Ontario Geological Survey
Aggregate Resources Inventory
Paper 102

Aggregate Resources Inventory of the Kitchener–Waterloo–Cambridge Area

Regional Municipality of Waterloo Southern Ontario

By Staff of the Cambridge District Office, Ontario Ministry of Natural Resources, and Staff of the Engineering and Terrain Geology Section, Ontario Geological Survey, Ministry of Northern Affairs and Mines

1985

Ontario

Ministry of Northern Affairs and Mines

Renė Fontaine
Minister
George Tough
Deputy Minister

ISSN 0708-2061
Printed in Ontario, Canada
ISBN 0-7743-7298-2

Publications of the Ontario Geological Survey, Ministry of Northern Affairs and Mines, are available from the following sources. Orders for publications should be accompanied by cheque or money order payable to the *Treasurer of Ontario.*

Reports, maps, and price lists (personal shopping or mail order):

Public Information Centre, Ministry of Natural Resources
Room 1640, Whitney Block, Queen's Park
Toronto, Ontario M7A 1W3

Reports and accompanying maps only (personal shopping):

Main Floor, 880 Bay Street
Toronto, Ontario

Reports and accompanying maps (mail order or telephone orders):

Publications Services Section, Ministry of Government Services
5th Floor, 880 Bay Street
Toronto, Ontario M7A 1N8
Telephone (local calls) 965-6015
Toll-free long distance 1-800-268-7540
Toll-free from Area Code 807 0-ZENITH-67200

This report was prepared by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources, Box 2186, Cambridge, Ontario, N3C 2W1, telephone (519) 658-9356, and Staff of the Aggregate Assessment Office, Engineering and Terrain Geology Section of the Ontario Geological Survey, Ontario Ministry of Northern Affairs and Mines, Room M1B-45, MacDonald Block, Queen's Park, Toronto, Ontario M7A 1W3, telephone (416) 965-1663.

Project Supervisors: D. Routly and Dale W. Scott

Field Work and Report by: E. Harvey

Compilation and Drafting by: Jane Eyles, Cambridge District Office, Ministry of Natural Resources, and Staff of the Aggregate Assessment Office, Ministry of Northern Affairs and Mines

The Mineral Resources Staff of Central Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

Every possible effort is made to ensure the accuracy of the information contained in this report, but the Ministry of Natural Resources and the Ministry of Northern Affairs and Mines do not assume any liability for errors that may occur. Source references are included in the report and users may wish to verify critical information.

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

Ontario Geological Survey
1985: Aggregate Resources Inventory of the Kitchener-Waterloo-Cambridge Area, Regional Municipality of Waterloo; Ontario Geological Survey, Aggregate Resources Inventory Paper 102, 35p., 7 tables, 3 maps, scale 1:50 000.

500-85

Contents

Abstract 2
Introduction 4
Part I — Inventory Methods 5
Field and Office Methods 5
Resource Tonnage Calculation Techniques 5
Sand and Gravel Resources 5
Bedrock Resources 5
Units and Definitions 6
Part II — Data Presentation and Interpretation 7
Map 1 Distribution of Sand and Gravel Deposits 7
Deposit Symbol 7
Texture Symbol 7
Map 2 Selected Sand and Gravel Resource Areas 7
Site Specific Criteria 8
Deposit Size 8
Aggregate Quality 8
Location and Setting 8
Regional Considerations 9
Map 3 Bedrock Resources 9
Selection Criteria 9
Selected Resource Areas 10
Part III — Assessment of Aggregate Resources in the Kitchener–Waterloo–Cambridge Area 11
Location and Population 11
Physiography and Surficial Geology 11
Extractive Activity 11
Selected Sand and Gravel Resource Areas 12
Selected Sand and Gravel Resource Area 1 12
Selected Sand and Gravel Resource Area 2 13
Selected Sand and Gravel Resource Area 3 13
Selected Sand and Gravel Resource Area 4 13
Selected Sand and Gravel Resource Area 5 13
Selected Sand and Gravel Resource Area 6 13
Selected Sand and Gravel Resource Area 7 13
Selected Sand and Gravel Resource Area 8 14
Selected Sand and Gravel Resource Area 9 14
Selected Sand and Gravel Resource Area 10 14
Selected Sand and Gravel Resource Area 11 14
Bedrock Geology 14
Selected Bedrock Resource Areas 15
Selected Bedrock Resource Area 1 15
Summary 15
References 27
Appendix A — Suggested Additional Reading 28
Appendix B — Glossary 29
Appendix C — Geology of Sand and Gravel Deposits 31
Appendix D — Geology of Bedrock Deposits 33

TABLES

1. Total Sand and Gravel Resources, Kitchener–Waterloo–Cambridge Area 16
2. Sand and Gravel Pits, Kitchener–Waterloo–Cambridge Area 17
3. Selected Sand and Gravel Resource Areas, Kitchener–Waterloo–Cambridge Area 19
4. Total Identified Bedrock Resources, Kitchener–Waterloo–Cambridge Area 20
5. Quarries, Kitchener–Waterloo–Cambridge Area 21
6. Selected Bedrock Resource Areas, Kitchener–Waterloo–Cambridge Area 22
7. Summary of Test Hole Data, Kitchener–Waterloo–Cambridge Area 23

FIGURES

1. Key Map Showing the Location of the Kitchener–Waterloo–Cambridge Area 2
2a. Aggregate Grading Curves, Kitchener-Waterloo-Cambridge Area 25
2b. Aggregate Grading Curves, Kitchener-Waterloo-Cambridge Area 26
3. Bedrock Geology of Southern Ontario 33

MAPS (back pocket)

1. Distribution of Sand and Gravel Deposits, Kitchener–Waterloo–Cambridge Area, Scale 1:50 000.
2. Selected Sand and Gravel Resource Areas, Kitchener–Waterloo–Cambridge Area, Scale 1:50 000.
3. Bedrock Resources, Kitchener–Waterloo–Cambridge Area, Scale 1:50 000.

Aggregate Resources Inventory of the Kitchener–Waterloo–Cambridge Area Regional Municipality of Waterloo

by Staff[1] of the Cambridge District Office, Ontario Ministry of Natural Resources, and Staff[1] of the Engineering and Terrain Geology Section, Ontario Geological Survey, Ministry of Northern Affairs and Mines

1. Project supervisors: D. Routly and Dale W. Scott; field work and report by E. Harvey; compilation and drafting by Jane Eyles, Cambridge District Office, Ministry of Natural Resources, and Staff of the Aggregate Assessment Office, Ontario Geological Survey, Ministry of Northern Affairs and Mines. The Mineral Resources Staff of Central Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

Manuscript accepted for publication by Chief, Engineering and Terrain Geology Section, June 15, 1985. This report is published with the permission of V.G. Milne, Director, Ontario Geological Survey.

Abstract

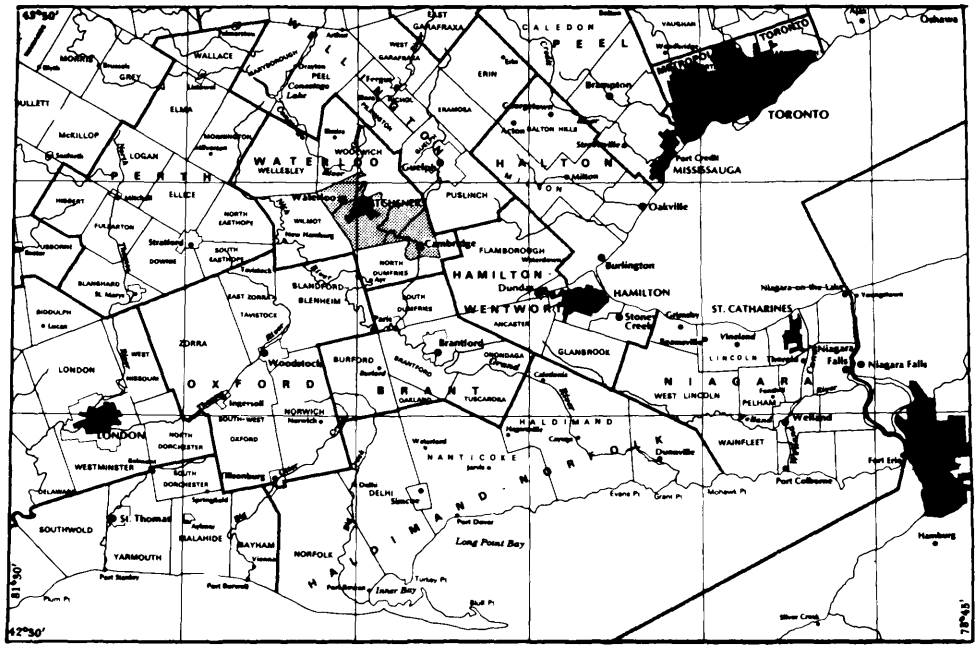


Figure 1. Key Map Showing the Location of the Kitchener–Waterloo–Cambridge Area. Scale 1:1 800 000.

This report includes both an inventory and evaluation of sand and gravel and bedrock resources in the Kitchener, Waterloo and Cambridge Area. The report is part of the Aggregate Resources Inventory Program for townships designated under the Pits and Quarries Control Act.

Eleven areas containing significant amounts of sand and gravel have been selected for possible resource protection. Selected Sand and Gravel Resource Areas occupy 3850 acres (1560 ha), exclusive of licenced properties. An estimated 2800 acres (1130 ha) are currently available for extraction, containing possible resources of 152 million tons (138 million tonnes). The parts of the selected areas which are available for extraction represent about 6 percent of the total area occupied by sand and gravel deposits in the municipalities and 7 percent of the total resource tonnage.

Selected Sand and Gravel Resource Area 1 is a large ice-contact stratified drift deposit which straddles the Wilmot-Kitchener boundary. It contains an estimated 69 million tons (63 million tonnes) of sand and gravel which is acceptable for high specification roadbase and surfacing aggregate.

Selected Sand and Gravel Resource Area 2, located west of King's Highway 8 in the Pioneer Tower area, is an outwash terrace which contains an estimated 11 million tons (10 million tonnes) and represents an important potential source for the City of Kitchener. Similar outwash terraces along the Grand River in Kitchener-Waterloo (Selected Resource Areas 3, 4, 5 and 6) contain high quality aggregate although several have not yet had extensive extraction. Total resources in these deposits are 33 million tons (30 million tonnes).

In the City of Cambridge, the largest remaining resource (Resource Area 7) is an upper terrace of the Speed River spillway system which has supplied high quality materials in Guelph and Puslinch Townships. Possible resources are estimated to be 13 million tons (12 million tonnes).

Three esker deposits (Areas 10a, 10b and 10c) have been selected to supply valuable crushable material for local use or for road construction projects. Approximately 4 million tons (4 million tonnes) are currently available for possible resource development.

The cities of Kitchener, Waterloo and Cambridge have possible sand and gravel resources which are locally important sources for road-building and construction. Care should be taken to protect as much of the primary selected areas as possible for future extractive development.

