Sydenham River
Landuse and Landcover Assessment

- Draft -

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1. INTRODUCTION

The watershed of the Sydenham River in southwestern Ontario has experienced extensive changes in the 200 years of European settlement. Forests and wetlands have been cleared for agriculture, and tributaries and the main stem have been modified to accommodate changing landuses. Despite these changes, the stream channel has remained relatively healthy (Parish 2000) and there are several areas where rare (i.e. species at risk) and unusual species of animals persist.

Assessment and analysis of landuse change over time can help to understand the causes of changes to landscape features. For example, landcover alteration within a watershed may change the water budget of the system that can radically alter the structure, composition, and functioning of rivers and streams. Some of these alterations and adjustments to the watershed and its network of streams and rivers undoubtedly contribute to the demise of many of the animals and plants that are considered rare in Ontario and North America.

Historic and present landuse and landcover analyses are important elements in understanding the watershed systems. Without an understanding of historical conditions and how they have changed over time, there is little context for understanding the present functioning or malfunctioning of the stream, its morphology, drainage network, drainage extensions, riparian system and biota.

Historical conditions and their trajectory of change provide some understanding of how the system may change if present conditions persist. Therefore, landuse/landcover analysis is considered an important component in the process to develop a recovery plan for species at risk in the Sydenham River. Many species of mussels, fish, macrophytes and aquatic invertebrates require very specific habitat characteristics in order to persist and thrive. Historical landuse/landcover changes such as deforestation, agricultural intensification, and agricultural drainage have altered aquatic habitat features of the river that include changes in channel morphology, substrate composition, pool depth, and bank stability. Consequently, few locations remain that are suitable for the range of sensitive aquatic species that once lived in the Sydenham watershed.

As with the fluvial geomorphic component of the recovery plan, the landuse/landcover component will follow the intent of the first of the design steps identified in the Stream Corridor Design Manual being finalized by the Natural Channel System Initiative (OMNR 1999). Specifically, the landuse/landcover component will assess historical changes in landuse and landcover and the role of drainage extension as a set of major disturbance patterns on the Sydenham River.

1.1. Purpose of Study

The primary goal of this report is to identify how landcover characteristics have changed over time, relate these changes to the present conditions, and suggest areas of potential interest for further investigation towards restoration opportunities. This study will also assess changes in the tile drainage characteristics of the system and changes to the drainage network and discuss potential implications of these changes to channel structure, water quality and aquatic biota.

Due to the nature of the various sources of data, different definitions of landuse and landcover, and different methods of data collection, analysis of trends over time must be done with the understanding of the limitations of data sources used.

2. Data Sources

Landuse, landcover, drainage extension and areas in tiled drainage within the Sydenham River subwatersheds were identified from the following sources:

Year	Data Source	Format	Identified features
1800s-1830s	Surveyors Historical Landcover Maps (Finlay 1975)	Paper Maps	Swamp and Woodlots
1983	OMAFRA Land Use Systems Maps (OMAFRA 1983a)	Digital Map	Landuse – Agricultural, woodlots, built-up areas, swamp
1983	OMAFRA Artificial Drainage Systems Maps (OMAFRA 1983b)	Paper Map	Area of tile drainage
1993	Ontario Base Maps (OMNR 2000)	Digital Map	Woodlots, Drainage extension
1984-1996	Evaluated wetland coverage (SCRCA 1993)	Digital Map	Evaluated wetlands

Early landcover was assessed using a map created by Finlay (1975). These maps illustrated the landcover within the Sydenham River watershed. The coverage for the Gore of Camden was unavailable, and thus not mapped. The landcover within each lot of was digitized on-screen as a new layer of an ArcView GIS database.

The 1983 OMAFRA Land Use Systems Maps (1983c) were used to interpret land use for the entire Sydenham River watershed between 1975 and 1983. This map coverage came in a digital format and was integrated into the GIS project.

The 1983 OMAFRA Artificial Drainage Systems Maps (OMAFRA 1983b) were used to characterise tiled agricultural lands within the Sydenham River watershed. These maps indicated, by township, the area of tiled drains up to and including 1983. Tile drains were digitized on-screen into the GIS database for the entire watershed coverage area.

Interpretation of land use and landcover between 1986 and 1996 was accomplished with two sources of data: a digital Ontario Base Map (OMNR 2000) woodlot coverage; and a digital GIS layer indicating OMNR Evaluated Wetland coverage from 1986 to 1996 (SCRCA 2001). These two digitally available coverages were integrated into the GIS database.

3. OVERVIEW

Ontario Base Map (OMNR 2000) coverage for Middlesex County, Lambton County and the northern sections of the county of Chatham-Kent was used to create a digital map of the watercourses within the watershed. From this digital format, the following geo-referenced information was available: roads, lots and concessions, watercourses, buildings, woodlots and municipal township lines.

The Sydenham River watershed was divided into seven subwatersheds (Figure 1). Watersheds were delineated to represent 5th order courses. Artificial Drainage Systems Maps (OMAFRA 1983b) were used to provide a greater level of detail when delineating watershed boundaries if the OBM coverage was inconclusive. These maps indicated the location and drainage of specific lots of land, and their associated open drains. A comparison to a digital elevation model produced for the St. Clair Region Conservation Authority indicates a close fit to the areas delineated within this process. Where the OBM stream or drain channel information was not conclusive, comparison to the Drainage Systems maps determined delineation of subwatershed boundaries.

