ISSN 1917-330X (online)
ISBN 978-1-4435-8380-0 (PDF)

ISSN 0708-2061 (print)
ISBN 978-1-4435-8379-4 (print)

Aggregate Resources Inventory of the

County of Bruce

Southern Ontario

Ontario Geological Survey
Aggregate Resources Inventory
Paper 190

2012

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By D.J. Rowell

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

ISSN 0708-2061 (print) ISSN 1917-330X (online)
ISBN 978-1-4435-8379-4 (print) ISBN 978-1-4435-8380-0 (PDF)

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PRINT

Library and Archives Canada Cataloguing in Publication Data

Rowell, D.J.
Aggregate resources inventory of the County of Bruce, Southern Ontario

(Ontario Geological Survey aggregate resources inventory paper, ISSN 0708-2061 ; 190)
Includes bibliographical references.
Available also on the Internet.
ISBN 978-1-4435-8379-4

1. Aggregates (Building materials)—Ontario—Bruce (County). 2. Geology—Ontario—Bruce (County)—Maps.
I. Ontario Geological Survey. II. Title. III. Series: Ontario Geological Survey aggregate resources inventory paper ; 190.

TN939 R68 2012 553.6'20971321 C2012-964000-X

ONLINE

Library and Archives Canada Cataloguing in Publication Data

Rowell, D.J.
Aggregate resources inventory of the County of Bruce, Southern Ontario [electronic resource]

(Ontario Geological Survey aggregate resources inventory paper, ISSN 1917-330X ; 190)
Includes bibliographical references.
Electronic monograph in PDF format.
Issued also in printed form.
ISBN 978-1-4435-8380-0

1. Aggregates (Building materials)—Ontario—Bruce (County). 2. Geology—Ontario—Bruce (County)—Maps. I. Ontario Geological Survey. II. Title. III. Series: Ontario Geological Survey aggregate resources inventory paper (Online) ; 190.

TN939 R68 2012 553.6'20971321 C2012-964001-8

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Cette publication est disponible en anglais seulement.

Parts of this publication may be quoted if credit is given. It is recommended that reference be made in the following form:

Rowell, D.J. 2012. Aggregate resources inventory of the County of Bruce, southern Ontario; Ontario Geological Survey, Aggregate Resources Inventory Paper 190, 94p.

Contents

FIGURES

TABLES*

MAPS*

***Maps 1A and 1B and Maps 2A and 2B 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 Map 1 and Map 2, Microsoft® Excel® versions of Tables 1 to 12, and other files that enhance this report.**

Abstract

The purpose of this study is to delineate and inventory the aggregate deposits within the County of Bruce, and to assess the quality and quantity of sand and gravel, and bedrock-derived aggregate resources. This information is required for infrastructure development and renewal, general construction applications and land use planning purposes. Over 1200 field station observations, 243 gradation results, 6219 other data points (e.g., water well and geotechnical records) and 17 newly collected samples were used to interpret the aggregate resources of the study area.

Thirteen (13) sand and gravel resource areas have been selected at the primary resource level in the County of Bruce. These selected resource areas have a total unlicenced area of 6009 ha with a possible resource area of 5352 ha after considering physical, cultural and environmental constraints. These resource areas have approximately 525 million tonnes of aggregate material. Unfortunately, the deposits are not evenly distributed throughout the county and there appears to be a definite lack of good quality, high-specification granular material along the Bruce Peninsula. The primary selected resource areas are concentrated in the southern part of the county and predominantly along the southeastern portion of the study area. It should be noted that the sand and gravel deposits of the County of Bruce are complex and, therefore, development of these resources will require drilling and extensive testing. Stone quality greatly limits the use of this granular material for many high-specification aggregate products (e.g., asphalt and concrete products).

There are a number of sand and gravel deposits that have been selected at the secondary level of significance. These deposits add greatly to the overall granular resources of the County of Bruce. Deposit thickness and, therefore, the quantity of granular material available, the variability of the material, the lower coarse aggregate content, concerns over the stone quality and the "dirtiness" of some of the deposits generally make these resource areas less attractive for development than the primary deposits. The deposits are still a valuable resource.

The unsubdivided Amabel Formation dolostone (Goat Island and Gasport formations) frequently crops out, or is present, within 8 m of surface, along the Niagara Escarpment. This rock unit is thick and consistent, and is recognized as a provincially significant aggregate resource capable of producing a wide range of granular, asphalt and concrete aggregate products. Areas underlain by the Amabel Formation and with less than 8 m of overburden have been chosen as a selected bedrock resource area (35 815 ha). National and provincial parks, and other physical, cultural and environmental constraints reduce this area to 27 249 ha or 10 828 million tonnes. The Niagara Escarpment Plan will reduce this area even further. Twenty-two (22) of 25 licenced quarries in the County of Bruce have been developed to extract building, dimension, decorative and landscaping stone. These quarries are not "aggregate operations" in the traditional sense.

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

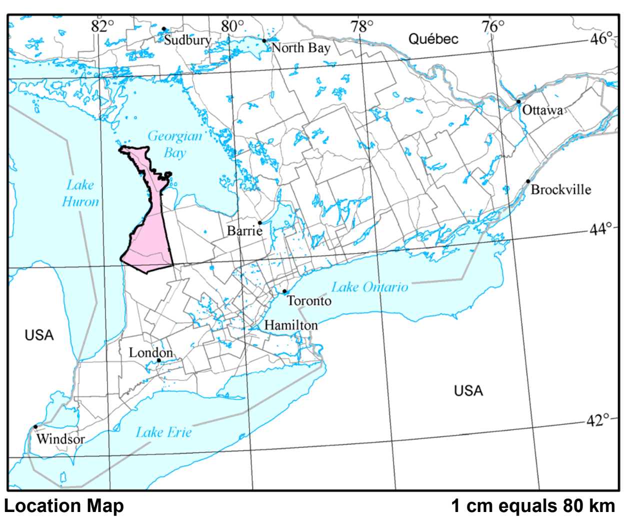

Figure 1. Map of southern Ontario showing the location of the County of Bruce.

Aggregate Resources Inventory of the County of Bruce

By D.J. Rowell[1]

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

Previous field work and observations by R.I. Kelly and M. Kunert in 1993 were referenced during the current study.

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

[1] Sedimentary Geoscience Section, Ontario Geological Survey

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Large quantities of these materials are used each year throughout the Province. For example, in 2010, the total tonnage of mineral aggregates extracted in Ontario was 166 million tonnes, greater than that of any other metallic or nonmetallic commodity mined in the Province (The Ontario Aggregate Resources Corporation 2011).

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

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

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

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

Inventory Methods, Data Presentation and Interpretation

FIELD AND OFFICE METHODS

The methods used to prepare the report involved the interpretation of published geological data such as bedrock and surficial geology maps and reports, as well as field examination of possible resource areas. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located by field surveys and from records held by the Ministry of Transportation of Ontario (MTO), the Ontario Geological Survey (OGS), and by Regional, District and Area Offices of the Ontario Ministry of Natural Resources (MNR). 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 Ontario 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 Ontario 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, 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

Four maps, each portraying a different aspect of the aggregate resources in the report area, accompany the report. Maps 1A and 1B, "Sand and Gravel Resources", provide an inventory and evaluation of the sand and gravel resources in the report area. Maps 2A and 2B, "Bedrock Resources", show the distribution of bedrock formations and the thickness of overlying unconsolidated sediments, and identify the Selected Bedrock Resource Areas.

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

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

Maps 1A and 1B: Sand and Gravel Resources

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

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

SELECTED SAND AND GRAVEL RESOURCE AREAS

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

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

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

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

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

SELECTION CRITERIA

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

Site Specific Criteria

DEPOSIT SIZE AND THICKNESS

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

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

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

AGGREGATE QUALITY

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

Four indicators of the quality of aggregate may be included in the deposit information: gravel content (G or S), fines (C), oversize (O) and lithology (L). Three of the quality indicators deal with grain size distribution.

The gravel content ("G" or "S") indicates the suitability of aggregate for various uses. Deposits containing at least 35% gravel ("G") in addition to a minimum of 20% material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced. In "sandy" deposits ("S"), the gravel-sized aggregate (greater than 4.75 mm) makes up less than 35% of the whole deposit making it difficult to produce coarse aggregate products. The gravel content is also recorded in Sand_Gravel | Sand_Gravel.dbf | **MATERIAL**.

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

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

Another indicator of the quality of an aggregate is lithology ("L"). Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high-quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate.

If the deposit information shows either "C", "O" or "L", or any combination of these indicators, the quality of the deposit is considered to be reduced for some aggregate uses. The deposit quality, if applicable, is recorded in Sand_Gravel | Sand_Gravel.dbf | **LIMITATION**. No attempt is made to quantify the degree of limitation imposed. Assessment of the 4 indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation (MTO) and the Sedimentary Geoscience 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 MNR, Ministry of Municipal Affairs and Housing staff, and/or regional and local planning officials.

Regional Considerations

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

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

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

Although an appreciation of the multitude of factors affecting aggregate availability (e.g., environmental and planning constraints) is required to develop comprehensive resource management strategies, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in the preceding sections.

SAND AND GRAVEL RESOURCE TONNAGE CALCULATIONS

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in hectares (ha). The deposit area is also recorded in Sand_Gravel | Sand_Gravel.dbf | **AREA**. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well records. Tonnage values can then be calculated by multiplying the volume of the deposit by 0.01770 (the density factor). This factor is approximately the number of tonnes in a 1 m thick layer of sand and gravel, 1 ha in extent, assuming an average density of 1770 kg/m^3.

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

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

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of hectares unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g., wayside, unlicenced and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 × Column 6 × 0.01770), to give an estimate of the sand and gravel tonnage (Column 7) possibly available for extractive development and/or resource protection. It should be noted, however, that studies (Planning Initiatives Limited 1993) have shown that substantial proportions of the resources in an area may be constrained due to environmental considerations (e.g., floodplains, environmentally sensitive areas). Lack of landowner interest in development, a range of planning considerations or other matters may also reduce the available resources.

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

Maps 2A and 2B: Bedrock Resources

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

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

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

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

SELECTED BEDROCK RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations within a specific geological formation are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Maps 2A and 2B by a line pattern and the calculated available tonnages are given in Table 6. The selected bedrock resource areas are also recorded in Bedrock | Drift_Thick.dbf | **SELECT_AREA**.

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

SELECTION CRITERIA

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

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

Deposit “size” is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. The deposit size is recorded in Bedrock | Drift_Thick.dbf | **AREA**; the favourable bedrock formations are reported in Bedrock | Drift_Thick.dbf | **FORMATION**. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

BEDROCK RESOURCE TONNAGE CALCULATIONS

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above for sand and gravel resources. The areal extent of bedrock formations overlain by less than 15 m of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records (Table 4). The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases, a standardized estimate of 18 m is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tonnes of a 1 m thick section of rock, 1 ha in extent). The areal extent of bedrock formations is also recorded in Bedrock | Drift_Thick.dbf | **AREA**.

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

Assessment of Aggregate Resources in the County of Bruce

LOCATION AND POPULATION

The County of Bruce (herein referred to as "Bruce County") occupies an area of 407 917 ha along the eastern shoreline of Lake Huron (Figure 1). It is bounded to the east by the County of Grey and to the south by County of Huron. The county is covered by all or parts of 14 National Topographic System (NTS) 1:50 000 scale map sheets. The 14 map sheets, from south to north, are Lucknow (40 P/13), Wingham (40 P/14), Palmerston (40 P/15), Durham (41 A/2), Walkerton (41 A/3), Kincardine (41 A/4), Tiverton (41 A/5), Chesley (41 A/6), Wiarton (41 A/11), Cape Croker (41 A/14), White Cloud Island (41 A/15), Dyer's Bay (41 H/3), Dorcas Bay (41 H/4) and Flowerpot Island (41 H/5).

In 2006, the population of Bruce County was 65 349 (Statistics Canada 2006), which represents a 2.3% increase from 2001 (Table A). Bruce County is largely rural in character and the majority of the county is either forested or farmed. The area is an important tourist and recreational area with numerous provincial and national parks. The area is also host to one of Ontario's nuclear generating stations along the shore of Lake Huron (the Bruce Nuclear facility), which, coincidently, required large quantities of aggregate material to construct.

There are a number of urban centres, including Tobermory, Wiarton, Sauble Beach, Southampton, Port Elgin, Tara, Chesley, Paisley, Tiverton, Kincardine, Ripley, Lucknow, Teeswater, Formosa, Walkerton and Mildmay. There are other communities within Bruce County, but these urban areas were identified as Primary Urban Communities in the Bruce County Official Plan. Hanover and Owen Sound are located just east of Bruce County in the County of Grey and provide additional services to the residents of Bruce County.

Table A – Area and Population, County of Bruce

Municipality (Listed Alphabetically)	Land Area (km^2)	2001 Population	2006 Population
Municipality of Arran–Elderslie	460.13	6577	6747
Municipality of Brockton	565.07	9658	9641
Township of Huron–Kinloss	440.59	6224	6515
Municipality of Kincardine	537.65	11 029	11 173
Municipality of Northern Bruce Peninsula	781.51	3599	3850
Town of Saugeen Shores	170.58	11 388	11 720
Municipality of South Bruce	487.17	6063	5939
Town of South Bruce Peninsula	531.90	8090	8415
First Nations Communities	104.57	1264	1349
TOTAL	**4079.17**	**63 892**	**65 349**

Road access to Bruce County is provided by Provincial Highways 6, 9 and 21. Highway 21 trends generally north-south, nearly parallel with the Lake Huron shoreline, connecting the towns of Kincardine, Port Elgin and Southampton before heading eastward. Highway 9 provides a major east-west link between the towns of Kincardine and Walkerton, then southward at Walkerton. Provincial Highway 6 trends northwestward through the centre of the Bruce Peninsula and continues on Manitoulin Island. In addition to these Provincial Highways, there are a number of well-maintained paved and gravel county and lower-tier municipal roads that provide an extensive transportation network throughout the county. There are also a number of small municipal airports throughout the county (e.g., Tobermory and Walkerton). At Tobermory, there is a ferry service between the north end of Bruce County and Manitoulin Island.

SURFICIAL GEOLOGY AND PHYSIOGRAPHY

The physiography and distribution of surficial material in Bruce County, including the sand and gravel deposits illustrated on Maps 1A and 1B, are primarily the result of glacial activity that took place in the Late Wisconsinan (Barnett 1992). This period, which lasted from approximately 23 000 to 10 000 years before present, was marked by the repeated advance and retreat of the massive Laurentide Ice Sheet (Barnett 1992). The direction of ice movement in the study area is recorded by erosional ice flow indicators (striae, grooves, chattermarks) and depositional forms (crag-and-tail features, fluted ground moraine, drumlins) and is generally in a southwest direction of 220° (Sharpe 1977a; Cowan and Sharpe 2007a). Variations in the ice-flow direction have been recorded throughout the county with the ice flow in a more southerly direction in the southern part of the county (Cowan 1978), an easterly ice flow in the southwest corner of the county (from the Huron [ice] lobe) and an ice flow direction of 237° being measured along the Bruce Peninsula (Kor and Cowell 1998).

Bruce County is covered by 7 physiographic regions as defined by Chapman and Putnam (1984). From south to north, these include the Teeswater drumlin field, Horseshoe moraines, Saugeen clay plain, Arran drumlin field, Huron slope, Huron fringe and the Bruce Peninsula (Figure 2).

Teeswater Drumlin Field

As the ice advanced across the region from the north-northeast, debris from the underlying soil and bedrock accumulated within and beneath the ice. The debris—a mixture of stones, sand, silt and clay—was deposited over large areas of Bruce County as till plains, drumlins and moraines. The Teeswater drumlin field lies in the southeastern part of the county, south of the community of Walkerton (*see* Figure 2). The till that comprises the ground moraine and drumlins within this physiographic region is the Elma Till, which is a stony, sandy silt till of Port Bruce Phase (Stadial) age (Cowan et al. 1978; Table B). In some areas, the Elma Till is underlain by the older Tavistock Till, at least as far west as Wingham; whereas, in other areas, the Elma Till lies directly on the bedrock surface (Cowan 1974). Cowan (1978) reports areas where greater than 15 m of Elma Till lies directly on the bedrock surface. The drumlins in this field are characteristically low, broad, oval-shaped hills with gentle slopes. Their orientation varies, but is almost due south in the Wingham–Teeswater area (Cowan 1978). Toward the outer margins of the field, the drumlins become less noticeable and gradually merge into an undulating till plain (Chapman and Putnam 1984).

As the ice margin receded northward from this physiographic region, large volumes of meltwater flowed from the glacial ice margin. Meltwater rivers and streams drained southward and deposited outwash sediments, occurring mainly as channel fills or terraces, along meltwater channels. These deposits are shown on Map 1B as outwash deposits and are predominantly concentrated in the south end of Bruce County (Chesley–Walkerton–Teeswater area). These meltwater rivers also cut deeply into the till and occasionally eroded the underlying bedrock (outcrops are noted on Map 2B). Locally, the continuity of the drumlin field is broken by the presence of ice-contact deposits that are also concentrated in the southeastern portion of Bruce County; an example being the large area of sand hills lying in the former Carrick Township (now part of the Municipality of South Bruce), northeast of Mildmay.

As the Laurentide Ice Sheet continued to melt and retreat from southern Ontario, it split into a number of glacial lobes that behaved semi-independently. Bruce County was affected by both the Georgian Bay lobe centred in Georgian Bay to the north-northeast, and the Huron lobe centred in the Lake Huron basin to the west-northwest.

Table B – Summary of Tills, County of Bruce

	Huron Lobe	**Georgian Bay Lobe**
Port Huron Phase (Stadial)	St. Joseph Till – Wyoming moraine	St. Joseph Till – Banks and Williscroft moraines
Mackinaw Interstadial	---------- Glaciolacustrine Sediments ----------	
Port Bruce Phase (Stadial)	Rannoch Till – Wawanosh moraine	Dunkeld Till – Gibraltar moraine
		Elma Till – Teeswater drumlin field – Arran drumlin field

Source: *after* Cowan et al. (1978)

Horseshoe Moraines

Chapman and Putnam (1984) have documented the occurrence of a series of subparallel moraines in the study area, deposited by the Huron and Georgian Bay lobes as they retreated and had minor re-advances. They have referred to this physiographic region as the Horseshoe moraines (*see* Figure 2), which is part of the larger Port Huron moraine system. The largest moraine in the general area is the Singhampton moraine, which is centred in the County of Grey and trends eastward toward the Village of Creemore in the County of Simcoe, and extends south of Bruce County into the County of Huron. The building of the Singhampton moraine is generally believed to have involved active but rapidly ablating ice (Cowan et al. 1978). The Gibraltar, Banks, Williscroft, Wawanosh and Wyoming moraines are also part of this physiographic region and represent the ice margin location during the retreat of the 2 ice lobes. The moraines are composed of different till sheets of different ages (*see* Table B).

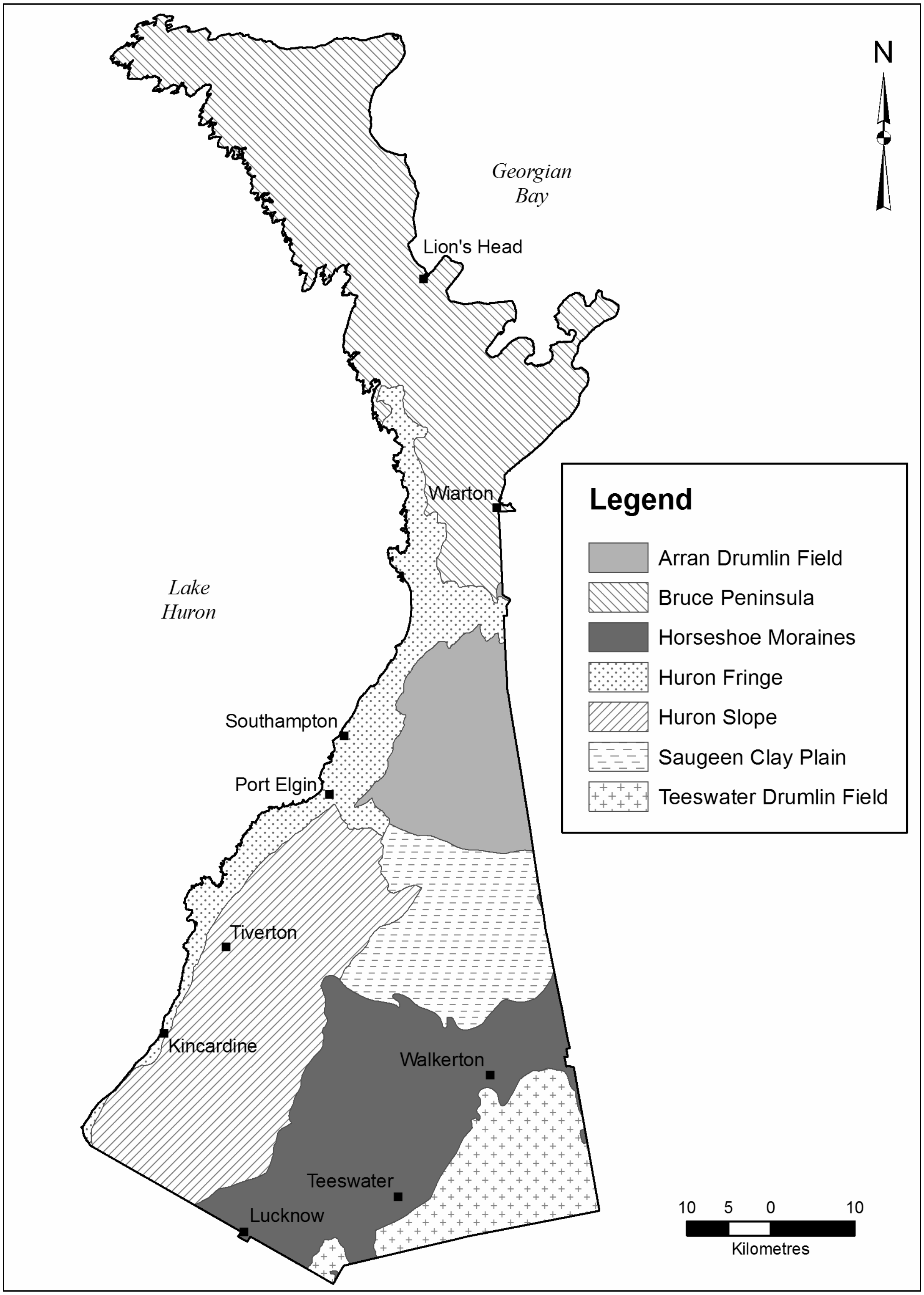

Figure 2. Physiographic regions in the County of Bruce (*after* Chapman and Putnam 1984).

Near the community of Walkerton in southern Bruce County is a moraine that was originally called the Walkerton moraine (Chapman and Putnam 1984). Feenstra (1975) and Sharpe (1975) have demonstrated that the Walkerton moraine is the equivalent of the Gibraltar moraine to the east. Cowan (1977) suggests that the apparent contact between the Walkerton moraine and the Wyoming moraine to the west (Chapman and Putnam 1984)—the Glammis kame (actually an ice-contact delta)—is older than the Wyoming moraine. Till beds within the delta are interpreted as Dunkeld Till, the till that comprises the Gibraltar moraine (Feenstra 1975; Sharpe 1975). Therefore, the previously named Walkerton moraine is re-designated as the Gibraltar moraine (Cowan et al. 1978). It is believed that the Gibraltar moraine is late Port Bruce Phase (Stadial) in age (*see* Table B). Glaciofluvial deposits are associated with the Gibraltar moraine (Sharpe 1976).

The Wawanosh moraine, located to the west of the Teeswater drumlin field, represents a Huron lobe ice-marginal position. The moraine is composed of Rannoch Till that has been described as a silt till. It is believed that this moraine was formed by Lake Huron ice during the Port Bruce Phase (Stadial) (*see* Table B). Farther to the west is the Wyoming moraine. It is believed to be an ice-marginal position of the Huron lobe and is of Port Huron Phase (Stadial) age (*see* Table B). The moraine is composed of the St. Joseph Till: a till that Sharpe (1977b) traced to the Banks and Williscroft moraines to the north.

The Banks and Williscroft moraines, situated north of the Gibraltar moraine, would have been deposited by the Georgian Bay lobe and are believed to be of Port Huron Phase (Stadial) age. These moraines have also been constructed largely of the St. Joseph Till. Sharpe (1976) believes that the Gibraltar and Banks moraines are strongly defined moraines built by active ice; whereas the Williscroft moraine is a brief standstill of ice floating in water. All of these moraines are associated with occurrences of sand and gravel. Esker fragments and/or segments have been identified within, and adjacent to, these moraines and the general landscape and occurrence of these features is suggestive of a chaotic sedimentary regime (Sharpe and Edwards 1979; Feenstra 1994).

Saugeen Clay Plain

As the glacial ice margin continued to recede northward, large volumes of meltwater accumulated between the ice margin and topographic highs creating glacial lakes. North of the Horseshoe moraines physiographic region, within the Saugeen River drainage basin, lies the physiographic region known as the Saugeen clay plain (Chapman and Putnam 1984). The area is underlain by thick, stratified clay-rich sediments deposited in a bay of glacial Lake Warren. The clay is pale brown in colour and highly calcareous and is derived from the local limestone and dolostone bedrock. Sediments were transported into the area from drainage channels emanating from the ice margin to the east (Chapman and Putnam 1984). The largest area of thick clay lies immediately north of the Gibraltar moraine.

Although the dominant landscape of the area is that of a clay plain, minor topographic variations do occur. Between the hamlets of Eden Grove and Ellengowan is a small sand plain that formed through the coalescence of deltas deposited by the Saugeen and Teeswater rivers where they emptied into glacial Lake Warren. Along the southern boundary of the former Elderslie Township (now the Municipality of Arran–Elderslie) is a series of sand-rich ice-contact deposits. The northern boundary of this physiographic region is approximately 6 km north of the community of Chesley (*see* Figure 2).

Arran Drumlin Field

North of the Saugeen clay plain, between Southampton and Owen Sound, is a large drumlin field (Chapman and Putnam 1984). This physiographic region, known as the Arran drumlin field, is named after the former Arran Township, now the Municipality of Arran–Elderslie (*see* Figure 2). The drumlins are composed of calcareous, stony, silty sand till. The till forming these drumlins and most of the ground moraine in the area is a loose, stony, sandy silt till similar to the Elma Till. Two local till facies occurs within this region, which are related to the underlying bedrock (Sharpe 1977b). One facies is very bouldery and loose in an area east and south of Wiarton. Large angular to subangular blocks of dolostone were picked up by the ice from the clint-and-gryke dolostone pavement to the north and transported a short distance. A second facies is a reddish brown, clayey till, which reflects the incorporation of the soft underlying shales of the Cabot Head and Queenston formations. Locally, thin layers or lenses of sand or gravel are found within the till.

Numerous drumlins have been mapped as part of this drumlin field. The drumlins have a general south to southwest orientation, reflecting the area's ice-flow direction. It is possible to observe several areas where bedrock relief has modified the local ice-flow direction. Ice-contact glaciofluvial deposits, esker segments and associated kame features also occur in this physiographic region west of Owen Sound. Two moraine strands provide the southern boundary of the Arran drumlin field. The Algonquin shoreline marks a clearcut western boundary. The old shorecliff is steep and some of the drumlins have been cut away and partially dissected. Some of the northern drumlins have been isolated, lying directly on dolostone bedrock. Areas between the drumlins are often floored with organics (swampy areas) or glaciolacustrine clay (Chapman and Putnam 1984).

As the drumlin field was being constructed, the margin of the ice fluctuated, thus building a series of eastward-trending moraines. At one time, these were referred to as the Tara strands, but have more recently been referred to as the Tara moraines. Sharpe (1977b) believes that the Tara moraines represent brief standstills of ice floating in water. The Tara moraines formed as ice-marginal deltas and, as a result, the Tara moraines have provided a convenient supply of aggregate for many projects in the Owen Sound area.

Huron Slope

Along the Lake Huron shoreline in the southwestern part of Bruce County, and between the shore bluff of glacial Lake Algonquin and the Wyoming moraine, is the physiographic region known as the Huron slope (*see* Figure 2). The Huron slope generally represents a strip of land with an elevation from about 181 m (600 feet) to about 257 to 273 m (850 to 900 feet). The region is essentially a plain of clay and till, modified by a narrow strip of sand and the twin beach deposits of glacial Lake Warren that flank the Wyoming moraine (*see* Map 1B). Below the level of the glacial Lake Warren beaches, the ground surface has been smoothed by wave action, and low-lying areas on the till surface have been infilled by glaciolacustrine fine-grained sediments (silt and clay). Streams that cross the physiographic region often cut deep gullies into the sediments because of the energy (stream-flow velocity) that would be associated with such a change in elevation. Glaciolacustrine beach deposits are numerous, but are often thin, shallow and discontinuous. Other short-lived glacial lake deposits that have been observed within the physiographic region belong to relatively short-lived glacial lakes Grassmere and Lundy.

Huron Fringe

Lying below and adjacent to the Huron slope physiographic region is a narrow ridge of land that extends along Lake Huron from Sarnia to Tobermory. This region, known as the Huron fringe consists of the wave-cut terraces of glacial lakes Algonquin and Nipissing, and their related boulder lag, gravel bar and sand dune deposits (*see* Figure 2). On the Bruce Peninsula, the fringe area is a scoured belt of dolostone just above the current lake level with a series of small shallow beaches, sand dunes or even swampy areas. A few kilometres south of the community of Wiarton, the Huron fringe swings inland around a sand plain. At this point, a large gravel beach skirts along the northern border of the Arran drumlin field. Across the mouth of the Saugeen River, glacial Lake Algonquin built a massive beach deposit.

Bruce Peninsula

The physiography of the northern part of Bruce County (the Bruce Peninsula) is dominated by the Niagara Escarpment, which is a major bedrock feature trending subparallel to the shoreline of Georgian Bay (*see* Figure 2). Bedrock occurs at, or near, the surface in the vicinity of the Niagara Escarpment and in much of the area between the escarpment westward to the shore of Lake Huron. In general, the escarpment forms a high east-facing bluff along the shore of Georgian Bay with topographic relief that can exceed 60 m. The Georgian Bay shoreline is rugged and deeply incised and, as a result, is an attractive tourist destination (Photo 01, ArcGIS® version only).

The bedrock then dips southwestward toward Lake Huron where the shoreline is much smoother with a gradual slope. The bedrock of this physiographic region is covered by a gradually thickening wedge of glacial sediments as one moves south and west from the brow of the Niagara Escarpment. It is believed that the Bruce Peninsula was continuously ice covered from about 25 000 to 12 500 years BP. At some point during this glacial period, massive sheetfloods of released subglacial meltwaters, which had accumulated beneath the glacier up ice, stripped most of the glacial drift from the peninsula, eroded great quantities of dolostone from the escarpment brow and created sculpted rock features (Kor and Cowell 1998). The timing of this event has been estimated at about 13 000 to 14 000 years BP.

The local till on the Bruce Peninsula, often referred to as the Bruce till, is a silty to sandy silt till. The till occurs as ground moraine and thin, shallow, streamlined drumlinoid forms. Areas of thin ground moraine intermixed with bedrock outcrops are commonly observed along the peninsula (Photo 02, ArcGIS® version only). Shoreline features are relatively sparse due to the lack of drift and the release of these subglacial meltwaters. Therefore, the Bruce Peninsula has extremely limited sand and gravel deposits and any aggregate material has been extensively exploited in the past.

Clint-and-gryke structures are well developed on the peninsula and greatly influence the drainage pattern and surface runoff. Development of karst features through the dissolution of carbonate rocks is pervasive and large conduits, although rare, have been developed and mapped. Some of the national and provincial parks host dissolution caves that attract tourists to the area. In the central part of the Bruce Peninsula (former townships of Albemarle and Eastnor) are thick, fine-grained glacial lake sediments that create a relatively flat glaciolacustrine plain. This plain provides agricultural opportunities along the peninsula (Photo 03, ArcGIS® version only).

SEDIMENTS

Till

A number of surface glacial tills have been identified within Bruce County and include, from oldest to youngest, the Elma, Rannoch, Dunkeld and St. Joseph tills. An enigmatic till, referred to as the “lower stony till”, was identified by Cowan, Cooper and Pinch (1986) along the shoreline of Lake Huron. This till occurs beneath the St. Joseph Till; however, its stratigraphic relationship to the other tills in the area is somewhat unclear. There is also a till unit located along the Bruce Peninsula, informally referred to as the Bruce till, as noted earlier.

The oldest surface till, the Elma Till (Cowan et al. 1978), is characterized by a silty to sandy silt matrix containing a high total carbonate content that is strongly dolomitic (Cowan and Pinch 1986). This till occurs in the southeastern and central parts of the study area as ground moraine and in the drumlins of the Teeswater and Arran drumlin fields. Till fabric analysis indicates deposition by glacial ice of the Georgian Bay lobe that advanced in a south to southwesterly direction across the study area (Cowan et al. 1978). It is believed to be Port Bruce Phase (Stadial) in age and its age relationship to the other tills in the area is provided in Table B. The till is generally a very dense, stony, sandy silt to silt till with low plasticity. Average grain size analysis of the matrix indicates approximately 37% sand, 50% silt and 13% clay. Table 10 provides a number of till analyses that were completed by Cowan, as well as a few samples collected as part of this study.

The next oldest surface till, the Rannoch Till (Cowan et al. 1978), was deposited by ice of the Huron lobe. It is characterized by a strongly calcareous, silt to silty clay matrix; except where deposited over sand, when the matrix may be quite loose and exhibit a sandy silt texture. The till occurs in the former Kinloss Township (now part of the Township of Huron–Kinloss) and the former Culross Township (now part of the Municipality of South Bruce) often in association with the Wawanosh moraine. Average grain size analysis of the till matrix is approximately 25% sand, 57% silt and 18% clay (*see* Table 10).

The next surface till, the Dunkeld Till, is a strongly calcareous, silt till (Cowan and Pinch 1986). It is found in association with the Gibraltar moraine and as ground moraine within the Saugeen River valley. It is believed that the Dunkeld Till represents a minor southward readvance over glaciolacustrine sediments (Cowan and Pinch 1986). The till is further described as compact, slightly blocky, brown, fine sand to silt till with a pebble count that can be as low as less than 5% (Cowan and Pinch 1986). The analyses of samples collected as part of this study are provided in Table 10.

The youngest surface till in the study area is the St. Joseph Till (Photo 04, ArcGIS® Version). It is strongly calcareous, has a low stone content and a clayey silt to silt texture (Sharpe and Edwards 1979; Cowan and Pinch 1986). This till is found in the Wyoming moraine, which parallels the shore of Lake Huron; in the Banks and Williscroft moraines of the Georgian Bay lobe; and in large areas of ground moraine in the west and southwest of the county (Sharpe and Edwards 1979). The grain size analysis for the till matrix averages 12% sand, 54% silt and 34% clay (*see* Table 10). Results of geochemical analyses of till samples collected as part of this study are provided in Table 12.

Till is usually not well suited for aggregate use as it often contains excess fines and oversized clasts. In some cases, till may be suitable for fill. The Elma Till has been utilized for fill in local projects in southern Bruce County.