Surficial materials in the report area are underlain by bedrock of the Guelph and Salina Formations. Dolostone of the Guelph Formation is suitable for the manufacture of chemical lime. One Resource Area containing an estimated 84 million tons (76 million tonnes) of dolostone has been selected for possible 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.

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 1982, the total tonnage of mineral aggregates extracted was 101 million tons (92 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1983).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which 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 urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such 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 is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. 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 a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of 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 primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing, hand augering and geophysical techniques are used to assess subsurface materials. Airphotos at various scales are used to determine the continuity of deposits, especially in areas where information is limited.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100- pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution and in some cases Los Angeles abrasion, absorption, and Magnesium Sulphate soundness tests along with petrographic analyses are performed.

Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey. In areas of limited subsurface exposure, test holes are drilled and geophysical surveys using hammer seismic equipment are undertaken. The symbols for and locations of sample and test hole sites along with geophysical traverse lines are noted on Map 1.

In the office, the field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. 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 chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate thickness estimates or to indicate the presence of buried granular material. These records are 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, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, 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 acres. 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 logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

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 acres 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 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 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve 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 50 feet (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. 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 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one-foot (0. 3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

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

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

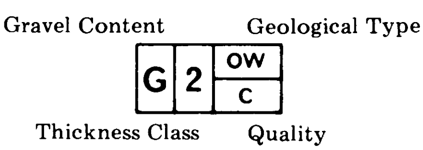
Map 1 is derived from existing surficial geology maps of the area or from airphoto interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, all sand and gravel deposits are outlined and shaded. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control 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, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2.

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. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

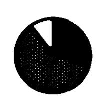
The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of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

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken for analysis during field study. The information from which these symbols are derived has been plotted in grain size distribution graphs. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:



Test hole locations are shown on Map 1 by a solid drill hole symbol. Geophysics lines are shown on the map by a line symbol.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light shading on Map 2. 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 quanitities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no 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 but are unlikely to support large-scale development.

Selected Sand and Gravel Resource Areas of primary significance are not 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.

The process by which deposits are evaluated and selected involves the consideration of two 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 reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6 m), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

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

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the 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 percent gravel in addition to a minimum of 20 percent 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 percent may impede drainage in road sub-base 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 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, 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.

The other 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 indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Analyses of unprocessed samples obtained from test holes, pits or sample sites have been plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course A, B and C; 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.

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 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, powerlines, 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).

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. 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 District Office of the Ontario Ministry of Natural Resources.

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.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalites 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 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three levels of shading. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas consitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource ares. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (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 3 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 Pits and Quarries Control 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, location, licenced acreage 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 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected drill hole which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

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 and Communications. 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 approch. First, quality and quantity variations 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 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock 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.

Part III — Assessment of Aggregate Resources in the Kitchener–Waterloo–Cambridge Area

LOCATION AND POPULATION

The cities of Kitchener, Waterloo and Cambridge occupy a combined area of 77,124 acres (31 212 ha) along the Grand River in the central part of the Regional Municipality of Waterloo. Portions of the cities are shown on the Conestogo (40 P/10), Stratford (40 P/7), Guelph (40 P/9) and Cambridge (40 P/8) map sheets of the National Topographic System, at a scale of 1:50 000. The cities are served by a variety of well developed transportation routes including railway lines, paved provincial highways and municipal roads.

The cities are regional trade and retail centres for the Regional Municipality of Waterloo and have a significant local industrial economic base. The combined population of the municipalities in 1982 was 275 355 (Ontario Ministry of Municipal Affairs and Housing 1983); an increase from 240 289 in 1974 (Regional Official Policies Plan, Regional Municipality of Waterloo 1975). Indications are that similar rates of increase may continue for at least the next decade but may increase at a smaller rate thereafter (Regional Official Policies Plan, Regional Municipality of Waterloo 1975). Demand for aggregate can be expected to keep pace with these projections.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The cities of Kitchener and Waterloo lie on the eastern slopes of the Waterloo Interlobate Moraine (called the Waterloo Hills by Chapman and Putnam (1984, p. 136)). This hummocky rolling landscape with ridges of sandy till or ice-contact stratified drift reaches a maximum elevation along the Waterloo-Wilmot boundary of 1325 feet (404 m) above sea level. The area has several particularly fine examples of steep kame hills such as at Pinnacle Hill (1250 feet, 381 m a.s.l.), near Doon, and Chicopee Hill (1225 feet, 373 m a.s.l.) near Centreville. The line formed by these kame hills (called the Breslau Moraine by Karrow (1963)) marks a short-lived ice front position of westward-advancing ice.

The eastern part of the map area, the City of Cambridge, is a broad terraced valley occupied by the Grand and Speed Rivers which converge in the community of Preston. The Paris Moraine forms the eastern boundary of the City of Cambridge and is part of the Horseshoe Moraines physiographic unit. Chapman and Putnam (1984, p. 127) characterized this region with two landform components: irregular stony knobs and ridges which are composed partly of till and partly of kame deposits (Paris Moraine); and the more or less horizontally bedded sand and gravel terraces and swampy valley floors (Grand and Speed valleys).

The form and distribution of unconsolidated materials in the municipalities are the result of glacial and glaciofluvial activity during the Quaternary Period (the last two million years) and are largely related to the last major glacial event (Late Wisconsinan time, 23 000 years to 10 000 years ago). In general, ice fluctuated from minor centres (lobes) in the lake basins and left a series of end moraines so that the high central part of southwestern Ontario was isolated like an island (Ontario Island).

The Kitchener-Waterloo-Cambridge area was influenced by ice advances of the Lake Ontario lobe which deposited first the clayey Maryhill Till and then the silty to sandy Port Stanley Till. These tills cap, in part, the Waterloo Interlobate Moraine and the Breslau Moraine as well as forming the gently rolling lower slopes in Kitchener (Karrow 1974; 1983). The Paris Moraine marks the western extent of a sandy unit called the Wentworth Till. These till sheets have little value as an aggregate source because of their excessive fines content.

The Waterloo Interlobate Moraine and the Breslau Moraine contain extensive ice-contact and glaciofluvial stratified deposits either at the surface or beneath till units. Locating viable gravel resources is particularly difficult because of the overall sandy character of the moraines. Significant aggregate production originates from gravel materials identified in the Mannheim area. In the past, small quantities of poorer quality aggregate have been available from the Breslau Moraine. Additional quantities of good crushable gravel have been located in an esker that straddles the Cambridge-Kitchener boundary near Freeport.

Outwash sands and gravels were deposited at the ice margin as it retreated eastward and a major spillway system developed along the present Speed River and Grand River valleys. A number of terraces, formed by successive water levels, contain variable thicknesses of sand and gravel. These deposits represent a major source of high quality aggregate.

Shallow, fine-grained pond and lake deposits may occur in depressions or on top of spillway materials as a result of temporary pondings during deglaciation.

EXTRACTIVE ACTIVITY

The current limits of Kitchener, Waterloo and Cambridge were designated under the Pits and Quarries Control Act on May 9, 1972. At present, eleven operations have a total licenced area of approximately 1004.6 acres (406.6 ha) (Table 2).

Numerous pits have been opened and operated in these municipalities and many have since been rehabilitated to industrial, residential or recreational uses. Several of these former sites have been described by Hewitt and Karrow (1963) but a few others, such as several of E. E. Seegmiller's recently cancelled licenced operations, are worth noting here. The Dutchman Pit at part lot F, Bechtel's Tract (pit no. 21) was developed in kame gravel. Up to 30-foot (9 m) faces exposed sandy contorted units with gravelly pockets. The Weber Pit (pit no. 22) worked thin kame gravel and has since been returned to agricultural uses. The Buildevco Pit (pit no. 20) was developed in an upper terrace of Selected Resource Area 3 and produced granular base course and fill materials.

In Cambridge, Preston Sand and Gravel (pit no. 28) and Martini Sand and Gravel (pit no. 27) extracted material for many years from lot 5, Beasley's Lower Block, and the site is still used for processing.

Gravel contents of 60 to 75 percent were recorded by Hewitt and Karrow (1963) over pit faces of 20 to 25 feet (6 to 8 m). Preston Sand and Gravel's Ira Good site (pit no. 23) was licenced between 1976 and 1980 and yielded high quality sand and gravel products suitable for high specification roadbase and surfacing aggregate.

Production from licenced sources in the Kitchener–Waterloo–Cambridge Area averaged 1.5 million tons (1.3 million tonnes) from 1977 to 1980 but, at the same time has also shown a marked decline over this period. The City of Waterloo has no licenced properties at present and several sites in the City of Cambridge are nearly depleted. Wayside pits, opened to meet the requirements of local road authority projects, had an average production of 50,000 tons (45 000 tonnes) from 1977 to 1980. Most of this production has been derived from the City of Cambridge in conjunction with the development and grading of several industrial parks.

SELECTED SAND AND GRAVEL RESOURCE AREAS

The sand and gravel deposits selected for possible resource protection in the Kitchener-Waterloo-Cambridge area are shown on Map 2. Large parts of these municipalities are no longer available for resource extraction because of their urbanized character. Particular attention has been paid to selecting areas which are non-urban and for which extraction is still possible. Areas of secondary significance have not been selected because of the rapid urbanization which is occurring.

The highest potential resource area lies along Kitchener's western boundary and is part of the Waterloo Interlobate Moraine, an upland area derived from ice-contact and glaciofluvial activity. Aside from three esker deposits, the remaining resource areas are important outwash terrace deposits which originated from the large meltwater system along the Grand River and Speed River valleys. One of these deposits is principally sandy outwash, presently utilized for pressed brick manufacture.

The portions of the Selected Sand and Gravel Resource Areas of Primary Significance which are available for extraction occupy a total of 2800 acres (1130 ha) and have available sand and gravel resources of approximately 152 million tons (138 million tonnes). The selected resource areas occupy about 6 percent of the total area of sand and gravel resources in the combined municipalities and about 7 percent of the total resource tonnage. The aggregate deposits selected for possible protection in this study are similar to those identified in an earlier study by Bryant and McLellan (1974).

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 straddles Kitchener's western boundary near Mannheim and represents a major source of aggregate for the city. This section of the Waterloo Moraine occupied an interlobate position and was deposited by opposing ice lobes at several different times, one ice front retreating westward and the other retreating eastward. Substantial thicknesses of fine sand, silt or a sandy silt till (subsequently correlated as Port Stanley Till; Karrow 1974) overlie the resource area and appear to be related to an advance from the east. This buried deposit was initially identified and mapped from well logs by Bryant and McLellan (1974).

