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Ontario

Aggregate Resources Inventory of

Dufferin County

Southern Ontario

Ontario Geological Survey
Aggregate Resources Inventory
Paper 163—Revision 2

2014

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Aggregate Resources Inventory
Paper 163—Revision 2

By MacNaughton Hermsen Britton Clarkson Planning Limited,
White LandScience, Robinson Consultants, D.J. Rowell and F.R. Brunton

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***Map 1 and Map 2 accompanying this report are simplified to depict information critical to the majority of users. Enhanced information on the aggregate resources for this area is provided in a compressed (*.zip*) file available for download from GeologyOntario (www.ontario.ca/geology). Additional documents in the *.zip* file provide further details on the vector ESRI® ArcGIS® files for Maps 1 and 2, Microsoft® Excel® versions of Tables 1 to 9, and other files that enhance this report.**

Abstract

This report includes an inventory and evaluation of the sand and gravel, and bedrock resources in Dufferin County. It provides a consolidation and update of the original township Aggregate Resources Inventory Papers (ARIP) prepared between 1979 and 1981. The report is part of the ongoing Aggregate Resources Inventory Program for areas designated under the *Aggregate Resources Act, 1989*.

In Dufferin County, a total of 20 Selected Sand and Gravel Resource Areas of primary significance have been selected and identified for possible resource protection. These 20 resource areas have, in some cases, been split into subareas along township boundaries in order to provide descriptions and data on a township by township basis. The Selected Sand and Gravel Resource Areas have an unlicenced area of 7192 ha. Following removal of previously extracted areas and consideration of some cultural constraints, an estimated 5820 ha remain containing possible resources of approximately 674 million tonnes. This portion of the Selected Sand and Gravel Resource Areas comprise approximately 9% of the total area occupied by sand and gravel deposits in the county.

Possible aggregate resources derived from bedrock in Dufferin County are from the unsubdivided Goat Island and Gasport formations (formerly Amabel Formation). At present, however, there are no quarries operating within the county. Aggregate from the unsubdivided Goat Island and Gasport formations (formerly Amabel Formation) is highly valued as it is suitable for a wide range of applications including road building and construction aggregates. Possible resources in 6 Selected Bedrock Resource Areas amount to 875 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.

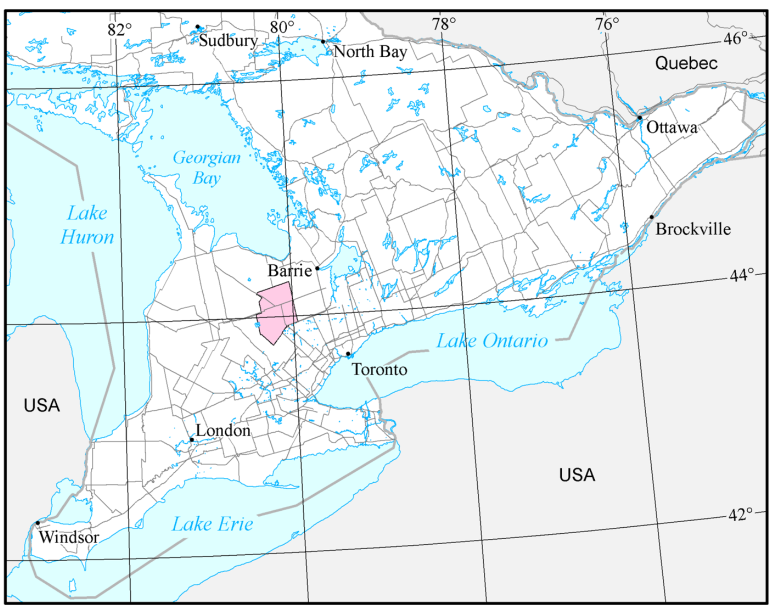

Figure 1. Map of southern Ontario showing the location of Dufferin County.

Aggregate Resources Inventory of Dufferin County

By MacNaughton Hermsen Britton Clarkson Planning Limited, White LandScience, Robinson Consultants, D.J. Rowell[1] and F.R. Brunton[1]

Project Supervisors: C.L. Baker and R.I. Kelly; field work by T. White; report by J. Parkin, T. White and Staff of the Ontario Geological Survey; compilation and drafting by MacNaughton Hermsen Britton Clarkson Planning Limited and Robinson Consultants. Assistance with review provided by the Ontario Geological Survey, Ministry of Northern Development and Mines, Sudbury, Ontario.

In 2009, the Ontario Geological Survey was provided with a number of properly georeferenced boreholes that significantly altered the 1998 Dufferin County Bedrock Resources Maps (overburden/drift thickness). As a result, the 1998 report was revised.

In 2011 and 2012, Ontario Geological Survey staff were granted access to privately drilled bedrock core, which has significantly altered the bedrock geology of Dufferin County, thereby requiring another revision to Map 2 - Bedrock Resources, as well as Tables 4 and 6. These revisions were considered important and significant; and, in keeping with the principles of aggregate reports as outlined in the last paragraph of the “Introduction” to this document, information about the bedrock has been updated. The remainder of the report remains the same.

In addition, the original (1998) maps were completed using MicroStation® computer-assisted design (CAD) software. The Ontario Geological Survey no longer uses this software to produce its maps; therefore, it became necessary to update the digital versions of the publication maps using ESRI® ArcGIS® software. Because changes were being made to both the report and Map 2 - Bedrock Resources, it was decided to produce both Maps 1 and 2 using the current Aggregate Resources Inventory Paper format (as outlined in “Parts I and II”); however, the geological and technical data remain the same (e.g., Map 1 - Sand and Gravel Resources) except for the changes to Map 2 - Bedrock Resources as noted above.

Manuscript accepted for publication in 2013 by J.R. Parker, Senior Manager, Earth Resources and Geoscience Mapping Section, Ontario Geological Survey. This report is published with the permission of the Director, Ontario Geological Survey.

[1] for further information, contact staff of the 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 1993, the total tonnage of mineral aggregates extracted in Ontario was 131 million tonnes, greater than that of any other metallic or nonmetallic commodity mined in the Province (Ministry of Natural Resources 1995).

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.

Parts I and II – 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 1, "Sand and Gravel Resources", provides an inventory and evaluation of the sand and gravel resources in the report area. Map 2, "Bedrock Resources", shows the distribution of bedrock formations and the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

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

Enhanced information on the aggregate resources for this area (e.g., complete deposit information for Map 1) is provided in vector ESRI® ArcGIS® files available for download as a compressed (*.zip*) file from GeologyOntario (www.ontario.ca/geology). A "readme" file included in the *.zip* file provides further details regarding the contents of these vector files. In addition, cross-references to data provided in the *.zip* file are provided for clients who wish to access digital data that does not require opening the vector ArcGIS® files. The 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**).

Map 1: Sand and Gravel Resources

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

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

SELECTED SAND AND GRAVEL RESOURCE AREAS

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

Areas of primary significance are coloured red on Map 1 and identified by a deposit number that corresponds to numbers in Table 3. The deposit number is also recorded in Sand_Gravel | 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 Map 1. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the best resources in the report area, they may contain large quantities of sand and gravel and should be considered as part of the overall aggregate supply of the area.

Deposits of tertiary significance are coloured yellow on Map 1. They are not considered to be important resource areas because of their low available resources or because of possible difficulties in extraction. Such areas may be useful for local needs or extraction under a wayside permit, but are unlikely to support large-scale development.

SELECTION CRITERIA

The process by which deposits are evaluated and selected involves the consideration of 2 sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

Site Specific Criteria

DEPOSIT SIZE AND THICKNESS

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall resources in the rest of the project area.

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

Map 2: Bedrock Resources

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

Inventory information presented on Map 2 is designed to give an indication of the present level of extractive activity in the report area. Those areas licenced for extraction under the *Aggregate Resources Act* are shown by a solid outline and identified by a number that refers to the quarry descriptions in Table 5. Each description notes the owner/operator, licenced hectarage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 2 and described in Table 5. Drill hole locations or other descriptive stratigraphic sections appear as a point symbol on Map 2. Table 7 provides these descriptions. These descriptions are also recorded in Bedrock | Add_Info.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 Map 2 in blue 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 Map 2 by a line pattern and the calculated available tonnages are given in Table 6. The selected bedrock resource areas are also recorded in Bedrock | Drift_Thick.dbf | **SELECT_AREA**.

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

SELECTION CRITERIA

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

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

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. The deposit size is recorded in 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).

Part III – Assessment of Aggregate Resources in Dufferin County

LOCATION AND POPULATION

Dufferin County occupies 149 019 ha in south-central Ontario. It is surrounded by the counties of Grey, Simcoe and Wellington and the Regional Municipality of Peel (Figure 1). The county consists of 8 local municipalities including the towns of Orangeville and Shelburne, and the townships of Amaranth, East Garafraxa, East Luther, Melancthon, Mono and Mulmur. The study area is covered by parts of the Bolton (30 M/13), Alliston (31 D/4), Orangeville (40 P/16), Dundalk (41 A/1) and Collingwood (41 A/8) 1:50 000 scale map sheets of the National Topographic System (NTS).

The population of Dufferin County was 40 997 in 1994 (Ministry of Municipal Affairs 1995), representing an increase of 5.7% from 1991 (Ministry of Municipal Affairs 1992) (Table A). The major economic activity in the county is agriculture, however, activity in this sector is declining.

Provincial highways 9, 10, 24, 25 and 89 provide access across the study area. These provincial highways are supplemented by well-maintained county and township roads which provide a complete road network across the county. Rail service is provided by the Canadian Pacific Railway (CPR). No major airports are located in the area.

SURFICIAL GEOLOGY AND PHYSIOGRAPHY

The physiography and distribution of surficial materials in Dufferin County, including the sand and gravel deposits shown on Map 1, are the result of glacial activity that took place in the Late Wisconsinan Substage of the Pleistocene Epoch. This period of time, which lasted from approximately 23 000 to 10 000 years before present, was marked by the repeated advance and retreat of the ice sheet margin (Barnett 1992).

At the time of the maximum glacial extent, Dufferin County was covered by a submass of the main ice sheet, known as the Georgian Bay lobe (Cowan 1976). The Georgian Bay lobe advanced to the southeast and deposited a thick layer of till on both the bedrock surface and pre-existing glacial sediments. The uppermost till, Tavistock Till, has a clayey silt matrix with a minor stone content (Cowan 1976). This till forms part of an extensive physiographic region known as the Dundalk Till Plain (Chapman and Putnam 1984), which covers large areas of Melancthon, Amaranth, East Luther and East Garafraxa townships. The till is not suitable for use as aggregate because of its fine texture.

Within the Dundalk Till Plain, localized deposits of sand and gravel occur as stratified deposits and eskers. A large esker occurs at Shrigley near the northern boundary of the county. Smaller eskers occur near Corbetton, Riverview and Peepabun; these contain limited and variable quantities of crushable aggregate.

Ice-contact stratified deposits are found throughout the county and are typified by a deposit near Horning's Mills. Here, several pits have been developed in relatively limited deposits of poorly sorted sand and gravel. Together, these ice-contact and esker deposits are the only significant sources of crushable material on the west side of the county.

At the point of its furthest advance, the Georgian Bay lobe met the Lake Ontario and Lake Simcoe lobes. Meltwa-

Table A – Area and Population, Dufferin County

Municipality	Area in 2006 (Hectares)	1991 Population	1994 Population
Orangeville	1457	17 227	19 036
Shelburne	334	3352	3450
Amaranth Township	26 544	3146	3187
East Garafraxa Township	16 474	2037	2012
East Luther Township	16 213	2445	2537
Melancthon Township	31 264	2320	2286
Mono Township	27 881	5766	5980
Mulmur Township	28 852	2483	2509
TOTAL	**149 019**	**38 776**	**40 997**

ters flowing between the Georgian Bay and Lake Ontario lobes in the southern part of the county deposited vast amounts of sand and gravel. As a result, a large irregular shaped interlobate ridge, known as the Orangeville Moraine, was formed (Cowan 1976). The moraine extends for many kilometres in a southwesterly direction and covers much of Mono and East Garafraxa townships. It is characterized by high relief (approximately 23 to 38 m above the surrounding till plain) and hummocky topography and contains large amounts of sand and gravel. The sand and gravel material is irregularly distributed and texturally variable.

After the deposition of the Orangeville Moraine, the ice margin of the Georgian Bay lobe retreated to the northwest. Sediment-laden meltwaters flowed off the ice margin towards the south in several meltwater channels. Large quantities of sand and gravel were deposited along the courses of the meltwater channels. The Lavender–Violet Hill meltwater channel contains 2 terraces: an upper terrace composed of 3 to 4 m of gravel over pebbly silty sand and a poorly exposed lower terrace with similar material. Southward-flowing meltwater close to the edge of the Niagara Escarpment deposited large quantities of sand and gravel around the head of Hockley Valley.

In the Orangeville area, southward- and westward-flowing meltwater deposited large quantities of coarse material. One of these meltwater channels is now occupied by the Grand River, where narrow terraces of sand and gravel are present along the banks. This high-quality, but limited sand and gravel resource, contains several working pits.

Extensive outwash plains were formed during the eastward retreat of the Lake Simcoe lobe across Dufferin County. Silty, medium sand fan deposits were laid down east of the Niagara Escarpment by west-flowing meltwaters. These have limited economic value, and consist of 2 to 9 m of sand over interbedded sand, gravel, till and silt.

The physiography of the northern part of Dufferin County, particularly on the west side of Mulmur and Mono townships, is dominated by the Niagara Escarpment. It is a cuesta scarp, produced by erosion of the bedrock surface for millions of years. The escarpment has a local relief of 244 m. Black Bank Hill is an erosion-severed portion of the escarpment in northern Mulmur Township, whereas, further south, the escarpment is incised by re-entrant valleys of the Pine and Bowring rivers. The Singhampton and Gibraltar moraines extend southwards through Mulmur and Mono townships in a band up to 4 km wide with its broad flat crest 15 to 45 m above the surrounding terrain (Chapman and Putnam 1984). In common with many morainic deposits, this feature contains poorly sorted fine or medium sand with minor amounts of gravel and crushable material. Textural variability gives the deposit low aggregate potential with particle size ranging from oversized material to fine sand and silt. Some deleterious shale and siltstone is also present.

On the east side of Dufferin County, rivers have downcut through the outwash plain leaving terraces at elevations of 328 m, 297 m and 282 m. To the west, postglacial landscape changes have been limited to the development of marshes (e.g., Luther Marsh) and localized bogs on the poorly drained till plains.

EXTRACTIVE ACTIVITY

In 1995, there were 43 licenced sand and gravel pits in Dufferin County. Table B shows the distribution of these licences by township. The total area currently under licence in the county is 1355 ha (*see* Table B).

The majority of the licences are located in Mono and East Garafraxa townships (11 and 14 licences, respectively). In East Garafraxa Township, the pits have been developed in several scattered outwash and ice-contact stratified drift deposits. In Mono Township, the pits are predominantly located in the meltwater and outwash deposits located north and northeast of the Town of Orangeville.

Production from licenced pits in Dufferin County has averaged approximately 1.41 million tonnes over the period of 1993–1995 (Ministry of Natural Resources 1993, 1994, 1995) (*see* Table B).

Table B – Aggregate Production, Dufferin County

Municipality	Number of Licences	Licenced Area (ha)	1993 Production (tonnes)	1994 Production (tonnes)	1995 Production (tonnes)
Amaranth Township	5	134	147 072	125 406	133 920
East Garafraxa Township	14	573	359 759	521 159	379 726
East Luther Township	4	83	92 422	270 927	55 486
Melancthon Township	4	141	293 402	247 442	168 041
Mono Township	11	288	354 110	360 232	552 230
Mulmur Township	5	136	36 163	48 572	91 872
TOTAL	**43**	**1355**	**1 282 928**	**1 573 738**	**1 381 275**

SELECTED SAND AND GRAVEL RESOURCES AREAS

Map 1 indicates the deposits in Dufferin County that contain granular materials. These deposits occupy 64 686 ha and contain an original resource tonnage of 7252 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 products.

Twenty sand and gravel deposits of primary significance have been selected for possible resource protection in Dufferin County. These Selected Sand and Gravel Resource Areas occupy a possible aggregate resource area of 5820 ha with a possible aggregate resource of 674 million tonnes (Table 3). The selected resource areas represent about 9% of the total area occupied by all sand and gravel deposits in Dufferin County and include most of the possible resources of crushable aggregate. Aggregate depletion in parts of these areas has been considerable since 1979.

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 is part of a large esker located in northern Melancthon Township near Shrigley. The esker consists of a well-defined central ridge, with local relief of approximately 15 m, flanked by relatively thin and sandy ice-contact stratified drift material.

Several pits have been developed in the esker, although none are currently licenced for extraction. A sample (DF-SS-1) was taken from this deposit and test results indicate a high percentage of fine material (Figures 2a and 2b). The sand fraction is too fine for hot mix products unless blended. The Petrographic Number (PN) was 163 for granular and 16 mm crushed and 203 for hot mix and concrete (Table 9).

