Riparian Buffer Removal and Associated Land Use in the Sackville River Watershed, Nova Scotia, Canada

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Abstract

"To what extent has riparian area been removed in the Sackville River watershed and what land uses are associated with this riparian area removal?" I investigate this question by assessing the extent of riparian area removal in the Sackville River watershed north of Halifax and characterizing each riparian impact zone with the neighbouring land use. Stream, lake and road data and air photographs are used in Geographic Information Systems (GIS) to document the degree of riparian area removal and the land uses associated with the riparian area (agriculture, industry, forestry, residential etc). I consider the riparian area to be a 20m zone extending from the water body's edge. Over 143km of streams are assessed and all streams are broken down into reaches of discrete lengths based on riparian impact and land use category. Four qualitative indicators of riparian removal are used: Severe, Moderate, Low and Intact. The length of every reach as well as the degree of impact and associated land use are calculated using the summary statistics function in GIS. I found that one third of the total riparian area length is missing up to 50% of its vegetation and that residential, transportation and energy infrastructure were the leading drivers of this riparian buffer removal. I present a map of impacted riparian "hot spots" that will highlight the areas in which riparian area removal is the most severe as well as summaries of the land uses most associated with the greatest degree of riparian vegetation removal. Identification of the land use drivers of riparian area removal in this watershed will help the design of effective regulations for future development in riparian buffer zones.

Table of Contents

Figures

Tables

1. Introduction

1.0 Overview

As the interface between terrestrial and aquatic habitat along streams, riparian zones play an important role in riparian ecosystem functioning. Riparian zones offer many ecosystem services including the absorption of nutrients and pollution, maintenance of in-channel stream structure, and the provision of habitat. When riparian zones are removed, ecosystem functioning breaks down and a multitude of negative effects can occur including increases in sedimentation, habitat reduction or destruction, changes in temperature and the amount of organic matter and large woody debris entering the stream.

The removal of vegetation in the riparian zone is often caused by the development of the land by a variety of land uses. Some land uses exhibit characteristic riparian area removal patterns and contribute a significant amount of deforestation in riparian areas, whereas other land uses often retain the riparian zone for a variety of reasons including aesthetics, ecosystems functioning or legislation.

In 2007, the Nova Scotia Department of Environment embarked upon the process of creating the first provincial water strategy focused on drinking water, water quality and quantity, and wastewater to be released at the end of 2009. A water strategy will help government make decisions about threats to water resources in Nova Scotia and how the government can better protect these resources. During the development of this water strategy, several information gaps have been revealed (Patterson & Brazner 2009). In general, little research has been done to assess the extent of the impacts on riparian functions from adjacent land use changes. In particular, no studies have been conducted to quantify the extent of damages to riparian area zones in the Sackville watershed. The absence of any previous policy has likely contributed to the lack of quantitative data about Nova Scotian water resources. The provincial policy may also serve to resolve jurisdictional conflicts between provincial and municipal responsibilities that may result in improved municipal approaches to water resource management.

The riparian area refers to the uncultivated vegetated area between the water body's edge and the upland area (EPA 2009, Rose 2004, NS DOE 2002, Schueler et al 2008). In other words it is the vegetated interface between a river and the surrounding landscape. Riparian areas are distinct from upland landscapes due to the higher availability of water and unique combination of hillslope and fluvial geomorphic ecosystems.

In many cases riparian buffer zones are required by legislation and can vary in size from 10-50m (NS DNR 2002; Stoffyn-Egli 2009; Lee, Smyth & Boutin 2003). The prescribed minimum buffer width is sometimes modified by factors such as the terrain slope in the riparian area, the type and size of the water body, and whether it is fish-bearing (Phillips et al., 2000; Young, 2000; Blinn and Kilgore, 2001; Lee et al., 2004). The pressing need to protect freshwater ecosystems from damaging human activities has prompted many jurisdictions in North America to adopt guidelines – either mandatory (regulations) or recommended (best management practices) – controlling land use along watercourses (Young, 2000; Blinn and Kilgore, 2001; NRC, 2002; Lee et al., 2004; Olson et al., 2007). The outcome of these regulations is the establishment of "riparian buffers", also called "streamside (or riparian) management zones" (Phillips et al., 2000), which set down the width along a water body over which certain activities, such as timber harvest, are limited. It should be noted that the term "riparian buffer zone" is unique to resource management terminology and differs from the term "riparian area" which is a more comprehensive term. For the purposes of this study, the term riparian area or riparian zone will be used when discussing ecological function, extent of riparian buffer removal and land use drivers but the term riparian buffer zone or riparian buffer will be used when discussing policy implications.

1.2 Research Problem

My research question is "To what extent have riparian areas been removed in the Sackville River watershed and what land uses are driving this riparian area removal?" I hypothesize that there are multiple drivers including residential and high density residential development, agriculture (row crops, field crops, and pasture), industry/commercial, municipal uses, recreation, forestry, energy infrastructure and transportation (roads, railroads, airports). In order to answer this question, I have five objectives.

My primary objective is to identify the extent and degree of riparian area removal in the Sackville River watershed. My second objective is to identify which land use category is responsible for the most riparian area removal. My third objective is to create policy recommendations for the protection of riparian areas in this watershed. My fourth objective is to create a map which will easily identify areas which are most in need of immediate, midterm and long term protection and rehabilitation under the provincial water strategy and by HRM. My fifth objective is to identify and fill information gaps and to contribute to the literature about the Sackville watershed. I will also maintain a record of inaccuracies in existing data. There are three poles relevant to this research question: the extent and degree of riparian buffer removal, the land uses driving this removal and the policy implications of my findings around extent and degree of removal. The structure of this paper reflects theses poles.

2. Literature Review

Riparian zones are unique and valuable ecosystems that have been the subject of scientific investigation for the past 100 years and are being used more and more as a water quality protection measure (Lee, Smyth & Boutin 2004). Riparian zones produce far-reaching watershed-wide benefits for ecological functioning and drinking water and that are exponentially larger than the relatively simple measures required to maintain them (Cahill & Molles 2007). The increasingly widespread protection of riparian areas in North American policy can be attributed to the increased use of the watershed as management unit and the emergence of integrated water resource management strategies across Canada and the US in recent decades (Lee, Smyth & Boutin 2004; EPA 2009; Young 2000).

