The Middlesex Natural Heritage Study

A Natural Heritage Study to Identify Significant Woodland Patches in Middlesex County

Prepared by:
Upper Thames River Conservation Authority
in cooperation with the Middlesex Natural Heritage Study Steering Committee

Final Draft
July 2003

Table of Contents

Table of Contents i

List of Tables ii

List of Figures iii

1. Introduction 1
- 1.1 Project Coordination 2
- 1.2 Project phases 2
- 1.3 Budget 2

2. Study Area 3

3. Methods 6
- 3.1 Selection of Sites for Inventory 6
- 3.2 Landowner Contact 6
- 3.3 Field Survey Methods 6
  - 3.3.1 vascular plants 6
  - 3.3.2 vegetation communities 6
  - 3.3.3 woodland patch type 7
- 3.4 Field Data Entry and Analysis 8
  - 3.4.1 database 8
- 3.5 Mapping and Geographical Information System Analysis 8
  - 3.5.1 update woodland patch layer 8
  - 3.5.2 change in forest composition 9
  - 3.5.3 spatial parameters 9
- 3.6 Statistical Analysis 10

4. Results and Analysis 11
- 4.1 Woodland Physiography 11
- 4.2 Landowner Contact 12
- 4.3 Change in Forest Composition 12
- 4.4 Field Survey Findings 13
  - 4.4.1 vascular plants 13
  - 4.4.2 vegetation communities 18
  - 4.4.3 woodland patch type 23
- 4.5 Results of Mapping and GIS Analysis 23
  - 4.5.1 woodland patch size 23
  - 4.5.2 woodland patch interior 23
  - 4.5.3 forest connectivity 23
- 4.6 Results of the Statistical Analysis 26
  - 4.6.1 native species richness 26
  - 4.6.2 non-native species richness 27
  - 4.6.3 weediness 28
  - 4.6.4 mean conservatism coefficient 28
  - 4.6.5 basal area 30
- 4.7 Summary of Key Results and Recommendations 30

5. Identification of Significant Woodland Patches **32**
5.1 Rationale for Landscape Criteria 32
5.2 Development of Landscape Criteria 33
5.2.1 criterion 1 33
5.2.2 criterion 2 33
5.2.3 criterion 3 34
5.2.4 criterion 4 35
5.2.5 criterion 5 35
5.2.6 criterion 6 36
5.3 Identification of Significant Woodlands 36
5.4 Summary of Key Points and Recommendations 37

6. Implementation **38**
6.1 Implementation Tools 38
6.2 Land Use Planning 38

7. References **39**

8. Appendices
Appendix 1 Landowner Contact Package A1-1
Appendix 2 Standard Field Data Forms A2-1
Appendix 3 Glossary A3-1
Appendix 4 Database Relationship Diagram A4-1
Appendix 5 Vascular Plants of Middlesex County A5-1
Appendix 6 Geodatabase Digital Mapping Layers A6-1
Appendix 7 Tree Species by Physiographic Type A7-1
Appendix 8 Landowner Follow-up Package A8-1
Appendix 9 Recognized Natural Heritage Features in Middlesex County A9-1

List of Tables

Table 1. Project Revenue (Cash) 1
Table 2. Forest cover of counties abutting and including Middlesex County 4
Table 3. Forest health indicators and landscape parameters calculated for each surveyed patch in Middlesex County 10
Table 4. Comparison between the area of physiographic types in Middlesex County and the area covered by woodlands for each physiographic type 11
Table 5. The average wetness coefficient for all native plants found in a particular physiographic type 18
Table 6. Regressional analysis table showing relationship between native species richness per patch and the independent landscape variables 27
Table 7. Regressional analysis table showing relationship between non-native plant species and the independent landscape variables 27
Table 8. Total native and non-native plant species richness, mean number of native and non-native plant species per woodland patch and mean conservatism per woodland patch in nine woodland patch size classes 28
Table 9. Regressional analysis table showing relationship between sum of weediness scores per patch and the independent landscape variables 28
Table 10. List of the six landscape criteria used to evaluate woodland patches in Middlesex County 32
Table 11. The percent of woodland patches in geographic Middlesex County that meet a certain number of criteria 36

List of Figures

Figure 1. Location of Middlesex County in southwestern Ontario 3
Figure 2. Location of Middlesex County in the forest regions of southern Ontario 3
Figure 3. Physiography of Middlesex County 4
Figure 4. The proportion of physiographic types for Middlesex County 5
Figure 5. Calculation of basal area showing a) good forest management with a mixture of trees of different size classes and b) poor forest management with only small trees remaining 7
Figure 6. Calculation of woodland patch interior 9
Figure 7. A comparison of the relative dominance of canopy tree species in the surveyed patches between the 1950s to 1960s and data collected in the field for MNHS and LSWS 13
Figure 8. The number of native species (excluding grasses and sedges) that occur in a certain number of patches 14
Figure 9. The number of non-native species (excluding grasses and sedges) that occur in a certain number of patches 15
Figure 10. The number of plant species found only once in Middlesex County per area of physiographic type studied in MNHS and LSWS 15
Figure 11. Distribution of the conservatism coefficient for native plant species (excluding grasses and sedges) for all of Middlesex County and for plants surveyed in the MNHS and LSWS 16
Figure 12. Sum of patch weediness scores per sampled area for each physiographic type 17
Figure 13. Distribution of the coefficient of wetness for native plant species (excluding grasses and sedges) for all of Middlesex County and for plants surveyed in the MNHS and LSWS 17
Figure 14. Comparison of the average coefficient of wetness per patch for herbaceous plants and trees 18
Figure 15. Proportion of woodland communities of a particular successional age 19
Figure 16. Soil textures of Middlesex County 19
Figure 17. Diameter size class distribution of upland hardwood trees in Middlesex County compared with the recommended residual diameter size class according to the provincial standard 21
Figure 18. Basal area distribution of medium and large trees in upland hardwood woodland patches surveyed in MNHS 21
Figure 19. Basal area of medium and large upland trees plotted against average tree size for forest communities surveyed in MNHS 22
Figure 20. Disturbance scores summed over all woodland patches surveyed in MNHS 22
Figure 21. The distribution of woodland patch size class in Middlesex County by a) the number of woodland patches and b) the total area of woodland patches 24
Figure 22. Distribution of interior size classes for woodland patches in Middlesex County 25
Figure 23. The amount of interior for patch sizes between 6 to 15 ha in area 25
Figure 24. Woodland patches in Middlesex County that are greater than 10 ha and buffered by 100 m on outside of patch 26
Figure 25. Regression of a) native and b) non-native plant species richness against patch area surveyed in MNHS and LSWS 29
Figure 26. Regression of mean conservatism coefficient against patch area for surveyed patches in MNHS and LSWS 30
Figure 27. Woodland patches in Middlesex County that meet one or more landscape criteria 37