To date, delineation of the buried deposit has relied upon published well logs but without the benefit of good information in the southern part of the deposit (Bryant and McLellan 1974). Two holes were drilled in this area in January 1981 (KI-TH-3 and WL-TH-1, Map 1) using a hollow stem auger. Split spoon samples were taken at five-foot (1.5 m) intervals (Table 7). The first hole on Huron Road (KI-TH-3 in the City of Kitchener) indicated between 15 and 20 feet (4.6 and 6.1 m) of silt to fine sand. Sieve analysis of a grab sample showed that the material is too dirty to meet most specifications without processing and has a gravel content of 20 percent (Figures 2a and 2b). The second drill hole, in the Township of Wilmot (WL-TH-1) returned 30 feet (9 m) of clean, fine to medium sand. It is concluded that significant aggregate deposits do not extend further southward. On the basis of test information supplied by Paul Tuerr Construction Ltd. (Peto MacCallum Ltd. 1981) the eastern boundary of the resource area was modified to include significant sand and gravel materials (pit no. 31) on their property.

Four licenced pits (pit nos. 1, 4, 5 and 7) are located within the selected resource area. Pit faces reveal 20 to 30 feet (6 to 9 m) of highly contorted sand and gravel strata. Good crushable gravel is available in some beds but others are extremely sandy and can grade dirty for some uses. Several of the pits have been given a 'moderate-high' use rating by the Ontario Ministry of Transportation and Communications (M.T.C.) because of their ability to supply good quality crushable gravel products suitable for asphalt paving mixes as well as lower specification uses such as Granular Base Course (G.B.C.) A, B and C road base (Deike 1978). Warren Paving operated an asphalt plant in this deposit for a number of years (pit no. 7, Hewitt and Karrow 1963). Some sandy portions may, with selection and blending, be useful as fine products for concrete, mortar and asphalt uses (Peto MacCallum Ltd. 1981). In some areas, however, excessive overburden or sand may limit extractive development. Although water table depths of 40 to 50 feet (12 to 15 m) are not a major constraint to extraction, the Mannheim area is a major source of domestic water for the cities of Kitchener and Waterloo.

Testing and well log information in this deposit have shown a large variation in thickness of granular materials - up to 100 feet (30 m) of sand and gravel, buried by upwards of 25 feet (8 m) of sandy and silty materials. Outside of the deposit boundaries, granular materials may be present, but these are believed to lie at depths where economic recovery is unlikely. From computer mapping, Bryant and McLellan (1974) estimated that the total possible resources ranged from 213 million tons (193 million tonnes) to 370 million tons (335 million tonnes). For the purposes of this inventory, the total possible resources in the whole deposit (most of which lies in Wilmot Township) are conservatively estimated at 178 million tons

(161 million tonnes), assuming an average thickness of 30 feet (9 m). The portion of the deposit which lies in the City of Kitchener (Resource Area 1) occupies 1110 acres (450 ha), of which 920 acres (370 ha) are available for extraction. Estimated resources in Kitchener are thus 69 million tons (63 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Part of a large terraced outwash deposit west of King's Highway 8 in the Pioneer Tower area, has been selected for possible resource protection. This area contains a potential resource of major significance for the City of Kitchener.

To determine aggregate quality and thickness of the spillway terraces in this area, two holes were drilled with a hollow stem auger in January 1981 (KI-TH-1 and KI-TH-2, Map 1). Test Hole KI-TH-1 along the Pioneer Tower Road in the uppermost terrace returned only 10 feet (3 m) of gravelly sand. A second test hole (KI-TH-2) drilled in a middle terrace showed 30 feet (9 m) of sandy cobble-sized gravel. Subsequent testing of a lower terrace by the M.T.C. (pit reference no. 32) confirmed the presence of high quality aggregate. Coarse aggregate proved suitable for G.B.C. A, B and C, hot-laid asphaltic mixes, structural concrete stone and concrete paving stone base. The thickness of the lower terrace is variable and high water table conditions exist near the river.

There are no pits developed within Selected Area 2 and cultural setbacks are of only minor significance. The total area for possible resource development is 211 acres (85 ha) with an estimated 11 million tons (10 million tonnes) of aggregate available, assuming an average thickness of 20 feet (6 m).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Only part of the outwash deposit north of Bridgeport has been selected for possible resource protection because of encroaching urban development. The deposit is terraced but, without more detailed information for each terrace, an overall thickness of 15 feet (5 m) has been estimated on the basis of well log information. An abandoned pit (pit no. 16) shows about 10 feet (3 m) of uniform, sandy well sorted gravel. E. & E. Seegmiller Ltd. operated a pit (pit no. 20) in an upper terrace with exposures of 20 to 25 feet (6 to 8 m). Testing by the M.T.C. in 1974 indicated that the aggregate would be suitable for granular base products.

The unlicenced area of this selected resource is 350 acres (142 ha). When cultural constraints and previous extraction are considered, approximately 335 acres (136 ha) or an estimated 13 million tons (12 million tonnes) are available for possible resource extraction. Parts of this resource area may be constrained by high water tables adjacent to the Grand River.

SELECTED SAND AND GRAVEL RESOURCE AREA 4

The area selected as a resource of primary significance is the lower terrace of an outwash deposit which extends northward into the Township of Woolwich. A major portion of the deposit is unavailable because of rural estate residential development. Although there are no pits opened in the selected area, a licenced property in the same deposit in the Township of Woolwich shows about 15 feet (5 m) of sandy coarse gravel. With 227 acres (92 ha) still undeveloped and assuming a thickness of 20 feet (6 m), a total of 11 million tons (10 million tonnes) could be available for possible resource extraction.

SELECTED SAND AND GRAVEL RESOURCE AREA 5

The terraced outwash deposit near Breslau selected as a primary aggregate resource has been a source of aggregate for the City of Kitchener for many years. Industrial subdivisions have gradually replaced extractive operations throughout much of the area.

On a 90-acre (36 ha) property (pit no. 12, formerly licenced to T.A. Witzel) to the north of King's Highway 7, pit faces ranged from 10 to 35 feet (3 to 11 m) and exposed high quality aggregate. Two properties on the south side of Highway 7 are licenced to Forwell Ltd. (pit nos. 3 and 11). Both upper and lower terraces have few quality constraints, although oversize material and sand lenses were noted in testing (Planning Initiatives 1981). Testing by the M.T.C. in this property indicated that this site could meet granular specifications for G.B.C. A, B and C with coarse aggregate suitable for Hot- Laid No. 4 asphalt paving mixes. Sand fractions grade coarse for asphalt uses and with blending may be useful for concrete, mortar and asphalt.

Resource Area 5 occupies 325 acres (132 ha), exclusive of licenced properties. Only 28 acres (11 ha) remain available for extraction because of the long history of extraction and recent industrial development. Possible resources of sand and gravel are estimated to be 1 million tons (1 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 6

This terraced outwash deposit lies south of Breslau on the west side of the Grand River. A small abandoned pit (pit 30) exposes sandy, well sorted gravel in a 16-foot (5 m) pit face. Test results, provided by E. & E. Seegmiller Ltd. (G. Simpson, Personal Communication, 1982) in this area show that lower and upper terraces have thicknesses of 10 feet (3 m) and 20 feet (6 m) respectively and contain 30 to 70 percent gravel. The coarse aggregate is considered suitable for G.B.C. A, B and C and for hot-mix asphalt applications (except Hot-Laid 1).

Because of the lack of cultural constraints, this deposit has the potential to be an important aggregate source. Based on the differences in thickness, this deposit has been divided into two segments (Areas 6a and 6b). Combined resources in the two deposits total 8 million tons (7 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 7

No pits have been opened in Cambridge in the upper outwash terrace of the Speed River spillway system, but in Guelph Township 15 feet (5 m) of sandy gravel are exposed with a stone content of 20 percent. Similar thicknesses are recorded in several well logs. In general, outwash deposits in this area are capable of supplying high quality aggregate from the uniform, well sorted units. Sand frequently grades coarse so that blending is required to meet hot-mix specificatons (Deike 1981).

In Resource Area 7 approximately 345 acres (140 ha) are available for extraction after accounting for minor cultural setbacks. Assuming an average deposit thickness of 15 feet (5 m), possible resources of sand and gravel are estimated to be 13 million tons (12 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 8

This is a small undeveloped portion of a large terraced outwash deposit which underlies most of the communities of Preston and Galt. Former extractive operations in this deposit (see extractive activity section) have yielded high quality aggregates suitable for granular base course, structural concrete and asphalt products. A possible 2 million tons (2 million tonnes) could be available in the 106-acre (43 ha) parcel adjacent to Highway 401, assuming an average thickness of 20 feet (6 m).

SELECTED SAND AND GRAVEL RESOURCE AREA 9

This thick sandy outwash deposit is selected because of its potential to provide fine sand for the manufacture of pressed brick. Arriscraft Corporation screens fine sands at their licenced property in the eastern part of the deposit and produces decorative brick. Exposed faces in the deposit (pit nos. 8 and 19) average 15 to 20 feet (5 to 6 m) of sandy material (stone content 5 to 10 percent). Gravelly sands are recorded at depth from well records and might warrant more detailed investigation.

The unlicenced area of this selected resource is 540 acres (218 ha). When cultural constraints and previously extracted portions are considered, approximately 345 acres (140 ha) containing resources of 17 million tons (16 million tonnes) are available for possible resource extraction.

SELECTED SAND AND GRAVEL RESOURCE AREA 10

Three esker segments in the north part of the City of Cambridge are well situated to supply crushed aggregate for local use. Resource Area 10a lies northwest of the community of Hespeler and, although unopened, is believed to contain crushable materials about 10 to 20 feet (3 to 6 m) thick.

Two segments of the Freelton esker (10b and 10c) are oriented in a northwest-southeast direction along the Kitchener-Cambridge municipal boundary. Highly variable units in the northern segment are sandy, but useful coarse materials are reported at depth of 6 to 10 feet (2 to 3 m) (pit 15, Deike 1978). Backhoe testing on Ontario Land Corporation land (pit no. 13, Planning Initiatives 1983) encountered sandy gravels suitable for road base and sub-base aggregate, and with screening could meet G.B.C. A specifications. In some areas, 5 feet (1.5 m) of silty overburden was noted. The southern esker segment (Area 10c) is thinner (10 feet or 3 m) but is considered to contain aggregate of similar quality.

Development is occurring rapidly in the vicinity of these resources and may constrain their long term availability. Construction of a new Highway 8 bypass is planned in Resource Area 10b. Excluding these cultural constraints and previously extracted portions, a total of 86 acres (35 ha) are available from the three esker segments and contain possible resources of over 3 million tons (3 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 11

Only a small part of a terraced outwash deposit on the west side of the Grand River has been selected because of existing urbanization and previous extraction. Preston Sand and Gravel Ltd. (pit no. 23) extracted material under licence for several years from this deposit. The uniform evenly-bedded deposit yielded a variety of granular base and asphalt products from faces of 15 to 20 feet (5 to 6 m). Pit no. 18 shows similar good crushable gravel, although, as is common to most of the deposits, sand may require blending for hot-laid asphalt use.

Resource Area 11 occupies 121 acres (49 ha) of which only 52 acres (21 ha) are presently available for extraction. Assuming an average thickness of 20 feet (6 m), possible resources of sand and gravel are estimated to be 3 million tons (3 million tonnes).