This process of watershed delineation is limited by the fact that contour intervals were not used. However, reliance on a digital elevation model (which makes use of contour intervals) is problematic in a watershed with such low elevation. For example, it is common in the east branch of the Sydenham River to have water flowing in two directions, depending on the water levels in Lake St. Clair. The utility of a good digital elevation model must be evaluated in context of how well the model deals with this unique situation. In addition, the current system of watershed delineation does not provide accurate means of assessing stream order, which may be of importance for indicating areas of interest for restoration work. The area of each subwatershed in hectares was calculated using Arc View 3.2a (Table 1).

Table 1: Subwatersheds of Sydenham River

Branch	Subwatershed	Description		Area (ha)	Percent of total watershed area
North	Bear Creek	North upriver from junction with Black Creek at Wilkesport		58595.9	21.8%
	North Branch Lower	Drains Bear and Black Creek and flows toward confluence at Wallaceburg		10525.3	3.9%
	Black Creek	East of Wilkesport towards Oil Springs		32580.0	12.1%
			Total	101701.1	37.9%
East	East Branch Lower	From mouth of Sydenham to Florence		50893.5	19.0%
	East Branch Middle	Between Florence and Alvinston		54583.3	20.3%
	East Branch Upper	From Alvinston to upper reaches of Sydenham		45080.7	16.8%
	Brown Creek	From Alvinston upriver along Brown Creek		16016.2	6.0%
			Total	166573.7	62.1%
Sydenham			Total	268274.8	100.0%

The three subwatersheds of the north branch of the Sydenham include Bear Creek, Black Creek, and the lower section between the junction at the east branch of the Sydenham and the junction of Bear and Black Creek. These three subwatersheds comprise 37.9% of the total watershed area of the Sydenham River. The four subwatersheds of the east branch of the Sydenham River include Brown Creek, the upper reaches of the Sydenham (up-river of Alvinston), the middle reach (between Alvinston and Florence), and the lower reach (between Florence and the mouth of the river south of Wallaceburg). The four east branch subwatersheds comprise 62.1% of the total Sydenham River watershed area.

It is possible to differentiate the Sydenham River watershed into three main sections: upper reaches, middle reaches, and lower/mouth reaches. In doing this, the different levels can be described and compared with similar sections of the watershed. For instance, the watershed characteristics of the upper reaches of the east branch of the Sydenham can be compared to Bear Creek and Black Creek (the upper reaches of the north branch). Similarly, the lower section of the east branch of the Sydenham River can be compared to the lower reach of the north branch.

4. HISTORICAL LANDCOVER OF THE SYDENHAM RIVER

Finlay (1975) used diaries, surveyor's notes, and letters of surveyor's to assess pre-settlement vegetation coverage of Counties with the Sydenham watershed (Appendix A). Finlay then transcribed the written documentation (field notes, letters and correspondences) of landcover, by lot and concession, onto an Ontario Base Map. This Ontario Base Map was used to create a digital GIS layer through the process of on-screen digitizing. Two different landcover types – forest and swamp - were identified from this created GIS layer (Figure 2).

However, the surveyor record coverage for the Gore of Camden does not exist as the original surveyor records have been lost (Finlay 1975). Consequently, assessment of the historical landcover for the lower reach of the east branch totals is not representative of the entire subwatershed.

This digitally mapped information may not be accurate at the site level. It should not be used to compare land use change over time for specific sites and can only be considered accurate to the lot level. However, the area of each landcover within each subwatershed is representative of the original landcover within these particular subwatersheds. Another limitation is that the delineation of the watershed was done from 1993 data and most likely is not representative of the watershed in the early 1800s. Thus, this information can only be used as a rough guideline for identifying the characteristics of the land cover at this time. Additional information from historical sources such as reports, journals, and articles may also help to describe the historical state of the land use and landcover within the Sydenham River watershed. Table 2 indicates the historical swamp and forest landcover of the Sydenham River assessed from this digital GIS layer.

Table 2: Historical Vegetation of the Sydenham River

Branch	Subwatershed	Swamp (ha)	Forest (ha)	Area Not Mapped (ha)	Total Subwatershed Area (ha)	Percent Swamp	Percent Forest	Percent not mapped	Total
North Branch	Bear Creek	12100.2	46495.7	0.0	58595.9	20.7%	79.3%	0.0%	100.0%
	North Branch Lower	4206.9	6318.4	0.0	10525.3	40.0%	60.0%	0.0%	100.0%
	Black Creek	12451.7	20128.3	0.0	32580.0	38.2%	61.8%	0.0%	100.0%
	Total	28758.8	72942.3	0.0	101701.1	28.3%	71.7%	0.0%	100.0%
East Branch	East Branch Lower	19282.8	20179.4	11518.2	50980.4	*37.8%	*39.6%	22.6%	*77.4%
	East Branch Middle	24371.6	30211.7	0.0	54583.3	44.7%	55.3%	0.0%	100.0%
	East Branch Upper	3549.0	41531.7	0.0	45080.7	7.9%	92.1%	0.0%	100.0%
	Brown Creek	1036.4	14979.8	0.0	16016.2	6.5%	93.5%	0.0%	100.0%
	Total	48239.8	106902.6	0.0	166660.5	28.9%	64.1%	6.9%	93.1%
Total	Sydenham River	76998.6	179844.9	11518.2	268361.7	28.7%	67.0%	4.3%	100.0%

*Note: Area not mapped was due to the lack of information from Finlay (1975). Swamp and forest areas calculated in the lower east branch reflect this lack of mapping information, and percentage swamp and forest are calculated in absence of the mapped information.

The types and categories of landcover identified on the Finlay (1975) map include the following: various tree species, tamarack swamp, swamp, open marsh, open meadow, black ash swamp, oak stands, beech/maple stands, and willow swamp areas. Within the mapped subwatersheds, the grouping into two categories reflected the strong dominance of these two land cover types. However, it is interesting to note that below Wallaceburg an area of wet meadow and open marsh was indicated, that stretched south along the edge of the shoreline, outside of the Sydenham watershed. It is probably that this marsh was contiguous with Lake St. Clair Marshes (Andreae 2000).

