring within, and around, the City of Barrie.

Table A – Area and Population, County of Simcoe

Municipality (Listed Alphabetically)	Land Area (Hectares)	2001 Population	2006 Population
Township of Adjala–Tosorontio	37 233	10 082	10 695
City of Barrie	7699	103 710	128 430
Town of Bradford West Gwillimbury	20 103	22 228	24 039
Township of Clearview	55 732	13 796	14 088
Town of Collingwood	3346	16 039	17 290
Township of Essa	27 957	16 808	16 901
Town of Innisfil	28 418	28 666	31 175
Town of Midland	2909	16 214	16 300
Town of New Tecumseth	27 418	26 141	27 701
City of Orillia	2861	29 121	30 259
Township of Oro–Medonte	58 665	18 315	20 031
Town of Penetanguishene	2538	8316	9354
Township of Ramara	41 725	8615	9427
Township of Severn	53 478	11 135	12 030
Township of Springwater	53 630	16 104	17 456
Township of Tay	13 893	9162	9748
Township of Tiny	34 319	9035	10 784
Town of Wasaga Beach	5843	12 419	15 029
First Nations Communities	6289	1144	1467
TOTAL	**484 056**	**377 050**	**422 204**

Provincial Highways 400, 11, 12, 24, 26, 27, 89, 90 and 169, as well as a number of well-maintained county and township roads, provide an extensive transportation network throughout the county. Rail service is provided by both the Canadian National (CN) and Canadian Pacific (CP) railways, which have corridors in the southern and eastern part of the study area.

The county has a strong economic base including manufacturing (e.g., Honda Canada Inc. in Alliston) and agriculture. It has a large commuter population with many residents travelling to work in the Greater Toronto Area (GTA). It is a popular resort and tourist destination for year-round activities, including cottages around many of its water bodies, golfing, skiing in numerous ski resort areas, snowmobiling and casino operations near Orillia. It is an attractive retirement destination for residents who want to remain close to the GTA, but want a country lifestyle. The county is host to Canadian Forces Base Borden in the Angus–Lisle area. Finally, it has an important service sector which supports all of these economic activities.

SURFICIAL GEOLOGY AND PHYSIOGRAPHY

The physiography and distribution of surficial material in Simcoe County, including the sand and gravel deposits illustrated on Maps 1A and 1B, are primarily the result of glacial activity that took place in the Late Wisconsinan (Barnett 1992). This period, which lasted from approximately 23 000 to 10 000 years before present (BP), was marked by the repeated advance and retreat of the massive Laurentide Ice Sheet (Barnett 1992). The direction of ice movement in the study area is recorded by erosional ice-flow indicators (striae, grooves, chattermarks) and depositional forms (crag-and-tail features, fluted ground moraine, drumlins), and is generally in a south to southwesterly direction (Barnett 1992). In the Lake Simcoe area, drumlin orientation generally ranges from 200 to 240° (Chapman and Putnam 1984). In the Gravenhurst to Penetanguishene area, Bajc (1994) reports a fairly consistent ice flow of 190° and, in the Barrie–Innisfil area, Barnett (1986) reports a general ice flow direction of 213°.

Simcoe County is covered by 10 physiographic regions as defined by Chapman and Putnam (1984). From the northeast to the southwest, these include the Georgian Bay fringe, "Number 11 strip" (a physiographic region so named as it closely follows Highway 11), Carden plain, Peterborough drumlin field, Simcoe uplands, Simcoe lowlands, Horseshoe moraines, Schomberg clay plain, Niagara Escarpment and the Oak Ridges moraine physiographic regions (Figure 2).

Georgian Bay Fringe

As the ice advanced from the north-northeast, debris from the underlying soil and bedrock accumulated within and beneath the ice. The debris—a mixture of stones, sand, silt and clay—was deposited over large areas of the county as till plains, drumlins and moraines. In the northern part of Simcoe County, the hard, erosion-resistant Precambrian rocks provided little soil and weathered bedrock to the advancing glacier. As a result, the northern part of the county (Severn and Ramara townships) belongs to the physiographic region known as the Georgian Bay fringe (*see* Figure 2), which is described by Chapman and Putnam (1984) as rugged and characterized by thinly till-covered rock knobs and ridges. Outcrops of bare rock are common and relief in the area is generally controlled by the Precambrian bedrock surface. These outcrops impart a rugged appearance to the landscape, although, collectively, the outcrop belt represents a plain with maximum relief of approximately 6 to 9 m (Deane and Pollitt 1950). The bedrock geology of this physiographic region is described later in this report.

Low-lying areas between outcrops are covered by a thin layer of glacial till composed of a loose, reddish, stony, sandy till derived primarily from Precambrian bedrock material (Deane 1950). The rock-knob lowland was subsequently inundated by glacial Lake Algonquin resulting in the deposition of thin glaciolacustrine sediments over the till. The till and glaciolacustrine sediments rarely exceed 2 to 3 m in thickness. Other low-lying areas are filled with organic-rich sediments. During lower stages of glacial Lake Algonquin, Precambrian outcrops were swept clear by wave action. (The general topography of this physiographic region is illustrated in Photo 01 (ArcGIS® version only).)

Number 11 Strip

The "Number 11 strip" physiographic region (so named as it closely follows Highway 11), as defined by Chapman and Putnam (1984), is located in the southeast corner of Severn Township and the northern part of Ramara Township (*see* Figure 2). This area is characterized by a relatively flat strip of land where a low-lying valley, between 2 bedrock-dominated upland areas (both part of the Georgian Bay fringe physiographic region), was filled with sediment during the glacial Lake Algonquin phase. The sediment was deposited in 3 environments: 1) as outwash deposits formed by meltwater streams flowing away from the retreating ice margin; 2) glaciolacustrine plain deposits; and 3) subaqueous fan deposits laid down when sediment-laden meltwaters discharged into a standing body of water from tunnels at, or near, the base of the retreating ice (Ontario Geological Survey 1983). As a result, sand and gravel resources are available within this physiographic region, but their distribution and quality may be quite irregular and variable. The deposits consist primarily of stratified sand that may exhibit wide variations in grain size distribution. Gravel material may occur in the lower portion of the central core of subaqueous fan deposits. Varying amounts of silt and clay (fine-grained sediments) are associated with these deposits. (Photo 02 (ArcGIS® version only) illustrates the material found in this physiographic region.)

Carden Plain

The Carden plain is located in the northeastern part of Simcoe County, primarily in Ramara and Severn townships (*see* Figure 2). Named for the former township of Carden, located in the City of Kawartha Lakes (formerly Victoria County) to the east, the limestone plain forms a narrow southeast-trending band that increases in width from approximately 13 km just east of Orillia to 32 km farther east. The landscape is generally flat with small escarpments rising 1 to 8 m. In general, the Paleozoic bedrock in this physiographic region is covered by a thin veneer of till and glaciolacustrine sediments. (Photo 03 (ArcGIS® version only) shows the Gull River Formation along one of these small escarpment within the Carden plain physiographic region.) Glacial drift thickness increases southward. Clint-and-gryke structures are readily observed along the surface of the bedrock plain.

Fine-grained glaciolacustrine plain sediments deposited during glacial Lake Algonquin are common in this physiographic region. The lack of crushable material and the presence of fine-grained silt and clay restrict the use of these glaciolacustrine deposits for the production of high-quality aggregate products. Some small glaciolacustrine beaches have been identified along the main shoreline of glacial Lake Algonquin. Generally, the sand and gravel from these shallow beach deposits can be utilized for small, local road-building and construction projects.

The till in these first 3 physiographic regions is generally a stony to sandy till, containing a large proportion of Precambrian material. Clasts are generally subrounded to subangular in shape and the Precambrian clast content generally decreases to the south. Table 10 shows 22 analyses of the till in the area from Deane (1950) and, based on these data, the till matrix has an average of 53.2% sand, 35.4% silt and 11.5% clay. The sand content of the till decreases to the south and southwest where the silt and clay content begins to increase (Finamore 1984).

Simcoe Uplands

The Simcoe uplands (*see* Figure 2) consists of broad, gently rolling, till-covered hills, plains and moraines that are separated by deep valleys. The physiographic region is generally above 237 m asl (glacial Lake Algonquin water level) and rises to over 328 m asl. Some valley cuts can be up to 60 m deep and provide significant topographic relief to the physiographic region. These broad, south to southwesterly trending U-shaped valleys are believed to be tunnel valleys, carved subglacially by the catastrophic release of ponded subglacial meltwater (Barnett 1986, 1989, 1990a; Bajc 1994).

The surface till in this physiographic region has generally been defined as the Newmarket Till, which is a calcareous, silt to sandy till. It is a nonplastic till that ranges from soft to very stiff. The matrix carbonate content averages from 30 to 40% with calcite predominant east of the Niagara Escarpment and dolomite predominating above the escarpment. Clast content varies from 10 to 45% (Barnett 1992). Pebble lithology is variable with 20% Precambrian clasts near Orr Lake and 5% Precambrian clasts west of the Niagara Escarpment (Burwasser 1974a). In the northeastern part of Simcoe County, the till has large Precambrian boulders (Deane 1950). Analyses of Newmarket Till from other reports, as well as 2 samples collected as part of this study, are provided in Table 10. Table 12 shows the geochemical results of a Newmarket Till matrix sample collected as part of this study.

Burwasser (1974a), Barnett (1986) and Bajc (1994) all report at least 3 till units in the upland areas of Simcoe County. Bajc (1994) describes the oldest buried unit as a coarser textured till with 48% sand, 38% silt, 13% clay; and a total carbonate content of 34% in the Midland–Penetanguishene area. The calcite to dolomite ratio is 2.0. It is described as a massive, dense, overconsolidated, probably subglacial lodgement till. Overlying this till are sand and gravel sediments that probably represent glaciofluvial deposits (ice-contact, subaqueous fan) and glaciolacustrine sediments. Overlying these units is a finer textured till with 30% sand, 50% silt and 19% clay. Carbonate content is 30% and the calcite to dolomite ratio is 2.4. The fine-grained nature and predominance of Paleozoic clasts suggest a northwesterly source from the Lake Huron area. In the Collingwood–Nottawasaga area, Burwasser (1974a) has found a similar till and has suggested a similar source out of the Lake Huron basin. Overlying this till are stone-poor, interbedded, glaciolacustrine sediments suggestive of a glacial lake basin deposition. Bajc (1994) has suggested that these tills and other sediments could be early or pre-Late Wisconsinan, possibly Middle Wisconsinan in age. The oldest till may be early Wisconsinan or Illinoian in age (Bajc 1994). It is generally agreed that the Simcoe upland hills are cored with older sediments covered by Newmarket Till. (Photo 04 (ArcGIS® version only) illustrates an example of the surface till found in the Simcoe uplands area.)

The surface till within these uplands can sometimes be overlain by, or interstratified with, ice-contact deposits. The till upland areas are often encircled by shoreline deposits of glacial Lake Algonquin, particularly where buried ice-contact material has been exposed to glaciolacustrine shoreline processes, and the ice-contact material has been re-worked by glacial lake wave action into depositional structures that are indicative of a beach environment. The Newmarket Till is generally not well suited for aggregate production because it contains excessive fines and abundant oversized clasts.

Niagara Escarpment

The Niagara Escarpment dominates the physiography of the western part of Simcoe County. This major bedrock feature trends in a south to southeasterly direction throughout the study area. Bedrock occurs at, or near, the surface in the vicinity of the brow of the Niagara Escarpment. Bedrock can also crop out along the face of the escarpment as occasional isolated outcrops and in incised river valleys (re-entrants). In the study area, the unsubdivided Amabel Formation dolostone forms the caprock of the Niagara Escarpment, with the softer Georgian Bay Formation defining the base of the escarpment (Hewitt 1971). More information on the bedrock of the Niagara Escarpment is provided in this report (*see* "Bedrock Geology and Resource Potential"). In Simcoe County, the Niagara Escarpment rises nearly 350 m above the level of Georgian Bay, reaching its highest elevation near the community of Singhampton.

Horseshoe Moraines

As the Laurentide Ice Sheet continued to advance from the north-northeast, it overrode the Niagara Escarpment and con-

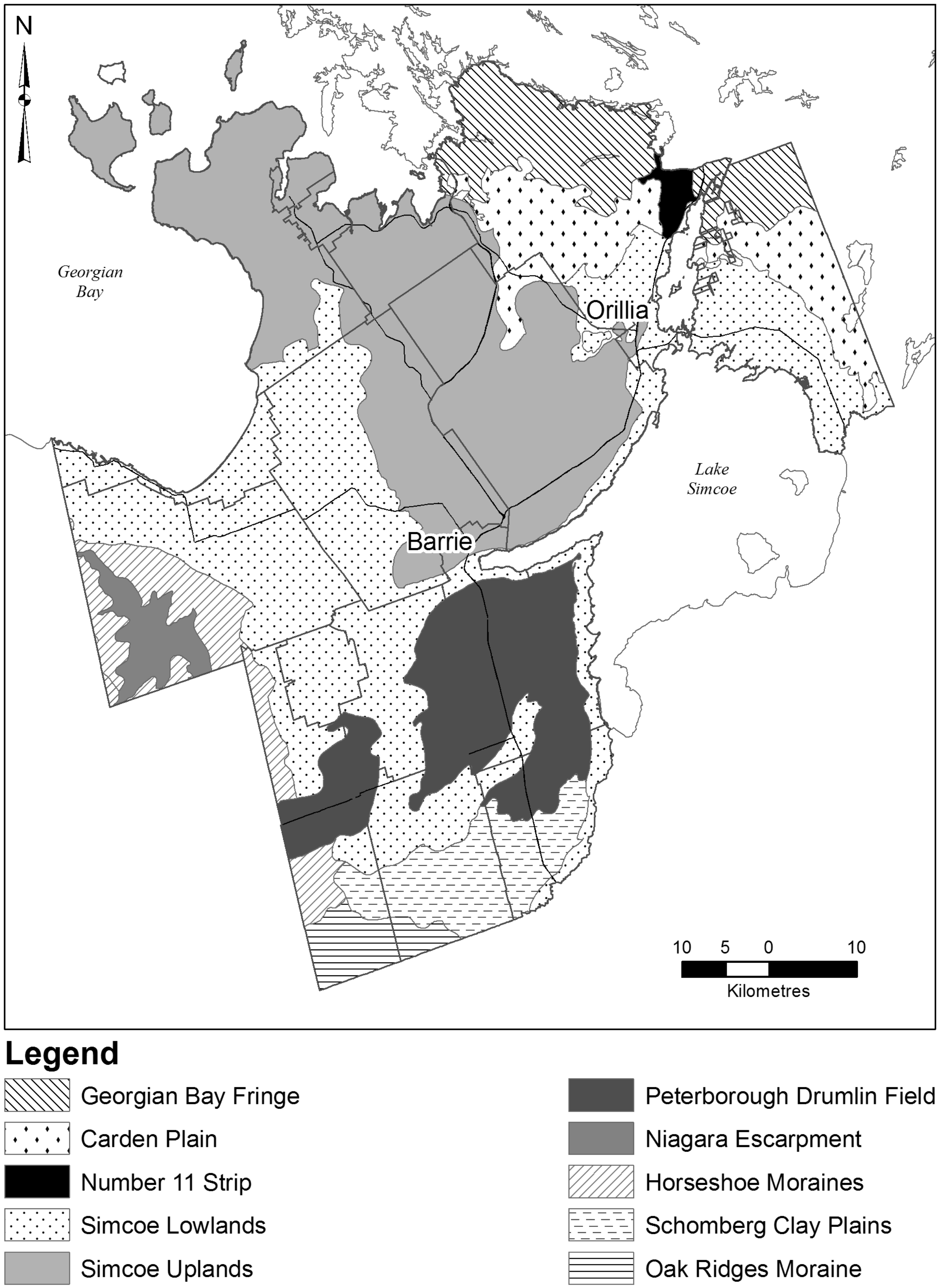

Figure 2. Physiographic regions of the County of Simcoe (*after* Chapman and Putnam 1984).

tinued to deposit glacial sediment on top of, and to the west of, the escarpment. Later, when the ice margin began to retreat from the area, it deposited a series of morainic ridges and other glacial and glaciofluvial deposits. Therefore, draping the eastern face of the Niagara Escarpment and located to the west of the escarpment in Simcoe County is the physiographic region known as the Horseshoe moraines, as defined by Chapman and Putnam (1984). The area is described as an area of glacial and glaciofluvial deposits with a highly irregular hummocky surface and deeply downcut river valleys (very irregular topography with relief often well in excess of 30 m). Bedrock outliers have been cut and isolated from the Niagara Escarpment, for example, Ten Hill located just north of Creemore.

Above the escarpment, this physiographic region includes the Banks, Gibraltar and Singhampton moraines. Burwasser (1974a), Gwyn (1972a) and Cowan et al. (1978) all indicate that the Singhampton moraine (the most easterly moraine in this physiographic region and located within the study area) is composed of Newmarket Till. The till is usually less than 3 m thick, but, in some locations, can reach 12 m in thickness. Below the escarpment, in the Creemore area and still part of this physiographic region, is the Corn Hill moraine that is also comprised of Newmarket Till (Burwasser 1974a). Glaciofluvial outwash and ice-contact deposits are associated and interspersed with the glacial sediments.

Peterborough Drumlin Field

As the ice continued to advance southward through Simcoe County, it continued to deposit till and formed the Peterborough drumlin field (Chapman and Putnam 1984). This physiographic region is located south of Kempenfelt Bay and extends westward into the Township of Adjala–Tosorontio along the western boundary of Simcoe County (*see* Figure 2). The drumlins are streamline, elongated hills oriented in a generally northeast-southwest direction. Pockets of sand and gravel are associated with drumlins and, if these pockets are located, they can be extracted for local aggregate production. Once again, the drumlins in Simcoe County are generally composed of dense, sandy silt to silty sand diamicton referred to as the Newmarket Till (Gwyn 1972a; Barnett 1986, 1990b).

The Peterborough drumlin field physiographic region is interspersed with the eastern uplands region in the Barrie, Innisfil, Bradford West Gwillimbury, eastern Essa and southern New Tecumseth areas. This area is characterized by broad, low- to moderate-relief plateaus ranging in elevation from 245 to 325 m asl. (Photo 05 (ArcGIS® version only) not only shows a licenced gravel pit operation, but illustrates the flat plateau-like area beyond.) The upland surface in Barrie, eastern Essa and western Innisfil is more subdued with local relief in the order of 5 to 10 m. Drumlins are uncommon in this area. Steep-walled valleys, 3 to 6 km wide and greater than 100 m deep, similar to the area north of the City of Barrie, trend south to southwesterly and cut through the upland surface at Kempenfelt Bay, Cookstown and at Cook's Bay on Lake Simcoe. These erosional valley surfaces are believed to have formed as a result of large subglacial, catastrophic meltwater discharge events similar, and probably related, to the Simcoe uplands noted earlier (Barnett 1989, 1990a). The bottom of these valleys are generally flat lying as they are infilled with younger glaciolacustrine sediments. The Kempenfelt and Cookstown valleys extend westward toward the Niagara Escarpment and are probably related to the Hockley and Terra Nova re-entrants, respectively. The Cook's Bay valley trends southward where it disappears under the younger Oak Ridges moraine sediments. Shoreline features related to glacial Lake Schomberg (such as the gravel pit noted in Photo 05) have been recognized on the upland areas at elevations ranging from 265 to 320 m asl.

Deposits of glaciolacustrine fine- to very-fine textured sand, silt and clay are exposed beneath the Newmarket Till on the flanks of many upland areas. In places, the glaciolacustrine deposits are rhythmically laminated or varved. Deposits of well-sorted, well-bedded sand and gravel, likely deposited in subaqueous fan or deltaic conditions adjacent to the retreating ice margin, also occur locally beneath the Newmarket Till cover. Paleocurrent measurements generally indicate a southward flow in these deposits. The ages of these sub-Newmarket Till deposits are not known, but are generally believed to be older than the Newmarket Till and maybe early Late or Middle Wisconsinan as discussed previously.

Oak Ridges Moraine

Farther to the south, the Oak Ridges moraine, reaching elevations in excess of 350 m asl, forms the dominant landform in the southwest corner of Simcoe County (Township of Adjala–Tosorontio and the Town of New Tecumseth). The moraine is built on a regional erosional surface consisting of the Newmarket Till and tunnel valleys. This premoraine surface partially controlled the distribution and thickness of the sediments that form the moraine (Barnett et al. 1998). As the Laurentide Ice Sheet began to melt and retreat from southern Ontario, it split into a number of glacial lobes that behaved semi-independently. The moraine formed where the Simcoe and Ontario lobes separated during deglaciation, several kilometres north of the present-day Lake Ontario shoreline. As the ice lobes melted, a re-entrant in the ice was created that acted as a focal point for meltwater flow and sediment deposition.

The depositional history of the Oak Ridges moraine is complex and is the result of the readvance and retreat of one or both ice margins bounding the moraine. Overall, deposition occurred in 4 stages: 1) subglacial sedimentation, 2) subaqueous fan sedimentation, 3) fan to delta sedimentation and 4) ice-marginal sedimentation (Barnett et al. 1998). The moraine sediments represent proximal (high-energy) to distal (low-energy) environments ranging from subglacial to proglacial lake environments. As a result, the granular material that comprises the Oak Ridges moraine is extremely variable, both laterally and vertically (Barnett and Rowell 2002).

Although the Oak Ridges moraine is a major source of aggregate for the GTA, not all of it is favourable for aggregate extraction. Sediments associated with the later stages (3 and 4) of the Oak Ridges moraine development are often too fine to satisfy the specifications for many aggregate products. These late-stage deposits cap and/or flank the core of coarse-grained sediments. Such coarse-grained sediments were deposited in glaciofluvial environments at or near the ice front, and within or under the glacier, as well as in subaqueous fan environments. These coarse-grained deposits have the greatest potential for meeting high-specification aggregate products. Unfortunately, these coarser sediments form the core of the moraine and their development is restricted by land use designations outlined in the *Oak Ridges Moraine Conservation Act* and accompanying documents.

Schomberg Clay Plains

As the Simcoe lobe receded in a generally northward direction, water became trapped between the ice margin in the north, the Oak Ridges moraine to the south and the Niagara Escarpment in the west. Therefore, located north of the Oak Ridges moraine are a series of stratified silt and clay (fine-grained) deposits collectively called the Schomberg clay plains (Chapman and Putnam 1984; *see* Figure 2). These sediments were deposited in a multi-phase series of high-level lakes (Schomberg ponds and/or glacial Lake Schomberg). Well-developed shoreline features associated with glacial Lake Schomberg have been mapped at elevations up to 320 m asl. The Schomberg clay plain sediments are generally too fine to be of value as an aggregate resource.

Along the face of the Niagara Escarpment, meltwater flowing eastward from the escarpment deposited glaciolacustrine deltaic sediments into glacial Lake Schomberg. These deposits can be observed in the Township of Adjala–Tosorontio along the western boundary of Simcoe County. Later, these sediments would be downcut and altered by rivers flowing eastward from the escarpment along the Nottawasaga, Pine and Boyne river valleys. This downcutting and re-deposition created a series of glaciofluvial outwash terraces. There is some debate as to whether these deposits are truly glaciofluvial outwash deposits or more accurately described as fluvial in origin. Regardless, the rivers continue to downcut through these sediments to the present day. A similar situation occurs along the Niagara Escarpment in the Township of Clearview where the Noisy, Mad, Batteaux and Pretty rivers continue to downcut through previously deposited outwash and ice-contact sediments.

It is believed that the Simcoe lobe had a small readvance during the Port Huron Phase (stade) when some of the clay-rich sediments deposited during the glacial Lake Schomberg phase were incorporated into the glacial sediment load and later deposited as the clay-rich Kettleby Till. The Kettleby Till is a highly calcareous, silty clay to clay till (*see* Table 10). It is usually clast poor, averaging less than 1% clasts. It often exhibits a blocky structure in exposures and has moderate plasticity. The Kettleby Till is generally less than 2 m thick and occurs as a discontinuous sheet of ground moraine overlying older sediments. Table 12 provides the results of geochemical analyses run on the matrix of 2 Kettleby Till samples collected as part of this study. Because of the fine-grained nature of this till, there is a higher concentration of metallic and rare earth element (REE) cations than in coarser grained sediments. Table 10 illustrates some of the physical characteristics of the same 2 samples.

Barnett (1997) has mapped the Kettleby Till in the Barrie–Innisfil area. Burwasser (1974a) describes a till that he informally named the Allenwood till, but which he recognizes as probably a local variation of the Kettleby Till. The Allenwood till is exposed on the surface of the Edenvale moraine. Burwasser (1974a) described the till as a silt till with as little as 12% clay; to a clay silt till; to a clay till with as much as 50% clay. The total carbonate content ranges from 25 to 35% (Burwasser 1974a). Bajc and Rainsford (2010) are unsure as to whether there is a Kettleby Till in the southern part of Simcoe County or if this is just a variation or facies of the Newmarket Till.

During the retreat of the Simcoe lobe, ice-contact deposits would have formed in cavities created by meltwater flowing in and beneath the ice. Glaciofluvial outwash deposits would have formed by meltwater flowing from the ice margin. Glaciofluvial subaqueous fans and deltaic deposits would have developed where sediment-laden meltwater flowed from the glacial ice margin into water ponded in front of the ice. These types of deposits are noticeable throughout Simcoe County: from glaciofluvial outwash channels and terraces east of the Niagara Escarpment to ice-contact and outwash deposits south of Barrie. These deposits consist primarily of variably bedded, fine sand to coarse gravel, but may contain a broad range of material including large boulders, till lenses and fine-grained sediments (silt and clay). These sediments may be suitable for the production of a wide range of aggregate products and many have been used for such a purpose in the past. Two examples are the large, ice-contact deposits near Midland in the Township of Tay and the esker–ice-contact complex southeast of Hillsdale.

Simcoe Lowlands

As the glacial ice margin continued to recede, low-lying areas were submerged beneath the waters of glacial Lake Algonquin, an ancestral glacial lake that occupied the Lake Huron–Georgian Bay basins. These areas form the Simcoe lowlands physiographic region. The Simcoe lowlands are situated along the western shore of Lake Simcoe; in the central part of the county along the Nottawasaga River; and extending from slightly east of Wasaga Beach westward to Collingwood (*see* Figure 2). The Simcoe lowlands rise from the current lake level of 177 m to the Algonquin Bluff height of approximately 237 m asl. General local relief is subdued and rarely exceeds 7.5 m. The lowlands consist largely of glaciolacustrine sand, silt and clay with isolated deposits of till and glaciolacustrine beach ridges. The lowlands also generally overlie what is believed to be the buried Laurentian valley—

a bedrock valley that trends south-southeastward from Georgian Bay to Lake Ontario (Bajc and Rainsford 2010). (Photos 06 and 07 (ArcGIS® version only) illustrate the general topography of the Simcoe lowlands physiographic region.)

In the area of the Township of Ramara, the Simcoe lowlands comprise a relatively flat-lying glaciolacustrine plain, interspersed with a drumlinized till plain. Drumlins in this area tend to form low-lying ridges rather than the classical teardrop and oval shapes associated with these landforms. They vary between 0.3 and 2.0 km in length and from 50 to 300 m in width. They seldom exceed 15 m in height and some project only a few metres above the surrounding glaciolacustrine sediments (Finamore 1984). The drumlins are moderately steep sided and the western exposures of some have been further steepened by wave action (Deane 1950). There is also an area of the Simcoe lowlands physiographic region located around the City of Orillia.

Glacial Lake Levels and Related Beaches

Burwasser (1974a) reports the main glacial Lake Algonquin shoreline at an elevation of 237 m asl in the Collingwood–Nottawasaga area. Bajc (1994) reports the main glacial Lake Algonquin shoreline at 260 m asl in the Penetanguishene area, whereas Barnett (1988, 1989) reports Algonquin shoreline elevations as high as 240 m asl in the Barrie area and 260 m asl near Coldwater. Two higher level shorelines of 290 m asl near Warminster and 270 m asl near Gilchrist could represent even higher levels of glacial Lake Algonquin (Barnett 1989). Barnett (1989) reports evidence of at least 6 glacial lake levels in the Barrie–Elmvale area. Cronin (1984) reported the main Algonquin shoreline in the Penetanguishene Peninsula at 255.7 m asl and measured at least 11 other shorelines or strandlines. The main shorelines (*from* Cronin 1984) are

Shoreline or Strandline Name	Measured Elevation (m asl)
Main Algonquin	255.7
Wyebridge	231.0
Lafontaine	224.3
Penetang	218.5
Cedar Point	212.1
Highland	207.9
Payette	202.1
Nipissing	192.9
Algoma–Waubaushene	187.1

Deane (1950) and Barnett (1988, 1989), have recorded additional lake levels near Ardtrea (east of Orillia at 250.5 m asl) and 2 other levels that they refer to as the Upper Orillia and Lower Orillia (244.8 and 236.2 m asl, respectively). Many of the higher topographic features in the Simcoe uplands physiographic region formed islands in glacial Lake Algonquin and, hence, are also referred to as the Algonquin Islands by Deane (1950). Based on these measurements, it has been proposed that there are 3 inter Main Algonquin to Nipissing phases: specifically, the Upper Algonquin consisting of the Ardtrea, Upper and Lower Orillia shorelines; the Middle Algonquin consisting of the Wyebridge, Lafontaine and Penetang water plain levels; and the Lower Algonquin consisting of the Cedar Point, Highland and Payette levels. In the discussion of primary and secondary sand and gravel resources, approximate elevations of beach deposits will be provided to show the relationship between the beach deposit and the shoreline or strandline phase.