A 7 m face at the site of sample location DF-SS-1 exposes poorly stratified, coarse gravel and sand in the esker core. Gravel content, consisting predominantly of dolostone, is estimated at more than 60%. Oversized material may need to be removed prior to crushing and processing.

Selected Sand and Gravel Resource Area 1 covers a total unlicenced area of 437 ha, but previous extraction and cultural setbacks reduce the possible resource area to 390 ha. With an assumed average thickness of 5 m, possible sand and gravel resources are estimated to be 35 million tonnes (*see* Table 3). This area is a valuable aggregate source and contains a high percentage of crushable gravel.

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 is an esker deposit located in central Melancthon Township. The deposit consists of a central ridge flanked by hummocky kame deposits and sandy deposits of lower relief. The esker is believed to be the southern extension of Selected Sand and Gravel Resource Area 1.

Several pits have been developed in the central ridge and expose 3 to 5 m of poorly sorted coarse sand and gravel with up to 5% oversized material. The gravel is of good quality and is suitable for a variety of crushed products; however, at some locations, the sand fraction may be too coarse and dirty for certain hot mix products. MTO data indicate sand control is necessary to meet Granular A specifications. Sample DF-SS-3, taken from this deposit, has a fines content in excess of 10% (Figures 2a and 2b). The Petrographic Numbers are 124 for granular and 16 mm crushed and 138 for hot mix and concrete (*see* Table 9).

Selected Sand and Gravel Resource Area 2 covers an unlicenced area of 145 ha of which 107 ha remain available for potential extraction. Assuming an average deposit thickness of 5 m, possible sand and gravel resources are estimated at 10 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 3

Selected Sand and Gravel Resource Area 3 is a large ice-contact stratified drift deposit located near Horning's Mills, where the terrain is characteristically irregular and hummocky. Several pits have been developed in the deposit and 3 are currently licenced (Pit Nos. 2, 3 and 4).

Pit faces range from 3 to 9 m and expose medium sand with some gravel and pebbly sand. This material is suitable for a range of applications, although selection and sand control is required for most crushed stone products. The sand fraction grades both too coarse and too fine for some hot mix asphaltic products. Field investigation recorded significant amounts of both oversize and shale materials. Sample DF-SS-4 has a low percentage of fines but processing to meet Granular A and hot mix specifications may be required (Figures 2a and 2b).

Selected Sand and Gravel Resource Area 3 occupies 1973 ha exclusive of licenced areas, but previous extraction and cultural setbacks reduce the possible resource area to 1588 ha. Assuming an average deposit thickness of 8 m, possible sand and gravel resources are estimated to be 225 million tonnes (*see* Table 3). This selected resource area is located within close proximity to several local markets. Access by both rail and road is available.

Selected Sand and Gravel Resource Area 4

Selected Sand and Gravel Resource Area 4 is an outwash deposit located along the eastern boundary of Melancthon Township and extending eastward into Mulmur Township. For convenience, the resource area has been divided into subareas 4a and 4b according to township boundaries.

Selected Sand and Gravel Resource Area 4a is part of an outwash deposit adjacent to the eastern boundary of Selected Sand and Gravel Resource Area 3 in Melancthon Township. The deposit continues through Horning's Mills into Mulmur Township. Face heights in previously worked pits and water well data indicate a sand and gravel deposit 6 to 12 m thick. The material may be suitable for crushed products. The deposit covers a total unlicenced area of 251 ha, but cultural setbacks and previous extraction reduce the possible resource area to 237 ha. Assuming an average thickness of 6 m, the possible aggregate resource for subarea 4a is 25 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 4b is located in Mulmur Township, approximately 2 km northeast of Horning's Mills. A 2.5 m high roadcut exposure on the northern edge of this deposit reveals up to 30% gravel of which the clasts are predominantly dolostone. Some deleterious material, including 2 to 5% fissile siltstone, is present.

Selected Sand and Gravel Resource Area 4b covers a total unlicenced area of 76 ha. Cultural setbacks reduce the possible resource area to 47 ha. Assuming a workable thickness of 6 m, the estimated possible resource is 5 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 5

Selected Sand and Gravel Resource Area 5 consists of a series of esker segments trending southeast through the southwest corner of Melancthon and northwest part of Amaranth townships. The resource area has been divided into subareas 5a and 5b based on township boundaries.

Selected Sand and Gravel Resource Area 5a consists of a discontinuous and narrow esker ridge, much of which is only about 3 m high, that is situated in the southwestern part of Melancthon Township. It has been partially depleted in past years through extraction from a number of wayside pit operations. Working faces expose poorly sorted coarse gravel and sand, but in general, the deposit is notably finer grained than the eskers in Selected Sand and Gravel Resource Areas 1 and 2. Sand is dominant in the esker flanks and, in places, this fraction grades coarse and too dirty for hot mix asphaltic products.

The total unlicenced area occupied by Selected Sand and Gravel Resource Area 5a is 23 ha, of which 15 ha remains after removal of cultural constraints and previously extracted areas. Assuming a deposit thickness of 6 m, possible aggregate resources would be about 2 million tonnes (*see* Table 3).

The southeast extension of the esker lies in Amaranth Township and forms Selected Sand and Gravel Resource Area 5b. It is now largely depleted and partially sterilized by residential development. The remaining resources are those most remote from the transportation corridors with some possible unworked material below the water table.

The unlicenced area of Selected Sand and Gravel Resource Area 5b is 25 ha. Cultural setbacks and previous excavation leaves 22 ha available for possible extraction. A deposit thickness of 5 m was used as it is possible to recover some material from below the water table. Possible aggregate resources are estimated at 2 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 6

Selected Sand and Gravel Resource Area 6 is located a few kilometres east of Honeywood in Mulmur Township. It is a lobate-shaped deltaic deposit situated on the south flank of Black Bank Hill, near the edge of the Niagara Escarpment. The material was deposited by southward-flowing meltwater during an early phase of the Lavender–Violet Hill meltwater channel. The deposit consists of an upper layer of gravel overlying gravel interbedded with medium to coarse sand. Data are sparse on this particular deposit, but total thickness may exceed 12 m with a stone content in the range of 40 to 60%.

A face within a wayside pit near Ruskview contains moderately well-sorted gravel and sand with greater than 35% subrounded pebbles and cobbles. A sample (DF-SS-2) from this deposit indicates greater than 4% fines and approximately 2% deleterious material (Figures 3a and 3b). The sand fraction requires blending for hot mix asphaltic products and processing is required to meet Granular A specification.

Several pits have been developed in the deposit including a licenced operation (Pit No. 11). The aggregate in this deposit has a reddish-brown hue, likely in part due to incorporation of material from the Queenston Formation. A 5 to 6 m high roadcut situated equidistant from Honeywood and Ruskview, exposes stratified ice-contact material that abuts the northern edge of the deposit. The generally level terrain in this area has been deeply dissected by tributaries of the Pine River. The steep wooded valley slopes could present serious access problems for aggregate operations. This deposit, identified by Telford and Narain (1976) as a high priority resource, lies entirely within the Niagara Escarpment Plan Area.

Selected Sand and Gravel Resource Area 6 occupies 325 ha exclusive of the licenced area. After deducting cultural setbacks and previously excavated areas, the potential resource area is calculated to be 302 ha. Using an assumed average deposit thickness of 8 m, possible aggregate resources are estimated at 43 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 7

Selected Sand and Gravel Resource Area 7 is located in Mulmur Township and consists of 2 outwash terraces produced by the downcutting action of the Pine River. The upper terrace lies close to Terra Nova; however, as both terraces grade downward to the east, they are not easily differentiated. There are no working pits in the area, but water well data indicate 6 to 15 m of gravelly sand may be available for possible extraction.

Selected Sand and Gravel Resource Area 7 covers 530 ha and, at present, no licenced extractive operations exist in the area. A considerable proportion of the area is now unavailable for extraction, particularly west from Terra Nova, as a result of expanding residential development.

After deducting cultural setbacks, the possible resource area is 418 ha. Assuming a minimum deposit thickness of 5 m, possible resources are estimated to be 37 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 8

Selected Sand and Gravel Resource Area 8 is a large outwash deposit situated in the south-central part of Mulmur Township extending southward into Mono Township. The resource area has been divided into subareas 8a and 8b based on township boundaries.

Selected Sand and Gravel Resource Area 8a is located in Mulmur Township and is situated on the upper terrace of the Lavender–Violet Hill meltwater deposit. This deposit extends southwards into Mono Township as Selected Sand and Gravel Resource Area 8b. At present, 4 licenced operations are located in this area (Pit Nos. 12, 13, 14 and 15).

The general stratigraphy of the deposit consists of gravel overlying interbedded medium to coarse sand and gravel. At one of the pits, uniform outwash gravel grades into sandier material at the foot of the working face. The stone content is approximately 30 to 40%; however, quality is variable and requires extensive selection and sand control for crushed products. Significant shale and siltstone contents render the material unsuitable for use as concrete aggregate and the fines content is too high for producing hot mix asphaltic products.

Selected Sand and Gravel Resource Area 8a occupies a total of 84 ha. After considering cultural constraints 39 ha are possibly available for extraction. Assuming an average deposit thickness of 8 m, the possible aggregate resource is 6 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 8b is the southward extension of the Lavender–Violet Hill meltwater deposit that is situated in Mono Township. The land is mainly cleared and under cultivation. Land surfaces are generally level, but are deeply dissected in several places by tributary streams of Sheldon Creek. These steeply sloping areas may present serious difficulties for aggregate development which may further limit the volume of extractable aggregate.

Several pits have been opened in the deposit. Pit No. 28 is a licenced operation covering 6.48 ha with a 5 m working face of moderately sorted and stratified sand and gravel with 30 to 45% stone content. The stone is suitable for most crushed products, although siltstone is a common constituent and may limit its use for higher quality applications. In particular, fine aggregate may be generally unsuitable for concrete or asphaltic mixes because of siltstone and the high percentage of fines. Suitability of the deposit is indicated by the test results of sample DF-SS-5 (Figures 4a and 4b). Results indicate a low fines content and moderate Petrographic Number (PN) values and the need for sand control as the sample grades too coarse for HL asphaltic products. Petrographic Number (PN) values for this sample are 129 for granular and 16mm and 159 for hot mix and concrete (*see* Table 9).

Selected Sand and Gravel Resource Area 8b occupies an unlicenced area of 264 ha. After deducting cultural setbacks the possible resource area is 198 ha. Assuming an average deposit thickness of 6 m, possible aggregate resources are estimated to be 21 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 9

Selected Sand and Gravel Resource Area 9 is part of a small esker deposit located south of Highway 89 and west of the Grand River near Keldon. The deposit has been worked in the past at several small pits, but none are currently active or licenced. The resource area comprises a total of 59 unlicenced ha, with a possible resource area of 48 ha. With an assumed 3 m thickness, the estimated possible resource is 3 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 10

Selected Sand and Gravel Resource Area 10 is part of the Grand River outwash terrace system. It extends from Grand Valley north to Tarbert. One licenced operation, Pit No.16, is currently working the deposit. Working faces are generally less than 3 m. Material consists of moderately sorted and stratified sand and gravel with a high percentage of crushable material. In places, the sand fraction grades too coarse and dirty for hot mix asphaltic products.

Selected Sand and Gravel Resource Area 10 covers a total of 134 ha of which 99 ha could be used for extraction. Assuming an average thickness of 2 m, possible sand and gravel resources are estimated at 4 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 11

Selected Sand and Gravel Resource Area 11 consists of an outwash deposit that is situated in the southeast corner of East Luther Township and extends eastward into Amaranth Township. The resource area has been subdivided into areas 11a and 11b based on the township boundary.

Selected Sand and Gravel Resource Area 11a is situated in the southeast corner of East Luther Township. It consists of 2 deposits contemporaneous with the terraces of outwash material described for Selected Sand and Gravel Resource Area 10. Textural properties and constraints are therefore similar. Several pits have been developed in the deposit and there are currently 2 licenced operations (Pit Nos. 18 and 19) with working faces generally less than 3 m.

Selected Sand and Gravel Resource Area 11a occupies a total of 48 ha exclusive of licenced areas. When cultural constraints are applied, the area possibly available for extraction is reduced to 15 ha. With an assumed thickness of 6 m, possible aggregate resources are estimated to be 2 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 11b lies in the southwest corner of Amaranth Township and extends eastward from Selected Sand and Gravel Resource Area 11a. Its origin and properties are therefore similar. Selected Sand and Gravel Resource Area 11b covers a total of 27 unlicenced ha that is reduced to 22 ha by cultural setbacks. Assuming an average thickness of 6 m, estimated possible aggregate resources are 2 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 12

Selected Sand and Gravel Resource Area 12 consists of the southern part of the Brice Hill esker and is located at the western boundary of Amaranth Township, north of the hamlet of Campania. The esker consists of a northwest-trending single ridge. Local relief is 6 to 9 m and the esker is less than 200 m wide.

The deposit is mainly silty medium to coarse sandy gravel with up to 35% stone content. Pit faces of approximately 5 m expose poorly sorted sandy gravel with less than 30% crushable material. Dolostone is the dominant lithology in the coarse fraction. Parts of the deposit are predominantly sand and a high percentage of fines may limit the range of possible aggregate uses. Sand control may be necessary. This deposit is now partially depleted and, in places, worked down to ground level. It is felt, however, that some additional material may remain below the water table.

Selected Sand and Gravel Resource Area 12 occupies a total of 70 ha. After considering cultural constraints 51 ha are possibly available for extraction. Assuming an average deposit thickness of 5 m, the sand and gravel resources are estimated to be 5 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 13

An extensive meltwater channel system consisting of a series of terraces situated along the banks of the present-day Grand River and a broad indistinct channel deposit with low relief and level topography trending east from Waldemar, through a well-defined valley in the Orangeville Moraine, has been chosen as Selected Sand and Gravel Resource Area 13. The resource area has been divided into subareas 13a and 13b based on township boundaries.

The outwash terrace deposits of Selected Sand and Gravel Resource Area 13a cover a wide area extending from the banks of the Grand River near Waldemar, to eastward through Amaranth hamlet. Numerous pits have been developed in this deposit and reserves are now considerably depleted at some locations. Currently, one licenced operation (Pit No. 24) is active in the area. Working face heights are variable, but are generally less than 6 m. Exposures reveal moderately sorted and stratified sand and gravel with significant crushable gravel content. The sand fraction grades too coarse and dirty in places for hot mix asphaltic products.

Selected Sand and Gravel Resource Area 13a occupies approximately 380 ha. Cultural constraints and previously extracted areas reduce the possible resource area to 292 ha. Some parts of this resource may not be available for extraction due to the location within the floodplain of the Grand River or because of encroaching residential development. Assuming an average thickness of 5 m, possible aggregate resources are estimated to be 26 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 13b consists of 3 small deposits in the northwest corner of East Garafraxa Township. The largest of these extends southward along the banks of the Grand River. Based on exposed faces in the deposit 2 to 3 km to the north, aggregate with a depth of up to 5 m may be present. Approximately 3 km to the east, 2 smaller areas extend from Selected Sand and Gravel Resource Area 13a south of Highway 9. In this area, pit working faces are 2 to 5 m high.

Together the areas of Selected Sand and Gravel Resource Area 13b total 68 ha. After allowing for cultural setbacks, the potential resource area is 53 ha. With an assumed average thickness of 5 m, estimated possible resources are 5 million tonnes (*see* Table 3). It should be noted that the location of some of these resources within the floodplain of the Grand River may restrict their availability.

Selected Sand and Gravel Resource Area 14

This selected resource area consists of a large ice-contact stratified drift deposit that is situated primarily within the Township of East Garafraxa; however, a portion of the deposit extends northward into Amaranth Township. The resource area has been subdivided into 2 subareas 14a and 14b based on the township boundary.

Selected Sand and Gravel Resource Area 14a consists of an ice-contact stratified drift deposit situated near the northern boundary of East Garafraxa Township. Several pits have been developed in the resource area, including 3 licenced operations (Pit Nos. 43, 44 and 45). Faces of up to

6 m expose poorly to well sorted sand and gravel. Sample DF-SS-9, from Pit No. 45, has moderate Petrographic Number (PN) values and the presence of considerable fines in a dominantly sandy deposit (Figures 6a and 6b; *see* Table 9).

Selected Sand and Gravel Resource Area 14a occupies a total of 216 ha. After considering cultural setbacks, the area potentially available for extraction is 130 ha. Assuming an average thickness of 6 m of usable aggregate, the possible sand and gravel resources in Selected Sand and Gravel Resource Area 14a are estimated to be 14 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 14b has properties very similar to those for the contiguous Selected Sand and Gravel Resource Area 14a. The area covered by Selected Sand and Gravel Resource Area 14b is approximately 3 ha. After considering cultural setbacks, the area possibly available for extraction is less than 1 ha. Assuming a working thickness of 6 m, possible resources of less than 1 million tonnes are available in Selected Sand and Resource Area 14b (*see* Table 3).

Selected Sand and Gravel Resource Area 15

Selected Sand and Gravel Resource Area 15 consists of a large ice-contact stratified drift deposit that forms part of the Orangeville Moraine. The resource area is situated primarily within East Garafraxa Township; however, it extends northward into Amaranth Township. As a result, the resource area has been divided into 2 subareas 15a and 15b based on the township boundary.