BEDROCK GEOLOGY

The Kitchener-Waterloo-Cambridge Area is underlain by Silurian dolostones and shales of the Guelph and Salina Formations. The units trend northwest and dip gently to the southwest. The gently rolling bedrock surface occurs at an elevation of about 900 feet (274 m) above sea level. The thickness of unconsolidated overburden is as much as 325 feet (99 m) but is less than 50 feet (15 m) along the Grand River and Speed River valleys (Map 3).

The Guelph Formation underlies the eastern half of the report area (Caley 1941; Sanford and Baer 1981; Telford 1979). Where the unit occurs as high cliffs bordering the Grand River, through the communities of Galt and Preston, it is usually thick-bedded, light brown, medium- to fine-crystalline, sucrosic dolostone. Areas of porous, chemically pure rock are common throughout the unit. Drilling in the area indicates that the Guelph Formation has a maximum thickness of 130 feet (40 m) (Telford 1979). It is quarried for lime at several localities along the Speed River such as at Glenchristie and Guelph (Hewitt 1960). It is well suited for lime production because of its high chemical purity. However, the Guelph Formation is generally soft and not resistant to physical weathering processes, rendering the stone unacceptable for production of most road-building or construction aggregates (occasionally, it has been crushed for granular base course). Outcrops of the Guelph are confined to the Speed River and the Grand River channels through Galt and Preston. Drift cover is also less than 50 feet (15 m) between Breslau and Freeport along the Grand River (Miller et al. 1979), however, extractive development appears feasible only in the extreme northeastern corner of the City of Cambridge.

The Guelph Formation is overlain by the Salina Formation in the western half of the report area. A small outlier has been mapped along the Grand River at Doon. The Salina consists of grey soft shale and thin- to medium-bedded dolostone with numerous seams and lenses of gypsum. Drilling indicates that the Salina Formation may be 330 feet (100 m) thick in this area (Telford 1979). Although the Salina is not suitable for production of crushed aggregate, it has economic value as a source of gypsum and is being mined at Hagersville, Caledonia and Drumbo. The Salina Formation is not exposed in the area and drift cover is greater than 50 feet (15 m) throughout the area. A study of drill cuttings from oil and gas exploration wells failed to show a significant concentration of gypsum in the Regional Municipality of Waterloo (only a few drill hole records were available for study) (Guillet 1983). No areas have been selected for possible resource protection.

SELECTED BEDROCK RESOURCE AREAS

Possible bedrock resources in the Kitchener–Waterloo–Cambridge Area are located in the Guelph Formation. The dominant use of rock from the Guelph Formation is in the manufacture of lime for the chemical industry. One resource area has been selected for possible resource protection in the northeast corner of Cambridge.

SELECTED BEDROCK RESOURCE AREA 1

Selected Bedrock Resource Area 1 consists of 520 acres (210 ha) just southwest of Glenchristie. Outcrops of the Guelph Formation can be seen along a railway cut and as exposed cliffs along the Speed River. This resource area lies adjacent to the Guelph Dolime Limited (formerly Domtar Chemicals Group Lime Division) Glenchristie quarry (Lots 1, 2 and 3, Concession 4, Puslinch Township) which produced dolomitic lime, hydrated lime and limestone for many years (Hewitt 1960). The lower 72 to 76 feet (22 to 23 m) of a 98-foot (30 m) section contain reefal structures comprised of massive, vuggy, grey and blue-grey, very finely crystalline dolostone. The upper part of the quarry section contains uniformly thick-bedded, light brown, fine- to medium-crystalline dolostone with alternating bands of even-textured sucrosic dolostone and vuggy, coralline or coquinoid dolostone (Telford 1979). In addition to chemcal lime, construction aggregates have also been produced at this site.

The area currently available for extraction is calculated to be 390 acres (158 ha) after allowing for cultural setbacks. Assuming a workable thickness of 60 feet (18 m), possible resources are estimated to be approximately 84 million tons (76 million tonnes).

SUMMARY

The Kitchener–Waterloo–Cambridge Area has possible sand and gravel resources which are locally important sources of road-building and construction aggregate. Eleven areas of primary significance have been selected for possible protection. The Selected Resource Areas contain approximately 152 million tons (138 million tonnes) of granular material capable of providing a variety of high quality products. Additional resources of secondary significance have not been identified because of rapid urbanization. Care should be taken to protect as much of the primary selected areas as possible for future extractive development.

Possible bedrock resources have been selected in the Guelph Formation, a rock important in the manufacture of lime for the chemical industry. One area containing possible resources of 84 million tons (76 million tonnes) has been selected for possible resource protection in the northeast corner of Cambridge near Glenchristie.

Enquiries regarding the Aggregate Resources Inventory of the Kitchener–Waterloo–Cambridge Area should be directed to the Ontario Ministry of Natural Resources either at the Cambridge District Office, Box 2186, Cambridge, Ontario, N3C 2W1 (Tel. (519) 658-9355) or at the Central Region Office, 10670 Yonge Street, Richmond Hill, Ontario, L4C 3C9 (Tel. (416) 884-9203), or to the Aggregate Assessment Office, Ontario Geological Survey, Ministry of Northern Affairs and Mines, Room M1B-45, MacDonald Block, Queen's Park, Toronto, M7A 1W3 (Tel. (416) 965-1663).

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, KITCHENER–WATERLOO–CAMBRIDGE AREA.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
1	G-OW	7600 (3100)	380 (345)
	S-OW	3600 (1460)	180 (163)
	G-K	4150 (1680)	260 (236)
	S-K	21,600 (8700)	1080 (980)
2	G-OW	6200 (2500)	232 (211)
	S-OW	1400 (570)	52 (47)
	G-K	295 (119)	11 (10)
	S-K	325 (131)	12 (11)
	G-E	104 (42)	3 (3)
3	G-OW	395 (160)	6 (5)
	S-OW	8 (3)	<1 (<1)
	G-K	39 (16)	1 (1)
	S-K	110 (44)	2 (2)
	G-E	126 (51)	2 (2)
4	S-OW	80 (32)	1 (1)
		46,000 (18 600)	2220 (2010)

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

TABLE 2. SAND AND GRAVEL PITS, KITCHENER-WATERLOO-CAMBRIDGE AREA.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
LICENCED PITS							
1	S11-114	Kieswetter Holdings	Pt. 133, 134, 140	GCT	88.7 (35.9)	16 (5)	45
2	G01-233	E. & E. Seegmiller (Cober Pit)	151,152	GCT	160.0 (64.8)	20-25 (6-8)	45
3	G01-165	Forwell Ltd.	Pt. 123 (lower portion)	GCT	21.9 (8.9)	7-16 (2-5)	50
4	-	B.W. Kieswetter	Pt. 140	GCT	20.4 (8.3)	40 (12)	20
5	-	B.W. Kieswetter	Pt. 133	GCT	24.6 (9.9)	25 (8)	20
6	-	Blacktop Const. Ltd. (Steed & Evans)	Pt. 112	GCT	131.0 (53.0)	10 (3)	40
7	S11-067	Warren Bitulithic Limited	Pt. 130, 131, 132	GCT	120.0 (48.6)	35-50 (11-15)	50
8	-	Arriscraft Corporation	Pt. 7, 8, 9, 10	I	270.0 (109.3)	12-15 (4-5)	5-10
9	G01-102	Corp. of the City of Cambridge	Pt. 5	II	51.7 (20.9)	15-20 (5-6)	45
10	-	Preston Sand and Gravel Co. Ltd.	Pt. 6,7	BLB	97.5 (39.5)	20 (6)	60
11	G01-165	Forwell Ltd.	Pt. 123 (upper portion)	GCT	18.8 (7.6)	10-16 (3-5)	50
					1004.6 (406.6)		
UNLICENCED PITS*							
12	-	T.A. Witzel	123	GCT		10-35 (3-11)	40
13	-	Ontario Land Corporation	22	BBF		-	40 unopened
14	G01-188	Snider	12	GCT		20 (6)	45
15	G01-077	DHO - T. Hilborn	9	BBF		20 (6)	50
16	-	Unknown	125	GCT		10 (3)	40

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

N.B. GCT - German Company Tract, BLB - Beasley's Lower Block, EGR - East of Grand River, BBF - Beasley's Broken Front

TABLE 2. SAND AND GRAVEL PITS, KITCHENER–WATERLOO–CAMBRIDGE AREA.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
17	G01-193	Dr. Lockner	118	Beasley's Upper Block		50 (15)	60 overgrown
18	-	Unknown	6	Beasley's Old Survey		15 (5)	15
19	-	Unknown	27	BBF		25 (8)	5-10
20	G01-161	E. & E. Seegmiller Limited (Buildevco Pit)	Pt. 60, 61	GCT		20-25 (6-8)	45 rehabilitated
21	G01-257	E. & E. Seegmiller Limited (Dutchman's Pit)	Pt. F	Bechtel's Tract		30 (9)	55 rehabilitated
22	-	E. & E. Seegmiller Limited (Weber Pit)	Pt. 66	Beasley's Upper Block		6 (2)	rehabilitated
23	G01-153	Preston Sand and Gravel Ltd.	Pt. 9,10	Beasley's Old Survey		15-20 (5-6)	50 rehabilitated
24	-	City of Cambridge	3	3 BLB		25 (8)	30
25	-	Unknown	13	1		12 (4)	5-10
26	-	Taylor	3	9 EGR		20 (6)	35 rehabilitated
27	-	Martini Sand and Gravel	5	1 BLB		20 (6)	60 depleted
28	G01-002	Preston Sand and Gravel	5	1 BLB		20 (6)	75 depleted
29	G01-187	Unknown	6	II		12 (4)	30
30	-	E. & E. Seegmiller Limited	117	GCT		16 (5)	50
31	-	P. Tuerr Const. Limited	141	GCT		40 (12)	50 unopened
32	G01-244	Grand River Conservation Authority (Adam property)	12	BBF		-	50 unopened

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, KITCHENER-WATERLOO-CAMBRIDGE AREA.

1 Deposit No.	2 Unlicenced Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
1	1110 (450)	190 (77)	0 (0)	920 (370)	30 (9)	69 (63)
2	250 (101)	37 (15)	2 (1)	211 (85)	20 (6)	11 (10)
3	350 (142)	12 (5)	5 (2)	335 (136)	15 (5)	13 (12)
4	239 (96)	12 (5)	0 (0)	227 (92)	20 (6)	11 (10)
5	325 (132)	155 (63)	142 (57)	28 (11)	20 (6)	1 (1)
6a	109 (44)	27 (11)	2 (1)	80 (32)	20 (6)	4 (4)
6b	140 (57)	0 (0)	0 (0)	140 (57)	10 (3)	4 (4)
7	400 (162)	57 (23)	0 (0)	345 (140)	15 (5)	13 (12)
8	106 (43)	62 (25)	2 (1)	42 (17)	20 (6)	2 (2)
9	540 (218)	185 (75)	10 (4)	345 (140)	20 (6)	17 (16)
10a	20 (8)	0 (0)	0 (0)	20 (8)	15 (5)	1 (1)
10b	116 (47)	45 (18)	20 (8)	51 (21)	15 (5)	2 (2)
10c	33 (13)	16 (6)	2 (1)	15 (6)	9 (3)	<1 (<1)
11	121 (49)	67 (27)	2 (1)	52 (21)	20 (6)	3 (3)
	3850 (1560)	865 (350)	187 (76)	2800 (1130)		152 (138)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, KITCHENER–WATERLOO–CAMBRIDGE AREA

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
0-3 (0-1)	Guelph Formation	60 (18)	730 (295)	158 (143)
3-25 (1-8)	Guelph Formation	60 (18)	2900 (1170)	630 (570)
25-50 (8-15)	Guelph Formation	60 (18)	5600 (2270)	1210 (1100)
			9200 (3700)	2000 (1810)

TABLE 5. QUARRIES, KITCHENER–WATERLOO–CAMBRIDGE AREA.

