Historical GIS research in Canada

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Imprint University of Calgary Press, 2013

Extent 1 online resource

ISBN 9781552387566, 9781552387443, 9781552387504, 9781552387511

Permalink https://books.scholarsportal.info/en/read?id=/ebooks/ebooks3/upress/2014-03-15/1/9781552387443

Pages 77 to 145

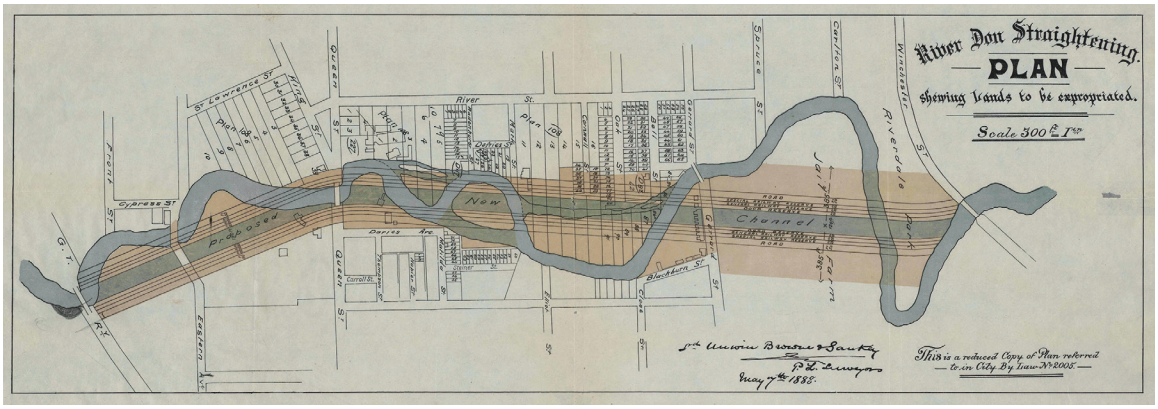


Fig. 3.6. River Don straightening plan. (Unwin, Browne and Sankey, Surveyors. May 7, 1888. City of Toronto Archives, Series 725, File 12.)

interpreting these changes, facilitating as it did the detection of patterns and anomalies over time – something very difficult to achieve in the one-to-one comparison of print or even scanned maps. This increased capacity is evident in Figure 7, which depicts the river's changing course in three different periods. The extent of the lakeshore is also visible in its different stages of reclamation during these periods. Without GIS technology, the overlay of historic data is both more difficult, and it lacks interoperability – the capacity to be used in a variety of software for different purposes – which is crucial for data sharing and reuse.

GIS also created interpretive possibilities in tracking smaller landscape changes unmentioned in the textual sources, and perhaps not readily apparent in a review of paper or digital maps of the period. References to isolated relocations of the river channel in association with the construction of the Don Valley Parkway in the 1950s and 60s, for example, are easily discernible by overlaying polygons of the river channel before and after highway construction and adjusting the scale of the map to view particular reaches of the river.

In other aspects of the project, the capacity to select out certain information for analysis (for example, the locations of oil refineries that established in the lower valley in the early twentieth century) and the ability to adjust the scales of analysis – to zoom out to see the large picture of industrial development in the lower valley, and the concentration of particular types of industries; to zoom in to analyze the outlines of individual buildings and their relationship with the river – provided opportunities for insights into the history of pollution in the river valley and the services the river provided in different places and periods.

A GIS of a river's history is, of course, only as good as the source material upon which it is based. While we would have liked to gain an appreciation, in spatial terms, of historical changes to the condition and character of the river, including depth and flow rates and levels of pollution and sediment, the absence of detailed historical source materials made this impossible. An understanding of the changing sensory experience of the river – its visual appearance, sounds, and smells – was another

Fig. 3.7. River and Lake Ontario shoreline, 1857, 1891, and 1918. (Sources: Don Watershed boundary: Toronto Region Conservation Authority 2008; current shoreline: DMTI CanMap Postal Geography FSA Boundaries, v2008; Historical Roads [1818–1884]: University of Toronto Map and Data Library 2011.)

aspect of the river's past that would remain dependent upon scattered textual references often lacking in spatial specificity.

CONCLUSION

On average, about two hundred people per month visit the Don Valley Historical Mapping web pages (see maps.library.utoronto.ca/dvhmp/). Presentations on the project to local environmental and citizens' advocacy groups such as Lost Rivers and the Task Force to Bring Back the Don have generated substantial interest; these groups aim to incorporate project data and maps into their own planning and public education initiatives for the valley. People have used the data we created in ways we didn't expect. For example, the scanned map images and the Google Earth files, and not the GIS files, have been by far the most popular downloads. Students and the general public, rather than GIS researchers, have been the main beneficiaries of the project, and, consequently, the "web ready" and open format files such as our Google Earth data are downloaded with much greater frequency than the more stringent and difficult-to-use but highly versatile and powerful shapefiles.[8]

By digitizing hundreds of historical maps and producing over fifty features in GIS and Google Earth format, all freely available for download by the public and other researchers, the project accomplished its primary goal of making library resources more accessible. Its results demonstrate the possibilities opened up through collaboration. From the library's perspective, projects such as these showcase what libraries are all about. They justify the acquisition and maintenance of expensive collections and the hiring of skilled and academically inclined personnel that are dedicated to research and services. For the historian on the team, participation in such a project stemmed from the recognition that, despite the time and energy invested to learn HGIS methods, she was unlikely to become proficient enough to produce her own data and maps expediently. An understanding of how GIS works, however, and the particular challenges of HGIS did prove extremely useful in working with the data, and members of the project team, effectively.

The project presents numerous opportunities for expansion. A wider geographic expanse would provide a striking demonstration of the spatial distribution of industry across the city. More lost streams and rivers could be uncovered, bringing Toronto's history alive cartographically and enhancing, at the same time, the appreciation of the map collections at the University of Toronto and other libraries. The project might also be expanded to include other important geospatial features, such as tree cover, topography, elevation change, agricultural development, and transportation and municipal infrastructure development.

Projects such as these can also fuel the development of other projects. They can feed into existing ones, such as the Ontario County Map Project currently underway,[9] and stimulate future projects. A commitment to open access to the data produced by projects such as this one is an essential part of this process. Agreements between institutions to share not only aggregated data but source materials such as archival maps and images is another way forward. Many historical GIS projects fail to get off the ground in part due to the prohibitive cost of acquiring digital map reproductions. A large proportion of the material we work with in urban environmental history is in the public domain but restricted from use because of cost-recovery mechanisms in a number of institutions that restrict reproductions without payment. Making this information accessible to researchers is the first step in enabling new historical knowledge. New relationships and new practices within archives and other collecting institutions are vital to the development of HGIS projects in Canada.

NOTES

1 For a detailed history of the Don River Valley and the various infrastructure projects that have altered the landscape of the river valley over time, see Jennifer L. Bonnell, *Reclaiming the Don: An Environmental History of Toronto's Don River Valley* (Toronto: University of Toronto Press, forthcoming). See also Bonnell, "A Social History of a Changing Environment: The Don River Valley, 1910–1931," in *Reshaping Toronto's Waterfront*, ed. Gene Desfor and Jennefer Laidley (Toronto: University of Toronto Press, 2011), 123–50; Gene Desfor and Jennifer Bonnell, "Socio-ecological

Change in the Nineteenth and Twenty-first Centuries: The Lower Don River," in *Reshaping Toronto's Waterfront*, 305–25; and Bonnell, "An Intimate Understanding of Place: Charles Sauriol and Toronto's Don River Valley, 1927–1989," *Canadian Historical Review* 92, no. 4 (2011): 607–36.

2 H. Richardson, W. Chisholm, and J. G. Chewett, "Report of the Select Committee on the Improvement of the Harbour of York," in *Memorandum with Accompanying Plans and Documents Relative to the Past and Present State of the Harbour of Toronto* (Ottawa: Department of Public Works, 1881), Appendix, pp. 1–3.

3 For an excellent history of the reclamation of Ashbridge's Bay Marsh and the creation of the Port Industrial District, see Gene Desfor, "Planning Urban Waterfront Industrial Districts: Toronto's Ashbridge's Bay, 1889–1910," *Urban History Review* 17, no. 2 (1988): 77–91; and Gene Desfor and Jennefer Laidley, eds., *Reshaping Toronto's Waterfront* (Toronto: University of Toronto Press, 2011).

4 For a good overview of the history of Toronto and its development, see J.M.S. Careless, *Toronto to 1918: An Illustrated History* (Toronto: James Lorimer, 1984); James Lemon, *Toronto since 1918: An Illustrated History* (Toronto: James Lorimer, 1985). Bonnell details the history of the Don Valley Parkway and floodplain acquisition in the valley in *Reclaiming Toronto's Don River Valley*. See also Stephen Bocking, "Constructing Urban Expertise: Professional and Political Authority in Toronto, 1940–1970," *Journal of Urban History* 33, no. 1 (2006): 51–76; Wayne Reeves, "From Acquisition to Restoration: A History of Protecting Toronto's Natural Places," in *Special Places: The Changing Ecosystems of the Toronto Region*, ed. Betty I. Roots, Donald A. Chant, and Conrad E. Heidenreich (Vancouver: UBC Press, 1999), 229–41; Richard W. White, *Urban Infrastructure and Urban Growth in the Toronto Region: 1950s to the 1990s* (Toronto: Neptis Foundation, 2003).

5 On the history of the urban ecology movement in Toronto and the significance of valley green spaces, see Gene Desfor and Roger Keil, "Every River Tells a Story: The Don River (Toronto) and the Los Angeles River (Los Angeles) as Articulating Landscapes," *Journal of Environmental Policy and Planning* 2, no. 1 (2000): 5–23; Gene Desfor and Roger Keil, *Nature and the City: Making Environmental Policy in Toronto and Los Angeles* (Tucson: University of Arizona Press, 2004).

6 Several maps still fall under copyright and cannot be made available as digital copy. Other maps were obtained through licensing, which restricts their availability to the public. The Don Valley Historical Mapping Project can be accessed at maps.library.utoronto.ca/dvhmp/.

7 Although detailed classification codes exist for industries in the present (the North American Industrial Classification System [NAICS] and the Standard Industrial Classifications [SIC] are two examples), they are not easily applied to historical industry types, a number of which no longer exist, or are difficult to distill into a single category in the present. With this in mind, we devised our own classification system based on the industries represented in our source materials, and the themes that emerged from the valley's environmental history. These categories included: saw mills; paper mills; grist mills; breweries, distilleries, and their suppliers; foundries and machinists; oil and gas refineries and paint manufacturers; soap works; textile manufacturers and carding mills; other food production; other light manufacturing; fuel storage; building materials producers and suppliers; agricultural suppliers; general suppliers and warehousing; transportation; utilities and public works; chemical producers and suppliers; printers and lithographers; and animal processing.

8 Not widely known outside the GIS community, shapefiles are the most commonly used GIS format around the world. While the format is proprietary and owned by ESRI, most GIS software packages, including open source software, can read and write this format.

9 The Ontario County Map Project can be accessed at: http://maps.library.utoronto.ca/hgis/countymaps/. The project's goal is to compile land occupancy, cultural and physical information in the form of geospatial data, from nineteenth-century Ontario County Maps. The ongoing collaborative project is a partnership between the University of Toronto, the University of Guelph, Western University, and McGill University.

4

The Best Seat in the House: Using Historical GIS to Explore Religion and Ethnicity in Late-Nineteenth-Century Toronto

Andrew Hinson, Jennifer Marvin, and Cameron Metcalf

In 1881 Toronto's Knox Presbyterian Church underwent major renovations to the inside of the building. The pulpit was lowered, the gallery front changed to iron, the pews comfortably upholstered, the entire floor carpeted, and the ceiling repainted and decorated. Most significantly, the seating arrangement was changed from the traditional straight-benched pews in formal order to a modified amphitheatrical layout with semi-circles forming around the pulpit. The realignment of the church's pews necessitated a reshuffling of where congregants were seated. Yet if contemporary reports were true that the refurbished auditorium was "virtually a new room" and in terms of artistic arrangement and taste "second … to no church in Toronto,"[1] this congregant reshuffling was only a minor inconvenience.

In choosing a new pew, church members had to decide not only where they wished to be seated but also how much they were willing to pay for the privilege. Pew rents were a long-established mechanism for generating church income and enabled parishioners to contribute an amount in keeping with their means. From 1881 Knox had five levels of rental, the amount reflective of the pew's proximity to the pulpit. With the exception of those at its side, which were rented at $1 per

quarter, all seats within the body of the church were $1.25. In the gallery all front rows were also $1.25, with the second, third, and fourth tiers along the length of the church being 80¢, 60¢ and 50¢, respectively, and those facing the front $1. Where everyone opted to sit was recorded in the Knox Presbyterian Church Pew Rent Book, 1882–1887.[2]

While surviving pew rent books are relatively rare, the value of documents that provide insight into the lives of "ordinary" people have long been recognized by social historians, including those focusing on religious history who since the 1980s have been primarily concerned with the "view from the pew" rather than a top-down history.[3] Organized by pew number, the book clearly shows who sat next to whom, how much rent each entrant paid, and the duration in which they remained in that place. Arrivals to and departures from the church can easily be determined, as can movement within the church, the pew rent book recording when and where a change in pew occurred. Also preserved are details of those who paid the rent, which in most cases would be the head of family, including their name, occupation, and address. For example, throughout 1882 sitting in pew 44 (a $1.25 seat in the body of the church) was George Noble, a merchant residing at 701 Yonge Street, who sat next to John Ritchie, a plumber living at 189 Jarvis Street. Both paid for three sittings at a cost of $3.75 per quarter, meaning each was accompanied by two companions, possibly a wife and child, or an elder dependant. Although the disappearance of historical blueprints of the church interior make it impossible to determine the exact layout of the church, it can be surmised that both men were surrounded in some fashion by Alexander Cameron, a barrister at pew 42, John Sinclair, another merchant at 43, James Fleming, a seedsman and florist at 45, and A. M. Smith, a wholesale grocer at pew 46. As such, the data from the pew rent book can be used to shed considerable light on the Knox congregation, fitting alongside the work of other historians and social scientists in Canada who have used church memberships and similar types of records.[4]

Yet as well as being located within a few seats of each other, these men shared something else in common. Although ethnicity was not recorded in the pew rent book, by linking them to the 1881 Canadian census we discover that they were each Scottish, a finding consistent with another study, which showed a high proportion of Scots among church elders and managers from Toronto Presbyterian churches.[5] This is not particularly surprising considering Presbyterianism originated primarily in Scotland, and Knox Church itself was established after members broke away from Toronto's St. Andrew's Church following a major schism in the Church of Scotland in 1843. The church also had a connection with the city's Scottish Gaelic community, playing host to the Toronto Gaelic Society's bible classes and holding occasional Gaelic sermons. Although not all Scots were Presbyterian, and not all Presbyterians living in Toronto were Scottish, Knox, along with most Presbyterian churches in the city, did maintain a strong Scottish character and, as with the relationship between other ethnic groups and their religious buildings, there is much evidence to suggest that these churches formed the core of Toronto's Scottish community.[6] Indeed the correlation between the Scots and the Presbyterian Church is arguably of greater significance than similar connections with other groups owing to the fact that,

in almost every other respect, Scots blended into the wider Toronto population.[7] This was particularly so regarding their geographic concentration. Whereas Little Italies and Chinatowns were readily identifiable ethnic enclaves, there was no such common equivalent among Scots in Toronto. While ethnic trappings such as cafes, grocery stores and restaurants, travel agencies, and other services were apparent in other ethnic neighbourhoods, the same does not appear to have existed in any one particular area for the Scots.[8] Although there were Scottish clubs and societies throughout the city, none enjoyed the same level of membership nor were any as pivotal to Scottish identity as the Presbyterian Church.

The pew rent book is therefore of value to both religious and ethnic history and, by using traditional historical methods, could help to inform in both these areas. It is, however, by combing the data from the pew rent book with GIS technology that genuinely significant steps can be taken in providing new insights into previously unexplored relationships between where congregants lived and their place of worship. With the use of GIS, residential patterns can be examined, which not only inform about the geographic dynamics of Toronto's decentralized Scottish community but enable spatial questions of a Canadian church congregation that otherwise could not be answered. Whereas the drive for a "bottom-up" history of religion in Canada has led to considerable advances in our understanding of church demographics, the role of family and gender in worship, and the cultural history of religion, to date there are few detailed geographic analyses. Even where studies of religion and ethnicity intertwine, these have yet to take advantage of the potential of GIS.

The research in this chapter shows how GIS can make a significant contribution to religious and ethnic history. In presenting our findings, we have two aims. The first is to provide a general spatial analysis of the Knox congregation using the address data for the period between 1882 and 1887. What we find is a church that drew its congregants from across the city. Congregants demonstrated considerable loyalty to the Knox community, choosing Knox over other Presbyterian churches closer to home. This study also reveals a dynamic social space, both within the church, where congregants changed pews regularly, and outside it, as a large number of congregants moved house, some more than once, within the period of study. The second objective is more specific and pertains to the unusual insight offered by the pew rent book into where congregants in the church were seated. Recall the merchant George Noble, who was seated next to John Ritchie, a plumber. On the one hand, it may be surprising to find two individuals from different socioeconomic classes seated next to each other; on the other, the church was a setting where, at least in theory, social divisions did not matter. Using GIS, we explore the socioeconomic dynamics within Knox and show how they manifested themselves outside the church building.

METHODOLOGY

Detailing all quarterly payments for seats occupied between 1882 and 1887 along with those who made them, the pew rent book provides a fascinating insight into a church community in this period. What is not given are the

names and details of family members for whom payments were made. In order to capture this information, Communion Rolls were used as a second, complementary data source. Published in the church's annual reports, these lists include the name of each church member, their address, the church district in which they lived, and whether or not they were receiving communion. As well as providing details of the excluded family members, the primary advantage of introducing this second source is the inclusion of addresses for all church members throughout the six-year period, which unlike those in the pew rent book, appear to have been kept up-to-date.

The data from both sources were entered into spreadsheets and then imported into a relational database, which was required to link the two datasets. Having the data stored in a database also enabled anomalies to be corrected, including variations in first names, where, for example, "Wm" and "William" might both appear as separate entries for the same individual. The completed database contains a total of 785 persons in the pew rent data set, 2,736 in the Communion Rolls, with 389 linkages being made between the two sources, a valuable analytical tool in its own right. It also provided a secure repository for the data, protecting the investment of time and effort associated with data collection, revision, and consolidation for the project. Finally, it ensured compatibility with GIS software, enabling the creation of tables that could in turn be imported into a GIS environment.

To accurately reflect Toronto in the late nineteenth century, a modern street network dataset was backdated to 1884 using contemporary fire insurance plans as a reference, by altering the physical road layout, street names, and address ranges. The addresses from the database were then geocoded, a process by which addresses are plotted onto a map surface, with a match rate of 87 per cent (7,383) matched, 7 per cent (594) tied or possible match, and only 6 per cent (509) unmatched. While the database administration and the historic roads layer preparation were both time-consuming pursuits, the high match rate meant that any results produced through spatial analysis could be regarded with considerable confidence. Throughout the project various GIS techniques were used. All the maps were generated using GIS and several different tools were employed to analyze the spatial data that contribute to our findings. The project utilized a diverse range of skill sets brought to it by a project team that consisted of a database administrator, a GIS librarian, and a historian.

A COMMUNITY OF THE MIND

Having grown steadily since its establishment in 1843, from the 1880s Knox underwent unprecedented growth. These changes reflected Toronto's dramatic rise in population in the last decades of the nineteenth century. From 86,000 residents in 1881, Toronto's population more than doubled to 181,000 by 1891. Although this was in part due to annexations of some of the city's neighbouring districts, the onset of industrialization precipitated the arrival of many newcomers in search of employment opportunities. An increasing number of Toronto residents, new and established, chose Knox Presbyterian Church as their place of worship.

During the six-year period covered by the pew rent book, the church's population climbed from 1,093 in 1882 to 1,624 by 1887. That so many new members could be physically accommodated was due to the increased seating capacity brought about by the church's timely renovations. Certain administrative changes did, however, have to be made. Most notably the number of church elders and deacons who were responsible for the care and oversight of the congregation had to be increased. All congregants were assigned to a church district, each with their own elder and deacon. The boundaries of these districts were printed alongside the Communion Rolls and can be recreated in a GIS to visualize how these administrative units changed over time (Fig. 4.1). As well as revealing the creation of three new districts over the six years, the map can also be used to show the proportion of congregants living in each district. Comparisons of the before (1882) and after (1887) images demonstrate that in redrawing the boundaries and establishing new districts, the church's administrators sought a more equal distribution of population among them. This is clearly illustrated by examining district 12, which in 1882 contained an above-average proportion of the church's population (between 9 and 12 per cent) but was subsequently split in two (with the creation of district 17), both of which by 1887 contained less than 6 per cent of church members. What is also evident is that, along with a growth in congregation size, there was a considerable increase in the church's geographical catchment area. Whereas, in 1882, the districts' northern boundaries stopped at Bloor Street and did not go much east of Berkeley Street, within five years they incorporated parts of the Rosedale and Yorkville neighbourhoods

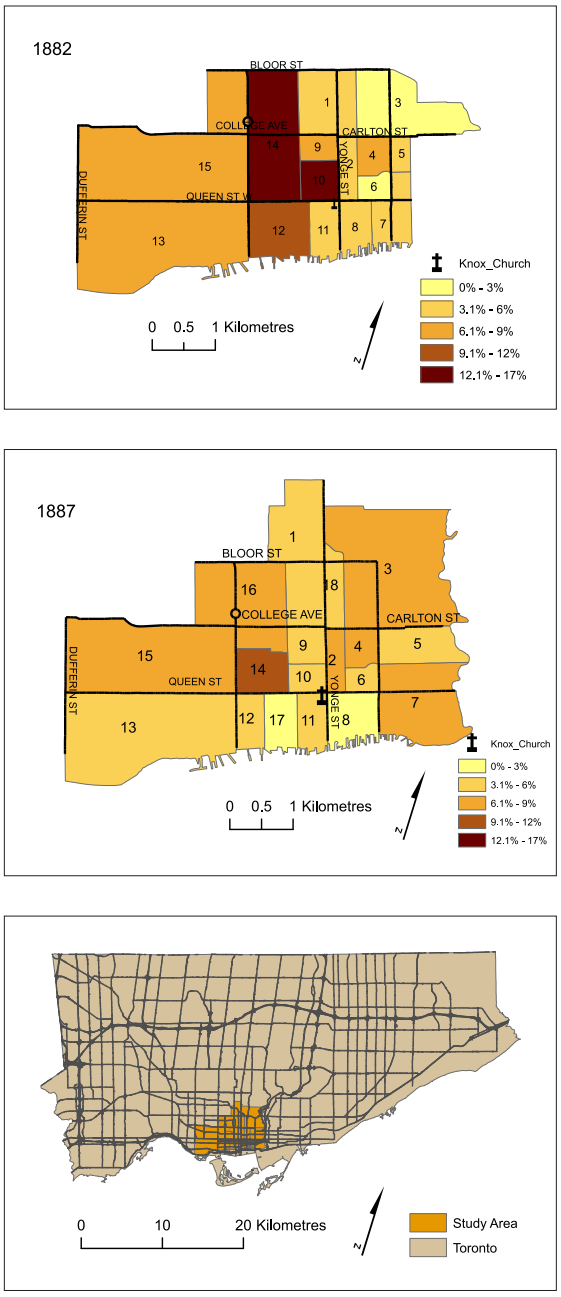


Fig. 4.1. Percentage of Knox congregants by church district. (Sources: 1882 and 1887 Church Districts: created using description of districts in Knox Presbyterian Congregation Rolls 1882–1887; Knox Presbyterian Church Congregants: Knox Presbyterian Congregation Rolls 1882–1887.)

in the north, and stretched to the Don River in the east. In total the church districts went from covering an area of fifteen square kilometres to twenty.

