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Paul Hess, André Sorensen,
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Executive Summary

The Ontario government has recently taken a proactive approach to growth planning in the Toronto region, now known as the Greater Golden Horseshoe (GGH). To carry out and monitor its policies, the Province needs reliable ways of measuring density and monitoring how it changes over time. However, definitions of density vary and there are many approaches to its measurement.

This paper reviews common definitions and discusses methodological and data problems associated with density measurements in the GGH. The authors examine existing density distributions in the GGH using 2001 census data at the scale of municipal areas, census tracts, and census dissemination areas, and analyse 10 sample census tracts in Urban Growth Centres to compare gross and net densities for different types of development areas in the GGH. Detailed profiles are provided for five of those tracts. The authors note problems with using gross density for making comparisons between areas or time periods, and problems with using census data in density calculations.

Consistent, region-wide definitions and data are needed to develop a detailed understanding of existing trends in population and jobs density, land use, development patterns, and housing issues. The authors recommend the delineation of small census tracts with permanent boundaries for the area of the GGH that is expected to build up during the next 20 to 30 years, as well as the creation of a regional database on employment location, density, and output. They also urge the government to make parcel data, or a comparable database, available to researchers and policy analysts.

Note

This paper originated as part of a research project on existing patterns of urban density undertaken for the Ministry of Public Infrastructure Renewal (MPIR) in 2005. The research was designed to help MPIR better understand targets for densities in the GGH and determine the suitability of census data for establishing baseline densities and measuring and monitoring changes in density. This paper presents only the most significant findings, and is neither the full report submitted to MPIR, nor is it endorsed by MPIR.

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Introduction

Since 2003, the Ontario government has taken a proactive approach to regional planning in the Toronto region, now known as the Greater Golden Horseshoe (GGH). Major initiatives include the *Greenbelt Act* (2004), the *Places to Grow Act* (2005), and the Places to Grow Plan, released in June 2006.

Ontario is embarking on an ambitious experiment in regional structure management that has profound implications for future patterns of urban and rural change in the region. Of particular significance are plans to promote the intensification of urban density in existing urban areas, urban growth centres, and new greenfield developments in the GGH. Particular interest has been expressed in centres that either are, or have the potential to become, regional service providers because they have or can develop effective services, infrastructure, and transportation linkages that promote the goals of Smart Growth, including greater housing choice, and diversity in travel modes (Ontario Growth Secretariat 2005).

Population and jobs densities in urban regions are a key, but highly controversial issue for managing regional growth. The lower the overall density of new development, the more land is needed for a given amount of population increase. Given the huge scale of growth that is expected in the GGH during the next decades, even small increases in density could greatly reduce total land consumption. The new GGH Greenbelt further increases the imperative to use the remaining development land in the region as effectively as possible. Equally important, public transit is not viable in low-density communities, and large areas of the GGH simply do not have enough people within walking distance of transit stops, or enough high-density mixed-use walkable centres that make attractive destinations for transit users. Increasing public transit use will require not only better public transit facilities, but also a change in the larger patterns of density in the region.

As noted by Blais (2003), Smart Growth does not mean just a general increase in high-density urban form. Intensifying all parts of the region would be less effective in promoting transit use than selective intensification of mixed-use nodes and the corridors that join them. Similarly, it is now widely recognized that a key aspect of urban quality of life and of social and economic vitality is the existence of fine-grained walkable urban places with a mix of jobs, activities, and housing. Many of the older downtowns in the region have such places, but most of the suburbs built since the 1960s lack such destinations, and are virtually impossible to get to without a car. All

these issues point to increased density as a way of improving the livability of the region. However, in order to monitor the effects of this type of policy and urban development over time, it is important to first understand the concept of density: how it is measured, and which aspects of density different measurements are able to capture.

The current Provincial efforts at managing regional growth in the GGH correctly identify density as a key issue. Policies set density targets for new areas of growth in greenfield sites as well as density targets in designated Urban Growth Centres (UGCs). Additionally, the policies set targets for the amount of new growth that should occur in already built-up areas that would benefit from general intensification.

To carry out and monitor these policies, the Province needs robust and reliable ways of measuring density and monitoring how it changes over time. This is not a straightforward matter. There are many definitions of density and many approaches to its measurement. Also, the suitability of various data sets for measuring different types of density varies widely.

Census data produced by Statistics Canada is clearly attractive for measuring density, since it is comprehensive for the entire population and is produced every five years, allowing changes in density to be monitored over time. At the same time, census data has many limitations. For one thing, it is focused on residential population counts and thus is less useful for examining employment density. For another, it uses predefined geographic units for measurement that may not capture the types of changes that are of most interest to the Province. This report evaluates the use of census data for measuring existing density and monitoring changes in the GGH.

The first section of this working paper compares existing definitions of gross density and net density. A wide variety of definitions have been and are currently employed by planners and urban analysts in the study of urban density. We review the planning literature for common definitions and discuss some of the methodological and data problems associated with density measurements in the GGH.

Section 2 examines existing density distributions in the GGH using 2001 census data. We examine the distributions and spatial patterns of gross density of population, jobs, and population-and-jobs combined in the GGH at the scale of municipal areas, census tracts, and census dissemination areas.

Section 3 analyses 10 sample Census Tracts in Urban Growth Centres to compare gross and net densities for different types of development areas in the GGH, and provides detailed profiles for five of those tracts.

A final section draws out the main conclusions.

1. Gross Density, Net Density: Concepts and Definitions

1.1 Why is Density Studied and How is it Measured?

Density is relevant to "environmental quality, transportation systems, physical infrastructure and urban form, social factors, and economic factors" (Churchman 1999, 398). Understanding urban density concerns planners, regional economists, community organizations, psychologists, and ecologists. The reasons for studying density influence how it is measured. For example, a psychologist interested in the effects of perceived density on mental well-being might use surveys to assess residents' *perceptions* of density. As this study is meant to inform planning practice, the literature review that follows focuses on physical and quantifiable measurements of urban density.

The two major sources of data on urban density are censuses and remote sensing. Statistics Canada conducts a full population census every decade, and a slightly more limited survey every five years. The census provides a rich source of data collected in a consistent way. Census data is usually aggregated to protect the anonymity of respondents, so it cannot provide a sense of population distributions at a very small scale.

Some researchers supplement census data with data acquired through remote sensing. This data can provide details of urban form that can be integrated with census data using Geographical Information Systems (GIS) to clarify population distribution and density (Langford 2003; Donnay and Unwin 2001).

Remote sensing offers a number of ways to observe variables such as land cover, land use, and other density indicators. Dasymetric mapping uses remotely sensed images to identify residential areas within a census tract, thereby allowing for a better estimation of net densities. Images can be analyzed[1] to determine approximate land uses (Langford 2003). For a more precise classification of land uses, satellite images can be studied in raster format in GIS, allowing for the analysis of individual pixels. Land use classifications of remotely sensed data at a pixel level are carried out using "maximum likelihood classifier" statistical formulas, many of which

1 The analysis draws on spectral band reflectances and measures of variability and image texture.

have been incorporated into software packages (Mesev et al.1995). Although pixel-based approaches can reduce the effects of the modifiable areal unit problem[2] (Lo 2003), this type of classification is still imperfect, as it is only an estimation of land uses and not a direct observation (Donnay and Unwin 2001).

Longley and Mesev (2000, 2002) and Harris and Longley (2000) suggest that the use of satellite images in analyzing population data can be improved by supplementing these images with additional data sources that can be obtained commercially, such as Address Point, a product that gives the geographical coordinates of all residential and commercial mail delivery points in the United Kingdom. Harris and Chen (2005) discuss the procedures of converting these point data sets from vector to raster data to allow them to occupy an area rather than individual points, as is required for determining densities. This process is referred to as a "space-filling" technique. In carrying out this conversion, the authors use population surface modelling to estimate the density gradient at each point of observation.

GIS can also be used to display density analyses that have been computed by other means. For example, Bracken and Martin have developed a method of extrapolating densities from the centroids of census tracts to obtain localized density measures. While this process is largely based on mathematical formulas, it can provide less generalized density information that can inform public policy decisions (1989). There is also a potential to use this centroid approach with remote sensing of residential areas in order to determine localized population densities (Martin et al. 2000).

Statistics Canada has recognized the value of GIS technology. Before 2001, the land area of census tracts was manually calculated using a planimeter. Beginning in 2001, land areas have been derived from the National Geographic Base using GIS software. However, Statistics Canada (2005) warns that its own land area estimations are unofficial, and are less accurate at smaller scales. Therefore, there is a need to explore more precise methods of assessing land area. Additionally, Statistics Canada measures *gross* population density, meaning that its calculations are not specific to particular land uses (such as residential or commercial). A more sophisticated measure of density is needed to identify the potential for urban intensification.

Parcel data, which contains details about individual lots of land, can provide a comprehensive catalogue of urban land uses that can be manipulated to calculate different types of density.

Following is a discussion of various density calculations based on direct observations of land area.

1.2 Calculating Density

The main practical difficulty with population density measures is in deciding what aspects of population and land area are to be observed. Density is a ratio in which a measure of population

2 "The definition of zonal objects used for many geographical studies are modifiable and vary greatly" (Openshaw and Taylor 1981; 61). The modifiable areal unit problem (MAUP) describes how the aggregation of data divided into zones, or areas with discrete boundaries, can be problematic: "different areal arrangements of the same data produce different results" (Openshaw and Taylor 1981; 63). Additionally, it can be difficult to spatially represent meaningful units of analysis.

or built form serves as the numerator and a measure of land area as the denominator. The numerator can be total population, number of rooms or dwelling units, or available dwelling space (floor area). The denominator can be either total land area (as in "gross density"), or a pared-down measure of usable land area (as in "net density").

Table 1.1 displays the possible combinations of these numerators and denominators. Common terminology for each ratio and the authors who describe each concept are also listed. The shaded cells are those that represent gross densities; the white cells represent various forms of net density.

Table 1.1: The Diverse Terminology of Density

Land area	Population measurement	Rooms/dwelling unit measurement	Floor area measurement
Total urban land area	"Population density" (Statistics Canada 2005) "Total density" (Hall et all 1973) "Metropolitan density; Gross neighbourhood density "Gross census tract density" (Forsyth 2003) "Gross municipal area density" (Hitchcock 1994)**	"Metropolitan density; Gross neighbourhood density; Gross census tract density" (Forsyth 2003) "Gross municipal area density" (Hitchcock 1994)**	
Developed urban land	"Overall residential density" (Hall et al.1973) "City density" (Forsyth 2003)	"City density" (Forsyth 2003)	
Residential land (includes local non-residential land uses such as schools, parks etc.)	"Gross residential density" (Hall et al.1973) "Net neighbourhood density" (Forsyth 2003) "Gross residential area density" (Hitchcock 1994)**	"Net neighbourhood density" (Forsyth 2003) "Gross residential area density" (Hitchcock 1994)**	
Residential land (excluding local non-residential land uses, including streets)	"Net residential density" (Hall et al.1973) "Net residential density at city or metropolitan level; Net neighbourhood residential population density" (Forsyth 2003)*	"Net residential density at city or metropolitan level; Net neighbourhood residential dwelling density" (Forsyth 2003)*	

Land area	Population measurement	Rooms/dwelling unit measurement	Floor area measurement
Parcel area plus half of public street right-of-ways		"Street density" (Hitchcock 1994)**	
Block area / part block area (measured to the curb)	"Block density / part block density" (Forsyth 2003)	"Block density" / "part block density" (Forsyth 2003)	"Building block coverage" (ground floor footprint only) (Forsyth 2003) "Impervious surface block coverage [ground floor footprint plus all paved areas]" (Forsyth 2003)
Residential lot area/ parcel area	"Parcel density" (Forsyth 2003; Hall et al. 1973)	"Parcel density" (Forsyth 2003) "Parcel density – units per hectare" (Hitchcock 1994)**	"Floor area ratio" (all floors) (Forsyth 2003) "Building site coverage" (ground floor footprint only) (Forsyth 2003) "Impervious surface parcel coverage" (ground floor footprint plus all paved areas) (Forsyth 2003) "Parcel density – floor space index" (Hitchcock 1994)**
Floor Area	(Hall et al.1973)		

*Forsyth's "Net neighbourhood residential building type density" is calculated in a similar manner, although only residents living in a particular type of dwelling are included in the calculation. This measure can be calculated with either population or dwelling units as a numerator. Forsyth also lists building intensity measures, including building height, front setbacks, side-to-side distance between buildings, and back-to-back distance between buildings (2003).

**Hitchcock (1994) also lists alternative terms for the density measures he describes, as follows:

- Parcel density – net-net density, net site density, net density, lot density
- Street density – net density
- Gross residential area density – gross site density, residential density, residential area density, gross density, gross living area density, neighbourhood density
- Gross municipal area density – population density, community density

In addition to the above definitions, measures that use "people-plus-jobs" as a numerator can be used to assess both residential and employment land use intensity. For example, Carruthers (2002) has used "urban density" in a study assessing the effectiveness of state growth management measures in the United States, defined as the number of jobs plus people per acre of developed land.

Each of the above ratio calculations reveals a different aspect of urban density, so they are used in different situations. For example, a ratio expressing density as a function of rooms per acre may be used in residential development (Cowan 2005). A ratio of floor space to land area can be used to "define the nature of development appropriate over an area of many lots, or to

control the intensity of development permitted on any given private parcel of land" (Hitchcock 1994; 4), and can therefore be useful in drawing up municipal official plans. Gross densities, on the other hand, give a bigger picture of land use as they express the amount of space a population consumes for all residential and non-residential uses (Hitchcock 1994).

Blais (2003) notes that it is important to measure and monitor both net and gross densities in order to capture the amount of development land taken up by non-residential land uses such as public infrastructure, employment lands, and protected greenspaces. Increasing net residential density alone may not lead to increased gross densities.

1.3 Difficulties in Calculating Density

A number of problems arise in calculating densities. One of the most readily apparent lies with the variety of available definitions and measurements. As there are so many ways to calculate densities using so many different units of measurement, consistency and comparability across studies can be difficult. For example, in 1995, Lehman and Associates found no consistency in the measurement of density among municipalities in the Greater Toronto Area (Churchman 1999).

Another barrier to comparing densities lies in the variation within variables. Dwelling size and household size vary from one country to another, one city to another, one neighbourhood to another, and one housing type to another (Churchman 1999; Forsyth 2003; Laplante 2005; Alexander 1993). Essentially, density is an average, and as happens with averages, local variations in density become less apparent as the area across which the average is taken becomes larger (Hitchcock 1994). To address one aspect of this difficulty, Alterman and Churchman have suggested calculating densities for each building type in an area to make explicit the variations within a site (1998, cited in Churchman 1999). Other authors have attempted to catalogue dwelling density within different housing types to make comparison easier (Alexander 1993; Fader 2000; Wentling 1988).

The scale of density measurement is another challenge to measuring density. For example, calculations of parcel density, block density, neighbourhood density, and gross density for the same area will each produce distinct results. Generally speaking, the more land is removed from the denominator (in other words, the more land that is "netted out"), the higher the density will be (Forsyth 2003). This phenomenon is related to the modifiable areal unit problem (MAUP).

The MAUP accounts for measurement errors that occur due to boundary definition and the aggregation of data. Redefining the boundaries used as the geographic unit of measurement will produce different results, *even though the underlying data is exactly the same* (Openshaw and Taylor 1981). For example, if a boundary is moved so that a large office cluster becomes part of a different census tract, neither the combined employment nor the combined land area of the two tracts will have changed. The measured employment densities of both tracts, on the other hand, will differ: one increases in measured density and the other decreases.

This may not be a problem if boundaries are drawn to capture particular phenomena of interest, but in practice it is difficult to identify meaningful units of analysis that are not simply random aggregations of space (Openshaw and Taylor 1981). Even more problematic, boundaries are

often drawn in ways that systematically obscure a phenomenon of interest. If an analyst is using census tracts to identify high-density areas, for example, the way boundaries are drawn may defeat this purpose, because census boundaries are often drawn along major roads, but higher-density urban uses often cluster around major intersections. As a result, high-density clusters are often separated into several adjoining census tracts that also contain much lower-density uses. Such clusters may not show up in a density analysis, because they have been divided among several census tracts and averaged out.

Appendix A contains a list of papers on the mathematical modelling of density.

1.4 The Limitations of Using Canadian Census Data for Density Measurements

Detailed data on existing population density, recent trends in population density, and the extent of built-up areas are needed to measure trends in the density of urban development. Although a population census is undertaken every five years by Statistics Canada, Canadian data on population is surprisingly weak.

Before the 2001 census, the main, fairly stable unit of data collection was the Census Tract (CT). Areas smaller than CTs were called enumeration areas (EAs), and were defined as the area that could be managed by one enumerator. The boundaries of EAs changed from census to census, so EAs are useless for measuring changes in population density over time. To solve that problem, in 2001 EAs were replaced by Dissemination Areas (DAs) whose boundaries are intended to be consistent in future censuses. That means that in future researchers will be able to measure population change at the DA scale, which is an important gain.

Even at the level of DAs, however, serious boundary problems limit the usefulness of DAs for measuring urban population density, as illustrated in **Figure 1.1**.

The figure shows a satellite photograph of a group of DAs in North York bounded by Cummer Avenue to the north, Willowdale Avenue to the east, Bishop Avenue to the south, and Yonge Street to the west. Within this area there are three very different kinds of urban land use: (a) the strip along Yonge Street, which includes high-rise condominium blocks and low-rise commercial with extensive surface parking; (b) the large area of low-density single-family homes and public parks; and (c) the long parking lot along Bishop Avenue under the hydroelectric transmission lines.

This area is divided into three DAs, as shown with red lines: one large one for most of the area, and two small ones, apparently corresponding to the high-rise condominiums. The area is also divided into eight Census Blocks, shown in green. The two DAs associated with the high-rises are symbolically shown as trapezoids. The small DA and block fronting on Yonge Street has a population in 2001 of 379, and a notional area of 357m^2, indicating a population density of 10,608 people/ha, while the DA and block at the corner of Yonge and Bishop has a population of 503 and an area of 1,210 m^2 for a population density of 4,155 people/ha. A careful look at the satellite image shows that the geographic location and size of these two small DAs is not accurate. That will mean that the recorded population density of the larger DA that occupies most of the area bounded by Yonge, Cummer, Willowdale, and Bishop will also be inaccurate.

Figure 1.1: North York DAs and Census Blocks east of Yonge Street

In 2001 the population of this DA was recorded as 977, with a population density of 25.57 people/ha. As the two small DAs in the southwest corner are smaller than the actual building sites of the condominiums, the area recorded for the larger DA is larger than its actual area. The only way to get an accurate population density for the area would be to aggregate the three DAs. As this is impractical for analysis of any significant area, it seems fair to conclude that the current Block and DA geography is not appropriate for measuring population density, and we are left with Census Tracts, which almost always contain large variations of population density and built form.

For census data to be useful in measuring changes of population density in a detailed way, the DAs and Blocks would have to be drawn accurately to reflect the actual parcels on which these

high-rise buildings were built. It would also make sense for DAs and Blocks to follow major patterns of land use and built form, so that the strip along Yonge Street would be separate from the single-family homes area and from the hydro right-of-way parking lot along Bishop Avenue. As DAs are supposed to remain stable, and have already been drawn for existing areas, this approach will not be possible for areas in which DAs have already been defined, but it would clearly be an advance for newly developing areas. It may also be possible to change Blocks to fit more tightly to major urban form types. This would allow both a more precise understanding of where changes are occurring, as well as the identification of areas and capacities for future intensification.

A second major problem with census data is that to measure change before 2001, only Census Tracts (CTs) are available, but CTs themselves have changed enormously in the urban fringe areas where the greatest changes are occurring. Within existing built-up areas, CT boundaries are kept relatively constant, although they may occasionally be divided to reflect major increases in population. On the urban fringe, however, they tend to be very large in order to include a target population of 2,500 to 8,000. As urban fringe areas are built up, CTs are divided into smaller areas. That means that while changes in population can be calculated for the larger areas of the pre-division CT by aggregating later, smaller CTs, no data is available for those smaller areas at earlier periods. As a result, the level of detail available for analysis of the urban fringe areas where change is occurring rapidly is limited. For example, a typical CT in York Region north of Markham is 20 km^2, whereas in recently built-up areas of Markham the typical area is 1.71 km^2.

Limiting the number of CTs outside the built-up area is a practical approach to data management, as for each CT there are hundreds of data points for all the variables that the census monitors. In the days before computers, creating too many CTs in rural areas with low population densities would have been a waste of resources. It does seem reasonable now, however, to define urban-sized CTs that will retain permanent boundaries for at least all Designated Urban Areas within the GGH, and perhaps the whole area inside the Greenbelt as well. The Ontario government should request that these new CTs be defined in advance of the next census in 2011, so that a stable census geography can be established to allow monitoring of change in the region in future. DAs and Blocks can be demarcated only after urbanization, but a new policy should be established to ensure that DAs and Blocks follow major types of urban form.