1 NO.	2 MTC NO.	3 OWNER/ OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

-NONE-

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, KITCHENER–WATERLOO–CAMBRIDGE AREA.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
Guelph Formation							
1	0-25 (0-8)	520 (210)	128 (52)	0 (0)	390 (158)	60 (18)	84 (76)

TABLE 7. SUMMARY OF TEST HOLE DATA, KITCHENER–WATERLOO–CAMBRIDGE AREA.

Test Hole Number: KI-TH-1
Location: Lot 11, Beasley's Broken Front Conc., City of Kitchener
Elevation: Approx. 1010 feet (308 m) a.s.l.

Depth feet (metres)	**Description**
5.0 (1.5)	silty fine to coarse **sand** with fine gravel
10.0 (3.0)	clayey **silt** with a thin layer of fine sand at top of core
15.0 (4.6)	grey **clay** and **silt** in varve-like layers
20.0 (6.1)	grey massive gritty clay **till** (Maryhill Till?)

Test Hole Number: KI-TH-2
Location: Lot 11, Beasley's Broken Front Conc., City of Kitchener
Elevation: Approx. 980 feet (299 m) a.s.l.

Depth feet (metres)	**Description**
0-5.0 (0-1.5)	crushable **gravel** coming up on auger
5.0 (1.5)	fine to coarse **sand** with fine to medium **gravel**
7.5 (2.3)	silty fine to coarse **sand** with fine to medium **gravel**
19.5 (5.9)	silty fine to coarse **sand** with fine to cobble-sized **gravel**
25.0 (7.6)	fine to cobble-sized **gravel** with some silty sand
30.0 (9.1)	light brown gritty silty sand **till** (Catfish Creek Till?) likely reworked by meltwaters

Test Hole Number: KI-TH-3
Location: Lot 147, Beasley's Block Conc., City of Kitchener
Elevation: Approx. 1120 feet (344 m) a.s.l.

Depth feet (metres)	**Description**
5.0 (1.5)	fine **sand**
10.0 (3.0)	massive **silt** overlying clean medium to coarse **sand** with some fine gravel
15.0 (4.6)	silty medium to coarse **sand** with some fine to medium gravel
20.0-25.0 (6.1-7.6)	silty medium to coarse **sand** with medium **gravel**
30.0 (9.1)	clean coarse **sand** with some fine gravel
35.0 (10.7)	silty fine **sand**
40.0 (12.2)	fine to medium **sand** with laminated **silt**
45.0 (13.7)	laminated **silt** with fine **sand**

Test Hole Number: KI-TH-4
Location: Bechtel's Tract, City of Kitchener
Elevation: Approx. 1085 feet (331 m) a.s.l.

Depth feet (metres)	**Description**
5.0 (1.5)	laminated fine **sand** with layers of silt, clay and coarse sand
10.0 (3.0)	grey gritty clay **till**
15.0 (4.6)	brown massive clayey **silt**
20.0 (6.1)	silty fine to medium **sand** overlying grey massive **silt** with some fine sand
25.0 (7.6)	dark brown massive uniform silty **clay,** with a thin layer of fine to medium sand at top of core

TABLE 7. SUMMARY OF TEST HOLE DATA, KITCHENER–WATERLOO–CAMBRIDGE AREA.

Test Hole Number: WL-TH-1
Location: Lot 2, Conc. 2, Block A, Township of Wilmot
Elevation: Approx. 1160 feet (354 m) a.s.l.

Depth feet (metres)	**Description**
5.0 (1.5)	light brown uniform silty fine **sand**
10.0 (3.0)	light brown silty fine **sand** with crossbedded lamination
15.0 (4.6)	light brown silty fine to medium **sand**
20.0 (6.1)	6 inches (15.2 cm) light brown medium to coarse **sand**; 8 inches (20.3 cm) laminated silty fine **sand**
25.0 (7.6)	light brown silty fine to medium **sand**
30.0 (9.1)	light brown fine **sand** and **silt**

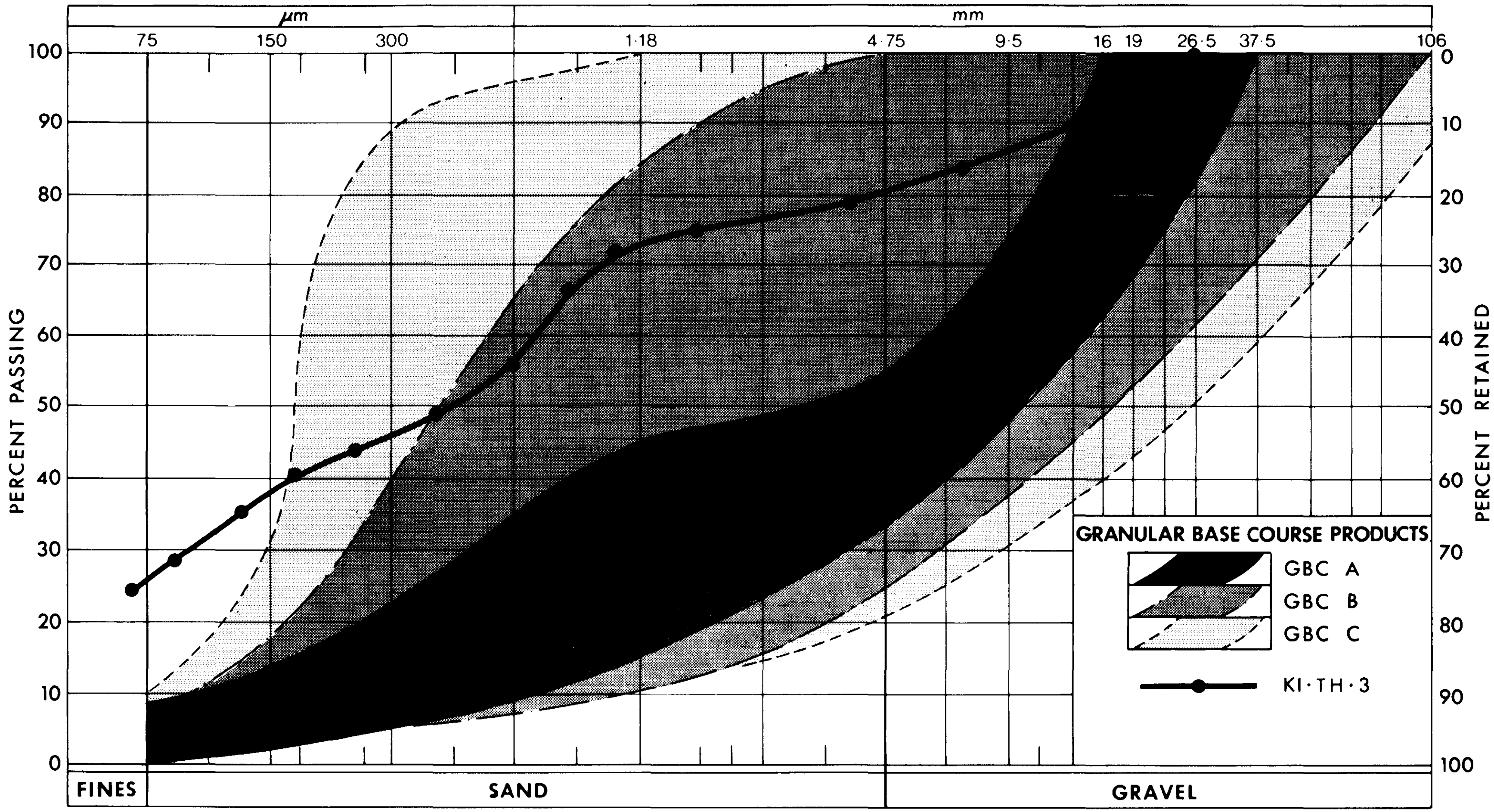


FIGURE 2a: AGGREGATE GRADING CURVES, Kitchener-Waterloo-Cambridge Area.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

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.