The specific whereabouts of the congregation by 1887, as detailed in the Communion Rolls, is shown in Figure 4.2. Confirming the extent to which the membership was dispersed across the city, it is apparent that Knox cannot be considered a neighbourhood church. This is contrary to what may be assumed in an age when the primary means of getting to church was on foot. Although some may have relied on private carriages or hired hacks (taxi drivers), streetcars were the city's primary form of transport and were utilized by all classes of the population but would not be introduced on Sundays for at least another decade.[9] GIS can be used to measure distances, and by doing so it can be calculated that on average parishioners travelled 2.4 kilometres to and from church, and for those living in the city's outer limits, it could involve a round trip of up to ten kilometres.

In other respects, however, it is not unexpected that the Knox congregation mostly came from outside the church's immediate proximity. When the eighty-three members broke away from St. Andrew's to form Knox Presbyterian Church, it was because of differences they had with its parent body, the Church of Scotland. As the city's only representative of the Free Church of Scotland, its congregation was probably never confined to its immediate geographic locality. The significance of this, however, should have lessened after 1861 when the Free Church Synod in Canada and the United Presbyterian Church (formed following an earlier Church of Scotland schism) merged to form the Canadian Presbyterian Church, and even more so after 1875, when the Church of Scotland in Canada was brought into the fold to form the Presbyterian Church in Canada. In theory these changes eliminated any of the denominational differences that had previously existed, leaving no theological reason to prevent Toronto's Presbyterians from attending their local branch. Yet this appears not to have happened. Within its historical records, the only real reference to Knox's immediate surroundings around this time pertains to its missionary activities. In a sermon to the Knox congregation to mark the Rev. H. M. Parsons' tenth anniversary at the pulpit, the minister made an appeal for a greater voluntary effort from his parishioners, stating: "The field around this church building is more needy than ever.… The city between Queen Street and the Bay, from Sherbourne to York, is our field with no one else to till it."[10] He made reference to the good work being carried out by the church's mission on Duchess Street but appealed for another on York Street, where a special effort was needed within what he described as a "leprous portion of the city." While the church may have accepted responsibility for this part of the city, few of the church's congregants actually lived there.

As well as displaying the distances congregants lived from the church, Figure 4.2 shows that, in making their way to Knox, many had to pass other Presbyterian churches on route. By using GIS to calculate which Presbyterian church parishioners resided nearest, it is found that only 145 members (14 per cent) lived closer to Knox than another Presbyterian church. Considering the close proximity of some of the churches, a degree of membership crossover would be expected, but the extent to which this occurred reaffirms that any relationship

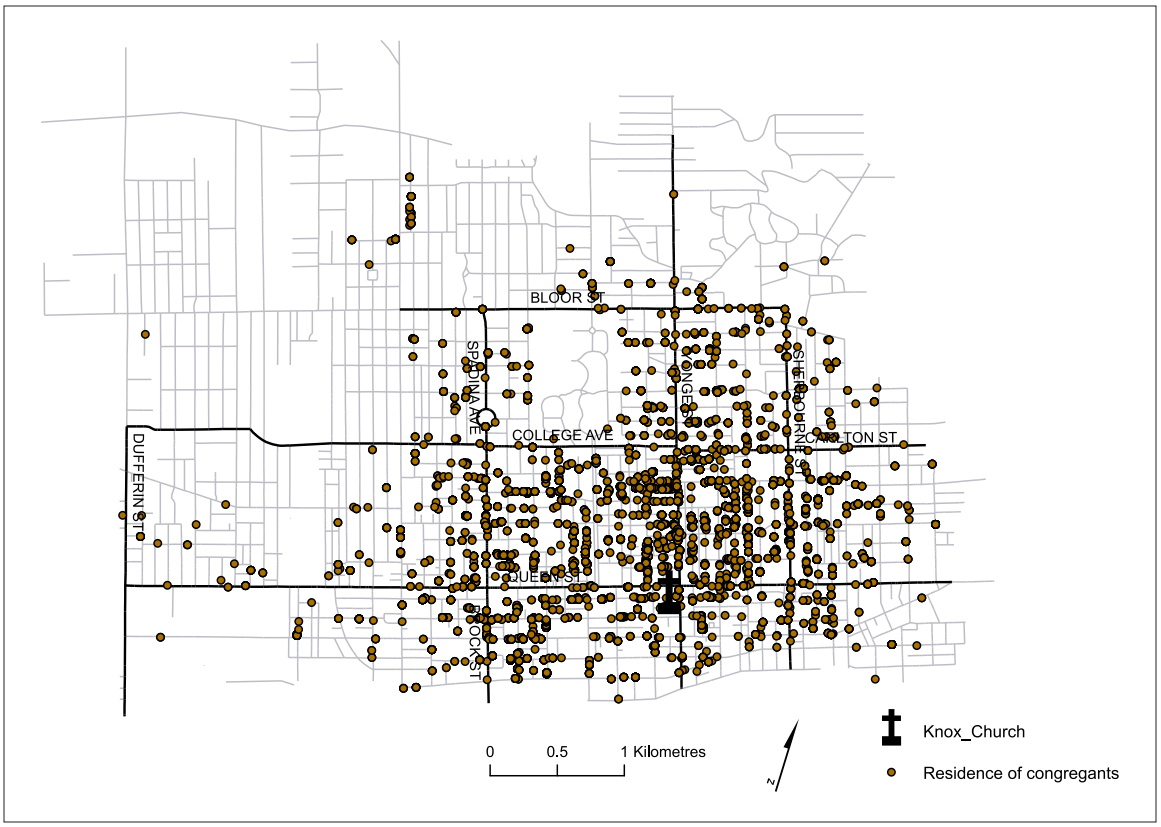


Fig. 4.2. Residential distribution of Knox congregants, 1887. (Sources: 1884 Toronto Streets: Adaptation of DMTI rte 2010; Knox Presbyterian Church Congregant Addresses: Knox Presbyterian Congregation Rolls 1882–1887.)

between Knox and its immediate geographical community was minimal.

In *Streets of Glory: Church and Community in a Black Urban Neighbourhood*, American sociologist Omar McRoberts has shown a similar lack of attachment between parishioners and the surrounding area of their church building in Boston at the turn of the twenty-first century.[11] Rather than being connected through geography, he argues congregants shared something else in common, such as ethnicity, class, lifestyle, or political orientation. This helps to explain another recent observation by religious commentators, that of "shopping for Faith," where worshippers find where they are most comfortable by trying out not only different branches of the same denomination but different religions altogether.[12] While this may be recognized among social scientists as a current trend, this study indicates that it is not a new one. Hannah Lane's demographic analysis of small-town New Brunswick in the mid-nineteenth century shows that there was a high degree of religious fluidity with worshippers moving frequently among the major and minor Protestant denominations, but what we see here is that churches of the same Protestant denomination were also theoretically in competition with each other for members.[13]

The question that arises is what specifically attracted worshippers to Knox.

Of the possible commonalities between church members listed by McRoberts, several may have been applicable to Knox. Ethnicity was undoubtedly one factor, and in the case of Knox's nearest Presbyterian neighbour, Cooke's Church, it can be used to explain why one church was chosen over the other. Cooke's was established in 1851 after a group of Irish members left Knox to form their own congregation. What led to this break remains a mystery, but, from the outset, ethnicity was an important part of the breakaway church's identity, its name being taken from a key figure in the development of Irish Protestantism, and the membership and ministers being mostly of Irish origin.[14] But while Cooke's may have been the city's only Irish Presbyterian Church, Knox was certainly not alone in being of Scottish character. Regionalism offers another possibility. With Knox playing host to city's Gaelic Society bible classes and occasional Gaelic sermons, there could have been a link to Scotland's Highland community, but beyond the Gaelic connection there is little evidence to support this.

Although there are no data to support an analysis of political orientation (another possible commonality), John Moir, author of the most authoritative history of Presbyterianism in Canada, argues that members of the Established Church of Scotland were more likely to support the Conservative party in politics, whereas the Free Church Secession groups usually could be counted as Liberals.[15] Separate denominations within the Presbyterian Church in Canada no longer existed, but it is quite possible that erstwhile traditions lived on.

The inclusion of occupational data in the pew rent book makes it possible to analyze the socioeconomic characteristics of the church. Occupations are given in the pew rent book for 270 congregants, which have subsequently been divided into occupational classifications.[16] As Table 4.1 demonstrates, occupations that fell into the skilled non-manual category were greatest in number, followed by skilled manual, and then professional. Although there were members in the unskilled and semi-skilled categories, these groups were underrepresented with a combined proportion of only 12 per cent. There are several possibilities as to why this was. First, only 34 per cent of entrants in the pew rent book have their occupation listed next to them, and it is probable that those with higher status occupations would be more inclined to share this information than those at the opposite end. In Scotland, where lower attendance has also been found among the poorer classes, several explanations have been offered, including alienation through the implementation of church discipline based on middle-class values, or simply being too poor to attend.[17] As well as not possessing "Sunday best" attire, the demand for pew rents was given by the urban poor as a reason for not attending church. A Royal Commission into Religious Instruction in Scotland carried out in 1836 stated:

> The dislike of the people to occupy low priced or gratuitous sittings, avowedly set apart for the poor, which in general such as to make those who occupy them marked and distinguished from the rest of the Congregation, and the inferior nature of the accommodation provided for them, operate in preventing attendance…. [W]hile it may

> not be difficult to supply himself with a sitting, a poor man is frequently unable to pay for adequate accommodation for himself and his family.[18]

While exceptions exist, such as the case of Mrs. Adams of 18 Ord Street whose fees were waived because of her inability to pay, Knox did not assign general free seats. The church did of course have variations in pew rents, and it is possible that there was a stigma attached to sitting in the cheaper seats. Rosalyn Trigger's study of Protestant churches in Montreal discusses moves to abolish pew rents at certain churches in the late nineteenth century specifically because they made distinctions on the basis of wealth, and, at Knox, some of the movements between pews that took place from 1882 to 1887 suggest that ability to pay did influence where people sat.[19] Mrs. Hunter of 149 Sherbourne Street, for example, started out at a $1.25 seat (pew 123) but moved to a $1 pew (pew 183) when the number of sittings she was paying for increased from one to three. William McFarlane, on the other hand, when paying for three sittings, was located at a $1 pew (pew 11) but moved to a $1.25 seat (pew 107) when the number of sittings he was paying for reduced to two. Money does not however appear to have been the only factor influencing why people moved seats. One of the most striking features of the original pew rent book is the extent of transiency between pews. Overall, 132 separate rent payers changed pew between 1882 and 1887, many of whom moved more than once. A clerk named James Donaldson was recorded as moving pew no fewer than five times, shifting inconsistently between the $1 and $1.25 seats. With a skilled non-manual occupation and no apparent dependents, it is unlikely that cost was an influencing factor in where he sat.

Table 4.1:
Occupational Categorization of Knox Congregants, 1882–87.

	No.	%
Professional	59	21.9
Skilled non-manual	95	35.2
Skilled manual	84	31.1
Semi-skilled	20	7.4
Unskilled	12	4.4
Total	270	100

Table 4.1: Occupational Categorization of Knox Congregants, 1882–87. (Sources: occupation: Knox Pew Rent Books 1882–1887.)

Just as it would involve little more than guesswork to provide a reason as to what prompted James Donaldson to move around the church with such regularity, explanations of what brought the Knox community together are equally speculative. Individuals may have preferred the church for reasons previously mentioned; they may, too, have made their choices based on much less quantifiable reasons, such as a shared preference for the Rev. Parsons' preaching style or the comforts of sitting on a cushioned as opposed to a hardback wooden pew. Indeed, one of the purposes behind the Knox renovations was to boost church membership, an acknowledgment that, even in 1882, aesthetics (and comfort) mattered.[20] Another localized issue that may have affected membership was the use of organ music. A hotly debated topic among the Presbyterian Church in Canada's General Assembly, the issue was passed down to individual congregations to decide for themselves. At Knox, the

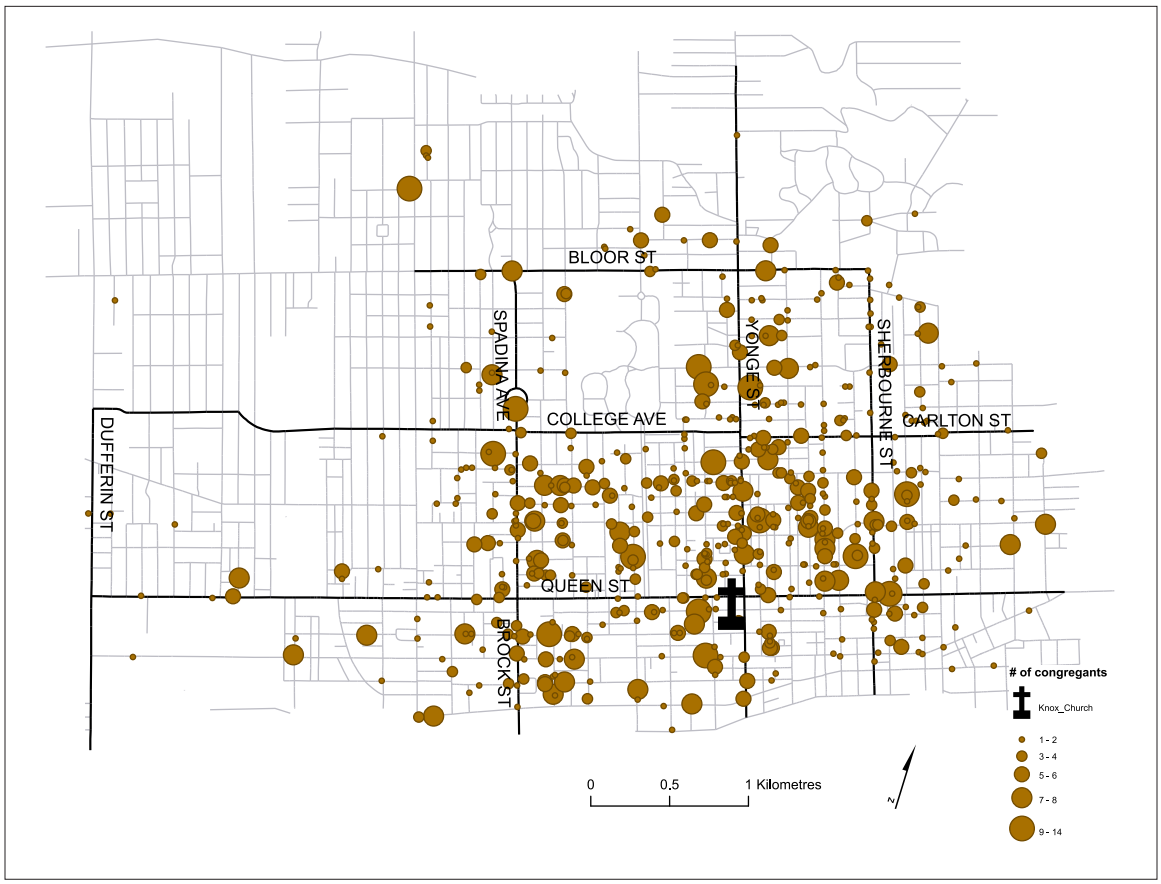


Fig. 4.3. Number of Knox congregants by address, 1887. (Sources: 1884 Toronto Streets: Adaptation of DMTI rte 2010; Knox Presbyterian Church Congregant Addresses: Knox Presbyterian Congregation Rolls 1882–1887.)

use of organ music was first raised in 1873 but was consistently voted against until 1878, after which a further three years passed before an organ was finally installed. That the controversy was long to abate is suggested by a *Telegram* reporter who, after recounting the offering being taken after the service "in silence," commented: "no doubt this unusual custom is a concession to those who yet, *in spite*, oppose the use of the organ."[21] While some clearly opposed the bringing of music into the church, for others it may have been what enticed them to Knox over other places of worship.

Finally, one of the most likely reasons that people chose Knox over other places of worship was because of family. Although neither the pew rent book or Communion Rolls indicate family relationships, Figure 4.3 gives an indication of the multiple-person households among the congregation. Not all, but probably most, of these households were made up of families. Furthermore, not all family members lived in the same household. Scottish households in Toronto consisted of mostly nuclear families, and it is quite possible that many of the congregants were part of extended families

who attended the church. More than just a place of Sunday worship, church for Scottish Presbyterians formed an important part of their lives. As such it makes sense that families attended the same church and more generally that, in picking where to become a member, parishioners did not simply choose the church closest to home.

A TRANSIENT COMMUNITY

In spite of the considerable growth Knox experienced between 1882 and 1887, the church also lost many members during this time. The fluidity of church membership can be seen in the statistical tables included in most of its annual reports. In 1883, for example, although 138 new communicants were added to the roll during the year, the net increase was only 56.[22] That it was not higher was due to nine deaths, thirty-one members being placed on the retired list due to absence, and forty-two being removed by certificate to other churches. Over the entire period between 1882 and 1887, of the 311 heads of household recorded in the pew rent books at the beginning, less than half (189) were still there in 1887. According to the Communion Rolls, 433 joined the church in this period, and 250 left. The destinations of those who left the church are largely unknown. An 1885 annual report for Knox, however, grants us a small insight in stating the destinations of those parishioners who were granted certificates to join another church. Some were leaving the city, such as Alice Brodie, who was destined for Edinburgh, Scotland; a further seven were headed to the United States and four to other parts of Canada. Most, however, (twenty-four) were to remain in Toronto, splitting themselves between Charles Street, West, Cooke's, Leslieville, St. Andrew's, Old St. Andrew's, Parkdale, College Street, and Central Churches. In at least three cases, the moves seem to have been the result of a marriage; for others, the reasons for leaving are as debatable as those that brought congregants to Knox in the first place. That no one church was favoured would suggest that individuals considered a range of factors in making their decisions. This level of transiency was not unique to Toronto and, as Peter Hillis' study of church membership in Glasgow would suggest, was part of a much wider phenomenon. Of the 2,481 members recorded on the Barony of Glasgow Communion Roll between 1879 and 1883, 668 people joined the church in this period while 713 left.[23] As with Knox, some of the members who left did so for destinations far afield while others moved on a more local scale, remaining within Glasgow.

Those who remained in Glasgow, Hillis argues, left the church because they moved house. While this may account for some of the membership turnover at Knox, as has been shown, close geographical proximity to the church building was not of great priority to its members. Furthermore, it can be seen from the Knox Communion Rolls that many congregants who did move house continued to worship at Knox. In total 759 parishioners (28 per cent) moved house and remained at Knox, and many did so several times in the period of study. This high level of mobility is consistent with other North American studies of urban centres. Howard Chudacoff's examination of residential mobility in Omaha found that, between 1880 and 1920, only 3 per cent of his case

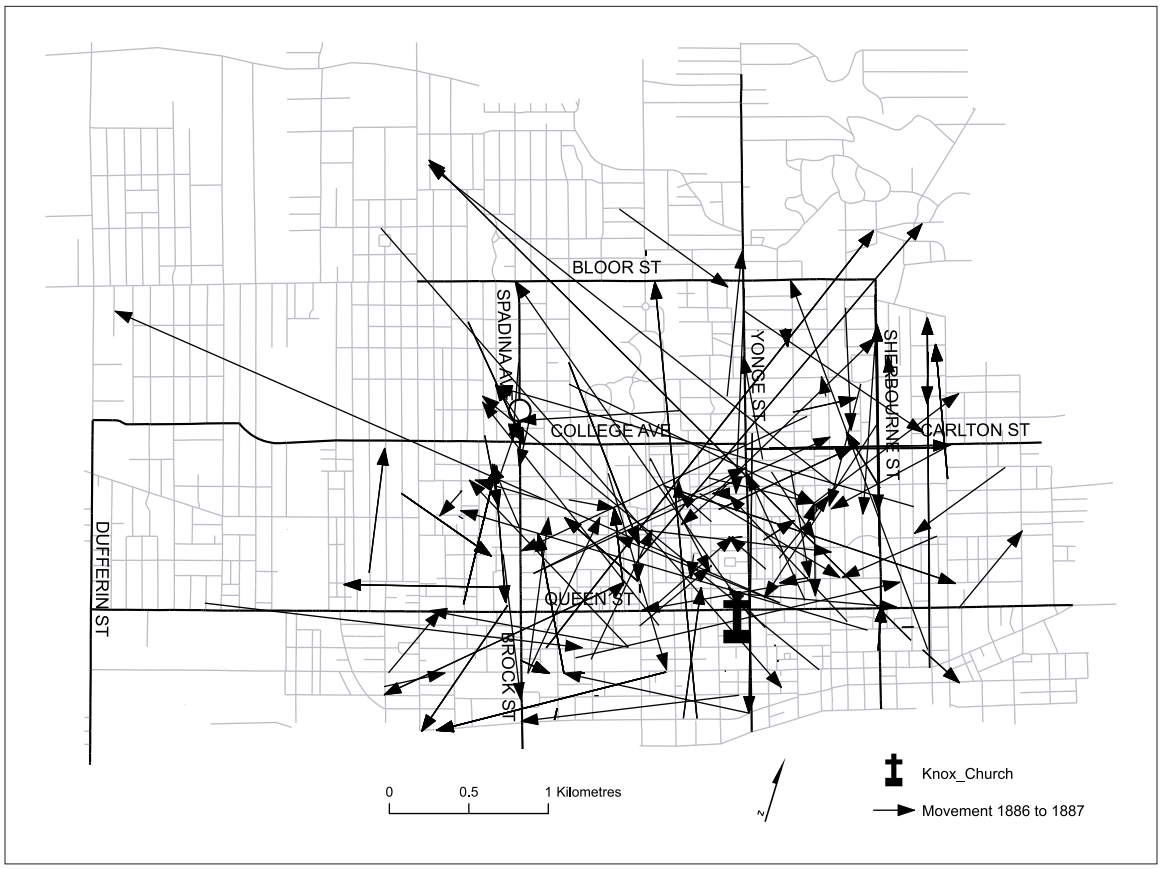


Fig. 4.4. Tracking residential movement of Knox congregants, 1886–87. (Sources: 1884 Toronto Streets: Adaptation of DMTI rte 2010; Knox Presbyterian Church Congregant Addresses: Knox Presbyterian Congregation Rolls 1882–1887.)

study lived in the same place for as long as two decades. Slightly under half moved away from the city within five years and over two-thirds left within twenty. Of those who remained in Omaha for twenty years, the overwhelming majority occupied three or more homes.[24] Closer to Toronto, Michael Katz's study of Hamilton, Ontario, has shown a similarly high turnover in population. Looking at the decades between 1851 and 1871 in his study, only 6 per cent of those living in Hamilton at the end of this period had been there twenty years earlier. Of those who were there at the beginning of each decade, about two-thirds of the entire population and over one-half of household heads left Hamilton in the ten years that followed.[25] What Katz's study does not take into consideration, however, is the levels of transiency amongst those living within the city.

