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CHANGES IN THE MAJOR ROADS OF SOUTHERN ONTARIO, CANADA 1935-1995: IMPLICATIONS FOR PROTECTED AREAS

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ABSTRACT: Roads are important indicators of environmental change as forested lands are cleared and wetlands are drained to make the roads. Roads also open up areas to further human development leading to declining wildlife habitat and increased introduction of invasive species. This study examines changes in the major roads of southern Ontario every decade from 1935 to 1995. The authors began with a digitized 1995 road map of Ontario and hard copy road maps from the Ontario archives for 1985, 1975, 1965, 1955, 1945 and 1935. Using a geographic information system, roads not present on the 1985 map were removed from the 1995 digitized map. This was repeated for every ten year interval map. Maps are presented to illustrate the dramatic changes in roads around three areas of southern Ontario with varying levels of environmental protection: the Oak Ridges Moraine, the Niagara Escarpment and Algonquin Park.

Keywords: roads; environmental impacts; wildlife; Oak Ridges Moraine; Niagara Escarpment; Algonquin Park; southern Ontario

1. Introduction

Roads have existed for several hundred years in southern Ontario, originally for the movement of humans by foot or by animals, and for transportation using animal-drawn vehicles. It is only in the twentieth century, with the enormous increase in the number of motorized vehicles and the greater scale of movements, that there has been a large expansion in the network of road systems. Roads and motorized transport are now an integral part of the way humans live in Canada. Roads are transport corridors imposed on the environment by humans for the movement of people and the goods and materials required by human society (Bennet, 1991).

Studies (Andrews, 1990) have revealed the following harmful effects of roads:

1. habitat loss and modification with accompanying effect on wildlife populations;
2. intrusion of the edge effect into the core of natural areas;

3. subdivision and isolation of wildlife populations by acting as a barrier;
4. a source of disturbance to wildlife;
5. increased road-kills; and
6. increased human access to natural areas with undesirable impacts.

This study first examines the overall changes in the major roads of southern Ontario every decade from 1935 to 1995. Then, in an attempt to focus on areas of southern Ontario with ecological significance and under threat of human development, the study focuses on changes in roads around three geographic areas with varying levels of environmental protection: the Oak Ridges Moraine, the Niagara Escarpment and Algonquin Park.

2. The Implications of Increased Road Networks on Ecosystems and Human Health

As urban areas continue to expand and the human population steadily grows, pressure for more roads and more lanes on existing roads also rises. Even though the economic and social benefits of road network improvements may seem obvious - for example, improving linkages between communities, reducing commuter times, transporting goods - the impacts of roads on the natural environment and human health should be considered.

Roads impact the natural environment directly through habitat destruction and fragmentation. Roads affect many habitat types and exert their influences at a range of scales; road networks can alter the functional integrity of habitats throughout while individual roads have direct, localized effects. Roads through natural areas reduce the amount of mature vegetative cover, increase the amount of edge habitat, and fragment the landscape into isolated patches (Andrews, 1990). These habitat impacts can have damaging effects on wildlife populations. The removal of natural cover eliminates habitat required by locally adapted organisms. An increase in the amount of edge habitat causes additional stress by attracting edge-adapted, generalist species that compete with native wildlife for diminishing resources.

Habitat fragmentation by roads, and its associated barrier effects to species movement, leads to the severance of wildlife communities and their gradual isolation from one another. The degree of isolation depends on the relative success of different species in crossing roads. A number of studies have shown how roads inhibit wildlife movement and in many cases affect population numbers. For example, small mammals demonstrate a reluctance to cross roads where the distance between forest margins exceeds 20 metres (Mader, 1984). Similarly, amphibians, insects, and even some species of birds exhibit this behaviour. In most cases, the barrier effect of the road is dependent on traffic flow levels and the type of road surface.

Increasing traffic intensity has been shown to reduce the population densities for many types of species within fragmented habitats. For roadside breeding bird populations, low densities are attributed in part to collisions with cars, but mostly to the disturbances (i.e., noise and visibility) caused by traffic (Reijnen *et al.,* 1995). Steady traffic flow is believed to cause stress and hinder communication among bird populations, affecting their ability to reproduce and inciting them to emigrate from the area. Road-related wildlife mortality or “roadkills” of ground-dwelling animals are much more prevalent than birds. Conservative estimates suggest that 5.5 million reptiles and frogs are killed annually by traffic in Australia and that tens to hundreds of millions of snakes have been victims of roadkills in the United States (Fahrig *et al.,* 1995).

The direct loss of habitat from road network construction is important, but the progressive fragmentation and isolation of habitats will eventually reach the point where populations of associated species can no longer be sustained. For this reason, habitat fragmentation, of which roads play a major role, has been identified as a contributing factor to biodiversity loss.