Selected Sand and Gravel Resource Area 15a is situated in the eastern corner of East Garafraxa Township. Characterized by rolling hummocky terrain, this ice-contact stratified drift deposit has a local relief of over 30 m. There are many pits, including 3 licenced operations (Pit Nos. 47, 48 and 49), in this resource area. Working faces range from 3 to 11 m in height and expose moderately sorted sand and minor gravel. Selection and sand control are required for crushed aggregates as the deposit contains only minor amounts of crushable material. Detailed field investigation would be required to determine whether any localized concentrations of gravel occur within this predominantly sand-rich deposit.

Selected Sand and Gravel Resource Area 15a occupies 891 ha exclusive of licenced properties, but cultural constraints reduce the potential area to 794 ha. With an assumed average deposit thickness of 6 m, possible resources are estimated to be 84 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 15b consists of 2 small areas located at the southeast corner of Amaranth Township. These areas are contiguous with the ice-contact deposit described under Selected Sand and Gravel Resource Area 15a. The resource area covers a total of 29 ha of which 28 ha are possibly available for extraction. Assuming an average thickness of 6 m, possible resources are estimated to be 3 million tonnes (*see* Table 3).

Most of the resource area has been cleared and is used predominantly for pasture. There is good road and rail access to the resource. Residential development extending westward from the Town of Orangeville is exerting considerable pressure on the resource and may limit future development.

Selected Sand and Gravel Resource Area 16

Selected Sand and Gravel Resource Area 16 forms a part of the Hockley Valley outwash and is situated on the north side of the valley. Nearly all of the resource area has been cleared and is under cultivation. The terrain is generally level, but there may be practical difficulties for extractive operations around the steeply sloping, dissected topography on the southern edge of the deposit.

No pits have been developed in the area, therefore estimates of texture and aggregate quality are based on data from other parts of the Hockley Valley outwash deposit. The stratigraphy of this area is assumed to be similar to that of Selected Sand and Gravel Resource Area 17, with 6 to 12 m of outwash gravel overlying sandier ice-contact stratified drift.

Selected Sand and Gravel Resource Area 16 covers a total unlicenced area of 392 ha. After considering cultural setbacks, the potential resource area is reduced to 330 ha. Assuming an average deposit thickness of 9 m, possible resources are estimated to be 53 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 17

Selected Sand and Gravel Resource Area 17 consists of outwash material and forms an important aggregate resource. The deposit lies immediately north of the Orangeville Reservoir at the head of the Hockley Valley. The surrounding land surface is generally smooth and level, except along the very dissected northern edge of the Hockley Valley.

Ice-contact sand deposits are exposed on the lower slopes of the valley. Similar ice-contact material may underlie most of the outwash material in Selected Sand and Gravel Resource Area 17 at depths ranging from 6 to 12 m.

This resource area contains medium- to coarse-textured sand and gravel, with stone content generally 40 to 60% and observed thicknesses of up to 6 m. The underlying ice-contact material is likely of poorer quality because of siltstone and shale fragments incorporated from the Georgian Bay and Queenston formations. These fragments have low abrasion resistance and can cause pop-outs in concrete. Some of the aggregate in the outwash may have incorporated this deleterious material from the ice-contact deposit and, consequently, may be unsuitable for crushed products. Water well and borehole data suggest thicknesses, including the lower ice-contact deposit, may exceed 30 m in places.

Several pits have been developed along the western edge of the deposit and there are currently 2 licenced operations present (Pit Nos. 33 and 34). Pit faces range from 6 to 12 m in height and expose moderately sorted and stratified sand and gravel with 40 to 45% stone content. The coarse aggregate from the deposit is generally acceptable for Granular A and some hot mix products. Sample DF-SS-7, indicates the need for sand control if hot mix products are to be produced from the deposit (Figures 4a and 4b).

The lower slopes of the terrace are hazard lands requiring detailed examination to assess their suitability for extraction. Much of the southwest portion of the Hockley Valley outwash deposit is becoming increasingly unavailable for extraction due to the encroachment of residential development.

Selected Sand and Gravel Resource Area 17 has a total unlicenced area of 185 ha which is reduced to 120 ha by cultural setbacks. Assuming an average deposit thickness of 7 m, possible aggregate resources are estimated to be 15 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 18

Selected Sand and Gravel Resource Area 18 forms part of the Mono Mills meltwater channel. During its formation, the west bank of the channel was the Niagara Escarpment, whereas the east bank was probably the margin of the glacier itself. The resultant ice-contact terrace deposit consists of a unit 1 to 5 m thick of medium to coarse sand, overlying moderately sorted and stratified gravel and sand, with stone content of approximately 40 to 50%. The coarser material is exposed in pits and along the valley of the Humber River.

There are 2 licenced operations (Pit Nos. 36 and 37) extracting material in the southern part of the deposit. Pit faces range from 5 to 8 m and some development is now progressing below the water table. Quality limitations are typical of many other outwash deposits in the area, that is, stone quality is limited by the presence of fissile siltstone. The fine fraction grades coarse and too dirty for asphaltic products. Selection and sand control are therefore required to produce crushed products.

The terrain is mainly flat except at the dissected terrace margins, which could raise some operational difficulties. Selected Sand and Gravel Resource Area 18 occupies a total area of 252 ha. After removing cultural constraints the possible resource area is reduced to 212 ha. Assuming an average deposit thickness of 5 m, estimated possible resources are 19 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 19

Selected Sand and Gravel Resource Area 19 is an outwash deposit located near the eastern corner of East Garafraxa Township. The area lies between 2 large ice-contact stratified drift deposits and was probably formed by meltwaters cutting a channel through the pre-existing ice-contact deposits.

A number of pits have been developed in the deposit. One licenced operation now operates in the deposit (Pit No. 46). Working faces expose moderately sorted sand and gravel in these pits. The thickness and texture of the outwash gravel is typically more uniform than in adjacent ice-contact drift deposits. Consequently, this area provides a more valuable resource, well suited to supply material suitable for most road building and construction applications. Sample DF-SS-10 was taken from this area and indicates that selective extraction may be required (Figures 6a and 6b). Road access is good and the area lies close to local markets.

Selected Sand and Gravel Resource Area 19 occupies 246 ha exclusive of licenced areas. Cultural setbacks reduce the possible area for extraction to 212 ha. Assuming an average deposit thickness of 6 m, possible sand and gravel resources are estimated to be 23 million tonnes (*see* Table 3).

Selected Sand and Gravel Resource Area 20

This selected area is a small portion of an outwash deposit situated on the southwest border of the Town of Orangeville. Commercial development is encroaching from the northeast. The resource area occupies 59 ha exclusive of licenced areas, and is reduced to 51 ha after considering cultural setbacks. Assuming an average deposit thickness of 5 m, possible resources are calculated to be 5 million tonnes (*see* Table 3).

Resource Areas of Secondary Significance

A sand-rich outwash deposit located in the vicinity of Mansfield (Mulmur Township) has been selected at the secondary level of significance. Gwyn (1975) describes 3 small pits developed in this area. Faces in the pits expose interbedded medium sand, pebbly sand and sandy gravel ranging in thickness from 2 to 18 m. Water well data indicate that the thickness of sandy material ranges from 1 to 6 m. Much of the material in this area may be used for sand cushion and other low specification road-building products.

The lower terrace of the meltwater channel situated north and east of Selected Sand and Gravel Resource Area 8a in Mulmur Township has also been identified as a resource area of secondary significance. This deposit consists of silty medium sand, pebbly sand and minor gravel. Moderate amounts of aggregate suitable for fill and sand cushion may be available.

A small segment of the Brice Hill Esker in the northeast corner of East Luther Township has been selected as a resource area of secondary significance. This deposit forms the westward extension of a resource area of secondary significance located in Amaranth Township. The deposit is small, but contains sand and gravel resources suitable for local use.

Two ice-contact stratified drift deposits located in the southwest corner of East Luther Township have also been selected at the secondary level of significance. The deposits are associated with the Mount View Esker that lies to the west in West Luther Township (Cowan 1976). Faces in pits developed in the 2 deposits expose sandy material suitable for road subbase aggregate.

Several deposits in Amaranth Township have been selected for possible resource protection at the secondary level of significance. Some deposits are substantial, whereas others are small and contain limited resources. All may be of value as alternative sites for local extraction in the event that deposits of primary significance are unavailable.

The low relief esker segments located in the northern part of Amaranth Township, at the southern end of the Riverview Esker, have been selected at the secondary level of significance. These segments may contain limited resources of crushable gravel, but because of their proximity to local demand areas and the ease of extraction, they may be valuable local sources of aggregate. Similarly, the low relief, westernmost part of the Brice Hill Esker has been selected at the secondary level of significance. The third deposit selected at the secondary level of significance is the sand-rich outwash associated with an ice-contact deposit located 2 km west of Laurel in the south-central portion of the township. Licenced Pit Nos. 22 and 23 are located in this deposit. Although the sand deposit itself has no possible resources of crushable aggregate, it overlies coarser material and, therefore, further investigation of this area may be justified.

The lower terrace of the Lavender–Violet Hill meltwater channel, situated adjacent to Selected Sand and Gravel Resource Area 8b in Mono Township, may have resources of sandy aggregate suitable for sand cushion and fill. A similar terrace extending south from Selected Sand and Gravel Resource Area 8b to Mono Centre contains higher proportions of crushable gravel and a greater depth of material. These deposits are classified as secondary resources due to operational difficulties imposed by topography, height of water table and deposit geometry. These restrictions are similar to, but more severe than, those discussed for selected resource area 8b.

Two outwash terraces located along the Nottawasaga River in the eastern part of Mono Township have been selected as resource areas of secondary significance. These deposits form the western extensions of areas selected for possible resource protection in Adjala Township. Both deposits may contain large resources of aggregate suitable for low-specification uses.

Two outwash deposits, one situated northeast of Purple Hill and the second located north of Orangeville along Highway 24, are similar in size and character to Selected Sand and Gravel Resource Area 17. Both deposits are part of the important Hockley Valley outwash complex; however, until further information is available, they should be considered as resources of secondary significance.

A series of ice-contact stratified drift deposits located in the southwest corner of Mono Township have been selected at the secondary level of significance. The deposits form part of the Orangeville Moraine and extend west into Amaranth Township. A few pits have been developed in these resource areas. Pit faces reveal predominantly sandy aggregate with irregularly distributed gravel lenses. The presence of excess oversize material, siltstone, silt and clay, may limit the range of uses for the aggregate. Previously recorded Petrographic Number (PN) values range from 130 to 250 which may preclude use of the material for higher specification products. Water well data indicate granular material of variable thickness (15 to 45 m) and stone content (10 to 60%) that is overlain by a considerable thickness of sand. The deposits are accessible by road and rail and form an important resource for the Town of Orangeville.

The entire extent of that part of the Orangeville Moraine which is located in East Garafraxa Township has been selected as a sand and gravel resource area of secondary significance. The western and southern extensions of this moraine into West Garafraxa and Erin townships, Wellington County, have also been selected at the secondary level of significance.

The Orangeville Moraine is characterized by rolling to hummocky topography and, locally, has relief of more than 30 m. The uppermost portions of the deposit consist almost entirely of sand, but isolated pockets of gravel may be present in some areas. A number of licenced properties have been developed within the deposit. One of the operations exposes poorly to well sorted stratified sand and minor gravel. This pit is not considered by the Ministry of Transportation to be a source of crushed aggregate. Detailed field investigation would be required to identify areas within the moraine suitable for the production of crushed aggregates.

An outwash terrace situated on the north bank of the Grand River in the western part of East Garafraxa Township has been selected for possible resource protection at the secondary level. Very little is known about the thickness or quality of the deposit in this area but, it is likely that crushable gravel is available. The deposit lies on the floodplain of the Grand River.

One small ice-contact deposit in the central portion of East Garafraxa Township has been selected at the secondary level. Although the deposit is small, it constitutes a good local source for crushed road-building aggregates.

Significant additional resources of sand and smaller amounts of gravel may also be available in an extension of the Orangeville Moraine that is located just south of Shelburne and in an extensive ice-contact stratified drift deposit located in the northwestern part of Mono Township. These deposits have not been selected for resource protection at the primary or secondary level of significance because of the generally fine texture of the aggregate and the lack of quantitative subsurface data. Further investigation is recommended.

BEDROCK GEOLOGY

The Paleozoic rocks underlying Dufferin County comprise a portion of the eastern rim of the Michigan Basin. The rocks are of Ordovician and Silurian age and consist mainly of limestones, dolostones and shale. The rock formations, in general, lie conformably over each other and dip gently towards the southwest. The structural geology of Dufferin County is relatively simple and is not disturbed by folding or faulting. The areal distribution of the bedrock formations are shown on Map 2 (Sanford 1969; Ontario Geological Survey 1991).

The oldest formation underlying the county is the Upper Ordovician Blue Mountain Formation, which is located in the northeast corner of the county in Mulmur Township. The formation is 40 to 60 m thick and consists of poorly fossiliferous, non-calcareous, blue-grey to grey-brown shales with thin, minor interbeds of limestone and siltstone (Johnson et al. 1992). The Blue Mountain strata were previously included in the upper and middle parts of the Whitby Formation. This rock is not suitable for the production of 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 manufacturing where the overlying Quaternary sediments are thin (Guillet 1977).

The Georgian Bay Formation overlies the Blue Mountain Formation and occurs in both Mulmur and Mono townships. This formation ranges from 125 to 200 m thick and consists of blue-grey to green-grey shale interbedded with fossiliferous grey shaly limestone, sandstone and green-grey siltstone. The Georgian Bay Formation has been used for brick manufacture in the Toronto area and, until the 1970s, for heat-expanded lightweight aggregate at Cooksville (Wilson 1980). The formation has little value as a load-bearing road-building aggregate and, apart from a few places along the slopes of the Pine River Valley, the unit is extensively drift covered. As a result, the Georgian Bay Formation has not been selected for aggregate resource protection.

The Georgian Bay Formation is overlain by the red and green shales of the Queenston Formation. The Queenston Formation crops out at various locations in Mulmur and Mono townships, east of the Niagara Escarpment. Outcrops are particularly noticeable on the eastern side of the county in stream valleys and along the north side of Hockley Valley. The Queenston Formation consists of red to maroon and green shales with minor interbeds of siltstone and limestone. The formation ranges in thickness from 50 m at the north end of Bruce County to over 300 m beneath Lake Erie (Johnson et al. 1992).

The Queenston Formation 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 a low load-bearing capacity and are unsuitable for use as construction aggregate.

The Queenston Formation is unconformably overlain by the sandstones of the Silurian 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 groups do not cover large areas of the county and are generally covered by more than 8 m of overburden, except for areas of outcrop and thin drift cover along the edge of the escarpment.

The Whirlpool Formation is the lower unit of the Cataract Group. The formation has a thickness of 3 to 5 m (Hewitt 1971) and consists of thin- to massive-bedded, medium- to fine-grained calcareous quartz sandstone. The formation often forms a low-level terrace at the base of the escarpment. The sandstone is suitable for building stone and flagstone, and has been extracted at several quarries along the Niagara Escarpment. The stone is commercially known as the “Credit Valley Sandstone” and has been used in the construction of such buildings as the main block of the Ontario Parliament Buildings and the Royal Ontario Museum (Hewitt 1971). The formation is not generally suitable for the production of crushed aggregate.

The Manitoulin Formation is a thin-bedded, blue-grey to buff-brown dolomitic limestone and dolostone. Outcrops occur mainly along the upper slope of the Niagara Escarpment. An exception is the area northeast of Black Bank Hill in Mulmur Township where drift cover is thin to non-existent. The formation has potential to supply crushed stone aggregate products and is presently quarried near Collingwood and Owen Sound. 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 consists of maroon to green and grey, non-calcareous shales with minor interbeds of siltstone, limestone and dolostone. Total thickness of the unit ranges from 10 to 39 m (Johnson et al. 1992). The formation has no utility for crushed stone aggregate products.

The Silurian Fossil Hill Formation, part of the Clinton Group, has limited exposure in Dufferin County with outcrops restricted to the upper slopes of the Niagara Escarpment. The formation consists of grey-brown, thin- to medium-bedded, crystalline dolostone. The unit is generally thin, less than 3 m on average, but may reach up to 24 m in places. The upper beds of the Fossil Hill Formation in this area are similar to parts of the Reynales Formation of the Niagara Peninsula (Liberty, Bond and Telford 1976). Locally, the Fossil Hill Formation has not been used for crushed stone aggregate due to its high silica (chert) content which may hinder its use for some aggregate products.

The brow and upper surface of the Niagara Escarpment is formed by the tough, erosion-resistant unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation). The formations underlie the western part of Mulmur and Mono townships, and subcrop in a southerly trending band, 5 to 15 km wide, that underlies the central part of the county. Extensive outcropping occurs along the brow of the Niagara Escarpment in Mono Township. The unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation) consist of medium- to massive-bedded, fossiliferous, crystalline dolostone.

The unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation) dolostone constitutes an aggregate source of both regional and provincial significance. Because of its high resistance to abrasion and chemical weathering, the rock is suitable for a wide range of applications including road building and construction aggregate (granular subbase material, asphalt and concrete stone). In addition, the formation also provides a valuable source of armour and architectural stone.

The Silurian Guelph Formation is the youngest rock unit in Dufferin County. The Guelph Formation consists mainly of buff coloured, irregular, medium- to massive-bedded, fine- to medium-crystalline, sucrosic dolostone (Liberty and Bolton 1971; Telford 1976). Its average thickness is about 40 m; however, because of its reefal nature, the unit may range in thickness from 4 to 100 m (Johnson et al. 1992). Some beds contain abundant fossils that weather irregularly.

The Guelph Formation occurs in a wide band running from Melancthon Township south through East Luther and Amaranth townships into East Garafraxa Township. The formation is generally covered by a thick blanket of Quaternary sediments throughout the county. In Melancthon Township, there is an area with less than 8 m of drift cover.

In general, because of the rock's reefal origin, it tends to be soft and weather easily. Consequently, it is not well suited for high-quality road construction uses, such as hot mix paving and Portland cement concrete aggregate. However, inter-reefal parts of the Guelph Formation may be more competent and more resistant to weathering. In such locations, the rock may be acceptable for some higher quality aggregate uses. The Guelph Formation dolostone does have value as an industrial mineral resource due to its high chemical purity. As such, it is a valuable raw material for chemical and metallurgical stone products (Hewitt 1960).

SELECTED BEDROCK RESOURCE AREAS

Areas with less than 8 m of overburden overlying the unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation) have been identified and selected for possible resource protection because of its suitability in the road building and construction industry. 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 in the building and dimension stone industry should not be dismissed or minimized. 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; whereas the Guelph Formation dolostone, due to its high chemical purity, is a valuable raw material for chemical and metallurgical stone.

The total available resources of the unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation) in the 6 selected bedrock resource areas are estimated to be 875.1 million tonnes (Table 6). The bedrock resource areas have been selected on the basis of current geological information. Parts of the selected areas are coincident with protected areas of the Niagara Escarpment Plan and, therefore, the availability of the resource will be less than indicated.

Selected Bedrock Resource Area 1

Selected Bedrock Resource Area 1 covers a large area in the northwestern part of Mulmur Township and the northeastern and central part of Melancthon Township. This area is underlain by the unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation). The bedrock is generally covered by less than 8 m of glacial drift which consists primarily of till.

Selected Bedrock Resource Area 1 covers a total unlicenced area of 2015 ha that is reduced to 1678 ha when cultural, physical and environmental constraints are applied. Assuming a conservative workable thickness of 15 m, possible bedrock resources of the unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation) dolostone are estimated to be 666.9 million tonnes (*see* Table 6).

Selected Bedrock Resource Area 2

Selected Bedrock Resource Area 2 is the Black Bank outlier located in the northwest corner of Mulmur Township. Here, the unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation) are covered by less than 8 m of overburden, as indicated on Map 2. A portion of this bedrock resource area is covered by the Niagara Escarpment Plan.

The resource area occupies approximately 94 ha that is reduced to 91 ha by cultural setbacks. Assuming a workable thickness of 15 m, possible bedrock resources of Selected Bedrock Resource Area 2 are estimated at 36.1 million tonnes (*see* Table 6).

Selected Bedrock Resource Area 3

Selected Bedrock Resource Area 3 is located approximately 2 km northeast of Shelburne and straddles the Mulmur and Melancthon townships boundary. The area is underlain by the unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation) and is covered by less than 8 m of glacial drift.

Selected Bedrock Resource Area 3 occupies a total area of 189 ha, with a possible resource area of 170 ha. Using an assumed workable thickness of 15 m, possible bedrock resources are estimated at 67.5 million tonnes (*see* Table 6).

Selected Bedrock Resource Area 4

Selected Bedrock Resource Area 4 is located near the face of the Niagara Escarpment north of Mono Centre (Mono Township). Outcrop exposures are common in this area. The resource area covers a total unlicenced area of 173 ha that is reduced to 148 ha after cultural setbacks are considered. Using a workable thickness of 15 m, possible bedrock resources are 58.6 million tonnes (*see* Table 6).

Selected Bedrock Resource Area 5

Selected Bedrock Resource Area 5 consists of a small area located a few kilometres south of Mono Centre in Mono Township that is underlain by the unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation). The resource area covers a total unlicenced area of 74 ha. The area available for possible extraction is reduced to 67 ha after cultural, physical and environmental constraints are considered. Assuming a workable thickness of 15 m, possible resources in Selected Bedrock Resource Area 5 are estimated at 26.7 million tonnes (*see* Table 6).

Selected Bedrock Resource Area 5 was previously identified as a high priority resource area by Telford and Narain (1976). The resource area falls within the Niagara Escarpment Plan Area, which will limit extraction opportunities.

Selected Bedrock Resource Area 6

Selected Bedrock Resource Area 6 is located in the southeast corner of Mono Township and consists of a small area of unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation) bedrock. Overburden is primarily a sandy-silt till and unlikely to cause problems in stripping; however, removal of an older layer of hard, compact till at the bedrock interface may cause some difficulty.

The area occupies 73 ha that is reduced to a possible available resource area of 49 ha after considering cultural setbacks. With an assumed workable thickness of 15 m possible resources are estimated at 19.3 million tonnes (*see* Table 6). A series of township and county roads provide access to the resource area.

SUMMARY

Twenty areas have been identified as sand and gravel resource areas of primary significance within Dufferin County. These Selected Sand and Gravel Resource Areas occupy a total unlicenced area of 7192 ha, which is reduced to 5820 ha after considering cultural constraints and previous extractive activity. Combined, these selected sand and gravel resource areas have possible aggregate resources of 674 million tonnes (*see* Table 3).

Six areas overlying the unsubdivided Goat Island and Gasport formations (formerly the Amabel Formation) and with less than 8 m of overburden cover have been chosen as Selected Bedrock Resource Areas. Rock from these formations has excellent potential for the production of bedrock-derived aggregates and is suitable for a wide range of construction and road building products. Some of the selected bedrock resource areas are located within the Niagara Escarpment Plan area and may, therefore, be affected by additional planning, environmental and other cultural constraints. Other bedrock formations that are present within the county have limited or little value as sources of crushed stone aggregate; however, several are suitable for other industrial mineral applications.

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

Table 1 - Total Identified Sand and Gravel Resources, Dufferin County			
1 Class Number	**2 Deposit Type**	**3 Areal Extent (Hectares)**	**4 Original Tonnage (Million Tonnes)**
Melancthon Township			
1	G-E	100	11
	G-IC	2092	293
	G-OW	251	28
	S-IC	21	2
	S-OW	305	34
2	G-E	547	46
	G-IC	221	19
	S-OW	283	24
3	G-E	12	<1
	G-IC	32	2
	S-IC	222	10
	S-OW	888	39
4	G-E	74	2
	G-IC	6	<1
	S-OW	1393	32
Subtotal		**6447**	**544**
Mulmur Township			
1	G-OW	609	85
	S-IC	4520	680
	S-OW	10 677	1795
2	G-IC	529	44
	G-OW/C	530	42
	S-IC	1546	120
	S-OW	434	32
3	S-IC	136	5
4	S-IC	16	<1
Subtotal		**18 997**	**2804**
East Luther Township			
1	G-OW	74	8
	S-OW	19	2
2	G-E	48	4
	G-OW	44	7
3	G-E	15	1
	G-IC	141	6
	G-OW	150	8
	S-OW	945	42
4	G-IC	15	<1
	G-OW	102	2
	S-OW	1014	23
Subtotal		**2567**	**104**

Table 1 - Total Identified Sand and Gravel Resources, Dufferin County			
1 Class Number	**2 Deposit Type**	**3 Areal Extent (Hectares)**	**4 Original Tonnage (Million Tonnes)**
Amaranth Township			
1	G-IC	35	4
	G-OW	88	10
	S-IC	1577	179
	S-OW	134	15
2	G-E	67	6
	G-IC	43	4
	G-OW	382	26
	S-IC	9	<1
	S-OW	268	18
3	G-E/C	96	6
	G-IC	46	2
	G-OW	127	6
	S-IC	48	2
	S-OW	1455	59
4	G-OW	<1	<1
	S-OW	3373	78
Subtotal		**7749**	**417**
Mono Township			
1	G-IC	396	57
	G-OW	1674	222
	S-IC	7447	1358
	S-OW	1811	237
2	G-IC	275	23
	G-OW	784	46
	S-IC	6066	633
	S-OW	347	33
3	G-OW	111	4
	S-IC	765	33
	S-OW	853	48
4	G-OW	33	1
	S-IC	29	<1
	S-OW	1073	30
Subtotal		**21 664**	**2726**

Table 1 - Total Identified Sand and Gravel Resources, Dufferin County			
1 Class Number	2 Deposit Type	3 Areal Extent (Hectares)	4 Original Tonnage (Million Tonnes)
East Garafraxa Township			
1	G-IC	299	34
	G-OW	335	40
	S-IC	4214	500
2	G-IC	62	7
	G-OW	275	18
	S-IC	44	3
	S-OW	65	5
3	G-E	49	3
	G-IC	54	2
	G-OW	123	5
	S-IC	59	3
	S-OW	48	2
4	G-OW	3	<1
	S-IC	58	1
	S-OW	1574	33
Subtotal		**7262**	**657**
TOTAL		**64 686**	**7252**

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): E = esker; IC = undifferentiated ice-contact stratified drift; OW = outwash; “/C” following letters denotes “class C” fines.

Table 2 - Sand and Gravel Pits, Dufferin County

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Melancthon Township					
Licenced					
1	Township of Melancthon	21.70	3 - 5	25	Substantial depletion
2	Nelson Arnold and William Arnold	28.35	5 - 8	-	
3	Lockyer Brothers Limited	66.82	5 - 9	20	Substantial depletion
4	679899 Ontario Limited	23.61	-	-	
Unlicenced					
5	-	-	3 - 9	35 - 60	
6	-	-	2 - 3	25 - 35	
7	-	-	4 - 10	-	
8	-	-	3.00	20 - 40	
9	-	-	9.70	-	
10	-	-	5.00	-	
Mulmur Township					
Licenced					
11	Mulmur Stone Inc.	16.20	5	20	Red shale content
12	C. Doney Construction Ltd.	11.30	6	55 - 70	
13	Mulmur Aggregates Inc.	58.74	-	-	
14	Mulmur Aggregates Inc.	16.20	5	<20	Depleted 30%
15	Township of Mulmur	33.33	5	30	Depleted 40%
Unlicenced					
East Luther Township					
Licenced					
16	Allto Holdings Inc. and MTJN II Holdings Inc.	25.40	-	-	Substantial depletion
17	Greenwood Construction Company Limited	11.34	3 - 4	-	Substantial depletion
18	Allto Holdings Inc. and MTJN II Holdings Inc.	6.08	3 - 8	-	Substantial depletion
19	Amaranth Aggregates	40.31	-	-	Substantial depletion
Unlicenced					
20	-	-	2 - 3	50	Overgrown
21	-	-	2 - 4	60	Overgrown
Amaranth Township					
Licenced					
22	Township of Amaranth	7.71	3 - 6	40 - 60	
23	Lafarge Construction Materials	49.92	3 - 9	variable	Substantial depletion
24	Township of Amaranth	17.70	-	-	Part overgrown
25	John LaVielle	17.01	3 - 7	-	Part overgrown
26	Lockyer Brothers Limited	41.71	8 - 9	10 - 20	70% depleted
Unlicenced					

Table 2 - Sand and Gravel Pits, Dufferin County

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Mono Township					
Licenced					
27	Lorne Patton	4.00	2 - 10	<15	Part depleted
28	Glen Robson	6.48	3 - 5	>30	Part depleted
29	Greenwood Construction Company Limited	13.97	-	variable >35	Substantial depletion
30	G.R.M. Contracting Limited	22.70	-	-	Substantial depletion
31	Greenwood Construction Company Limited	34.02	6	-	Substantial depletion
32	Township of Mono	23.80	-	-	
33	Lockyer Brothers Limited	15.30	-	-	100% depleted
34	Lockyer Brothers Limited	38.00	-	40	10% depleted
35	Doug's Haulage	4.46	5	-	
36	The Warren Paving and Material Group Limited	40.47	-	-	
37	Lafarge Construction Materials	84.47	-	15 - 20	Underwater extraction
Unlicenced					
38	-	-	3		
39	-	-	3 - 8		
40	-	-	3 - 6.1		
41	-	-	4.0 - 5.5		
East Garafraxa Township					
Licenced					
42	Gowland's Sand and Gravel Limited	9.31	-	-	
43	James and Lorna Gray	78.00	-	-	
44	Bill Wood	39.16	-	-	
45	John Wood	39.17	-	-	
46	Greenwood Construction Company Limited	40.47	-	-	
47	Trevor Henry	31.73	-	-	
48	Roy Black	64.39	8 - 11	-	
49	Rayburn Construction Limited	18.62	3 - 6	-	
50	Dixie Sand & Gravel Company Limited	20.25	-	-	
51	Dixie Sand & Gravel Company Limited	40.66	3	-	
52	Greenwood Ready Mix Contracting Limited	87.50	2 - 3	-	
53	Township of East Garafraxa	9.20	-	-	
54	John Rayburn	61.63	8	-	
55	Greenwood Construction Company Limited	33.08	-	-	
Unlicenced					

Table 3 - Selected Sand and Gravel Resource Areas, Dufferin County						
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)**
Melancthon Township						
1	437	37	10	390	5	35
2	145	31	7	107	5	10
3	1973	371	14	1588	8	225
4a	251	12	2	237	6	25
5a	23	6	2	15	6	2
Subtotal	**2829**	**457**	**35**	**2337**		**297**
Mulmur Township						
4b	76	29	-	47	6	5
6	325	21	2	302	8	43
7	530	112	-	418	5	37
8a	84	39	6	39	8	6
Subtotal	**1015**	**201**	**8**	**806**		**91**
East Luther Township						
9	59	7	4	48	3	3
10	134	33	2	99	2	4
11a	48	22	11	15	6	2
Subtotal	**241**	**62**	**17**	**162**		**9**
Amaranth Township						
5b	25	2	1	22	5	2
11b	27	4	1	22	6	2
12	70	17	2	51	5	5
13a	380	82	6	292	5	26
14b	3	3	-	<1	6	<1
15b	29	-	1	28	6	3
Subtotal	**534**	**108**	**11**	**415**		**38**
Mono Township						
8b	264	64	2	198	6	21
16	392	62	-	330	9	53
17	185	60	5	120	7	15
18	252	40	-	212	5	19
Subtotal	**1093**	**226**	**7**	**860**		**108**

Table 3 - Selected Sand and Gravel Resource Areas,
Dufferin County

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)
East Garafraxa Township						
13b	68	15	-	53	5	5
14a	216	46	40	130	6	14
15a	891	89	8	794	6	84
19	246	19	15	212	6	23
20	59	8	-	51	6	5
Subtotal	**1480**	**177**	**63**	**1240**		**131**
TOTAL	**7192**	**1231**	**141**	**5820**		**674**

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

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

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

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

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

Table 4 - Total Identified Bedrock Resources, Dufferin County				
1 Drift Thickness (Metres)	**2 Formation**	**3 Estimated Deposit Thickness (Metres)**	**4 Areal Extent (Hectares)**	**5 Original Tonnage (Million Tonnes)**
Melancthon Township				
<1	Guelph	15	29.7	11.8
1-8	Guelph	15	10 275.5	4083.0
8-15	Guelph	15	12 206.2	4850.1
<1	Eramosa	15	17.1	6.8
1-8	Eramosa	15	40.0	15.9
8-15	Eramosa	15	1162.7	462.0
<1	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	74.9	29.8
1-8	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	1037.9	412.4
8-15	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	542.2	215.4
<1	Clinton–Cataract Groups	15	10.8	4.3
1-8	Clinton–Cataract Groups	15	10.4	4.1
8-15	Clinton–Cataract Groups	15	23.3	9.3
1-8	Queenston	15	0.1	0.0
8-15	Queenston	15	0.4	0.1
Subtotal			**25 431.2**	**10 105.1**
Mulmur Township				
1-8	Guelph	15	1.7	0.7
8-15	Guelph	15	5.3	2.1
<1	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	75.6	30.0
1-8	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	1225.4	486.9
8-15	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	1561.2	620.3
<1	Clinton–Cataract Groups	15	18.3	7.3
1-8	Clinton–Cataract Groups	15	214.8	85.4
8-15	Clinton–Cataract Groups	15	506.9	201.4
<1	Queenston	15	8.7	3.1
1-8	Queenston	15	161.6	58.4
8-15	Queenston	15	980.7	354.2
<1	Georgian Bay	15	9.7	3.5
1-8	Georgian Bay	15	9.3	3.4
8-15	Georgian Bay	15	150.2	54.3
Subtotal			**4929.4**	**1911.0**
East Luther Township				
<1	Guelph	15	7.8	3.1
1-8	Guelph	15	43.8	17.4
8-15	Guelph	15	1302.8	517.7
Subtotal			**1354.4**	**538.2**

