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# GCUT

GIS and Cartography at the  
University of Toronto  
Technical Paper Series

Paper No. 2:

A methodology for estimating the historical rate  
of residential intensification  
between 1991 and 2001  
for the Toronto Region

Marcy Burchfield, Byron Moldofsky  
Jo Ashley

GCUT Theme: GIS and Remote Sensing  
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**GCUT - GIS and Cartography at the University of Toronto Technical Paper Series - Paper no. 2**

**A methodology for estimating the historical rate of residential intensification between 1991 and 2001 for the Toronto Region**

**Abstract**

Building on the method for determining the urban extent described in GCUT Paper no. 1, A guide for deriving a consolidated built-up urban area for the Toronto metropolitan region using satellite imagery, this paper uses Statistics Canada housing data to determine the number of residential units created within the urbanized area of municipalities in the Greater Golden Horseshoe between 1991 and 2001. This number is compared to the total number of residential units created throughout the entire municipality (including greenfield development) to derive the residential intensification rate for that 10-year period. The goal of the research was to provide context for the 40% residential intensification rate target in Ontario's Growth Plan for the Greater Golden Horseshoe.

Keywords: residential intensification, urban form, growth management

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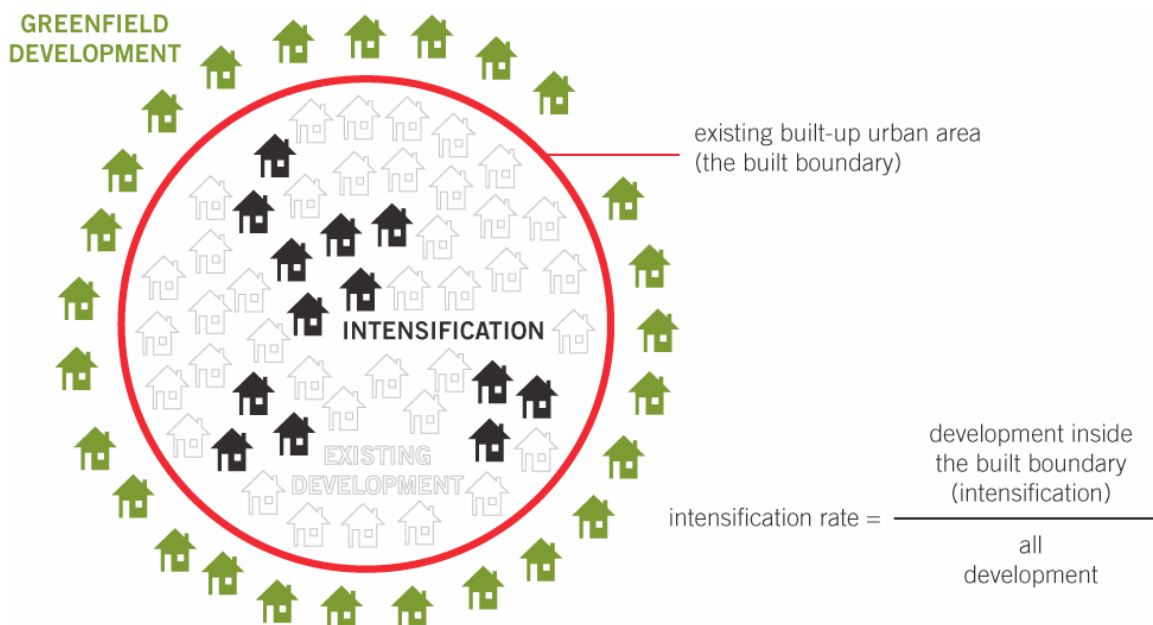
## Introduction

The Government of Ontario's Growth Plan for the Greater Golden Horseshoe (the region surrounding Toronto), was released on June 16, 2006.<sup>1</sup>

One of the cornerstone policies in the plan is its residential intensification target. This policy requires that by 2015, at least 40% of all new residential development must take the form of intensification – that is, it must be built within the already urbanized areas of municipalities in the Greater Golden Horseshoe.

It is not clear how the figure of 40% was arrived at, since research on historical trends in intensification has never been conducted in a uniform manner for the region. Given this research gap, we conducted research to establish a method for estimating an historical rate of residential intensification for a built-up urban area within a specified time period.

A simplified representation of the Province's proposed approach to measuring the intensification rate is illustrated in Figure 1.<sup>2</sup>



**Figure 1: An illustration of the Province of Ontario's method for calculating residential intensification rates**

In Figure 1, the red line represents the edge of the existing built-up urban area at a given date. All dwellings built after that date inside the line count as intensification units, and all new dwellings built outside the line are considered greenfield units. The number of

- 1 Ministry of Public Infrastructure Renewal, **Places to Grow: Better Choices. Brighter Future: Growth Plan for the Greater Golden Horseshoe**, Government of Ontario, 2006.
- 2 Source: Neptis Papers on Growth in the Toronto Metropolitan Region Paper 4, **Commentary on Residential Intensification: The Ins and Outs of Effective Growth Management** (forthcoming).

new dwellings built within the line over a specified time period, divided by the sum of all new dwellings built both inside and outside the line, produces the intensification rate in the form of a percentage.

The Ontario Government's Growth Plan policy requires municipalities to establish the edge of the built-up urban area as of June 1, 2006. The period over which intensification will be measured is June 1, 2006, to June 1, 2015. The process is described in a technical paper released in 2006.<sup>3</sup>

Since we were interested in historical trends, we established an urban boundary for 1990 and measured the intensification rate for the period 1991-2001.