The historical vegetation of the watershed is predominantly forest with large tracts of swampy areas. Very predominant is the area of swamp centrally located within the Black Creek subwatershed and the Upper reaches of the Bear Creek subwatershed. This was historically referred to as the Enniskillen Swamp and was the predominant landcover within this area in pre-settlement times (DesRivieres 1972). DesRivieres (1972) describes the history of The Great Enniskillen Swamp, "…a flat, wet tract of more than 150, 000 acres spreading over large sections of Enniskillen, Brooke, Dawn and Sombra townships within Lambton County."

Other authors have documented the change in wetland area over time in southwestern Ontario. Snell (1982) surveyed 38 counties in southern Ontario between 1800 and 1970 and estimates that over 70% of southern Ontario pre-settlement wetland areas have been converted to other uses by 1970. The main factor for this decline was indicated as agricultural drainage and agricultural land reclamation (Snell 1982). For Essex, Kent, and Lambton counties, Snell (1982) indicated that 95%, 93%, and 81% of the wetland area had been lost during this period.

5. CURRENT LAND USE AND LANDCOVER ASSESSMENT

This component of the study aimed at determining the percent of various land use/landcover types across two year sets. The Agricultural Land Use Systems Maps (OMAFRA 1983c), 1993 Ontario Base Maps (OMNR 2000), and digital coverage of MNR Evaluated wetlands from 1984-1993 (SCRCA 2001).

5.1. AGRICULTURAL LAND USE

Agricultural Land Use Systems Maps (OMAFRA 1983c) were used to document landuse and landcover within the Sydenham watershed between 1975 and 1983. These maps are unique in that they do not describe the land use of a system at an instant in time, as do other remote sensing techniques. This is a valuable dataset in that it described land use as a management unit across time, relating the actual management practices of specific plots of land. Specifically these maps are valuable in that the agricultural land uses were groups to form agricultural land use systems that identify the crop sequence being applied to each farm management unit. The 1:50,000 scale at which the maps were created precludes the identification of small parcels of land under 2.5 hectares (OMAFRA 1983).

The 1983 land use for the Sydenham River watershed was integrated into a GIS database, mapped and areas of different land uses were calculated (Figure 4). Two different assessment processes were taken in the assessment of land use within this time period. First, the total area of each of the 28 distinct land use categories was calculated by subwatershed (see Appendix B). These categories were then grouped together by subwatershed, and calculated as percent of total area (Table 6 and Appendix C and D). These larger subcategories were then mapped by subwatershed (Figure 4).

Table 3: Summary of Sydenham River Land Uses in 1983 from Agricultural Land Use Systems Maps (OMAFRA 1983b)

Branch	Sub-watershed	Idle agricultural land	Built-up	Grazing, pasture	Row and grain crops	Specialty Agriculture	Water	Swamp	Woodland	Total
North	Bear Creek	1.2%	3.2%	1.0%	82.3%	0.2%	0.6%	0.0%	11.5%	100%
	Black Creek	0.6%	2.4%	3.0%	81.0%	0.0%	0.4%	0.0%	12.7%	100%
	Lower	1.8%	4.9%	2.0%	81.1%	0.0%	1.7%	0.0%	8.7%	100%
East	Upper	2.2%	4.1%	3.8%	70.9%	5.3%	0.3%	0.0%	13.0%	100%
	Brown Creek	1.3%	0.3%	6.5%	79.2%	0.0%	0.1%	0.0%	12.5%	100%
	Middle	0.9%	0.7%	3.5%	79.6%	0.7%	0.5%	0.0%	14.2%	100%
	Lower	0.4%	1.6%	4.6%	82.1%	1.3%	0.6%	0.0%	8.7%	100%
Sydenham River	Total	1.1%	2.3%	3.3%	79.4%	1.3%	0.5%	0.0%	11.8%	100%

Row and grain crop systems dominated the land use systems of the Sydenham River watershed in 1983. Eighty-four percent of the land in the Sydenham River watershed is under an intensive agricultural system of corn, small grains, and/or hay. It is interesting to note that the percent of total land use under these systems is roughly equivalent for each subwatershed.

The amount of swampy area identified in the 1983 map totaled only 9 hectares. This is a decrease of close to 100% from 1800s levels. At that time, 28.3% of the total land was described by surveyors as swamp and marsh habitat (Figure 2 and Table 2). The continual clearing and draining of lands and construction of tile drains had all but eradicated wet, swampy habitat from the entire Sydenham watershed by 1983. The extent of the tile drainage by 1983 also suggests that there is not a lot of opportunity to reclaim much of this habitat type especially if agriculture is occurring on the land. Conversely, it may be that there are areas within the watershed that are not drained and can be viewed as swamp and marshland habitat that are not reflected within this 1983 OMAF dataset. Current land use assessment may indicate areas of opportunity for wetland enhancement.

Similar decreases in forest cover have occurred from the 1800s to the 1980s. A reduction from about 70% to 12% forest cover has taken less than 200 years to progress. It is difficult to describe the rate at which accelerated forest cover loss occurred without further exploration of new year classes, but it can probably be predicted that most of the forested area was lost. This loss likely occurred concomitantly with the increase in tile drain for agriculture and the settlement of the region, predominantly for agriculture and the petroleum related industry between the 1830s and early 1900s. The level of forest cover loss does not appear to be more dramatic in any particular areas of the watershed.