Glaciofluvial Deposits

Ice-contact deposits are common throughout the southern part of the study area. Large sand and gravel-rich deposits occur in the Mildmay–Neustadt and Lucknow–Teeswater areas. These occur in association with both the Elma and Rannoch tills, and the Teeswater drumlin field. Smaller and more scattered ice-contact deposits occur in the northern and western parts of the area. Some ice-contact deposits are buried by the St. Joseph Till and may represent subaquatic deposition.

Ice-contact deposits are important sources of aggregate within the county and, for the most part, the resource potential of these deposits is rated as good. In some instances, constraints such as lithology (i.e., Precambrian quartzites and argillites, and excess chert and shale clasts) and an excess of fines or oversized material may limit the range of aggregate usage. In addition, some of the sand and gravel deposits exhibit localized cementation and encrustation, which also restricts their use. This problem appears to be most severe where sand and gravel deposits are buried by the finer textured Rannoch and St. Joseph tills.

Numerous north-trending esker ridges and/or segments occur in the vicinity of Kinloss Township (now part of the Township of Huron–Kinloss) and the former townships of Culross and Carrick (now the Municipality of South Bruce). Granular material is generally clean and varies from sand to gravel to crushable size clasts. The aggregate potential of these deposits is good, although lithological constraints similar to those described above for other ice-contact sediments may limit usage.

Glaciofluvial outwash deposits occur as meltwater channel fills and outwash plains, throughout much of the southern part of the county. Sand and gravel–rich channel-fill and terrace deposits occur south of the community of Walkerton, extending southwesterly to Lucknow. Many of these deposits are limited in size or thickness, and may lack desirable gradation for high-specification aggregate products. Sand-rich deltaic deposits occur north of Walkerton; however, lack of crushable material limits the use of these deposits. The lithology of some of the coarse aggregate clasts may limit the suitability of these granular resources in the production of high-end aggregate products.

Glaciolacustrine Deposits

Within the study area, glacial and postglacial lacustrine deposits are common. Generally, these deposits are thin and comprise fine-textured sediments (sands, silts and clays): materials that have limited usage as aggregate. Beach deposits represent a suite of proglacial and postglacial lake levels ranging from glacial Lake Warren to present-day Lake Huron (Cowan and Pinch 1986). From an aggregate perspective, beach deposits of glacial Lake Algonquin are most important. Near Port Elgin, the glacial Lake Algonquin bar–spit–beach complex is well developed, consisting of up to 10 m of well-sorted sand and pebbly gravel. This material is slowly being depleted through extractive activities and sterilization by urban growth. At Kincardine, a large barrier bar constructed by glacial Lake Algonquin has been mined extensively in the past for a variety of aggregate products.

Eolian, alluvial and organic sediments within the study area have extremely limited potential as aggregate resources.

In general, granular resources within the study area have the potential to supply a wide range of aggregate products. Materials range from sandy aggregate suitable for road subbase to coarse aggregate suitable for crushing. Large resources exist in the southern and southeastern parts of the county; however, the stone quality may limit the development and usage of these resources. In the southwest, some townships only have very limited resources remaining. In these areas, aggregate suitable for specific construction projects may have to be transported from elsewhere.

Glacial Lake Levels

Glacial Lake Warren–related features occur at approximately 282 m asl (925 feet). The most notable glacial Lake Warren features occur along the Gibraltar moraine (Sharpe 1976) and west of the Wyoming moraine. Glacial lakes Grassmere and Lundy occur at lower levels. Glacial Lake Algonquin–related features occur at an elevation of about 240 to 244 m asl on the Bruce Peninsula (Cowan and Sharpe 2007a). Farther south in Bruce County, a prominent bluff related to glacial Lake Algonquin is up to 30 m high and at an elevation of 221 m asl. Glacial Lake Nipissing–related features have been measured at approximately 190 to 195 m asl (Cowan and Sharpe 2007a). Shingle gravel bars and other weak shoreline features associated with glacial Lake Algoma have been measured at 183 m asl (Stadelman 1973).

In addition to the references already cited, more detailed information on the Quaternary geology of Bruce County is provided in the following maps and publications: Cowan (1975), Cowan and Sharpe (2007b), Sharpe and Broster (1977) and Sharpe and Jamieson (1982).

SAND AND GRAVEL EXTRACTIVE ACTIVITY

The sand and gravel deposits of Bruce County are shown on Maps 1A and 1B that accompany this report. Sand and gravel deposits occupy approximately 106 318 ha (roughly 26% of the area of the county), and contain an original resource tonnage of 8426 million tonnes (*see* Table 1). **These figures represent a comprehensive inventory of all granular material in Bruce County, although much of the material included in the estimate has no potential for use in aggregate products**. Unfortunately, the sand and gravel deposits are not evenly distributed throughout the county and, in fact, the northern and southwestern parts of the county are “aggregate poor”.

Two hundred and seventy-seven (277) sand and gravel pits have been identified in Bruce County. The majority of these have been developed in ice-contact, ice-contact esker, glaciofluvial outwash, glaciolacustrine beach, subaquatic fan and deltaic deposits. At the time of writing, 130 pits (representing 2891.66 ha or 0.7% of the county’s total land base) were licenced for operation under the *Aggregate Resources Act*. This information was provided by the Ministry of Natural Resources, Land Information Ontario (LIO) in the summer of 2011. In general, many of the pits are small operations capable of meeting local demand for low-specification aggregate; a few operations can meet the requirements for higher specification aggregate products. The average annual production for the period from 2005 to 2010 for Bruce County was approximately 2.142 million tonnes (Table C). Lower tier municipality production for 2010 is provided in Table D. Pit locations are shown on Maps 1A and 1B and individual descriptions are provided in Table 2.

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

Table C – Aggregate Production (2005–2010), County of Bruce

Year	Production (×1000 tonnes)
2005	2171
2006	2259
2007	2394
2008	2013
2009	1753
2010	2261

Table D – Aggregate Production (2010) by Municipality, County of Bruce

Municipality (Listed Alphabetically)	Production (tonnes)	Percentage of the County Total
Municipality of Arran–Elderslie	159 394	7.05
Municipality of Brockton	243 673	10.77
Township of Huron–Kinloss	420 752	18.6
Municipality of Kincardine	100 863	4.46
Municipality of Northern Bruce Peninsula	196 749	8.70
Town of Saugeen Shores	364 529	16.12
Municipality of South Bruce	384 517	17.00
Town of South Bruce Peninsula	391 347	17.30
TOTAL	**2 261 824**	

Source: The Ontario Aggregate Resources Corporation (2011)

SAND AND GRAVEL AGGREGATE QUALITY

Significant changes have occurred in the testing and specifications applied to aggregates since the original Aggregate Resources Inventory Papers (ARIPs) were completed. The Los Angeles abrasion test (LS-603) is no longer used in the Ontario Provincial Standard Specifications (OPSS) and the magnesium sulphate soundness test (LS-606) has been reduced to an alternate test. Two newer tests, the micro-Deval abrasion test (LS-618 and LS-619) and the unconfined freeze–thaw test (LS-614) have been added. The accelerated mortar bar expansion bar test (LS-620) has also become a standard test for the determination of potential alkali–silica reactivity in concrete aggregate.

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

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

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

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

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

This is particularly important in Bruce County where many of the underlying bedrock formations contain deleterious lithologies (e.g., chert, shale, siltstone). Therefore, many of the granular deposits with a good percentage of crushable and gravel-size clasts may be limited in the production of high-specification coarse aggregate products by poor stone quality. Ingham and Dunikowska-Koniuszy (1965) reviewed the distribution, character and basic properties of chert in southwestern Ontario, including their use in asphalt and concrete. Chert particles and clasts have a higher porosity than other rock type clasts resulting in higher absorption. Ingham and Dunikowska-Koniuszy (1965) also concluded that chert failed the asphalt stripping tests and, therefore, should not be used in asphalt products. The chert particles had greater breakage in freeze–thaw testing and are highly reactive for alkali reactivity (an alkali–silica reaction) and should be avoided in the production of concrete. Areas of the Bois Blanc Formation can be from 30.3 to 62.3% chert, by volume, and some gravel deposits in southwestern Ontario can be 1 to 50% chert (Ingham and Dunikowska-Koniuszy 1965). This stone quality may also affect the fine aggregate material, rendering it unsuitable for the production of fine aggregate products such as Hot-Laid and concrete (fine aggregate). Table 9 of this report provides the results of extensive aggregate quality testing completed throughout the study area.

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

SELECTED SAND AND GRAVEL RESOURCES AREAS

Maps 1A and 1B show the geographic distribution of sand and gravel in Bruce County. Thirteen (13) areas have been chosen as Selected Sand and Gravel Resources Areas of primary significance and are indicated on Maps 1A and 1B in red.

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 is located in the northern part of the Bruce Peninsula just south of Tobermory, in the Municipality of Northern Bruce Peninsula (formerly St. Edmunds Township). Based on the nature of the sediments, the lower part of this deposit would appear to be a glaciofluvial ice-contact deposit, quite possibly a subaqueous fan. The upper portion of the deposit has been reworked by glacial lake wave action and the depositional structures resemble a beach deposit.

Pit faces expose medium- to thick-bedded, unsorted to poorly sorted, rounded to subrounded, cobbly gravel within a medium to coarse sand matrix interbedded with clean, horizontally thin- to medium-bedded, moderately sorted, medium to coarse sand to gravelly sand. Maximum clast sizes range from 10 to 15 cm. Clast lithology varies from 15 to 32% limestone, 60 to 75% dolostone, 0 to 9% sandstone, 0 to 2% siltstone and 1 to 5% Precambrian material. Minor amounts of shale were observed.

Previous gradation results indicate a coarse aggregate content that varies from 37.8 to 76.0%, from 19.5 to 61.5% sand and from 0.7 to 11.0% fines. Magnesium sulphate soundness test results vary from 4.1 to 34.7 for coarse aggregate and from 9.3 to 23.0 for fine aggregate. Petrographic Number values range from 100.0 to 156.6 for Granular and 16 mm crushed and from 132.8 to 208.0 for Hot-Laid (HL) and concrete products (*see* Table 9). With proper beneficiation (crushing and screening), the granular material within this deposit should be capable of meeting the specifications for Granular A, Granular B and Select Subgrade Material (SSM) products. High Petrographic Number values (stone quality) are of concern and would greatly limit the use of this granular material for the production of HL and concrete products.

The deposit appears to be approximately 3 to 6 m thick based upon observations at licenced pit exposures. The selected resource area appears to thin toward the boundaries of the deposit and, in some locations, there is a high water table. This high water table may mean that the granular material is underlain by glaciolacustrine fine-grained sediments, till or bedrock; or it may mean that additional granular resources lie below the water table. If this is the case, extraction may be possible, but extensive studies would have to be completed before such a venture is undertaken.

Selected Sand and Gravel Resource Area 1 has a total unlicenced area of 279.3 ha (*see* Table 3). There are 7 licenced operations (Pit Nos. 1 to 7) and 1 unlicenced pit (Pit No. 16) currently located within this deposit. The local airport and a number of homes have also been built within this deposit; therefore, after considering physical, cultural and environmental constraints, the area available for extraction is reduced to 253.5 ha or approximately 20.2 million tonnes, based on a conservative deposit thickness of 4.5 m (*see* Table 3).

Because of the extensive extractive activity that has occurred within this deposit, the high water table in some locations, the thinning of the deposit away from the centre or core of the deposit and other land use constraints placed upon this deposit, this deposit would normally have been selected as a resource of secondary or possibly tertiary significance. The fact that this is the only extensive sand and gravel deposit in the northern part of the Bruce Peninsula means that the remaining resources are important, and extraction and development of the remaining resources should occur carefully and with due consideration.

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 is located in the southern part of the Municipality of Northern Bruce Peninsula (formerly Eastnor Township). The deposit trends southwest from the community of Lion's Head.

The lower part of the deposit appears to be an ice-contact deposit, quite possibly a subaqueous fan (Cowan and Sharpe 2007a). The upper portion of the deposit has been reworked by glacial lake wave action and the depositional structures resemble a beach deposit. The material can generally be described as moderately to well stratified, thin- to medium-bedded sand and gravel. Coarse aggregate clasts are generally less than 15 cm and are rounded to subrounded. A field lithology count provided the following results: 21% limestone, 68% dolostone, 5% Precambrian clasts, 1% sandstone and 4% siltstone. Minor amounts of shale were also observed.

The deposit has been formed along a bedrock trough that trends northeastward toward Lion's Head. A water-well record in the centre of this deposit records 7.62 m of gravel over 16.15 m of silty fine sand over 1.22 m of till over bedrock. Therefore, the total depth to bedrock in the centre of this deposit, based on this water-well record, is 24.99 m. The granular material thins toward the boundaries of the deposit and, in fact, numerous bedrock outcrops were observed to the east of the deposit. Water-well information from just north of the deposit indicates bedrock at 1 to 2 m.

The aggregate test results for a sample, 11DJR-0022, collected within this selected resource area as part of this study are provided in Table 9, and are shown in Figures 5A and 5B. The gradation results for this sample were 46.9% coarse aggregate, 49.7% sand and 3.4% fine aggregate; with 17.6% of the coarse aggregate fraction being crushable. Magnesium sulphate soundness test results were 24.0 for coarse aggregate and 22.8 for the fine aggregate fraction. The micro-Deval abrasion value for coarse aggregate was 33.2 and the sample had a high absorption of 2.770. No water was noticed in any of the licenced properties, but cementation of the granular material was observed. In fact, a "wall" of cemented material was observed in the field (Photo 05, ArcGIS® version only). As a result, the Petrographic Number value for HL and concrete was 379.5 with a high percentage of the clasts being encrusted. As a result of these test results, the granular material in this deposit is suitable for the production of Granular B and SSM products. The aggregate is not suitable for the production of HL and concrete products.

Selected Sand and Gravel Resource Area 2 has a total unlicenced area of 322.5 ha (*see* Table 3). There are 6 licenced operations (Pit Nos. 9, 10, 11, 12, 13 and 14) and 1 unlicenced pit (Pit No. 22) currently located within this deposit. After considering previously extracted areas, physical, cultural and environmental constraints and assuming a deposit thickness of 6 m, the remaining deposit area available for extraction is reduced to 246.1 ha or 26.1 million tonnes (*see* Table 3).

Similar to Selected Sand and Gravel Resource Area 1, the amount of previous extraction that has occurred within this deposit and the limitation of the granular material based on the cementation would normally render this deposit as a secondary or probably tertiary resource area. The fact that sand and gravel resources are limited in this area of Bruce County means that the remaining resources are important, and extraction and development of the remaining resources should occur carefully and with due consideration, also taking into consideration the quality limitations. Sand material from this deposit could be blended with higher quality bedrock-derived coarse aggregate material to meet higher specification aggregate products.

Selected Sand and Gravel Resource Area 3

Selected Sand and Gravel Resource Area 3 is the long, linear, relatively narrow, glacial Lake Algonquin beach-bar-spit–shoreline complex and associated ice-contact deposits that trends northeastward through the centre of the Town of Saugeen Shores, along the east side of the community of Port Elgin. This selected area has been a significant source of good quality sand and gravel to western Bruce County for a number of years and still hosts 14 licenced operations (Pit Nos. 73 to 86) and 2 unlicenced pits (Pit Nos. 88 and 90).

Because the deposit is so long and has a variety of depositional environments, the material that comprises the selected area has many descriptions based on individual site locations. Generally, the deposit can be described as thin- to thick-bedded, well-sorted to unsorted, well-rounded to subrounded, fine to cobbly gravel interbedded with thin- to thick-bedded, moderately to well-sorted, fine to coarse sand to gravelly sand. Fine-grained silt and clay layers were observed. Bedding varies from cross-bedded, predominantly flat and horizontal bedding, to beds that dip gently to the west.

Previous aggregate test results provided the following information. The aggregate content varies from 18.1 to 73.1% coarse, 25.4 to 81.0% sand and 0.9 to 16.3% fine aggregate. Petrographic Number values range from 104.7 to 131.7 for Granular and 16 mm crushed and from 127.3 to 237.7 for HL and concrete stone. Magnesium sulphate soundness test results vary from 3.8 to 5.0 for coarse aggregate and from 6.7 to 12.8 for fine aggregate (*see* Table 9). The aggregate material in this deposit has been used for the production of Granular A, Granular B, SSM, HL4 (coarse aggregate), HL4 (fine aggregate) and concrete (fine aggregate) products. Beneficiation is required to produce some of the aggregate products listed above, and quality control is required since some of the Petrographic Number values are quite high.

Crushable coarse aggregate clasts are generally less than 17 cm and average from 2.5 to 8 cm. The percentage of crushable coarse aggregate varies from 21.3 to 56.4% of the coarse aggregate fraction. The lithology varies from 20 to 34% limestone, 52 to 64% dolostone, 0 to 5% sandstone, 0 to 3% siltstone, 5 to 11% Precambrian clasts and 1 sample had 7% chert.

Selected Sand and Gravel Resource Area 3 has a total unlicenced area of 336.3 ha (*see* Table 3). After considering previously extracted areas and physical, cultural and environmental constraints, the remaining area is reduced to 178.7 ha (*see* Table 3). Pit faces generally expose 6 to 9 m of granular material. Records for 2 water wells drilled in the centre of the deposit indicate 10.67 m of sand and gravel and 19.20 m of sand and gravel. Water was observed in the pit floors of some of the licenced pits; therefore, assuming a conservative deposit thickness of 7.5 m, 23.7 million tonnes of aggregate may still be available for extraction (*see* Table 3). Much of the demand for the granular material within this selected resource area was related to the construction of the Bruce Nuclear facility.

Selected Sand and Gravel Resource Area 4

Selected Sand and Gravel Resource Area 4 is located in the southwestern corner of the Municipality of Arran–Elderslie (formerly Elderslie Township). The selected resource area has been mapped as a southwesterly trending, oval-shaped beach deposit with an elevation of approximately 280 m (918.6 feet) (therefore, associated with glacial Lake Warren) surrounding an ice-contact deposit located in the core of the geological feature (Sharpe and Edwards 1979). This feature lies just south of the Williscroft moraine.

The granular material is quite variable. Pit faces developed within the 5 licenced properties (Pit Nos. 99, 100, 101, 102 and 103) expose areas of thin- to thick-bedded, moderately to well-sorted, subrounded to rounded, cobbly to fine gravel interbedded with moderately to well sorted, thin- to thick-bedded fine to coarse sand. Clasts were generally less than 18 cm and are predominantly dolostone. There are also pockets of fine-grained sediments (silt and clay layers) and till. One of the western pit faces revealed about 1 m of yellowish-brown to brown, clayey silt till (St. Joseph Till) overlying the aggregate material below.

Previous aggregate test results for this resource area indicate Petrographic Number values that range from 104.0 to 117.9 for Granular and 16 mm crushed and from 110.6 to 130.9 for HL and concrete stone. Gradation varies from 13.9 to 62.1% coarse aggregate, 36.9 to 72.4% sand and 1.0 to 13.7% fines. Magnesium sulphate soundness test results for coarse aggregate are variable from 1 to 6% and from 10 to 14% for fine aggregate (*see* Table 9). With appropriate crushing and screening, this material should be suitable for the production of Granular A, Granular B, SSM and some HL products. Control of the fines fraction will be important and previous test results indicate that the material can be "dirty" for some aggregate products.

Selected Sand and Gravel Resource Area 4 has a total unlicenced area of 52.6 ha (*see* Table 3). Previous extraction activities and cultural constraints reduce the size of the selected area: in fact, only 46.4 ha may be available for future development (*see* Table 3). Assuming a conservative deposit thickness estimate of 6 m, this resource area has approximately 4.9 million tonnes. Water was noted in part of the extracted area.

Selected Sand and Gravel Resource Area 5

Along the Lake Huron shoreline from the Town of Saugeen Shores southward to the Township of Huron–Kinloss (particularly the former Huron Township and indeed all along the Highway 21 corridor), aggregate resources are scarce (notwithstanding Selected Sand and Gravel Resource Area 3). Part of the reason for this present-day shortage is the incredible amount of granular material that the Bruce Nuclear station would have required during the construction of this facility. Later in this report, there will be a discussion of some beach and buried deposits that have provided aggregate material to this area in the past, but these reserves are greatly depleted, are difficult to identify and delineate and are expensive to develop. As a result of this general shortage of good-quality granular material in this particular part of Bruce County, Selected Sand and Gravel Resource Area 5, located in the southeastern part of the Municipality of Kincardine (formerly Bruce Township) and crossing over into the former Greenock Township (now the Municipality of Brockton), has been selected as a resource of primary importance. Parts of this selected area have stone-quality issues as well as a high percentage of fines, but the granular complex is important to this part of the county. In order to produce some high-specification aggregate products, crushing, screening and washing may be required.

Selected Sand and Gravel Resource Area 5 is the apparent contact between the Gibraltar and Wyoming moraines: an area called the Glammis kames (Chapman and Putnam 1984). This feature is named after the small community of Glammis. The resource area has been mapped as a combination of ice-contact and glaciofluvial outwash deposits (*see* Map 1B). Cowan et al. (1978) have suggested that sediments within this resource area may be deltaic in origin.

The aggregate material can generally be described as thin- to medium-bedded, moderately sorted, rounded to subrounded, pebbly gravel in a fine to medium sand matrix interbedded with poorly to moderately sorted, thin- to medium-bedded fine to coarse sand. The crushable coarse aggregate is quite variable and can be up to 50.1% of the coarse aggregate fraction. The largest clast size ranges from 15 to 19 cm. Pockets of till and fine-grained sediments (silt and clay) are present. Lithology results indicate 15 to 19% limestone, 69 to 74% dolostone, 2 to 3% sandstone, 1% siltstone, 4 to 5% Precambrian clasts and 2 to 4% chert.

Previous aggregate test results indicate Petrographic Number values that range from 100.0 to 133.9 for Granular and 16 mm crushed and from 131.3 to 170.7 for HL and concrete (coarse aggregate). Gradation varies from 50.8 to 75.0% coarse aggregate, 22.3 to 43.1% sand and 1.1 to 7.5% fines. Magnesium sulphate soundness test values range from 6.2 to 16.1% for coarse aggregate and from 11.8 to 23.7% for fine aggregate. High absorption values greater than 2.0% (ranging from 2.03 to 2.61) reflect the high percentage of porous dolostone clasts in the coarse granular material (*see* Table 9).

Granular material from this selected area has been used for the production of Granular A, Granular B and SSM products in the past. The stone quality (high Petrographic Number values noted previously) and high absorption values would be of concern for the production of HL and concrete (coarse aggregate); and the high fines content (7.5%) and quality of the stone would be a concern for the production of HL and concrete (fine aggregate). Beneficiation of the granular material and possibly washing would be required to meet higher specification aggregate products.

Selected Sand and Gravel Resource Area 5 has a total unlicenced area of 1006.8 ha (*see* Table 3). Previous extractive activities and cultural constraints reduce the available resource area to 885.3 ha (*see* Table 3). There are currently 3 licenced operations (Pit Nos. 139, 140 and 141) and 4 unlicenced pits (Pit Nos. 146, 149, 150 and 164) located within this selected area. Assuming an average, conservative deposit thickness of 5 m, this selected resource area has approximately 78.3 million tonnes remaining (*see* Table 3).

Selected Sand and Gravel Resource Area 6

Selected Sand and Gravel Resource Area 6 is located just southeast of Selected Sand and Gravel Resource Area 5 in the Municipality of Brockton (formerly Greenock Township). This selected resource area is a complex of ice-contact and glaciofluvial outwash deposits. The area also includes at least 3 noticeable ice-contact esker deposits and/or segments. There are currently 6 licenced operations (Pit Nos. 155, 156, 157, 158, 159 and 160) and 5 unlicenced pits (Pit Nos. 166, 167, 168, 169 and 170) located within this ice-contact–outwash complex.

Because of the size of this complex and the variety of depositional environments within this selected area, the granular material can best be described as thin- to medium-bedded, poorly to well-sorted, rounded to subrounded, cobbly gravel in a fine to coarse sand matrix interbedded with moderately to well-sorted, thin- to medium-bedded, fine to coarse sand. Beds of silty fine sand and fine-grained sediments (silt and clay) were observed in pit faces. The largest, non-boulder, crushable clast size observed during field work was approximately 18 cm. The crushable coarse aggregate content varied from 15 to 42% of the coarse aggregate fraction. The lithology of the coarse aggregate varied from 8 to 28% limestone, 66 to 82% dolostone, 1 to 6% Precambrian clasts, 0 to 2% siltstone and 0 to 4% sandstone. One sample contained 2% chert.

Previous aggregate test results provide the following results for this selected area. The aggregate content ranges from 25.8 to 76.3% coarse, 18.7 to 53.9% sand and 1.5 to 20.3% fines. Petrographic Number values vary from 101.0 to 114.4 for Granular and 16 mm crushed and from 118.7 to 158.3 for HL and concrete stone. Magnesium sulphate soundness test results range from 4.8 to 7.8 for coarse aggregate and from 9.2 to 14.7 for fine aggregate. Los Angeles abrasion values were available for this selected area and they varied from 24.1 to 25.9. Micro-Deval abrasion test results range from 11.0 to 12.3 for coarse aggregate and from 12.6 to 18.5 for fine aggregate (*see* Table 9).

Granular material from this selected resource area has been used to produce Granular A, Granular B, SSM, HL4 (coarse aggregate) and HL4 (fine aggregate) products in the past. Stone quality can be a concern when the material is used for HL (coarse aggregate), as is quite evident by some of the Petrographic Number values noted in Table 9. Some sections of this selected area are "dirty" (e.g., fine aggregate content of 20.3%) and would require beneficiation and possible washing to meet some of the higher fine aggregate specifications.

Selected Sand and Gravel Resource Area 6 has a total unlicenced area of 1185.2 ha (*see* Table 3). Previous extractive activities and cultural constraints reduce the available resource area to 1122.9 ha (*see* Table 3). Assuming an average, conservative deposit thickness of 6 m based on field observations, this selected resource area has approximately 119.3 million tonnes remaining (*see* Table 3). Records from 3 water-wells drilled within this selected resource area indicate a sand and gravel thickness of 7.01 m, 14.94 m and 10.67 m.

Selected Sand and Gravel Resource Area 7

Selected Sand and Gravel Resource Area 7 is located in the southern part of the Township of Huron–Kinloss (in the former Kinloss Township), in an area surrounding the community of Lucknow. The resource area is a combination of an ice-contact deposit and glaciofluvial outwash deposits, located in a glacial spillway. The selected area is located along the northern portion of the Wawanosh moraine. There are currently 7 licenced operations that have been developed in this selected resource area (Pit Nos. 196, 197, 198, 199, 200, 201 and 202). The outwash deposits along the western part of this selected area continue southward into the County of Huron, where Gao (2004) has designated the deposits as a resource of secondary importance. For this reason, they are designated as secondary in Bruce County.

Since the granular material has been deposited in a variety of depositional environments, exposures throughout the selected area reveal variations in the sediments, including homogeneous coarse sandy gravel that is clast supported; well-stratified, well-sorted and horizontally bedded fine gravel, interbedded with clast-supported, coarse sandy gravel; fine to coarse laminated sand with good cross-bedding; unsorted, non-stratified, coarse, cobbly, sandy gravel. Fault structures were noted in the ice-contact portions of the selected area.

Previous aggregate test results provided the following information. Petrographic Number values vary from 100.0 to 123.0 for Granular and 16 mm crushed and from 101.0 to 177.9 for HL and concrete stone. The aggregate content ranges from 49.8 to 85.4% coarse, from 13.6 to 42.3% sand and from 1.1 to 7.9% fines. Magnesium sulphate soundness test results vary from 2.0 to 16.1% for coarse aggregate and from 7.5 to 13.8% for fine aggregate (*see* Table 9).

Clasts were generally rounded to subrounded. Crushable material ranges from 25.7 to 61.0% of the coarse aggregate fraction. Maximum clast size was generally about 19 cm; however, boulders were observed in some locations. The lithology of this selected resource area is 42 to 64% limestone, 27 to 49% dolostone, 0 to 1% siltstone, 3 to 8% Precambrian clasts and 0 to 4% chert.

In general, the granular material from this selected area is suitable for the production of Granular A, Granular B and SSM products with screening or crushing of the larger clasts. Fine-aggregate products such as HL4 (fine aggregate) would require fine sediment control since some of the material can be "dirty". Washing may be required for some high-specification aggregate products. The Petrographic Number values for HL and concrete, as well as the absorption test results, would indicate that meeting the specifications for HL and concrete (coarse aggregate) may be difficult.

Selected Sand and Gravel Resource Area 7 has a total unlicenced area of 711.7 ha (*see* Table 3). Previous extractive activities and cultural constraints reduce the available resource area to 658.1 ha (*see* Table 3). The community of Lucknow reduces the granular resources available from this selected area. Water-well records indicate a granular material thickness that varies from 2.44 m sand to 1.52 m gravel to 11.58 m gravel. Therefore, assuming an average, conservative deposit thickness of 5 m, this selected resource area has approximately 58.2 million tonnes remaining (*see* Table 3).

Selected Sand and Gravel Resource Area 8

Selected Sand and Gravel Resource Area 8 is located in the west-central area of the Municipality of South Bruce (formerly Culross Township), west of the community of Teeswater. The selected area is a complex of ice-contact and glaciofluvial outwash deposits. As a result of the 2 different depositional environments, the sediments vary from well-stratified, interbedded, coarse and fine gravel with silty sand layers; to thin- to thick-bedded, coarse, cobbly gravel with a clean, coarse sand matrix; to laminated, finely cross-bedded, silty sand; to well-stratified, poorly sorted and horizontally bedded sand and gravel. Faulting structures were observed in the ice-contact portions of the selected resource area.

Previous aggregate test results indicate Petrographic Number values that vary from 100.6 to 115.3 for Granular and 16 mm and from 126.4 to 157.0 for HL and concrete stone. Gradation results indicate an aggregate content of 42.6 to 73.6% coarse, 22.6 to 51.4% sand and 0.6 to 7.3% fines. Magnesium sulphate soundness test results for coarse aggregate vary from 7.6 to 20.7% and, for fine aggregate, from 9.8 to 21.3% (*see* Table 9). The test results indicate that the granular material in this complex is suitable for the production of Granular A, Granular B and SSM products with crushing or screening of coarse aggregate, and fine aggregate control. Stone quality and absorption test results are a concern for the production of HL and concrete coarse aggregate. Hot-Laid (HL) and concrete fine aggregate require control of the fines content since some areas of the complex are “dirty”.

Clasts were rounded to subrounded and the crushable content varied from 17 to 50%. Maximum clast size was approximately 19 cm. The lithology ranged from 29 to 59% limestone, 33 to 55% dolostone, 0 to 1% sandstone, 4 to 6% Precambrian clasts and 3 to 11% chert. The high percentage of chert is of concern in the production of HL and concrete products and is reflected in the Petrographic Number values (*see* Table 9).

Selected Sand and Gravel Resource Area 8 has a total unlicenced area of 529.1 ha (*see* Table 3). Previous extractive activities and cultural constraints reduce the available resource area to 494.5 ha (*see* Table 3). Assuming an average, conservative deposit thickness of 5 m, this selected resource area has approximately 43.8 million tonnes remaining (*see* Table 3). There are currently 6 licenced operations located within this selected resource area (Pit Nos. 215, 216, 217, 218, 219 and 220).

Selected Sand and Gravel Resource Area 9

Located to the east of Selected Sand and Gravel Resource Area 8 is another ice-contact and glaciofluvial outwash deposit complex that currently hosts 6 licenced operations (Pit Nos. 222, 223, 224, 225, 226 and 227). Part of this selected resource area was formed by southward-flowing glacial meltwater in the Formosa Creek tributary emptying into the Teeswater River spillway.

Previous aggregate test results for this selected resource area indicates an aggregate content from 48.4 to 78.8% coarse, sand from 20.3 to 50.2% and fines from 0.5 to 4.0%. The crushable component of the coarse aggregate content varies from 19 to 55%. Petrographic Number values range from 100.0 to 117.4 for Granular and 16 mm crushed and from 110.0 to 229.8 for HL and concrete stone. Magnesium sulphate soundness test results vary from 3.0 to 19.4 for coarse aggregate and from 14.6 to 17.3 for fine aggregate. A sample collected as part of this study had a Petrographic Number value for HL and concrete stone of 229.8, which reflects the high chert content (16.8%) in this particular sample. This same sample had a coarse aggregate micro-Deval abrasion test value of 13.3 (*see* Table 9).

The granular material in this complex will once again be variable depending upon the depositional environment and the flow regime of the glacial meltwaters, but can generally be described as moderately to well-stratified, thin- to thick-bedded, rounded to subrounded, pebbly to cobbly gravel in a fine to coarse sand matrix interbedded with thin- to medium-bedded, stratified, fine to medium sand. Beds of silt were observed. The lithology of the coarse aggregate was 16 to 57% limestone, 22 to 79% dolostone, 0 to 2% sandstone, 1 to 6% siltstone, 5 to 9% Precambrian clasts and 3 to 16.8% chert.

The granular material within this complex should be suitable for the production of Granular A, Granular B and SSM products with crushing of the coarse aggregate component and screening of fines. Production of HL and concrete coarse aggregate will be dependant upon the stone quality and the absorption values. The fine content will have to be monitored for the production of HL and concrete fine aggregate since some areas of the complex are “dirty”.

Selected Sand and Gravel Resource Area 9 has a total unlicenced area of 242.3 ha (*see* Table 3). Cultural constraints and previous extractive activities reduce the available resource area to 221.2 ha (*see* Table 3). Assuming an average, conservative deposit thickness of 5 m, this selected resource area has approximately 19.6 million tonnes remaining (*see* Table 3). A water-well record within the selected resource area indicated only 3.35 m of sand and gravel, but pit face exposures indicated a greater granular material thickness (*see* Table 2).

Selected Sand and Gravel Resource Area 10

Selected Sand and Gravel Resource Area 10 is located in the northeast corner of the Municipality of South Bruce (formerly Carrick Township). This deposit has been mapped as an ice-contact deposit (Cowan and Pinch 1986) and includes a noticeable esker ridge. There are currently 3 licenced operations (Pit Nos. 229, 230 and 235) within this selected resource area.

Pit and roadcut exposures within the resource area reveal sediments that vary from massive, thick-bedded, unsorted to poorly sorted, coarse, cobbly gravel with some boulders in a coarse sand matrix to interbedded, rippled and cross-bedded sand with some fine gravel beds and lenses. The material appears to be coarser along the eastern and southern part of the deposit and becomes progressively finer and thinner to the west. There would also appear to be a general fining-upward sequence with the upper part of the deposit consisting of interbedded sand and fine gravel. The fining-upward sequence would suggest a decrease in the meltwater flow and velocity. The paleocurrent direction is generally toward the south.

Previous aggregate test results indicate Petrographic Number values from 100.3 to 101.4 for Granular and 16 mm crushed and 107.1 to 113.9 for HL and concrete. The aggregate content varies from 43.0 to 73.3% coarse, 24.9 to 53.3% sand and 1.8 to 3.7% fines. The percentage of crushable material varied from 24.5 to 50.5% of the coarse aggregate fraction. Magnesium sulphate soundness test results range from 8.0 to 15.2% for coarse aggregate and 8.7 to 17.3% for fine aggregate (*see* Table 9). The granular material within this ice-contact deposit should be suitable for the production of Granular A, Granular B and SSM products with crushing and screening. The material should also be capable of producing HL and concrete products with proper beneficiation.