As the glacial ice margin continued to recede northward and drainage outlets changed from the Kirkfield–Fenelon Falls outlet to more northerly outlets near Algonquin Park, and later into the North Bay–Mattawa area, the water level in the Lake Huron–Georgian Bay basins began to drop (Finamore 1985). Approximately 4500 years BP (Bajc 1994), the water level in Georgian Bay began to rise again to a level 18 m higher (195 m) than the present-day level (177 m). This was known as the Nipissing Phase of the Upper Great Lakes and many of the sand and gravel beach deposits in the Edenvale, Wasaga Beach and Collingwood areas are related to this lake level. The main Nipissing strandline nearly parallels the current shoreline of Georgian Bay (Burwasser 1974a). The beaches of the Nipissing Phase are typically thinner and contain finer sediments than those of glacial Lake Algonquin. The water level began to drop once again to its present-day level of 177 m.

Postglacial erosional and depositional processes continue to modify the physiography and topography of Simcoe County. Modern alluvial and recent organic deposits have accumulated in low-lying areas and have created important swamp and wetland areas (e.g., Minesing Wetland). Eolian sand dunes and associated deposits are found along the shoreline of Georgian Bay. Typical of sand dunes or windblown deposits, the granular material is clean and uniform. The majority of the sand is less than 300 μm and is greater than 150 μm (passes the No. 50 sieve, but retained on the No. 100 sieve) and, as a result, is not useful in the production of MTO-type aggregate products. The rivers flowing from the Niagara Escarpment continue to downcut sediments and re-deposit them farther downstream (e.g., sediment deposition near the mouth of the Nottawasaga River as it enters Georgian Bay). The scale of this activity is significantly less than the erosional and depositional activity that occurred during the time of the active glacier and immediately following the retreat of the glacial ice.

Barnett (1989) noted that, if a fine-grained unit is present at the base of a bluff, groundwater piping may occur along its upper surface resulting in slippage and the formation of large, circular or oval-shaped erosional scars. Evidence of such a landslide scar is present just north of Bradford (Barnett 1989). Bajc (1994) has observed similar features on the eastern side of Lafontaine Hill and along the northeastern flank of a topographic high north of Laurin.

More detailed account of the glacial history and surficial geology of the county are provided by Deane (1950), Burwasser (1970, 1973, 1974a, 1974b), White (1971), Gwyn (1972a), Finamore (1984, 1985), Barnett (1986, 1988, 1989, 1990b) and Bajc (1994).

Drainage

Drainage in the area is provided by a number of rivers and creeks. In the northwestern part of the county, the Pretty and Batteaux rivers drain directly from the Niagara Escarpment into Georgian Bay. The Mad River (source area near Singhampton) and Noisy River (source area near Maple Valley) in the south of Clearview Township, drain from the Niagara Escarpment into the Nottawasaga River which drains the western portion of Simcoe County. In Adjala–Tosorontio Township, the Boyne River (source area near Mansfield in Dufferin County) and Pine River (source area near Terra Nova in Dufferin County) drain from the Niagara Escarpment into the Nottawasaga River (source area near Hockley Valley). Many smaller rivers and creeks drain directly into Georgian Bay and Lake Simcoe. A number of groundwater and hydrology studies have been completed for, and near Simcoe County, including Deane and Pollitt (1950), Sibul and Choo-Ying (1971), Turner (1981, 1982), Vallery, Wang and Chin (1982), Beckers and Frind (2000, 2001), Davies and Holysh (2005) and Davies, Holysh and Sharpe (2008).

SAND AND GRAVEL EXTRACTIVE ACTIVITY

At the time of writing, there were a total of 222 licenced and unlicenced sand and gravel pits located throughout Simcoe County of which 131 were licenced (Table 2). The total licenced area for sand and gravel extraction is 3916.17 ha. Some of the licenced operations are both sand and gravel and bedrock-derived (quarry) operations. These “dual” operations have been identified in both Tables 2 and 5. This information was provided by the Ministry of Natural Resources, Land Information Ontario (LIO) in the summer of 2010.

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 may appear on Maps 1A and 1B. 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 re-vegetated, 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* of 1971 and the *Aggregate Resources Act* of 1989 have been effective in preventing the establishment of new unlicenced pits.

For 8 of the last 10 years, Simcoe County has been the largest producer of aggregate, by volume, in Ontario. During that time, Simcoe County has had an average annual aggregate production of 11.64 million tonnes. Five municipalities within the county consistently produce in excess of 1 million tonnes of aggregate per year (Table B). It must be emphasized that Simcoe County does not use all of this aggregate and that the municipality is a major supplier or net exporter to the GTA (Regional Municipalities of Halton, Peel, York and Durham and the City of Toronto). In fact, in 2009, the GTA used 61 million tonnes of aggregate while only producing 19.8 million tonnes. Clearly the surrounding rural municipalities are supporting the economic growth and infrastructure development of the GTA.

Table B – Aggregate Production (2000 and 2009) by Municipality, County of Simcoe

Municipality (Listed Alphabetically)	2000 Production (tonnes)	2009 Production (tonnes)
Township of Adjala–Tosorontio	541 826.35	559 806.64
Town of Bradford West Gwillimbury	208 160.15	0
Township of Clearview	1 313 587.03	1 132 136.18
Township of Essa	126 619.65	48 477.23
Town of Innisfil	144 331.93	48 509.60
Midland–Penetanguishene areas	—	337 062.82
Town of New Tecumseth	70 231.20	92 152.00
Township of Oro–Medonte	1 986 819.69	2 180 602.03
Township of Ramara	2 086 360.58	1 926 109.68
Township of Severn	1 346 462.97	2 571 324.55
Township of Springwater	1 152 545.68	1 116 392.34
Township of Tay	97 213.46	138 571.68
Township of Tiny	191 118.13	309 796.13
TOTAL	**9 265 276.82**	**10 460 940.88**

Source: The Ontario Aggregate Resources Corporation (2009)

SAND AND GRAVEL AGGREGATE QUALITY

Test data from MTO files have been used extensively in the assessment of the resources of the county. Significant changes have occurred in the testing and specifications applied to aggregates since the original Aggregate Resources Inventory Papers (ARIPs) were completed. 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 Simcoe County commonly contain test results for the Los Angeles abrasion and magnesium sulphate tests. These data are extensive and 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 (e.g., Oro moraine, Oak Ridges moraine). 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 position 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 only relate to aggregate products that are generally used by the MTO. Many licenced operations are economically viable and are successfully producing other aggregate products, including winter road sand, fill, septic and mortar sand, and river stone, to name a few.

The granular material that is found in a particular deposit is a reflection of the glacial activity that occurred within an area. Generally, it is also a reflection of the local bedrock units since the glacier would easily crush, grind and transport broken pieces of bedrock. Meltwater coming from the glacier would also transport these local bedrock clasts. Therefore, it is not surprising that a sand and gravel deposit that is down ice from a poor aggregate-producing bedrock unit may have limited use as a high-specification granular source due to the lithology of the clasts within the deposit.

It is recommended that, where sand and gravel extraction and development is contemplated, that 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

Maps 1A and 1B show the geographic distribution of sand and gravel in Simcoe County. The total area occupied by these deposits is approximately 196 880.24 ha, representing 40.7% of the total land area of the county. These deposits contain sand and gravel resources of approximately 17 187.1 million tonnes (Table 1). **These figures represent a comprehensive inventory of all granular materials in the map area, although much of the material included in the estimate has no potential for use in aggregate production.**

Eleven (11) areas have been designated as Selected Sand and Gravel Resource Areas of primary significance and are indicated by red shading on Maps 1A and 1B. These areas occupy an unlicenced area of about 3325 ha that is reduced to 2404 ha after considering previous extraction and cultural, physical and environmental constraints (0.49% of the county's land base). These areas represent a possible aggregate resource of 283.7 million tonnes (Table 3).

Selected sand and gravel resources of primary significance are generally located in the northern half of the county. Many of the larger sand and gravel resources of secondary significance (orange shading) are also located in the northern half of the county. Generally, these deposits are the larger and thicker ice-contact, glaciofluvial outwash or glaciolacustrine beach deposits. Many of these deposits have been producing a variety of aggregate products for a number of years and, as a result, large portions of these deposits have been extracted and depleted.

The sand and gravel deposits in the southern half of the county have been exploited for years and many are near depletion. In addition, many of these southern deposits were generally smaller in areal extent to begin with, and the aggregate material generally finer. Some of the remaining deposits in the southern part of the county are under increased pressure by housing developments and urban expansion (e.g., near the communities of Thornton, Beeton and Alliston). Table B indicates that the southern municipalities have seen a sharp and significant decline in aggregate production between 2000 and 2009. In fact, the Town of Bradford West Gwillimbury no longer has any aggregate production as recorded by The Ontario Aggregate Resources Corporation (2009). This is a reflection of the depletion of existing resources and the sterilization of other aggregate deposits.

As discussed earlier, it is important to recognize that based on the geology of the Simcoe Uplands area that good quality granular resources may be buried as older, unexposed sediments covered by younger till. An extensive drilling program would be required to clearly define and delineate these resources.

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 consists of 2 segments of a glaciolacustrine beach deposit (approximate elevation of 250 to 260 m asl) located west of the Town of Penetanguishene. This deposit has been divided into a western and eastern arc. This beach deposit surrounds a topographically higher, till upland area known locally as Lafontaine Hill (elevation up to approximately 315 m). Licenced Pit Nos. 33 and 34 have been developed along the northeast corner of the deposit; whereas Pit No. 37 has been developed along the southwestern portion of the deposit. A spit has been developed off the northeast corner of this beach deposit (Pit No. 34) and can be clearly seen on Map 1A.

Licenced Pit No. 34 exposes 10 to 18 m of variable material ranging from a fine-grained till in the north end of the property to fine-grained rhythmites along the western part of the license. Licenced Pit No. 37 exposes a 4 to 15 m face of stratified sand and gravel. There is a large percentage of crushable pebble- and cobble-sized material in Pit No. 37, so much so that the material is being screened and sold as "river" stone. Both segments of the selected area suggest that subtill, ice-contact stratified sediments were exposed and reworked by glaciolacustrine shoreline processes resulting in the upper part of the deposit resembling a typical beach or spit deposit.

Other exposures in this area reveal medium- to thick-bedded, unsorted to poorly sorted, rounded to subrounded, cobbly gravel within a medium to coarse sand matrix; interbedded with clean, horizontally thin- to medium-bedded, moderately sorted, medium to coarse sand to gravelly sand. Maximum clast sizes generally range from 15 to 20 cm. Clast lithology varies from 63 to 72% limestone, 22 to 33% dolostone, and 0 to 6% Precambrian clasts.

The coarse aggregate content ranges from 15 to 45% (field estimate). An actual previous gradation analysis for a sample collected within the deposit indicates a coarse aggregate content of 18.3%, 76.6% sand and 5.1% fines. Petrographic Number values were 117.2 for Granular and 16 mm and 132.2 for Hot-Laid (HL) and concrete (coarse aggregate). Magnesium sulphate soundness test results were 11.3% for coarse aggregate, with a Los Angeles abrasion test result of 35.5%.

Based on these test results and previous aggregate production, this deposit should be capable of producing Granular A, Granular B, Select Subgrade Material (SSM) and some HL and concrete (coarse aggregate) products. Sand control, blending, crushing and other beneficiation would be required to make some of the high-specification aggregate products. Certain sections of this deposit would be "dirty" for the production of HL and concrete fine aggregate. As always, further investigation is recommended.

Selected Sand and Gravel Resource Area 1 occupies 401.4 ha, exclusive of licenced properties, and cultural, physical and environmental constraints. Assuming a conservative average thickness of 8 m, this resource area contains approximately 56.8 million tonnes of sand and gravel (*see* Table 3). This resource area has supplied aggregate to the local market for a number of years; therefore, the amount of good quality aggregate left in some portions of this deposit has been greatly reduced.

Selected Sand and Gravel Resource Area 2

A large ice-contact stratified drift deposit located south of the Town of Midland has been designated as Selected Sand and Gravel Resource Area 2. This selected resource area contains 1 large licenced property (Pit No. 61). At this site, pit faces range from 7 to 15 m exposing a variety of granular material ranging from relatively clean ice-contact sediments to pockets of fine-grained till. Boulders were noted in the till sections.

Exposures elsewhere throughout the deposit reveal 4 m of well-stratified and interbedded, coarse gravel and coarse cross-bedded sand layers. Another exposure revealed coarse, rounded, clast-supported gravel with a clean, medium to coarse sandy matrix. Elsewhere, 2 m of thick-bedded, interbedded sand with rare gravel layers and silty sand were exposed. Finally, another area revealed 4 m of coarse, cross-bedded, granular sand with interbedded, fine, sandy gravel. Faulting and slumping features were observed within the resource area. The coarse aggregate clasts are subrounded to rounded, generally with a maximum size of about 19 cm. The coarse aggregate lithology varies from 75 to 88% limestone, 4 to 15% dolostone, and 7 to 10% Precambrian clasts. (Photo 08 (ArcGIS® version only) shows some of the material that is located within this deposit.)

Aggregate from this deposit should be suitable for the production of Granular A, Granular B, SSM, HL and concrete products. Sand control will be required for HL and concrete (fine aggregate) products. Anti-stripping agents maybe required for HL (coarse aggregate) products.

Selected Sand and Gravel Resource Area 2 occupies 708.8 ha, exclusive of the licenced property. Cultural, physical and environmental constraints reduce the area available for extraction to approximately 380.4 ha. Certainly, a major constraint on this deposit is the location of the Town of Midland immediately north of the licenced property. The presence of Highways 12 and 27 also reduces the amount of material that could be extracted from this deposit, but, ironically, also provides transportation to the resource area. Assuming an average deposit thickness of 8 m, sand and gravel resources are estimated to be 53.9 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 3

An ice-contact deposit and a small glaciolacustrine beach deposit (approximate elevation of 250 to 260 m), located in the southeastern end of the Township of Tiny and extending easterly into the Township of Tay just north of Waverley, has been designated as Selected Sand and Gravel Resource Area 3. The selected area currently hosts 2 licenced pits (Pit Nos. 42 and 68) and 1 unlicenced pit (Pit No. 73). Once again, the subtill ice-contact sediments have been exposed and altered by shoreline processes, and lie on the side of a topographic high (the approximate elevation of the topographic high is 300 to 310 m asl).

The 11 to 14 m face at Pit No. 42 exposes interbedded fine to coarse gravel, and medium to coarse sand and thin layers of fine-grained sediment. Pit No. 68 exposes 3 to 5 m of predominantly fine to coarse gravel. Previous gradation results from this deposit indicate an aggregate content that ranges from 41.5 to 59.8% coarse, from 36.5 to 56.4% sand and from 1.5 to 3.7% fines. Petrographic Number values range from 103.3 to 108.0 for Granular and 16 mm and from 126.1 to 132.2 for HL and concrete. Magnesium sulphate soundness test values range from 7.2 to 7.4% for coarse aggregate and from 10.3 to 12.4% for fine aggregate. A Los Angeles abrasion test value of 38.8 has also been recorded for this selected resource area. (Photo 09 (ArcGIS® version only) illustrates some of the aggregate material found in this deposit.)

Based on the aggregate test results and on previous aggregate production, this deposit should be capable of producing Granular A, Granular B and SSM products with sand control, blending and beneficiation. The granular material should also be suitable for the production of HL and concrete aggregate products with proper beneficiation.

Selected Sand and Gravel Resource Area 3 covers approximately 114.7 ha. After considering previously extracted areas and cultural, physical and environmental constraints, this area is reduced to 96.0 ha. Based on a conservative average deposit thickness of 6 m, aggregate resources are estimated at 10.2 million tonnes (*see* Table 3). Transportation to the selected area is provided by Highway 27.

Selected Sand and Gravel Resource Area 4

Selected Sand and Gravel Resource Area 4 is located south of Waubaushene and consists of 2 glaciolacustrine beach deposits and 3 glaciofluvial ice-contact deposits. Three licenced pits (Pit Nos. 65, 66 and 67) have been developed in this selected resource area. Material exposed in the 2 to 30 m pit faces varies greatly both laterally and vertically.

Stratified beach sand and gravel, and silty ice-contact sand and gravel was observed at all 3 sites. Thick clay layers are present in Pit No. 66 and till is present in both Pit Nos. 65 and 66. At Pit Nos. 65 and 66, sand control is necessary for the production of Granular A and Granular B or SSM; and oversize material must be removed or crushed to produce Granular B. The coarse aggregate is acceptable for HL4; however, the fine aggregate requires blending for HL4. Selective extraction is necessary in all pits to avoid areas of excess fines.

Pit No. 67 has an incredible face of cobble and oversized material. In fact, large Precambrian boulders from the pit area have been stockpiled and are actually being used for landscaping stone. Subsurface investigation is recommended prior to extraction in this area because of the highly variable nature of the aggregate material, and the possibility of intersecting till material at depth.

Approximately 205.5 ha are available in Selected Sand and Gravel Resource Area 4, after considering cultural, physical and environmental constraints. One of the physical constraints in this area includes an Ontario Power Generation (OPG) powerline corridor. Assuming a conservative deposit thickness of 8 m, aggregate resources are estimated to be 29.1 million tonnes (*see* Table 3). These deposits have been extracted for a number of years to provide a valuable local supply of aggregate products.

Selected Sand and Gravel Resource Area 5

Selected Sand and Gravel Resource Area 5 is located northwest of Orr Lake in the Township of Springwater. This ice-contact deposit has subsequently been reworked by wave action into a glaciolacustrine beach deposit (Burwasser and Lloyd 1974; Hewitt and Karrow 1963). Therefore, the deposit is mapped as a glaciolacustrine beach (approximate elevation of 240 to 260 m asl) on Map 1A and is included in Table 1 under the same category.

Five licenced pits (Pit Nos. 75, 76, 77, 78 and 79) have been developed in the deposit. Face heights in the pits range from 2 to 9 m and expose moderately to well-stratified, poorly to moderately well-sorted, sandy gravel; overlain in places by stratified, well-sorted fine to medium gravel and silty sand. Hewitt and Karrow (1963) estimated the coarse aggregate content at 50%, with 30% of the clasts greater than 10 cm and 60% of the clasts greater than 2.5 cm. The clasts are generally subrounded to rounded. (Photo 10 (ArcGIS® version only) shows the type of aggregate material found within this deposit.) The material is quite variable over the lateral extent of the deposit and there are areas of the deposit that contain very little coarse aggregate.

A sample (10DJR-0031) collected as part of this study provided an aggregate content of 46.5% coarse, 52.5% sand and 1.0% fines. The Petrographic Number value for HL and concrete is 136.0, which would indicate that the material in this deposit, based solely on this sample, may be borderline for some aggregate products (Table 9; Appendix E). Micro-Deval abrasion loss (coarse aggregate), absorption capacity, bulk relative density and accelerated mortar bar expansion test results all indicate that there are still many aggregate products that can be produced from the granular material in this deposit. This aggregate material should be suitable for the production of Granular A, Granular B and SSM products with proper beneficiation. The Petrographic Number value for HL and concrete (coarse aggregate) was high due to encrustation on, and cementation of, coarse aggregate clasts.

The selected area occupies 20.0 ha, excluding licenced areas. Previous extraction, cultural, physical and environmental constraints reduce the remaining part of the resource area to 16.1 ha. Assuming a conservative average deposit thickness of 5 m, available sand and gravel resources are estimated to be 1.4 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 6

Selected Sand and Gravel Resource Area 6 is a glaciofluvial ice-contact deposit located southwest of the community of Phelpston in the Township of Springwater. The glaciofluvial sediments have been modified by subsequent glaciolacustrine processes and some of the deposit is buried under glaciolacustrine shallow water sediments (glaciolacustrine plain) (Burwasser and Lloyd 1974).

Four licenced pits (Pit Nos. 80, 81, 82 and 83) have been developed within this deposit. Face heights in these pits range from 2.5 to 8 m and expose poorly to moderately well-sorted gravel with numerous sand layers. The coarse aggregate content is quite variable throughout the deposit making sand selection and control a common requirement for the production of crushed aggregate products. The presence of silt and clay seams may limit the aggregate's suitability for some higher specification uses; however, the gradation and lithology of the aggregate are generally good. The 2 licenced pits on the eastern part of the deposit (Pit Nos. 82 and 83) have reached the water table and aggregate material is being removed from below the water table: an elaborate dragline operation is in use at Pit No. 83, whereas, at Pit No. 82, aggregate is being removed through the use of high-hoe equipment. Till was observed along the north and south flanks of the deposit. (Photo 11 (ArcGIS® version only) provides an example of the aggregate material that is located within this deposit.)

Aggregate suitability data obtained from the MTO indicate that the aggregate is of high quality and is acceptable for a wide range of road-building and construction products with suitable processing and quality control as noted above. These products include Granular A, Granular B and SSM products, as well as HL and concrete products. Processing may be required to remove or crush oversize cobbles for the production of some aggregate products.

Selected Sand and Gravel Resource Area 6 occupies 89.7 ha, excluding licenced properties. Cultural, physical and environment constraints reduce the resource area to 69.1 ha. Assuming a conservative average thickness of 8 m, available sand and gravel resources are estimated to be 9.8 million tonnes (*see* Table 3). The current licenced properties cover a large proportion of this deposit.

Selected Sand and Gravel Resource Area 7

Selected Sand and Gravel Resource Area 7 consist of glaciolacustrine beach deposits (approximate elevation of 220 to 240 m asl) related to the abandoned shoreline of glacial Lake Algonquin, in the south-central portion of the Township of Springwater and crossing over into the north end of the Township of Essa (just west of the City of Barrie). In some areas of this deposit, these beach-like structures overlie older ice-contact sediments as discussed earlier in this report.

There are currently 8 licenced properties (Pit Nos. 91, 92, 93, 95, 96, 97, 98 and 170) and 3 unlicenced pits (Pit Nos. 114, 178 and 179) found within the resource area. The licenced properties located in the resource area have faces ranging in height from 3 to 9 m and expose a variable coarse aggregate content ranging from 30 to 70.3%. A previously collected and tested sample from this deposit indicated 70.3% coarse aggregate, 27.6% sand and 2.1% fines. Pit faces in these properties generally expose irregularly stratified, medium gravel with interstratified fine to coarse sand (Hewitt and Cowan 1969). Pockets of good-quality coarse granular material were observed during the 2010 field season. Aggregate material from this deposit has been used for the production of Granular A, Granular B, SSM and HL4 (coarse aggregate) products. Blending is required in order to produce higher specification aggregate products.

The 3 unlicenced pits in the resource area expose faces ranging in height from 3 to 8 m. The pits reveal moderately sorted, fine to coarse gravel overlying silty medium to coarse sand. Gravel content in these pits range from 20 to 40%. Pit No. 114 contains high quality aggregate that is acceptable for a wide range of road-building and construction products with suitable processing and quality control. Because the deposit covers a reasonably large area, aggregate material can be quite variable over the length of the deposit.

There has been a long history of sand and gravel extraction from this selected area. Since the early 1940s, sand and gravel have been extracted from these deposits and much of the material has been removed. Sand now predominates in some of the selected resource area and the remaining coarse aggregate is generally located in pockets. The southern pits are either being rehabilitated or are water filled (Photo 12, ArcGIS® version only).

Selected Sand and Gravel Resource Area 7 occupies 1190.5 ha, exclusive of licenced properties. Cultural, physical and environmental constraints and previously extracted areas reduce the area presently available to 887.7 ha. Water-well data from the selected area indicate a wide variety of aggregate thickness. Assuming a conservative average deposit thickness of 5 m, sand and gravel resources are estimated at 78.6 million tonnes. The growth and development of the City of Barrie has been, and will continue to be, a factor in the development of this deposit.

Selected Sand and Gravel Resource Area 8

A large esker–ice-contact drift complex in the west-central portion of the Township of Oro–Medonte, and crossing westward into the Township of Springwater, has been designated as Selected Sand and Gravel Resource Area 8. This deposit hosts 2 large licenced properties (Pit Nos. 118 and 119). Faces in Pit No. 119 expose 6 to 25 m of stratified sand and gravel with lenses of finer material. In Pit No. 118, approximately 15 m of gravel overlies 1.5 m of silt and clay, which, in turn, overlies 4 m of silty gravel.

Previous gradation results indicate that the aggregate content varies from 27.7 to 52.2% coarse, 45.6 to 62.5% sand and 2.2 to 9.8% fines. Petrographic Number values for Granular and 16 mm range from 109.0 to 111.5 and from 121.0 to 143.4 for HL and concrete. Magnesium sulphate soundness test results were 3% for coarse aggregate and 6.2% for fine aggregate. A single Los Angeles abrasion test result of 29.6 and a single accelerated mortar bar expansion test result of 0.039 has been recorded for the selected resource area.

Based on these test results and previous aggregate production, granular material from these 2 pits is suitable for a wide variety of products, with some restrictions. Historically, for the production of Granular A products, sand control is required; for Granular B and SSM products, the oversize material must be removed or crushed; HL (coarse aggregate) requires the use of an anti-stripping agent; and sand for HL4 requires blending and control of "dirty" material.

In Pit No. 141, crushable material may be obtained using selective extraction techniques and sand control; however, based on 2010 field observations, sand appears to be the predominant material left in the pit area. Several MTO test holes located to the west of the pit revealed more than 3 m of sand and gravel suitable for the production of Granular A, Granular B, SSM and HL4 (coarse aggregate) products. Oversize material would have to be removed or crushed to produce Granular B, SSM and HL4 (coarse aggregate) products.

Selected Sand and Gravel Resource Area 8 covers approximately 175.3 ha, exclusive of licenced properties. After considering cultural, physical and environmental constraints, 67.3 ha are available for extraction. A conservative deposit thickness of 8 m results in an estimated resource of 9.5 million tonnes (*see* Table 3). This area is ideally situated for any road-building or reconstruction activities along Highway 400; however, much of the granular material in the deposit has been extracted, and the location of Highway 400 actually reduces the amount of material left for development.

Selected Sand and Gravel Resource Area 9

Selected Sand and Gravel Resource Area 9 is a series of ice-contact stratified drift deposits located throughout the Oro moraine. The Oro moraine is believed to be constructed as a series of coalescing and overlapping subaqueous fan deposits (Barnett 1991; P.J. Barnett, OGS, personal communications, 2010). The aggregate material within these fan structures are quite variable and are generally fine grained except where the core of the subaqueous fan can be found and isolated. As a result, most of the Oro moraine has been designated as an aggregate source of secondary significance as shown on Map 1A. There are substantial reserves of sand within these secondary areas. The primary selected areas represent sections of the Oro moraine that are composed of primarily coarse aggregate and that appear to be ice-contact esker deposits and/or segments.

Gradation results across the Oro moraine indicate an aggregate content that varies from 1.8 to 68.9% coarse, 19.3 to 92.3% sand and 3.6 to 29.6% fines. The gradation results that correspond to the primary selected resource areas generally have the highest percentage of coarse aggregate. Samples collected as part of this survey (10DJR-0035 and 10DJR-0036) and located in the coarser esker segments provide the following results. Sample 10DJR-0035 was 35.2% coarse aggregate, 62.5% sand and 2.3% fines. Sample 10DJR-0036 was 43.2% coarse aggregate, 53.4% sand and 3.4% fines. The results of the Petrographic Number testing for HL and concrete and micro-Deval abrasion loss (coarse aggregate) test are high and, therefore, caution should be exercised. The reason for the high Petrographic Number values was due to the presence of encrustation on, and cementation of, the coarse aggregate clasts, and not objectionable lithology. Absorption capacity, bulk relative density and accelerated mortar bar expansion test results are quite acceptable (*see* Table 9; *see* Appendix E). (Photos 13 and 14 (ArcGIS® version only) show the nice blend of coarse aggregate and sand located in these primary areas of the Oro moraine.)

In the primary selected areas of the Oro moraine, the aggregate material is capable of producing a wide range of products. Oversize material has to be either crushed or removed to produce Granular B products. In sections, the sand grades "dirty" for HL and blending is required; however, with proper processing, beneficiation and caution, these primary areas should be able to produce Granular A, Granular B, SSM, HL (fine aggregate) and concrete aggregate products.

Selected Sand and Gravel Resource Area 9 occupies an area of 171.2 ha. Previously extracted areas and cultural, physical and environmental constraints reduce the available area to 163.2 ha. Assuming a conservative average deposit thickness of 8 m, sand and gravel resources are estimated to be 23.1 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 10

A glaciolacustrine beach deposit (approximate elevation of 260 to 280 m asl and associated with glacial Lake Algonquin), located northeast of the Oro moraine and north of the City of Orillia, has been designated as Selected Sand and

Gravel Resource Area 10. The beach sediments would appear to overlie ice-contact material. In this deposit, licenced Pit No. 153 exposes a 3 to 13 m face of beach sand and gravel containing sections of silty sand. In Pit No. 154, the beach-type sediments are once again exposed, but they appear to overlie ice-contact material.

Previous gradation results for this deposit indicate an aggregate content from 31.3 to 49.3% coarse, 46.1 to 63.1% sand and 4.6 to 5.6% fines. Petrographic Number values range from 100.4 to 106.4 for Granular and 16 mm and from 104.9 to 127.5 for HL and concrete. Magnesium sulphate soundness test values range from 3.2 to 6.6% for coarse aggregate and from 8.7 to 11.3% for fine aggregate. Los Angeles abrasion values range from 24.0 to 28.4.

As a result of the previous aggregate testing and the aggregate products that have been produced within this selected area, the material is suitable for the production of Granular A, Granular B, SSM and HL products. Any oversized material must be removed or crushed. Sand control and other beneficiation measures may be required to produce some aggregate products.

Selected Sand and Gravel Resource Area 10 occupies approximately 27.3 ha, exclusive of the licenced properties and cultural, physical and environmental constraints. Assuming an average deposit thickness of 7 m, sand and gravel resources are estimated to total 3.4 million tonnes (*see* Table 3). Pit No. 154 is currently undergoing rehabilitation of some of its slopes. Other faces in the pit expose fine-grained (silt and clay) rhythmites. (Photo 15 (ArcGIS® version only) illustrates these older fine-grained rhythmites.)