This section will examine the extent of scientific debate surrounding the functioning and importance of riparian area zones, debate surrounding the minimum required width of buffer zones, provincial and municipal legislation regarding buffer zone requirements for various land use sectors as well as the necessity of this study in addressing several information gaps about riparian zones in Nova Scotia. Literature was located using a non-systematic snowball method by searching academic journal databases using various combinations of the terms “riparian”, “buffer” and “zone”. Cited works in relevant articles were examined for other relevant articles. Policy documents used were found on provincial and municipal websites based on the author’s previous knowledge of the subject.

2.1 Riparian Ecosystem Functions & Effects of Area Removal

Riparian zone research has examined the following elements pertaining to riparian ecosystem health and functioning. When riparian vegetation is removed many negative ecological impacts often follow, including the loss of terrestrial and aquatic habitat, increased sedimentation and turbidity in watercourses and increased overland runoff rates.

Table 2.1 Scope of Riparian Zone Research	
Element of Literature	**Sources**
Riparian vegetation mitigate the effects of overland runoff from agriculture, construction sites, forestry operations and urban areas which deposit sediment, salt and nitrogen and phosphorus-laden fertilizers and toxic pesticides into water bodies	Rose 2004, NS DOE 1998 & 2002, Schueler et al 2008, EPA 2009
Riparian vegetation root systems control stream structure by holding soils in place and prevent channel widening	Rose 2004, NS DOE 2000 & 2002, EPA 2009
Intact riparian areas aid in nutrient cycling when vegetation root systems absorb nutrients contained in overland runoff from agriculture	Botkin, Heathcote & Keller 2004, EPA 2009
Riparian vegetation provide habitat and food for terrestrial and riparian obligate species via the physical habitat and micro-climate moderation	Stoffyn-Egli 2009, EPA 2009
Intact riparian areas provide shade for aquatic species	Botkin, Heathcote & Keller 2004, EPA 2009
Impact of upland land use changes on riparian functioning which create on-site erosion and sedimentation and lead to increased sediment deposition in nearby streams. Paved urban areas do not permit infiltration which increase flow rates of overland runoff	Schumm, Mosley & Weaver 1987, EPA 2009
Riparian areas control infiltration rates; both the above-ground and root systems of riparian vegetation help slow the flow of water over land allowing water to infiltrate more slowly	Rose 2004, EPA 2009, Cahill & Molles 2004
Riparian areas control runoff by allowing sediment contained in overland runoff to be filtered out by vegetation before reaching the stream	Rose 2004, EPA 2009
Vegetation protects soil particles from falling or flowing water which means the soil particles are less likely to be dislodged from soil aggregates and as a result, are much less subject to movement by water flowing across the soil surface	EPA 2009, Cahill & Molles 2004

2.1.1 Extent of Riparian Area Removal

Riparian areas are important to maintain hydrologic pathways. Figure 2.1 focuses on one of the effects of riparian zone removal, on salmon habitat in this case, in order to illustrate the complexities of riparian functioning. When riparian zones are removed or thinned, riparian hydrology is altered. The proportion of water that enters watercourses as water flowing underground via throughflow and piping can be reduced, due to soil compaction caused by heavy machinery during riparian deforestation, or by loss of soil root structure. The amount of water flowing as overland runoff is therefore increased as is the quantity of sediment delivered to watercourses from erosion. Further, when the riparian zone is removed, overland runoff enters waterways more quickly than when riparian zone are intact because of less vegetation available to slow the flow of runoff over land. Increased rates of water delivery to the stream can affect in-stream peak flows, potentially causing flooding if water enters too quickly; this also causes increased erosion and sediment delivery (Rose 2004). Low flows may also be reduced.

