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Ontario

Aggregate Resources Inventory of

Huron County

Ontario Geological Survey
Aggregate Resources Inventory
Paper 177

2004

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Contents

FIGURES

TABLES

GEOLOGICAL MAPS

Abstract

This report includes an inventory and evaluation of the sand and gravel, as well as bedrock resources, in Huron County, southwestern Ontario. The report is based on a detailed field assessment of potential aggregate deposits undertaken in the summers of 2000 and 2001 and on previous studies completed in the area. The investigation was conducted to delineate and determine the quality and quantity of aggregate within the area to help ensure that sufficient aggregate resources are available for future use. This report is part of the Aggregate Resources Inventory Program for areas designated under the *Aggregate Resources Act* (ARA) 1989.

In Huron County, 24 areas containing significant resources of sand and gravel have been identified as resource areas of primary significance. In addition, many deposits have been selected as areas with secondary significance. The former townships of Howick, Turnberry, East Wawanosh, Goderich and Colborne in the northern and west–central portions of Huron County are rich in sand and gravel resources. The host geological deposits are outwash spillway channels, fans and eskers. The area south of Goderich, including the former townships of Stanley, Hay, Stephen and Tuckersmith, generally has low potential for sand and gravel. The remainder of the county has moderate aggregate potential with sand and gravel found mostly in eskers, outwash channels and deltas.

In Huron County, the aggregate deposits are suitable primarily for the production of granular products ranging from granular base course to select subgrade material. Most of the samples tested by the Ministry of Transportation (MTO) yield poor results in absorption tests, although aggregate quality appears to improve in the south and southwest parts of the county. Although hot-laid (HL) asphaltic products may be produced from some sites, the deposits are, in general, unsuitable for hot-laid (HL) and other high specification aggregate products. Site-specific testing is highly recommended prior to extraction.

The report area is underlain by Paleozoic dolostones and limestones of Upper Silurian to Middle Devonian age. The bedrock in the report area exhibits wide variations in aggregate quality and is generally overlain by a thick cover of Quaternary sediments. For these reasons, no bedrock resources have been selected for resource protection.

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

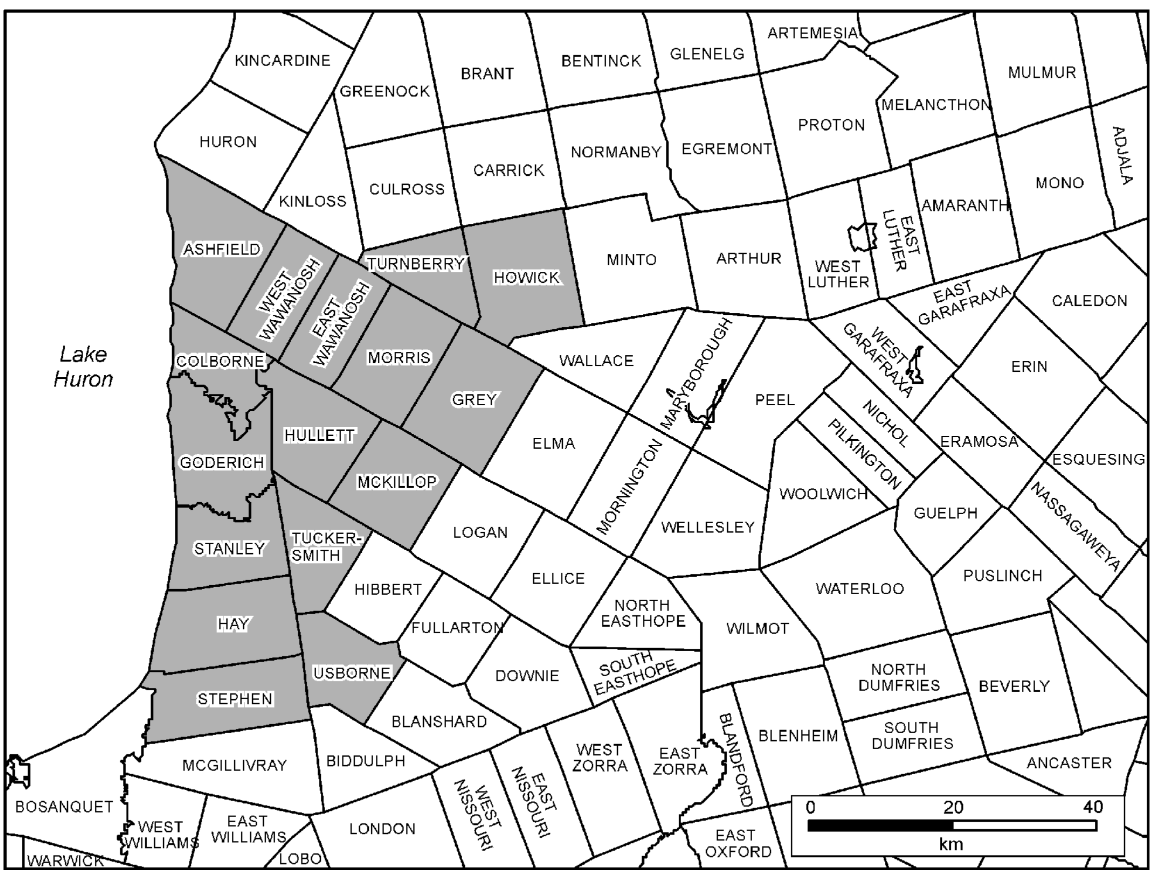

Figure 1. Key map showing the location of the study area.

Aggregate Resources Inventory of Huron County

By Ontario Geological Survey

Project Supervisor: C.L. Baker; field work by C. Gao and assistants; report by C. Gao; compilation and drafting by Staff of the Sedimentary Geoscience Section, Ontario Geological Survey. Assistance with review provided by R.I. Kelly.

Manuscript accepted for publication by C.L. Baker, Senior Manager, Sedimentary Geoscience Section, Ontario Geological Survey, 2004.

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Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 2000, the total tonnage of mineral aggregates extracted in Ontario was 170 million tonnes, greater than that of any other metallic or non-metallic commodity mined in the Province (Ontario Aggregate Resources Corporation 2000).

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.

Part I – Inventory Methods

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 (see References), 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 from records held by the Ontario Ministry of Transportation (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 and test pitting.

Deposits with potential for further extractive development or those where existing data are scarce, were studied in greater detail. Representative sections in these deposits were evaluated by taking 11 to 45 kg samples from existing pit faces or from test pits. The samples were tested for grain size distribution, and in some cases the Los Angeles abrasion and impact test, absorption, magnesium sulphate soundness test and petrographic analyses are carried out. Analyses were performed in the laboratories of the Ontario Ministry of Transportation.

The field data were supplemented by pit information on file with the Geotechnical Section of the Ontario Ministry of Transportation. 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 sources were obtained from records held by Regional, District and Area Offices of the Ontario Ministry of Natural Resources. In addition, reports on geological testing for type, quantity and quality of aggregates were also obtained from numerous aggregate licence applications on file with the MNR, and with specific individuals and companies. The co-operation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are 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, 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 with information taken from maps of the National Topographic System by permission of Natural Resources Canada, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

Sand and Gravel Resources

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 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 17 700 (the density factor). This factor is approximately the number of tonnes in a 1 m thick layer of sand and gravel, 1 ha in extent, assuming an average density of 1770 kg/m^3.

Tonnage = Area x Thickness x Density Factor

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

The Selected Sand and Gravel Resource Areas in Table 3 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 x Column 6 x 17 700), 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 anywhere from 15 to 80% of the resources in an area may be further constrained or not accessible because of such things as environmental considerations (e.g., floodplains, environmentally sensitive areas), lack of landowner interest, resident opposition or other matters.

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.

Bedrock Resources

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. 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).

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).

Units and Definitions

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

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

Part II – Data Presentation and Interpretation

Two map sets, each portraying a different aspect of the aggregate resources in the report area, accompany the report. Map 1, "Sand and Gravel Resources", gives a comprehensive inventory and evaluation of the sand and gravel resources in the report area. There are 4 maps in this set—1A to 1D—covering the northern, northeastern, central and southern areas of Huron County, respectively. Map 2, "Bedrock Resources", shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments and identifies the Selected Bedrock Resource Areas. There are 3 maps in this set—2A to 2C— covering the northern, northeastern and central areas of Huron County, respectively. The southern area has no near-surface (>15 m overburden) Bedrock Resources.

MAP 1: SAND AND GRAVEL RESOURCES

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

The present level of extractive activity is also indicated on Map 1. Those areas which are licenced for extraction under the *Aggregate Resources Act* are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner/operator and licenced hectarage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or pits operating on demand under authority of a wayside permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

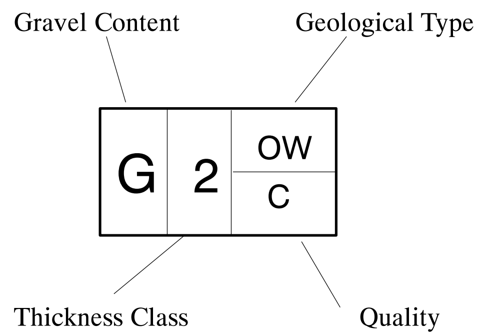
Deposit Symbol

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type) and quality limitations for every deposit shown on Map 1.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35% of the whole deposit. "G" indicates that the deposit contains more than 35% gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

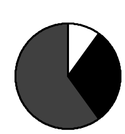
Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C), and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.



For example, the above symbol identifies an outwash deposit 3 to 6 m thick containing more than 35% gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

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 found in 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 30% gravel, 60% sand and 10% silt and clay.



SELECTED SAND AND GRAVEL RESOURCE AREAS

All the Selected Sand and Gravel Resource Areas are first delineated by geological boundaries and then classified into 3 levels of significance: primary, secondary and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by red shading on Map 1.

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 local and Regional/County Official Plans primary, and in some cases resources of secondary significance, are identified and protected.

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

Areas of tertiary significance are indicated by yellow shading. 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.

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

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. Generally, deposits in Class 1 (greater than 6 m thick), 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 symbols. They are: 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 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.

Excess fines (high silt and clay content) 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 known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20% oversize material (greater than 10 cm in diameter) may also have use limitations. The oversize component is unacceptable for uncrushed road base, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. 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. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol 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. 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 MTO 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.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular A and Granular B Type 1; Hot-Laid Asphaltic Sand Nos. 1, 2, 3, 4 and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

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 which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, power lines and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

In addition to man-made and cultural features, certain natural features, such as provincially significant wetlands, may prove to be contraints. 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 constraints, anywhere from a minimum of 15 to 80% of the total resources in a municipality can become inaccessible when these or other specific local constraints are considered (Planning Initiatives Limited 1993).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. Since the approval under the Planning Act of the Mineral Aggregate Resource Policy Statement (MARPS) in the mid 1980s and the Comprehensive Set of Policy Statements, including MARPS, in March 1995, many of the more recently approved local and regional Official Plans now contain detailed policies regarding the location and operation of aggregate extraction activity and should be consulted at an early date in regard to considering 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 MNR, and 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 "market share" of an area will remain roughly at the same level. In most cases, however, the market demand for aggregate products, especially in urban areas, is greater than the amount of production found within the local market area. Consequently, conflicts often arise between the increasing demand for aggregates in such areas and the frequent pressures to restrict aggregate operations, especially in the near urban areas.

The aggregate resources in the region surrounding a project area should be assessed in order to properly evaluate specific resource areas and to adopt 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 high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 2: BEDROCK RESOURCES

Map 2 is an interpretative map 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 Non-Renewable Resources Section (MNR), and from geotechnical test hole data from various sources. Map 2 is based on concepts similar to those outlined for Map 1.

The geological boundaries of the Paleozoic bedrock units are shown by dashed lines. Isolated Paleozoic outcrops are indicated by an "X". 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 shown by 3 shades of grey. The darkest shade indicates where bedrock outcrops is within 1 m of the ground surface. These areas constitute potential resource areas because of their easy access. The medium shade 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 indicates bedrock areas overlain by 8 to 15 m of overburden. These latter areas constitute resources that have extractive value only in specific circumstances, such as when the bedrock has other industrial mineral uses (e.g., chemical lime and metallurgical rock). 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 (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 2 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner/operator, licenced hectarage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 2 and described in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness in metres, is shown beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock, in metres, shown beside it. The test holes may be further described in Table 7.

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. 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.

Selected Resource Areas

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

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

Part III – Assessment of Aggregate Resources in Huron County

LOCATION AND POPULATION

Huron County covers approximately 3402 km^2 and includes portions of the Kincardine (41 A/4), Lucknow (40 P/13), Wingham (40 P/14), Palmerston (40 P/15), Goderich (40 P/12), Seaforth (40 P/11), Grand Bend (40 P/5), St. Marys (40 P/6) and Parkhill (40 P/4) 1:50 000 scale map sheets of the National Topographic System. A recent municipal amalgamation in Huron County reduces the number of township to 9 from 16. In this report and accompanying maps, however, the 16 former geographic townships are used so as to provide a greater degree of geographic detail. The 16 former townships, in a approximately north to south order, are Ashfield, West Wawanosh, East Wawanosh, Colborne, Turnberry, Howick, Morris, Grey, Goderich, Hullett, McKillop, Stanley, Tuckersmith, Hay, Usborne, and Stephen.

The population of Huron County was 60 220 in 1996, an increase of 2% over the 1991 figure; this growth rate is below the 6.6% increase for Ontario for the same period (Statistics Canada 1999). Major population centres in Huron County include the towns of Goderich (7553), Exeter (4472), Clinton (3216), Wingham (2941) and Seaforth (2302). In 1996, of the employed population (29 820), 16.9% were engaged in agriculture (2.4% for Ontario), 16.9% in manufacturing (17.1% for Ontario) and 65.4% in tertiary industries.

Highways 4, 12 and 21 provide the major north–south road access routes within Huron County. The towns of Exeter, Clinton, Wingham are connected by Highway 4. Highway 21 runs parallel with the Lake Huron shoreline, connecting the towns of Grand Bend, St. Joseph, Bayfield, Goderich and Port Albert. Highway 12 connects Seaforth, Brussels and Wroxeter in the inner part of the county. Highways 8 and 86 are the major east–west roads, with Highway 8 connecting the towns of Goderich, Clinton and Seaforth. Highway 86 provides the link between Lucknow to Wingham in the north. In addition to these highways, a network of paved and gravel-surfaced county and township roads provides good access to the interior of the county.

SURFICIAL GEOLOGY AND PHYSIOGRAPHY

Huron County was covered by 2 ice lobes, namely the Huron and Georgian Bay ice lobes. These ice lobes advanced from the west and north, respectively, during the last glaciation (Cooper 1977; Karrow 1977; Cowan 1979; Chapman and Putnam 1984). The study area is divided into 4 major physiographic regions: the Huron Slope; Horseshoe Moraines; Stratford Till Plain; and the Teeswater Drumlin Field (Chapman and Putnam 1984). The first 3 regions trend parallel to the Lake Huron shoreline and occur, respectively, in a west to east order. The Teeswater Drumlin Field occurs primarily in the northeastern part of the county, mainly within Turnberry and Howick townships.

The Huron Slope, a flat to undulating plain, is composed chiefly of the low-stone content St. Joseph Till (Cooper 1977; Cooper and Fitzgerald 1977; Cowan 1986; Cowan, Cooper and Pinch 1986). Glaciolacustrine and beach sand or sand and gravel occurs as thin beds or low ridges on the plain. The aggregate material is shallow and generally does not exceed 6 m in thickness. The beach ridges contain sand and gravel, however, they become increasingly sand rich to the south. In the past, the beach material was extensively extracted for aggregate in Goderich, Hay and Stephen townships. Although a large amount of material has been removed, potential aggregate resources still exist in this type of deposit in Ashfield Township.

The Horseshoe Moraines physiographic region extends in a north-trending belt through Huron County. The region consists of several morainic ridges in the south which connect with the Wawanosh Moraine at Clinton; the feature then continues northward through East and West Wawanosh townships. Large, drainage spillway or meltwater channels occur within the moraines, particularly in Goderich, Colborne, Stanley and Hay townships. The spillway channels tend to contain coarse-grained aggregate in the north and fine-grained sediments in the south. Hence, sand and gravel is found in Goderich and Colborne townships, and sandy material occurs more frequently in the southern townships of Stanley, Hay and Stephen. Calcareous, clayey silt tills, namely the St. Joseph and Rannoch tills, are found in the Wyoming and Wawanosh moraines, respectively. Although present in all the moraines, sorted crevasse or kame sandy or gravelly deposits occur more often in the Wawanosh Moraine.

The Stratford Till Plain lies east of the Horseshoe Moraines and adjoins the Teeswater Drumlin Field to the north. This physiographic region is a rolling to flat till plain that is divided by 3 major morainic ridges lying subparallel to the Lake Huron shoreline. The plain and the moraines consist primarily of Rannoch Till (Cooper, Fitzgerald and Clue 1977; Karrow 1977).

The drumlinized till plain in the northeastern part of Huron County forms the southern half of the Teeswater Drumlin Field. This physiographic region has a larger distribution in Bruce County to the north (Chapman and Putnam 1984). The drumlins are composed primarily of sandy to silty Elma Till, which has a moderate to high stone content. There is a large distribution of outwash sand and gravel between Lakelet Lake in the north and the Maitland River in the south. As a result, Howick Township contains some of the richest aggregate deposits in Huron County.

Eskers occur frequently in the Stratford Till Plain, Wawanosh Moraine and the eastern part of the Teeswater Drumlin Field. They generally trend to either the south or the east, reflecting the general flow directions of the Georgian Bay and Huron ice lobes. Numerous eskers with a south or south-southeast alignment are found in East Wawanosh and Morris townships and in the northeastern part of Grey Township. East-trending eskers are most frequently located in the southern parts of East Wawanosh and Morris townships, and in McKillop and Hullett townships. Large eskers are also located near the northern boundary of Usborne Township. Because of their importance as aggregate sources, many of the large eskers have been mined intensively, and their surface or near surface resources are nearly depleted, particularly in Grey and Morris townships.

Many small to medium-size eskers were found, particularly in forested areas, through aerial photograph interpretation or field investigations. Where possible, these features were examined in the field. In McKillop Township, a buried 5 km long, easterly trending esker was detected on aerial photographs. Subsequent field examination indicated that, although difficult to see on the ground, the esker occurs as low sand or gravel-rich ridges at certain localities.

Fans or fan deltas deposited in subaqueous or subaerial conditions were identified within the morainic complex in East Wawanosh and Howick townships through field investigations. Some of the fans display kettles (formed in a dead-ice environment) at the fan heads and steep slopes at the edges, suggesting ice-proximal and ice-walled conditions. These geological entities often stand above the surrounding landscape and contain a substantial thickness of relatively consistent, high-quality sand and gravel. They are, therefore, important aggregate sources. Further detailed studies of these glaciofluvial deposits may yield new aggregate sources.

SAND AND GRAVEL EXTRACTIVE ACTIVITY

The sand and gravel deposits within Huron County are shown on the Map 1 set that accompanies this report. Sand and gravel deposits occupy a total of approximately 92 019 ha and contain an original resource of 5847 million tonnes (Table 1).

In Huron County, 604 sand and gravel pits have been identified. Most of these are situated in esker, glaciofluvial outwash, ice-contact and glaciolacustrine beach deposits. At the time of investigation, 163 pits were licenced for operation under the Aggregate Resources Act. Grey and Goderich townships have the most licenced pits: 27 and 26, respectively. The total area occupied by the licences is 3888.1 ha. In general, many of the pits are small operations capable of meeting local demands for low-specification aggregate. The average annual production for the period from 1992 to 2000 for Huron County was 2.7 million tonnes (Ontario Aggregate Resources Corporation 2000). Many of the unlicenced pits have been abandoned and are overgrown. Pit locations are shown on Map 1 and descriptions are presented in Table 2.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Many of the sand and gravel deposits of the study area have limited potential for extraction because of the restricted amount of aggregate they contain and, in places, the poor quality of the material. Consequently, only the most significant sources have been selected for possible resource protection. At the primary level of significance, 24 sand and gravel resource areas have been selected. These deposits contain aggregate resources considered suitable for the production of a variety of Granular Base and sub-base products such as Granular A and B. The selected sand and gravel resource areas of primary significance occupy a total of 4884.6 ha. Cultural constraints and previous extraction reduce the area currently available to 3831.8 ha. The selected areas contain possible sand and gravel resources of approximately 413.6 million tonnes. The sand and gravel deposits selected as primary resource areas are shown on Map 1. Details regarding these resource areas are presented in Table 3.

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 consists of a glaciofluvial outwash deposit situated between the Wyoming and Wawanosh moraines in Goderich Township (Map 1C). The resource area forms part of a flat-bottomed spillway valley that has a width of about 2 km (Cooper and Fitzgerald 1977). At the time of field investigation, 15 licenced pits were present within the resource area, most of which were in active production.

Within this selected resource area, 2 to 5 m pit faces, exposed above the water table, reveal well-sorted gravel and sand with massive to near horizontal bedding structures. Interbedded lenses of sand or pebbly sand are common. Most of the deposit occurs below the water table and, as a result, extraction by dragline is common. Near-surface till layers are occasionally encountered, particularly in the northern part of the resource area. For example, in the eastern part of Pit 399, clay-rich till with a low stone content occurs near the surface. In the deposit, water wells indicate sand and gravel thicknesses of up to 26 m.

Observed gravel content in the deposit ranges from 20 to 70% with an estimated overall average of 40% for the resource area. Field observations indicate that the deposit contains hard and durable clasts and should be suitable for the production of various granular products ranging from Granular Base course to Select Subgrade Material (SSM), provided that oversized clasts are removed or crushed.

A sample collected from a stockpile in Pit 404 yielded PN values of 131 for granular material and 174 for hot mix and asphalt; absorption losses were 2.18% (Table 9; Figures 2A and 2B). Previous MTO testing of the pit material returned PN values ranging from 128 to 216 for hot mix and asphalt, and absorption and magnesium sulphate soundness losses for coarse aggregate of 1.84 to 2.64% and 2.4 to 13.6%, respectively. These test results indicate that some samples are beyond the MTO specifications for HL4 products. Further testing is required to assess the suitability of the coarse portion of the deposit for HL products at specific locations.

Selected Sand and Gravel Resource Area 1 has an areal extent of 773.2 ha. Previous extraction and cultural setbacks reduce the area to 694.7 ha. Assuming an average thickness of 6 m, the possible aggregate resource of this deposit is estimated to be 73.8 million tonnes.

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 consists of a glaciofluvial outwash deposit located in the southern part of Colborne Township (Map 1A). The deposit is positioned in a flat area between the Maitland River to the south and morainic ridges to the north.

Pits in the deposit expose 3 to 9 m sections that reveal primarily stratified gravel and sand. In Pit 139, 8 to 9 m sections show a coarsening-upward sequence from horizontal to cross-bedded sand and gravel overlain by, massive to faintly stratified, clast-supported coarse gravel. To the east in Pit 140, 3 to 5 m sections reveal gravel and sand with massive to horizontal bedding structures. The sedimentary assemblages suggest that the cross-bedded sand and gravel in the lower part of the sequence may be foreset beds deposited in a delta or fan delta. The upper part of the sequence, resembles that of a gravel-rich braided river regime (e.g., Williams and Rust 1969), and may represent a river mouth bar complex resulting from the rivers progradation over the delta topset beds.

Gravel content in the pits was observed to range from 40 to 70%; an overall average of 50% is estimated for the resource area. Field examination indicates that the deposit contains good quality gravel suitable for the production of various granular products. Potential products range from Granular Base course to Select Subgrade Material, provided that oversized clasts are removed or crushed. Previous MTO testing indicates that some samples meet MTO specifications for HL8 hot-mix products based on PN values (range of 117 to 177) and abrasion testing (range of 27 to 36%); however, all samples exhibit excessive losses (2.2 to 2.58%) in the absorption test. Based on the test results, the deposit is not suitable for high specification aggregate products.

Selected Resource Area 2 has an areal extent of 226.9 ha. Previous extraction and cultural setbacks reduce the potential area to 178.5 ha. Assuming an average thickness of 7 m, the possible aggregate resource of this deposit is estimated to be 22.1 million tonnes.

Selected Sand and Gravel Resource Area 3

The glaciofluvial outwash deposit of Selected Sand and Gravel Resource Area 3 is located near Lakelet Lake in the northern part of Howick Township (Map 1B). The deposit forms part of an outwash spillway system mapped by Chapman and Putnam (1984) and Cowan, Cooper and Pinch (1986). There are 4 licenced and unlicenced pits in the resource area, none of which were active at the time of field investigation.