Selected Sand and Gravel Resource Area 11

Three glaciolacustrine beach deposits (approximate elevation of 230 to 250 m asl), located northeast of the City of Orillia, have been designated as Selected Sand and Gravel Resource Area 11. Licenced Pit No. 152 has been developed within this resource area. The east face of this pit exposes 12 to 15 m of fine to coarse gravel with cobble layers. It is likely that this deposit consists of beach and/or shoreline structures overlying a buried ice-contact sand and gravel deposit, similar to those observed elsewhere in Simcoe County and discussed previously.

Previous gradation results indicate an aggregate content of 54.3% coarse, 43.8% sand and 1.9% fines. Petrographic Number results are 100.0 for Granular and 16 mm and 113.2 for HL and concrete. Data provided from the MTO indicate that aggregate from this deposit can be used for Granular A, Granular B, SSM and other crushed aggregate products. High-quality coarse aggregate for HL4 has been produced from this deposit in the past. The sand requires blending for other HL products.

Selected Sand and Gravel Resource Area 11 occupies 124.1 ha, exclusive of the licenced property (*see* Table 3). A previously extracted area to the south of the licenced property has already been rehabilitated. After considering cultural, physical and environmental constraints, the area available for extraction is reduced to 89.7 ha. A conservative deposit thickness of 5 m would provide an estimated 7.9 million tonnes of aggregate resource.

Resource Areas of Secondary Significance

A number of sand and gravel deposits within Simcoe County have been selected as resource areas of secondary significance. Areas of secondary significance do not have the best aggregate, specifically a nice blend of crushable coarse aggregate and relatively clean, well-graded sand sized material; however, they may contain large quantities of aggregate material. In some cases, resource areas of secondary significance are classified as secondary due to the lack of reliable geological data. This lack of data may not allow for an accurate assessment of either the quality or quantity of sand and gravel within a deposit.

Resource areas of secondary significance serve as important alternate extraction sites and should be considered as part of the county's total aggregate supply. Secondary aggregate resource areas can also be used for wayside pit operations that are generally related to specific, time-restricted construction projects. These deposits are particularly important if they are located close to, and within the general vicinity of, a major transportation corridor. The secondary deposits are not labelled individually on Maps 1A and 1B and only selected descriptions of the deposits are provided herein.

TOWNSHIP OF CLEARVIEW (FORMERLY NOTTAWASAGA TOWNSHIP)

An ice-contact deposit located in the northwest corner of the Township of Clearview (formerly Nottawasaga Township), just west of the Town of Collingwood, has been selected as an aggregate resource of secondary significance. The deposit currently hosts 1 licenced property (Pit No. 1). Previous gradation results from this deposit indicate an aggregate content of 55.3% coarse, 42.5% sand and 2.2% fines. This aggregate material could be used for the production of Granular A, Granular B and SSM products. Because of the proximity of the Town of Collingwood and the urban expansion that is currently taking place around the town and westward toward the Blue Mountain area, a good portion of this deposit is constrained and quickly becoming sterilized.

A long, curving, glacial Lake Algonquin beach deposit (approximate elevation of 230 m asl), located west of Stayner and trending southeastward, has been selected as a sand and gravel resource area of secondary significance. Two licenced pits (Pit Nos. 2 and 3) have been developed along this beach ridge. Two abandoned pits (Pit Nos. 19 and 20) were identified during this study, but these areas have either been partially rehabilitated or are badly overgrown, essentially making them difficult to recognize. Previous gradation results indicate an aggregate content that varies from 6.7 to 50.5% coarse, 48.5 to 92.3% sand and 1.0 to 2.1% fines. The material has been used in the past for the production of Granular A, Granular B, SSM, fill and HL (coarse and fine aggregate) products. The beach ridge is generally narrow and the deposit is thin. In other areas along the beach ridge, the water table has been exposed. As a result, this deposit is nearing depletion and the remaining material may only be suitable as a wayside-type operation.

A series of glaciofluvial outwash or fluvial deposits have been selected as an aggregate resource of secondary significance. These are located just north of Creemore; extend from just west of Creemore in a southeasterly direction toward the Township of Adjala–Tosorontio boundary; and near the community of Glencairn (Township of Adjala–Tosorontio). In the Township of Clearview, Burwasser (1974a) refers to this area as the "Creemore channel outwash/fluvial deposit". Just north of Creemore, the deposit has developed along the south side of a bedrock topographic high (outlier) known locally as Ten Hill. Four licenced operations (Pit Nos. 8, 9, 17 and 161) are located within this selected area. The aggregate material within this selected area is extremely variable. Aggregate content varies from 0.1 to 70.4% coarse, 21.3 to 73.3% sand and 5.7 to 26.6% fines. An overgrown pit located in the Township of Clearview (formerly Sunnidale Township) exposes a 3 m face of stratified, clean, medium- to coarse-grained sand, and well-rounded fine gravel. Material in this selected area can be used for Granular A, Granular B and SSM products with proper sand control, beneficiation, and crushing or removal of oversized material. The material at Pit No. 161 is predominantly sand (distal end of the deposit), whereas the material at Pit No. 17 has a good percentage of coarse aggregate. The clasts at Pit No. 17 are generally subangular to subrounded. The good aggregate material is underlain by grey-blue, silty clay material.

TOWNSHIP OF CLEARVIEW (FORMERLY SUNNIDALE TOWNSHIP)

An extensive glaciolacustrine beach deposit related to an abandoned shoreline of glacial Lake Algonquin (approximate elevation of 220 to 230 m asl) has been selected as an aggregate resource of secondary significance in the Township of Clearview (formerly Sunnidale Township). A very pronounced abandoned glacial Lake Algonquin shoreline bluff marks the erosional edge of the Corn Hill moraine on the northern boundary of this selected area. There are currently 7 licenced operations located in this deposit (Pit Nos. 10, 11, 12, 13, 14, 15 and 16). The licenced properties have faces ranging in height from 1.5 to 5 m. The faces expose a variable coarse aggregate content ranging from 10 to 48.2%. Pit faces generally expose well-rounded, well-sorted fine to medium gravel with interstratified medium to coarse sand. Faces in the eastern part of the deposit reveal a coarsening-upward sequence of well-rounded crushable gravel with interstratified clean coarse sand. Previous aggregate suitability data obtained from the MTO indicate that this deposit has produced Granular A, Granular B, SSM, HL and concrete aggregate products. Processing and blending is required to produce high-specification products. There has been substantial aggregate extraction from this resource area in the past; consequently, much of the coarse material has been removed and sand tends to be the dominant sediment encountered in the deposit. Sections of these licenced properties are either depleted, water filled or rehabilitated.

Another glacial Lake Algonquin beach deposit (approximate elevation of 220 m asl) is located along the eastern boundary of the township and has been selected as a resource of secondary significance. This beach deposit has been extensively worked in the past. There are presently 2 licenced properties (Pit Nos. 4 and 5) operating in the deposit. Faces in the pit areas range from 1.5 to 8 m and expose a coarse aggregate content of between 20 and 35%. Pit faces expose stratified fine to coarse sand, and well-rounded fine to medium gravel. A sample (10DJR-0030) collected and tested as part of this study indicates 35.5% coarse aggregate, 61.3% sand and 3.2% fines. The Petrographic Number value for HL and concrete (129.0) and micro-Deval abrasion loss (coarse aggregate) are a little high (*see* Table 9; *see* Appendix E). Absorption capacity, bulk relative density and accelerated mortar bar expansion results are quite acceptable. Aggregate suitability data obtained from the MTO indicate that, in the past, aggregate from this deposit was acceptable for the production of Granular A, Granular B, SSM and HL (coarse aggregate) products. Blending was required in order to produce high-specification fine aggregate products. A good portion of the material from this deposit has been extracted; however, there is enough material left in the deposit to support a wayside operation, particularly any reconstruction projects along the Highway 26 corridor.

Two portions of a glaciolacustrine beach deposit (approximate elevation of 195 m asl), located immediately south of the Town of Wasaga Beach, have been selected as a resource of secondary significance. These 3 to 5 m high remnant shorelines were formed by glacial Lake Nipissing. The deposits extend eastward and westward into the Township of Springwater and the Township of Clearview (the former Township of Nottawasaga), respectively. A number of abandoned pits have been developed in the larger portion of this deposit and are now largely overgrown (e.g., Pit No. 30). Pit faces expose subangular to rounded, fine to medium gravel with interstratified fine to coarse sand. Previous gradation results indicate an aggregate content of 18.4% coarse, 76.5% sand and 5.1% fines. Data from the MTO indicate that the aggregate material from this deposit can be used for the production of Granular B and SSM products. The sand tends to grade fine for HL fine aggregate. If the excess fines were removed from the material, then some high-specification products such as HL sand may be produced. A good portion of the material from this deposit has been extracted; however, there is enough material left in the deposit to support a wayside operation, particularly for reconstruction work along the Highway 26 corridor.

TOWNSHIP OF TINY

A glaciolacustrine beach (approximate elevation of 220 to 260 m) located in northwestern Township of Tiny has been selected as a sand and gravel resource of secondary significance. The beach deposit structures overlie older glaciofluvial ice-contact deposits. The topographic high that this selected area surrounds has an elevation of about 270 to 290 m asl and is covered by till. Five unlicenced pits (Pit Nos. 44, 45, 46, 47 and 48) have been developed in this deposit. Pit faces of 2 to 7 m generally expose well-rounded, fine to coarse gravel and fine to coarse sand. Coarse aggregate material is not consistent across the entire deposit and areas of finer material are present. Till is exposed at the base of unlicenced Pit No. 48, and may locally crop out throughout the beach deposit. In areas where there is no subsurface information, further investigation is recommended. A sample (10DJR-0032) was collected as part of this study and submitted to the MTO for testing. Gradation results indicate an aggregate content of 47.5% coarse, 49.5% sand and 3.0% fines. Petrographic Number values, micro-Deval abrasion loss (coarse aggregate), absorption capacity, bulk relative density and accelerated mortar bar expansion test results are quite acceptable for a number of aggregate products (*see* Table 9; *see* Appendix E). The production of Granular A, Granular B, SSM and some HL and concrete aggregate products should be possible with proper beneficiation.

In the northeast corner of the Township of Tiny, east of Farlain Lake, a glaciolacustrine beach deposit, at an approximate elevation of 200 to 220 m asl, has been selected as a resource of secondary significance. The 8 to 15 m working face (2 benches) of licenced Pit No. 35 exposes mainly fine to medium sand with a coarse aggregate content of approximately 20%. Sediments exposed in licenced Pit No. 35 have been interpreted as an ice-contact deposit. It is believed that these ice-contact sediments underlie the younger, surface till and have been exposed in this upland area (as discussed previously). Glacial lake wave action has reworked this material forming typical beach-like structures on the surface of the deposit. The glaciolacustrine beach deposit to the north and northeast of licenced Pit No. 35 may be underlain by similar ice-contact material. In areas where there is little or no subsurface information, further investigation is highly recommended. Two unlicenced pits (Pit Nos. 52 and 53) are located to the northeast of the licenced property.

A beach deposit (approximate elevation of 250 m asl) located in the Township of Tiny, southeast of Perkinsfield and west of Midland, has been selected as an aggregate resource of secondary significance. This deposit has been worked extensively and much of the material has already been extracted. There is currently a licenced pit (Pit No. 39) developed in this deposit. A 2 to 5 m face at Pit No. 39 exposes fine to coarse gravel. Aggregate from this pit has been used for Granular A, Granular B and SSM products. Sand control, blending and other beneficiation processes may be required to produce a range of higher specification aggregate products. As noted above, a good portion of this deposit has been extracted; however, there is good aggregate still available for use as a wayside operation; perhaps to be used along the Highway 27 corridor located to the east.

TOWNSHIP OF TAY

Three beach ridges (approximate elevation of 240 to 250 m asl), that trend in a southwesterly direction from the southern portion of the Township of Tay into the northern part of the Township of Oro–Medonte, have been selected as sand and gravel resource areas of secondary significance. The westernmost beach deposit is composed of sand and gravel overlying till. The aggregate appears suitable for crushing and the production of at least pit-run material. The central beach deposit is primarily a sand source and is host to unlicenced pit (Pit No. 137). Data from the MTO for this site indicate that some material is suitable for crushable gravel as well as pit-run material. In some areas, test holes, excavated by the MTO, revealed till underlying 3 to 4 m of sand and gravel. These deposits tend to be shallow and will provide only limited amounts of granular material, but they could provide material to reconstruction projects located along Provincial Highways 12 or 400.

TOWNSHIP OF SPRINGWATER (FORMERLY FLOS TOWNSHIP)

A glaciofluvial ice-contact deposit that was subsequently modified by shoreline processes, located in the Township of Springwater (formerly Flos Township) just south of Selected Sand and Gravel Resource Area 6, has been selected as a resource of secondary significance (approximate elevation 210 to 220 m asl). Three licenced pits (Pit Nos. 85, 86 and 87) as well as 1 unlicenced pit (Pit No. 110) have been developed in this deposit. Face heights in these deposits range from 2 to 15 m, and the coarse aggregate content ranges from 0 to 40%. The aggregate from pits in this deposit has been used for production of Granular A, Granular B, SSM and HL (coarse aggregate) products in the past. Sand control and blending of portions of the deposit are required in order to produce higher specification fine aggregate products. From 2010 field observations, it would appear that the remaining southern part of this deposit is predominantly sand with layers of silty fine sand. The licenced pit on the western part of the deposit, which is designated as a tertiary deposit, has been rehabilitated and water filled. Material from this deposit could be used for local construction projects.

TOWNSHIP OF SPRINGWATER (FORMERLY VESPRA TOWNSHIP)

A glaciofluvial outwash deposit, situated east of Anten Mills and south of County Road 22 in the Township of Springwater (formerly Vespra Township), has been selected as an aggregate resource of secondary significance. This outwash deposit has been modified by subsequent shoreline processes by the waters of glacial Lake Algonquin (approximate elevation of 240 m asl). In places, the outwash deposit sediments have been completely obscured (Burwasser and Cairns 1974). Therefore, on Map 1A, the deposit has been identified as a glaciolacustrine beach deposit. Presently, there is 1 licenced property (Pit No. 88) situated in the northern part of the deposit. Previous descriptions of Pit No. 88 indicate a 3 to 5 m face of well-rounded outwash gravel, and interstratified coarse sand deposited by meltwaters flowing away from the ice margin of the receding glacier (Burwasser 1974a). In places, the gravel content reaches 40%. A sample (10DJR-0033), collected and tested as part of this survey, indicates an aggregate content of 36.7% coarse, 59.2% sand and 4.1% fines. The Petrographic Number result for HL and concrete is of concern and reflects encrustation on, and cementation of, the coarse aggregate clasts, not a problem with lithology. The other test results for this sample are all quite acceptable (*see* Table 9; *see* Appendix E). This deposit is capable of producing aggregate acceptable for a wide range of road-building and construction products. Sand control is required for the production of Granular A products and blending is necessary for HL sand products. A good portion of this deposit has been depleted, including the licenced pit area. Other areas of the deposit have been sterilized by development along the Highway 27 corridor; however, there is enough material left in the deposit to support a wayside operation, particularly for reconstruction work along the Highway 27 corridor or Simcoe County Road 22.

The remaining ice-contact, outwash and beach deposits, located just west of the City of Barrie and north of Highway 90, have been selected as aggregate resources of secondary significance. There are presently 6 licenced properties (Pit Nos. 93 (part), 94, 99, 100, 101 and 102) and 1 unlicenced pit (Pit Nos. 115) located in these deposits. Pit faces range from 3 to 12 m and expose a limited gravel content. Many of these pits expose faces of poorly sorted, silty fine to medium to coarse sand containing irregularly bedded, fine to coarse gravel. (Photo 16 (ArcGIS® version only) illustrates the type of material that can be found within this deposit.) The aggregate from these deposits is generally not suitable for all uses, but, with sand control and blending, the material should be acceptable for SSM, pit run and Granular B products. A good portion of these deposits located in and around the City of Barrie have been sterilized by the westward growth of the city. Ironically, the proximity of these operations to the City of Barrie and Highway 90 make the deposits attractive for supplying aggregate material to the area.

TOWNSHIP OF ORO–MEDONTE (FORMERLY MEDONTE TOWNSHIP)

A glaciolacustrine beach deposit (approximate elevation of 240 to 250 m asl), near Orr Lake in the northwestern part of the Township of Oro–Medonte (formerly Medonte Township) and extending westward into the Township of Springwater (formerly Flos Township), has been selected as an aggregate resource of secondary significance. The beach-like structures likely overlie older ice-contact sediments. One licenced property (Pit No. 116) is located in the eastern part of the deposit. Fine to coarse gravel, and fine- to medium-grained sand are exposed in the 2 to 6 m faces of Pit No. 116. Thin clay beds and cobble layers were also noted along the extent of the deposit. Previous data from this deposit indicated an aggregate content of 43.6% coarse, 53.4% sand and 3.0% fines. Petrographic Number values were 116.0 for Granular and 16 mm and 144.5 for HL and concrete. Magnesium sulphate soundness test results were 4.7% for coarse aggregate and 9.6% for fine aggregate. A Los Angeles abrasion test result of 27.8 has been recorded for this deposit. Data from the MTO indicate that aggregate from this deposit is acceptable for Granular B and SSM products. Sand control is required for the production of Granular A products. The sand generally grades fine for HL products and blending would be required. The deposit is located north of Highway 400 and east of Highway 27. Material from the deposit could be used for any reconstruction work located along these corridors.

An ice-contact stratified drift deposit, located in the north-central part of the Township of Oro–Medonte, has been selected as a sand and gravel resource of secondary significance. One licenced pit (Pit No. 121) and 1 unlicenced pit (Pit No. 139) have been developed in this deposit. Pit No. 121 exposes up to 15 m of variable material consisting of silty fine sand to coarse sand to coarse gravel. The coarse aggregate in Pit No. 121 is acceptable for crushing; however, blending is required for HL sand. Selective extraction is necessary to avoid silty fine sand and clay layers. The unlicenced pit has been rehabilitated, but more material is available. Material from this deposit could be used for reconstruction projects along the Highway 400 corridor.

Also located in the north-central part of the Township of Oro–Medonte is a glaciolacustrine beach deposit (approximate elevation of 210 to 220 m asl) that has been selected as a resource of secondary significance. This beach deposit hosts 1 licenced property (Pit No. 120). Pit faces expose 6 to 9 m of moderately to well-stratified, well-sorted beach gravel. Subsurface investigation is recommended to determine the full nature of the aggregate throughout the deposit since it is quite possible that till may underlie the beach material. Till material was observed along the east side of the deposit. (Photo 17 (ArcGIS® version only) illustrates the beach type of material that can be found within this deposit.)

A glaciolacustrine beach deposit (approximate elevation of 240 to 260 m asl), located in the north-central part of the Township of Oro–Medonte and running subparallel to Highway 400, has been selected as a resource of secondary significance. There are currently no pits in this deposit, but roadcuts reveal primarily gravel material. Further investigation would definitely be required to delineate the potential of this deposit; however, it is assumed that the material in this ridge is similar to other beach ridges in the area. This deposit may be able to provide valuable aggregate material to any reconstruction or redevelopment work along Highway 400 as a wayside operation.

Another glaciolacustrine beach deposit in the Township of Oro–Medonte, north of Warminster, has been selected for resource protection. This deposit has an approximate elevation of 250 to 260 m asl and is, therefore, related to glacial Lake Algonquin. At the time of field investigation, the only pit in this deposit (Pit No. 140) was rehabilitated, but historical MTO information was available. Pit faces exposed 1.5 to 3 m of granular material and several test holes, located in the pit floor, indicated another 3 to 4 m of sand. At this site, pit-run was the primary product; however, Granular A products could be produced with selective extraction techniques.

TOWNSHIP OF ORO–MEDONTE (FORMERLY ORO TOWNSHIP)

A small ice-contact stratified drift deposit located east of Dalston has been selected as a deposit of secondary significance. Licenced pit (Pit No. 122) is located within the deposit. Pit faces range from 3 to 6 m and expose a coarse aggregate content of 25 to 50%. The aggregate in this deposit is suitable for a wide range of products, but sand control would be required for the production of Granular A. Faces in the pit reveal clean, fine to medium sand and gravel as well as some oversized material. Material from this deposit could be transported to reconstruction work along Highway 400 or northward to Simcoe County Road 22. The deposit is small and the licenced area covers most of the remaining valuable aggregate material.

Two glaciolacustrine beach deposits located in the southeast corner of the Township of Oro–Medonte have been selected as an aggregate resource of secondary significance. These glaciolacustrine beach deposits are related to the abandoned shoreline of glacial Lake Algonquin (approximate elevation of 250 to 260 m asl). There is currently 1 unlicenced property situated in these deposits (Pit No. 146). Faces in the pit are 5 m high and expose well-sorted and well-stratified fine to medium sand and gravel, with a coarse aggregate content ranging from 20 to 40%. Generally, the gravel is subrounded to rounded. The material from the pit is generally of value in supplying coarse aggregate for HL products and subbase material. The sand grades “dirty” for HL products and blending is required. Roadcuts in the area reveal rounded medium to coarse gravel. The location of these deposits maybe valuable for reconstruction work along the Highway 11 and 12 corridors, which are located to the south and east (respectively) of these deposits.

The remainder of the Oro moraine has been selected as an aggregate resource of secondary significance. The moraine extends westward into the Township of Springwater and trends eastward into the Township of Severn, just south of Bass Lake and north of the City of Orillia. Some sand and gravel pits have been developed in the secondary areas of the Oro moraine (e.g., Pit Nos. 89 and 90, Township of Springwater) because there can still be good coarse aggregate in these secondary areas. Previous gradation and test results have been provided earlier in the discussion of the primary area located along the moraine. In other areas of the moraine, the material is predominantly a silty fine sand grading to a medium sand (e.g., unlicenced Pit No. 142 just south of Craighurst (Photo 18, ArcGIS® version only)). Many areas within the Oro moraine include till material as can be noted in the drill hole information on Table 7. Extensive drilling by the OGS has taken place across the Oro moraine as part of a groundwater study. A generalized log of these drill holes is provided in Table 7 (locations shown in ArcGIS® versions only). Subsurface investigation would be required in order to clearly define additional coarse aggregate material located along or within the Oro moraine. A sample (10DJR-0034) collected from the secondary area of the Oro moraine provides the following test results. The gradation results indicate an aggregate content of 3.0% coarse, 86.2% sand and 10.8% fines. The Petrographic Number value (142.0) for this particular sample is of concern, but the other test results for micro-Deval abrasion loss (coarse aggregate), absorption capacity, bulk relative density and accelerated mortar bar expansion are all quite acceptable. The Petrographic Number value appears to be high because the mica content of this particular sample is 4.3%.

TOWNSHIP OF SEVERN

A glaciolacustrine beach deposit (approximate elevation of 250 m asl) located southeast of Coldwater, in the Township of Severn (formerly Orillia Township) has been selected as an aggregate resource of secondary significance. The beach-like structures appear to overlie a subaqueous fan deposit. This deposit currently hosts 1 licenced pit (Pit No. 148). Pit faces range from 3 to 6 m and expose a layer of clay and silt approximately 1.5 m thick. With selective extraction, crushed gravel can be produced from this deposit. A test hole drilled in the floor of this pit revealed an additional 4 m of sand over till. Another test hole, also located in the pit floor, penetrated 3 m of fine to coarse gravel before encountering the water table. A sample from this deposit had a coarse aggregate content of 42% gravel and appears suitable for the production of Granular B and SSM products.

Located north of Bass Lake in the Township of Severn (formerly Orillia Township), segments of a glaciolacustrine beach deposit (approximate elevation of 250 to 260 m asl) have been selected at the secondary level. This deposit continues from a deposit located in the Township of Oro–Medonte to the west. Although generally overgrown, unlicenced pits expose up to 6 m of fine gravel overlying fine to coarse sand, with the gravel content ranging from 30 to 40%. The MTO excavated several test holes in this deposit that revealed more than 3 m of primarily coarse gravel. Aggregate acceptable for a wide range of road-building and construction products has been produced from this deposit. Sand control was required for the production of Granular A products. Till material was also noted within this deposit, reasonably close to surface (Barnett 1991). Because of the proximity to the Highway 12 corridor, material from these beach segments could provide aggregate material to any reconstruction work.

Three glaciolacustrine beach deposits located to the northeast of the City of Orillia (in the former Orillia Township) have been selected as secondary resource area. The approximate elevation of these deposits is 250 to 260 m asl and are therefore related to glacial Lake Algonquin. Most of these deposits are undeveloped, however, a small pit (Pit No. 158) exposes up to 3 m of beach gravel. These deposits are expected to contain material similar to, but thinner than, those associated with Selected Sand and Gravel Resource Area 11. For undeveloped deposits, further investigation is necessary to determine the nature and distribution of the aggregate at depth. These deposits are located just north of the Highway 11 corridor.

The last deposit selected at the secondary level of significance in this area is a subaqueous fan located in the northern portion of the Township of Severn (formerly Matchedash Township). This deposit contains 1 small pit (Pit No. 147) exposing 2 to 5 m faces of fine sand to fine gravel. Due to the lack of sand and gravel deposits in this part of the report area, this deposit may represent a locally significant source of granular. A deposit such as this would not normally be selected at the secondary level, but granular material is scarce. This material could be used locally for fill material and other low-specification aggregate products.

TOWNSHIP OF ADJALA–TOSORONTIO

Major re-entrant valleys coming from the Niagara Escarpment and into the study area are located near Hockley, Mansfield and Terra Nova along which the Nottawasaga, Boyne and Pine rivers flow, respectively (the communities of Mansfield and Terra Nova are located in the County of Dufferin to the west). A series of terraced outwash deposits were deposited along the Boyne and Pine rivers along the western boundary of the Township of Adjala–Tosorontio. The original sediments in this area were probably deltaic as discussed previously. The upper terrace is at an elevation of about 297 to 304 m asl, whereas the middle terrace has an elevation of about 266 m asl (Gwyn 1972b). The lower terrace is approximately 7 to 8 m above the current level of the rivers. The outwash terrace located along the Boyne River has provided crushable coarse aggregate in the past and, therefore, is selected as an aggregate resource of secondary significance. Previous gradation analysis indicates a coarse aggregate content ranging from 44.6 to 71.2% with the sand content varying from 22.1 to 50.7%. The fine content varies from 1.3 to 6.7%. There are currently 2 licenced pits located in this deposit (Pit Nos. 162 and 163). Both are nearing depletion and both expose the water table. Older pits in the same deposit and located near these licenced areas have either been rehabilitated or water filled (ponds). The lithology of the aggregate material may be of concern since the coarse aggregate is a mixture of siltstone, chert, sandstone, dolostone and limestone. This lithology clearly confirms that the Niagara Escarpment is the source of the coarse aggregate material. High concentrations of siltstone and chert are of concern in aggregate production. Recent (2011) drilling by A.F. Bajc (OGS, personal communication, 2011) indicates about 3.5 m of predominantly sand with minor gravel over silty fine sand.

Terraced outwash deposits located on the north and south sides of the Nottawasaga River in the southern portion of the Township of Adjala–Tosorontio (formerly Adjala Township) have been selected as a resource of secondary importance. Although no pits have been opened in the deposit (either in Simcoe County or in the County of Dufferin to the west), water-well data, topography, geology and surface exposures indicate that the deposits consist of fairly uniform, moderately sorted sand and sandy gravel. The land surface in the area is level and smooth and lies above the Nottawasaga River floodplain. The area has been selected as a resource of secondary significance in the County of Dufferin.

The Oak Ridges moraine, located along the southern boundary of the Township of Adjala–Tosorontio and extending eastward into the Town of New Tecumseth, has been selected as a sand and gravel deposit of secondary significance. This large, hummocky deposit extends southward into the Regional Municipalities of Peel and York and westward into the County of Dufferin. As noted previously in this report, the Oak Ridges moraine has a complex depositional history. Based on observations of the limited exposures in this portion of the moraine, it is suggested that this part of the moraine was formed in a subaqueous fan depositional environment with paleocurrent flow predominantly to the west and northwest. The sediments are primarily silty fine sand to fine- to medium-grained sand. Fine-grained sediments (silt and clay) are dispersed both laterally and vertically throughout the deposit. Crushable coarse aggregate is present in isolated glaciofluvial deposits intermixed with the previous sediments (Pit Nos. 164 and 165). Till was observed in some roadcuts and riverbank exposures underlying the sediments noted above.

Previous gradation results from samples in this portion of the Oak Ridges moraine indicate that the coarse aggregate is extremely variable from 0 to 65.1%. Sand content varies from 34.1 to 99.0%; the fine content varies from 0.9 to 6.7%. Previous Petrographic Number values range from 111.1 to 148.0 for Granular and 16 mm and from 120.9 to 175.0 for HL and concrete. With proper sand control, blending and other beneficiation processes, the material in this deposit could be used for a wide range of aggregate products. This secondary area of the Oak Ridges moraine has also been selected as a resource of secondary significance in the Regional Municipalities of York and Peel, and the County of Dufferin.

Within the Township of Adjala–Tosorontio, some of the outwash deposits are probably more accurately reworked deltaic deposits. It is believed that these deposits were deposited when meltwaters flowing eastward from the Niagara Escarpment emptied into the standing water of glacial Lake Schomberg, and, therefore, are more deltaic in origin than outwash. These deltaic deposits have been evaluated as tertiary. Sample 10DJR-0011 was collected from one of these fine-grained deltaic deposits in the Township of Adjala–Tosorontio and provided gradation results of 52.5% sand, 40.0% silt and 7.5% clay (*see* Table 10).