Although these difficulties in calculating density can be discouraging, researchers need to persist in collecting information about urban population density patterns and changes to them over time. Examining methods used in other regions to measure and monitor densities can also provide suggestions for alternative ways of calculating density. However, there are limitations in conducting this type of survey. While many authorities publish their urban intensification policies, few publish the means (and even fewer, the results) of their density monitoring. As a result, this information often cannot be translated into meaningful comparisons between different administrative units. Appendix B includes an overview of some of the more readily available density measurements used in other parts of the world, and a chart detailing a variety of growth management policies, including their definitions of density. Appendix C contains a bibliography of papers evaluating growth management policies.

1.5 Measuring Density in the Greater Golden Horseshoe

Density has occasionally been assessed in areas of the Greater Golden Horseshoe over the past 35 years. These accounts provide insight into changes in densities over time, and a series of snapshots of urban development in the area. The following literature relies largely on models of density gradients based on census data. Not all reports cover the entire Greater Golden Horseshoe; rather, they focus on the most urbanized areas, and most look exclusively at Toronto.

Latham and Yeates (1970) observed that commercial activities at the centre of the city could reduce residential densities in the Central Business District. They proposed a model (the "second degree negative exponential model") to describe this phenomenon, and used Metropolitan Toronto as a case study. The authors found that their model described Toronto's densities better than the traditional first degree negative exponential model.

In 1981, Griffith tested the theory of polycentricity on the Toronto area using a multinodal model based on 1971 census data. He found that only the Central Business District accounted for increased residential densities; no other centres did. The author speculated that this phenomenon would change over time as Toronto grew.

Edmonston et al. (1985) also used 1971 census data to examine density gradients, but his results were more generalized. He compared all CMAs in Canada and the United States, and observed that Canadian cities were more compact than American cities.

Churchman (1999) discusses the concept of "gross reurbanization density" as proposed by Berridge Lewinberg Greenberg Ltd. in their 1991 *Reurbanisation Plan for Metropolitan Toronto*. This measure of density assesses the number of residents and employed people/ha, as opposed to residents only. According to Churchman, the use of this measure encourages mixed land uses and not just residential intensification. The *Reurbanisation Plan* set density goals for different city centres:

- low-density centres should have 125-175 residents plus workers per hectare;
- medium-density centres should have 250-350 residents plus workers per hectare;
- high-density centres should have 400-500 residents plus workers per hectare.

Bunting et al. (2002) compared density gradients from 1971 and 1996 census data for the 15 CMAs in Canada with more than 250,000 people. The authors reported a number of results relevant to the Greater Golden Horseshoe:

- Toronto had the highest overall density of all Canadian CMAs in 1996 with 3,322 people/km^2; the rate for Hamilton was 2,355 people/km^2, Kitchener 1,791 people/km^2, and St. Catharines–Niagara had the lowest density of all CMAs, with 1,176 people/km^2.
- Toronto's population density had decreased 4.6 percent from 1971 to 1996, while Hamilton's decreased by 5.1 percent, Kitchener's increased 6.1 percent, and St. Catharines-Niagara's increased 4.8 percent.
- All these CMAs had major increases in urbanized land area over the period: Toronto's increased by 55.8 percent, Hamilton's by 32.3 percent, Kitchener's by 64.4 percent, and St. Catharines-Niagara's by 28.7 percent.

- Toronto had the highest core area density of the CMAs, with 8,738 people/km^2; Hamilton ranked third (after Vancouver) with a core density of 6,479 people/km^2, and St. Catharines-Niagara had the lowest density of 2,221 people/km^2.
- Toronto had the greatest increase in central area density over the observation period; this change was attributed to in-fill housing and high rates of central employment growth.
- All the Greater Golden Horseshoe municipalities had increases in suburban density from 1971 to 1996: Toronto's suburban density grew by 9.4 percent, Hamilton by 4.6 percent, Kitchener by 15.7 percent, and St. Catharines-Niagara by 17.2 percent.
- With respect to suburban population dispersal, Toronto was found to have the highest Canadian density, and St. Catharines-Niagara still had the lowest density of all of the observed CMAs. The authors conclude that Toronto's high suburban densities are related to planning controls that were enacted to encourage varied types of housing built in the suburban areas, in addition to increased densities due to high land costs.

Filion et al. (2004) modelled density gradients for twelve U.S. urban areas and three Canadian ones (Montreal, Vancouver, and Toronto). The authors used 1991 data from the Canadian census, and 1990 census data from the United States. They found that Canadian cities generally had high inner-city densities and higher inner suburban densities. Toronto also had the highest outer suburban densities of all of the observed cities. However, Canadian cities had larger gaps in density between their inner and outer suburbs. The authors speculate that this disparity in densities occurs because of poor transit services in the middle suburban areas, and the nature of the outer suburbs as self-sufficient centres in their own right.

Blais (2000) studied development densities of new suburban development as part of the Neptis Foundation's "Portrait of the Region" studies, and found that new developments were occurring at steadily higher unit densities.

Gordon and Vipond (2005) studied New Urbanist areas in Markham to assess the impact of this new – and purportedly more compact – form of urban development on residential density rates. The authors created ratios of dwelling units and population density, as reported in the 1996 and 2001 censuses, relative to developable land areas, as measured by planimeter. They found that the New Urbanist areas had mean gross residential densities that were about 76 percent higher than the mean densities of conventional suburban areas.

Clearly, researchers still have more work to do in measuring and monitoring patterns and densities of development in the GGH.

2. Population and Jobs Density in the Greater Golden Horseshoe

In this section, we examine patterns of population, jobs, and household density in the GGH based on an analysis of census data. Although there are some important limitations in the census data, some of which were discussed in the previous section, it is the best data available, particularly as the census collects data periodically, on a consistent basis, for the whole region.

This section covers three topics: measuring population using municipalities as the unit of analysis; measuring population and jobs using Census Tracts (CTs) and Dissemination Areas (DAs); and patterns of household size distribution.

2.1 Population Density at the Municipal Scale

A key variable in any spatial analysis is the size of the unit of measurement, and the degree to which those units correspond to the phenomena being studied. The best-known area units in the region are:

- municipalities, of which there are 108 in the GGH;
- Census Tracts (CTs) of which there are 1,459 in the GGH;
- Dissemination Areas (DAs), of which there are 11,606 in the GGH.

The GGH includes an enormous land area of about 32,000 km^2, centred on the City of Toronto, as shown in **Figure 2.1**. The GGH includes extensive non-urban areas, and a large area that is not divided into Census Tracts, being considered too sparsely populated to justify them.

Figure 2.1 also shows the gross population density of municipal areas, as calculated by dividing the total municipal population by the total area of the municipality. The map shows Toronto to be by far the highest in municipal gross population density. This is certainly true, but the result is exaggerated by the fact that Toronto is almost fully built out, while most other municipalities include large greenfield areas.

This finding illustrates a problem with measuring population density using municipalities as the area unit: there is a great variation in the proportion of the various municipalities that is urban-

ized or slated for development under current planning time horizons. Comparing the gross population density of a city such as Toronto, where official plans designate over 90 percent of land in the city for development, almost all of which is already built-up, to Hamilton, where only 20 percent of the land area has been designated for development and of this only 76 percent is already built up, is clearly comparing apples and oranges.

This fact is borne out by recent data prepared by MPIR defining the Existing Built-up Area (EBA) and Designated Urban Area (DUA) as of 2004. The Existing Built-up Area represents land in the GGH that was already urbanized in 2004. This includes everything from older, dense city cores, such as Toronto and Hamilton, to new subdivisions and employment areas recently built on agricultural and other previously undeveloped land. The Designated Urban Area includes this built-up land, as well as land that is not built up, but is designated for development in local municipal plans. These boundaries are useful, because they allow comparisons of population densities of the built-up areas, or Designated Urban Areas only.

Figure 2.1: Municipal Population Density, Greater Golden Horseshoe

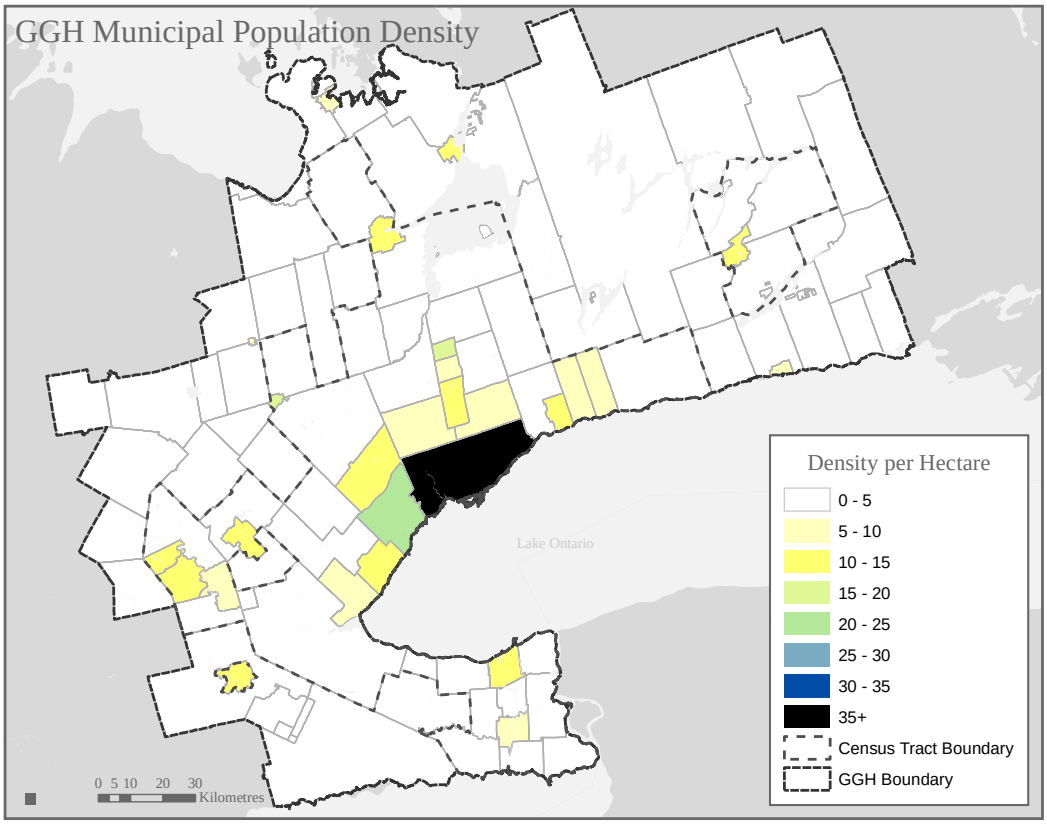


Table 2.1: Comparing the Designated Urban Area to the Existing Built-up Area in the Greater Golden Horseshoe

	Greater Golden Horseshoe	Designated Urban Area (DUA)	Existing Built-up Area (EBA)	% of DUA that is EBA	DUA minus EBA	EBA Average Population Density
Area (km^2)	**32,000 km^2**	**4,232 km^2**	**2,876 km^2**	_	**1,356 km^2**	**18.6 people/ha**
Percent	**100%**	**13% of GGH**	**9% of GGH**	**68% of DUA**	**32% of DUA is not built up**	**-**

Using the Existing Built-up Area boundary as defined by the Ministry of Public Infrastructure Renewal for 2004 matched to the census population data from 2001, the Designated Urban Area (DUA) is 13 percent of the total area of the Greater Golden Horseshoe (GGH), the Existing Built-up Area (EBA) is 9 percent of the GGH area, the percentage of DUA that is EBA is 68 percent. Meanwhile, 32 percent of the DUA is not yet built up. The average population density of all built-up areas in the GGH is 19 people/ha.

There is a significant variation in the degree to which municipalities in the GGH fill out their whole municipal area. Some, such as the City of Toronto, are in effect, fully built up, and no significant amount of developable greenfield land remains within the city's boundaries. In other municipalities, particularly in suburban or exurban areas, the DUA is only a small portion of the whole municipal area, and the EBA is only a small portion of the DUA. Of course, in such cases, measuring density averaged over the whole municipal area greatly underrepresents the actual densities of built-up areas.

Table 2.2 ranks all municipalities in the Greater Golden Horseshoe by the population density of the EBA, as well as the percentage of the municipal area that is DUA, the percentage that constitutes the EBA, and the percentage of the DUA that is EBA. The latter shows the degree to which the existing designated area is built up. For example, 68 percent of Guelph's DUA is EBA, meaning that 32 percent of the DUA is still greenfields.

Table 2.2 includes data on EBA population density, percent DUA, percent EBA, and percent unbuilt land for all municipalities in the GGH. The density calculations depend greatly on the accuracy of the designation of the EBA, particularly in the smallest municipalities, where it may be only a few hectares. It is safe to assume that in the larger municipalities, the density calculations will be more robust. Most of the larger municipalities show EBA gross population densities of between 17 and 26 people/ha, with Toronto much denser at 45.7 people/ha.

Figure 2.2 presents the data from **Table 2.2** comparing population densities of the EBA in each municipality in the region, and also shows in pink the significant areas of greenfield land surrounding many municipalities. This map is a more accurate indication of densities than Figure 2.1, as we are comparing the population density of existing built-up areas only, and excluding the greatly varying greenfield areas within each municipality. Toronto is still an outlier: at 45 people/ha, it is much denser than anywhere else in the region. Toronto is followed by a second tier of large municipalities that are over the 25 people/ha threshold such as Hamilton (27),

Ajax (26.3), Newmarket (26.3), and Brampton (26). Above 20 people/ha are Kitchener (24.6), Richmond Hill (24.3), Mississauga (24.9), Burlington (23), Pickering (22.9), Oshawa (22.4), St. Catharines (22.1), Waterloo (21.1), Markham (21.1), Aurora (20.9), and Barrie (20.5).

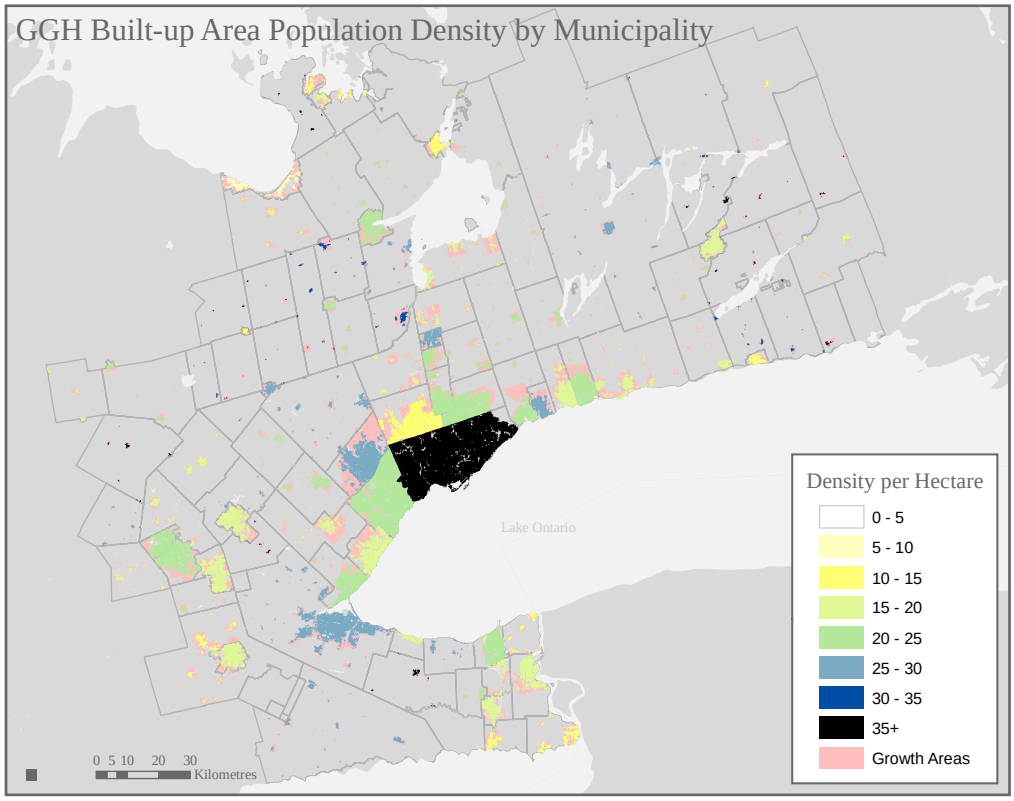
Table 2.2: Top 30 Greater Golden Horseshoe Municipalities Ranked by Total Population plus Jobs*

Municipality	Pop. + jobs	EBA pop. + job density /ha	EBA pop. density /ha	EBA job density /ha	% DUA	% EBA	% DUA that is EBA
Toronto	3,809,109	65.4	42.7	22.8	92.5%	92.5%	100.0%
Mississauga	961,705	37.6	23.9	13.6	93.9%	88.7%	94.5%
Hamilton	678,633	38.4	27.0	10.7	20.6%	15.8%	76.7%
Brampton	447,708	35.9	26.0	9.8	85.4%	46.8%	54.8%
Markham	325,205	33.0	21.1	11.8	55.8%	46.3%	82.9%
Vaughan	294,597	23.2	14.3	8.9	63.0%	46.3%	73.6%
Kitchener	271,949	35.2	24.6	10.5	82.7%	56.5%	68.4%
Burlington	221,841	34.1	23.0	10.9	42.8%	34.9%	81.5%
Oakville	212,893	28.0	19.1	9.0	81.8%	54.8%	67.0%
Oshawa	196,886	31.9	22.4	9.4	59.4%	42.4%	71.4%
St. Catharines	187,375	32.5	22.1	10.1	67.7%	59.3%	87.6%
Richmond Hill	179,475	33.2	24.3	8.8	69.1%	53.6%	77.6%
Guelph	168,485	31.4	19.8	11.6	89.9%	61.8%	68.8%
Cambridge	166,272	29.8	19.8	10.0	72.0%	49.5%	68.7%
Barrie	149,400	29.6	20.5	9.1	95.8%	65.5%	68.4%
Waterloo	139,973	34.1	21.1	13.0	85.6%	64.0%	74.8%
Brantford	123,867	26.0	18.1	7.9	91.3%	66.5%	72.9%
Pickering	118,774	31.6	22.9	8.4	31.3%	16.2%	51.7%
Whitby	117,333	24.9	18.5	6.3	47.4%	32.1%	67.7%
Niagara Falls	113,405	24.3	10.0	9.8	34.1%	23.0%	67.4%
Peterborough	107,961	25.9	17.2	8.8	100.0%	71.0%	70.2%
Newmarket	98,553	39.4	26.3	13.1	94.3%	65.7%	69.7%
Ajax	96,803	34.5	26.3	8.2	65.1%	41.8%	64.2%
Kawartha Lakes	87,334	33.2	12.9	6.9	1.6%	0.7%	48.4%
Clarington	86,009	23.0	17.4	4.3	13.6%	5.9%	43.29%
Welland	67,867	24.7	17.3	7.1	46.7%	32.6%	69.91%
Caledon	67,030	35.5	20.4	8.7	5.2%	2.6%	49.10%
Halton Hills	62,784	28.7	20.8	6.7	14.3%	7.7%	54.21%
Haldimand	58,733	38.8	17.0	9.9	2.1%	1.0%	45.9%
Aurora	56,522	29.4	20.9	8.5	72.2%	38.7%	53.7%

Figures for all GGH municipalities are shown in Appendix D

It is important to remember, however, that these are population densities only, and do not include jobs. In some cities, employment areas represent a major part of the built-up area, but include almost no residential population. Mississauga is an excellent example, as it includes Pearson International Airport and nearby employment lands. If we excluded the employment areas, the population densities of Brampton and Mississauga would probably be closer. Comparing population-plus-jobs densities within built-up areas corrects this effect only slightly, as employment densities tend to be much lower than population densities.