1. Introduction

The Middlesex Natural Heritage Study (MNHS) was initiated in 1999, when the County of Middlesex asked the five Conservation Authorities with jurisdiction within its boundaries, as well as the Ontario Ministry of Natural Resources (OMNR), to participate in a natural heritage study that would provide information on woodland significance. Middlesex County recognized the need to develop a solid information and policy basis for its woodland and wetland features, in order to fulfil the County's obligations under the Provincial Policy Statement. The County had adopted an official plan which identified the natural heritage areas of Provincial significance in 1997 but it was recognized that other natural heritage areas on the landscape are critical to the health of the County's natural heritage system.

Woodlands are important components of the County's natural heritage system. The definition of a woodland in context of the Provincial Policy Statement (PPS) are treed areas that provide environmental and economic benefits such as erosion prevention, water retention, provision of habitat, recreation and the sustainable harvest of woodland products. For the purposes of this report, woodlands cover the continuum from wetland (bottomland) through to upland, and include treed areas, woodlots and forested areas. Woodland and forest are considered equivalent terms. All woodlands or forests that occur within wetlands, as well as uplands that are at least 0.5 ha in size, were subject to criteria for designation as significant in Middlesex County.

The original partners in the project agreed to proceed with a scientific study of the County's woodland ecosystem which would allow for the identification of areas of County significance and consider options for maintaining and enhancing these areas for future generations. The following specific study goals were identified:

1. To collect biological information on the County's forest-dominated ecosystems *(e.g.* woodlands, wetlands) that would act as background information for the woodland system in official plan policy (County and local plans).

2. To encourage self-sustaining natural ecosystems by increasing the certainty about woodland patches on the landscape that support areas of provincial significance, such as ANSIs (Areas of Natural and Scientific Interest) and PSWs (Provincially Significant Wetlands), as well as areas of local interest such as ESAs (Ecologically Significant Areas) and LSWs (Locally Significant Wetlands). The MNHS will provide baseline data for these supporting natural heritage features.

3. To develop land use planning information and policy to enable the protection and rehabilitation of the County's forest-dominated natural heritage features and systems. The MNHS will provide criteria for the local definition of woodland recognition, associated criterion mapping for significant woodlands and identification of sites for future restoration and rehabilitation.

4. To encourage and facilitate private stewardship and conservation, as well as public education.

5. To increase the representation of forest-dominated natural heritage features in the County.

The MNHS is a pilot project for the Carolinian Canada Big Picture Project and the Ministry of Natural Resources Ecological Land Classification System (ELC) for Southern Ontario (Lee *et al.* 1998), as well as landowner outreach and stewardship approaches. The MNHS provides a methodology where detailed, site specific woodland information is combined with landscape level analysis tools to identify woodlands which are considered to be of County significance. For the site specific field component of the study, the study area was limited to the lands within the corporate jurisdiction of the County of Middlesex. The study limit was expanded to include the geographic County for the landscape level analysis component. The application of the landscape methodology to the broader study area does allow for the identification of significant woodland patches that are beyond the Corporate boundary of the County of Middlesex.

While the primary focus of the study is to identify woodland patches that are of County significance, the study also needed to anticipate methods for implementing the study findings to achieve the goals that were identified. With the County of Middlesex having a fairly new official plan, and the expectation that the MNHS would serve as a background document to support the first five year review of the official plan, it is not surprising that land use planning was contemplated throughout the process as a means of implementing the goals of the MNHS. While there is a focus on implementation of the study findings through the planning process, it is also recognized that there are other means of implementation that should be explored. To address this, a brief discussion on implementation options is included in this report.

1.1 PROJECT COORDINATION

The MNHS was coordinated by the Upper Thames River Conservation Authority (UTRCA) in partnership with the County of Middlesex, Middlesex Stewardship Committee, Elgin Stewardship Council, Middlesex County Conservation Authorities (Ausable Bayfield, St. Clair Region, Lower Thames Valley, Kettle Creek and Upper Thames River), City of London, Carolinian Canada, Nature Conservancy of Canada, Ministry of Natural Resources, Ministry of Municipal Affairs and Housing and the Thames Talbot Land Trust. A review of the draft methodology and the derived criterion mapping was undertaken with the partners.

1.2 PROJECT PHASES

The project is being funded from several sources. The UTRCA is managing the funding and the service contracts for this project. The project tasks with costs are summarized as follows:

PHASE I: GEOGRAPHIC INFORMATION SYSTEMS (GIS) MAPPING (1999)

- Transcribe and digitize heritage and hazard information
- Import and verify data from OMNR and Middlesex County
- Compile data layers for the five Authorities to assist with Conservation Authority planning services

Value: $6,600.00 (completed by UTRCA staff as an in-kind contribution)

PHASE II: LANDSCAPE DESCRIPTION/ CLASSIFICATION (2000)

- Establish steering committee
- Develop woodland significance criteria and assessment guidelines
- Review background reports and studies
- Verify woodland patch location and boundaries
- Review and assimilate Big Picture data
- Apply scoping methodology to identify woodland patches for field inventories
- Complete drive-by assessments/audits for final verification
- Finalize known information mapping layers on GIS
- Complete preliminary woodland patch analysis using GIS

Value: $24,000.00

PHASE III: GIS MODELLING & ANALYSIS, FIELD INVENTORIES (2001)

- Set up field database
- Complete landowner contact approach and education program
- Field inventory in selected woodland patches across the County using ELC
- GIS modelling and analysis of patch parameters including: patch size, shape, amount of forest interior, proximity to satellite woodlots, *etc.*
- Data entry, analysis and documentation of field results

Value: $48,000.00

PHASE IV: PRODUCTS/IMPLEMENTATION (2002)

- Finalize data trends and scientific findings
- Develop mapping showing County-wide natural heritage system
- Develop policy implementation options
- Assist lower tier municipalities with implementation
- Develop land stewardship programs
- Finalize woodland significance criteria and assessment guidelines
- Refine Conservation Authority policies and program targets
- Prepare summary reports
- Identify future project stages

Value: $24,000.00

1.3 BUDGET

The total project budget for the MNHS is $102,600.00. This amount was funded by cash ($63,500) from various sources (Table 1) and in-kind contributions from the project partners ($39,100) including Conservation Authorities and OMNR. The UTRCA managed the funding and the service contracts for this project.