By separately plotting the addresses from each of the annual Communion Rolls, GIS makes it possible to track the movements of parishioners who changed residences from year to year. Figure 4.4 shows the relocations between 1886 and 1887, the year in which there was greatest movement. Not only does this reinforce the extent of transiency, but the map gives a sense of where people were moving.

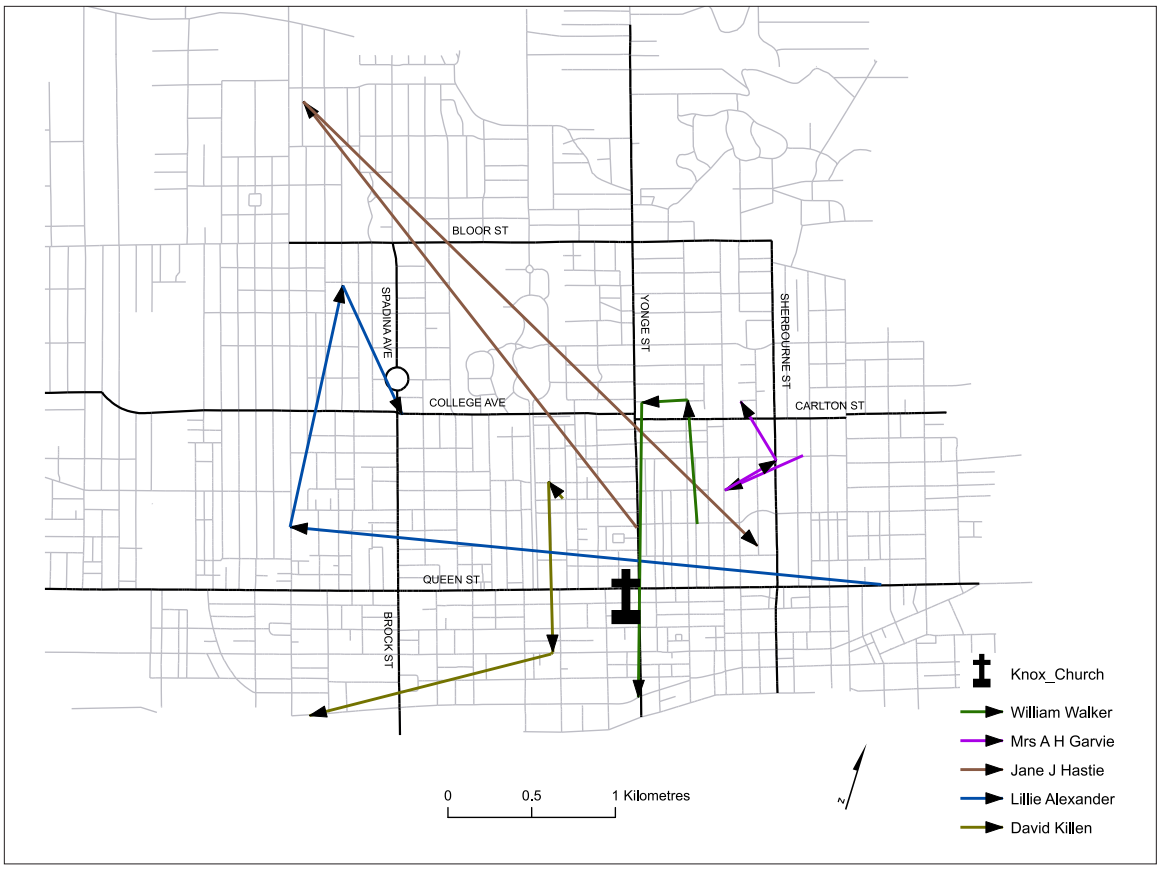


Fig. 4.5. Residential movement of selected Knox congregants, 1882–87. (Sources: 1884 Toronto Streets: Adaptation of DMTI rte 2010; Knox Presbyterian Church Congregant Addresses: Knox Presbyterian Congregation Rolls 1882–1887.)

What is striking is the lack of discernible pattern, there being no consistency to the direction or distances moved. This is not unique to this year, and when the movements for each consecutive year are compared (not shown), the only notable trends are the general increase in people moving, which is most likely a reflection of the congregation's growth, and a greater average distance being moved each year.

Even more intriguing are those congregants who moved more than once. Chudacoff's study of Omaha recognizes that multiple moves took place over two decades. Some Knox congregants had different addresses for each of the six years under examination, suggesting that the levels of transiency within Toronto may have been even greater. This should be of particular interest to urban historians and is a good illustration of how the findings of a narrowly focussed case study such as this can inform more widely. Focussing on the individual movements of several of those parishioners who relocated more than once between 1882 and 1887, Figure 4.5 gives a sense of their contrasting relocation patterns. Of those shown, the shortest overall distance moved was by Mrs. A. H. Garvie: although she relocated on three occasions over those six years, the

accumulated distance between houses was little over 1.2 kilometres. Clearly in moving house, Mrs. Garvie made a conscious effort to remain in the same area. Elizabeth Platt, on the other hand, moved a total of seven kilometres in only two moves. As can be seen though, having moved to the outskirts of the city, where she stayed for two years, she subsequently returned to within a few hundred metres of where she originally resided. Both David Killan and William Walker can be seen making two relatively localized moves before a more significant shift, in the case of Killan considerably to the east of the downtown core. Conversely Lillie Alexander begins with a significant move across the city, before two further localized moves.

Why were people moving in these ways? Michael Katz warned that "the search for tidy reasons to explain why some men moved and others did not will never succeed." Even still, economic reasons are generally seen as being at the heart of the decision to move.[26] On the one hand, this could involve moving to be nearer a place of work, or as a recent study by William Jenkins on the Irish in Buffalo argues, it could reflect a change in occupational status.[27] Using a sample of Irish heads of household, Jenkins traces them at five-year intervals from 1881 to 1911 using city directories. Consistent with the two previously mentioned studies, half of these were not traceable in 1881, and by 1911 there were details for only seventy-four households. For those who could be traced, however, Jenkins's analysis shows a spreading out of families from a distinctively Irish and working-class area of the city to those with mixed class and ethnicity. Although he cautions against overdrawn conclusions of a blooming Irish American "middle class," he does suggest that Buffalo's west side emerged as the "choice destination" for the city's Irish working class.[28] While the overall inconsistency of the movement among the Knox parishioners makes it difficult to identify a similar pattern, it is possible to explore movement among those living in one of the city's poorer areas. We tracked the movement of sixty-one parishioners who either moved to, from, or within Knox's missionary area. Of these, only seven moved from one part of the zone to another, while a total of sixteen moved in and thirty-eight moved out. As can be seen in Figure 4.6, although there is no consistent destination, most made significant moves away from the city's downtown core. While this could be an indication of upward social mobility, the apparent randomness of their destinations suggests that other factors were at work. In his study of Omaha, Chudacoff found that the most important factors affecting the decision to move were household and environmental needs. As a family passed through its lifecycle, those needs changed, and the inflexibility of any one home in meeting these needs produced residential turnover. Pointing to a mid-twentieth-century survey of American urban dwellers, Chudacoff notes that the prime complaint against a former residence was lack of closets and lack of open space. "In other words, when a man made the decision to move, he had in mind a series of optimal specifications concerning the quality of and amount of space in his new and still unchosen residence."[29] The inconsistency in the pattern of residential mobility among Knox parishioners would suggest that the decision to move was an independent choice based on factors pertinent to each individual.

More research is required to determine the specific reasons as to why people moved when and where they did. While GIS cannot alone

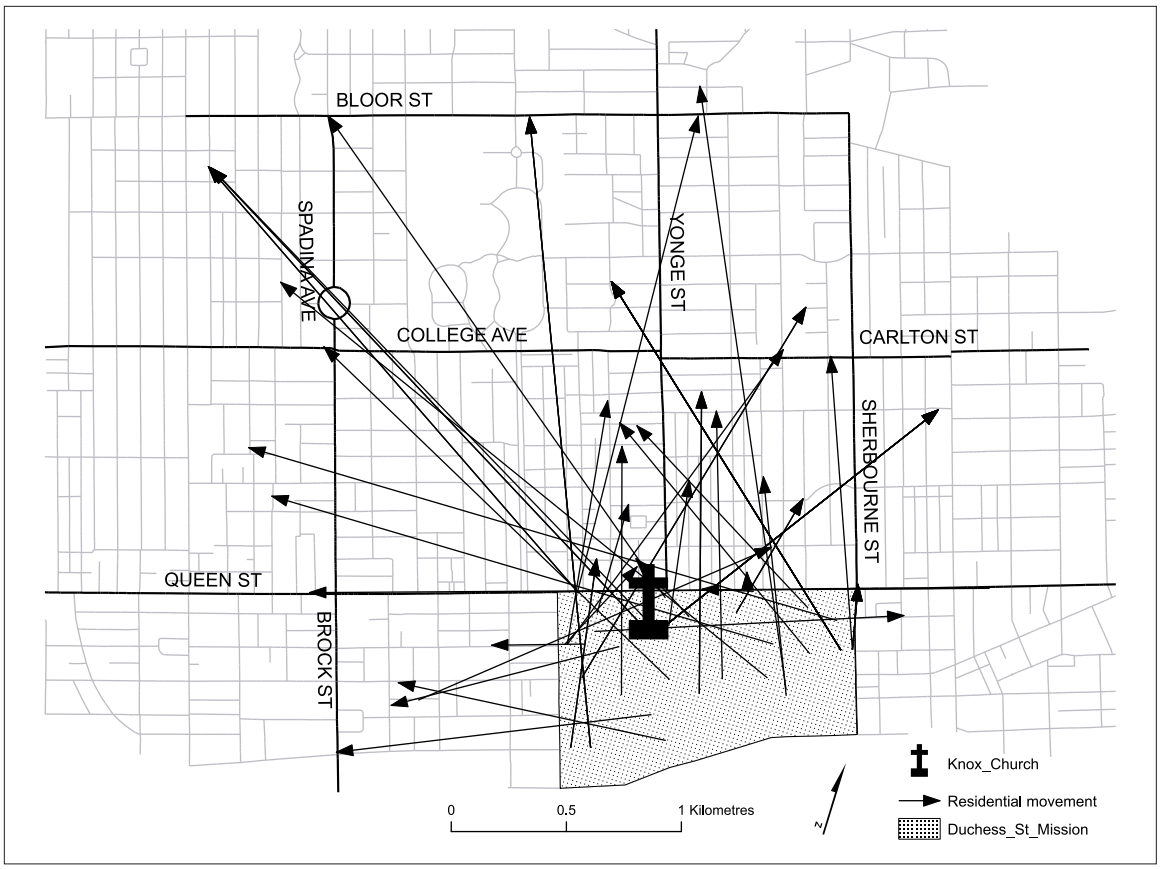


Fig. 4.6. Residential movement from Knox missionary zone, 1882–87. (Sources: 1884 Toronto Streets: Adaptation of DMTI rte 2010; Knox Presbyterian Church Congregant Addresses: Knox Presbyterian Congregation Rolls 1882 –1887.)

answer these questions, it is because of GIS that our understanding of transiency among the Knox congregation is considerably greater than simply knowing its extent. By being able to project onto a map the destinations to which individuals moved, we have gained a significant insight into, not only the Knox community in the late nineteenth century, but Toronto urban history more generally.

AN EGALITARIAN COMMUNITY?

Although upward social mobility does not appear to have been the primary factor behind moving, it does return us to the issue of social status. As we have shown, one of the values of the pew rent book is its insight into the seating arrangements of the church, which, paired with its accompanying occupational information, gives the potential for examining how the socioeconomic dynamics of the congregation manifested themselves within the church

Table 4.2: Occupational Categorization Cross-tabulated with Quarterly Pew Amount, 1882–87.

	Quarterly pew amount					Total
	50¢	60¢	80¢	$1	$1.25	
Professional	0	2	0	8	115	125
Skilled non-manual	4	3	3	22	91	123
Skilled manual	3	7	18	61	84	172
Semi-skilled	0	0	0	8	19	27
Unskilled	0	0	0	3	9	12
Total	6	12	21	102	318	459

Table 4.2: Occupational Categorization Cross-tabulated with Quarterly Pew Amount, 1882–87. (Sources: Pew rent amount and occupation: Knox Pew Rent Books 1882–1887.)

walls. It has already been shown that there were socioeconomic differences among parishioners, but as our example of the plumber seated next to the merchant suggests, these may have mattered little. Further scrutiny using the pew rent data (Table 4.2) reveals that, while those in the top occupational category (professional) were predominantly seated in $1.25 seats, the converse was not true for those in the lower levels. Most congregants with skilled non-manual occupations were also in $1.25 value pews, as were almost half of those in the skilled manual category. Clearly socioeconomic status had some bearing on where one sat but not to the extent that it could be considered a barrier to being seated next to a higher socioeconomic grouped parishioner, and certainly not to enjoying a good view of the alter. Before concluding that Knox Presbyterian Church was a place where socioeconomic realities could be left outside, however, it is important to determine if this was something that occurred only inside the church or if it was part of a more general phenomenon. That professionals and manual workers sat alongside each other could in fact be a reflection of Toronto's Scottish community or Toronto as a whole. It must therefore be ascertained if there was any evidence of class "segregation" outside the church.

Unlike Buffalo, Toronto did not have a clear frontier dividing social classes, but as with all Victorian cities the extremes of rich and poor were all too evident. Charles Pelham Mulvany's *Toronto: Past and Present*, published in 1884, describes some of the city's main arteries. Among the most elite addresses were the "sumptuous private residences" of Rosedale, closely followed by Jarvis and Sherboure Streets, both of which were lined on either side "by the mansions of the upper ten." In contrast were Elizabeth Street with its "unsavoury appearance and repute," Centre Street, "another slum," and worse still York Street, which according to Mulvany was "occupied by dingy and rotten wooden shanties."[30] By mapping the pew rent payers based on their occupational groups, it is possible to determine the extent to which these correlate to Mulvany's evaluation.

The GIS techniques used so far have mostly involved producing maps that can

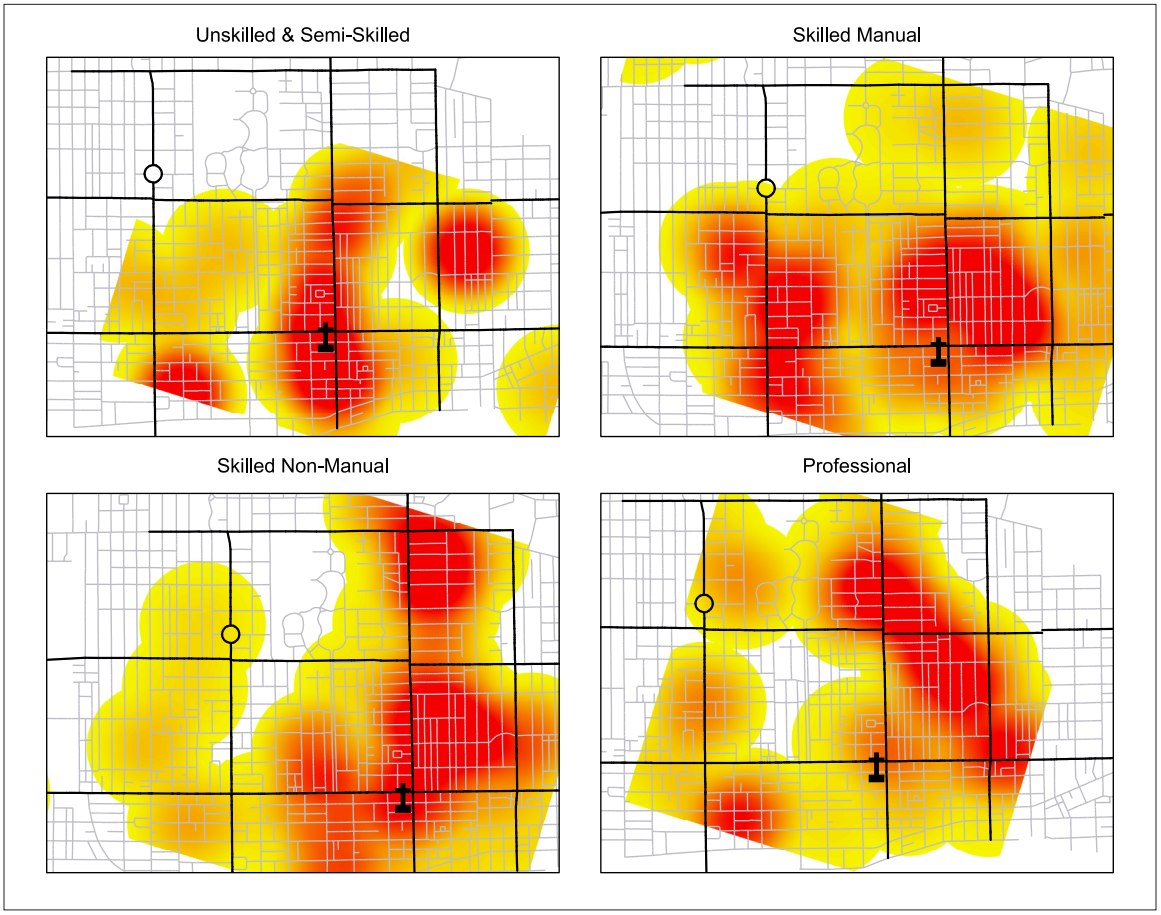


Fig. 4.7. Residential density of Knox congregants by occupational categorization, 1882–87. (Sources: 1884 Toronto Streets: Adaptation of DMTI rte 2010; Knox Presbyterian Church Congregant Addresses: Knox Presbyterian Congregation Rolls 1882–1887; Pew rent amount and occupation: Knox Pew Rent Books 1882–1887.)

subsequently be analyzed through observation. While the GIS maps allow us to visually compare the household locations of parishioners of different occupational levels, spatial statistics enable heavily populated areas to be more easily compared, and with greater accuracy. We used a kernel density technique, which aggregates address points together within a specified search radius and creates a smooth, continuous surface representing the density of members from a particular group. In Figure 4.7, the parameters have been adjusted to show clearly defined hotspots which are useful for comparative purposes but statistically less reliable than using a smaller search radius. As can be seen, the greatest concentration of unskilled and semi-skilled congregants resided within a few blocks west of Yonge, between College Avenue and Lake Ontario. Skilled manual category members were concentrated between Yonge and Sherbourne, and College and Queen, as well as several blocks either side of Spadina and Brock, between College Avenue and the lake. Many of the skilled non-manual congregants lived between Yonge and Sherbourne and College and Queen, but also to the east of Yonge,

several blocks north of College Avenue. The professional category members overlap both of the skilled non-manual areas of concentration but also the area in between. While there was clearly some crossover in where those classified in different occupational levels lived, there is a definite contrast in where the lowest and highest level congregants lived, which roughly corresponds with Mulvaney's observations.

The confirmation that late-nineteenth-century Toronto can be divided into areas in which congregants of different socioeconomic status lived is not in itself a major research finding. It is not surprising that doctors are found living separately from labourers; factory workers from clerks; or merchants from plumbers. Yet taken in the context of what we have previously established about the seating arrangements of Knox Church, it is highly significant. Knox was evidently a place where congregants could come where socioeconomic status was of little consequence. The absence of more unskilled and semi-skilled workers should caution us against making sweeping claims of a truly egalitarian community, but that the class divisions so evident outside the church walls were even somewhat reduced is a significant breakthrough in our understanding of this religious and ethnic community.

CONCLUSION

GIS has the potential to answer specific research questions or to be used as a general investigative tool. It offers a valuable complement to traditional methods, which, as has been demonstrated, can lead to significant and in some cases unexpected findings. In this project GIS was used most fundamentally to plot onto a contemporary map where the parishioners of Knox Presbyterian Church lived. In doing this, we found that Knox cannot be considered a neighbourhood church, and, while the factors that drew the congregation together remain open to speculation, GIS methods allowed us to look for reasons beyond geography. Furthermore, we know that these factors were strong enough to keep people worshipping at Knox, even when most worshippers lived closer to another church of the same denomination. One of the most striking aspects of the pew rent book was the extent of transiency, both inside and outside the church. For those who moved house, GIS can be used to track their movements and determine patterns that could not be detected from the written records alone. Regarding the Knox congregants, it is the lack of consistency to these movements that is interesting, which, together with the exceptionally high levels of transiency, make this a clear area of future research. Another area that has wider implications for urban historians is the identification of distinct residential areas in relation to socioeconomic backgrounds. With further investigation, this could lead to a much deeper understanding of class dynamics in Toronto. Here, it is enough to confirm that, among the Knox congregation, unlike inside the church, socioeconomic differences did manifest themselves quite clearly. By incorporating HGIS methods into our study, we came to see Knox as a place where people from, not only different parts of town, but also from very different backgrounds, could comfortably mix. The question that arises, and which will only be answered when data from similar sources are analyzed in a GIS, is whether or not our findings extend to other houses of religious worship beyond Knox.

NOTES

1 J. Ross Robertson, *Robertson's Landmarks of Toronto: A Collection of Historical Sketches of York from 1793 to 1837 and of Toronto from 1834 to 1904* (Toronto: J. R. Robertson, 1904), 215.

2 Deacon's Court and Board of Managers Seat Rents, 1882–1887, Knox Presbyterian Church Toronto collection, Presbyterian Church in Canada Archives.

3 Mark McGowan, "Coming Out of the Cloister: Some Reflections on the Developments in the Study of Religion in Canada, 1980–1990," *International Journal of Canadian Studies* 1–2 (1990): 175–202.

4 See for example Hannah M. Lane, who uses church census records in "Tribalism, Proselytism, and Pluralism: Protestant, Family, and Denominational Identity in Mid-Nineteenth-Century St Stephen, New Brunswick," in Nancy Christie, ed., *Households of Faith: Family, Gender, and Community in Canada, 1760–1969* (Montreal and Kingston: McGill-Queen's University Press, 2002); Rosalyn Trigger, "God's Mobile Mansions: Protestant Church Relocation and Extension in Montreal, 1850–1914," PhD thesis, McGill University, 2004; and Jordan Stanger-Ross, who uses marriage records in "An Inviting Parish: Community without Locality in Postwar Italian Toronto," *Canadian Historical Review* 87, no. 3 (2006): 381–407.

5 Andrew Hinson, "A Hub of Community: The Presbyterian Church in Toronto and its Role among the City's Scots," in Tanja Bueltmann, Andrew Hinson, and Graeme Morton, eds., *Ties of Bluid Kin and Countrie: Scottish Associational Culture in the Diaspora* (Guelph, ON: Centre for Scottish Studies, 2009).