Figure 2.2: Population Density by Municipality, Greater Golden Horseshoe Built-up Area



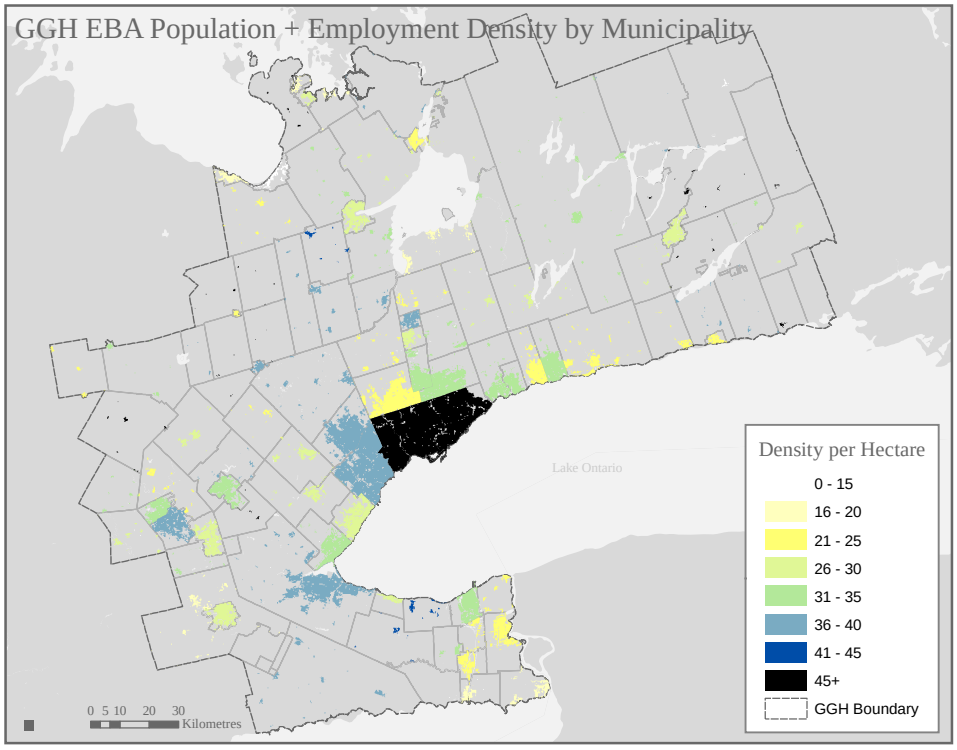
Another factor that heightens the disparities between municipalities may be that different municipalities have different proportions of protected greenspace and protected environmental lands within their built-up areas. That is certainly a significant factor behind Toronto's higher densities, particularly in inner areas that have few parks and were built during an era when it was common to put watercourses into underground pipes and build over them. In today's developments, much larger areas are devoted to parks, wetlands, streams, and rivers, and other protected greenspace. Not all municipalities have the same proportion of such greenspace, however, and those with a higher share of greenspace have lower EBA population densities.

Figure 2.3 shows the data from **Table 2.2** of EBA population-plus-jobs densities for all municipalities in the region. Note the large gap between the density of Toronto and any other municipality. Toronto is not only the densest municipality in the region, but no other municipality even comes close. Other job-rich municipalities that appear much denser relative to the measurement

of population alone are Kitchener, Hamilton, and Mississauga. When comparing to **Figure 2.2**, it is important to note that the density ranges are categorized differently.

It would be valuable to compare population densities net of both employment lands and protected greenspace and environmental lands, but because of data limitations, such a comparison is beyond the scope of this project.

Figure 2.3: Population-plus-Jobs Density by Municipality, Greater Golden Horseshoe Built-up Area

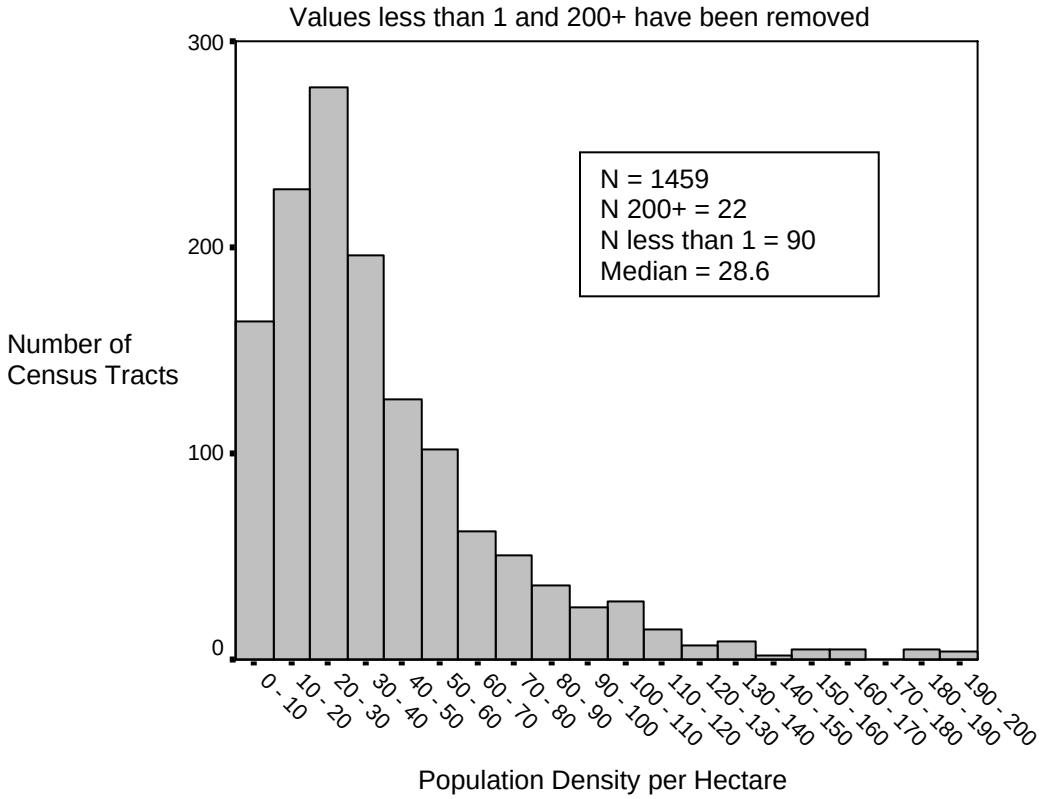


2.2 Population Density at the Census Tract Scale

Measuring population density averaged over whole municipal areas conceals considerable variation within municipal areas. This section looks at the finer scale of analysis made possible by Census Tracts (CTs). In examining population densities of CTs, it is not as important to distinguish Designated Urban Areas and Existing Built-Up Areas. CTs are already small enough that most are either wholly built up, or not built up at all. A few tracts on the urban fringe have both built-up and non-built-up areas, and low overall population densities.

To get a sense of the overall distribution of CT population densities in the region, it helps to show the number of CTs in each density range as a histogram, as in **Figure 2.4**. Most tracts have densities of between 20 and 30 people/ha. The median is 28.6 people/ha, so half of all tracts are below that level. The number with higher densities drops sharply in density categories above 30 people/ha. Only 22 tracts (1.5 percent of all CTs) are above 200 people/ha. As almost all CTs with less than 10 people/ha are either rural, or only partly built up, well over half of existing built-up tracts in urban areas have densities between 10 and 30 people/ha.

Figure 2.4: Distribution of Population Density of Census Tracts



A different picture of population density patterns in the region emerges from an analysis of the finer grain of CTs, as shown in **Maps 2.5a** and **b**. Note that, as shown in **Map 2.1**, not all of the GGH is divided into CTs. This does not, however, greatly affect the analysis of population density, because all the areas without CTs are rural areas with low population densities. **Map 2.5a** shows all CTs in the region. The smaller municipalities farthest from Toronto, such as Barrie and Peterborough, are almost entirely within the density range of 10-40 people/ha. We therefore focus on the central GGH at the larger scale, as that is where the greatest variation in population density occurs.

The high-density tracts that have more than 120 people/ha are almost entirely within the City of Toronto, other than two tracts with more than 200 people/ha in Mississauga, and one of more than 120 people/ha just west of Hamilton's Central Business District. All CTs of more than 200 people/ha include significant concentrations of high-rise residential buildings, although it is possible in principle to achieve such densities with mid-rise buildings such as stacked townhouses. Note also that not all tracts with high-rise residential buildings are over the 200+ people/ha density threshold. This is commonly the result where the tract also includes significant low-density residential or employment areas. A large area in central Toronto, corresponding roughly to the urban area built-up before the Second World War, has population densities of more than 80 people/ha, the only such area in the region.

Figure 2.5a: Population Density by Census Tract, Greater Golden Horseshoe

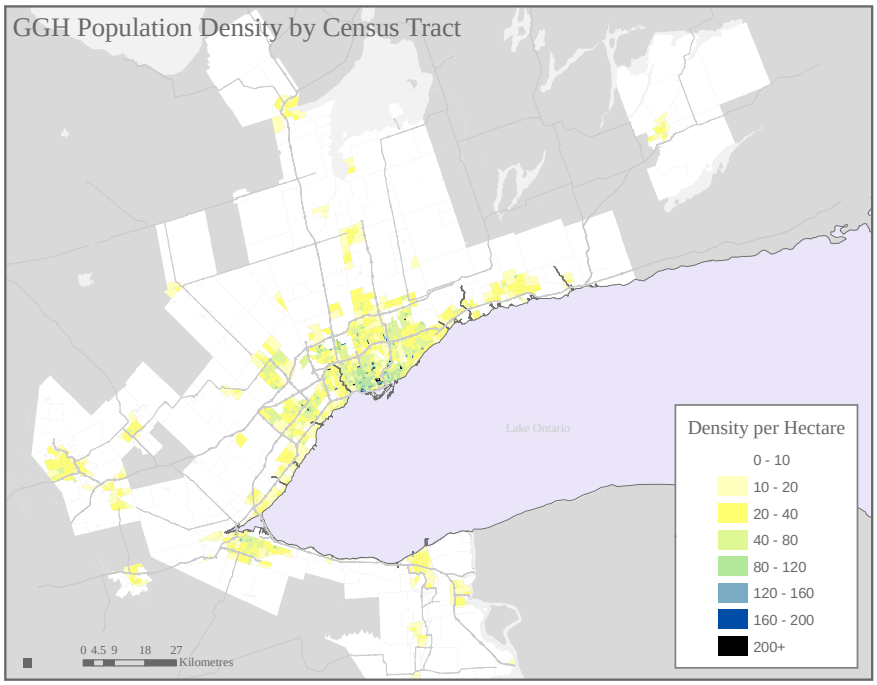
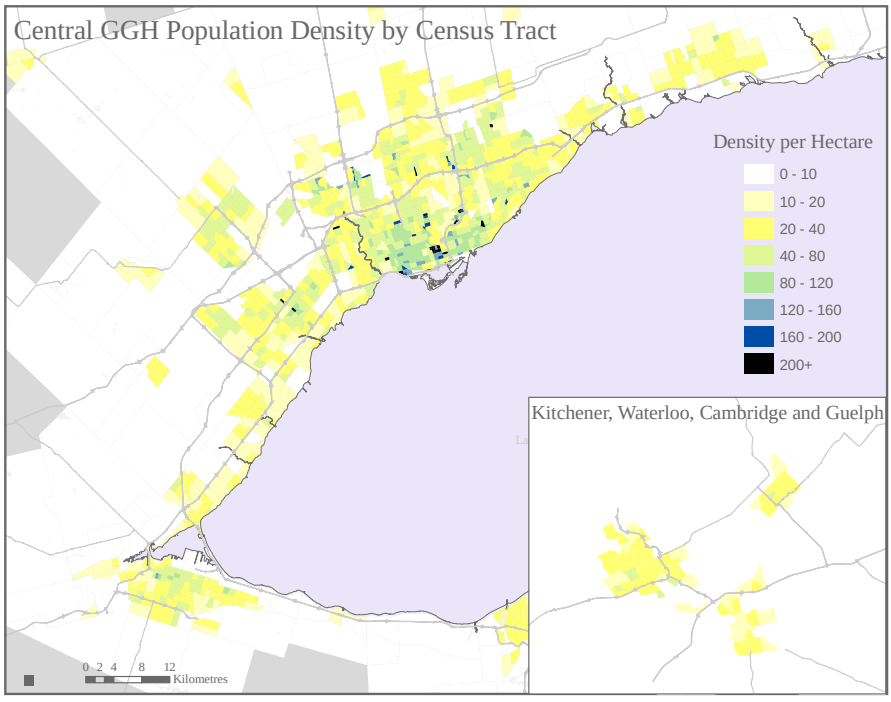


Figure 2.5b: Population Density by Census Tract, Central Greater Golden Horseshoe



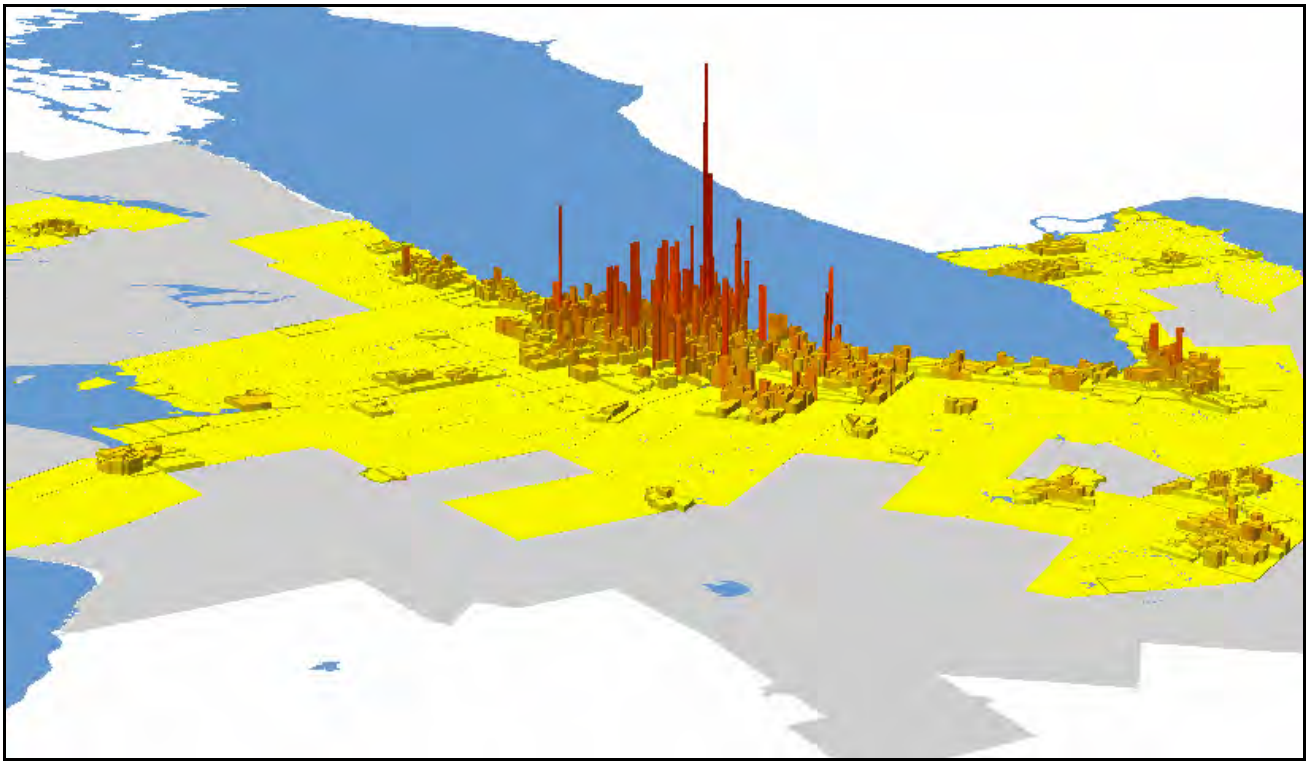
Although we examine employment densities and combined population and employment densities in a later section, it is worth noting one point here: in the older central-city areas of Toronto, Hamilton, Kitchener-Waterloo, and others, population densities are high even in areas with many jobs, but in newer suburban areas, employment areas appear as empty spaces in the

population density maps. These are not greenfields, however, but densely built-up employment lands that have no population. All the areas that appear white in Toronto, except for the Bridle Path area, the Toronto Islands, and Rouge Park, are large-scale employment areas. This is a significant feature of urban form in the region. While older areas combine both population and jobs at high densities, newer areas tend to be either residential or employment areas, with few tracts showing both jobs and population.

Very few CTs outside Toronto exceed the threshold of 80 people/ha. The most common population density in municipalities outside Toronto is 20 to 40 people/ha, with significant areas between 10 and 20 people/ha. Only a few recently developed suburban areas, such as southern Markham, have more than 40 people/ha.

Figure 2.6 is a simulation of a three-dimensional view of population densities in the region, looking from the northwest towards the southeast. The whole area of CTs is shown as a base of yellow, while higher densities are graduated towards red shades with higher densities appearing taller.

Figure 2.6: Three-dimensional View of Population Density by Census Tract



Showing population densities as a 3D projection has both advantages and disadvantages. The main advantage is that the 3D representation is intuitively understandable for most people, and some features are easier to see, such as the relative sizes of the clusters centred on Toronto, Hamilton, and Oshawa. Also, more information is provided on the high-density tracts, since in **Figure 2.5a,** the black tone indicates merely “over 200.” In **Figure 2.6,** we can see that some tracts that have more than 200 people/ha, such as those near Scarborough Town Centre and Mississauga Town Centre, are denser than others.

The main disadvantage with the 3D projection is that some tracts unavoidably hide others, so it is hard to make any detailed examination of the patterns in central Toronto. It is also easy to mistake the map as a representation of built form, with lots of tall towers, instead of an abstract projection of CT population densities.

Perhaps the most striking impression created by the map is that the Toronto area appears to be a compact, relatively contained cluster. This is certainly partly a result of the exaggerated heights of the red columns. Although the Toronto region and its nearby suburbs have been built in a relatively contiguous pattern, most of the suburban areas have been built at fairly low densities, as shown in **Figure 2.5b**.

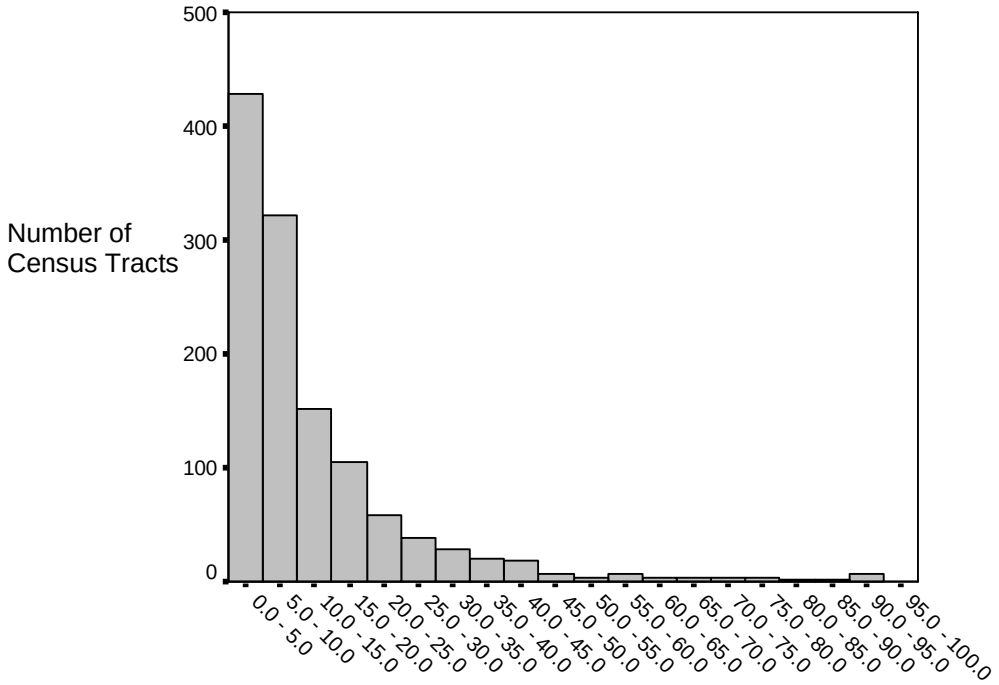
2.3 Employment Density at the Census Tract Scale

Patterns of employment density are quite different from population density. The main difference is that there are far fewer CTs with high employment densities than CTs with high population densities.