The crushable coarse aggregate clasts are rounded to subrounded and have a maximum clast size of about 18 cm, with the exception of the boulders noted above. Field observations of the lithology of this deposit indicate approximately 10% limestone, 80% dolostone and about 10% Precambrian clasts. There did not appear to be a noticeable presence of chert and other deleterious lithologies. The lower Petrographic Number values within this deposit, when compared to some of the previous selected resource areas, would seem to confirm the lower percentage of deleterious material as noted in the field.

Selected Sand and Gravel Resource Area 10 has a total unlicenced area of 126.4 ha (*see* Table 3). Previous extractive activities and cultural constraints reduce the available resource area to 114.4 ha (*see* Table 3). Assuming an average conservative deposit thickness of 7 m, this selected resource area has approximately 14.2 million tonnes remaining (*see* Table 3). Deposit thickness estimates are based on current and previous extractive faces and available water-well records located throughout the deposit.

This deposit continues northward into the Municipality of Brockton (the former Brant Township) where the deposit has been evaluated as a resource area of secondary importance. It may be that this northern section of the deposit should also be a primary resource, but there is a general lack of aggregate data and exposures to evaluate the deposit properly.

Selected Sand and Gravel Resource Area 11

Southeast of Selected Sand and Gravel Resource Area 10 is another large ice-contact deposit with a number of noticeable and quite distinguishable small esker segments that have been selected at the primary level of significance. This selected resource area is currently host to 1 licenced operation (Pit No. 236) and 6 unlicenced pits (Pit Nos. 260, 261, 262, 263, 264 and 265).

In the sections that were observed in the field, the granular material can best be described as a well-stratified, clean, coarse, cobbly gravel overlain by coarse gravel, fine silty sand with rippled, cross-bedded development. Another section exposed gravelly sand with matrix supported cobbles overlain by well-sorted, matrix-free, fine pea-sized gravel, in turn, overlain by fine, sorted sandy gravel. There appears to be a general fining-upward sequence with some of the upper parts of the deposit being predominantly thick accumulations of sand. Overall, the deposit appears to be a core or main channel of massive, unstratified, relatively homogeneous coarse, cobbly, clast-supported, clean gravel with a sandy matrix, which would appear to indicate very rapid deposition with little sorting. Outward from the main channel, meltwater velocities probably decreased allowing some sorting and stratification of the finer sand and gravel.

Previous aggregate test results indicate an aggregate content of 53.7 to 71.5% coarse, 27.9 to 43.7% sand and 0.6 to 5.2% fines. Petrographic Number values vary from 100.0 to 111.5 for Granular and 16 mm crushed and 108.9 to 124.8 for HL and concrete. Magnesium sulphate soundness test values range from 3.0 to 9.9% for coarse aggregate and 9.5 to 17.5% for fine aggregate. A sample collected as part of this investigation had a coarse aggregate micro-Deval abrasion value of 8.9 and a fine aggregate micro-Deval abrasion value of 15.7 (*see* Table 9).

Crushable coarse aggregate clasts were subrounded to rounded, with a maximum size of about 16 cm. A few boulders were observed in the field. The coarse aggregate lithology varies from 8 to 10% limestone, 82 to 85% dolostone, and 7 to 8% Precambrian clasts. Crushable material varied from 35 to 51% of the coarse aggregate fraction. The coarse aggregate material is similar in many ways to the material in Selected Sand and Gravel Resource Area 10.

The granular material from this selected area would appear to be suitable for the production of Granular A, Granular B and SSM products with proper beneficiation. The coarse and fine aggregate should also be suitable for the production of HL and concrete (coarse aggregate and fine aggregate) with beneficiation and “fines” control.

Selected Sand and Gravel Resource Area 11 has a total unlicenced area of 833.6 ha (*see* Table 3). Cultural constraints and previous extractive activities reduce the available resource area to 788.4 ha (*see* Table 3). Assuming an average, conservative deposit thickness of 6 m, this selected resource area has approximately 83.7 million tonnes remaining (*see* Table 3). One water-well record located within this selected area indicated 14.63 m of gravel, whereas a second water-well record indicated 16.46 m of sand and gravel.

Selected Sand and Gravel Resource Area 12

Selected Sand and Gravel Resource Area 12 is located just northwest of the community of Mildmay, along the Highway 9 corridor. The selected resource area is an ice-contact deposit and has been described as a large, prominent circular hill with a maximum relief of about 35 m (Chapman and Putnam 1984).

The granular material can best be described as extremely variable. Coarse, unsorted, massive, clast-supported, cobbly gravel with a sand, silt and clay matrix overlain by fine, sandy, clean gravel with coarse gravel interbeds was observed in one area of a licenced pit. A massive cobble bed with some boulders was observed in another portion of the pit. In the western part of the deposit, well-sorted, fine to coarse sand and silty sand with some thin clay seams were noted. The extreme variability of the sediments within this deposit would suggest a complex, chaotic depositional history where very rapid rates of deposition and large volumes of meltwater have produced the extensive coarse cobbly gravel beds; and slower, quieter meltwater would have deposited the fine-grained sediments.

The coarse aggregate clasts are subrounded to rounded with a maximum size of about 16 cm. Boulders were observed as noted above. The coarse aggregate lithology was approximately 4% limestone, 93% dolostone and 3% Precambrian clasts based on field observations. Crushable material varied from 12 to 89% of the coarse aggregate fraction.

Previous aggregate test results indicate Petrographic Number values range from 100.3 to 105.2 for Granular and 16 mm crushed and 115.6 to 130.3 for HL and concrete. The aggregate content ranges from 26.3 to 90.1% coarse, 8.3 to 62.9% sand and 0.4 to 10.7% fines. Magnesium sulphate soundness test results vary from 14.5 to 22.8% for coarse aggregate and 22.0 to 32.6 for fine aggregate. The granular material within this ice-contact deposit should be suitable for the production of Granular A, Granular B and SSM products with crushing and screening. Petrographic Number values for HL and concrete would also seem to indicate the use of this granular material for HL and concrete products. Hot-Laid (HL) fine aggregate is also suitable, but control of “fines” would be required.

Selected Sand and Gravel Resource Area 12 has a total unlicenced area of 89.7 ha (*see* Table 3). Previous extractive activities and cultural constraints reduce the available resource area to 72.9 ha (*see* Table 3). Water-well records located within the selected area indicate varying thicknesses: 12.80 m of sand and gravel; 6.71 m of gravel; 14.33 m of sand and gravel; and 5.18 m of sand over 3.35 m of sand and clay. Therefore, assuming an average, conservative deposit thickness of 7 m, this selected resource area has approximately 9.0 million tonnes remaining (*see* Table 3).

Selected Sand and Gravel Resource Area 13

Selected Sand and Gravel Resource Area 13 is an area of hummocky topography on a highland area to the southwest of Mildmay (in the former Carrick Township). The area represents the watershed boundary or divide between the Teeswater and Saugeen rivers and has been mapped as an ice-contact deposit (Cowan and Pinch 1986).

Exposures of the sediment in the area reveal a varied and complex depositional history. In one exposure, 6 m of well-stratified and interbedded, coarse gravel and coarse cross-bedded sand layers were observed. Another exposure revealed coarse, rounded, clast-supported gravel with a clean, medium to coarse sandy matrix. Elsewhere, 2 m of thick-bedded, interbedded sand with rare gravel layers and silty sand were exposed. Finally, another area revealed 6 m of coarse, cross-bedded, granular sand with interbedded, fine, sandy gravel. Faulting and slumping features were observed within the resource area.

Previous aggregate test results indicate an aggregate content of 52.5 to 71.9% coarse, 19.7 to 44.2% sand and 1.3 to 9.2% fines. Petrographic Number values vary from 100.0 to 131.0 for Granular and 16 mm crushed and from 112.8 to 166.7 for HL and concrete. Magnesium sulphate soundness test values range from 12.6 to 28.1% for coarse aggregate and 7.7 to 25.5% for fine aggregate. A sample collected as part of this study had a Los Angeles abrasion test result of 25.56, a coarse aggregate micro-Deval abrasion value of 16.2 and a fine aggregate micro-Deval abrasion value of 30.5 (*see* Table 9).

The coarse aggregate clasts are subrounded to rounded, with a maximum size of about 16 cm. The coarse aggregate lithology varies from 4 to 15% limestone, 75 to 88% dolostone, 0 to 2% chert, 1 to 5% siltstone and 3 to 7% Precambrian clasts. Crushable material varied from 27 to 46% of the coarse aggregate fraction.

The granular material from this selected area would appear to be suitable for the production of Granular A, Granular B and SSM products with proper beneficiation. The stone quality of the coarse aggregate fraction is of concern for the production of HL and concrete (coarse aggregate) products as indicated by the high Petrographic Number values and absorption test results. Sections of the deposit appear "dirty" (silty sand layers as noted above) for the production of HL and concrete (fine aggregate) products.

Selected Sand and Gravel Resource Area 13 has a total unlicenced area of 293.9 ha (*see* Table 3). Previous extractive activities and cultural constraints reduce the available resource area to 269.6 ha (*see* Table 3). Assuming an average, conservative deposit thickness of 5 m, this selected resource area has approximately 23.9 million tonnes remaining (*see* Table 3). Deposit thickness estimates were calculated based on current and previous extractive slopes and/or faces and a number of water-well records located throughout the deposit.

Resource Areas of Secondary Significance

There are numerous secondary deposits throughout Bruce County that add significantly to the overall aggregate resource supply in the study area. Most of the secondary deposits in the central portion of the county (former Amabel Township southward to the former Brant Township) are small glaciolacustrine beach and glaciofluvial ice-contact deposits. In the south and southeastern part of the county are larger, predominantly glaciofluvial outwash and ice-contact deposits. Deposit thickness and, therefore, the quantity of granular material available, variability of the material, lower coarse aggregate content, concerns over the stone quality and the "dirtiness" of some of the deposits generally make these resource areas less attractive for development than the primary deposits. Many of these secondary resource areas can be used locally to supply lower specification aggregate products.

TOWN OF SOUTH BRUCE PENINSULA

In the southern part of the Town of South Bruce Peninsula (formerly Amabel Township) are a series of glaciolacustrine beach ridges associated with proglacial lake levels. These beach ridges have been selected as sand and gravel resource areas of secondary importance. The granular material within these beach ridges can generally be described as moderately to well-stratified, horizontally thin- to medium-bedded, relatively clean sand and gravel. The coarse aggregate content is roughly 35 to 50%. The maximum clast size is approximately 12 to 15 cm. The lithology is about 25% limestone, 65% dolostone and 10% Precambrian clasts. The granular material from these beach deposits has been used for local construction projects in the past, for the production of Granular A, Granular B, SSM, HL4 (coarse aggregate) and HL4 (fine aggregate) products. Beneficiation of the material is required in order to meet higher specification aggregate products. Field observations and water-well data from the smaller beach ridges north of Hepworth indicate that the deposits are about 3 m thick. Water-well data and field observations in the beach deposits in the southern part, west of Park Head, indicates a thickness of up to 6 m. Water was observed in the floors of some of these pits. A good portion of these deposits have been mined extensively in the past and it may be prudent to use the remainder of the granular material wisely.

In the southeast corner of the Town of South Bruce Peninsula (formerly Amabel Township) is a series of small ice-contact esker ridges that have been selected at the secondary level. Previous aggregate test results indicate an aggregate content of 68.0% coarse, 29.1% sand and 2.9% fines. Crushable coarse aggregate clasts are rounded to subrounded and have an approximate maximum size of 16 cm. The Petrographic Number value was 110.0 for Granular and 16 mm crushed. Magnesium sulphate soundness test results were 2.1% for coarse aggregate and 6.5% for fine aggregate. A Los Angeles abrasion result of 22.3 was also recorded (*see* Table 9). The granular material would appear to be acceptable for Granular A, Granular B, SSM, HL4 (coarse aggregate) and HL4 (fine aggregate) products; however, further testing is required since this is based on a single test result. The deposits are generally not very large and current licenced operations (Pit Nos. 43, 44, 45 and 46), as well as previous extractive activity, greatly reduce the amount of granular material available in these deposits.

MUNICIPALITY OF ARRAN–ELDERSLIE

Within the northern part of the Municipality of Arran–Elderslie (formerly Arran Township) are a series of glaciofluvial ice-contact deposits that are evaluated at the secondary level of significance. These ice-contact deposits are either associated with, or are part of, the Tara moraine (Sharpe and Edwards 1979). Previous aggregate test results, and a sample that was collected as part of this investigation, indicate Petrographic Number values that range from 101.5 to 121.7 for Granular and 16 mm crushed and from 110.7 to 161.0 for HL and concrete. The aggregate content varies from 14.4 to 66.5% coarse, 32.0 to 71.7% sand and 1.5 to 13.9% fines. Magnesium sulphate soundness test results vary from 2.3 to 8.0% for the coarse aggregate fraction and from 8.6 to 11.8% for the fine aggregate fraction (*see* Table 9). The lithology results indicate 10 to 42% limestone, 53 to 77% dolostone, 0 to 2% sandstone, 0 to 1% siltstone, 2 to 13% Precambrian clasts and 0 to 1% chert. The majority of samples did not contain chert. The granular material in these deposits has been used for the production of Granular A, Granular B and SSM products. Hot-Laid–4 (HL4) (coarse aggregate) and HL4 (fine aggregate) products have been produced as well, but beneficiation is required and stone quality needs to be monitored closely. Part of this selected resource area continues eastward into Grey County (Jagger Hims Limited and Rowell 2009) and has been evaluated as a secondary resource within that municipality.

In the southern part of the Municipality of Arran–Elderslie (formerly Elderslie Township) are 4 glaciofluvial ice-contact deposits that have been selected as aggregate resource areas of secondary importance. Water-well records in the northeastern deposit indicate a granular resource thickness of up to 24.69 m, whereas the southeastern deposit near the community of Chesley may be up to 26.82 m thick. Water was observed in the pit floors of some of these deposits suggesting that the extractable amount of granular material may be substantially less than what is suggested by the water-well records, or that dredging may be required. The aggregate test results for a sample collected as part of this investigation, 11DJR-0023, is provided in Table 9.

MUNICIPALITY OF BROCKTON

In the southwest corner of the Municipality of Brockton (formerly Greenock Township) and extending into the Municipality of South Bruce (formerly Culross Township) is a series of ice-contact deposits (including esker ridges and/or segments) that have been selected as an area of secondary significance. Exposures within this selected resource area reveal horizontal to slightly inclined (dipping), medium to massive bedded, moderately sorted gravel, with a silty to fine sand matrix; interbedded with thin, moderately sorted, rippled laminated silt and fine sand, and planar- and cross-bedded, coarse sand and poorly sorted gravel. Previous aggregate test results for this area indicate an aggregate content of 50.8 to 58.8% coarse, 30.0 to 46.2% sand and 2.6 to 14.4% fines. Petrographic Number values vary from 100.0 to 103.9 for Granular and 16 mm crushed and from 133.1 to 177.2 for fine aggregate. Magnesium sulphate soundness test results range from 1.8 to 12.9% for coarse aggregate and from 12.5 to 15.2% for fine aggregate (*see* Table 9). Lithology results indicate 25 to 39% limestone, 55 to 66% dolostone, 5 to 6% Precambrian clasts, 2% sandstone and 2% siltstone. The material should be suitable for the production of Granular A, Granular B and SSM products. Stone quality will be an issue for HL and concrete (coarse aggregate) products. Without beneficiation, some sections of this deposit are “dirty” for HL and concrete (fine aggregate) products. A water-well record in the west end of this deposit indicates 15.24 m of sand and gravel, whereas a water-well record in the eastern part of this deposit indicates 8.53 m of sand and gravel, over 3.05 m of sand, over 4.88 m of sand and gravel for a total thickness of 16.46 m. There are currently 5 unlicenced pits (Pit Nos. 171, 172, 173, 174 and 175) located within this selected area.

Ice-contact and glaciofluvial outwash deposits located in the Municipality of Brockton (formerly Brant Township) have been selected as aggregate resource deposits of secondary significance. Previous aggregate test results, as well as test results for samples collected as part of this investigation, are presented in Table 9. The aggregate content for these deposits varies from 39.7 to 53.6% coarse, 41.7 to 53.3% sand and 4.7 to 7.0% fines. The lithology is 18.0 to 21.2% limestone, 69.7 to 71.0% dolostone, 0 to 4% sandstone, 4 to 9% Precambrian clasts, and 0 to 3% shale. The granular material would appear suitable for Granular A, Granular B and SSM products. Stone quality may be of concern for HL and concrete (coarse aggregate) products, whereas the material may be “dirty” for HL and concrete (fine aggregate) products without beneficiation.

TOWNSHIP OF HURON–KINLOSS

In the south-central part of the Township of Huron–Kinloss (formerly Huron Township) is a glaciolacustrine beach deposit that has been selected as an aggregate resource of secondary importance. The beach sediments actually overlie an ice-contact deposit. Exposures within the deposit reveal sediments that vary from massive, coarse, cobbly gravel with cross-bedded, rippled silt and sand; to clast-supported, coarse, cobbly gravel with a sand matrix overlain by very well-sorted, interbedded sand and fine gravel; to thinly interbedded sequences of finely cross-rippled, fine sands and silts. There are also noticeable sections of fine-grained till material (St. Joseph Till). Paleocurrent flow measurements varied from north-south to slightly northeast-southwest. The sediments along the top of the western exposure resemble typical beach-like sediments. Previous aggregate test results are presented in Table 9. Previous gradation results indicate an aggregate content from 60.7 to 74.2% coarse, 22.5 to 34.3% sand and 2.0 to 6.9% fines. Crushable coarse aggregate is roughly 35 to 50% of the coarse aggregate fraction and the maximum clast size is about 18 cm (larger clasts and some boulders were observed, but are rare). The lithology of the coarse aggregate is approximately 38% limestone, 52% dolostone and 10% Precambrian clasts. The granular material is suitable for the production of Granular A, Granular B and SSM products. Stone quality is a concern for the production of HL and concrete (coarse aggregate) products (Petrographic Number values range from 115.1 to 135 and absorption values are >2.0%). Licenced Pit No. 191 has been developed within the northern part of this deposit (*see* Map 1B).

In the north-central portion of the Township of Huron–Kinloss (formerly Kinloss Township) is a southeast-trending ice-contact deposit that currently hosts 2 licenced operations (Pit Nos. 192 and 193). This deposit has been designated as an area of secondary significance. Previous gradation results for this deposit indicate an aggregate content that varies from 37.4 to 71.3% coarse, 28.2 to 58.1% sand and 0.5 to 7.7% fines. The lithology ranges from 5 to 30% limestone, 62 to 76% dolostone, 4 to 6% Precambrian clasts and 0 to 12% chert. Other previous aggregate test results for this deposit are presented in Table 9. Field observations of this deposit revealed areas of fine sand and silt. The lithology of this deposit is of concern as it contains a moderate to high percentage of chert material (up to 12%). The granular material within this deposit should be suitable for the production of Granular A, Granular B and SSM products.

Located to the southeast of the last secondary resource area, in the Township of Huron–Kinloss (in the central part of the former Kinloss Township), is another area of secondary importance. This area is a mixture of ice-contact and glaciofluvial outwash deposits. Licenced Pit No. 194 has been developed within an ice-contact esker segment within this selected area. The aggregate content of this selected area varies from 50.6 to 56.3% coarse, 26.2 to 40.1% sand

and 3.6 to 23.2% fines. The lithology ranges from 40 to 42% limestone, 42 to 52% dolostone, 0 to 1% sandstone, 3 to 6% Precambrian clasts, and 2 to 10% chert. Other previous aggregate test results are presented in Table 9. The granular material in these select deposits should be suitable for the production of Granular A, Granular B and SSM products with proper processing.

Located in the Township of Huron–Kinloss (in the very southeast corner of the former Kinloss Township) is a small esker deposit that has been selected as a secondary resource area. Previous aggregate test results for this selected area are presented in Table 9. Previous gradation results indicate an aggregate content of 65.5 to 71.3% coarse, 25.8 to 28.6% sand and 1.8 to 5.9% fines. The lithology of the coarse aggregate clasts is approximately 36% limestone, 48% dolostone, 11% Precambrian clasts and 5% chert. The granular material should be suitable for the production of Granular A, Granular B and SSM products. This deposit continues southward into the County of Huron where Gao (2004) has selected the deposit as a resource area of secondary significance.

In the southeastern corner of the Township of Huron–Kinloss (in the former Kinloss Township) and extending eastward into the Municipality of South Bruce (in the former Culross Township) is a large area of glaciofluvial outwash that has been evaluated at the secondary level of significance. Within this outwash area is also a series of ice-contact esker ridges and/or segments. There is currently 1 licenced operation (Pit No. 195) and 5 unlicenced pits (Pit Nos. 208, 209, 210, 211 and 212) located in the Township of Huron–Kinloss part (western portion) of this area. Previous aggregate test results are provided in Table 9. Gradation results indicate an aggregate content that ranges from 26.5 to 74.6% coarse, 23.2 to 72.4% sand and 1.0 to 9.3% fines. Clast lithology varies from 27 to 54% limestone, 33 to 61% dolostone, 0 to 1% sandstone, 1 to 6% Precambrian clasts and 0 to 7.4% chert. The granular material within this selected area should be suitable for the production of Granular A, Granular B and SSM products with proper crushing and screening. The stone quality (7.4% chert) is of concern for the production of HL and concrete (coarse aggregate) products and some sections of the selected area are "dirty" for the production of HL and concrete (fine aggregate) products. Crushing, screening and washing may be required to produce higher specification aggregate and a strict quality-control testing program may be required. Records from 3 water wells located throughout this deposit vary from 4.57 m of gravel over till, to 4.27 m of gravel over 5.48 m of sand and gravel, to 7.62 m of sand over 2.74 m of gravel.

MUNICIPALITY OF SOUTH BRUCE

There is a large secondary resource area in the north-central portion of the Municipality of South Bruce (formerly Carrick Township). Gradation results for this deposit area indicate 45.8% coarse aggregate, 48.0% sand and 6.7% fines. Despite this gradation result, these ice-contact deposits have been selected as a secondary resource area because the deposits display predominantly sand material. Observations along roadcuts and other exposures confirm this conclusion. The only previous aggregate test result available for this selected area indicates a coarse aggregate magnesium sulphate soundness test value of 6.3%.

Southeast of the community of Mildmay in the former Carrick Township (now the Municipality of South Bruce) are 2 glaciofluvial outwash and an ice-contact deposits that have been selected as a secondary resource. There is currently 1 licenced operation within this selected resource area (Pit No. 241) as well as 1 unlicenced pit (Pit No. 268). Previous gradation results for this area indicate an aggregate content from 45.9 to 68.3% coarse, 30.5 to 51.4% sand and 1.2 to 3.5% fines. Other aggregate test results are presented in Table 9. The granular material should be suitable for the production of Granular A, Granular B and SSM products. Stone quality and high absorption values are of concern for use in HL and concrete (coarse aggregate) products. A water-well record from 1 of the outwash deposit areas indicates 4.57 m of gravel over till.

Along the southern boundary of the former Carrick Township (now the Municipality of South Bruce) and crossing southward into the County of Huron are a series of glaciofluvial outwash deposits that have been selected as a secondary resource. These deposits have been selected as a resource of secondary significance within the County of Huron (Gao 2004). These deposits currently host 1 licenced operation (Pit No. 242) and a number of unlicenced pits (Pit Nos. 269, 270, 271, 275 and 276). A sample collected and tested as part of this investigation indicates an aggregate content of 64.4% coarse, 30.0% sand and 5.6% fines. The high Petrographic Number values (129.9 for Granular and 16 mm crushed and 216.6 for HL and concrete) are a reflection of this sample containing 14.4% chert. Table 9 presents the rest of the aggregate test results for this sample, including a high absorption result of 3.011.

As noted in "Township of Huron–Kinloss", the secondary selected area in the southeast corner of the former Kinloss Township continues eastward into the southwest corner of the Municipality of South Bruce (former Culross Township). The previous gradation results for this portion (eastern part) of the selected area are 29.4 to 56.3% coarse aggregate, 40.7 to 62.3% sand and 1.9 to 8.3% fines. The lithology varies from 21 to 33% limestone, 47 to 61% dolostone, 0 to 1% sandstone, 3.1 to 6% Precambrian clasts and 3.4 to 10.5% chert. Other previous aggregate test results are presented in Table 9. The granular material in this selected area is suitable for the production of Granular A, Granular B and SSM products. There is 1 licenced operation (Pit No. 221) and the southern parts of 2 other licenced pits (Pit Nos. 219 and 220) located in this area. There are also 7 unlicenced pits within this secondary area (Pit Nos. 248, 250, 251, 252, 253, 254, and 255). Water-well data indicate that the granular material can be as thin as 6.10 m of gravel or as thick as 20.42 m of sand and gravel within this selected resource area. Similar deposits in the County of Huron have been selected as secondary resource areas by Gao (2004).

Other Sand and Gravel Resources: Comments

MUNICIPALITY OF NORTHERN BRUCE PENINSULA

Near the community of Dyer's Bay, in the former Lindsay Township, is a small beach deposit. Pit No. 20, while still noticeable during this survey, has essentially been sloped and rehabilitated with the southern part of the old pit now a municipal parking lot (Photo 06, ArcGIS® version only). From an exposure near the pit, the deposit consists of horizontally thin- to thick-bedded, coarse to cobbly beach gravel supported by a silty fine sand matrix overlying thick, horizontal beds of bouldery coarse gravel with a fine sand matrix. Boulder-sized angular to subangular slabs are strewn around the area. The deposit formed as a beach undercutting the Niagara Escarpment and the crushable clasts are locally derived (~36% dolostone, 1% chert and 63% sandstone). (Photo 07 (ArcGIS® version only) shows a cobble beach deposit slightly north of the community of Dyer's Bay.) Previous test results (Ontario Geological Survey 1995) are presented in Table 9. The high Petrographic Number and absorption values reflect the high sandstone and dolostone lithology.

There is a small remnant pit (Pit No 21) located southwest of Cape Chin. The material in this very shallow pit has been removed and bedrock is now exposed. A very small exposure reveals poorly sorted, cobbly beach gravel with a medium to coarse sand matrix. Striae at this location indicates an ice-flow direction of 234°. The granular material in this pit has essentially been removed.

As mentioned in the descriptions for Selected Sand and Gravel Resource Areas 1 and 2, there are very few large, thick deposits of sand and gravel in the Municipality of Northern Bruce Peninsula. Many of the deposits are thin beach ridges that may provide small quantities of granular material, if they have not already been exploited and depleted.

TOWN OF SOUTH BRUCE PENINSULA

In the northern part of the Town of South Bruce Peninsula (formerly Albemarle Township), there are a few small sand and gravel deposits. Despite what appears to be large resource areas located along the Lake Huron shoreline that continue southward into the former Amabel Township (*see* Map 1A), these deposits are predominantly composed of a fine sand that can be used for fill, perhaps septic sand and other low-specification aggregate purposes. The deposits are generally eolian (windblown) and glaciolacustrine plain deposits. Samples of this fine sand dune material were collected as part of this study and are presented in Table 10 (samples 11DJR-0001 and 11DJR-0002). Typical of sand dune or windblown deposits, the granular material is clean and uniform. In fact, sample 11DJR-0001 had only 1.23% fines (<75 μm) and sample 11DJR-0002 had even less fine material at 0.24%. The majority of the sample is less than 300 μm, but greater than 150 μm (passes the No. 50 sieve, but is retained on the No. 100 sieve). Sample 11DJR-0001 had 81.68% of the sample in this size fraction, and sample 11DJR-0002 had 77.29% retained on the No. 100 sieve. Neither sample is useful in the production of MTO type aggregate products.

The dune deposits are associated with glacial Lake Nipissing (Chapman and Putnam 1984; Stadelman 1973) because the elevation of the contact between the leeward slope (eastern edge) and the bedrock surface has been measured from 191 to 197 m asl (Davidson-Arnott and Pyskir 1988). The crest of the main ridge is generally 10 to 25 m, but can exceed 30 m in some areas. The western dune area spans an elevation of 183 to 191 m asl and records the shoreline regression in the time after glacial Lake Nipissing.

Small beach ridges scattered throughout this area provide some coarse aggregate material; however, these have generally been exploited in the past and are substantially depleted.

TOWN OF SAUGEEN SHORES

Because of the complex depositional history of Bruce County (*see* "Surficial Geology and Physiography" and "Sediments"), there are aggregate resources that are buried by younger, more recent sediments. One such buried aggregate resource area is identified in the Town of Saugeen Shores by a dashed-line circle on Map 1B. Table 9 provides the results of aggregate quality testing completed on a sample that was collected as part of this study. The sample was 34.7% coarse aggregate material, 55.6% sand and 9.7% fines. The high fines content of this sample is of concern when trying to meet high-specification aggregate products.

MUNICIPALITY OF KINCARDINE

Similar to the buried deposits in the Town of Saugeen Shores, there are a series of buried deposits located in the Municipality of Kincardine (formerly Bruce Township). These ice-contact deposits have been buried by younger, more recent sediments. These areas are identified on Map 1B by a series of dashed-line circles. Exploration and delineation of these deposits generally begins with a comprehensive review of water-well records followed by extensive drilling. This process can be very time consuming and expensive. Previous aggregate test data for these buried deposits indicate an aggregate content that varies from 20.5 to 70.8% coarse, 31.0 to 76.9% sand and 1.0 to 3.2% fines. Magnesium sulphate soundness test values range from 1.0 to 12.6% for coarse aggregate and from 11.1 to 16.3% for fine aggregate. Petrographic Number values vary from 100.0 to 121.3 for Granular and 16 mm crushed and from 115.6 to 156.0 for HL and concrete. Lithology results indicate 19 to 29% limestone, 63 to 78% dolostone, 0 to 2% sandstone, 0 to 2% siltstone, 0 to 11% Precambrian clasts and 0 to 1% chert. Some absorption values are high (>2%), possibly reflecting the high dolostone, sandstone or siltstone content of that particular sample.

TOWNSHIP OF HURON–KINLOSS

A glacial Lake Algonquin beach deposit in the Township of Huron–Kinloss (in the northwest corner of the former Huron Township) has been mined, and is currently being extracted, to provide quantities of granular material to the local area (Pit Nos. 190 and 204). The granular material is generally well-stratified, thin- to medium-bedded, pebbly to fine gravel interbedded with clean medium to coarse sand. Beds are generally flat with a slight dip to the west. Low-angle cross-bedding was also observed. Previous test results for this beach deposit are presented in Table 9. Gradation results indicate 44.2 to 62.7% coarse aggregate, 34.9 to 48.2% sand and 2.4 to 7.6% fines. The granular material has been used for the production of Granular A, Granular B and SSM products. Stone quality is a concern for HL and concrete (coarse aggregate) products (high Petrographic Number and absorption values as provided in Table 9); fines control would have to be implemented to produce HL and concrete (fine aggregate) products. Pit No. 204 has been completely rehabilitated and turned into a park, including a baseball diamond (Photo 08, ArcGIS® version only). Water fills most of Pit No. 190, although it may be possible to dredge below the water surface. Much of the deposit is sterilized by a housing development. A similar beach deposit can be found in the southwest corner of the former Huron Township. The characteristics of this deposit may be similar to this northern deposit, but no exposures or previous test results were available for this area. Much of the southern deposit has been sterilized by housing development. Water-well records in this southern area indicate 3.35 m to 6.40 m of sand to 3.35 m of sand and gravel.

Previous aggregate extraction (Pit No. 205) in the Township of Huron–Kinloss (in the former Huron Township) has occurred just west of the community of Ripley. An exposure developed in a broad circular knoll (*see* Map 1B) exposes granular material that varies from unsorted, clast-supported coarse gravel with some cobbles in a sand matrix to well-sorted, fine gravel interbedded with medium to coarse sand. Previous aggregate test results for this knoll are presented in Table 9. The aggregate content varies from 46.3 to 70.2% coarse, 25.1 to 48.3% sand and 4.7 to 5.4% fines. Lithology results indicate 57% limestone, 25% dolostone, 1% siltstone, 5% chert and 11% Precambrian clasts. The granular material from this deposit has produced Granular A, Granular B and SSM products. Stone quality is of concern with regard to the production of HL and concrete (coarse aggregate) products; control of the fines would be required for the production of HL and concrete (fine aggregate) products. This deposit is not very large and, between the community of Ripley and other cultural constraints, this deposit has little granular material readily available.

BEDROCK GEOLOGY AND RESOURCE POTENTIAL

Bruce County is underlain by a thick sequence of Paleozoic bedrock ranging from the Ordovician Queenston Formation located along Georgian Bay on the east side of the Bruce Peninsula, to the Devonian Lucas Formation in the southwest corner of the county. In fact, recent drilling at the Bruce Nuclear site, north of the community of Kincardine, indicates a Paleozoic sequence thickness of approximately 820 m (AECOM Canada Limited and Itasca Consulting Canada Incorporated 2011). The formations are relatively flat lying, but do have a slight regional dip of 4.8 to 7.6 m per km to the southwest (Kor and Cowell 1998) toward the centre of the Michigan Basin. This slight regional dip combined with the differential resistance to weathering of the various rock units has given rise to a series of escarpments in the Paleozoic rocks of southwestern Ontario, such as the Niagara Escarpment, which is the most notable bedrock feature in Bruce County. Only formations that crop out in the study area will be discussed in this report. Other formations (e.g., the Irondequoit Formation) occur in the subsurface (Rowell and Brunton 2011).

The oldest formation in the study area is the Ordovician Queenston Formation that crops out along Georgian Bay on the east side of the Bruce Peninsula (Map 2A; Figure 3). The formation consists of brick red to maroon, noncalcareous to calcareous shales, with subordinate amounts of green shale, siltstone, sandstone and limestone (Armstrong and Carter 2010). Gypsum can occur as locally abundant nodules and thin subhorizontal fracture in-fillings (Rowell 2009). The formation ranges in thickness from 50 m at the north end of Bruce County to over 300 m beneath Lake Erie (Sanford 1961). Recent drilling at the Bruce Nuclear site indicates that the buried Queenston Formation is 70.4 m thick at that location (Raven et al. 2009).

These shales have a low load-bearing capacity and, therefore, are unsuitable for use as construction aggregate; however, the Queenston Formation is well suited for the production of structural clay products such as brick and tile (Guillet 1977; Rowell 2009) and is a resource of provincial significance (Guillet and Joyce 1987). Rocks from this formation have been extracted from quarries along the base of the Niagara Escarpment in southern Ontario since the late 1890s. The suitability of the Queenston Formation shale for manufacturing brick and tile may be constrained by carbonate layers, concentrations of gypsum, or soluble salts. Site-specific testing would be required to assess suitability. Because of its location in Bruce County (within the Niagara Escarpment Plan, and national and provincial parks) and the limited exposure of this rock unit, development opportunities for the extraction of the Queenston Formation are extremely limited.