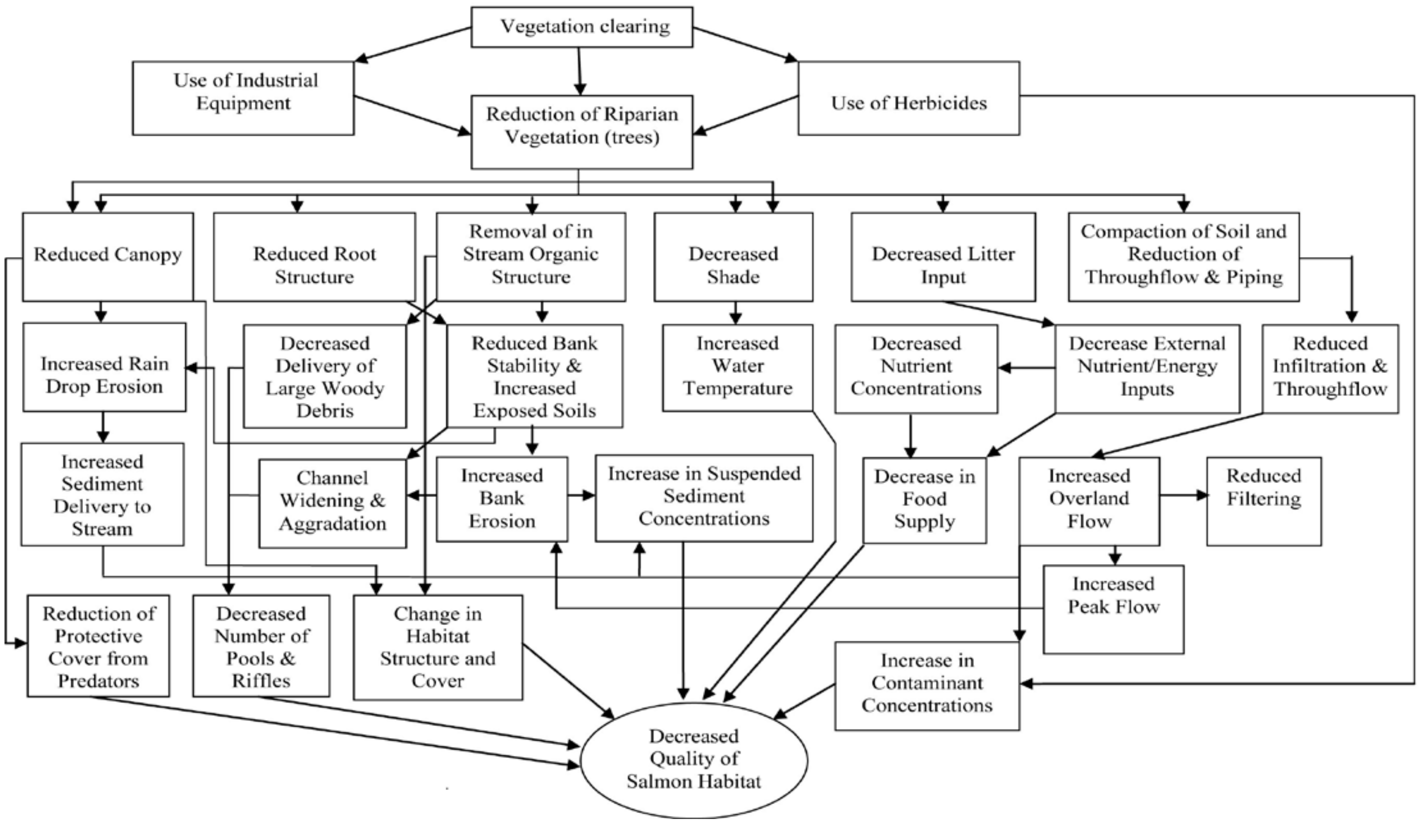

Figure 2.1 Effects of Riparian Vegetation Clearing on Salmonid Habitat

Riparian area removal can also have important implications for water quality and human health. Human consumption of nitrite-nitrogen laden water from agricultural land uses can also cause health issues, particularly in babies (EPA 2009). Overland runoff carries pollution and salt from urban areas, nitrogen, phosphorus and bacteria from fertilized agricultural lands and livestock, as well as soil particles from agriculture, construction sites, urban areas and forestry operations (Rose 2004, NS DOE 1998 & 2002, Schueler et al 2008, EPA 2009). Acute and chronic chemical pollution can cause either immediate fish kills or create long term illness in fish, often manifested in reproductive mutations or sores. Nutrient pollution can lead to eutrophication, a phenomenon that occurs when algae is fertilized, blooms and then dies consuming oxygen in the decaying process, making it less available to fish (EPA 2009, Botkin et al 2004, Rose 2004). Increased sediment deposition increases turbidity which can reduce drinking water quality, reduce light penetration, suffocate fish spawning grounds, reduce dissolved oxygen content and can cause fish gill abrasions (NS DOE 2000, EPA 2009). Removal of riparian zones also negatively affects stream structure as the root systems of trees and other vegetation hold stream banks in place (EPA 2009). Without root systems and soil cover, soils can be easily eroded by overland runoff which will cause a stream channel to widen as the banks retreat (NS DOE 2000).

Finally, riparian area removal constitutes the loss of wildlife habitat for aquatic and terrestrial species and protection from predators (EPA 2009). While the connection between forest and habitat for terrestrial species is obvious, riparian vegetation protect fish habitat in a more subtle manner: trees shade the stream and maintain cool temperatures ideal for fish (EPA 2009). The Sackville watershed is home to a resident Atlantic salmon population which thrives in relatively specific stream structures, temperatures and levels of turbidity. Deforestation in the riparian zone can increase stream temperatures by removing shade-providing trees (Macdonald, MacIsaac & Herunter 2003). Riparian area removal can cause sedimentation by reducing the amount of soil particles absorbed by riparian vegetation, which can suffocate salmon eggs (EPA 2009). Large woody debris creates a riffle-pool stream structure that provides still pools for spawning (Mossop & Bradford 2004). Reduced forest canopy also increases erosion from falling water droplets. It is clear that protecting or restoring riparian areas is a direct way to significantly reduce harm to watercourses.

It should be noted that the effect of riparian area removal on riparian health varies with the type of channel morphology (See Figure 2.2). The main types of channel

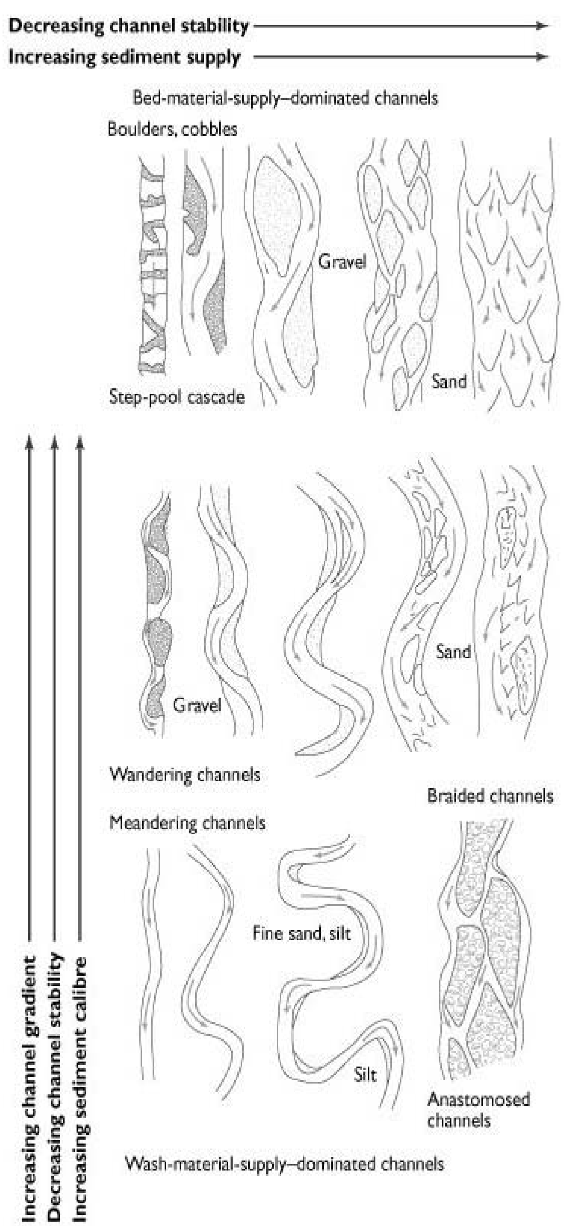

Figure 2.2 Relationship Between Channel Morphology, Gradient & Sediment Characteristics (Church 1992).

morphologies are straight, meandering, braided and anabranching (Church 1992). Based on these typologies, the type and degree of impacts from riparian area removal will vary based on channel morphology. Riparian area removal will have a less of an impact on river reaches that are confined by bedrock, and stream temperature and fish habitat can be less impacted in wide, braided reaches. Meandering streams are particularly sensitive to riparian area removal because they are in alluvial reaches. Alluvial reaches are characterized by fine soil particles that have already been transported by the river in the past and are easily transported by overland runoff and flooding. Steeper gradients can increase the velocity of overland runoff into streams thereby possibly increasing in-channel erosion rates. Steeply graded streams in bedrock are eroded less easily because the soil particles are more likely to be rocks and gravel rather than sand and small soil particles found in alluvial reaches, and require more energy than the river has available to transport the material (Rose 2004).