Sections of 3 to 8 m exposed in pits, road cuts and a lake bluff are composed of clast-supported, massive to weakly stratified coarse gravel. Cobbles are common. Observed gravel content in the deposit ranges from 50 to 80% and an overall average of 60% is estimated for the resource area.

Field observations suggest that the deposit is characterized by hard and durable clasts and should be suitable for the production of various granular products provided that oversized clasts are removed or crushed. Previous tests completed by MTO indicate excessively high absorption losses (2.84 to 3.01%), although the PN values for hot mix and asphalt (range 137 to 145) meet the MTO specification for HL4 hot mix products. Based on previous test results, the deposit is not recommended for the production of high specification aggregate products.

Selected Sand and Gravel Resource Area 3 has an areal extent of 682.7 ha. Previous extraction and cultural setbacks reduce the area to 516.4 ha. Assuming an average thickness of 6 m, the possible aggregate resource of this deposit is estimated to be 54.8 million tonnes.

Selected Sand and Gravel Resource Area 4

The glaciofluvial outwash deposit of Selected Sand and Gravel Resource Area 4 is located in the southwestern part of Howick Township (Map 1B) and exhibits a slightly hummocky to nearly level surface topography. The deposit was probably formed in an outwash fan or fan delta environment. A southeast-trending esker situated to the northwest of the deposit (see Map 1B), may have acted as the feeder system for the deposit.

Pit faces of 5 to 7 m consist of clast-supported gravel and sand with massive to near horizontal bedding structures. Test holes completed within the deposit reveal the presence of mainly sand-rich material at depth, as well as an increasingly higher percentage of sand to the south and southeast. The northern part of the deposit displays a hummocky surface topography. An exposure within this part of the resource area reveals a sequence of thick, coarse gravel and sand layers with frequent cobbles in the coarse gravel bed. In Pit 220, a 1.5 m thick layer of silt-rich diamicton caps the sequence. The observed gravel content varies from 10 to 75% in the pits and test holes, and an overall average of 45% is estimated for the resource area.

Field observations suggest that the deposit is characterized by hard and durable gravel clasts and should be suitable for the production of various granular products ranging from Granular Base course and Select Subgrade Material. Any oversized clasts present in the deposit would require removal or crushing. Previous MTO tests indicate that all samples failed to meet the specifications for HL hot mix products in sulphate soundness (15.5 to 23.1%), and

Tonnage estimates for deposit types in Selected Sand and Gravel Resource Area 5.

Deposit Type	Unlicenced Area (ha)	Cultural Setbacks (ha)	Extracted Area (ha)	Possible Area (ha)	Estimated Thickness (m)	Possible Resources (million tonnes)
Fan	101	4.5	0.5	96	6	10.2
Eskers (3)	52.0	2.75	5	47.3	6	5.0
Ice-contact terrain units (2)	29.0	1.75	1	26.3	6	2.8
Total	182.1	9	3.5	169.6		18.0

absorption (2.71 to 3.01%) tests. However, some samples have satisfactory PN values (148 to 170) for lower specification hot mix and asphalt products. Based on the test data, the deposit is not suitable for the production of high specification aggregate products.

Selected Resource Area 4 has an areal extent of 162.1 ha. Previous extraction and cultural setbacks reduce the area to 127.6 ha. Assuming an average thickness of 7 m, the possible aggregate resource is estimated to be 15.8 million tonnes.

Selected Sand and Gravel Resource Area 5

Selected Sand and Gravel Resource Area 5 is situated in the southern part of East Wawanosh Township (Map 1A). The resource area comprises an outwash fan, 3 eskers and 2 ice-contact deposits located in the Wawanosh moraine. At the time of field investigation, 5 unlicenced and 2 licenced pits were present within the resource area. None of the pits were active.

The outwash fan has a near-level surface topography that dips gently to the southeast. The western edge of the fan displays a very steep face with slopes of up to 60°. Kettle holes (formed in a dead-ice environment) of several metres depth and up to 10 m in diameter occur in the western and northern parts of the fan. The morphological features suggest that the western and northern parts of the fan were ice proximal and probably ice-walled during deposition of the sediments. Several shallow test holes were completed across the fan and revealed the presence of massive, clast-supported, coarse gravel and sand with cobbles in the western and northern parts of the fan. The deposit fines to the southeast where sand and pebbly sand is common. Gravel content ranges from 20 to 80% in the pits and test holes, and an overall average of 50% is estimated for the fan.

The 3 eskers have relief of 5 to 10 m and trend at right angles or parallel to the fan. Extraction in the eskers has been limited and most of them remain intact. Pit sections and shallow test holes dug in the eskers show sorted gravel and sand with gravel content ranging from 30 to 70%. The overall gravel percentage is estimated to be 40%.

The ice-contact deposits have a hummocky surface topography with variation in relief caused by small ridges and depressions. The northernmost deposit is almost entirely covered by licenced Pit 76. The southern ice-contact deposit is situated in a lowland area. As observed in road cuts and test holes, both ice-contact deposits are characterized by coarse gravel and sand. A water well at the East Wawanosh Township landfill indicates up to 10 m of gravel and sand. An overall average of 50% gravel is estimated for the deposits.

Field observations suggest that this resource area contains hard and durable gravel clasts and should be suitable for the production of various granular base and sub-base products provided that the oversized clasts are removed or crushed. Adequate amounts of crushable gravel may be a problem in the distal part of the outwash fan deposit and sand control may be required. Previous MTO testing of a single sample collected from the large esker in the north part of the resource area provided a petrographic number value and sulphate soundness test results that meet the MTO specifications for HL products. However, further testing is necessary to assess the deposits as to their suitability for high specification aggregate products.

The tonnage for each individual deposit within the resource area is listed above. The total areal extent is 182.1 ha and, after removing areas of previous extraction as well as cultural and physical constraints, the available area is 169.6 ha. Assuming an average thickness of 6 m, the possible aggregate resource is estimated to be 18 million tonnes for Selected Sand and Gravel Resource Area 5.

Selected Sand and Gravel Resource Area 6

The glaciofluvial outwash deposits of Selected Sand and Gravel Resource Area 6 contain 3 subareas (6a, 6b and 6c) that occur in east-central and southern Howick Township (Map 1B). The deposits have a flat to gently rolling surface topography and form part of an outwash spillway channel system mapped by Chapman and Putnam (1984) and Cowan, Cooper and Pinch (1986). Four licenced and unlicenced pits were present in the resource area at the time of field investigation, however, none were active.

In subareas 6a and 6c, 4 to 6 m pit sections reveal clast-supported gravel and sand with massive to roughly horizontal bedding structures. Water well records indicate that sand and gravel deposits can reach 10 to 15 m in thickness in these subareas. Cobbles are common in subarea 6c. Gravel content observed in exposed sections varies from 50 to 70% and an overall average of 60% is estimated for subareas 6a and 6c.

In subarea 6b, sections exposed in pits and road cuts consist primarily of well-sorted, interbedded sand, pebbly sand and gravel. The 8 to 10 m pit faces in Pit 217 show a fining-upward sequence from sandy gravel to sand and pebbly sand. At the northeastern corner of the pit, the sequence is capped by a massive, 2 to 4 m thick, coarse gravel layer. Water wells in the area indicate deposits of sand and gravel up to 18 m in thickness. The gravel content varies between 10 and 70% in the pits and road cuts, and an overall average of 40% is estimated for subarea 6b.

Field observations suggest that the deposits in all subareas are characterized by hard and durable gravel clasts and should be suitable for various products ranging from Granular Base course to Select Subgrade Material provided that any oversized clasts are removed or crushed. MTO has conducted some quality testing of samples in subarea 6b. Results indicate that some samples failed to meet MTO specifications for HL products due to high PN values (156 to 168) and excessive absorption and sulphate soundness losses (0.86 to 2.87% and 11.6 to 17.2%, respectively). Further testing is required in all subareas to assess the suitability of the coarse aggregate fraction for HL products.

The areal extent for each of the subareas is shown in Table 3. Previous extraction and cultural setbacks reduce the potentially available area for each of the subareas 6a, 6b and 6c to 110.2, 135.9 and 95.3 ha, respectively. Assuming an average thickness of 6 m, the possible aggregate resources are estimated to be 11.7, 14.4 and 10.1 million tonnes for each of subareas 6a, 6b and 6c, respectively. The total possible aggregate resource is, therefore, estimated to be 36.3 millions tonnes for Selected Sand and Gravel Resource Area 6.

Selected Sand and Gravel Resource Area 7

The glaciofluvial outwash deposit of Selected Sand and Gravel Resource Area 7 comprises 2 subareas, 7a and 7b, as shown on Map 1A. Subarea 7a is located east of the Wawanosh moraine in the northeastern corner of West Wawanosh Township, whereas subarea 7b occurs along the eastern bank of the Maitland River in the northern part of East Wawanosh Township.

In subarea 7a, the surface topography shows slightly variable relief caused by small depressions and mounds. The area surrounding the subarea is generally flat lying with a gentle dip to the southeast. The deposit likely accumulated in an outwash fan-like environment with feeder streams located to the west and northwest.

In subarea 7a, 8 to 10 m pit faces exposed in Pit 35 show a fining-upward sequence of massive to horizontally stratified gravel and sand. The uppermost part of the sequence consists mainly of sand and pebbly sand. Within this subarea, sediments fine to the southeast as evidenced by the predominance of sand and pebbly sand in the southern part of Pit 35. In Pit 33, which was inactive at the time of field investigation, 8 to 10 m faces expose massive to cross-bedded, coarse gravel and sand. Occasional distortion of bedding structures and some silt in the matrix were also noted. Gravel content in the pits ranges from 25 to 75% and an overall percentage of 60% is estimated for subarea 7a.

Subarea 7b has a nearly flat surface and forms part of an outwash spillway channel system mapped by Chapman and Putnam (1984) and Cowan, Cooper and Pinch (1986). The 4 to 7 m faces in Pit 71 reveal clast-supported coarse gravel and sand with massive to roughly horizontal bedding structures. Occurrences of cross-bedded sand and pebbly sand were noted. Gravel content in the pit ranges from 45 to 55% and an overall average of 50% is estimated for subarea 7b.

Field observations suggest that the deposits in the 2 subareas are characterized by hard and durable gravel clasts and should be suitable for the production of various granular products ranging from Granular Base course to Select Subgrade Material provided that any oversized clasts are removed or crushed. In subarea 7a, numerous samples tested by MTO show consistent values of 22.3 to 29.3% and 1.6 to 2.8% in the Los Angeles abrasion and absorption tests, respectively. As well, PN values for samples range from 131 to 175 for hot-mix and asphalt. These test results indicate that some samples fail to meet MTO specifications for HL products based on petrographic number and absorption losses. Further testing is necessary to assess the suitability of the deposit for HL products.

In subarea 7b, available data from 2 samples tested by MTO indicate that the absorption losses are over 2% and PN values range from 150 to just below 200 for hot-mix and asphalt. Based on the test results, subarea 7b is not recommended for the production of high specification aggregate products because of the poor absorption test results.

After the removal of previously extracted areas and cultural and physical constraints, the areal extents for subareas 7a and 7b are reduced to 53.6 and 79.7 ha, respectively. Assuming an average thickness of 8 and 6 m for subareas 7a and 7b, respectively, the possible aggregate resources are estimated to be 7.6 and 8.5 million tonnes, respectively. The total possible aggregate resource is, therefore, estimated to be 16.1 million tonnes for Selected Sand and Gravel Resource Area 7.

Selected Sand and Gravel Resource Area 8

The glaciofluvial outwash deposit of Selected Sand and Gravel Resource Area 8 occurs within the northwestern corner of Howick Township (Map 1B). The resource area appears to represent the remnants of an outwash deposit situated in a spillway (Chapman and Putnam 1984; Cowan, Cooper and Pinch 1986). The deposit is marked by irregular surface topography that is likely the result of post-depositional erosion processes.

Pit faces of 8 to 10 m exhibit massive, clast-supported, coarse gravel and sand with frequent occurrences of cobbles and boulders. Lenses of cross-bedded sand occur on occasion. Gravel content in Pit 211 ranges from 60 to 70% and an overall average of 60% gravel content is estimated for Selected Sand and Gravel Resource Area 8.

Field observations suggest that the deposit is suitable for various granular products, including Granular Base course and Select Subgrade Material, provided that the oversized clasts are removed or crushed. Previous MTO quality tests indicate that some samples fail to meet MTO specifications for HL or asphaltic products. These samples have PN values ranging from 148 to 168 and all yield excessive absorption losses (2.21 to 2.47%). The test results suggest that the deposit is not suitable for high specification aggregate products.

Selected Sand and Gravel Resource Area 8 has an areal extent of 67.8 ha and when previous extraction and cultural setbacks are considered the potential area is reduced to 65.8 ha. Assuming an average thickness of 8 m, the possible aggregate resource of this deposit is estimated to be 9.3 million tonnes.

Selected Sand and Gravel Resource Area 9

Selected Sand and Gravel Resource Area 9 consists of a glaciofluvial outwash deposit situated in southeastern Ashfield Township (Map 1A). The deposit forms part of a spillway channel system mapped by Chapman and Putnam (1984) and Cowan, Cooper and Pinch (1986). The surrounding area exhibits a flat surface topography that dips gently to the southwest. At the time of field investigation, 4 licenced and unlicenced pits were present in the deposit, none of which were active.

Pit sections ranging from 5 to 10 m in height reveal clast-supported gravel and sand with massive to roughly horizontal bedding structures. The deposit coarsens northward and, in Pit 24, an exposed 6 m face is dominated by coarse gravel with abundant cobbles. In Pit 5, an exposed 10 m section in the north pit face reveals a lower cross-bedded unit of fine gravel and sand overlain by an upper unit of massive, coarse gravel in channel-like troughs of 4 to 5 m depth. Gravel content in the pits ranges from 70 to 80% and an overall percentage of 70% is estimated for Selected Sand and Gravel Resource Area 9.

Field observations suggest that the deposit should be suitable for various granular products provided that oversized clasts are removed or crushed. Previous MTO testing indicated that samples met MTO specifications for HL4 products. Petrographic numbers range from 122 to 158 and soundness losses are between 3.7 and 4.3%. Although some samples showed excessive losses in absorption tests (1.6 to 2.2%), the quality of the coarse aggregate appears to improve to the south in Pit 5 where absorption losses are in the lower half of the above noted value range (1.6 to 1.73%). This latter range of absorption values meets MTO specifications for HL 4 products.

Selected Sand and Gravel Resource Area 9 has an areal extent of 140.6 ha. Previous extraction and cultural setbacks reduce the potential area to 106.1 ha. Assuming an average thickness of 6 m, the possible aggregate resource of this deposit is estimated to be 11.3 million tonnes.

Selected Sand and Gravel Resource Area 10

Selected Sand and Gravel Resource Area 10 comprises a series of south- to southeast-trending eskers and kames located in the eastern part of Howick Township (Map 1B). Due to the number of eskers and kames, the resource area has been divided into a series of subareas labelled 10a through 10d. At the time of field investigation, 8 licenced and unlicenced pits were located within the resource area.

Subarea 10a consists of a large, south-trending esker. Pit faces of 6 to 10 m reveal clast-supported coarse gravel and sand with massive to stratified bedding. The sequence coarsens upward from interbedded sand and gravel in the lower part to massive-bedded coarse gravel and cobbles in the upper. The gravel content ranges from 60 to 70% in the pits and road cuts, and an overall average of 60% is estimated for subarea 10a.

Subarea 10b is a composite of kame and south- to southeast-trending esker deposits. Pit faces of 10 to 15 m in the kame consist of interbedded stratified sand and massive-bedded coarse gravel. Sand and pebbly sand occur primarily in the upper part of the section and cobbles and boulders are common in the lower part. Three to 12 m pit sections in the eskers consist predominantly of sand and pebbly sand with interbedded gravel layers. The gravel content ranges from 20 to 70% in the pits and road cuts, and an overall average of 40% is estimated for subarea 10b.

Subarea 10c consists of a south- to southeast-trending esker with relief of 5 to 12 m and a length of about 1 km. Due to the poor road access, only limited extraction has occurred and, as a result, the majority of the esker remains intact. Pit sections of 6 to 8 m and shallow test holes show clast-supported coarse gravel and sand with massive to stratified bedding. Gravel content in Pit 253 and test pits ranges from 50 to 70%, with an overall percentage of 40% estimated for subarea 10c.

Subarea 10d comprises a kame–esker system. A small, south- to southeast-trending esker with pit faces of 10 to 12 m has been largely mined out. Parallel or subparallel to the esker are broad kame ridges 6 to 15 m high and 50 to 200 m wide at the base. The kame ridges located west of the esker are gravel-rich deposits. Sections of 3 to 6 m in an inactive pit (230) exhibit sand and pebbly sand overlain by clast-supported coarse gravel and sand with massive-bedding structures. The kame ridge situated east of the esker, along the township road known as Malcolm Line, is composed of sand and pebbly sand with pockets of gravel. The overall average gravel content is estimated to be 40% for subarea 10d.

Field observations suggest that deposits in the resource area should be suitable for various granular products ranging from Granular Base course to Select Subgrade Material provided that oversized clasts are removed or crushed. Adequate amounts of crushable material may be a problem at some localities and sand control may be necessary for the production of Granular A and M products.

MTO conducted some aggregate suitability testing on samples from subareas 10a and 10b. One test sample from subarea 10a returned a PN value of 130 for hot mix and asphalt, and percentage losses of 14% and 2.6% for coarse aggregate in magnesium sulphate soundness and absorption tests, respectively. Three samples were tested in subarea 10b and the results indicate PN values ranging from 132 to 170 for hot mix and asphalt, and sulphate soundness and absorption losses of 15.4 to 23% and 2.77 to 3.38%, respectively, for coarse aggregate. Based on these results, the samples failed to meet MTO specifications for HL products in absorption and soundness tests. While the material from subareas 10a and 10b is not suitable for high specification aggregate products, further testing is required to assess the potential of subareas 10c and 10d to produce HL products.

After deducting previously extracted areas and cultural setbacks, subareas 10a, 10b, 10c and 10d have areal extents of 10, 30.4, 11.3 and 24.6 ha, respectively. Assuming an average thickness of 8 m for the former 2 subareas, the possible aggregate resources are estimated to be 1.4 and 4.3 million tonnes for subareas 10a and 10b, respectively. A conservative depth of 6 m is used for subareas 10c and 10d and the possible aggregate resources are estimated to be 1.2 and 2.6 million tonnes, respectively. The total aggregate resource is, therefore, estimated to be 9.5 million tonnes for Selected Sand and Gravel Resource Area 10.

Selected Sand and Gravel Resource Area 11

Selected Sand and Gravel Resource Area 11, subdivided into subareas 11a and 11b, is located in Colborne Township (Map 1A). Both subareas occur within part of an outwash spillway system mapped by Cooper and Fitzgerald (1977), Chapman and Putnam (1984) and Cowan, Cooper and Pinch (1986).

Situated between Sharpes Creek and the Maitland River, subarea 11a has a near-level surface topography. At the time of field investigation, 7 licenced sand and gravel pits were located within the subarea; most were inactive. Pit faces of 7 to 12 m reveal light greyish, clast-supported gravel and sand with massive to near horizontal bedding structures. Since post-depositional erosion is stronger near the river, it is suggested that the deposit decreases in thickness to the east.

Subarea 11b has an areal extent of 75.8 ha and exhibits a near-level surface topography. The northern part of the deposit extends into Ashfield Township. Pit faces of 10 to 12 m are dominated by clast-supported coarse gravel and sand with massive to near horizontal bedding structures. Cobbles are common within the deposit. On occasion, cross-bedded fine-textured gravel and sand beds occur in the lower part of the sections. The sedimentary assemblages resemble those of a gravel bed form or bar complex in a braided river regime (e.g., Miall 1985; Gao et al. 2000). Similar gravel and sand deposits also occur to the south in an area within the spillway that extends from the western boundary of subarea 11a to the Maitland River.

Within Selected Sand and Gravel Resource Area 11, the gravel content in pit exposures ranges from 50 to 75%. An overall percentage of 60% gravel is estimated for the resource area. Field observations suggest that both subareas contain materials that should be suitable for various granular products provided that oversized clasts are removed or crushed. Previous MTO testing indicates that the petrographic number and soundness results meet MTO specifications for HL8 products. However, the absorption losses in some samples exceed the maximum of 2% allowed for HL products. Further testing at specific localities is necessary to assess the suitability of the deposits for HL products.

After deducting previously extracted areas as well as cultural and physical constraints, the areal extents of subareas 11a and 11b are 187.5 and 66.1 ha, respectively. Assuming an average thickness of 6 m, the possible aggregate resources are estimated to be 19.9 and 7 million tonnes for the 2 subareas. The total aggregate tonnage is, therefore, estimated to be 26.9 million tonnes for Selected Sand and Gravel Resource Area 11.

Selected Sand and Gravel Resource Area 12

Selected Sand and Gravel Resource Area 12, designated as subareas 12a and 12b, consists of a glaciofluvial outwash deposit located in southern Turnberry Township (Map 1B). The deposit is part of an outwash spillway system mapped by Chapman and Putnam (1984) and Cowan, Cooper and Pinch (1986). The areas were also selected in an earlier investigation of aggregate resources of the township (Fraser 1976).

Within the 2 subareas, 2 to 7 m pit and road-cut sections reveal primarily clast-supported gravel and sand with massive to approximately horizontal bedding structures. Data from water wells indicate sand and gravel of up to 10 m in thickness in the resource area. The gravel content ranges from 25 to 80% in the pits and an overall average of 50% is estimated for both subareas.

Field observations suggest that the deposit is characterized by hard and durable gravel clasts and should be suitable for various granular products ranging from Granular Base course to Select Subgrade Material provided that oversized clasts are removed or crushed. For Granular A and M products, the percentage of crushable material may pose a problem and sand control may be required at some localities.

After deducting areas previously extracted, as well as cultural and physical constraints, the areal extents for subareas 12a and 12b are 228.8 and 145.9 ha, respectively. Assuming an average thickness of 6 m, the possible aggregate resource is estimated to be 24.3 and 15.5 million tonnes for each of the subareas. The total possible aggregate resource for Selected Sand and Gravel Resource Area 12 is therefore estimated to be 39.8 million tonnes.

Selected Sand and Gravel Resource Area 13

Selected Sand and Gravel Resource Area 13 consists of a series of east-trending eskers and kame deposits, designated as subareas 13a, 13b and 13c, located in the central part of McKillop Township (Map 1C). At the time of field investigation, 21 pits were licenced in the deposits, however, most were inactive.

Subarea 13a is a composite of esker and kame deposits in which 4 to 20 m pit sections reveal coarse gravel and sand. In Pit 502, faces up to 20 m show a coarsening-upward sequence from pebbly sand and gravel to cobbles and boulders. Subareas 13b and 13c consist of 2 east-trending eskers with lateral extents of over 7 and 10 km, respectively. Although extraction from these deposits has occurred for many years, they remain as important aggregate sources in the region.

Gravel content was observed to range from 30 to 70% and an overall average of 40% is estimated for the resource area. Field observations indicate that the deposit is characterized by hard and durable gravel clasts and should be suitable for various products provided that oversized clasts are removed or crushed.

A sample from Pit 511 returned PN values of 166 for granular and 232 for hot mix and asphalt, and losses of 2.13% and 29% for absorption and Los Angeles abrasion tests, respectively (Table 9; Figures 2A and 2B). Previous MTO testing indicate PN values ranging from 107 to 274 for hot mix and asphalt and percentage losses of 1.03 to 2.74% for absorption and 20.4 to 28.1% for Los Angeles abrasion tests. These test results indicate that some samples are suitable for lower specification HL products. It is recommended that further testing be completed at specific sites being considered for production of HL products.

After deducting previously extracted areas as well as cultural and physical constraints, the areal extents for subareas 13a, 13b and 13c are 21.1, 37.9 and 55.6 ha, respectively. Assuming an average thickness of 6 m for subareas 13a and 13b and 4.5 m for 13c, the possible aggregate resources are estimated to be 2.2, 4 and 4.4 million tonnes, respectively. The total possible aggregate resource for Selected Sand and Gravel Resource Area 13 is estimated to be 10.7 million tonnes.