Roads are built for use by motorized vehicles – cars, trucks, motorcycles, and buses - that are the source of air pollution. With an increase in the number of vehicles operating in a region, the problem of air pollution intensifies. Currently, almost all motorized vehicles operate on some form of fossil fuel (e.g., gasoline, diesel) and the emissions from exhaust contain harmful pollutants. Individually, the impact of an automobile’s emissions is negligible. Collectively, the hundreds of thousands of vehicles operating in the region have a dramatic effect on air quality. Among other compounds, exhaust contains nitrogen oxides and carbon dioxide.

Photochemical reactions in the atmosphere turn nitrogen oxides into tropospheric ozone, which is the principle component of SMOG. Because the reactions are dependent on temperature and radiation, ground-level ozone accumulation tends to be greater on hot, humid summer days. The impacts of ozone and SMOG on plants and human health are well documented. Long-term exposure to even low concentrations of ozone can cause changes in plant growth productivity and quality (MacIver and Urquizo, 1998). Acute symptoms in plants include chlorosis, delayed growth, premature senescence and necrosis. Ozone levels of 40 parts per billion can also cause respiratory problems in humans, particularly among the elderly and children (MacIver and Urquizo, 1998). Ozone damages lung tissue, reducing breathing capability and making airways more susceptible to air-borne irritants and other allergens. Records indicate that when ozone concentrations peak, hospital admissions increase (Last *et al.*, 1998).

Another major pollutant emitted from motorized vehicles is carbon dioxide. Carbon dioxide is among the three most important greenhouse gases that are contributing to global climate change. Climate models, based on elevated atmospheric carbon dioxide concentrations, predict a global warming between 1.0°C and 3.5°C by the year 2100 (MacIver and Urquizo, 1998). Carbon dioxide is produced by both natural and anthropogenic sources. The contribution from anthropogenic sources has increased dramatically since the 1700s due to industrial emissions and deforestation. Collectively, automobiles and their relatives have become one of the largest contributors of carbon dioxide. In the Greater Toronto Area, transportation accounts for over 25 percent of carbon dioxide emissions (Harvey, 1993).

3. Selected Areas of Southern Ontario

Three areas of southern Ontario with varying levels of environmental protection have been selected for the study: the Oak Ridges Moraine, the Niagara Escarpment and Algonquin Provincial Park (see Figure 1).

3.1 Oak Ridges Moraine

The Oak Ridges Moraine is one of the most significant natural features in southern Ontario. It is the largest moraine in the province and among the largest in Canada, spanning 160 km east-west from the Niagara Escarpment to the Trent River (see Figure 1). The Oak Ridges Moraine was formed over 10,000 years ago from sand, gravel, and till deposited at the meeting point of two lobes of glacial ice (Ontario Ministry of Natural Resources, 1999). Natural forests and reforested areas cover 28 percent of the Moraine, representing most of the larger linked forest blocks that remain throughout the GTA. Wetlands are less common on the Moraine, covering 2 percent of its surface area, occurring either as isolated depressions, or kettles (thirty-one kettle lakes in all exist on the Moraine, varying in size from 5 to 130 hectares) along the top of the moraine or as headwater wetlands, where groundwater discharges to the surface at the margins of the moraine.

The diverse tracts of woodland and wetland on the Moraine provide habitat for a wide variety of plant and animal species, many of which require large,

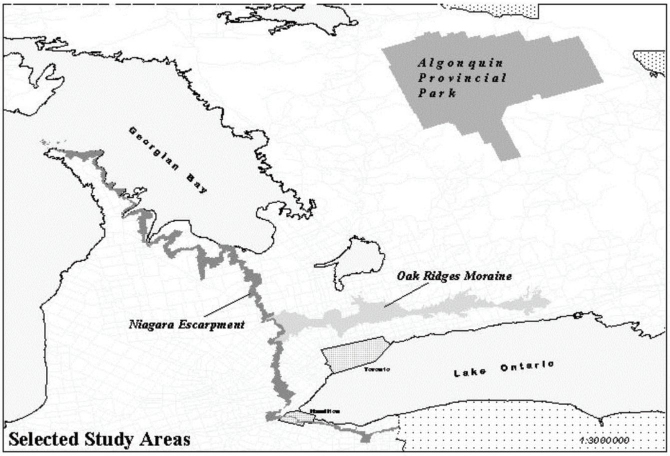


FIGURE 1
Selected Study Areas of Southern Ontario.

undisturbed natural areas. The Moraine's spring-flooded wetlands serve as breeding areas for woodland amphibians and support a variety of waterfowl species. The kettle lakes sustain rich fish assemblages and provide habitat for a large number of plant and animal species. The woodland areas harbour many plant and animal species that are rare in the GTA and several that are threatened in the province. The Moraine is one of 6 major centres for forest birds in southern Ontario, supporting a large and diverse breeding population.

The Moraine's aquifers are essential for maintaining base flow in the 65 watercourses that have headwaters on the Oak Ridges Moraine. The Moraine serves as a fresh-water source for more than 250,000 people in the GTA, providing water for numerous uses including agriculture, residential, commercial, recreation, and industrial. Public lands occupy about 6% (or 9,000 hectares) of the Moraine within the GTA and approximately 4 million people are within an hour's drive of the moraine. All of the natural features of the Oak Ridges Moraine add significant recreational value to the area.