The Silurian Manitoulin Formation of the Cataract Group disconformably overlies the Queenston Formation in Bruce County. The formation consists of blue-grey to buff-brown, thin- to medium-bedded, fine- to medium-crystalline dolomitic limestone, dolostone and argillaceous dolostone (Armstrong and Carter 2010). Shale partings are common and weathered outcrops often expose flat sheets of dolostone several centimetres thick where the grey-green argillaceous shale partings have been removed due to weathering. White

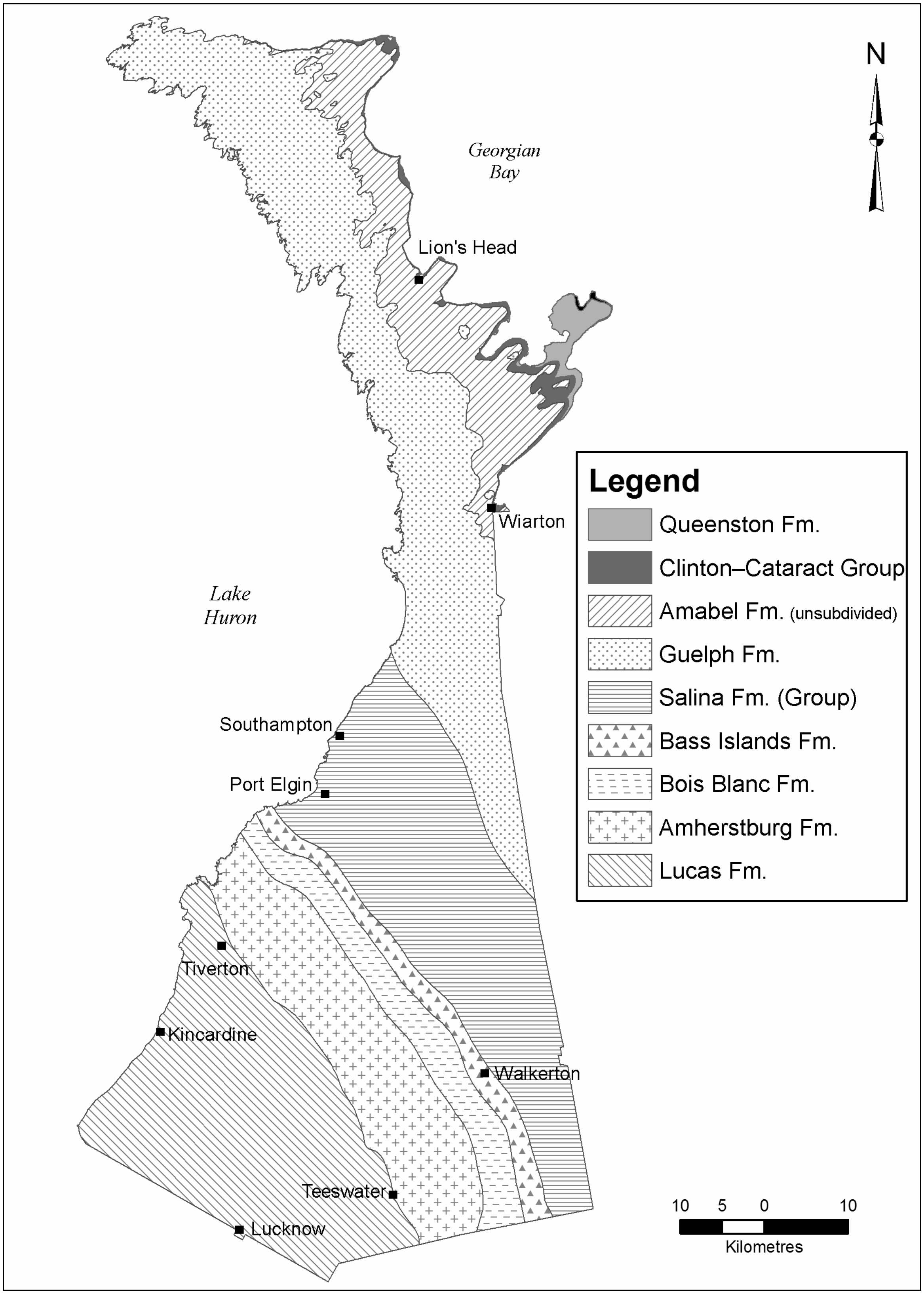

Figure 3. Simplified bedrock geology of the County of Bruce (*after* Armstrong and Dodge 2007).

chert nodules or lenses, and silicified fossils have been observed within the formation (Vos 1969). It is believed that the formation was deposited on a shallow marine carbonate ramp. The Manitoulin Formation can be up to 25 m thick. At the Bruce Nuclear site, 12.9 m of Manitoulin Formation was intersected in one of the drill holes (Raven et al. 2009), whereas only 1.22 m of the Manitoulin Formation was intersected in an OGS drill hole near Cyprus Lake along the eastern side of the Bruce Peninsula (Rowell and Brunton 2011).

The Manitoulin Formation crops out along Georgian Bay on the eastern shoreline of the Bruce Peninsula. The formation is more resistant to weathering than the rocks both above and below it and, as a result, it often forms minor subsidiary scarps along the face of the Niagara Escarpment. The Manitoulin Formation has not been selected for possible resource protection due to its poor physical quality and land use planning constraints that overlie the formation (Niagara Escarpment Plan, and national and provincial parks).

The Cabot Head Formation of the Cataract Group overlies the Manitoulin Formation. The formation often occurs as a subcrop band in the face of the Niagara Escarpment and is commonly covered with talus from the overlying dolostone units. The type locality for the Cabot Head Formation is the cliff exposure located just west of Rocky Bay, east of Cabot Head. The formation consists of maroon to reddish to greenish-grey, noncalcareous shale, with subordinate sandstone and carbonate interbeds (Armstrong and Carter 2010). The formation is generally fossil poor, although a few bryozoan-rich shale and argillaceous beds have been documented. Gypsum is present, which would suggest a shallow water to restricted marine depositional environment. The formation has a varying thickness ranging from approximately 40 m under west-central Lake Erie to approximately 12 m over the Algonquin Arch to approximately 36 m in the Owen Sound area. Drill results from the Bruce Nuclear site indicate a Cabot Head Formation thickness of 23.8 m (Raven et al. 2009), whereas the formation was 31.14 m in the subsurface at the Cyprus Lake drill hole 09OGS-DDH15 (Rowell and Brunton 2011).

Similar to the Queenston Formation noted above, the Cabot Head shales have a low load-bearing capacity and, therefore, are not a potential aggregate source. Vos (1969) and Guillet (1977) have indicated that this rock unit has the potential for the manufacture of expanded lightweight aggregate, and brick and tile. Brick testing results for the Cabot Head Formation near Cyprus Lake indicate that this formation can be used to manufacture brick (Rowell and Brunton 2011). The Cabot Head Formation crops out along Georgian Bay on the eastern shoreline of the Bruce Peninsula. Because of its location (overlain by the Niagara Escarpment Plan, and national and provincial parks) no areas have been selected for possible resource protection.

The Cabot Head Formation is disconformably overlain by the Dyer Bay Formation. In fact, when fairly regularly spaced drill holes are examined from Cabot Head southward to Owen Sound, the middle and lower parts of the Fossil Hill Formation and the underlying formations, including the Dyer Bay Formation, are missing. This erosional surface means that several million years of strata are missing (Brintnell et al. 2009). Stott and von Bitter (1999) noted similar observations southeast of the study area. The Dyer Bay Formation is described as a thin- to medium-bedded, fine- to medium-grained, blue-green to brown, fossiliferous, argillaceous dolostone with green-grey shaly partings (Armstrong and Carter 2010). Grainstone storm pulses and rip-ups from interbedded shale partings have also been observed. The formation has a low-diversity population of coral and brachiopod fossils, is extensively horizontally bioturbated and displays well-developed ripple marks (Brintnell et al. 2009). The Dyer Bay Formation can be up to 8 m thick. Only 4.59 m of the formation was intersected in the Cyprus Lake core (Rowell and Brunton 2011). Outcrops occur along Georgian Bay on the east side of the Bruce Peninsula, generally as far south as Owen Sound. This formation has limited aggregate potential and, for that reason, has not been selected for possible resource protection.

Disconformably overlying the Dyer Bay Formation is the Wingfield Formation. The contact with the Dyer Bay Formation is gradual to sharp as is the contact with the overlying St. Edmund Formation. The Wingfield Formation is described as being up to 15 m of grey to brown, fine- to medium-grained, argillaceous dolostone interbedded with olive green, noncalcareous, sparsely fossiliferous shale (Armstrong and Carter 2010). The formation crops out along Georgian Bay on the east side of the Bruce Peninsula and has been observed cropping out in the northern two-thirds of the Peninsula and northward onto Manitoulin Island. The type locality for the formation is just west of Rocky Bay, east of Cabot Head. The Cyprus Lake drill core intersected 10.74 m of Wingfield Formation (Rowell and Brunton 2011).

The Wingfield Formation is disconformably overlain by the St. Edmund Formation, the type locality for which is located just west of Rocky Bay, east of Cabot Head. The formation is also exposed south of Cabot Head at Boulder Bluff and along the eastern shore of the Bruce Peninsula near Dyer Bay and Cape Chin and, generally, has been mapped in the northern one-third of the Bruce Peninsula and northward onto Manitoulin Island. The formation is described as up to 25 m of tan to brown, medium to dark grey, thin- to medium-bedded, finely crystalline to microcrystalline dolostone (Armstrong and Carter 2010). Sparse green shaly partings and rip-up clasts have been observed. There is a thin green shale bed at the top of the St. Edmund Formation, which represents a sharp upper contact with the overlying Fossil Hill Formation. The Cyprus Lake drill core intersected 5.32 m of St. Edmund Formation (Rowell and Brunton 2011). Because of the lack of surface exposure, restrictive overlying land use designations and aggregate quality data, neither the Wingfield nor St. Edmund formations have been selected for possible resource protection.

The Fossil Hill Formation of the Clinton Group is a thin- to medium-bedded, brownish-grey, very fine- to coarse-crystalline, very fossiliferous dolostone (Armstrong and Carter 2010). Brintnell et al. (2009) have subdivided the formation into 3 parts: lower, middle and upper. The lower part is brachiopod rich, whereas the middle part of the formation is poorly fossiliferous lime mudstone to wackestone. This middle part resembles the St. Edmund or Mindemoya formations and has sometimes been referred to as the "False Mindemoya". The upper part of the formation is richly fossiliferous with brachiopod beds, corals and sponges. The formation is exposed along the Georgian Bay shoreline on the east side of the Bruce Peninsula. A complete sequence of the Fossil Hill Formation is exposed at Boulder Bluff south of Cabot Head. Other good exposures exist at Rocky Bay, Isthmus Bay, and north and south of Dyer's Bay (Armstrong and Dubord 1992).

The type locality for the Fossil Hill Formation is a roadcut on Highway 6 near New England Road on Manitoulin Island. The formation is approximately 33.5 m thick on Manitoulin Island and has been intersected in the subsurface on Fitzwilliam Island (AMEC plc 2010). The Cyprus Lake drill core intersected 10.71 m of Fossil Hill Formation (Rowell and Brunton 2011). Drill-hole data from the Bruce Nuclear site indicates that only 2.3 m of Fossil Hill Formation was intersected at that location (Raven et al. 2009). The formation often forms minor subordinate scarps along the face of the Niagara Escarpment and, therefore, is part of very restrictive land use policies. For this reason and the lack of good quality aggregate data, the Fossil Hill Formation has not been selected for possible resource protection. The overlying Rockway and Irondequoit formations do not crop out in the study area and, therefore, are not discussed further in this report. The Cyprus Lake drill core did intersect 1.00 m of Rockway Formation and 0.44 m of Irondequoit Formation (Rowell and Brunton 2011).

The brow and upper surface of the Niagara Escarpment is formed by the tough, erosion-resistant unsubdivided Amabel Formation (*see* Figures 3 and 4). The Amabel Formation generally consists of medium crystalline, fossiliferous, medium- to massive-bedded dolostone that is well suited for the production of road-building and construction aggregate. It has also been used for the production of high-performance concrete. The Amabel Formation is considered to be an aggregate resource of provincial significance for these products. The Ontario Geological Survey is in the midst of a multi-year project to revise the Silurian stratigraphic sequence of southwestern Ontario, to delineate all key water-bearing units or aquifers, and to define the hydrogeologic properties of the strata. An important component of the project will be a review of the Silurian stratigraphy including a refinement of the various formations (Brunton 2009; Brunton et al. 2010). The result of some of the early work from this project is the formal separation of the unsubdivided Amabel Formation into a series of formations (e.g., Gasport and Goat Island). For the purpose of this report, the term "Amabel Formation" continues to be used since the Amabel Formation is widely understood within the aggregate industry; however, the stratigraphic and lithologic description below reflect the work as suggested by Brunton (2009).

Therefore, unconformably overlying the Fossil Hill Formation in the study area is the Lions Head Member of the Gasport Formation (part of the unsubdivided Amabel Formation). The type section for this member is located along the Georgian Bay shore at Isthmus Bay, approximately 400 m north of the lighthouse at the village of Lions Head. This lower member has been described as light grey to grey-brown, fine crystalline, thin- to medium-bedded, sparsely fossiliferous dolostone with locally abundant chert nodules. Brunton (2009) indicates that the Lions Head Member is the carbonate equivalent of the Rochester Formation farther south in southern Ontario (Niagara Peninsula). Drilling at the Bruce Nuclear site intersected 4.4 m of Lions Head Member dolostone (Raven et al. 2009), whereas 11.46 m of this rock unit was intersected at Cyprus Lake (Rowell and Brunton 2011). The formation is also present in the subsurface at Fitzwilliam Island (AMEC plc 2010).

The overlying upper member (Gothic Hill) of the Gasport Formation (unsubdivided Amabel Formation) consists of thick- to massive-bedded, fine- to coarse-grained, blue-grey mottled, light grey to white to pinkish, porous, crinoidal dolostone, dolomitic limestone and crinoidal grainstone (Brunton 2009). One such crinoidal grainstone unit provides a sharp disconformable contact with the overlying Goat Island Formation. The Cyprus Lake drill core intersected 17.60 m of Gasport Formation (Rowell and Brunton 2011), whereas the Bruce Nuclear site drill holes intersected approximately 6.8 m of Gasport Formation.

Overlying the Gasport Formation is the Goat Island Formation (unsubdivided Amabel Formation). The general description of this formation, as provided by Armstrong and Carter (2010), is a dark to light grey brown, very fine- to fine-crystalline, thin- to medium-bedded, irregularly bedded, variably argillaceous dolostone with abundant chert or vugs filled with gypsum, calcite or fluorite. Brunton (2009) has proposed that the Goat Island Formation has 2 distinct members. The lower Niagara Falls Member is a finely crystalline, cross-laminated, brachiopod-bearing, crinoidal grainstone. The upper member, the Ancaster Member, is a chert-rich, finely crystalline, medium to ash grey, thin- to medium-bedded dolostone. The Goat Island Formation has an intersected thickness of 18.8 m at the Bruce Nuclear site (Raven et al. 2009) and a thickness of 13.35 m at Cyprus Lake (Rowell and Brunton 2011).

There has been a long-standing debate as to whether the Eramosa Member is the upper member of the underlying Amabel Formation (Bolton 1957) or the lower member of the overlying Guelph Formation (Armstrong and Carter 2010). Brunton (2009) has suggested that the Eramosa Member be elevated to formational status and, thus, has proposed the Eramosa Formation. Armstrong and Carter (2010) provide the following general description of the Eramosa: thin- to thick-bedded, tan to black, fine- to medium-crystalline, variably fossiliferous dolostone with microstylolitic, bituminous seams; and locally well laminated, argillaceous or cherty. Brunton (2009) has divided the Eramosa Formation into 3 members: Stone Road, Reformatory Quarry and Vinemount, based on fossil content, lithology and sedimentary structures. Regardless of the stratigraphic debate, the Eramosa has not been used extensively for the production of aggregate material, but has been extracted extensively in the study area for building, dimension, decorative and landscaping stone. There are currently 25 licenced quarries in Bruce County with only 3 extracting material for aggregate production; the remaining 22 quarries are producing building, dimension, decorative and landscaping stone from the Eramosa and upper portion of the unsubdivided Amabel Formation.

The Guelph Formation dolostone overlies the Amabel and Eramosa formations in the central, northern and western part of the Bruce Peninsula. The Guelph Formation is a well-laminated, tan to brown, fine- to medium-crystalline, saccharoidal dolostone (Armstrong and Carter 2010). There are a number of biohermal (reef) structures in the rock with a porous, coarser texture and numerous fossil fragments. There are a number of these reefal structures exposed in roadcuts along Highway 6. Biohermal ridges can cause up to 15 m of topographic relief (Kor and Cowell 1998). The Guelph Formation is generally acknowledged to have high chemical purity (Kelly 1996) and has been used for the production of cement, metallurgical flux, agricultural lime and chemical stone in the Guelph area. The Guelph Formation is locally soft and porous and may not be suitable for use as aggregate, particularly where the formation contains reefal material; however, the Guelph Formation can also be quite competent in other locations and is capable of meeting high-end aggregate specification. This formation is truly an enigma. At the Bruce Nuclear site, 4.1 m of Guelph Formation was intersected (Raven et al. 2009).

Overlying the Guelph Formation are the buff, fine crystalline dolostones and the greenish grey and reddish shales of the Upper Silurian Salina Formation (Group). Outcrops are restricted to the valleys of the South Saugeen River at Neustadt, the Saugeen River north of Walkerton and the Teeswater River south of Paisley. In this region, the Salina Formation (Group) has not been utilized for aggregate due to poor accessibility, a high shale content (Hewitt 1960), and poor physical properties. The Salina Formation (Group) was believed to have been formed due to uplift along the Algonquin Arch and reasonably rapid basin subsidence, drastically changing the depositional environment (Armstrong and Carter 2010). Repeated carbonate, evaporite and argillaceous sedimentation characterize the Salina Formation (Group) and the various rock units. For greater detail on these units, *see* Armstrong and Carter (2010). Salt extraction from the Salina Formation (Group) occurs in southwestern Ontario near Windsor and Goderich, as well as a number of salt brine wells. A significant thickness of 205.2 m of Salina Formation (Group) was intersected at the Bruce Nuclear site (Raven et al. 2009).

The Upper Silurian Bass Islands Formation conformably overlies the Salina Formation (Group). The lithology of the Bass Islands Formation strata consists of buff to brown, fine-grained dolostone in even, vertically jointed thin to medium beds (Armstrong and Carter 2010). Locally, thick beds up to 60 cm are present. The formation is relatively nonfossiliferous. Outcrops of the formation are limited to the Saugeen River valley, north and south of Walkerton; along the Teeswater River north of Pinkerton; and in a small stream east of Bradley. The Bass Islands Formation has not been utilized for aggregate in the study area; however, some strata have historical use for the manufacture of lime (Hewitt 1960). Field examination indicates that this unit may have some utility for aggregate production. A sample of Bass Islands Formation rock was submitted for standard aggregate testing: the results are discussed later in this report. The drill hole at the Bruce Nuclear site intersected 45.3 m of Bass Islands Formation (Raven et al. 2009). The Bass Islands Formation is roughly equivalent to the Bertie Formation located farther south (Johnson et al. 1992).

Overlying the Bass Islands Formation are the greenish-grey to grey-brownish, thin- to medium-bedded, fine- to medium-grained, fossiliferous, bioturbated, cherty limestones and dolostones of the Middle Devonian Bois Blanc Formation (Armstrong and Carter 2010). The unit is locally very fossiliferous containing rugose and tabulate corals, brachiopods and some amphipora. Perhaps most characteristic of this unit is the presence of abundant nodules and lenses of white weathered chert. In some local exposures, the chert can form up to 90% of the rock. The formation is between 3 and 50 m thick and is generally thicker toward the centre of the Michigan Basin (Johnson et al. 1992). At the Bruce Nuclear site, drill holes intersected approximately 49 m of the Bois Blanc Formation (Raven et al. 2009). Exposures of the formation are limited to 1 to 2 m sections along a tributary of the Saugeen River north of Walkerton, along the Teeswater River between Chepstow and Pinkerton, and along the Lake Huron shoreline south of Port Elgin. A good section of approximately 5.5 m occurs along the Teeswater River, immediately north of Cargill. Farther south of the study area, the formation has been quarried at Hagersville, Cayuga and Port Colborne for crushed stone suitable for base course. The high chert content of this unit makes it unsuitable for asphalt and concrete aggregate.

The youngest strata in the study area belong to the Middle Devonian Detroit River Group. The Detroit River Group comprises, in ascending order, the Sylvania, Amherstburg and Lucas formations. The Sylvania Formation, an orthoquartzitic sandstone, is restricted to the subsurface in the Windsor–Sarnia area (Uyeno, Telford and Sanford 1982) and will not be discussed further in this report.

The Amherstburg Formation is a Middle Devonian formation with the lower part of the formation quite possibly Lower Devonian in age (Armstrong and Carter 2010). The formation varies from 0 to 50 m thick and consists of tan to grey-brown to dark brown, fine- to coarse-grained, bituminous, bioclastic, fossiliferous, commonly cherty limestones and dolostones. Drill holes at the Bruce Nuclear site have intersected 44.6 m of Amherstburg Formation (Raven et al. 2009). Fossils that have been noted in the formation include rugose and tabulate corals, brachiopods, crinoids, cephalopods and trilobites. In the Teeswater–Formosa area of southern Bruce County, biohermal limestones and dolostones are considered to belong to the Amherstburg Formation (Uyeno, Telford and Sanford 1982). This biohermal facies, known as the Formosa Reef Limestone or Formosa reef facies, forms an oval-shaped outcrop about 9 km wide, extending southward from Chepstow to just northeast of Wingham. Most outcrops occur near the community of Formosa and the type section is located approximately 4 km north of the village. Historically, the main utility of the strata has been for the production of cement, metallurgical flux, agricultural lime and chemical stone (Hewitt 1960). Use of the stone for aggregate is less likely, due to the porous and sometimes soft nature of the rock (Hewitt 1960). Exposures of non-biohermal strata of the Amherstburg Formation were not observed in the study area.

Uyeno, Telford and Sanford (1982) indicate that the boundary between the Amherstburg and Lucas formations was observed in an excavation opened during construction of the Bruce Nuclear facility. Drill results at the Bruce Nuclear site intersected 10.4 m of Lucas Formation (Raven et al. 2009). Outcrops along the Lake Huron shoreline between Douglas Point and Kincardine, and along the Penetangore River southeast of Kincardine are considered to belong to the Lucas Formation. The formation consists of brownish-grey, brown and cream, thin- to thick-bedded, fine crystalline dolostone. Minor interbeds of limestone occur in association with small bioherms and brecciated beds (Armstrong and Carter 2010). Locally, the strata contain chert nodules, bituminous streaks and algal laminae. Anhydritic beds have also been observed and recorded within the formation. Rutka and Birchard (1993) and Birchard, Rutka and Brunton (2004) have proposed 4 depositional environments for the various lithologies noted within the Lucas Formation in the Michigan Basin. These include upper sabkha mud flat evaporate, lower sabkha mud flat evaporate, supratidal/ shallow intertidal and subtidal depositional environments.

Historically, the Lucas Formation has been used for a variety of chemical and metallurgical stone purposes, especially in the Ingersoll area of southern Ontario. Within the study area, historical usage of this unit includes lime production and aggregate for road construction. Current field investigations indicate that the strata may be suitable for a variety of aggregate products, although aggregate quality testing is required to confirm this. Access to the resource is restricted by physical, cultural and environmental constraints. Results of aggregate testing for the Lucas Formation are presented in Table 9. Table E and Figure 4 provide a stratigraphic summary for Bruce County indicating the thickness of the various formations across the county.

There are 11 abandoned quarries located in the study area (*see* Maps 2A and 2B; Table 5). In the past, these quarries provided some crushed stone aggregate, raw material for lime production, and building stone. The sites are now largely overgrown, are difficult to access or, in some cases, are filled with water.

Table E – Stratigraphic Summary, County of Bruce

Age	Formation	Outcrops in Study Area?	Thickness (m) in Northern Portion of Study Area (Bruce Peninsula)*	Thickness (m) in Southern Portion of Study Area (Bruce Nuclear Site)**
Devonian	Lucas	Yes	0	≈ 10.4
	Amherstburg	Yes	0	≈ 44.6
	Bois Blanc	Yes	0	≈ 49.0
Silurian	Bass Islands	Yes	0	≈ 45.3
	Salina	Yes	0	≈ 205.2
	Guelph	Yes	≈ 45.00	≈ 4.1
	Eramosa	Yes	≈ 31.00	NL
	Goat Island	Yes	≈ 13.35	≈ 18.8
	Gasport	Yes	≈ 17.6	≈ 6.8
	Fossil Hill	Yes	≈ 10.71	≈ 2.3
	St. Edmund	Yes	≈ 5.32	NL
	Wingfield	Yes	≈ 10.74	NL
	Dyer Bay	Yes	≈ 4.59	NL
	Cabot Head	Yes	≈ 31.14	≈ 23.8
	Manitoulin	Yes	≈ 1.22	≈ 12.9
Ordovician	Queenston	Yes	≈ 50.00	≈ 70.4

* Source: A variety of information sources (various drill hole locations).
**Source: AECOM Canada Limited and Itasca Consulting Canada Incorporated (2011)
NL = Formation may be present, but was not logged (NL) as part of the drill-core logging process.

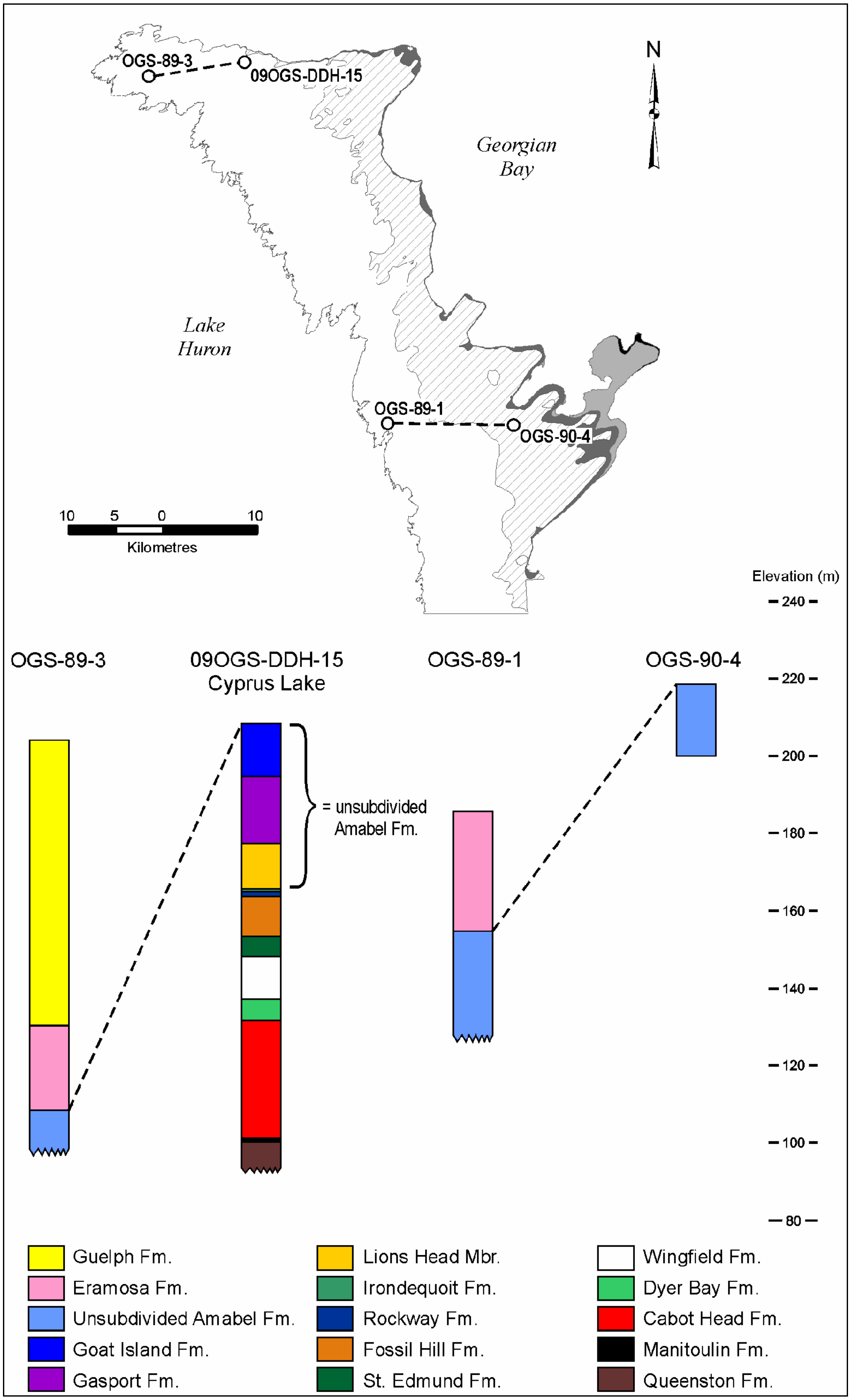

Figure 4. Stratigraphic cross sections along the Bruce Peninsula.

BEDROCK AGGREGATE QUALITY AND SUITABILITY

Aggregate quality test results for a Goat Island Formation (unsubdivided Amabel Formation) sample, collected as part of this study, is suitable for the production of Granular A, Granular B, SSM, HL and concrete (coarse aggregate) products (*see* Table 9). All test result values fall well within specification for most aggregate products. The unconfined freeze–thaw test result is a little high, but the sample was a weathered surface sample; perhaps a fresh, unweathered sample may have provided different results. The unsubdivided Amabel Formation has also been extracted along the Bruce Peninsula for the production of building stone.

As discussed in "Bedrock Geology and Resource Potential", the Guelph Formation continues to be an enigma. Petrographic Number values for the Guelph Formation vary from 100.0 to 193.4 for Granular and 16 mm crushed and from 100.0 to 240.6 for HL and concrete. Coarse aggregate magnesium sulphate soundness test results range from 1.0 to 6.0; Los Angeles abrasion test results vary from 23.60 to a high of 51.86. One sample had an absorption value of greater than 2.0% (2.046). Most of the samples tested would be suitable for the production of Granular A, Granular B, SSM, HL and concrete (coarse aggregate) products, but some of the results are well beyond acceptable limits (*see* Table 9).

One sample of Bass Islands Formation and a sample of Lucas Formation were also collected and tested as part of this study. The test results for the Bass Islands Formation sample would appear to indicate that the formation is suitable for the production of Granular A, Granular B and SSM products, but unsuitable for the production of HL and concrete products. The aggregate quality test results for the Lucas Formation sample indicates that the rock is unsuitable for aggregate production (*see* Table 9).

Other formations, such as the Queenston, Cabot Head and the Guelph formations, have not been identified for possible resource protection; however, they are important and valuable industrial mineral formations. The Queenston and Cabot Head formation shales are well suited for the manufacture of structural clay products such as brick and tile (Rowell 2009; Rowell and Brunton 2011), whereas the Guelph Formation dolostone, due to its high chemical purity, is a valuable raw material for chemical processes, metallurgical stone and the production of lime (Kelly 1996). Geochemical results for Amabel and Guelph formation samples, collected as part of this study, are provided in Table 11.

As noted in "Bedrock Geology and Resource Potential", the Eramosa Formation has been mined and extracted extensively for production of building, dimension, decorative and landscaping stone. Twenty-two (22) of the 25 licenced quarry operations are involved with this activity. Table F provides some of the physical test results of this formation. Armstrong and Meadows (1988) conservatively estimated the "marble unit" of the Eramosa to be approximately 3 m thick. The Eramosa Formation has not been a traditional aggregate-producing formation because the formation contains beds of silicified fossils and the presence of chert nodules and sulphide minerals (pyrite and sphalerite), often associated with vugs (Armstrong and Meadows 1988).

Table F – Physical Test Results on Building Stone, Eramosa Formation, County of Bruce

Compressive Strength (pounds per square inch (psi))						
Maximum	24 750	23 500	21 162	17 800	22 875	19 875
Minimum	19 750	14 750	18 555	17 425	15 225	17 250
Average*	22 833	18 016	19 721	17 612	18 483	18 958
Absorption	1.20	0.61	—	1.62	1.68	0.93
Bulk Specific Gravity	2.60	2.68	2.831	2.53	2.54	2.63
Abrasive Hardness	27.1	—	—	18.1	22.2	19.7

*Average is not simply maximum + minimum divided by 2, but is the average based on multiple test results.

Source: Based on Hewitt (1964).

SELECTED BEDROCK RESOURCE AREA

Areas with less than 8 m of overburden overlying the unsubdivided Amabel Formation (Goat Island and Gasport formations) have been chosen as a selected bedrock resource area.These areas occur in the eastern part of the Bruce Peninsula (former townships of St. Edmunds, Lindsay, Eastnor, Albemarle and Amabel). The Amabel Formation is a provincially significant aggregate resource and has been used to manufacture a wide variety of aggregate products including crushed granular, asphalt and concrete products, building stone and lime. The Selected Bedrock Resource Area occupies a total unlicenced area of 35 815 ha, which is reduced to 27 249 ha after considering physical, cultural and environmental constraints and assuming a conservative resource thickness of 15 m. This selected area would have an original resource tonnage of 10 828 million tonnes (*see* Table 6). This selected area will be further constrained by the presence of the overlying Niagara Escarpment Plan, where extractive development opportunities will be extremely limited.

SUMMARY

Thirteen (13) sand and gravel resource areas have been selected at the primary resource level in Bruce County. These selected resource areas have a total unlicenced area of 6009 ha with a possible resource area of 5352 ha after considering physical, cultural and environmental constraints. These resource areas have approximately 525 million tonnes of aggregate material.

Unfortunately, the deposits are not evenly distributed throughout the county and there appears to be a definite lack of good-quality, high-specification granular material along the Bruce Peninsula. The primary selected resource areas are concentrated in the southern part of the county and predominantly along the southeastern portion of the study area. It should be noted that the sand and gravel deposits of Bruce County are complex and, therefore, development of these resources will require drilling and extensive testing. Stone quality greatly limits the use of this granular material for many high-specification aggregate products (e.g., HL and concrete products).

There are a number of sand and gravel deposits that have been selected at the secondary level of significance. These deposits add greatly to the overall granular resources of Bruce County. Deposit thickness and, therefore, the quantity of granular material available, variability of the material, lower coarse aggregate content, concerns over the stone quality and the "dirtiness" of some of the deposits generally make these resource areas less attractive for development than the primary deposits. However, the deposits are still a valuable resource.

The unsubdivided Amabel Formation dolostone (Goat Island and Gasport formations) has been chosen as a selected bedrock resource area where it is overlain by less than 8 m of overburden. This rock unit is thick and consistent, and is recognized as a provincially significant aggregate resource capable of producing a wide range of granular, asphalt and concrete aggregate products. Twenty-two (22) of 25 licenced quarries in Bruce County have been developed to extract building, dimension, decorative and landscaping stone. These quarries are not "aggregate operations" in the true and traditional sense.

Enquiries regarding the "Aggregate Resources Inventory of the County of Bruce" should be directed to the Sedimentary Geoscience Section, Ontario Geological Survey, Mines and Minerals Division, Ministry of Northern Development and Mines, 933 Ramsey Lake Road, Sudbury, Ontario P3E 6B5 [Tel: (705) 670-5758]; or to the Owen Sound District Office, Ministry of Natural Resources, Owen Sound, Ontario [Tel: (519) 371-8470].