Table 1. Project Revenue (Cash)

Amount	Source
$14,500.00	Middlesex Stewardship Committee
$5,000.00	Carolinian Canada
$24,000.00	County of Middlesex
$15,000.00	Ontario Trillium Foundation with Elgin Stewardship Council support
$5,000.00	Nature Conservancy of Canada
$63,500.00	

2. Study Area

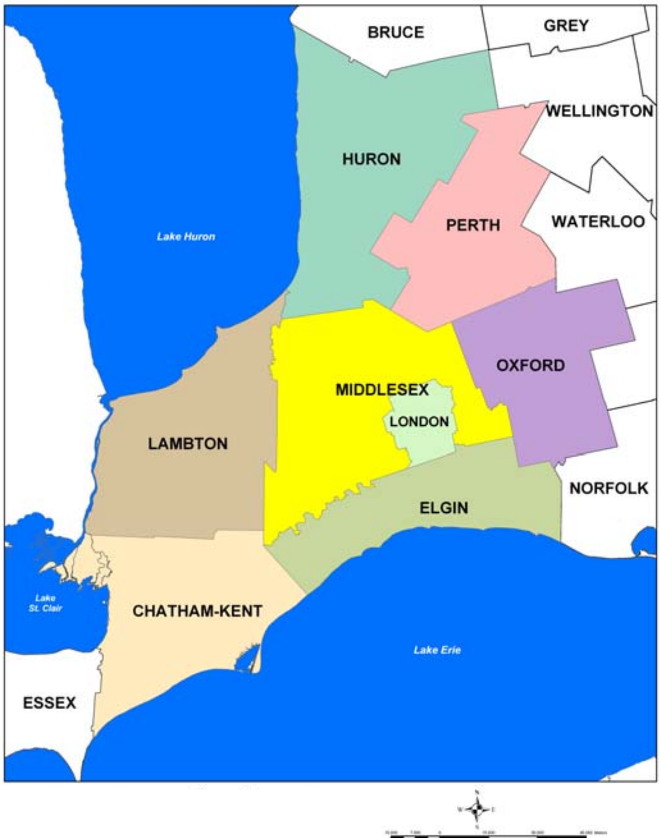

Figure 1. Location of Middlesex County in southwestern Ontario.

The County of Middlesex is located in the agricultural heartland of southwestern Ontario between Oxford County to the east, Lambton County to the west, Perth and Huron Counties to the north and Elgin County to the south (Figure 1). According to the 1999 Middlesex County Official Plan, the County is in the watersheds of five Conservation Authorities (the Upper Thames River, St. Clair Region, Ausable-Bayfield, Kettle Creek and the Lower Thames Valley) and is a federation of eight municipalities covering an area of approximately 284,464 ha (1098 square miles). Although the largest municipality in the County is the City of London at 42,298 ha, it was not included as part of the study area because it is more urban than other parts of the County and might skew the results.

Middlesex County lies in the transition zone between the Great Lakes - St. Lawrence forest region to the north and the Carolinian Life Zone or Southern Mixed Deciduous forest region to the south (Figure 2). Remnant forests contain plants and animals with both the northern and southern affinities. The Carolinian Life Zone makes up less than 1% of Canada's land area, yet boasts more species of plants and animals than anywhere else in Canada. Archival records suggest that this rich, forest dominated ecosystem supported abundant populations of mammals, birds, reptiles and amphibians. Many of these species, such as the Tulip Tree, Sassafras, Eastern Spiny Softshell Turtle and Acadian Flycatcher, as well as several species of fish and mussels, are not found anywhere else in Canada.

Agriculture is the predominant land use and economic mainstay in the County. Between 1825 and 1875, increased settlement and the push for economic development led to the very rapid depletion of a large portion of the original forest for agriculture, timber, fuel wood and railway construction. The reduction was so rapid that by 1860 the forests of Middlesex County were depleted by more than 60% and by 1910 by more than 90% (Department of Planning and Development 1952). In 1940, the census of Canada showed woodland coverage for Middlesex County (not including London) to be 7.8 %. Forest cover has since rebounded to 12.3%.