TOWNSHIP OF ESSA

A glaciolacustrine beach deposit located in the central part of the Township of Essa has been selected as an aggregate resource of secondary significance. This beach deposit is associated with glacial Lake Algonquin at an elevation of 226 m asl. There has been a substantial history of sand and gravel extraction from this deposit over the years. Many of the previous sources of sand and gravel are depleted and the pits have either been rehabilitated or are so overgrown that they are no longer recognizable. Two licenced pits (Pit Nos. 172 and 173) and 1 unlicenced pit (Pit No. 180) have been identified within the resource areas. Both licenced pits are now depleted and largely rehabilitated. Pit No. 172 is being used for storage and the pit to the south has been rehabilitated except for a small portion in the southwest corner of the licenced area. In the past, the pits exposed well-rounded, fine to coarse gravel with interstratified medium to coarse sand. Previous aggregate suitability data obtained from the MTO indicate that the aggregate from this deposit was acceptable for the production of Granular A, Granular B, SSM and HL4 (coarse aggregate) products. Sand control was required for the production of some aggregate products, and the sand grades slightly too coarse for HL (fine aggregate) products; blending was recommended. Despite depletion of the aggregate material in some areas of the deposit, there is still material in this beach ridge and, for that reason, this deposit has been selected as a resource of secondary significance. This deposit may supply material on a limited basis to reconstruction projects along Highway 90.

A glaciolacustrine beach deposit (approximate elevation of 220 m asl) located just east of Canadian Forces Base (CFB) Borden has been selected as a resource of secondary importance. This deposit has hosted a number of small, reasonably shallow aggregate operations in the past: most of which are overgrown, water filled or depleted. Licenced Pit No. 174 is still active within this deposit. In places, pit faces expose well-rounded, fine to coarse gravel with interstratified medium to coarse sand. Coarse aggregate content was up to about 30%. Material from these pits has been used for the production of Granular A, Granular B, SSM and HL4 (coarse aggregate) products. The sand grades variable for HL products. Most of the deposit has been depleted or sterilized, but some material could still be extracted on a limited, as needed, basis and is located reasonably close to Highway 90 corridor.

A glaciofluvial ice-contact–beach deposit (approximate elevation of 300 m asl) located to the northwest of Cookstown has been selected as a resource of secondary significance. This deposit is host to 3 licenced pits (Pit Nos. 175, 176 and 177). The deposit has been extensively worked in the past. A sample from this deposit indicates a gravel content of 58.2% coarse, 40.0% sand and 1.8% fines. The deposit thickness appears to vary across the deposit. Field observations indicate that the aggregate material is underlain by a clayey silt till. This beach deposit is not associated with glacial Lake Algonquin because it is generally too high an elevation, but is probably associated with glacial Lake Schomberg at elevations up to 320 m asl. The material from this deposit would be suitable for Granular B and SSM products. Granular A and some sand products (HL and concrete sand) may be possible with proper beneficiation.

A sample of till was collected just northwest of Cookstown (10DJR-0012). The grain size analysis of the till matrix indicates a sandy-clayey silt till, specifically 26.8% sand, 42.1% silt and 31.1% clay (*see* Table 10). Table 12 provides geochemical results for this sample.

TOWN OF INNISFIL

A north-trending glaciolacustrine beach deposit (approximate elevation of 230 to 240 m asl) on the eastern side of the Town of Innisfil has been selected as a secondary deposit. This beach ridge has been a traditional source of aggregate for the area. One licenced pit (Pit No. 182) and several unlicenced pits (Pit Nos. 186 and 187) have been developed in the resource area. The northeastern corner of the deposit is located west of Sandy Cove. Pit faces in this deposit range in height from 1.5 to 6 m and expose well stratified sandy gravel. The material is generally of good quality and suitable for the production of pit-run and crusher-run products including HL4 (coarse aggregate) and granular base course products. Till was also noted in some sections of these pit faces. Sand control measures may be necessary to produce a suitable crushed product. The sand fraction of the aggregate requires blending for use as hot mix. The southern part of the beach ridge is located near the community of Lefroy. Previous information on the beach ridge in this area indicates that pit faces exposed between 1.5 and 6 m of well-stratified gravelly sand, although concentrations of gravel were observed in places. The aggregate extracted from these pits was generally suitable for use as Granular B and SSM products. In sections where gravel is more abundant, higher specification products such as Granular A may be produced with sand control. Blending would be required for the production of HL products. Housing developments around Lefroy and along the Lake Simcoe shoreline have generally reduced the amount of granular material available from this deposit. As with many beach ridges, the deposits tend to be long, narrow and shallow. Only limited quantities of aggregate material would be available, perhaps for a wayside operation.

An outwash deposit situated in the western part of the Town of Innisfil and located south of Barrie has been designated as a resource of secondary significance. A number of abandoned and licenced pits were located in this deposit. This deposit was tested extensively in the past, including a number of drill holes. Today, there is a single, unlicenced pit (Pit No. 188) located in this deposit exposing predominantly sandy aggregate, suitable for the production of Granular B and SSM products. The coarse aggregate has generally been removed. The outwash was deposited on a rolling till plain and may vary considerably in thickness from one location to another. Once again, there may be enough granular material located in this deposit to provide aggregate to specific, time limited reconstruction projects.

TOWN OF NEW TECUMSETH

A small ice-contact deposit that has been altered by shoreline processes (beach deposit at an approximate elevation of 280 to 300 m and, therefore, related to glacial Lake Schomberg) has been selected at the secondary level of significance. This deposit is located northeast of Tottenham and currently has 2 licenced properties located in this deposit (Pit Nos. 195 and 196). Pit faces range from 3.5 to 6.5 m in height and expose a gravel content that varies from 20 to 40%. Faces in the westerly most pit are overgrown; however, the fresh faces in the eastern pit expose stratified fine to coarse sand and fine gravel. The municipality has a licenced pit to the northeast of this deposit (Pit No. 194). The material is generally finer (5.1% coarse aggregate, 83.0% sand and 11.9% fines) and, as a result, the deposit has been evaluated as a tertiary deposit.

TOWN OF BRADFORD WEST GWILLIMBURY

An ice-contact deposit located east of Pinkerton in the central part of the Town of Bradford West Gwillimbury has been selected as an aggregate resource of secondary significance. The deposit has been altered by shoreline processes and, therefore, is mapped as a glaciolacustrine beach deposit (tombolo structure: P.J. Barnett, OGS, personal communication, 2010). The approximate elevation of the deposit is 310 to 320 m asl and, therefore, is related to glacial Lake Schomberg. The deposit has been mined extensively over a number of years; currently, the deposit hosts only licenced Pit No. 200. Pit faces have varied over the years, but they generally expose sandy fine gravel and gravely sand. Throughout the deposit, the gravel beds are usually concentrated near the surface. A test hole that was drilled in the area exposed 5 m of fine to medium sand at depth. The deposit has supplied limited quantities of Granular A, Granular B, SSM and pit-run products in the past. The sand generally grades too fine for HL products and blending would be required. Previous gradation results indicate about 3.1% gravel, 87.8% sand and 9.1% fines. The licenced pit is essentially depleted and is being used by the township for other important purposes. As noted in Table B, there was no aggregate production in 2009 for the Town of Bradford West Gwillimbury. This clearly reflects the depletion of aggregate resources in the area.

TOWNSHIP OF RAMARA

Two deposits within the Township of Ramara (formerly Rama Township) have been selected at the secondary level. These deposits are composed predominantly of fine to medium sand. There are, however, localized areas of coarse sand and gravel suitable for use as road subbase. Of the deposits selected at the secondary level, both are small ice-contact deposits. A sequence of glaciolacustrine sand, silt and clay often conceal the coarser ice-contact material.

The first selected resource area, located near Sebright, represents the southwestern end of an esker–subaqueous fan complex that trends northeastward into the former Township of Dalton, City of Kawartha Lakes (formerly Victoria County). The deposit is mainly silt to medium sand with an average depth of just over 6 m. Gravel is present at depth, but is generally at, or near, the water table. A small amount of gravel was also concentrated on the southwestern flank of the deposit. Two samples were collected from the deposit and analyzed by the MTO. The first sample contained very little coarse material (0.6%) and a high percentage of fines. This silty sand is generally suitable only for low-specification sand uses including SSM and blending sand. Portions of the deposit that contain excessive quantities of silt should be avoided. The second sample was collected from the southwestern flank of the deposit, where the percentage of coarse material is approximately 40%. Only a small percentage (0.5%) of the sample was finer than 75 μm. Selective extraction, combined with proper mixing and screening, would allow this material to meet Granular B and SSM specifications. Unfortunately, the quantity of granular material present within this deposit is limited.

The second resource area is an esker–kame complex located in the north-central part of the Township of Ramara. The deposit trends southwest in a direction roughly subparallel to the movement of the ice sheet and then continues in a southeasterly direction. It is bounded to the north by an upland region of Precambrian bedrock and appears to be confined to the south by the Black River and portions of the Lake Simcoe moraine. The esker ridge is discontinuous and morphologically variable. Relief ranges from approximately 4 m in the north to approximately 8 m in the south where the esker becomes kamic in form. The deposit, in general, is composed of silt to fine sand, grading to medium sand. Gravel is present at depth usually at, or near, the water table. Aggregate test results for this deposit indicate that only a small percentage (6.4%) of the sample is coarse material. A large percentage (22.4%) is finer than 75 μm. Low-specification applications and blending sand would appear to be the primary use for this material.

BEDROCK GEOLOGY

The northeastern part of Simcoe County is underlain by metamorphic and igneous Precambrian rocks of the Grenville Province, whereas the remainder of the county is underlain by a succession of relatively flat-lying sandstones, limestones, dolostones and shales of Paleozoic age. The Paleozoic strata dip gently in a south-southwest direction at less than 5 m/km (Armstrong 2000). Paleozoic rocks occur as outliers within areas dominated by Precambrian rock. These areas have been identified on Maps 2A and 2B.

The Precambrian rocks include metamorphosed volcanic rocks, clastic and chemical sediments, and plutonic rocks of Mesoproterozoic (0.9 to 1.6 Ga), and Neo- to Mesoproterozoic (0.57 to 1.6 Ga) age (Easton 1992). The rocks are part of the Go Home domain and the Fishog domain (west and east of Lake Couchiching, respectively) of the Central Gneiss Belt (Easton 1992). Easton (1992) reports that the age of metamorphism is *circa* 1045 Ma for the Go Home and Fishog domains. Metamorphism in the Go Home domain is upper amphibolite to granulite facies. Metamorphism in the Fishog domain is upper amphibolite facies, although some retrograded granulite-facies rocks may be present in the north end of the City of Kawartha Lakes (formerly Victoria County) to the east (Easton 1992). Detailed mapping and discussion of the Precambrian rocks is provided Easton (1992), Lumbers and Vertolli (2000a, 2000b), Lumbers, Vertolli and Schwerdtner (2000a, 2000b) and Culshaw et al. (2004).

The Precambrian surface upon which the Ordovician sea transgressed is generally thought of as being a peneplained, gently undulating surface. The Precambrian bedrock surface, although not seen on the surface, begins to rise just west of Creemore. This feature is referred to as the Algonquin Arch and is not visible because of the thick Paleozoic and Quaternary cover, but it does affect the height of land and, therefore, influenced drainage patterns. The Algonquin Arch may also influence the thickness of the Paleozoic strata. For example, the Cabot Head Formation is approximately 40 m thick in the west-central Lake Erie area and only 12 m thick over the Algonquin Arch. It then thickens to 36 m again in the Owen Sound area (Brintnell et al. 2009).

The Precambrian basement is unconformably overlain by the Paleozoic Shadow Lake Formation. This formation is the oldest Ordovician formation in central and southwestern Ontario (Johnson et al. 1992) and is the basal unit of the Black River Group (Armstrong and Carter 2010). The Shadow Lake Formation consists of poorly sorted, red and green sandy shales; argillaceous and arkosic sandstones; minor sandy argillaceous dolostones; and rare basal arkosic conglomerate (Armstrong and Carter 2006). These rock types are commonly interbedded and gradational with each other. The upper contact of the Shadow Lake Formation is generally gradational with the overlying Gull River Formation (Armstrong and Carter 2006). The formation varies from 0 to 15 m thick and is generally friable and not a potential aggregate source.

The Gull River Formation overlies the Shadow Lake Formation, where it is present, or lies directly on the Precambrian basement where the Shadow Lake Formation is missing (Figure 3). The formation is part of the Black River Group (Armstrong and Carter 2010). The Gull River Formation consists mainly of limestone, with lesser amounts of dolostone, shale and argillaceous sandstone (Armstrong and Carter 2006) and has been subdivided into 3 informal members: the lower, middle and upper. The lower member is the most lithologically variable containing light to dark grey to brown, fine-grained dolostones; light grey to dark brown, very fine-grained limestones; green argillaceous sandy dolostones; minor green-grey argillaceous dolomitic sandstone; and green to dark brown shale (Armstrong and Carter 2006). The lower member is often capped by a green argillaceous dolostone informally referred to as the "green marker bed". The middle member consists of mainly grey, sparsely fossiliferous lime mudstones that are commonly laminated. The upper member of the Gull River Formation consists of light grey to dark brown, thin- to very thick-bedded, bioturbated, fossiliferous limestone. The Gull River Formation ranges in thickness from 7.5 to 136 m and is a valuable rock formation in the production of aggregate material. (Photo 19 (ArcGIS® Version only) shows the Gull River Formation in the north end of Ramara.)

The Gull River Formation is conformably overlain by the Bobcaygeon Formation (*see* Figure 3). The Bobcaygeon Formation is divided into 3 informal members: the lower, middle and upper. The lower member consists of light grey-tan to brown-grey, medium- to very thick-bedded, fine- to medium-grained, bioclastic limestones, wackestones, packstones and grainstones. The lower member is sometimes divided into 2 parts, a lower unit informally referred to as the "Moore Hill beds" and an upper part that comprises the rest of the lower member. The main difference between these 2 units is that the grain size of the matrix is significantly coarser in the upper part (Armstrong 2000). In some literature (e.g., Armstrong and Carter 2010), the lower member of the Bobcaygeon Formation is equivalent to the Coboconk Formation, Black River Group. (Photo 20 (ArcGIS® version only) shows an example of the Bobcaygeon Formation located in Severn Township.)

The middle member consists of thin- to medium-bedded, bioclastic, very fine- to fine-grained limestones with green shale interbeds and partings. The upper member consists of fine- to medium-grained, dark grey to light brown, thin- to medium-bedded, bioturbated, fossiliferous limestones, ranging from bioclastic wackestones to packstones and grainstones. Shale content is limited to thin shaly partings (Armstrong and Carter 2006). The middle and upper Bobcaygeon Formation are the equivalent to the 2 informal members of the Kirkfield Formation, Trenton Group (Armstrong and Carter 2010). The contact between the middle and upper members is gradational (Armstrong and Carter 2006). The Bobcaygeon Formation ranges in thickness from 7 to 87 m and has a long history of use by the aggregate industry.

The Bobcaygeon Formation is conformably overlain by the Verulam Formation (*see* Figure 3). The Verulam Formation is the equivalent to the Sherman Fall Formation of the Trenton Group (Armstrong and Carter 2010). The formation consists of interbedded limestone and shale. The formation has been divided into an upper and lower member (Armstrong and Carter 2006). The lower member, ranging from 23 to 68 m in thickness, consists of interbedded dark grey to grey, fossiliferous, fine- to coarse-grained limestone and green shale. The upper member is a medium- to coarse-grained, buff to tan coloured, cross-bedded, bioclastic limestone, ranging from 2 to 9 m in thickness. Although generally unsuitable for the production of high-quality aggregate because of the high shale content, the Verulam Formation may be used for the production of Portland cement.

The Verulam Formation is conformably overlain by the Lindsay Formation (*see* Figure 3). This formation is up to 65 m thick and consists of a lower unnamed member and the upper Collingwood Member (Johnson et al. 1992). The lower member is fossiliferous, grey to greenish, fine-grained, argillaceous limestone. Armstrong and Carter (2010) relate the lower member of the Lindsay Formation to the Cobourg Formation of the Trenton Group. The upper Collingwood Member consists of up to 10 m of fossiliferous, interbedded, black, organic-rich limestone and highly calcareous black shale. In central Ontario, the Lindsay Formation is generally not suitable for high-quality aggregate use because of numerous shale interbeds and partings. In eastern Ontario, the formation is used extensively for the production of aggregate products and is quarried near Bowmanville for the manufacture of cement.

Conformably overlying the Lindsay Formation in the study area is the Blue Mountain Formation (*see* Figure 3). The Blue Mountain Formation consists of 40 to 60 m of blue-

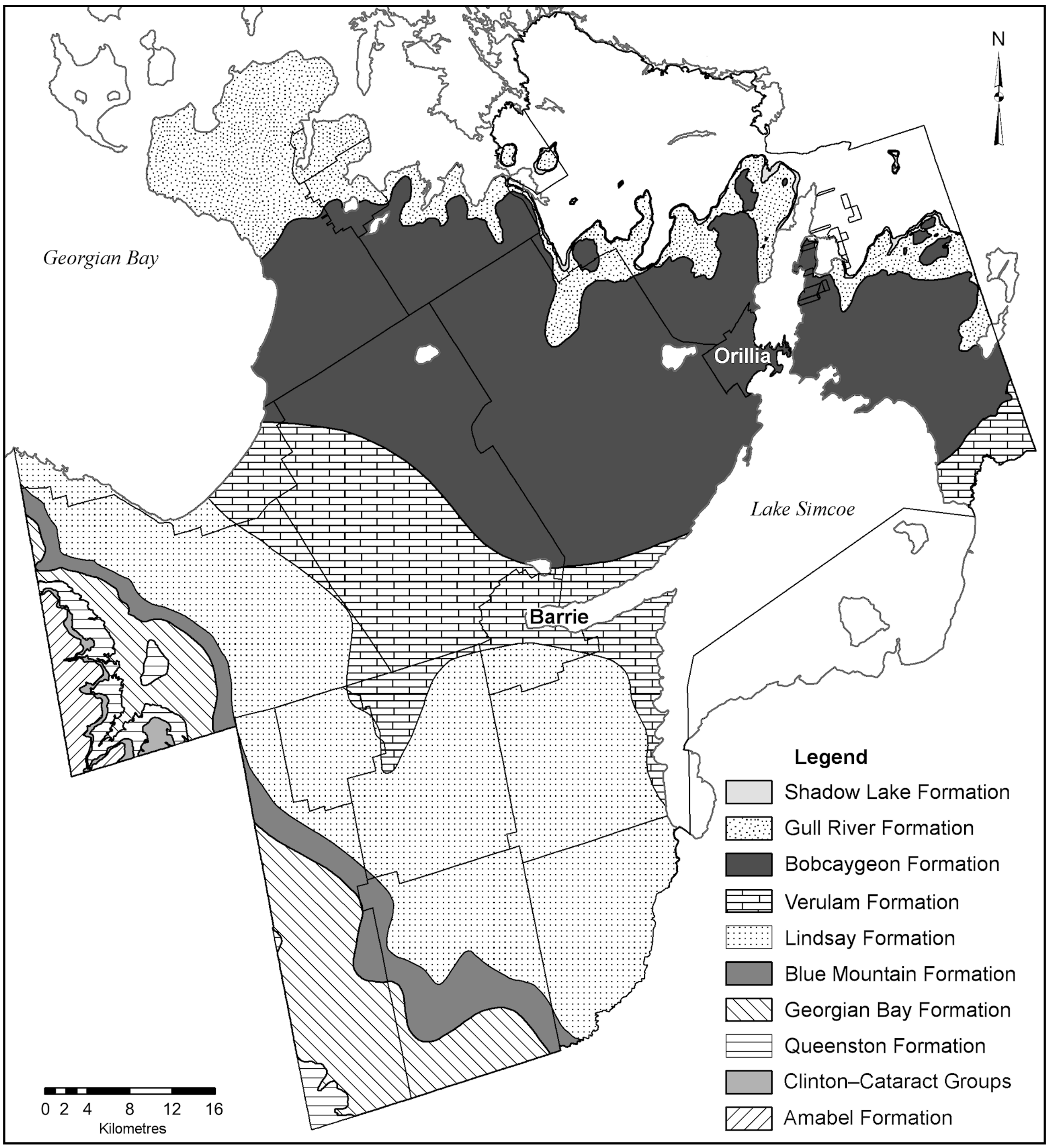

Figure 3. Bedrock geology in the County of Simcoe (*from* Armstrong and Dodge 2007).

grey to grey-brown, poorly fossiliferous, noncalcareous shale with thin, minor interbeds of limestone and siltstone (Johnson et al. 1992). This rock is unsuitable for road-building or construction aggregate. It has been exploited in the past as a local source of raw material for pottery and may represent a potential resource for brick or other heavy clay products where the overlying Quaternary sediments are thin (Guillet 1977).

The Blue Mountain Formation is conformably overlain by the Georgian Bay Formation. This formation is exposed in the western part of Simcoe County (*see* Figure 3), in the Township of Clearview and the Township of Adjala–Tosorontio. The formation consists of greenish to bluish-grey shale with interbedded limestone, siltstone and sandstone. The formation thickness varies from 125 to 200 m (Johnson et al. 1992). This formation has been used in the past as a source of raw material for manufacturing bricks in the Toronto area (Guillet 1977). It is not suitable for road-building or construction aggregate. Samples of the Georgian Bay Formation were collected as part of this study and analyzed at the Geoscience Laboratories. The geochemical results are presented in Table 11.

Overlying the Georgian Bay Formation are the brick red to maroon, noncalcareous to calcareous shales with subordinate amounts of green shale, siltstone, sandstone and limestone of the Queenston Formation (*see* Figure 3). The formation ranges in thickness from 50 m at the north end of the County of Bruce to over 300 m beneath Lake Erie. The Queenston shales are well suited for the production of structural clay products, such as brick and tile, and are a resource of provincial significance (Guillet and Joyce 1987). Shale has been extracted from quarries at the base of the Niagara Escarpment for this purpose since the turn of the century. These shales have low load-bearing strength and, therefore, are unsuitable for use as construction aggregate. (Photo 21 (ArcGIS® version only) shows the Queenston Formation located in an outcrop in the western part of Clearview Township.) Hamblin (2003) has logged in detail a roadcut in the Lavender area, which is predominantly Queenston Formation with a thin cap of Whirlpool Formation. Geochemical analysis, for samples of the Queenston Formation collected as part of this study, are presented in Table 11.

The Queenston Formation is unconformably overlain by the sandstones of the Whirlpool Formation or the dolostones of the Manitoulin Formation. The Whirlpool and Manitoulin formations, as well as the Cabot Head Formation, Reynales Formation and other minor formations, form the Clinton and Cataract groups, which form the face of the Niagara Escarpment. These formations generally have restricted lateral extent in the study area and are usually covered by more than 8 m of drift or talus, except for areas of outcrop and thin drift cover at the edge of the escarpment (*see* Figure 3).

The Whirlpool Formation is the lower unit of the Cataract Group. The formation has a thickness of 3 to 5 m (Hewitt 1960) and consists of thin- to massive-bedded, medium- to fine-grained calcareous quartz sandstone. The formation often forms a low terrace at the base of the escarpment. An old quarry (Quarry No. 4), west of Duntroon, exposes the Whirlpool–Queenston formation contact (OGS Drill Hole 80-01). Hamblin (2003) has logged this drill hole in detail. The Manitoulin Formation is a thin-bedded, blue-grey to buff-brown dolomitic limestone and dolostone. The Manitoulin Formation is reasonably resistant to erosion and, as a result, often forms minor scarps along the face of the Niagara Escarpment.

The Cabot Head Formation of the Cataract Group overlies the Manitoulin Formation. The formation occurs as a subcrop band in the face of the Niagara Escarpment and it is commonly covered with talus from the overlying dolostone units. The formation consists of reddish to greenish-grey shale with calcareous carbonate interbeds. The formation is known to be between 11 and 41 m thick (Liberty 1953). The shale is not suitable for aggregate use, but Vos (1975) has indicated the potential to use this unit for expanded light-weight aggregate, brick and tile. Rowell and Brunton (2011) have recently completed brick testing on a sample of Cabot Head Formation shale from the Bruce Peninsula. There are few areas where the Cabot Head Formation is exposed. No areas have been selected for possible resource protection.

The Fossil Hill Formation of the Clinton Group is a thin-bedded, brownish-grey, medium crystalline, fossiliferous dolostone (Johnson et al. 1992). The formation is poorly exposed, but available information suggests a thickness of approximately 4 to 5 m. There are no known exposures of the Fossil Hill Formation large enough to support the development of an extraction operation and no areas are recommended for protection.

The Ontario Geological Survey is in the midst of a multi-year project to revise the Silurian stratigraphy of southwestern Ontario and to delineate all key water-bearing units or aquifers and define the hydrogeologic properties of the strata. An important component of the project will be a review of the Silurian stratigraphy including a refinement of the various formations (Brunton 2009). The result of some of the early work from this project is the formal separation of the Amabel Formation into a series of formations (e.g., Gasport and Goat Island). Since this project has not yet been completed, this report will reference the Gasport and Goat Islands formations as the "unsubdivided Amabel Formation". The Amabel Formation is widely understood within the aggregate industry. Future work will incorporate the redefined and formally separated formations.

The brow and upper surface of the Niagara Escarpment is formed by the tough, erosion-resistant unsubdivided Amabel Formation (*see* Figure 3). The unsubdivided Amabel Formation consists mainly of medium crystalline, fossiliferous, medium- to massive-bedded dolostone that is well suited for the production of road-building and construction aggregate. It has also been used in high performance concrete and extracted for building and landscape stone elsewhere in the province. The unsubdivided Amabel Formation is considered to be an aggregate resource of provincial significance for these products.

Hewitt (1971) defines the base of the Niagara Escarpment generally as the point where the gradient of the slope changes from steep to gentle and overlies the Queenston Formation. Hewitt (1971) defines the brow of the Niagara Escarpment as the point where the gradient of the slope changes from gentle to steep and overlies the Amabel Formation. Because of the Algonquin Arch, the Creemore area is unique wherein Hewitt (1971) defines the base of the escarpment as overlying the Georgian Bay Formation (stratigraphically lower than the Queenston) and rising stratigraphically as high as the Guelph Formation.

Structurally, the Paleozoic rocks are relatively flat lying with the regional dip to the southwest as noted previously. A few small bedrock faults or small displacements were noted in the Township of Ramara. It is suggested that these are the result of vertical release following ice retreat because the positive topographic relief formed by these faults have not been destroyed by glaciation (Finamore 1984). White, Karrow and Macdonald (1974) have identified the effect of high horizontal residual stresses occurring in the rock close to surface. These horizontal stresses are attributed to the former presence of glacial ice.

Within the central portion of Simcoe County, and trending in a south to southeasterly direction from Georgian Bay to Lake Ontario, is a bedrock feature referred to as the buried Laurentian valley, briefly mentioned previously. In 1890, J.W.W. Spencer proposed that a major drainage valley existed between Georgian Bay and Lake Ontario, which is now buried by up to several hundred feet of overburden. This valley is approximately 100 km long and 25 km wide. This concept was based on the depth of many water-well records in the area and the resulting pattern that they formed. Wilson (1901) and Deane (1950) have suggested changes, provided additional information and modified Spencer's original work, but neither have discounted the concept and have only provided support for the idea. Studies by Davies, Holysh and Sharpe (2008) and Bajc and Rainsford (2010) have reconfirmed the presence of the buried valley, and are participating in a study to try to delineate the actual deep-river channels more accurately; the latest phase in this study is using a geophysical gravity survey. This buried valley would greatly influence the groundwater flow in this part of Simcoe County.

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 report 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 Precambrian rock is acceptable for the production of high-specification aggregate. An example of this is in the northern part of the Township of Ramara (Quarry No. 21). Precambrian bedrock is often quarried for use in the building and landscape stone industry. Of the Paleozoic rock formations that underlie the county, the Gull River, Bobcaygeon and Amabel formations are best suited for aggregate extraction and production.

Crushed stone from the Gull River Formation is extracted for a variety of aggregate uses in southern Ontario, including concrete, asphalt and granular base. 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). 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 non-reactive 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 blending 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.

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 (Rogers 1985). Ingham and Dunikowska-Koniuszy (1965) have studied the effects of chert in sand and gravel and in bedrock formations in southwestern Ontario. The shalier middle parts of the formation may not be as suitable for the production of concrete aggregate as the surrounding strata. As a result, selective extraction measures may be required for the production of concrete aggregate within the formation. The formation is generally well suited for most other aggregate uses including asphaltic stone and granular base.

Those areas of the unsubdivided Amabel Formation that are overlain by less than 8 m of overburden have been selected for possible resource protection. The Amabel Formation is a provincially significant aggregate resource and has been used to manufacture a variety of aggregate products, including crushed granular, asphalt and concrete products, building and landscape stone, and lime.

The soft and friable shales, siltstones, sandstones and conglomerates of the Shadow Lake Formation are unsuitable for most aggregate use. 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. The Lindsay Formation is used for aggregate production in eastern Ontario. The Verulam and Lindsay formations may be used to produce Portland cement. The Clinton and Cataract groups have not been selected for possible bedrock resource protection, although the use and importance of the formations that make up these groups to the building and landscape stone industry should not be dismissed. Other formations, such as the Queenston and the Guelph formations, have not been identified for possible resource protection; however, they are important and valuable industrial minerals. The Queenston Formation shale is well suited for the manufacture of structural clay products such as brick and tile (Rowell 2009; Rowell and Brunton 2011), whereas the Guelph Formation dolostone, because of its high chemical purity, is a valuable raw material for chemical and metallurgical stone (Kelly 1996). Geochemical results for unsubdivided Amabel Formation and Guelph Formation samples, collected as part of this study, are provided in Table 11. Aggregate test results for these samples are provided in Table 9.