Selected Sand and Gravel Resource Area 14

Selected Sand and Gravel Resource Area 14 consists of a series of south- to southwest-trending eskers located primarily in McKillop Township (Map 1C). Parts of some eskers extend north into Grey Township.

Pit faces of 8 to 25 m reveal primarily coarse gravel and sand. Numerous cobbles and boulders are present at some localities; for example, in Pit 492, boulders and cobbles dominate the deposit. Gravel content in the resource area ranges from 40 to 80% and an overall average of 50% is estimated.

Field observations indicate that the deposit is suitable for the production of various products provided oversized clasts are crushed or removed. In addition, sand blending may be necessary to improve the gradation at some localities. Additional quality testing is recommended to evaluate the suitability of the coarse portion of the deposit for HL products.

Selected Sand and Gravel Resource Area 14 has an areal extent of 44.3 ha. Removing previously extracted areas and cultural setbacks reduces the potential area to 29.2 ha. Assuming an average thickness of 7 m, the possible aggregate resource of this deposit is estimated to be 3.6 million tonnes.

Selected Sand and Gravel Resource Area 15

Selected Sand and Gravel Resource Area 15 consists of a glaciofluvial outwash deposit located in the southeastern part of West Wawanosh Township (Map 1A). The resource area is divided by the Maitland River into eastern and western parts. At the time of field investigation, 4 licenced and unlicenced pits were present in the deposit, none of which were active.

Pit faces of 5 to 8 m exposed in Pit 38 reveal predominantly clast-supported, coarse gravel and sand with massive and nearly horizontal bedding. Cobbles are common in the lower part of the sections. The deposit fines upward with fine-textured gravel beds 1 to 2 m thick occurring in the upper part of the sequence. In contrast, to the north, 6 to 8 m faces in Pit 63 are dominated by fine- to medium-textured sand and pebbly sand with gravel lenses or pockets in the lower part of the sequence. Gravel content in the pits ranges from 20 to 70% and an overall average of 40% is estimated for Selected Sand and Gravel Resource Area 15.

Field observations suggest that the deposit is characterized by hard and durable gravel clasts and should be suitable for the production of various granular products provided any oversized clasts are removed or crushed. Previous MTO tests indicate PN values of 176 to193 for hot mix and asphalt. These values exceed those allowable for the production of any HL products.

Selected Resource Area 15 has an areal extent of 204.5 ha. Previous extraction and cultural setbacks reduce the potential area to 143.5 ha. Assuming an average thickness of 6 m the possible aggregate resource of this deposit is estimated to be 15.2 million tonnes.

Selected Sand and Gravel Resource Area 16

Selected Sand and Gravel Resource Area 16 consists of 2 south-trending eskers, designated as subareas 16a and 16b, located in East Wawanosh Township (Map 1A). Pit faces of 3.5 to 7.5 m reveal primarily gravel and sand with some cobbles and boulders. Gravel content ranges from 40 to 60% in pits and road cuts, and an overall average of 40% is estimated for the resource area.

Field observations indicate that the gravel clasts are, in general, hard and durable, suggesting the deposits are suitable for the production of various products. Oversized clasts would have to be removed or crushed for the production of granular products.

After removal of previously extracted areas, as well as cultural and physical constraints, the potential areal extent of subareas 16a and 16b are 28 and 10.2 ha, respectively. Assuming an average thickness of 6 m, the possible aggregate resources are estimated to be 3.0 and 1.1 million tonnes for subareas 16a and 16b, respectively. The total possible aggregate resource is, therefore, estimated to be 4.1 million tonnes for Selected Sand and Gravel Resource Area 16.

Selected Sand and Gravel Resource Area 17

Selected Sand and Gravel Resource Area 17 comprises a series of south-trending eskers and kames located in the northeastern part of East Wawanosh Township (Map 1A). Pit exposures and road-cut sections of 2 to 6 m consist primarily of coarse gravel and sand with occasional cobbles and boulders. Sand lenses occur infrequently. Sand and pebbly sand dominate along the esker flanks. Excessive fines may occur in the kames as either matrix material within the aggregate or as silt lenses. Gravel content ranges from 40 to 75% in the pits and road cuts and an overall average of 40% is estimated for the resource area.

Field observations indicate that the deposit consists predominantly of hard and durable gravel clasts. The material should be suitable for the production of various aggregate products provided that any oversized clasts are removed or crushed. Selective extraction may be necessary to avoid excessive fines in the kame deposits. Previous MTO testing indicates that PN values for most samples (119 to 163) met specifications for HL4 products. Absorption testing, however, yielded unacceptably high losses for the production of any HL products (2.24 to 2.88%). Based on the MTO test results, the deposit is not recommended for the production of high specification aggregate products. It is possible that material suitable for the production of HL products may occur locally; sample testing to verify material suitability is required.

Selected Sand and Gravel Resource Area 17 has an areal extent of 50.3 ha. Previous extraction and cultural setbacks reduce the potential area to 35.1 ha. Assuming an average deposit thickness of 6 m, the possible aggregate resource of this deposit is estimated to be 3.7 million tonnes.

Selected Sand and Gravel Resource Area 18

Selected Sand and Gravel Resource Area 18 consists of a series of south-trending eskers (subareas 18a, 18b and 18c) located within Morris Township (Map 1B). This resource area has been the site of extensive aggregate extraction.

Pit faces of 3 to 8 m reveal primarily gravel and sand with occasional cobbles, boulders and occasional sand lenses. The flanks of the eskers are characterized by sand and pebbly sand. Excessive fine-textured sediment occurs locally and may limit usage of the aggregate in those areas. Gravel content was observed to range from 30 to 80% in the pits and an overall average of 40% is estimated for the resource area.

Field observations indicate that the deposit should be suitable for various products ranging from Granular Base course to Select Subgrade Material. For the production of Granular B and SSM, oversized clasts should be removed and crushed. Excessive fines, that are present locally, need to be avoided during extraction or removed by washing if used for sub-base coarse aggregate products. Although petrographic numbers for previously tested samples (PN of 131 to 146) meet MTO specifications for HL4 products, some samples show poor results (1.9 to 3.15%) in absorption tests. Therefore, it is recommended that further testing be done to determine the suitability of the coarse portion of the deposit for HL products at specific sites.

After removing areas previously extracted, as well as cultural and physical constraints, the potential resource area for subareas 18a, 18b and 18c are 29.5, 18.1 and 22.5 ha, respectively. Assuming an average thickness of 6 m, the possible aggregate resources are estimated to be 3.1, 1.9 and 2.4 million tonnes for subareas 18a, 18b and 18c, respectively. The total possible resource is, therefore, 7.4 million tonnes for Selected Sand and Gravel Resource Area 18.

Selected Sand and Gravel Resource Area 19

Selected Sand and Gravel Resource Area 19 consists of a series of south- to southeast-trending eskers and kames located in the northern part of Grey Township (Map 1B). This area has seen extensive extraction and the removal of a large amount of material. As a result, the surface or near surface resources are nearly depleted. However, potential aggregate material exists below the floors of current pits or the water table. At the time of field investigation, 12 licenced and unlicenced pits were located in the resource area; most were inactive.

Pit faces of 2 to 20 m reveal primarily gravel and sand with some cobbles and boulders. Sand and pebbly sand often occur in the flanks of the eskers. Contorted bedding structures are common. The gravel content observed in pits ranges from 20 to 70% and an overall average of 40% is estimated for the eskers.

Field observations indicate that the deposits should be suitable for the production of various products ranging from Granular Base course to Select Subgrade Material provided oversized clasts are removed or crushed. Previous testing by MTO indicates that some samples fail to meet MTO specifications for HL products. MTO test sample results for PN values ranged from 118 to 205 and absorption values between 1.26 to 2.27%. It is recommended that further, testing be conducted on a site-specific basis to assess the suitability of the coarse portion of deposits for high specification aggregate products.

Selected Resource Area 19 encompasses an area of 53.9 ha. Previous extraction and cultural setbacks reduce the potential area to 35.9 ha. Assuming an average thickness of 4.5 m, the possible aggregate resource of this deposit is estimated to be 2.9 million tonnes.

Selected Sand and Gravel Resource Area 20

Selected Sand and Gravel Resource Area 20 consists of a glaciofluvial outwash deposit located on the eastern bank of the Maitland River in the northwestern corner of Hullett Township (Map 1C). At the time of field investigation, 2 pits were located within the resource area, neither of which was active. It was also noted during field work that a high water table that may pose problems to extraction exists in the resource area.

Exposed pit faces of 2 to 3.5 m are composed of well-sorted, clast-supported gravel and sand with massive to approximately horizontal bedding structures. Gravel content in the pits ranges from 50 to 70% and an overall average of 60% is estimated for the resource area. Field observations suggest that the deposit is suitable for the production of various granular products provided that the oversized clasts are removed or crushed.

Selected Sand and Gravel Resource Area 20 has an areal extent of 244.7 ha. Previous extraction and cultural setbacks reduce the potential area to 151.8 ha. Assuming an average thickness of 4.5 m, the possible aggregate resource is estimated to be 12.1 million tonnes.

Selected Sand and Gravel Resource Area 21

Selected Sand and Gravel Resource Area 21 consists of 2 eskers (subareas 21a and 21b) located in central Hullett Township (Map 1C). Extensive extraction has occurred in this resource area and a considerable amount of material has been removed, in particular, from subarea 21b. As a result, only limited surface or near surface resources remain in subarea 21b. Aggregate material is likely present, however, beneath the floors of current pits and, hence, these eskers are still an important potential aggregate source for the region.

Pit faces of 1.5 to 10 m reveal coarse gravel and sand with some cobbles and boulders. On occasion, intrabedded sand lenses occur. Sand and pebbly sand dominate the flanks of the eskers. Contorted bedding structures occur frequently in the eskers. The gravel content ranges from 40 to 75 % in the pits and an overall average of 40% is estimated for the eskers.

Field observations suggest that the deposit should be suitable for the production of various products provided that oversized clasts are removed or crushed. Data from previous MTO testing indicates that samples met MTO specifications for HL4 products in PN values (115 to 129) and in absorption, magnesium sulphate soundness and Los Angeles abrasion tests for coarse aggregate (1.14 to 1.84%, 2.3 to 4.7% and 22 to 27%, respectively). Based on the test results, it is suggested that the coarse portion of the deposit is suitable for HL4 assuming that an adequate amount of crushable material is available.

After deducting previously extracted areas, as well as cultural and physical constraints, the potential areas for subareas 21a and 21b are 19.1 and 21.2 ha, respectively. Assuming an average thickness of 6 and 4.5 m, the possible aggregate resources are estimated to be 2 and 1.7 million tonnes for subareas 21a and 21b, respectively. The total possible aggregate resource is, therefore, estimated to be 3.7 million tonnes for Selected Sand and Gravel Resource Area 21.

Selected Sand and Gravel Resource Area 22

Selected Sand and Gravel Resource Area 22 consists of an ice-contact deposit located in the southern part of Hullett Township (Map 1C). The material is variable in composition as is typical of ice-contact stratified sediments. However, 4 to 6 m pit faces consist primarily of sand and gravel. Clay and silt lenses, and oversized clasts, up to 30 cm, are present locally. Gravel content in the pits ranges from 10 to 80% and an overall average of 40% is estimated for the deposit.

Field observations indicate that the deposit is characterized by hard and durable gravel clasts and would be suitable for various granular products provided that oversized clasts are removed or crushed. Previous quality testing indicates that the PN values meet MTO specifications for HL4 products (128 to 150); however, all tested samples show excessive losses in absorption tests (2.17 to 2.50%). Based on the testing results, the deposit is not recommended for high specification aggregate products.

Selected Sand and Gravel Resource Area 22 has an areal extent of 106.2 ha. Removal of previously extracted areas and cultural setbacks reduce the potential area to 66.8 ha. Assuming an average thickness of 6 m, the possible aggregate resource of this deposit is estimated to be 7.1 million tonnes.

Selected Sand and Gravel Resource Area 23

The ice-contact or kame deposit forming Selected Sand and Gravel Resource Area 23 is located near the community of Blyth in the northern part of Hullett Township (Map 1C). At the time of field investigation, 3 pits existed in the deposit, none of which were active.

Pit faces of 5 to 15 m consist primarily of sand and gravel to sand and pebbly sand with occasional silt lenses. The percentage of fines in the deposit is up to 8% (Ontario Geological Survey 1986). Gravel content ranges from 25 to 75% in the pits and an overall average of 40% is estimated for the deposit.

Field observations suggest that the deposit is suitable for the production of various granular products ranging from Granular Base course to Select Subgrade Material.

For pit-run products, Granular B and SSM, excessive fines should be avoided through selective extraction and oversized clasts removed or crushed. Previous MTO testing indicates PN values from 130 to 170 for hot-mix and asphalt, and losses of 8.7 to 14.1% and 1.91 to 2.17% for magnesium sulphate soundness and absorption tests, respectively, for coarse aggregate. The test results suggest that some samples do not meet MTO specifications for HL4 products. Further testing is required to assess the suitability of the material for HL products at specific localities.

Selected Resource Area 23 has an areal extent of 88.2 ha and, when previous extraction and cultural setbacks are removed, the potential area is reduced to 57.7 ha. Assuming an average thickness of 8 m, the possible aggregate resource of this resource area is estimated to be 8.2 million tonnes.

Selected Sand and Gravel Resource Area 24

Selected Sand and Gravel Resource Area 24 consists of an east-trending esker located in the northern part of Usborne Township (Map 1D). At the time of field investigation, 4 pits were present in the esker, none of which were active.

Pit faces of 4 to 8 m reveal sand, pebbly sand and gravel. At the time of field investigation, much of the gravel-rich esker core material had been removed from the pits with only the sand-rich flank material remaining. The central gravel sequence was examined at the western end of Pit 585 where massive, clast-supported coarse gravel and cobbles, with boulders, occurs in the 4 to 5 m pit faces as well as in the pond sections below the pit floor. Gravel content ranges from 20 to 70% in the pits and an overall average of 30% is estimated for the esker.

Field observations suggest that the esker material should be suitable for the production of various granular products including Granular Base course to Select Subgrade Material provided oversized clasts are removed or crushed. For Granular A and M products, an adequate percentage of crushable clasts may be a problem and sand control might be required at some localities, in particular, where extraction is occurring in the flanks of the esker. Previous MTO testing indicates that although most of the samples meet MTO specifications for HL4 products in PN values (107 to 153) and absorption tests (1.17 to 1.97%), a few samples, however, returned high PN values, up to 240, and excessive absorption losses of up to 2.04%. Based on the test results, it is suggested that the material may be acceptable for HL4 products provided that further testing is conducted to ensure site-specific aggregate quality and that an adequate amount of crushable material is available.

Selected Sand and Gravel Resource Area 24 has an areal extent of 20.1 ha. When previous extraction and cultural setbacks are considered, the potential area is reduced to 10.9 ha. If a conservative deposit thickness of 6 m is used, the possible aggregate resource for this deposit is estimated to be 1.2 million tonnes.

Secondary Sand and Gravel Resources

A number of areas within Huron County have been selected as resource areas of secondary significance. Areas of secondary significance do not have the best aggregate in the study area, however, they may contain large quantities of sand and gravel. In some cases, resource areas of secondary significance are classed as such due to the lack of reliable geological data. This lack of data may not allow an accurate assessment of either the quality or volume of sand and gravel within a deposit. Resource areas of secondary significance serve as important alternative extraction sites and should be considered as part of a region's total aggregate supply. Because of the large number of secondary deposits present in Huron County, they are not labelled individually on the accompanying maps and only selected descriptions are given herein.

Within Howick, Turnberry and Colborne townships, a number of sand and gravel-rich glaciofluvial deposits, situated in outwash spillway channels, have been selected as resource areas of secondary significance. Outwash deposits of secondary significance are also found in Ashfield, West and East Wawanosh, Hullett and Usborne townships, however, the areal extent of these deposits is limited. For instance, in the central part of Usborne Township, Karrow (1977) mapped an outwash delta that contains an estimated 40 to 70% gravel content. Water well records indicate that the deposit is up to 9 m thick. The deposit is characterized by hard and durable gravel clasts and is considered suitable for various granular products provided that oversized clasts are removed or crushed. Previous MTO quality tests indicate that some samples slightly exceed the MTO specification for HL4 as PN values range from 127 to 162 and absorption test results are between 1.56 to 2.07%. Although the outwash delta has an areal extent of 128.9 ha, 3 licenced pits (nos. 588, 589 and 590, Map 1D), cover much of the deposit. After deducting previously extracted areas and cultural setbacks, the available area is only 5 ha. Assuming an average thickness of 7 m, the possible aggregate resource of this deposit is estimated to be 0.6 million tonnes.

In Howick and Turnberry townships, outwash deposits of secondary significance are 3 to 5 m thick and contain, in general, 40 to 70% gravel. The deposits contain predominantly hard and durable gravel clasts that may be suitable for the production of various granular products ranging from Granular Base course to Select Subgrade Material. Two samples, one from site HR-DS-596 and one from Pit 186, were submitted for quality testing (Table 9; Figures 3A and 3B). Both samples failed to meet MTO specifications for HL products because of high PN values (255 and 258) and excessive losses in absorption tests (2.65% and 3.02%). Previous MTO testing of the deposits also indicate that most of the samples had excessive absorption losses. It is suggested that further testing be conducted on a site-specific basis to determine suitability for the production of any HL products.

In Colborne Township, a large outwash deposit, extending from the western boundary of Selected Sand and Gravel Resource subarea 11a to the Maitland River, has been mapped at the secondary level of significance. The deposit is located in the valleys of Sharpes Creek and an unnamed stream to the east. Shallow test holes dug in this area indicate that the deposit consists of well-sorted gravel, sand and pebbly sand. The 2.5 to 3 m face sections show clean pebbly sand and fine-textured gravel with gravel content ranging from 20 to 30%. Pit 136, on the western bank of Sharpes Creek, has 6 to 7 m sections that contain 70 to 80% gravel. The pit faces are characterized by clast-supported gravel and sand with massive to near horizontal bedding. Field observations suggest that this outwash deposit is suitable for the production of various granular products ranging from Granular Base course to Select Subgrade Material. Selective extraction and sand control may be required to produce Granular A and M at some localities. Previous MTO testing of a sample from Pit 136 yielded a PN value of 133 and magnesium sulphate soundness loss of 4.6%, thus meeting the MTO specification for HL4. However, the absorption (2.04%) slightly exceeded the maximum loss allowed for HL4. Further testing is necessary to assess the suitability of the deposit for HL products.

Glaciolacustrine beach deposits consisting of sand and gravel occur in a narrow, south-trending belt in the western part of Huron County. Because of extensive extraction, many areas within these deposits have been depleted or are nearly depleted, for instance, those in Goderich Township. With the exception of Ashfield Township, where deposit thickness may reach 3 to 5 m, most of the deposits are shallow with thicknesses of less than 3 m. However, taking into consideration the uneven distribution of aggregate resources in Huron County, these deposits are important local aggregate sources.

The glaciolacustrine deposits located in the southern part of Huron County (e.g., Hay and Stephen townships) contain primarily sand and pebbly sand with a gravel content of less than 35%. These deposits are suitable for the production of low-specification products including Granular B and SSM. In Ashfield Township, the deposits contain 20 to 70% gravel and may be used for the production of Granular B, SSM and other Granular Base course aggregate products if selective extraction and sand control are used (Table 9; Figures 4A and 4B). Previous MTO testing indicates that many samples meet the MTO specifications for HL4. Further testing is necessary to determine the suitability for high specification aggregate products at specific sites.

Ice-contact stratified deposits of secondary significance are scattered as hills and ridges throughout Huron County. They display a heterogeneous lithology ranging from sand to gravel. Some of the quality constraints that characterize these deposits include excess fines in the matrix; the presence of till-like units; and frequent large boulders. In general, the deposits are suitable primarily for the production of low-specification aggregate products such as Granular B and SSM provided that oversized clasts are removed or crushed. Selective extraction may be required to avoid layers containing excessive fines.

Ongoing extraction has removed the central gravel-rich core of an ice-contact or kame hill located in the southern corner of Grey Township. The deposit flanks are characterized by sand and pebbly sand, however, possible resources are likely present below the pit floor or water table. Field observations suggest that the deposit is a good source for pit-run products Granular B and SSM. Granular A and M aggregates may be produced if selective extraction is adopted and sand control applied. Previous MTO testing reveals that some samples fail to meet MTO specifications for HL products (PN of 116 to 206) although magnesium sulphate soundness and absorption tests indicate satisfactory results. Further testing is necessary to assess the suitability of the coarse portion of the deposit for high specification aggregate products. A large portion of the kame is covered by licenced Pit 332. After deducting previously extracted areas as well as cultural and physical constraints, the remaining available area is 4.2 ha. Assuming an average thickness of 7 m, the possible aggregate resource is estimated to be 0.5 million tonnes.

Many of the larger eskers in the county have been subjected to extensive extraction and the surface and near-surface aggregate resources are depleted or nearly depleted. However, resources may still be present below the water table, notably in the townships of East Wawanosh, Morris and Grey. Several esker deposits in these townships are ranked at the secondary level of significance. Physical constraints, such as a high water table, may pose problems in extraction and increase the cost of operations.

In Huron County, some eskers ranked as resource areas of secondary significance are less than 1 km in length or may have a longer extent, but have limited surface expression. In McKillop Township, a buried 5 km long, east-trending esker, located between Selected Sand and Gravel Resource subareas 13b and 13c, was detected on aerial photographs. At certain localities, the esker occurs as low sandy or gravelly ridges with an estimated gravel content ranging from 10 to 60% and averaging 30%. Field observations suggest that the deposit should be suitable for the production of low-specification pit-run products such as Granular B and SSM. Granular Base course aggregate may be produced if selective extraction is conducted in gravel-rich units. Further testing is required to adequately assess the aggregate quality.

A southeast-trending esker in the southeastern corner of Grey Township has been mapped by Cooper, Fitzgerald and Clue (1977). However, in the field, it is difficult to locate because of its low relief. Where the esker crosses the township boundary into Elma Township, it has been mined out and only a narrow pond indicates its presence. A shallow test hole (0.6 m) revealed sorted gravel and sand with 60% gravel. A ditch section (3 m deep) on the northern flank of the esker exhibited a sequence of 2 m of silty sand underlain by sorted gravel and sand containing about 70% gravel. An overall average of 40% gravel is estimated for the esker. The deposit may be suitable for the production of pit-run granular products, as well as Granular A and M, if selective extraction and sand control are adopted. Further testing is required to ensure aggregate quality, as well as, to assess the suitability of the deposit for HL products.

BEDROCK GEOLOGY AND RESOURCE POTENTIAL

The majority of Huron County is underlain by bedrock of the Devonian Dundee Formation and Detroit River Group. Parts of the county are also underlain by the Devonian Bois Blanc Formation and Silurian Salina and Bass Islands formations (Liberty and Bolton 1971; Uyeno, Telford and Sanford 1982; Johnson et al. 1992).

The Salina Formation, the oldest bedrock unit in Huron County, is characterized by dolomite, shale, gypsum and salt. This formation occurs in a limited area at the northeastern corner of Howick Township and has little value as a source for crushed stone aggregate, although salt is mined from this unit at Goderich and Windsor.

The Bass Islands Formation consists of medium- to massive-bedded dolomite with shaly partings. It is quarried for crushed stone at several sites on the Niagara Peninsula (Hewitt 1960). When this material is used for the production of high specification aggregate, beneficiation of the aggregate may be required due to the deleterious nature of the shaly partings.

The Bois Blanc Formation, which overlies the Silurian rocks, consists of cherty limestone with shale partings and minor interbedded dolomite. The formation has been quarried for crushed stone in southwestern Ontario and is suitable for the production of Granular Base course products. The high chert content in this formation makes the crushed rock unsuitable for hot-mix asphalt and Portland cement concrete coarse and fine aggregates (Hewitt 1960).

Two units of the Detroit River Group, the Amherstburg and Lucas formations, occur within Huron County (Uyeno, Telford and Sanford 1982). The Amherstburg Formation has limited occurrence in the northeastern part of the County and consists of massive-bedded, laminated dolomite and fine- to coarse-grained limestone. While the formation may be used in Granular Base course products, it is unsuitable for high-quality HL aggregate because of its relatively poor results in soundness, abrasion and absorption tests. The Formosa Reef Limestone, which has a thickness of 15 m, is a member of the Amherstburg Formation and occurs near Wingham (Fagerstrom 1961). This subunit consists of high-purity limestone and is suitable for lime and cement manufacture.