Today, demands for urban expansion are placing unprecedented development pressure on the Moraine. Recent development approvals forecast a 175 percent increase in urbanized area over the next 20 years (OMNR, 1999). Within the GTA, York, Durham, and Peel Regions have approved a population increase of

98,000 on the Moraine over the next 20 years. If pending Official Plan Amendments in York and Durham Regions are approved, a further 56,000 people could settle on the Moraine, 47,000 of whom would live outside of existing urban areas. Most urban development in the GTA is occurring within York Region, along the Yonge Street corridor in the municipalities of Vaughan, Richmond Hill, and Aurora, as well as in Markham (Toronto and Region Conservation Authority, 1999). A series of contentious development proposals involve an extensive development of the Yonge Street corridor portion of the Moraine in the Town of Richmond Hill (from Bathurst Street to Highway 404), a plan that would permit the construction of approximately 17,000 homes in the area (Pim, 2000). There is serious concern over the fragmenting affect of the proposed development on a significant natural corridor, as well as impacts on the major recharge areas for the Moraine's deep aquifers. The municipality of Richmond Hill rejected the proposal in March, 2000, and hearings are currently being undertaken at the Ontario Municipal Board which could order the town to allow housing development, as this arms-length provincial board has the ultimate authority in land-use matters in the province.

3.2 Niagara Escarpment

The southern Ontario portion of the Niagara Escarpment stretches 725 kilometres from Queenston (near Niagara Falls) to Tobermory. The total protected area of the Escarpment is 1,837 square kilometres, representing almost 2 percent of the total area of southern Ontario. The Niagara Escarpment has over 60 waterfalls (including Niagara Falls) and also contains the greatest concentration of cold-water streams in the southern Ontario region, involving 7 different watersheds.

Given its unique topography, the Niagara Escarpment supports an especially high diversity of plant and animal species (Coalition on the Niagara Escarpment, 1998). The southern extent of the Escarpment is within the Carolinian, or deciduous forest region, while the north of the Niagara Peninsula is in the Great Lakes-St. Lawrence forest region. Many plant species found on the Niagara Escarpment are regionally, and even globally significant. The Niagara Escarpment also supports a wide variety of wildlife – 36 species of herptiles, 55 mammal species, and over 300 species of birds.

Public concern about protecting the Niagara Escarpment began to emerge in the early 1960s (CONE,1998) primarily in response to mineral resource extraction. The government responded with the enactment of the Niagara Escarpment Protection Act, 1970 and the Pits and Quarries Control Act, 1971 which served to restrict aggregate extraction along the escarpment. In 1973, the Niagara Escarpment Planning and Development Act was enacted to: "provide for the maintenance of the Niagara Escarpment and land in its vicinity substantially as a continuous natural environment, and to ensure only such development occurs as is compatible with that natural environment" (Government of Ontario, 1990). The Act established the Niagara Escarpment Commission and required it to develop a land-use plan which would achieve several important objectives for the escarpment including protecting unique ecological and historic areas, and providing adequate opportunities for outdoor recreation and public access.

A process that had begun in the mid-1970s culminated in the 1985 Ontario government approval of the Niagara Escarpment Plan of land-use policies, development criteria and open space systems (Government of Ontario, 1994). All lands within the Niagara Escarpment Plan area were placed into one of seven land use designations - natural (protected in a natural state to protect ecological significance), protection (landforms of visual or environmental significance that have been altered by existing land uses and act as a buffer for natural), rural (another buffer acting as a transitional zone between natural/protected and human use), recreation (ski centres, cottage areas or resorts), mineral extraction (aggregate resource extraction areas), minor urban (villages and hamlets) and urban (larger towns and cities). About 92 percent of the Plan area has been designated as natural, protection or rural area.

The Niagara Escarpment was granted the international Biosphere Reserve designation by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1990 as one of the world's important ecosystems that expresses the balance between biological conservation and human development.

3.3 Algonquin Park

Algonquin Park, the largest canoe-camping park in Ontario, occupies over 7,500 square kilometres of land and water in the northern part of Southern Ontario (Algonquin Provincial Park, 1974). The Park has been described as an ecotone where the southern deciduous hardwood forests meet the boreal coniferous forests. The geographical position of the Park creates unusual variations in elevation, climate, soils, vegetation and aquatic conditions resulting in diverse wildlife habitat. Moose, timber wolf, deer, marten and fisher are the better known mammals of the Park area. The birds which are accorded special protection are the loon and blue herons. The majority of the lakes of the park contain cold water species including brook trout.