Table 4 - Total Identified Bedrock Resources, Dufferin County

1 Drift Thickness (Metres)	2 Formation	3 Estimated Deposit Thickness (Metres)	4 Areal Extent (Hectares)	5 Original Tonnage (Million Tonnes)
Amaranth Township				
<1	Guelph	15	7.9	3.1
1-8	Guelph	15	373.9	148.6
8-15	Guelph	15	1222.2	485.6
1-8	Eramosa	15	3.6	1.4
8-15	Eramosa	15	247.1	98.2
8-15	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	0.1	0.0
Subtotal			**1854.8**	**737.0**
Mono Township				
<1	Guelph	15	0.9	0.4
1-8	Guelph	15	6.0	2.4
8-15	Guelph	15	28.2	11.2
1-8	Eramosa	15	0.2	0.1
8-15	Eramosa	15	33.9	13.5
<1	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	80.3	31.9
1-8	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	366.5	145.6
8-15	Unsubdivided Goat Island–Gasport (formerly Amabel)	15	1442.9	573.3
<1	Clinton–Cataract Groups	15	1.7	0.7
1-8	Clinton–Cataract Groups	15	122.8	48.8
8-15	Clinton–Cataract Groups	15	321.5	127.7
<1	Queenston	15	1.7	0.6
1-8	Queenston	15	106.5	38.5
8-15	Queenston	15	326.5	117.9
1-8	Georgian Bay	15	0.8	0.3
8-15	Georgian Bay	15	46.1	16.7
Subtotal			**2886.6**	**1129.6**
East Garafraxa Township				
<1	Guelph	15	1.1	0.4
1-8	Guelph	15	7.9	3.1
8-15	Guelph	15	41.1	16.3
Subtotal			**50.1**	**19.9**
TOTAL			**36 506.4**	**14 440.7**

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, Dufferin County

Quarry No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	Remarks
Licenced				
		— NONE —		
Unlicenced				
		— NONE —		

Table 6 - Selected Bedrock Resource Areas, Dufferin County

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)
Unsubdivided Goat Island and Gasport Formations (formerly Amabel Formation)							
1	0-8	2014.6	336.3	0.0	1678.3	15	666.9
2	0-8	93.6	2.8	0.0	90.8	15	36.1
3	0-8	188.9	19.1	0.0	169.8	15	67.5
4	0-8	172.6	25.1	0.0	147.5	15	58.6
5	0-8	73.9	6.6	0.0	67.3	15	26.7
6	0-8	72.5	23.9	0.0	48.6	15	19.3
TOTAL		**2616.2**	**413.8**	**0.0**	**2202.4**		**875.1**

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

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

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

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

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

Table 7 - Summary of Test Hole Data, Dufferin County			
Test Hole Number	**Location**	**Depth (m)**	**Description**
Melancthon Township			
DF-DS-1	1 km southeast of Shrigley	0 - 0.25	Topsoil
		0.25 - 2.5	Poorly sorted coarse and fine sand and gravel; clasts predominantly subrounded dolostone, oversize (5%)
DF-DS-2	4 km south of Shrigley; north side County Road #21	0 - 2.5	Poorly sorted coarse to fine gravel and sand (partly worked wayside pit --no topsoil)
DF-DS-4	2 km southeast of Riverview	0 - 0.25	Sandy loam topsoil
		0.25 - 2.5	Coarse to fine sand with <10% gravel
Mulmur Township			
DF-DS-3	4 km east of Honeywood: roadcut at Blackbank Hill	0 - 0.5	Sandy loam topsoil and stony similar subsoil
		0.5 - 5.0	Poorly sorted coarse to fine sand and silt with subrounded, subangular and tabular gravel. Clasts predominantly dolostone, with <2% fissile siltstone and minor igneous clasts.
DF-DS-5	0.5 km east of Horning's Mills	0 - 0.20	Sandy loam topsoil
		0.20 - 5.0	Coarse to fine sand and silt with <15% stone content; clasts predominantly dolostone <20 cm, with <5% fissile siltstone and minor igneous clasts
DF-DS-6	2.5 km southwest of Terra Nova	0 - 0.5	Podzolic sandy loam soil profile
		0.5 - 2.5	Poorly sorted, coarse to fine sand and silt with <30% subangular to subrounded gravel

Table 8 - Summary of Geophysical Data, Dufferin County
— NONE —

Table 9 - Results of Aggregate Quality Tests, Dufferin County

Sample Number	Petrographic Number	
	Granular and 16 mm Crushed	**Hot Mix and Concrete**
Melancthon Township		
DF-SS-1	163	203
DF-SS-3	124	138
DF-SS-4	112	125
Mulmur Township		
DF-SS-2	119	183
Mono Township		
DF-SS-5	129	159
DF-SS-7	120	136
Amaranth Township		
DF-SS-6	100	102
DF-SS-8	133	173
East Garafraxa Township		
DF-SS-9	125	150
DF-SS-10	151	183

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.

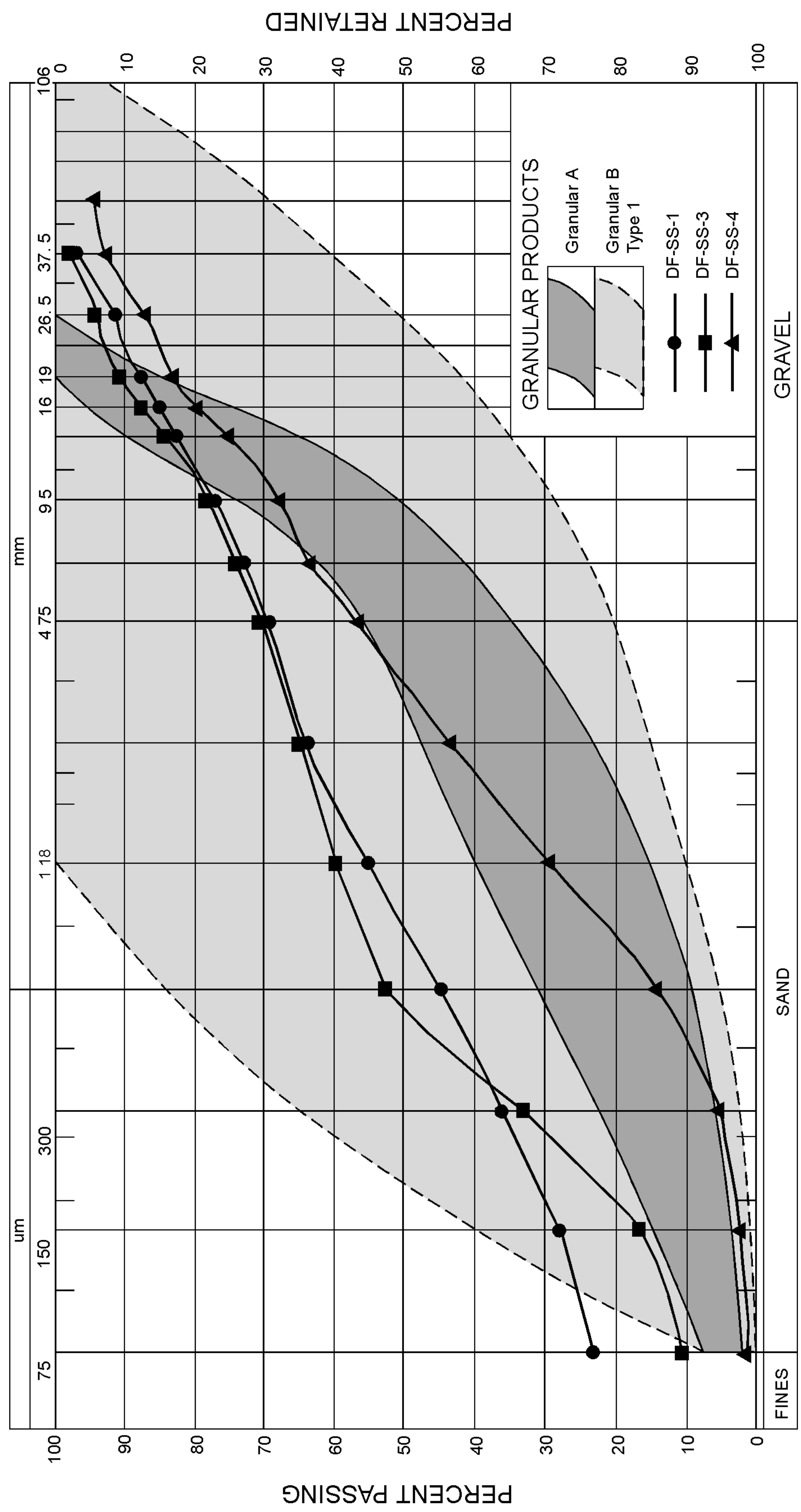

Figure 2a. Aggregate Grading Curves, Melancthon Township.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

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

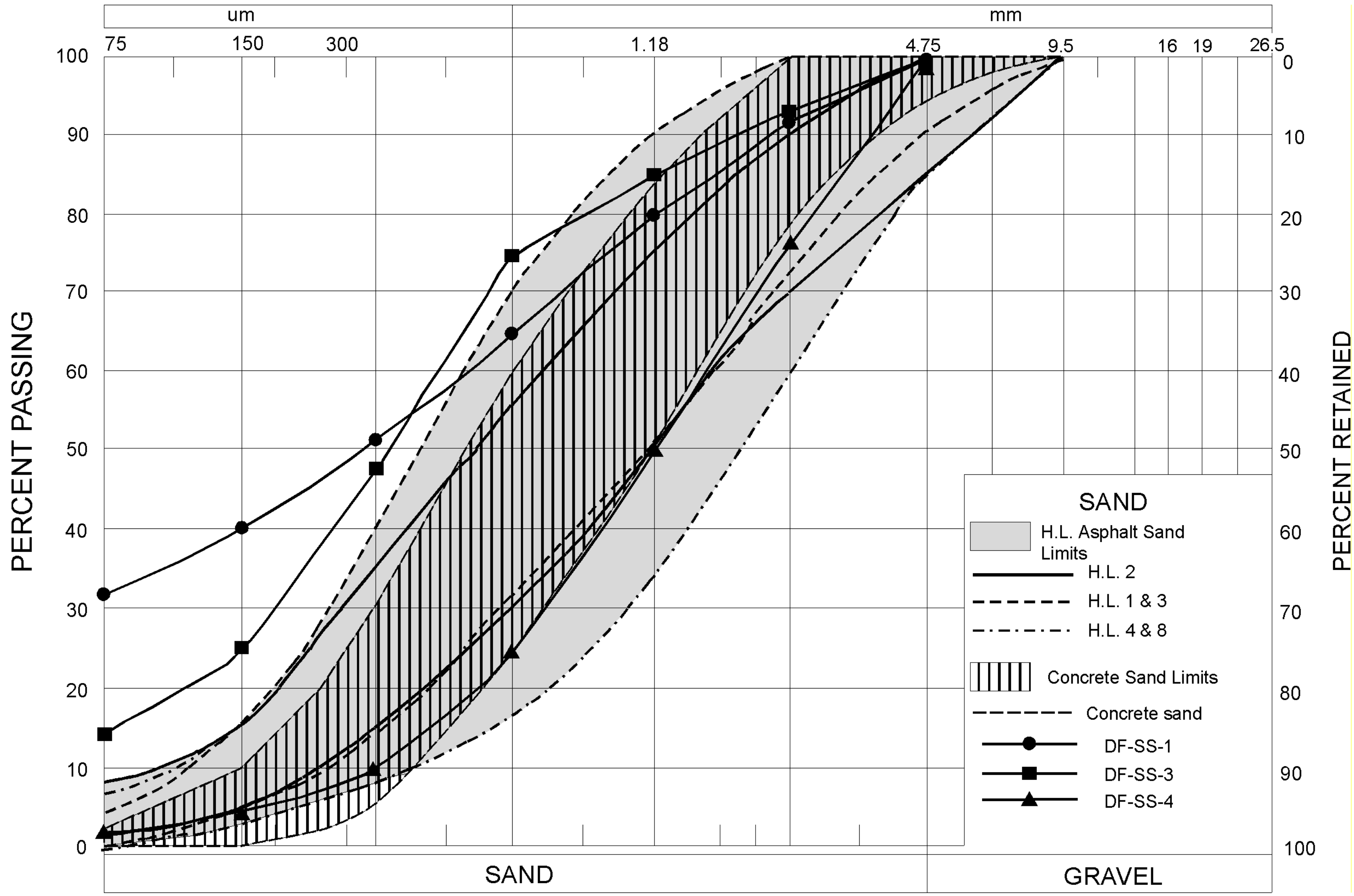

Figure 2b. Aggregate Grading Curves, Melancthon Township.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

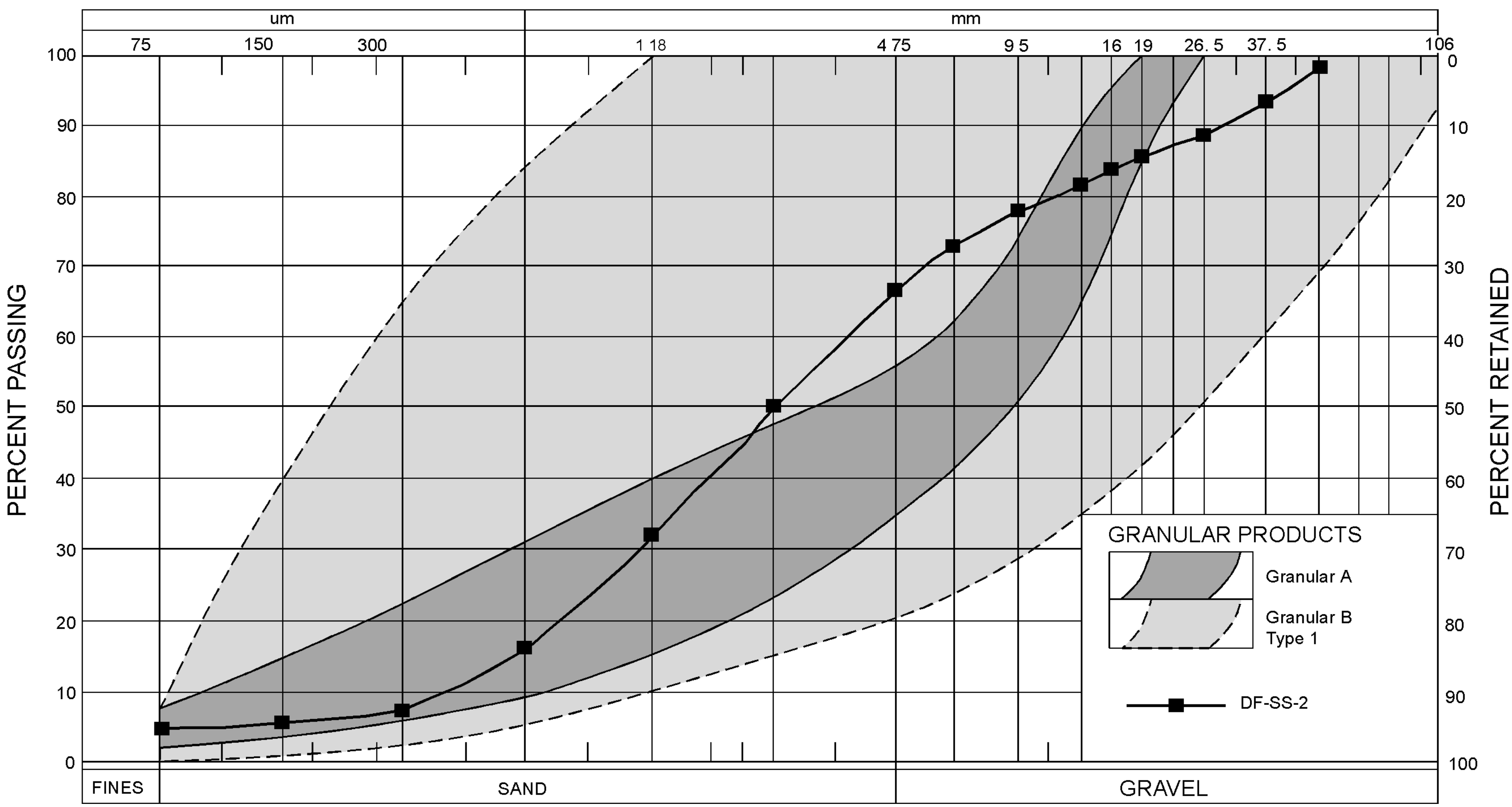

Figure 3a. Aggregate Grading Curves, Mulmur Township.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