6 Several examples of the importance of religious buildings to ethnic communities in Toronto are given in Robert Harney, ed., *Gathering Place: Peoples and Neighbourhoods of Toronto, 1834–1945* (Toronto: Multicultural History Society of Ontario, 1985).

7 Andrew Hinson, "Migrant Scots in a British City: Toronto's Scottish Community, 1881–1911," PhD thesis, University of Guelph, 2010.

8 John Zucchi, *A History of Ethnic Enclaves in Canada* (Ottawa: Canadian Historical Association, 2007), 2.

9 Christopher Armstrong and H. V. Nelles, *Revenge of the Methodist Streetcar Company: Sunday Streetcars and Municipal Reform, 1888–1897* (Toronto: P. Martin Associated, 1977), 32.

10 Rev. H. M. Parsons, sermon preached in Knox Church, 20 April 1890, reprinted in H. M. Parsons, *Biographical Sketches and Review, First Presbyterian Church in Toronto and Knox Church, 1820–1890* (Toronto: Oxford Press, 1890).

11 Omar M. McRoberts, *Streets of Glory: Church and Community in a Black Urban Neighbourhood* (Chicago: University of Chicago Press, 2003).

12 Richard Cimino and Don Lattin, *Shopping for Faith: American Religion in the New Millennium* (San Francisco: Jossey-Bass, 1998).

13 Lane, "Tribalism, Proselytism, and Pluralism."

14 Hinson, "A Hub of Community," 123.

15 John Moir, *Enduring Witness: A History of the Presbyterian Church in Canada* (Toronto: Presbyterian Publications, 1974), 136.

16 The occupational classification scheme used is the Social Power (SOCPO) scheme. The scheme distinguishes five levels of social class. Lower-class subgroups are SP (social power) level 1 (mainly unskilled workers), SP level 2 (mainly semiskilled workers), and SP level 3 (mainly skilled manual workers). SP level 4 is mainly composed of skilled non-manual workers and SP level 5 comprises white-collar and/or professional specialists (e.g., lawyers), wholesale dealers, factory owners and the like. Full details are available in Bart Van de Putte and Andrew Miles, "A Social Classification Scheme for Historical Occupational Data," *Historical Methods* 38, no. 2 (2005): 61–92.

17 Allan A. McLaren, *Religion and Social Class: The Disruption Years in Aberdeen* (London: Routledge and Kegan Paul, 1974) and Peter Hillis, *The Barony of Glasgow: A Window into Church and People in Nineteenth-Century Scotland* (Edinburgh: Dunedin Academic Press, 2007).

18 Hillis, *The Barony of Glasgow*, 143.

19 Trigger, "God's Mobile Mansions," 87.

20 Deacon's Court Minute Book, The Presbyterian Church in Canada Archive.

21 William Fitch, *Knox Church Toronto: Avant-garde Evangelical Advancing* (Toronto: John Deyell, 1971), 28.

22 *Annual Report of the Trustees and Deacons Court of Knox Church for Congregational Year 1883* (Toronto: Globe Printing, 1884).

23 Hillis, *The Barony of Glasgow*, 109.

24 Howard Chudacoff, *Mobile Americans: Residential and Social Mobility in Omaha, 1880–1920* (New York: Oxford University Press, 1972), 150, 151.

25 Michael B. Katz, Michael J. Doucet, and Mark J. Stern, "Population Persistence and Early Industrialization in a Canadian City: Hamilton, Ontario, 1851–1871," *Social Science History* 2, no. 2 (1978): 220.

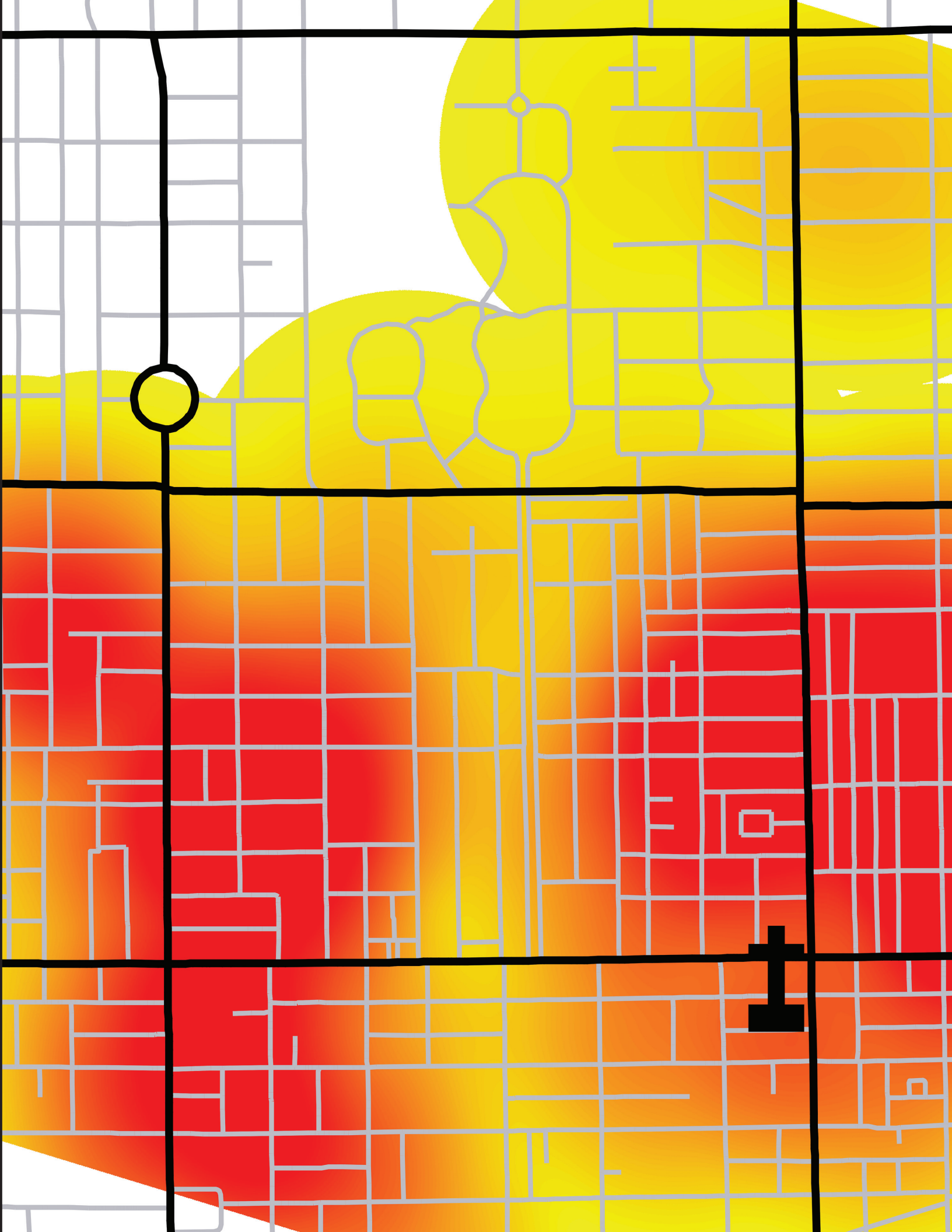
26 Michale Katz, *The People of Hamilton, Canada West: Family and Class in a Mid-Nineteenth-Century City* (Cambridge, MA: Harvard University Press, 1975), 104.

27 William Jenkins, "In Search of the Lace Curtain: Residential Mobility, Class Transformation, and Everyday Practise among Buffalo's Irish, 1880–1910," *Journal of Urban History* 35, no. 7 (2009): 970–97.

28 Jenkins, "In Search of the Lace Curtain," 982.

29 Chudacoff, *Mobile Americans*, 158.

30 Charles Pelham Mulvany, *Toronto: Past and Present* (Toronto: W. E. Caiger, 1884), 43.



5

Stories of People, Land, and Water: Using Spatial Technologies to Explore Regional Environmental History

Stephen Bocking and Barbara Znamirowski

INTRODUCTION

South-central Ontario is rich in the stories of Canadian environmental history. Extending north from Lake Ontario, the region encompasses diverse landscapes. Some are the products of glacial history: fertile plains, rolling hills, and lakes and rivers that became essential to transportation, settlement, and industry. The Canadian Shield imposes its own character on the region's north. These landscapes formed the setting for central themes in Canadian environmental history: survey, settlement, forest clearing and agriculture, formation of transportation networks, industrial development. There have also been efforts to make sense of this landscape, debate its appropriate use, and resolve conflicts between diverse interests. These themes played out in ways that were specific

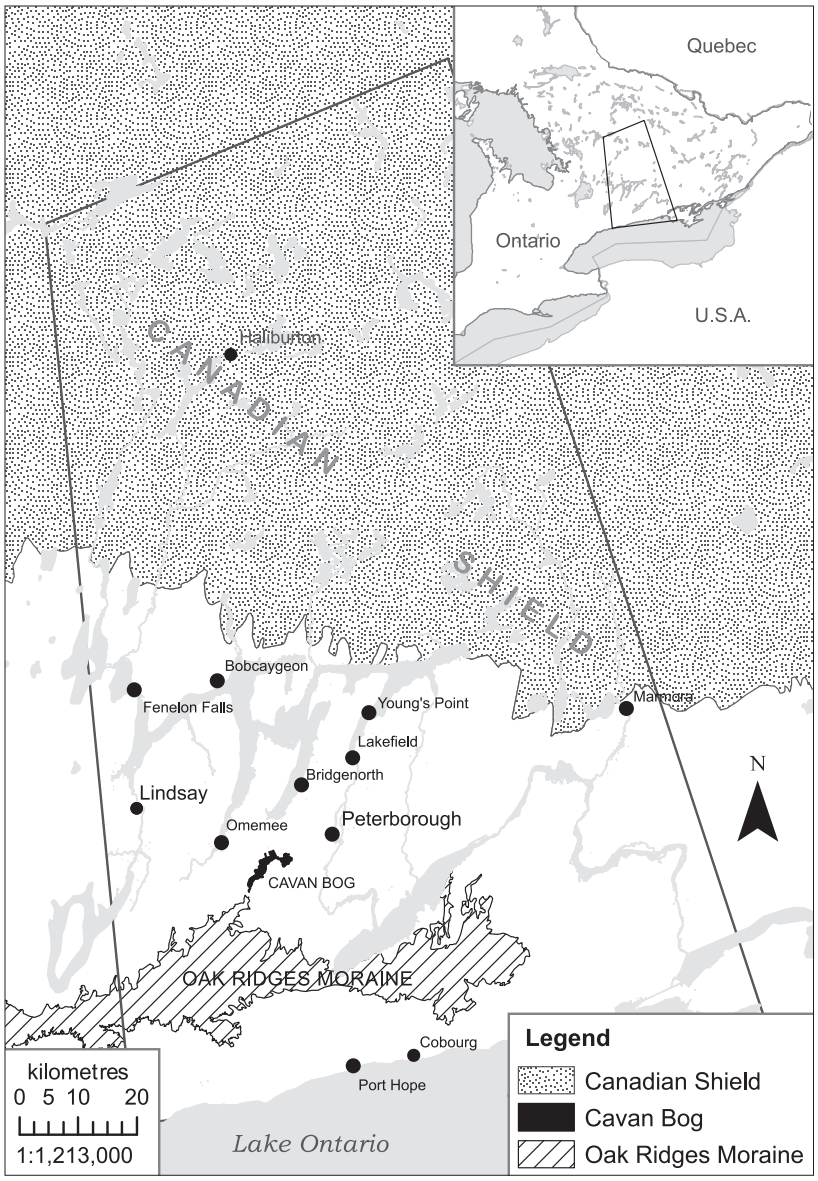


Fig. 5.1. Regional Environmental History Atlas (REHA): Project location and boundary. (Ontario. Ministry of Natural Resources, Structured Data. 2009–2011. Software: ESRI Inc. ArcGIS Desktop 10, Adobe CS4 Illustrator.)

to this regional landscape, and therefore study of its environmental history must relate to local geography and environmental features.

In this chapter we discuss the value of Historical Geographic Information Systems (HGIS) as a tool for the study of the environmental history of a region. We focus on South-central Ontario: an area extending from Lake Ontario in the south to Haliburton in the north, and from Oshawa in the west to Belleville in the east. This region, encompassing several counties and the Trent River watershed, is centred on Peterborough and Trent University, the home of our Regional Environmental History Atlas project (REHA) (Fig. 5.1).

This project responds to the opportunities and challenges inherent in diverse research resources that relate to environmental history.

These resources are closely tied to specific landscapes, and so it is appropriate to assemble them in a format that can make these ties immediately evident, enabling analysis of places and spatial patterns (including the novel patterns produced by industrialization, new forms of agricultural production, and new markets), and presenting the possibility of new interpretations of historical change. Beyond the display of geographically situated historical data, HGIS can support the telling and analysis of stories of Canadian environmental history, such as the expansion of agricultural settlement, the rise and decline of resource industries, and the emergence of perceptions of landscapes.[1] In doing so, they can serve as tools for research, communication, and teaching and as a foundation for collaboration between historians and others who share an interest in history. The contributions explored in this project also illustrate the potential for regional HGIS projects elsewhere in Canada.

South-central Ontario presents several advantages for a project of this kind. Numerous themes relevant to Canadian environmental history are present here. The region is also small enough to support the long-term goal of assembling a reasonably comprehensive collection of knowledge of its environmental history. And finally, this region is of the right size to enable affordable collaboration amongst the small but diverse group of individuals (environmental historians, historical geographers, map and data librarians, local historians, conservationists, and others) who share an interest in its history and heritage.

THE ENVIRONMENTAL HISTORY OF THE REGION: AN OVERVIEW

Before discussing the project itself, it is appropriate to outline its regional context. Glacial forces shaped this landscape and many of its features: the Oak Ridges Moraine, eskers, and countless drumlins; lakes that line the edge of the Shield; the transition zone between the Shield and the St. Lawrence Lowlands that is known as The Land Between; rivers (such as the Trent, Otonabee, and Moira) that channelled melt waters; and waterlogged areas (such as the Cavan Bog) created by glacial drainage and ice dams. Suitability for agriculture generally declines as one travels north. Although there is much fertile land, the land is often rough and stony, better suited to pasture than crops. Drumlins and other glacial remains are interspersed with poorly drained plains underlain by clay, creating areas of marsh and bog that posed obstacles to agriculture. On the Shield, thin soils discouraged permanent settlement.[2]

Our focus is on the period since European settlement. Aboriginal history is an essential and complex aspect of the history of this region. However, it also requires knowledge and experience that are beyond the expertise of the project team. We hope that future collaboration will enable the project to pay appropriate regard to the region's Aboriginal history.

In the 1800s, here as elsewhere in Ontario, the land was surveyed, as part of the Colonial Office's effort to impose an orderly system of land allocation. This occurred usually, but not always, prior to settlement. Areas near Peterborough were surveyed in the 1810s and 1820s; the northern region, including Haliburton, was

surveyed in the late 1840s and 1850s. Surveys imposed a rigid grid on the landscape, rendering the region amenable to ownership and settlement. They also neglected its ecological complexity, ignoring local features such as soil, slope, streams, and drainage patterns. This would become especially apparent where, for example, roads, property lines, and farm fields cross steep-sloped drumlins. These surveys were only the beginning of mapping: county maps followed, and in the twentieth century several agencies produced topographical map series, as well as other, more specialized maps.

Settlement took place in several stages. Beginning in the 1790s clearing and settlement near Lake Ontario proceeded unevenly, with much of the land allocated to absentee owners.[3] Soon, however, the region shared in Upper Canada's population growth (from 158,000 in 1825 to 952,000 in 1851), with settlement of lakeshore townships accelerating after the 1820s, while inland immigration initiatives focussed on the Peterborough area (including the settlement in 1825 of 2,000 Irish, arranged by Peter Robinson).[4] By the 1840s a predominantly agricultural landscape, made up mainly of family farms, had been established south of the Shield. A brief spasm of efforts to settle the Shield began in the late 1850s, and in the 1860s and 1870s the Canadian Land and Emigration Company sponsored mostly unsuccessful attempts to settle the Haliburton region. Rural population peaked around the 1880s, before declining, particularly in the north.[5] These trends reflected factors specific to the region, including abandonment of marginal areas, as well as wider patterns of migration: from rural areas to cities, and from Ontario to western Canada. Together these factors created the patchwork of settlements, bounded by rock, frost, and borders, that became characteristic of early Canada.[6]

Settlements often developed in response to environmental features. For example, Port Hope had fertile land, a sheltered harbour, and power from the river. Peterborough was a promising site for water power, and at the head of river transport. Many communities were established at sites for grist or saw mills, including Omemee, Lindsay, Bobcaygeon, and Fenelon Falls. In Smith Township, several settlements owed their origins to the timber trade: Bridgenorth, Young's Point, and Lakefield all grew up around sawmills.[7] Figure 5.2 exhibits the distribution of mills in this region, and the historical periods when they were established. The map demonstrates numerous features of their history, including their concentration in Peterborough, and their distribution in the region south of the Shield; by the 1850s the Shield had become the major source of timber, linked to mill sites by rivers and other waterways.

Transportation networks were essential to settlement and transformation. Natural waterways – the Trent and Otonabee Rivers, lakes, and portage routes – played an early role in moving people, goods, and raw materials.[8] From the 1830s to the 1920s, the Trent-Severn Waterway moved fitfully towards completion. The waterway's history was closely tied to regional economic and political developments and furnishes a local instance of the transformation of a river system to serve human purposes.[9] Early roads were also important, albeit of widely varying quality and comfort. They generally followed survey lines, respecting property rights while ignoring topography. Colonization roads were pushed north into the Shield in the 1850s and 1860s; they were stimulated by the *1853 Land Act*, which encouraged

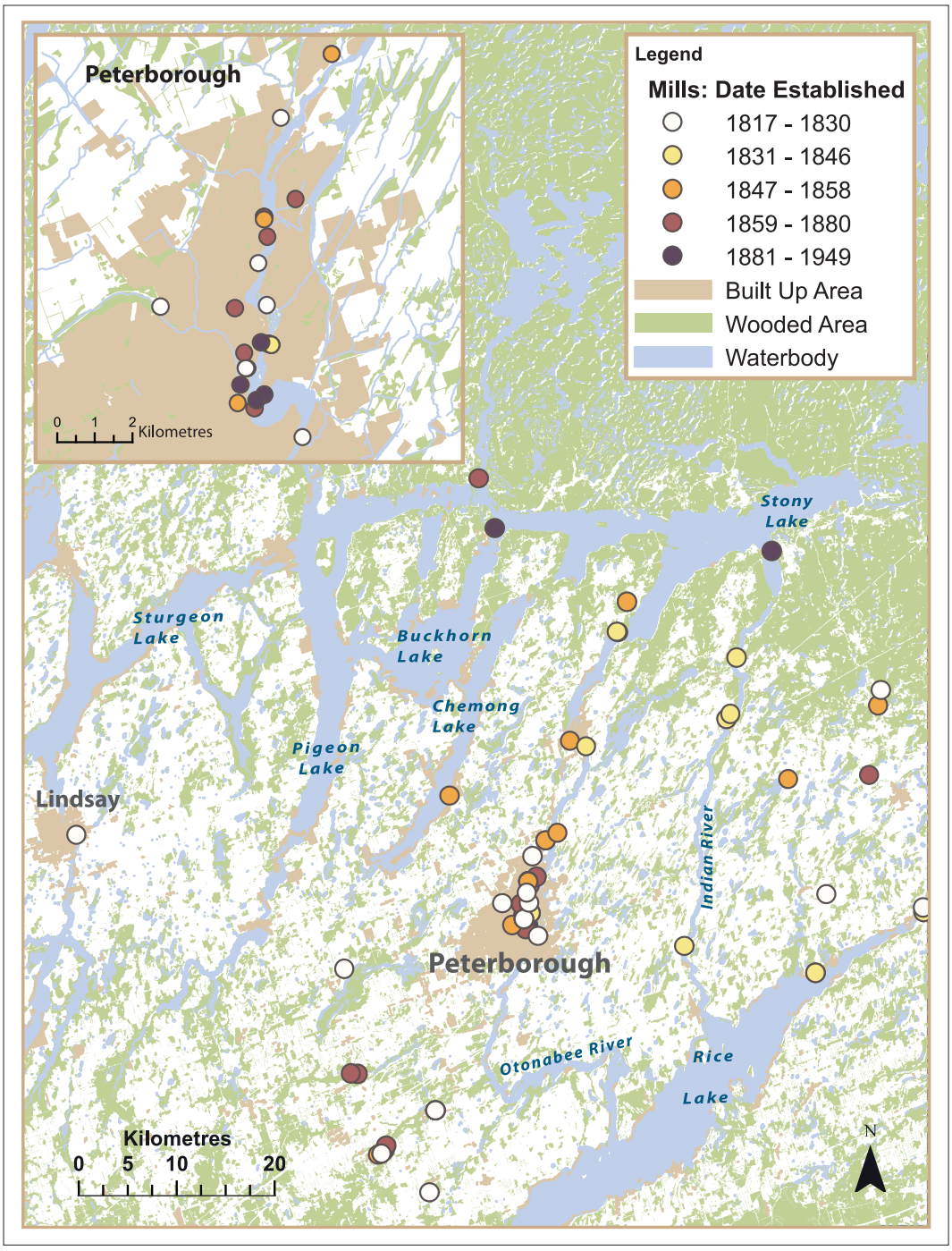


Fig. 5.2. Historic mill sites with dates. (Base Map: Ontario. Ministry of Natural Resources, Structured Data. 2009–2011. Software: ESRI Inc. ArcGIS Desktop 10, Adobe CS4 Illustrator and Photoshop.)

settlement by authorizing free grants of up to a hundred acres.[10] Beginning in the 1850s, railroads became essential to moving resources and people.[11] Railroads also rearranged regional trade relations (lines built at right angles to Lake Ontario both exhibited and reinforced trade ties to the United States) and encouraged concentration of industry and population. In the case of Haliburton in the 1870s, they encouraged depopulation of northern townships, when a new rail line made it less expensive for logging camps to import their supplies, thereby eliminating a major market for local farmers who had been making, at best, only a marginal living.[12] HGIS can enable analysis of the relations between transportation, settlement, and land clearing and aspects of the landscape, such as agricultural potential.

Initially, the regional economy was tied to the local environment. Industries produced essential goods such as leather, furniture, and food, at cheese factories, meat packers, distilleries, and breweries. Most industries were widely distributed across the region, relying on local materials from forest or field, and on local sources of energy, mainly waterpower, while producing goods for the local market. As transportation improved and shipping costs declined, manufacturing became gradually concentrated in fewer population centres.

In the case of the timber industry, external factors were important, such as British demand for squared timber and trade agreements with the United States, which accelerated exports of sawn lumber. The industry quickly transformed from meeting local needs (such as for building materials) using timber from areas cleared for agriculture into a commercial operation focussed on export. Lumber production developed rapidly after the 1830s, and the timber industry became a significant economic actor. This transformation was accompanied by a geographic shift: from small mills located near Lake Ontario to larger mills located to the north.[13] In 1860, for example, Peterborough County had thirty-seven mills, employing 637 workers. For its part, Port Hope became a busy export centre: in 1879, 50 million board feet of lumber passed through, and 68 million the following year.[14] Dependency on export (and on a resource that could be driven to exhaustion) also encouraged a boom and bust economy of the kind typically associated with the staples trade.[15] Maps can aid in the analysis of the development and transportation of this industry in relation to other factors, such as modes of transport (waterways and railroads) and the availability of timber.