Of particular interest are the categories of idle agricultural lands and woodlands. Idle agricultural lands are defined as “idle lands in a state of reversion to natural vegetation” (OMAFRA 1983). The 1983 maps were developed between 1975 and 1983, therefore, if some areas were identified as idle agricultural lands reverting back to native vegetation at that time, it would be worthwhile to attempt to locate these areas and identify their current land use status. Although only about 1.1% of the land within the Sydenham River watershed was denoted in this category, a third of this was located in the upper reaches of the east branch. These areas, if identified under the current land use assessment, could represent an opportunity for habitat enhancement, either to forest or to other appropriate land uses. Efforts should be directed to locate these areas within the current land use/landcover component to identify these areas.

In 1983 woodlands occupied approximately 11.9% of the Sydenham River watershed. The subwatersheds with the highest percentage of woodlots include the middle and upper reaches of the east branch (14.2% and 13.0% respectively). However, from a visual assessment of woodlots within each subwatershed it is clear that woodlots are not equally distributed across the watershed. Woodlots tend to be aligned with adjacent woodlots on corners of lots (Figure 5). The location and extent of the woodlots within the watershed will be important to consider when exploring types and locations of restoration activities. There appears to be higher than average woodlots coverage in several areas of the Sydenham watershed. First, the confluence of Black Creek and Bear Creek; second, directly south of Alvinston on the east branch of the Sydenham River for a distance of about 6 kilometres; and third, on Bear Creek just south of Petrolia at the point of confluence with Little Bear Creek. These locations, and others, may be candidates for further and more in-depth evaluation through very recent aerial photography or satellite imagery to assess the degree to which these areas are impacted compared to other areas in the watershed.

5.2. WOODLOT LANDCOVER

Woodlot coverage for 1993 from the Ontario Base Maps (OMNR 2000) support Agricultural Land Use Systems Maps (1983b) that woodlots are not evenly distributed across the watershed (Figure 5). Woodlot by subwatershed area in Table 4 indicates that the lower north branch (8.4%) and the lower east branch (7.9%) are the least forested in the watershed. Conversely, the upper reaches of the watershed, defined by Bear creek (12.9%), Black Creek (12.7%), and the upper (13.5%) and middle (13.6%) reaches of the east branch all have high levels of forest cover within the Sydenham River watershed. The illustrated small degree of change in woodland area between 1983 and 1993 suggest that minimal woodlot loss has occurred and that no significant increase forest cover was observed during this time. However, further site-level assessments with should be undertaken to determine the pattern of change within the past 20 years, as well as to determine the current location and extent of woodlot coverage within the watershed.

Table 4: Sydenham River Woodlot Area by Subwatershed in 1993

Branch	Subwatershed	Woodlot Area (ha)	Total Area (ha)	Percent of total area
North	Bear Creek	7,562.0	58595.9	12.9%
	Black Creek	4125.0	32580.0	12.7%
	Lower	883.0	10525.3	8.4%
	Total	12570.0	101701.1	12.4%
East	Upper	6096.0	45080.7	13.5%
	Brown Creek	1899.0	16016.2	11.9%
	Middle	7444.0	54583.3	13.6%
	Lower	4033.0	50893.5	7.9%
	Total	19472.0	166573.7	11.7%
Sydenham River	Total	32042.0	268274.8	11.9%

Caution must be observed when comparing the 1993 woodlot coverage to that of the 1983 coverage. First, the definitions of woodlot and forest may differ significantly between the Ontario Ministry of Natural Resources and the Ontario Ministry of Agriculture and Rural Affairs. Secondly, the different categories of woodlot in the 1983 dataset (reforested woodlot, pastured woodlot, and woodlot) may not correspond directly with the definition of woodlot in 1993. In addition, care must be taken when comparing any of the data sets amongst each other when different methodologies are used, and the different data sources are collected for different purposes. It is unfortunate that there is not a more recent Land Use Systems Map available, or an older Ontario Base Map coverage for woodlots to control for this difference.

A visual assessment of the woodlot coverage in from the 1993 Ontario Base Map (OMNR 2000) suggests that the area at the convergence of the Brown Creek subwatershed and the upper east branch have a high level of forest cover along the boundary of the stream channel. If rehabilitation activities are aimed at connecting existing forest patches together that are located in close proximity to the stream channel, this area indicates high potential.

5.3. WETLAND LANDCOVER

Wetland coverage from MNR evaluated wetlands was digitally available from the St. Clair Region Conservation Authority (SCRCA 2001). This GIS layer indicated the location and extent of evaluated wetlands in the Sydenham River watershed between 1984 and 1996. This information was mapped using Arc View 3.2a (Figure 6).

Table 5: Evaluated Wetland Areas in Sydenham River Between 1984 and 1996

Branch	Subwatershed	Wetland Area (ha)	Total Subwatershed Area (ha)	Wetland Area as percent of subwatershed
North	Bear Creek	121.8	58595.9	0.2
	Black Creek	39.1	32580.0	0.1
	Lower	37.5	10525.3	0.4
	Total	198.5	101701.1	0.2
East	Upper	1302.6	45080.7	2.9
	Brown Creek	11.2	16016.2	0.7
	Middle	422.9	54583.3	0.8
	Lower	10.6	50893.5	0.02
	Total	1747.4	166573.7	1.0
Sydenham River	Total	1945.8	268274.8	0.7

During evaluations of provincially significant wetlands between 1986 and 1993, surveys indicated that 1945 hectares of wetland areas exist within the Sydenham River watershed (Table 5). Most of the wetlands evaluated within these surveys are located in the upper east branch of the Sydenham (1302 hectares). From Figure 6, it is clear that at the time of the creation of this layer, there is a complex of wetlands within the upper east branch of the Sydenham located along the channel. With less than 1% of the landcover within the Sydenham River watershed suggest that the protection and enhancement of this area be given high priority. In addition, this coverage does not take into account the location and extent of non-evaluated wetlands within the watershed. It is recommended that wetland surveys be undertaken to assess the location of all wetlands in the Sydenham River. Any additional information regarding the location and extent of wetlands can be easily integrated within the GIS database.