The Lucas Formation (40 to 75 m thick) has a wide distribution in the report area and is composed predominantly of dolomite with bituminous laminations and minor chert. To the south of the report area, the upper part of this formation consists of a high-purity limestone unit, the Anderdon Member, which occurs near Ingersoll and Amherstburg in Oxford and Essex counties, respectively (Liberty and Bolton 1971; Uyeno, Telford and Sanford 1982; Birchard, Rutka and Brunton 2004). The formation is used as Granular Base course aggregate elsewhere in Ontario, however, excessive fines, high absorption, abrasion and soundness losses in test samples indicate that problems could arise when the rock is used in HL products (Koniuszy and Katona 1981).

The Dundee Formation (15 to 45 m thick) consists of fine- to medium-grained, medium- to thick-bedded dolomitic limestone with shaly partings, chert nodules and lenses of bioclastic material in some areas. The formation has been quarried near Port Dover and on Pelee Island primarily for the production of Granular Base course products, and used at St. Marys as a raw material for Portland cement. Test data indicate that the Dundee Formation often yields poor results in abrasion and absorption tests, and may cause problems when used in high-quality hot mix and concrete applications.

In most of Huron County, the bedrock is covered by 10 to 50 m of drift. Only in limited areas, mainly in the valleys of the Maitland River and its branches, is the drift less than 8 m thick. The thick drift cover suggests that quarrying for bedrock aggregate would be uneconomical in the county using current technologies under the present market demand.

SUMMARY

The sand and gravel deposits in the report area are the result of glacial, glaciofluvial, glaciolacustrine, and postglacial fluvial and lacustrine activities. Twenty-four deposits containing aggregate resources have been identified as Selected Sand and Gravel Resource Areas of primary significance. In addition, several deposits have been selected as areas of secondary significance.

In Huron County, most of the coarse aggregate resources are concentrated in outwash spillway systems and outwash fans deposited during the melting of glacial ice from the area. Large aggregate resources are also present in eskers, however, extraction has depleted near-surface aggregate resources in many of these features. Glaciolacustrine beach deposits also contain important aggregate resources in western Huron County. However, as these deposits are shallow and many are sand rich, they are classified as resource areas of secondary significance.

The former townships of Howick, Turnberry, East Wawanosh, Goderich and Colborne in the northern and west-central portion of Huron County are rich in sand and gravel resources contained in outwash spillway channels, fans and esker deposits. The townships south of Goderich, including Stanley, Hay, Stephen and Tuckersmith, generally have low potential for sand and gravel. The remainder of the county has moderate aggregate potential with sand and gravel found mainly in eskers, outwash channels and deltas. A study by Proctor and Redfern Limited and Gartner Lee Associates Limited (1977) also indicates a similar distribution of aggregate resources in Huron County.

MTO testing data suggest that the aggregate deposits in Huron County are, in general, suitable for the production of granular aggregate products ranging from Granular Base course to Select Subgrade Material. Most of the samples yield poor absorption test results. The aggregate quality appears to be better in the south and southwest portion of the county. Although HL products may be produced at some sites, most deposits are unsuitable for the production of HL and other high specification aggregate products.

The study area is underlain by Paleozoic (Upper Silurian to Middle Devonian) dolostones and limestones. The bedrock in the area exhibits wide variations in aggregate quality and is generally overlain by a thick cover of Quaternary sediments. For these reasons, no Selected Bedrock Resource Areas have been identified in Huron County.

Enquiries regarding the Aggregate Resources Inventory of Huron County area should be directed to the Sedimentary Geoscience Section, Ontario Geological Survey, Ministry of Northern Development and Mines, 933 Ramsey Lake Road, 7th Floor, Sudbury, Ontario, P3E 6B5 (Tel: (705) 670-5758); or to the Mines and Minerals Information Centre, Ministry of Northern Development and Mines, Macdonald Block, Room M2-17, 900 Bay Street (at Wellesley), Toronto, Ontario M7A 1C3 (Tel: (416) 314-3800); or to the Ministry of Natural Resources, Huron/Perth Office, Guelph District, 100 Don Street, P.O. Box 819, Clinton, Ontario N0M 1L0 (Tel: (519) 482-3428).

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES HURON COUNTY			
1 Class No.	2 Deposit Type	3 Areal Extent (Hectares)	4 Areal Extent Original Tonnage (Million Tonnes)
Ashfield Township			
1	G-IC	14.7	1.6
	G-OW	92.2	9.8
	S-IC	217.0	23.0
	S-LB	106.6	11.3
2	G-IC	347.7	27.7
	G-LB	495.4	39.5
	G-OW	47.2	3.8
	S-IC	40.5	3.2
	S-LB	46.2	3.7
	S-LP	297.5	23.7
	S-OW	179.6	14.3
3	G-OW	19.5	0.7
	S-IC	4.9	0.2
	S-LP	77.3	2.7
	S-OW	311.6	11.0
4	S-LP	1938.1	51.5
Subtotal		4235.8	227.6
West Wawanosh Township			
1	G-E	5.4	0.6
	G-IC	180.5	19.2
	G-K	5.1	0.5
	G-OW	344.5	36.6
	S-IC	285.1	30.3
	S-LP	15.7	1.7
2	G-IC	80.8	6.4
	G-K	21.2	1.7
	G-OW	382.8	30.5
	S-E	2.2	0.2
	S-IC	500.7	39.9
	S-OW	778.5	62.0
3	G-IC	11.0	0.4
	S-IC	8.8	0.3
	S-LP	977.7	34.6
	S-OW	552.1	19.5
4	S-LP	373.3	9.9
Subtotal		4525.4	294.3
East Wawanosh Township			
1	G-E	189.5	20.1
	G-IC	240.3	25.5
	G-K	42.1	4.5
	G-OW	121.2	12.9
	S-IC	802.4	85.2
	S-K	92.8	9.9
	S-OW	8.3	0.9

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES HURON COUNTY			
1 Class No.	2 Deposit Type	3 Areal Extent (Hectares)	4 Areal Extent Original Tonnage (Million Tonnes)
2	G-E	44.6	3.6
	G-IC	57.9	4.6
	G-OW	429.7	34.2
	S-E	5.8	0.5
	S-IC	2179.1	173.6
	S-LP	60.5	4.8
3	G-IC	23.2	0.8
	G-OW	269.3	9.5
	S-IC	508.8	18.0
	S-LP	1431.6	50.7
	S-OW	2055.7	72.8
Subtotal		8562.8	532.0
Colborne Township			
1	G-IC	54.2	5.8
	G-OW	653.5	69.4
	S-IC	1177.1	125.0
2	G-AL	36.0	2.9
	G-E	15.8	1.3
	G-LB	318.4	25.4
	G-OW	1167.3	93.0
	S-E	9.3	0.7
	S-IC	174.0	13.9
	S-LB	33.1	2.6
	S-OW	61.6	4.9
3	G-LB	323.4	11.4
	G-OW	251.2	8.9
	S-LP	457.5	16.2
4	S-LP	14.2	0.4
Subtotal		4746.4	381.7
Turnberry Township			
1	G-E	32.8	3.5
	G-IC	4.8	0.5
	G-OW	487.2	51.7
	S-IC	252.4	26.8
2	G-E	23.5	1.9
	G-OW	1273.2	101.4
	S-IC	1105.7	88.1
	S-OW	556.4	44.3
	G-E	23.3	1.9
3	G-IC	224.4	7.9
	G-OW	60.5	2.1
	S-IC	13.7	0.5
	S-LP	114.3	4.0
	S-OW	1825.5	64.6
4	G-IC	12.6	0.3

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES HURON COUNTY			
1 Class No.	2 Deposit Type	3 Areal Extent (Hectares)	4 Areal Extent Original Tonnage (Million Tonnes)
	S-LP	285.6	7.6
Subtotal		6295.7	407.2
Howick Township			
1	G-E	32.6	3.5
	G-IC	13.9	1.5
	G-K	82.2	8.7
	G-OW	1470.1	156.1
	S-IC	212.6	22.6
	S-OW	111.6	11.8
2	G-E	88.5	7.0
	G-IC	115.1	9.2
	G-K	10.9	0.9
	G-OW	4073.1	324.4
	S-E	8.0	0.6
	S-IC	2958.4	235.6
	S-LP	84.7	6.7
	S-OW	1327.8	105.8
3	G-OW	1173.6	41.5
	S-LP	178.6	6.3
	S-OW	2454.5	86.9
4	S-LP	25.9	0.7
Subtotal		14422.0	1029.9
Morris Township			
1	G-E	180.2	19.1
	G-IC	364.5	38.7
	G-K	8.4	0.9
	S-E	9.0	1.0
	S-IC	690.9	73.4
	S-K	7.1	0.7
	S-OW	121.5	12.9
2	G-E	183.3	14.6
	G-IC	10.0	0.8
	G-K	10.8	0.9
	G-OW	33.5	2.7
	S-E	28.4	2.3
	S-IC	1237.7	98.6
	S-LP	186.2	14.8
	S-OW	1101.3	87.7
3	G-IC	21.3	0.8
	G-OW	347.7	12.3
	S-LP	179.7	6.4
	S-OW	5272.6	186.6
Subtotal		9994.0	575.1
Grey Township			
1	G-E	15.7	1.7

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES HURON COUNTY			
1 Class No.	2 Deposit Type	3 Areal Extent (Hectares)	4 Areal Extent Original Tonnage (Million Tonnes)
	G-IC	163.9	17.4
	G-K	17.8	1.9
	S-IC	889.6	94.5
	S-K	92.3	9.8
2	G-E	228.2	18.2
	G-IC	369.3	29.4
	G-K	117.1	9.3
	G-OW	167.2	13.3
	S-E	54.1	4.3
	S-IC	2447.3	194.9
	S-OW	376.4	30.0
3	G-E	6.7	0.2
	G-IC	121.5	4.3
	G-OW	103.5	3.7
	S-IC	55.3	2.0
	S-LP	398.7	14.1
	S-OW	1108.7	39.2
Subtotal		6733.3	488.2
Goderich Township			
1	G-IC	13.7	1.5
	G-OW	1200.0	127.4
	S-IC	833.0	88.5
	S-K	73.0	7.8
	S-OW	18.8	2.0
2	G-LB	414.3	33.0
	G-OW	288.0	22.9
	S-IC	944.8	75.3
	S-LB	610.9	48.7
	S-OW	241.6	19.2
3	G-AL	12.2	0.4
	G-OW	431.9	15.3
	S-IC	461.2	16.3
	S-LB	1852.6	65.6
	S-OW	457.7	16.2
4	G-OW	181.2	4.8
	S-LB	1316.5	35.0
	S-OW	6.2	0.2
Subtotal		9357.6	580.0
Hullett Township			
1	G-IC	217.3	23.1
	G-K	57.7	6.1
	S-IC	1116.8	118.6
	S-K	29.8	3.2
2	G-E	60.8	4.8
	G-OW	312.6	24.9
	S-IC	5616.0	447.3

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES HURON COUNTY			
1 Class No.	2 Deposit Type	3 Areal Extent (Hectares)	4 Areal Extent Original Tonnage (Million Tonnes)
	S-OW	102.2	8.1
3	S-OW	1224.3	43.3
Subtotal		8737.4	679.5
McKillop Township			
1	G-E	160.7	17.1
	G-K	5.1	0.5
	S-E	2.0	0.2
	S-IC	340.3	36.1
2	G-E	137.1	10.9
	G-IC	53.2	4.2
	G-K	27.3	2.2
	G-OW	37.2	3.0
	S-E	36.9	2.9
	S-IC	1651.0	131.5
	S-OW	123.3	9.8
3	G-IC	7.4	0.3
Subtotal		2581.4	218.8
Stanley Township			
2	S-LB	5.5	0.4
	S-OW	69.2	5.5
3	G-LB	78.9	2.8
	G-OW	76.8	2.7
	S-IC	18.9	0.7
	S-LB	113.3	4.0
	S-OW	395.7	14.0
4	G-LB	29.0	0.8
	G-OW	137.9	3.7
	S-LB	71.4	1.9
	S-OW	1179.2	31.3
Subtotal		2175.7	67.8
Tuckersmith Township			
1	G-IC	117.7	12.5
	S-K	7.2	0.8
2	G-IC	102.4	8.2
	S-IC	485.8	38.7
3	G-OW	59.0	2.1
	S-IC	355.1	12.6
	S-OW	65.0	2.3
4	S-OW	17.6	0.5
Subtotal		1209.8	77.5
3	S-LB	516.2	18.3
Hay Township			
	S-OW	2806.1	99.3
4	S-LB	651.9	17.3

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES HURON COUNTY			
1 **Class No.**	**2** **Deposit Type**	**3** **Areal Extent (Hectares)**	**4** **Areal Extent Original Tonnage (Million Tonnes)**
	S-OW	1223.3	32.5
Subtotal		5197.5	167.4
Stephen Township			
3	S-LB	516.4	18.3
	S-OW	475.8	16.8
4	S-LB	954.5	25.3
	S-WD	78.2	2.1
	S-OW	629.4	16.7
Subtotal		2654.4	79.3
Usborne Township			
1	G-E	6.7	0.7
	G-IC	7.8	0.8
	G-OW	128.9	13.7
	S-E	30.2	3.2
	S-IC	16.0	1.7
	S-K	25.9	2.7
2	G-K	7.7	0.6
	G-OW	60.2	4.8
	S-E	23.1	1.8
	S-IC	8.9	0.7
	S-K	9.9	0.8
	S-OW	21.8	1.7
3	G-E	10.1	0.4
	G-IC	4.8	0.2
	G-OW	31.3	1.1
	S-IC	6.3	0.2
	S-OW	42.6	1.5
4	G-OW	143.0	3.8
	S-K	5.0	0.1
Subtotal		590.3	40.7
COUNTY TOTAL		**92019.3**	**5846.9**

Minor variations in all tables are caused by 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.

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Ashfield Township					
Licenced Pits					
1	L. Collins	2.5	5-7	10-30	
2	F. Hogan	16.2	6-8	45	
3	Johnston Brothers	58.0	5-7	70-80	
4	Jennison Construction	40.2	5-6	50-70	
5	Ashfield Twp	32.5	10	70-80	
6	Johnston Brothers	77.5	4-6	65	
Unlicenced Pits					
7	K.L. Mackenzie	-	-	0.2-0.6	K6-31
8	Rose	-	4.5	3	L8-15
9	McIntyre	-	2-2.5	65	L8-7
10	Courtney	-	2-3	25-55	L8-52
11	Unknown	-	2	40-70	
12	Unknown	-	4-5	Variable	
13	Kirkland	-	3-4	25	
14	Unknown	-	3	60-70	
15	Sandy Construction	-	-	50	L8-44
16	Unknown	-	1	40-50	
17	Jerome	-	-	15-20	L8-37
18	V. Austin	-	1.5-2	40-45	
19	H. Howard	-	2-3	41	L8-61
20	Bugeless	-	1.8	30-40	L8-6
21	Reid	-	1.8-3	10-25	L8-3
22	Unknown	-	2-2.5	50-60	
23	Unknown	-	1.8-2.1	55	L8-27
24	Unknown	-	6	60-70	
25	Ashfield Twp	-	3-6	53	L8-35
26	Dixon	-	2.5	10	L8-32
27	Doherty	-	1-1.5	15	L8-31
28	Culbert	-	4.5-6	30-70	
29	Unknown	-	1-1.5	<5	
30	Hodges	-	3.5	75-80	L8-41
31	H. Glen	-	3	30-40	L8-38
32	Unknown	-	4-5	5-20	
West Wawanosh Township					
Licenced Pits					
33	W. Wawanosh Twp	14.17	8-12	50-60	
34	Donegan's Haulage	129.5	-	25-75	
35	Donegan's Haulage	80.00	8-12	25-75	
36	T. Armstrong	7.1	4-8	20-70	
37	W. Wawanosh Twp	14	4-9	50-60	
38	B. Moss	18.6	5-8	60-70	

TABLE 2 - SAND AND GRAVEL PITS
HURON COUNTY

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Unlicenced Pits					
39	Willits	-	3-4	40-60	
40	P. McMillan	-	-	65	L8-16
41	Culbert	-	3.5-4	30-35	L8-1
42	W. Wawanosh Twp	-	4.5-6	30-70	L8-2
43	B. Raynard	-	3-5	40	L8-59
44	Unknown	-	3-9	10-40	
45	Unknown	-	3-3.5	40	
46	Leo Selent	-	5	40-70	W9-40
47	Leo Selent	-	3-4	10-30	W9-78
48	R. Lyons	-	2-2.5	20-50	L8-57
49	B. Raynard	-	2-3	45-50	L8-58
50	Unknown	-	3.5-4.5	25-30	
51	Unknown	-	2-2.5	30	
52	J. Miller	-	5-6	40-60	
53	John Shetler	-	6-10	60-70	
54	Unknown	-	3-8	<20	
55	E. Suitman	-	4-6	60-70	
56	Unknown	-	5-6	5-10	
57	Unknown	-	1.5-4.5	-	
58	Don Gibbson	-	6-10	40-70	
59	Unknown	-	7-8	20-30	
60	W. Wawanosh Twp	-	4-6	50	
61	Unknown	-	1.5-5	50-60	
62	Unknown	-	4.5-5	55	
63	Ken Leddy	-	6-8	40-50	
64	Unknown	-	1.5	30-40	
65	H. Wrightman	-	2-2.5	20-25	
66	Unknown	-	3	-	
67	Unknown	-	6-8	50	
68	K. Seeger	-	6-8	40-70	
East Wawanosh Township					
Licenced Pits					
69	1028094 Ontario Inc.	120.00	3	30-60	
70	East Wawanosh Twp.	22.00	8-10	40	
71	Lavis Ltd.	33.20	4-7	45-55	
72	Joe Kerr Ltd.	40.00	2	40	
73	Joe Kerr Ltd.	40.00	3-6	40-75	
74	Huron County	16.90	-	-	
75	East Wawanosh Twp.	10.19	15	50-70	
76	Tim & Maria Walden	40.00	-	60-70	
77	Howatt Bros.	23.00	4-5	55	
78	McCann Redimly Co.	38.00	6-7.5	26	
79	Howson & Howson Ltd.	120.00	3-9.6	34	

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
Unlicenced Pits					
80	H.S. Warorop	-	2.4	40	W9-33
81	B.Kuepfer	-	2-7	-	W9-12
82	R. Brandon	-	4.5	-	W9-32
83	Purdon	-	6	40	W9-38
84	Beecroft	-	7.5	30	W9-36
85	R. Clayhorn	-	4-5	30	
86	Unknown	-	4.5	-	
87	James	-	2.4-3	<35	W9-186
88	Unknown	-	-	<35	W9-125
89	Unknown	-	3-4	40	
90	Joe Kerr Ltd.	-	3	60-80	W9-47
91	Unknown	-	-	0-5	
92	Unknown	-	14	20	
93	Joe Kerr Ltd.	-	9	40-65	
94	Unknown	-	1-2	40	
95	Unknown	-	3	35	
96	Unknown	-	3-3.6	45	
97	Unknown	-	1	5	
98	Unknown	-	2-3	-	
99	Unknown	-	2-5	30-80	W9-198
100	Unknown	-	4.5-6	40-70	
101	Unknown	-	2.4-3	35-40	
102	Unknown	-	6	45	
103	Unknown	-	3.5	40	
104	J. Walsh	-	4-7.5	35	W9-94
105	Unknown	-	7	20	
106	Unknown	-	2.4-3	15	
107	Unknown	-	9	35	
108	Unknown	-	4-5	40	
109	Unknown	-	4	49-60	
110	Unknown	-	2-2.5	30	
111	Unknown	-	4	50	
112	Unknown	-	7.5	60	
113	Unknown	-	-	10	
114	Unknown	-	5	30-50	
115	Unknown	-	2	20-30	
116	Unknown	-	1.5	50-70	
117	Unknown	-	1.5-2	10-30	
118	Unknown	-	4-5	70-80	
119	Unknown	-	4-5	70-80	
120	Unknown	-	1.5-3.6	30	
121	Unknown	-	2	30-40	
122	K. McDougal	-	2-9	10	L8-47
123	Unknown	-	3.6	40	
124	Unknown	-	2-3	20-30	
125	P. Peck	-	4.5-6	40	W9-108

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
126	R. Walker	-	2.4-3	55-60	W9-61
Colborne Township					
Licenced Pits					
127	E.S. Johnston Farms Ltd.	15.90	10-12	60-70	
128	Johnston Bros. (Bothwell) Ltd.	74.00	12-15	50-70	
129	Merner Aggregates Ltd.	20.93	7-8	70	
130	D. Radford	18.00	7-9	60-75	
131	Lavis Contracting Co.	23.80	11-12	55-65	
132	Colborne Township	5.00	10-12	60-70	
133	Lavis Contracting Co.	6.00	9-12	50-65	
134	Lavis Contracting Co.	5.00	8-10	60-75	
135	Lavis Contracting Co.	5.26	-	-	
136	V. Vanstone	12.30	6-7	70-80	
137	Colborne Township	8.00	6-8	50-80	
138	Arnold Fisher	32.90	4	50-75	
139	Falleens Holding Inc.	25.80	8-9	50-70	
140	Chapman Canadian Corp.	36.70	3-5	40-60	
Unlicenced Pits					
141	R. & M. Baer	-	2.1-4	20-27	
142	Homan	-	2-2.5	40	L8-46
143	Unknown	-	2.4	40	
144	Unknown	-	2.4	40	
145	Westlake	-	2.4	30	G4-80
146	Sandy Const. Co.	-	-	40	G4-82
147	Lamb	-	-	35-75	G4-83
148	Unknown	-	5	70	
149	Glenn	-	2.4	40	G4-81
150	G. Ross	-	1.5-2.1	40	
151	Unknown	-	>2	20-40	
152	Craddock	-	6	50-65	G4-72
153	A.W. Hardy	-	-	70-75	
154	Unknown	-	2.5-3	20-30	
155	Brewer	-	-	60-75	G4-93
156	Carter	-	3-6	45-75	G4-94
Tunberry Township					
Licenced Pits					
157	Baker	50.00	4-5	30-60	
158	Turnberry Twp	32.50	5	65-70	
Unlicenced Pits					
159	Czerniawski	-	-	30-45	W9-172
160	Unknown	-	5-6	70	
161	Unknown	-	4-5	20	
162	McCormack	-	-	12-20	W9-92

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
163	Stoeder	-	3-9	45-65	W9-90
164	H. Tenpas	-	4-5	50	
165	Moir	-	-	30-40	W9-140
166	Bryce	-	1.8	Variable	W9-98
167	C.W. Kennedy	-	2.5-3	20	
168	Unknown	-	4-5	Variable	
169	Unknown	-	2.4	20-30	
170	Unknown	-	4-6	20-30	
171	Unknown	-	2.4-3	25	
172	Unknown	-	4-6	60	
173	Unknown	-	2.4	50	
174	Unknown	-	1.5	Variable	
175	Unknown	-	3-5	60	
176	Unknown	-	1.2-2.4	25-40	
177	Unknown	-	6	40	
178	Unknown	-	5	70	
179	Unknown	-	1.5	40	
180	Unknown	-	3-3.6	5	
181	Unknown	-	5.4	20-40	
182	J. Kerr	-	4-4.5	40-75	W9-2
183	Unknown	-	3	35	
184	Unknown	-	1.5-2	60	
185	Unknown	-	3.6	25	
186	J. Moffat	-	4-5	56	
187	Mitchell	-	-	5-10	W9-99
188	Courtney	-	-	50-70	W9-191
189	Hogg	-	4	25-65	W9-55
190	Unknown	-	1-2	-	
191	Unknown	-	9	45	
192	Unknown	-	4-5	60	
193	Glouser	-	-	5-10	W9-83
194	Unknown	-	6-8	60	
195	Unknown	-	4-5	25-30	
196	Unknown	-	2.5-3	30-60	
197	Unknown	-	5-7	60-80	
198	Joe Kerr	-	2.4-4.5	60-85	W9-145
199	Unknown	-	4	0-5	
200	Unknown	-	4-6	70	
201	Unknown	-	2-3	60	
202	A. MacTavish	-	6	50-80	W9-129
203	Unknown	-	5-6	60-70	
204	J.N. Ross	-	3-6	65-80	W9-4
205	Unknown	-	2.4-3	40-50	
206	B. Corrigan	-	2-3	25-70	W9-155
207	B. Corrigan	-	3-7	40-75	
208	Miller Bros	-	2.4-3	20-45	
209	Unknown	-	2.4	20-30	