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

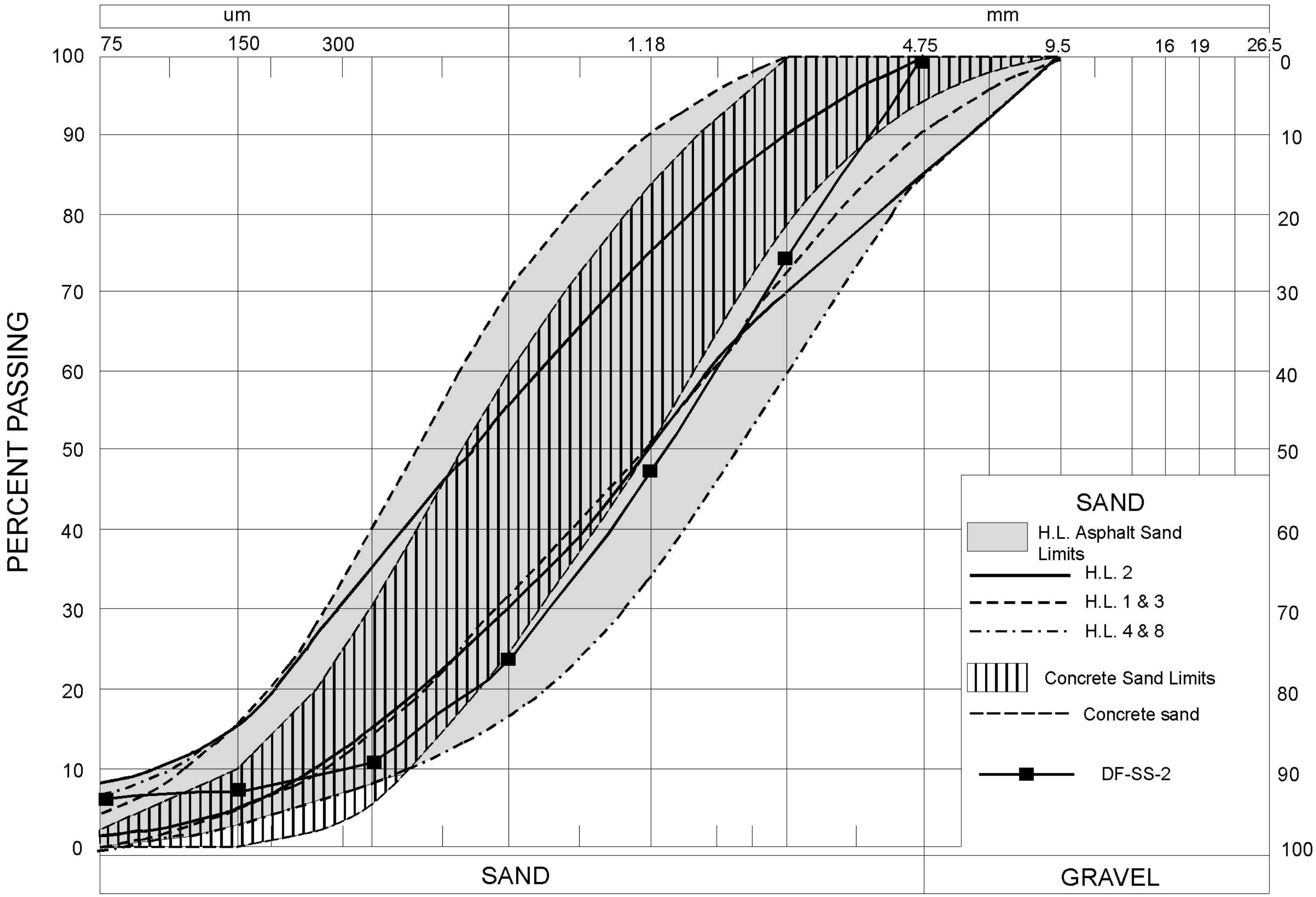

Figure 3b. Aggregate Grading Curves, Mulmur Township.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

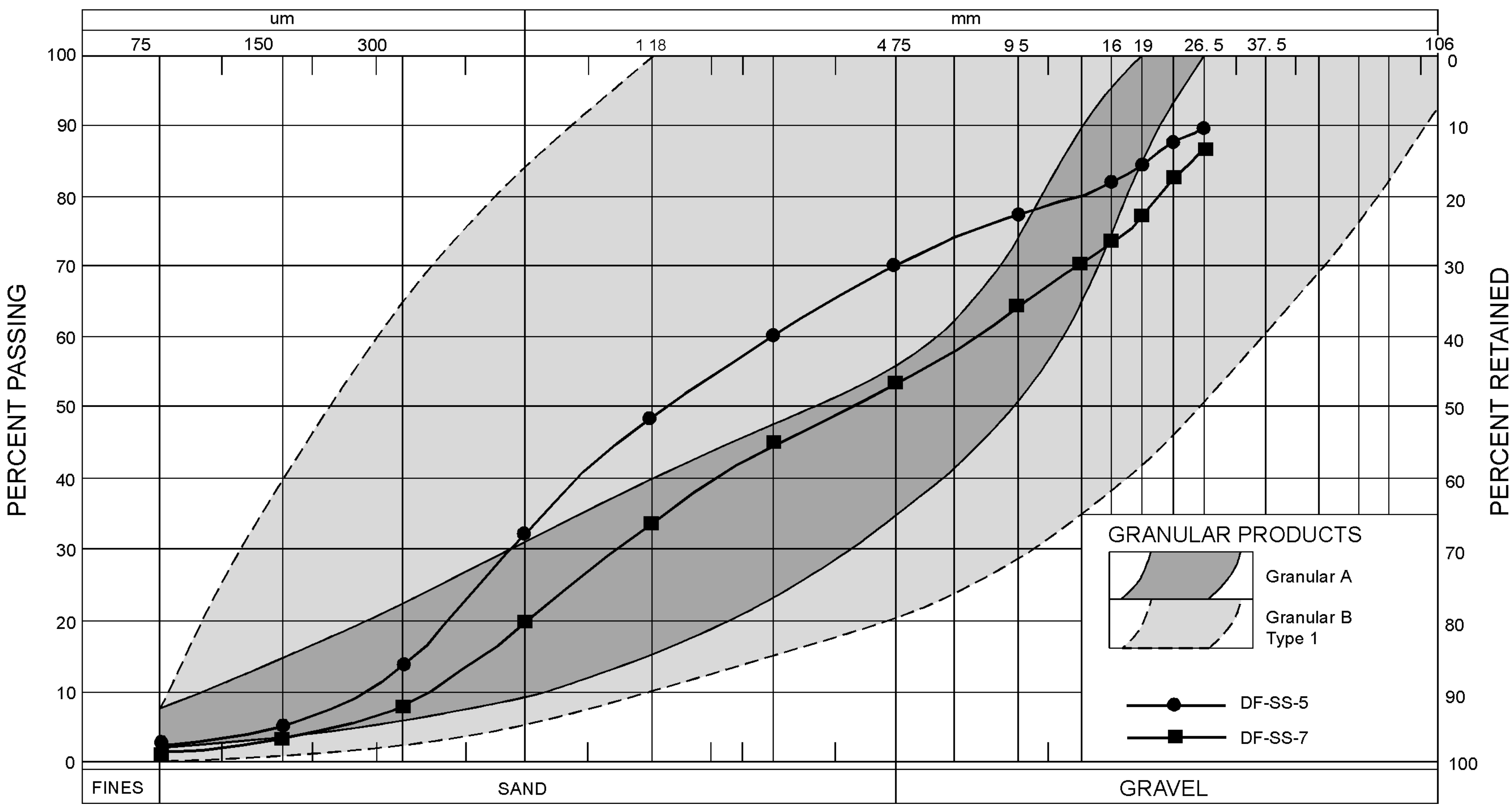

Figure 4a. Aggregate Grading Curves, Mono Township.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

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

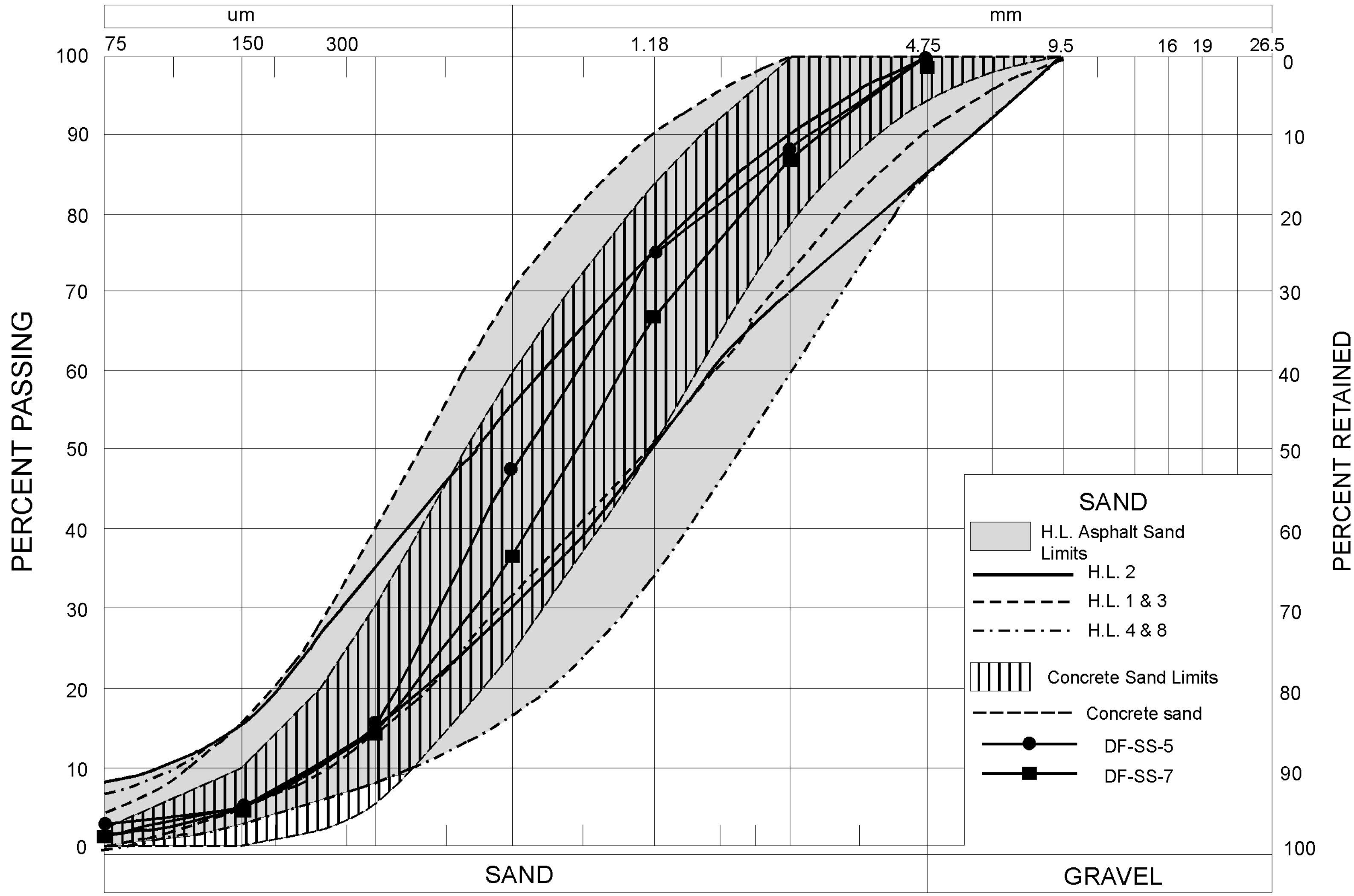

Figure 4b. Aggregate Grading Curves, Mono Township.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

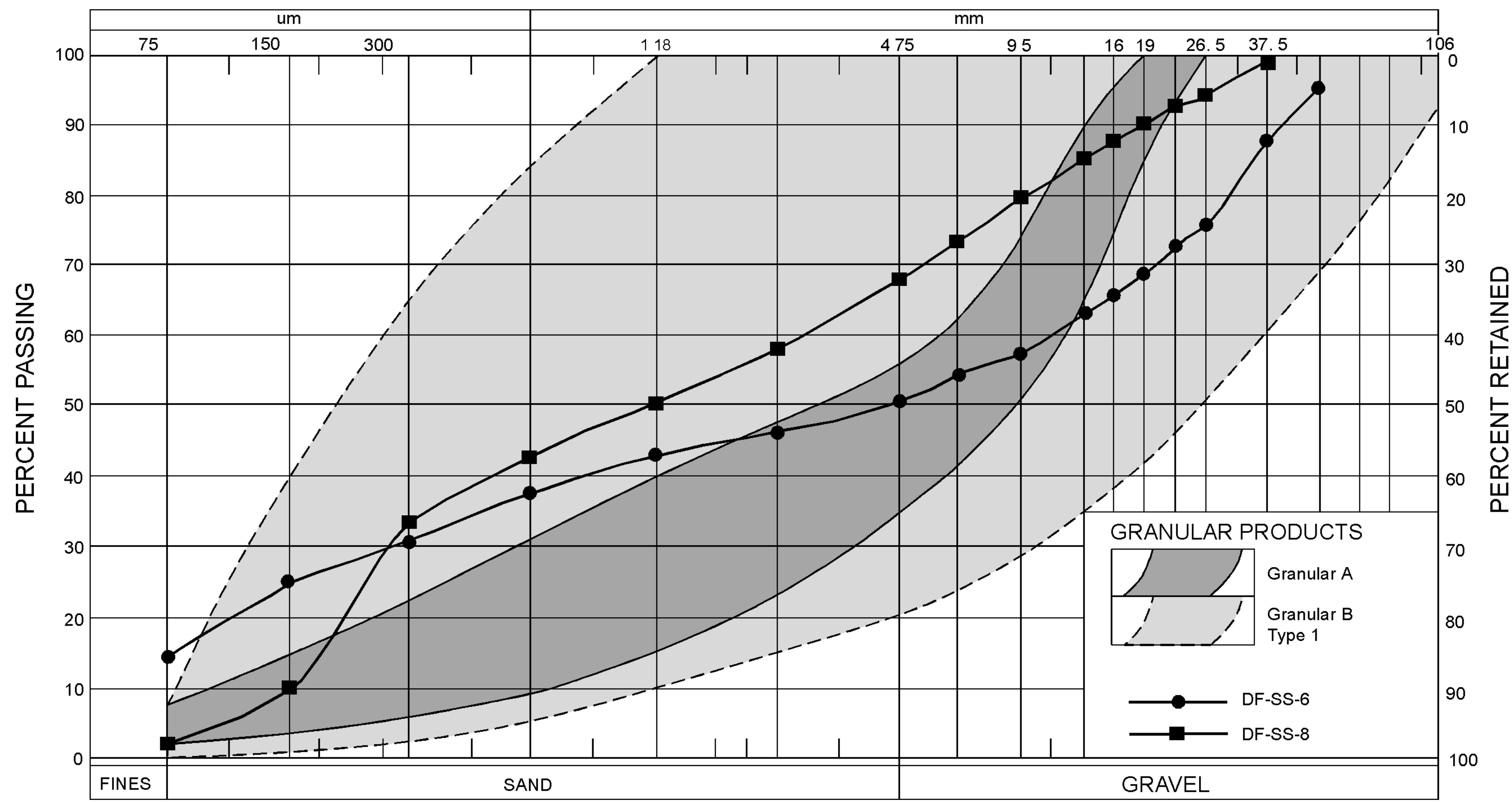

Figure 5a. Aggregate Grading Curves, Amaranth Township.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

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

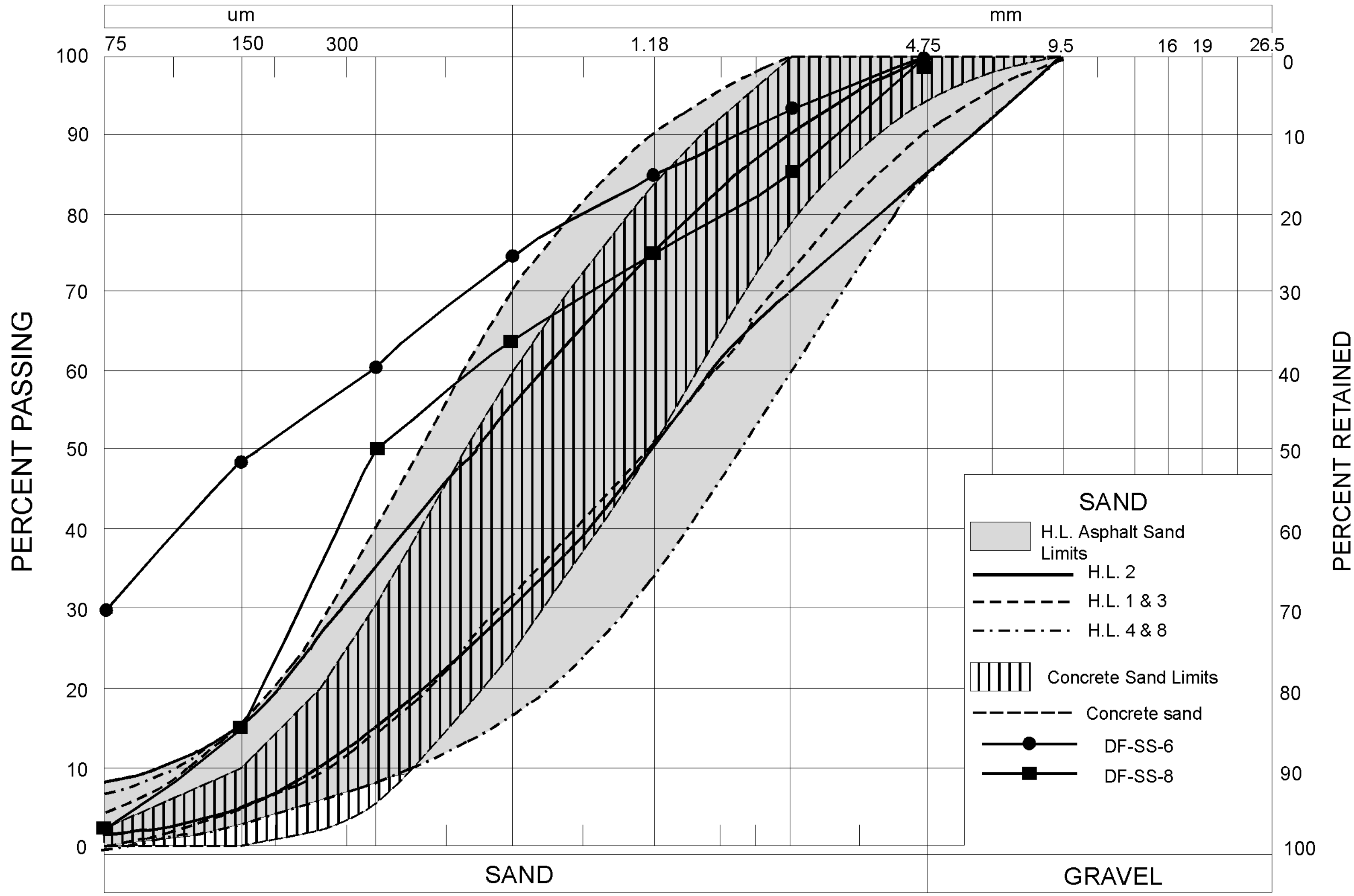

Figure 5b. Aggregate Grading Curves, Amaranth Township.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