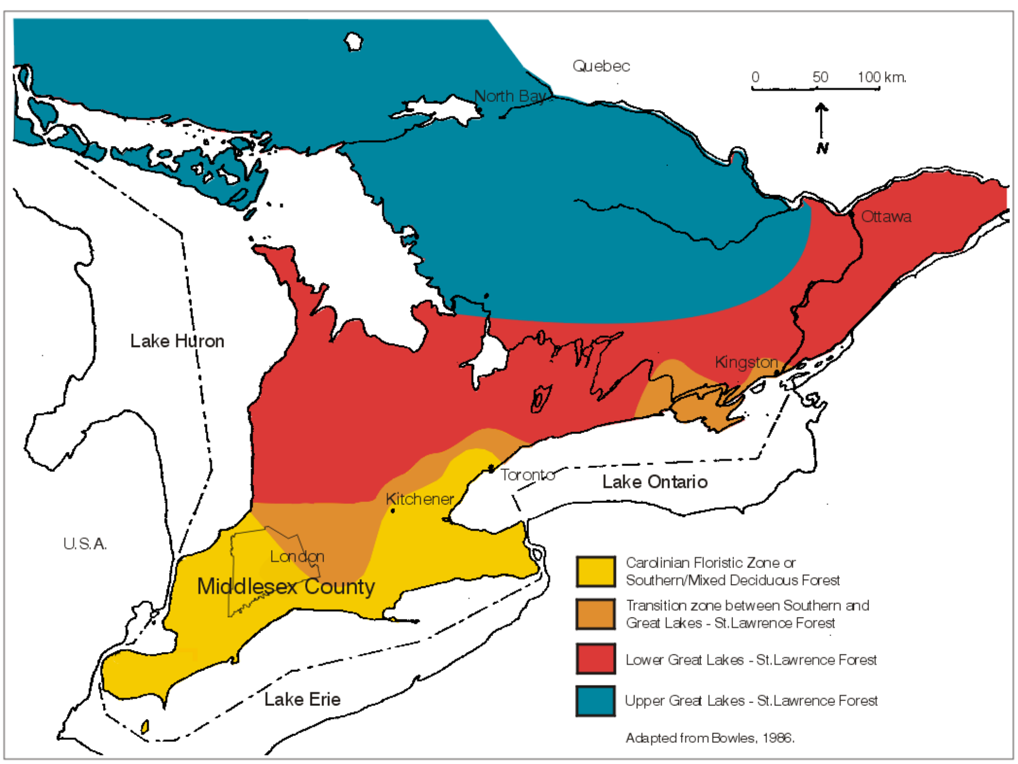

Figure 2. Location of Middlesex County in the forest regions of southern Ontario.

Table 2. Forest cover of counties abutting and including Middlesex County. Forest cover is based on the 1979 - 1981 Ontario Forest Resource Inventory and summarized in Riley and Mohr (1994).

COUNTY	FOREST COVER (%)
Middlesex	12.3
Oxford	13.4
Perth	9.0
Huron	15.3
Lambton	10.5
Chatham-Kent	4.2
Elgin	15.2

Table 2 shows the percent of forest cover for all counties abutting Middlesex County. Although it is difficult to define changes in total forest cover over time due to varying mapping criteria and the limitations of each source, the County's forest cover appears to have increased since the 1940s. This increase is consistent with trends across all of North America at this time (Tchir and Johnson 2002) and may be attributed to the implementation of tree planting programs and to changes in land management, where marginal agricultural areas were abandoned and left to naturally regenerate. However, human expansion continues to impact the environment in southern Ontario. Suburban sprawl and the creation and expansion of power lines, golf courses, road networks, aggregate extraction, *etc.* have created exaggerated flood regimes and further fragmented forests and wetlands into isolated components, reducing the habitat of flora and fauna.

Figure 3 shows the geographical (*i.e.* spatial) distribution of physiographic types in Middlesex County while Figure 4 illustrates the relative proportion of physiographic types found in Middlesex County. Till Moraine and Undrumlinized Till Plain occur primarily in the north east. Moraines, which comprise approximately 20% of the County, are composed chiefly of unsorted glacial materials and were formed at halts in the advance or retreat of the ice front. They may be classified as either Till or Kame, depending on whether they were laid down on land (Till) or under water (Kame). Till Plains account for approximately 28% of the County and are formed under moving glaciers. Till Plains can be beveled or undrumlinized. Beveled Till Plains have been molded into long oval hills (called drumlins or whale backs) or into ridges and flutings with natural drainage. Undrumlinized Till Plains do not have definite ridging.