Another issue related to riparian ecosystem integrity is that of the "edge effect". The edge effect occurs when "the adjacent forest is affected by changes in the physical environment along its edges [caused by clear cutting], by reduced habitat area and by isolation" (Cahill & Molles 2007. pg. 588) and "may exist along a broad belt or in a small pocket, such as a forest clearing" (Encyclopedia Britannica 2010). It is also defined as "an effect occurring following the forming of an ecological island" (Botkin, Keller & Heathcote 2004). When a section of forest is exposed to increased solar radiation and wind after cutting, the structure of the forest community is altered due to these new physical conditions which include desertification along the edge area (Cahill & Molles 2007). Tree mortality is high in these new edge areas which has implications for terrestrial habitat in riparian zones retained during development (Cahill & Molles 2007). Lee & Peres (2008) and Hannon et al. (2007), argue that areas are inherently too small to maintain certain non-edge adapted species and that in order to be large enough to maintain a broad range of species riparian areas would have to be so large that they could no longer be categorized as riparian zones. In other words, riparian zones can only support species that are edge-adapted species. In addition, Forsey & Baggs (2000) also argue that many mammals only utilize riparian zones under duress for example when their habitat is compromised.

2.1.2 Land Cover Drivers

Numerous studies have shown that surface water quality is affected by the land cover characteristics found within the watershed drainage areas of streams (Limburg and Schmidt, 1990; Jones et al., 1999; Bis et al., 2000; Riva-Murray et al., 2002; Woodcock et al., 2006). Land use adjacent to streams can have a large impact on riparian ecosystem functioning as it can determine how forest cover is managed and different land uses can impact riparian area functioning to varying degrees and in different ways. Some land uses require access to watercourses whereas others may have more freedom to protect riparian zones.

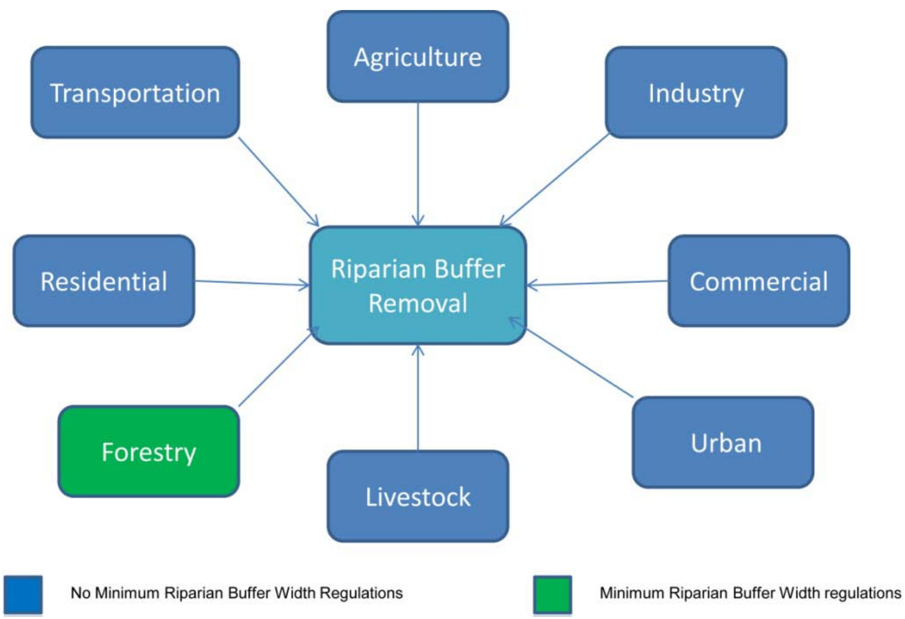

Figure 2.3 Causes of Riparian Buffer Removal in the Sackville Watershed

Forestry operations by nature, typically remove the majority of vegetation from the land, leaving large quantities of biomass and disturbed soils which can increase sedimentation and nutrient flow into nearby watercourses (Cahill & Molles 2004).

Energy infrastructure (utility pole corridors) and transportation (roads, rail tracks) typically remove the riparian zone completely. Transportation must at times cross streams and will remove a portion of a riparian zone and introduce pollutants used in vehicles into the watercourse via runoff. Energy infrastructure corridors are kept clear of vegetation (other than grass) to allow for access to utility poles and maintenance. The complete removal of riparian zone vegetation can lead to an increase in stream temperature from lack of shade and negatively impact salmon habitat. Damage to streams caused by maintenance vehicles in these corridors is also an issue (Schambach 1999).

Residential land uses exhibit a range of riparian zone practices. In HRM property setbacks are required however there are no regulations in place to ensure that vegetation (and trees in particular) is retained in these zones and landowners may wish to remove the riparian zone to increase the aesthetic value of the property. As a result, residential properties may have a full riparian zone, a thinned riparian zone, shrubbery or simply a grass lawn. The removal of riparian zone vegetation on residential land can allow fertilizers and cosmetic pesticides and herbicides to enter the watercourse without having been absorbed by riparian vegetation and soils (EPA 2009).

Agricultural land uses may seek to maximize their potential yield by using all of their available land and maintain a narrow or no riparian zone, however, awareness of the benefits of riparian zones for mitigating chemical-laden agricultural runoff has become more widespread and riparian buffer zones may be more widely used now than in recent decades (NRC 2002; Bentrup and Kellerman 2004; de la Crétaz and Barten 2007).

Industrial and commercial land uses may also exhibit a range of riparian zone practices. Industries that require access to watercourse necessarily remove a portion of the riparian zone. Industrial and commercial land uses can have significant impacts on water quality in neighboring watercourses depending on the industry (EPA 2009). Industrial waste products must be carefully managed in order to prevent chemical contaminants from entering the watercourse.