Table 1 – Total Identified Sand and Gravel Resources, County of Bruce			
1 **Class Number**	**2** **Deposit Type**	**3** **Areal Extent (Hectares)**	**4** **Original Tonnage (Million Tonnes)**
Municipality of Northern Bruce Peninsula (formerly St. Edmunds Tp., Lindsay Tp. and Eastnor Tp.)			
1	G-IC	30.23	3.2
2	G-IC-LB	713.88	56.9
	G-LB	17.26	1.4
	S-LP	278.37	22.2
	S-WD	64.11	5.1
3	G-LB	789.94	28.0
	S-AL	75.08	2.7
	S-LP	499.34	17.7
	S-WD	11.45	0.4
4	G-LB	673.76	11.9
	S-AL	64.74	1.1
	S-LB	1.37	0.0
	S-LP	627.13	11.1
Subtotal		**3846.66**	**161.6**
Town of South Bruce Peninsula (formerly Albemarle Tp. and Amabel Tp.)			
1	S-LB	224.24	23.8
	S-LP	5282.88	561.0
	S-WD	2207.12	234.4
2	G-IC	5.38	0.4
	G-LB	947.79	75.5
	S-LB	326.09	26.0
	S-LP	3665.60	292.0
	S-WD	110.90	8.8
3	G-IC	82.61	2.9
	G-LB	340.88	12.1
	G-OW	12.27	0.4
	S-AL	224.21	7.9
	S-LB	11.53	0.4
	S-LP	235.40	8.3
4	G-IC	18.01	0.3
	G-LB	258.44	4.6
	G-OW	39.49	0.7
	S-AL	118.75	2.1
	S-LB	8.52	0.2
	S-LP	664.05	11.8
Subtotal		**14 784.16**	**1273.6**

Table 1 – Total Identified Sand and Gravel Resources, County of Bruce			
1 Class Number	**2 Deposit Type**	**3 Areal Extent (Hectares)**	**4 Original Tonnage (Million Tonnes)**
Town of Saugeen Shores			
1	G-LB	617.50	65.6
	S-LP	4696.51	498.8
2	G-IC	7.42	0.6
	S-AL	1085.52	86.5
	S-LP	1069.03	85.1
3	G-AL	43.11	1.5
	G-IC	10.05	0.4
	G-LB	47.23	1.7
	S-AL	327.26	11.6
	S-LB	14.81	0.5
	S-LP	63.03	2.2
	S-OW	19.77	0.7
4	G-AL	60.46	1.1
	S-AL	123.10	2.2
	S-LB	63.74	1.1
	S-LP	2.56	0.0
	S-WD	98.91	1.8
Subtotal		**8350.01**	**761.3**
Municipality of Arran–Elderslie (formerly Arran Tp. and Elderslie Tp.)			
1	G-IC	182.85	19.4
	G-LB	15.50	1.6
	S-IC	197.66	21.0
	S-LP	2439.99	259.1
2	G-IC	521.36	41.5
	G-LB	113.58	9.0
	S-AL	1004.12	80.0
	S-IC	899.26	71.6
	S-LP	339.08	27.0
	S-OW	146.03	11.6
3	G-IC	690.16	24.4
	G-LB	128.74	4.6
	S-AL	168.54	6.0
	S-IC	686.59	24.3
	S-LP	102.47	3.6
	S-OW	35.84	1.3
4	G-AL	6.24	0.1
	G-IC	165.23	2.9
	G-LB	19.76	0.3
	S-AL	203.96	3.6
	S-IC	27.69	0.5
	S-LB	23.39	0.4
	S-OW	39.83	0.7
Subtotal		**8157.87**	**614.8**

Table 1 – Total Identified Sand and Gravel Resources, County of Bruce

1 Class Number	2 Deposit Type	3 Areal Extent (Hectares)	4 Original Tonnage (Million Tonnes)
Municipality of Kincardine (formerly Bruce Tp. and Kincardine Tp.)			
1	G-LB	7.25	0.8
	S-LP	172.49	18.3
2	G-IC	255.96	20.4
	G-LB	117.87	9.4
	G-OW	439.29	35.0
	S-AL	211.75	16.9
	S-IC-LB	34.06	2.7
	S-LB	671.68	53.5
	S-LP	685.74	54.6
3	G-AL	210.74	7.5
	G-IC	55.39	2.0
	G-LB	79.48	2.8
	G-OW	115.06	4.1
	S-AL	1324.74	46.9
	S-LB	135.92	4.8
	S-LP	156.77	5.5
	S-WD	29.87	1.1
4	G-AL	67.66	12.0
	G-LB	14.81	2.6
	G-OW	5.24	0.9
	S-AL	115.60	20.5
	S-IC	9.82	1.7
	S-LB	300.62	53.2
	S-LP	61.57	10.9
	S-OW	13.44	2.4
	S-WD	6.45	1.1
Subtotal		**5299.27**	**391.5**
Municipality of Brockton (formerly Greenock Tp. and Brant Tp.)			
1	G-IC	194.49	20.7
	S-LP	12095.45	1284.5
2	G-AL	277.81	22.1
	G-IC	1736.99	138.4
	G-OW	763.57	60.8
	S-AL	2015.27	160.5
	S-IC	1857.75	148.0
	S-LP	1244.99	99.2
	S-OW	1380.75	110.0
3	G-AL	197.97	7.0
	G-IC	506.82	17.9
	G-LB	12.06	0.4
	G-OW	373.90	13.2
	S-AL	803.75	28.5

Table 1 – Total Identified Sand and Gravel Resources, County of Bruce			
1 Class Number	**2 Deposit Type**	**3 Areal Extent (Hectares)**	**4 Original Tonnage (Million Tonnes)**
	S-IC	70.05	2.5
	S-LP	337.27	11.9
	S-OW	757.82	26.8
4	G-AL	204.75	3.6
	G-IC	71.54	1.3
	G-LB	8.39	0.1
	G-OW	89.68	1.6
	S-AL	41.69	0.7
	S-IC	105.48	1.9
	S-LP	23.04	0.4
	S-OW	101.19	1.8
Subtotal		**25 272.47**	**2163.9**
Township of Huron–Kinloss (formerly Huron Tp. and Kinloss Tp.)			
1	G-IC	917.39	97.4
	S-IC	3110.99	330.4
	S-LP	151.68	16.1
2	G-IC	634.07	50.5
	G-IC-LB	80.38	6.4
	G-LB	202.99	16.2
	G-OW	562.16	44.8
	S-AL	781.05	62.2
	S-IC	315.35	25.1
	S-LB	1672.13	133.2
	S-LP	717.80	57.2
	S-OW	1284.45	102.3
3	G-AL	80.19	2.8
	G-IC	341.60	12.1
	G-LB	54.48	1.9
	G-OW	270.86	9.6
	S-AL	1303.00	46.1
	S-IC	56.61	2.0
	S-LP	216.41	7.7
	S-OW	376.84	13.3
	S-WD	9.09	0.3
	G-AL	95.52	1.7
	G-IC	64.50	1.1
	G-LB	14.43	0.3
	G-OW	17.33	0.3
	S-AL	15.22	0.3
	S-IC	4.83	0.1
	S-LP	10.99	0.2
	S-OW	26.51	0.5
Subtotal		**13 388.85**	**1042.1**

Table 1 – Total Identified Sand and Gravel Resources, County of Bruce			
1 Class Number	**2 Deposit Type**	**3 Areal Extent (Hectares)**	**4 Original Tonnage (Million Tonnes)**
Municipality of South Bruce (formerly Culross Tp. and Carrick Tp.)			
1	S-IC	3478.29	369.4
	S-LP	712.26	75.6
2	G-IC	2578.29	205.4
	G-OW	3128.53	249.2
	S-AL	1330.39	106.0
	S-IC	3616.13	288.0
	S-LP	1600.32	127.5
	S-OW	4994.70	397.8
3	G-AL	17.92	0.6
	G-IC	830.77	29.4
	G-OW	1529.49	54.1
	S-AL	1019.84	36.1
	S-IC	30.59	1.1
	S-LP	719.86	25.5
	S-OW	1296.87	45.9
4	G-AL	7.07	0.1
	G-IC	101.44	1.8
	G-OW	50.09	0.9
	S-AL	20.63	0.4
	S-IC	17.96	0.3
	S-LP	28.06	0.5
	S-OW	109.75	1.9
Subtotal		**27 219.25**	**2017.6**
TOTAL		**106 318.54**	**8426.4**

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", <35% gravel (gravel-size (>4.75 mm) aggregate).

Letters after hyphen denote the geologic deposit type (*see also* Appendix C):
AL = alluvium; IC = ice-contact stratified drift, includes esker (E) and kame (K) deposits; ICT = ice-contact terrace; LB = glaciolacustrine beach deposit; LP = glaciolacustrine plain; OW = outwash; WD = windblown deposit.

Table 2 – Sand and Gravel Pits, County of Bruce					
Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Municipality of Northern Bruce Peninsula (formerly St. Edmunds Tp., Lindsay Tp. and Eastnor Tp.)					
Licenced					
1	Randy Munn	4.00	~5 - 6.5	~40 - 60	Pit has been developed in an ice-contact deposit that has been re-worked by glaciolacustrine shoreline processes (beach). The part of the licence on the south side of the road has been rehabilitated and the licence surrendered
2	Mike Robins	11.30	~5 - 6.5	~45 - 65	Pit has been developed in an ice-contact deposit that has been re-worked by glaciolacustrine shoreline processes (beach)
3	Mike Robins	12.30	~5 - 6.5	~45 - 65	Pit has been developed in an ice-contact deposit that has been re-worked by glaciolacustrine shoreline processes (beach)
4	Mike Robins	13.30	Variable, up to 5.5 m	~40 - 60	Pit has been developed in an ice-contact deposit that has been re-worked by glaciolacustrine shoreline processes (beach)
5	Municipality of Northern Bruce Peninsula	12.40	~4.5 - 6	~40 - 60	Pit has been developed in an ice-contact deposit that has been re-worked by glaciolacustrine shoreline processes (beach)
6	Wesley Alexander and Cory Adam Rydall	9.50	Variable, up to 6.5 m	~45 - 65	Pit has been developed in an ice-contact deposit that has been re-worked by glaciolacustrine shoreline processes (beach)
7	Wesley Alexander Rydall	1.52	Variable, up to 6.5 m	~45 - 65	Pit has been developed in an ice-contact deposit that has been re-worked by glaciolacustrine shoreline processes (beach)
8	Brent Robins Contracting	4.40	~1 - 1.5	~25 - 45	Pit has been developed in a small beach deposit. Bedrock was observed in pit floor
9	Harold Forbes	21.70	Variable, up to 3.5 m	~30 - 50	Pit has been developed in an ice-contact deposit (possibly a subaqueous fan) that has been re-worked by glaciolacustrine shoreline processes (beach deposit)
10	Harold Forbes	38.90	Variable, up to 3.5 m	~30 - 50	Pit has been developed in an ice-contact deposit (possibly a subaqueous fan) that has been re-worked by glaciolacustrine shoreline processes (beach deposit)
11	Marlene Hiltz	36.40	Variable, up to 5.5 m	~30 - 50	Pit has been developed in an ice-contact deposit (possibly a subaqueous fan) that has been re-worked by glaciolacustrine shoreline processes (beach deposit)
12	Hunter Haulage and Excavating Inc.	5.79	~4 - 5.5	~30 - 50	Pit has been developed in an ice-contact deposit (possibly a subaqueous fan) that has been re-worked by glaciolacustrine shoreline processes (beach deposit)
13	Alton Hunter	3.80	~4 - 5.5	~30 - 50	Pit has been developed in an ice-contact deposit (possibly a subaqueous fan) that has been re-worked by glaciolacustrine shoreline processes (beach deposit)
14	Harold Forbes	21.90	~4 - 5.5	~30 - 50	Pit has been developed in an ice-contact deposit (possibly a subaqueous fan) that has been re-worked by glaciolacustrine shoreline processes (beach deposit)
15	Harold Forbes	8.00	-	-	Pit has been developed in a beach deposit. Pit looks like it is in the final stage of complete rehabilitation
Unlicenced					
16	-	-	~1.5 - 2.5	~40 - 60	Pit has been developed in an ice-contact–subaqueous fan deposit. Building in pit area
17	-	-	~2.5 - 3	<5	Small pit. Predominantly a source of sand
18	-	-	Variable	~20 - 35	Pit has been developed in a small beach deposit
19	-	-	~5 - 6	<10	Predominantly a source of sand
20	-	-	-	-	Pit was developed in a beach deposit. It has been rehabilitated and the southern part is now a parking lot
21	-	-	~1	~30 - 50	Pit has been developed in a small beach deposit. Material is generally depleted
22	-	-	Variable	Variable	Pit has been developed in an ice-contact deposit (possibly a subaqueous fan) that has been re-worked by glaciolacustrine shoreline processes (beach deposit)

Table 2 – Sand and Gravel Pits, County of Bruce					
Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
23	-	-	~1	<15	Pit has been developed in a small beach deposit. Bedrock was observed in the pit floor
24	-	-	~3	Variable	Pit has been developed in a small beach deposit. Water in pit floor. The old pit to the south is now the landfill site
25	-	-	~1 - 1.5	<10	Predominantly a source of sand
26	-	-	~1.5 - 2.5	<10	Predominantly a source of sand
Town of South Bruce Peninsula (formerly Albemarle Tp. and Amabel Tp.)					
Licenced					
27	Elizabeth Reynolds	9.59	Variable, up to 14 m	<5	Pit has been developed in an eolian dune (windblown) deposit. Predominantly a source of fine sand
28	Mervyn and Kenneth Waugh	26.30	Variable	Variable	Pit has been developed in a small beach and small outwash deposit
29	1590361 Ontario Inc.	2.06	-	-	Licenced as both a pit and quarry - predominantly a quarry operation
30	Ken Clemens	9.78	~15	<5	Pit has been developed in an eolian dune (windblown) deposit. Predominantly a source of fine sand
31	914990 Ontario Inc. c/o Davis Contracting	12.10	~5 - 7	<5	Pit has been developed in an eolian dune (windblown) deposit. Predominantly a source of fine sand
32	Tom MacDonald	5.92	Variable	<5	Pit has been developed in an eolian dune (windblown) deposit. Predominantly a source of fine sand
33	Winetta R. Beirnes	33.60	Variable, up to 4 m	~35 - 50	Pit has been developed in a beach deposit. Water in the pit floor in some areas of the licenced area
34	Margaret Miller	6.00	~2.5 - 3.5	~35 - 50	Pit has been developed in a beach deposit
35	2200035 Ontario Inc.	35.34	Variable	~35 - 50	Pit has been developed in a beach deposit. Much of the material has been removed. Bedrock has been exposed in the pit floor
36	Ed Ruth	16.20	~2.5 - 3	~35 - 50	Pit has been developed in a beach deposit
37	Earl Beirnes	14.33	Variable, up to 4.5 m	~35 - 50	Pit has been developed in a beach deposit
38	Ross Trask	8.20	~2.5 - 3.5	~25 - 40	Pit has been developed in a beach deposit
39	2136464 Ontario Inc.	15.26	~2.5 - 3.5	~25 - 40	Pit has been developed in a beach deposit
40	E. C. King Contracting	21.80	~3 - 4.5	~25 - 40	Pit has been developed in a beach deposit
41	Ross Trask	11.85	~3 - 5.5	~25 - 40	Pit has been developed in an ice-contact deposit
42	Wayne Davidson	32.30	~5.5 - 7	Variable	Till
43	Ron Nickason	6.00	~2.5 - 3.5	Variable	Pit has been developed in an ice-contact deposit
44	Lincoln Park Holdings Inc.	19.20	~2.5 - 4.5	~25 - 50	Pit has been developed in an ice-contact esker deposit
45	Ron Nickason	15.00	~2.5 - 4	~25 - 50	Pit has been developed in an ice-contact esker deposit
46	Frank Zevenbergen	6.00	~2.5 - 4	~35 - 50	Pit has been developed in an ice-contact deposit
Unlicenced					
47	-	-	~6.5 - 7	-	Pit developed in till material
48	-	-	Variable	<5	Pit has been developed in eolian (windblown) fine sand deposit. May be part of licenced property
49	-	-	Variable	Variable	Old pit was developed in a small beach deposit. Part of pit looks to be rehabilitated; however, some of the pit is still noticeable
50	-	-	~1 - 2	-	A couple of small pits developed in till material (drumlin)
51	-	-	-	-	A small pit located in a drumlin (till material). Pit is still noticeable
52	-	-	Variable	-	Looks like rehabilitation has taken place but pit is still noticeable. Till material

Table 2 – Sand and Gravel Pits, County of Bruce

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
53	-	-	1	<5	Predominantly a source of sand
54	-	-	~1 - 1.5	Variable	Pit has been developed in a small beach deposit.
55	-	-	~2 - 2.5	~20 - 35	Pit has been developed in a small beach deposit
56	-	-	~1 - 1.5	~25 - 40	Badly overgrown pit has been developed in a small beach deposit
57	-	-	~1 - 2.5	<5	Predominantly a source of sand. Water in pit floor
58	-	-	~1.5 - 2.5	<10	Predominantly a source of sand. Pit located near buildings
59	-	-	1	<5	Pit has been developed in glaciolacustrine deposit
60	-	-	Variable	<5	Pit has been developed in glaciolacustrine deposit
61	-	-	~2 - 3	~25 - 40	Overgrown pit developed in beach deposit. Water in pit floor
62	-	-	-	-	Pit has been rehabilitated; however, it is still noticeable. Water in pit floor (ponds)
63	-	-	1	~20 - 30	Pit is located just east of licenced property
64	-	-	~2.5 - 3.5	~25 - 40	Pit has been developed in beach deposit
65	-				
66	-	-	~2 - 3	~25 - 40	Pit has been developed in a beach deposit.
67	-	-	~2 - 3	~25 - 40	Pit has been developed in a beach deposit
68	-	-	Variable	~25 - 40	Pit has been developed in a beach deposit
69	-	-	~2.5 - 3.5	Variable	Small, old pit has been developed in an ice-contact deposit (till present)
70	-	-	~2 - 3	Variable	Till
71	-	-	~1 - 2.5	Variable	Till
72	-				
Town of Saugeen Shores					
Licenced					
73	Keith Snyder Construction Limited	39.85	~2.5 - 4	Variable, ~35 - 50	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
74	Doug Welsh Construction Limited	27.60	~2.5 - 4	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
75	T.A. Stewart and Son Contracting Limited	18.20	~2.5 - 4	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
76	Donegan's Haulage Limited	32.20	~2.5 - 4.5	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
77	Corporation of the Town of Saugeen Shores	10.70	~2.5 - 4.5	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
78	Doug Welsh Construction Limited	21.60	~2.5 - 4.5	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
79	E. C. King Contracting	38.75	~7 - 9.5	Variable, ~35 - 50	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
80	Corporation of the Town of Saugeen Shores	7.96	~7 - 9.5	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
81	HSC Aggregates Limited	56.83	~7 - 9.5	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
82	The Warren Paving & Materials Group Limited	24.80	~5 - 7	Variable, ~35 - 50	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
83	Norman Campbell Construction Limited	40.40	~3 - 6	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
84	Norman Campbell Construction Limited	22.50	~3 - 6	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex

Table 2 – Sand and Gravel Pits, County of Bruce

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
85	Keith Snyder	6.90	~1 - 2	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
86	Keith Snyder	23.60	Variable, up to 6 m	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex
87	Mark Porter	18.20	Variable, up to 9.5 m	~20 - 35	Subaqueous fan deposit covered by till overburden
Unlicenced					
88	-	-	Variable, up to 3.5 m	Variable	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex. Material is quite variable
89	-	-	~1 - 1.5	-	Old pit; just noticeable. Rehabilitated
90	-	-	~5 - 7	Variable, ~25 - 40	Pit has been developed in a glacial Lake Algonquin beach (bar-spit) complex. Pit outside of licenced area
91	-	-	~.5 - 1	~20 - 35	Old, unlicenced pit. Very small. Water in pit floor. Small beach deposit.
Municipality of Arran–Elderslie (formerly Arran Tp. and Elderslie Tp.)					
Licenced					
92	Ed Horner	28.72	Variable, up to 8 m	Variable, ~35 - 50	Pit has been developed in an ice-contact deposit
93	Bessie Robinson	20.23	Variable, up to 4 m	Variable, ~35 - 50	Pit appears to be inactive
94	E. C. King Contracting	20.15	Variable, up to 6.5 m	Variable, ~35 - 50	Some pit faces have been rehabilitated
95	Rick Vansligtenhorst	4.00	Variable	~25 - 40	Pit has been developed in an ice-contact deposit
96	E. C. King Contracting	4.05	Variable, up to 5.5 m	~15 - 20	Predominantly a source of sand
97	Forbes Sand and Gravel Ltd.	31.00	~2.5 - 4	~40 - 55	Pit has been developed in an ice-contact deposit
98	John Gowan	25.00	Variable, up to 7 m	~15 - 30	Pit has been developed in an ice-contact deposit
99	Jessie Essington Hahn	16.70	~3.5 - 5.5	~35 - 50	Pit developed in ice-contact and glacial Lake Warren beach deposits
100	Ed Karcher	20.20	Variable, up to 7 m	~30 - 50	Pit developed in ice-contact and glacial Lake Warren beach deposits
101	Ron Gibbons	20.23	Variable, up to 7 m	~30 - 50	Pit developed in ice-contact and glacial Lake Warren beach deposits
102	Ed Karcher	39.90	Variable, up to 7 m	~30 - 50	Pit developed in ice-contact and glacial Lake Warren beach deposits
103	Ronald Gibbons	36.90	Variable, up to 7 m	~30 - 50	Pit developed in ice-contact and glacial Lake Warren beach deposits
104	Cummins Farms Limited	27.80	Variable, up to 5.5 m	~30 - 40	Pit has been developed in an ice-contact deposit
105	Paisley Brick and Tile Company Limited	2.80	-	-	Pit is licenced under *Aggregate Resources Act*, but is actually an industrial mineral deposit (brick manufacturing)
106	Bannerman Contracting Limited	18.80	Variable, up to 6.5 m	~25 - 30	Pit has been developed in an ice-contact deposit
107	Bev Nicoll	4.43	~1.5 - 2.5	~25	Small beach deposit
108	Municipality of Arran–Elderslie	24.80	Variable, up to 9.5 m	~30 - 45	Pit has been developed in an ice-contact deposit
Unlicenced					
109	-	-	~2.5 - 4	~35 - 55	Pit was developed in a small ice-contact deposit on southeast side of drumlin.
110	-	-	~2.5 - 3.5	~25 - 40	Pit was developed in a small ice-contact deposit. Pit is just noticeable now

Table 2 – Sand and Gravel Pits, County of Bruce

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
111	-	-	~1- 2	~40 - 55	Pit has been rehabilitated. Pit face is just noticeable along tree line
112	-	-	~1 - 2	Variable	Small pit is just noticeable. Pit was developed in till material
113	-	-	~1.5 - 2.5	~25 - 40	Small pit is just noticeable. Pit was developed in ice-contact deposit
114	-	-	~1.5 - 2.0	~25 - 40	Small pit is just noticeable. Pit was developed in till material
115	-	-	Variable	~30 - 50	Pit appears to lie outside the licenced area. Appears as though it is in the process of being rehabilitated
116	-	-	-	~30 - 50	Pit has been rehabilitated
117	-	-	-	~30 - 50	Pit has been rehabilitated
118	-				
119	-	-	~1.5 - 2.5	~20 - 30	Small pit is just noticeable. Pit was developed in ice-contact deposit
120	-	-	~1 - 2	~15 - 25	A couple of small pits located in a small esker ridge
121	-	-	~1.5 - 2.5	~20 - 30	Small pit is just noticeable. Pit was developed in ice-contact deposit
122	-	-	~1 - 2	Variable	Small, overgrown pit/rehabilitated. Just noticeable. Pit was developed in till material.
123	-	-	~3.5 - 5	~25 - 40	Pit face is just behind shed. Pit has been developed in ice-contact deposit
124	-	-	~1 - 2	~25 - 40	Small pit remains. Pit has been developed in ice-contact deposit
125	-	-	~2 - 4	-	Small abandoned pit
126	-	-	~2.5 - 3.5	-	Small, abandoned pit in ice-contact deposit
127	-	-	~2.5 - 4.5	-	Small, abandoned pit - most of pit has been rehabilitated - small face left
128	-	-	~2.5 - 4	-	Small, abandoned pit located in till
129	-	-	~2.0 - 3.0	-	Small, abandoned pit
130	-	-	~2.5 - 3.5	-	Small, abandoned pit
131	-	-	~3.5 - 5	-	Small, abandoned pit in ice-contact deposit
132	-	-	~1.5 - 2.5	-	Small, abandoned pit - partially rehabilitated
133	-	-	-	-	Small, abandoned pit located in beach deposit
Municipality of Kincardine (formerly Bruce Tp. and Kincardine Tp.)					
Licenced					
134	Norman Campbell Construction Limited	23.00	Variable, up to 9 m	Variable, ~25 - 40	Pit has been developed in ice-contact deposit with the top of the deposit modified by beach processes
135	Norman Campbell Construction Limited	5.20	Variable, up to 9 m	Variable, ~25 - 40	Pit has been developed in ice-contact deposit with the top of the deposit modified by beach processes
136	Larry Kozak	8.39	~2.5 - 4	~35 - 45	Ice-contact deposit buried beneath approximately 1-1.5 m of clay
137	Bannerman Contracting Ltd.	29.00	Variable, up to 9 m	Variable, ~25 - 40	Ice-contact deposit buried beneath substantial overburden cover
138	Jackson Aggregates Inc.	27.68	Variable, up to 9 m	Variable, ~25 - 40	Ice-contact deposit buried beneath substantial overburden cover
139	Norman Campbell Construction Limited	19.80	~1.5 - 3.5	~35 - 45	Pit has been developed in outwash deposit
140	Norman Campbell Construction Limited	40.40	~2.5 - 4	Variable, ~35 - 55	Pit has been developed in ice-contact deposit
141	Patricia Gras	40.47	~3.5 - 6.5	Variable, ~35 - 55	Pit has been developed in ice-contact deposit

Table 2 – Sand and Gravel Pits, County of Bruce

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
142	Ken Jackson Construction Limited	4.20	~8 - 10	Variable, ~20 - 35	Pit has been developed in small beach ridge
143	Wilbur Campbell	2.80	~6 - 9	Variable, ~5 - 20	Pit developed in ice-contact deposit
Unlicenced					
144	-	-	Variable	~20 - 30	Old, overgrown, unlicenced pits. Old pits were developed in ice-contact–outwash complex
145	-	-	~1.5 - 2.5	~25 - 40	Old, overgrown, unlicenced pits. Old pits were developed in ice-contact–outwash complex
146	-	-	~1 - 1.5	~20 - 30	Two, old, overgrown, unlicenced pits just north of road. Both are essentially naturally rehabilitated
147	-	-	Variable	~20 - 30	Old pit has been generally flattened - just a few old mounds remain
148	-	-	Variable, up to 9 m	Variable, ~25 - 40	Ice-contact deposit buried beneath substantial overburden cover
149	-	-	~3.5 - 5	~25 - 40	Old, overgrown pit has been developed in ice-contact deposit
150	-	-	~2.5 - 3.5	~25 - 40	Old, overgrown pit has been developed in ice-contact deposit
151	-	-	-	Variable, ~25 - 40	Pit has been rehabilitated. There is now a small pond
152	-	-	-	Variable, ~25 - 40	Pit has been rehabilitated. There is now a small pond
153	-	-	Variable	Variable, ~25 - 40	Looks like pit is in the process of being rehabilitated. Fill material is being brought in as part of rehabilitation
154	-	-	-	<3	Old, overgrown pit. Predominantly a source of sand.
Municipality of Brockton (formerly Greenock Tp. and Brant Tp.)					
Licenced					
155	Robert Foreman & Reta McKeeman	60.70	Variable, up to 6 m	~35 - 55	Pit has been developed in an ice-contact deposit
156	Bester Forest Products Limited	4.00	Variable, up to 5 m	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
157	Norman Campbell Construction Limited	7.56	~9 - 11	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
158	Harry and Jeannette A. Donegan	14.93	~2.5 - 3.5	Variable, ~30 - 50	Pit has been developed in an ice-contact deposit
159	Bester Forest Products Limited	49.00	~2.5 - 4.5	Variable, ~30 - 50	Pit has been developed in an ice-contact deposit
160	Lorne Bester and Sons Lumber Inc.	20.60	~3 - 5	~35 - 50	Pit has been developed in an ice-contact deposit
161	Lanydone Farms Ltd.	11.87	-	-	
162	Municipality of Brockton	36.00	Variable, up to 11 m	~40 - 60	Pit has been developed in an ice-contact esker–outwash deposit complex
163	Myron Messerschmidt	28.70	Variable	Variable, ~30 - 50	Pit has been developed in an ice-contact esker–outwash deposit complex
Unlicenced					
164	-	-	~1.5 - 2	Variable, ~35 - 55	Small, badly overgrown pit developed in an ice-contact deposit
165	-	-	~1.5 - 2.5	~20 - 30	Small pit developed in an outwash deposit near the property tree line
166	-	-	Variable	Variable	Pit has been developed in a small ice-contact deposit. Water in pit floor
167	-	-	~4 - 5	Variable, ~35 - 55	Pit has been developed in an ice-contact esker deposit

Table 2 – Sand and Gravel Pits, County of Bruce					
Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
168	-	-	~1.5 - 3	Variable, ~35 - 55	Pit has been developed in an ice-contact esker deposit
169	-	-	~3 - 4	~30 - 40	Old, overgrown pit developed in an ice-contact deposit
170	-	-	~3.5 - 4.5	~30 - 40	Old, overgrown pit developed in an ice-contact deposit
171	-	-	~2 - 3	~30 - 40	Old, overgrown pit developed in an ice-contact deposit
172	-	-	~2 - 3	~30 - 40	Old, overgrown pit developed in an ice-contact deposit
173	-	-	~5 - 7	<10	Old pit has been developed in an ice-contact deposit in behind house. Predominantly a source of sand
174	-	-	~4 - 6	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
175	-	-	~5 - 7	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit in behind buildings.
176	-	-	~4 - 5	~20 - 35	Old, overgrown pit has been developed in an outwash deposit
177	-	-	~2.5 - 4	~30 - 40	Pit has been developed in an ice-contact deposit
178	-	-	~9 - 11	Variable, ~30 - 50	Pit has been developed in an ice-contact deposit. Building in pit floor
179	-	-	~1 - 1.5	<5	Small pit located immediately beside road. Glaciolacustrine deposit. Predominantly a source of sand
180	-	-	~3 - 4.5	~25 - 40	Small, badly overgrown pit that is still noticeable. Developed in a small ice-contact deposit
181	-	-	~6.5 - 8	<5	Small pit developed in an alluvial deposit
182	-	-	Variable	~25 - 35	Small pit developed in an alluvial deposit
183	-	-	Variable	~15 - 25	Old, overgrown pit developed in an outwash deposit. Material removed to underlying till
184	-	-	Variable	Variable	Old, overgrown pit developed in an outwash deposit
185	-	-	Variable	~25 - 35	Old, overgrown pit developed in a shallow ice-contact deposit
186	-	-	Variable	Variable, up to 40%	Old pit has been developed in an ice-contact deposit
187	-	-	~1 - 2.5	~25 - 40	Small, overgrown pit developed in an outwash deposit
188	-	-	~2 - 3	~30 - 45	Small, overgrown, partially rehabilitated pit developed in an outwash deposit
189	-	-	~1 - 1.5	<5	Small pit developed in a glaciolacustrine deposit
Township of Huron–Kinloss (formerly Huron Tp. and Kinloss Tp.)					
Licenced					
190	Donald G. Emmerton	6.22	Variable	Variable, ~25 - 45	Pit has been developed in a beach deposit. Water in pit floor. Dredging operation
191	MacTavish Pits Limited	43.00	Variable, up to 10 m	Variable, ~20 - 60	Pit has been developed in an ice-contact deposit
192	Bannerman Contracting Limited	40.40	Variable, up to 11 m	Variable	Pit has been developed in an ice-contact deposit
193	Erlma J. Haldenby	17.00	Variable, up to 7.5 m	Variable	Pit has been developed in an ice-contact deposit
194	Bannerman Contracting Ltd.	41.00	Variable, up to 7.5 m	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
195	Township of Huron–Kinloss	56.00	Variable, up to 7.5 m	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
196	J. A. Porter Holdings (Lucknow) Ltd.	11.66	~4 - 6	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
197	Agnes Brindley	37.80	~3 - 4.5	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit

Table 2 – Sand and Gravel Pits, County of Bruce					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
198	Bill & Tom Kempton Construction Ltd.	82.22	Variable	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
199	Joe Kerr Limited	20.00	~4 - 6	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
200	J. A. Porter Holdings (Lucknow) Ltd.	37.40	~4 - 6	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
201	J. A. Porter Holdings (Lucknow) Ltd.	27.60	~4 - 6	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
202	South Kinloss Acres	40.50	~4 - 6	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
203	Open Valley Farms Incorporated (c/o Daniel Patrick Nott)	8.70	~4 - 6	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
Unlicenced					
204	-	-	-	Variable, ~25 - 45	Completely rehabilitated. Now a park and baseball diamond
205	-	-	~3.5 - 5	Variable, ~35 - 55	Pit is badly overgrown. Slopes are grassed and trees are reasonably mature. Pit is still noticeable and warning signs are posted
206	-	-	~2.5 - 3.5	~20 - 30	Old, overgrown pit in an outwash deposit
207	-	-	~3.5 - 6	~15 - 20	Small ice-contact deposit. Predominantly a source of sand
208	-	-	~2.5 - 3.5	~15 - 20	Small, overgrown pit developed in an outwash deposit
209	-	-	~1.5 - 2.5	~15 - 20	Small, overgrown pit developed in an outwash deposit
210	-	-	Variable	~20 - 30	Small, very badly overgrown pit developed in an outwash deposit
211	-	-	~1.5 - 3.5	~15 - 20	Pit has been developed in an ice-contact deposit
212	-	-	Variable, up to 7 m	~25 - 40	Pit has been developed in an ice-contact deposit
Municipality of South Bruce (formerly Culross Tp. and Carrick Tp.)					
Licenced					
213	Triax Inc.	112.00	Variable, up to 5 m	Variable, ~35 - 65	Pit has been developed in an outwash deposit
214	Evan Smyth	28.80	~2.5 - 3.5	Variable, ~25 - 40	Pit has been developed in an outwash deposit
215	Gregory McPherson	41.50	~3.5 - 5.5	Variable, ~35 - 60	Pit has been developed in an ice-contact–outwash deposit complex
216	Teeswater Concrete Limited	40.44	~3.5 - 5.5	Variable, ~35 - 55	Pit has been developed in an ice-contact–outwash deposit complex
217	Teeswater Concrete Limited	40.03	~3.5 - 5.5	Variable, ~35 - 55	Pit has been developed in an ice-contact–outwash deposit complex
218	Tony Lang Farms Limited	40.47	~3.5 - 5.5	Variable, ~40 - 60	Pit has been developed in an ice-contact–outwash deposit complex
219	Teeswater Concrete Limited	39.40	Variable, up to 6.5 m	Variable, ~35 - 55	Pit has been developed in an ice-contact–outwash deposit complex. Plant and garage area
220	Ken Maronets	40.50	Variable, up to 5 m	Variable, ~35 - 55	Pit has been developed in an outwash deposit
221	Brent Ireland	4.00	~6.5 - 8	Variable, ~30 - 50	Pit has been developed in an ice-contact deposit
222	Douglas Button	15.00	~2.5 - 4	Variable, ~30 - 50	Pit has been developed in an outwash deposit
223	Adrian Rehorst	17.97	~4 - 6	Variable, ~35 - 55	Pit has been developed in an outwash deposit