## Data

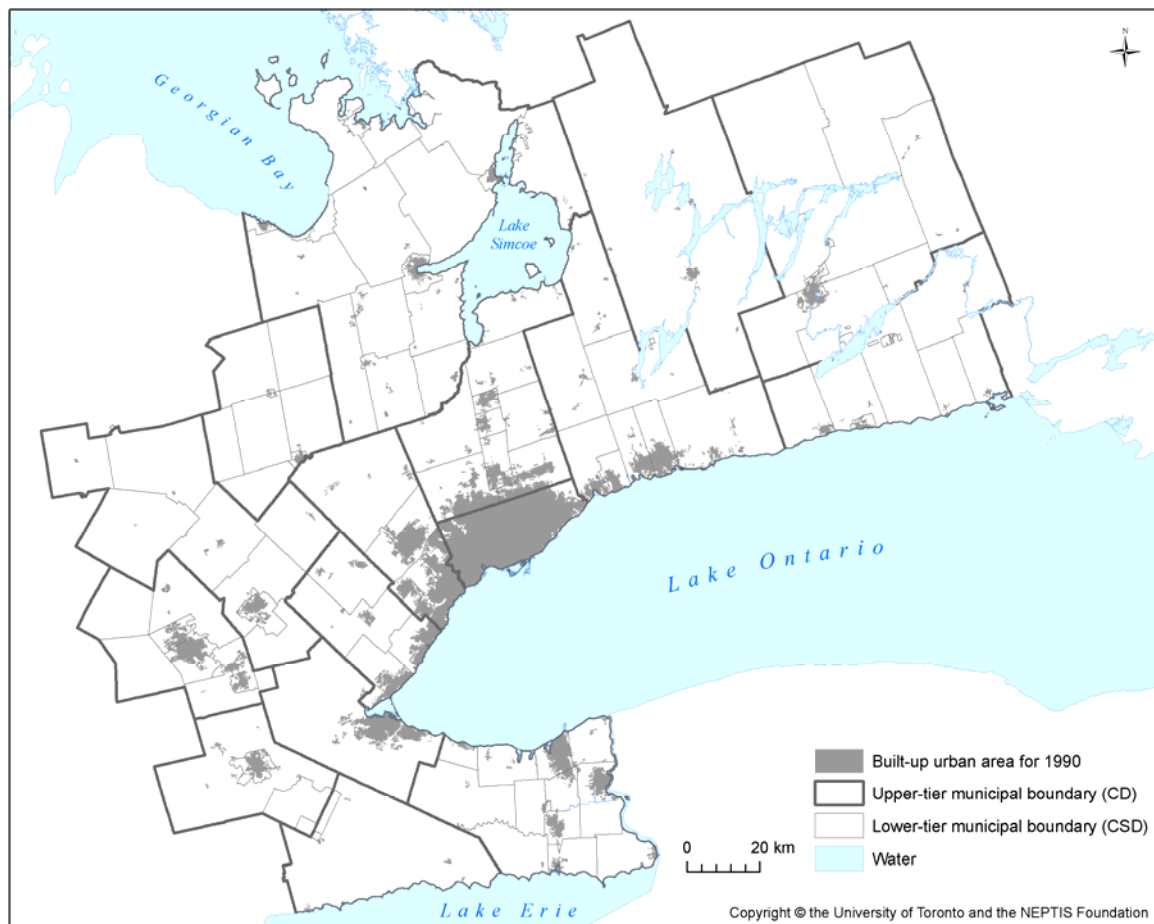
The Province will use parcel and assessment data to define the urban boundary, and building permit or assessment data to establish the dwellings counts needed to calculate a municipality's intensification rate. These data sets, however, are not freely available to the public. Parcel data are created and held by a private company, and assessment data are gathered and held by a municipal corporation. The cost of purchasing and assembling these data sets for the entire GGH would be prohibitive (\$100,000s). Further, the lineage of the data is such that a historical analysis of intensification using these data sets would be very difficult, if not impossible.

Therefore, we used alternative sources of data to create an estimate of recent historical rates of intensification to compare these rates to the proposed target. We used satellite imagery and image processing techniques to delineate the 1990 built-up urban area. The method is thoroughly described in technical paper No.1 from the GIS and Cartography at the University of Toronto (GCUT) Technical Paper Series.<sup>4</sup>

This method makes it possible to distinguish urban and non-urban land cover. In order to establish a continuous urban extent, we included non-urban areas within the main urban area (such as ravines, green spaces, parks, golf courses, etc.) as part of the urbanized area. The Ontario government describes a similar exercise in their technical paper.<sup>5</sup> This exercise of "filling in holes" creates a more manageable data set and allows for an easier integration with other data sets without compromising the intensification rates.

Figure 2 shows the consolidated built-up urban area for the Toronto region in 1990. The built-up urban area was defined using satellite imagery from 1990 instead of 1991, because the 1991 imagery is obscured in many places by cloud cover.

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- 3 Ministry of Public Infrastructure Renewal, **Places to Grow: Better Choices. Brighter Future. Technical Paper on a Proposed Methodology for Developing a Built Boundary for the Greater Golden Horseshoe**, Government of Ontario, 2006.
  - 4 Du, Paul; Burchfield, Marcy; Moldofsky, Byron; Ashley, Jo, **A guide for deriving a consolidated built-up urban area for the Toronto metropolitan region using satellite imagery**, Technical Paper No 1, University of Toronto, 2007.
  - 5 Ministry of Public Infrastructure Renewal, **Places to Grow: Better Choices. Brighter Future. Technical Paper on a Proposed Methodology for Developing a Built Boundary for the Greater Golden Horseshoe**, Government of Ontario, 2006.



**Figure 2: The built-up urban area of the Toronto region in 1990**

Once we had established the 1990 boundary, we needed to determine how many new dwellings were built inside and outside that boundary between 1991 and 2001 in order to calculate historical intensification rates. Dwellings located inside the 1990 boundary were considered intensification units and those outside were considered greenfield units.

We used Statistics Canada 2001 Census geography files (Blocks, Dissemination Areas, Subdivisions and Divisions) and two Census variables (Occupied Private Dwellings and Period of Construction) to locate and count dwellings.<sup>6</sup> The Census Block is the most detailed level of geographic data available to the public; blocks are bounded on all sides by roads or other standard geographic boundaries. Only two census variables are disseminated at the block level - counts of total population and total occupied private dwellings. These counts are part of the 100% census sample.<sup>7</sup>

6 For a full description of the Census of Canada geography files and variables used for this method, see the Statistics Canada 2001 Census Dictionary: <http://www.census2006.ca/english/census01/Products/Reference/dict/appendices/92-378-XIE02002.pdf>.

7 A private occupied dwelling is defined as being a separate set of living quarters in which a person or group of people live permanently.

The Census Dissemination Area (DA) is a small and relatively stable geographic unit made up of one or more Census Blocks. The DA is the smallest geographic unit at which data on all census variables are disseminated. This includes the “period of construction” variable, which specifies the number of dwellings constructed within certain time periods.<sup>8</sup> We used this variable to derive the number of dwellings constructed between 1991 and 2001.

In Ontario, the Census Subdivision (CSD) generally corresponds to lower-tier municipalities. The Census Division (CD) is an aggregation of CSDs and generally corresponds to upper-tier and single-tier municipalities. We carried out calculations at the smallest levels of geography, blocks and DAs, and aggregated the results to the lower-tier, single-tier, and the upper-tier municipal levels. The Growth Plan intensification target is intended to be applied at the level of upper-tier and single-tier municipalities.

## Method

Our method for estimating historical rates of intensification involves the integration of three geographic data sets. A series of selections based on thresholds determines whether a dwelling is categorized as inside or outside the urban area. Three main pieces of information are required for this analysis.

1. Built-up urban area for 1990 within a municipality.
2. The number of dwellings constructed between 1991 and 2001 within the 1990 built-up urban area of a municipality.
3. The number of dwellings constructed between 1991 and 2001 for the entire municipality.