Land used for recreational purposes can exhibit good and bad riparian zone practices depending on the type of recreation; forested trails are an excellent way to maintain riparian zones (and often more than the minimum required width) whereas athletic recreation land uses typically remove all vegetation in an area.

Wild/natural or untouched forest tracts generally have intact riparian zones and play an important role in maintaining riparian zone function.

2.1.3 Policy Implications

There is debate about the minimum width of riparian buffer zones required for various ecosystem functions (ie: terrestrial and aquatic habitat, bank stabilization, absorption of runoff etc.). In a quantitative review of riparian buffer width guidelines from Canada and the United States, Lee, Smyth and Boutin (2004) show that in practice minimum buffer widths range from 15.1m-29m. A review of the literature reveals no consensus about the minimum buffer width required for large mammals, likely because few large animals are riparian obligate species. The beaver is studied most often as an indicator of riparian health and minimum size because of its riparian obligated nature. Stoffyn-Egli recommends that buffer zones be a minimum of 50m in order to protect habitat for riparian obligate species. The Beaver was the largest mammal studied in the literature review; small mammals (rodents), birds and amphibians were studied most often although there was no consensus about the minimum width required to maintain populations. For a review of minimum buffer regulations for various riparian ecosystem functions in North America see *Quantitative Review of Riparian Buffer Width Guidelines from Canada and the United States* by Lee, Smyth & Boutin (2003).

The HRM Water Resource Management Study (Dillon Consulting 2002) recommends the following minimum buffer zone widths be maintained for various riparian functions (see Table 2.2).

Table 2.2 Example Ranges of Minimum Riparian Zone Widths (each side of stream) (Adapted from Dillon Consulting 2002)		
Riparian Zone Function	**Minimum Riparian zone Width (m)**	**Possible Consequences of Riparian zone Removal**
Protection of Fish Habitat (including salmon and other species)	15-60	Loss of Fish Habitat
Bank Stabilization and Erosion Control, Protection of Water Quality (Reduced Turbidity)	3 for sandy soils 120 for clay soils	Increased Turbidity, Changes in Stream Morphology, Bank Erosion
Channel Temperature Regulation and Shade	10-75	Fish and Invertebrates Unable to Adapt to Modified Environment
Pollutant Removal	4-43	Fish Kills, Poor Drinking Water Quality
Visual Recreational Purposes	Subjective	Reduced Aesthetic Value
Wildlife Habitat	Unknown	Loss of Wildlife Habitat

There is also debate about whether legislated buffer widths should be firm or flexible. Firm buffers are easier to legislate and implement but may not be appropriate for all circumstances. Some authors argue that buffer widths should be flexible to reflect site-specific context (Forsey & Baggs 2000; Phillips 1989; and Xiang 1993). For example Phillips (1989) and Xiang (1993) created a buffer delineation model based upon a pollution detention time equation of buffer effectiveness. In other words, a model is used to determine the minimum width of the buffer based on how long it takes runoff-borne pollutants to be absorbed by the buffer zone. The minimum size of the buffer therefore will vary from location to location depending upon the soil and vegetative structure of the buffer zone.

In general the literature supported the standardization of minimum buffer widths within a watershed as opposed to a patchwork of subregional policies (Lee & Peres 2008, Dillon Consulting Ltd 2002).

Because different land uses have varying buffer maintenance practices and impacts on riparian zone functioning, they are an important factor to consider when creating new land use policies. This variety of practices and effects provides an argument for flexible buffer widths. Whether flexible or firm minimum buffer widths are chosen in legislation, correlating land use with riparian zone removal (or maintenance) is important when assessing whether certain land uses within a watershed are driving riparian area removal more than others. If this is the case, legislation or policy can be targeted towards specific land uses. If all land uses are impacting riparian health equally then firm minimum buffer widths may be more useful to policy makers.

The presence of minimum riparian buffer zones in many municipal land use bylaws and planning strategies demonstrates an acknowledgement that land use and riparian ecosystem functioning are connected. By taking a watershed-level land use approach to riparian buffer management, it is possible to mitigate the potential effects of new development on riparian functioning by designing appropriately large minimum buffer zone requirements for some or all land uses.

2.2 Economic Costs of Protection of Riparian Areas

Much of the debate about appropriate minimum riparian zone widths stems from the effect of these riparian zones on land use and the landowner's rights to modify their property. Forestry operators are often critical of buffer requirements despite the fact that the Nova Scotia Department of Natural Resources *Wildlife Habitat and Watercourses Protection Regulations* 20m buffer zone allows for partial cutting in the buffer zone. Table 1.2 summarizes the economic costs of maintaining riparian buffers for different land uses.

Table 2.3 Economic Costs of Protection of Riparian Areas

Land Use Category	Negative Effects
Forestry	Financial & Labour Costs of Constructing Separate Access Roads – Unable to Move Timber Across Streams
Residential	Loss Of Partial or Entire Property, Loss of Scenic Views
Agriculture	Loss Of Productive Land, Limits Access to Water for Livestock & Irrigation
Urban	Loss of High-Value Real Estate
Transportation	Financial & Labour Costs of Constructing Roads Around Streams

While the ecosystem benefits of maintaining large riparian zones are clear, it is also evident why the issue of minimum riparian buffer zone widths and the necessity of riparian areas in general are heavily debated.

2.3 Existing Legislation in Nova Scotia

The government of Nova Scotia and the Halifax Regional Municipality (HRM) have taken a number of steps in recent decades to protect riparian ecosystems, particularly as it relates to drinking water quality, but also for the sake of protecting other ecosystem functions.

2.3.1 Provincial Legislation

The provincial government is responsible for ensuring that municipalities protect drinking water resources, flood plain management and agricultural land based on the essential services they provide as defined under the Statements of Provincial Interest within the Municipal Government Act. The statements of interest are designed to help provincial government departments, municipalities and individuals in making decisions regarding land use. Among other things, they set out separations between land use and watercourse and restrict development in floodplains. These statements of interest are based on the understanding the province is responsible for ensuring the essential services provided to Nova Scotians by flood plains, agricultural land and drinking water and form the foundation for much of the policy work that has been developed in recent years.

The provincially legislated Municipal Government Act:

> "enable[s] municipalities to assume the primary authority for planning within their respective jurisdictions, consistent with their urban or rural character, through the adoption of municipal planning strategies and land-use by-laws consistent with interests and regulations of the Province"
> (Government of Nova Scotia 1998, section 190b)

The *Municipal Government Act* also requires Municipalities to create a drainage master plan.