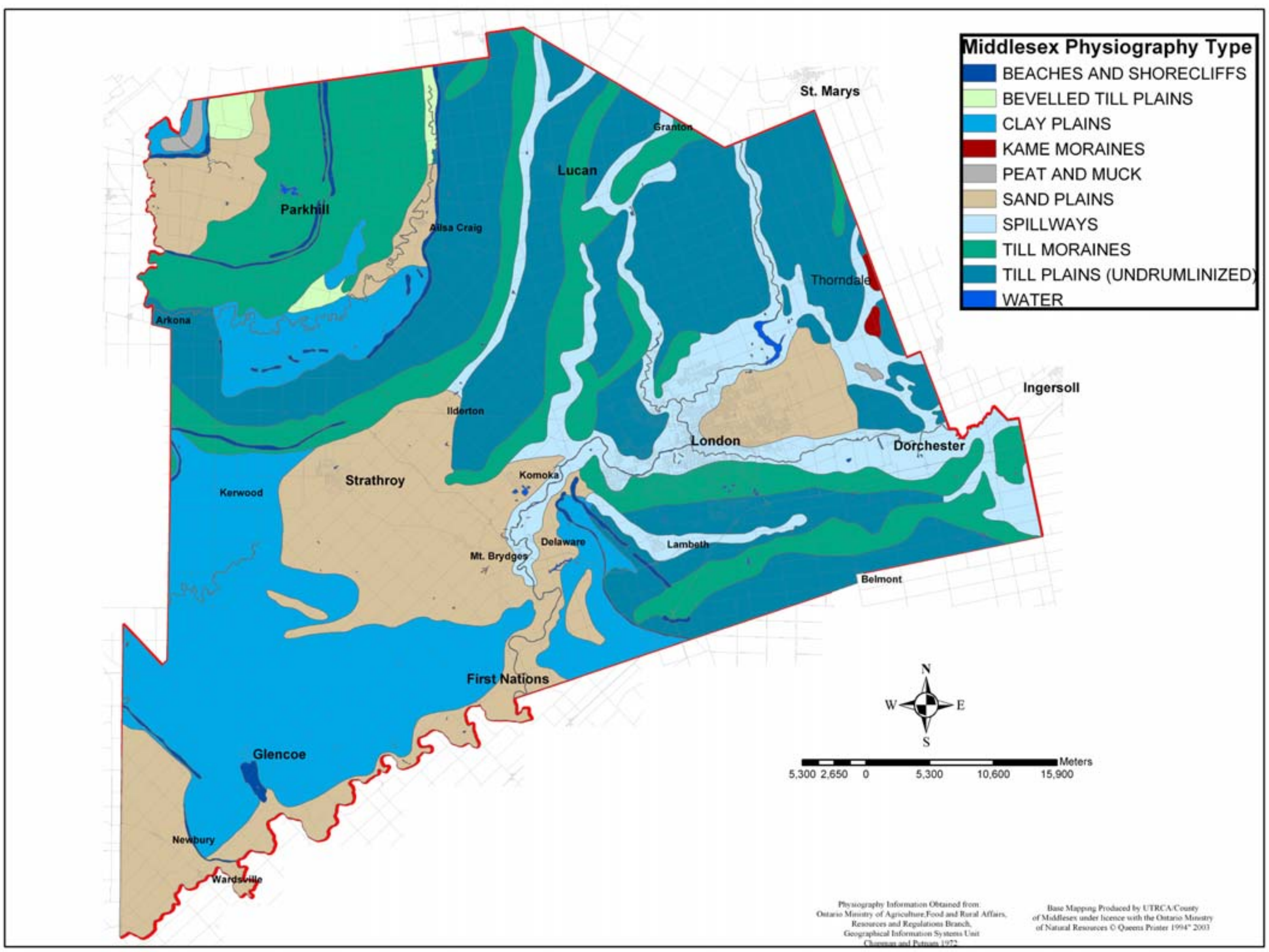

Figure 3. Physiography of Middlesex County.

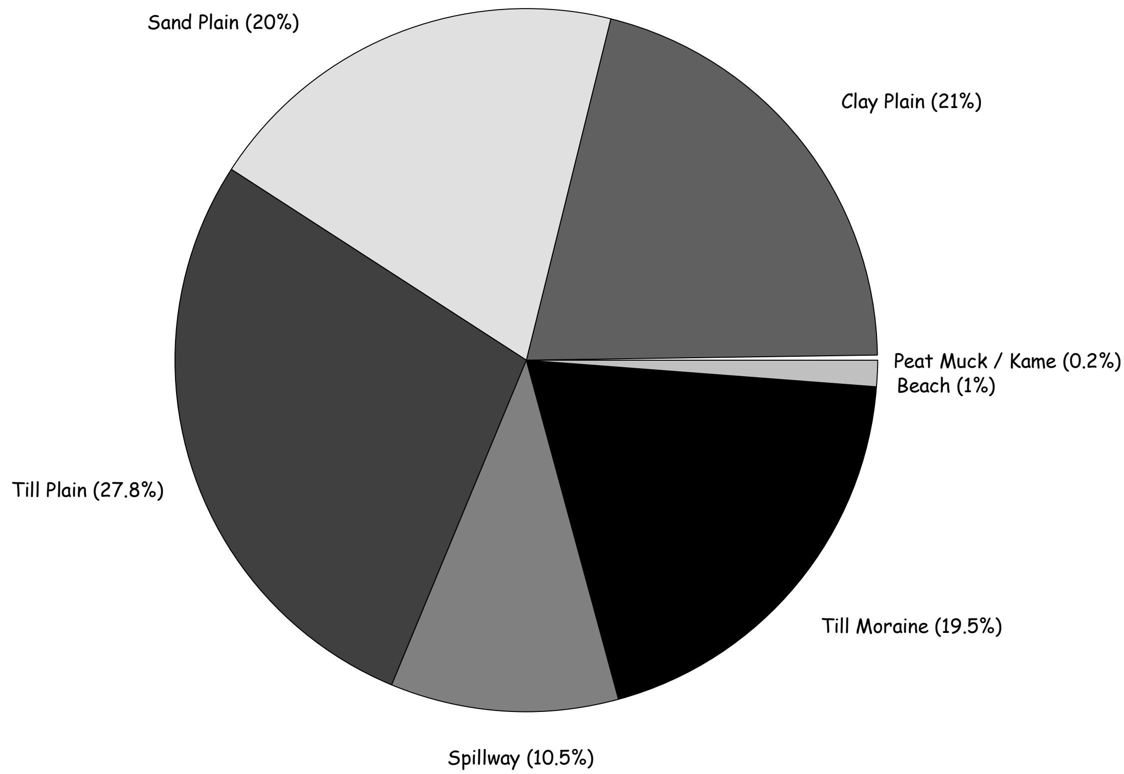

Figure 4. The proportion of physiographic types for Middlesex County (source: Chapman and Putnam 1972).

To the east and southwest of London, broad sand and clay plains account for approximately 40% of Middlesex County. Sand Plains are the remains of deltas and off-shore sand deposits from post-glacial bodies of water. Clay Plains are bottom deposits of glacial lakes. Spillways are interspersed throughout the east and comprise approximately 12% of Middlesex County. Spillways are meltwater channels formed by glacial waters and are characterized by surficial deposits of sand and gravel.

Muck and peat deposits, which occur in scattered pockets throughout the County, only account for 0.2% of the area. Muck and peat are formed in areas of poor drainage by the accumulation of decayed vegetation (organic matter). Muck soils are developed through the accumulation of eighteen inches or more of decomposed organic matter and occur in low lying areas with no surface drainage. Peat is formed in areas where the water table is permanently high and the organic matter does not decompose completely.

3. Methods

This chapter provides a general summary of the methodology used to develop trends in Middlesex County. Sampling methodology and biological information from both the 68 woodland patches surveyed in the Middlesex Natural Heritage Study (MNHS) and the 85 woodland patches surveyed in the City of London Sub-Watershed Studies (LSWS) by Bowles *et al.* (1994) were used in developing trends for Middlesex County.

3.1 SELECTION OF SITES FOR INVENTORY

Approximately 34,990 ha (12.3 %) of Middlesex County is woodlands, broken into approximately 8684 woodland patches. Given the size of the County, landscape stratification was used to select sites in both the MNHS and LSWS. The County was divided by physiographic units in order to sample a range of woodland types and sizes. Then, a range of woodland patch sizes was selected from each. A total of 200 woodland patches were selected. In the LSWS, the landscape was further subdivided according to sub-watersheds.

3.2 LANDOWNER CONTACT

In the MNHS, a total of 200 woodland patches representing 556 landowners were selected for sampling. Each woodland patch in the county was given a unique number identifier. For each property selected, property assessment records were obtained from the appropriate township and the township roll number was assigned to the property for internal use. A database was created to record the names and mailing addresses of the landowners and the location of their properties. The database information was added to the Geographic Information System (GIS) as point attribute files based on a common field for the woodland patch number.