BEDROCK EXTRACTIVE ACTIVITY

At the time of writing, there were 44 licenced and abandoned quarries located throughout Simcoe County of which 26 are licenced (Table 5). The total licenced area is 3192.16 ha, which includes a number of operations that are licenced as both a pit and quarry operation. Many of the quarry operations in Simcoe County do not produce aggregate for road-building and construction purposes, but are focussed on the landscaping and building stone industry. The landscape stone is often slabbed in a variety of thicknesses to meet market demand. Compressive strength testing on 2 samples of Gull River Formation indicated 25 708 psi (177.1 MPa) and 22 968 psi (158.2 MPa).

SELECTED BEDROCK RESOURCE AREAS

Areas with less than 8 m of overburden and overlying the Gull River Formation, the Bobcaygeon Formation and the unsubdivided Amabel Formation have been designated as selected bedrock resource areas because of the suitability of these formations in producing a wide range of aggregate products. These areas are identified on Maps 2A and 2B with a diagonal hachured pattern.

Selected Bedrock Resource Area 1

Selected Bedrock Resource Area 1 is an area where the Gull River Formation is overlain by less than 8 m of overburden. This selected bedrock resource area is generally located in the north end of the Township of Ramara, in the northeast corner of the Township of Severn and in the Township of Tay—generally along the Precambrian–Paleozoic contact. Outliers of the Gull River Formation are also included.

A sample of Gull River Formation (10DJR-0037), collected as part of this study, was submitted for aggregate testing. Results indicate a Petrographic Number value of 100.0 for HL and concrete. Micro-Deval abrasion loss, magnesium sulphate soundness, absorption capacity, bulk relative density and accelerated mortar bar expansion test results for this sample are all acceptable for a wide range of aggregate products (*see* Table 9; *see* Appendix E). Geochemical results for this sample are provided in Table 11. As noted previously, the lithology of the Gull River Formation can be variable, but, based on the geochemical results, this particular sample was predominantly limestone.

The total unlicenced area of Selected Bedrock Resource Area 1 is 10 725 ha. After consideration of cultural, physical and environmental constraints, this unlicenced area is reduced to 9141 ha. Assuming a conservative bedrock thickness of 15 m, the possible bedrock-derived aggregate resource of this selected area is 3632 million tonnes (Table 6).

Selected Bedrock Resource Area 2

Selected Bedrock Resource Area 2 stretches across the townships of Ramara and Severn in the northeast corner of Simcoe County. This is an area where there is less than 8 m of overburden overlying the Bobcaygeon Formation.

A sample of Bobcaygeon Formation (10DJR-0038) was submitted for aggregate testing as part of this study. Results indicate a Petrographic Number value of 107.4 for HL and concrete. Micro-Deval abrasion loss, magnesium sulphate soundness, absorption capacity, bulk relative density and accelerated mortar bar expansion test results for this particular sample are all acceptable for a wide range of aggregate products (*see* Table 9; *see* Appendix E). As discussed previously in this report, certain beds within the Bobcaygeon Formation can be alkali-silica reactive when used with Portland cement mix. In Table 11, one can readily see that the SiO_2 content of the Bobcaygeon Formation sample, collected as part of this study, is higher than the samples of Gull River, unsubdivided Amabel and Guelph formations, which were also tested as part of this study.

Selected Bedrock Resource Area 2 occupies a total unlicenced area of 21 158 ha. After considering cultural, physical and environmental constraints, this area is reduced to 15 815 ha. Assuming a conservative bedrock thickness of 15 m, possible bedrock-derived aggregate resources of this selected area are 6284 million tonnes (*see* Table 6).

Since the Paleozoic strata in southern Ontario are essentially a "layer cake", it is possible to extract the overlying Bobcaygeon Formation and continue to extract the underlying Gull River Formation. Certain bedrock areas within Simcoe County allow for this opportunity provided other considerations such as groundwater, quarry design and permitting issues can be addressed. This is also true for other Paleozoic strata. Two quarries, located in the south end of the Township of Ramara, have extracted the overlying Verulam Formation and are currently extracting the underlying Bobcaygeon Formation (Quarry Nos. 34 and 35).

Selected Bedrock Resource Area 3

Selected Bedrock Resource Area 3 is located along the western boundary of Simcoe County in the Township of Clearview. This is an area where there is less than 8 m of overburden overlying the unsubdivided Amabel Formation.

A sample of unsubdivided Amabel Formation (10DJR-0039) was submitted for aggregate testing as part of this study. Results indicate a Petrographic Number value of 104.3 for HL and concrete. Micro-Deval abrasion loss, magnesium sulphate soundness, absorption capacity, bulk relative density and accelerated mortar bar expansion test results for this sample are all acceptable for a wide range of aggregate products (*see* Table 9; *see* Appendix E). Geochemical results for this sample are presented in Table 11 and indicate that this particular sample was approximately 95.14% pure dolostone.

Selected Bedrock Resource Area 3 occupies a total unlicenced area of 3339 ha. After considering cultural, physical and environmental constraints, this area is reduced to 2547 ha, with a possible bedrock-derived aggregate resource of 1012 million tonnes (*see* Table 6), based on a conservative bedrock thickness of 15 m. This area will be significantly constrained by the Niagara Escarpment Development Plan.

A sample of Guelph Formation (10DJR-0040) was also collected for aggregate testing as part of this study; however, this sample was actually located immediately west of Simcoe County in the County of Grey. The results of these tests are provided in Table 9 and the geochemical results are presented in Table 11. The aggregate test results for this particular sample indicate that the Guelph Formation is not acceptable for many aggregate products. Of particular concern, as shown in Table 9, are the high Petrographic Number value, high absorption capacity test result and the high micro-Deval abrasion loss (fine aggregate) value.

SUMMARY

Eleven (11) sand and gravel resource areas have been selected at the primary resource level in Simcoe County. These selected resource areas have a total unlicenced area of 3325 ha with a possible resource area of 2404 ha after considering physical, cultural and environmental constraints. These resource areas have approximately 283.7 million tonnes of aggregate material (*see* Table 3). The majority of these primary deposits are located in the northern portion of Simcoe County. Most of these deposits have been a source of aggregate extraction for many years and many are beginning to become depleted of granular material.

The county also has considerable quantities of sand and gravel resources of secondary significance. Glaciofluvial outwash, ice-contact and glaciolacustrine beach deposits spread throughout the county add greatly to the overall aggregate resource supply. Many of the secondary deposits are nearing depletion (particularly in the southern part of the county) and may only be suitable for time-restricted, contract-specific wayside operations, that is, to provide limited quantities of granular material. Simcoe County is beginning to run out of good quality granular material. As noted previously in the production statistics, some areas of south Simcoe County no longer produce aggregate material (e.g., the Town of Bradford West Gwillimbury).

However, Simcoe County has large areas of possible bedrock-derived aggregate resources. The total unlicenced area is 35 223 ha with a possible resource area of 27 503 ha after cultural, physical and environmental constraints have been considered. This represents a bedrock resource of about 10 928 million tonnes (*see* Table 6).

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 Simcoe may be directed to the Earth Resources and Geoscience Mapping Section (formerly Sedimentary Geoscience 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].

Table 1 - Total Identified Sand and Gravel Resources, County of Simcoe			
1 Class Number	2 Deposit Type	3 Areal Extent (Hectares)	4 Original Tonnage (Million Tonnes)
Town of Collingwood			
2	G-IC	29.57	2.4
	S-LB	121.37	9.7
	S-LP	351.82	28.0
3	G-LB	22.67	0.8
	S-LB	225.38	8.0
4	S-LB	6.91	0.1
Subtotal		**757.72**	**48.9**
Township of Clearview (formerly Nottawasaga Tp. and Sunnidale Tp.)			
1	G-FL	1070.90	113.7
	G-IC	770.61	81.8
	S-FL-LD	1407.31	149.5
	S-IC	1063.55	112.9
	S-LP	4192.51	445.2
	S-OW	2324.79	246.9
2	G-IC	575.47	45.8
	G-LB	543.99	43.3
	G-OW	161.21	12.8
	S-AL	1002.82	79.9
	S-FL	92.82	7.4
	S-IC	266.83	21.3
	S-LB	41.78	3.3
	S-LP	6668.49	531.1
	S-OW	2467.64	196.5
3	G-IC	72.19	2.6
	G-LB	253.84	9.0
	G-OW	11.51	0.4
	S-AL	902.42	31.9
	S-IC	86.56	3.1
	S-LB	36.15	1.3
	S-LP	335.38	11.9
	S-OW	409.50	14.5
4	G-LB	29.55	0.5
	S-AL	6.63	0.1
	S-LP	9.72	0.2
Subtotal		**24 804.17**	**2167.1**
Town of Wasaga Beach			
1	S-LP	418.32	44.4
	S-WD	691.92	73.5
2	S-AL	192.45	15.3
	S-LB	2256.82	179.8
	S-LP	8.47	0.7
	S-WD	367.93	29.3
3	S-AL	18.56	0.7
	S-LB	3.23	0.1
Subtotal		**3957.70**	**343.7**
Township of Tiny			
1	G-IC	343.39	36.5
	G-LB	543.85	57.8
	S-IC	145.41	15.4
	S-LB	13.80	1.5

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

1 Class Number	2 Deposit Type	3 Areal Extent (Hectares)	4 Original Tonnage (Million Tonnes)
	S-LP	44.59	4.7
	S-WD	22.03	2.3
2	G-IC	17.67	1.4
	G-LB	1147.85	91.4
	S-AL	41.55	3.3
	S-IC	81.04	6.5
	S-LB	3797.87	302.5
	S-LP	13 342.71	1062.7
	S-OW	994.06	79.2
	S-WD	611.45	48.7
3	G-LB	49.63	1.8
	S-AL	377.38	13.4
	S-IC	245.75	8.7
	S-LB	718.09	25.4
	S-LP	463.26	16.4
	S-OW	780.72	27.6
	S-WD	73.81	2.6
4	S-AL	511.55	9.1
	S-LB	2.65	0.0
	S-LP	1.22	0.0
	S-WD	27.46	0.5
Subtotal		**24 398.79**	**1819.4**
Township of Tay			
1	G-IC	665.64	70.7
	G-LB	115.40	12.3
	S-LB	282.84	30.0
2	G-LB	22.27	1.8
	S-IC	58.58	4.7
	S-LB	389.97	31.1
	S-LP	5562.39	443.0
	S-OW	933.71	74.4
3	G-IC	6.34	0.2
	G-LB	147.87	5.2
	S-AL	63.12	2.2
	S-IC	146.77	5.2
	S-LB	140.36	5.0
	S-LP	1520.68	53.8
	S-OW	81.34	2.9
4	G-LB	10.70	0.2
	S-AL	1.37	0.0
	S-IC	16.00	0.3
	S-LP	12.97	0.2
Subtotal		**10 178.32**	**743.2**
Township of Springwater (formerly Flos Tp. and Vespra Tp.)			
1	G-IC	429.59	45.6
	G-LB	1539.66	163.5
	S-IC	1536.78	163.2
	S-LB	194.29	20.6
	S-LP	1907.46	202.6
	S-OW	2106.73	223.7
2	G-IC	514.93	41.0
	G-LB	114.84	9.1

Table 1 - Total Identified Sand and Gravel Resources, County of Simcoe			
1 Class Number	**2 Deposit Type**	**3 Areal Extent (Hectares)**	**4 Original Tonnage (Million Tonnes)**
	G-OW	270.22	21.5
	S-AL	249.14	19.8
	S-IC	206.76	16.5
	S-LB	880.61	70.1
	S-LP	11 342.35	903.4
3	G-IC	12.93	0.5
	G-LB	141.81	5.0
	S-AL	753.07	26.7
	S-FL-LD	55.05	1.9
	S-LB	130.73	4.6
	S-LD	360.72	12.8
	S-LP	35.85	1.3
4	G-LB	82.50	1.5
	S-FL-LD	3.29	0.1
	S-OW	533.84	9.4
Subtotal		**23 403.15**	**1964.6**
Township of Oro–Medonte (formerly Medonte Tp. and Oro Tp.)			
1	G-IC	963.46	102.3
	G-LB	53.08	5.6
	S-FL-LD	1057.38	112.3
	S-IC	324.32	34.4
	S-IC-SF	11 149.23	1184.0
	S-LP	296.93	31.5
2	G-IC	267.48	21.3
	G-LB	637.97	50.8
	S-AL	35.83	2.9
	S-IC	520.03	41.4
	S-LB	329.27	26.2
	S-LP	4959.06	395.0
3	G-IC	276.90	9.8
	G-LB	864.67	30.6
	S-AL	190.28	6.7
	S-FL-LD	207.29	7.3
	S-IC	322.87	11.4
	S-LB	57.19	2.0
	S-LP	1490.27	52.8
4	G-IC	57.20	10.1
	G-LB	211.33	37.4
	S-AL	3.13	0.6
	S-FL-LD	100.84	17.8
	S-IC	19.48	3.4
	S-LB	108.53	19.2
	S-LP	159.12	28.2
Subtotal		**24 663.14**	**2245.3**
Township of Severn (formerly Matchedash Tp. and Orillia Tp.)			
1	G-LB	146.79	15.6
	S-LB	1.85	0.2
2	G-LB	345.35	27.5
	S-IC	90.28	7.2
	S-LB	71.39	5.7
	S-LP	7191.99	572.8

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

1 Class Number	2 Deposit Type	3 Areal Extent (Hectares)	4 Original Tonnage (Million Tonnes)
3	G-LB	180.42	6.4
	S-AL	47.27	1.7
	S-IC	2.89	0.1
	S-LB	245.51	8.7
	S-LP	196.81	7.0
4	G-IC	28.95	0.5
	G-LB	120.59	2.1
	S-AL	3.99	0.1
	S-LB	185.04	3.3
	S-LP	948.19	16.8
Subtotal		**9807.31**	**675.6**
City of Orillia			
1	G-IC	26.64	2.8
	S-IC	96.88	10.3
2	G-LB	131.28	10.5
	S-LP	871.44	69.4
3	G-IC	3.22	0.1
	S-LB	34.31	1.2
	S-LP	13.59	0.5
4	G-LB	0.85	0.0
Subtotal		**1178.21**	**94.8**
Township of Adjala–Tosorontio (formerly Tosorontio Tp. and Adjala Tp.)			
1	G-OW	118.56	12.6
	S-AL	311.07	33.0
	S-FL	3474.78	369.0
	S-IC	6489.89	689.2
	S-LP	3822.97	406.0
	S-OW	5616.58	596.5
2	G-OW	1209.15	96.3
	S-AL	665.59	53.0
	S-IC	82.62	6.6
	S-LB	44.67	3.6
	S-LP	9.11	0.7
	S-OW	413.89	33.0
3	G-LB	2.99	0.1
	S-AL	97.14	3.4
	S-OW	6.17	0.2
Subtotal		**22 365.18**	**2303.3**
Township of Essa			
1	G-IC	30.92	3.3
	G-LB	166.89	17.7
	S-AL	575.00	61.1
	S-IC	152.70	16.2
	S-LP	10 738.02	1140.4
2	G-IC	249.95	19.9
	G-LB	358.26	28.5
	S-AL	632.85	50.4
	S-IC	91.95	7.3
	S-LB	263.07	21.0
	S-LP	588.56	46.9
	S-OW	141.13	11.2

Table 1 - Total Identified Sand and Gravel Resources, County of Simcoe			
1 Class Number	**2 Deposit Type**	**3 Areal Extent (Hectares)**	**4 Original Tonnage (Million Tonnes)**
3	G-IC	17.32	0.6
	G-LB	13.14	0.5
	S-AL	21.01	0.7
	S-FL	86.11	3.0
	S-LB	10.35	0.4
	S-LP	59.11	2.1
4	G-LB	12.01	0.2
	S-LP	6.46	0.1
Subtotal		**14 214.81**	**1431.6**
Town of Innisfil (formerly Innisfil Tp.)			
1	G-IC	970.29	103.0
	S-IC	37.28	4.0
	S-LP	2059.88	218.8
	S-OW	27.69	2.9
2	G-IC	2099.41	167.2
	G-LB	906.61	72.2
	S-FL	71.36	5.7
	S-IC	31.03	2.5
	S-LP	2052.17	163.5
	S-OW	85.08	6.8
3	G-IC	278.08	9.8
	G-LB	67.65	2.4
	S-AL	48.54	1.7
	S-FL	138.30	4.9
	S-LP	195.66	6.9
	S-OW	3.51	0.1
4	G-IC	8.03	1.4
	G-LB	19.89	3.5
	S-FL	5.34	0.9
	S-LP	18.06	3.2
Subtotal		**9123.86**	**781.5**
City of Barrie			
1	G-IC	441.89	46.9
	S-LP	1222.25	129.8
2	G-IC	1482.30	118.1
	G-LB	100.18	8.0
	S-FL	90.37	7.2
	S-LP	343.45	27.4
3	G-IC	34.32	1.2
	G-LB	460.70	16.3
	S-AL	24.27	0.9
	S-FL	48.70	1.7
Subtotal		**4248.43**	**357.4**
Town of New Tecumseth (formerly Tecumseth Tp.)			
1	S-FL	145.88	15.5
	S-IC	1609.43	170.9
	S-LP	8208.72	871.8
2	S-AL	717.86	57.2
	S-IC	111.81	8.9
	S-LP	425.63	33.9
	S-OW	39.06	3.1

Table 1 - Total Identified Sand and Gravel Resources, County of Simcoe			
1 Class Number	2 Deposit Type	3 Areal Extent (Hectares)	4 Original Tonnage (Million Tonnes)
3	S-AL	83.14	2.9
	S-IC	48.81	1.7
4	S-IC	0.94	0.2
Subtotal		**11 391.28**	**1166.1**
Town of Bradford West Gwillimbury (formerly West Gwillimbury Tp.)			
1	S-IC	1909.77	202.8
	S-LP	896.16	95.2
	S-OW	225.04	23.9
2	G-OW	157.53	12.5
	S-AL	301.61	24.0
	S-LP	1058.97	84.3
	S-OW	64.02	5.1
3	S-FL	44.53	1.6
Subtotal		**4657.63**	**449.5**
Township of Ramara (formerly Rama Tp. and Mara Tp.)			
1	G-IC	182.98	19.4
	S-LP	120.47	12.8
2	G-IC	450.26	35.9
	G-LB	23.69	1.9
	S-AL	50.11	4.0
	S-LP	6191.84	493.2
3	G-IC	12.57	0.4
	G-LB	56.23	2.0
	S-LP	619.99	21.9
	S-OW	3.48	0.1
4	S-LP	18.92	3.3
Subtotal		**7730.54**	**595.0**
TOTAL		**196 880.24**	**17 187.1**

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; FL = fluvial deposit; IC = undifferentiated ice-contact stratified drift;
LB = glaciolacustrine beach deposit; LD = glaciolacustrine delta; LP = glaciolacustrine plain;
OW = outwash; SF = subaqueous fan; WD = windblown deposit.

Table 2 - Sand and Gravel Pits, County of Simcoe

Pit. No	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Town of Collingwood					
Licenced					
1	Ken Winters Construction Ltd.	21.90	Variable	~35 - 50	Pit has been developed in an ice-contact deposit
Township of Clearview (formerly Nottawasaga Tp. and Sunnidale Tp.)					
Licenced					
2	The Corporation of the Township of Clearview	10.01	~2 - 3.5	~20 - 35	Pit has been developed in a beach deposit
3	Cedarhurst Quarries and Crushing Ltd.	32.58	~2 - 3.5	~20 - 35	Pit has been developed in a beach deposit
4	Lafarge Canada Inc.	109.11	~1- 3	~30 - 40	Pit has been developed in a beach deposit
5	Mike Croft Contracting Inc.	22.30	~3 - 6.5	~30 - 40	Pit has been developed in a beach deposit
6	Nelson Arnold and William Arnold	3.53	~5 - 8	~25 - 45	Pit has been developed in an ice-contact deposit
7	MacDonald Construction and Aggregates Ltd.	1.89	-	-	Pit has been rehabilitated and licence is to be surrendered
8	Ken Winters Construction Ltd.	13.09	~3 - 5.5	~25 - 45	Pit has been developed in an ice-contact deposit
9	1580478 Ontario Ltd.	24.80	-	-	No apparent activity
10	Stabb Sand and Gravel Ltd.	14.90	Variable	Variable	Pit has been developed in a beach deposit. Previous gradation tests indicate up to ~50% coarse aggregate. Most of the material left today is sand. Much of the original beach deposit has been extracted
11	Lafarge Canada Inc.	15.20	Variable	Variable	Similar to Pit 10
12	The Corporation of the Township of Clearview	13.64	Variable	Variable	Similar to Pit 10
13	Ralph Macdonald Construction Ltd.	11.01	Variable	Variable	Similar to Pit 10
14	Lafarge Canada Inc.	16.27	Variable	Variable	Similar to Pit 10
15	Ronald MacDonald and Larry MacDonald	5.36	Variable	Variable	Similar to Pit 10
16	Lafarge Canada Inc.	31.89	Variable	Variable	Similar to Pit 10
17	Lafarge Canada Inc.	148.00	~2 - 3.5	~35 - 55	Pit has been developed in a fluvial deposit
Unlicenced					
18	-	-	-	-	Pit has been rehabilitated
19	-	-	~2 - 3.5	~20 - 35	Old, overgrown pit, water in pit floor
20	-	-	-	~25 - 40	Old, badly overgrown pit
21	-	-	~2	~15 - 30	Small pit
22	-	-	~2.5 - 3.5	~15 - 25	
23	-	-	~4.5 - 6	~25 - 45	Pit located west of barn
24	-	-	~1 - 2.5	~25 - 45	Old, partially overgrown
25	-	-	~4.5 - 6	~35 - 50	Old, overgrown, partially rehabilitated
26	-	-	~2.5 - 3.5	~20 - 35	Small pit
27	-	-	~4.5 - 6	~25 - 45	Partially overgrown
28	-	-	~12 - 14	~0 - 10	Mainly sand
29	-	-	~4 - 7	~0 - 10	Mainly sand, pit is actually located in Provincial Park
30	-	-	~1.5 - 2.5	~20 - 35	Old, overgrown pit along beach ridge
31	-	-	~2 - 3	~30 - 40	Old, overgrown pit along beach ridge
Township of Tiny					
Licenced					
32	Lawrence Jules Duquette	12.20	~2.5 - 4.5	~0 - 10	Subaqueous fan deposit, mainly sand
33	Cyrille Gignac	10.52	~2 - 5	~0 - 10	Predominantly a sand deposit
34	Lafontaine Sand and Gravel Ltd.	55.56	Variable	Variable	Pit has been developed in a beach deposit
35	E. Mailloux Construction	68.40	Variable	Variable	Pit has been developed in a beach deposit
36	William D. Lediard	6.60	~3.5 - 7	~0 - 10	Predominantly a sand deposit
37	Eric Pauze Construction Ltd.	24.50	~5 - 14	Variable	Pit has been developed in a beach deposit
38	1356360 Ontario Inc.	9.30	-	~0 - 10	Predominantly a sand deposit, pit does not appear to be active

Table 2 - Sand and Gravel Pits, County of Simcoe

Pit. No	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
39	The Corporation of Township of Tiny	20.78	~2 - 5.5	~30 - 50	Pit has been developed in a beach deposit
40	Lawrence Moreau (Moreau Haulage)	16.33	Variable	~0 - 10	Predominantly a sand deposit
41	Ross E. Hastings	5.60	~2.5 - 4	~25 - 40	Pit has been developed in an outwash deposit
42	Cedarhurst Quarries and Crushing Ltd.	85.45	~9 - 13	~35 - 55	Pit has been developed in an ice-contact deposit
43	The Sarjeant Company Ltd.	52.74	-	~0 - 10	Under Application
Unlicenced					
44	-	-	~1.5	~15 - 25	Old, overgrown pit in beach deposit
45	-	-	~2.5 - 3.5	~15 - 25	Old, overgrown pit in beach deposit
46	-	-	~2.5 - 4	~40 - 50	Old pit in beach deposit
47	-	-	~ 2.5 - 3	~40 - 50	Old, overgrown pit in beach deposit
48	-	-	~2.5 - 4	~20 - 40	Beach deposit - now used for a stump dump
49	-	-	~2.5 - 3.5	~0 - 10	Old, overgrown pit in beach deposit
50	-	-	~2 - 3	~10 - 20	Beach deposit, mainly sand
51	-	-	~2.5 - 4	~5 - 15	Beach deposit, mainly sand
52	-	-	~1.5 - 2.0	~20 - 30	Old, overgrown pit in beach deposit
53	-	-	~1.5 - 2.5	~20 - 30	Old, overgrown pit in beach deposit
54	-	-	~3.5 - 4.5	Variable	Pit developed in ice-contact deposit
55	-	-	~4.5 - 6.5	~0 - 10	Mainly sand
56	-	-	~1 - 1.5	~0 - 10	Mainly sand
57	-	-	~3.5 - 5	~0 - 10	Mainly sand
58	-	-	~2.5 - 3.5	~0 - 10	Badly overgrown pit, mainly sand
Town of Penetanguishene					
Licenced					
59	William Lediard	16.04	Variable	~0 - 10	Pit has been developed in glaciolacustrine plain deposit
Town of Midland					
Licenced					
60	Morden Construction Inc.	22.98	~4.5 - 6	~0 - 10	Pit has been developed in glaciolacustrine plain deposit
61	Cedarhurst Quarries and Crushing Ltd.	70.66	~6 - 13	Variable	Pit has been developed in an ice-contact deposit, till is also present
Township of Tay					
Licenced					
62	Steve Duncan	12.10	Variable	~0 - 10	Mainly sand
63	1617113 Ontario Inc.	7.50	~5 - 7	Variable	Pit has been developed in an ice-contact deposit, till cap
64	Miller Paving Ltd.	20.23	~2 - 3	Variable	Small beach ridge, till is also present
65	Morden Construction Inc.	15.94	Variable	Variable	Pit has been developed in an ice-contact deposit
66	North Simcoe Aggregates Inc.	40.79	Variable	Variable	Pit has been developed in an ice-contact deposit
67	Gratrix Sand and Gravel Ltd.	42.70	Variable	Variable	Pit has been developed in an ice-contact deposit
68	948288 Ontario Inc.	6.27	Variable	~35 - 55	Pit has been developed in an ice-contact deposit
69	David Mattison	5.70	Variable	~0 - 10	Mainly sand
Unlicenced					
70	-	-	~1 - 1.5	~10 - 20	Old, badly overgrown pit
71	-	-	~5.5 - 6.5	~10 - 20	Old, badly overgrown pit, till
72	-	-	~2 - 3.5	~5 - 15	Old, badly overgrown pit
73	-	-	~2.5 - 3.5	~35 - 55	Old, badly overgrown pit
74	-	-	~2 - 3.5	~10 - 20	Old, badly overgrown pit
Township of Springwater (formerly Flos Tp. and Vespra Tp.)					
Licenced					
75	St. Marys Cement Inc.	18.47	Variable	Variable	Pit has been developed in a beach deposit
76	Elmvale Sand and Gravel Inc.	18.57	~3 - 8	~40 - 50	Pit has been developed in a beach deposit
77	Sherree L. Buchanan	17.80	~3 - 6	~40 - 50	Pit has been developed in a beach deposit
78	Elmvale Sand and Gravel Inc.	28.70	~5 - 11.5	~40 - 50	Pit has been developed in a beach deposit

Table 2 - Sand and Gravel Pits, County of Simcoe

Pit. No	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
79	The Corporation of the Township of Springwater	38.50	~3.5 - 5.5	~40 - 50	Pit has been developed in a beach deposit
80	Lafarge Canada Inc.	37.60	~5 - 11	~25 - 45	Pit has been developed in a buried ice-contact deposit
81	DG Sand and Gravel Inc.	12.11	~3 - 5.5	~25 - 45	Pit has been developed in a buried ice-contact deposit
82	DeGroot Sand and Gravel Ltd.	40.54	Variable	~30 - 50	Pit has been developed in a buried ice-contact deposit, dredging aggregate material
83	The Sarjeant Company Ltd.	64.00	Variable	~30 - 50	Pit has been developed in a buried ice-contact deposit, dredging aggregate material
84	796475 Ontario Ltd.	19.70	-	-	Beach deposit, pit has been rehabilitated
85	William Priest	23.00	Variable	Variable	Beach deposit
86	G. Priest Construction Ltd.	14.63	Variable	Variable	Beach deposit
87	G. Priest Construction Ltd.	19.43	Variable	Variable	Beach deposit
88	Lafarge Canada Inc.	21.40	Variable	-	Beach deposit, most of pit has been rehabilitated, a few stockpiles are still present
89	Hillway Equipment Ltd.	32.38	Variable	~25 - 35	Pit has been developed in an ice-contact deposit
90	St. Marys Cement Inc.	110.48	Variable, up to 12 m	~10 - 25	Pit has been developed in an ice-contact deposit
91	1693297 Ontario Inc.	20.25	~4 - 6.5	~30 - 45	Pit has been developed in a beach deposit
92	Dwayne Kneeshaw	16.02	~5.5 - 7	~30 - 40	Pit has been developed in a beach deposit
93	The Corporation of the Township of Springwater	20.63	Variable	~30 - 40	Pit has been developed in a beach deposit
94	Altona Feed and Supplies Ltd.	20.16	Variable	~ 30 - 40	Pit has been developed in a beach deposit
95	Keown and Corbett Masonary Ltd.	35.99	~3.5 - 5	~0 - 10	Pit has been developed in a beach deposit
96	Keown and Corbett Masonary Ltd.	28.86	~3.5 - 5	~0 - 10	Pit has been developed in a beach deposit
97	Eisses Brothers Ltd.	35.50	~3.5 - 5	~ 30 - 45	Pit has been developed in a beach deposit
98	The Corporation of the Township of Springwater	15.84	~3.5 - 5	~ 30 - 45	Pit has been developed in a beach deposit
99	Lafarge Canada Inc.	13.19	~4 - 8	~25 - 35	Pit has been developed in an ice-contact deposit
100	Lafarge Canada Inc.	8.46	~4 - 8	~25 - 35	Pit has been developed in an ice-contact deposit
101	1194233 Ontario Ltd.	20.24	~6 - 12	~15 - 30	Pit has been developed in an ice-contact deposit
102	Lafarge Canada Inc.	6.32	Variable	~15 - 30	Pit has been developed in an ice-contact deposit
Unlicenced					
103	-	-	~1.5	~0 - 10	Small pit, silty fine to medium sand
104	-	-	~1.5 - 2	~0 - 10	A couple of small pits located in a beach deposit, mainly sand
105	-	-	~1 - 1.5	~0 - 10	Old, badly overgrown pit
106	-	-	~2.5 - 3.5	~0 - 10	Old pit, mainly sand
107	-	-	~1 - 2.5	~5 - 15	Old, badly overgrown pit
108	-	-	~2 - 3	~5 - 15	Old, badly overgrown pit, mainly sand
109	-	-	~1 - 2	~ 40 - 50	Old, badly overgrown pit
110	-	-	~2 - 3	~ 25 - 35	Old, badly overgrown pit
111	-	-	~1 - 3	~30 - 40	Old pit located in beach deposit
112	-	-	~3 - 5.5	~25 - 35	Old pit located in beach deposit, used as a shooting range, another pit on south side of road
113	-	-	Variable	~10 - 20	Pit is partially rehabilitated, but still noticeable
114	-	-	~4 - 6.5	~30 - 45	Beach deposit, west end of pit has been rehabilitated, but east end of pit is still quite noticeable
115	-	-	Variable	~25 - 35	Pit is located in beach deposit
Township of Oro–Medonte (formerly Medonte Tp. and Oro Tp.)					
Licenced					
116	Mrs. Phyllis Truax	58.80	Variable	~25 - 40	Pit has been developed in a beach deposit
117	Douglas Bidmead	13.30	Variable	~25 - 40	Pit has been developed in a beach–ice-contact deposit. No recent extractive activity
118	Cedarhurst Quarries and Crushing Ltd.	40.90	Variable, ~6 - 20	~30 - 50	Pit has been developed in an ice-contact deposit, including an esker ridge