The Park was established in 1893 through the passage of the Algonquin Park Act which set aside a portion of the ungranted Crown domain as a forest reservation and "national" park. The report that led to the establishment of the Park reflected a commendable interest in all aspects of land management (Algonquin Provincial Park Advisory Committee, 1973) including forest preservation and conservation, climate influences, soil, watershed and wildlife protection, recreation, and logging. They projected the ends to be attained by the reservation or park as the maintenance of water supply in half a dozen major water systems, preservation of a primeval forest, protection of birds and animals, a field for experiments in forestry, a place of health resort and beneficial effects on climate. The Act did not refer to roads specifically, but one of the overriding objectives of the park act was "the maintenance of the Park in a state of nature as far as possible" (Ontario Ministry of Natural Resources, 1980).

In 1933, construction of a highway through the park was begun, partly as a "make work" project during the depression (Lambert and Pross, 1967). By 1936, this new highway, now known as Highway 60, was used by 3,809 automobiles (Sutter, 1967), and provided a road that intersected the park. This road provided at least two-thirds of the access to the Park interior (Master Plan). In 1968, public hearings on a park Master Plan were held, focussing on the conflicting land-uses (primarily development/logging versus preservation/recreation). None of the briefs in the summary published (Department of Lands and Forests, 1969) mention road development, either from those advocating protection, or the economic development councils. When the Algonquin Provincial Park Advisory Committee reported in 1973, it was well recognized that "under no circumstances should another high speed through-highway be directed through the park", a recommendation accepted by the government of the day and extended to include the construction or widening of transmission lines (Ontario Ministry of Natural Resources, 1973). The primary purpose of the park changed at this time "to provide the means for a wilderness recreational experience for park visitors who will travel within the park, by canoe, horseback, on foot or by scenic automobile roads". The Master Plan encouraged the development of "a comprehensive road system both leading into, and inside, the Park".

The movement away from settlement and development in the Park area was balanced with the need to allow recreational access to the park. As the 1974 Master Plan says, "access to the Algonquin interior is gained through points scattered around the perimeter of the Park and along the parkway corridor", and an elaborate "ring of roads" was planned to allow for this access. Scenic road access corridors, as they came to be known, were suggested for Algonquin Park to be linked with perimeter parks and the ring of major highways surrounding the Park. The balance was to "scale down internal development" so that the character of Algonquin Park could be maintained. The Master Plan provided for a ban on roads in historic, nature reserve, or wilderness zones, and phasing out existing roads in these zones; a minimum of roads in recreation/utilization zones; and roads crossing the Park boundary to be kept at a minimum (Master Plan), all of which were adhered to in the first five years of the Plan according to the 1979 Master Plan Review (Ontario Ministry of Natural Resources, 1979).

The discussions on the conflicting land-uses of development/logging versus preservation/recreation continue, with the added issues of privatization of Park operations, and increased pressures for economic development.

4. Methodology

4.1 Methods to Determine Changing Roads of Southern Ontario

Full-size photocopies of original hardcopy road maps for southern Ontario were obtained for 1935, 1945, 1955, 1965, 1975, 1985, and 1995 from the Ontario Archives. A digital layer of 1995 southern Ontario roads was provided by the Ontario Ministry of Transportation (MTO). Relevant road data for the study was contained in the ORMROADS ArcInfo coverage of the MTO's Digital Cartographic Reference Base (DCRB). A digitized version of the 1995 roadmap provided a starting point so that earlier maps could be created by editing backwards from the digital 1995 map within a geographic information system (GIS).

Prior to proceeding with map creation, two potential problems had to be addressed:

1. Consistency of the original roadmaps from decade to decade (i.e., Do the hardcopy maps accurately reflect the changes in the southern Ontario road network between 1935 and 1995?). Specifically, were smaller loose surface and earth roads included on older maps displayed on more recent roadmaps?

2. Each of the original maps used a unique classification system for roads. Furthermore, the ORMROADS coverage uses 30 distinct road type classifications, distinguishing between the jurisdiction (e.g., provincial vs. upper tier/lower tier) and characteristics of roads (e.g., multilane divided/undivided vs. two-lane paved/loose). To observe road network changes over the time period would require a simplified standard legend for all of the maps. A simple classification system had to be developed that

would adequately represent the physical differences between different road types and be applicable to all of the maps in the time series.

MTO was consulted to resolve each of these concerns. MTO confirmed that the representation of roads was consistent on hardcopy maps between 1935 and 1995. Therefore, the digital maps created would accurately reflect road changes over the study period (e.g., all roads included on earlier maps were carried over to later versions.)

On advice from the MTO, a simplified road classification scheme was devised, including the following four categories: *multilane paved, two-lane paved, two-lane loose, and earth/unimproved*. These four categories would adequately represent the major road type differences from all source maps.

Digital road maps for 1935, 1945, 1955, 1965, 1975, and 1985 were created using a geographic information system (GIS). Roads on the 1995 digitized map were re-classified according to the simplified scheme. The 1995 digital map was then edited to match the 1985 hardcopy map. Roads not present on the 1985 map were removed. Road classification changes were also made (e.g., multilane _ two-lane, paved _ loose). The process was repeated for each ten-year interval map.