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
210	Unknown	-	6-8	60-70	
Howick Township					
Licenced Pits					
211	M. Wylie	15.16	8-10	60-70	
212	Huron County	23.4	4-5	60-70	
213	K. Dettman	12.3	9-10	60-70	
214	B. Dinsmore	23.60	10-15	50	
215	Joe Kerr	20.00	3-4	60-70	
216	Joe Kerr	41.50	4-5	60-70	
217	J. Sothern	29.3	8-10	10-70	
218	R. Drudge	12.00	7	50-60	
219	Hanna & Hamilton	18.70	6	50-75	
220	Robert Farrish	20.50	6-6.5	10-50	
221	Joe Kerr	13.10	4.5-6	60-70	
Unlicenced Pits					
222	Douglas	-	4-5	40-75	W9-169
223	Finlay	-	4.5	40-60	
224	Unknown	-	6-10	40	
225	Unknown	-	3	70	
226	Unknown	-	2	40	
227	Unknown	-	6-8	70	
228	Unknown	-	3.5	70	
229	Reddon	-	4-6	65	
230	Unknown	-	5	30-40	
231	Murray	-	3	Variable	W9-95
232	H. Hohnstein	-	3.5-4	60-70	
233	Douglas	-	5	30	
234	Unknown	-	5-6	60-70	
235	Pfeffer	-	4	70	
236	Unknown	-	2.4	20	
237	Unknown	-	3.5-4	40-60	
238	Unknown	-	5	60	
239	H. Litt	-	-	50-60	W9-7
240	Hogh Litt	-	10-12	20-40	
241	Coupland	-	3-4.5	40-50	
242	Unknown	-	4-5	65-70	
243	Ruton	-	3-3.6	-	W9-15
244	Unknown	-	4	40-50	
245	Unknown	-	1-1.5	70	
246	Unknown	-	2	10-20	
247	K. Hastie	-	3-4	40-50	
248	Huron County	-	5	85	W9-22
249	Unknown	-	6-8	70	
250	L. Halliday	-	4.5	30-50	W9-118
251	Unknown	-	10-15	30	

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
252	Winters	-	3-4.5	75	P1-24
253	Unknown	-	4-7	20	
254	Unknown	-	4	50-60	
255	McCutcheon	-	3	Variable	W9-81
256	Unknown	-	3.6	40	
257	Hyslop	-	3.6	45	W9-148
258	Hyslop	-	3-7.5	30-60	W9-16
259	Adams	-	6	65	W9-181
260	McCreary	-	-	50-55	W9-130
261	Unknown	-	2.4	10-20	W9-148
262	Earl Reichard	-	4.5	40%	W9-17
263	Unknown	-	6-8	70	
264	Unknown	-	12-15	50-70	
265	Unknown	-	1	20	
266	Vogan	-	4-5	20	W9-52
267	Unknown	-	2.4-3	-	
Morris Township					
Licenced Pits					
268	P. Jurchuk	5.00	12-14	50	
269	D & I Wattam Construction Ltd.	40.50	5-7	45-75	
270	Joe Kerr Ltd.	21.40	6-8	45-80	
271	Gordon Nicholson	41.00	8-10	55-60	
272	Joe Kerr Ltd.	11.00	4-12	59	
273	C. Yuill	20.00	8-10	40	
274	George Radford Construction Ltd.	30.00	4-20	65-80	
275	R.S. Procter	32.00	7	75	
276	Hugh Ives	40.00	10-15	45-65	
277	Mark Lichty	32.00	4-5	40-50	
278	K. Jorritsma	2.30	6-7	40	
279	K. Jorritsma	1.20	6-7	40	
280	John McKercher	6.00	8	50-65	
281	John McKercher	5.20	6-10	60-80	
Unlicenced Pits					
282	W. Wesseling	-	4.5	Variable	W9-93
283	D. Golly	-	4-5	50-70	
284	Unknown	-	2-3	40	
285	W. Haines	-	6-7	10	W9-187
286	H. Kerr	-	2.4	5	
287	Michie	-	5-6	60	W9-190
288	Unknown	-	-	40	
289	Unknown	-	3-6	40	
290	R. Huber				
291	Unknown	-	4-5	10-20	

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
292	Jacklin Construction	-	1-8	40-60	W9-151
293	G. Vancamp	-	-	10	W9-165
294	Unknown	-	-	40	
295	Shortreed	-	7.5-9	44	S4-46
296	Bell's	-	10	-	S4-50
297	Unknown	-	10	40	
298	Unknown	-	3	40	
299	T. Bernard	-	-	73	S4-130
300	I. Gascho	-	2.4-3	50	W9-8
301	Unknown	-	-	40	
302	Schwartzentruber	-	2-7	40	W9-194
303	H. Johnson	-	2-4	40	W9-193
304	Unknown	-	-	30	
305	R. Somer	-	10	70	S4-147
306	Unknown	-	-	10	
307	McCall	-	-	30	S4-60
308	J. Blake	-	6	30	S4-105
309	Unknown	-	3	40	
310	A. Henderson	-	9-10	45-60	W9-91
311	A. Cardiff	-	3-7	50-65	W9-195
312	Unknown	-	-	30	
313	Unknown	-	-	30	
314	Breckenridge	-	4.5	25	W9-124
315	Wheeler	-	3-6	33	W9-30
316	D. Chapman	-	1.5-4.5	10	W9-180
317	Unknown	-	-	20	
Grey Township					
Licenced Pits					
318	Donegan's Haulage	8.50	15-25	80	
319	Hanna & Hamilton	5.90	4-5	40-60	
320	John McKercher	21.80	4-6	60-65	
321	Robert Farrish	14.40	9-12	35-75	
322	Donegan's Haulage	94.50	4-10	30-75	
323	Hanna & Hamilton	3.40	8-9	60-70	
324	Hanna & Hamilton	2.75	7-8	40-70	
325	Robert Mitchell & Robert Leslie	2.51	5-8	60-70	
326	Hanna & Hamilton	4.30	8-9	45-70	
327	Hanna & Hamilton	11.06	4-15	30	
328	Robert Farrish	13.68	10-15	20-60	
329	Grey Township	11.70	5-10	60-70	
330	Paul Krauter	10.20	3-9	40-50	
331	R.J. Steel	26.02	3-5	30-50	
332	Douglas Rathwell	40.62	6-20	10-30	
333	Lloyd Jacklin	21.00	4-20	25-70	
334	Donegan's Haulage	40.50	2-3	60	

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
335	Grey Township	13.80	5-6.5	70	
336	Grey Township	12.80	3-9	30-40	
337	Balla Hi Farms Ltd.	4.60	4-10	25-70	
338	Machan Construction	15.81	3-7	20-40	
339	Grey Township	17.11	3-4	70	
340	Vern Willoughby	16.24	8.5	40	
341	Elma Township	10.00	9-10	60-65	
342	Lloyd Jacklin	20.00	2-10	30-80	
343	Hanna & Hamilton	17.78	4-6	45-70	
344	Robert Farrish	34.89	4-5	30-50	
Unlicenced Pits					
345	Unknown	-	3-4	60	
346	Unknown	-	5-7	40-50	
347	Unknown	-	3.6	70	
348	Unknown	-	3	-	
349	Unknown	-	5-7	30-70	
350	Unknown	-	4	35-50	
351	Unknown	-	1.8	-	
352	Hornack	-	3-4.5	-	W9-173
353	Nicholson	-	3	25-50	W9-175
354	Unknown	-	3-4	20	
355	Unknown	-	4	30	
356	K. Tyerman	-	4-8	40-70	
357	S. Johnston	13.78	3-4.5	30-70	W9-62
358	Ross	-	3-4	30-50	
359	MaCouty	-	4-5	50-70	
360	Unknown	-	4-5	60-70	
361	Stewart	-	3	10	
362	Unknown	-	3-4	-	
363	Unknown	-	5.6-7.5	10-15	
364	Clayton Knorr	-	5-7	40	
365	Adams	-	7.5	50-60	
366	Unknown	-	1.8-2	30	
367	Unknown	-	1.8	25	
368	Unknown	-	3	40	W9-159
369	Allister	-	2.7	80	W9-126
370	Stewart	-	3	-	Sandy
371	Unknown	-	4.5	50-70	
372	Unknown	-	6-7	60	
373	Unknown	-	2.4	40	
374	Unknown	-	3	50	
375	MacDonald	-	-	-	W9-102
376	McKay	-	2.4	20-30	S4-81
377	Bremmer	-	-	-	S4-91
378	Unknown	-	3.6-4.5	70	
379	Clarke	-	3	30-65	S4-126

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
380	Unknown	-	3-3.6	30-40	
381	McNaught	-	7-8	20-30	
382	Shaw	-	-	-	
383	Speiren	-	-	30	S4-89
384	C. Stevenson	-	1.5-4.5	50-80	S4-127
385	Kesso	-	-	50-60	S4-115
386	Unknown	-	1.5	40-50	
387	Menzies	-	1.8	20	W9-27
Goderich Township					
Licenced Pits					
388	779087 Ontario Inc.	7.50	2.5-4	30-70	G4-17
389	Goderich Investments Ltd.	13.00	4.5-6	40-50	G4-9, G4-21
390	Donald Crich	24.00	2	-	
391	A. Vanden Heuval	24.40	4-6	20-60	G4-20
392	Falleens Holdings Inc.	29.10	3-4	40-70	G4-57
393	Lavis Contracting Ltd.	3.2	4-5	10-50	
394	C.E. Reid & Sons (Hensall) Ltd.	17.60	8-10	40-70	G4-46
395	J.F. Murray	6.50	4-5	25-30	G4-63
396	Lavis Contracting Ltd.	37.70	5.5-6	20-30	
397	George Lavis	47.50	3-4	20-50	
398	Lavis Contracting Ltd.	9.50	6-9	60-70	
399	Lavis Contracting Ltd.	3.70	2-3	60-70	G4-66
400	John B. Lavis	4.84	5-6	10-50	
401	Stanley Township	46.60	2-3	30-60	
402	McCann Redi-Mix Inc.	22.00	3-5	30-60	G4-28
403	Merner Aggregates Ltd.	53.95	2.5-3	30-60	
404	Robert M. Elliott	67.40	1-2	50	
405	Steven C. Cooke	18.90	2-3	60-70	
406	Lakeland Sand and Stone Ltd.	41.72	2-3.5	20-65	G4-26
407	Goderich Township	18.00	1-2	60-70	
408	Simon and Yolanda VanDriel	4.05	-	45-60	
409	Jennison Construction Ltd.	27.48	2-2.5	30	
410	Lavis Contracting Ltd.	37.30	2-4	50-60	
411	Lavis Contracting Ltd.	25.80	4-5	20-30	
412	W.T. Trick	60.00	2.5-3	40-60	
413	Kenneth G. Merner	7.25	-	-	
Unlicenced Pits					
414	Unknown	-	3	30	
415	C.L. Bissett	-	1.5-3	-	G4-11
416	Harvey	-	1.5	-	G4-8
417	Maitland River Pit	-	2-3	40-50	G4-89
418	Bradford-Brewer	-	2-2.5	50-70	G4-38
419	Unknown	-	4	50-60	

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
420	Unknown	-	6	0-5	
421	Klazinga	-	1.2	20	G4-24
422	Lassaline	-	1.8	10-20	G4-51
423	Unknown	-	1.8-4.5	15-20	G4-13
424	Orr	-	3	-	G4-15
425	Unknown	-	2.4	20	
426	Unknown	-	3	15-20	G4-19
427	Falconer	-	3	15	G4-39
428	Porter Bros.	-	1.5-3	0-10	G4-41
429	Timms	-	3	-	G4-42
430	W.K. Porter	-	3-3.5	0-5	G4-47
431	Mervinlobb	-	-	25-45	G4-50
432	Bell	-	1.2-1.8	30	G4-2
433	Proctor # 1	-	2.4-2	0-5	G4-5
434	G. Elliot	-	2.5-3	60	G4-30
435	Unknown	-	5-6	10-20	
436	R.S. Thompson	-	-	0-20	G4-12
437	Lavis Contracting Ltd.	-	4-10	0-40	G4-12
438	Unknown	-	3-7	10-30	G4-64
439	Lavis Contracting Ltd.	-	3.6-4.5	35-40	G4-12
440	Unknown	-	2.5	0-10	
441	D. Henderson	-	1.5-3	0-5	G4-101
442	G. Picot	-	1.8	10	G4-48
443	Unknown	-	4-4.5	30-50	
444	R. Studson	-	2.5-3	15	
445	Scotchmer	-	2.4-3	>20	G4-10
446	Steenstra	-	-	-	G4-107
447	Lindsay #1	-	3	5	G4-3
448	T. Rathwell	-	1.8-3	25	G4-96
449	Unknown	-	-	0-15	G4-95
Hullett Township					
Licenced Pits					
450	Hullett Township	12.70	3-3.5	60-70	
451	George Radford Construction Ltd.	5.80	5-15	25-75	
452	Carl Nesbitt	12.30	6	40-75	S4-9, S4-86
453	George Radford Construction Ltd.	30.3	3-9	50-60	S4-38, S4-29
454	Lynne and Stephen Flynn	32.5	5-8	20-30	G4-84
455	Hullett Township	20.1	4-6	70	
456	George Radford Construction Ltd.	28.3	5-6	20-70	S4-85
Unlicenced Pits					
457	W. Vincent	-	3	20-40	
458	P. Yongblut	-	1.5-5	-	S4-59

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
459	L. Popp	-	3	30	S4-106
460	N. Knapp	-	-	0-5	S4-98
461	J. Weirsma	-	6	20-30	
462	Unknown	-	2-3	50-70	
463	G. Hoggart	-	3-45	50-70	
464	E. Joshling	-	4.5	-	S4-84
465	Fangan	-	5-10	50-75	S4-62
466	Caldwell	-	1.5-6	20	S4-67
467	Unknown	-	8	30-40	
468	Unknown	-	1.5-2	-	
469	Unknown	-	2-3	10-15	
470	Unknown	-	1.5-2	40-50	
471	M. Roy	-	7.5-10	70	S4-19
472	Adams	-	6-9	40-50	S4-32
473	Arnold Riley	-	3	20-30	
474	George Radford Construction Ltd.	-	3	40	S4-44
475	Unknown	-	3	-	
476	Snell	-	3-4.5	0-60	S4-97
477	I. Carter	-	8	45-70	S4-96
478	L. Snell	-	3-9	30	S4-93
479	Tibbetts	-	5-6	0-5	S4-117
480	Unknown	-	5	-	
481	C. Mann	-	6-12	45-75	G4-85
482	Unknown	-	8	-	
483	J. Beane	-	-	0-5	S4-134
484	C. Dale	-	6-9	60-80	S4-53
485	M. Dale	-	9	10-20	S4-41
486	Unknown	-	5	-	
487	Unknown	-	3-5	-	
488	N. Glazier	-	5	30	S4-52
489	Glazier	-	3	10	S4-45
490	Seagram	-	5-6	15-25	S4-18
491	Fowler	-	3	-	S4-58
McKillop Township Licenced Pits					
492	George Radford Construction Ltd.	35.00	10-12	70-75	
493	N. & B. McGavin	9.60	8-12	40-60	S4-102
494	Logan Township	7.10	4-6	65-70	
495	K. M. Hulley	15.60	3-4	40-60	S4-120
496	George Radford Construction Ltd.	24.00	3-4	40-60	S4-104
497	B. Whitmore	12.00	3-4	50-70	
498	D. Dalton	8.90	10-11	40-60	
499	Frank Kling Ltd.	21.20	10	-	

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	% Gravel	Remarks
500	G. Pryce	34.00	2-3	50-70	
501	W. Whyte	1.00	3-8	60-70	
502	Frank Kling Ltd.	17.30	15-20	50-70	
503	D. Dodds	40.90	4.5-9	70	S4-43
504	John H. McLlwain Construction Ltd.	7.40	3-9	50-60	S4-49
505	John H. McLlwain Construction Ltd.	11.67	8-15	60-70	
506	Earl Roney	20.80	5	55	S4-103
507	D.J. Moylan	7.40	3-6	40-70	S4-12
508	John H. McLlwain Construction Ltd.	46.00	3-5	35-40	
Unlicenced Pits					
509	Bourenmann	-	4.5	30	S4-121
510	Unknown	-	-	-	
511	Unknown	-	3	40-50	
512	N. White	-	3-6	50-70	S4-118
513	Unknown	-	-	40-50	
514	Flanagan	-	1.5-3.6	40-50	S4-73
515	Gavenlock	-	1.5-3	64	S4-110
516	Scott #2	-	6-10	70-75	S4-14.
517	Nash	-	3-4.5	40-50	S4-68
518	Maloney	-	3	50-60	S4-61
519	Frank Kling Ltd.	-	-	40-50	S4-10
520	Nixon	-	3-6	5-10	S4-40
Stanley Township					
Licenced Pits					
521	John B. Chapman	4.05	4	10-20	
522	G. Heard Construction Ltd.	19.10	1-1.5	50-60	
523	Huron County	35.06	2-3	10-20	
Unlicenced Pits					
524	J. Brandon	-	2-2.5	30-80	G4-4-1
525	Brandon #2	-	4-5	60-70	G4-78-1
526	J. Brandon	-	-	80	G4-4-2
527	Heard	-	3-4	10-25	G4-36
528	Bill Peck #1	-	2-3	50-70	G4-73
529	Bill Peck #2		1.5	0-50	G4-73
530	Unknown	-	12	80	
531	Unknown	-	1.2-1.5	0-5	
532	Reid	-	1.5	0-20	G4-76
533	C. Reid	-	1.5	0-20	G4-88
534	McLymont	-	-	0-5	G4-99
535	R.V. Becker	-	3-6	20-30	G4-31
536	Gingerich	-	3	20	G6-35

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
537	Unknown	-	-	-	
538	Unknown	-	1.8	30	
539	Unknown	-	3.6	40	
Tuckersmith Township					
Licenced Pits					
540	Tuckersmith Township	40.00	8-10	40-50	
541	D.G. Heard	5.00	4-5	40-50	
542	Jennison Construction	4.65	-	50-80	
543	Jennison Construction	18.00	3-8	50-80	S8-2
544	Reid	10.25	6-7	0-5	S8-160
Unlicenced Pits					
545	Berg	-	2.1	0-5	G4-103-2
546	Berg	-	-	0-5	G4-103-1
547	McKenzie #2	-	-	0-10	S4-17
548	Green	-	4-5	-	S8-110
549	Passmore	-	4-5	30	S8-5
550	Brock	-	-	0-20	S8-146
551	Unknown	-	2-3	20-30	
552	Pepper	-	-	0-5	S8-145
553	Arnold Westelaken	-	7-8	0-10	
Hay Township					
Licenced Pits					
554	M.J. Zandwyk	16.60	2-3	0-40	G6-40
555	E & B Johnson (Sarnia) Ltd.	9.00	2-3	5-40	G6-7
556	Hay Township	5.05	1.2	23	
557	Anna Schroeders	40.50	-	0-5	
Unlicenced Pits					
558	Unknown	-	-	-	
559	Unknown	-	-	-	
560	K. Gascho	-	1.8-3.9	0-20	G6-9
561	Jerome Dietrich	-	2.4-3	0-10	G6-12
562	Clarke	-	1.5-3.6	0-10	G6-30
563	Duward McAdams	-	3	10-30	G6-60
564	Bassow	-	1.5-3.6	0-40	G6-29
565	Hartman	-	-	-	G6-41
566	Unknown	-	-	-	
567	Ardzirk	-	1.2-3	10-40	G6-21
568	Grenier	-	1.8-2.4	0-20	G6-11
569	Becker	-	2-2.5	0-15	G6-31
570	Oestreicher	-	-	-	G6-10
571	Unknown	-	-	-	
572	Miller	-	1.8-2.4	0-20	G6-14
573	Unknown	-	-	-	

TABLE 2 - SAND AND GRAVEL PITS HURON COUNTY					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
Stephen Township					
Unlicenced Pits					
574	Unknown	-	2.4	10-30	
575	Unknown	-	-	-	
576	Unknown	-	-	-	
577	McBride	-	1.5	-	G6-38
578	John Campbell	-	2	12	
579	Jennison	-	-	20	
580	Unknown	-	2.1	20	
581	Unknown	-	-	-	
582	C.P. Dietrich	-	1.2-3	0-10	G6-18
583	Locke	-	1-2	0-20	G6-37
Usborne Township					
Licenced Pits					
584	Jennison Construction Ltd.	7.30	2-3	20-30	S8-113
585	Raymond Cann	13.72	5-6	30	S8-1
586	McCann Redi-Mix Inc.	20.30	7-8	20-30	S8-6, S8-11
587	Usborne Township	25.50	5-6	70-80	
588	Jeffrey Taylor	23.76	3-5	60-70	
589	Jennison Construction Ltd.	11.24	2-3	50-70	
590	Prout Farms	90.60	2-4	40-70	S8-63
591	Alan E. Scott	47.50	2.5-6	40-60	S8-29
592	McCann Construction Inc.	40.47	2-4	60-70	S8-13
593	Usborne Township	16.13	3-4	70-80	S8-13
Unlicenced Pits					
594	Parsons	-	2.7	0-10	S8-144
595	Town of Hensall	-	-	20-30	S8-103
596	Rowcliffe	-	-	75-80	S8-142
597	Unknown	-	4-5	50-70	
598	J. Quick	-	3-4	10-65	S8-138
599	Unknown	-	3-4	20-40	
600	Unknown	-	4-5	50	
601	Barry Greffary	-	3-5	50-60	
602	Unknown	-	4-5	60-70	
603	Unknown	-	3-4	70-80	
604	Unknown	-	6-9	20-30	

TABLE 3 - SELECTED SAND AND GRAVEL RESOURCE AREAS HURON COUNTY						
1 Deposit No.	**2 Unlicenced Area (Hectares)***	**3 Cultural Setback (Hectares)****	**4 Extracted Area (Hectares)*****	**5 Possible Area (Hectares)**	**6 Estimated Deposit Thickness (Metres)**	**7 Possible Aggregate Resources**** (Million Tonnes)**
1	773.2	65.0	13.5	694.7	6	73.8
2	226.9	43.4	5.0	178.5	7	22.1
3	682.7	163.3	3.0	516.4	6	54.8
4	162.1	34.5	0.0	127.6	7	15.8
5	182.1	9.0	3.5	169.6	6	18.0
6a	127.2	13.0	4.0	110.2	6	11.7
6b	189.4	51.5	2.0	135.9	6	14.4
6c	125.3	22.5	7.5	95.3	6	10.1
7a	56.8	3.3	0.0	53.6	8	7.6
7b	87.2	7.0	0.5	79.7	6	8.5
8	67.8	2.0	0.0	65.8	8	9.3
9	140.6	34.0	0.5	106.1	6	11.3
10a	14.8	3.8	1.0	10.0	8	1.4
10b	46.7	14.3	2.0	30.4	8	4.3
10c	11.5	0.0	0.2	11.3	6	1.2
10d	36.6	6.0	6.0	24.6	6	2.6
11a	221.0	31.5	2.0	187.5	6	19.9
11b	75.8	7.6	2.0	66.1	6	7.0
12a	293.3	56.0	8.5	228.8	6	24.3
12b	193.9	38.0	10.0	145.9	6	15.5
13a	21.4	0.0	0.3	21.1	6	2.2
13b	50.1	12.3	0.0	37.9	6	4.0
13c	81.6	24.8	1.3	55.6	4.5	4.4
14	44.3	8.9	6.2	29.2	7	3.6
15	204.5	58.5	2.5	143.5	6	15.2
16a	35.7	3.3	4.5	28.0	6	3.0
16b	11.7	0.0	1.5	10.2	6	1.1
17	50.3	11.8	3.5	35.1	6	3.7
18a	40.0	6.5	4.0	29.5	6	3.1
18b	30.6	6.5	6.0	18.1	6	1.9
18c	35.0	5.5	7.0	22.5	6	2.4
19a	25.4	6.5	0.0	18.9	4.5	1.5
19b	28.5	11.5	0.0	17.0	4.5	1.4
20	244.7	90.3	2.6	151.8	4.5	12.1