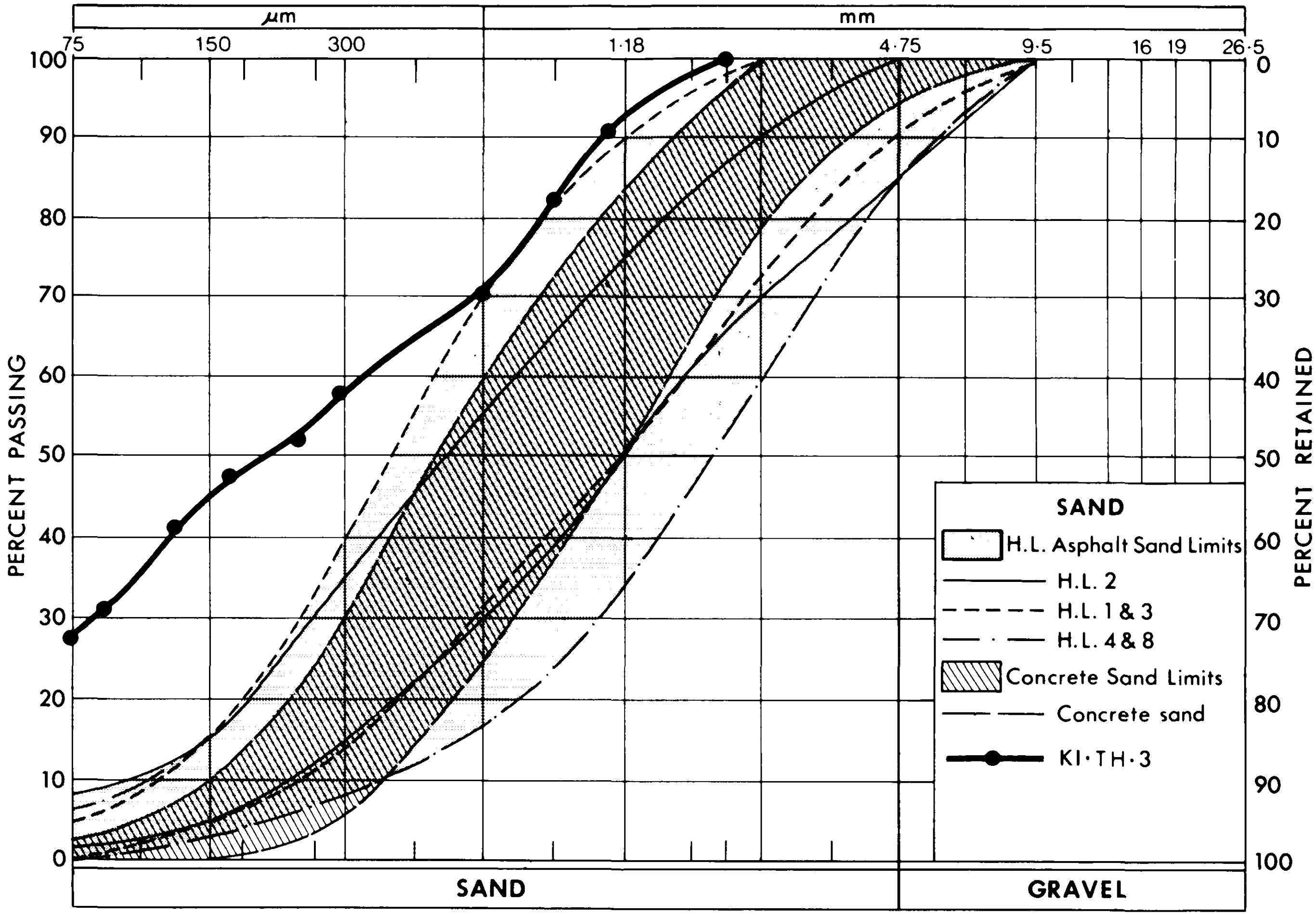


FIGURE 2b: AGGREGATE GRADING CURVES, Kitchener-Waterloo-Cambridge Area.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T C. Forms 1002, 1979 and 1003, 1981).

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.

References

Association of Professional Engineers of Ontario
1976: Performance Standards for Professional Engineers Advising on and Reporting on Oil, Gas and Mineral Properties; Association of Professional Engineers of Ontario, 11 p.

Bryant, C.R. and McLellan, A.G.
1974: The Aggregate Resources of Waterloo/South Wellington Counties: Towards Effective Planning for the Aggregate Industry; Ontario Division of Mines, Open File Report 5100, 246 p.

Caley, J.F.
1941: Paleozoic Geology of the Brantford Area, Ontario; Geological Survey of Canada, Memoir 226, 176 p.

Chapman, L.J. and Putnam, D.F.
1984: The Physiography of Southern Ontario; Ontario Geological Survey, Special Volume 2, 270p. Accompanied by Map P.2715 (coloured), scale 1:600 000.

Deike, W.
1978: Aggregate Evaluation, Kitchener-Waterloo; Aggregate Unit, Engineering Materials Office, Ontario Ministry of Transportation and Communications, 2 p., unpublished report.
1981: Aggregate Suitability Evaluation, Township of Guelph including the City of Guelph; Aggregate Sources Research, 28 p., unpublished report.

Guillet, G.R.
1983: Mineral Resources of South-Central Ontario; Ontario Geological Survey, Open File Report 5431, 155 p.

Hewitt, D.F.
1960: The Limestone Industries of Ontario; Ontario Department of Mines, Industrial Mineral Circular 5, 177 p.

Hewitt, D.F. and Karrow, P.F.
1963: Sand and Gravel in Southern Ontario; Ontario Department of Mines, Industrial Mineral Report 11, 151 p.

Karrow, P.F.
1963: Pleistocene Geology of the Hamilton-Galt Area, Southern Ontario; Ontario Department of Mines, Geological Report 16, 68 p. Accompanied by Maps 2029, 2030, 2033 and 2034, scale 1:63 360.
1968: Pleistocene Geology of the Guelph Area; Ontario Department of Mines, Geological Report 61, 38 p. Accompanied by Map 2153, scale 1:63 360.
1971: Quaternary Geology of the Stratford-Conestogo Area, Ontario; Geological Survey of Canada, Paper 70-34, 11 p. Accompanied by Maps 26-1970, 27-1970, 28- 1970 and 29-1970, scale 1:50 000.
1974: Till Stratigraphy in Parts of Southwestern Ontario; Geological Society of America Bulletin, vol. 85, pp. 761-768.
1976: Bedrock Topography of the Stratford Area, Southern Ontario; Ontario Division of Mines, Preliminary Map P.168 Revised, Bedrock Topography Series, scale 1:50 000.
1983: Quaternary Geology of the Hamilton-Cambridge Area, Southern Ontario; Ontario Geological Survey, Open File Report 5429, 147 p. Accompanied by Map P.2604, scale 1:50 000.

Miller, R.F., Farrell, L. and Karrow, P.F.
1979: Bedrock Topography of the Cambridge Area, Southern Ontario; Ontario Geological Survey, Preliminary Map P.1985, Bedrock Topography Series, scale 1:50 000. Geology 1978.

Ontario
1983: Pits and Quarries Control Act; Revised Statutes of Ontario, 1980, Chapter 378, Queen's Printer for Ontario.

Ontario Interministerial Committee on National Standards and Specifications (Metric Committee)
1975: Metric Practice Guide; 67 p.

Ontario Ministry of Municipal Affairs and Housing
1983: Municipal Directory 1983; Queen's Printer for Ontario, 241 p.

Ontario Ministry of Natural Resources
1983: Statistics 1983; Ontario Ministry of Natural Resources, 123 p.

Peto MacCallum Ltd.
1981: Gravel Investigation Bleams Road and Gehl Place, Kitchener, Ontario for Dimension Investments Limited; Ref. No. 79F 307A, July 1981, unpublished report, 11 p.

Planning Initiatives
1981: Summary Report: Inventory of Aggregate Resources on the Bickle Property, Part of Lot 123, German Company Tract, City of Kitchener; unpublished report, 8 p.
1983: Development Potential Study for Ontario Land Corporation, City of Kitchener, September 1983; unpublished report, 45 p.

Regional Municipality of Waterloo
1975: Regional Official Policies Plan.

Robertson, J.A.
1975: Mineral Deposit Studies, Mineral Potential Evaluation, and Regional Planning in Ontario; Ontario Division of Mines, Miscellaneous Paper 61, 42 p.

Sanford, B.V.
1969: Geology of the Toronto-Windsor Area, Ontario; Geological Survey of Canada, Map 1263A, scale 1:250 000.

Sanford, B.V. and Baer, A.J.
1981: Map 1335A - Southern Ontario Sheet 30S; Geological Survey of Canada, Map 1335A; Sheet 30S, Geological Atlas, scale 1:1 000 000.

Telford, P.G.
1976: Paleozoic Geology of the Guelph Area, Southern Ontario; Ontario Division of Mines, Map 2342, scale 1:50 000.
1979: Paleozoic Geology of the Cambridge Area, Southern Ontario; Ontario Geological Survey, Preliminary Map P.1983, scale 1:50 000.

Appendix A — Suggested Additional Reading

American Geological Institute
1972: Glossary of Geology; Washington, D.C., 858 p.

Bauer, A.M.
1970: A Guide to Site Development and Rehabilitation of Pits and Quarries; Ontario Department of Mines, Industrial Mineral Report 33, 62 p.

Cowan, W.R.
1977: Toward the Inventory of Ontario's Mineral Aggregates; Ontario Geological Survey, Miscellaneous Paper 73, 19 p.

Fairbridge, R.W. (ed.)
1968: The Encyclopedia of Geomorphology; Encyclopedia of Earth Sciences, Vol. III, Reinhold Book Corp., N.Y., 1295 p.

Flint, R.F.
1971: Glacial and Quaternary Geology; John Wiley and Sons Inc., 892 p.

Hewitt, D.F.
1960: The Limestone Industries of Ontario; Ontario Department of Mines, Industrial Mineral Circular 5, 177 p.
1964a: Building Stones of Ontario, Part I Introduction; Ontario Department of Mines, Industrial Mineral Report 14, 43 p.
1964b: Building Stones of Ontario, Part II Limestone; Ontario Department of Mines, Industrial Mineral Report 15, 43 p.
1964c: Building Stones of Ontario, Part III Marble; Ontario Department of Mines, Industrial Mineral Report 16, 89 p.
1964d: Building Stones of Ontario,. Part IV Sandstone; Ontario Department of Mines, Industrial Mineral Report 17, 57 p.
1972: Paleozoic Geology of Southern Ontario; Ontario Division of Mines, Geological Report 105, 18 p.

Hewitt, D.F. and Karrow, P.F.
1963: Sand and Gravel in Southern Ontario; Ontario Department of Mines, Industrial Mineral Report 11, 151 p.

Hewitt, D.F. and Vos, M.A.
1970: Urbanization and Rehabilitation of Pits and Quarries; Ontario Department of Mines, Industrial Mineral Report 34, 21 p.

Lowe, S.B.
1980: Trees and Shrubs for the Improvement and Rehabilitation of Pits and Quarries in Ontario; Ontario Ministry of Natural Resources, 71 p.

McLellan, A.G., Yundt, S.E. and Dorfman, M.L.
1979: Abandoned Pits and Quarries in Ontario; Ontario Geological Survey, Miscellaneous Paper 79, 36 p.

Ontario Mineral Aggregate Working Party
1977: A Policy for Mineral Aggregate Resource Management in Ontario; Ontario Ministry of Natural Resources, 232 p.

Ontario Ministry of Natural Resources
1975: Vegetation for the Rehabilitaion of Pits and Quarries; Forest Management Branch, Division of Forests, 38 p.

Peat, Marwick and Partners and M.M. Dillon Limited
1981: Mineral Aggregate Transportation Study; Industrial Mineral Background Paper 1, 133 p. Summary Report 26 p.

Proctor and Redfern Limited
1974: Mineral Aggregate Study, Central Ontario Planning Region; Prepared for the Ontario Ministry of Natural Resources, over 100 p.

Proctor and Redfern Limited and Gartner Lee Associates Limited
1975: Mineral Aggregate Study of Part of the Eastern Ontario Region; Prepared for the Ontario Ministry of Natural Resources, about 200 p.
1977: Mineral Aggregate Study and Geological Inventory, Southwestern Region of Ontario; Prepared for the Ontario Ministry of Natural Resources, about 200 p.

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.

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

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

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

Cambrian: The first period of the Palezoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

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 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent 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 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found 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 southern Ontario.

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

Granular base course: Components of the 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. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

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

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

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

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

Paleozoic Era: One of the major divisions of the geologic time scale thought to have covered the time 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. The test result is a Petrographic Number (P.N.). The higher the P.N. 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".

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.

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.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 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 southern 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 southern 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 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.

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 southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (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 southern 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 base course 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 southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists 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

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

Bass Islands Formation (Upper Silurian)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18 m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunnville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate because of high soundness losses.