Building on the Statements of Interest, the provincial government enacted the *Environment Act* in 1995 the purpose of which is to "maintain environmental protection as essential to the integrity of ecosystems, human health and the socio-economic well-being of society" (NS DOE 1995, section 2 (a)) and outlines areas requiring protection including water resources and the powers of government relating to these issues. Specifically it requires the Minister of Environment (MOE) to "promote the rehabilitation and restoration of degraded areas of the environment" (NS DOE 1995, section 8 (2) f). The Act also outlines regulations limiting the release of deleterious substances into watercourses; this issue is also covered in the federal *Fisheries Act* as well as any activities that harm fish habitat (Government of Canada Department of Fisheries & Oceans 1985).

The most significant piece of provincial legislation pertaining to riparian buffer zones is the *Wildlife Habitat and Watercourses Protection Regulations* (NS DNR 2002). This piece of legislation requires forestry operations to create "Special Management Zones (SMZ's). SMZ's are "an area of forest required to be established adjacent to a watercourse… to protect the watercourse and bordering wildlife habitat from the effects of forestry operations" (NS DNR 2002. p. 1). The regulation requires that forestry operations maintain a buffer of 20m on either side of the length of every stream wider than 50cm and around lakes, marshes and salt water bodies (NS DNR 2002). Within this buffer forestry operators must not conduct any activities that would result in sediment being deposited in the watercourse. When the average slope of a stream bank within the 20m buffer is greater than 20%, 1m of buffer must be added for every 2% of slope increase up to a maximum of 60m (NS DNR 2002). In addition, no vehicles may be operated within 7m of the watercourse. Partial clearing is permitted within the buffer zone however $20m^2$/ha of basal area must be retained and small and non-harvestable trees, shrubs and ground cover should be maintained to the fullest extent possible. In addition, canopy openings may not exceed 15m in width (NS DNR 2002). For streams smaller than 50cm, no vehicles may be operated within 5m of the watercourse, sediment must not enter the water course and small trees and shrubs must be retained when possible (NS DNR 2002). It should be noted that these regulations apply only to forestry operations. There is some uncertainty about whether these guidelines are followed to the letter by forestry operators as it unclear whether or not these regulations are strictly enforced.

The Department of Environment (DOE) has also co-sponsored the Nova Scotia Eastern Habitat Joint Venture in partnership with the Department of Natural Resources, the Department of Agriculture and Fisheries, the Canadian Wildlife Service, Wildlife Habitat Canada, Ducks Unlimited Canada, Nature Conservancy of Canada and has provided approximately $19,500,000 in funding to over 60 participants through habitat securement (36,700 hectares), enhancement (10,400 hectares) and management (13,200 hectares) of wetland in Nova Scotia to date. The program includes a riparian zone management system for wetlands and waterways to control agricultural runoff, protect waterfowl habitat and biodiversity in general (Wildlife Habitat Canada 2009). The provincial DOE is currently in the process of drafting a wetland management strategy that builds on regulations outlined in the *Wildlife Habitat and Watercourses Protection Regulations* in particular the strategy will encourage the creation of buffers between wetlands and developments and agricultural operations. Consideration of the use of buffers in Environmental Assessment approvals for projects with a high potential to negatively impact wetlands is also recommended in the strategy (NS DOE 2009). The use of buffers to protect wetlands will presumably benefit riparian health in areas where streams flow in and out of wetlands.

The forthcoming provincial water strategy is still being drafted; however a discussion paper was released in 2008 requesting input on a number of factors. Following the publication of a discussion paper in 2008 (NS DOE 2007) the NS DOE conducted public consultation from January 30 to June 1 2008, the results of which are summarized in the *What We Heard* document (NS DOE 2008). Via these consultations, the public demonstrated that there was strong support for the use of riparian buffer zones, although no consensus was reached about the minimum width of these buffers (NS DOE 2008). Support was also shown for watershed level management rather than municipal, provincial or federal level management units (NS DOE 2008). Participants also noted a significant gap regarding scientific data about water resources in the province (NS DOE 2008).

The province has also created a *Drinking Water Strategy* (2002) based on a “multi barrier” approach to protecting drinking water resources. It bans the bulk export of water as well as specifies that on-site septic systems, composting facilities, C&D waste disposal sites must be sited away from watercourses however it does not specify a setback distance (NS DOE 2002). The strategy outlines which departments are responsible for regulating erosion and runoff from agriculture (Department of Agriculture and Fisheries) and for wetland management (Department of Natural Resources).

2.3.2 Municipal Legislation

At the municipal level, the most significant research regarding the protection of water resources is the HRM Water Resource Management Study carried out by Dillon Consultants in 2002. This report outlines key water resource management issues for HRM and provides policy recommendations to address these issues. The report highlights the significant loss of watercourse and wetland habitat in the HRM, particularly on the Halifax peninsula the cause of which is often channelization and infilling and its associated removal of riparian buffer zones. Currently the HRM is not responsible for protecting inland water resources including rivers and streams (the province bears this responsibility) however it is able to direct land use and development by including riparian buffer zone requirements (including widths) in its Municipal Planning Strategy (MPS) or Land Use Bylaws (LUB). At the time that the report was written, no entity had the jurisdiction for complete watershed planning, however the Nova Scotia Department of Environment is releasing a water strategy and it is expected that a watershed approach will be utilized.

The HRM is the overarching governing body for the Halifax region since the amalgamation of several municipalities in the mid 1990’s (HRM 2006a). Since amalgamation former municipalities now adhere to the HRM guidelines for minimum riparian buffer zones as described in the HRM Regional Plan which are as follows:

> "HRM shall, through the applicable land use by-law, require the retention of a minimum 20 metre wide riparian buffer along all watercourses throughout HRM to protect the chemical, physical and biological functions of marine and freshwater resources. The by-law shall generally prohibit all development within the riparian buffer but provisions shall be made to permit board walks, walkways and trails of limited width, fences, public road crossings, driveway crossings, wastewater, storm and water infrastructure, marine dependent uses, fisheries uses, boat ramps, wharfs, small-scale accessory buildings or structures and attached decks, conservation uses, parks on public lands and historical sites and monuments within the buffer. In addition, no alteration of land levels or the removal of vegetation in relation to development will be permitted." (HRM 2006b, p. 29)

However the HRM MPS neglects to define which land uses these buffers apply to and whether thinning is permitted in riparian buffer zones and whether or not riparian areas will be protected on existing development s or only during new development (HRM 2006b). The Halifax Watershed Advisory board recommends the use of 30m buffers on either side of a stream for new developments and recommends that buffers be replanted with native species in areas where no buffer exists (Halifax Watershed Advisory Board 2005).