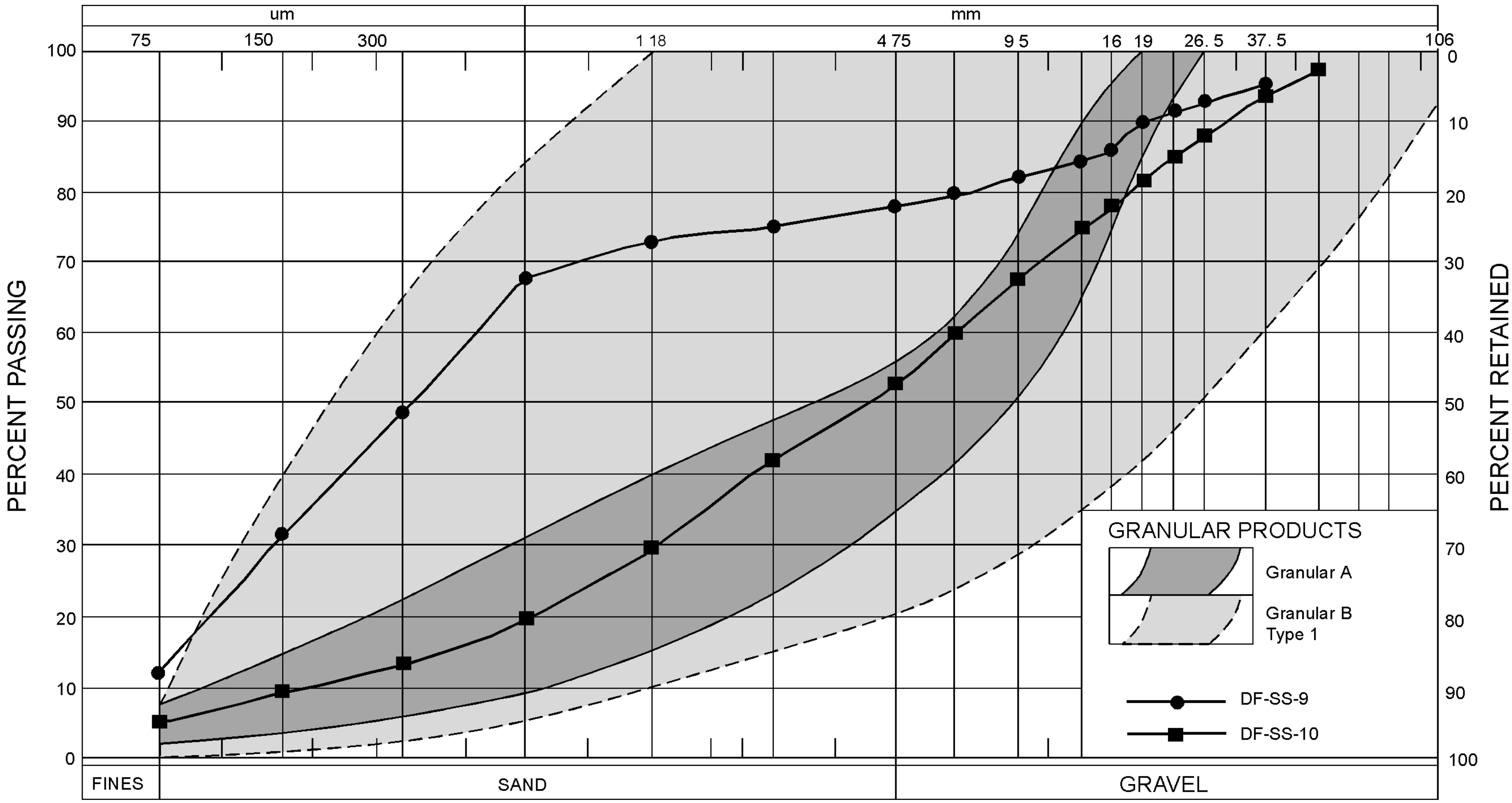

Figure 6a. Aggregate Grading Curves, Garafraxa Township.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

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

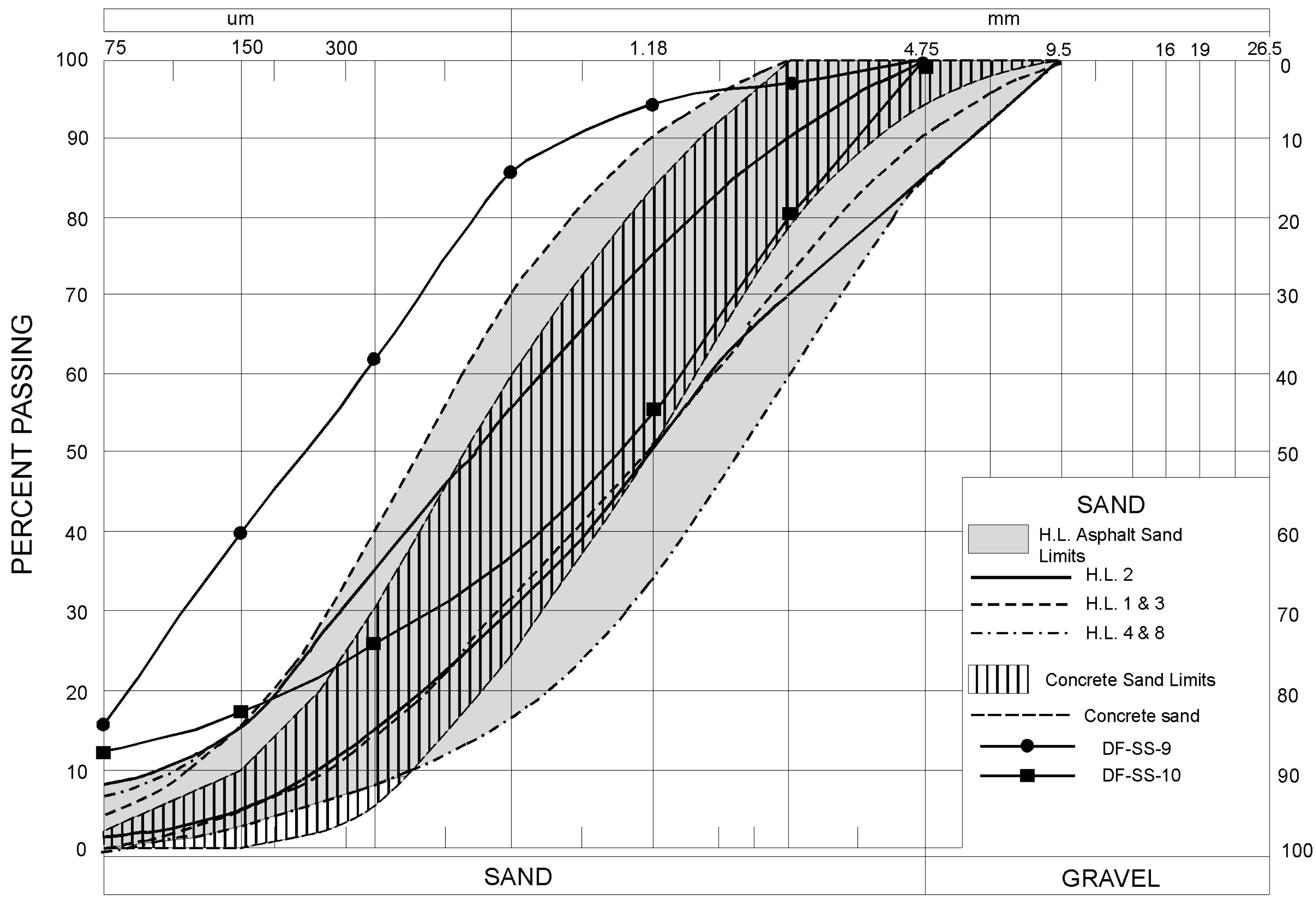

Figure 6b. Aggregate Grading Curves, Garafraxa Township.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes *adapted from* the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

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Appendix B – Glossary

Abrasion Resistance: Tests such as the Los Angeles abrasion test (*see* Appendix E) are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

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

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.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high-quality asphalt surface course uses, values of less than 6 are desirable.

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.

Bulk Relative Density: The density of a material related to water at 4°C and atmospheric pressure at sea level. 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.

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.

Los Angeles Abrasion and Impact Test: 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.

Magnesium Sulphate Soundness Test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing 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.

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.

Petrographic Examination: An aggregate quality test based on known field performance of various rock types. In Ontario, the test result is a Petrographic Number (PN). The higher the PN, the lower the quality of the aggregate.

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".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abrasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

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.

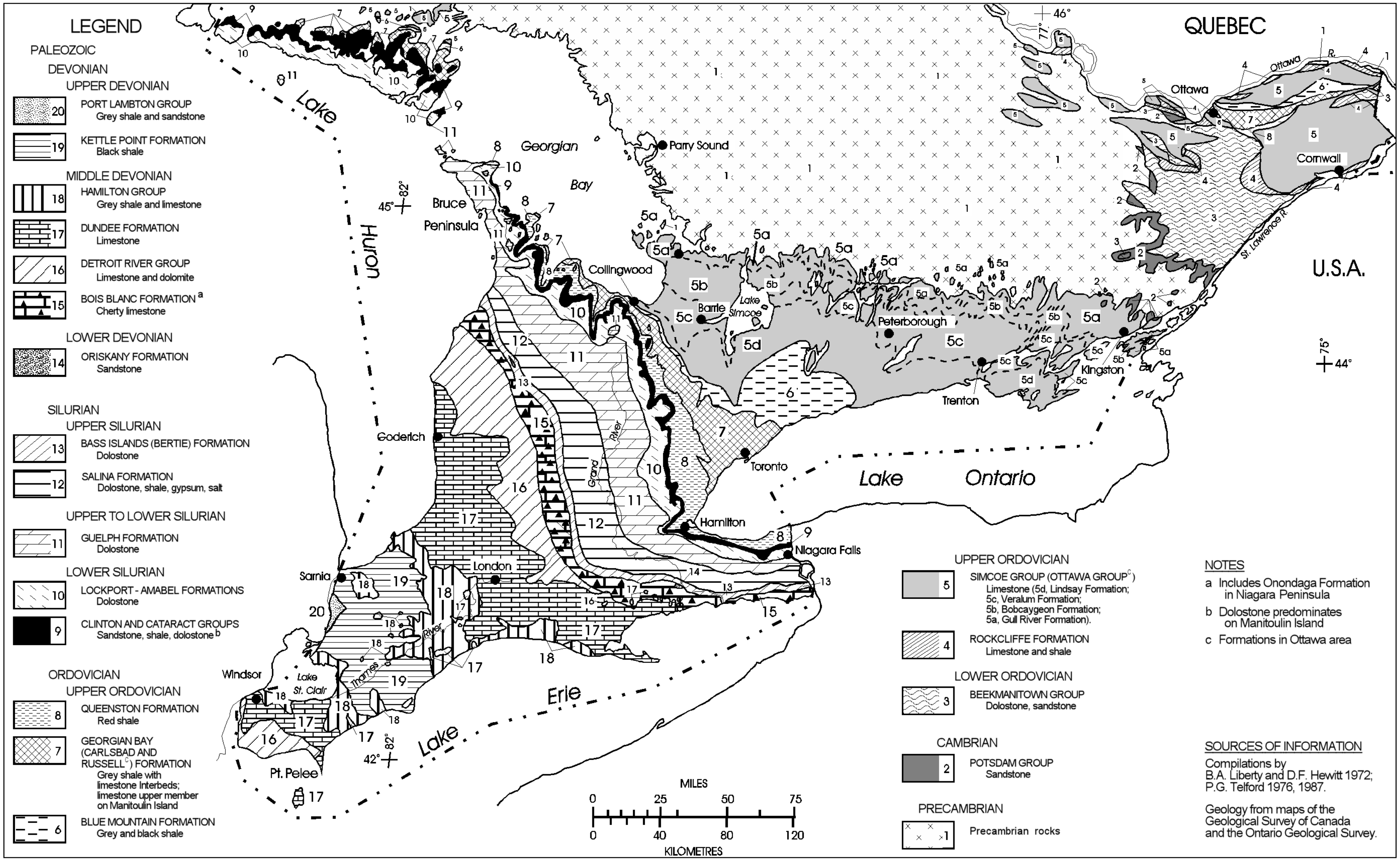

Figure D1. Bedrock geology of southern Ontario.

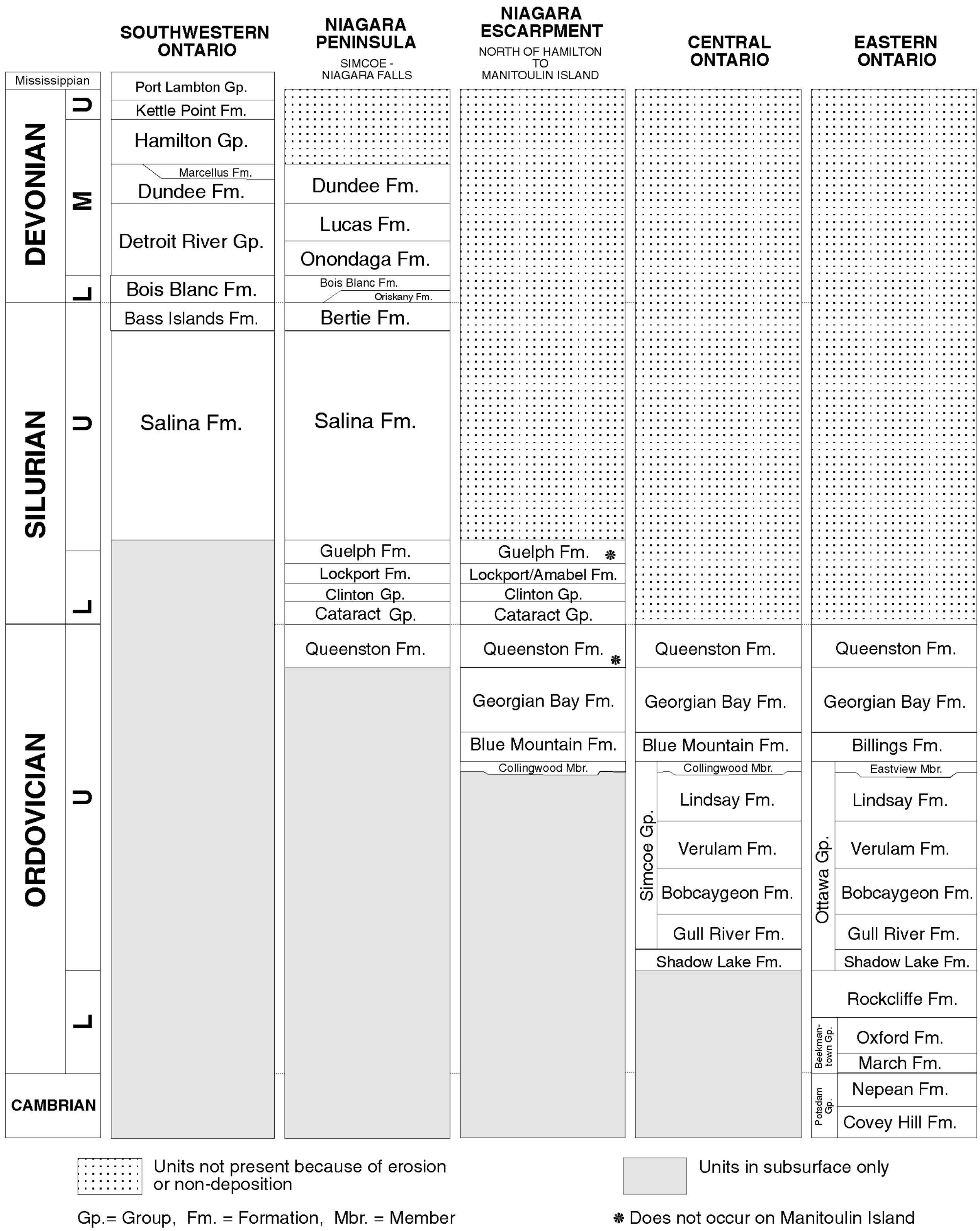

Figure D2. Exposed Paleozoic stratigraphic sequences in southern Ontario (*adapted from* Bezys and Johnson 1988 and Armstrong and Dodge 2007).