Bobcaygeon Formation (Middle Ordovician)

Composition: Compact, homogeneous, medium- to thin-bedded, fine- grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

Bois Blanc Formation (Lower-Middle Devonian)

Composition: Brownish grey, medium-crystalline, medium- to thin- bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High cherty content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

Dundee Formation (Middle Devonian)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys as raw material for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

Gull River Formation (Middle Ordovician)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

Lockport and Amabel Formations (Middle Silurian)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive- bedded, fine-to medium-grained dolostone.

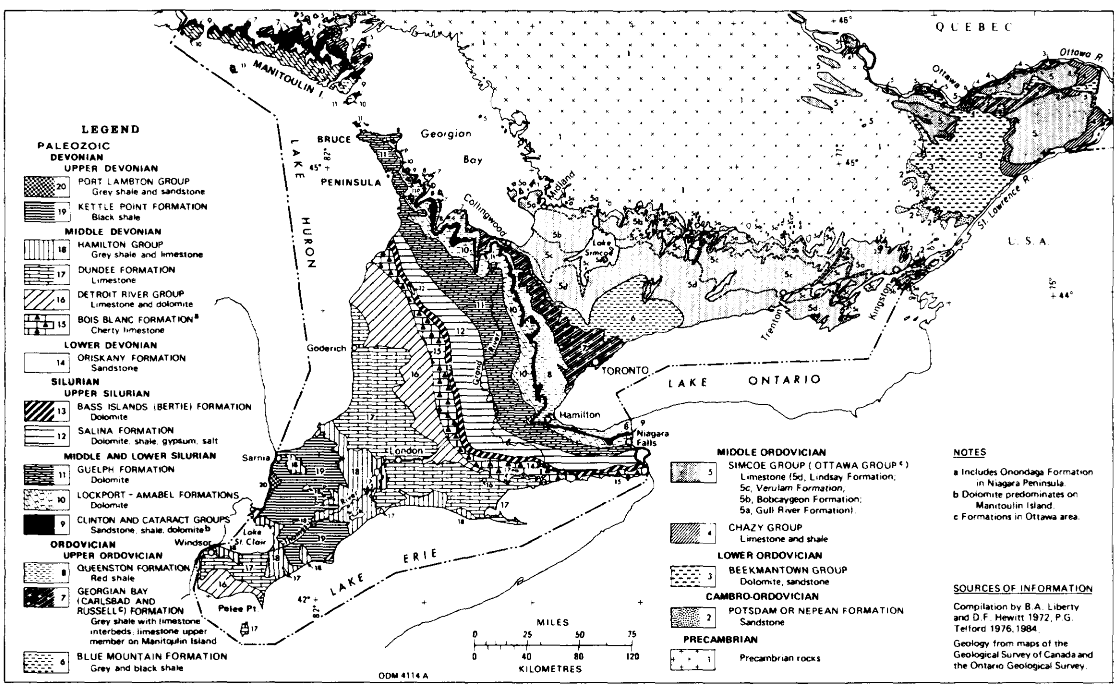


Figure 3. Bedrock Geology of Southern Ontario.

Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel 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. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

Onondaga Formation (Middle Devonian)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium- grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey- brown, fine-grained, very cherty limestone having estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey-brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High cherty content makes much of the material unsuitable for concrete aggregate.

Ottawa Formation (Middle Ordovician)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of limestone for cement production and agricultural uses.

Oxford Formation (Lower Ordovician)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

Detroit River Group (Middle Devonian)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to microcrystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces much of Ontario's lime and cement. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

Grenville Marble (Precambrian)

Composition: Recrystallized fine- to coarse-grained white limestone and dolostone, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

Guelph Formation (Middle Silurian)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. Thickness: 100 to 170 feet (30 to 52 m). Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

Lindsay Formation (Upper Ordovician)

Composition: fine-crystalline, rubbly, nodular-weathering limestone. Collingwood Member: organic-rich interbedded calcareous shales and limestones. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

Verulam Formation (Middle Ordovician)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for use in cement manufacture. The formation is unsuitable for crushed stone because of clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

Georgian Bay Formation (Upper Ordovician) (Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue-grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in the vicinity of Metro Toronto produce brick and structural tile. Lightweight aggregate has been produced at Streetsville by heat expansion of the shale.

Hamilton Group (Middle Devonian)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona Formation is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). The Arkona Formation has a thickness of 14 to 121 feet (4 to 37 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile.

Queenston Formation (Upper Ordovician)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

Nepean (Potsdam) Formation (Cambro-Ordovician)

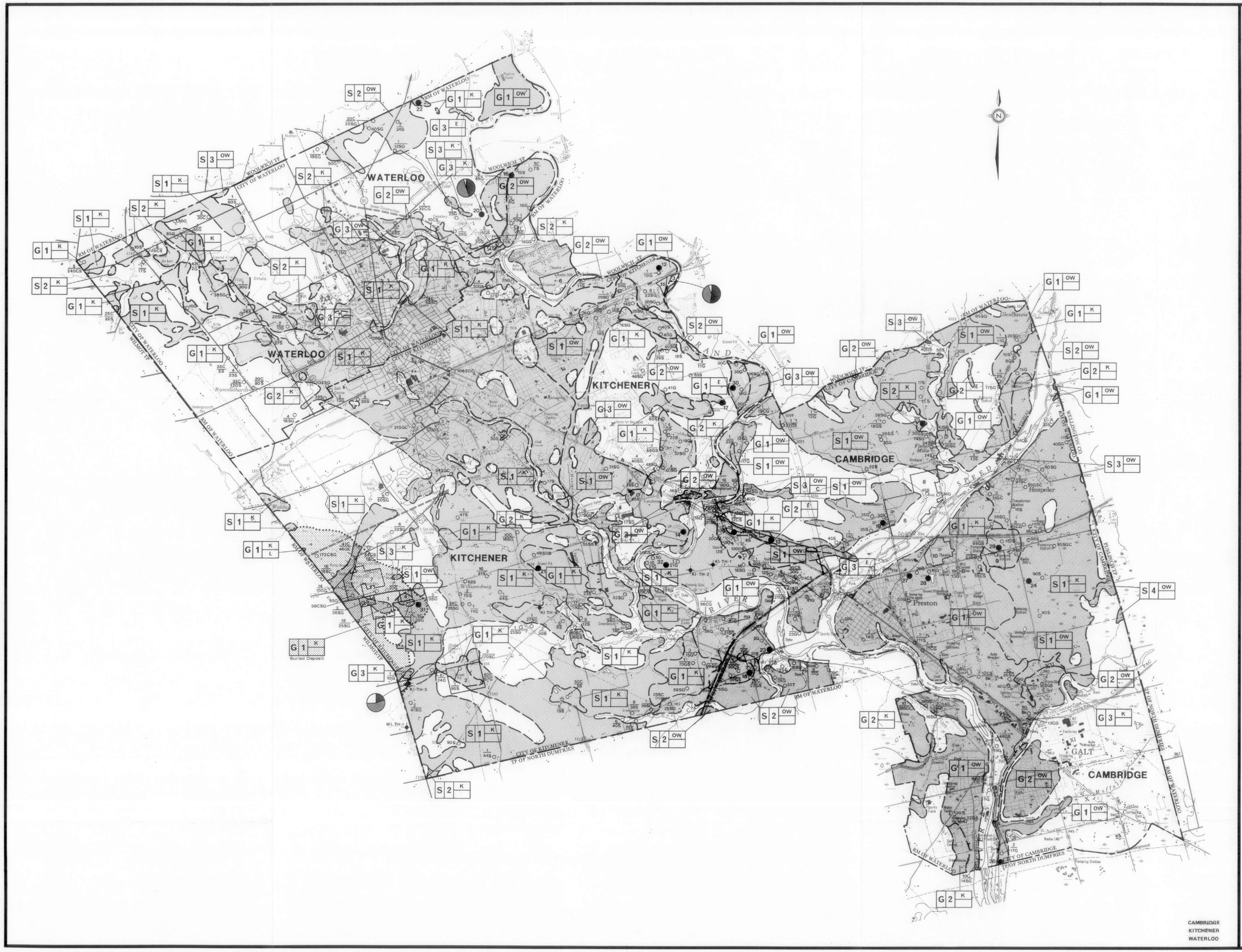
Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

Salina Formation (Upper Silurian)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

Blue Mountain Formation (Upper Ordovician)

(Formerly known as the Whitby Formation) Composition: Blue-grey, predominantly non-calcareous shale. Uses: Quarried at Bowmanville for use in cement production.



Ministry of Northern Affairs and Mines
Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

KITCHENER, WATERLOO AND CAMBRIDGE AREA

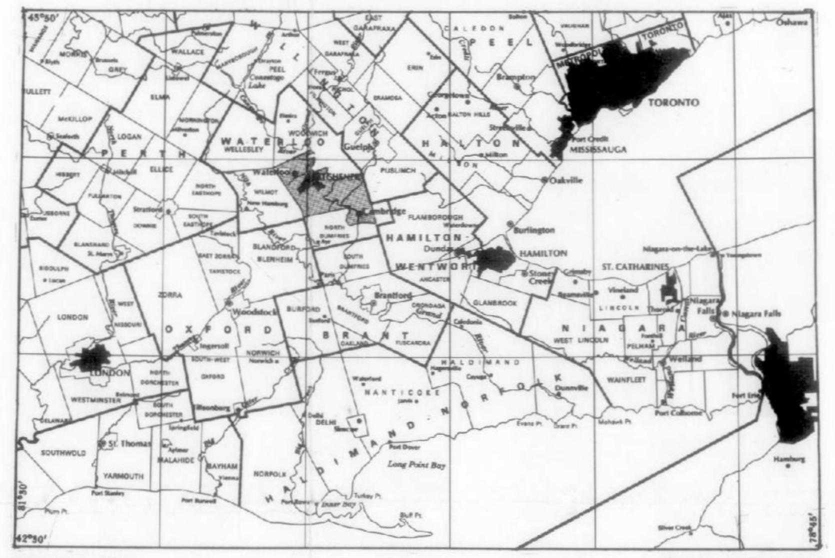
REGIONAL MUNICIPALITY OF WATERLOO

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale 1:50 000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: **40 P/7, 40 P/8**
40 P/9, 40 P/10



Location Map Scale: 1:800,000

SYMBOLS

(Some symbols may not apply to this map.)

Geological and aggregate thickness boundary. Shading indicates deposit area.

Buried geological and aggregate thickness boundary. Shading indicates deposit area.

Municipal boundary.

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.

KI-TH-2 Selected test hole location; Identification number: see Table 7.

6 / 23 G Selected drilled water well location; reported thickness of material (in feet); reported type of material (number only - overburden, T - till, G - gravel, S - sand, C - clay, Bk - bedrock,

G 1 IC / C·O Deposit Symbol: see below.

Texture symbol; see below: see Figures 2a and 2b.

TEXTURE SYMBOL

(This symbol is used where sample analysis data are available.)