The 2002 HRM Water Resource Management Study carried out by Dillon Consultants weighs the costs and benefits of three riparian buffer approaches: advanced, moderate and fixed. The advanced approach includes generous buffers which seek to provide "comprehensive protection of aquatic and terrestrial riparian ecosystems" (Dillon Consulting 2002, p. 5-19). Buffer widths would be flexible based on the characteristics each site but would still remain generous. While ideal for the protection of riparian functioning, advanced buffers add significant time and costs to the development approvals process, requires costly scientific analysis to establish the buffer width necessary for the particular location, and would likely be hotly contested by developers and land owners. Under this approach, it is possible to establish wide buffer widths in sensitive areas and smaller ones in less sensitive areas, but this may result in pressure from developers and landowners seeking to comply with the minimum possible width. The moderate approach is based on the *Wildlife Habitat and Watercourses Protection Regulations* which requires 20m buffer zones, and increased width for slopes above 20% for streams larger than 50cm. The fixed approach recommends buffers of 30m for all cases regardless of stream width, sensitivity of the riparian zone, or slope. This fixed width may result in excessive buffer zones in some cases and inadequately small ones in others.

Dillon Consulting recommended that the HRM adopt the moderate approach and use the *Wildlife Habitat and Watercourses Protection Regulations* for all new development. This would constitute a drastic improvement in the protection of riparian habitat and functioning over the existing *Wildlife Habitat and Watercourses Protection Regulations* which are only applicable to forestry operations. This report also suggests that ideally no soil or vegetation will be removed from the buffer zone and that holes in the canopy be limited to 15m; however it concedes that the *Wildlife Habitat and Watercourses Protection Regulations* allow for some cutting. It also concedes that the waters' edge may be occasionally compromised for access points or for public uses such as roads or boat launches.

Finally, the Dillon report identifies three options for riparian buffer management in terms of ownership: retention of riparian zone by the developer, by the adjacent land owner or by the municipality. The first option was rejected based on the temporary nature of development entities. The second was identified as the best option because of the low cost. The third option was partially accepted. Municipalities should purchase riparian buffers when possible but recognizes the difficulty of purchasing most or all of the buffer zones in the HRM.

Attempts to find any studies similar to the one proposed by the author yielded no information. The most relevant study found was that conducted by Patricia Stoffyn-Egli (2009) wherein she delineates the minimum buffer zone required to support riparian obligate species using GIS. It appears that the proposed study by the author will be the first of its kind in Nova Scotia and in the Sackville watershed specifically.

The methods that will be used to document the extent of riparian zone removal and its relation to specific land uses are original and unique to this study. As no similar studies have been conducted in the region and because so much baseline data is absent, a novel approach was required. Other studies carried out on North American watersheds are often highly scientific in nature and use sophisticated statistical analysis. The proposed study is basic in nature as it involves the use of maps and aerial photos, whereas the methods used in other riparian studies are too complex and deal with field data and are therefore inappropriate in this context.

2.4 Identification of Literature Gaps

A review of the relevant literature indicates that while there is scientific consensus about the importance of riparian zones to riparian and watershed health, there exists some debate about the appropriate minimum buffer width. There also exists a plethora of water resource related federal, provincial and municipal legislation and policy that indirectly or directly affects riparian health including policies addressing drinking water quality, Land Use Bylaws, Municipal Planning Strategies, water and wetland policies, Statements of Provincial Interest, the *Municipal Government Act*, the *Environment Act*, the *Fisheries Act*, the *Wildlife Habitat and Watercourses Protection Regulations*, and the HRM Water Resource Management Strategy Study. Currently only the *Wildlife Habitat and Watercourses Protection Regulations* set out specific riparian buffer zones for forestry operations. There is a considerable absence of regulations in Nova Scotia which require the use of riparian buffer zones for agriculture, commercial, residential, urban, industrial, transportation related development. However, some policies and programs promote or encourage the use of buffer zones such as the Nova Scotia Eastern Habitat Joint Venture and the provincial drinking water strategy. At the municipal level, governments have the power to protect riparian buffer zones via Municipal Planning Strategies, Land Use Bylaws and the NS

Drinking Water Strategy; however, these methods of protection have been inconsistently applied throughout the HRM (via regulations established by former municipalities) and Nova Scotia and would benefit from a unified approach coordinated by the HRM or by a provincial mandate via the Municipal Government Act. Because of this lack of coordination, I expect to find a wide range in the degree of riparian area removal within the different former municipalities in HRM for various land uses.

A review of the relevant local literature reveals significant gaps in baseline information (GIS maps or field data) about the state of riparian area in Nova Scotia including. I have not found any other studies that measure the extent of riparian area removal in Nova Scotia on a watershed basis. Nor have I found any studies which assess the land uses have the largest impact on riparian health in terms of erosion, sedimentation, pollutants, nor which land uses are the largest contributors to riparian zone removal. Municipal and provincial governments admit that there is a noticeable gap in the information concerning the health and extent of riparian zones in the province, and the public appears to agree with that (NS DOE 2007; NS DOE 2008). The proposed study aims to increase my understanding of the current state of riparian zones and the cause of any riparian zone removal by assessing the extent of riparian zone removal in the Sackville watershed and which land uses dominate the removal of riparian zones. By identifying these factors, the author hopes to inform provincial and municipal policy regarding the use and regulation of riparian buffer zones for land use sectors beyond forestry. If the findings indicate that riparian zone removal is caused by a variety of land uses other than forestry, it will be clear that regulations for non-forestry sectors would benefit riparian ecosystem health and improve the riparian ecosystem services provided by them.

3. Methods

In accordance with my research objectives, my approach examines three study variables:

1. Extent and location of riparian zone removal
2. Degree of riparian zone removal
3. Identification of land uses associated with riparian zone removal

The methods that will be used to document the extent of riparian zone removal and its relation to specific land uses have are original and unique to this study. As no similar studies have been conducted in the region and because so much baseline data is absent, a novel approach was required. Other studies carried out on North American watersheds are often highly scientific in nature and use sophisticated statistical analysis. This study takes a straightforward approach to use topographical maps and aerial photos, and do not involve collection of field data, in part due to the timeline of the thesis (Appendix B).