TABLE 3 - SELECTED SAND AND GRAVEL RESOURCE AREAS
HURON COUNTY

1 Deposit No.	2 Unlicenced Area (Hectares)*	3 Cultural Setback (Hectares)**	4 Extracted Area (Hectares)***	5 Possible Area (Hectares)	6 Estimated Deposit Thickness (Metres)	7 Possible Aggregate Resources**** (Million Tonnes)
21a	24.1	2.0	3.0	19.1	6	2.0
21b	27.7	3.5	3.0	21.2	4.5	1.7
22	106.2	33.4	6.0	66.8	6	7.1
23	88.2	28.5	2.0	57.7	8	8.2
24	20.1	8.8	0.5	10.9	6	1.2
TOTAL FOR STUDY AREA						
	4884.6	**927.8**	**125.0**	**3831.8**		**413.6**

Minor variations in all tables are caused by the rounding of 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, 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 HURON COUNTY				
1 Drift Thicknes (Metres)	2 Formation	3 Estimated Deposit Thickness (Metres)	4 Areal Extent (Hectares)	5 Originals Tonnage (Million Tonnes)
Ashfield Township				
		None		
Subtotal				
West Wawanosh Township				
<1	Lucas	18	4.8	2.3
1 to 8	Lucas	18	9.0	4.3
8 to 15	Lucas	18	85.1	40.6
Subtotal			98.9	47.1
East Wawanosh Township				
<1	Lucas	18	1.8	0.8
1 to 8	Lucas	18	27.8	13.3
8 to 15	Lucas	18	186.7	89.0
Subtotal			216.2	103.1
Colborne Township				
<1	Lucas	18	5.7	2.7
1 to 8	Lucas	18	12.6	6.0
8 to 15	Lucas	18	14.4	6.9
<1	Dundee	18	279.9	133.5
1 to 8	Dundee	18	396.7	189.2
8 to 15	Dundee	18	66.1	31.5
Subtotal			775.4	369.7
Turnberry Township				
1 to 8	Amherstburg	18	164.1	78.3
8 to 15	Amherstburg	18	626.1	298.5

TABLE 4 - TOTAL IDENTIFIED BEDROCK RESOURCES HURON COUNTY				
1 Drift Thicknes (Metres)	**2 Formation**	**3 Estimated Deposit Thickness (Metres)**	**4 Areal Extent (Hectares)**	**5 Originals Tonnage (Million Tonnes)**
1 to 8	Formosa Reef Limestone Member (Amherstburg Formation)	18	52.8	25.2
8 to 15	Formosa Reef Limestone Member (Amherstburg Formation)	15	1245.9	495.0
<1	Lucas	18	4.9	2.3
1 to 8	Lucas	18	4.5	2.1
8 to 15	Lucas	18	156.4	74.6
Subtotal			2254.6	976.0
Howick Township				
8 to 15	Bass Island	18	23.8	11.3
1 to 8	Bois Blanc	18	21.4	10.2
8 to 15	Bois Blanc	18	316.7	151.0
<1	Amherstburg	18	4.6	2.2
1 to 8	Amherstburg	18	220.7	105.2
8 to 15	Amherstburg	18	2859.0	1363.2
8 to 15	Lucas	18	324.5	154.7
Subtotal			1798.0	3770.8
Morris Township				
8 to 15	Formosa Reef Limestone Member (Amherstburg Formation)	15	9.3	3.7
<1	Lucas	18	31.8	15.1

TABLE 4 - TOTAL IDENTIFIED BEDROCK RESOURCES HURON COUNTY				
1 Drift Thicknes (Metres)	2 Formation	3 Estimated Deposit Thickness (Metres)	4 Areal Extent (Hectares)	5 Originals Tonnage (Million Tonnes)
1 to 8	Lucas	18	1056.0	503.5
8 to 15	Lucas	18	3863.6	1842.2
8 to 15	Dundee	18	36.7	17.5
Subtotal			4997.3	2382.1
Grey Township				
1 to 8	Lucas	18	293.1	139.7
8 to 15	Lucas	18	2278.8	1086.6
<1	Dundee	18	65.4	31.2
1 to 8	Dundee	18	693.5	330.7
8 to 15	Dundee	18	861.0	410.5
Subtotal			4191.8	1998.7
Goderich Township				
<1	Dundee	18	32.3	15.4
1 to 8	Dundee	18	515.2	245.7
8 to 15	Dundee	18	409.2	195.1
Subtotal			956.8	456.2
Hullett Township				
8 to 15	Lucas	18	410.0	195.5
1 to 8	Dundee	18	0.16	0.1
8 to 15	Dundee	18	1181.6	563.4
Subtotal			1591.8	759.0
McKillop Township				
8 to 15	Lucas	18	81.4	38.8
1 to 8	Dundee	18	8.6	4.1

TABLE 4 - TOTAL IDENTIFIED BEDROCK RESOURCES
HURON COUNTY

1 Drift Thicknes (Metres)	2 Formation	3 Estimated Deposit Thickness (Metres)	4 Areal Extent (Hectares)	5 Originals Tonnage (Million Tonnes)
8 to 15	Dundee	18	2557.9	1219.7
Subtotal			39447.2	2648.0
Stanley Township				
		None		
Subtotal				
Tuckersmith Township				
1 to 8	Dundee	18	44.1	21.0
8 to 15	Dundee	18	1708.9	814.8
Subtotal			1753.0	835.9
Hay Township				
		None		
Subtotal				
Stephen Township				
		None		
Subtotal				
Usborne Township				
		None		
Subtotal				
Huron County Total				
			23254.4	10988.4

Minor variations in all 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 potential and some is unavailable for extraction due to land use restrictions.

TABLE 5 - QUARRIES HURON COUNTY				
Quarry No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)**	**Remarks**
		- NONE -		

TABLE 6 - SELECTED BEDROCK RESOURCE AREAS
HURON COUNTY

1 Area No.	2 Depth of Overburden (Metres)	3 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)

- NONE -

TABLE 7 - SUMMARY OF TEST HOLE DATA OR SELECTED SAMPLE DATA HURON COUNTY
- NONE -

TABLE 8 - SUMMARY OF GEOPHYSICAL DATA HURON COUNTY
- NONE -

TABLE 9 - AGGREGATE QUALITY TEST DATA
SAND AND GRAVEL SAMPLES
HURON COUNTY

		COARSE AGGREGATE					FINE AGGREGATE
Sample No.	Pit No.	Petrographic Number Granular & 16 mm Crushed	Petrographic Number Hot Mix & Concrete	Absorption (%)	Los Angeles Abrasion* (% Loss)	Micro Deval Abrasion (% Loss)	Micro Deval Abrasion (% Loss)
Ashfield Township							
HR-PT-95	14	147.2	175.5	2.34	27	14.4	26.8
West Wawanosh Township							
HR-PT-72	58	103	112	1.28	24	10.3	17.1
Turnberry Township							
HR-PT-377	160	106	147	2.32	26	12.4	17.9
HR-PT-402	186	181	258	3.02	35	16.7	22.7
Howick Township							
HR-DS-556	215	117	250	2.44	23	10.8	21.1
HR-DS-596		151	255	2.65	29	13.2	21.5
HR-DS-519		105	193	2.01	26	7.4	20.1
Goderich Township							
HR-PT-852	404	131	174	2.19	29	16.6	17
McKillop Township							
HR-TH-S245	511	166	232	2.13	18	13.7	16.1
Usborne Township							
HR-PT-827	591	136	181	1.79	29	16.7	20.4

Note - the quality test data refers strictly to a specific sample. Because of inherent variability of sand and gravel deposits, care should be exercised in extrapolating such information to the rest of the deposit.

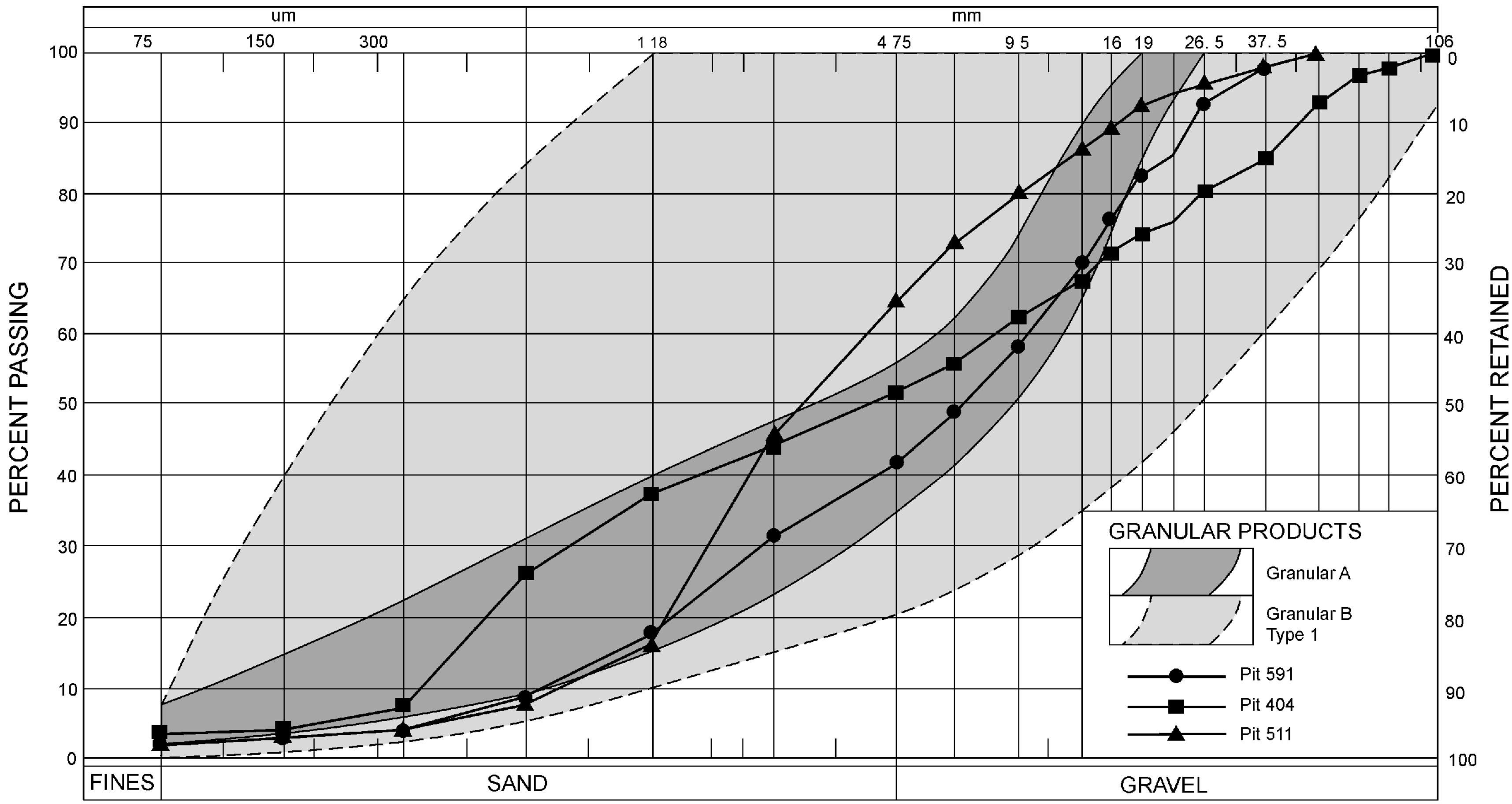


FIGURE 2A AGGREGATE GRADING CURVES, HURON COUNTY

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from 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. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

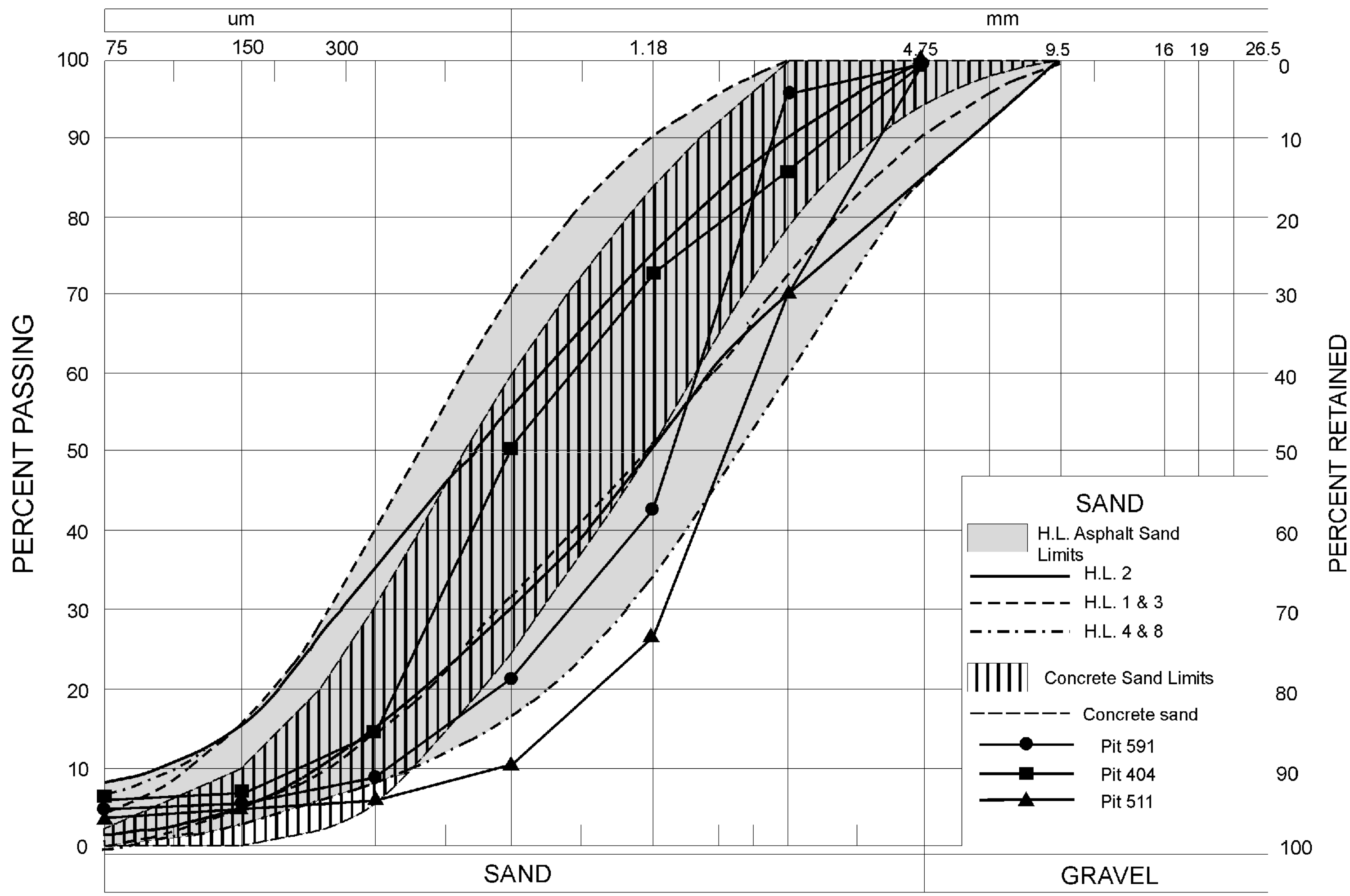


FIGURE 2B AGGREGATE GRADING CURVES, HURON COUNTY

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from 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. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

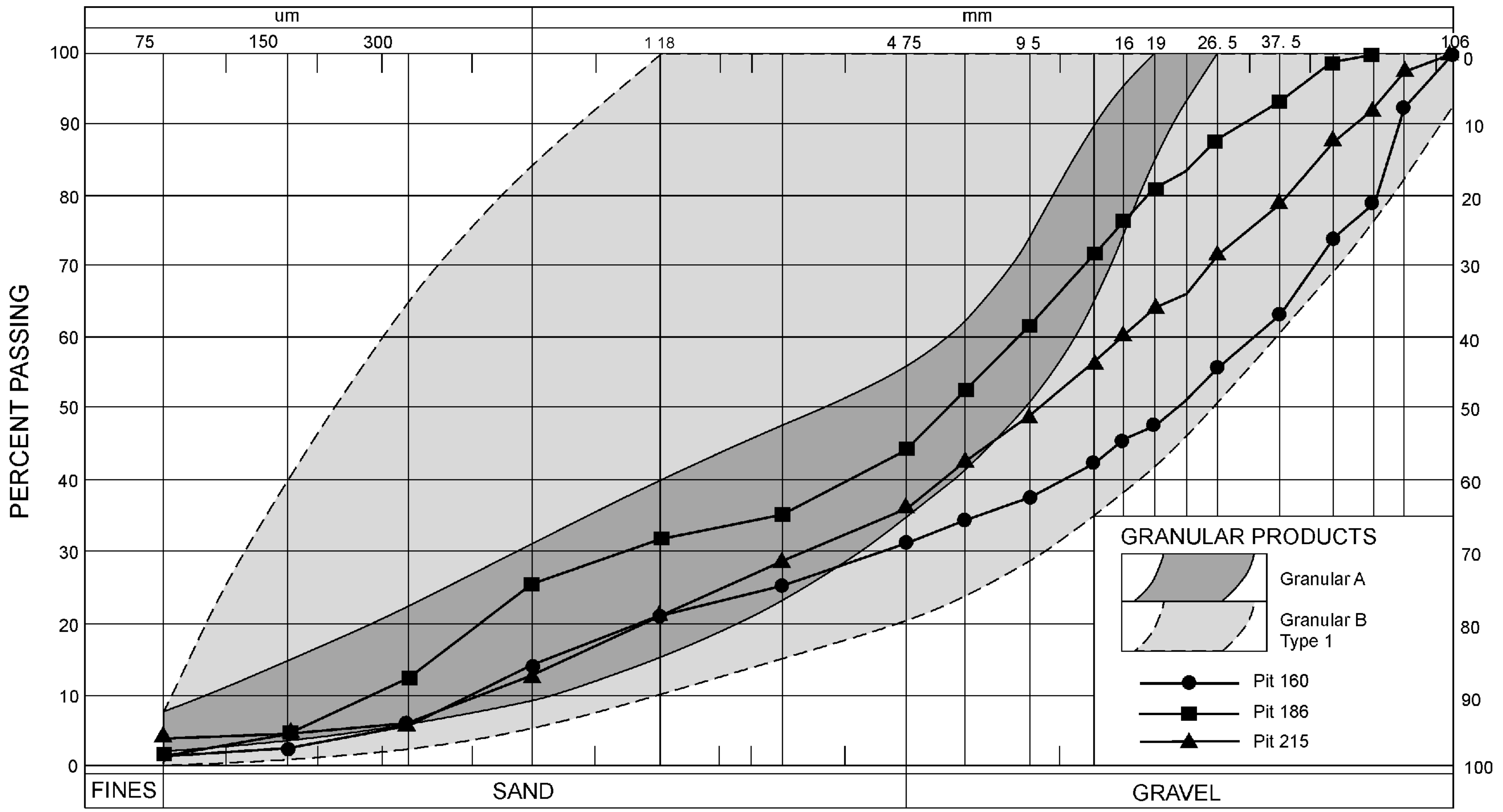


FIGURE 3A AGGREGATE GRADING CURVES, HURON COUNTY

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from 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. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

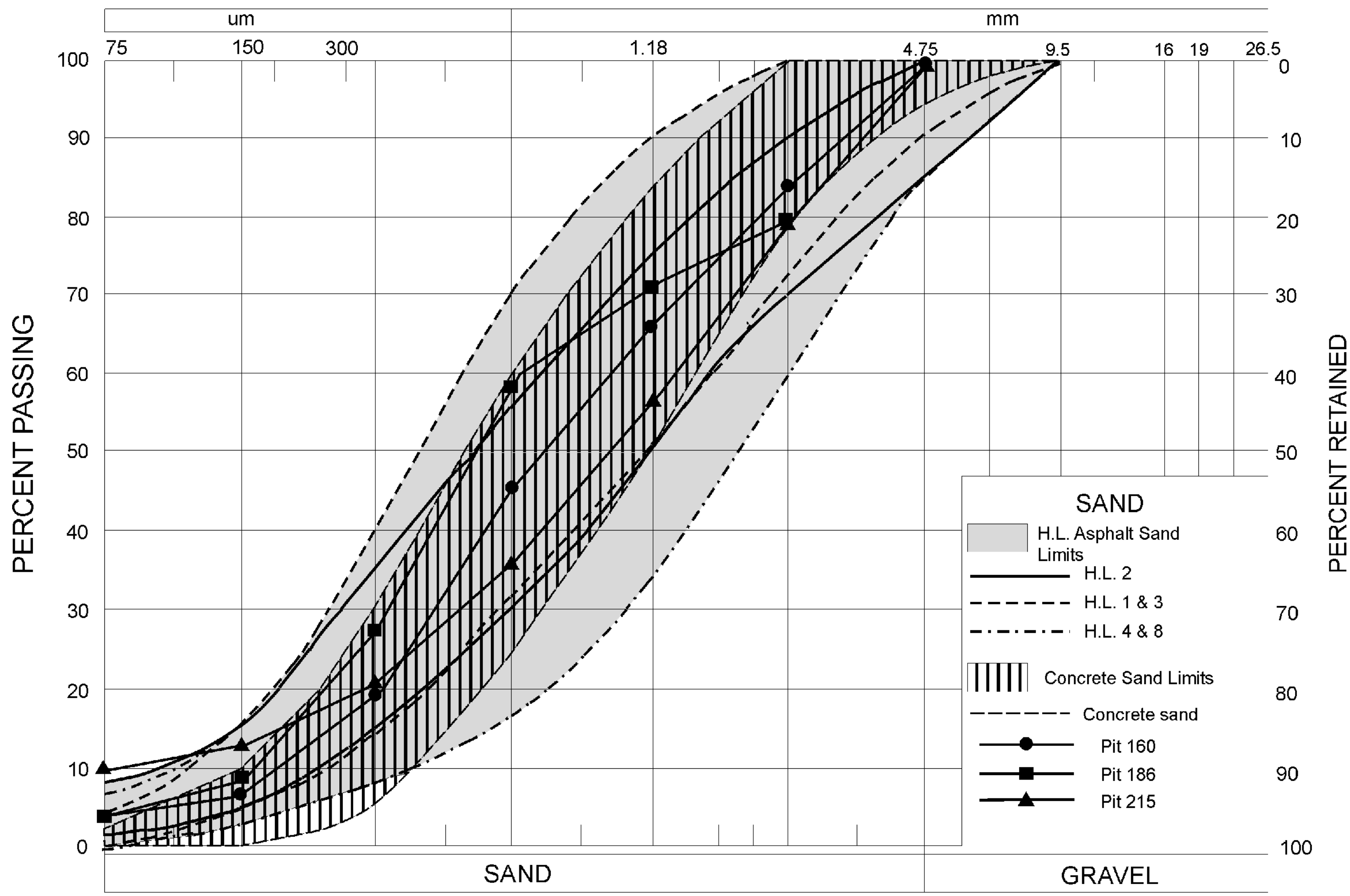


FIGURE 3B AGGREGATE GRADING CURVES, HURON COUNTY

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from 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. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

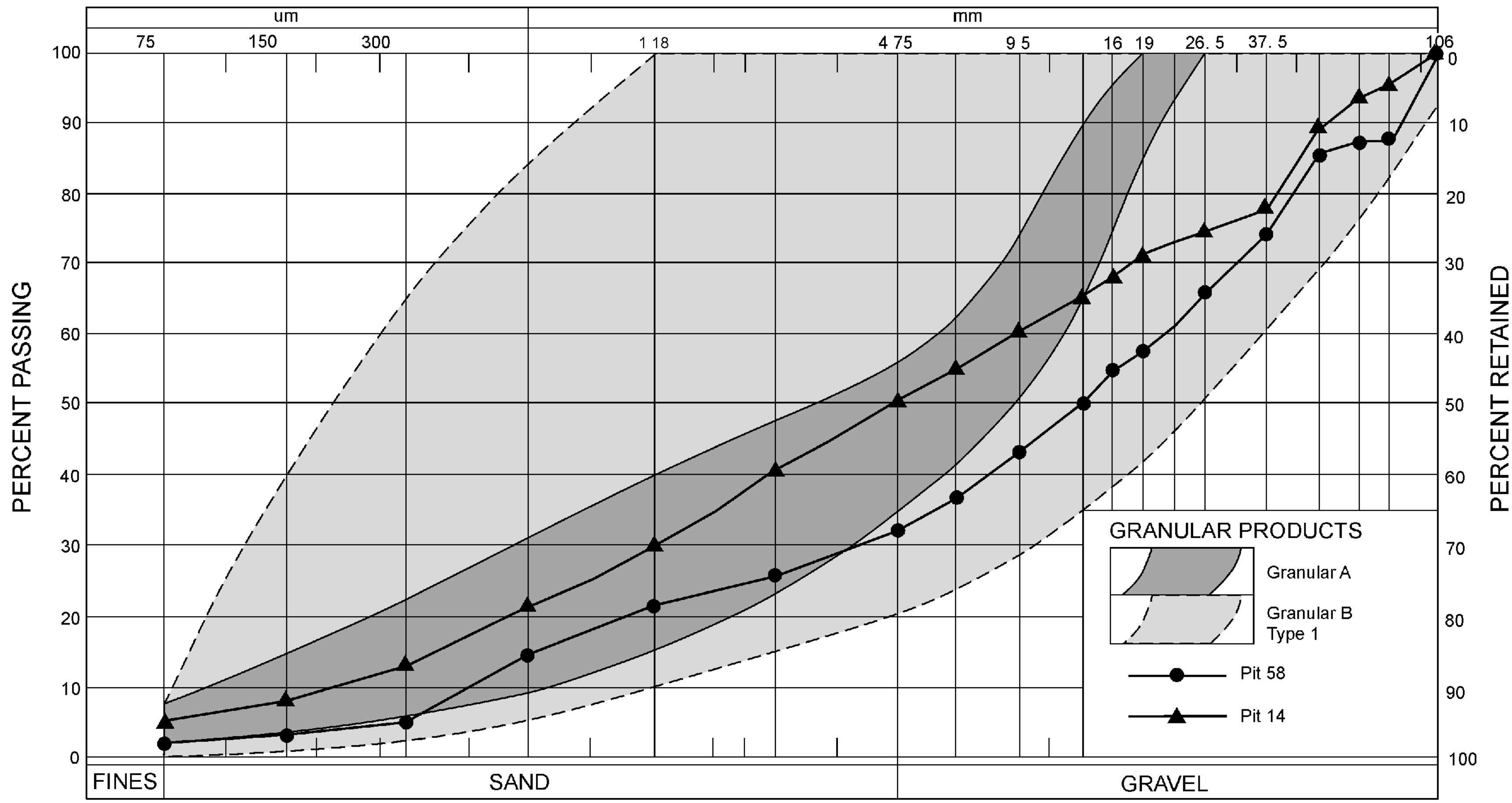


FIGURE 4A AGGREGATE GRADING CURVES, HURON COUNTY
Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988).