The existence of provincially significant evaluated wetlands within this GIS layer may not indicate the existence of these wetlands at present. Changes in the methods of determining wetland class and significance have occurred since 1984, suggesting that appropriate protection of these areas may not exist. For instance, if wetlands were re-evaluated at a later date when the criteria for determining wetland significance had changed, the wetlands may have lost the protection afforded them through prior assessments. This reinforces the importance of a current assessment of wetland extent and location.

6. DRAINAGE PATTERN AND EXTENT

The Sydenham River watershed has had extensive drainage alterations throughout the past 200 years of European settlement. Drainage works and channel modification have been a part of the agricultural history and culture of the early settlers since the late 1790s and especially after the inception of the "Municipal Institutions Act" in 1859 (Matt 1979). This Act allowed landowners to remove surplus water in swampy areas, and to construct drainage works by petitioning the township council. People requesting drainage works could come together to petition the township council for funding assistance. However, due to a lack of available funds, the government passed "An Act Respecting Public Works in Ontario" in 1868, which employed engineers to survey swamp and bog land. By 1873 the *Ontario Drainage Act* was in effect to provide further sources of funding assistance to drainage works.

6.1. HISTORY OF TILE DRAINAGE IN THE SYDENHAM RIVER

Tile drainage has also had a long history within the Sydenham River watershed. In 1879 the *Ontario Tile, Stone, and Timber Drainage Act* was in place which provided funding assistance to those wishing to install tile drains. During the early years of the loaning process few people took advantage of this opportunity. For instance, although $10,000 was available as loans to each of Plympton, Warwick, and Brooke Townships, only $5200 was spent on tile drainage works.

Matt (1979) reported that the process of tiling within Chatham-Kent County increased considerably by 1910 and experienced continued growth between 1920-1925.

Table 2 indicates the disbursement of loans and the availability of financial support for tile drainage between 1914 and 1937. In the early 1960s another dramatic increase in total loans being acquired was apparent, with values increasing from $6 million to $12 million dollars in the province. By 1976, the government put a ceiling on the amount of funding that was available provincially, resulting in a need to allocate loans by township.

Table 6: Historical Tile Loans Available by Township in Kent County

Township	Earliest Debenture on Record	Payment Policy
Dover	1914	75% of work
Chatham	1928	75% with no maximum
Camden	1893	75% of work
Zone	1937	75% of work

The creation of the Artificial Drainage Systems Maps by the OMAFRA was possible by recording the lots and concessions of each applicant. Considerable amounts of money were loaned to parties interested in undertaking construction of tile drains between 1878 and 1979. Table 3 illustrates the total dollar amount borrowed under the *Tile Drainage Act* between 1878 and 1979, the year that the funding program ended.

Table 7: Total Dollar Amount Borrowed in Ontario Under the Tile Drainage Act between 1878 and 1979

Year	Amount ($)	Number of Years in Period	Total Dollars Spent Per Year During Time Period ($)
1878-1920	1,120,718	42	26,684
1921-1948	4,146,326	27	153,568
1948-1960	6,028,400	12	502,367
1960-1965	7,583,299	5	1,516,660
1965-1970	16,862,000	5	3,372,400
1970-1975	37,051,600	5	7,410,320
1975-1976	16,219,600	1	16,219,600
1976-1977	16,077,700	1	16,077,700
1977-1978	18,772,400	1	18,772,400
1978-1979	17,870,700	1	17,870,700

There have been over 125 years of tile drainage works across Ontario. The amount of money spent on tile drainage works has increased over time, with over $17 million dollars being loaned in a single year for the purposes of tile drain construction between 1978 to 1979. In addition, the rate at which money was borrowed over time has increased. For instance, annually, the rate of monies being borrowed under the Tile Drainage Act increased from an average of $26,684 to over $7 million dollars by 1975. Between 1975 and 1979, the average amount of monies being borrowed to undertake tile drainage work increased dramatically to $16 million dollars annually for each year between 1976 through 1979.

The historical progression of drainage works and tile drain construction in the Sydenham River watershed since the early 1800s was not completed within this study. Information does not exist describing township wide practices of drainage works and tile drain construction. However, each drain that has been constructed and maintained within the past 200 years has been recorded and its relevant information is available by consulting the corresponding Drainage Superintendent at the Township office. This process is also effective to describe the location and history of tile drain construction. It is recommended that in-depth investigations be undertaken to determine the surrounding land use, preferably through interviews with Drainage Superintendents.

6.2. IMPACT OF TILE DRAINAGE ON WATER QUALITY

Understanding the impact of tile drainage on water quality is of particular importance to the Sydenham River. The Sydenham River is predominantly an agricultural land use, is comprised of highly erodible materials including clay and silts, and a large percentage of its area is in tile drainage. These factors have unknown synergistic consequences on sediment delivery and discharge, contaminant movement, and impacts to water quality.

Stone and Krishnappan (1997) explored the physical and chemical characteristics of tile drain sediments from an agricultural watershed of the Thames River. They showed that tile drain sediments have a tendency to form lumps and soil masses when being discharged into a watercourse. As well, sediments in tile drain discharge was found to be depleted in Si, Al, K, Fe and P but enriched in Ca and Mg (Stone and Krishnappen 1997). Results from this work suggest that fine-grained surface materials are selectively transported through soil macropores into the tile drains, which are then resuspended during rainfall events and transported directly through the tile drain into a drain or the stream directly. As this influx of fine-grained sediment does not have the opportunity to be contained, absorbed or filtered though buffer zones or strips, it can pose a serious impact on many geomorphologic aspects of the stream corridor (Parish 200). Elevated levels of nitrate were found within tile drain sediments, and were attributed to the leaching of the chemical fertilizers and liquid manure applied to soils. It is recommended that a better understanding of the potential influence of tile drains on water quality and sediment discharge be completed within the Sydenham River.