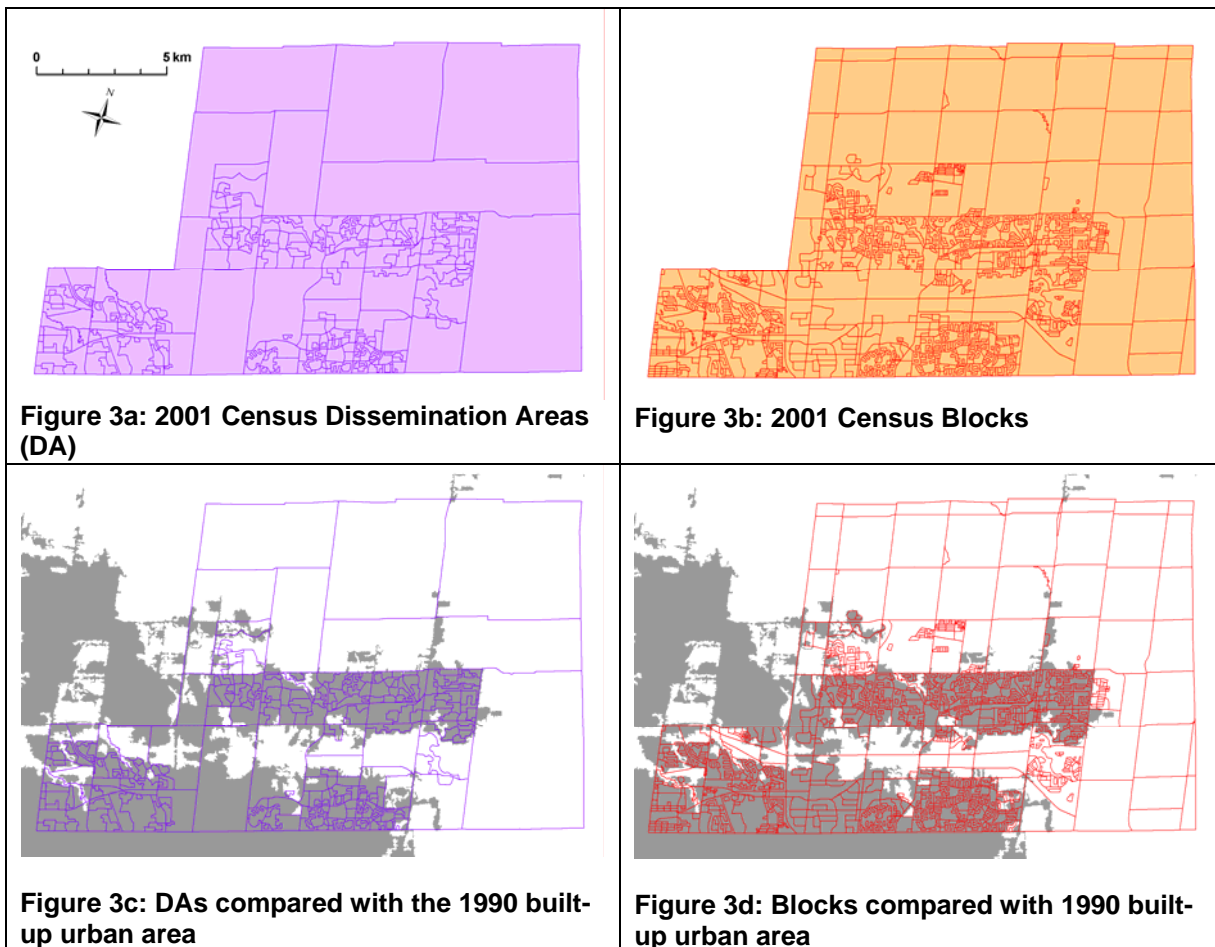
This method can be represented as an equation whereby the second number described above is the numerator and the third number is the denominator:

Intensification rate	<b><i>Equals</i></b>	Number of dwellings constructed between 1991 and 2001 within the built-up urban area for 1990	<b><i>Divided by</i></b>	Number of dwellings constructed between 1991 and 2001 for the entire municipality
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Our data source for categorizing dwellings as inside or outside the 1990 urban boundary is the 2001 census geography, along with the two census variables: total occupied private dwellings and period of construction. One challenge in using census geographic data sets in combination with non-census geographic data sets is that the boundaries of the census geography may not exactly align with non-census geography. Second, the census variable of interest, in our case the period of construction variable, may not be available at the desired level of geography due to data suppression rules created to protect individuals' privacy. An example of this dilemma is explained below and illustrated in figures 3a-d.

<sup>8</sup> This variable is part of the 20% census sample.