Table 2 - Sand and Gravel Pits, County of Simcoe

Pit. No	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
119	James Richardson	91.50	Variable, ~12 - 24	~30 - 50	Pit has been developed in an ice-contact deposit, including an esker ridge
120	The Corporation of the Township of Oro–Medonte	13.30	~4.5 - 8	~25 - 40	Pit has been developed in a beach deposit
121	Shirley Nash	4.14	Variable	~25 - 40	Pit has been developed in an ice-contact deposit
122	Cedarhurst Quarries and Crushing Ltd.	10.77	~2.5 - 5.5	~25 - 45	Pit has been developed in a beach–ice-contact deposit
123	Lafarge Canada Inc.	165.64	-	-	Pit is located along the Oro moraine. Pit development has not started yet
124	The Sarjeant Company Ltd.	43.82	-	-	Pit is located along the Oro moraine. Pit development has not started yet
125	Lafarge Canada Inc.	38.81	Variable	~35 - 55	Pit has been developed in the Oro moraine. Esker deposit
126	The Sarjeant Company Ltd.	42.90	Variable, up to ~24 m	~35 - 55	Pit has been developed in the Oro moraine. Esker deposit
127	Walker Aggregates Inc.	51.84	Variable, ~6 - 16	~35 - 55	Pit has been developed in the Oro moraine. Esker deposit
128	The Corporation of the Township of Oro–Medonte	25.04	Variable, ~9 - 16	~35 - 55	Pit has been developed in the Oro moraine. Esker deposit
129	Southview Asphalt and Aggregates Inc.	36.94	Variable, up to ~11 m	~35 - 55	Pit has been developed in the Oro moraine. Esker deposit
130	Rita Jonaitis	17.00	~ 3.5 - 6.5	~35 - 55	Pit has been developed in the Oro moraine. Esker deposit
131	Hillway Equipment Ltd.	112.58	Variable, up to ~11 m	~35 - 55	Pit has been developed in the Oro moraine. Esker deposit
132	Hillway Equipment Ltd.	20.78	Variable, up to ~9 m	~35 - 55	Pit has been developed in the Oro moraine. Esker deposit
133	Lafarge Canada Inc.	62.48	Variable, up to ~12 m	~35 - 55	Pit has been developed in the Oro moraine. Esker deposit
134	Hillway Equipment Ltd.	110.60	Variable, up to ~9 m	Variable	Pit has been developed in the Oro moraine. Esker deposit. Most of the coarse material has been extracted
135	Cedarhurst Quarries and Crushing Ltd.	40.90	-	-	Pit located along the eastern end of the Oro moraine
Unlicenced					
136	-	-	~1 - 2	~0 - 10	Small pit, silty fine sand
137	-	-	~1.5 - 2.5	~ 10 - 25	Old, badly overgrown pit in beach deposit
138	-	-	~2 - 4	~20 - 35	Old, badly overgrown pit in beach deposit
139	-	-	~4 - 5	~25 - 40	Old, badly overgrown pit in small ice-contact deposit
140	-	-	-	-	Pit has been rehabilitated, small stockpile present
141	-	-	~2.5 - 3.5	~35 - 55	Old, badly overgrown pit in small ice-contact deposit
142	-	-	~4.5 - 5.5	~0 - 10	Mainly medium to coarse sand
143	-	-	~2 - 3	~25 - 40	Ice-contact deposit
144	-	-	~3.5 - 4.5	~10 - 20	Ice-contact deposit, mainly sand
145	-	-	~7	~25 - 40	Ice-contact deposit, the old pit is still quite noticeable
146	-	-	~2.5 - 3.5	Variable	Ice-contact deposit, mounds of material
Township of Severn (formerly Matchedash Tp. and Orillia Tp.)					
Licenced					
147	Joseph B. Silk	10.45	~2 - 4.5	~0 - 10	Predominantly a source of sand
148	The Corporation of the Township of Severn	26.16	~2.5 - 4.5	~30 - 50	Pit has been developed in a beach–ice-contact deposit
149	Royel Paving Ltd.	34.12	-	Variable	Property licenced as both a pit and quarry operation
150	Royel Paving Ltd.	7.22	-	Variable	Property licenced as both a pit and quarry operation
151	J.W. (Pat) Paterson	4.73	~2.5 - 3.5	~0 - 10	Predominantly a source of sand
152	The Corporation of the Township of Severn	19.90	Variable, up to ~9 m	~35 - 55	Pit has been developed in a beach deposit
153	Cedarhurst Quarries and Crushing Ltd.	42.09	Variable, up to ~14 m	Variable	Pit has been developed in a beach deposit
154	Hillway Equipment Ltd.	28.50	Variable, up to ~6.5 m	Variable	Pit has been developed in a beach deposit. Varved clays showing along western boundary of pit

Table 2 - Sand and Gravel Pits, County of Simcoe

Pit. No	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Unlicenced					
155	-	-	~1.5 - 3	~20 - 35	Old, badly overgrown pit in beach deposit
156	-	-	~2 - 5	~20 - 35	Old, badly overgrown pit is still noticeable, beach deposit
157	-	-	~2 - 3.5	~0 - 10	Mainly sand, badly overgrown
158	-	-	~2.5 - 4.5	~20 - 35	Old, overgrown pit
159	-	-	Variable	~20 - 35	Pit is located in a beach deposit
City of Orillia					
Licenced					
160	Keith Smith Contracting Ltd.	5.43	Variable, up to ~9 m	~20 - 35	Pit has been developed in a beach deposit
Township of Adjala–Tosorontio (formerly Tosorontio Tp. and Adjala Tp.)					
Licenced					
161	Stephens and Company Glencairn Ltd.	20.58	~2.0 - 4.0	~15 - 25	Predominantly as source of sand
162	Victor Shanab	58.20	~2.0 - 4.0	~25 - 40	Pit has been developed in a fluvial deposit
163	The Corporation of the Township of Adjala–Tosorontio	14.49	~1.5 - 2	~25 - 40	Pit has been developed in a fluvial deposit
164	James Dick Construction Ltd.	36.90	Variable	Variable	Pit has been developed in the Oak Ridges Moraine
165	James Dick Construction Ltd.	158.76	Variable	Variable	Pit has been developed in the Oak Ridges Moraine
Unlicenced					
166	-	-	~1 - 1.5	~0 - 10	Small pit, mainly sand
167	-	-	~5 - 7	~15 - 25	Mainly sand, outwash deposit
168	-	-	~1 - 2	~20 - 35	Small pit, fluvial material
Township of Essa					
Licenced					
169	Munro Concrete Products Ltd.	13.00	Variable	~0 - 10	Small pit, mainly sand, part of a concrete plant–industrial area
170	The Corporation of the Township of Essa	8.20	Variable	~ 30 - 45	Pit has been developed in a beach deposit. Water in pit floor. Mainly a stockpile storage area
171	Glenn Lawrence and Jane King	19.10	Variable, up to ~6.5 m	~20 - 35	Small ice-contact deposit
172	The Corporation of the Township of Essa	12.60	-	-	Pit has generally been rehabilitated. Used for aggregate material storage
173	Anne and Brian Banting	11.90	-	-	Pit has generally been rehabilitated. One small sandy face to be rounded off
174	Russell et al.	8.49	~1 - 3	~10 - 20	Pit has been developed in a small beach deposit
175	Vanderpost Aggregate Inc.	15.85	~1 - 2.5	Variable	Pit has been developed in a beach deposit. Water in pit floor. Till material also present
176	Barbara and Gregg Fullarton	25.13	-	-	Unopened during the 2010 field season
177	James Brian Ross	19.97	2.5 - 5.5	~ 20 - 45	Pit has been developed in a beach deposit. Water in pit floor
Unlicenced					
178	-	-	-	-	Pit is being rehabilitated during summer 2010
179	-	-	-	-	Old pits partially water filled, beach deposit
180	-	-	-	~20 - 35	Old pit located behind township office - used for stump dump
181	-	-	~2 - 3.5	~0 - 10	Outwash deposit, mainly fine to medium sand
Town of Innisfil (formerly Innisfil Tp.)					
Licenced					
182	The Corporation of the Town of Innisfil	8.11	Variable, up to ~12 m	~20 - 35	Pit has been developed in a beach deposit. Pit is overgrown. Used for fill and stump dump
183	Thomas William Bowman	20.48	~3.5 - 5.5	~0 - 10	Predominantly a source of sand
184	1386084 Ontario Ltd.	16.81	-	~0 - 10	Pit has been developed in a glaciolacustrine plain deposit. Predominantly a source of sand
185	John Eek	4.07	-	~15 - 25	Property has been rehabilitated and licence surrendered

Table 2 - Sand and Gravel Pits, County of Simcoe

Pit. No	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Unlicenced					
186	-	-	~1.5 - 3	~10 - 20	Beach deposit, old pit - partially rehabilitated
187	-	-	~1.5 - 3	~10 - 20	Beach deposit, old pit - partially rehabilitated
188	-	-	~2.5 - 4	~30 - 50	Old, overgrown pit in ice-contact deposit
189	-	-	Variable	~0 - 10	Old pit, partially rehabilitated?
190	-	-	~1.5 - 2	~10 - 20	Old, small pit
191	-	-	~3.5 - 6	~0 - 10	Ice-contact deposit
192	-	-	-	~15 - 25	Old, badly overgrown pit
193	-	-	-	~15 - 25	Old, badly overgrown pit
Town of New Tecumseth (formerly Tecumseth Tp.)					
Licenced					
194	The Corporation of the Town of New Tecumseth	22.50	~2.5 - 3.5	~0 - 10	Mainly a source of sand
195	George E. Elmer	6.88	~2.5 - 5.5	~20 - 40	Outwash deposit
196	North Rock Group Ltd.	15.12	~2.5 - 5.5	~20 - 40	Outwash deposit
197	David Wilson	13.23	Variable, up to ~16 m	~0 - 10	Pit has been developed in the Oak Ridges Moraine
198	Terra-Rock Holdings Inc.	21.00	Variable	Variable	Pit has been developed in an ice-contact deposit. Industrial building up for sale
Unlicenced					
199	-	-	~2.5 - 3.5	~10 - 20	Old, overgrown pit
Town of Bradford West Gwillimbury (formerly West Gwillimbury Tp.)					
Licenced					
200	The Corporation of the Town of Bradford West Gwillimbury	9.00	~1.5 - 3.5	~0 - 10	Beach deposit (tombolo). Mainly a source of sand. Being used for fill and storage
Unlicenced					
201	-	-	~2.5 - 3	~0 - 10	Old, overgrown pit
202	-	-	Variable	Variable	Till material
203	-	-	~1.5 - 3	Variable	Old, badly overgrown pit, till material
204	-	-	~1 - 2.5	~15 - 25	Old, badly overgrown pit
205	-	-	~2 - 2.5	~15 - 25	Old, overgrown pit, ice-contact material
Township of Ramara (formerly Rama Tp. and Mara Tp.)					
Licenced					
206	Darren Bunker	9.07	~2.5 - 3.5	~5 - 15	Mainly a source of sand
207	Darren Bunker	24.29	~2.5 - 3.5	~5 - 15	Mainly a source of sand
208	Joe Carrick	10.06	~4.5 - 6.5	~5 - 15	Mainly a source of sand
209	1693352 Ontario Ltd.	11.92	~2.5 - 3.5	~0 - 10	Mainly a source of sand
210	Jason and Janet Camartin	8.44	~2.5 - 3.5	~0 - 10	Mainly a source of sand
211	Joe Carrick	36.70	~2.5 - 3.5	~5 - 15	Mainly a source of sand, till on east side of property
212	Cut Above Natural Stone	57.20	-	-	Licenced as both a pit and quarry operation
213	Robert Hamilton	29.20	~3 - 6.5	~5 - 15	Mainly a source of sand
214	Keith Smith Contracting Ltd.	9.86	-	Variable	Till material
215	Thomas Stan McCarthy and Barbara McCarthy	80.08	~1 - 1.5	~20 - 35	Licenced as both a pit and quarry operation
Unlicenced					
216	-	-	~1 - 1.5	~15 - 20	Small, badly overgrown pit. Part of small esker deposit
217	-	-	~1 - 2.5	~5 - 15	Material grades from fines to gravel
218	-	-	~1 - 1.5	~0 - 10	Fine sand and silt
219	-	-	~1 - 2.5	~5 - 15	Badly overgrown
220	-	-	~1 - 2.5	~5 - 15	Badly overgrown, water in pit floor
221	-	-	~1 - 3	~5 - 15	Part of esker deposit, water in pit floor
222	-	-	~1 - 3	~5 - 15	Mainly sand, badly overgrown

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

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	468.5	67.1	0.0	401.4	8	56.8
2	708.8	328.4	0.0	380.4	8	53.9
3	114.7	17.0	1.7	96.0	6	10.2
4	234.5	29.1	0.0	205.5	8	29.1
5	20.0	4.0	0.0	16.1	5	1.4
6	89.7	20.7	0.0	69.1	8	9.8
7	1190.5	265.0	37.8	887.7	5	78.6
8	175.3	105.3	2.8	67.3	8	9.5
9	171.2	4.9	3.1	163.2	8	23.1
10	27.3	0.0	0.0	27.3	7	3.4
11	124.1	24.3	10.1	89.7	5	7.9
Total	**3324.8**	**865.6**	**55.5**	**2403.6**		**283.7**

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 4 - Total Identified Bedrock Resources, County of Simcoe

1 Drift Thickness (Metres)	2 Formation	3 Estimated Deposit Thickness (Metres)	4 Areal Extent (Hectares)	5 Original Tonnage (Million Tonnes)
Town of Collingwood				
<1	Lindsay	15	165.06	65.6
1-8	Lindsay	15	1896.15	753.4
8-15	Lindsay	15	270.30	107.4
Subtotal			**2331.51**	**926.4**
Township of Clearview (formerly Nottawasaga Tp. and Sunnidale Tp.)				
<1	Lindsay	15	16.38	6.5
1-8	Lindsay	15	527.79	209.7
8-15	Lindsay	15	666.57	264.9
<1	Georgian Bay	15	134.53	48.6
1-8	Georgian Bay	15	279.95	101.1
8-15	Georgian Bay	15	493.71	178.3
<1	Queenston	15	116.53	42.1
1-8	Queenston	15	818.38	295.6

Table 4 - Total Identified Bedrock Resources, County of Simcoe				
1 Drift Thickness (Metres)	**2 Formation**	**3 Estimated Deposit Thickness (Metres)**	**4 Areal Extent (Hectares)**	**5 Original Tonnage (Million Tonnes)**
8-15	Queenston	15	1716.99	620.2
<1	Clinton-Cataract Groups	15	37.55	14.9
1-8	Clinton-Cataract Groups	15	853.60	339.2
8-15	Clinton-Cataract Groups	15	367.95	146.2
<1	Amabel	15	240.05	95.4
1-8	Amabel	15	3264.66	1297.2
1-8	Amabel	15	1027.65	408.3
Subtotal			**10 562.29**	**4068.2**
Township of Tiny				
1-8	Gull River	15	11.65	4.6
8-15	Gull River	15	156.85	62.3
Subtotal			**168.50**	**67.0**
Township of Tay				
<1	Shadow Lake	10	110.65	26.6
<1	Gull River	15	338.90	134.7
1-8	Gull River	15	322.89	128.3
8-15	Gull River	15	206.34	82.0
Subtotal			**978.78**	**371.6**
Township of Oro–Medonte (formerly Medonte Tp. and Oro Tp.)				
1-8	Gull River	12	40.88	13.0
8-15	Gull River	12	37.58	11.9
1-8	Bobcaygeon	12	0.89	0.3
8-15	Bobcaygeon	12	12.52	4.0
Subtotal			**91.87**	**29.2**
Township of Severn (formerly Matchedash Tp. and Orillia Tp.)				
<1	Shadow Lake	10	75.29	18.1
1-8	Shadow Lake	10	600.38	144.6
8-15	Shadow Lake	10	69.33	16.7
<1	Gull River	12	440.17	139.9
1-8	Gull River	12	5569.07	1770.3
8-15	Gull River	12	1329.94	422.8
<1	Bobcaygeon	15	223.59	88.8
1-8	Bobcaygeon	15	1011.80	402.0
8-15	Bobcaygeon	15	365.67	145.3
Subtotal			**9685.24**	**3148.6**
Township of Adjala–Tosorontio (formerly Tosorontio Tp. and Adjala Tp.)				
<1	Georgian Bay	15	5.97	2.2
1-8	Georgian Bay	15	115.33	41.7
8-15	Georgian Bay	15	145.45	52.5
<1	Queenston	15	6.78	2.4
1-8	Queenston	15	28.65	10.3
8-15	Queenston	15	60.14	21.7
Subtotal			**362.32**	**130.9**

Table 4 - Total Identified Bedrock Resources, County of Simcoe

1 Drift Thickness (Metres)	2 Formation	3 Estimated Deposit Thickness (Metres)	4 Areal Extent (Hectares)	5 Original Tonnage (Million Tonnes)
Township of Ramara (formerly Rama Tp. and Mara Tp.)				
<1	Shadow Lake	10	8.45	2.0
1-8	Shadow Lake	10	390.79	94.1
<1	Gull River	15	1769.51	703.1
1-8	Gull River	15	3787.47	1505.0
8-15	Gull River	15	20.27	8.1
<1	Bobcaygeon	15	1615.37	641.9
1-8	Bobcaygeon	15	18 911.42	7514.5
8-15	Bobcaygeon	15	1546.39	614.5
<1	Verulam	15	368.11	146.3
1-8	Verulam	15	3620.81	1438.7
8-15	Verulam	15	225.43	89.6
Subtotal			**32 264.02**	**12 757.6**
TOTAL			**56 444.53**	**21 499.4**

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 Simcoe

Quarry No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	Remarks
Town of Collingwood				
Unlicenced				
1	-	-	~1.5	Small, badly overgrown quarry
Township of Clearview (formerly Nottawasaga Tp. and Sunnidale Tp.)				
Licenced				
2	Georgian Aggregates and Construction Inc	127.02	-	Unopened. Under application
3	Walker Aggregates Inc.	57.50	~17 - 22	Quarry produces a number of high-quality aggregate products from the unsubdivided Amabel Formation
Unlicenced				
4	-	-	~7 - 10	Badly overgrown quarry. Quarry is significant because it exposes the contact between the Whirlpool and Queenston formations
Township of Tay				
Licenced				
5	Lafarge Canada Inc.	274.10	~10 - 12	Extracting the Gull River Formation
Unlicenced				
6	-	-	~6 - 9	The former Canada Iron Furnace Company of Midland extracted the lower and middle members of the Gull River Formation. Partially overgrown. Water covering quarry floor

Table 5 - Quarries, County of Simcoe

Quarry No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	Remarks
Township of Severn (formerly Matchedash Tp. and Orillia Tp.)				
Licenced				
7	Nelson Aggregate Company	590.15	~10 - 21	Extracting both the Gull River and Bobcaygeon formations
8	MAQ Aggregates Inc.	81.00	-	Quarry development is just beginning
9	MAQ Aggregates Inc.	20.00	-	Licence amalgamated, and adjoining, with Quarry No. 8
10	Rockleith Quarry Ltd.	12.89	Variable	Extracting the Gull River Formation
11	Walker Aggregates Inc.	178.80	~8 - 11	Extracting the Gull River Formation
12	Royel Paving Ltd.	34.12	~2 - 6	Extracting the Gull River Formation. Licenced as both a pit and quarry operation
13	Royel Paving Ltd.	7.22	~2 - 6	Extracting the Gull River Formation. Licenced as both a pit and quarry operation. Exposes the Shadow Lake Formation
Unlicenced				
14	-	-	~7 - 12	Extracted both the Gull River and Bobcaygeon formations
15	-	-	~2 - 4	Extracted the Gull River Formation
16	-	-	~1.5	Extracted the Gull River Formation
17	-	-	~6 - 7.5	Extracted both the Gull River and Bobcaygeon formations
18	-	-	~1	Extracted the Gull River Formation
19	-	-	~2.5	Extracted the Gull River Formation
20	-	-	~2.5	Extracted the Gull River Formation
Township of Ramara (formerly Rama Tp. and Mara Tp.)				
Licenced				
21	Rama Stone Quarries Ltd.	18.19	-	Precambrian bedrock quarry
22	Fowler Construction Company Limited	23.52	~5 - 9	Extracting the Gull River Formation
23	Stone Cottage Inn Limited	49.67	~1 - 3	Landscape stone operation
24	Lamb Quarries	7.98	~4 - 6	Landscape stone operation
25	Diane E. Speiran	15.86	~1 - 3	Landscape stone operation
26	Cut Above Natural Stone	57.20	~1 - 3	Landscape stone operation. Licenced as both a pit and quarry operation
27	John DiPoce	40.35	-	Under Application
28	1300488 Ontario Limited	150.00	~1 - 3	Landscape stone operation
29	Attia Quarry	150.00	~1 - 3	Landscape stone operation
30	James Dick Construction Limited	359.17	-	Quarry development is just beginning
31	James Dick Construction Limited	90.23	-	Quarry development is just beginning
32	BOT Aggregates Limited	37.92	-	Extracting slabs of Gull River Formation. Aggregate operation is just beginning
33	BOT Aggregates Limited	37.92	-	Extracting slabs of Gull River Formation. Aggregate operation is just beginning
34	Lafarge Canada Inc.	332.10	24.8	Quarry exposes Bobcaygeon and Verulam formations
35	Limestone Aggregates Limited	90.23	10.5	Quarry exposes Bobcaygeon and Verulam formations
36	Thomas Stan McCarthy and Barbara McCarthy	80.08	-	Licenced as both a pit and quarry operation. Under application for quarry operation
Unlicenced				
37	-	-	~5 - 8	Extracted both the Gull River and Bobcaygeon formations as a source of building stone (“Rama” and “Longford” stone)
38	-	-	~5 - 8	Extracted both the Gull River and Bobcaygeon formations as a source of building stone (“Rama” and “Longford” stone)
39	-	-	-	
40	-	-	~5	Quarry is located just north of the road
41	-	-	-	Small, abandoned quarry
42	-	-	-	Small quarry is filled with water
43	-	-	~2 - 3	Small, abandoned quarry
44	-	-	~0.5 - 1	Small, abandoned quarry. Middle member of the Bobcaygeon Formation

Table 6 - Selected Bedrock Resources Areas, County of Simcoe

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)
Gull River Formation							
1	0 - 8	10 725.08	1573.09	11.27	9140.72	15.0	3632.1
Bobcaygeon Formation							
2	0 - 8	21 158.32	5340.39	3.21	15 814.72	15.0	6284.0
Amabel Formation							
3	0 - 8	3339.45	792.10	0.00	2547.35	15.0	1012.2
TOTAL		**35 222.85**	**7705.58**	**14.48**	**27 502.79**		**10 928.2**

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 (such as abandoned and wayside quarries), are largely depleted.

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

Table 7 - Summary of Borehole Data, County of Simcoe

Borehole Number	Generalized Description of Material
B.90-05	*UTM: 604954m E 4939335m N, NAD83,m N, NAD83, Zone 17* *Elevation: ~265 m* ~1 m of fine to medium sand ~1.5 m of silt with occasional beds of clay ~6.5 m of fine to medium sand with silt and clay beds **End of Hole**
B.90-06	*UTM: 602536m E 4938027m N, NAD83, Zone 17* *Elevation: ~312 m* ~1.5 m of sand ~0.3 m of till ~2 m of sand ~3 m of interbedded silt and fine to medium sand ~1 m of gravel **End of Hole**
B.90-07	*UTM: 603132m E 4937057m N, NAD83, Zone 17* *Elevation: ~250 m* ~3 m of fine to medium sand with occasional beds of silt and clay ~8.5 m of silt **End of Hole**

Table 7 - Summary of Borehole Data, County of Simcoe	
Borehole Number	**Generalized Description of Material**
B.90-08	*UTM: 612954m E 4933116m N, NAD83, Zone 17* *Elevation: ~358 m* ~2.5 m of fine to coarse sand with occasional gravel beds ~4.5 m of sand and gravel ~1.5 m of fine to medium sand **End of Hole**
B.90-09	*UTM: 614956m E 4928979m N, NAD83, Zone 17* *Elevation: ~305 m* ~1 m of fill ~0.3 m of sand ~6 m of till **End of Hole**
B.90-10	*UTM: 601402m E 4906755m N, NAD83, Zone 17* *Elevation: ~305 m* ~1.5 m of sand and gravel ~0.6 m of sand ~1 m of sand and gravel ~6.5 m of sand with occasional beds of gravel ~1.5 m of silt ~2 m of till **End of Hole**
B.90-14	*UTM: 617280m E 4946055m N, NAD83, Zone 17* *Elevation: ~256 m* ~1.5 m of medium to coarse sand ~0.3 m of gravel ~0.6 m of till ~0.6 m of coarse sand > 10.5 m of till **End of Hole**
B.90-15	*UTM: 615779m E 4927017m N, NAD83, Zone 17* *Elevation: ~290 m* ~7 m of till ~1 m of sand **End of Hole**
BH-03-AKB-2004	*UTM: 618423m E 4927400m N, NAD83, Zone 17* *Elevation: 274 m* ~26 m of till with occasional beds of sand ~8 m of till **End of Hole**
BH-06-AKB-2004	*UTM: 605129m E 4931419m N, NAD83, Zone 17* *Elevation: 366 m* ~42 m of interbedded sand, gravelly sand and gravel with occasional till beds **End of Hole**
BH-11-AKB-2004	*UTM: 603664m E 4941614m N, NAD83, Zone 17* *Elevation: 341 m* ~15 m of interbedded till and gravelly sand ~19 m of silt and fine sand **End of Hole**

Table 7 - Summary of Borehole Data, County of Simcoe

Borehole Number	Generalized Description of Material
BH-13-AKB-2004	*UTM: 607521m E 4925633m N, NAD83, Zone 17* *Elevation: 250 m* ~7 m of till ~10 m of sand, gravelly sand ~2 m silt and clay ~1 m of till ~1 m of silt and clay ~2 m of till **End of Hole**
BH-18-AKB-2004	*UTM: 607990m E 4940029m N, NAD83, Zone 17* *Elevation: 240 m* ~13 m of medium to coarse sand and gravelly sand ~22 m of fine to medium sand and silt **End of Hole**
BH-19-AKB-2004	*UTM: 612248m E 4934589m N, NAD83, Zone 17* *Elevation: 339 m* ~2 m of sand and gravelly sand ~5 m of till ~7 m of fine sand and silt ~12 m of silt and fine sand ~13 m of silt and clay **End of Hole**
BH-20-AKB-2005	*UTM: 599187m E 4929796m N, NAD83, Zone 17* *Elevation: 238 m* ~5 m of sand ~2 m of gravel ~3 m of silt and clay ~34 m of interbedded silt and very fine to medium sand with occasional clay layers **End of Hole**
BH-21-AKB-2005	*UTM: 595453m E 4935155m N, NAD83, Zone 17* *Elevation: 290 m* ~9.5 m of till ~24.5 m of interbedded fine to medium sand and silt **End of Hole**
BH-22-AKB-2005	*UTM: 616827m E 4936063m N, NAD83, Zone 17* *Elevation: 327 m* ~22 m of gravel, sandy gravel and sand ~8 m of till **End of Hole**
BH-23-AKB-2005	*UTM: 620415m E 4938324m N, NAD83, Zone 17* *Elevation: 291 m* ~4 m of till ~34 m of fine to medium sand with occasional silt and clay beds **End of Hole**
BH-24-AKB-2005	*UTM: 621012m E 4952873m N, NAD83, Zone 17* *Elevation: 197 m* ~5 m of silt and clay ~0.5 m of till Precambrian Bedrock **End of Hole**