The distribution of employment densities is clear from the histogram shown as **Figure 2.7**. Two-thirds of all CTs (66 percent) have less than 10 jobs/ha. This is primarily a result of postwar planning policies, which separated employment areas and residential areas. Most of the very low-employment-density tracts are residential areas where most employment land uses are

Figure 2.7: Distribution of Job Density of Census Tracts

0's and 100+ job densities have been filtered out



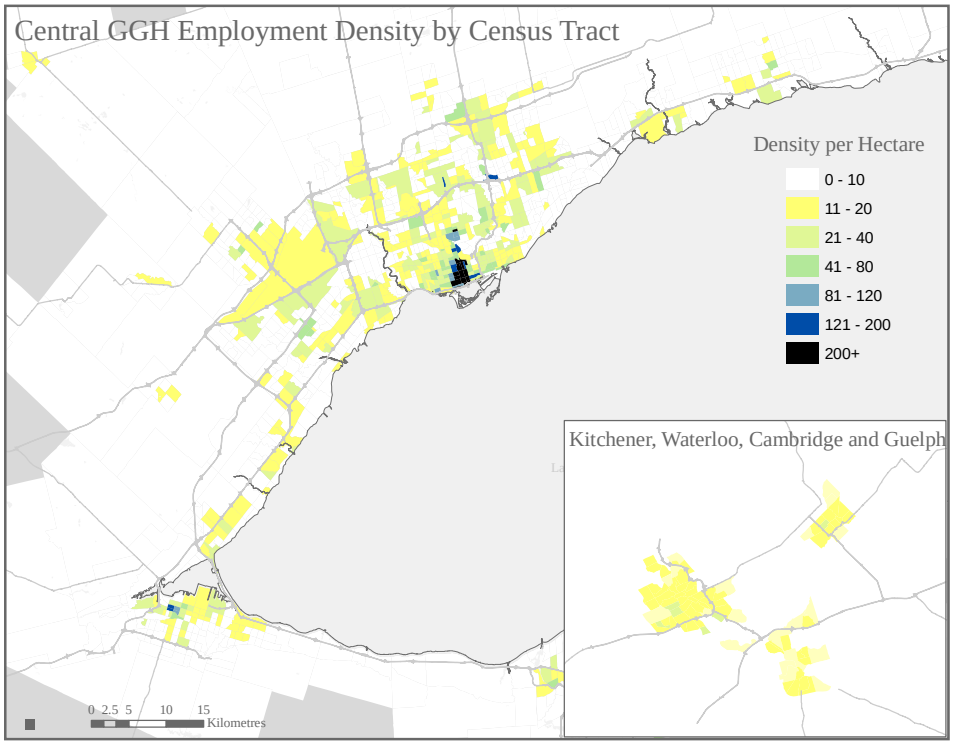
prohibited. Many CTs thus have either no employment at all, or employment only in primary schools or small neighbourhood retail centres. Also, Statistics Canada has tended to draw CT boundaries differently for employment areas compared with residential areas; the tracts that represent employment areas are usually much larger than those for residential areas. Therefore, some small areas of high-density jobs within large tracts may exist, but can be obscured by surrounding low-density employment uses.

One should be cautious about interpreting census data on employment, because these data are based on a 20 percent sample, and therefore not as accurate as the population numbers, which approach 100 percent coverage. Even taking those qualifications into account, however, densities in employment areas are much lower, with only 6 percent of all CTs over 40 jobs/ha, and only 2 percent over 100 jobs/ha.

It would be valuable to examine employment densities within primarily employment areas separately, but there is no reliable method of distinguishing primarily employment CTs from primarily residential CTs, particularly as many older employment areas are mixed-use districts in which much land is occupied by housing. An analysis of employment density at the scale of either census DAs, or even individual land parcels, would provide a more detailed picture of employment patterns in the region, but neither land use data nor employment data are currently available at finer scales.

Employment densities have a different pattern from population densities, as shown in **Figure 2.8**. The only major concentration of high-density employment is in the City of Toronto, with the Central Business District around King and Bay streets representing the only significant concen-

Figure 2.8: Employment Density by Census Tract, Central Greater Golden Horseshoe

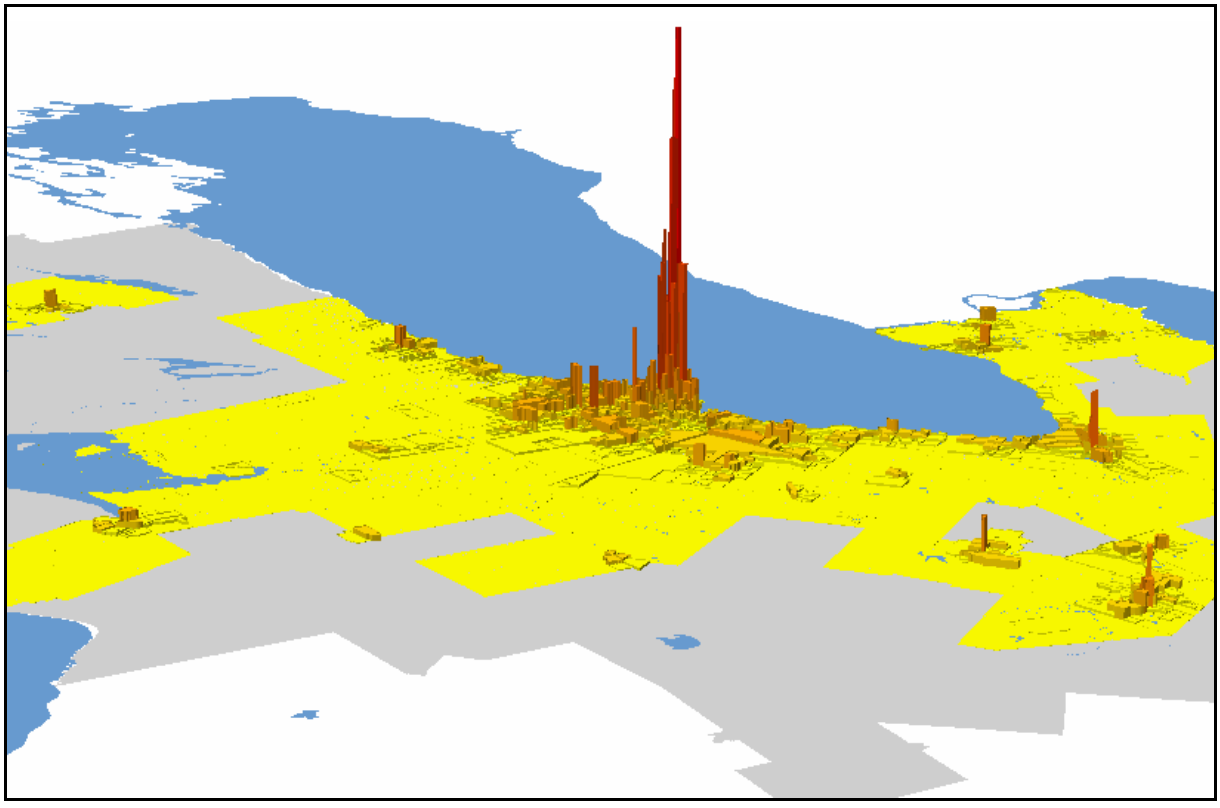


tration of high-density jobs in the region. Other, much smaller, areas of high-density employment exist at Yonge and Eglinton, North York Centre, downtown Hamilton, downtown Kitchener, and the intersection of Highways 407 and 404. Virtually everywhere else, employment densities are much lower, seldom exceeding 40 jobs/ha.

Most of the tracts that are exclusively in employment use are between 20 and 40 jobs/ha, except for the vast Pearson Airport site, which has lower densities because of the extensive area of runways. Many of the areas that show densities of 10 to 20 jobs/ha are tracts that include both employment and residential uses. Because of land use segregation, suburban employment densities are something of a reverse-image of residential densities – where one is high, the other is low. This is not true in central Toronto, where high employment densities co-exist with high population densities.

Another way of representing employment density by CT, **Figure 2.9** shows a 3D projection of employment densities in the region. The high-density jobs cluster at King and Bay clearly dominates as the only such cluster in the region, and dwarfs any other downtown. The Yonge-Eglinton cluster is also visible, as is a larger cluster in North York. Hamilton and Kitchener-Waterloo each has a small cluster of higher-density employment downtown. Other downtowns are also visible, but much smaller. Elsewhere, relatively low job densities predominate.

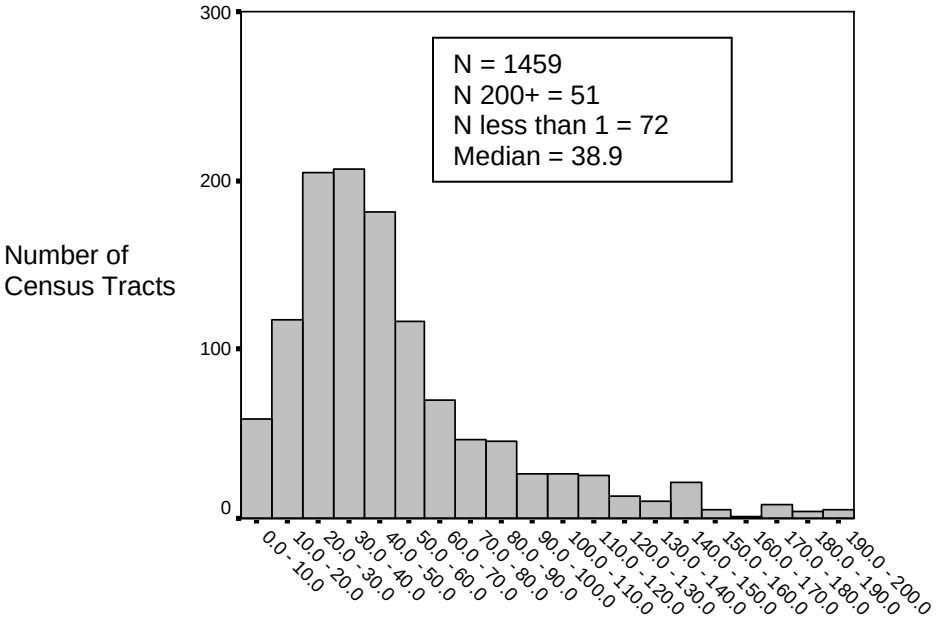
Figure 2.9: Three-dimensional Projection of Employment Density by Census Tract



2.4 Population-plus-Employment Densities at the Census Tract Scale

As we have seen, there are real disadvantages in looking at population and jobs densities separately. Where residential and jobs areas are separate, only portions of the urban area are legible; where they are mixed, we see only half the picture. On the other hand, it is easier to make sense of the combined population-plus-jobs patterns after looking first at each separately. Following the earlier pattern, it is worth looking at a histogram showing distribution of population-plus-jobs densities (see **Figure 2.10**).

Figure 2.10: Distribution of Population plus Jobs Density of Census Tracts



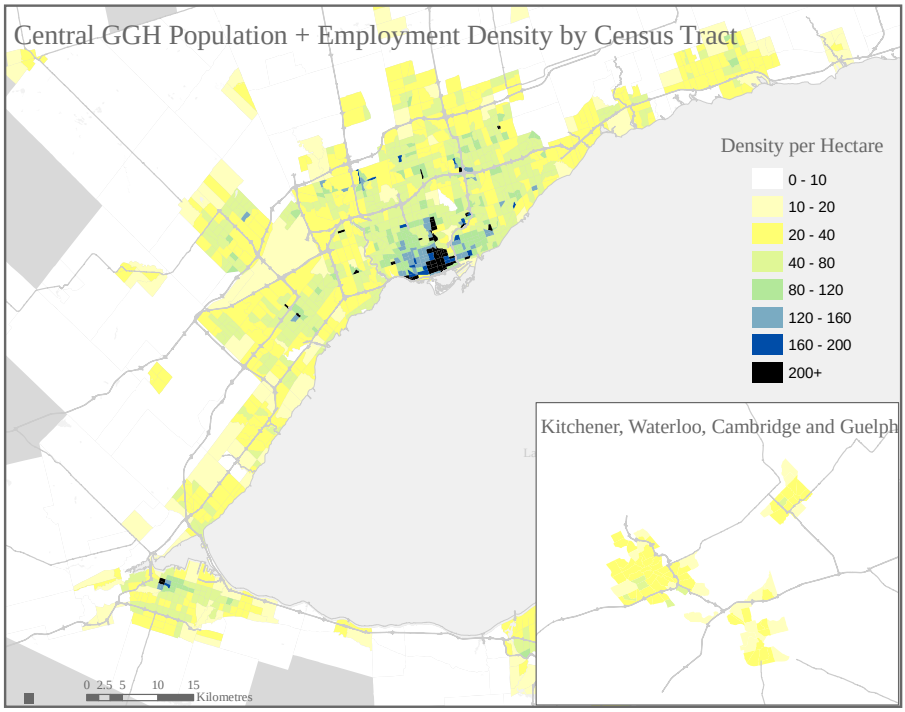
The most important advantage of looking at combined population-plus-jobs densities is that this measure provides more information about the intensity of land use, particularly in tracts that have both jobs and population. As the median population-plus-jobs density is 38.9, almost half of all tracts have a combined density of more than 40 people-plus-jobs/ha. The number of CTs with more than 200 people-plus-jobs/ha is 51, or 3.5 percent.

The most obvious difference between the earlier maps and the combined population-plus-jobs densities shown in **Figure 2.11** is that there are fewer blank areas. Instead, the area around Toronto appears as a contiguous urban area as far as Brampton to the west, Richmond Hill to the north, and Whitby to the east. The density gradient from centre to periphery is also clearer, as is a similar, lower, density gradient in each of the smaller centres of Hamilton, Kitchener, Barrie, Oshawa, and Peterborough.

In particular, the much higher overall densities of central Toronto are clearly visible. Not only the Central Business District, but also a broad surrounding area has population-plus-jobs densities of more than 120/ha, and an even larger area is over 80/ha. Generally, most population-plus-jobs densities are over 20/ha. Only very large employment areas, such as Pearson and Downs-

view airports, the GM assembly plants in Oshawa, and exceptional areas such as the Bridle Path, have lower densities.

Figure 2.11: Population-plus-Jobs Density by Census Tract, Central Greater Golden Horseshoe



2.5 Population Densities at the Dissemination Area Scale

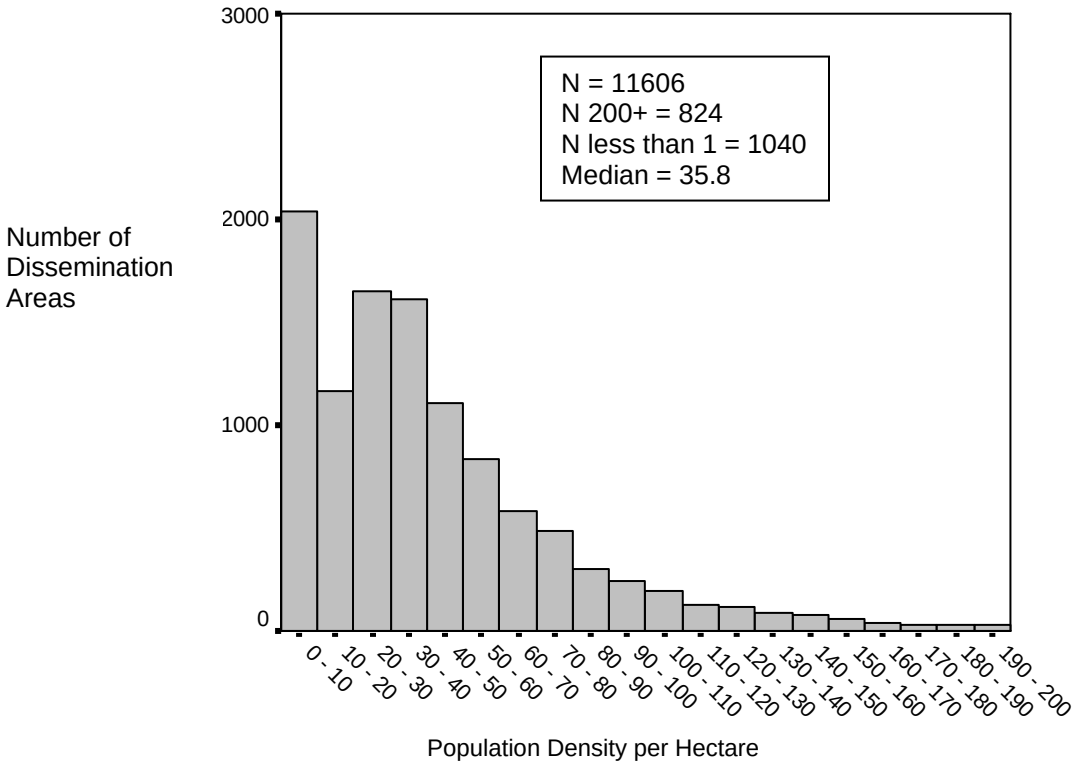
The histogram of distribution of Dissemination Areas (DAs) by population density shown in **Figure 2.12** differs from that of CTs by population density, for two main reasons.

First, DAs exist throughout the GGH, even in areas where there are no CTs. As there are DAs in all rural areas with low population densities, there is a much higher proportion of DAs with low population densities.

Second, there is a more even distribution of DAs across a wider range of densities, as shown by the more gradual slope down from the top of the curve to the right compared to that of CTs. Since DAs are smaller, they are more likely to have a consistent urban form, which results in a wider range of densities, and sometimes in higher average densities within an individual DA.

The small size of DAs is also reflected in the significantly higher percentage of all DAs that are over 200 people/ha (7 percent of all DAs, as opposed to only 1.5 percent of CTs). Still, most DAs still have densities between 10 and 40 people/ha.

Figure 2.12: Distribution of Population by Dissemination Area



Examining population density by DA allows a much more fine-grained analysis of density patterns in the region, as shown in **Figures 2.13a and 13b**. Unfortunately, jobs data is not available at the DA scale, as the sample size is too small for it to be accurate. Also, DAs for high-rise residential buildings pose problems, as we have seen. Nevertheless, the finer degree of detail is useful in looking at patterns of population density, as several new patterns are apparent.

As expected, when smaller areas are used, there is a greater range of population densities. Single types of built form are more likely to cover a whole DA than a whole CT. If a DA consists entirely of higher-density housing forms, the average density will be much higher than that of a CT, which may include a range of housing densities, as well as parks, schools, commercial areas with parking, or other low-density land uses.

As a result, there is a scattering of high-density DAs (over 200 people/ha) over the whole region, even in suburban areas, although most are in Toronto. Some of these DAs are tiny, representing single high-rise buildings, but others contain clusters of high-density housing. Particularly notable is the fact that many of the higher-density DAs (120 people/ha and over) in Toronto are found along major corridors such as Finch Avenue, Sheppard Avenue, Eglinton Avenue, Keele Street, Bathurst Street, Don Mills Road, and Victoria Park Avenue. Clearly, some of the corridors of higher-density development along major avenues proposed by the current Toronto Official Plan already exist.

Also notable are the many DAs with densities of between 80 and 120 people/ha, even in the suburbs. Both Brampton and Mississauga, for example, have large numbers of DAs with more

Figure 2.13a: Population Density by Dissemination Area, Central Greater Golden Horseshoe

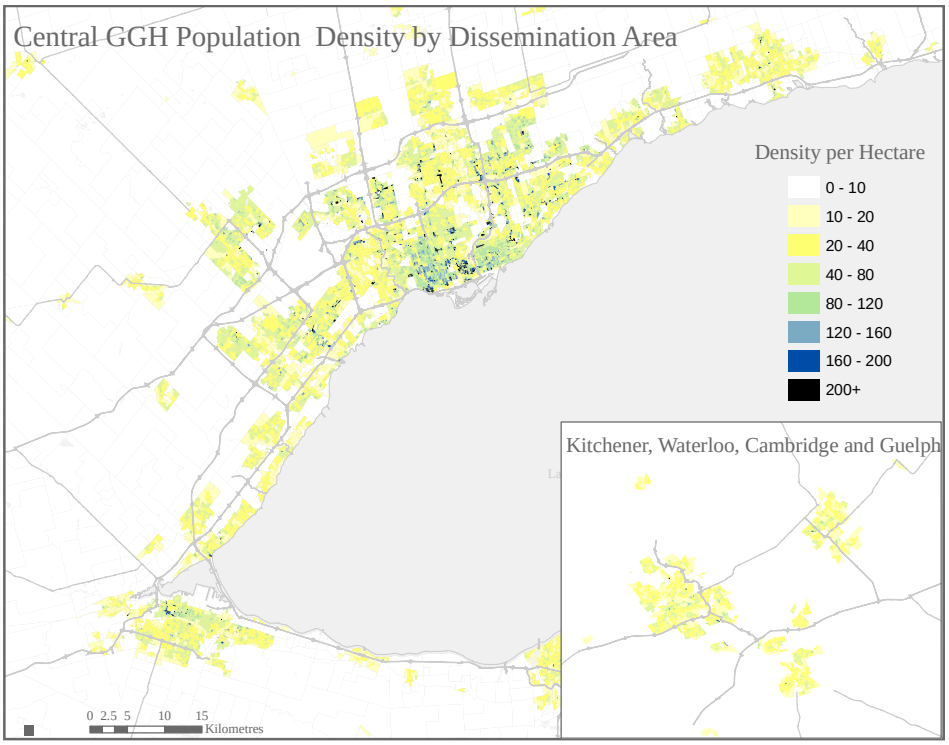
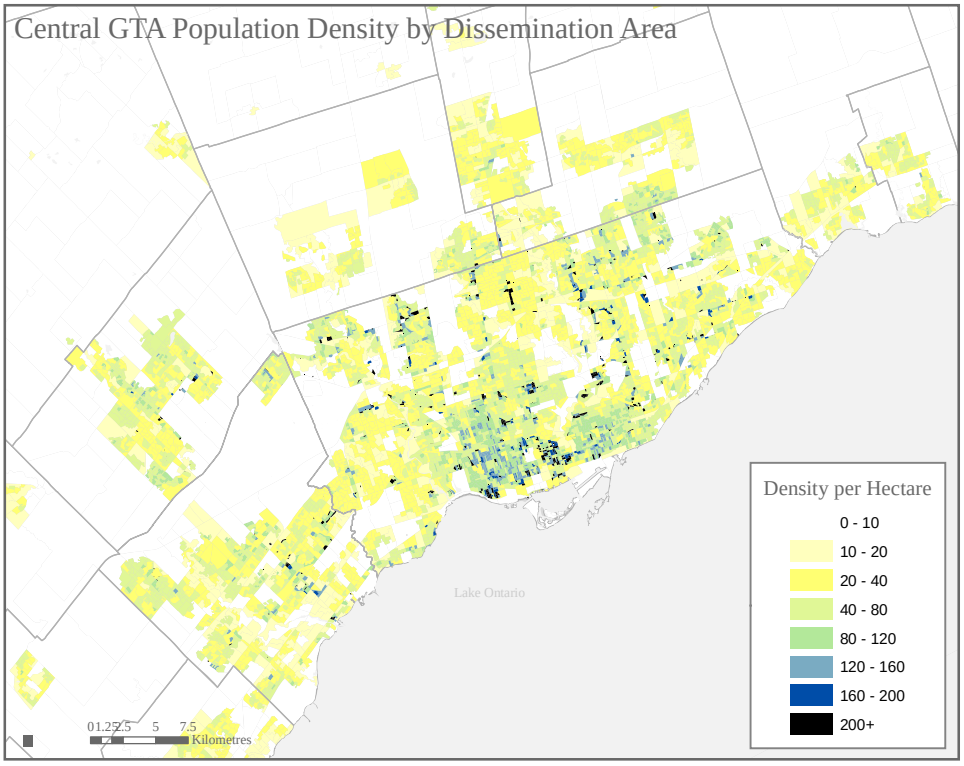


Figure 2.13b: Population Density by Dissemination Area, Central Greater Toronto Area



than 80 people/ha, and some newly built residential areas are over 120 people/ha. Several of these areas consist entirely of single-family detached dwellings. Others include low-rise terraces. Few include any mid-rise, yet have high population densities in areas with traditional suburban-style layouts.