6.3. TILE DRAINAGE IN THE SYDENHAM RIVER

The present area of land in tile drainage in the Sydenham watershed was mapped and calculated (Figure 3 and Table 5). As indicated in Table 5, a large percentage of each of the subwatersheds has been tile drained with relatively higher percentages tile drained lands in the lower reaches. For example, the highest percentage of land in tile drainage occurs in the lower reach of the north branch (76%) and the lower reach of the east branch (77.1%). Although not represented well in the tables, the area representing the historical extent of the Great Enniskillen Swamp also shows extensive tile drainage. This area is covered by the upstream section of Black Creek, the northwest section of middle reach of the east branch and the upper reaches of Little Bear Creek in the Bear Creek subwatershed.

Table 8: Area of Tile Drainage in the Sydenham River in 1983

Branch	Subwatershed	Area tile drained (ha)	Subwatershed Area (ha)	Percent land in tile drainage
North	Bear Creek	41204.7	58595.9	70.3%
	Black Creek	21653.7	32580.0	66.5%
	Lower	7996.8	10525.3	76.0%
	Total	70855.1	101701.1	69.7%
East	Upper	12764.0	45080.7	28.3%
	Brown Creek	10420.5	16016.2	65.1%
	Middle	31469.5	54583.3	57.7%
	Lower	39228.6	50893.5	77.1%
	Total	93882.6	166572.7	56.4%
	Sydenham River	164737.7	268274.8	61.4%

*The GIS database contains digital locations of the tiled drains in the Sydenham watershed in Arc View format.

A large portion of the upper reach of the east branch was not in tile drainage in 1983. Only 28.3% of the total land in this subwatershed was tile drained. If the extent of tile drainage impacts upon water quality, sediment transport and/or erosion rates, these areas of the Sydenham River deserve special attention. Similarly, areas of low tile drain extent may warrant further exploration to determine areas of rehabilitation potential.

As this table is based on mapping completed in 1983, it can only be assumed that the area tile drained since 1983 has increased for each subwatershed. The process to calculate the areas within tile drainage did not take into account built-up areas or taken up by water channels.

Consequently, the percentage area under tile drainage would likely be higher in each subwatershed as the total land available would be reduced.

The Sydenham River watershed has a high percentage of its land under tile drainage. In particular, the lower reaches of the east and north branch show high levels of area drained by tile. Tile drainage impacts the nature of sediment discharge and the transport of chemicals from agricultural soils into the watercourse. Within the Sydenham River, understanding the relative importance and significance of these impacts will be important when considering restoration options. For example, the planting of riparian buffer strips will not have a significant benefit if planted on agricultural lands with tile drains, as the sediment will not pass through the riparian buffer strip before entering the stream channel. Options to create sediment capture basins at tile outlets; creation of fine filters within tile drains, and capping of tile drains after the spring could be explored.

6.4. Drainage Extent

Understanding the role of drainage extension of the Sydenham River over time is important when considering the functions present in natural channel systems. Changes to the drainage pattern of the Sydenham River over time may have impacted upon the natural functions of the river corridor, such as transporting sediments and nutrients, ameliorating against temperature fluctuations, buffering against inputs of sediments and discharges from surrounding landuses, and the provision of habitat for species.

Changing the natural path of a river channel system may impact on sediment yields across a basin. Stone and Saunderson (1996) explored the regional patterns of sediment yield across the Laurentian Great Lakes basin and found the Sydenham River at Strathroy and Bear Creek at Petrolia had extremely high sediment yields well in their upper reaches. Stone and Sauderson (1996) suggested that the upstream locations of the stations where the sediment information was collected indicated that the highest yields were attained along short reaches of the river. It is significant that the channels within these subwatersheds (upper Bear Creek and upper reaches of the east branch) do not appear to be significantly altered, straightened, or modified when compared to other subwatersheds. If the stations at these positions yield some of the highest sediment levels in agricultural watersheds, it may be likely to assume that similar or greater sediment yields would be obtained from subwatersheds closer to the mouth of the Sydenham where increased channel modifications and straightening had occurred.

The extent of the drainage channels and streams within the Sydenham River watershed is depicted in Figure 1. The figure is limited as that it does not identify all drains and tributaries within the watershed. However, a visual assessment of Figure 1 and of Artificial Drainage Systems Maps indicate that the upper subwatersheds have fewer higher order drains and less extensive drain coverage (Upper east branch, Brown Creek, and Bear Creek). The other four subwatersheds all exhibit widespread drain creation of up to third order drains. This characteristic appears to increased in intensity within the lower east branch subwatershed and the lower north branch where large drains divert and direct a large portion of each respective subwatershed.

7. DISCUSSION

The land use and land cover of the Sydenham River watershed has changed dramatically during the 200 years since first European settlement in the area. Extensive changes to the land cover and land use and changes to the physical layout of the drainage network have occurred since pre-settlement times.

Almost 100% of the swamp, bog and marshy areas of the watershed have been lost between the early 1800s and 1983 from comparison of historical surveyor's maps and 1983 Agricultural Land Use Systems Maps (OMAFRA 1983b). The impacts of this loss on watershed function is not well demonstrated. It is probable that changes in functions related to water storage capacity, temperature amelioration, sediment capture and retention, and nutrient capture result from this loss in wetland area. Further, this dramatic loss of wetland and swamp areas within the entire watershed suggest the importance of enhancement of these habitats within the watershed. Broad subwatershed areas of interest include the upper east branch where the greatest area of wetlands exists as of 1993. Further site-specific examination of enhancement opportunities are required to identify locations where enhancement can be made, and potential benefits of these enhancements.