Agriculture played essential roles in regional environmental history. Production evolved from subsistence crops (potatoes, turnips, corn) in the early years of settlement, to, by 1850, wheat for export and modest mixed agriculture for local consumption. There was also a substantial early presence of livestock: in 1851–52, more than one third of farm land in Cavan, Emily, Douro, and Ops townships was used for pasturing; in three other townships more than one quarter of the land was used for pasturing. In the 1870s American wheat displaced Ontario farmers from that market, encouraging farmers to switch to mixtures of field crops and livestock. Overall, the nineteenth-century agricultural landscape formed a complex mosaic of wheat cultivation, livestock and other mixed cultivation, and woodlots.[16] Much marginal land has also been abandoned. In South Victoria, for example, area under crops decreased from 196,603 acres in 1920 to 121,844 in 1964.[17] HGIS can aid in

understanding in more detail the relation between agricultural potential (particularly soil quality) and patterns of clearing, cultivation, and abandonment.

Throughout this history, landscape features were manipulated to serve human purposes. Rivers were transformed to generate power, to create the Trent-Severn Waterway (raising water levels and flooding shorelines), and to transport timber. These transformations could also be indirect, as when land clearing changed the hydrological regime, making floods more common, as occurred on the Ganaraska River. Much of the forest cover was destroyed to make way for agriculture, and beginning in the early 1860s there was a rush to secure and harvest the pine forests of the Shield. With habitat transformation, several species declined, including salmon (virtually eliminated by stream obstructions such as mill dams and by damage to spawning habitat) and passenger pigeons, among others.

Throughout the history of the region, a variety of forms of knowledge have been significant. One was farmers' skills and knowledge: essential to adapting to this landscape, guiding land uses such as raising potatoes and pasturing livestock. Some skills were brought from Ireland (where the landscape and glacial features were somewhat similar to those in this region), and farmers obtained others from the Mississauga people (particularly relating to the use of fire to clear land) and from their own observations in Canada.[18]

Evolving attitudes and perceptions of the landscape also influenced its transformation. The nineteenth-century aspiration to "conquer" and clear the landscape was dominant; but other attitudes, including admiration for the scenery, were also present, particularly among those with the wealth and leisure to enjoy it.[19] The Shield was the object of diverse and shifting views: at first a potential new farming frontier, it became (in Al Purdy's words) a "country of defeat" for farmers, as well as a valuable source of timber, a recreational playground, and an iconic landscape, representing Canadian identity.[20] Conflicts on the Shield between settlement and the timber industry also provoked discussion of the need to define distinct areas for each activity. By 1913 the region had become central to Canadian discussions about resource conservation.[21]

Evolving uses and perceptions of the landscape were also reflected in the development of tourism and recreation. Tourist facilities appeared, such as hotels and resorts, as well as transportation facilities, including railroads and steamship lines.[22] Landscapes that once produced timber or agricultural crops became redefined as landscapes of consumption; today, the contemporary landscape of cottages and resorts still reflects the influence of the timber industry: its railways, dams, canals, locks, and boarding houses were reconfigured to exploit tourists rather than trees.[23] These evolving land uses and perceptions can be mapped in order to better understand how they related to economic activities and to specific features of the landscape.

These various trends and transformations: immigration and settlement, land clearing and agriculture, industrial development (particularly the timber industry), formation of transportation routes, and new uses of the landscape, including for recreation, together constituted, as J. David Wood has suggested, an ecological revolution.[24] As such, the history of this region parallels landscape transformations elsewhere that have received more attention

from environmental historians.[25] And, as this brief review suggests, a conventional historical narrative can provide a solid basis for understanding this revolution.

DEVELOPING AN ATLAS OF REGIONAL ENVIRONMENTAL HISTORY

Much can be added to this narrative, however, by integrating it with spatial technologies. Historians have demonstrated the contribution of conventional mapping to understanding the historical geography and environmental history of southern Ontario; they have used maps to illustrate patterns in agriculture, population growth, railroads, timber cutting and export, and industry.[26] HGIS and other spatial technologies can enhance these advantages of mapping. Their benefits include the capacity to assemble and display diverse forms of information – documents, maps, photos, environmental information – to enable exploration of spatial patterns. Visualizing places and the relations between them can make evident patterns that an historian may only otherwise vaguely sense. Specific questions can also be explored, including those that concern the causes and effects of historical change, such as the relation between transportation routes and industrial development. With its potential to extend spatial analysis across several scales, HGIS can also assist in the telling of complex stories of social and environmental change.[27] Most fundamentally, these technologies present the possibility of using maps and related materials, not just as the end products of research, but as research tools.

The aim of our project is to explore these benefits by constructing an online atlas of regional environmental history that juxtaposes the products of historical research with materials for further study. We see this atlas as encompassing four types of resources and tools for research:

1. An online HGIS, with historical sites identified and linked to relevant information, to support dynamic generation of maps, as well as queries and classification. Clicking on a point of the map would provide access to a range of information about that site, and would, eventually, permit users to add their own content.
2. Presentation of historical information in spatial form, including changes over time. This would include, for example, the formation and discontinuation of railroad lines, and the construction of the Trent-Severn Waterway.
3. Georeferenced historical materials, presented through overlay of the base map with primary sources, such as topographic maps, historic maps, and aerial photos, to enable comparison of past environmental features and land uses (such as forest cover) with current conditions.
4. Linking of the HGIS with diverse other materials: historical, geographical, literary and scientific documents, legislative debates and acts (these are sometimes specific

> to a region), photos, oral histories, bibliographies, and landscape observations. Where possible, these materials would be georeferenced, perhaps to county or township.

This design reflects the two chief purposes of the atlas. First, because it is organized in terms of the landscape itself, it will present environmental history information in a more accessible and intuitive format than conventional bibliographies or other research tools. This will expand the possibilities for communication between environmental historians and their audiences. Second, it will provide a point of departure for further study of the region's environmental history. The geographic presentation of historical information can itself become a research instrument, by enabling study of spatial patterns and relationships, making evident otherwise obscure aspects of historical change.

To fulfill these purposes, our project uses spatial technologies to assemble and juxtapose historical materials and to explore how they relate to each other and how they can illuminate our understanding of the region's environmental history. As practitioners often note, HGIS projects can require several years before they begin to be useful in scholarly or practical contexts.[28] They require major investment and collaboration amongst individuals with academic qualifications and technical expertise. This has also been our experience. Our project is intended to be a long-term undertaking – a "living" project, always open to additions and revisions and to collaborative partnerships.

Our work on this project began in late 2008, with seed funding from the Network for Canadian History and Environment (NiCHE). Since then, the project has developed through collaboration with several institutions and individuals. Additional funding and in-kind support has been obtained from various sources, including Trent University and the GEOIDE (GEOmatics for Informed Decisions) Network. Major work on assembly and processing of historical resources and spatial technologies has been accomplished by the Maps, Data, and Government Information (MaDGIC) Unit of Trent University Library. The emerging roles of academic map libraries as spatial and statistical data centres and also as research collaborators make them natural partners in HGIS projects. This collaboration also aligns with the strategic priority of many university libraries – including that of Trent University – to become more involved in academic research. Collaboration with regional organizations has demonstrated the benefits of working with the local heritage community; these relationships take time to develop but also enrich and help to sustain projects.

Since its origins, the project has evolved considerably. This evolution and the numerous decisions that have been made regarding technical design reflect how the project has been a learning process for its developers, as challenges have been encountered and overcome. Project development has comprised several distinct activities: developing and applying software, assembling and processing historical materials and information, relating these to geographic locations, and exploring their application to environmental history.

A major focus of effort has been the development of spatial technologies, operating on multiple platforms. This includes a range of proprietary and open source technologies for desktop GIS, publishing web map services (for

serving and consuming dynamic maps over the web), database development, and spatial processing. With this broadening of technologies, it has become appropriate to describe this project in terms of the application not just of GIS but of spatial technologies more generally.

Development of these technologies has been a complex process – one not yet completed. This complexity reflects a process of learning and experimentation and also of change in the GIS web mapping technologies themselves. For example, when our project started, we used proprietary software to publish maps over the web following a process that was relatively compatible with how we developed spatial content in our GIS desktop production. The end-product, however, was fairly "out of the box," with only limited customization.

With the emergence of the next generation of web mapping software – ESRI's ArcGIS for Server – we accordingly began migrating components of the project into it. In addition, and in tandem with our work with ArcGIS for Server, we experimented with the use of the Google Maps API (Application Programming Interface) to present time-series of maps: initially with historic topographic maps, but eventually expanding to include other historic materials, including aerial photos. Our evolving use of these spatial technologies provided considerable opportunity to explore their potential. New web mapping technologies have rapidly affected the potential of HGIS: we have gone from using technology with largely limited functionality – mostly displaying spatial information that can be turned "on" or "off" – to combining GIS with web programming scripts to support interactive processing by the user. For example, users can change opacity and overlay features to support their own time-series analysis. However, this has also required frequent rethinking of technical design and writing of new or upgraded code. For example, the upgrade to ArcGIS for Server involved a complete change in how we publish maps and a very different set of programming skills. The outcome in terms of presentation of historical materials has certainly been worth it, but the work has been time-consuming and technically demanding.

Another significant change has been the manner in which spatial content itself has become available. For example, the emergence of a variety of online base maps makes creation of base maps for web projects no longer essential. Our site, for example, now uses ESRI's ArcGIS Online Base Maps for parts of the project. As in Google, users can directly select what base map they wish to show, enabling use of topographic, imagery, relief, or street maps as background. This has many advantages, as the maps are already created and do not require local hosting. However, these maps function as "backdrops" only, and they cannot replace the detailed information provided through provincial layers. For example, we have included Ontario provincial soils information and hydro network surface water information, which show streams, rapids, dams, locks, and obstacles in water. Overall, this development work has provided the basis for relating the environment, including land forms, soil types, water bodies, and other geographic features, to human activities such as agriculture, settlement, and transportation. This environmental information, when mapped against land use, can also provide clues as to how, historically, people have evaluated the landscape's potential and limitations.[29]

A wide range of texts, maps, photos, fire insurance maps, and other historical resources have been assembled for the project. They include maps at different scales and dates (such as nineteenth-century county maps and twentieth-century topographical maps), as well as historical aerial photographs from the Trent map collection. A major effort has been devoted to scanning and georeferencing these materials, so as to make them available in digital form and to relate them to the region's geography. Depending on the age and quality of the image, this process can be time-consuming and requires skill and patience. We began this effort by selecting, scanning, and georeferencing aerial photography held by the Trent University Library. We were able to identify approximately 4,400 aerial photographs in the collection from our project area. Air photos range from 1928 to 1977 (federal photographs purchased from the National Air Photo Library (NAPL) and from 1977 to 1993 (photography purchased from the Ontario Ministry of Natural Resources (OMNR). Aerial photos were scanned to meet archival standards, with scanning and georeferencing largely completed by student assistants who received training as well as written instructions. The NAPL also assisted: our library provided NAPL with information about the air photo holdings (including year, the "A" flight line number, and picture numbers); NAPL compared this information against their database and supplied spreadsheets that included a variety of information about each photo, including, for example, spatial references for all corners and the centre, the altitude, NTS sheet number location, camera details, season, scale and precise date. This information considerably reduced the work required for georeferencing and provided valuable metadata for our geodatabase.

The project has also drawn on Canada's rich history of topographic mapping. We have drawn on maps prepared by several agencies, including the Geographical Section, Department of National Defence, and Canada Surveys and Mapping Branch, Department of Energy, Mines and Resources.[30] For historical GIS, awareness of how maps differ over time and what different series show is essential. For example, only early military maps distinguish coniferous and deciduous trees (using hand-drawn symbols), and they are also unique in distinguishing masonry and wood buildings, which was done until 1927. Both topographic maps and aerial photos are highly relevant to environmental history: they reveal changes in land cover and land use, as well as the expansion of settlements and transportation routes, including roads and railways. By superimposing these materials and adjusting their transparency, it is possible to compare different aspects of these historical changes.

Starting with 1:50,000 scale maps (and their predecessor, the 1:63,360 [one inch to one mile] map) our objective was to archive and make digitally available all editions of historic maps at this scale going back to the first edition (the editions we are working with span from 1929 to 1985). Several challenges have been encountered in locating, digitizing, and georeferencing these maps, and developing associated databases. Our first challenge was to determine what was available for our area, as there is no central record of map availability. While Canada's Map and Chart Depository Program has ensured that maps are readily available in libraries, early maps are often kept in storage and must be requested, and not all universities

(including our own institution) have been able to acquire editions that predate the institution. A fiche inventory does exist for 1:50,000 and 1:250,000 maps produced by Energy, Mines and Resources, Surveys and Mapping Branch. Another challenge related to copyright, which can restrict digitization and presentation. For example, many archives prohibit the scanning of fire insurance plans. We have also found that the policies regarding digital pictures of even small areas of a fire insurance map differed significantly between institutions: some allow (even encourage) this, while others view even pictures of sections as a violation of copyright.

We have been interested in seeing how Google Maps and Google Earth could be used for HGIS. At this time, we use Google Maps to display early topographic maps. Several steps were required to post maps on Google. Maps were scanned and saved as uncompressed tiff files, at a resolution of 600 dpi. By testing scans at different resolutions, we found that the improved quality of detail justified this high resolution. Our choice of this resolution was also influenced by the fact that we are archiving early maps and imagery collected for this project; as the main university library in our region, this has become an important consideration in terms of local heritage preservation. Although there is the risk of slowing down the visualization of maps when working at higher resolutions (because of the size of these files – the scanned maps ranged from 414 MB to 1.04 GB each), the use of tiling and map caches (in which maps are pre-rendered into thousands of small image tiles) has made this less of an issue. Tiling was done using Map Cruncher, a freeware program designed by Microsoft Research for Virtual Earth (now Bing Maps) and also useful in Google Maps.[31]

One example of the results of this effort is displayed in Figure 5.3. This displays an excerpt from the atlas: a georeferenced 1933 topographic map superimposed on Google Maps. Below this (left side) is a detail of this map (the black box), focused on the west end of Rice Lake. To its right is another excerpt from the atlas: a detail of a georeferenced 1973 topographic map of the same area. These (and other topographic maps) overlay each other in our atlas; by adjusting their transparency, the history of environmental change in this area – including, in this case, changes in the distribution of wetlands and forest, road construction, and growth of the town of Bewdley – can be easily displayed.

Another focus of the project was on mapping the thousands of features that are relevant to the region's environmental history, using information drawn from documents, historic maps, and other sources. As a first step towards developing mapping strategies, we decided to focus on a specific category of features: mills (including saw mills and grist mills used for grinding corn, wheat, and other crops). Historically, these were an essential feature of the Ontario landscape, important to early settlement, agriculture, and industry. By 1836, there were 350 grist mills in Upper Canada, and, by 1840, 1,000 saw mills, growing to 1,600 in 1848.[32] Saw mills relate to the distribution of land clearing and settlement activities, the timber industry, and appropriate sites on watercourses. The appearance and disappearance of grist mills relates to several factors, including the distribution of settlements and the agricultural economy.

This pilot project involved several steps: i) tracking down the locations of mills, using published and archival sources, such as old maps,

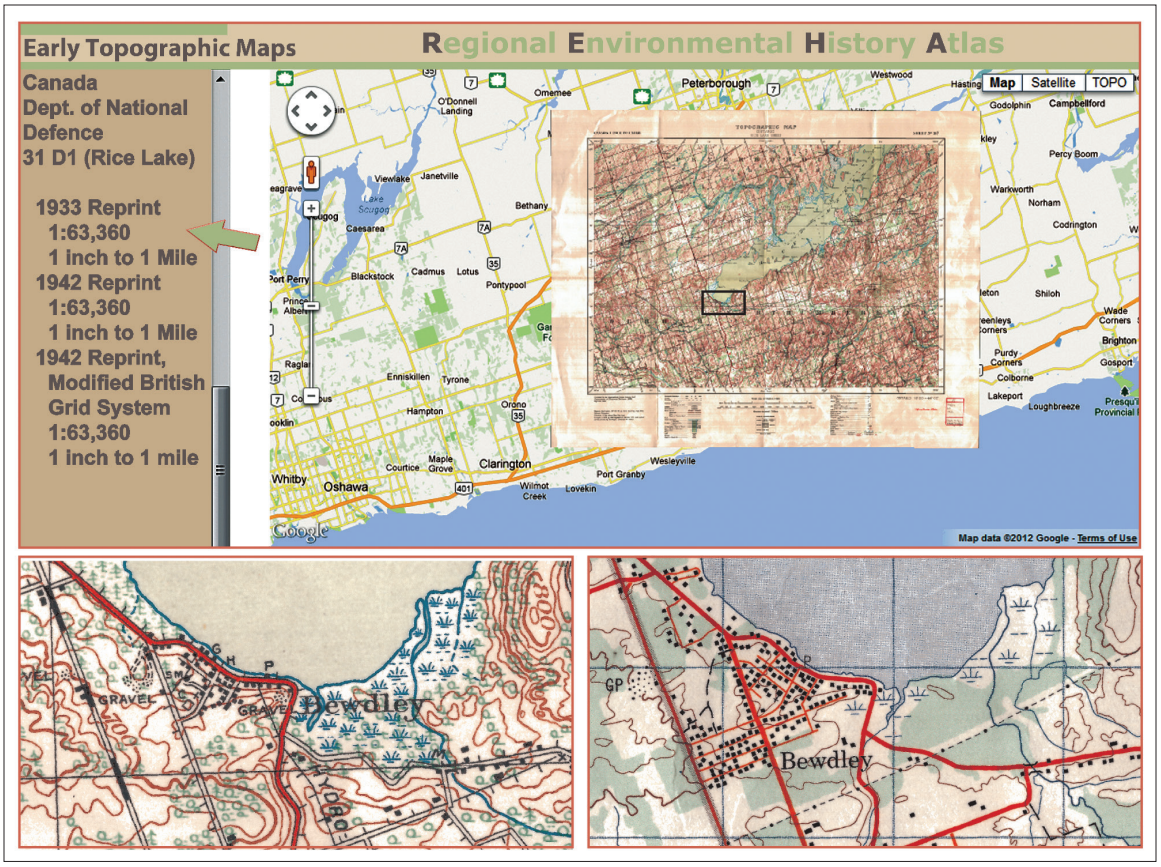


Fig. 5.3. Using Google to display historic topographic maps. (Topographic Map: Canada. Geographical Section, Department of National Defence. Topographic Map Ontario Rice Lake Sheet, 31 D1, 1 inch to 1 mile, 1:63,360, 1932, Reprinted 1933.) (Topographic Map: Canada. Surveys and Mapping Branch, Department of Energy, Mines and Resources, Rice Lake, Ontario, 1:50,000, edition 4, produced 1970, printed 1973. Base Map: Google Maps, January 2012. Software: Google Maps API, MSR MapCruncher, Adobe CS 4 Photoshop.)

historic county atlases, and fire insurance maps (no trace remains today of most mills at their original sites);[33] ii) constructing a database of attribute data (descriptions of the mills), spatial data (locations), and temporal data (when the mills were constructed, changed purpose or location, or ceased to exist); iii) presenting mills information using HGIS. To date, the project has identified 310 unique mills, and this number is expected to increase. Of the 310, 171 are located on unique sites, a different set of 171 have known dates of establishment, 66 have known closing dates, and 170 have text annotations. As much as possible, we tried to maintain a consistent approach to location and attribute information. This could be a challenge, particularly for those mills whose location could be determined only approximately. A spreadsheet template was devised for research assistants to collect spatial and attribute information. This template, which formed the basis for our geodatabase, was designed with community partners in mind to enable sharing and integration of database information.[34]

Some of the functions of the atlas can be demonstrated using information gathered and mapped as part of this pilot project on mills. All figures are excerpted from the atlas and are available online. Figure 5.2 displays the distribution of mills in the central portion of the study region and the time periods in which they were established. Mapping this distribution of mills provides a useful foundation for examining the geographic distribution over time of this industry in relation to land-clearing and settlement. This distribution can also be compared with published maps of wood production in the region.[35] Figure 5.4 (left side) displays the distribution of mill sites in the city of Peterborough, with an overlay of an 1878 map of the city. This figure thus illustrates the atlas's ability to integrate historical data with georeferenced historical materials. On the right of Figure 5.4 are two close-ups of this base map, with part of a georeferenced fire insurance plan; these exhibit the use of these plans to identify the locations of mills. Figure 5.5 demonstrates the atlas's query function: as described earlier in this chapter, clicking on a point of the online atlas provides access to a range of relevant information. In this case, the information includes text and a photo relating to a mill in Millbrook.

The mills project thus served as an opportunity to experiment with assembly, manipulation, and presentation of data and to explore their relevance to environmental history. The project also demonstrated several of the challenges involved in relating historical information to geographic locations. Information regarding the location of mills is often uncertain, contradictory, or non-existent. Mills themselves, and particularly saw mills, were usually transitory: located close to where trees were being cut, they were often moved elsewhere after the timber supply had been exhausted. Others were carried away by floods or were simply abandoned.[36] Conservation authorities have pulled down many abandoned mills, dams, and foundations. Other challenges related to the construction of the database, such as ensuring compatibility between Excel files and ArcGIS. Although compatibility problems encountered were overcome, they prompted us to evaluate more robust relational database management systems (RDBMS). Advantages of these systems would include more efficient storage and linkages between database content, multi-user editing, and the capacity for a greater number of users to query the database without conflict.