In Milliken in southern Markham, built since the 1990s, densities peak at over 120 people/ha, with large areas of over 80 people/ha, and most of the area over 40 people/ha, even though there are no high-rise developments at all, only single-family detached homes. The density of housing is consistent, and the DA density appears to fluctuate mainly according to how much of the DA is local park or school grounds. It seems that densities of over 40 people/ha are not all that hard to achieve in new suburban development, even without high-rises or multi-family dwellings.

2.6 Population per Household at the Census Tract Scale

Three key variables affect population density in any given area:

- the ratio of land in residential use;
- the number of housing units per unit area of residential land;
- the number of people per household.

Each can vary significantly within urban areas. This section looks at the number of people per household at the CT scale. The influence of the ratio of land in residential use is examined in the analysis of individual Urban Growth Centres in Section 3.

As shown in **Figure 2.14**, over two-thirds of all CTs have an average household size of between 2.2 and 3.4 people. The bell-shaped curve indicates what statisticians describe as a “normal” distribution. Only a small minority of census tracts have average household sizes of less than 2.0 or greater than 4.0.

The spatial pattern of household size is significant for population densities in the region, as shown in **Figure 2.15**. In most metropolitan areas, including the GGH, the central city has smaller households, while suburban areas tend to have larger households. This has traditionally been explained as a result of the housing preferences of young families, who are believed to trade off longer commuting distances for larger houses and gardens in lower-density, newer suburbs, while single-person households tend to cluster in central-city areas.

This explanation is possibly still valid in general, but it is certainly true in the Toronto area, because housing prices in the central city have risen so rapidly that most first-time home buyers look instead to newer suburban developments with lower housing costs. Further, as most newly constructed housing in the GGH is built on greenfield sites on the urban fringe, that is where most younger families live. Meanwhile, because many households stay in the neighbourhoods where they first settled, the older inner suburbs have many aging households that are shrinking as children move out, and spouses separate or pass away. At the same time, immigrant households, who tend to have larger household sizes than Canadian-born households, have in recent years tended to move directly to the suburbs (rather than settling first in the central city), including the outer suburbs, further increasing average household sizes there.

Figure 2.14: Number of People per Household by Census Tract, Greater Golden Horseshoe

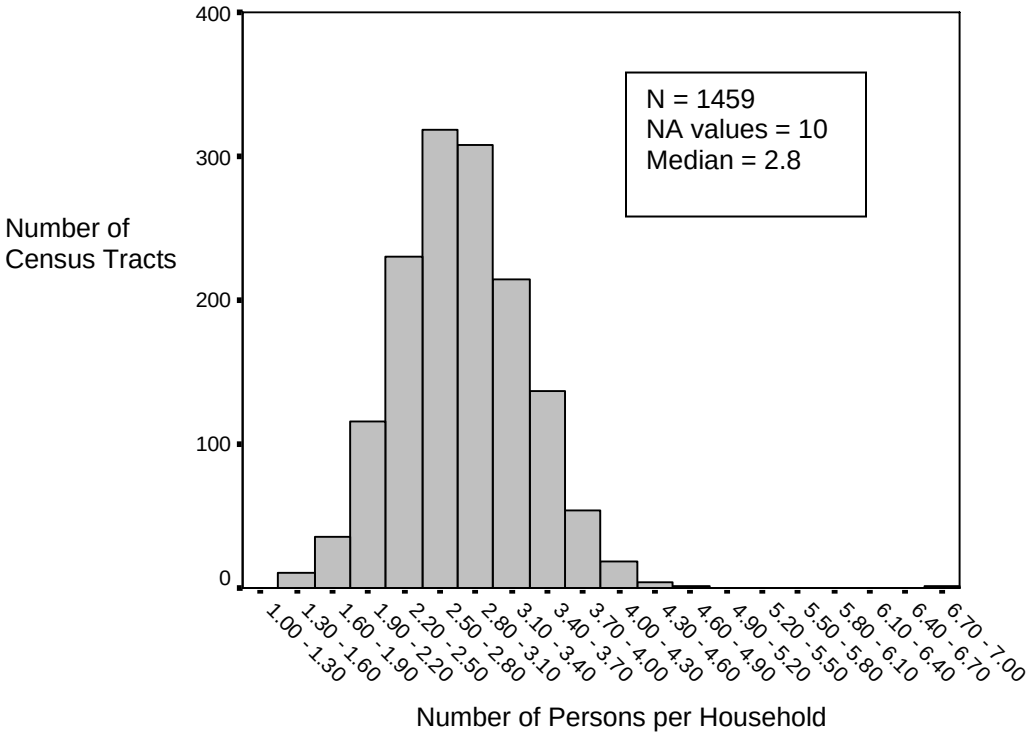
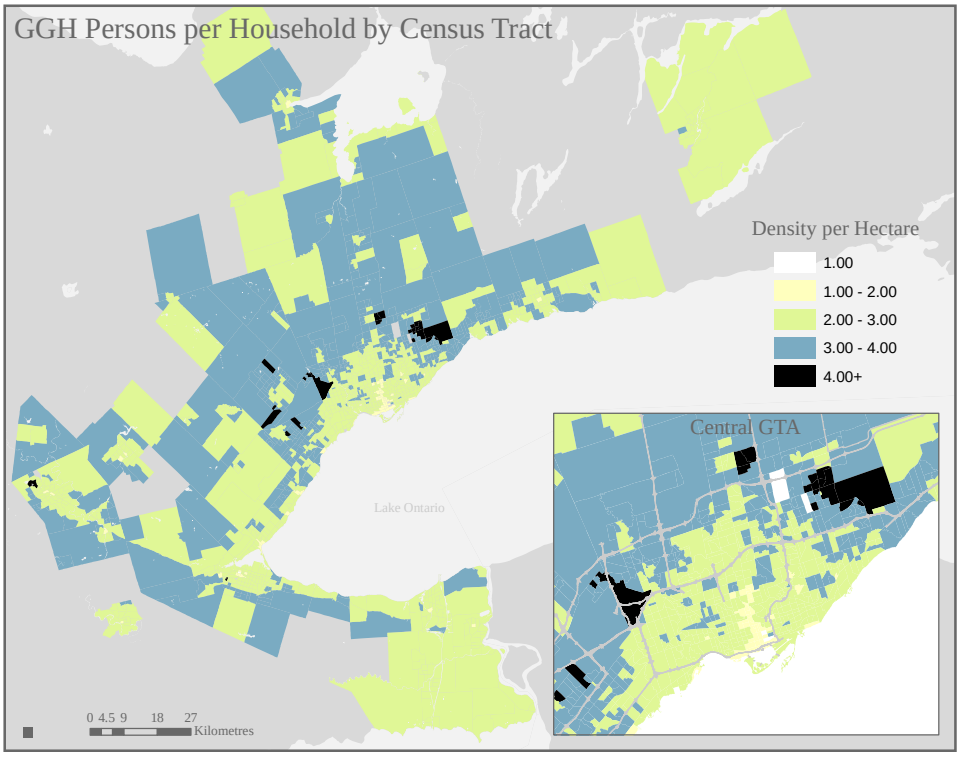


Figure 2.15: Number of People per Household by Census Tract, Greater Golden Horseshoe



These spatial patterns of household size must be set in the context of overall declines in average household size throughout Canada, Ontario, and the GTA (Bourne et al. 2000). An aging population, increasing affluence, and changing patterns of marriage and childrearing (as more and more couples are postponing marriage or choosing not to have families at all) mean that household sizes have steadily decreased since the 1950s.

Whatever the underlying causes, which are certainly more complex than those we have just described, the pattern in the Toronto area is clear: a large area centred on Yonge Street, from Harbourfront to north of Eglinton, has an average household size of 1 to 2 people. Similarly, in the older town centres of Hamilton, Kitchener, Guelph, Burlington, and Oshawa, an inner area with a smaller average household size is surrounded by a large area with an average household size between 2 and 3 people. Most of the suburban areas built since the 1970s, including much of Mississauga, Brampton, Scarborough, and Richmond Hill, as well as most urban fringe and exurban areas, have average household sizes of between 3 and 4 people. The areas with largest average household sizes (over 4 people) are the most recently built housing tracts in Vaughan, Brampton, northeast Scarborough, and Richmond Hill.

These patterns raise several policy issues. First, in areas with small and declining average household sizes, an increasing number of housing units is needed to accommodate the same population. The demographic aging of neighbourhoods means that population densities are decreasing in areas where significant new investment in housing is not occurring. Any policy to promote increased population densities through intensification must counter this trend towards decreasing population density before any increases in density will be seen.

This trend also has important consequences for the efficient use of public infrastructure, especially primary schools. Schools in the inner suburbs have experienced declining enrolments, and many have been forced to close, while municipalities in the outer suburbs cannot build schools fast enough to meet booming populations. Hospitals, childcare facilities, social services, public transit, and some types of retail uses face similar problems, mitigated by the fact that people are often willing to travel farther to access these facilities.

A policy of encouraging the gradual, ongoing intensification of the number of housing units within most urban areas would seem a logical response to this trend of decreasing household size. This policy could help to maintain, for example, school enrolments, as well as the clientele of a wide range of other public services. It could also help ensure that urban areas house a diverse range of population ages, which might counter the trend of aging communities. Continual reinvestment in new housing units would also mean that neighbourhoods would contain buildings of different ages, which could offset or prevent the decline of entire districts. The problem, of course, is that intensification has been vigorously opposed by existing residents as a threat to the community environments that they value. Developing forms and methods of intensification that are generally and locally recognized as adding to urban environmental quality and livability will be the challenge, if the government intends to pursue a strategy of gradual intensification.

3. Analysis of Land Use, Population, and Jobs Density: Selected Urban Growth Centres

This section analyses 10 census tracts (CTs) associated with Urban Growth Centres designated in the provincial *Places to Grow* Plan, in terms of their basic land use composition, population density, job density, and the density of population plus jobs together. For five of the selected tracts, we provide additional details to illustrate basic differences between older and new development patterns and their relationship to census geography.

As the scale of analysis changes from the regional to that of individual CTs, the effects of the modifiable areal unit problem (that is, the influence of the location of boundaries used for aggregation and analysis as discussed in Section 1), becomes significant. Within individual CTs, including or excluding a single-family housing area, an apartment cluster, an area in open space uses, or an employment or institutional area can affect density and other land use measurements considerably. The measured density of CTs depends on the mix of different intensities of land use within the tract.

Examining CTs in Urban Growth Centres shows differences in how census boundaries are drawn in older areas compared with newer areas. Boundary effects are not entirely random. In the most intensely developed CT examined, downtown Hamilton, the centre is much larger than the selected CT. This problem could be overcome by aggregating several CTs. In other older but smaller areas, such as Guelph or Kitchener, downtown CT boundaries bear more relation to the boundaries of the historic downtowns they contain. In newer centres, such as Mississauga and Scarborough, CT boundaries bear little relation to the area of the centre and tend to be very large, containing many types of development (including single-family subdivisions, land set aside for various kinds of open space, and even undeveloped land). These large areas in single use with large differences in density are in marked contrast to the older centres with their more mixed development. In places such as Markham, where centres are planned but not yet fully built, CTs tend to be very large and to contain a wide variety of development types separated into individual, relatively homogeneous areas.

Before we compare land use patterns and densities across the 10 selected tracts, we will identify the data sources and measurement issues involved.

3.1 Selected Tracts and Boundaries

Table 3.1 shows the CTs that were selected for the following Urban Growth Centres.

Table 3.1: Census Tracts and Urban Growth Centres

Name	Description	Tract
Barrie	Downtown	568000600
Brampton	Downtown	535057400
Hamilton	Downtown	537003700
Guelph	Downtown	550000600
Kitchener	Downtown	541001700
Markham	Markham Centre	535040103
Mississauga	Mississauga Centre	535052701
Oshawa	Downtown	532001000
Scarborough	Scarborough Town Centre	535036303
Waterloo	Downtown	541010200

The correspondence between CT boundaries and Urban Growth Centre planning areas varies. The CT for Hamilton is centred on the downtown, but does not contain the entire downtown area. The CT for Guelph contains and corresponds well to its traditional downtown core. CTs in newer centres tend to be problematic. That selected for Markham, for instance, excludes a large part of the area planned for Markham City Centre, but contains large areas of low-density employment and residential uses outside the planned centre. Given these anomalies, straightforward comparisons between the densities of selected tracts should not be made without taking into account boundary definitions and underlying land use patterns. We will discuss these points more fully when in the profiles of the individual tracts.

3.2 Data Sources

Density analysis of the Urban Growth Centres used two basic data sources. First, as in the regional analysis, 2001 census data was used for population and employment figures. Second, the Province supplied some basic land use information coded to individual parcels for the CTs of interest. Not all parcels were not coded. Basic land use categories were:

- residential;
- condominium;
- multi-residential;
- industrial;
- commercial;
- farm;
- vacant;
- park.

These data were compared to aerial photography, commercially available street maps, web mapping services, and the websites of the local municipalities to fill in missing values and identify parcels used for parks and open space, vacant land, and institutional uses. Obvious coding errors were also fixed, but data were not field-checked, nor was the legal status of open space determined. Therefore, land use designations should not be taken as definitive.

For analysis, all parcels in tracts were categorized as:

- residential;
- commercial (including industrial);
- institutional;
- open space;
- vacant.

The area of each designation was measured using GIS software. All remaining land was considered to be right-of-way (ROW). Some parcels associated with railway corridors were also included in ROW.

3.3 Definitions

Gross and net densities were measured for each of the CTs. As in the regional analysis, separate density calculations were made for population, jobs, and population-plus-jobs. Land use composition is presented in **Table 3.2**. Densities in all selected tracts are presented in **Table 3.3**.

- *Gross density* was measured by dividing the population, the number of jobs, or the population plus the number of jobs by the entire land area of the CT.
- *Net population density* was measured as the population divided by the aggregate area of residential parcels.
- *Net jobs density* was measured as the number of jobs divided by the aggregate area of commercial and institutional parcels.
- *Net population-plus-jobs density* was measured as the population plus the number of jobs divided by the aggregate area of residential, commercial, and institutional parcels.
- *Land use composition* for each CT was measured as hectares of land and the percentage of land in each use.

Gross and net densities represent the intensity of residential and employment development and the amount of land in each CT devoted to each intensity of use. The *intensity* of development is a familiar concept that captures the amount of activity in a defined area. For a given parcel of land, a high-rise apartment represents a more intense use than a detached house; a high-rise office building is more intense than a one-storey warehouse with few workers. When resident associations oppose increased density, it is more likely the increased intensity of development that is at issue.

The *extensiveness* of different uses is a less familiar but equally important aspect of density across a larger area. When measuring densities across any bounded area, the *amount* of land

devoted to different uses is as important as the intensity of development on individual parcels. For example, for similar intensities of development, CTs containing more residential and employment uses will have higher densities than tracts in which smaller areas are devoted to these uses and larger areas to parks, rights-of-way, or vacant land.

The distinction between the intensity and extensiveness of development is partly, but not entirely, related to the difference between net and gross densities. In practice, most CTs contain several types of development, with each type varying in intensity and extensiveness. For example, for two CTs with identical gross and net densities, one may have large areas devoted to detached housing, small areas devoted to high-rise apartments, and almost no open space, while the other has only small areas of detached housing, a substantial area of apartments, and large amounts of open space. This example demonstrates the importance of the *mix* of development intensities. This is not the same as *land use mix*, since any particular land use category may contain several types of development built at different intensities.

The heterogeneity of development types accounts for the crucial importance of the boundaries used in density calculations: does the boundary include or exclude a cluster of office towers, apartment buildings, or open space? The answer will strongly affect measured densities, whether gross or net. Therefore, unless the development being measured is homogeneous or the density ranges are at the extreme ends of the spectrum, the intensity and extensiveness of residential and employment uses combine in complex ways that make it impossible to relate density directly to urban form or built patterns.

3.4 Land Use Composition

Comparing the large variations in land use composition for the selected CTs highlights these issues. **Table 3.2** indicates that the size of CTs varies by about a factor of 25, from the 32-hectare Hamilton tract to the almost 800-hectare Markham tract. Generally, the older downtowns of Guelph, Hamilton, Kitchener, and Waterloo are smaller, while the newer centres of Markham, Mississauga, and Scarborough tend to be very large. Although Statistics Canada ostensibly uses population to define CT size, there is no clear pattern evident in this sample of CTs, where populations also vary widely and some very large tracts also have large populations (**Table 3.3**).

The percentage of land devoted to different use categories also varies greatly. In the sample CTs, much of the land is non-residential. For example, in Hamilton, Kitchener, Markham, and Scarborough, only 8 to 12 percent of the land is devoted to housing. Brampton has the largest proportion of residential land, at about 42 percent. Even this latter figure is low compared to the general distribution of urban land uses, where housing typically takes up far more than half of all urban land. Unlike CT size, however, these variations in residential use have little to do with the age of the centre or with population densities. For example, although only 12 percent of the Hamilton tract is in residential use, the tract has the highest gross population density of any tract studied (**Table 3.3**), because residential uses are very intensive, although not extensive. In general, CT boundaries that contain different mixes and intensities of land uses make comparisons difficult.

Table 3.2: Land Use

UGC		Total	Resi-dential	Comm	Institu-tional	ROW	Open Space	Vacant
Barrie	*percent*	100	17.9	34.2	8.2	27.1	6.7	5.9
	hectares	148.6	26.5	50.8	12.2	40.2	10.0	8.8
Brampton	*percent*	100	41.7	10.9	12.9	21.8	9.4	3.3
	hectares	197.8	82.6	21.6	25.5	43.1	18.7	6.5
Guelph	*percent*	100	8.0	38.8	2.7	42.5	3.4	4.6
	hectares	60.1	4.8	23.3	1.6	25.6	2.0	2.8
Hamilton	*percent*	100	12.8	37.2	22.3	27.6	0	0
	hectares	31.6	4.1	11.8	7.0	8.7	0	0
Kitchener	*percent*	100	11.7	48.0	6.5	27.8	0	6.0
	hectares	66.3	7.8	31.8	4.3	18.4	0	4.0
Markham	*percent*	100	11.5	34.3	1.3	14.0	3.8	35.2
	hectares	791.1	90.7	271.1	10.4	110.7	29.8	278.4
Mississauga	*percent*	100	15.0	27.3	3.3	37.9	1.5	15.0
	hectares	245.6	36.9	66.9	8.1	93.0	3.8	36.9
Oshawa	*percent*	100	24.3	37.2	6.5	24.9	3.5	3.6
	hectares	131.7	32.0	48.9	8.6	32.8	4.6	4.7
Scarborough	*percent*	100	11.4	31.4	14.2	20.0	16.5	6.5
	hectares	310.2	35.3	97.5	44.0	62.2	51.2	20.1
Waterloo	*percent*	100.0	31.7	25.8	4.2	24.3	6.2	7.8
	hectares	116.2	36.9	30.0	4.9	28.2	7.2	9.0

Much of the tracts are devoted to employment uses. Commercial uses, including retail, office, and industrial land uses, are the largest category of land use in most cases, ranging from about a quarter (Waterloo) to almost half (Kitchener) of the land. The exception is Brampton, in which only 11 percent of the land is in commercial uses.