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

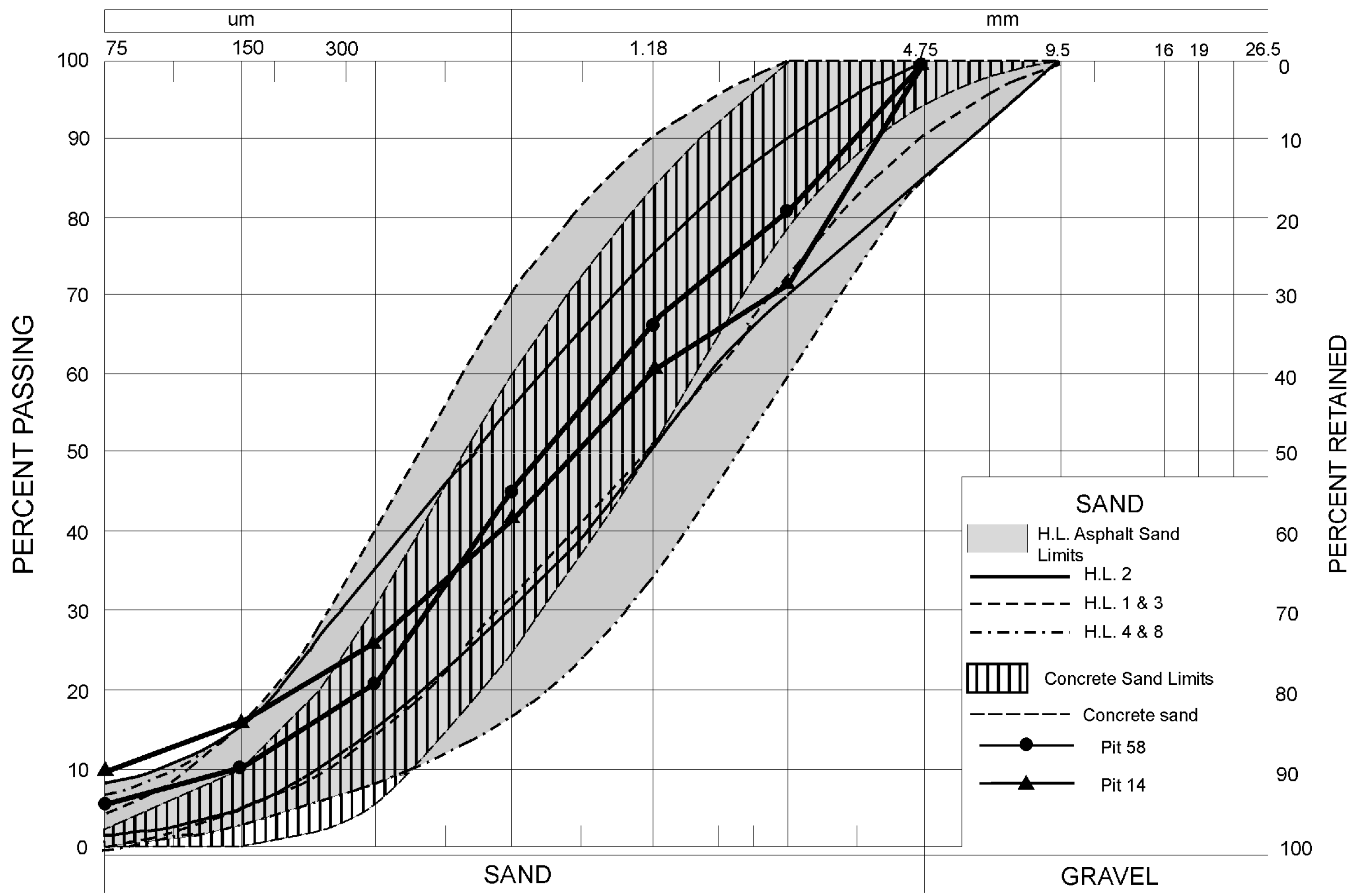


FIGURE 4B AGGREGATE GRADING CURVES, HURON COUNTY
Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1002, 1988 and 1003, 1988).

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

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Appendix B – Glossary

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

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

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

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

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

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

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

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

Bulk Relative Density: The density of a material related to water at 4°C and atmospheric pressure at sea level. An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 505 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 finally 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 alkalies 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 which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 408 and 360 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 whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (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. Four types have been defined: 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 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).

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 (HL 1, 3 and 4), or as binder course (HL 2, 4 and 8) used to bind the surface course to the underlying granular base.

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

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

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

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

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

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

Ordovician: An early period of the Paleozoic Era thought to have covered the span of time between 505 and 438 million years ago.

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

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

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

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

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

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 438 and 408 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 two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous 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 crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers, consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout 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 which may exhibit wide variations in grain size distribution. As these features were deposited under glacial lake waters, silt and clay which 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. The sediments which form the plain are predominantly fine to medium sand, silt and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources 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.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best 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 the Geological Survey of Canada should be referred to for more detailed information. The composition, thickness and uses of the formations are discussed. 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 this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use. The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded non-calcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 14 m. USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: part of the Potsdam Group. COMPOSITION: 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 (Asphalt & Concrete) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 6 to 64 m. USES: quarried extensively for aggregate in area of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate. 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 (Asphalt & Concrete) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: 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 (Asphalt & Concrete) = 105-120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. 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 (Asphalt & Concrete) = 122-440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: eastern Ontario - the basal unit of the Ottawa Group; central Ontario - overlain by the Simcoe Group. COMPOSITION: in eastern Ontario - silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario - conglomerates, sandstones, and shales. THICKNESS: eastern Ontario - 2 to 3 m; central Ontario - 0 to 12 m. USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and Ottawa Group (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. COMPOSITION: in central and eastern Ontario the lower member consists of alternating units of limestone, dolomitic limestone and dolostone, the upper member consists of thin-bedded limestones with thin shale partings; west of Lake Simcoe the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 7.5 to 136 m. USES: quarried in the Lake Simcoe, Kingston, Ottawa and Cornwall areas for crushed stone. Rock from certain layers in eastern and central Ontario has proven to be alkali-reactive when used in Portland cement concrete (alkali-carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-13, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (Asphalt & Concrete) = 100-153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin-bedded fine-crystalline limestone with numerous shaly partings in the middle member. 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 (Asphalt & Concrete) = 100-320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 32 to 65 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. 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 (Asphalt & Concrete) = 120-255.

Lindsay Formation (Middle Upper Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups; in eastern Ontario is divisible into an unnamed lower member and the Eastview Member; in central Ontario is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: eastern Ontario - the lower member is interbedded, very fine- to coarse-crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine- to fine-crystalline, petroliferous limestone; central Ontario – Collingwood Member is a black, calcareous shale whereas the lower member is a very fine- to coarse-crystalline, thin-bedded limestone with very thin, undulating shale partings. THICKNESS: 25 to 67 m. USES: eastern Ontario - lower member is used extensively for aggregate production; central Ontario - quarried at Picton, Ogden Point and Bowmanville for cement. 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 (Asphalt & Concrete) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: central Ontario – Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; eastern Ontario – Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: Blue Mountain Formation - blue-grey, noncalcareous shales; Billings Formation - 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 61 m; Billings Formation - 0 to 62 m. USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: central Ontario – Georgian Bay Formation composed of interbedded limestone and shale; eastern Ontario – Carlsbad Formation composed of interbedded shale, siltstone and bioclastic limestone. THICKNESS: Georgian Bay Formation - 91 to 170 m. Carlsbad Formation - 0 to 186 m. USES: Georgian Bay Formation - used by several producers in 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. Carlsbad Formation - used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 45 to 335 m. USES: There are several large quarries developed in the Queenston Formation in the Toronto–Hamilton region and one at Russell, near Ottawa. All extract shale for brick manufacturing. The Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Peninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium- to coarse-grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 - 8 m. USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin-bedded, blue-grey to buff-brown dolomitic limestones and dolostones. THICKNESS: 0 to 25 m. USES: extracted for crushed stone in St. Vincent and Sarawak townships, Grey County, and for decorative stone on Manitoulin Island.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs in subsurface throughout southwestern Ontario and outcrops along the length of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 10 to 39 m. USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile. Extraction limited by lack of suitable exposures.

Grimsby Formation (Lower Silurian)

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 15 m. USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick-bedded quartz sandstone. THICKNESS: 2 - 3 m. USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION: dark-grey to green shale with minor interbedded limestone. THICKNESS: 0 to 2 m. USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 7.5 m. USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 15 m. USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: occurs on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff-brown, micro- to medium-crystalline, thin- to medium-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 (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation - fine- to coarse-crystalline dolostone with high silica content; Reynales Formation - thin- to thick-bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation 6 to 26 m; Reynales Formation 0 to 3 m. USES: both formations quarried for aggregate with 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 (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. COMPOSITION:

massive, coarse-crystalline crinoidal limestone. THICKNESS: 0 to 2 m. USES: not utilized extensively.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. COMPOSITION: black to dark grey calcareous shale with numerous limestone lenses. THICKNESS: 5 to 24 m. USES: not utilized extensively. AGGREGATE SUITABILITY TESTING: PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Asbn = 2.2, BRD = 2.67, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. COMPOSITION: sandy to shaly dolomitic limestone and dolostone. THICKNESS: 0 to 5 m. USES: too shaley for high quality uses, but is quarried along with Lockport Formation in places. AGGREGATE SUITABILITY TESTING: PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa Members, and an informal member (the "Vinemount shale beds"); the approximately equivalent Amabel Formation, found from Waterdown to Cockburn Island, has been subdivided into Lions Head, Wiarton/Colpoy Bay and Eramosa Members. On the Bruce Peninsula and in the subsurface of southwestern Ontario the Eramosa Member is considered to be part of the overlying Guelph Formation. COMPOSITION: Lockport Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone; Amabel Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone with reef facies developed near Georgetown and on the Bruce Peninsula. The Eramosa Member is thin bedded and bituminous. THICKNESS: (Lockport/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 (Asphalt & Concrete) = 100-105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: exposed south and west of the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. COMPOSITION: fine- to medium-crystalline, medium- to thick-bedded, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity. 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. Main use is for dolomitic lime for cement manufacture. Quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; only rarely exposed at surface. COMPOSITION: grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic-rich material with up to eight units identifiable. THICKNESS: 113 to 330 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: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, rarely outcrops in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville and Akron Members. COMPOSITION: medium- to massive-bedded, micro-crystalline, brown dolostone with shaly partings. THICKNESS: 14 to 28 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. Has also been extracted for 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 (Asphalt & Concrete) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. COMPOSITION: thick- to massive-bedded, coarse-grained, grey-yellow sandstone. THICKNESS: 0 to 5 m. USES: has been quarried for silica sand, building stone and armour stone. 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 (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. COMPOSITION: a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium- to coarse-grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. THICKNESS: 3 to 40 m. USES: quarried at Hagersville, Cayuga and Port Colborne for crushed stone. Material generally unsuitable for concrete aggregate because of 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 (Asphalt & Concrete) = 102-290.

Onondaga Formation (Lower - Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence and Moorehouse Members. COMPOSITION: 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. High chert content makes much of the material unsuitable for use as concrete aggregate and asphaltic concrete. Has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff Members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (Asphalt & Concrete) = 190-276.

Amherstburg Formation (Lower - Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Peninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid-rich limestone with grey chert nodules; Formosa Reef Limestone - high purity (calcium-rich) limestone; Sylvania Sandstone Member - quartz sandstone. THICKNESS: 0 to 60 m; Formosa Reef Limestone - 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 (Asphalt & Concrete) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock–Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey-brown dolostone with bituminus laminations and minor chert; Anderdon Member consists of very high purity (calcium-rich) limestone and locally, sandy limestone. THICKNESS: 40 to 75 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. 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 (Asphalt & Concrete) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: fine- to medium-crystalline, brownish-grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. THICKNESS: 15 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 (Asphalt & Concrete) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern USA, pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 12 m. USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no outcrop in Ontario. COMPOSITION: soft, blue and grey calcareous shale. THICKNESS: 0 to 14.5 m. USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no outcrop in Ontario. COMPOSITION: grey-brown, very fine-grained limestone with occasional shale layers. THICKNESS: 0 to 6 m. USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. 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: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fossiliferous calcareous shale. THICKNESS: 0 to 2 m. USES: suitable for some crushed stone and fill with selective quarrying.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous calcareous shale interbedded with blue-grey, fine-grained fossiliferous limestone. THICKNESS: 0 to 21 m. USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium- to coarse grained, grey-brown, bioclastic limestone. THICKNESS: 2 to 14 m. USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a northwest-trending band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic-rich shale with minor interbeds of grey-green silty shale. THICKNESS: 0 to 75 m. USES: possible source of material for use as sintered lightweight aggregate or fill.

Bedford Formation (Upper Devonian or Mississippian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 30 m. USES: no present uses.

Berea Formation (Upper Devonian or Mississippian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine- to medium-grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 60 m. USES: no present uses.

Sunbury Formation (Upper Devonian or Mississippian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 20 m. USES: no present uses.

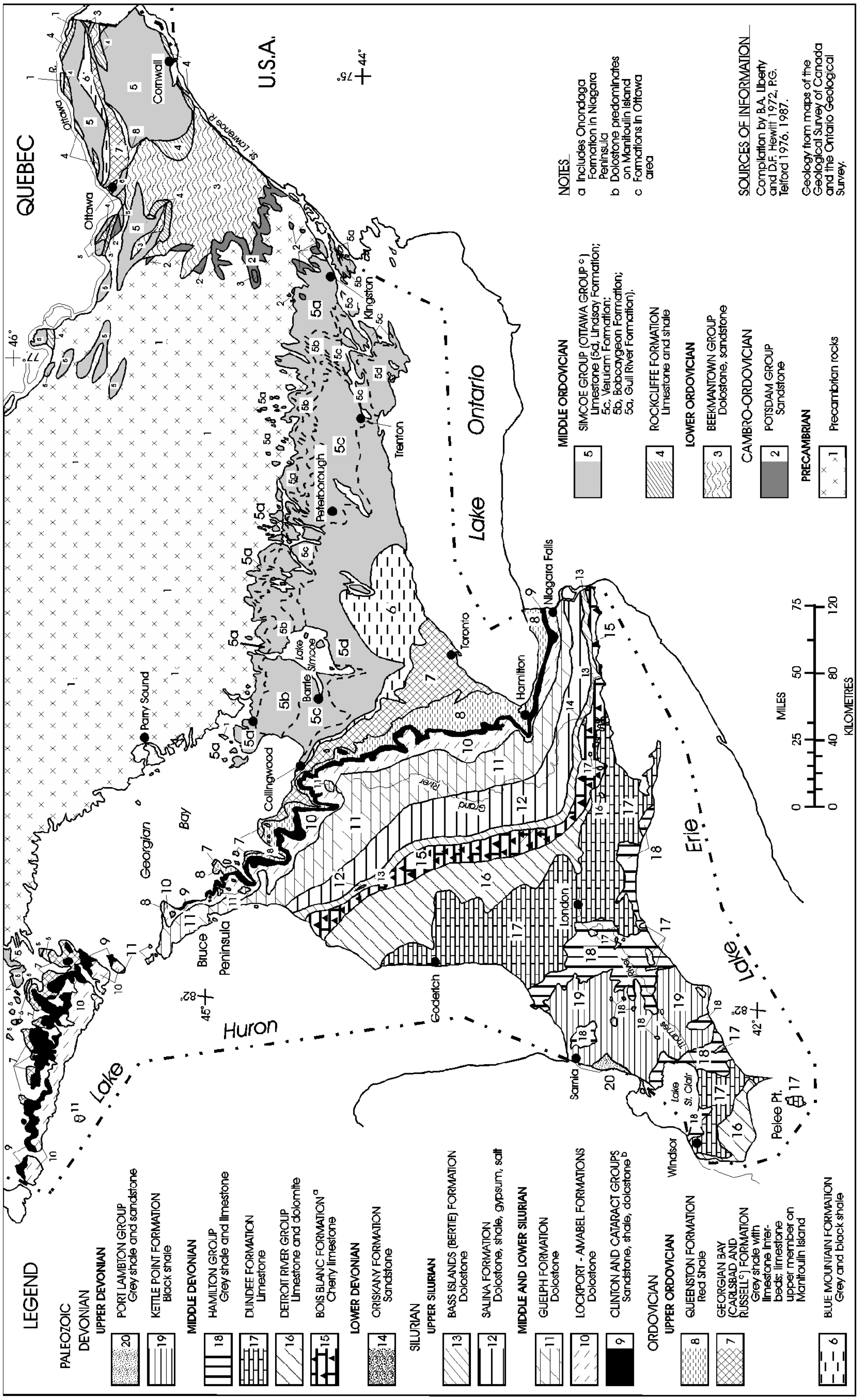

Figure D1. Bedrock geology of southern Ontario.

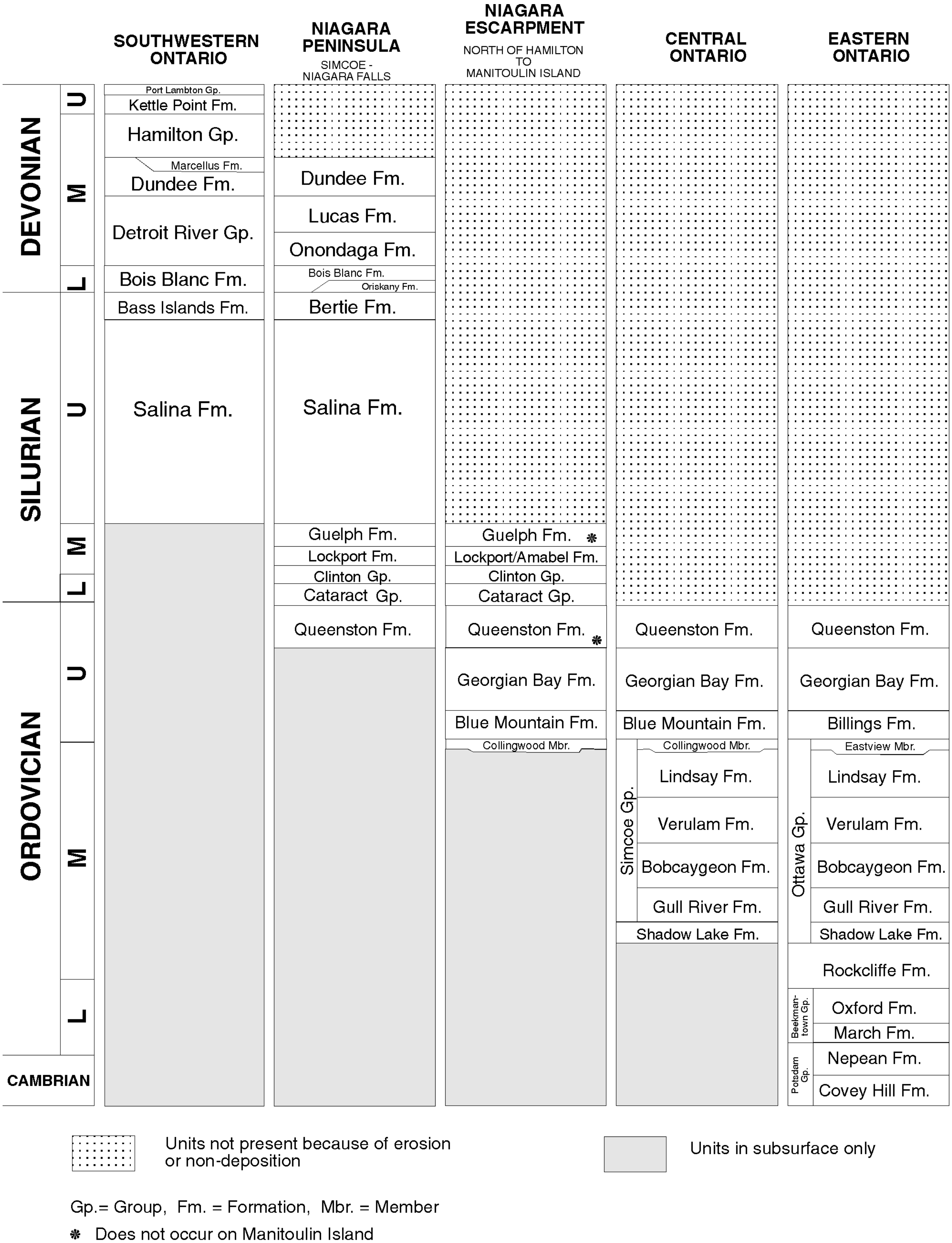

Figure D2. Exposed Paleozoic stratigraphic sequences in southern Ontario (*adapted from*: Bezys, R.K. and Johnson, M.D. 1988. The geology of the Paleozoic formations utilized by the limestone industry of Ontario; The Can. Mining and Metallurgical Bulletin,v.81, no. 912, p.49-58.)

Appendix E – Aggregate Quality Test Specifications

Six types of aggregate quality tests are often performed by the Ontario Ministry of Transportation on sampled material. A description and the specification limits for each test are included in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the six tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the Ontario Ministry of Transportation.

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

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

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

Micro-Deval Abrasion Test: The Micro-Deval Abrasion test is an accurate measure of the amount of hard, durable materials in sand-sized particles. This abrasion test is quick, cheap and more precise than the fine aggregate Magnesium Sulphate Soundness test that suffers from a wide multilaboratory variation. The maximum loss for HL 1/HL 3 is 20%, for HL 2 and HL 4/HL 8 it is 25% and for structural and pavement concrete it is 20%. It is anticipated that this test will replace the fine aggregate Magnesium Sulphate Soundness test.

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

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

Table E1. Selected quality requirements for major aggregate products.