Landowner permission was sought to survey the selected patches. A landowner contact package was generated that consisted of a contact letter, a consent form and a fact sheet (Appendix 1). The contact letter explained the purpose of the field inventory, the timing of the field visits, the selection of sites, what would be required of the landowner and how landowners could become involved in the study. The consent form provided room for signatures for permission or not and comments from the landowner about the study. The fact sheet provided information on the purpose of the study, project partners and general facts about Middlesex County. A self-addressed, stamped envelope was enclosed to ensure that there would be no financial cost to the landowners when returning their completed consent forms. The package was mailed to all 556 landowners.

3.3 FIELD SURVEY METHODS

Field data forms were produced using prototypes from the Ecological Land Classification (ELC) for Southern Ontario (Lee *et al.* 1998) and modified for this study. For both the MNHS and the LSWS, field surveys concentrated on vascular plants. Field assessments for the MNHS were carried out in 68 woodland patches by two surveyors, a vegetation specialist and field assistant, on 34 dates between June 14 and August 22, 2001. Field assessments for the LSWS were carried out in 85 woodland patches by three surveyors on 57 dates between April 18 and June 27, 1994. For both studies, patches had to be at least 0.5 ha in size and were surveyed at approximately the same level of effort, based on time per unit area.

For the field assessments, each of the 153 woodland patches selected for inventory was visited once. Patches were surveyed by walking in a criss-cross fashion across the patch over its entire length (keeping 30 m from the edge to avoid edge effects) in an attempt to apply a uniform level of effort per unit area. Woodland patch and community identification information, names of surveyors, slope, aspect and a brief description of the location were recorded. For MNHS, aerial photos of each patch from 1998 ortho imagery were used by the surveyors to confirm patch area and to identify potential vegetation community types within the patch.

3.3.1 Vascular Plants

In each woodland / wetland patch, a running list was developed for both the MNHS and the LSWS of all vascular plant species that were encountered in a vegetation community. Vascular plants were chosen as the primary indicators of environmental conditions because of the relative ease with which they can be sampled and because much is known about their distribution in southern Ontario. Specimens of unknown species, or species difficult to identify, were collected for later identification. Since sedge (*i.e. Carex* species) identification is a specialized knowledge, the field staff in the MNHS did not feel confident that identification was to the level used in the LSWS and so all sedges were removed from the analysis.

3.3.2 Vegetation Communities

Major vegetation community types identified in each patch were recorded on field data forms during the floral surveys. Community descriptions were adopted from the hierarchical approach used in the ELC for Southern Ontario (Lee *et al.* 1998). Community boundaries were confirmed on the aerial photo and later digitized in the office. Lee *et al.* (1998) define a vegetation community type as a group of similar vegetation stands that share common characteristics of vegetation, structure and soils. Communities had to be 0.5 acres or greater in size. This is consistent with Lee *et al.* (1998), which recommends 0.5 ha as the minimum mapping unit when using vegetation maps at 1:10,000.

For each community, dominant plant species by percent cover and height in the canopy, sub-canopy and shrub layers were recorded in descending order by stratum. All plant species found in the herbaceous layer were recorded for each community.

<u>Soil Type and Moisture</u>
Soil type and moisture were recorded in the MNHS for each vegetation community following the methodology outlined in Lee *et al.* (1998). Each community was sampled once. At each of the soil sampling points, a soil auger was used to sample up to 120 cm deep or to an obstruction. The soil sample was laid out on the ground to measure depth. The soil profile was described by first separating the organic and mineral layers and measuring their depth to determine if the soil was organic (*i.e.* accumulated organics exceed 40 - 60 cm) or mineral (*i.e.* accumulated organics are less than 40 cm). To determine effective texture, the soil horizons (*i.e.* changes in color and soil texture) were then delineated and their depths measured. Depth to mottles was also recorded. Various field tests including the feel, moist cast, ribbon, taste and shine tests were used to differentiate soil texture. Both effective texture and soil texture measurements were used to determine the soil moisture regime and drainage. Since measurements of soil texture did not follow the same methodology in the LSWS, they were not included in the analysis.

<u>Basal Area</u>
Basal area measures the area of the forest that is taken up by standing trees (Figure 5). Basal area by tree species and size class was determined for each community in the MNHS by completing prism sweeps in two to five random locations within each community. Prism sweeps (see Husch *et al.* 1972 for explanation of technique) were used to record tree species in three tree size classes: small (3-10 cm diameter at breast height), medium (10 - 25 cm diameter at breast height) and large (> 25 cm diameter at breast height). Sweeps were separated so that no tree was counted more than once and so that sweeps did not overlap the community boundary. Total basal area, as well as basal area by tree species and size class, were calculated by multiplying the number of trees by the prism factor and dividing the product by the number of locations. The prism factor represents the thickness and therefore the degree of the refraction angle of the prism (Husch *et al.* 1972). For MNHS, a prism factor of 2 was used. Basal area was not recorded in the LSWS and therefore was not included in this analysis.