Note that all road estimations of this study are based on road maps and have not been ground-truthed.

4.2 Methods to Determine Changing Roads of Selected Areas of Southern Ontario

Digital boundaries of the Oak Ridges Moraine, the Niagara Escarpment and Algonquin Park were layered on the road maps of southern Ontario using the geographic information system (GIS). The GIS was then used to query the length (in kilometres) of roads in the Oak Ridges Moraine, and the Niagara Escarpment, every ten years. Note that, in some cases, these roads were beyond the planning boundaries but no more than 1 kilometre. The GIS was used to query the area of each protected area, and the road densities were determined from both results (road density = kilometres of road/square kilometre area).

Roads in the Algonquin Park that appeared on the southern Ontario maps were limited to Highway 60 only. Information on the other roads in the Park for logging and other uses is not readily available. There are maps available of historical and current logging roads, and these will be digitized in future research. Instead, the roads around Algonquin Park were mapped, and historical maps were viewed to show the changes in "access" points to the Park.

The digital layer for the Niagara Escarpment was divided by classifications of land use - natural, protection, rural, recreation, mineral extraction, minor urban and urban. The GIS was used to query the changes in roads in each of the land use classifications for 1975, 1985 and 1995 (note: urban land designations were combined).

5. Results

5.1 Changes in the Roads of Southern Ontario 1935-95

The major roads of southern Ontario increased from 7,133 kilometres in 1935 to 23,806 kilometres in 1965 to 35,637 kilometres in 1995 (see Figure 2) - a time of increasing human settlement and economic growth in southern Ontario.

Examining major road growth in southern Ontario by decade from 1935 to 1995 shows that 1955 to 1965 had the most growth at 7,567 kilometres with 1945 to 1955 and 1965 to 1975 following close behind. Multi-lane paved road development in southern Ontario by decade from 1935 to 1995 shows that 1955 to 1965, at 983 kilometres, was the busiest expansion decade while 1975 to 1985, at 838 kilometres, was the second busiest.

The major road development from 1935 to 1995 spreads throughout southern Ontario, yet most occurred around the major human population centres of the Golden Horseshoe (1945 to 1955) that wraps around the tip of Lake Ontario; the city of Toronto (1945-1965) and the city of Ottawa (growth through all decades). The incentive to settlement of having a transportation corridor to markets and employment is enhanced through the development of multi-lane paved highways, shown as blue areas, around the Golden Horseshoe and around the city of Ottawa.

5.2 Changes in Major Roads in the Oak Ridges Moraine 1935-95

The major (paved) roads in the Oak Ridges Moraine increased from 126 kilometres in 1935 to 554 kilometres in 1965 to 1016 kilometres in 1995 (see Figure 3). Most roads, which by 1995 includes four multi-lane highways, run north to south creating a series of paved barriers to wildlife movement.

The road density of the Oak Ridges Moraine was 0.065 kilometres in 1935, 0.283 kilometres in 1965, and 0.518 kilometres in 1995. Compared with a typical county in the region (see Figure 4), the road density of the Oak Ridges Moraine

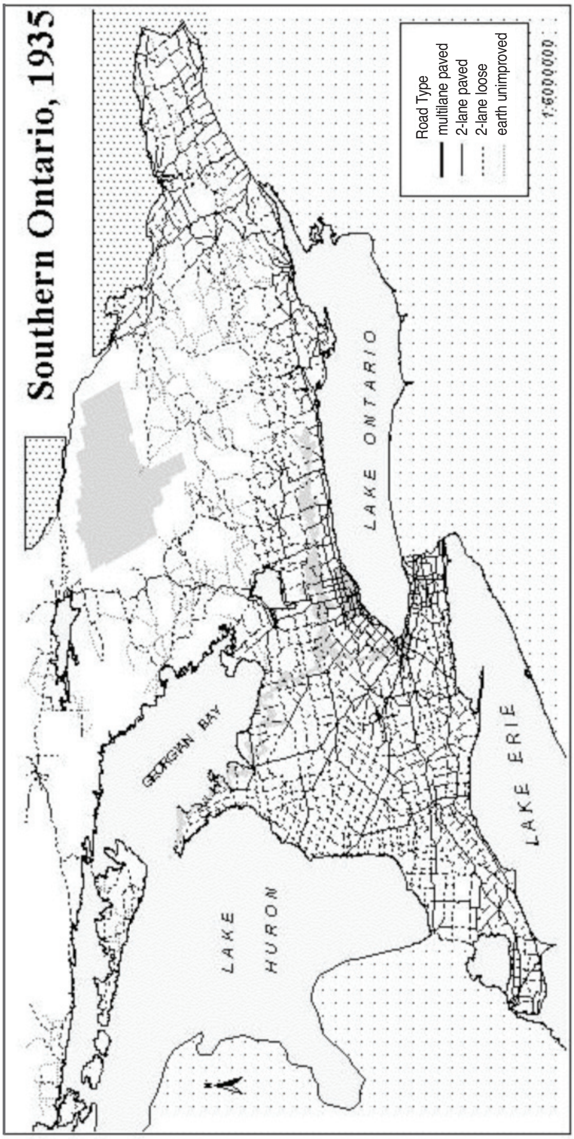


FIGURE 2
Changes in the Major Roads of Southern Ontario, Canada 1935 to 1995.