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

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

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	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 which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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Ontario

Ontario Geological Survey

Aggregate Resources Inventory

HURON COUNTY

ARIM 177 - 1A

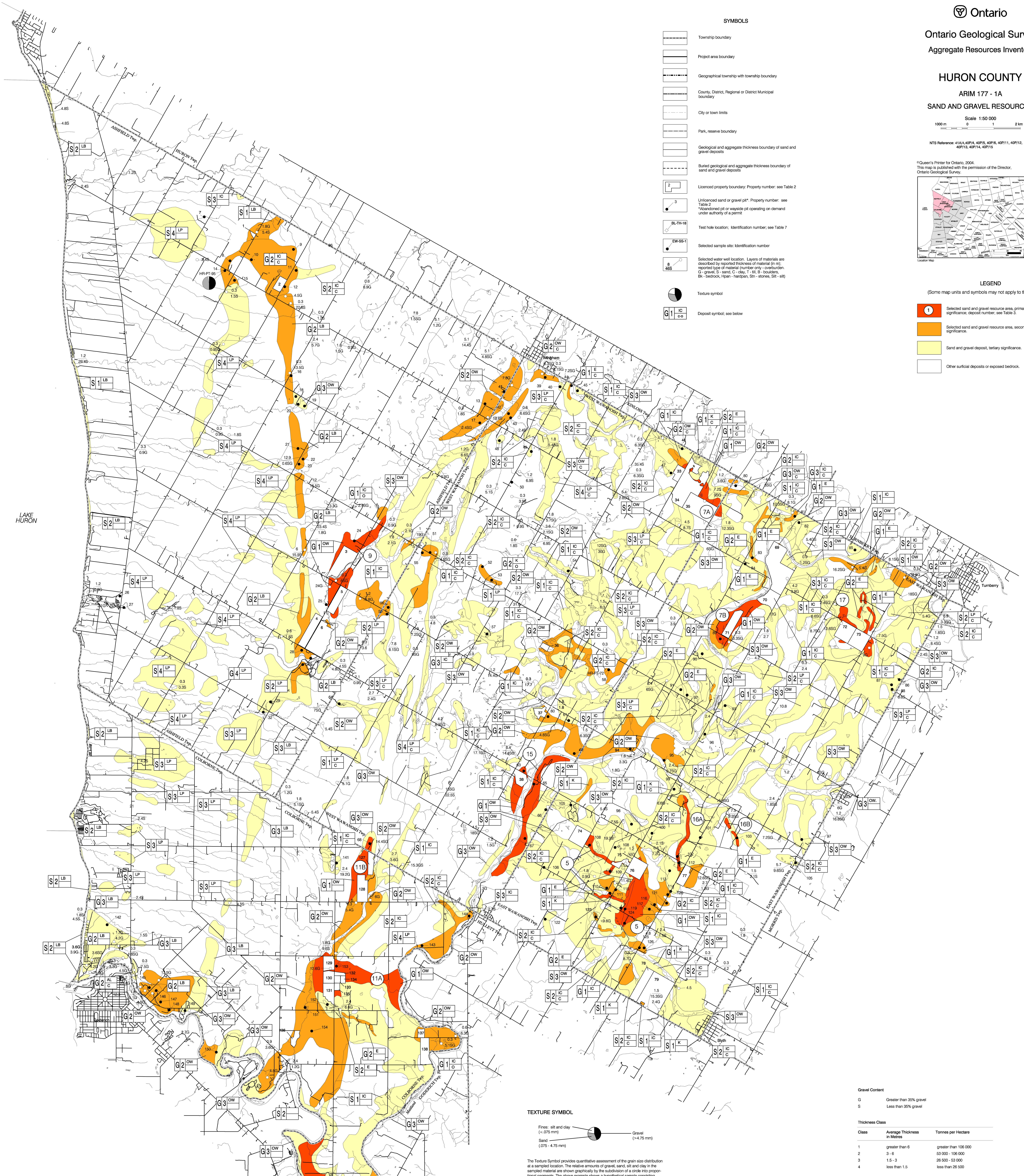
SAND AND GRAVEL RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 41A/4,40P/4, 40P/5, 40P/6, 40P/11, 40P/12, 40P/13, 40P/14, 40P/15

Location Map



SYMBOLS

- Township boundary
- Project area boundary
- Geographical township with township boundary
- County, District, Regional or District Municipal boundary
- City or town limits
- Park, reserve boundary
- Geological and aggregate thickness boundary of sand and gravel deposits
- Buried geological and aggregate thickness boundary of sand and gravel deposits
- 2 — Licenced property boundary: Property number: see Table 2
- 3 — Unlicenced sand or gravel pit*. Property number: see Table 2
  *Abandoned pit or wayside pit operating on demand under authority of a permit
- BL-TH-18 — Test hole location; Identification number; see Table 7
- EW-SS-1 — Selected sample site: Identification number
- 8 / 46S — Selected water well location. Layers of materials are described by reported thickness of material (in m); reported type of material (number only - overburden. G - gravel, S - sand, C - clay, T - till, B - boulders, Bk - bedrock, Hpan - hardpan, Stn - stones, Silt - silt)
- Texture symbol
- G 1 IC c·o — Deposit symbol; see below

LEGEND

(Some map units and symbols may not apply to this map)

- 1 — 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.

TEXTURE SYMBOL

Fines: silt and clay (<.075 mm)
Sand (.075 - 4.75 mm)
Gravel (>4.75 mm)

The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

DEPOSIT SYMBOL

Gravel Content — G; Thickness Class — 1; Geological Type — IC; Quality Indicator — c·o

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e., material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per hectare. Geological Type refers to geological origin. Quality indicator describes objectionable grain size and lithology.

Gravel Content

G	Greater than 35% gravel
S	Less than 35% gravel

Thickness Class

Class	Average Thickness in Metres	Tonnes per Hectare
1	greater than 6	greater than 106 000
2	3 - 6	53 000 - 106 000
3	1.5 - 3	26 500 - 53 000
4	less than 1.5	less than 26 500

Geological Type

AL	Older Alluvium	LB	Lacustrine Beach
E	Esker	LD	Lacustrine Delta
M	Moraine	LP	Lacustrine Plain
IC	Undifferentiated Ice-Contact Stratified Drift	OW	Outwash
ICT	Ice-Contact Terrace	SF	Subaqueous Fan

(see Appendix C for descriptions of Geological Types.)

Quality Indicator

	If blank, no known limitations present.
C	Clay and/or silt (fines) present in objectionable quantities.
L	Deleterious lithologies present.
O	Oversize particles or fragments present in objectionable quantities.

SOURCES OF INFORMATION

This map is based on information taken from the National Topographic System map sheet numbers 41A/4, 41P/4, 40P/5, 40P/6, 40P/11, 40P/12, 40P/13, 40P/14, 40P/15, © Her Majesty the Queen in Right of Canada with permission of Energy, Mines and Resources Canada.

Aggregate suitability data from the Ontario Ministry of Transportation.
Selected water well data from the Ontario Ministry of the Environment.

Geology by: Cooper, A.J. 1977
Cooper, A.J., Fitzgerald, W.D. and Clue, J. 1977
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Karrow, P.F. 1977
Additional Geology by: Cunhai (George) Gao and assistants 2000, 2001.
Drafting by: Julie Chartrand of the Sedimentary Geoscience Section.
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Ontario

Ontario Geological Survey

Aggregate Resources Inventory

HURON COUNTY

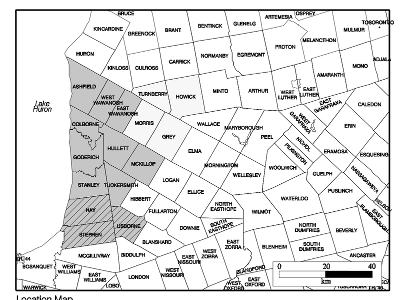
ARIM 177 - 2B

BEDROCK RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS References: 41A/4, 40P/4, 40P/5, 40P/6, 40P/11, 40P/12, 40P/13, 40P/14, 40P/15



Location Map

Note: Hachured area represents townships with no near-surface (>15m overburden) Bedrock Resources.

LEGEND

(Some units and symbols may not apply to this map.)

BEDROCK UNITS

PALEOZOIC

DEVONIAN

MIDDLE DEVONIAN

DUNDEE FORMATION

Limestone

LOWER-MIDDLE DEVONIAN

DETROIT RIVER GROUP

AMHERTSBURG FORMATION

Dolostone and Limestone

AMHERTSBURG FORMATION

Formosa Reef Limestone Member

LUCAS FORMATION

Dolostone

LOWER DEVONIAN

BOIS BLANC FORMATION

Cherty limestone

SILURIAN

UPPER SILURAIN

BASS ISLANDS FORMATION

Dolostone

SALINA FORMATION

Shale, Gypsum, salt and dolostone

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)

Undifferentiated Precambrian bedrock; predominantly bedrock covered by thin drift. Bedrock outcrops are common and localized areas of thick overburden may occur in bedrock depressions.

SYMBOLS

Township boundary

Project area boundary

Park, reserve boundary

Geological formation boundary

Geological formation member boundary

Formation thickness boundary (see text)

15 Drift thickness contour. (1 m, 8 m and 15 m contours are shown)

Selected bedrock resources area; Deposit number: see Table 6.

EW-SS-1 Selected sample sites

Licenced quarry boundary: Property number: see Table 5

Q5 Unlicenced quarry*; Property number: see Table 5
*Abandoned quarry or wayside quarry operating on demand under authority of a permit

× Isolated bedrock outcrop

8 Selected water well location; reported depth to bedrock (in metres)

SOURCES OF INFORMATION

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Aggregate suitability data from the Ontario Ministry of Transportation.
Selected water well data from the Ontario Ministry of the Environment.

Geology by : Fagerstrom, J.A. 1961
Johnson et al. 1992
Liberty, B. A. and Bolton, T.E. 1971
Drafting by: Julie Chartrand of the Sedimentary Geoscience Section.
This map is to acompany O.G.S. Aggregate Resources Inventory Paper 177.
Issued 2004.

Ontario

Ontario Geological Survey

Aggregate Resources Inventory

HURON COUNTY

ARIM 177 - 2A

BEDROCK RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS References: 41A/4, 40P/4, 40P/5, 40P/6, 40P/11, 40P/12, 40P/13, 40P/14, 40P/15

Location Map

Note: Hachured area represents townships with no near-surface (>15m overburden) Bedrock Resources.

LEGEND

(Some units and symbols may not apply to this map.)

BEDROCK UNITS

PALEOZOIC

DEVONIAN

MIDDLE DEVONIAN

DUNDEE FORMATION

Limestone

LOWER-MIDDLE DEVONIAN

DETROIT RIVER GROUP

AMHERTSBURG FORMATION

Dolostone and Limestone

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SALINA FORMATION

Shale, Gypsum, salt and dolostone

SYMBOLS

Township boundary

Project area boundary

Park, reserve boundary

Geological formation boundary

Geological formation member boundary

Formation thickness boundary (see text)

15 Drift thickness contour. (1 m, 8 m and 15 m contours are shown)

Selected bedrock resources area; Deposit number: see Table 6.

EW-SS-1 Selected sample sites

Licenced quarry boundary: Property number: see Table 5

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

Isolated bedrock outcrop

8 Selected water well location; reported depth to bedrock (in metres)

SOURCES OF INFORMATION

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Ontario

Ontario Geological Survey

Aggregate Resources Inventory

HURON COUNTY

ARIM 177 - 1D

SAND AND GRAVEL RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS References: 41A/4, 40P/4, 40P/5, 40P/6, 40P/11, 40P/12, 40P/13, 40P/14, 40P/15

SOURCES OF INFORMATION

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Karrow, P.F. 1977
Additional Geology by: Cunhai (George) Gao and assistants 2000, 2001.
Drafting by: Julie Chartrand of the Sedimentary Geoscience Section.
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Issued 2004.

TEXTURE SYMBOL

Fines: silt and clay (<.075 mm)
Sand (.075 - 4.75 mm)
Gravel (>4.75 mm)

The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

DEPOSIT SYMBOL

Gravel Content — G 1 IC c·o — Geological Type
Thickness Class — Quality Indicator

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e., material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per hectare. Geological Type refers to geological origin. Quality indicator describes objectionable grain size and lithology.

Gravel Content

G	Greater than 35% gravel
S	Less than 35% gravel

Thickness Class

Class	Average Thickness in Metres	Tonnes per Hectare
1	greater than 6	greater than 106 000
2	3 - 6	53 000 - 106 000
3	1.5 - 3	26 500 - 53 000
4	less than 1.5	less than 26 500

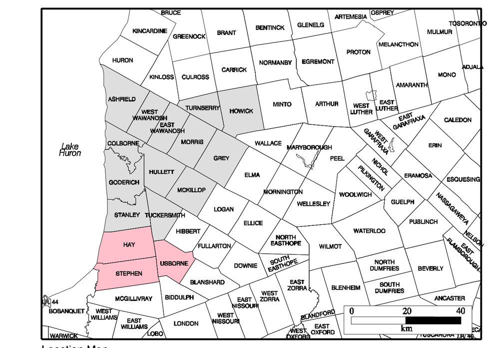
Geological Type

AL	Older Alluvium	LB	Lacustrine Beach
E	Esker	LD	Lacustrine Delta
M	Moraine	LP	Lacustrine Plain
IC	Undifferentiated Ice-Contact Stratified Drift	OW	Outwash
ICT	Ice-Contact Terrace	SF	Subaqueous Fan

(see Appendix C for descriptions of Geological Types.)

Quality Indicator

	If blank, no known limitations present.
C	Clay and/or silt (fines) present in objectionable quantities.
L	Deleterious lithologies present.
O	Oversize particles or fragments present in objectionable quantities.



Location Map

LEGEND

(Some map units and symbols may not apply to this map)

- 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

- Township boundary
- Project area boundary
- Geographical township with township boundary
- County, District, Regional or District Municipal boundary
- City or town limits
- Park, reserve boundary
- Geological and aggregate thickness boundary of sand and gravel deposits
- Buried geological and aggregate thickness boundary of sand and gravel deposits
- Licenced property boundary: Property number: see Table 2
- Unlicenced sand or gravel pit*. Property number: see Table 2
  *Abandoned pit or wayside pit operating on demand under authority of a permit
- BL-TH-18 Test hole location; Identification number; see Table 7
- EW-SS-1 Selected sample site: Identification number
- 8 / 46S Selected water well location. Layers of materials are described by reported thickness of material (in m); reported type of material (number only - overburden. G - gravel, S - sand, C - clay, T - till, B - boulders, Bk - bedrock, Hpan - hardpan, Stn - stones, Silt - silt)
- Texture symbol
- G 1 IC c·o Deposit symbol; see above

Ontario

Ontario Geological Survey

Aggregate Resources Inventory

HURON COUNTY

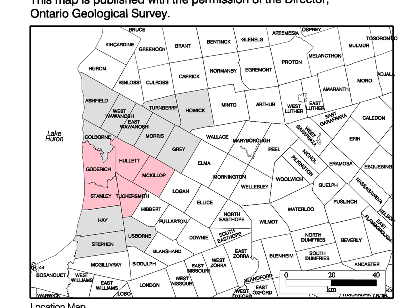
ARIM 177 - 1C

SAND AND GRAVEL RESOURCES

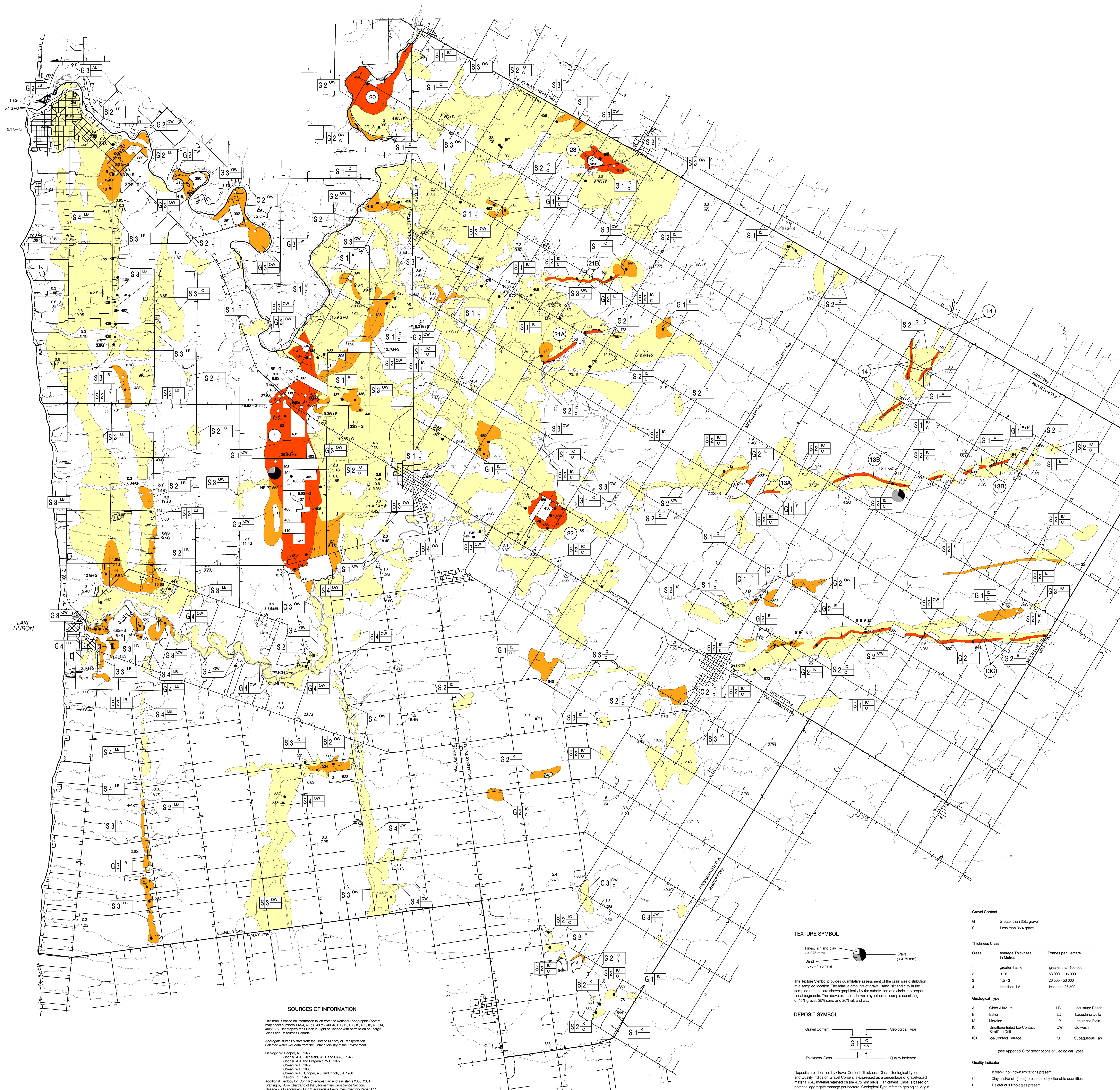
Scale 1:50 000

1000 m 0 1 2 km

NTS References: 41A/4, 40P/4, 40P/5, 40P/6, 40P/11, 40P/12, 40P/13, 40P/14, 40P/15



Location Map



LEGEND

(Some map units and symbols may not apply to this map)

- 1 — 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

- Township boundary
- Project area boundary
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- Texture symbol
- G 1 IC C·O — Deposit symbol; see below

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Sand (.075 - 4.75 mm)
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DEPOSIT SYMBOL

Gravel Content → G; Thickness Class → 1; Geological Type → IC; Quality Indicator → C·O

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e., material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per hectare. Geological Type refers to geological origin. Quality indicator describes objectionable grain size and lithology.

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Thickness Class

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(see Appendix C for descriptions of Geological Types.)

Quality Indicator

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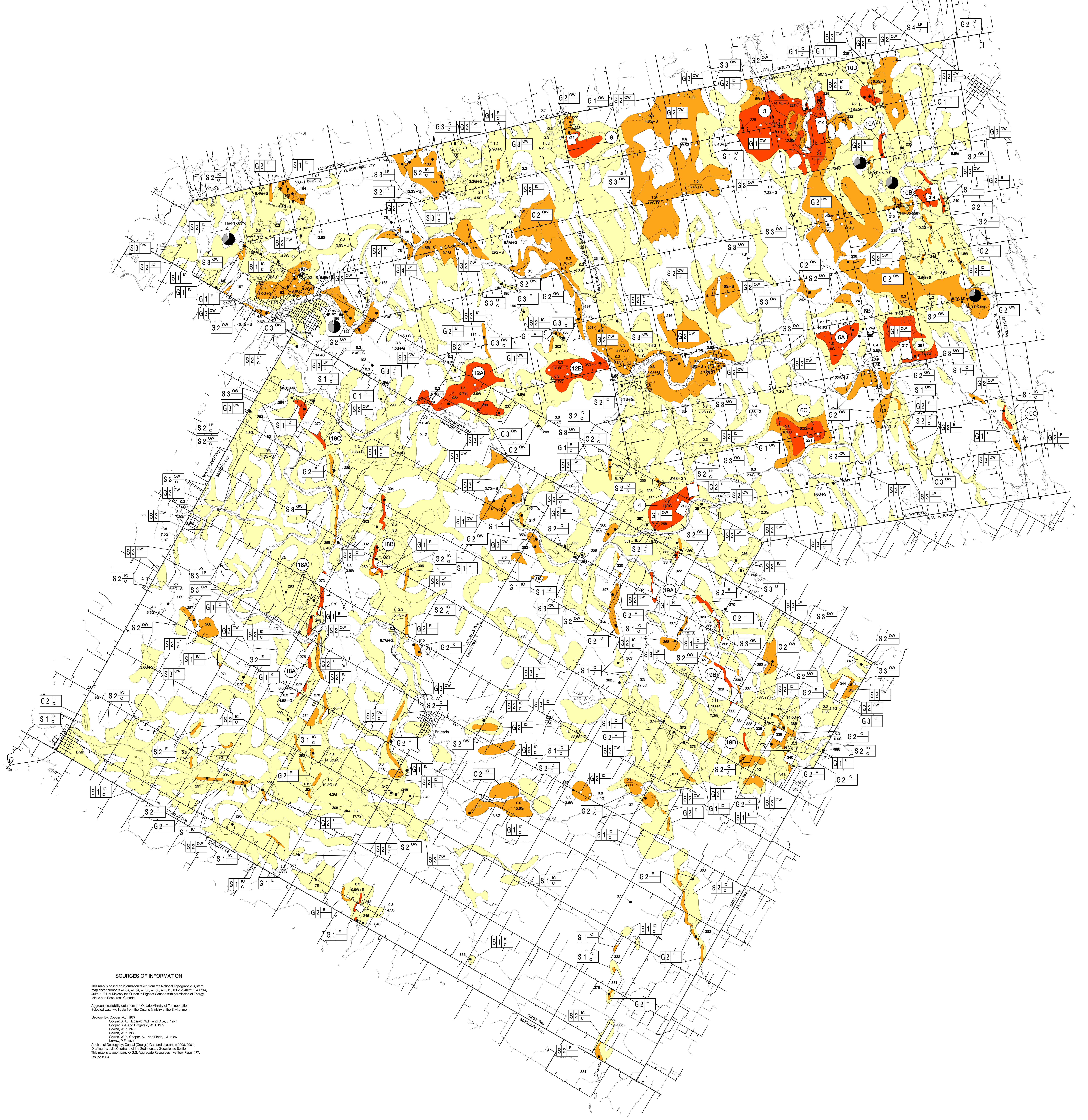


Ontario

Ontario Geological Survey

Aggregate Resources Inventory

HURON COUNTY

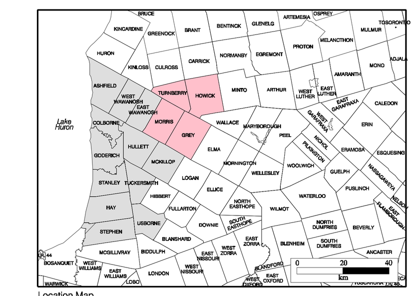
ARIM 177 - 1B

SAND AND GRAVEL RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS References: 41A/4, 40P/4, 40P/5, 40P/6, 40P/11, 40P/12, 40P/13, 40P/14, 40P/15



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- × — Isolated bedrock outcrop
- 8 — Selected water well location; reported depth to bedrock (in metres)

Ontario

Ontario Geological Survey

Aggregate Resources Inventory

HURON COUNTY

ARIM 177 - 2C

BEDROCK RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

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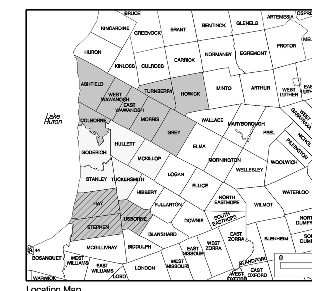

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BEDROCK UNITS

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