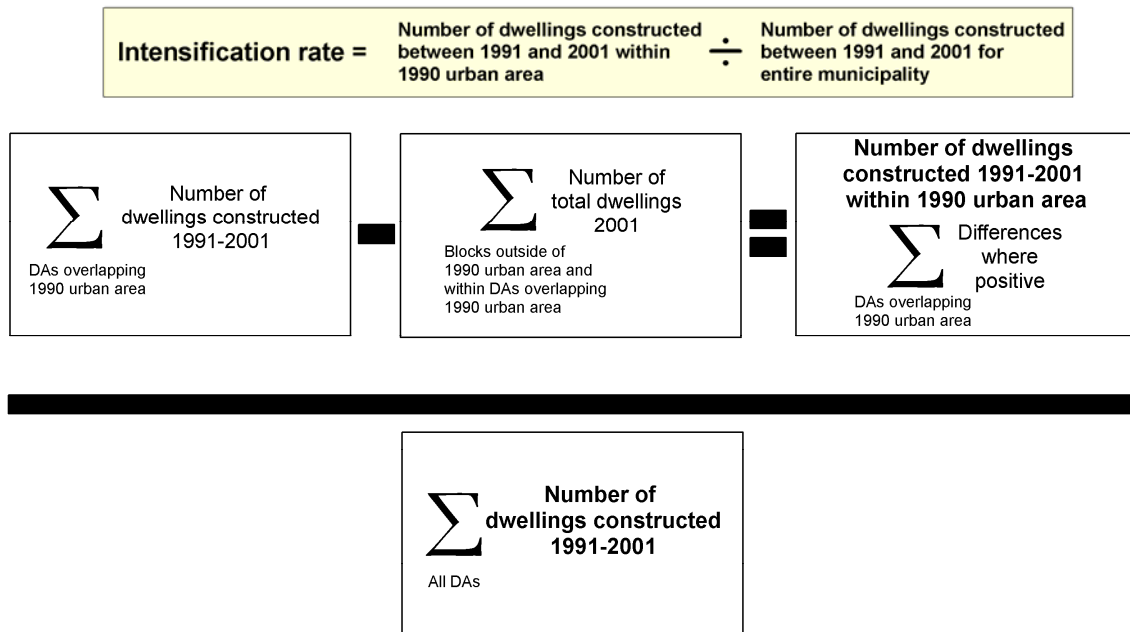




**Figure 3: Comparison of census geography and built-up urban area for the lower-tier municipality of Markham**

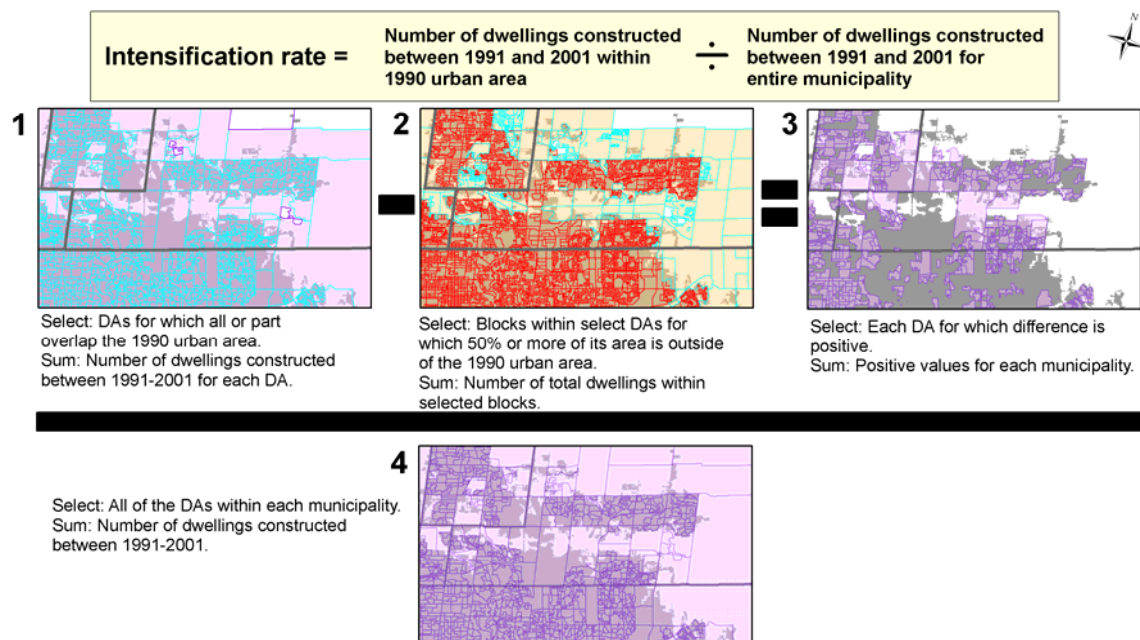
Census blocks align well with the built-up urban area, since they are a small level of geography and their boundaries typically align with roads (see figure 3d). However, the period of construction variable is not available at this level of geography. The variable is disseminated only at the DA level, but since DAs are much larger than blocks, particularly at the edge of urban development, they do not align well with the built-up urban area (see figure 3c). Therefore in calculating the numerator of our intensification rate equation, we used the period of construction variable at the DA level and the total occupied private dwelling variable at the block level.

Figure 4 represents in generic terms the method we used to estimate the number of intensification units in each municipality (the numerator), as a prerequisite to estimating the overall intensification rate for a municipality.



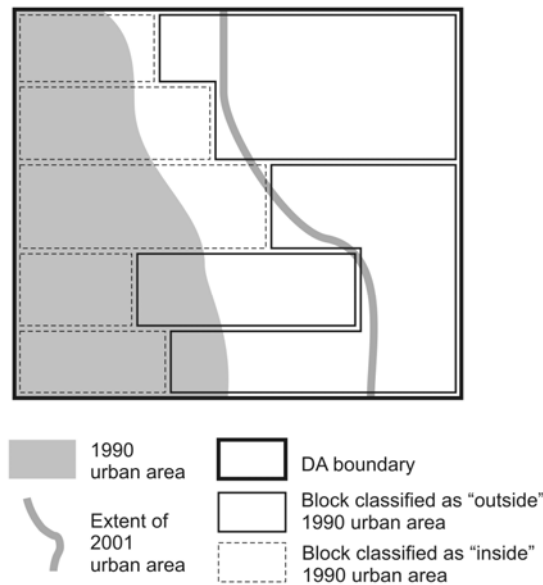
**Figure 4: Calculation used to estimate the intensification rate for each municipality**

We used a Geographic Information System (GIS) to make the necessary selections and sum up the data required to produce the numerator. Figure 5 is a pictorial representation of this process.



**Figure 5: Pictorial representation of the calculation for estimating the intensification rate**

Since the edge of the urban area does not correspond exactly with either Block or DA boundaries, a threshold has to be established to classify these geographic units as inside or outside the urban area. We decided that if more than 50% of the area of a Block fell within the urban boundary, it would be classified as inside the urban area, and if less than 50% of the area of a Block is within the urban boundary, it would be classified as outside the urban area. DAs are included in the analysis only if they contain at least one Block which is classified as inside the urban boundary (see figure 6 for illustration).



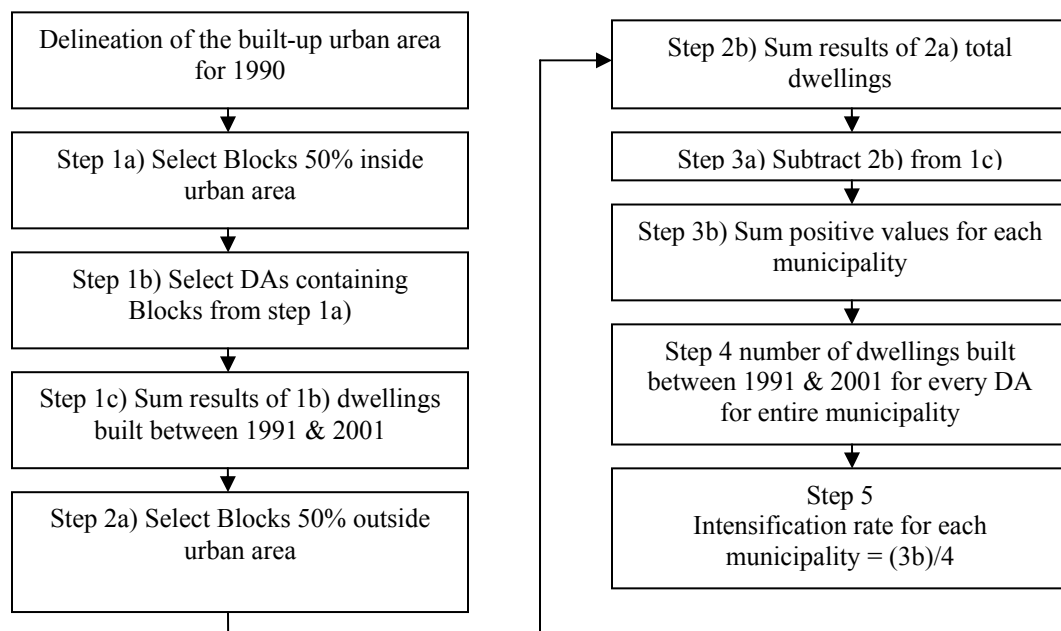
**Figure 6: Schematic illustration of Block classification within a single DA**

The following set of instructions summarizing our method for estimating historical rates of intensification is provided below.