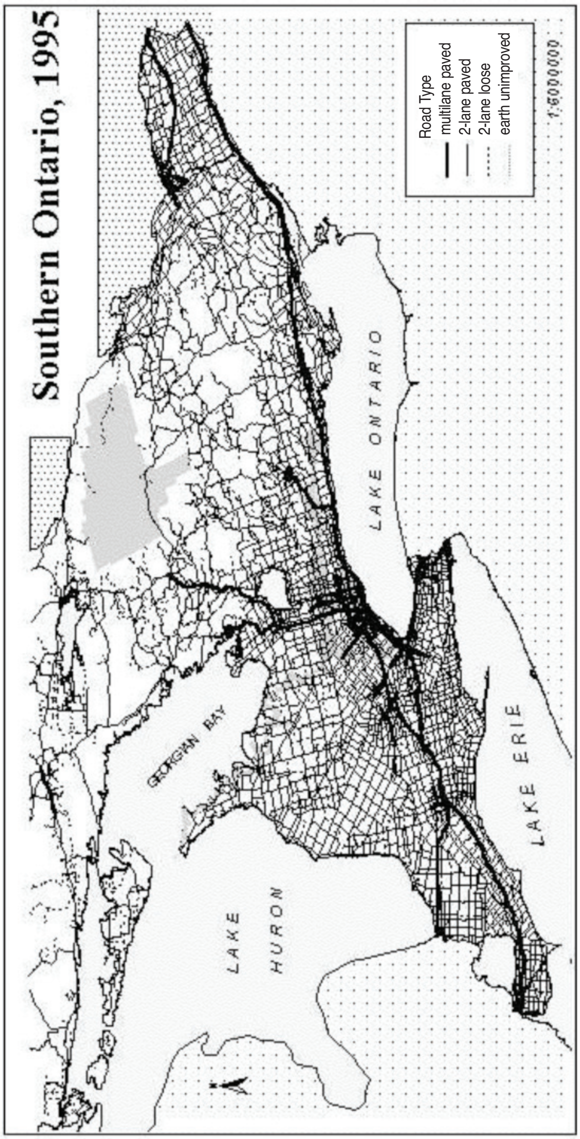


FIGURE 2 continued
Changes in the Major Roads of Southern Ontario, Canada 1935 to 1995.

FIGURE 3
Changes in the Major Roads on the Oak Ridges Moraine, Ontario, Canada 1935 to 1995.

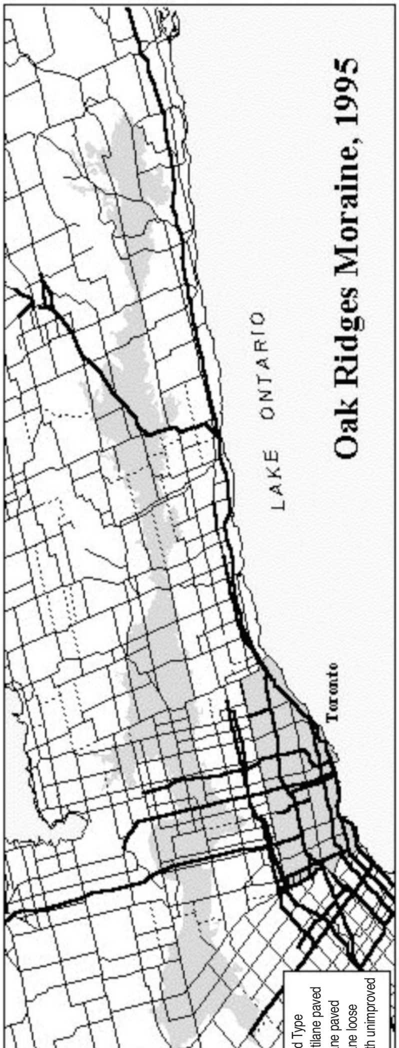


FIGURE 3 continued
Changes in the Major Roads on the Oak Ridges Moraine, Ontario, Canada 1935 to 1995.