Institutional uses are a relatively minor category. The exception is the Brampton tract, with 13 percent institutional land, and the Hamilton tract, with an unusually high 22 percent of land devoted to institutional uses (the tract happens to contain Hamilton's city hall). When commercial and institutional lands are combined, about 60 percent of the Hamilton tract is devoted to employment uses. With only 1.3 percent of land in institutional use, the Markham tract is at the other end of the spectrum, but this percentage still represents 10 hectares of land, more institutional land than in six other tracts.

Most tracts have similar percentages of right-of-way (ROW). Six tracts have between 22 and 27 percent of their area in ROW, typical of many urban areas. Only 20 percent of the Scarborough tract consists of ROW; this includes the ROW for Highway 401, so local streets make up an even lower percentage. This pattern is a reflection of the large superblocks and sparse street systems associated with postwar modernist planning practices. Markham is an even more ex-

treme case, with only 14 percent of land in ROW, but the tract includes a large area of undeveloped land and excludes Highway 407 (which is not defined in the parcel data set).

At the other end of the range is Mississauga, where Highway 403 constitutes a large proportion of the tract, raising its ROW percentage to 38 percent. Otherwise, ROW makes up a low percentage of the tract area, similar to the Scarborough tract. Also on the high end is Guelph, with 42 percent of land in ROW, but this is because of an unusual early 19th-century street and block plan.

The CT boundaries are defined inconsistently with respect to major highways, a fact that highlights the modifiable areal unit problem. In the Scarborough tract, for example, the boundary runs along the centre of the ROW, while in the Mississauga tract the whole highway is included, raising the percentage of ROW and decreasing measures of gross density.

Open space, made up of park and environmental lands, varies substantially. It tends to be low in the older centres – both the Kitchener and Hamilton tracts have no land at all classified as open space – but newer centres, such as Mississauga with only 1.5 percent, can also have very little. Scarborough, with 16.5 percent of land in open space, has the largest proportion of the tracts studied.

Most tracts have little vacant land. In eight tracts, less than 8 percent of the total land is vacant. This means that any substantial increase in densities would require taking out some existing uses. Some tracts do have parking lots, classified as commercial land, as well as extensive areas of low-intensity uses that could be available for redevelopment. Mississauga, with 15 percent of its land vacant, has substantial capacity for new growth without redevelopment. The Markham tract, where 35 percent of the land is classified as vacant, is a potential centre, but not yet an actual one.

3.5 Density

Here too, we need to be cautious in drawing comparisons. Tract boundaries often have little relationship to actual or likely Urban Growth Centre planning areas and density measurements cannot necessarily be used to indicate built form. We will provide an overview of the range of densities among tracts and consider differences between gross and net densities. A more detailed description of the individual tracts is provided in the next section.

At the level of raw population and job numbers, there are large variations between the tracts. Populations vary from about 1,600 in the Guelph tract to almost 10,000 in the Scarborough tract. Jobs vary from about 5,000 in the Brampton tract to about 15,000 in the Markham tract. With the exception of Brampton, all tracts have more jobs than residents, but the ratio of jobs and people also varies widely.

There are also large variations in tract densities, both gross and net, and in the densities for population, employment, or population-plus-employment. For example, the Markham tract has 28 people-plus-jobs/ha while the Hamilton tract has 249 people-plus-jobs/ha, almost nine times as many.

For all types of density measured, the Hamilton tract has the highest density and the Markham tract has the lowest, except for net population density. In Hamilton, this reflects the fact that the tract contains only relatively intense downtown development. In Markham, the tract is extremely large and even net densities are low. **Table 3.3** shows gross and net densities for the 10 CTs.

Table 3.3: Gross and Net Densities for Selected Census Tracts

Urban Growth Centre	Pop.	Jobs	Jobs/ Pop	Pop. Density (rank)			Emp. Density (rank)			Pop + Employment Density (rank)		
				gross	net	g/n	gross	net	g/n	gross	net	g/n
Barrie	3,509	6,005	1.7	24 (6)	132 (6)	5.6	40 (7)	95 (8)	2.4	64 (7)	106 (8)	1.7
Brampton	5,222	4,950	0.9	26 (5)	63 (10)	2.4	25 (9)	105 (7)	4.2	51 (9)	78 (9)	1.5
Guelph	1,610	5,670	3.5	27 (4)	335 (2)	12.5	94 (3)	228 (4)	2.4	121 (3)	245 (2)	2.0
Hamilton	2,503	5,360	2.1	79 (1)	618 (1)	7.8	170 (1)	285 (1)	1.7	249 (1)	344 (1)	1.4
Kitchener	1,501	8,330	5.5	23 (7)	193 (4)	8.5	126 (2)	230 (3)	1.8	148 (2)	224 (3)	1.5
Markham	7,494	14,765	2.0	9 (10)	83 (8)	8.7	19 (10)	52 (10)	2.8	28 (10)	60 (10)	2.1
Mississauga	4,212	9,955	2.4	17 (9)	114 (7)	6.7	41 (6)	133 (6)	3.3	58 (8)	127 (7)	2.2
Oshawa	4,585	9,250	2.0	35 (2)	143 (5)	4.1	70 (5)	161 (5)	2.3	105 (4)	154 (4)	1.5
Scarborough	9,968	11,520	1.1	32 (3)	282 (3)	8.8	37 (8)	81 (9)	2.2	69 (6)	122 (7)	1.8
Waterloo	2,516	8,220	3.3	22 (8)	68 (9)	3.2	71 (4)	235 (2)	3.3	92 (5)	150 (5)	1.6

Despite the contrast between the Hamilton and Markham tracts, the distinction between older downtowns and newer suburban areas is not a good predictor of population density, either gross or net. For example, Scarborough and Guelph have fairly similar gross and net population densities, but very different development patterns.

The ratio of gross to net population densities varies tremendously. In the Guelph tract, for example, net population density is 12.5 times higher than gross, but in the Brampton tract, net population density is only 2.5 times higher than gross. The old centre of Kitchener and the new centre of Markham have very similar gross-to-net ratios, for example, but very different built environments, since the ratio of gross to net density is affected by the intensity and extensiveness of residential land uses, rather than built form.

Older downtowns tend to have higher employment densities than newer, suburban areas. With gross employment density, this finding is partly a result of CT boundaries being more tightly drawn around old downtowns so that they contain a larger proportion of employment uses than newer areas. Older downtowns also have higher net employment densities, because they have more intensely developed employment uses than newer suburban areas. The ratio of gross to net job densities varies from 1.7 to 4.2, a more compressed range than that of the ratio of gross to net population densities. This is another indicator that employment land uses predominate in these tracts.

Population-plus-employment densities are more influenced by employment than are residential densities in most tracts. For either gross or net figures, the ranking of tracts in terms of population-plus-employment density is very similar to that for employment density alone, mainly because these tracts are dominated by employment uses.

3.6 Tract Profiles

Five of the CTs associated with Urban Growth Centres are described in detail below. These profiles illustrate the large differences in the way CTs capture development patterns in centres. For each tract, we provide a land use map, density figures, the mix of structural types of housing units, and a brief description. We also present some comparisons among the tracts, taking into account the mix, extent, and intensity of uses. The profiles show how these factors interact with tract boundaries to affect density measurements.

3.6.1 Brampton (CT 535057400)

This CT is centred on Brampton's old downtown around the intersection of Main and Queen Streets. The tract is fairly large – 198 hectares. Compared to other selected tracts, employment land uses are neither extensive (comprising only 24 percent of the tract area), nor intensive (with net densities of about 100 jobs/ha). In combination, this pattern gives rise to the lowest gross employment densities of any tract studied.

Large areas of parking, including a large GO commuter lot, indicate low development intensities. Institutional uses with large grounds also contribute to the low employment intensity.

Half the tract's housing units are single detached or semi-detached houses, giving rise to net population densities of only 63 people/ha, the lowest of any tract studied. Extremely large-lot housing in the southeast area of the tract is noteworthy. Although not intensive, housing is an extensive use, making up 42 percent of the tract. The gross population density is 26 people/ha, in the mid-range of the tracts studied. However, both gross and net population-plus-employment densities are low, at 51 and 78, respectively.

The area devoted to ROW is low, partly because fairly large areas are devoted to open space, and partly because of the large blocks in the tract, especially around larger institutional uses.

There is little vacant land in the tract, representing slightly more than 3 percent of the tract area, but some low-intensity uses could be redeveloped at higher intensities over time.

Table 3.4: Land Use – Brampton CT

	percent	*hectares*
Residential	41.7	82.6
Commercial	10.9	21.6
Institutional	12.9	25.5
ROW	21.8	43.1
Open Space	9.4	18.7
Vacant	3.3	6.5
Total	100.0	197.8

Table 3.5: Densities per Hectare – Brampton CT

Total Population	5,222
Total Jobs	4,950
Jobs/Population	0.9
Population Density	
Gross (change fm 1996)	26 (0.7)
Net	63
Gross/net	2.4
Employment Density	
Gross	25
Net	105
Gross/net	4.2
Population + Employment Density	
Gross	51
Net	78
Gross/net	1.5

Figure 3.1: Brampton Census Tract Land Use

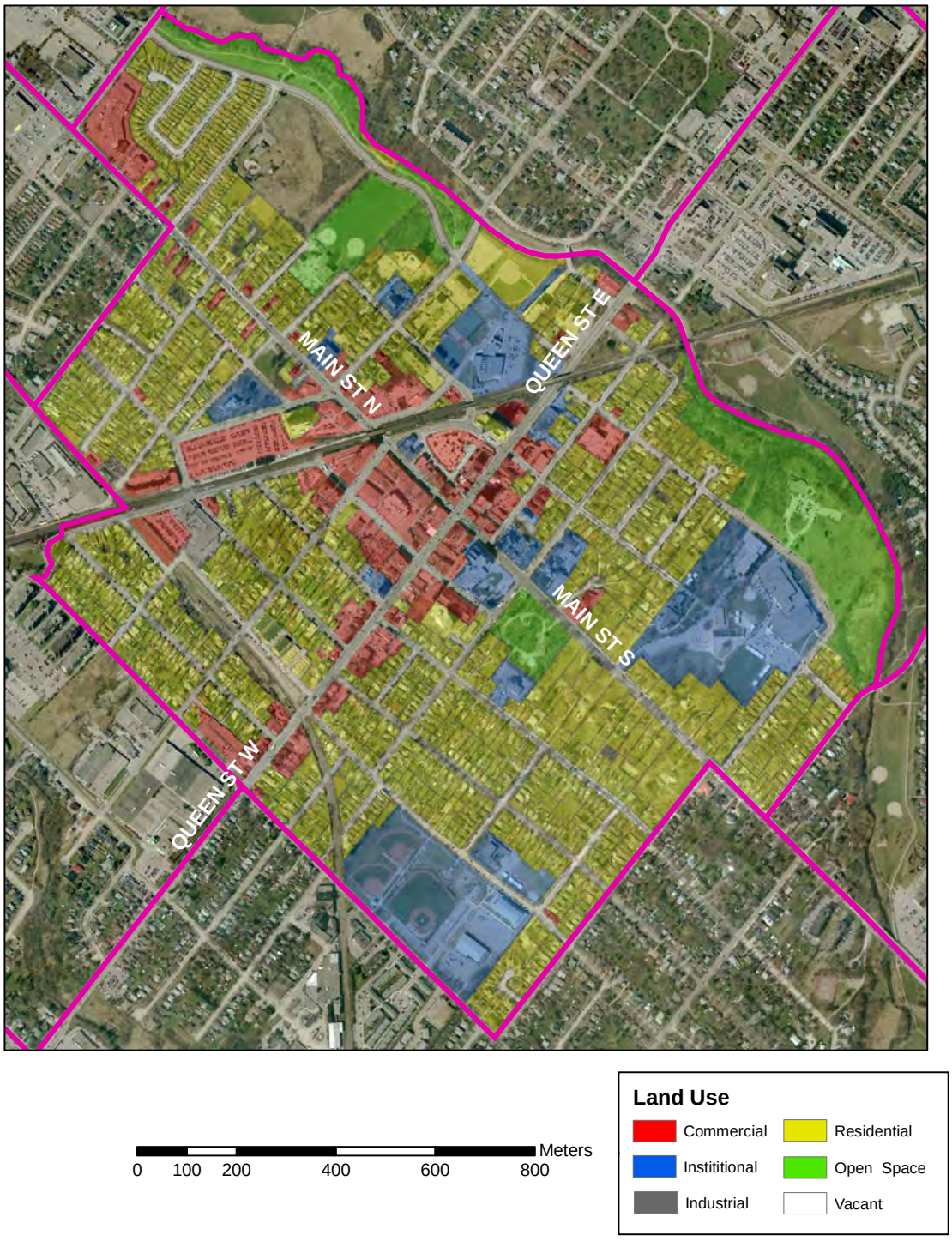


Table 3.6: Occupied Housing Units by Structural Type – Brampton CT

Structural Type	Units	Percent
Single detached houses	1,060	44.3
Semi-detached houses	145	6.1
Row houses	15	0.6
Apartment − duplex	75	3.1
Apartment − five or more storeys	755	31.5
Apartment – fewer than five storeys	340	14.2
Other single attached dwellings	10	0.4
Total	2,395	100

3.6.2 Guelph (CT 550000600)

The Guelph CT also includes the city's old downtown, but compared to Brampton's downtown, it is much more tightly drawn. The tract covers only 60 hectares, a third the size of the Brampton tract, and does not incorporate surrounding residential areas. The Guelph tract is about equally split between employment uses and ROW, each covering more than 40 percent of the tract area.

The amount of land in ROW derives from Guelph's unusual 1827 plan, and this proportion is by far the highest of any tract. Little of the tract is devoted to residential uses, open space, or vacant land. In combination with net employment densities that are among the highest studied, this pattern gives rise to relatively high gross employment density, at 94 jobs/ha.

With over 90 percent of housing units in the form of apartments, net residential densities are also high, at 335 people/ha. However, because there is so little residential land, gross population densities are only 27 people per hectare. This result illustrates a pattern of intensive but non-extensive residential uses, creating a very high net-to-gross population density ratio of 12.5.

Employment contributes most to the density of population plus employment, and both net and gross figures are in the top third of those tracts studied.

Table 3.7: Land Use – Guelph CT

	percent	*hectares*
Residential	8	4.8
Commercial	38.8	23.3
Institutional	2.7	1.6
ROW	42.5	25.6
Open Space	3.4	2
Vacant	4.6	2.8
Total	100	60.1

Table 3.8: Densities per Hectare – Guelph CT

Total Population	1,610
Total Jobs	5,670
Jobs/Population	3.5
Population Density	
Gross (change fm 1996)	27 (1.89)
Net	335
Gross/net	12.5
Employment Density	
Gross	94
Net	228
Gross/net	2.4
Population + Employment Density	
Gross	121
Net	245
Gross/net	2.0

Figure 3.2: Guelph Census Tract Land Use

Table 3.9 Occupied Housing Units by Structural Type – Guelph CT

Structural Type	Units	Percent
Single detached houses	25	2.4
Semi-detached houses	25	2.4
Row houses	5	0.5
Apartment − duplex	30	2.9
Apartment − five or more storeys	515	49.8
Apartment – fewer than five storeys	440	42.5
Other single attached dwellings	0	0.0
Total	1,035	100.0

3.6.3 Hamilton (CT 537003700)

The CT covers just part of Hamilton's downtown area and is centred on the intersection of Bay and Main Streets. Data for this tract could be combined with data for tracts to the north to better capture the centre. The tract is very small, just 32 hectares. Employment land uses predominate, with 37 percent of the tract devoted to commercial uses, including part of the Hamilton Convention Centre, and another 22 percent to institutional uses, including City Hall. Despite the presence of extensive parking lots, gross and net employment densities – at 170 and 285 jobs/ha respectively – are quite high relative to the other tracts.

Since apartments make up 95 percent of the housing units, net residential population densities, at 618 people/ha, are almost twice as high as those in any other tract. Because of this intensity, gross population density, at 79 people/ha, is still higher than any other tract studied, although residential uses account for a small area of the tract.

Given the high population and employment densities, both gross and net densities for population-plus-employment/ha are much higher than those of any other tract studied. Further contributing to high gross densities is the complete absence of any open space or vacant land. However, the presence of large areas devoted to parking suggests that there is still room for intensification.

Table 3.10: Land Use – Hamilton CT

	percent	*hectares*
Residential	12.8	4.1
Commercial	37.2	11.8
Institutional	22.3	7
ROW	27.6	8.7
Open Space	0	0
Vacant	0	0
Total	100	

Table 3.11: Densities per Hectare – Hamilton CT

Total Population	2,503
Total Jobs	5,360
Jobs/Population	2.1
Population Density	
Gross (change fm 1996)	79
Net	618
Gross/net	7.8
Employment Density	
Gross	170
Net	285
Gross/net	1.7
Population + Employment Density	
Gross	249
Net	344
Gross/net	1.4

Figure 3.3: Hamilton Census Tract Land Use

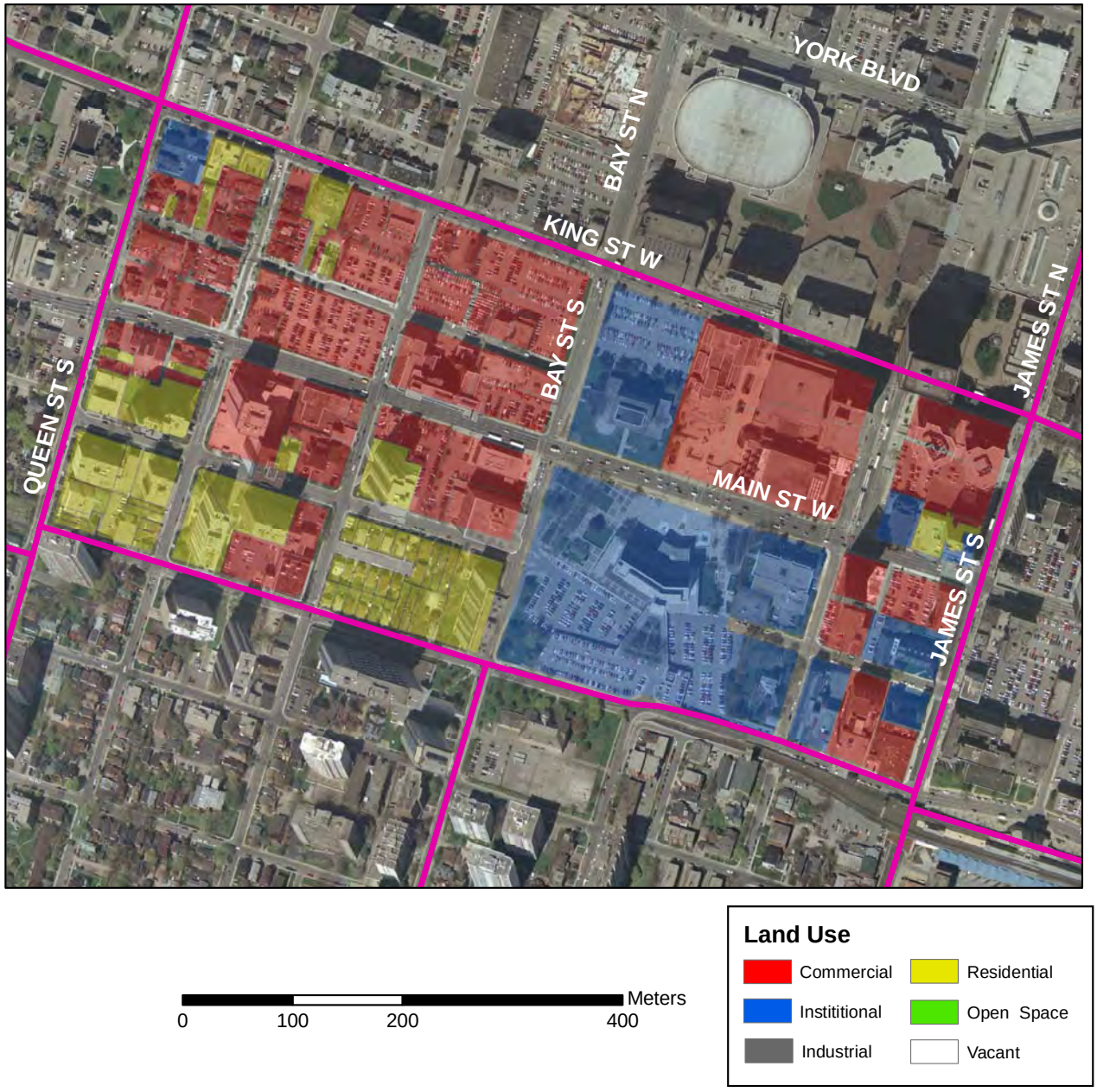


Table 3.12: Occupied Housing Units by Structural Type – Hamilton CT

Structural Type	Units	Percent
Single detached houses	30	1.6
Semi-detached houses	5	0.3
Row houses	10	0.5
Apartment − duplex	15	0.8
Apartment − five or more storeys	1,690	88.0
Apartment – fewer than five storeys	165	8.6
Other single attached dwellings	0	0.0
Total	1,920	100

3.6.4 Markham (CT 535040103)

This CT features a development pattern dating almost entirely from the postwar period. The tract is enormous, at almost 800 hectares, and unlike the previous tracts profiled, its boundaries are not defined around a recognizable centre or distinct area of development. The tract certainly does not capture the Markham City Centre planning area, a large part of which is to the west of Warden Avenue, in two other tracts. Also, most of the area is devoted to extensive but non-intensive residential and employment uses outside the Centre planning area, south of Highway 407.