1. Select all DAs overlapping the 1990 built-up urban area, in the following way<sup>9</sup>:
  - a) Overlay the Block data on the built-up urban area. If more than 50% of the area of any Block is within the urban area, all of the block is classified as inside the urban area.
  - b) Select the DAs which contain the selected Blocks for use in the analysis.
  - c) Sum the number of dwellings constructed between 1991 and 2001 (taken from data on the period of construction of dwellings in the 2001 Census) for each selected DA. This number represents the first portion of the numerator in the equation.
2. a) Select Blocks within included DAs which have less than 50% of their area within the urban area. These are classified as outside the 1990 built-up urban area.

<sup>9</sup> For the current analysis, the selection was performed using a spatial selection. As sometimes happens in a spatial selection between two spatial data sets that do not exactly align, a geographic unit that overlaps by a sliver, an extremely, small polygon, is selected. Therefore, it is recommended that in future analyses this procedure be changed an attribute selection based on coincidental census block and DA identification codes.

- b) Sum: number of dwellings (total) within selected Blocks for each DA. This number represents the second portion of the numerator in the equation.
3.
  - a) For each selected DA, subtract the results of Step 2b (total number of dwellings in Blocks outside the 1990 built-up urban area) from the results of Step 1c (total number of dwellings constructed between 1991 and 2001). This gives an estimate of the number of dwellings constructed between 1991 and 2001 within the 1990 built-up urban area for each DA.
  - b) Select all DAs for which the difference is positive. (There may be some DAs for which the difference is a negative number, due to the nature of the variables and the differing DA and Block geography. These are discarded from the analysis.)
  - c) Sum: positive values for each municipality.
4. Determine the total number of dwellings constructed between 1991 and 2001 for all DAs in each municipality.
5.
  - a) Sum the numerator, which is at the DA level, for the entire municipality; this number represents dwellings built between 1991 and 2001 inside the urban area (step 3b).
  - b) Divide the result by the denominator, representing all dwellings built between 1991 and 2001 for the entire municipality (step 4).



**Figure 7: Flow chart showing residential intensification estimation method**

Our method produces an estimate of historical intensification that is not without possible sources of error. In any data analysis, there are inexactitudes and sources of error, but we are confident that these are minimal and within an acceptable margin. The following may have a minimal effect on the accuracy of the results:

1. Random rounding and suppression of census data
2. Delineation of extent of 1990 urban area
3. Classification of Blocks as “inside” or “outside” the 1990 urban area
4. Assumption that all dwellings in Blocks “outside” 1990 urban area were built after 1990

The first point relates to the choice of data used in the analysis. The use of the “period of construction” variable introduces some inexactness, since data suppression occurs in DAs with a relatively small number of dwellings and since random rounding to the nearest five occurs in all DAs. This is true of all census variables that are part of the 20% sample.

The last three points relate to the method used to calculate intensification rates. Some imprecision is introduced into the method, since it is based on imagery from 1990 instead of 1991 and since the boundary is derived from an image analysis process that was designed to capture the consolidated urban area, as opposed to every urban feature in the study area, e.g. isolated, residential or commercial buildings outside of the main urban area. But any method for deriving an urban boundary has some level of imprecision and generalization.

The choice of 50% as the threshold for inclusion introduces some uncertainty into the method. There is a risk of improperly classifying units as some Blocks classed as “inside” will include some dwellings “outside,” and vice versa. The assumption is that these will offset each other. The risk has also been mitigated by the use of Blocks, the smallest geographic units available. Because of the way Block boundaries are defined, the risk is small and again, within acceptable limits. The classification threshold represents a conservative selection of Blocks. See figure 6 for illustration of this possible source of error.

Another possible source of error is the assumption that all dwellings in Blocks outside the 1990 urban area were built after 1990. The method for deriving the built-up urban area concentrated on capturing consolidated urban development. Isolated dwellings in rural areas may not be included. During the selection of Blocks (step 2 in the numerator calculation), these isolated dwellings built before 1990 may be included in the total private occupied dwelling count. It is assumed, however, that the number of these dwellings is small, so including them would introduce only a minor underestimate of intensification.

## **Results**

Our analysis allows us to produce historical intensification rates for each upper-, single-, and lower-tier municipality in the Greater Golden Horseshoe and to locate and measure the amount of intensification within a municipality. We used a variety of mapping techniques to display the results of our analysis.

Figures 8a and 8b illustrate our results using graduated and proportional circles mapping techniques. In Figure 8a, the 1990 built-up urban area is shown as the dark grey background and the grey circles represent the number of intensification units by DA and their approximate location. A circle's location corresponds to the centroid of each DA. Mapping the results at the DA-level using graduated circles allows us to represent the location and magnitude of intensification and to display the spatial distribution and pattern of intensification throughout the study area.

Figure 8b maps the results at the lower-tier municipality using proportional circles. The overall size of the pie charts represents the total number of new dwellings built between 1991 and 2001 for Mississauga and Brampton. Within the pie charts, the red portion represents intensification units (dwellings built within the 1990 urban area) and the green represents greenfield residential development. In this example, proportional circle mapping allows the reader to compare the total amount of new residential development and the amount apportioned to greenfield and intensification development for each municipality. The intensification rate is shown as the percentage of all new dwellings that were built between 1991 and 2001 within the 1990 urban area.