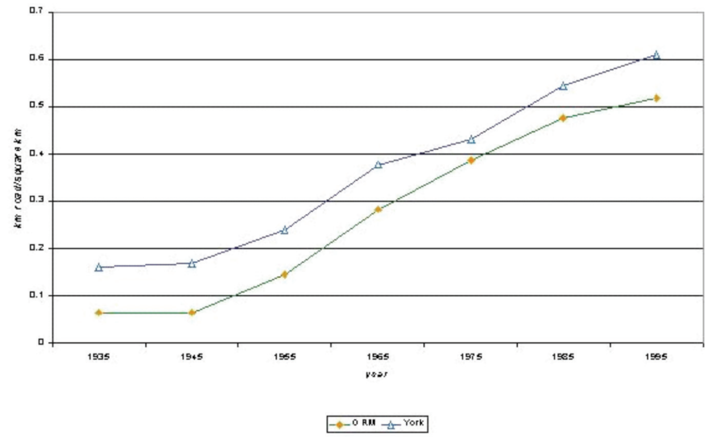


FIGURE 4

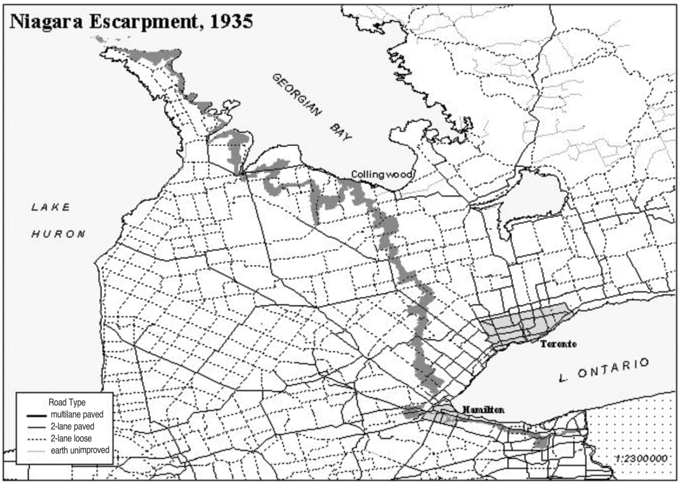
Changes in the Densities of Major Roads on the Oak Ridges Moraine and York Region 1935 to 1995, a comparison.

is about one-half that of York Region, yet changes at about the same rate over time to the point where the road density in the Oak Ridges Moraine is about 90 percent of the road density in York County.

5.3 Changes in Major Roads in the Niagara Escarpment 1935-95

The major roads in the Niagara Escarpment increased from 173 kilometres in 1935 to 567 kilometres in 1965 to 923 kilometres in 1995 (see Figure 5). This is equivalent to a road density of 0.094 km in 1935 to 0.309 km in 1965 to 0.503 km in 1995. What is obvious from the maps is the increasing number of intersections of the natural corridor that the Niagara Escarpment is intended to protect. By 1995, there are 9 points at which multi-lane highways cross the escarpment, presenting an significant barrier to wildlife movement.

The major road changes in the Niagara Escarpment since the enactment of the 1973 Niagara Escarpment Planning and Development Act increased from 712 km in 1975 to 842.5 km in 1985 to 923.5 km in 1995 - a steady increase. These represent the changes in paved roads only. Overall roads (including the 2-lane loose and earth roads) did not change as dramatically during the 1975 to 1995 time period. In recent history, the overall roads did not



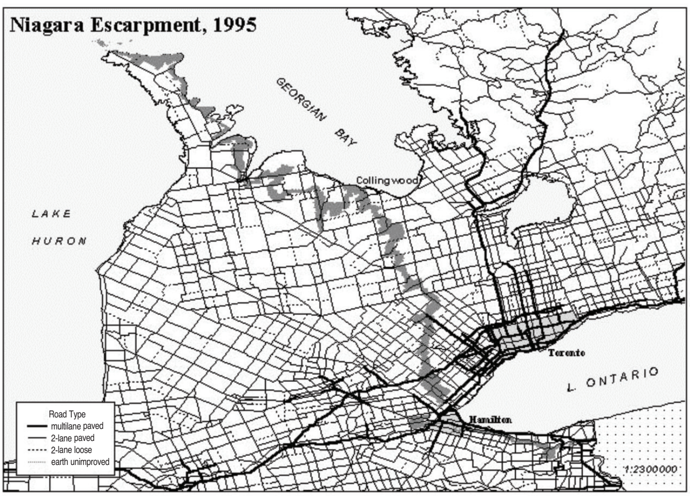


FIGURE 5

Changes in Major Roads Along the Niagara Escarpment 1935 to 1995.

change within the Niagara Escarpment Planning Area from 1985 to 1995 with a total of 1075.5 kilometres of roads. During this time period, 81 kilometres of gravel road were paved, but no new roads were added. Paving dirt or loose roads tends to increase the speed and volume of road traffic which impacts wildlife more significantly and leads to further human development of the area.

The land designations of the Niagara Escarpment reveals that 8 percent of the land falls within the urban, minor urban, recreation and mineral land designations (known as the zone of co-operation by the UNESCO Biosphere Reserve design), while 92 percent lies within the natural, protected and rural designations. From an environmental perspective, roads would be clustered ideally in the zone of co-operation. However, examining the distribution of roads within the Niagara Escarpment in 1975 shows that 12 percent of the roads were in the zone of co-operation while fully 88 percent were in the natural, protected and rural lands designations. By 1995, with an additional 100 kilometres of paved roads, this has changed little with the additional paved roads occurring in the lands designated as Escarpment "natural".