Changes in landcover within the Sydenham River watershed are similar to those experienced in southwestern Ontario. Snell (1987) suggests similar rates of wetland decline in southern Ontario. Since the 1800s, Snell (1987) showed that wetland decline since settlement has been most severe in southwestern Ontario where nearly 90% of the original wetlands have been converted to other uses. During the 1800s Essex, Kent and Lambton counties wetlands comprised approximately 61.1% of the region, while by 1982, only 6.1% wetland cover remained. Additionally, Snell (1982) showed that the net change in wetland area between 1967 and 1982 was 15.7%, resulting in a net loss of 8400 hectares.

Close to 58% of the forest cover has been lost within the entire watershed, from 70% in pre-settlement times to 12% forest cover by 1993. Changes in the extent of woodlands across southern Ontario since the 1800s have also been well documented. It appears that rates of loss described within this study are within the ranges outlined for most of southwestern Ontario by Riley (1999). If increasing the areas of forest cover and connecting existing forest patches is a goal, the areas of focus are clearly located where existing forest cover is near watercourses. For this reason, it is recommended that further assessment of woodlot cover and extent be detailed for subwatersheds of highest forest cover. These areas are represented by Bear Creek, Black Creek in the north branch, and the upper, middle and Brown Creek subwatersheds within the east branch. In particular,

The area tile drained has dramatically increased with agricultural intensification to current levels of 60% across the watershed, with close to 80% in lower reaches of the east and north branch. The prevalence of tile drainage within the entire watershed suggest options for increasing the level of understanding of this on broad watershed functions. Options for characterizing these impacts, and providing recommendations for the reduction of impacts should continue from the work of Stone and Krishnappen (1997).

Despite the changes in the Sydenham watershed over the past 200 years most species at risk are still present in the watershed, and several are widely distributed. Future work should continue to build on the GIS project platform to increase the information available to make decisions based on the changes in land use and landcover as well as the drainage extent and pattern over time.

When assessing land use and landcover change over time care must be taken when using different datasets, obtained from different sources, and collected for different purposes. It is not appropriate to make strict linear comparisons between the landcover of the early 1800s and the percent of forest in 1993 because of differences in definitions. However, this information can be utilized from a broad, watershed-based perspective to gain insight into the changes that have occurred throughout this recent stage of the Sydenham River's life.

A GIS mapping database can be of use to determine locations in the watershed that have been least affected by major changes. It is possible to query the maps within the system to identify areas of interest adjacent to streams, areas of interest located near GPS coordinates of species identification, and areas of interest surrounding GPS measurements of channel morphology. For example, the program can identify idle agricultural lands, woodlands, reforested woodlands, or pastured woodlands within 25 meters of watercourses, for example. This GIS dataset can be made more useful if layers that provide additional information for decision-making are added. Such data sets might include: OMAFRA soils databases; geomorphology data from the fluvial geomorphology assessment to indicate areas where sampled habitat matches species' requirements; GPS locations of dams, channel impairments, channel crossings and other site specific information.

8. RECOMMENDATIONS FOR FUTURE WORK

- Interpret 1998 landuse from available Indian Research Satellite imagery and infrared aerial photography (1995-1998) from the Ontario Ministry of Natural Resources to gain a better perspective on both current land use, and type of landuse change over time.

- Integrate geomorphology field assessment component with GIS database. Coordinates from surveyed sites and their corresponding physical attributes can be identified and integrated with the GIS database. Together, this can be used as a powerful tool to describe the linkages between land use, habitat features, and channel structure.

- Obtain and interpret aerial photography for a single subwatershed in 1954 and 1978. Integrate this assessment with the digital dataset to provide an additional in-depth view of land use change over time.

- Complete a thorough investigation of the history of tile drainage and drainage extension for a single subwatershed of interest. This will involve interviews with township drainage superintendents. Information that can be gained from this level of study would include: a history of drain and channel construction, modification and maintenance; a history of tile drain construction, maintenance, and alteration; and result in a better understanding of the location and rate of drainage extent within the Sydenham over time.

- Integrate available OMAFRA digital soils databases with GIS database. This work may complement the recommendation of the Geomorphology Assessment to define the relationship between land use and sediment delivery to the channels.

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10. APPENDICES

APPENDIX A: DATES OF HISTORICAL VEGETATION SURVEYS BY TOWNSHIP

County	Township	Date Surveyed
Middlesex	Adelaide	1833
	Carradoc	1820
	Ekfrid	1820
	Lobo	1820
	Mosa	1820
Kent	Camden	1832
	Zone	1821, 1822, 1837, 1838

*Note: The original Field Notes for the Township of Dawn have either been lost or misplaced. As the Gore of Camden was once a part of the larger Township of Dawn in Lambton County. As a result, the Gore of Camden could not be mapped (Finlay 1975)

APPENDIX B: SYDENHAM RIVER LAND USE BY SUBWATERSHED (OMAFRA 1983B)