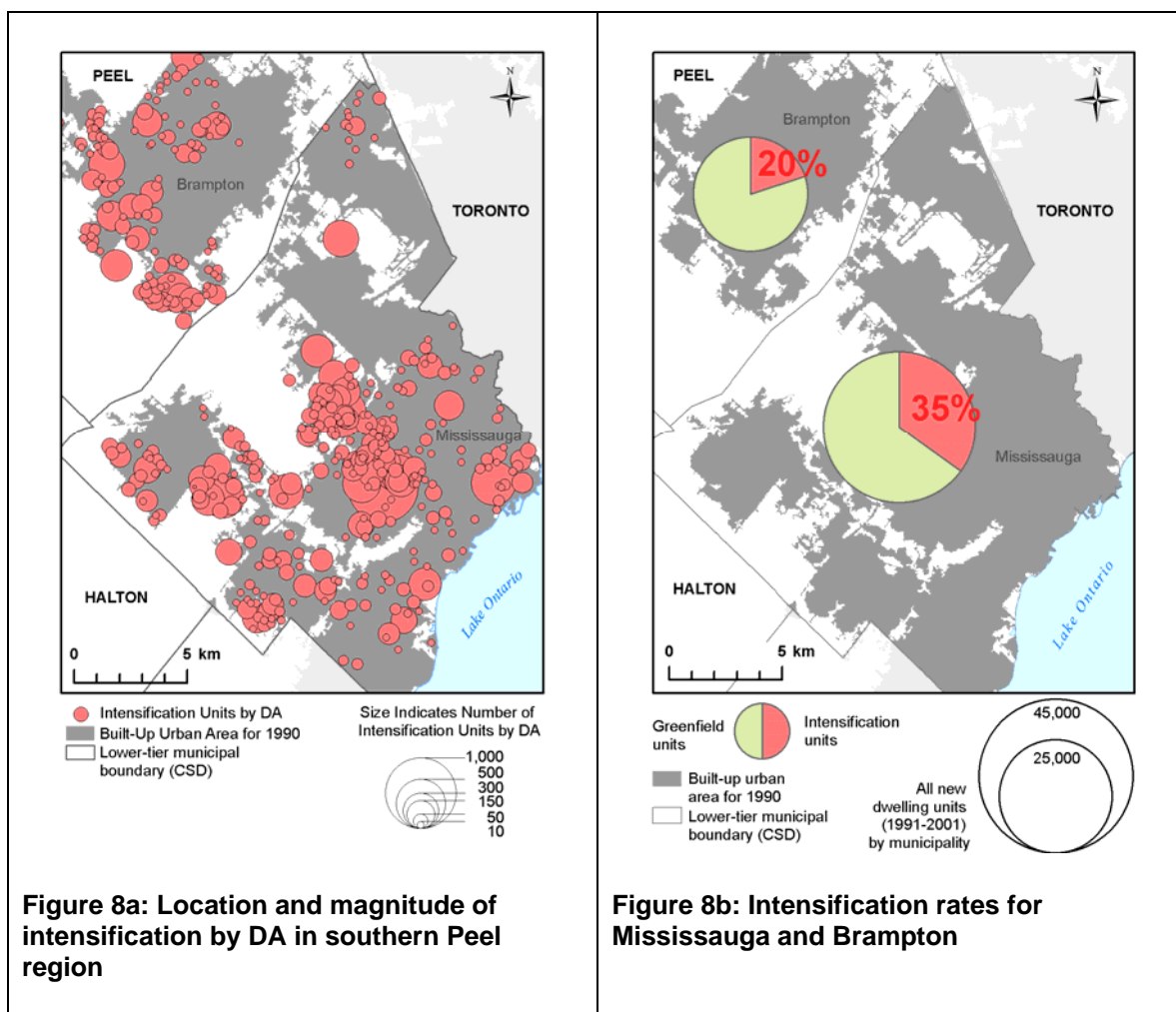


Figure 9 and table 1 show the results of our analysis, aggregated by upper-tier municipality, for the Greater Golden Horseshoe. The 1990 built-up urban area is shown as the dark grey background, and the 2001 urban area is shown in orange and represents the extent of greenfield development. As in figure 8b, the size of each pie chart represents the number of all new dwelling units built between 1991 and 2001 by municipality and within each circle, the red portion of the pie represents the percentage of intensification units versus greenfield units.

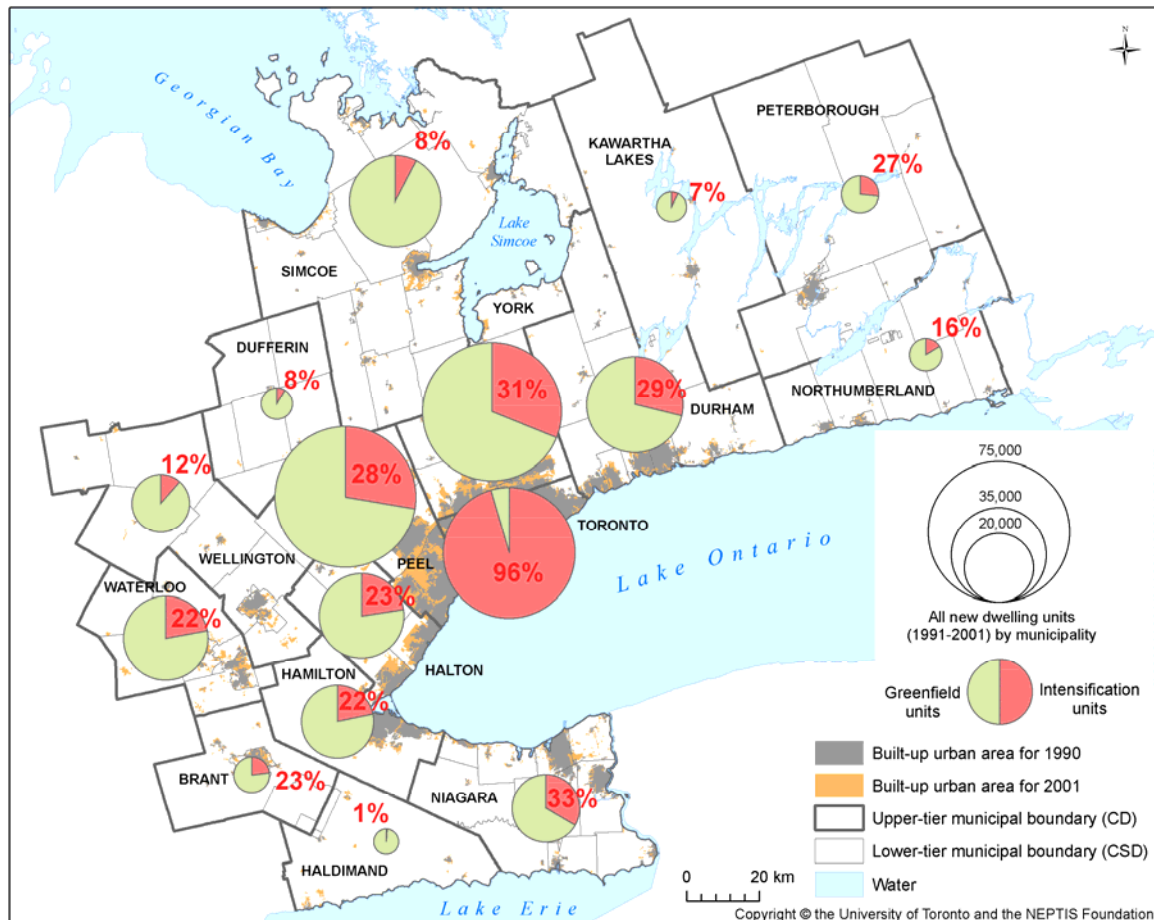
The Government of Ontario's Growth Plan categorizes the 16 upper-tier municipalities in the region into two groups, Inner Ring and Outer Ring. The City of Toronto, its adjacent fast-growing suburban municipalities, and the City of Hamilton are part of the Inner Ring. The Outer Ring contains a few "satellite-city" municipalities as well as rural municipalities that are receiving increased development pressure. Table 1 also contains intensification rates for the region (GGH), the Inner Ring and Outer Rings, including and excluding the City of Toronto.