Appendix E – Aggregate Quality Test Specifications

Six types of aggregate quality tests are often performed by the Ministry of Transportation of Ontario (MTO) on sampled material. A 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 six tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the MTO.

Absorption Capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate. This test is conducted in conjunction with the determination of the sample's relative density.

Los Angeles Abrasion and Impact Test: 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.

Magnesium Sulphate Soundness Test: This test is designed to simulate the action of freezing and thawing on aggregate. Those aggregates which are susceptible will usually 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: The micro-Deval abrasion test 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 maximum loss for HL 1/HL 3 is 20%, for HL 2 and HL 4/HL 8 it is 25% and for structural and pavement concrete it is 20%. It is anticipated that this test will replace the fine aggregate Magnesium Sulphate Soundness test.

Mortar Bar Accelerated Expansion Test: 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.

Petrographic Examination: 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.

Table E1. Selected quality requirements for major aggregate products.

	Type of Test					
	Coarse Aggregate				Fine Aggregate	
Type of Material	**Petrographic Number (maximum)**	**Magnesium Sulphate Soundness (maximum % loss)**	**Absorption (maximum %)**	**Los Angeles Abrasion (maximum % loss)**	**Micro-Deval Abrasion Loss (maximum % loss)**	**Magnesium Sulphate Soundness (maximum % loss)**
Granular A	200	—	—	60		—
Granular B Type 1	250*	—	—	—		—
Granular B Type 2	250	—	—	60		—
Granular M	200	—	—	60		—
Granular S	200	—	—	—		—
Select Subgrade Material	250	—	—	—		—
Open Graded Drainage Layer (1)	160	15	2.0	35		—
Hot Mix - HL 1, DFC, OFC	See OPSS 1149 and Special Provision No. 313S10					
Surface Treatment Class 1	135	12	1.75	35		—
Surface Treatment Class 2	160	15	—	35		—
Surface Treatment Class 3	160	12	2.0	35		—
Surface Treatment Class 4		—	—	—		20
Surface Treatment Class 5	135	12	1.75	35		—
Hot Mix - HL 1	100	5	1.0	15	20	16
Hot Mix - HL 2		—	—	—	25	20
Hot Mix - HL 3	135	12	1.75	35	20	16
Hot Mix - HL 4	160	12	2.0	35	20	20
Hot Mix - HL 8	160	—15	2.0	35	25	20
Structural Concrete, Sidewalk, Curb, Gutter and Base	140	12	2.0	50	20	16
Pavement Concrete	125	12	2.0	35	20	16

* Requirement waived if the material has more than 80% passing the 4.75 mm sieve.
(1) Hot mix and concrete petrographic number applies
(Ontario Provincial Standard Specifications OPSS 304, OPSS 1002, OPSS 1003, OPSS 1010 and OPSS 1149).

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 163—Revision 2

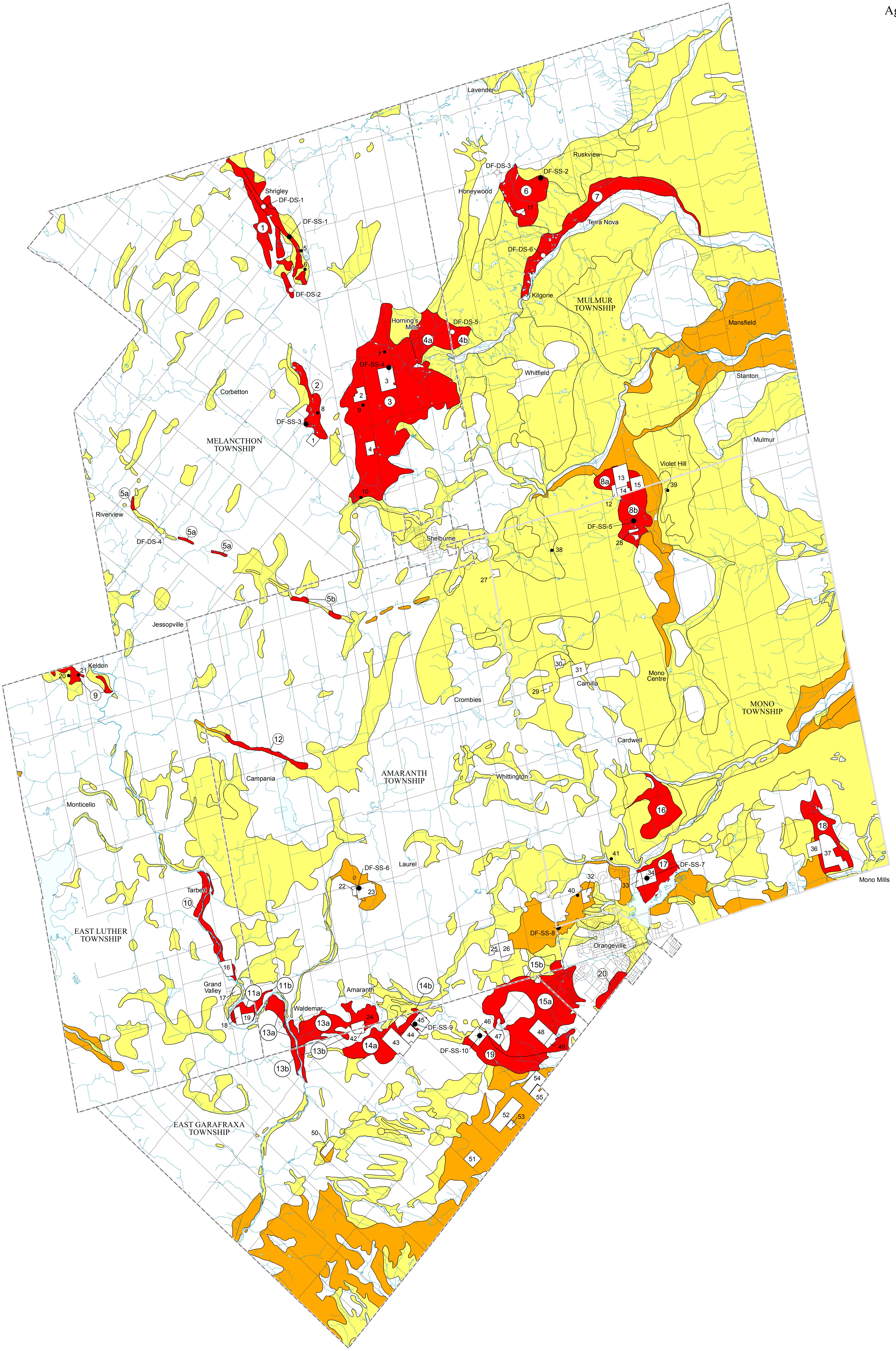
MAP 1

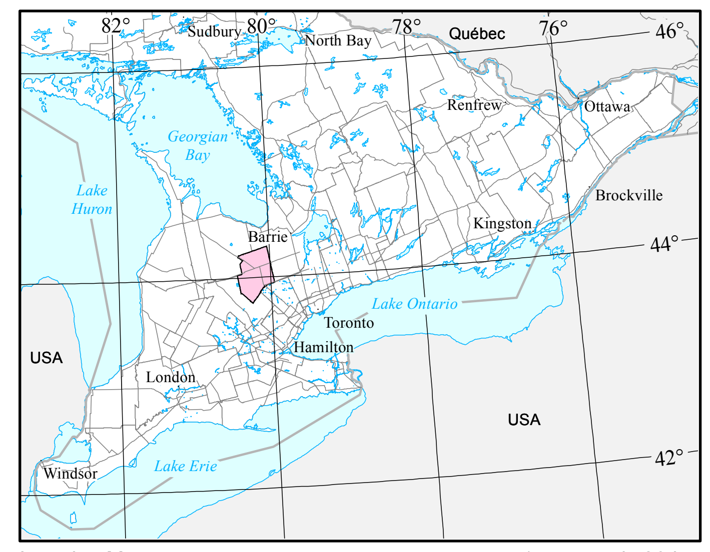
Sand and Gravel Resources for Dufferin County

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 30 M/13, 31 D/4, 40 P/16, 41 A/1, 41 A/8





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).
- Test hole location; identification number (*see* Table 7)
- Sample site; identification number (*see* Table 9)
- Geological and aggregate thickness boundary of sand and gravel deposits
- Administrative boundary

SOURCES OF INFORMATION

Base map information derived from National Topographic System (NTS) maps, Natural Resources Canada, scale 1:50 000, and from the Ontario Land Information Warehouse, Land Information Ontario, Ministry of Natural Resources, Ontario, 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 drilled 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
Cowan, W.R. 1976
Gwyn, Q.H.J. 1975

Additional geology by White LandScience and MacNaughton Hermsen Britton Clarkson Planning Limited. Compilation by J. Parkin and T. White; field work by T. White. Report by J. Parkin and T. White. Compilation and drafting by MacNaughton Hermsen Britton Clarkson Planning Limited and Robinson Consultants. Additional drafting by S.A. Evers, Sedimentary Geoscience Section, Ontario Geological Survey. This map is published with the permission of the Director, Ontario Geological Survey.

White LandScience and MacNaughton Hermsen Britton Clarkson Planning Limited 2014. Aggregate resources inventory for Dufferin County, southern Ontario; Ontario Geological Survey, Aggregate Resources Inventory Paper 163—Revision 2, Map 1–Sand and Gravel Resources, scale 1:100 000.

Aggregate Resources Inventory Paper 163—Revision 2

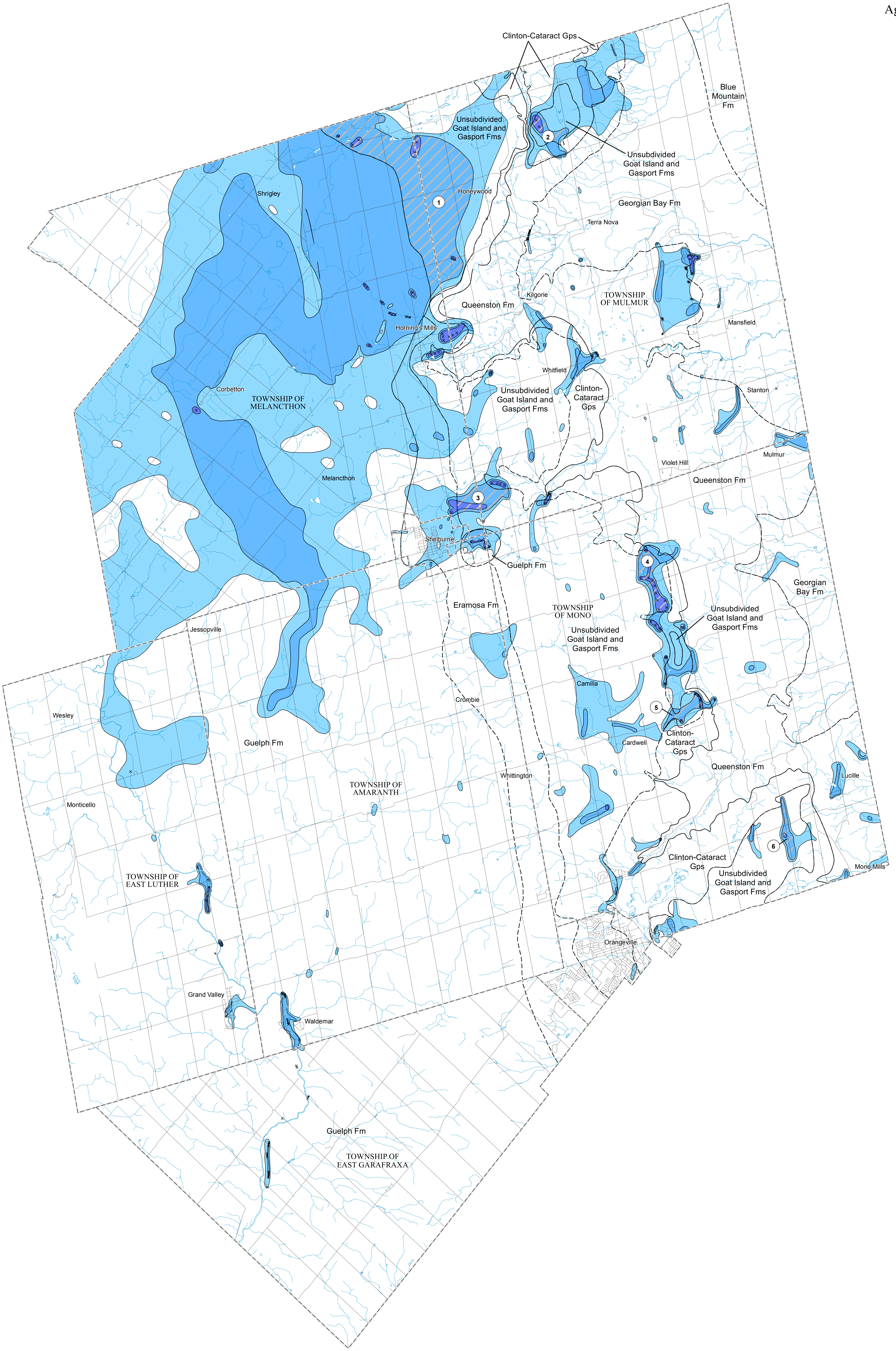
MAP 2

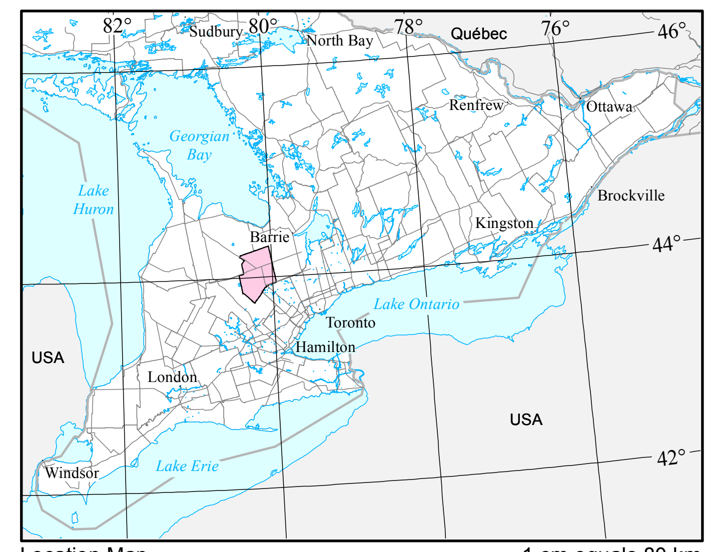
Bedrock Resources for Dufferin County

Scale 1:100 000

1000 m 0 1 2 km

NTS References: 30 M/13, 31 D/4, 40 P/16, 41 A/1, 41 A/8





Location Map 1 cm equals 80 km

LEGEND – BEDROCK UNITS

PHANEROZOIC

PALEOZOIC

SILURIAN

MIDDLE AND LOWER SILURIAN

Guelph Formation: Dolostone

Eramosa Formation: Dolostone

Unsubdivided Goat Island and Gasport Formations (formerly Amabel Formation): Dolostone

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

ORDOVICIAN

UPPER ORDOVICIAN

Queenston Formation: Red shale

Georgian Bay Formation: Limestone, shale

Blue Mountain Formation: Limestone, 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).

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).

Geological formation and/or member boundary

Drift thickness contour

× Isolated bedrock outcrop

Administrative boundary

SOURCES OF INFORMATION

Base map information derived from National Topographic System (NTS) maps, Natural Resources Canada, scale 1:50 000, and from the Ontario Land Information Warehouse, Land Information Ontario, Ministry of Natural Resources, Ontario, scale 1:50 000, with modifications by staff of the Ministry of Northern Development and Mines.
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Geology based on
Telford, P.G., Bond, I.J. and Liberty, B.A. 1976

Compilation and additional geology by D.J. Rowell and F.R. Brunton. Drafting by S.A. Evers. This map is published with the permission of the Director, Ontario Geological Survey.

Rowell, D.J. and Brunton, F.R. 2014. Aggregate resources inventory for Dufferin County, southern Ontario; Ontario Geological Survey, Aggregate Resources Inventory Paper 163—Revision 2, Map 2–Bedrock Resources, scale 1:100 000.