Table 2 – Sand and Gravel Pits, County of Bruce

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
224	Municipality of South Bruce	40.00	~4 - 6	Variable, ~35 - 60	Pit has been developed in an outwash deposit
225	Municipality of South Bruce	34.40	~4 - 6	Variable, ~35 - 60	Pit has been developed in an outwash deposit
226	Wesley Riley Contracting Company Limited	6.13	~2.5 - 5	Variable, ~30 - 50	Pit has been developed in an outwash deposit
227	Lorraine and Wesley Riley	15.10	~2.5 - 5	Variable, ~30 - 50	Pit has been developed in an outwash deposit
228	John and Joyce Farrell	15.10	~2 - 4	Variable	Pit may be partially rehabilitated. Developed in an ice-contact deposit
229	Russell Zettler	4.00	Variable, up to 10 m	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
230	Joseph Francis Poechman	48.20	Variable, up to 9.5 m	Variable, ~35 - 55	Pit has been developed in an ice-contact deposit
231	Al Reich	3.96	Variable, up to 8.5 m	Variable, ~30 - 50	Pit has been developed in an ice-contact deposit
232	Al Reich	8.20	Variable, up to 8.5 m	Variable, ~30 - 50	Pit has been developed in an ice-contact deposit
233	Bart Dirven	4.00	~3 - 6	Variable, ~30 - 50	Pit has been developed in an ice-contact deposit
234	1599942 Ontario Limited	25.20	Variable, up to 12 m	Variable, ~35 - 60	Pit has been developed in an ice-contact deposit
235	Winston and Madeline Riley	13.60	Variable, up to 8.5 m	Variable, ~35 - 60	Pit has been developed in ice-contact esker deposit
236	Erwin Haack	9.10	Variable, up to 8.5 m	Variable, ~35 - 60	Pit has been developed in ice-contact esker deposit
237	Tom Reinhart	8.60	Variable, up to 6.5 m	Variable, ~30 - 50	Pit has been developed in an ice-contact deposit
238	Lorne Bester and Sons Lumber Inc.	39.25	Variable, up to 8 m	Variable, ~40 - 60	Pit has been developed in an ice-contact deposit
239	Murray and Jane Lang-Mawhinney	8.60	Variable	Variable, ~40 - 60	Pit has been developed in an ice-contact deposit
240	Kevin M. Goetz	4.70	Variable	Variable, ~30 - 50	Pit has been developed in an ice-contact deposit
241	Thomas Detzler	13.65	Variable, ~3 - 6	Variable, ~35 - 60	Pit has been developed in an ice-contact deposit
242	Ron Harkness	18.12	~4.5 - 6	~35 - 55	Pit has been developed in an outwash deposit
Unlicenced					
243	-	-	~5	~30 - 40	Badly overgrown pit developed in ice-contact deposit
244	-	-	~2 - 3	~25 - 35	Badly overgrown pit developed in ice-contact deposit
245	-	-	~5	~25 - 35	Badly overgrown pit developed in ice-contact deposit
246	-	-	~2 - 3.5	~25 - 40	Pit has been developed in an ice-contact - outwash deposit complex
247	-	-	~3	~25 - 35	Pit has been developed in an outwash deposit
248	-	-	~2 - 3.5	~25 - 40	Pit has been developed in an ice-contact deposit
249	-	-	~2 - 3.5	<5	Pit has been developed in an outwash deposit. A source of sand only
250	-	-	~5.5 - 7	~25 - 40	Pit has been developed in an ice-contact deposit
251	-	-	~3 - 4	~25 - 40	Pit has been developed in an ice-contact deposit
252	-	-	Variable, up to 13 m	~10 - 20	Old, overgrown pit located north of the licenced property
253	-	-	~1.5 - 2.5	~25 - 40	Pit has been developed in an ice-contact deposit

Table 2 – Sand and Gravel Pits, County of Bruce

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
254	-	-	~2 - 3	~30 - 40	Pit has been developed in an ice-contact deposit
255	-	-	Variable, up to 8 m	~30 - 50	Pit has been developed in an ice-contact deposit
256	-	-	~4 - 4.5	~10 - 20	Predominantly a source of sand
257	-	-	~5 - 6	~35 - 40	Pit has been developed in an outwash deposit
258	-	-	~2 - 3	~25 - 35	Pit has been developed in an outwash deposit
259	-	-	~1 - 2	~10 - 20	Small pit has been developed in an outwash deposit along side of a drumlin
260	-	-	~7 - 8	~30 - 50	Pit has been developed in an ice-contact deposit
261	-	-	~7	Variable, ~20 - 45	Pit has been developed in ice-contact esker deposit
262	-	-	~7	Variable, ~20 - 45	Pit has been developed in ice-contact esker deposit
263	-	-	~7	Variable, ~20 - 45	Pit has been developed in ice-contact esker deposit
264	-	-	Variable	Variable, ~20 - 45	Badly overgrown pit that was excavated in an ice-contact esker deposit
265	-	-	Variable	Variable, ~20 - 45	Badly overgrown pit that was excavated in an ice-contact esker deposit
266	-	-	~3.5 - 4	-	Till
267	-	-	Variable	~35 - 50	Old, overgrown pit has been developed in ice-contact deposit
268	-	-	~6.5 - 8	~35 - 45	Old, overgrown pit has been developed in an outwash deposit
269	-	-	-	~35 - 50	Partially rehabilitated pit is still noticeable. Pit has been developed in an ice-contact deposit
270	-	-	Variable, up to 4 m	~35 - 50	Old, overgrown pit and perhaps partially rehabilitated, has been developed in ice-contact–outwash deposit complex
271	-	-	~4 - 4.5	~35 - 50	Old, partially rehabilitated pit has been developed in an ice-contact deposit
272	-	-	~2 - 4	~30 - 40	Pit is still noticeable. Developed in an ice-contact deposit
273	-	-	~4	~20 - 25	Pit has been developed in ice-contact deposit
274	-	-	~1.5 - 2	~20 - 25	Pit has been developed in ice-contact deposit
275	-	-	~1.5 - 2	~20 - 30	Pit is still noticeable. Developed in an ice-contact deposit
276	-	-	~4	~20 - 30	Pit has been partially rehabilitated. Developed in an ice-contact deposit
277	-	-	~2.5 - 4	~20 - 30	Badly overgrown, partially rehabilitated pit developed in an ice-contact deposit

Table 3 – Selected Sand and Gravel Resource Areas, County of Bruce

1 Deposit No.	2 Unlicenced Area* (Hectares)	3 Cultural Setbacks** (Hectares)	4 Extracted Area*** (Hectares)	5 Possible Resource Area (Hectares)	6 Estimated Deposit Thickness (Metres)	7 Possible Aggregate Resources**** (Million tonnes)
1	279.3	17.9	7.8	253.5	4.5	20.2
2	322.5	74.8	1.6	246.1	6	26.1
3	336.3	155.9	1.7	178.7	7.5	23.7
4	52.6	4.2	2.0	46.4	6	4.9
5	1006.8	113.9	7.6	885.3	5	78.3
6	1185.2	57.4	4.9	1122.9	6	119.3
7	711.7	53.7	0.0	658.1	5	58.2
8	529.1	34.6	0.0	494.5	5	43.8
9	242.3	21.1	0.0	221.2	5	19.6
10	126.4	12.0	0.0	114.4	7	14.2
11	833.6	40.3	4.8	788.4	6	83.7
12	89.7	16.8	0.0	72.9	7	9.0
13	293.9	24.3	0.0	269.6	5	23.9
TOTAL	**6009.2**	**626.8**	**30.4**	**5352.0**		**525.0**

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

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

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

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

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

Table 4 – Total Identified Bedrock Resources, County of Bruce				
1 Drift Thickness (Metres)	**2 Formation**	**3 Estimated Deposit Thickness (Metres)**	**4 Areal Extent (Hectares)**	**5 Original Tonnage (Million of Tonnes)**
Municipality of Northern Bruce Peninsula (formerly St. Edmunds Tp., Lindsay Tp. and Eastnor Tp.)				
<1	Queenston	15	5.52	2.0
<1	Clinton–Cataract Groups	15	1508.12	599.3
1-8	Clinton–Cataract Groups	15	65.13	25.9
8-15	Clinton–Cataract Groups	15	41.58	16.5
<1	Amabel	15	18 791.78	7466.9
1-8	Amabel	15	5415.62	2151.9
8-15	Amabel	15	1020.23	405.4
<1	Eramosa	15	464.75	184.7
1-8	Eramosa	15	12.56	5.0
<1	Guelph	15	46 657.00	18539.2
1-8	Guelph	15	2445.03	971.5
8-15	Guelph	15	11.12	4.4
Subtotal			**76 438.44**	**30372.6**
Town of South Bruce Peninsula (formerly Albemarle Tp. and Amabel Tp.)				
<1	Clinton–Cataract Groups	15	964.28	383.2
1-8	Clinton–Cataract Groups	15	91.41	36.3
8-15	Clinton–Cataract Groups	15	13.10	5.2
<1	Amabel	15	10 721.38	4260.1
1-8	Amabel	15	1302.16	517.4
8-15	Amabel	15	244.47	97.1
<1	Eramosa	15	3909.87	1553.6
1-8	Eramosa	15	5442.13	2162.4
8-15	Eramosa	15	778.81	309.5
<1	Guelph	15	8671.16	3445.5
1-8	Guelph	15	8363.87	3323.4
1-8	Guelph	15	2396.01	952.1
Subtotal			**42 898.65**	**17045.8**
Municipality of Arran–Elderslie (formerly Arran Tp. and Elderslie Tp.)				
<1	Guelph	15	11.93	4.7
1-8	Guelph	15	778.20	309.2
8-15	Guelph	15	2981.01	1184.5
1-8	Salina Formation (Group)	15	2.42	1.0
8-15	Salina Formation (Group)	15	4.95	2.0
Subtotal			**3778.51**	**1501.4**
Town of Saugeen Shores				
1-8	Salina Formation (Group)	15	18.79	7.5
8-15	Salina Formation (Group)	15	9.79	3.9
Subtotal			**28.58**	**11.4**

Table 4 – Total Identified Bedrock Resources, County of Bruce

1 Drift Thickness (Metres)	2 Formation	3 Estimated Deposit Thickness (Metres)	4 Areal Extent (Hectares)	5 Original Tonnage (Million of Tonnes)
Municipality of Kincardine (formerly Bruce Tp. and Kincardine Tp.)				
8-15	Amherstburg	15	18.95	7.5
<1	Lucas	15	7.59	3.0
1-8	Lucas	15	702.10	279.0
8-15	Lucas	15	592.74	235.5
Subtotal			**1321.38**	**525.1**
Township of Huron–Kinloss (formerly Huron Tp. and Kinloss Tp.)				
8-15	Lucas	15	289.51	115.0
Subtotal			**289.51**	**115.0**
Municipality of Brockton (formerly Greenock Tp. and Brant Tp.)				
1-8	Salina Formation (Group)	15	34.49	13.7
8-15	Salina Formation (Group)	15	54.09	21.5
1-8	Bass Islands	15	270.31	107.4
8-15	Bass Islands	15	204.82	81.4
1-8	Bois Blanc	15	270.31	107.4
8-15	Bois Blanc	15	677.24	269.1
1-8	Amhertsburg	15	654.24	260.0
8-15	Amhertsburg	15	1063.71	422.7
Subtotal			**3229.21**	**1283.1**
Municipality of South Bruce (formerly Culross Tp. and Carrick Tp.)				
8-15	Salina Formation (Group)	15	595.13	236.5
8-15	Bass Islands	15	221.02	87.8
1-8	Bois Blanc	15	48.05	19.1
8-15	Bois Blanc	15	304.76	121.1
<1	Amherstburg	15	36.93	14.7
1-8	Amherstburg	15	830.15	329.9
8-15	Amherstburg	15	2781.19	1105.1
<1	Lucas	15	13.31	5.3
1-8	Lucas	15	45.85	18.2
1-8	Lucas	15	495.01	196.7
Subtotal			**5371.40**	**2134.3**
TOTAL			**133 355.68**	**52 988.7**

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, County of Bruce				
Quarry No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**Remarks**
Municipality of Northern Bruce Peninsula (formerly St. Edmunds Tp., Lindsay Tp. and Eastnor Tp.)				
Licenced				
1	Bridge Excavating Limited	21.60	Variable, up to 6 m	Producing a variety of aggregate products
2	HSC Quarries Limited	28.33	Variable, up to 9 m	Producing a variety of aggregate products
Unlicenced				
3	Lindsay Twp - Cape Chin Quarry	-	~4	Old, badly overgrown quarry. Guelph Formation
4	Eastnor Twp - Lions Head Quarry	-	~7	Old, badly overgrown quarry. Amabel Formation
Town of South Bruce Peninsula (formerly Albemarle Tp. and Amabel Tp.)				
Licenced				
5	Amsen Quarry Limited	40.46		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
6	Limberlost Stone Inc.	40.40		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
7	Limberlost Stone Inc.	30.35		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
8	William Chamberlain	121.41		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
9	Hope Bay Quarry Inc.	64.70	Variable, up to 8 m	Bridge Excavating and Hunter Haulage are producing a variety of aggregate products
10	Arriscraft International Limited	65.00		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
11	Arriscraft International Limited	63.90		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
12	Arriscraft International Limited	100.30		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
13	Bruce Peninsula Stone Limited	24.28		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
14	Douglas and Jennifer Pruder	20.86		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
15	Bruce Peninsula Stone Limited	20.24		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations

Table 5 – Quarries, County of Bruce

Quarry No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	Remarks
16	Marmo Quarries Canada Inc.	10.12		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
17	Wiarton Buckskin Quarry Company Inc.	2.51		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
18	Wiarton Buckskin Quarry Company Inc.	6.80		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
19	Owen Sound Ledgerock Limited	87.97		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
20	John DiPoce	20.60		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
21	Ebel Quarries Inc.	10.06		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
22	Bluewater Quarry Inc.	10.20		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
23	Carl Anson Barfoot	15.80		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
24	Wiarton Stone Quarry Inc.	7.10		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
25	Owen Sound Ledgerock Limited	64.79		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
26	Ebel Quarries Inc.	7.10		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
27	Ebel Quarries Inc.	77.04		Quarry is licenced under the *Aggregate Resources Act*, but is actually extracting stone for other industrial mineral purposes. Quarries tend to be shallower than traditional aggregate operations
Unlicenced				
28	Amabel Twp - Boat Lake Quarry	-	~1	Old, overgrown, water-filled quarry. Guelph Formation
Municipality of Kincardine (formerly Bruce Tp. and Kincardine Tp.)				
Unlicenced				
29	Kincardine - Inverhuron	-	-	Unknown
30	Kincardine - MTO	-	~1	Old, badly overgrown quarry
31	Kincardine - Penetangore	-	~15	Old, badly overgrown quarry

Table 5 – Quarries, County of Bruce

Quarry No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	Remarks
Municipality of Brockton (formerly Greenock Tp. and Brant Tp.)				
Unlicenced				
32	Brant - Hydro Formosa	-	~9	Old, badly overgrown quarry
33	Brant - Cargill	-	~13	Old, badly overgrown quarry
34	Brant - Walkerton	-	~2	Old, badly overgrown quarry
Municipality of South Bruce (formerly Culross Tp. and Carrick Tp.)				
Unlicenced				
35	Culross - Teeswater Gypsum	-	~15	Old, badly overgrown quarry
36	Carrick - Formosa Quarry	-	~5	Old, badly overgrown quarry

Table 6 – Selected Bedrock Resource Areas, County of Bruce

1 Area Number	2 Depth of Overburden (Metres)	3 Unlicenced Area* (Hectares)	4 Cultural Setbacks** (Hectares)	5 Extracted Area*** (Hectares)	6 Possible Resource Area (Hectares)	7 Estimated Workable Thickness (Metres)	8 Possible Bedrock Resources**** (Million Tonnes)
1	< 8	35815.6	8566.1	0.0	27249.5	15.0	10827.6
TOTAL		**35815.6**	**8566.1**	**0.0**	**27249.5**	**15.0**	**10827.6**

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

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

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

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

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

Table 7 – Borehole Data, County of Bruce	
Borehole Number	**Generalized Description of Material**
15	*UTM: 487702m E 4886999m N, NAD83, Zone 17*
	Elevation: ~800 feet (243.84 m)
	~5 feet (1.52 m) of sandy silt with organics and molluscs
	~10 feet (3.05 m) of alluvial sand and gravel with thin beds of clay and silt
	~10 feet (3.05 m) of stiff, massive silty fine sand - sandy silt
	~15 feet (4.53 m) of wet, pale, brown, fine sand; grey medium- to fine-grained sand; and grey medium-fine sand
	~15 feet (4.53 m) of stiff to very stiff, grey clayey silt with laminated sand beds; varved, brown clay and grey silt
	~32 feet (9.75 m) of brownish grey, gritty, sandy silt diamicton; grey clayey silt interbedded with medium-coarse sand and plastic grey silt; thin bedded sandy silt till; grey medium-fine sand; sand with till lenses or till balls; medium and fine sand
	~3 feet (0.91 m) of silt with grits and balls of clayey silt
	End of Hole ~90 feet (27.43 m)
16	*UTM: 470975m E 4892604m N, NAD83, Zone 17*
	Elevation: ~925 feet (281.94 m)
	~2.5 feet (0.76 m) of Dunkeld Till - gritty silt till
	~77.5 feet (23.62 m) of grey to yellowish brown, faintly laminated silt and clayey-silt. In places, silty clay lamina and may be varved. Rare fine pebbles
	~25 feet (7.62 m) of laminated silty clay with fine sand partings
	~10 feet (3.05 m) of grey, silty fine sand
	~20 feet (6.10 m) of grey sandy silt till, pebbly; lens or beds of fine sand with silt-clay lamina
	~5 feet (1.52 m) of gravel, coarse sand and rock fragments
	End of Hole ~140 feet (42.67 m)
17	*UTM: 476781m E 4896672m N, NAD83, Zone 17*
	Elevation: ~270 m
	~3 feet (0.91 m) of St. Joseph silty clay till
	~12 feet (3.66 m) of stiff fine sand
	~67 feet (20.42 m) of stratified fine sand; silt with clay layers; interbedded very fine sand to silt; laminated clayey silt; interbedded silt and clayey silt or silty clay; laminated fine sand and silty clay; fine sand
	~28 feet (8.53 m) of coarse sand and gravel
	End of Hole ~110 feet (33.53 m)
18	*UTM: 469656m E 4880773m N, NAD83, Zone 17*
	Elevation: ~280 m
	~4 feet (1.22 m) of weathered sandy till
	~22 feet (6.71 m) of yellowish brown, pebbly silt till
	~17 feet (5.18 m) of grey, hard, pebbly silt till
	~6 feet (1.83 m) of fine to very fine sand
	~3 feet (0.91 m) of interbedded till and sand
	~19 feet (5.79 m) of very stiff sandy silt till with sand lenses; sand silt till
	- light brown, tan, petroliferous dolostone
	End of Hole ~82 feet (24.99 m)
20	*UTM: 470931m E 4887590m N, NAD83, Zone 17*
	Elevation: ~900 feet (274.32 m)
	~4 feet (1.22 m) of muck
	~31 feet (9.45 m) of saturated grey silt to clayey silt
	~10 feet (3.05 m) of 1 cm thick clay layers interbedded with silt (varved?)
	~10 feet (3.05 m) of varved silt and clay

Table 7 – Borehole Data, County of Bruce	
Borehole Number	**Generalized Description of Material**
	~15 feet (4.57 m) of clay with sand-silt partings ~15 feet (4.57 m) of varved silt and clay ~5 feet (1.52 m) of medium to coarse sand **End of Hole ~90 feet (27.43 m)**
07A	*UTM: 477478m E 4899322m N, NAD83, Zone 17* *Elevation: ~250 m* ~1.5 feet (0.46 m) of alluvial fine sand ~3.5 feet (1.07 m) of alluvial coarse gravel ~4 feet (1.22 m) of greyish brown sandy silt till, possibly slump material ~13 feet (3.96 m) of saturated fine sand ~9 feet (2.74 m) of coarse sand and gravel ~11 feet (3.35 m) of grey to greyish brown, pebbly sand silt till with silt inclusions near base of interval - bedrock **End of Hole ~45 feet (13.72 m)**
08	*UTM (approximate location): 472134m E 4898414m N, NAD83, Zone 17* *Elevation: ~260 m* ~4 feet (1.22 m) of fill ~14 feet (4.27 m) of pebbly medium to coarse sand; water at 14 feet ~7 feet (2.13 m) of laminated reddish brown clay ~50 feet (15.24 m) of reddish brown to grey clayey silt till; rare pebbles and coarse sand grains; silty sand lens at 71 feet **End of Hole ~76 feet (23.16 m)**
09	*UTM (approximate location): 459818m E 4902821m N, NAD83, Zone 17* *Elevation: ~250 m* ~3 feet (0.91 m) of fill ~3 feet (0.91 m) of yellowish brown stoney, sandy silt till ~12 feet (3.66 m) of fine to medium sand ~7 feet (2.13 m) of oxidized, yellowish brown till ~25 feet (7.62 m) of unoxidized, brownish grey very stiff, stoney, sandy silt till ~1 feet (0.30 m) of gravel beds or lens ~14 feet (4.27 m)of very stiff, stoney sandy silt till ~18 feet (5.49 m) of gravel and broken carbonate rock fragments (probably from bedrock below) **End of Hole ~85 feet (25.91 m)**

Table 8 – Summary of Geophysical Data, County of Bruce
— NONE —

Table 9 – Aggregate Quality Test Data, County of Bruce

Sample Number	Sample Information	COARSE AGGREGATE									FINE AGGREGATE	
		Petrographic Number										
		Granular and 16 mm	Hot Mix and Concrete	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)	Los Angeles Abrasion Test	Freeze–Thaw (% Loss)	Absorption (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<1.150%*	*<25%*	*<15–25%*
Municipality of Northern Bruce Peninsula												
Selected Sand and Gravel Resource Area 1												
	Sand & gravel	122.4	158.1	9.5	-	-	-	1.690	2.630	-	19.7	-
	Sand & gravel	110.5	160.9	19.1	-	-	-	1.640	2.680	-	13.9	-
	Sand & gravel	135.3	158.0	11.3	-	-	-	1.580	2.670	-	20.7	-
	Sand & gravel	100.0	132.8	4.1	-	-	-	1.420	2.710	-	9.3	-
	Sand & gravel	156.6	208.0	34.7	-	-	-	1.470	2.710	-	23.0	-
	Sand & gravel	113.4	139.4	9.9	-	-	-	1.180	2.730	-	19.6	-
	Sand & gravel	133.5	172.1	13.3	-	-	-	1.410	2.700	-	17.2	-
Selected Sand and Gravel Resource Area 2												
11DJR-0022	Sand and gravel	-	379.5	24.0	33.2	-	-	2.770	2.507	-	22.8	-
Other Aggregate Test Results for Northern Bruce Peninsula												
*	Sand & gravel	-	-	-	-	-	-	-	-	-	6.7	-
*	Sand & gravel	101.0	115.0	2.0	-	25.0	-	1.800	-	-	-	-
*	Sand & gravel	137.0	204.0	18.0	-	-	-	2.700	-	-	-	-
*	Sand & gravel	164.5	230.5	7.7	-	-	-	2.950	2.520	-	14.1	-
Town of South Bruce Peninsula												
Southeast Secondary Deposits (former Amabel Township)												
	Sand & gravel	110.0	-	2.1	-	22.30	-	1.240	2.680	-	6.5	-
Town of Saugeen Shores												
Selected Sand and Gravel Resource Area 3												
	Sand & gravel	116.9	134.8	5.0	-	-	-	1.370	2.650	-	12.8	-
	Sand & gravel	131.7	237.7	-	-	-	-	-	-	-	7.1	-
	Sand & gravel	-	-	-	-	-	-	-	-	-	7.2	-
	Sand & gravel	105.1	182.6	3.8	-	-	-	1.500	2.640	-	9.0	-
	Sand & gravel	117.4	166.8	-	-	-	-	-	-	-	9.3	-
	Sand & gravel	106.4	165.5	4.3	-	-	-	1.470	2.650	-	9.7	-
	Sand & gravel	104.7	127.3	-	-	-	-	-	-	-	6.7	-
Buried Ice-Contact Deposit												
	Sand & gravel	127.1	143.5	1.0	12.2	-	-	0.908	2.681	-	-	-
Municipality of Arran–Elderslie												
Selected Sand and Gravel Resource Area 4												
	Sand & gravel	104.0	110.6	1.0	-	-	-	1.140	2.660	-	10.0	-
	Sand & gravel	117.9	130.9	6.0	-	-	-	1.360	2.680	-	14.0	-
Secondary Deposits (former Arran Township)												
	Sand & gravel	107.9	117.8	-	10.8	22.90	-	0.935	2.692	-	-	12.5
	Sand & gravel	115.2	127.4	3.0	-	-	-	1.210	2.660	-	-	-
**	Sand & gravel	-	-	6.0	13.4	-	12	1.795	-	-	-	-

Table 9 – Aggregate Quality Test Data, County of Bruce

		COARSE AGGREGATE									FINE AGGREGATE	
		Petrographic Number										
Sample Number	Sample Information	Granular and 16 mm	Hot Mix and Concrete	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)	Los Angeles Abrasion Test	Freeze–Thaw (% Loss)	Absorp-tion (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<1.150%*	*<25%*	*<15–25%*
**	Sand & gravel	-	-	8.0	12.7	-	4	1.423	-	-	-	-
	Sand & gravel	121.7	161.0	4.7	-	-	-	0.760	2.700	-	8.6	-
	Sand & gravel	101.5	110.7	2.3	-	-	-	1.200	2.670	-	11.8	-
Secondary Deposits (former Elderslie Township)												
11DJR-0023	Sand and gravel	139.1	193.0	-	12.5	-	-	1.530	2.628	-	14.5	-
Municipality of Kincardine												
Selected Sand and Gravel Resource Area 5												
	Sand & gravel	100.0	170.7	7.8	-	-	-	1.330	2.670	-	23.7	-
	Sand & gravel	100.6	167.1	6.2	-	-	-	2.050	2.610	-	11.8	-
	Sand & gravel	117.3	147.1	9.6	-	28.70	-	2.030	2.605	-	13.7	-
	Sand & gravel	130.3	161.5	15.4	-	28.60	-	2.610	2.588	-	18.0	-
	Sand & gravel	104.2	131.3	10.8	-	30.80	-	2.111	2.620	-	16.9	-
	Sand & gravel	133.9	156.0	16.1	-	31.30	-	2.100	2.630	-	15.7	-
Buried Deposits (former Bruce Township)												
	Sand & gravel	108.3	141.4	7.7	-	-	-	2.940	2.520	-	16.2	-
	Sand & gravel	101.6	156.0	12.6	-	-	-	-	-	-	11.7	-
	Sand & gravel	114.5	154.9	1.0	12.2	-	-	1.672	2.627	-	-	-
	Sand & gravel	121.3	149.5	6.3	-	-	-	2.590	2.550	-	11.1	-
	Sand & gravel	100.0	118.6	4.6	-	-	-	1.780	2.620	-	11.5	-
	Sand & gravel	100.0	115.6	5.4	-	-	-	1.930	2.600	-	15.2	-
Sand Deposits (former Kincardine Township)												
	Sand	-	-	-	-	-	-	-	-	-	12.1	-
	Sand	-	-	-	-	-	-	0.929	2.678	-	-	9.7
Beach Deposits (former Kincardine Township)												
	Sand & gravel	101.3	150.2	3.7	-	-	-	2.340	2.560	-	16.2	-
	Sand & gravel	109.8	154.7	-	-	28.40	-	-	-	-	8.4	-
Municipality of Brockton												
Selected Sand and Gravel Resource Area 6												
	Sand & gravel	107.9	146.1	6.4	-	-	-	1.300	2.700	-	14.4	-
	Sand & gravel	114.4	151.8	-	12.3	24.10	-	-	-	-	-	18.5
	Sand & gravel	105.1	135.5	-	11.0	25.90	-	1.438	2.670	-	-	12.6
	Sand & gravel	108.1	158.3	7.8	-	-	-	1.610	2.660	-	11.4	-
	Sand & gravel	101.6	118.7	4.8	-	-	-	1.260	2.680	-	14.7	-
	Sand & gravel	101.0	122.4	-	-	-	-	-	-	-	9.2	-
	Sand & gravel	109.7	141.7	5.6	-	-	-	1.810	2.650	-	13.6	-
	Sand & gravel	107.9	146.0	6.4	-	-	-	1.610	2.700	-	14.4	-
11DJR-0024	Sand and gravel	127.2	178.9	-	9.7	-	-	2.140	2.590	-	18.0	-

Table 9 – Aggregate Quality Test Data, County of Bruce

Sample Number	Sample Information	COARSE AGGREGATE: Petrographic Number Granular and 16 mm	Petrographic Number Hot Mix and Concrete	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)	Los Angeles Abrasion Test	Freeze–Thaw (% Loss)	Absorption (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	FINE AGGREGATE: $MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<1.150%*	*<25%*	*<15–25%*
Ice-Contact Deposits (former Greenock Township)												
	Sand & gravel	101.1	133.1	5.0	-	24.80	-	1.570	2.750	-	-	-
	Sand & gravel	103.9	157.2	12.9	-	28.50	-	2.110	2.741	-	12.7	-
	Sand & gravel	100.0	177.2	1.8	-	-	-	1.800	2.620	-	12.5	-
	Sand & gravel	102.4	164.0	2.0	-	-	-	1.700	2.630	-	15.2	-
	Sand & gravel	101.3	136.9	6.9	-	-	-	1.840	2.610	-	11.7	-
Secondary Deposits (former Brant Township)												
	Sand & gravel	142.3	162.2	1.0	-	-	-	1.170	2.669	-	-	10.1
	Sand & gravel	122.3	140.4	2.0	9.9	-	-	1.034	2.695	-	-	13.9
	Sand & gravel	103.0	113.4	3.0	-	-	-	0.730	2.710	-	7.8	-
Township of Huron–Kinloss												
Secondary Deposit (former Huron Township)												
	Sand & gravel	103.5	123.8	14.1	-	-	-	2.410	2.550	-	11.4	-
	Sand & gravel	103.8	135.1	15.8	-	-	-	2.070	2.560	-	12.8	-
	Sand & gravel	101.6	115.1	13.8	-	-	-	2.410	2.570	-	16.4	-
	Sand & gravel	107.2	132.9	8.9	-	-	-	2.380	2.540	-	13.5	-
Tertiary Beach Deposits (former Huron Township)												
	Sand & gravel	115.0	193.4	7.4	-	-	-	2.260	2.590	-	14.3	-
	Sand & gravel	109.5	170.0	5.2	-	-	-	1.800	2.620	-	12.0	-
	Sand & gravel	106.7	206.2	6.3	-	-	-	3.350	2.570	-	14.8	-
	Sand & gravel	144.2	208.2	7.6	-	-	-	1.510	2.690	-	16.5	-
Ripley Deposit (former Huron Township)												
	Sand & gravel	105.2	116.8	15.8	-	-	-	-	-	-	13.3	-
	Sand & gravel	100.0	129.8	5.3	-	-	-	2.010	2.590	-	13.7	-
Selected Sand and Gravel Resource Area 7												
	Sand & gravel	-	-	2.0	14.6	-	-	2.104	2.577	-	-	-
	Sand & gravel	123.0	145.6	5.8	-	-	-	2.400	2.550	-	-	-
	Sand & gravel	118.0	145.0	3.6	-	-	-	2.350	2.550	-	12.2	-
	Sand & gravel	105.0	154.0	16.1	-	-	-	2.910	2.510	-	8.5	-
	Sand & gravel	100.0	177.9	9.1	-	-	-	2.430	2.540	-	13.3	-
	Sand & gravel	101.1	138.5	3.5	-	-	-	2.330	2.540	-	-	-
	Sand & gravel	100.0	108.0	3.5	-	-	-	2.070	2.590	-	9.0	-
	Sand & gravel	109.3	161.3	4.7	-	-	-	1.920	2.590	-	11.0	-
	Sand & gravel	106.6	131.1	5.2	-	-	-	1.740	2.560	-	12.7	-
	Sand & gravel	100.0	116.0	6.9	-	-	-	1.880	2.580	-	9.1	-
	Sand & gravel	100.0	101.0	6.7	-	-	-	2.010	2.580	-	7.5	-
	Sand & gravel	100.0	125.4	2.3	-	-	-	1.840	2.590	-	13.0	-
	Sand & gravel	102.6	115.6	5.8	-	-	-	2.370	2.570	-	13.8	-
	Sand & gravel	100.0	114.8	5.8	-	-	-	2.070	2.580	-	11.8	-

Table 9 – Aggregate Quality Test Data, County of Bruce

Sample Number	Sample Information	COARSE AGGREGATE									FINE AGGREGATE	
		Petrographic Number		$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)	Los Angeles Abrasion Test	Freeze–Thaw (% Loss)	Absorption (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)
		Granular and 16 mm	Hot Mix and Concrete									
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<1.150%*	*<25%*	*<15–25%*
Northern Secondary Deposit (former Kinloss Township)												
	Sand & gravel	101.1	126.0	14.0	-	-	-	2.780	2.530	-	18.3	-
	Sand & gravel	107.8	144.9	16.0	-	-	-	3.340	2.500	-	12.8	-
	Sand & gravel	100.0	148.3	2.1	-	-	-	2.430	2.550	-	-	-
	Sand & gravel	107.7	127.1	14.2	-	-	-	3.090	2.530	-	16.7	-
	Sand & gravel	102.9	138.4	14.5	-	-	-	2.980	2.530	-	23.2	-
	Sand & gravel	101.4	140.1	15.1	-	-	-	3.010	2.520	-	18.1	-
Central Secondary Deposit (former Kinloss Township)												
	Sand & gravel	100.0	127.2	7.7	-	-	-	1.440	2.590	-	14.3	-
	Sand & gravel	132.4	158.8	18.1	-	-	-	-	-	-	8.8	-
Southeast Esker Deposit (former Kinloss Township)												
	Sand & gravel	100.4	125.4	12.6	-	-	-	2.370	2.570	-	14.0	-
	Sand & gravel	116.4	143.8	21.9	-	-	-	3.290	2.500	-	16.0	-
	Sand & gravel	101.4	124.6	14.6	-	-	-	2.440	2.560	-	15.8	-
Southeast Secondary Deposits (former Kinloss Township and Culross Township)												
	Sand & gravel	128.5	196.5	1.0	14.4	-	-	2.639	2.544	-	-	-
	Sand & gravel	110.4	148.7	2.0	13.2	-	-	2.104	2.586	-	-	-
	Sand & gravel	102.3	117.5	20.1	-	-	-	3.610	2.480	-	14.4	-
	Sand & gravel	100.9	151.7	23.7	-	-	-	-	-	-	25.7	-
	Sand & gravel	107.4	161.1	-	13.9	24.96	-	2.036	2.587	-	-	16.2
	Sand & gravel	104.4	145.7	13.9	-	-	-	2.810	2.520	-	11.3	-
	Sand & gravel	115.6	169.5	3.0	22.5	-	-	2.005	2.594	-	-	12.2
Municipality of South Bruce												
Selected Sand and Gravel Resource Area 8												
	Sand & gravel	102.4	150.2	20.7	-	-	-	3.250	2.510	-	10.7	-
	Sand & gravel	102.6	126.4	7.6	-	-	-	2.170	2.590	-	17.7	-
	Sand & gravel	101.4	136.1	16.7	-	-	-	2.680	2.540	-	19.9	-
	Sand & gravel	100.6	157.0	14.0	-	-	-	2.640	2.550	-	9.8	-
	Sand & gravel	101.0	143.2	18.2	-	-	-	2.110	2.590	-	21.3	-
	Sand & gravel	100.8	136.9	20.3	-	-	-	2.840	2.550	-	13.9	-
	Sand & gravel	103.1	142.8	17.6	-	-	-	2.650	2.560	-	14.9	-
	Sand & gravel	115.3	138.5	16.5	-	-	-	2.510	2.600	-	19.6	-
	Sand & gravel	106.7	149.1	18.5	-	-	-	3.120	2.510	-	-	-
Selected Sand and Gravel Resource Area 9												
	Sand & gravel	100.7	130.3	12.1	-	-	-	2.040	2.610	-	15.5	-
	Sand & gravel	101.9	151.2	8.6	-	-	-	2.710	2.520	-	16.6	-
	Sand & gravel	101.6	143.9	19.4	-	-	-	2.650	2.580	-	17.3	-
	Sand & gravel	100.0	123.2	14.1	-	-	-	2.040	2.610	-	17.2	-
	Sand & gravel	104.5	128.5	11.7	-	-	-	1.880	2.640	-	17.2	-