	Subwatershed							
	North Branch			East Branch				
Land Use	Bear Creek	Lower	Black Creek	East Branch Lower	East Branch Middle	East Branch Upper	Brown Creek	Total
Idle Agricultural Land (1-10 yrs.)	164	6	111	31	183	494	37	1,025
Idle Agricultural Land (>10 yrs.)	530	185	73	160	303	514	167	1,931
Built Up	1,853	510	764	825	330	1,801	53	6,136
Built Up	9	0	0	0	0	3	0	12
Corn System	18,447	2,323	8,539	16,592	14,682	15,653	5,615	81,851
Extraction (Sand, gravel)	25	0	0	23	0	29	7	84
Extraction (Topsoil)	2	0	0	0	0	6	0	8
Grazing	43	27	87	311	587	752	243	2,051
Grazing System	0	0	0	0	0	32	0	32
Hay	2,173	583	2,066	1,339	1,657	1,438	607	9,862
Pasture	426	159	687	1,928	1,160	868	800	6,028
Extensive field vegetables	0	0	0	391	16	144	0	551
Market gardens/truck farms	37	0	0	7	3	20	0	67
Nursery	62	0	0	6	18	242	0	328
Tobacco system	0	0	0	259	312	1,882	0	2,454
Mixed	5,717	527	2,770	2,245	5,044	4,408	1,552	22,262
Grain system (sod crops, grains)	2,390	563	1,823	811	887	488	608	7,569
Not mapped	0	0	1	301	1	0	0	302
Orchards	11	0	0	10	0	99	5	125
Monoculture (row cropping)	19,540	4,530	11,173	20,786	21,309	9,989	4,343	91,668
Recreation	33	0	4	0	32	60	0	129
Sod farms	0	0	0	0	32	118	0	150
Water	0	0	0	0	19	24	2	46
Swamp, marsh	0	0	0	2	7	0	0	9
Woodland	6,722	910	4,111	4,403	7,662	5,824	2,012	31,643
Pastured woodland	100	19	218	125	191	75	0	728
Reforestation	2	0	20	4	105	25	0	156
Water	327	174	129	309	236	104	18	1,297
Total	58,612	10,516	32,574	50,869	54,776	45,090	16,068	268275

APPENDIX C: DESCRIPTION OF AGRICULTURAL LAND USE SYSTEM CATEGORIES

Land Use (OMAFRA 1983)	**Description**
Idle Agricultural Land (1-10 years)	Land idle for 1-10 years and in a state of reversion to natural vegetation
Idle Agricultural Land (>10 years)	Land idle for more than 10 years and supporting native vegetation
Built Up	Land supporting a stand of artificially stocked trees. Urban related uses.
Corn System	A continuous arrangement of four or more fields of uniform size. 40-75% of the area is corn, the remainder is a mixture of hay, pasture and sometimes grain.
Extraction (Sand and gravel pits)	Sand and gravel pits and quarries
Extraction (Topsoil removal)	Topsoil removal
Grazing	Contiguous arrangement or four or more fields or a minimum of 16 hectares with no field separation of either permanent or native grass pasture, or a combination. It may have minor amounts (less than 10%) of hay.
Grazing System	Native grass pasture where topography precludes the use of machinery. Usually on poorer land where slopes, river valleys, rock outcrops or shallow soils occur. Most often seen in association with another system.
Hay	Contiguous arrangement of four or more fields with a mixture of hay, grain and pasture, the largest portion being hay.
Pasture	Contiguous arrangement of two or more fields with a mixture of hay and pasture, about equal quantities each.
Extensive field vegetables	Large fields of cucumbers, broccoli, tomatoes, peas, etc. Includes associated fallow or plough-down crops.
Market gardens/truck farms	Small intensive plots of lettuce, onions, carrots, celery and the like. In general, these operations will be less than 30 acres in size.
Nursery	Intensive production of trees, shrubs, vines or flowers for transplant or sale. Includes associate fallow or plough-down crops.
Tobacco system	Tobacco occupies more than 50% of the area, but corn in rotation may occur. Includes associated plough-down or fallow crops.
Mixed	Contiguous arrangement of four or more fields of uniform size. There must be some corn, but less than 40% of the area. The remainder is a mixture of hay, grain and pasture
Grain system (sod crops, grains)	A combination of sod crops and grains in which grain is predominant, occupying more than 85% of the area and in some cases as much as 100%. The field sizes are usually large with fences often absent. A lower intensity cash cropping system. There are no row crops; good quality hay or pasture may compose up to 15% of the area.
Not mapped	Areas of the map that are not mapped
Orchards	Primarily hardy fruit production, usually with a combination of pears, plums and apples dominant. Orchard must occupy more than 90% of the area. If peaches and/or cherries occur, they must occupy less than 50% of the area.
Monoculture (row cropping)	Contiguous arrangement of four or more fields or a minimum of 16 hectares of corn or small grains.
Recreation	Parks, golf courses, campgrounds, etc.
Sod farms	Public or commercial sales
Water	Rivers, streams, lakes, etc.
Swamp, marsh, bog	Supports vegetation characteristic of a depressed and poorly drained area
Woodland	Forest cover with a minimum of 45% crown closure density and not less than ½ hectare in area
Pastured woodland	Woodlands that are grazed by livestock
Reforestation	Land supporting a stand of artificially stocked trees.
Water	Rivers, streams, lakes, etc.

APPENDIX D: EXPLANATION OF AGRICULTURAL LAND USE CATEGORIES

Land use	Combination (from OMAFRA 1983)
Idle agricultural land	Idle Agricultural Land (1-10 yrs.), Idle Agricultural Land (>10 yrs)
	Built Up
Built up	Recreation
Grazing, pasture, pastured woodland	Grazing, grazing system, hay, pasture,
Row and grain crops	Monoculture, grain system, mixed, corn system,
Specialty agriculture	Sod farms, tobacco, market gardens/truck farms, extensive field vegetables, nursery,
Extraction	Both extraction types
Water	Water
Swamp	Swamp
Orchards	Orchards
Woodland	Woodland, reforestation
Not mapped	Not mapped