<b>Municipality</b>	<b>New dwellings 1991-2001</b>	<b>Intensification units, 1991-2001</b>	<b>Intensification rate, 1991-2001</b>
Toronto	66,000	63,000	96%
Durham	35,600	10,200	29%
Halton	27,400	6,200	23%
Peel	75,900	21,000	28%
York	73,600	22,900	31%
Hamilton	19,900	4,400	22%
<b>INNER RING</b>	<b>298,300</b>	<b>127,700</b>	<b>43%</b>
<b>INNER RING (excluding Toronto)</b>	<b>232,300</b>	<b>64,700</b>	<b>28%</b>
Brant	4,900	1,100	23%
Dufferin	3,800	300	8%
Haldimand	2,300	25	1%
Kawartha Lakes	3,400	200	7%
Niagara	17,300	5,700	33%
Northumberland	4,100	700	16%
Peterborough	5,300	1,400	27%
Simcoe	32,000	2,400	8%
Waterloo	27,100	6,000	22%
Wellington	12,700	1,500	12%
<b>OUTER RING</b>	<b>112,700</b>	<b>19,400</b>	<b>17%</b>
<b>GGH</b>	<b>411,000</b>	<b>147,100</b>	<b>36%</b>
<b>GGH (excluding Toronto)</b>	<b>345,000</b>	<b>84,100</b>	<b>24%</b>

**Table 1: Estimates of new dwellings, intensification dwellings, and intensification rates(1991-2001). All estimates are rounded to the nearest hundred.<sup>10</sup>**

10 If the change in procedure for selecting DAs, as explained in footnote 9, had been applied here, the numbers reported in table 1 would reduce the intensification units for the Inner Ring by approximately 100 units. The impact of this procedural change is well within the margin of error for the analysis. It accounts for less than 0.1% of all intensification units in the Inner Ring.

The City of Toronto has the highest intensification rate among the 16 municipalities in the Greater Golden Horseshoe region, at 96%. The other fast-growing municipalities within the Inner Ring have intensification rates between 22% and 31%, not far from the Government of Ontario's residential intensification target of 40%. Many of the "satellite city" municipalities in the Outer Ring that have established urban cores also register a relatively high intensification rate, such as Niagara, Brant, Waterloo and Peterborough. However, most municipalities in the Outer Ring tend to have low intensification rates, like Haldimand with 1%. Surprisingly, fast-growing Simcoe County which added 32,000 new dwellings over the 10-year study period registers a low intensification rate of 8%.