Table 9 – Aggregate Quality Test Data, County of Bruce

Sample Number	Sample Information	COARSE AGGREGATE									FINE AGGREGATE	
		Petrographic Number		MgSO$_4$ (%)	Micro-Deval Abrasion (% Loss)	Los Angeles Abrasion Test	Freeze–Thaw (% Loss)	Absorption (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	MgSO$_4$ (%)	Micro-Deval Abrasion (% Loss)
		Granular and 16 mm	Hot Mix and Concrete									
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<1.150%*	*<25%*	*<15–25%*
	Sand & gravel	100.0	110.1	18.7	-	-	-	2.040	2.600	-	14.6	-
	Sand & gravel	117.4	229.8	3.0	13.3	-	-	2.642	2.556	-	-	-
	Sand & gravel	100.0	110.0	12.6	-	-	-	1.880	2.660	-	17.3	-
Selected Sand and Gravel Resource Area 10												
	Sand & gravel	100.9	107.1	8.0	-	-	-	1.210	2.660	-	8.7	-
	Sand & gravel	101.4	113.9	15.2	-	-	-	1.640	2.690	-	17.3	-
	Sand & gravel	100.3	107.8	12.5	-	-	-	-	-	-	14.9	-
Selected Sand and Gravel Resource Area 11												
	Sand & gravel	103.3	108.9	8.9	-	-	-	1.540	2.660	-	17.5	-
	Sand & gravel	111.5	118.3	9.9	-	-	-	1.570	2.670	-	15.7	-
	Sand & gravel	100.0	111.2	9.7	-	-	-	1.370	2.680	-	11.9	-
	Sand & gravel	103.5	112.6	8.9	-	-	-	1.270	2.680	-	9.5	-
	Sand & gravel	111.0	124.8	3.0	8.9	-	-	1.133	2.688	-	-	15.7
Selected Sand and Gravel Resource Area 12												
	Sand & gravel	100.3	121.3	14.5	-	-	-	1.870	2.640	-	32.6	-
	Sand & gravel	105.2	130.3	22.8	-	-	-	2.210	2.650	-	35.1	-
	Sand & gravel	103.9	124.4	18.7	-	-	-	2.040	2.630	-	35.1	-
	Sand & gravel	102.5	115.6	20.7	-	-	-	2.070	2.630	-	-	-
	Sand & gravel	101.4	130.3	22.8	-	-	-	-	-	-	22.0	-
Selected Sand and Gravel Resource Area 13												
	Sand & gravel	104.7	126.4	24.9	-	-	-	2.110	2.600	-	21.1	-
	Sand & gravel	104.8	130.0	25.0	-	-	-	2.310	2.630	-	25.4	-
	Sand & gravel	101.1	112.8	28.1	-	-	-	1.910	2.700	-	25.5	-
	Sand & gravel	105.7	134.2	28.1	-	-	-	1.970	2.630	-	25.5	-
	Sand & gravel	103.0	124.7	20.0	-	-	-	2.000	2.630	-	14.0	-
	Sand & gravel	131.0	157.1	-	16.2	25.56	-	2.700	2.630	-	-	30.5
	Sand & gravel	101.7	157.8	21.2	-	-	-	2.510	2.560	-	16.5	-
	Sand & gravel	100.0	166.7	12.6	-	-	-	2.640	2.580	-	7.7	-
	Sand & gravel	106.0	137.5	20.5	-	-	-	2.640	2.560	-	15.3	-
	Sand & gravel	101.8	142.4	12.7	-	-	-	2.370	2.580	-	19.8	-
Secondary Deposit (north-central former Carrick Township)												
	Sand & gravel	-	-	6.3	-	-	-	-	-	-	-	-
Secondary Deposit Southeast of Mildmay												
	Sand & gravel	106.6	122.3	-	-	-	-	2.200	2.632	-	-	-
	Sand & gravel	105.8	124.6	-	-	29.10	-	2.510	2.603	-	-	-
	Sand & gravel	109.5	129.3	-	-	-	-	2.710	2.589	-	-	-
	Sand & gravel	128.9	141.0	-	-	-	-	2.100	2.638	-	-	-
	Sand & gravel	108.4	135.2	-	-	-	-	2.700	2.590	-	-	-
	Sand & gravel	144.6	177.4	7.0	17.0	29.10	-	1.872	2.652	-	-	-
Secondary Deposit Along Southern Boundary												
	Sand & gravel	129.9	216.6	5.0	14.3	-	-	3.011	2.546	-	-	30.5

Table 9 – Aggregate Quality Test Data, County of Bruce

Sample Number	Sample Information	COARSE AGGREGATE: Petrographic Number: Granular and 16 mm	Petrographic Number: Hot Mix and Concrete	$MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)	Los Angeles Abrasion Test	Freeze–Thaw (% Loss)	Absorption (%)	Bulk Relative Density	Accelerated Mortar Bar (14 days) (% Loss)	FINE AGGREGATE: $MgSO_4$ (%)	Micro-Deval Abrasion (% Loss)
Generally Acceptable Values:			*125–140*	*<12–15%*	*<14–17%*	*<35–45%*	*<6%*	*<2%*	*>2.5*	*<1.150%*	*<25%*	*<15–25%*
Bedrock Results												
11DJR-0020	Goat Island Fm	100.0	113.7	11.0	7.5	-	8.5	1.680	2.641	0.010	-	-
*	Guelph Fm	100.0	100.0	1.8	-	22.60	-	0.301	2.802	-	-	-
*	Guelph Fm	100.0	100.4	1.6	-	26.80	-	0.906	2.753	-	-	-
*	Guelph Fm	100.0	100.0	3.1	-	28.50	-	0.870	2.716	-	-	-
*	Guelph Fm	100.0	100.0	2.4	-	29.90	-	-	-	-	-	-
	Guelph Fm	193.4	240.6	6.0	-	51.86	-	2.046	2.620	-	-	-
	Guelph Fm	113.8	140.3	1.0	-	-	-	0.970	2.725	-	-	-
11DJR-0021	Guelph Fm	100.0	115.9	1.7	7.3	-	8.7	0.980	2.717	0.021	-	-
	Bass Islands Fm	120.2	145.7	1.0	-	31.02	-	2.836	2.595	-	-	-
	Lucas Fm	153.6	243.4	-	24.6	44.48	-	5.152	2.401	-	-	-

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

* Samples collected as part of Ontario Geological Survey (1995) study.

** Samples collected as part of the Jagger Hims Limited and Rowell (2009) study of Grey County.

Table 10 – Till Analysis – Physical Properties, County of Bruce

	Texture			Pebble Lithology							Carbonates				Heavy Minerals	
Sample Number*	**Clay (%)**	**Silt (%)**	**Sand (%)**	**Limestone (%)**	**Dolostone (%)**	**Chert (%)**	**Sandstone (%)**	**Siltstone (%)**	**Shale (%)**	**Precambrian Clasts (%)**	**Calcite (%)**	**Dolomite (%)**	**Total (%)**	**Cal/Dol (ratio)**	**Total (%)**	**Magnetics (%)**
	Elma Till															
	10	46	44	-	-	-	-	-	-	-	15.4	36.9	52.3	0.4	3.0	9.1
	12	48	40	29	31	1	-	-	-	39	13.1	39.2	52.3	0.3	2.5	10.0
	12	48	40	-	-	-	-	-	-	-	16.5	31.6	48.1	0.5	2.4	9.7
	12	45	43	-	-	-	-	-	-	-	15.2	39.0	54.2	0.4	2.2	14.2
	19	50	31	38	58	-	-	1	-	2	14.2	34.8	49.0	0.4	2.4	10.9
	19	53	28	-	-	-	-	-	-	-	18.2	30.2	48.4	0.6	1.1	13.0
	11	43	46	-	-	-	-	-	-	-	19.0	41.1	60.1	0.5	13.3	31.0
	11	54	35	40	51	3	-	1	-	4	17.4	58.9	76.3	0.3	2.7	8.9
	12	52	36	34	55	2	-	1	-	8	18.0	43.6	61.6	0.4	2.3	10.5
	9	56	35	-	-	-	-	-	-	-	14.7	41.7	56.4	0.4	2.4	10.2
	10	46	44	50	41	3	-	1	1	4	25.3	42.5	67.8	0.6	2.6	10.4
	8	51	41	26	48	10	1	3	-	12	14.7	40.9	55.6	0.4	3.2	9.1
	6	45	49	16	61	7	2	5	1	8	9.8	43.6	53.4	0.2	3.0	10.1
	7	52	41	23	51	9	3	8	-	6	10.2	44.8	55.0	0.2	2.8	10.9
	12	58	30	15	69	-	1	6	-	8	3.9	45.7	49.6	0.1	3.9	16.5
	9	53	38	16	72	3	4	1	-	4	16.4	40.6	57.0	0.4	2.5	10.4
11DJR-0012	10.58	60.79	28.63								3.1	38.63	41.8	0.1		
11DJR-0013	11.12	62.21	26.67								6.2	34.09	40.3	0.2		
	Dunkeld Till															
	23	58	19	35	51	-	-	3	-	11	19.6	29.1	48.7	0.7	3.0	10.0
	11	62	27	36	53	-	-	-	-	12	8.4	33.1	41.5	0.3	3.3	14.6
	16	66	18	17	76	1	-	4	-	3	18.0	33.9	51.9	0.5	3.1	13.4
	20	68	12	21	72	2	-	1	-	3	15.7	33.7	49.4	0.5	2.0	6.2
	21	67	12	20	64	1	-	-	-	14	21.7	29.5	51.2	0.7	3.0	14.0
	20	59	21	37	53	-	-	-	-	11	14.5	40.4	54.9	0.4	2.8	10.8
	18	54	28	22	73	-	-	-	-	5	5.6	37.3	42.9	0.2	2.8	10.6
	20	66	14	25	65	-	-	-	-	10	19.0	30.6	49.6	0.6	3.2	13.6
	18	55	27	43	45	-	-	-	-	11	15.0	31.8	46.8	0.5	2.9	11.1
	18	67	15	-	-	-	-	-	-	-	15.9	34.8	50.7	0.5	2.9	11.1
	14	51	35	28	63	5	1	-	-	3	18.3	37.3	55.6	0.5	2.3	17.2
	18	52	30	-	-	-	-	-	-	-	17.3	27.7	45.0	0.6	2.3	16.0
	19	56	25	24	65	-	1	-	3	7	15.6	51.7	67.3	0.3	2.5	11.3
	34	63	3	-	-	-	-	-	-	-	23.0	23.5	46.5	1.0	2.4	33.3
	19	71	10	22	64	4	-	-	1	9	19.7	20.6	40.3	1.0	1.3	40.0
	20	59	21	37	59	-	1	-	1	3	12.9	33.1	46.0	0.4	2.4	11.5
	19	60	21	-	-	-	-	-	-	-	14.9	30.6	45.5	0.5	2.3	13.8
	20	59	21	30	66	1	1	-	-	2	20.4	31.2	51.6	0.7	1.8	21.3
	25	68	7	-	-	-	-	-	-	-	25.4	27.2	52.6	0.9	2.1	23.8
	16	57	27	24	67	-	1	-	2	6	18.5	31.2	49.7	0.6	2.0	15.8
	13	51	36	-	-	-	-	-	-	-	11.1	33.7	44.8	0.3	2.0	13.5
	21	70	9	-	-	-	-	-	-	-	19.2	30.0	49.2	0.6	1.7	27.2
11DJR-0014	23.05	56.64	20.31								7.3	30.0	37.3	0.2		
11DJR-0015	23.60	59.77	16.63								7.3	39.1	46.4	0.2		

Table 10 – Till Analysis – Physical Properties, County of Bruce

Sample Number*	Texture			Pebble Lithology							Carbonates				Heavy Minerals	
	Clay (%)	Silt (%)	Sand (%)	Limestone (%)	Dolostone (%)	Chert (%)	Sandstone (%)	Siltstone (%)	Shale (%)	Precambrian Clasts (%)	Calcite (%)	Dolomite (%)	Total (%)	Cal/Dol (ratio)	Total (%)	Magnetics (%)
	Rannoch Till															
	11	49	40	38	56	-	1	-	-	5	12.3	47.3	59.6	0.3	2.7	11.0
	23	62	15	40	41	3	2	3	-	11	16.1	34.4	50.5	0.5	2.5	9.4
	15	52	33	33	51	1	3	2	-	10	11.9	44.2	56.1	0.3	2.7	8
	18	63	19	37	57	1	-	2	-	3	16.2	39.4	55.6	0.4	2.6	10.4
	29	53	18	-	-	-	-	-	-	-	12.6	33.7	46.3	0.4	2.2	8.8
	14	64	22	41	49	4	1	1	-	4	16.8	32.3	49.1	0.5	2.3	9.4
	St. Joseph Till															
	38	49	13	-	-	-	-	-	-	-	16.6	30.4	47.0	0.5	2.8	8.7
	45	49	6	-	-	-	-	-	-	-	17.4	28.1	45.4	0.6	2.9	10.0
	32	49	19	-	-	-	-	-	-	-	21.2	24.5	45.7	0.9	2.6	3.2
	29	63	8	-	-	-	-	-	-	-	14.2	28.9	43.1	0.5	2.9	6.6
	32	57	11	-	-	-	-	-	-	-	19.0	33.3	52.3	0.6	3.3	8.9
	38	54	8	40	49	-	-	-	-	9	21.8	28.5	50.3	0.8	3.4	6.6
	31	53	16	46	45	3	2	-	-	4	17.6	27.4	45.0	0.6	3.1	6.1
	30	54	16	46	36	2	-	-	-	16	20.3	30.6	50.9	0.7	2.8	7.9
	35	52	13	37	50	3	-	-	-	10	17.5	27.0	44.5	0.6	2.9	9.8
	26	58	16	57	32	1	-	-	-	10	19.2	32.5	51.7	0.6	2.3	10.3
	35	52	13	-	-	-	-	-	-	-	18.9	26.4	45.3	0.7	2.7	4.1
	35	59	6	-	-	-	-	-	-	-	23.7	25.6	49.3	0.9	3.4	8.0
	35	55	10	-	-	-	-	-	-	-	17.7	25.1	42.8	0.7	2.7	2.6
	36	60	4	-	-	-	-	-	-	-	22.6	25.3	47.9	0.9	1.6	10.0
	34	41	25	63	29	2	-	-	1	5	15.6	32.9	48.5	0.5	1.2	17.3
	31	54	15	62	23	4	-	-	-	10	16.8	30.0	46.8	0.6	2.1	10.0
	40	53	7	58	36	1	-	-	1	4	15.5	28.3	43.8	0.5	2.2	33.3
	45	53	2	-	-	-	-	-	-	-	7.0	28.5	35.5	0.2	-	-
	33	54	13	50	36	4	1	-	-	9	20.8	29.3	50.1	0.7	2.8	7.1
	33	55	12	55	30	2	-	-	-	13	19.1	34.4	53.5	0.6	2.7	9.5
	31	55	14	59	33	3	-	-	-	5	20.2	31.2	51.4	0.6	2.3	4.6
	26	58	16	48	40	3	1	-	-	8	18.2	32.5	50.7	0.6	2.3	9.9
	14	56	30	43	47	1	2	-	-	7	18.7	35.2	53.9	0.5	1.8	4.7
	31	56	13	46	37	2	-	-	-	15	17.9	31.0	48.9	0.6	2.0	9.8
	24	58	18	50	33	1	-	1	-	15	17.7	34.8	52.5	0.5	1.8	10.3
	45	52	3	-	-	-	-	-	-	-	18.6	23.3	41.9	0.8	3.4	9.4
	43	49	8	-	-	-	-	-	-	-	22.0	21.4	43.4	1.0	3.9	12.1
11DJR-0016	27.23	58.73	14.04								16.8	17.3	34.1	1.0		
11DJR-0017	33.55	50.85	15.60								18.6	20.0	38.6	0.9		
	Bruce till															
11DJR-0010	10.12	55.72	34.16								14.8	21.4	36.1	0.7		
11DJR-0011	12.05	50.74	37.21								17.2	20.5	37.6	0.8		
	Eolian Sand															
11DJR-0001	0.00	1.23	98.77													
11DJR-0002	0.00	0.24	99.76													

* This study.

Analytical results without a sample number are from W.R. Cowan's mapping in the Bruce County area (*see* Cowan 1974, 1975, 1977, 1978; Cowan, Cooper and Pinch 1986; Cowan and Pinch 1986; Cowan and Sharpe 2007a, 2007b; Cowan, Sharpe, Feenstra and Gwyn 1978).

Table 11 – Results of Geochemical Analyses of Bedrock Samples, County of Bruce

Sample No.	11DJR-0020	11DJR-0021	11DJR-0031
Formation	Amabel (unsubdiv.*) (Goat Island)	Guelph	Guelph
Major Oxide Analyses			
SiO_2 (%)	0.29	0.28	0.25
Al_2O_3	0.08	0.19	0.15
MnO	0.01	0.02	0.01
MgO	18.06	17.92	18.00
CaO	28.24	28.13	28.47
Na_2O	<0.01	<0.01	<0.01
K_2O	0.01	0.02	<0.01
P_2O_5	<0.01	<0.01	<0.01
TiO_2	<0.01	0.01	0.01
$Fe_2O_3^{total}$	0.04	0.05	0.07
LOI	52.67	52.59	52.74
Total	99.22	99.03	99.53
S	<0.01	<0.01	<0.01
CO_2	50.80	47.20	45.90
H_2O^+	0.57	0.80	0.89
H_2O^-	0.48	0.50	0.49
Atomic Absorption (Flame) Spectroscopy Analyses			
Cd (ppm)	<5	<5	<5
Co	<30	<30	<30
Cu	<3	<3	<3
Li	16	17	18
Ni	<6	<6	<6
Pb	<12	<12	<12
Zn	<6	11.00	<6
Inductively Coupled Plasma Mass Spectroscopy Analyses			
Ba (ppm)	3.80	3.80	3.60
Be	0.04	0.08	0.09
Bi	<0.15	<0.15	<0.15
Cd	0.019	0.232	0.019
Ce	0.86	1.04	1.35
Co	0.45	0.52	0.57
Cr	<3	5.00	5.00
Cs	0.022	0.037	0.077
Cu	1.4	1.4	<1.4

Sample No.	11DJR-0020	11DJR-0021	11DJR-0031
Formation	Amabel (unsubdiv.*) (Goat Island)	Guelph	Guelph
Inductively Coupled Plasma Mass Spectroscopy Analyses (cont'd)			
Dy (ppm)	0.077	0.089	0.109
Er	0.050	0.059	0.069
Eu	0.017	0.021	0.028
Ga	0.11	0.21	0.20
Gd	0.091	0.091	0.108
Hf	<0.14	<0.14	<0.14
Ho	0.017	0.020	0.023
In	0.002	0.002	0.003
La	0.60	0.84	0.87
Li	1.1	1.4	2.4
Lu	0.006	0.008	0.008
Mo	0.12	0.24	0.09
Nb	0.094	0.167	0.176
Nd	0.47	0.53	0.68
Ni	6.2	8.0	8.4
Pb	1.3	1.4	0.6
Pr	0.133	0.172	0.196
Rb	0.630	1.170	1.710
Sb	<0.04	0.05	0.04
Sc	<1.1	<1.1	1.1
Sm	0.092	0.102	0.116
Sn	<0.16	<0.16	<0.16
Sr	38.10	44.80	63.30
Ta	<0.023	<0.023	<0.023
Tb	0.011	0.013	0.018
Th	0.030	0.080	0.076
Ti	27	490	58
Tl	0.005	0.015	0.009
Tm	0.007	0.009	0.009
U	0.082	0.384	0.181
V	<0.8	1.8	3.5
W	<0.05	<0.05	<0.05
Y	0.57	0.71	0.85
Yb	0.042	0.055	0.054
Zn	<7	10	<7
Zr	<6	<6	<6

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

Table 12 – Results of Geochemical Analyses of Till Samples, County of Bruce

Sample No. / Till Unit	11DJR-0010 Bruce	11DJR-0011 Bruce	11DJR-0012 Elma	11DJR-0013 Elma	11DJR-0014 Dunkeld	11DJR-0015 Dunkeld	11DJR-0016 St. Joseph	11DJR-0017 St. Joseph
Inductively Coupled Plasma Mass Spectroscopy (ICP–MS) Analyses								
Ag (ppm)	0.02	0.02	0.04	0.03	0.29	0.16	0.02	0.02
As	3.4	2.4	2.5	2.4	4.0	3.5	2.9	3.7
Au	0.004	<0.002	0.002	0.002	0.004	0.002	0.002	0.002
Ba	15.6	14.3	22.2	20.3	36.9	32.5	29.9	45.9
Be	0.20	0.17	0.24	0.19	0.37	0.33	0.34	0.45
Bi	0.07	0.04	0.06	0.05	0.09	0.08	0.09	0.11
Cd	0.08	0.06	0.11	0.08	0.06	0.06	0.05	0.06
Ce	28.0	21.3	22.1	18.6	29.6	28.1	33.2	30.6
Co	3.30	2.92	3.30	3.13	6.11	5.68	6.40	7.99
Cr	28	27	9	8	12	11	13	17
Cs	0.21	0.22	0.25	0.23	0.39	0.37	0.40	0.57
Cu	17.9	14.1	8.30	8.30	15.90	14.80	16.80	18.10
Dy	1.73	1.37	1.41	1.30	2.15	1.99	1.90	1.98
Er	0.78	0.67	0.71	0.62	1.01	0.91	0.86	0.88
Eu	0.51	0.39	0.43	0.37	0.67	0.59	0.58	0.62
Ga	1.35	1.13	1.54	1.39	2.29	2.14	2.57	3.11
Gd	2.47	1.90	2.00	1.80	3.00	2.84	2.83	2.87
Hf	0.05	0.14	0.05	0.05	0.06	0.08	0.16	0.19
Hg	0.02	0.01	0.03	0.02	0.04	0.03	0.01	0.02
Ho	0.303	0.251	0.259	0.235	0.377	0.352	0.334	0.343
In	0.018	0.012	0.012	0.011	0.019	0.018	0.017	0.017
La	12.63	9.25	11.05	8.85	13.56	12.64	14.89	13.16
Li	5.29	4.51	6.20	5.52	11.20	10.60	10.50	15.01
Lu	0.083	0.074	0.078	0.071	0.111	0.103	0.091	0.096
Mo	0.27	0.33	0.23	0.18	0.22	0.23	0.20	0.20
Nb	0.33	0.33	0.29	0.28	0.29	0.27	0.20	0.21
Nd	13.31	10.04	11.14	9.28	15.68	14.44	15.79	15.11
Ni	8.6	8.1	8.7	8.4	13.7	13.0	15.1	19.0
Pb	9.7	4.2	6.1	5.0	6.9	6.6	4.1	5.4
Pr	3.34	2.49	2.85	2.33	3.90	3.67	4.08	3.78
Pt	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Rb	4.64	4.01	4.86	4.38	7.46	6.86	6.86	10.09
Sb	0.06	<0.06	0.08	0.07	0.08	0.08	0.07	0.09
Sc	2.20	1.92	1.65	1.55	3.02	2.76	2.85	3.18
Se	<0.4	<0.4	<0.4	<0.4	0.4	<0.4	<0.4	<0.4
Sm	2.54	1.92	2.14	1.87	3.25	3.00	3.06	3.16
Sn	0.67	1.68	0.20	0.16	0.24	0.23	0.24	0.30
Sr	138.91	122.88	47.61	56.32	62.21	66.21	104.03	110.33
Ta	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Tb	0.336	0.262	0.270	0.241	0.405	0.373	0.380	0.385
Te	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Th	1.93	2.04	1.38	1.29	2.79	2.82	3.74	4.00
Ti	149.7	166.6	119.5	118.7	160.3	159.9	171.7	172.7
Tl	0.066	0.063	0.066	0.061	0.088	0.085	0.092	0.095
Tm	0.102	0.083	0.090	0.082	0.126	0.118	0.104	0.114
U	0.28	0.36	0.49	0.49	0.39	0.38	0.34	0.41
V	12	11	15	13	17	16	17	20
W	0.10	0.10	0.10	0.10	<0.02	<0.02	<0.02	<0.02
Y	8.70	6.92	7.75	6.80	10.42	9.60	8.74	9.34
Yb	0.62	0.54	0.55	0.49	0.77	0.73	0.65	0.70
Zn	17.88	37.92	20.78	17.73	25.74	23.50	28.66	34.78
Zr	1.26	4.61	1.51	1.30	3.09	3.66	7.04	8.49

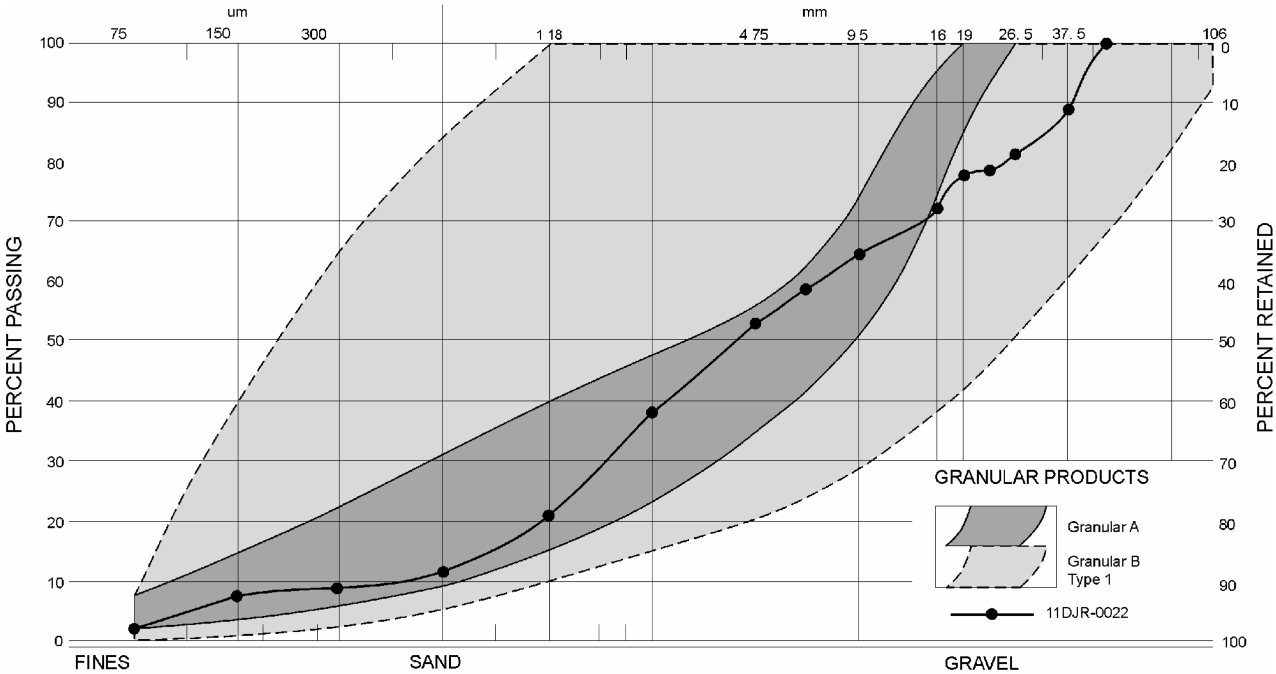

Figure 5A. Aggregate Grading Curves, County of Bruce – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from the Ontario Provincial Standard Specifications OPSS 1010 (1988)).

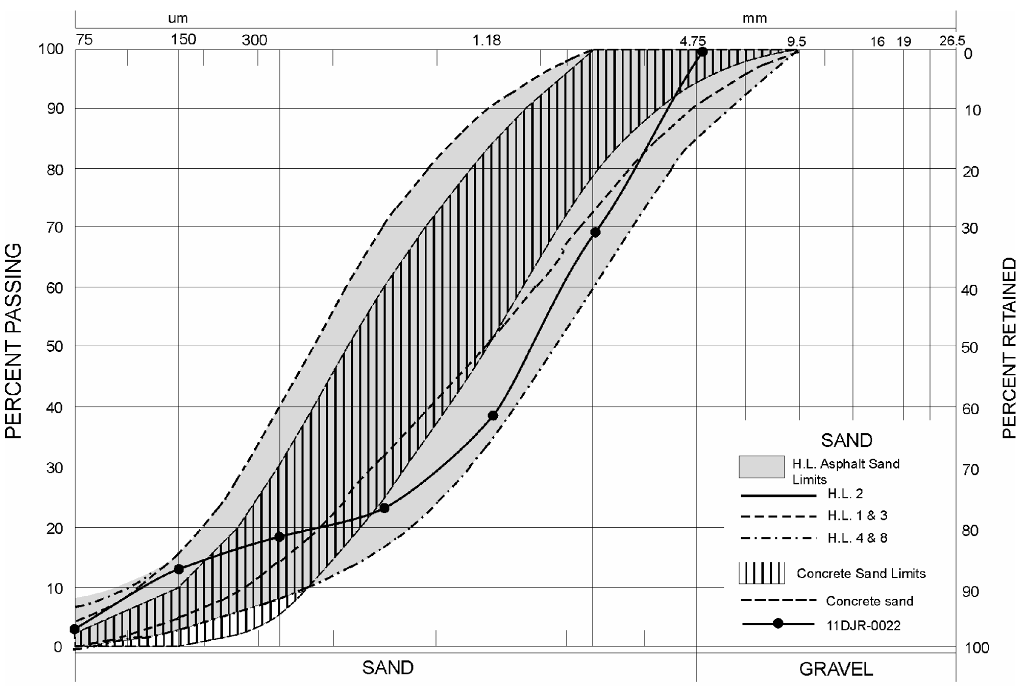

Figure 5B. Aggregate Grading Curves, County of Bruce – Sand Fraction.
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from the Ontario Provincial Standard Specifications OPSS 1002 (1988) and 1003 (1988)).

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

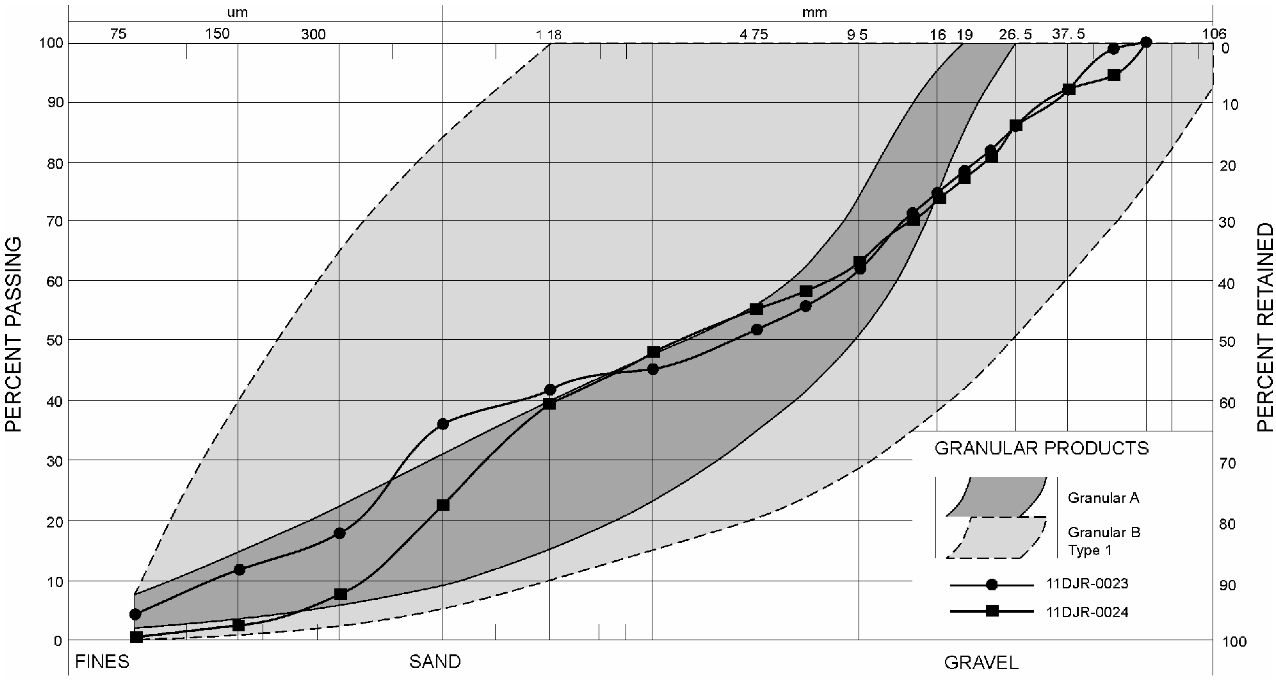

Figure 6. Aggregate Grading Curves, County of Bruce – Total Aggregate.
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from the Ontario Provincial Standard Specifications OPSS 1010, 1988).

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

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Appendix B – Glossary

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

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

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

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

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

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

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 540 and 500 million years age. The Cambrian precedes the Ordovician Period.

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

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

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

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

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 410 and 355 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest Paleozoic rocks in Ontario.

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

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

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

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

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

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

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

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

Boulder	more than 200 mm
Cobbles	75–200 mm
Coarse Gravel	26.5–75 mm
Fine Gravel	4.75–26.5 mm
Coarse Sand	2–4.75 mm
Medium Sand	0.425–2 mm
Fine Sand	0.075–0.425 mm
Silt, Clay	less than 0.075 mm

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

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

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

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

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

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

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

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

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

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

Pleistocene: An epoch of the recent geological past including the time from approximately 1.75 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the “Great Ice Age”.

Possible Resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications, but do not take into account many site-specific natural and environmental constraints that could render the resource inaccessible.

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

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

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

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

Silurian: An early period of the Paleozoic Era thought to have covered the time between 435 and 410 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

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

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

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

Appendix C – Geology of Sand and Gravel Deposits

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

GLACIOFLUVIAL DEPOSITS

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

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

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

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

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

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

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

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

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

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

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

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake is called a glaciolacustrine plain. The sediments that form the plain are predominantly fine to medium sand, silt and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular subbase aggregate.

GLACIOMARINE DEPOSITS

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

Glaciomarine 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 Ontario Ministry of Transportation. 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–Grenville.

Nepean Formation (Cambrian)

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

March Formation (Lower Ordovician)

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

Oxford Formation (Lower Ordovician)

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

Rockcliffe Formation (Lower Ordovician)

STRATIGRAPHY and/or OCCURRENCE: Divided into a lower member and an upper (St. Martin) member.
LITHOLOGY: Interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominate in the upper member.
THICKNESS: 0 to 125 m.
USES: Upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high-purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production.
AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, $MgSO_4$ = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (A-C) = 122-440.