Table 7 - Summary of Borehole Data, County of Simcoe	
Borehole Number	**Generalized Description of Material**
BH-25-AKB-2005	*UTM: 607988m E 4944928m N, NAD83, Zone 17* *Elevation: 196 m* ~9.5 m of silt and clay with occasional beds of sand ~0.5 m of till ~1.5 m of gravel Paleozoic Bedrock **End of Hole**
BH-26-AKB-2005	*UTM: 612856m E 4939849m N, NAD83, Zone 17* *Elevation: 296 m* ~6 m of till ~4 m of sand, silt and till ~30 m of silt and clay with occasional sand beds **End of Hole**
BH-27-AKB-2006	*UTM: 600624m E 4923215m N, NAD83, Zone 17* *Elevation: 284 m* ~0.75 m of sand ~7.25 m of till with occasional beds of silt and sand ~14 m of fine to medium sand with occasional beds of silt and gravelly sand **End of Hole**
BH-28-AKB-2006	*UTM: 595724m E 4926355m N, NAD83, Zone 17* *Elevation: 237 m* ~1.5 m of gravel ~3.5 m of sand and silty sand ~3 m of silt and clay ~6 m of till ~12 m of sand with occasional beds of gravel **End of Hole**
BH-29-AKB-2006	*UTM: 612977m E 4921140m N, NAD83, Zone 17* *Elevation: 263 m* ~10 m of till with occasional beds of sand ~14 m of fine to medium sand with occasional till beds **End of Hole**
BH-30-AKB-2006	*UTM: 612147m E 4943667m N, NAD83, Zone 17* *Elevation: 298 m* ~8 m of till with occasional beds of sand ~22 m of interbedded sand and silty sand with occasional beds of clay **End of Hole**
BH-31-AKB-2006	*UTM: 599320m E 4921063m N, NAD83, Zone 17* *Elevation: 236 m* ~30 m of medium to coarse sand with occasional beds of silt **End of Hole**
BH-32-AKB-2006	*UTM: 609032m E 4928931m N, NAD83, Zone 17* *Elevation: 320 m* ~48 m of till **End of Hole**
BH-33-AKB-2006	*UTM: 619529m E 4931889m N, NAD83, Zone 17* *Elevation: 285 m* ~4 m of till ~4 m of interbedded till and clay ~9 m of interbedded sand and gravel

Table 7 - Summary of Borehole Data, County of Simcoe

Borehole Number	Generalized Description of Material
	~5 m of till with occasional beds of sand and gravel ~16 m of fine to coarse sand and occasional beds of gravel **End of Hole**
BH-34-AKB-2006	*UTM: 599542m E 4941656m N, NAD83, Zone 17* *Elevation: 240 m* ~27 m of interbedded coarse sand and silty sand with occasional beds of till **End of Hole**
BH-35-AKB-2006	*UTM: 594998m E 4942859m N, NAD83, Zone 17* *Elevation: 302 m* ~1 m of fine sand ~5 m of till ~64 m of fine to coarse sand with occasional beds of silt and gravel **End of Hole**
BH-36-AKB-2006	*UTM: 607033m E 4936056m N, NAD83, Zone 17* *Elevation: 337 m* ~7 m of fine to medium sand with occasional gravel, silt and till beds ~16 m of till with occasional sand beds ~9 m of silt and clay with occasional till beds **End of Hole**
BH-37-AKB-2006	*UTM: 610966m E 4927024m N, NAD83, Zone 17* *Elevation: 290 m* ~8 m of till with occasional silt and sand beds ~32 m of till with occasional clay beds **End of Hole**
BH-01-SRS-2004	*UTM: 603560m E 4926495m N, NAD83, Zone 17* *Elevation: 254 m* ~6 m of till ~9 m of sand, gravelly sand and gravel with occasional till beds **End of Hole**
BH-02-SRS-2004	*UTM: 605451m E 4919003m N, NAD83, Zone 17* *Elevation: 229 m* ~1 m of fill ~8 m of till ~38 m of sand and gravelly sand **End of Hole**
BH-05-SRS-2004	*UTM: 613633m E 4931161m N, NAD83, Zone 17* *Elevation: 303 m* ~10 m of interbedded sand, gravelly sand and gravel ~4 m of till ~8 m of interbedded sand and silt ~24 m of interbedded gravelly sand, gravel and sand with occasional till beds **End of Hole**
BH-08-SRS-2004	*UTM: 600289m E 4934865m N, NAD83, Zone 17* *Elevation: 247 m* ~8 m of sand and gravelly sand ~8 m of silt and clay with occasional sand beds ~32 m of interbedded sand, gravelly sand and gravel **End of Hole**

Table 7 - Summary of Borehole Data, County of Simcoe	
Borehole Number	**Generalized Description of Material**
BH-09-SRS-2004	*UTM: 603641m E 4937451m N, NAD83, Zone 17* *Elevation: 260 m* ~36 m of sand and sandy gravel with occasional clay beds **End of Hole**
BH-15-SRS-2004	*UTM: 624463m E 4950058m N, NAD83, Zone 17* *Elevation: 256 m* ~1 m of fill ~9 m of till with occasional beds of sand ~17 m of interbedded fine sand and silt with occasional beds of clay ~2 m of till **End of Hole**
BH-16-SRS-2004	*UTM: 609607m E 4933022m N, NAD83, Zone 17* *Elevation: 360 m* ~17 m of interbedded sand, gravelly sand and gravel with occasional till and silt beds ~1 m of till ~3 m of silt ~8 m of interbedded fine to medium sand and silt **End of Hole**
BH-J1-SRS-2004	*UTM: 623788m E 4946488m N, NAD83, Zone 17* *Elevation: 232 m* ~3 m of sand and gravel ~8 m of till ~4 m of sand with occasional beds of silt and gravel ~5 m of till with occasional beds of sand and gravelly sand ~3 m of till Paleozoic Bedrock **End of Hole**
FL-TH-1	*UTM: 593586m E 4943003m N, NAD83, Zone 17* *Elevation: ~274 m* ~5 m of fine to medium sand ~4 m of silty to fine sand ~6 m of medium to coarse sand with a trace of silt **End of Hole**
FL-TH-2	*UTM: 596576m E 4938086m N, NAD83, Zone 17* *Elevation: ~259 m* ~3 m of fine to medium sand ~2 m of medium sand with occasional silt and fine gravel beds ~3 m of medium to coarse sand **End of Hole**
OR-TH-1	*UTM: 604772m E 4932144m N, NAD83, Zone 17* *Elevation: ~350 m* ~1.5 m of coarse sand ~1.5 m of gravel and fine sand ~3 m of silty fine sand ~3 m of coarse sand and fine gravel ~5 m of fine sand and silt ~1 m of sand and gravel **End of Hole**

Table 7 - Summary of Borehole Data, County of Simcoe

Borehole Number	Generalized Description of Material
OR-TH-2	*UTM: 607088m E 4930575m N, NAD83, Zone 17* *Elevation: ~343 m* ~1.5 m of coarse sand ~1.5 m of gravel and medium to coarse sand ~2 m of sand with occasional clay beds ~3 m of sand and gravel ~3 m of fine to coarse sand ~1 m of gravel **End of Hole**
OR-TH-3	*UTM: 609720m E 4930449m N, NAD83, Zone 17* *Elevation: ~366 m* ~1.5 m of clay ~3.5 m of sand ~4 m of coarse sand ~6 m of fine to coarse sand with occasional silt beds **End of Hole**
OR-TH-4	*UTM: 609074m E 4932245m N, NAD83, Zone 17* *Elevation: ~366 m* ~1.5 m of sand ~4.5 m of sand and gravel ~9 m of sand with occasional gravel beds **End of Hole**
OR-TH-5	*UTM: 608454m E 4934042m N, NAD83, Zone 17* *Elevation: ~350 m* ~5 m of sand with occasional gravel beds ~6 m of fine to medium sand with occasional gravel and silt beds **End of Hole**
OR-TH-6	*UTM: 611301m E 4934270m N, NAD83, Zone 17* *Elevation: ~335 m* ~1.5 m of sand and silt ~1.5 m of sand with occasional gravel beds ~3 m of silty sand with occasional gravel beds ~5 m of fine sand **End of Hole**
OR-TH-7	*UTM: 611884m E 4931220m N, NAD83, Zone 17* *Elevation: ~366 m* ~5 m of gravel ~1.5 m of sand ~1.5 m of gravel ~6 m of fine to coarse sand ~3 m of medium sand and silt ~2 m of coarse sand ~1 m of medium sand and silt **End of Hole**
OR-TH-8	*UTM: 613111m E 4931866m N, NAD83, Zone 17* *Elevation: ~335 m* ~5 m of fine to medium sand ~4 m of coarse sand with occasional gravel beds ~2 m of gravel ~4 m of fine to coarse sand **End of Hole**

Table 7 - Summary of Borehole Data, County of Simcoe	
Borehole Number	**Generalized Description of Material**
OR-TH-9	*UTM: 613604m E 4931220m N, NAD83, Zone 17* *Elevation: ~320 m* ~5 m of sand and gravel ~1 m of medium to coarse sand with occasional silt beds ~9 m of sand and gravel **End of Hole**
OR-TH-10	*UTM: 613048m E 4934169m N, NAD83, Zone 17* *Elevation: ~335 m* ~3 m of sand and gravel ~8 m of medium to coarse sand ~4 m of fine sand and silt **End of Hole**
OR-TH-11	*UTM: 614920m E 4934839m N, NAD83, Zone 17* *Elevation: ~320 m* ~6 m of sand and gravel ~5 m of fine sand and silt ~1 m gravel ~3 m of fine sand and silt **End of Hole**
OR-TH-12	*UTM: 616009m E 4932372m N, NAD83, Zone 17* *Elevation: ~305 m* ~8 m of fine to medium sand **End of Hole**
OR-TH-13	*UTM: 618299m E 4935485m N, NAD83, Zone 17* *Elevation: ~305 m* ~8 m of sand and gravel ~6 m of fine to coarse sand ~1 m of sand and gravel **End of Hole**
P92-01	*UTM: 586226m E 4959599m N, NAD83, Zone 17* *Elevation: ~229-244 m* ~ 2 m of fine to medium sand ~ 3.5 m of sandy gravel and gravelly sand ~ 12 m of fine to medium sand with occasional beds of silt and till ~ 5 m of fine to medium sand to gravelly sand **End of Hole**
P92-02	*UTM: 580275m E 4958100m N, NAD83, Zone 17* *Elevation: ~305-320 m* ~ 13 m of till ~ 2 m of silt and clay ~ 3 m of till ~ 1 m of gravel ~ 8 m of till **End of Hole**
P92-03	*UTM: 580880m E 4959398m N, NAD83, Zone 17* *Elevation: ~244-259 m* ~ 1.5 m of fill ~ 12.5 m of fine sand ~ 3.5 m of fine to medium sand ~ 6 m of silt with occasional beds of sand and clay **End of Hole**

Table 7 - Summary of Borehole Data, County of Simcoe	
Borehole Number	**Generalized Description of Material**
P92-04	*UTM: 568942m E 4955849m N, NAD83, Zone 17* *Elevation: ~177-183 m* ~ 5 m of gravel, sandy gravel and gravelly sand ~ 3.5 m of till ~16 m of fine to medium sand with occasional beds of silt **End of Hole**
P92-06	*UTM: 569700m E 4959525m N, NAD83, Zone 17* *Elevation: ~251-259 m* ~ 13.5 m of till ~ 36.5 m of fine to medium sand with occasional beds of silt and gravel **End of Hole**
TC-TH-1	*UTM: 598348m E 4873835m N, NAD83, Zone 17* *Elevation: ~297 m* Pit Face is 3-6 m of sand and gravel - hole was drilled in pit floor ~6 m of pebbly coarse sand **End of Hole**
TC-TH-2	*UTM: 600518m E 4874079m N, NAD83, Zone 17* *Elevation: ~290 m* ~3 m of fine to medium sand ~3 m of medium sand with <10% gravel ~1 m of medium sand with clay beds at 7 m **End of Hole**
TC-TH-3	*UTM: 599234m E 4873902m N, NAD83, Zone 17* *Elevation: ~282 m* ~2 m of till **End of Hole**
TC-TH-4	*UTM: 599411m E 4877401m N, NAD83, Zone 17* *Elevation: ~259 m* ~1.5 m of fine to medium sand with <10% gravel Hole terminated because of a boulder **End of Hole**
TC-TH-5	*UTM: 598857m E 4879837m N, NAD83, Zone 17* *Elevation: ~305 m* Pit Face is 3-5 m of sand and <20% gravel ~2 m of fine sand ~1 m of fine sand with occasional beds of clay ~3 m of fine sand **End of Hole**
TO-TH-1	*UTM: 600695m E 4906968m N, NAD83, Zone 17* *Elevation: ~305 m* Pit Face is 1.5-3 m of sand and gravel ~4 m of fine sand **End of Hole**
TO-TH-2	*UTM: 600518m E 4907478m N, NAD83, Zone 17* *Elevation: ~274 m* ~1 m of till **End of Hole**

Table 7 - Summary of Borehole Data, County of Simcoe	
Borehole Number	**Generalized Description of Material**
TT-TH-1	*UTM: 609758m E 4950100m N, NAD83, Zone 17* *Elevation: ~244 m* ~0.5 m of till ~12 m of sand and gravel ~2 m of coarse gravel ~3 m of sand and gravel **End of Hole**
TT-TH-2	*UTM: 609783m E 4949960m N, NAD83, Zone 17* *Elevation: ~244 m* ~2 m of medium sand ~1 m of medium to coarse sand ~2 m of medium sand ~3 m of till **End of Hole**
TT-TH-3	*UTM: 597129m E 4942824m N, NAD83, Zone 17* *Elevation: ~274 m* ~3 m of till **End of Hole**
TT-TH-4	*UTM: 597205m E 4942874m N, NAD83, Zone 17* *Elevation: ~274 m* ~3 m of till **End of Hole**
TT-TH-5	*UTM: 599635m E 4945443m N, NAD83, Zone 17* *Elevation: ~289 m* ~2 m of till ~1 m of fine to medium sand ~3 m of till ~2 m of medium to coarse sand with occasional beds of till ~1 m of sand and gravel **End of Hole**
TT-TH-6	*UTM: 604367m E 4950631m N, NAD83, Zone 17* *Elevation: ~274 m* ~2 m of till with occasional beds of sand ~3 m of till **End of Hole**
TT-TH-7	*UTM: 604177m E 4948151m N, NAD83, Zone 17* *Elevation: ~274 m* ~6 m of till ~2 m of medium sand with occasional beds of gravel **End of Hole**
TT-TH-8	*UTM: 604152m E 4943406m N, NAD83, Zone 17* *Elevation: ~335 m* ~2 m of sand and minor gravel ~6 m of silt **End of Hole**
TT-TH-9	*UTM: 601963m E 4939281m N, NAD83, Zone 17* *Elevation: ~320 m* ~3 m of till ~5 m of medium sand with occasional beds of fine gravel and silt **End of Hole**

Table 7 - Summary of Borehole Data, County of Simcoe

Borehole Number	Generalized Description of Material
VE-TH-1	*UTM: 602578m E 4929160m N, NAD83, Zone 17* *Elevation: ~282 m* ~1.5 m of coarse sand with occasional silt and clay beds ~1.5 m of fine to medium sand and fine gravel ~2 m of till with occasional sand and gravel beds ~4 m of sand ~2 m of gravel and sand **End of Hole**
WG-TH-1	*UTM: 600976m E 4910937m N, NAD83, Zone 17* *Elevation: ~310 m* ~6 m of fine to medium sand **End of Hole**
WG-TH-2	*UTM: 601495m E 4907596m N, NAD83, Zone 17* *Elevation: ~305 m* ~9 m of fine to coarse sand **End of Hole**
WG-TH-3	*UTM: 611504m E 4903762m N, NAD83, Zone 17* *Elevation: ~300 m* Pit Face is 6-9 m of sand and 20-30% gravel ~5 m of silty, very fine sand **End of Hole**
WG-TH-4	*UTM: 607822m E 4902560m N, NAD83, Zone 17* *Elevation: ~280 m* ~3 m of till **End of Hole**
WG-TH-5	*UTM: 605354m E 4901029m N, NAD83, Zone 17* *Elevation: ~300 m* ~3 m of till **End of Hole**
WG-TH-6	*UTM: 604582m E 4899700m N, NAD83, Zone 17* *Elevation: ~290 m* ~3 m of till **End of Hole**
WG-TH-7	*UTM: 606620m E 4897714m N, NAD83, Zone 17* *Elevation: ~260 m* ~3 m of till **End of Hole**
WG-TH-8	*UTM: 611226m E 4891842m N, NAD83, Zone 17* *Elevation: ~305 m* ~12 m of fine to medium sand **End of Hole**
WG-TH-9	*UTM: 609011m E 4889097m N, NAD83, Zone 17* *Elevation: ~310 m* ~5 m of fine to medium sand **End of Hole**

Data summarized *from* Bajc (1994), Barnett (1991), Burt (2007) and Ontario Geological Survey (1980, 1982, 1983, 1984a, 1984b, 1988a, 1988b, 1991, 1994a, 1994b, 1994c).

Table 8 - Summary of Geophysical Data, County of Simcoe

– NONE –

Table 9 - Results of Aggregate Quality Tests, County of Simcoe

		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)	Freeze–Thaw (% Loss)	Absorption (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	Micro-Deval Abrasion (% Loss)
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<6%*	*<2%*	*>2.5*	*<0.150%*	*<15–25%*
10DJR-0030	Beach deposit	-	129.0	-	15.8	-	1.140	2.619	0.089	
10DJR-0031	Beach deposit	-	136.0	-	13.3	-	1.126	2.622	0.061	
10DJR-0032	Beach deposit	-	121.5	-	15.1	-	1.270	2.614	0.028	
10DJR-0033	Beach deposit	-	157.5	-	14.4	-	1.160	2.618	0.035	
10DJR-0034	Ice-contact deposit	-	142.0	-	-	-	0.391	2.716	0.079	6.24
10DJR-0035	Ice-contact deposit	-	264.1	-	15.8	-	1.115	2.627	0.090	
10DJR-0036	Ice-contact deposit	-	202.2	-	14.2	-	1.100	2.621	0.073	
10DJR-0037	Gull River Formation	-	100.0	1.0	8.7	-	0.720	2.658	0.019	
10DJR-0038	Lower Bobcaygeon Formation	-	107.4	1.0	11.6	-	0.710	2.662	0.015	
10DJR-0039	Amabel Formation	-	104.3	3.3	9.9	-	0.951	2.714	0.021	16.76
10DJR-0040	Guelph Formation	-	140.4	7.6	13.1	-	2.805	2.551	0.008	25.05

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 - Till Matrix Data (Till Characterization), County of Simcoe

Sample	Source*	Sand (%)	Silt (%)	Clay (%)	Calcite (%)	Dolomite (%)	Cal:Dol Ratio	Total Carbonate (%)
Till Data from Township of Ramara								
1	[6]	39	37	24				
2	[6]	57	30	13				
3	[6]	58	34	8	31	10	3.1	
4	[6]	60	34	6	21	21	1.0	
5	[6]	55	32	13				
6	[6]	52	40	8				
7	[6]	58	38	4	4	22	0.2	
8	[6]	65	30	5	11	24	0.5	
9	[6]	55	34	11	37	20	1.9	
10	[6]	50	29	21				
11	[6]	61	27	12				
12	[6]	61	31	8	19	12	1.6	
13	[6]	48	44	8	16	16	1.0	
14	[6]	59	35	6	14	22	0.6	
15	[6]	50	35	15	49	14	3.5	
16	[6]	60	30	10	19	21	0.9	
17	[6]	64	31	5	14	21	0.7	
18	[6]	47	39	14	36	10	3.6	
19	[6]	37	46	17	38	17	2.2	
20	[6]	45	42	13	41	14	2.9	
21	[6]	37	45	18	61	8	7.6	
22	[6]	52	35	13	51	5	10.2	
		53.2	**35.4**	**11.5**	**28.9**	**16.1**	**2.6**	
Oldest Coarse-Grained Till								
	[1]	48	38	13			2.0	34
Younger Finer Grained Till								
	[1]	30	50	19			2.4	30
Newmarket Till								
	[4]	54	36	10			1.0	36
	[1]	65	27	8			1.0	19
	[2]	60.8	35.9	4.2			1.4	15.7
	[5]	55	36	9			0.98	34.2
	[7]	51	44	5				
	[7]	63	34	3				
	[8]	55.12	34.27	10.61	27.47	15.98	1.7	43.45
	[8]	51.46	39.11	9.43	37.80	8.22	4.6	46.02
		56.9	**35.8**	**7.4**			**1.8**	**32.4**
Kettleby Till								
	[3]	19	50	31			1.65	34.7
	[8]	26.81	42.11	31.08	34.18	3.65	9.4	37.83
	[8]	28.34	57.58	14.08	32.17	6.98	4.6	39.15

*** Sources of Data:**
[1] Bajc (1994); [2] Burt (2007); [3] G.J. Burwasser (OGS, unpublished data, 1974a); [4] Cowan (1976); [5] Cowan et al. (1978); [6] Deane (1950); [7] Ministry of Transportation of Ontario (written communication of compiled data); [8] this study.

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

Sample No.	10DJR-0020	10DJR-0021	10DJR-0022	10DJR-0023	10DJR-0024	10DJR-0037	10DJR-0038	10DJR-0039	10DJR-0040
Formation	Georgian Bay (weathered)	Queenston (weathered)	Queenston (partially weathered)	Georgian Bay	Queenston (partially weathered)	Gull River	Lower Bobcaygeon	Amabel (unsubdivided*)	Guelph
Major Oxide Analyses									
SiO_2 (%)	52.91	41.67	47.18	51.22	50.20	2.41	5.65	0.21	0.15
Al_2O_3	15.50	12.20	11.45	6.96	11.29	0.61	0.98	0.12	0.05
MnO	0.09	0.10	0.12	0.17	0.12	0.09	0.04	0.03	0.02
MgO	2.84	2.79	3.91	3.11	2.96	0.72	0.59	19.47	18.28
CaO	4.39	13.85	10.64	14.78	10.69	51.52	45.58	30.42	28.03
Na_2O	0.42	0.04	0.11	0.67	0.26	<0.01	0.09	0.00	<0.01
K_2O	4.40	3.97	3.87	2.25	3.65	0.17	0.25	0.01	<0.01
P_2O_5	0.24	0.14	0.14	0.12	0.15	0.01	0.01	<0.01	<0.01
TiO_2	0.85	0.64	0.70	0.49	0.69	0.04	0.03	0.01	0.02
$Fe_2O_3^{total}$	6.93	5.92	5.53	2.95	5.39	0.26	0.28	0.10	0.09
LOI	10.49	17.88	15.62	17.47	14.09	46.85	47.82	49.97	52.92
Total	99.06	99.22	99.26	100.20	99.50	102.53	101.32	100.15	99.36
S	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.02	0.00
CO_2	3.39	11.10	9.44	12.80	9.03	41.10	42.10	46.10	45.50
H_2O^+	5.86	4.46	4.09	1.90	4.84	0.77	0.46	0.15	0.49
H_2O^-	3.00	2.12	1.74	0.63	1.79	0.47	0.44	0.13	0.43
Atomic Absorption (Flame) Spectroscopy Analyses									
Cd (ppm)	<5	<5	<5	<5	<5	<5	<5	<5	<5
Co	44	39	36	30	34	31	<30	<30	<30
Cu	24	11	13	33	25	3	3	<3	<3
Li	63	54	49	39	50	30	29	17	17
Ni	36	31	30	18	25	<6	<6	<6	<6
Pb	<12	<12	<12	<12	<12	<12	<12	<12	<12
Zn	90	70	69	45	71	11	9	8	8
Inductively Coupled Plasma Mass Spectroscopy (ICP–MS) Analyses									
Ba (ppm)	367.5	355.3	318.4	225.5	319.0	21.6	14.5	5.5	818.1
Be	2.59	1.96	1.72	0.80	1.74	0.08	0.06	0.06	2.53
Bi	0.24	0.23	0.19	<0.15	0.21	<0.15	<0.15	<0.15	<0.15
Cd	0.040	0.072	0.052	0.047	0.075	0.021	0.013	<0.013	0.071
Ce	87.61	70.24	71.53	53.33	73.89	3.67	4.50	1.21	78.95
Co	19.81	15.62	14.21	9.41	14.16	1.57	1.11	0.82	2.20
Cr	82	62	60	34	59	7	5	5	20
Cs	7.402	5.652	5.361	1.835	4.974	0.375	0.250	0.057	3.028
Cu	23.7	9.3	12.9	34.7	25.5	<1.4	1.6	<1.4	8.5
Dy	5.823	4.458	4.951	5.214	5.375	0.200	0.234	0.070	2.200
Er	3.324	2.492	2.869	2.639	3.083	0.103	0.119	0.044	1.323
Eu	1.518	1.168	1.258	1.347	1.357	0.068	0.075	0.023	2.521
Ga	22.04	16.94	15.71	8.28	15.25	0.84	0.48	0.22	17.08
Gd	6.438	4.792	5.271	5.615	5.716	0.258	0.292	0.085	2.450
Hf	4.46	3.59	4.93	5.14	5.96	<0.14	<0.14	<0.14	4.74

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

Sample No.	10DJR-0020	10DJR-0021	10DJR-0022	10DJR-0023	10DJR-0024	10DJR-0037	10DJR-0038	10DJR-0039	10DJR-0040
Formation	Georgian Bay (weathered)	Queenston (weathered)	Queenston (partially weathered)	Georgian Bay	Queenston (partially weathered)	Gull River	Lower Bobcaygeon	Amabel (unsubdivided*)	Guelph
Ho (ppm)	1.142	0.880	0.972	0.966	1.061	0.037	0.046	0.015	0.439
In	0.078	0.065	0.062	0.046	0.060	0.005	0.005	0.002	0.013
La	42.23	34.46	34.69	22.79	35.25	2.20	2.74	0.67	47.69
Li	51.5	43.3	40.3	26.6	38.2	3.9	2.2	1.5	11.3
Lu	0.459	0.362	0.401	0.349	0.429	0.011	0.015	0.006	0.209
Mo	0.34	0.81	0.87	0.46	1.08	0.15	<0.08	0.28	1.96
Nb	16.163	11.281	13.228	8.938	13.035	0.563	0.212	0.243	56.413
Nd	39.06	31.11	31.75	27.92	33.23	1.81	1.92	0.51	23.92
Ni	43.0	34.3	33.7	20.4	32.1	10.9	11.4	6.6	1.6
Pb	4.6	10.9	7.3	3.9	10.6	1.1	0.7	1.3	17.0
Pr	10.438	8.361	8.398	6.929	8.709	0.461	0.532	0.141	7.587
Rb	138.65	125.56	117.14	54.65	112.42	6.77	3.42	1.65	239.04
Sb	0.56	0.78	0.72	0.30	0.73	0.11	0.13	0.07	0.19
Sc	18.1	14.2	13.4	8.0	13.3	<1.1	1.2	<1.1	1.5
Sm	7.714	5.881	6.305	6.178	6.657	0.322	0.372	0.099	3.663
Sn	3.16	2.38	2.38	1.12	2.23	<0.16	<0.16	<0.16	1.79
Sr	121.30	154.00	107.20	110.80	118.10	258.30	353.10	41.30	277.80
Ta	1.137	0.820	0.904	0.598	0.908	0.036	<0.023	<0.023	2.929
Tb	0.974	0.731	0.816	0.874	0.895	0.037	0.040	0.010	0.370
Th	11.924	9.213	9.974	5.875	9.480	0.046	<0.018	0.184	15.567
Ti	4914	3564	3943	2727	4073	200	88	59	698
Tl	0.674	0.551	0.505	0.264	0.477	0.047	0.014	0.020	0.383
Tm	0.478	0.373	0.416	0.373	0.448	0.012	0.017	0.007	0.203
U	3.185	1.959	2.660	1.604	2.646	0.271	0.364	0.268	3.205
V	128.9	90.9	95.3	47.1	89.5	3.8	3.9	1.9	4.0
W	1.45	1.08	1.18	0.74	1.16	0.23	0.14	0.08	1.55
Y	30.74	23.66	26.76	27.24	29.09	0.55	1.31	0.48	12.24
Yb	3.104	2.428	2.723	2.403	2.919	0.070	0.097	0.040	1.411
Zn	85	62	64	38	62	<7	<7	<7	23
Zr	157	125	178	190	216	<6	<6	<6	247

* Amabel Formation (unsubdivided) (*see* Brintnell et al. 2009; Brunton 2009; Brunton et al. 2010).