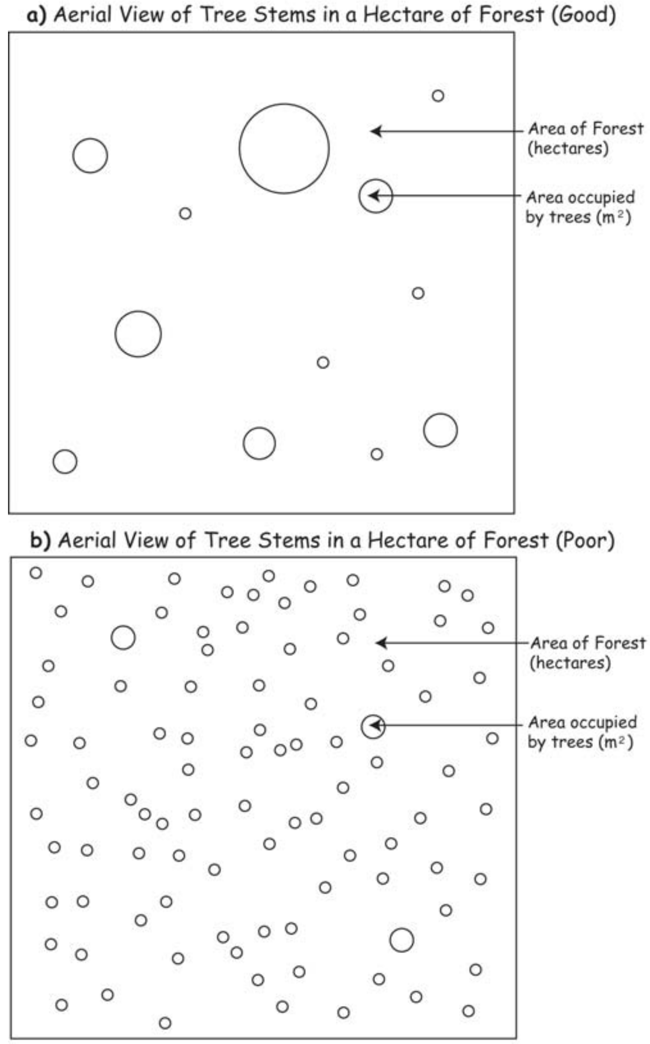

Figure 5. Calculation of basal area showing **a)** good forest management with a mixture of trees of different size classes (e.g. selection cutting) and **b)** poor forest management with only small tees remaining. (e.g. diameter limit cutting)

3.3.3 Woodland Patch Type

Woodland patches were classified following the system developed by Lee *et al.* (1998) in which forests and woodlands are distinguished on the basis of canopy closure. According to Lee *et al.* (1998), any treed community with a canopy cover of at least 60 % is classified as a <u>forest</u>. <u>Woodlands</u> have a canopy cover of coniferous or deciduous trees between 35 % to 60 % while <u>savannas</u> are treed communities that are often associated with prairie species and have a cover of 25 % to 35 %. <u>Thickets</u> are characterized by <10% tree cover and > 25% tall shrub cover. <u>Plantations</u> are forests or woodlands that have been planted by humans, rather than being the product of natural dispersal mechanisms. Plantations do not include orchards. For the purposes of this study, all five of these categories are considered to be woodlands (*i.e.* tree cover > 10% or tall shrub cover > 25%). This applies to both wetland and upland systems.

Disturbance

For each woodland patch in MNHS, major anthropogenic disturbances (*i.e.* plantation, sugar bush operations, non-native plant species, livestock, trails, dams, dumping, earth movement, recreation and noise) and natural disturbances (*i.e.* wind throw, disease or insects, canopy gaps, fire, flood and browse) were listed and assessed for both intensity and extent (how widespread). Following Lee *et al.* (1998), each disturbance type was scored from 0-3 for intensity and 0-3 for extent as they applied to the whole patch. Intensity and extent scores were then multiplied together and summed over all surveyed patches to produce a score for each disturbance type. As well, total human and natural disturbance indices for each patch were calculated by multiplying the intensity and extent scores for each type of disturbance and summing the resulting products for each patch. Therefore, the disturbance index is a composite of several kinds of disturbance types. Disturbances were not scored in the LSWS and therefore are not included in this analysis.

3.4 FIELD DATA ENTRY AND ANALYSIS

3.4.1 Database

The information recorded on the field data forms (Appendix 2) were entered into a database for analysis. Appendix 3 contains the glossary and definitions used in the field data forms. Appendix 4 shows the relationships between the various MNHS databases. The structure of the field data forms and database for the LSWS is outlined in a separate report by Bowles *et al.* (1994). Both MNHS and LSWS databases were added to the GIS as point attribute files based on a common field for the vegetation patch number. The databases were linked to an annotated list of vascular plant species (Appendix 5) developed from Oldham *et al.* (1995) that contains additional ecological, taxonomic and status information for each plant species. From this data (Appendix 5), the following computations were performed to assess the state and health of the woodland patches:

Species Richness

Species richness was calculated by adding together the number of different plant species, both native and non-native, found in a particular community and summed over the entire patch.

Mean Conservatism Coefficient (MCC)

The methodology for the MCC was first developed in the Chicago region (Wilhelm and Ladd 1988) and has since been adapted to Ontario (Oldham *et al.* 1995). A conservatism coefficient (CC) between 0 and 10 is assigned to each native plant species, reflecting each species' fidelity to a particular habitat type, or the likelihood that any plant will be found in a pristine and undisturbed site. A plant with a high conservatism score (*i.e.* 9-10) is considered extremely conservative, requiring very limited and specialized conditions. There is a low probability that these species will be found in a disturbed habitat. A plant with a low score (*i.e.* 0-3) can tolerate a variety of different ecological conditions and might be found in a range of habitats, either disturbed or not. Wilhelm and Ladd (1988) also emphasize that species with the lowest values have little affinity for conditions that occurred prior to European settlement while those with higher numerical values tend to have increasingly greater affinity for native communities and are more likely to be part of stable communities. Therefore, the higher the number, the higher the quality of the site.

A conservatism coefficient (CC) was assigned to each native plant species recorded in the MNHS and the LSWS. MCC is simply an average of CC values for a given woodland patch. Mean conservatism coefficients were calculated for each inventoried patch in the study.

Weediness

Oldham *et al.* (1995) also developed weediness coefficients for non-native species. Non-native species that are non-invasive are given a score of -1. Highly invasive weedy species, that have the potential to invade natural habitats and displace the native flora, are assigned a weediness coefficient of -3. Total weediness was calculated for each inventoried patch in this study. Average weediness scores were not calculated since measures of species evenness (*i.e.* how many times a species occurs in a patch) were not recorded. Therefore, very low (large negative) numbers for patches can contain numerous non-invasive (-1) weeds or a few highly invasive (-3) weeds.

Wetness

A coefficient of wetness was assigned to native plant species by Oldham *et al.* (1995). Wetness scores range from 5 for obligate upland species to -5 for obligate wetland species. Mean wetness coefficients were also calculated for each inventoried patch in the study by averaging the scores of all the native species recorded.

3.5 MAPPING AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) ANALYSIS

Appendix 6 lists the digitized mapping layers that were used in this study. A Geographical Information System (GIS) was used to overlay the multiple mapping layers and perform detailed data queries for landscape analysis.