Shadow Lake Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: The basal unit of the Black River Group. Informally, the formation is known as the basal unit of the Ottawa Group in eastern Ontario and the basal unit of the Simcoe Group in central Ontario.
LITHOLOGY: Poorly sorted, red and green sandy shales; argillaceous and arkosic sandstones; minor sandy argillaceous dolostones and rare basal arkosic conglomerate.
THICKNESS: 0 to 15 m.
USES: Potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: Part of the Black River Group. Informally, the formation is part of the Simcoe Group in central Ontario and the Ottawa Group in eastern Ontario. In eastern Ontario, the formation is subdivided into upper and lower members; in central Ontario, it is presently subdivided into upper, middle and lower members.
LITHOLOGY: In central and eastern Ontario, the lower member consists of alternating units of limestone, dolomitic limestone and dolostone. West of Lake Simcoe, the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone. The upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. The upper member also consists of thin-bedded limestones with thin shale partings.
THICKNESS: 7.5 to 135 m.
USES: Quarried in the Lake Simcoe, Kingston, Ottawa and Cornwall areas for crushed stone. Rock from certain layers has proven to be alkali reactive when used in Portland cement concrete (alkali–carbonate reaction).
AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-17, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (A-C) = 100-153, micro-Deval (C) = 8.8-18.7, mortar bar (14 days) = 0.004-0.030.

Bobcaygeon Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: Informally, the formation is part of the Simcoe Group in central Ontario and the Ottawa Group in eastern Ontario. The formation is subdivided into upper, middle and lower members. Formally, some researchers refer to the lower member as the Coboconk Formation of the Black River Group. The upper and middle members are sometimes referred to as the Kirkfield Formation, a part of the Trenton Group.
LITHOLOGY: The lower member is light grey-tan to brown-grey, medium- to very thick-bedded, fine- to medium-grained, bioturbated to current-laminated, bioclastic limestones, wackestones, packstones and grainstones. The middle member is thin- to medium-bedded, tabular-bedded, bioclastic, very fine- to fine-grained limestones with green shale interbeds and partings. The upper member is similar to the middle member, but also includes fine- to medium-grained, dark grey to light brown, thin- to medium-bedded, irregular to tabular bedded, bioturbated, horizontal to low-angle cross-laminated, bioclastic, fossiliferous limestones, wackestones, packstones and grainstones.
THICKNESS: 7 to 87 m.
USES: Quarried at Brechin, Marysville and in the Ottawa area for crushed stone. Generally suitable for use as granular base course aggregate. Rock from certain layers has been found to be alkali reactive when used in Portland cement concrete (alkali–silica reaction).
AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (A-C) = 100-320.

Verulam Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: The Verulam Formation is often referred to as the Sherman Fall Formation of the Trenton Group. Informally, the formation is part of the Simcoe and Ottawa groups.
LITHOLOGY: The Verulam Formation is informally subdivided into 2 members. The lower member consists of interbedded with limestone and calcareous shale. The limestone beds are very fine to coarse grained, thin to thick bedded, nodular to tabular bedded, light to dark grey-brown and fossiliferous. The upper member is thin- to thick-bedded, medium- to coarse-grained, cross-stratified, tan to light grey, fossiliferous, bioclastic limestone.
THICKNESS: 32 to 67 m.
USES: Quarried at Picton and Bath for use in cement manufacture. Quarried for aggregate in Ramara Township, Simcoe County and in the Belleville–Kingston area. The formation may be unsuitable for use as aggregate in some areas because of its high shale content.
AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (A-C) = 120-255.

Lindsay Formation (Upper Ordovician)

STRATIGRAPHY and/or OCCURRENCE: The Lindsay Formation is divided into 2 members. The lower member is often referred to as the Cobourg Formation of the Trenton Group. The upper member is referred to as the Collingwood Member of the Trenton Group. In eastern Ontario, the Collingwood Member is often referred to as the Eastview Member. Informally, the Lindsay Formation is part of the Simcoe and Ottawa groups.
LITHOLOGY: The lower member is interbedded, very fine- to coarse-grained, bluish-grey to grey-brown limestone with undulating shale partings and interbeds of dark grey calcareous shale. The Collingwood Member is a black, organic-rich, petroliferous, calcareous shale with very thin, fossiliferous, bioclastic limestone interbeds.
THICKNESS: The upper member is up to 10 m thick, whereas the lower member can be up to 60 m thick.
USES: In eastern Ontario, the lower member is used extensively for aggregate production; in central Ontario, it is quarried at Picton, Ogden Point and Bowmanville for

cement. The formation may be suitable or unsuitable for use as concrete and asphalt aggregate.

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

Blue Mountain and Billings Formations (Upper Ordovician)

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

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

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

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

Georgian Bay and Carlsbad Formations (Upper Ordovician)

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

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

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

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

Queenston Formation (Upper Ordovician)

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

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

THICKNESS: 45 to 335 m.

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

Whirlpool Formation (Lower Silurian)

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

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

THICKNESS: 0 to 9 m.

USES: Building stone, flagstone.

Manitoulin Formation (Lower Silurian)

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

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

THICKNESS: 0 to 25 m.

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

Cabot Head Formation (Lower Silurian)

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

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

THICKNESS: 12 to 40 m.

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

Grimsby Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Upper formation of the Cataract Group. The formation has been identified along the Niagara Peninsula as far north as Clappison's Corners.

LITHOLOGY: Interbedded sandstone, dolomitic sandstone and red shale. The lower part of the Grimsby Formation becomes greener and shalier as it grades into the upper Cabot Head Formation.

THICKNESS: 0 to 15 m.

USES: No present uses.

Thorold Formation (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: Lower formation in the Clinton Group.

LITHOLOGY: Grey-green to white, fine- to coarse-grained, quartzose sandstone with minor thin grey to green shale or siltstone partings.

THICKNESS: 2 to 7 m.

USES: No present uses.

Neagha Formation (Lower Silurian)

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

Dyer Bay Formation (Lower Silurian)

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

Wingfield Formation (Lower Silurian)

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

St. Edmund Formation (Lower Silurian)

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

Fossil Hill Formation (Lower Silurian)

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

Reynales Formation (Lower Silurian)

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

Irondequoit Formation (Lower Silurian)

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

Rochester Formation (Lower Silurian)

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

Decew Formation (Lower Silurian)

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

Lockport and Amabel Formations (Lower Silurian)

STRATIGRAPHY and/or OCCURRENCE: The Lockport Formation occurs from Waterdown to Niagara Falls and is subdivided into 2 formal members: the Gasport and Goat Island members. The Amabel Formation is found from Waterdown to Cockburn Island and has been subdivided into the Lions Head and Wiarton members.

LITHOLOGY: The Gasport Member consists of thick- to massive-bedded, fine- to coarse-grained, blue-grey to white to pinkish grey dolostone and dolomitic limestone, with minor argillaceous dolostone. The Goat Island Member is dark to light grey to brown, very fine- to fine-crystalline, thin- to medium-bedded, irregularly bedded, variably argillaceous dolostone with locally abundant chert and vugs filled with gypsum, calcite or fluorite. Near Hamilton, abundant chert nodules and lenses in the Goat Island member have been informally named the Ancaster chert beds. A shaly interval, termed the Vinemount shale, occurs at the top of the Goat Island near and east of Hamilton.

The Wiarton Member consists of massive-bedded, blue-grey mottled, light grey to white, fine- to coarse-crystalline, porous crinoidal dolostone. Underlying the Wiarton Member in the Bruce Peninsula is the Colpoy Bay Member which is browner, finer grained and less fossiliferous than the Wiarton Member. The Lions Head Member consists of light grey to grey-brown, fine-crystalline, thin- to medium-bedded, sparsely fossiliferous dolostone with abundant chert nodules.

THICKNESS: (Lockport and Amabel) 3 to 40 m.

USES: Both formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance.

AGGREGATE SUITABILITY TESTING: PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (A-C) = 100-105.

Guelph Formation (Lower to Upper Silurian)

STRATIGRAPHY and/or OCCURRENCE: Exposed south and west of the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula. The formation is also present in the subsurface of southwestern Ontario.

LITHOLOGY: The formation is tan- to brown-coloured, fine- to medium-crystalline, moderately to very fossiliferous, commonly biostromal to biohermal, sucrosic dolostones. In places, the formation is characterized by extensive vuggy, porous reefal facies of high chemical purity. The Eramosa Member consists of thin- to thick-bedded, tan to black, fine- to medium-crystalline, variably fossiliferous, bituminous dolostone. Locally, the Eramosa Member is argillaceous and cherty.

THICKNESS: 4 to 100 m.

USES: Some areas appear soft and unsuitable for use in the production of load-bearing aggregate. This unit requires additional testing to fully establish its aggregate suitability. The main use is for dolomitic lime for cement manufacture. The formation is quarried near Hamilton and Guelph.

Salina Formation (Group) (Upper Silurian)

STRATIGRAPHY and/or OCCURRENCE: Present in the subsurface of southwestern Ontario; only rarely exposed at surface. In southern Ontario, the succession of evaporates and evaporite-related sediments underlying the Bass Islands and Bertie formations, and overlying the reefal dolostones of the Guelph Formation, have been termed the Salina Formation. In other jurisdictions, this formation is often referred to as the Salina Group.

LITHOLOGY: Grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic-rich material with up to 8 units identifiable. The Salina Group is dominated by evaporate lithologies in the Michigan Basin and become gradually shalier into the Appalachian Basin.

THICKNESS: 113 to 420 m.

USES: Gypsum mines at Hagersville, Caledonia and Drumbo. Salt is mined at Goderich and Windsor and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

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

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

THICKNESS: 10 to 90 m.

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

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

Oriskany Formation (Lower Devonian)

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

LITHOLOGY: Grey to yellowish white, coarse-grained, thick- to massive-bedded, calcareous quartzose sandstone.
THICKNESS: 0 to 5 m.
USES: The formation has been quarried for silica sand, building stone and armour stone. The formation may be acceptable for use as rip rap and well-cemented varieties may be acceptable for some asphaltic products.
AGGREGATE SUITABILITY TESTING: (of a well-cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (A-C) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY and/or OCCURRENCE: The formation disconformably overlies Silurian strata or, where present, the Lower Devonian Oriskany Formation. The Springvale Member forms the lower portion of formation.
LITHOLOGY: Greenish grey to grey-brown, thin- to medium-bedded, fine- to medium-grained, fossiliferous, bioturbated, cherty limestone and dolostone. The Springvale Member is a white to green-brown, commonly glauconitic, rarely argillaceous, quartzitic sandstone with minor sandy carbonates.
THICKNESS: 3 to 50 m. The Springvale Member is generally from 3 to 10 m thick; however, 30 m thickness has been reported.
USES: Quarried at Hagersville, Cayuga and Port Colborne for crushed stone. Material is generally unsuitable for concrete aggregate because of a high chert content.
AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (A-C) = 102-290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Correlated to part of the Detroit River Group. Outcrops occur on the Niagara Peninsula from Simcoe to Niagara Falls. The formation includes the Edgecliffe, Clarence and Moorehouse members.
LITHOLOGY: Medium-bedded, fine- to coarse-grained, dark grey-brown or purplish-brown, variably cherty limestone.
THICKNESS: 8 to 25 m.
USES: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. The high chert content makes much of the material unsuitable for use as concrete and asphaltic aggregate. The formation has been used as a raw material in cement manufacture.
AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliffe members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (A-C) = 190-276.

Amherstburg Formation (Lower to Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Part of the Detroit River Group. The formation correlates to the Amherstburg Formation of Michigan and the lower part of the Onondaga Formation in western New York. The Onondaga Formation terminology has been used in the outcrop belt of southern Ontario east of Norfolk County.
LITHOLOGY: Tan to grey-brown to dark brown, fine- to coarse-grained, bituminous, bioclastic, fossiliferous limestones and dolostone. Stromatoporoid-dominated bioherms are locally significant in Bruce and Huron counties and have been termed the Formosa Reef Limestone or Formosa reef facies.
THICKNESS: 0 to 60 m. The Formosa Reef Limestone is up to 26 m.
USES: Cement manufacture, agricultural lime, aggregate.
AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (A-C) = 105-300.

Lucas Formation (Middle Devonian)

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

Dundee Formation (Middle Devonian)

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

Marcellus Formation (Middle Devonian)

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

Bell Formation (Middle Devonian)

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

Rockport Quarry Formation (Middle Devonian)

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

Arkona Formation (Middle Devonian)

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

Hungry Hollow Formation (Middle Devonian)

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

Widder Formation (Middle Devonian)

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

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY and/or OCCURRENCE: Upper formation of the Hamilton Group; very limited distribution in Ontario.
LITHOLOGY: Grey-brown, fine- to coarse-grained, argillaceous and bioclastic limestone with shaly interbeds.
THICKNESS: 2 to 13 m.
USES: No present uses.

Kettle Point Formation (Upper Devonian)

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

Bedford Formation (Upper Devonian)

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

Berea Formation (Upper Devonian)

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

Sunbury Formation (Lower Mississippian)

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

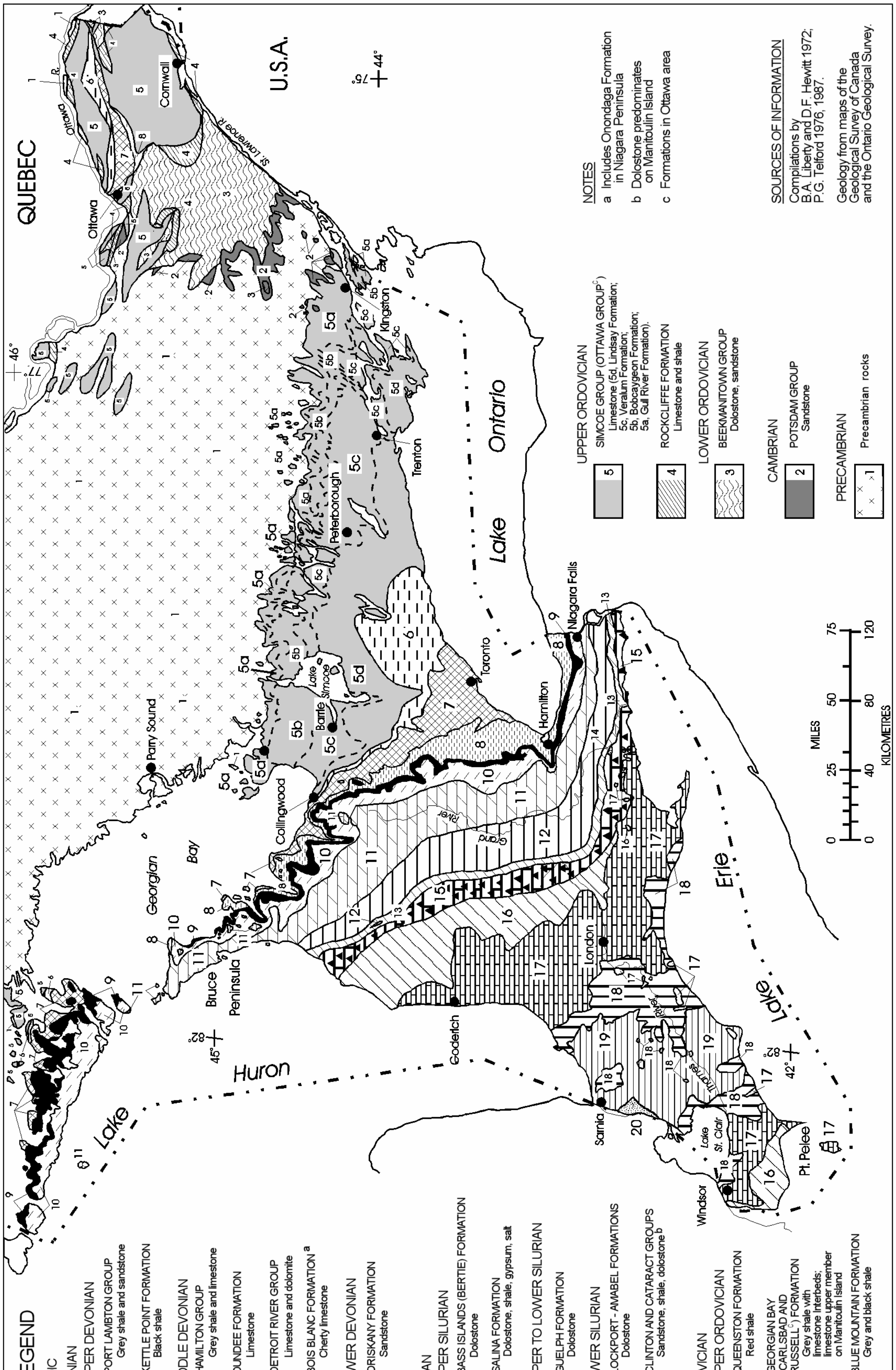


Figure D1. Bedrock geology of southern Ontario.

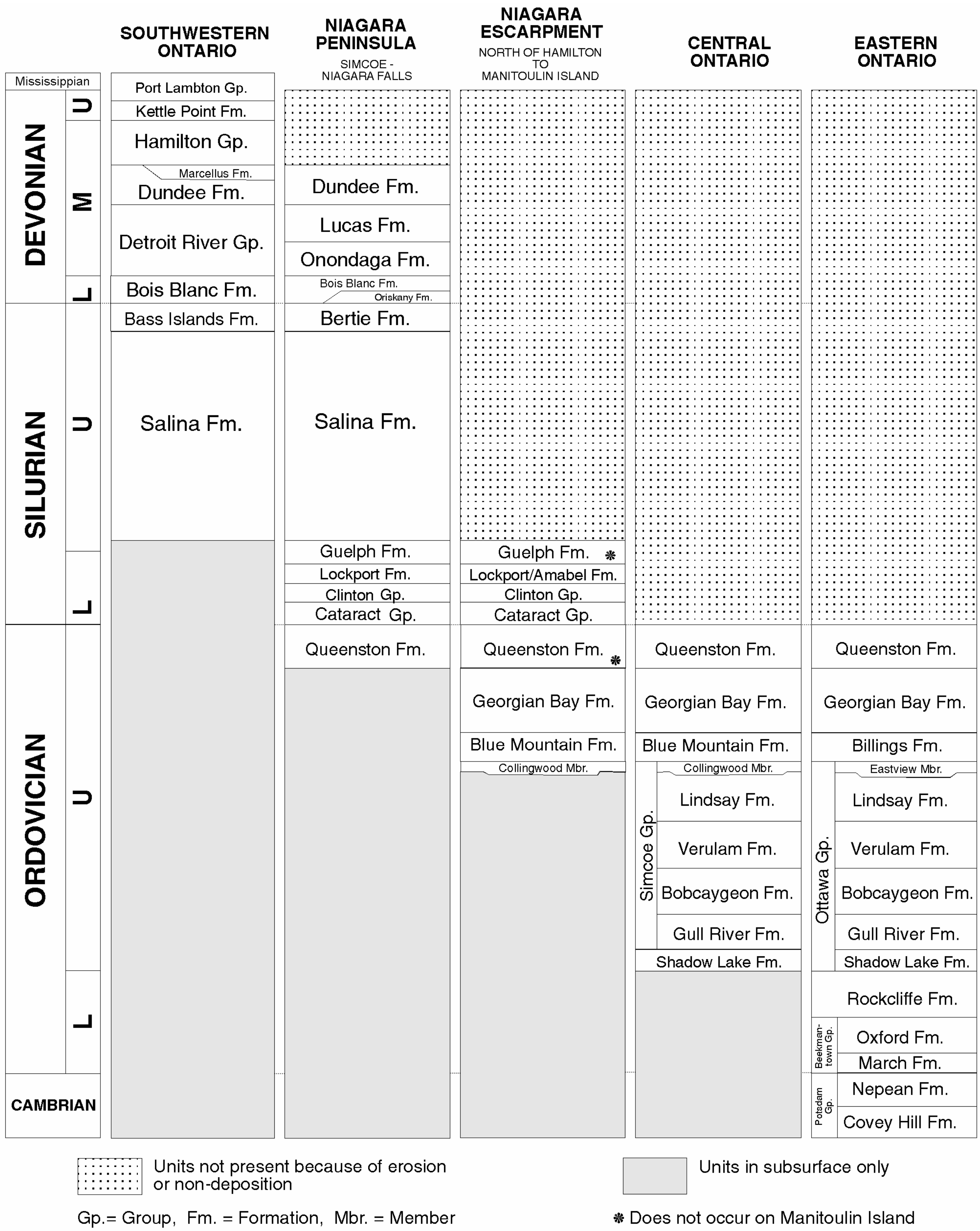


Figure D2. Exposed Paleozoic stratigraphic sequences in southern Ontario (*adapted from* Bezys and Johnson 1988 and Armstrong and Dodge 2007).

Appendix E – Aggregate Quality Test Specifications

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

Absorption Capacity (LS-604): This test is related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate. This test is conducted in conjunction with the determination of the sample's relative density.

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

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

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

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

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

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

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

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

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

MATERIAL SPECIFICATIONS FOR AGGREGATES: BASE AND SUBBASE PRODUCTS

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

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

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

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

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

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

MATERIAL SPECIFICATIONS FOR AGGREGATES: HOT MIX ASPHALT PRODUCTS

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

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

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

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

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

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

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

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

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

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

* Designer fill-in, contact the MTO.

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

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

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

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

MATERIAL SPECIFICATIONS FOR AGGREGATES: CONCRETE PRODUCTS

Table E5. Physical property requirements for coarse aggregate.

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

General Notes:

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

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

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

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

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

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

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

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

Table E6. Physical property requirements for fine aggregate.

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

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

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

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

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

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

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

Metric Conversion Table

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

OTHER USEFUL CONVERSION FACTORS

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

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

ISSN 0708-2061 (print)
ISBN 978-1-4435-8379-4 (print)

ISSN 1917-330X (online)
ISBN 978-1-4435-8380-0 (PDF)

Aggregate Resources Inventory Paper 190

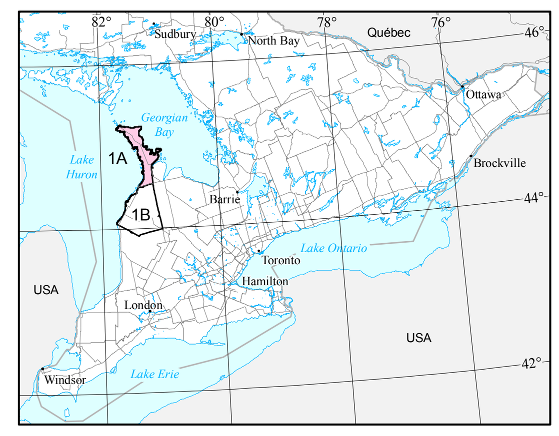
MAP 1A

Sand and Gravel Resources for the County of Bruce

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 41 A/11, 14, 15; 41H/3, 4, 5



Location Map 1 cm equals 80 km

SAND AND GRAVEL RESOURCES

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

SYMBOLS

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

SOURCES OF INFORMATION

Base map information derived from National Topographic System (NTS) maps, Natural Resources Canada, scale 1:50 000, and from the Ontario Land Information Warehouse, Land Information Ontario, Ontario Ministry of Natural Resources, scale 1:50 000, with modifications by staff of the Ministry of Northern Development and Mines.
Projection: North American Datum 1983 (NAD83), Zone 17.

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

Geology based on
- Cowan, W.R., Cooper, A.J. and Pinch, J.J. 1986
- Cowan, W.R. and Pinch, J.J. 1986
- Cowan, W.R. and Sharpe, D.R. 2007b
- Sharpe, D.R. and Edwards, W.A.D. 1979
- Sharpe, D.R. and Jamieson, G.R. 1982

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

Rowell, D.J. 2012. Aggregate resources inventory for the County of Bruce, southern Ontario; Ontario Geological Survey, Aggregate Resources Inventory Paper 190, Map 1A–Sand and Gravel Resources, scale 1:100 000.

Aggregate Resources Inventory Paper 190

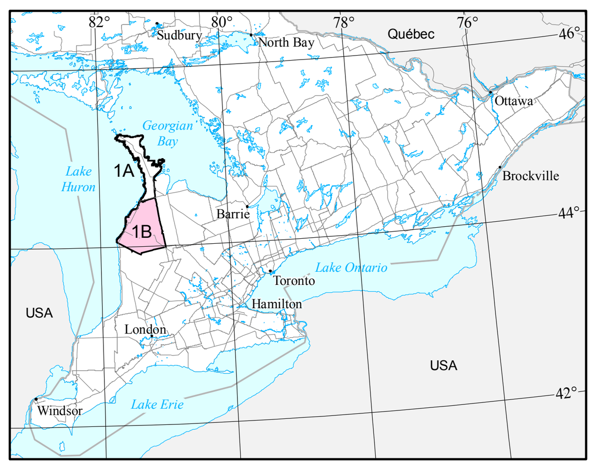
MAP 1B

Sand and Gravel Resources for the County of Bruce

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 40 P/13, 14, 15; 41 A/2, 3, 4, 5, 6, 11



Location Map 1 cm equals 80 km

SAND AND GRAVEL RESOURCES

- Selected Sand and Gravel Resource Area, primary significance; deposit number (*see* Table 3)
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- Borehole location; identification number (*see* Table 7)
- 09DJR-0001 Sample site; identification number (*see* Table 9)
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- Buried geological and aggregate thickness boundary of sand and gravel deposits
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Geology based on
- Cowan, W.R., Cooper, A.J. and Pinch, J.J. 1986
- Cowan, W.R. and Pinch, J.J. 1986
- Cowan, W.R. and Sharpe, D.R. 2007b
- Sharpe, D.R. and Edwards, W.A.D. 1979
- Sharpe, D.R. and Jamieson, G.R. 1982

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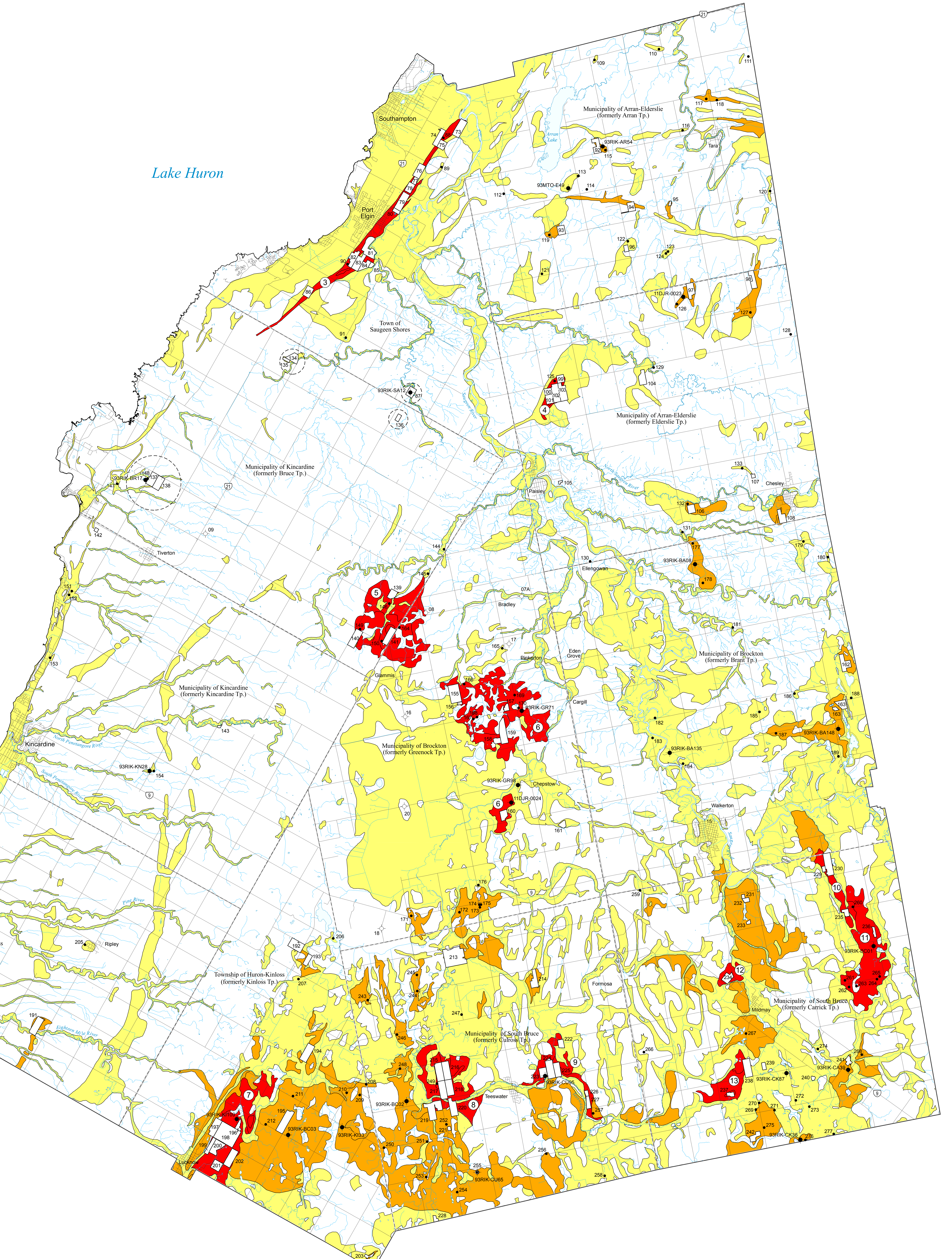
Information from this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form:

Rowell, D.J. 2012. Aggregate resources inventory for the County of Bruce, southern Ontario; Ontario Geological Survey, Aggregate Resources Inventory Paper 190, Map 1B–Sand and Gravel Resources, scale 1:100 000.



Aggregate Resources Inventory Paper 190

MAP 2A

Bedrock Resources for the County of Bruce

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 41 A/11, 14, 15; 41H/3, 4, 5

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).

LEGEND – BEDROCK UNITS

PHANEROZOIC
PALEOZOIC
DEVONIAN
MIDDLE DEVONIAN
Lucas Formation: Dolostone and limestone
Amherstburg Formation: Dolostone and limestone
Bois Blanc Formation: Limestone and dolostone
SILURIAN
UPPER SILURIAN
Bass Islands Formation: Dolostone
Salina Group: A variety of rock units
MIDDLE AND UPPER SILURIAN
Guelph Formation: Dolostone
Eramosa Formation: Bituminous dolostone
Amabel Formation: Dolostone
Clinton and Cataract Groups: Sandstone, shale, limestone and dolostone
ORDOVICIAN
UPPER ORDOVICIAN
Queenston Formation: Red shale

SYMBOLS

- Selected Bedrock Resource Area; deposit number (*see* Table 6)
- Licenced quarry boundary; property number (*see* Table 5)
- Unlicenced quarry (i.e., abandoned quarry or wayside quarry operating on demand under authority of a permit); property number (*see* Table 5).
- Borehole location; identification number (*see* Table 7)
- Sample site; identification number (*see* Table 9)
- Geological formation and/or member boundary
- Drift thickness contour
- Isolated bedrock outcrop
- Administrative boundary

SOURCES OF INFORMATION

Base map information derived from National Topographic System (NTS) maps, Natural Resources Canada, scale 1:50 000, and from the Ontario Land Information Warehouse, Land Information Ontario, Ontario Ministry of Natural Resources, scale 1:50 000, with modifications by staff of the Ministry of Northern Development and Mines.
Projection: North American Datum 1983 (NAD83), Zone 17.

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

Geology based on
Armstrong, D.K. 1993a, 1993b
Armstrong, D.K. and Dodge, J.E.P. 2007
Armstrong, D.K. and Dubord, M.P. 1992
Armstrong, D.K. and Meadows, J.R. 1968

Additional drift thickness information based on
Davies, L.L. and McClymont, W.R. 1962
Hamblin, A.P. 2003
Kelly, R.I. and Carter, T.R. 1993a, 1993b
Sharpe, D.R. 1982
Sharpe, D.R., Hradsky, M. and Farrell, L.E. 1979
Sharpe, D.R., Hradsky, M. and West, L.W. 1979

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Rowell, D.J. 2012. Aggregate resources inventory for the County of Bruce, southern Ontario; Ontario Geological Survey, Aggregate Resources Inventory Paper 190, Map 2A–Bedrock Resources, scale 1:100 000.

Aggregate Resources Inventory Paper 190

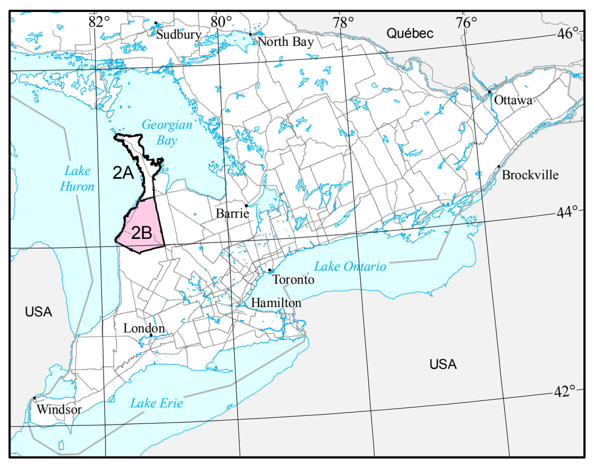
MAP 2B

Bedrock Resources for the County of Bruce

Scale 1:100 000

2000 m 0 2 4 km

NTS References: 40 P/13, 14, 15; 41 A/2, 3, 4, 5, 6, 11



Location Map 1 cm equals 80 km

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).
- 15 — Borehole location; identification number (*see* Table 7)
- WE-01 — Sample site; identification number (*see* Table 9)
- Geological formation and/or member boundary
- Drift thickness contour
- × Isolated bedrock outcrop
- Administrative boundary

LEGEND – BEDROCK UNITS

PHANEROZOIC

PALEOZOIC

DEVONIAN

MIDDLE DEVONIAN

Lucas Formation: Dolostone and limestone

Amherstburg Formation: Dolostone and limestone

Bois Blanc Formation: Limestone and dolostone

SILURIAN

UPPER SILURIAN

Bass Islands Formation: Dolostone

Salina Group: A variety of rock units

MIDDLE AND UPPER SILURIAN

Guelph Formation: Dolostone

Eramosa Formation: Bituminous dolostone

Amabel Formation: Dolostone

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

ORDOVICIAN

UPPER ORDOVICIAN

Queenston Formation: Red shale

SOURCES OF INFORMATION

Base map information derived from National Topographic System (NTS) maps, Natural Resources Canada, scale 1:50 000, and from the Ontario Land Information Warehouse, Land Information Ontario, Ontario Ministry of Natural Resources, scale 1:50 000, with modifications by staff of the Ministry of Northern Development and Mines.
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Geology based on
Armstrong, D.K. 1993a, 1993b
Armstrong, D.K. and Dodge, J.E.P. 2007
Armstrong, D.K. and Dubord, M.P. 1992
Armstrong, D.K. and Meadows, J.R. 1988

Additional drift thickness information based on
Davies, L.L. and McClymont, W.R. 1962
Hamblin, A.P. 2003
Kelly, R.I. and Carter, T.R. 1993a, 1993b
Sharpe, D.R. 1982
Sharpe, D.R., Hradsky, M. and Farrell, L.E. 1979
Sharpe, D.R., Hradsky, M. and West, L.W. 1979

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