Another component of our project involved reading text sources (such as township histories), identifying information relevant to regional environmental history, and georeferencing this information. Our purpose was to "harvest" the knowledge accumulated by local historians across various thematic categories, including conservation, fisheries, industry, mills, natural heritage, settlement, timber industry, tourism, transportation, and water development. Information relating to approximately 300 locations of historical interest was extracted from these sources. While this exercise was valuable, the extraction of geographic information from textual sources also proved to be very time-consuming. As one author has noted, while this approach can be described as "data mining," it is, at best, mining using only a pick and shovel. These sources also typically provided only vague, incomplete, or ambiguous geographic information.[37]

Finally, we note that mapping census information relating to changing populations and activities in townships can provide a basis

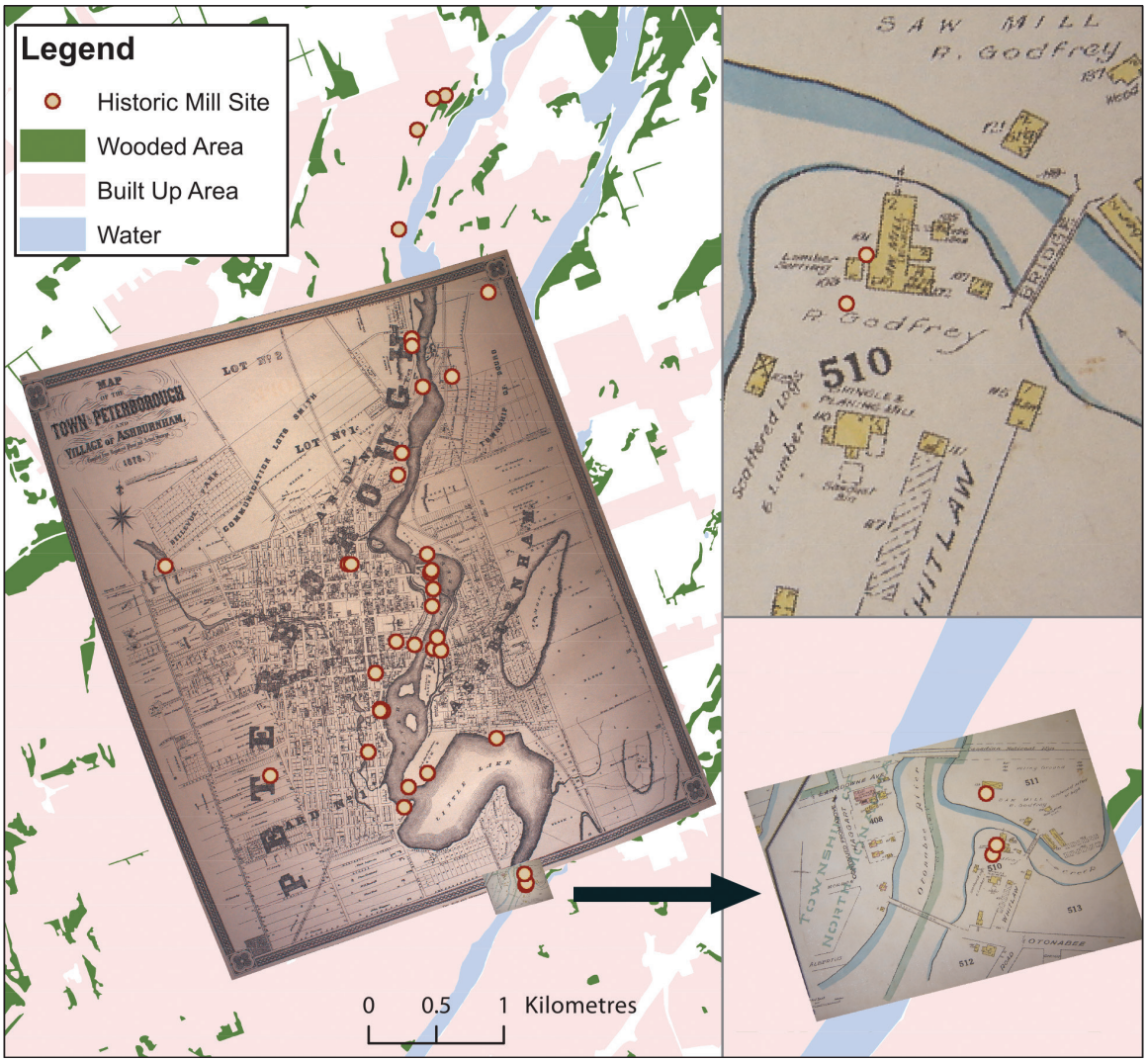


Fig. 5.4. Integrating historic and geographic resources: Base Data, Historic Map, Fire Insurance Plans and Location of Mills. (Left Panel of Figure: Historic Map: Map of the Town of Peterborough and Village of Ashburnham; compiled from registered plans and actual surveys, The Burland Desbarats Lith. Co. Montreal, 1878, in: H.C. Miles & Co. Toronto (Ont.), The New Topographical Atlas of the Province of Ontario, Canada: Compiled from the Latest Official and General Maps and Surveys, and Corrected to Date from the most Reliable Public and Private Sources of Information, Comprising an Official Railway, Postal and Distance Map of the Whole Province and a Correct and Complete Series of Separate County Maps on a Large Scale … also a Series of Recently Issued Maps Showing the Whole Dominion of Canada and the United States. Toronto: Miles, 1879, p. 60. Base Map: Ontario. Ministry of Natural Resources, Structured Data. 2009–2011. All panels: Insurance Plan of the City of Peterborough Ontario, Toronto and Montreal: Underwriters Survey Bureau Limited 1929, p. 31. Software: ESRI Inc. ArcGIS Desktop 10, Adobe CS4 Illustrator and Photoshop.)

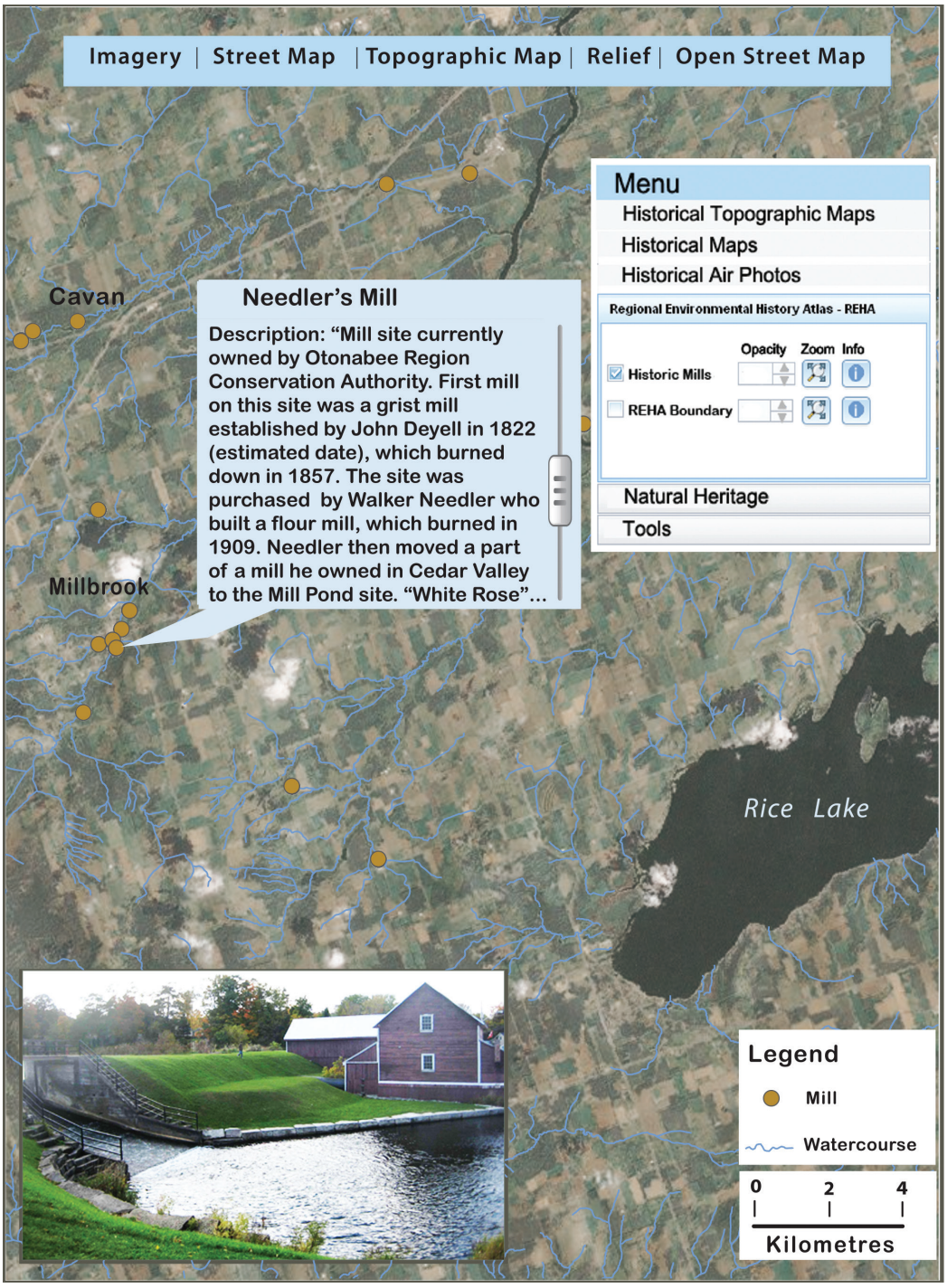


Fig. 5.5. Demonstrating REHA Web Site Query Function: Needler's Mill, Millbrook. (Photo of Needler's Mill, Millbrook. Courtesy of Stephen Bocking, 2010. Water layer: Ontario. Ministry of Natural Resources. Ontario Hydro Network. 2011. Satellite Imagery Base Map: ESRI Inc. ArcGIS Online ESRI World Imagery Base Map, January 2012. Software: ESRI Inc. ArcGIS for Server 10, Adobe CS 4 Photoshop, Adobe CS4 Illustrator.)

for understanding spatial patterns of land uses and economic activities in relation to environmental features. This component of the project awaits development.

USING THE ATLAS: TELLING STORIES OF ENVIRONMENTAL HISTORY

The spatial technologies applied in this atlas have several applications for environmental history. These include the presentation and comparison of historical materials and information, enabling exploration of questions of interest to historians and opening up the possibility of visualizing the spatial dimensions of history in novel and productive ways. Another potential use is as a basis for collaboration between historians and other interested parties. There is a substantial local community of interest: amateur historians and naturalists, academic researchers (retired professors have extensive knowledge of the region's natural history and historical geography), conservationists, and local agencies (including the Trent-Severn Waterway, the OMNR [headquartered in Peterborough], and Otonabee Conservation). An atlas of environmental history can expand and consolidate the community that is interested in the region's history.

In this chapter, however, we wish to examine in more detail how spatial technologies can contribute to telling the stories of environmental history. Places hold multiple meanings and identities: they "gather" ideas, activities, and practices. Several recent environmental histories have emphasized this aspect of various regions such as Georgian Bay, the Chilcotin, and the Trent Valley.[38] Our region has also gathered diverse meanings and activities. Many stories can therefore be told of its environmental history, which together illustrate how environmental features have shaped human activities, while being, in turn, transformed. Spatial technologies cannot on their own tell these stories.[39] But what they can do is support conventional narrative text by illustrating spatial patterns and processes. Three brief examples and a more detailed case study of the role that can be played by HGIS in telling stories of environmental history are presented below.

Our first example relates to the history of land clearing and agriculture. This is, most obviously, a story of expansion and retreat, and of transformation of the regional environment. However, spatial technologies also present an opportunity to tell a more subtle and complex story of the encounter between cultivation and environment. External factors were important, such as market demands and trading relationships. Factors within the region must also be considered, each of which had distinctive spatial patterns.[40] Agricultural potential varied greatly: on and off the Shield, as well as on the finer scales of drumlins and other glacial relics, patterns of drainage, bodies of water, and other features. The role of potential in influencing agricultural development can be difficult to determine: farmers had varying levels of awareness (tree cover was not always a reliable indicator of soil fertility), and other attributes such as drainage and road access could be more important when they evaluated a plot.[41] Roads, railways, and other transportation networks also influenced agricultural patterns: by the 1860s improved transportation and declining

shipping costs were making agriculture more sensitive to local environments and land costs, encouraging local specialization.[42] These patterns can be represented spatially. Using spatial technologies, a variety of questions can also be asked. How did patterns of mixed farming relate to agricultural potential at different scales? How were land clearing and choice of crops tied to the formation of transportation networks? Through these and other questions, possibilities for interpreting subtle patterns in the encounter between agriculture and the environment can emerge.

The story of industry in this region has been one of evolving relations with the landscape: from the use of local inputs such as waterpower, wood, leather, and food to supply local markets, to industries disengaging from these inputs (particularly as steam power replaced water power), and, thanks to the railroads, exporting to markets elsewhere. Local features shaped this story. For example, while the Marmora iron works were situated close to waterpower and steam power, there was no railway nearby. Accordingly, neither raw nor refined materials could be carried economically to or away from the site, and hence the works survived for only a brief period.[43] On the other hand, Peterborough was a promising site for water-powered industry because the Otonabee River had a significant drop at that location. Mapping mills and other industrial sites on the landscape, relating their distribution to environmental factors such as sites of energy production (especially waterpower and local electricity generation) and transportation networks, can add depth and complexity to the story of shifts in materials and markets and of concentration of industry in larger communities.

Our third example concerns the history of ideas about the value and purpose of this landscape. In many instances, these ideas were related to specific features of the landscape. Among the earliest and most well-known European perceptions were those of Catherine Parr Traill and Susanna Moodie. In *The Backwoods of Canada*, Traill recorded her observations as she travelled in the 1830s north from Lake Ontario to the Peterborough area, and these can be at least roughly situated. A more recent chapter in the history of landscape perception relates to tourism and to the role of this region as a resort, sometimes in opposition to the perceived ill-health and crowded conditions of the city. As early as the 1850s, certain sites, such as the shores of Rice Lake, had gained status as vacation resorts. By the late 1800s, the lakes lining the Shield, with their rocky shorelines and islands, had begun to attract tourists.[44] Resorts such as the Viamede Hotel and the Mount Julian Hotel began to host tourists in the 1870s. In 1883, the American Canoe Association held a meet on Stoney Lake, and this also encouraged tourism. Sites such as Sturgeon Point and Pleasant Point became noteworthy resorts. Many children's camps were established. Recreational activity north of the lakes was slower to develop, especially in areas distant from railway lines. Algonquin Park began its shift from lumber centre to camping resort. Some cottage lots or camping took place near colonization roads, such as on Big Cedar Lake and Long Lake. In the 1930s, new or improved roads, such as the Burleigh Road, encouraged tourism.[45] However, relatively isolated cottages on the Shield also encouraged perceptions of remote wilderness.

This history of perceptions and activities can be interpreted in terms of Canadian art and

literature – through the work, for example, of the local poet Isabella Valancy Crawford, who in the 1880s expressed disgust for the crowded, noisy city and a preference for the healthy countryside. This history can also be placed in the context of the history of nature tourism.[46] The history of perceptions of landscapes of health and ill-health, and the development of health resorts, is also relevant.[47] However, there are also opportunities to situate these perceptions: to understand how they related, not just to general views of the countryside, but to specific environmental features, such as lake coastlines, or communities with distinctive social and economic features. This presents its own challenges: statements regarding beauty, recreation, or health benefits were often not tied to specific places. But they often were, too: the benefits of hunting, fishing, and canoeing in the lake country were extolled by Victorian health movements, and the 1888 Peterborough Directory referred to Stoney Lake as "Peterborough's supplementary lungs."[48] We can also consider the significance to Crawford of her life in the Kawarthas, or the placement of resorts on Stoney Lake and elsewhere, and the movement of tourists through the railways and steamship lines that carried tourists into the region, thereby relating the material evidence of situated activities to landscape perceptions. Several relevant questions can also be examined using spatial technologies. For example: What landscapes were particularly important in inspiring aesthetic appreciation and recreation? What were the links between perceptions and how landscapes were used – for example, the shift from timber exploitation to tourism? How did landscape features encourage this shift from production to consumption? The extensive history of landscape art in this region can provide much geographically situated information regarding perceptions and uses of the land. For example, A. J. Casson painted extensively in this region; his paintings of Lakes Kushog and Kashagawigamog in the 1920s illustrate not only their appearance ninety years ago but how access to these lakes have changed: today largely privatized through cottage development, they are off-limits to all but a select few.[49]

A CASE STUDY: THE TIMBER INDUSTRY

To continue our exploration of the potential of spatial technologies to assist in telling stories, we will examine in more detail the evolving relationship between the timber industry, settlement, and conservation. This industry has been the basis for a classic narrative. Between 1850 and 1910, the industry experienced rapid northward expansion, followed by contraction as forests were depleted and mills closed. Observers have presented this as a morality tale of a rapacious industry, shortsightedly exhausting its own resources:

> The ravenous sawmills in this pine wilderness are not unlike the huge dragons that used in popular legend to lay waste the country; and like dragons, they die when their prey, the lordly pines, are all devoured.[50]

Later observers agreed (albeit employing a less poetic but more managerial language) and drew implications regarding the waste of a once-valuable resource:

> The following report … will serve to exhibit in a precise and detailed manner the consequences of mismanagement.… The slopes, once, for the most part, covered with valuable pine and hardwood forest, had been cut over. A large area, the pinery in particular, had been repeatedly subjected to fires and rendered liable to eventual total destruction … if the present policy of indifference and neglect continues, what might have been a continuous source of wealth will become … a useless waste.[51]

The moral was clear: conservation was an imperative. Ideas of conservation in Canada have been attributed to perceptions of resource waste and the influence of ideas from the United States. Evolving views of forests were also important: from being merely temporary obstructions to farmers to renewable resources meriting their own place on the landscape. South-central Ontario is at the centre of this narrative as one of the most noteworthy studies of the Canadian Commission of Conservation (1909–21) focussed its attention here.[52]

But a more complex story is also possible, of evolving relations between the timber industry, settlement, and the landscape. Using spatial technologies, the factors affecting the timber industry can be examined and related to each other. This would include economic factors and policies that influenced the formation of the timber industry: trading patterns and agreements, colonization policies, and elite conservation discourse. These factors could be related to circumstances within the region itself: the distribution of forests, settlements, agricultural areas, transportation routes (colonization roads, railroads, rivers, and the Trent-Severn Waterway), protected areas such as Algonquin Park, land ownership, and timber company initiatives.

Industry initiatives, including acquisition of timber rights, and cutting operations, were also important. In broad terms, the industry swept northwards, beginning in the 1840s with the "Pine Land Grab" in the middle and northern reaches of the Ganaraska River, followed by exploitation of the Otonabee Region, the Pigeon Lake area, and, beginning in the 1860s, the Haliburton region. In the 1860s, Peterborough declined as a sawmilling centre because of rising transport costs (as cutting went further north) and the use of portable steam sawmills.[53] Major timber operators (such as the Mossom Boyd Company) typically dispersed their activities across several townships to adapt to unreliable spring stream flows that were needed to move logs downstream.

Mapping transportation routes in relation to industry activity can contribute to understanding how these were linked, and, thus, how the availability of timber – that is, the redefinition of forests as resources – was partly a question of access, with transportation playing a role in the transition from cutting for local purposes to commercial export. Logs were usually supplied to mills in the spring by streams, but movement of milled lumber required navigable waterways or railways.[54] Considerable information is available regarding these routes. Between the 1840s and the 1860s, the Trent, Indian, Otonabee, and possibly Cavanville Creek were being used for running timber.[55] In Dummer Township, canals were built to supplement the Indian River as a transportation route for lumber. In one day in 1864, 280 cribs of timber came down the Otonabee

River from Lakefield.[56] The role of railways was related to the shifting importance of the ports of Cobourg and Port Hope, which was in turn tied to increasing timber exports to the United States after the 1840s. The significance of the Trent-Severn Waterway can also be explored: an early priority in building the waterway and dams on upstream lakes and rivers to control stream flow was to ease the passage of timber. In 1844–45, timber slides were built at Healey's Falls, Middle Falls, and Chisholm Rapids, on the section of the waterway between Rice Lake and Trenton.

The conversion of forests into resources can also be understood by mapping the relationship between settlement and industry. Timber-cutting and settlement co-existed across the region. However, the relationship varied in different areas: in the south clearing for settlement occurred without industrial development, while elsewhere clearing fed the industry; on the Shield, timber exploitation took place alongside small-scale settlement. One factor shaping this relationship was views of the suitability of particular areas for either activity. In the predominantly agricultural landscape of the south, some areas were set aside as woodlots, and their distribution may reflect, among other factors, local variations in soil, slope, and other conditions. On the Shield, timber interests were dominant and were able to impose their view of agriculture as inappropriate. Timber companies alleged that settlers took land only to cut timber and that they started fires and filled rivers with rubbish, impeding log runs. However, at a finer scale, the relationship appeared to combine antagonism and co-existence. Timber companies established depot farms to lessen their dependence on local farmers. Yet the industry also provided a market for local farmers who, given the poor state of the roads, had few other options.[57] In some cases, colonization roads served both interests. In fact, this had been one motivation for the roads: industry would cut the timber, and settlers would occupy the cleared land. The roads sometimes provided access to good timber-cutting sites as well as pockets of soil suitable for agriculture. But given the poor quality of the land, such outcomes were likely exceptional.

Divergent views of the Shield's agricultural potential complicated this interaction. In the 1820s, the surveyor Alexander Shirreff expressed an optimistic view of this potential – a conclusion apparently based on the abundant forests.[58] Other observers agreed: in 1847, the first survey evaluated the region as suitable for settlement, as did the 1856 report of the Commissioner of Crown Lands. In the 1860s, this view was apparently widespread: an 1862 ad in the *Peterborough Examiner* noted the region's "fertile soil." The English Land Company apparently assumed the wealth of Haliburton lay primarily in its soil, not its timber.[59] Such views were consistent with the general assumption that the progress of Upper Canada depended on continued northwards expansion of settlement, especially given concerns that settlers were draining away to the United States.[60] However, other surveyors expressed skepticism regarding this optimistic view. These divergent evaluations – either optimistic or skeptical – were often expressed in relation to specific townships, raising the possibility that they were related to specific places – perhaps, for example, to surveyors' routes. To what extent were contrasting impressions of potential based on different preconceptions, attitudes, or territories? The specific landscapes that inspired contradictory impressions could be assessed by

examining surveyors' original records and relating these to the territories covered.

Mapping the timber industry and settlement can assist in situating their relationship and in understanding how it could be both antagonistic and complementary. More generally, with the centre of the industry shifting over time, the evolving relations between the industry and other activities reflected an evolving geography of land use: different landscapes, with different associated values, were at stake at different times. Several questions are amenable to spatial analysis. For example, to what extent was co-existence or antagonism between industry and settlement organized geographically: co-existence where agriculture was on suitable soils and could serve industry needs, but antagonism elsewhere? To what extent was the conflict between industry and settlement instigated by the industry's move onto the Shield country?

The emerging conflict between timber and settlement became most evident in the last decades of the nineteenth century, coinciding with the period of most rapid exploitation of the northern forests.[61] This conflict, as well as associated anxieties regarding future timber supplies, eventually encouraged interest in planning and conservation. Solutions to the conflict tended to be framed in spatial terms, including recommendations that areas suitable for settlement or for timber be identified and kept separate. In 1866, the Commissioner of Crown Lands advocated distinguishing between land that was and was not suitable for agriculture, with settlement prohibited on the latter. The 1868 *Ontario Free Grant and Homestead Act* imposed this compromise, effectively acknowledging that the forests were themselves a valuable industrial resource.[62] Algonquin Park was another, and the most prominent, effort to impose this kind of spatial solution. A series of similar recommendations, often based on the argument that settlement would destroy lands better suited for forestry, culminated in the 1913 Commission of Conservation report on the Trent Watershed.[63] Other approaches to conservation also became evident in this region. In the early 1900s, Edmund Zavitz, an influential forester and conservationist, expressed concern about the state of the land and streams of Northumberland County adjacent to Lake Ontario (and especially on the Oak Ridges Moraine). He also stressed the financial benefits of forests and urged reforestation.[64] In the 1920s, county forests were established in Northumberland and Durham counties.[65] These activities illustrated how conservation had different meanings in different environments: in the south, tree planting and rehabilitation of degraded landscapes; in the north, separation of forests and settlement and protection of forests against fire. A spatial analysis can provide the basis for exploring these divergent meanings and implications of conservation.