3.5.1 Update Woodland Patch Layer

Information on the woodland patch boundaries for Middlesex County was cut from the (1994) Natural

Resources Values Information System (NRVIS) database and provided in NAD 83, UTM Zone 17 format by the Ontario Ministry of Natural Resources (OMNR). These data provided the basis for the woodland analysis. Since this mapping source is relatively old, a variety of sources were used to update the woodland patch cover for the County of Middlesex:

- The Ausable Bayfield Conservation Authority (ABCA) provided orthoimagery taken in spring 1999 and orthorectified by ABCA. The data was in ECW format (digital photography compression format created by Earth Resources mapping) and was referenced as NAD 83, UTM Zone 17.

- The Upper Thames River Conservation Authority, Municipalities of Thames Center, Middlesex Center, and Lucan-Biddulph as well as the County of Middlesex provided orthoimagery taken in spring 2000 and orthorectified by Triathlon Ltd . The data is in Mr. SID format (digital photography compression format created by Lizardtech Inc. Software Company) and was referenced as NAD 83, UTM Zone 17.

- The St. Clair River Conservation Authority (SCRCA) identified discrepancies based on their 1992 air photography. The Lower Thames Valley Conservation Authority (LTVCA) used hard copy maps produced by St. Clair Pipelines Ltd. Ecological Services Group (Map #1. Natural Features. June 1997) to identify areas of discrepancy. However, the corrections provided by both the SCRCA and LTVCA could not be geo-referenced from the hard copy maps. Therefore, a 5 metre Panchromatic Satellite Image (IRS D 291-39B) taken May 26, 1998 and referenced as NAD 83 UTM Zone 17 was provided by the OMNR as a reference for the discrepancies identified by the SCRCA and LTVCA. Colour infrared photography contact prints (1997/1998) at 1:10,000 were also used to identify any discrepancies in the interpretation of the satellite imagery.

ESRI ArcView 8.2 was used to update the woodland patch layer. The data were imported into a geodatabase that has the capability of immediately updating perimeter and area information. The orthoimagery / satellite image was used as a backdrop to the NRVIS information. Individual nodes in woodland patches were adjusted to meet the current shape of the patch based on the ortho / satellite image. Areas that needed to be verified were printed at 1:10,000 and provided to the ecologist for interpretation.

Recognizing that the mapping of woodlands from aerial photography would not reliably distinguish young plantations, early successional forests and continuous or discontinuous valley lands, an aerial reconnaissance was completed by the ecologist. Coordinates from each woodland that needed to be verified were entered as way points into the plane's GPS. The pilot was then able to fly to the woodland that required verification.

3.5.2 Change in Forest Composition

Comprehensive forest inventories were compiled in the past for the Upper Thames Valley (Department of Planning and Development 1952), the Lower Thames Valley (Department of Energy and Resources Management 1966), the Ausable River (Department of Planning and Development 1949), the St. Clair (Department of Energy and Resources Management 1965) and Kettle Creek (Department of Energy and Resources Management 1967). At the time of inventory, most woodland patches greater than 0.5 ha were ground-truthed by forestry crews and mapped at 1:63,360. GIS was used to link the dominant tree species recorded in these reports to the updated digital woodland patch layer. Then, GIS was used to compare the dominant tree species composition found in the field for the surveyed woodland patches in the MNHS and LSWS to the dominant tree species composition from the historical reports for the same woodland patches. This provided valuable historical information for the County.

3.5.3 Spatial (Landscape) Parameters

Queries were performed with GIS on the updated woodland patch layer to determine the following spatial parameters for surveyed woodland patches in Middlesex County:

- woodland patch area (size)
- woodland patch interior (core) area after a 100 m buffer was removed from around the patch perimeter (Figure 6)
- distance to nearest neighbouring woodland patch greater than ten hectares in size
- distance to nearest road / railroad
- distance to nearest ANSI , ESA or wetland (Provincial or Locally Significant)

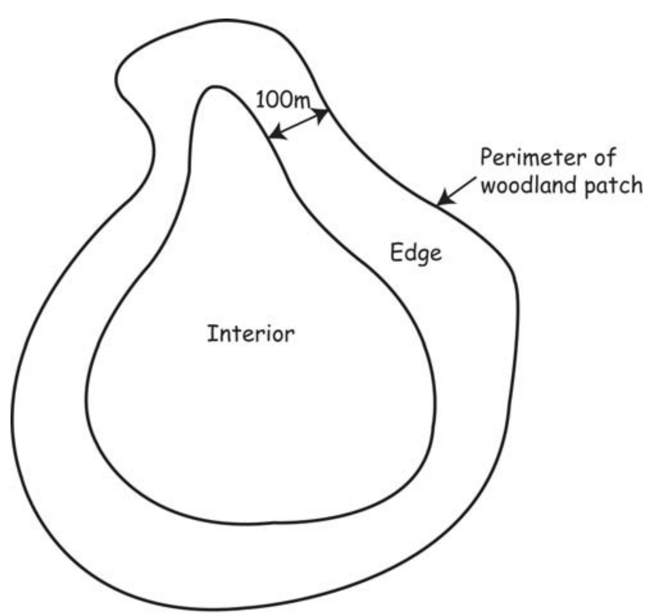

Figure 6. Calculation of woodland patch interior

These spatial parameters were linked to the updated digital woodland patch layer and added to the database. Woodland patch area and interior were also calculated for all woodland patches in Middlesex County, not just the surveyed patches.

3.6 STATISTICAL ANALYSIS

Each surveyed patch was given a score for each of the forest health indicators and the landscape parameters (Table 3). The GIS was then queried to correlate these forest health indicators to landscape parameters. A series of multiple regressions was used to identify relationships between the health of the woodland patch and the size, shape and distribution of the remaining forest-dominated ecosystems in Middlesex County. Correlations between different physiographic types and forest health indicators were not conducted since certain physiographic classes did not meet an adequate sample size for statistical work.

Table 3. Forest health indicators and landscape parameters calculated for each surveyed patch in Middlesex County.

FOREST HEALTH INDICATORS	LANDSCAPE PARAMETERS
native species richness	woodland patch area
non-native species richness	woodland patch interior
total weediness	nearest neighbour greater than 10ha in size
mean conservatism coefficient basal area	nearest road / railroad nearest ANSI, ESA or wetland