Beyond its size, the Markham tract is remarkable for the large amount of vacant land – over 35 percent of the tract, or 278 hectares. Indeed, there is more vacant land in this tract than in the Barrie, Kitchener, and Guelph tracts combined. Most of the vacant land is in the planned centre, but because of limitations in the data, the figure also includes the Highway 407 ROW.

The remaining ROW makes up only 14 percent of the study area, a very low figure. Beyond the unaccounted-for Highway 407 ROW, this finding is explained by the undeveloped centre area, where ROWs have not yet been established and the very large block pattern south of Highway 407, where some blocks are more than 700 metres long.

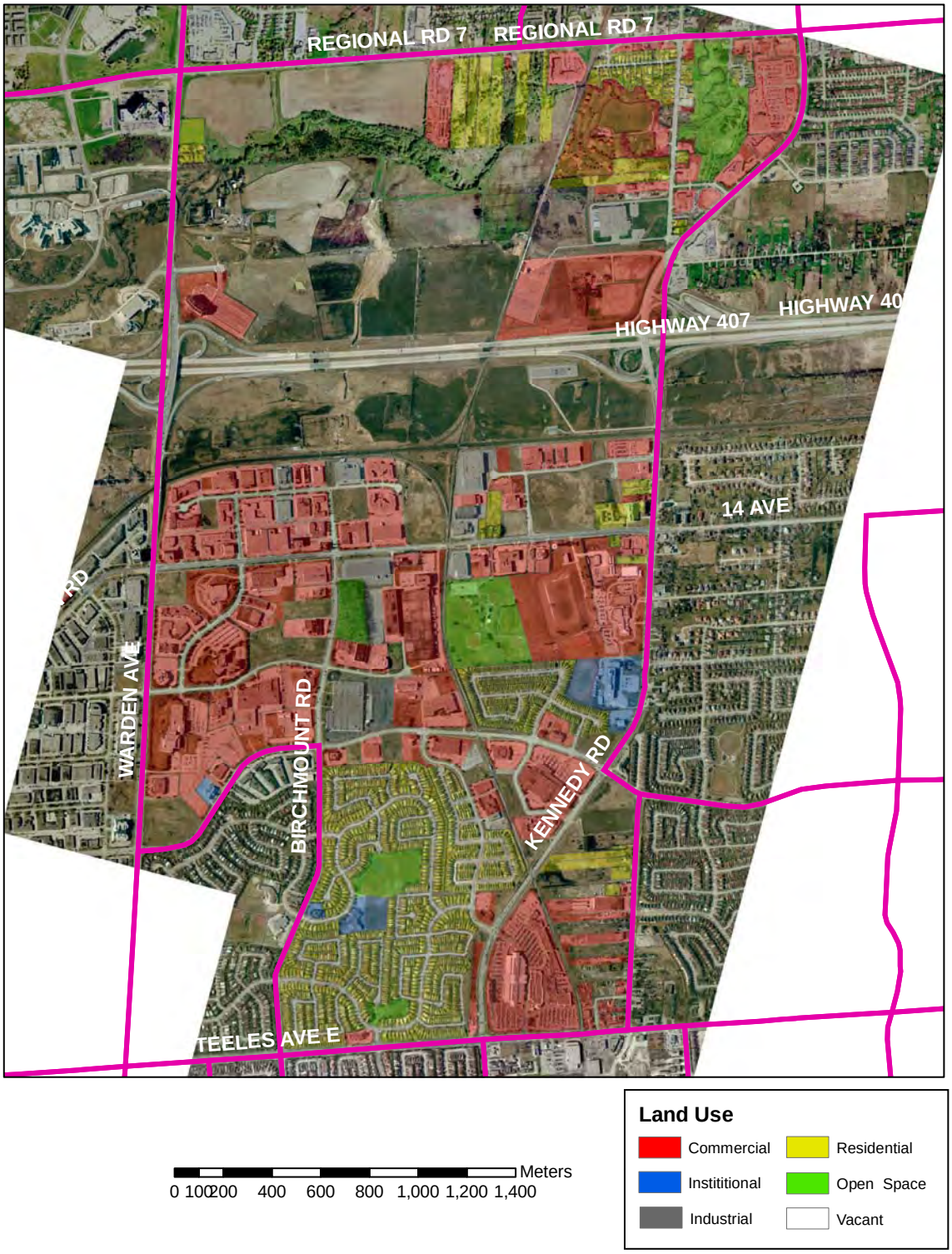
Table 3.13: Land Use – Markham CT

	percent	*hectares*
Residential	11.5	90.7
Commercial	34.3	271.1
Institutional	1.3	10.4
ROW	14	110.7
Open Space	3.8	29.8
Vacant	35.2	278.4
Total	100	791.1

Table 3.14: Densities per Hectare – Markham CT

Total Population	7,494
Total Jobs	14,765
Jobs/Population	2.0
Population Density	
Gross (change fm 1996)	9 (1.9)
Net	83
Gross/net	8.7
Employment Density	
Gross	19
Net	52
Gross/net	2.8
Population + Employment Density	
Gross	28
Net	60
Gross/net	2.1

Figure 3.4: Markham Census Tract Land Use



The proportion of commercial and residential land is similar to that in other centres, but because there are so few apartments and the tract contains a large low-rise employment district, net residential, commercial, and combined densities are very low. Markham has the lowest gross densities of all tracts studied.

Table 3.15: Occupied Housing Units by Structural Type – Markham CT

Structural Type	Units	Percent
Single detached houses	1,660	85.1
Semi-detached houses	5	0.3
Row houses	60	3.1
Apartment − duplex	0	0.0
Apartment − five or more storeys	75	3.8
Apartment – fewer than five storeys	140	7.2
Other single attached dwellings	0	0.0
Total	1,950	100

3.6.5 Scarborough (CT 535036303)

Scarborough is another CT that was developed in the postwar period. The tract lies between Highway 401 and Ellesmere Road. It does not contain areas that would be considered part of an Urban Growth Centre, such as the Scarborough Town Centre mall or the Scarborough Civic Centre, located just across McCowan Road to the west. At over 300 hectares, the tract is very large. It contains a wide array of land uses: office and apartment towers, single-family subdivisions, large educational campuses, low-rise commercial, warehousing, and industrial uses, and a substantial amount of open space. However, development in the tract is carefully laid out according to postwar planning principles, with large superblocks containing strictly segregated areas of land use.

Table 3.16: Land Use – Scarborough CT

	percent	*hectares*
Residential	11.4	35.3
Commercial	31.4	97.5
Institutional	14.2	44
ROW	20	62.2
Open Space	16.5	51.2
Vacant	6.5	20.1
Total	100	310.2

Employment uses in the tract are extensive – more than 130 hectares are devoted to commercial and institutional land uses, or 45 percent of the tract. With the exception of a few parcels, however, employment uses are not intensive, so net densities are only 81 jobs/ha, the lowest figure of any tract other than Markham. Gross employment density is also low, at 37 jobs/ha. Only Brampton, where a relatively small area is devoted to employment, and the enormous Markham tract have lower figures.

Population densities are much higher. Although only 11 percent of the tract is devoted to housing, 92 percent of units are in intensive high-rise housing forms. Net population densities are 282 people/ha; only Hamilton and Guelph have denser populations. At 32 people/ha, gross population densities are also in the top tier of tracts studied. Interestingly, between 1996 and 2001, gross population densities increased by almost 10 people/ha, an increase that is more than five times higher than that of any other tract profiled so far.

The combined population-and-employment density, as with all the tracts, is most affected by employment, and both gross and net figures are fairly low for the tracts studied, 69 and 122 people-plus-jobs/ha, respectively.

Table 3.17: Densities per Hectare – Scarborough CT

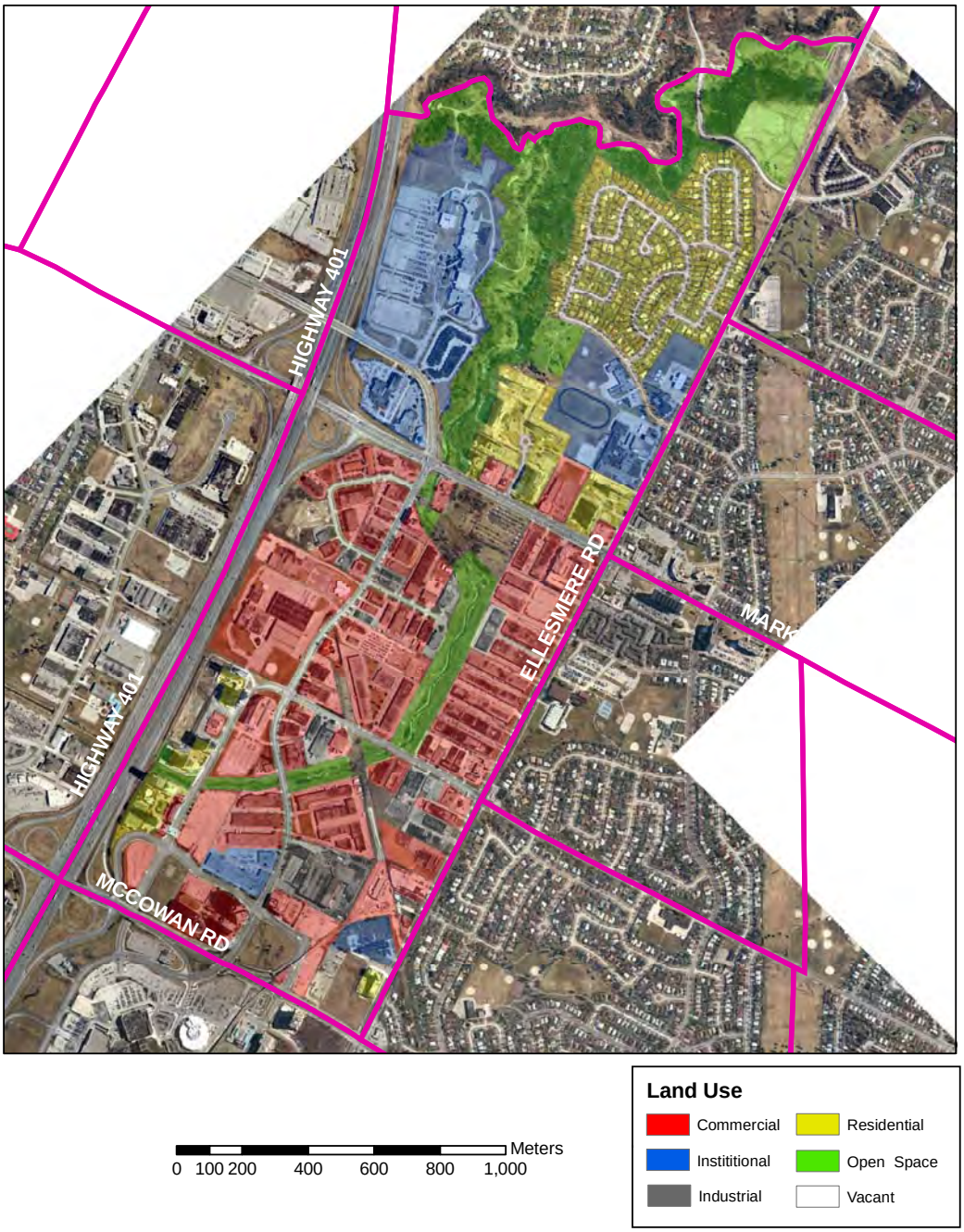
Total Population	9,968
Total Jobs	8,220
Jobs/Population	3.3
Population Density	
Gross (change fm 1996)	32 (9.7)
Net	282
Gross/net	3.2
Employment Density	
Gross	37
Net	81
Gross/net	2.2
Population + Employment Density	
Gross	69
Net	150
Gross/net	1.6

The Scarborough tract is unusual in that 16 percent of the area is devoted to open space, a higher proportion than in any other tract. On the other hand, only 20 percent of the land is devoted to ROW, including part of the Highway 401 ROW. This low proportion reflects the modernist, superblock street system in which some blocks are almost 800 metres long. At 6.5 percent of the tract, the proportion of vacant land is similar to many other tracts studied, but given the large tract area, this adds up to 20 hectares. The low intensity of much of the commercial uses suggests that intensification through redevelopment is possible.

Table 3.18: Occupied Housing Units by Structural Type – Scarborough CT

Structural Type	Units	Percent
Single detached houses	295	7.6
Semi-detached houses	0	0.0
Row houses	0	0.0
Apartment − duplex	15	0.4
Apartment − five or more storeys	3,555	92.0
Apartment – fewer than five storeys	0	0.0
Other single attached dwellings	0	0.0
Total	3,865	100

Figure 3.5: Scarborough Census Tract Land Use



3.7 General Lessons From Census Tract Analysis

The boundaries of tracts with older downtowns are generally defined relative to the downtown. The boundaries for Barrie, Brampton, Guelph, Kitchener, Oshawa, and Waterloo also contain fairly well-defined commercial cores. Given reliable data, these tracts are adequate for tracking numbers of jobs in these centres. The exception is Hamilton, where the tract contains only a part of the downtown, but it could be combined with adjoining tracts to give a more complete picture.

Tract boundaries may be drawn tightly around the commercial core, as in the Guelph tract, or contain very large areas of housing surrounding the core, as in the Brampton tract. This type of variation makes straightforward comparisons of gross densities, whether population, employment, or both together, very difficult. Different boundary definitions will change the mix of residential and employment lands and affect density figures, regardless of the intensity of either use. For example, including more detached housing around a centre may or may not decrease gross population densities, but will certainly decrease gross employment densities. The combined figure is also likely to be lower.

Unlike tracts around older downtowns, tracts containing postwar development are not defined with respect to employment centres. The tract boundaries for Mississauga and Scarborough do not include all the commercial or residential uses that could reasonably be considered part of these centres, but do include large areas of land that are really outside the centres, in part because, unlike the older downtowns, the boundaries of these tracts predate the development of the centre. Also, these postwar centres are more spread out and can be very difficult to define as distinct places. Markham is the extreme case, as the centre is planned, but not yet developed. For all these reasons, it is hard to compare densities among tracts, whether population, employment, or the combination of both. When tract boundaries are defined independently from development patterns, resulting density measurements are largely arbitrary.

4. Discussion and Conclusions

On a regional basis, census data can be used for a general depiction of patterns of population and job densities. These patterns are largely as expected: central Toronto has by far the highest residential and job densities in the region. Some smaller, older centres such as Hamilton and Kitchener also stand out, but beyond the central GTA, both population and employment densities are generally low, although there are scattered areas of newly developed residential areas with relatively high densities, certainly more than 40 people/ha. These densities occur in dissemination areas that, in effect, measure net densities because boundaries are tightly defined around subdivisions of very small-lot, ground-related housing. Other higher-density areas may be obscured by how census boundaries are drawn and the inclusion of large amounts of non-residential land.

In studying density beyond generalized patterns or the density of small areas, census data should be used very carefully. Measured densities depend on such things as the quality and consistency of data, how density is defined and measured, the size of the units of measurement, and where the boundaries of census tracts and dissemination areas happen to be drawn.

In this section, we review some of these issues and make some observations and recommendations for improving density calculations. Section 4.1 discusses general issues with defining and measuring density. Section 4.2 focuses on the use of census data. Section 4.3 recommends using parcel data to overcome some of the limitations of census data.

4.1 Defining Density

Definitions of density are diverse; there is no standardized definition or method of measuring density. The reasons for studying density influence how it is measured. Definitions and methodologies vary widely because of different research interests and policy concerns. **Table 1.1** catalogues the wide range of approaches used. In promoting regional planning and consistent monitoring of policy impacts, the Province needs to adopt its own definition and standard methodology for measuring the types of density that are of concern. If local municipalities are responsible for measuring and tracking densities in their jurisdictions, a single definition and methodology should be used throughout the region so that the results can be compared.

Gross density is not adequate for comparing densities or measuring intensification over time. The key issue in defining density is the distinction between gross and net density. Measures of gross density are easy to calculate and understand, but may be misleading, because very different types of land use are found in different places. Because some municipalities like Toronto are almost fully built-up and others have large amounts of undeveloped land, the use of gross or net measurements will make a huge difference in the way municipalities appear relative to each other. For example, **Figure 2.1** shows that Mississauga has a higher gross population density than Brampton, but **Figure 2.2** shows the reverse for net density. The same problem also emerges in the analysis of smaller units such as tracts or dissemination areas and in measuring changes in density over time. Different areas may have exactly the same amount of growth at the same intensity of development, but areas with smaller amounts of unbuilt land will appear to have grown denser than areas with larger amounts of unbuilt land, all else being equal.

Clearly defining what should be included in net measures of density is complex and difficult. The various development patterns found throughout the region was shown in the analysis of CTs associated with Urban Growth Centres in Section 3. Ideally, all built-up lands should be included, but it is difficult to obtain consistent, reliable data and to define exactly what "built-up" means. Greenspace and protected lands are especially hard to define. For example, small neighbourhood parks are usually seen as integral to development and defined as part of the built-up area, but large tracts of protected, environmentally sensitive lands are not. In between these extremes are an array of sizes and types of open space protected to different degrees by different levels of government. Roads present a similar problem: local streets are seen as integral to development and are often included as "built-up," but limited-access highways serve regional purposes and do not provide direct access to development. Whether or not the rights-of-way for highways are included can substantially affect measured densities, without affecting the intensity of nearby development. Again, the Province needs to establish consistent criteria in this area.

A consistent method of defining the boundaries of measurement units is critical to meaningful density measurement and monitoring. The modifiable areal unit problem (MAUP) complicates the measurement of density. The size of the geographic units used and the location of their boundaries can have enormous impacts on the results. These problems are particularly acute in the analysis of census data.

4.2 Boundaries and Census Data

Using census data to describe urban form and measure changes in density is subject to several problems. Census data on population are the most complete, detailed, varied, and consistent data available, so it makes sense to use them to monitor population change, but the limitations of these data should also be clearly understood.

(1) *The size of Census Tracts on the urban fringe where most change is taking place makes detailed analysis of change in those areas impossible*. Tracts on the urban fringe tend to be extremely large and are only divided into smaller tracts as urbanization occurs. A typical CT in York Region north of Markham is 20 km^2, for example, whereas in recently built-up areas of Markham, the typical CT is about 1.7 km^2. It is possible to aggregate new tracts to correspond to

their previous boundaries and compare population changes across the larger, older area. It is not possible to go the other way and examine changes over time in the newer, smaller tracts where change is greatest. This problem will continue in the GGH as growth occurs in areas that now have very large CTs. Although it is too late to alter the 2006 census, the Province should work with Statistics Canada to define small CTs for all designated urban areas, if not for the entire GGH. This collaboration would allow for more consistent measurement of change over time.

(2) *The definition of boundaries for Dissemination Areas (DAs) and Census Blocks are inconsistent and problematic, especially in locations with high-rise apartments*. The problem of large tracts is mirrored at the DA and block level. DAs and blocks also become very large beyond Existing Built-up Areas. Moreover, DAs and blocks are geographically inaccurate and inconsistent in they way they capture dense, high-rise buildings. This problem is presumably a holdover from the days of Enumeration Areas (which were not designed to have stable boundaries over time), in which some apartment buildings were symbolically represented as trapezoids with areas smaller than the parcels on which the actual buildings sit. These trapezoids cannot be used for density calculations. If all high-rise apartment buildings of a certain size were identified the same way, measurements would at least be consistent, but this is not the case either. This is not an easy problem to fix. The Province should work with Statistics Canada to ensure that new DAs and Blocks are defined in a consistent way, either by aggregating them with the blocks in which they are located, or by defining them based on actual parcel boundaries.

(3) The census is designed to study residential populations and poorly captures employment data. In the data released to the public, jobs by place of employment is available only at the CT level or above, making small area analysis impossible. Statistics Canada can provide jobs data at the DA level, but because the data is based on a 20 percent sample, rather than 100 percent as for population, the accuracy and reliability of DA level employment data is questionable. Furthermore, suburban employment areas often have little or no residential population. Because census boundaries are defined according to population, CTs and DAs in employment zones tend to be very large. As with tracts on the urban fringe, this pattern reduces the value of density measurements in these areas. And beyond the census data, there are no consistent, reliable, region-wide data on place of work. These data are crucial for developing and monitoring growth policies, for transportation planning and modelling, and for the general analysis of urban form. The Province should work towards developing such a data set.