Table 12 - Results of Geochemical Analyses of Soil Samples, County of Simcoe					
Sample No.	**10DJR-0010**	**10DJR-0012**	**10DJR-0013**	**10DJR-0015**	**10DJR-0016**
Sample Type	**Glaciolacustrine Silty Clay**	**Kettleby Till Matrix**	**Newmarket Till Matrix**	**Glaciolacustrine Silty Clay**	**Kettleby Till Matrix**
Inductively Coupled Plasma Mass Spectroscopy (ICP–MS) Analyses					
Ag (ppm)	0.09	0.03	0.02	0.03	0.17
As	2.80	2.70	2.10	2.70	2.40
Au	0.043	0.006	0.002	0.006	0.033
Ba	96.8	105.0	55.5	147.3	72.6
Be	0.37	0.54	0.35	0.44	0.41
Bi	0.06	0.08	0.04	0.04	0.04
Cd	0.13	0.07	0.05	0.07	0.06
Ce	27.2	44.9	30.8	20.7	39.1
Co	5.10	6.67	4.99	4.70	5.79
Cr	33	23	21	13	17
Cs	0.44	0.75	0.48	0.45	0.57
Cu	12.4	21.2	11.5	12.9	16.4
Dy	1.68	2.44	1.77	1.19	2.20
Er	0.84	1.21	0.96	0.64	1.13
Eu	0.42	0.57	0.46	0.33	0.54
Ga	2.52	4.10	2.73	2.48	3.13
Gd	2.45	3.43	2.62	1.70	3.34
Hf	0.06	0.16	0.09	<0.05	0.14
Hg	0.01	0.01	0.01	0.02	0.01
Ho	0.321	0.424	0.334	0.219	0.409
In	0.017	0.027	0.019	0.014	0.022
La	12.76	21.77	14.38	10.09	18.40
Li	8.14	11.34	6.85	8.29	7.07
Lu	0.099	0.148	0.114	0.077	0.143
Mo	1.85	0.35	0.31	0.22	0.30
Nb	0.61	0.37	0.44	0.66	0.40
Nd	12.64	19.05	13.60	9.66	17.98
Ni	14.9	19.6	12.1	13.0	14.3
Pb	5.2	5.8	3.9	3.3	5.2
Pr	3.29	5.21	3.64	2.53	4.67
Pt	<0.003	0.007	0.003	<0.003	<0.003
Rb	7.44	15.79	10.06	8.24	10.41
Sb	<0.06	0.06	<0.06	<0.06	<0.06
Sc	3.07	4.37	3.15	2.68	3.99
Se	0.5	0.4	0.5	0.6	<0.4
Sm	2.42	3.68	2.69	1.96	3.30
Sn	0.39	0.62	0.37	0.33	0.42
Sr	221.01	206.60	233.27	240.76	240.49
Ta	<0.004	0.010	<0.004	<0.004	<0.004
Tb	0.331	0.469	0.356	0.233	0.467
Te	0.01	0.02	0.01	0.02	0.04
Th	3.06	5.24	3.40	2.26	4.27

Table 12 - Results of Geochemical Analyses of Soil Samples, County of Simcoe					
Sample No.	**10DJR-0010**	**10DJR-0012**	**10DJR-0013**	**10DJR-0015**	**10DJR-0016**
Sample Type	**Glaciolacustrine Silty Clay**	**Kettleby Till Matrix**	**Newmarket Till Matrix**	**Glaciolacustrine Silty Clay**	**Kettleby Till Matrix**
Ti (ppm)	307.4	640.5	432.5	351.6	544.5
Tl	0.070	0.134	0.094	0.067	0.108
Tm	0.116	0.151	0.124	0.078	0.149
U	0.45	0.43	0.35	0.22	0.38
V	37	43	36	35	40
W	0.1	0.1	0.1	0.1	0.1
Y	8.93	12.28	10.21	6.40	11.79
Yb	0.70	0.98	0.80	0.53	0.96
Zn	30.33	41.97	25.81	29.82	30.06
Zr	2.82	6.16	4.59	1.78	6.61

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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.

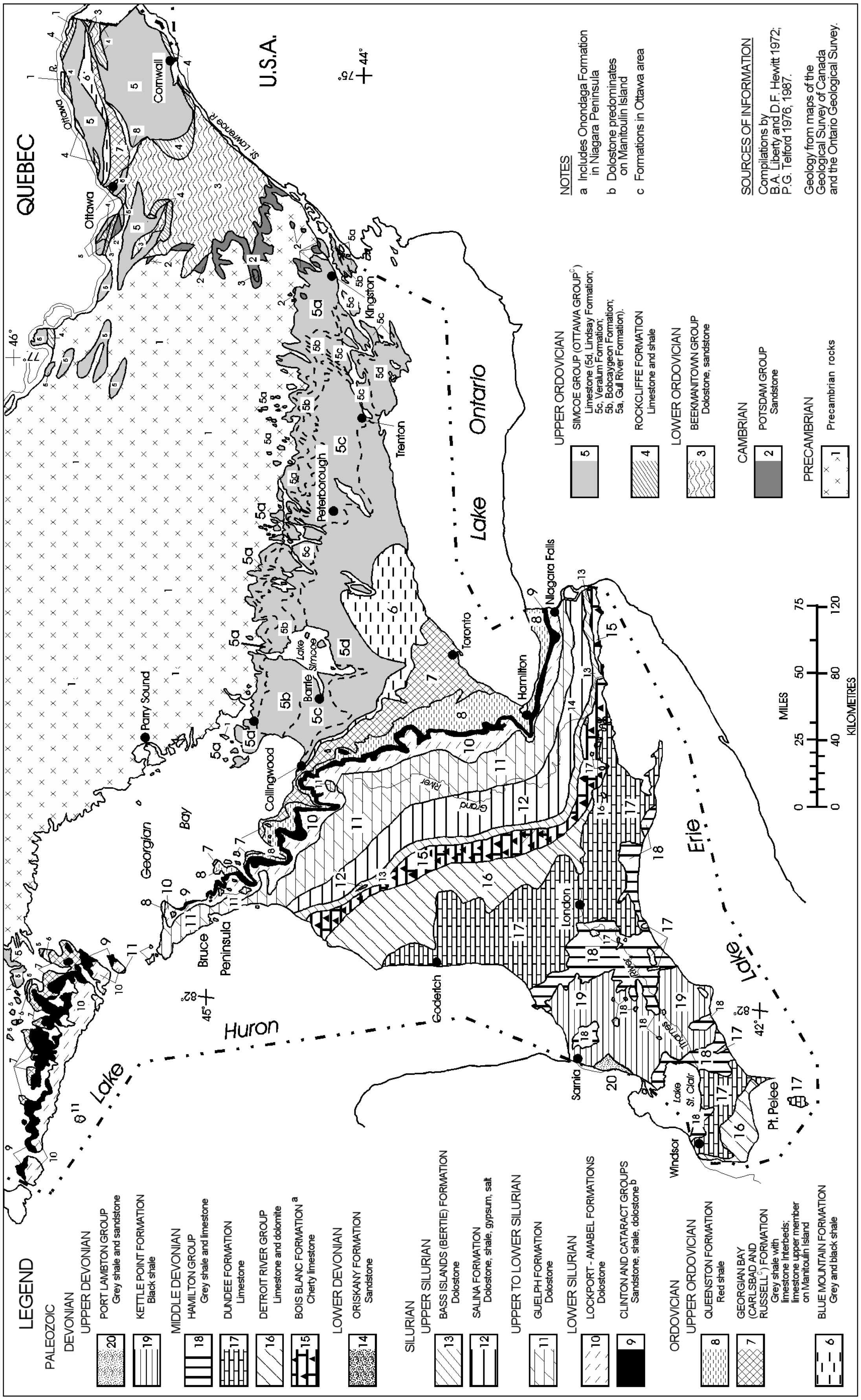

Figure D1. Bedrock geology of southern Ontario.

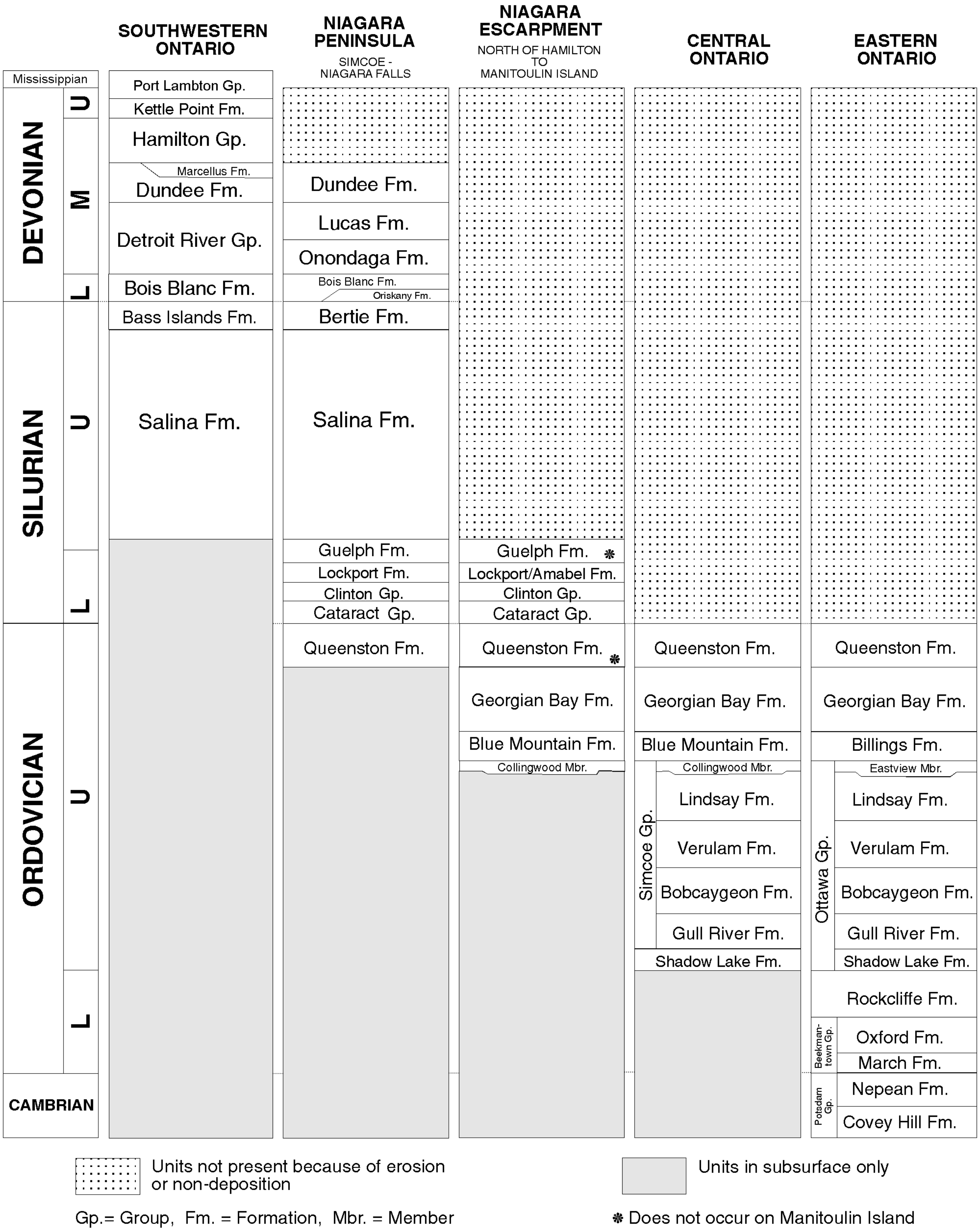

Figure D2. Exposed Paleozoic stratigraphic sequences in southern Ontario (*adapted from* Bezys and Johnson 1988 and Armstrong and Dodge 2007).

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 $>1.0 \times 10^{-4}$ 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 188

MAP 1A

Sand and Gravel Resources for the County of Simcoe

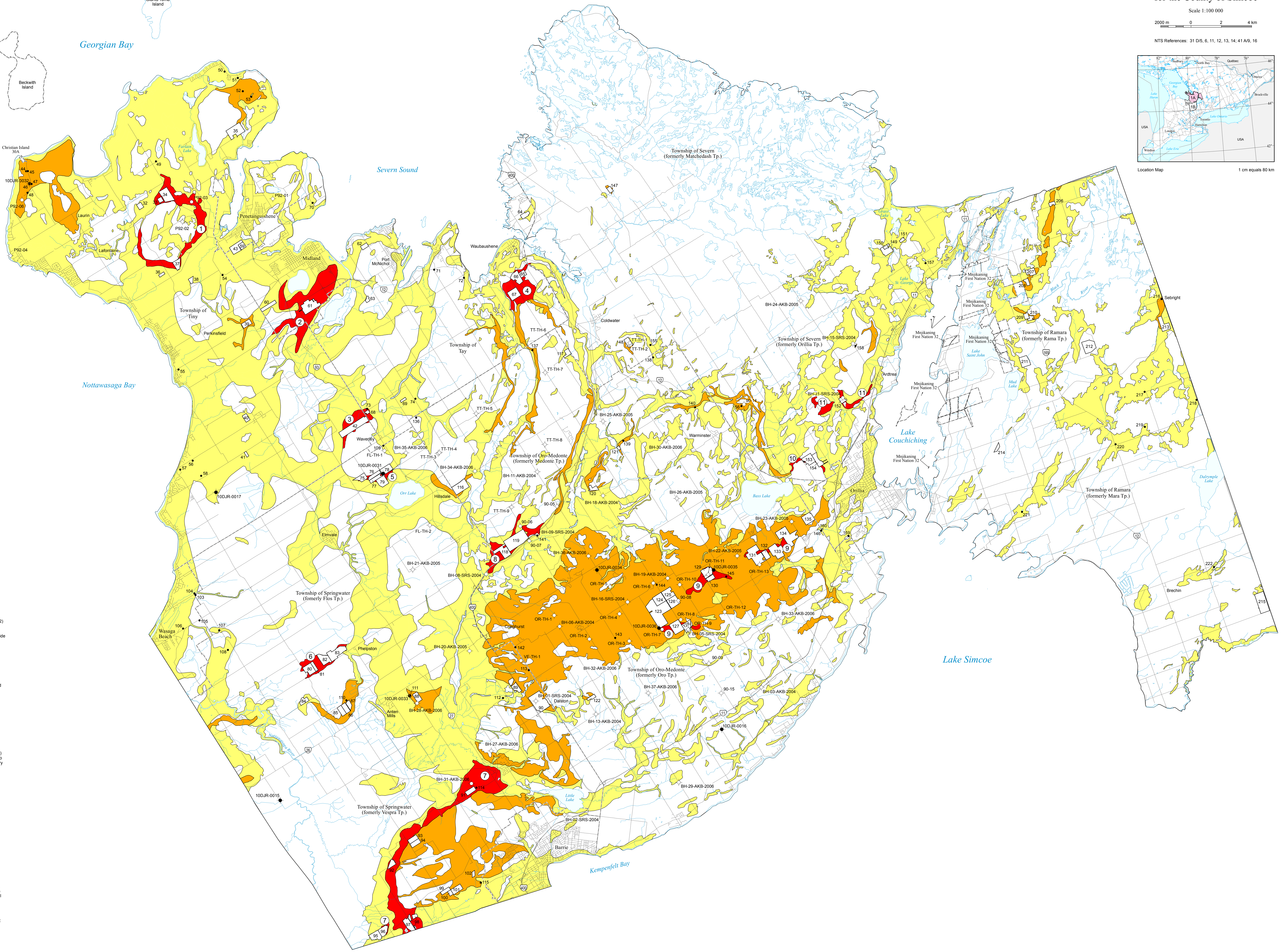
Scale 1:100 000

2000 m 0 2 4 km

NTS References: 31 D/5, 6, 11, 12, 13, 14; 41 A/9, 16

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).
- 90-05 Borehole location; identification number (*see* Table 7)
- 09DJR-0001 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, 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 17.

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

Geology based on
- Bajc, A.F. and Paterson, J.T. 1992a, 1992b
- Barnett, P.J. 1997
- Barnett, P.J. and Mate, D.J. 1998
- Burwasser, G.J. 1973, 1974c
- Burwasser, G.J. and Cairns, B.D. 1974
- Burwasser, G.J. and Lloyd, S.T. 1974
- Finamore, P.F. and Bajc, A.F. 1984
- Gwyn, Q.H.J. 1972a, 1972b
- Gwyn, Q.H.J. and White, S. 1973
- Ontario Geological Survey 2003
- Russell, H.A.J. and Dumas, S. 1997
- White, O.L. and Karrow, P.F. 1973

Additional geology by D.J. Rowell, 2010 and 2011. Compilation by D.J. Rowell. Drafting by D.J. Rowell; additional drafting by S.A. Evers. This map is published with the permission of the Director, Ontario Geological Survey.

Rowell, D.J. 2013. Aggregate resources inventory for the County of Simcoe, southern Ontario; Ontario Geological Survey, Aggregate Resources Inventory Paper 188, Map 1A–Sand and Gravel Resources, scale 1:100 000.

Aggregate Resources Inventory Paper 188

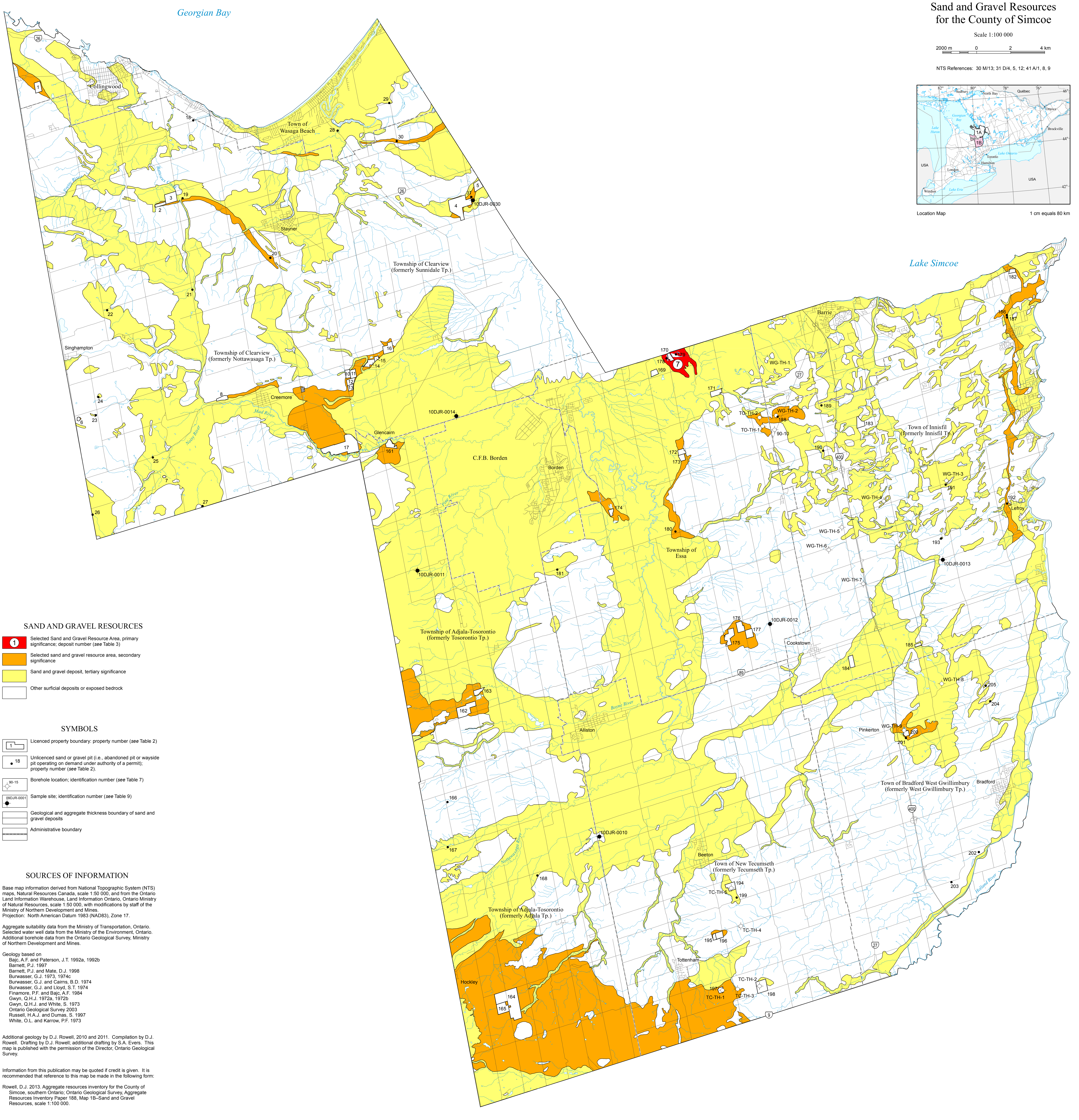
MAP 1B

Sand and Gravel Resources for the County of Simcoe

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 30 M/13; 31 D/4, 5, 12; 41 A/1, 8, 9



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

- 1 — Licenced property boundary: property number (*see* Table 2)
- 18 — 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).
- 90-15 — Borehole location; identification number (*see* Table 7)
- 09DJR-0001 — Sample site; identification number (*see* Table 9)
- Geological and aggregate thickness boundary of sand and gravel deposits
- Administrative boundary

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- Finamore, P.F. and Bajc, A.F. 1984
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Aggregate Resources Inventory Paper 188

MAP 2A

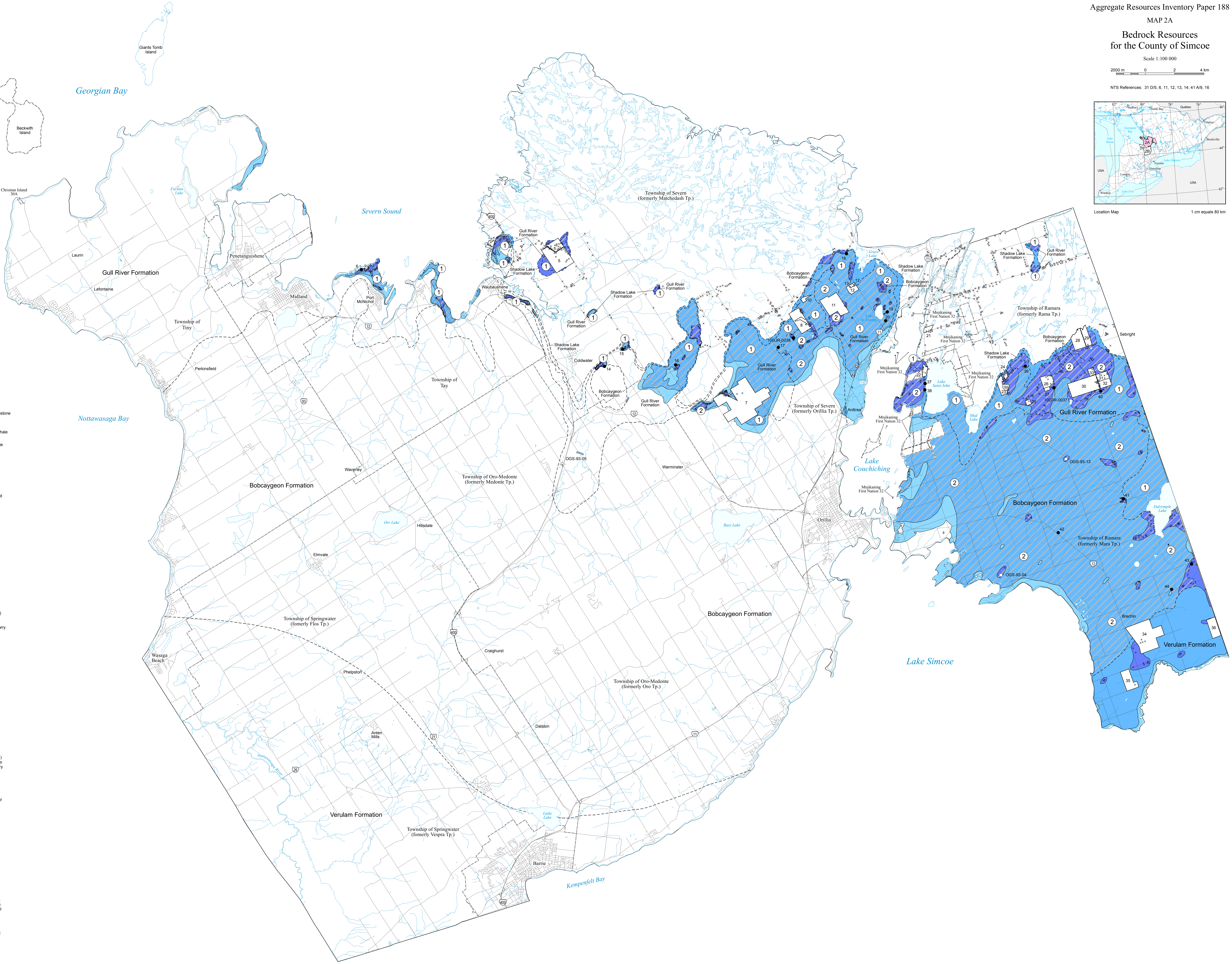
Bedrock Resources for the County of Simcoe

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 31 D/5, 6, 11, 12, 13, 14; 41 A/9, 16

Location Map 1 cm equals 80 km



LEGEND – BEDROCK UNITS

PHANEROZOIC

PALEOZOIC

SILURIAN

MIDDLE AND UPPER SILURIAN

Amabel Formation: Dolostone

Clinton and Cataract Groups: Sandstone, shale, limestone and dolostone

ORDOVICIAN

UPPER ORDOVICIAN

Queenston Formation: Red shale

Georgian Bay Formation: Shale and limestone

Blue Mountain Formation: Shale and minor limestone

Lindsay Formation: Limestone and shale

Verulam Formation: Limestone and shale

Bobcaygeon Formation: Limestone and minor shale

Gull River Formation: Limestone and dolostone

Shadow Lake Formation: Siltstone, conglomerate and shale

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

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

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

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

90-05 Borehole location; identification number (*see* Table 7)

90-DJR-0001 Sample site; identification number (*see* Table 9)

Geological formation and/or member boundary

Drift thickness contour

Isolated bedrock outcrop

Administrative boundary

SOURCES OF INFORMATION

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- Armstrong, D.K. and Anastas, A.S. 1993
- Armstrong, D.K. and Dodge, J.E.P. 2007
- Armstrong, D.K. and Rheaume, P. 1995
- Bond, I.J. and Telford, P.G. 1976
- Liberty, B.A. 1953
- Liberty, B.A., Bond, I.J. and Telford, P.G. 1976
- Telford, P.G. 1976

Additional drift thickness information based on
- Burwasser, G.J. 1974d
- Burwasser, G.J. and Ford, M.J. 1974a, 1974b
- Gwyn, Q.H.J. and Frazer, J.Z. 1975
- Holden, K.M., Thomas, J. and Karrow, P.F. 1993a, 1993b

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Aggregate Resources Inventory Paper 188

MAP 2B

Bedrock Resources for the County of Simcoe

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 30 M/13; 31 D/4, 5, 12; 41 A/1, 8, 9

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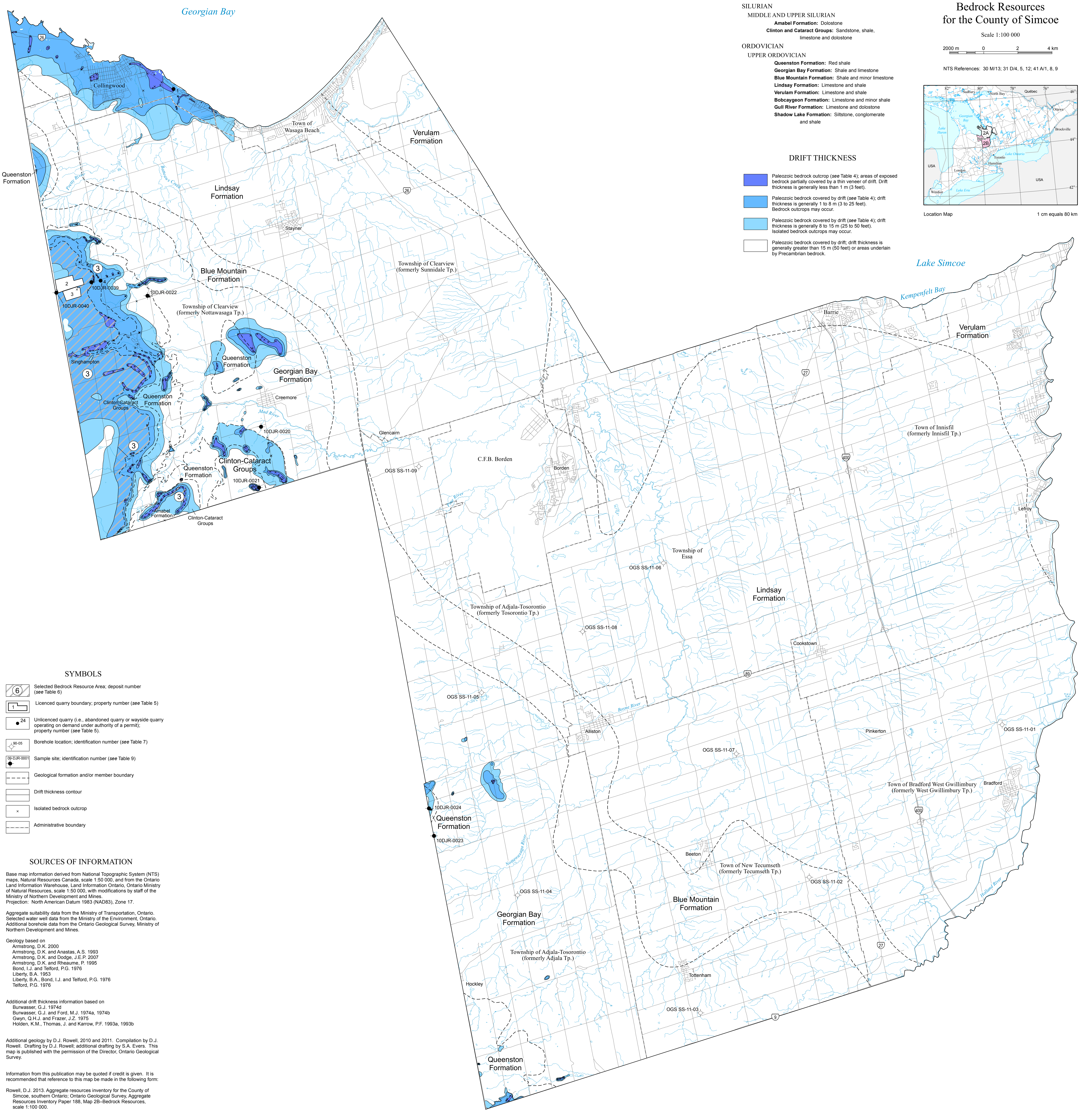

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Licenced quarry boundary; property number (*see* Table 5)

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Borehole location; identification number (*see* Table 7)

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

Geological formation and/or member boundary

Drift thickness contour

Isolated bedrock outcrop

Administrative boundary

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Telford, P.G. 1976

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