A key issue is understanding how elite discussions regarding conservation played out in the local context, as expressed through government and industry initiatives, with a variety of consequences for the environment and for other land uses in the region. Conversely, and acknowledging that this region was a key terrain for Canadian conservation, it is worth examining how local circumstances framed national conservation perspectives.[66]

Finally, these analytical approaches regarding timber exploitation, conflicts with other land uses, and efforts to manage these conflicts through conservation can also be applied to other contexts. These include other

resource development conflicts in the region, such as that stemming from the transformation of the region's rivers into transportation conduits and disposal sites for sawdust and other industrial wastes.[67] They also present the potential of comparing this region's history to the history of other regions, such as New England, that have experienced potentially similar episodes of resource conflict and that have been studied more thoroughly by historians.[68]

CONCLUSIONS

Spatial technologies have much to contribute to the practice of environmental history. These contributions range from presenting primary sources and information in ways that enable visualization of relationships between historical phenomena to supporting the telling of complex stories about the historical relation between people and the land. Three roles of HGIS are especially evident: i) organizing historical sources in relation to the landscape to make these available to anyone with an interest in the history of the region; ii) visualizing the geographic implications of information from these sources, including visualization of past landscapes; and iii) performing spatial analysis of this information to understand the development of patterns of environmental features, land uses, and other human activities. Of particular promise is the potential to identify meaningful relationships between diverse factors: for example, the relation between agricultural expansion and soil fertility; or between industry location, water power potential, and railroads; or, more unexpectedly, between the nineteenth-century timber industry and twenty-first century recreational landscapes.

Spatial technologies therefore provide intriguing possibilities for generating and communicating new interpretations of historical change: serving not just as products of research but as research tools by enabling the asking of novel questions regarding the spatial arrangements of historical events and processes. They thus carry implications for historical practice, including the need for historians to consider explicitly the geographical dimensions of their research. In teaching contexts, they present opportunities for interactive exploration of historical themes and for online "publishing" of student work. In the community, there are possibilities for collaboration between academic historians and those interested in heritage conservation.

At the same time, there are numerous challenges. These include practical issues relating to the technical skills and work required before useful benefits become evident. These challenges imply a need for collaboration between individuals with historical, geographical, information science, GIS, and other technical expertise and for substantial funding and access to technical facilities. There is also the challenge inherent in translating historical information into geographic formats, given that this information is often not tied to specific locations. Applying GIS to historical work is not just a technical but a social and conceptual challenge – one inherent in the contrast between the precisely defined locations and spatial patterns represented by GIS and the more subtle concepts of place and landscape employed by geographers and historians.[69]

However, as this project demonstrates, it is possible to overcome these challenges while generating novel insights into the historical relation between humans and their environment. The regional scale of this project can also serve as a model for initiatives elsewhere. Indeed, given the specificity of Canada's regions (however they are defined), initiatives at this scale may have a special role to play in relating historical knowledge to Canada's geographical context.

NOTES

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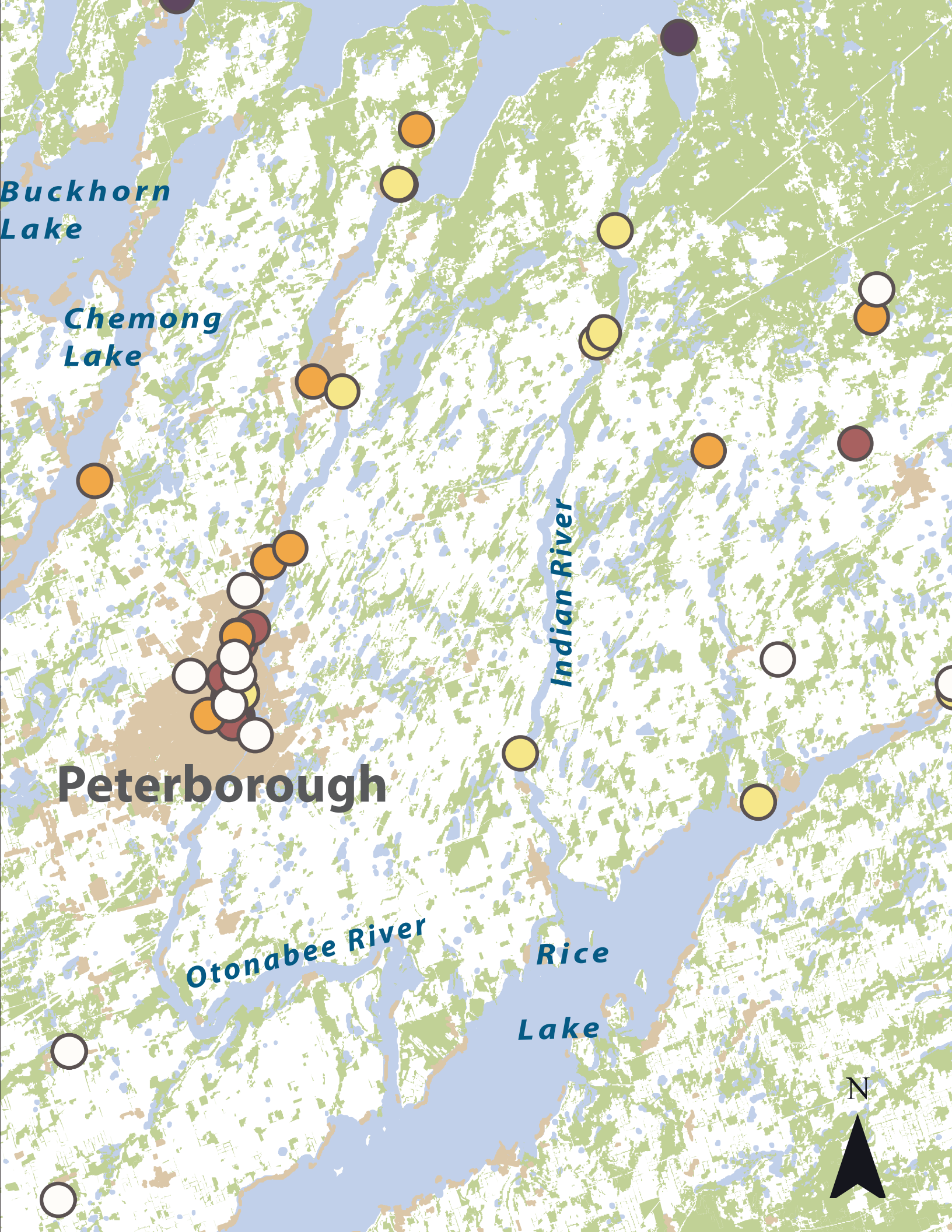
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6

Mapping Ottawa's Urban Forest, 1928–2005

Joanna Dean and Jon Pasher

Like many HGIS projects, this research began with a question that could not be answered with traditional historical sources. Municipal records showed dramatic shifts in attitudes to city trees in the mid-twentieth century. We wanted to know whether these cultural shifts reflected changes in the urban forest itself.[1] Were there too many trees in the 1920s, as critics charged? Were there too few in the 1960s, as environmentalists claimed? And how many trees are too many, anyway? The question was of more than academic interest. Urban foresters have established that trees provide significant health and climate benefits by cleaning and cooling city air. Trees can live for decades, and historical analysis can contribute to our understanding of forest growth and improve management in the future.

Our pilot project assessed the use of historical aerial photographs to measure canopy cover on selected neighbourhoods in Ottawa. The techniques for measuring forest canopy cover from aerial photographs and satellite images are well tested, but little historical analysis has been done, and the use of historical aerial photographs complicated the project in a variety of ways.[2] We found that it was possible to measure canopy cover within a reasonable margin of error. It appears that the critics may have been right, that tree cover was dense in central parts of the city in the early twentieth century and that it subsequently declined. It appears that the environmentalists were also right to worry about trees in the 1960s, when the inner-city decline was matched by the deforestation in early suburbs like Alta Vista.

What was interesting, however, was that geospatial analysis took the research beyond the original question: not only could we draw connections between canopy cover and shifts in popular opinion, but we could also correlate canopy cover to social indices such as class, income, or race. Inner-city neighbourhoods were subjected to close scrutiny for urban renewal in the postwar period, and a wealth of statistics are available. Our pilot project had not been designed with this analysis in mind, but even so the correlation of income and canopy cover is clear. The statistics allow us, following Nik Heynen in the United States, to insert the urban forest into an environmental justice framework as an environmental benefit that is socially produced and unevenly distributed.[3]

The project also offered an opportunity to move beyond statistics. Our methodology created maps of canopy cover that can be read visually and stacked in a dynamic time series. This has the potential to alter our perception of the urban forest. Trees appear to humans to be static entities, and their growth is only recognized retrospectively: it is a common trope of memoir writers to observe with surprise that a childhood tree has grown. The dynamic changes of canopy cover visible in a time series reminds us that forests are living agential communities that move and respond to changes in the built environment.

While our own work and experiences are focussed on urban forests, the methods and issues are applicable to other HGIS applications. The observations arise from the different perspectives of project team members. Jon Pasher, who was completing his doctorate in Geography at the time of the project, focussed on the methods, development, and accuracy of the statistics. Joanna Dean, a historian of the urban forest, with very little experience in HGIS, focussed on the applicability of the method for environmental history. The project described here was a pilot project, funded with a small SSHRC grant, and possible only because of the generosity of colleagues in the Geomatics and Landscape Ecology Laboratory at Carleton. We analyzed only five carefully selected areas, and, as in any good pilot project, we learned from our mistakes. We offer the following observations as "lessons learned," intended to be useful to others interested in incorporating historical air photos into their HGIS research.

CONTEXT

Urban forests have been the subject of much recent analysis in Europe and North America. The recognition of the environmental benefits or services provided by city trees led to a growing demand for the quantification and monetization of these benefits, and the developing science has provided the context for our research.[4] The term "urban forest" was coined by Erik Jorgensen, at the University of Toronto Faculty of Forestry, and has been widely adopted. The term is generally understood to include all urban trees: the street trees that line roads, as well as single trees and groups of trees in gardens, yards, cemeteries, parks, and woodlands. Although the urban tree is normally distinguished from shrubs and other vegetation by its trunk and crown (the urban tree is defined as "a woody perennial plant growing in towns and cities, typically having a single stem or trunk – and usually a distinct crown – growing to a considerable height, and bearing lateral

branches at some height from the ground,"[5]) most observers include shrubs within an urban forest. For those involved in canopy cover analysis of aerial photographs and remote sensing, it is often difficult to distinguish between trees and shrubs, and, as the ecoservice benefits are similar, the inclusion of shrubs makes sense methodologically. Ecologists sensitive to the interrelationships between plants and animals tend to think more broadly, and the term urban forest is sometimes extended to include grass, and even the related biota in an urban ecosystem.[6]

Urban foresters have established that urban trees provide a wide array of ecosystem services: they moderate air temperature, attenuate storm water flooding, mitigate urban heat island effects, and reduce noise and air pollution. Trees have been shown to have a measurable impact on urban levels of particulate matter, ozone, sulphur dioxide, nitrogen dioxide, and ozone. Woodlands increase urban biodiversity by providing semi-natural habitats to a wide variety of species, and at a broader scale urban trees contribute to carbon sequestration and storage.[7] They also provide social benefits: not only do they make a city aesthetically pleasing, (and raise real estate values), but they have measurable impact on residents' health and sense of wellbeing. Trees growing within sight of a hospital room have been shown to improve recovery rates of patients.[8] At the same time, urban trees also provide disservices: they produce allergenic pollen, volatile organic compounds (contributing to smog), and green waste. The costs and inconveniences of tree management can be high in urban areas, especially during storms, when they do significant damage to infrastructure. Not all city residents value the aesthetics of a treed urban landscape.[9] But the consensus is that the services outweigh the disservices, or have the potential to do so if well managed, and so the emphasis in the literature is on improved understanding and management of urban trees.[10]

Because of the focus on these ecosystem services, and the interest in assigning monetary values, many urban forest studies adopt quantitative methods: field surveys for smaller areas and GIS, aerial photography and remote sensing for larger areas.[11] The science has developed with advances in remote sensing and spatial analysis. It is often possible to acquire high-resolution satellite images with a spatial resolution of 60 cm and as well many municipalities have acquired low-altitude aerial photographs, which, although often intended for other purposes, can prove very useful for identifying canopy cover. One recent study demonstrated the inequitable distribution of greenspace in Montreal by extracting vegetation indicators from high-resolution satellite images, indicating the proportion of city blocks, streets, alleys, and backyards covered by total vegetation and trees/shrubs. These data were correlated to census data at the level of the dissemination area (400–700 people, roughly a city block in Montreal) to show environmental inequities.[12] One of the authors of this chapter, Jon Pasher, is currently engaged in a national-scale analysis of carbon sequestration within the urban areas of Canada. As a pilot project at Environment Canada, high-resolution imagery is being used to assess urban canopy cover to improve on previous estimates of the contribution to Canada's urban area carbon budget calculations.

Historical studies are limited by the available data: aerial photographs from the mid-twentieth century do not permit this kind

of close digital analysis. Historical studies are worth attempting, however, because of the longevity of trees. Unlike most vegetation, trees survive for decades, even in some cases centuries. In a young city like Ottawa, trees can be older than the city itself. Dendrochronology showed that a bur oak, recently cut down for infill housing, was 154 years old, the same age as the City of Ottawa, ninety years older than the house it shaded and at least a hundred years older than the man who felled it.[13] Trees also take many years to die. Analysis of a group of bur oaks in Winnipeg showed that they had been in decline for decades because of changes in water table levels caused by residential construction in the 1940s.[14] In another project, core analysis of urban Norway maples led ecologists to conclude that the trees had been in decline for twenty years. They speculated the decline was related to a combination of drought and sidewalk renovation and noted: "serious symptoms of deterioration in the crown may not occur for many years after the onset of decline."[15] If the purpose of urban forest analysis is to improve management, then historical studies capable of assessing arboreal growth and decline over a number of decades will be essential.

METHODOLOGY

Historical air photos were obtained from the Canadian National Air Photo Library. Each photo was scanned and georeferenced to real-world geographic coordinates within a GIS environment by collecting matching tie-points on both the older photos as well as more recent digital air photos, which were already georeferenced. While the scales of the photos differed greatly, the pixel size, or "spatial resolution" was standardized for all the photos in a time series in order to standardize the level of detail at which the interpreter would outline the canopy. A minimum bounding study area was set in a neighbourhood that included as large an area as possible but at the same time as many historical photos as possible. Within these reduced study areas, tree cover was manually interpreted and digitized in a GIS environment. The methodology resulted in maps of canopy cover that can be interpreted visually. The resultant GIS layers provided a per cent canopy coverage within each study area over time, by taking the aerial estimates of digitized canopy cover as a percentage of the total area of the neighbourhood being analyzed.

This methodology was adopted from landscape ecology and represents a departure from the dot-grid methodology used for most urban forest analysis. Dot grid, used for political ecology by Nik Heynen and by urban forester David Nowak, has developed from the pre-digital era, when a clear dot grid was placed over an aerial photograph, and the number of dots lying on forest canopy were counted. (See Figure 6.1B.) The results provide an average measure of canopy cover for an entire city but do not provide precise measures of individual neighbourhoods and streets unless intensive sampling is done in small areas.

Our methodology relied on the painstaking manual digitization of the canopy cover of each and every tree, but the results are dramatic. Patterns of canopy cover change can be read visually and can be read at the street-by-street, and even tree-by-tree level. While point based sampling might be faster to carry out, it does not allow for close analysis of changing spatial

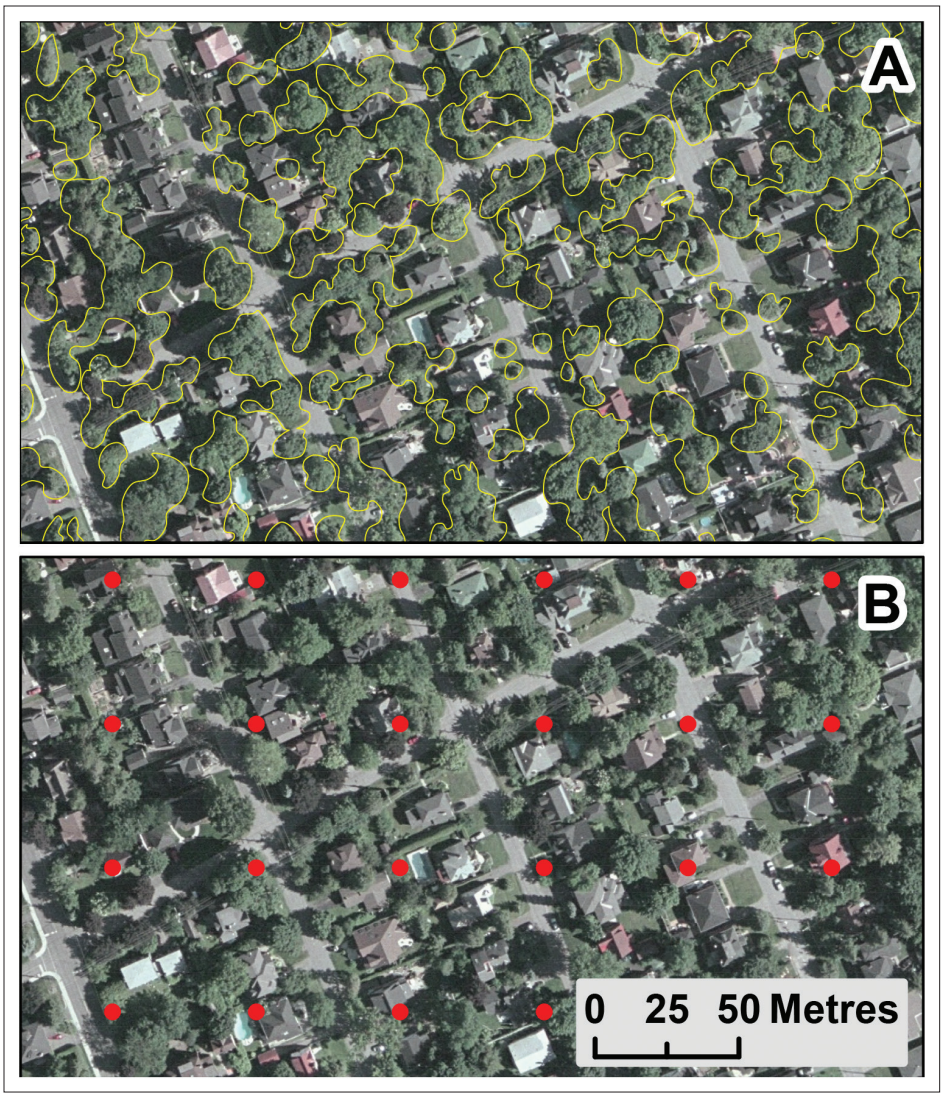

Fig. 6.1. Commonly used canopy cover analysis methods including (A) manual digitizing of canopy cover and (B) point-based sampling.

patterns. (Figure 6.1 demonstrates the difference between the two most common methods.) A second benefit is that individuals with no expertise in geospatial analysis can easily grasp the meaning of the maps. This is important for communicating results with other historians and sharing them with community groups.

We encountered interpretation difficulties that can be classified into three main categories: 1) data availability, 2) data quality, and 3) photo attributes. The availability of historical aerial photographs limits the spatial coverage and depth of analysis that can be performed. In the early years, the flight paths along which photos were taken were sporadic both in terms of spatial coverage and temporal coverage, limiting the neighbourhoods available for analysis, as well as the number of photos available through time for the different neighbourhoods. In many cases, we were able to go back to 1946 photos (and occasionally as far back as 1928); however, regular time intervals were not always

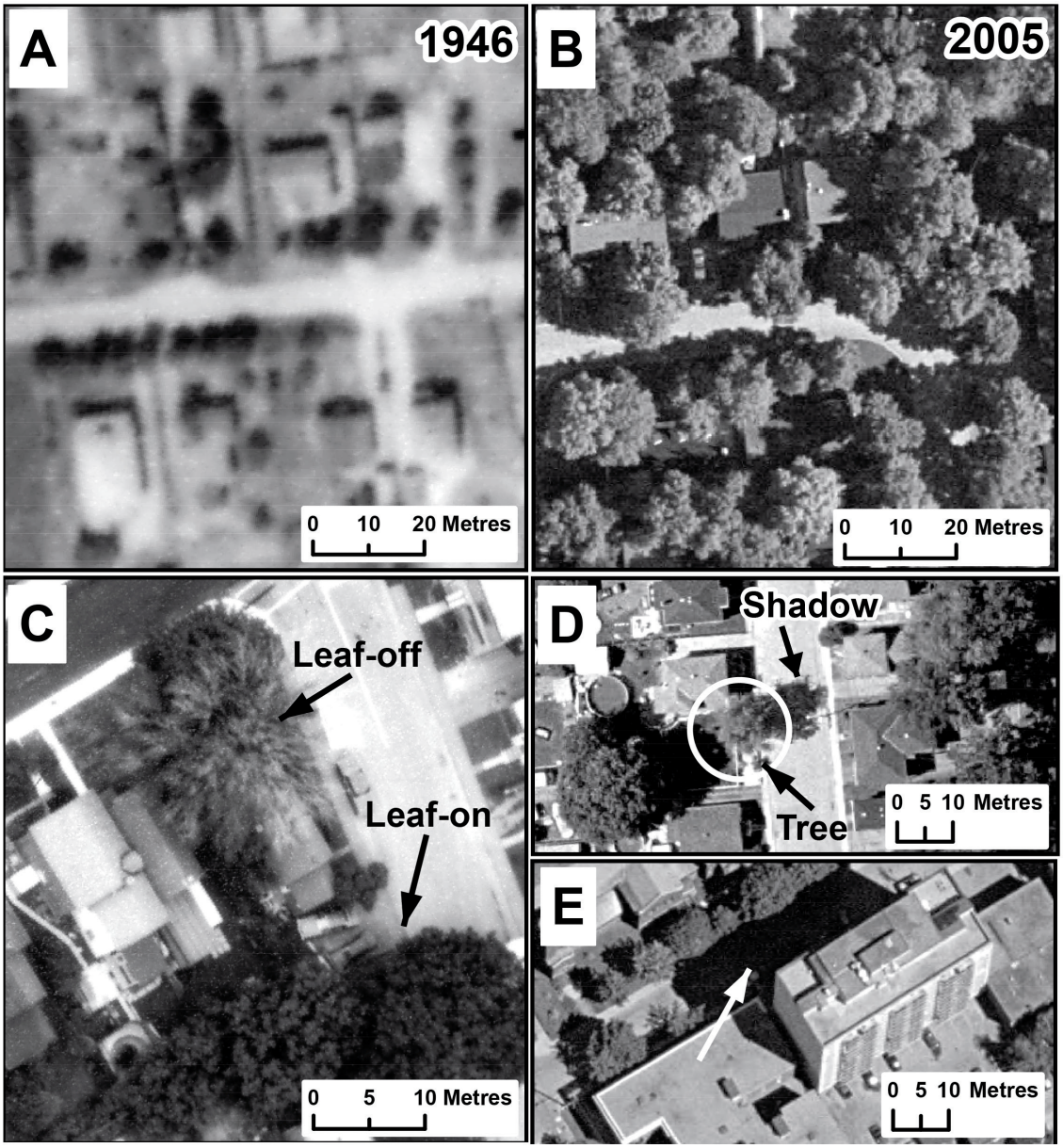

Fig. 6.2. Close-up examples of air photos illustrating some of the issues encountered when digitizing and analyzing. (A) Poor-quality photo (taken in 1946) as a result of technology as well as aircraft height compared with a 2005 photo (B) taken at a lower height using new technology. (C) A comparison between leaf-on and leaf-off conditions demonstrating the difficulty in delineating the crowns of the trees. (D) A large tree-shadow as a result of the low sun angle at the time the photo was taken, demonstrating interpretation difficulties. (E) Shadows created by an apartment building, potentially hiding trees lining the street behind.