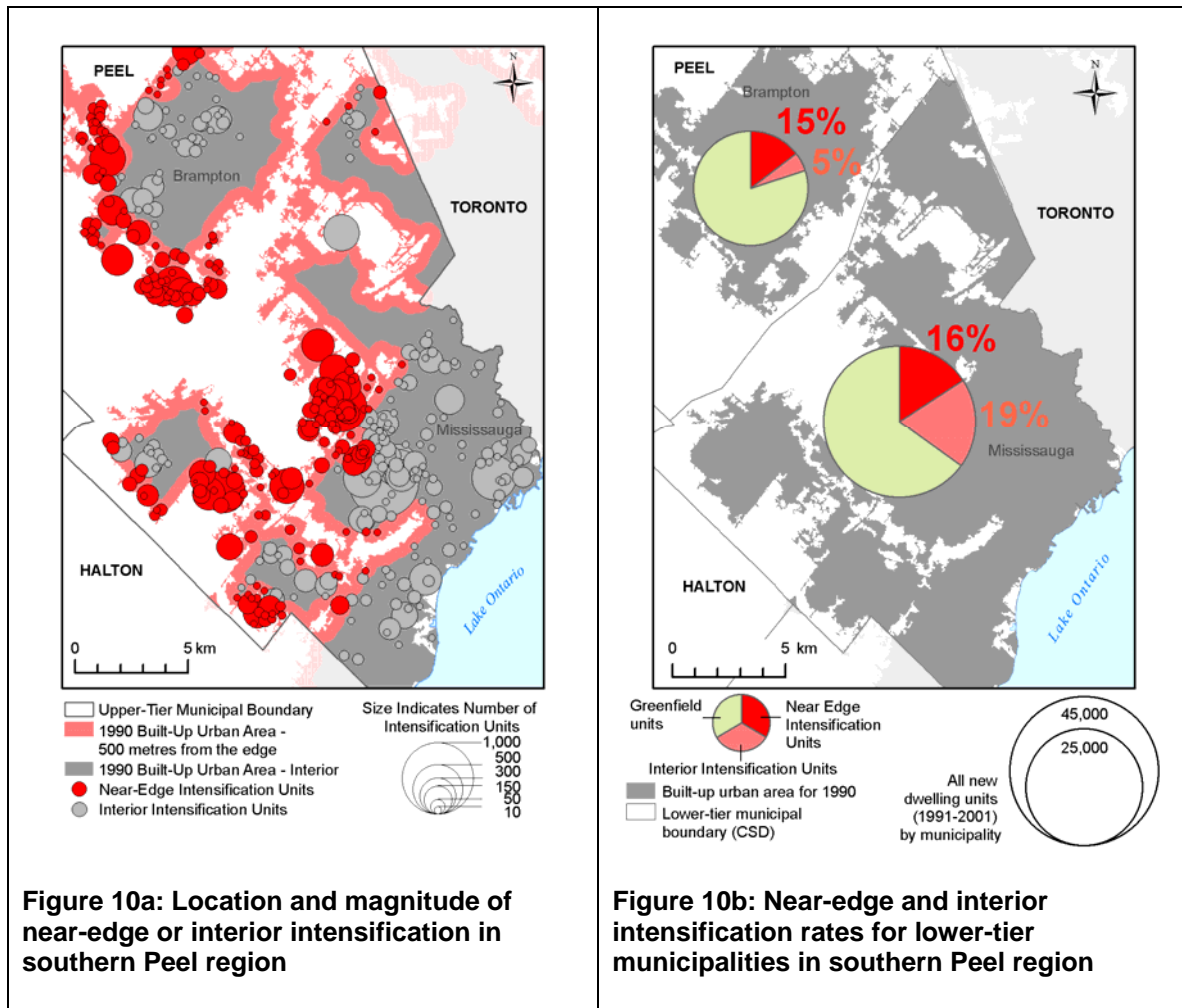


**Figure 9: Intensification rates for the Greater Golden Horseshoe**

While identifying the location and calculating the number of intensification units within each municipality, we found that many intensification units were built close to the edge of the 1990 built-up urban area. To investigate this finding further, we drew a 500-metre buffer zone just inside the edge of the built-up urban area and analyzed the numbers of intensification units built within this buffer zone. A DA was included in the analysis if 90% or more of its area was inside the buffer. These DAs that fell within the threshold were identified and their intensification units were summed. We call dwelling units built within 500 metres of the edge of the urban area "near-edge" intensification units.

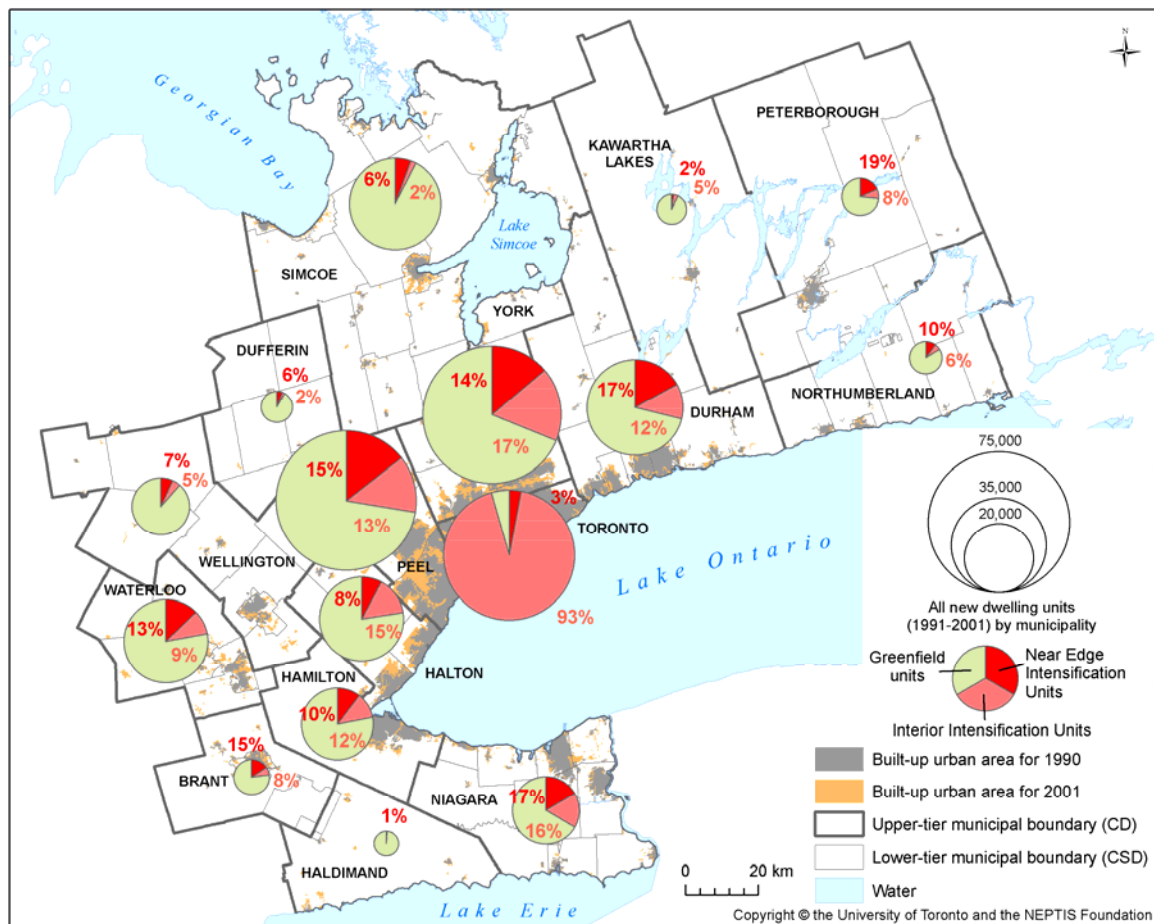


Figure 10a distinguishes intensification units built inside and outside this 500-metre buffer zone in southern Peel Region. The size of the circles indicates the number of dwelling units constructed in each census DA between 1991 and 2001. The colour of the circles indicates whether the dwelling units are near-edge intensification units (red) or interior intensification units (grey).



Near-edge intensification units accounted for 52% of all residential intensification in Peel Region between 1991 and 2001. Figure 10b shows these results for southern Peel region calculated for the two lower-tier municipalities, Mississauga and Brampton. Each pie is divided into three sections; near-edge intensification units (red), interior intensification units (pink), and greenfield units (green).

Figure 11 displays the results of the near-edge analysis applied to the entire Greater Golden Horseshoe, using the same pie chart scheme as in Figure 10b, aggregated to the upper-tier municipalities. Outside the City of Toronto, about half of all dwelling units constructed within the 1990 built-up urban area in the Toronto region were near-edge. However, this finding may mask substantial differences between individual municipalities.



**Figure 11: Near-edge and interior intensification rates for the Greater Golden Horseshoe**

The proportion of near-edge to interior intensification units may, for example, characterize distinctive patterns of growth, or stages in a municipality's development cycle. This distinction bears further investigation.

## Future Publications and Research

The method described in this paper can be used to estimate the historical rate of residential intensification for any urbanized region for any particular time period. We have applied this method to two other Canadian urban regions – the Greater Vancouver region and the City of Calgary, which will be published in a forthcoming research paper published by the Neptis Foundation. This paper describes and discusses the results of the estimated historical residential intensification rates for these three metropolitan regions in the context of regional planning policy and urban form. Future research will involve applying this method to other Canadian and U.S. metropolitan regions.

We have begun to update our analysis of the Greater Golden Horseshoe for the study period between 2001 and 2006, starting with the Region of Waterloo. In this study, we

are able to compare our method for deriving the built-up urban area and for estimating historical rates of intensification with data provided by the Planning Department at the Region of Waterloo. This comparison will allow us to produce some estimate of the margin of error introduced in our analysis. The study will be published in 2008 as part of the GCUT technical paper series.

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