5.4 Changes in Major Roads Around Algonquin Park 1935-95

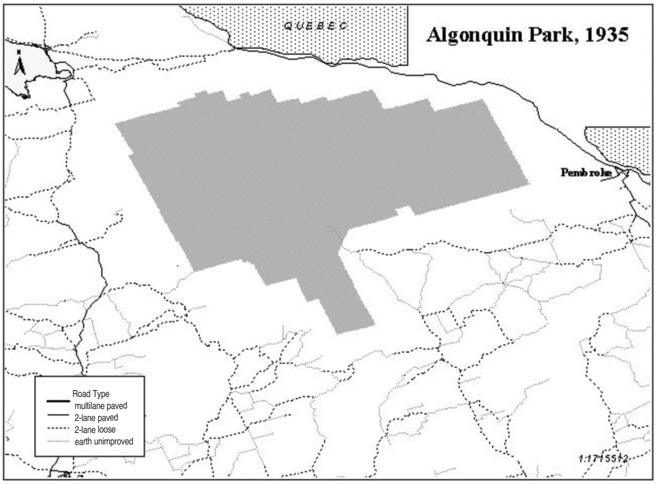
While no quantitative analysis has been possible for the roads around Algonquin Park, it is clear from viewing the maps that a series of access roads (see Figure 6) now branch out to reach the Park, creating the "ring of roads" for recreation use at various access points to the Park. The primary concern now is not so much the barrier effect but the potential for increases in invasive species and the potential increases of traffic volume into the Park as the number of access roads has increased, yet remains not very large in number when compared with the Oak Ridges Moraine and the Niagara Escarpment.

6. Future Research

This analysis of road changes in southern Ontario provides an interesting graphic of human development and the potential environmental and human health changes that accompany this development. It also calls for additional studies.

6.1 National Scale Studies

Probably most important, at this time, is to conduct a study of the changes in major roads of the remainder of the province of Ontario, of other provinces and territories, and of the entire country in order to have a database of major road changes for all of Canada that can be used for environmental assessment purposes.



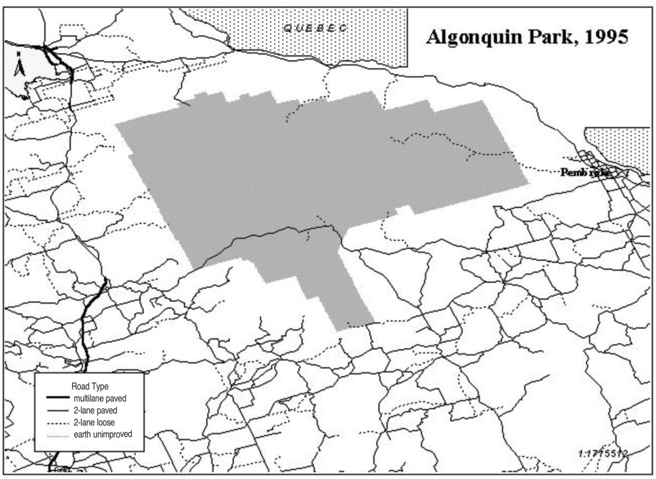


FIGURE 6
Changes in the Major Roads around Algonquin Park, Ontario, Canada 1935 to 1995.

6.2 Southern Ontario Scale Studies

These maps of the major road changes in southern Ontario from 1935 to 1995 provide an excellent basis for comparison with other road-related databases including traffic densities and emissions; use of road salt and water quality; road-related wildlife mortality or "roadkill"; and road and weather hazards.

Another fruitful research area would be to examine the issue of climate change as a result of increasing anthropogenic emissions of greenhouse gases. The change in overall greenhouse gas emissions from the transportation sector in southern Ontario can be studied through the shift from railway transport to road transport as a result of the "just-in-time" delivery increases.

Several international studies have examined the effects of traffic densities and its subsequent noise and disturbance for roadside breeding birds. The major road change maps of this study can be related to overall changing traffic density and noise, as well as direct mortality on breeding birds of southern Ontario.

It is important to test the magnitude of the effects, and the timing of the effects, of major road changes on human settlement, economic activity, overall agricultural land and overall forested land in order to better understand how roads lead to significant environmental change.

6.3 Selected Areas Scale Studies

Additional studies need to examine the questions raised by the analysis of road changes in the Oak Ridges Moraine, the Niagara Escarpment and Algonquin Park including: digitize the historical maps of roads within Algonquin Park; examine the reasons for paving the 100 kilometres of gravel roads in the protected areas of Niagara Escarpment; examine the road changes and forest cover changes in the Niagara Escarpment; examine the cumulative effects of road development on the Oak Ridges Moraine; investigate the possibilities for wildlife crossings in these areas; and investigate recommendations for roads and land use planning on the Oak Ridges Moraine.

7. Acknowledgements

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