Fig. 6.3. Guiges and King Edward Avenue, 1938. Street trees, many of them silver maples, shaded Lowertown in the 1930s. This photograph is from a series of streetscapes used by landscape architect Jacques Gréber that emphasize the beauty of the trees. (Guiges and King Edward [west], Library and Archives Canada/ Department of Public Works fonds/ e010869284.)

possible. In one case, although we had photos from 1946, 1952, and 1956, there were no photos available again until 1985. Such gaps in time have a significant impact on results, especially in such a dynamic environment. Spatial gaps were also problematic. The Canadian government began to gather data for urban "census tracts" in the postwar period, but our study areas rarely matched these tracts, and so the correlations with social indices are not as exact as we might have wished.

Even when photos were available over a specific area, we encountered problems with different acquisition scales (i.e., the aircraft was at a different height during the acquisition, or a different camera lens was used), which resulted in differing levels of image resolution and clarity. (See Figs. 6.2A and 6.2B) While older photos were interpretable by an expert, the results were not as accurate.

The attributes of the photos related to the seasonality and time of day of the acquisitions also caused variability. We sometimes were forced to rely upon photos that were taken in the spring when not all of the tree leaves had opened up and in the fall when some of the leaves had already fallen off. Figure 6.2C demonstrates this issue, with crown delineation hindered when the leaves were not present. Further, as with any work using air photos in an urban environment, shadows are often present. Figure 6.2D provides an example of a large tree shadow cast across the road. Interpretation of these shadows was particularly difficult in older air photos that were only available in greyscale (as opposed to true colour, which is available in more recent photos). Figure 6.2E demonstrates the fact that buildings cast shadows, preventing interpreters from seeing and therefore mapping trees lining the street. Issues of shadows are magnified by photos taken with a low sun angle as well as the presence of taller buildings. Despite these difficulties, we concluded that, while the statistics calculated were by no means exact, the relative measures calculated tell interesting and useful stories about changes over time and provide additional information unobtainable without such techniques.

LOWERTOWN, 1946–2005

Analysis of Ottawa's oldest neighbourhood, Lowertown, reveals the impact of natural and social forces on tree canopy cover. Lowertown was built upon a cedar swamp, and it was initially occupied by the Irish and French Canadian labourers employed in building the Rideau Canal. In the 1940s, when our analysis starts, it was a cohesive francophone working class neighbourhood, distinguished by a landscaped federal avenue, King Edward Avenue, leading from the Governor General's residence, and the bustling commerce of the Byward Market. Street-level photographs taken in the 1930s show a dense canopy cover with tree trunks crowding narrow residential streets.[16] (See Fig. 6.3.) Today there are a few remaining massive street trees, some new street tree plantings, and large spreading trees to the rear of the houses. GIS analysis of one small section of Lowertown shows that the canopy cover was 32 per cent in 1946, dropped to 22 per cent a decade later, and further to 10 per cent in 1966 and 1976. It has only risen to 15 per cent in recent years. (Figure 6.4 shows a time series of photos from 1946 to 2005, and Fig. 6.5 shows mapped canopy cover changes from 1946 to 2005).

The study area for Lowertown was small, but this example shows the importance of occasionally working at an even lower scale, on a street-by-street basis. King Edward Avenue is visible on the right in Figs. 6.4 and 6.5: it was landscaped by the Ottawa Improvement Commission in the early twentieth century with a wide central boulevard of American elm trees. The trees grew magnificently (they were planted over a bywash from the Rideau Canal) and by the 1940s provided deep shade. This avenue was selected by urban planner Jacques Gréber to illustrate the beauties of Ottawa trees; a photograph of King Edward Avenue is featured in his *Plan for the National Capital*. The boulevard of trees was removed in 1965 when Dutch elm disease (DED) struck, to be replaced with additional lanes of traffic, as the avenue became the main traffic artery leading to a new interprovincial bridge.[17] The tree-cutting coincided with a devastating urban renewal project that destroyed the fabric of the neighbourhood, and the avenue has attained iconic status in the memory of Lowertown residents as a symbol of all that they lost.[18] (See Figure 6.6.)

The loss of tree cover on this one avenue skews the results for the entire neighbourhood. If we take this avenue out of the analysis, the tree cover in this working class neighbourhood was only 22 per cent in 1946, declined to 9 per cent in 1956, and then hovered in the low teens until it reached 18 per cent in 2005. Analysis of a second study area in Lowertown showed a similar pattern: 16 per cent cover in 1946; 6 per cent in 1954; 11 per cent in 1976; 8 per cent in 1983, and 15 per cent in 2005. This is the same pattern noted in other neighbourhoods in the inner city. The adjacent neighbourhood of New Edinburgh dropped from 20 per cent in 1928 to 19 per cent in 1956. New Edinburgh, however, was not impacted by urban renewal. (They successfully resisted plans to run the interprovincial artery adjacent to their neighbourhood.) As New Edinburgh gentrified, the canopy cover recovered to 23 per cent in 1966, and 26 per cent in 2005. In a third inner-city neighbourhood, Golden Triangle, the canopy cover dropped from 27 per cent in 1950 to 20 per cent in 1966 and 18 per cent in 1990 and

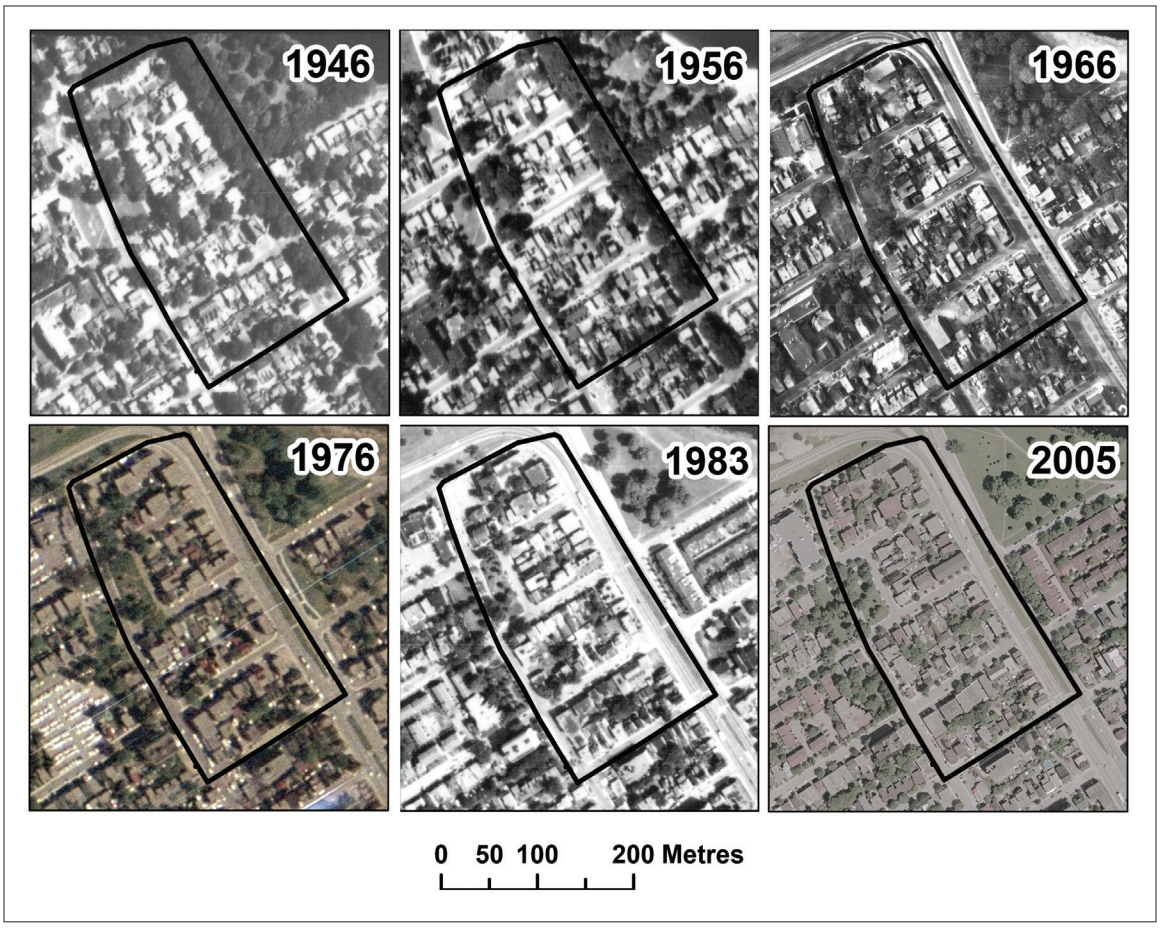

Fig. 6.4. Lowertown. Close analysis of canopy cover in this inner-city neighbourhood demonstrates that the urban forest is an inequitably distributed environmental benefit. Not only is canopy cover currently lower than that of wealthy neighbourhoods, like Alta Vista (see Fig. 6.7), but the densest cover in Lowertown was for many years along one federal boulevard, King Edward Avenue, on the right. In 1946, overall canopy cover was 32 per cent, but if King Edward Avenue is removed from the analysis, the cover on the adjacent residential streets was only 22 per cent. In the 1960s, the trees on this avenue were removed because of Dutch elm disease, and the avenue is now a six-lane interprovincial highway. For street-level photographs of King Edward Avenue, and a sense of neighbourhood anger at the loss of this boulevard, see the King Edward Task Force website, available at http://www.kingedwardavenue.com. (Aerial photographs courtesy of the National Air Photo Library [Series A10371,2; 1946] and City of Ottawa [2005].)

Fig. 6.5. Changes in canopy cover for Lowertown from 1946 to 1950.

has recently risen to 22 per cent in 2005. In all three neighbourhoods, we observe dramatic declines in the middle of the twentieth century and a varying degree of recovery subsequently. These figures, combined with street-level photographs, support the conclusion drawn from textual evidence that the canopy cover was relatively dense in the 1920s and thin in the 1960s.

We might attribute the decline to the management policies of the City of Ottawa. American elm was a favourite tree in Ottawa, as in most cities in eastern North America, and was so thickly planted that it became a problem in the 1920s. Municipal records show that the City engaged in a radical program of tree-trimming and removal to control fast growing "nuisance" trees in the 1930s and 1940s: over 4,000

Fig. 6.6. King Edward Avenue, ca. 1960. Lowertown was subjected to a massive urban renewal project in the 1960s. Photographs justified renewal by documenting poverty in the neighbourhood; they reveal the presence of mature trees planted by an earlier generation. (291–293 King Edward Avenue, ca. 1960. City of Ottawa Archives/2009.0413.1/CA15960.)

trees were removed between 1921 and 1945.[19] Dutch elm disease brought an unexpected denouement. The disease hit Ottawa in the 1950s, after moving from the United States through Toronto and Montreal, and its impact was only felt in the 1960s and 1970s as the elm trees disappeared from the streetscape. But municipal foresters were cognizant of the impact in other cities and reviewed their street tree policy in 1956. They increased tree planting dramatically, planting a total of 2,600 street trees in 1961 (a significant number in a city with a total of 55,000 shade trees, especially compared to 24 trees planted in 1944) and called for street tree planting and improved management and conservation of existing trees in a 1962 report.[20] Municipal authorities noted the dearth of trees in inner-city neighbourhoods and blamed the residents "in the central wards where too many people are inclined to believe that shade trees are part of the past, or that they are the sole responsibility of the Department."[21]

ALTA VISTA, 1946–2005

Analysis of the Alta Vista suburb, in Fig. 6.7, shows the impact of suburban development on forest cover.[22] Alta Vista was an upper-middle-class suburb, developed in the 1950s to the southeast of Ottawa. We initially selected two areas for mapping: 1) an agricultural area, which had only hedgerows and a few individual trees prior to development; and 2) a forested area. Mapping both areas together, we found that canopy cover nearly halved in ten years of construction, dropping from 57 per cent to 29 per cent between 1946 and 1956. It recovered slowly to 34 per cent over the next thirty years and then twenty years later to 48 per cent. (The numbers are high throughout because the mapping area includes a woodlot that was held in reserve for future highway development.) The lesson here is that canopy cover recovers after suburban development but does so very slowly.

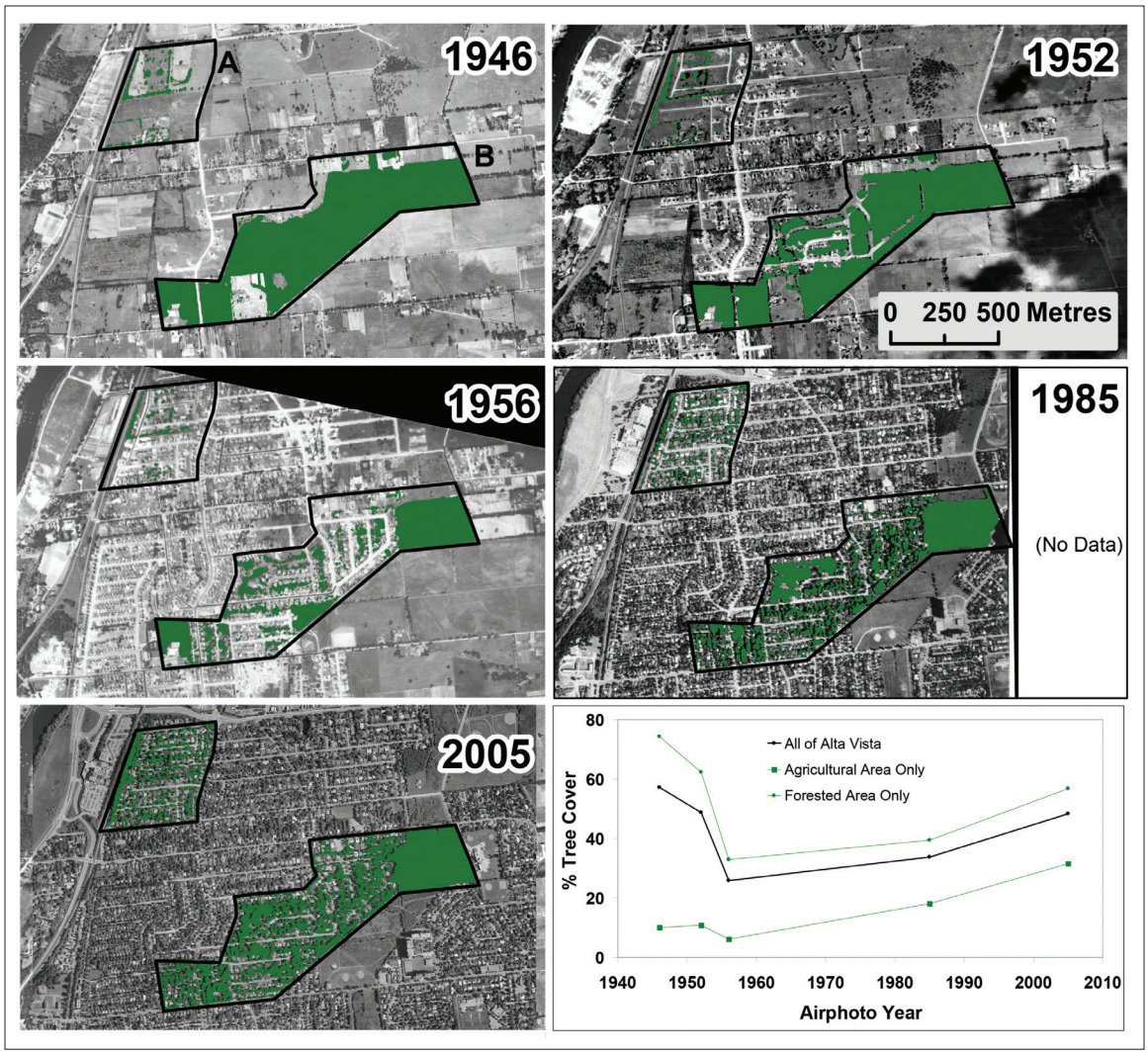

Fig. 6.7. Alta Vista. This prosperous postwar suburb is known for its large lots and mature trees. Two areas were mapped in order to compare the impact of suburban development on open fields and on a dense woodlot. The canopy cover in Area A (see 1946 photo), which began as an agricultural area, was only 10 per cent before construction in 1946. It dropped further to 6 per cent in 1956 with the construction of roads and houses. By 2005, canopy cover had rebounded to 31 per cent. The canopy cover in Area B (see 1946 photo), the original woodlot, was 96 per cent in 1946. It dropped precipitously with construction to 18 per cent in 1956. By 2005, this area had returned to half of its original canopy cover, at 46 per cent. This new forest, however, includes a large proportion of ash trees, now threatened with emerald ash borer. For a complete series of canopy cover mappings of Alta Vista, see http://www.carleton.ca/~jdean/urbanforest.htm. (Aerial photographs courtesy of the National Air Photo Library [Series A 10347, 26; 1946] and City of Ottawa [2005].)

We then analyzed the agricultural area alone (see the region labeled 'A' in 1946 image, Fig. 6.7). Canopy cover here was very low initially, at 10 per cent, and it fell further to 6 per cent before rebounding as new homeowners planted shade trees. It surpassed the original measure in 1985 when it reached 18 per cent and by 2005 had tripled to 32 per cent. It is not perhaps surprising but still useful to know that this kind of low-density suburban development offers a better forest cover than agricultural areas.

Finally, we identified a small densely forested area with 97 per cent canopy cover in 1946 (see the region labeled 'B' in 1946 image, Fig. 6.7). The decline of canopy cover in this area with suburbanization was dramatic, dropping to 18 per cent in 1956, and the recovery fifty years later had only reached about half of the original canopy cover at 46 per cent. The lesson here? The canopy cover in even the greenest suburb is a poor replacement for a forest.

The analysis shows that Alta Vista was the beneficiary of renewed interest in trees in the 1950s and 1960s. Lots in suburban Alta Vista were spacious, especially compared with Lowertown, and thickly planted with large trees. This intent does not show up in the GIS analysis until the trees matured, thirty years after the planting. In Alta Vista, however, the apparent health of the 2005 urban forest is belied by the fact that it is made up of a large number of ash trees. The emerald ash borer (EAB) was first observed in Michigan in 2002 and was confirmed in the Ottawa area in July 2008. This wood-boring beetle has decimated urban forests in southwestern Ontario and parts of the United States and is expected to have a devastating impact in Ottawa. The City of Ottawa has identified Alta Vista as a hot spot for EAB. Ironically, the ash was often selected as a substitute for the America elm; although the ash did not have the elegant vase shape of the American elm, it was a tall tree with dense foliage and offered many of the benefits of elm. Some streets in Alta Vista were planted with 60 per cent ash trees. Tree removals and replacement began in 2011, and a limited program of injections with insecticides began in 2012, but it is expected that the canopy cover in this neighbourhood will be dramatically reduced.

ENVIRONMENTAL JUSTICE

Although natural forces like DED and EAB dramatically impact urban forest canopy cover, social forces are also significant. HGIS allows us to incorporate an environmental justice analysis, using census returns to draw some correlations between canopy cover and the income levels of residents.[23] Our findings are only suggestive as the census areas are not entirely congruent with our mapping areas, but they do consistently suggest that canopy cover follows wealth. Lowertown was a heavily (72 per cent) francophone neighbourhood in 1941, with only 18 per cent of the residents owning their homes, and relatively low median male income of $1,692, 83 per cent of the city average. By 1961 the median male income was $3,219, a relative decline to 69 per cent of the city average. In Alta Vista, by comparison, the median male income was $5,678 in 1961.[24] Although we have not yet correlated income to canopy cover in the remaining urban neighbourhoods, it appears that the recovery of the canopy is related to the gentrification of New Edinburgh and

the Golden Triangle. Urban renewal reports of inner-city neighbourhoods provide further statistics: substandard buildings are mapped, and charts tabulate the number of residents and the state of the plumbing. It would be possible to correlate these statistics with canopy cover if two inner-city neighbourhoods were compared. Alta Vista, however, was not subjected to intrusive urban renewal surveys, so we were unable to develop further correlations.

There was, however, a significant lag to the correlation with income: prosperous Alta Vista residents had to wait for their trees to grow in 1961, while Lowertown residents benefited for years from turn-of-the-century tree planting efforts. The evidence for time lag in tree canopy cover is significant and shows the importance of a long-term historical analysis of environmental inequities. An analysis of vegetation cover in Baltimore in 1960 and 2000 led the authors to argue that "the landscapes we see today are therefore legacies of past consumption patterns." They explain: "[Our] findings suggest that herbaceous or grassy areas, typically lawns, are good reflections of contemporary lifestyle characteristics of residents while neighborhoods with heavy tree canopies have largely inherited the preferred landscapes of past residents and communities. Biological growth time scales of trees and woody vegetation means that such vegetation may outlast the original inhabitants who designed, purchased, and planted them."[25]

Close analysis also shows a second pattern. In the residential streets of Lowertown, the recent recovery in canopy cover is more apparent than real. The large street trees that dominated the canopy in the 1940s were not replaced. The new street trees are smaller species, such as Japanese lilac and choke cherry, which will never attain the height and breadth of the large silver maples and other forest trees that lined the streets (and crowded the front yards) in the 1940s. Much of the existing canopy cover is provided by large Manitoba maples that have grown to the rear of the buildings. Manitoba maple or box elder are weed trees that self-seed in neglected yards and along fence lines. These trees are considered a liability. Although their extensive canopy provides ecosystem services, they also create a disproportionate amount of disservices such as limbs liable to crack during windstorms, extensive sucker growth, foundation damage from invasive roots and prolific seed production. GIS analysis of canopy cover alone misses this kind of qualitative change.

LIMITATIONS OF HGIS

If used in isolation, the statistics provided by canopy mapping can be misleading. Mapping, for example, measures only breadth and does not take into account the depth of the canopy. A squat Japanese lilac might be the geospatial equivalent to a tall columnar oak. Mapping does not distinguish between species of trees or calculate the biodiversity of the forest. The predominance of ash in the Alta Vista neighbourhood is not apparent on the canopy maps. Nor does the method distinguish between trees on public and private property; something that is significant in the weighing of social benefits and costs of urban trees. In Lowertown, the numbers do not reveal that massive silver maple street trees, managed by the municipality, were replaced in part by Manitoba maples that self-seeded along fence lines and were a private responsibility.