(4) *In general, census data does not consistently or accurately capture urban form, a purpose for which it is often used, but for which it was not designed*. The main reason has to do with boundary definition. In Section 3 we described the inconsistent ways in which census boundaries are defined with respect to employment centres: some CTs are drawn tightly around old downtowns, others capture large areas of residential use surrounding the downtown, and others capture only part of the downtown. In newer suburban areas, boundaries are seemingly drawn without reference to employment centres at all. The kinds of uses contained within these tracts, and therefore the results of either gross or net density calculations, appear to be arbitrary. Density calculations therefore measure different elements of form in all these cases and cannot be compared to each other. Although, over time, census data could be improved by predefining tracts throughout the entire GGH, defining DAs and blocks consistently, and collecting better employment information, the poor relationship between census boundaries and urban form probably cannot be fixed.

4.3. More Detailed Data on Land Use and Development

The Province of Ontario has recently launched an ambitious new approach to regional planning and growth management. It is the authors' opinion that census data are not adequate to monitor the impacts of these policies and other data must be found or developed. Consistent, region-wide data are needed to develop a detailed understanding of existing trends in population and jobs density, land use, development patterns, and housing issues.

Data collected to monitor policy impacts should be made widely and easily available to all those with an interest in regional development. As soon as possible, small CTs with permanent boundaries should be created for the whole area expected to build up during the next 20 to 30 years. Similarly, Dissemination Areas and Census Blocks should in future be drawn to fit built form more closely to capture patterns of density, intensification, and stability in urban areas.

A regional database on employment location, density, and output should be created. A better understanding of the trends in land consumption for employment purposes is essential in setting policy for employment lands, as well as in understanding the economic and land-use impacts of recent policy approaches.

Much better land use data, particularly at the regional scale, is also needed to analyse recent trends in land consumption and development densities, set targets for intensification, as well as monitor policy impacts. Parcel-level data, such as that held by Ontario's Municipal Property Assessment Corporation (MPAC), is increasingly used for regional policy development across North America. Although these data are not designed to measure population or employment, they are invaluable in measuring and tracking urban form for several reasons.

First, the parcel is the actual unit of land development. Being able to track the attributes of individual development units provides rich data on floor area, number of living units, number of storeys, date of development, and other attributes useful to tax assessment that can be used to describe built form at a very fine scale. Second, because these data are based on such small units of analysis, they can be aggregated in different ways to capture built patterns over larger areas. The analysis is not restricted by predefined boundaries. Also, how the data are aggregated and analyzed can be driven by the research and policy questions of interest. Using widely available GIS software, such data can be used at any scale from the parcel to the region. Compared to the limitations of census data discussed in this report, parcel data offer a potentially powerful tool for analysis.

The difficulty of getting access to parcel-based tax assessment data is a barrier to advancing research on patterns of existing development and change in the region. To assess provincial policy and its impacts, basic information on the density of new suburban employment areas, the amount of land set aside for parks, and the spatial relationship between retail and residential uses must be known. To answer these and other questions, parcel data, or a comparable data base, must be made as widely available as possible to researchers and policy analysts. More broadly, the Province should be working to develop its research and monitoring capacity, and encouraging independent research projects on the implementation and impacts of these far-reaching policies.

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Appendix B: Density Measurement and Growth Management Practices Elsewhere

This appendix contains an overview of density measurements used elsewhere, as well as a chart detailing the growth management policies of some regions and municipalities for which information is readily available; the table is by no means exhaustive. Because so few details are provided on the methods and results of the density measurements discussed below, their relevance to this report is largely tangential.

Density measurements in practice elsewhere

The Office of the Deputy Prime Minister in Britain has created guidelines for calculating net density that are used throughout the United Kingdom. Net density includes access roads within a site, private garden space, car parking areas, incidental open space and landscaping, and children's play areas. It excludes major roads, primary schools, open spaces that serve wider areas, and significant landscaped buffer strips.[3]

The City of Renton in Washington State provides a density worksheet for calculating net density. Public streets, private access easements, and critical areas are subtracted from property area in making these calculations.[4] Tacoma, Washington, calculates "Net Developable Acreage" as the gross site acreage minus public or private street rights-of-way and environmentally constrained lands.[5] The City of Ames, Iowa, requires that net density calculations exclude public or private rights-of-way, public or private open space, areas of severe slope, areas containing certain natural resources, easements, part of the front yard setback on corner lots, and buffer lots next to large estate lots.[6]

3 Office of the Deputy Prime Minister. 2000. "Planning Policy Guidance 3: Annex C." Accessed online at www.odpm.gov.uk.

4 City of Renton, Washington. 2004. "Density Worksheet." Accessed online at www.ci.renton.wa.us.

5 City of Tacoma, Washington. 2004. "Parkland-Spanaway-Midland Urban Residential Zone Summary Sheet." Accessed online at www.co.pierce.wa.us.

6 City of Ames, Iowa. "Minimum Density Requirements for Single Family Housing." Accessed online at www.ci.ames.ia.us.

Growth Management regimes: a selective overview (States/regions with white background; municipalities with grey)

	Density definition	Density measurement	Scale of measurement	GM efforts	Carrots and sticks
Washington State[7]	None	None	Counties and municipalities	Infill development, "urban growth areas," transportation planning	Growth Management Act – requires counties and cities to plan in accordance with state goals; Growth Management Hearings Boards; grants to local governments
Oregon[8]	Population density (gross)	people per square mile	Counties	Urban growth boundaries (UGB)s, Transportation and land-use planning, "Direct Community Assistance"	Oregon Transportation Rule – legislation requiring all levels of government to plan for decreased automobile use and increased use of alternatives; grants to municipalities
Florida[9]	None given (assumed to be gross density)	people per square miles	Local governments	Protection of critical environmental areas; land use regulation	Financial sanctions against local governments whose plans are not consistent with the State Comprehensive Plan and the Growth Management Act; citizen participation is encouraged in challenging developments that are not compliant with local growth plans

7 http://www.mrsc.org/subjects/planning/compplan.aspx?r=1

8 http://www.oregon.gov/LCD/TGM/index.shtml

9 http://www.dca.state.fl.us/growth/

	Density definition	Density measurement	Scale of measurement	GM efforts	Carrots and sticks
Tennessee[10]	None	Population growth is used as an indicator	Counties	Law requires a growth policy plan in each county, outlining urban growth boundaries (UGBs), planned growth areas (PGAs), and rural areas (RAs)	Implementation of the growth law is monitored by the Tennessee Advisory Commission on Intergovernmental Relations; state grants are given to those counties with growth plans; state agencies will sanction counties without plans
Ohio[11]	None	None	"Communities"	Brownfield development	Housing Enhancement Loan Program (HELP) – grants for revitalizing housing stock in older suburbs; Community Revitalization Initiative to encourage government and community cooperation
New Jersey[12]	Various; not explicitly defined	People per square mile; dwelling units per acre	"Planning areas"	Integrated state planning; state infrastructure policy – anti-sprawl; urban revitalization; housing and transportation planning; resource protection	"Cross-acceptance" process ensures that local plans are harmonized with state-wide planning goals, and that the interests of citizens and local governments are met

10 http://tennessee.gov/tacir/Portal/Growth_Tennessee.htm

11 http://www.firstsuburbs.org

12 http://www.nj.gov/dca/osg/plan/plan.html

	Density definition	Density measurement	Scale of measurement	GM efforts	Carrots and sticks
Maryland[13]	Net density	Dwelling units per acre; excludes land dedicated for public use, land protected from development by easements and local ordinances, cemeteries, and non-tidal wetlands	Local governments; parcel level	State infrastructure policy – anti-sprawl; brownfield development; Live Near Your Work program; job creation tax credit; Main Street Maryland program (urban revitalization); low interest mortgage loans in revitalization areas	Denial of state funding for infrastructure and schools in sprawling communities; Smart Growth Scorecard
Vermont[14]	None	population growth	Municipalities	Encourage "the historic settlement pattern of compact village and urban centers separated by rural countryside;" preserve open spaces; urban intensification	Tax breaks to promote business developments downtown; tax to prevent land speculating; training for municipal land-use officials; state grants for municipal planning projects
Capital Region, BC (includes New Westminster, Nanaimo, Parksville, North Vancouver, Park Coquitlam, Kelowna, Vancouver, Richmond)[15]	Population density; employment density; density of commercial space	Population / urbanized land area; population/ Metro Core area or other major centres; dwelling units / Metro Core area or other major centres; Jobs/ Metro Core or major centres or special employment areas; commercial floor space / Metro Core or major centres or special employment areas	Cities or districts	Infill; redevelopment; brownfield development; urban containment; natural resource management; housing and transportation policy	Implementation agreements between the CRD and any other level of government, first nations, school board or other authority; Smart Growth Scorecard

13 http://www.smartgrowth.state.md.us/; see also Siebert, S. 2000. "Growth Management Programs: a Comparison of Selected States." State of Florida Department of Community Affairs. Accessed online at www.floridagrowth.org

14 http://www.dhca.state.vt.us/Planning

15 http://www.crd.bc.ca/regplan/rgs

	Density definition	Density measurement	Scale of measurement	GM efforts	Carrots and sticks
Auckland City, New Zealand[16]	Net density	Households / developable residential land; population /developable residential land	Suburban town centres	Intensification in urban centres (infill and mixed-use housing)	Participatory planning; increased municipal service provision
Phoenix, Arizona[17]	None	---	---	Infill housing	---
Shelburne, Vermont[18]	None	---	---	Sewer infrastructure planning – anti-sprawl	---
Twin Cities, Minnesota[19]	None	---	---	Sewer infrastructure planning – anti-sprawl	---
Boulder, Colorado[20]	Net density	Number of dwelling units per "net site acreage," which is the land inside the parcel boundary excluding dedicated public street right-of-ways	Parcels	UGBs	---

16 http://www.aucklandcity.govt.nz/council/documents/growthstrategy/default.asp

17 http://www.plannersweb.com/sprawl/solutions.html; http://www.ci.phoenix.az.us/BUSINESS/infilpgm.html

18 http://www.plannersweb.com/sprawl/solutions.html

19 http://www.plannersweb.com/sprawl/solutions.html

20 http://www.plannersweb.com/sprawl/solutions.html; see also City of Boulder, Colorado. "Understanding Density and Floor Area Ratio." Accessed online at www.ci.boulder.co.us.

Appendix C: Papers Evaluating Growth Management Policies

This appendix contains academic evaluations of growth management regimes around the world. Although these sources offer little in the way of transferable knowledge on density measurement and monitoring, they include articles on land monitoring (the process of assessing current and potential land uses) as it is applied to Smart Growth goals, particularly in the United States. These articles provide some insight into the development of a land monitoring policy.

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Appendix D: All Greater Golden Horseshoe Municipalities Ranked by Total Population plus Jobs Density of Existing Built-up Area (EBA)

Municipality	Population + Jobs	EBA Pop. + Job Density /ha	Population Density /ha	EBA Job Density /ha	% Des-ignated Urban Area (DUA)	% EBA	% DUA that is EBA
Toronto	3,809,109	65.4	42.7	22.8	92.5%	92.5%	100.0%
Mississauga	961,705	37.6	24.0	13.6	93.9%	88.7%	94.5%
Hamilton	678,633	38.4	27.0	10.7	20.6%	15.8%	76.7%
Brampton	447,708	35.9	26.0	9.8	85.4%	46.8%	54.8%
Markham	325,205	33.0	21.1	11.8	55.8%	46.3%	82.9%
Vaughan	294,597	23.2	14.3	8.9	63.0%	46.4%	73.6%
Kitchener	271,949	35.2	24.6	10.5	82.7%	56.5%	68.4%
Burlington	221,841	34.1	23.0	10.9	42.8%	34.9%	81.5%
Oakville	212,893	28.1	19.1	9.0	81.8%	54.8%	67.0%
Oshawa	196,886	31.9	22.4	9.4	59.4%	42.4%	71.5%
St. Catharines	187,375	32.5	22.2	10.1	67.7%	59.3%	87.6%
Richmond Hill	179,475	33.2	24.3	8.8	69.1%	53.6%	77.7%
Guelph	168,485	31.4	19.8	11.6	89.9%	61.8%	68.8%
Cambridge	166,272	29.8	19.8	10.0	72.0%	49.5%	68.8%
Barrie	149,400	29.6	20.5	9.1	95.8%	65.5%	68.4%
Waterloo	139,973	34.1	21.1	13.0	85.6%	64.0%	74.8%
Brantford	123,867	26.0	18.2	7.9	91.3%	66.6%	72.9%
Pickering	118,774	31.6	22.9	8.4	31.3%	16.2%	51.7%
Whitby	117,333	24.9	18.5	6.4	47.4%	32.1%	67.7%
Niagara Falls	113,405	24.3	10.0	9.8	34.1%	23.0%	67.4%
Peterborough	107,961	26.0	17.2	8.8	101.1%	71.0%	70.2%
Newmarket	98,553	39.4	26.3	13.1	94.3%	65.8%	69.7%

Municipality	Population + Jobs	EBA Pop. + Job Density /ha	Population Density /ha	EBA Job Density /ha	% Des-ignated Urban Area (DUA)	% EBA	% DUA that is EBA
Ajax	96,803	34.5	26.3	8.2	65.1%	41.8%	64.2%
Kawartha Lakes	87,334	33.2	12.9	6.9	1.6%	0.8%	48.4%
Clarington	86,009	23.0	17.4	4.3	13.6%	5.9%	43.3%
Welland	67,867	24.7	17.4	7.1	46.7%	32.6%	69.9%
Caledon	67,030	35.5	20.4	8.7	5.2%	2.6%	49.1%
Halton Hills	62,784	28.7	20.8	6.7	14.3%	7.7%	54.2%
Haldimand	58,733	38.8	17.1	9.9	2.1%	1.0%	45.9%
Aurora	56,522	29.4	20.9	8.5	72.2%	38.8%	53.7%
Milton	51,641	25.4	13.8	9.9	16.9%	5.4%	32.3%
Georgina	46,143	19.4	14.7	2.9	23.8%	8.1%	34.0%
Brant	43,714	19.7	11.2	5.4	8.1%	2.4%	29.7%
Orillia	43,641	21.3	14.2	7.1	96.9%	71.5%	73.8%
New Tecumseth	41,446	37.3	18.2	13.8	6.7%	4.0%	60.2%
Fort Erie	38,868	16.3	10.9	4.5	23.9%	14.2%	59.4%
Orangeville	36,233	38.0	26.3	11.5	95.2%	61.2%	64.3%
Innisfil	33,601	32.2	18.6	4.7	6.3%	3.5%	56.1%
Centre Wellington	32,185	25.5	15.8	6.3	4.4%	3.0%	66.7%
Whitchurch-Stouffville	29,478	30.0	16.7	7.6	13.9%	4.6%	33.3%
Lincoln	29,162	40.4	23.5	11.8	6.3%	4.4%	69.0%
Woolwich	28,566	23.7	14.4	8.6	7.1%	3.5%	49.6%
Bradford West Gwillimbury	28,038	39.4	29.0	8.2	9.2%	3.4%	37.1%
Grimsby	27,592	25.6	17.2	5.8	17.3%	15.7%	90.6%
Scugog	26,373	26.6	13.9	6.2	4.0%	2.0%	49.9%
Cobourg	26,347	22.8	14.9	8.0	68.3%	51.6%	75.6%
Midland	25,674	27.1	15.9	10.0	57.2%	32.2%	56.4%
Collingwood	25,634	15.3	9.6	5.7	96.9%	50.1%	51.7%
Thorold	25,253	23.5	16.3	6.7	25.8%	12.7%	49.2%
East Gwillimbury	24,765	22.8	17.0	3.9	14.6%	4.4%	30.1%
King	24,408	23.0	13.8	5.5	11.8%	3.0%	25.2%
Port Colborne	24,385	19.5	13.7	4.7	17.9%	10.0%	55.7%
Niagara-on-the-Lake	23,149	23.4	16.1	7.2	11.9%	7.0%	59.3%
Essa	22,848	43.7	19.5	11.6	6.1%	1.6%	25.4%
Uxbridge	22,302	29.5	17.4	6.5	2.8%	1.5%	52.4%
Oro-Medonte	21,780	29.2	14.5	4.6	2.0%	1.1%	57.7%
Port Hope	21,650	22.4	13.2	6.3	6.1%	3.2%	52.3%
Wilmot	20,141	25.9	17.3	6.8	5.1%	2.7%	53.4%
Smith-Ennismore-	20,114	65.5	17.7	12.0	2.2%	0.8%	34.8%

Municipality	Population + Jobs	EBA Pop. + Job Density /ha	Population Density /ha	EBA Job Density /ha	% Des-ignated Urban Area (DUA)	% EBA	% DUA that is EBA
Lakefield							
Springwater	19,799	30.4	18.5	5.7	1.5%	1.1%	71.4%
Pelham	18,852	30.5	19.6	5.8	8.1%	4.9%	59.9%
Clearview	16,951	20.5	12.8	3.8	4.9%	1.3%	26.5%
Campbellford/Seymour, Percy, Hastings	16,669	26.3	10.7	6.5	2.5%	1.2%	47.7%
Wellington North	16,365	31.2	14.4	9.7	2.4%	0.9%	38.3%
Brock	15,800	32.6	16.4	7.6	2.6%	1.0%	39.4%
West Lincoln	15,378	44.3	17.0	9.0	1.9%	0.7%	34.9%
Wasaga Beach	14,399	8.6	7.4	1.2	76.3%	28.6%	37.5%
Guelph/Eramosa	14,349	36.1	17.1	8.0	2.8%	1.1%	40.5%
Severn	14,095	36.5	20.8	7.7	1.2%	0.6%	48.5%
Erin	13,617	24.8	12.3	4.7	3.6%	1.7%	45.9%
North Dumfries	13,204	34.2	17.0	11.5	5.8%	1.6%	28.2%
Mapleton	12,528	47.4	11.0	12.2	1.2%	0.3%	23.0%
Hamilton-Northumberland	12,465	37.5	15.4	5.1	20.5%	15.7%	76.5%
Penetanguishene	12,281	15.5	11.6	5.0	94.2%	31.2%	33.2%
Wellesley	11,940	34.3	18.9	7.4	1.8%	1.1%	61.2%
Adjala-Tosorontio	11,192	36.6	16.2	3.6	3.1%	0.6%	19.8%
Minto	10,784	21.6	11.2	5.3	2.9%	1.6%	54.4%
Cavan-Millbrook-North Monaghan	10,618	29.7	9.8	6.1	2.8%	0.9%	31.8%
Tay	10,382	16.3	10.0	1.9	7.6%	4.3%	56.9%
Ramara	10,160	28.4	12.5	4.3	3.2%	0.6%	19.6%
Tiny	10,055	65.8	22.6	6.7	1.2%	0.3%	25.8%
Puslinch	8,935	83.0	14.5	28.3	1.4%	0.4%	27.8%
Otonabee-South Monaghan	8,489	77.6	35.7	16.6	1.0%	0.1%	9.2%
Mono	8,357	243.4	45.4	41.8	0.5%	0.1%	14.4%
Douro-Dummer	7,527	103.2	21.6	12.0	0.9%	0.1%	9.8%
Cramahe	7,148	52.1	15.1	10.5	3.0%	0.7%	22.8%
Alnwick/Haldimand	7,041	38.3	14.8	6.5	1.7%	0.4%	20.9%
Shelburne	6,262	21.2	13.9	7.2	96.4%	65.1%	67.6%
Havelock-Belmont-Methuen	5,424	61.0	18.1	10.6	0.7%	0.1%	20.4%
Galway-Cavendish and Harvey	5,122	39.8	14.3	5.8	0.5%	0.1%	10.4%
Asphodel-Norwood	4,955	30.1	10.3	5.9	2.0%	0.7%	36.7%

Municipality	Population + Jobs	EBA Pop. + Job Density /ha	Population Density /ha	EBA Job Density /ha	% Des-ignated Urban Area (DUA)	% EBA	% DUA that is EBA
Amaranth	4,260	113.0	26.6	13.0	1.2%	0.1%	10.4%
Mulmur	3,669	71.3	0.0	11.1	1.0%	0.0%	0.0%
Mnjikaning First Nation 32 (Rama First Nation 32)	3,382	768.2	12.3	632.6	0.4%	0.4%	98.7%
East Luther Grand Valley	3,367	38.7	25.7	6.0	1.2%	0.3%	25.0%
Melancthon	3,131	53.3	0	5.7	0.9%	0.0%	0.0%
North Kawartha	2,629	13.0	6.0	2.4	0.8%	0.2%	28.4%
East Garafraxa	2,544	142.4	0	18.5	0.3%	0%	0%
Six Nations (Part) 40	0	0	0	0	0%	0%	0%
Wainfleet	0	0	0	0	0%	0%	0%