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 — **Geological Type** — **Thickness Class** — **Quality Indicator**

G 1 IC / 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 acre. Geological Type refers to geologic 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 feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (> 112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10 (1.5-3)	12,500 - 25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12, 500 (< 28 000)

Geological Type

AL	Older Alluvium	**K**	Kame
E	Esker	**LB**	Lacustrine Beach
EM	End Moraine	**LD**	Lacustrine Delta
IC	Undifferentiated Ice-Contact Stratified Drift	**LP**	Lacustrine Plain
		OW	Outwash
ICT	Ice-Contact Terrace	**WD**	Windblown Forms

(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

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Test hole data from Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Northern Affairs and Mines.
Selected drilled water well data from the Ontario Ministry of the Environment.
Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: P.F. Karrow, 1968, 1971, 1983.

Compilation and Drafting by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources; Aggregate Assessment Office, Ontario Ministry of Northern Affairs and Mines.
This map is to accompany O.G.S. Aggregate Resources Inventory Paper 102.
This map is published with the permission of V. G. Milne, Director, Ontario Geological Survey.
Issued 1985.

Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.

Ministry of Northern Affairs and Mines
Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

KITCHENER, WATERLOO AND CAMBRIDGE AREA

REGIONAL MUNICIPALITY OF WATERLOO

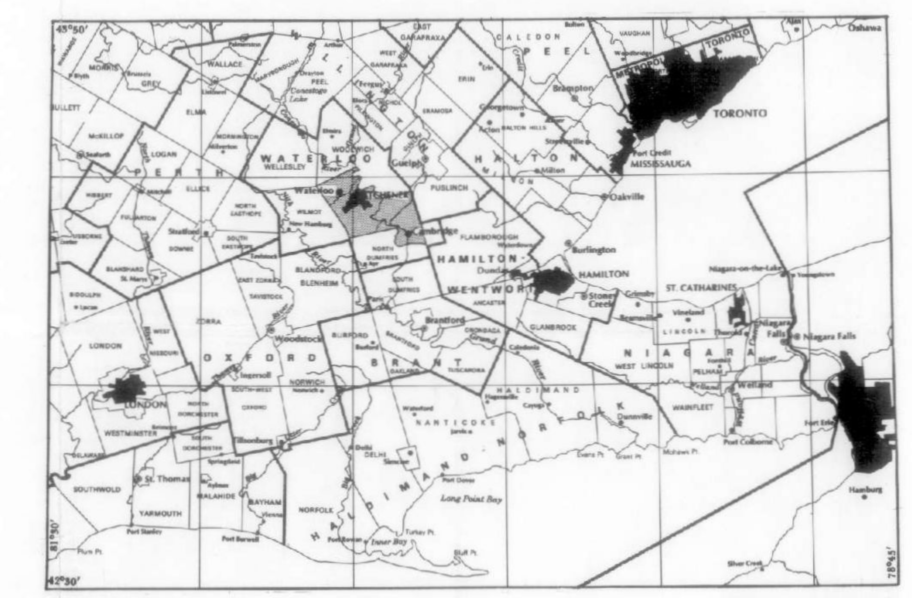
MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: **40 P/7, 40 P/8**
40 P/9, 40 P/10



Location Map — Scale: 1:800,000

SYMBOLS

(Some symbols may not apply to this map.)

- Geological and aggregate thickness boundary.
- Buried geological and aggregate thickness boundary.
- Municipal boundary.
- (2) Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area; Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
- 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.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Geology by: P.F. Karrow, 1968, 1971, 1983.

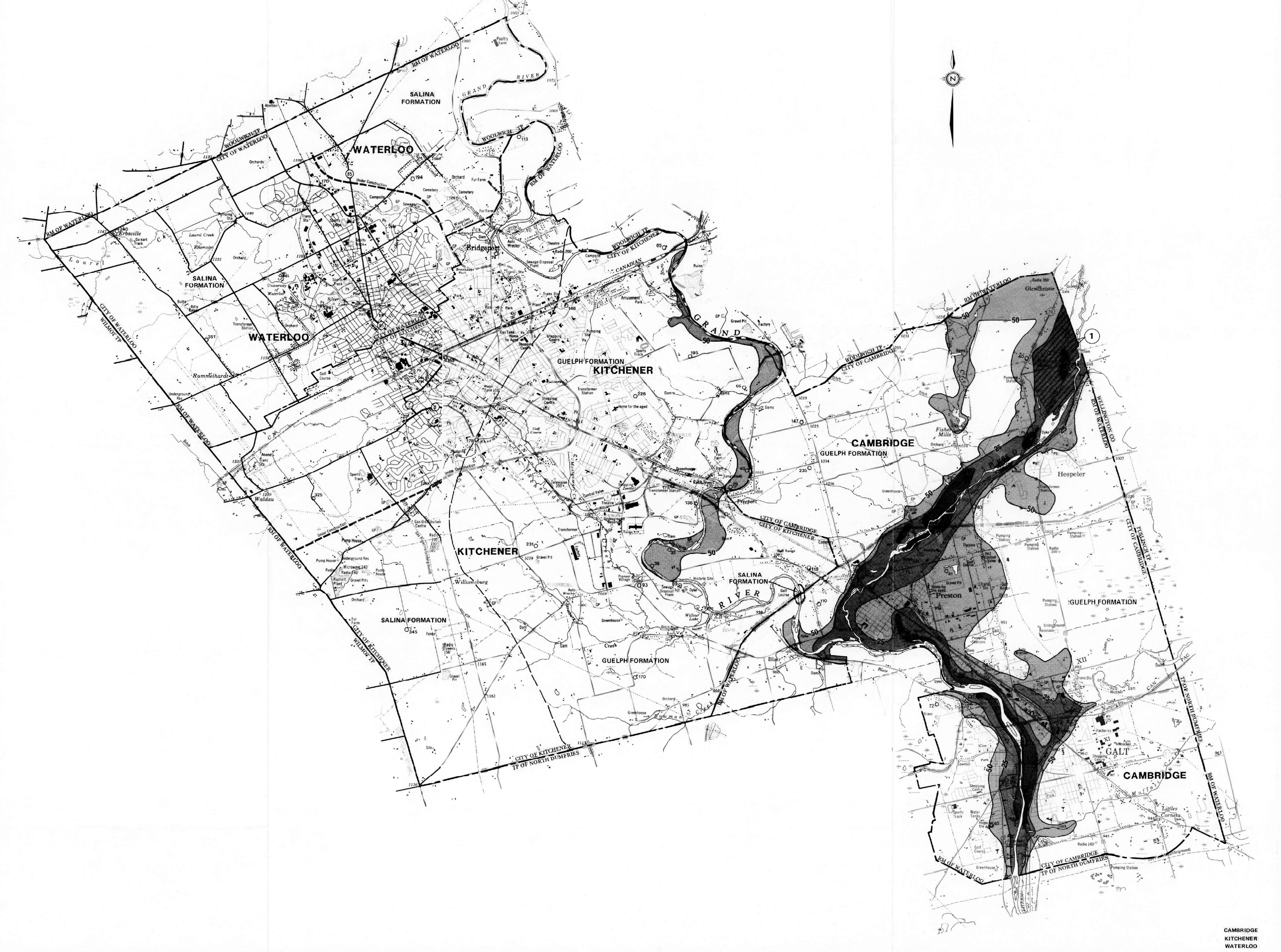
Compilation and Drafting by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources; Aggregate Assessment Office, Ontario Ministry of Northern Affairs and Mines.

This map is to accompany O.G.S. Aggregate Resources Inventory Paper 102.

This map is published with the permission of V G. Milne, Director, Ontario Geological Survey.

Issued 1985.

CAMBRIDGE
KITCHENER
WATERLOO



Ministry of Northern Affairs and Mines
Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

KITCHENER, WATERLOO AND CAMBRIDGE AREA

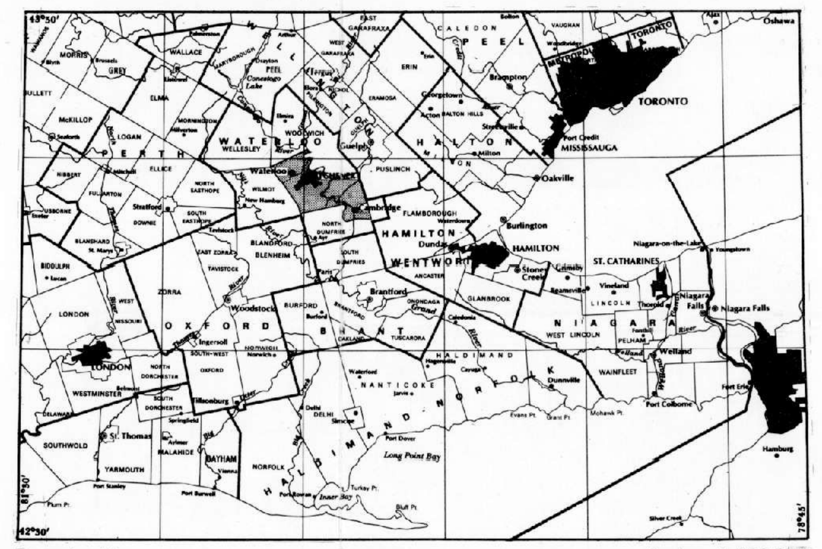
REGIONAL MUNICIPALITY OF WATERLOO

MAP 3
BEDROCK RESOURCES

Scale 1:50 000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: 40 P/7, 40 P/8
40 P/9, 40 P/10



Location Map — Scale: 1:800,000

LEGEND

PALEOZOIC
SILURIAN
UPPER SILURIAN
SALINA FORMATION
Dolostone, shale, gypsum, salt
MIDDLE AND LOWER SILURIAN
GUELPH FORMATION
Dolostone

SYMBOLS

(Some symbols may not apply to this map.)

Geological formation boundary.
Geological formation member boundary.
Formation thickness boundary (see text).
25 — Drift thickness contour: 25 foot (8 m) interval.
Municipal boundary.
2 — Selected bedrock resource area; Deposit number: see Table 6.
Bedrock exposed or near surface; covered by less than 3 feet (1 m) of overburden: see Table 4.
Bedrock covered by 3 to 25 feet (1 to 8 m) of overburden: see Table 4.
Bedrock covered by 25 to 50 feet (8 to 15 m) of overburden: see Table 4.
x — Isolated bedrock outcrop.
Q2 — Licenced quarry boundary; Property number: see Table 5.
Q3 — Unlicenced quarry*; Property number: see Table 5.
*Abandoned quarry or wayside quarry operating on demand under authority of a permit.
O 28 — Selected drilled waterwell location; reported depth to bedrock (in feet).

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected drilled water well data from the Ontario Ministry of the Environment.
Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: J. F. Caley, 1941. B. V. Sanford, 1969. P. F. Karrow, 1976. B. V. Sanford and A. J. Baer, 1981. R. F. Miller et al., 1979. P. G. Telford, 1976, 1979.

Compilation and Drafting by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources; Aggregate Assessment Office, Ontario Ministry of Northern Affairs and Mines.
This map is to accompany O.G.S. Aggregate Resources Inventory Paper 102.
This map is published with the permission of V. G. Milne, Director, Ontario Geological Survey.

Issued 1985.