3.1 Selection of Watershed

This topic merits exploration because there are notable information gaps regarding riparian zone integrity in the Sackville River watershed. A watershed plan is being created for the Sackville Rivers Association, and the information from this study will be useful for this. It is my aim that this research will fill some of the information gaps identified in the literature review and contribute to the body of knowledge about threats to the Sackville watershed and to the Halifax Harbour.

The 150 sq km Sackville River watershed (Sackville Rivers Association 2010) was chosen for a number of reasons. This watershed contains a significant degree of urban, residential, agricultural and industrial development. Due to the density of development, there is a significant degree of deforestation in this watershed. In addition, there is a diverse range of land uses within this watershed including residential, agricultural, industrial/commercial, transportation and forestry. The Sackville River watershed is an important watershed in Nova Scotia because of its salmon population. This watershed was also chosen for its proximity to central Halifax where the provincial government and the author are located and for the availability of GIS data and aerial photos. The Sackville River and the Little Sackville River are designated Flood Risk Areas under the Canada-Nova Scotia Flood Damage Reduction Program. An assessment of riparian zone integrity along these two rivers may contribute to flood risk assessments and protection and/or rehabilitation of riparian areas could contribute to a reduction in flood risk by absorbing overland runoff (Figure 2.1).

Research has shown that the impact on riparian zones is greater for some land uses than others. Impact of land use on the riparian system is a function of several variables including the extent of the riparian zone removal, initial severity of initial disturbance, the time since initial disturbance and whether or not forest cover has been permitted to recover or if it is continually removed. We assessed the impact of land use on the riparian system, according to the following model:

$Y = E \; x \; S \; x \; 1/t$ (where recovery is possible) *(1)*

$Y = E \; x \; S$ (where recovery is not possible) *(2)*

where E is extent of impact, S is initial severity of initial disturbance, t is time since initial disturbance. Two equations are used to differentiate between scenarios in which riparian vegetation is permitted to regenerate or not depending on the land use.

3.2 Sources of Data

The majority of the data (digital aerial photos, GIS layers) was obtained from Ray Jahnke of the Dalhousie University GIS Centre and the remainder (hard copy aerial photos and flight line map) was sourced from the Nova Scotia Department of Natural Resources map library. The quality of the digital aerial photos was functional up to 1:1,000. The digital aerial photos only covered the eastern portion (the Little Sackville River sub watershed) of the Sackville River watershed. Aerial photos of the remainder of the watershed used were in hard copy format. In some cases the resolution of the digital aerial photos made it difficult to assess the height of the vegetation in the riparian area. This issue was resolved when using hard copy aerial photos by using a stereoscope.

Table 3.1 Sources of Data	
Data	**Reference**
Sackville River Streams GIS Layer - Contains Data About Location Of Streams	Service Nova Scotia & Municipal Relations 2005
Sackville River Lakes GIS Layer - Contains Data About Location Of Lakes	Service Nova Scotia & Municipal Relations 2005
Sackville River Watershed GIS Layer - Contains Data About Watershed Boundaries	Service Nova Scotia & Municipal Relations 2005
Sackville River Roads GIS Layer - Contains Data About Location Of Roads & Highways	Service Nova Scotia & Municipal Relations 2005
Sackville River Digital Aerial Photos - Contains Data About The Land Cover	Service Nova Scotia & Municipal Relations 2005
Uniacke Flight Line Map	Service Nova Scotia & Municipal Relations 2003
Hard Copy Aerial Photos	Nova Scotia Department of Natural Resources 2003

3.3 Procedures

Using ArcGIS version 9 and ArcMap version 9.3.1, the following layers were set over each other: watershed boundaries, streams, lakes, and roads for the Sackville River watershed (Table 3.1). Three new layers were created. The first was for the boundary of the Sackville River in which a line was drawn linking the high elevation points surrounding the tributaries of the Sackville River using the ArcGIS Editor tool. The second layer was created for the 20m (on either side) riparian buffer polygon

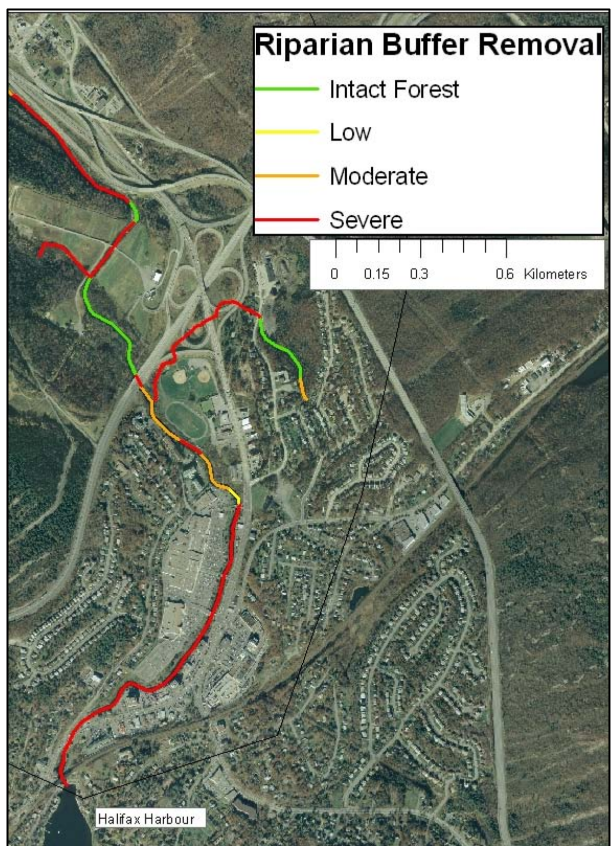

Figure 3.1. Example of Colour Coding Methodology

beginning at the stream bank. The third new layer was created for the reach delineations. The scale is 1:10,000. The coordinate system used is North American Datum (NAD) 1983 in UTM zone 20N.

If the reach retained 0-25% of an intact forest then it was categorized as Severe. If the reach retained 26-50% of an intact forest then it was categorized as Moderate. If the reach retained 51-75% of an intact forest then it was categorized as Low If the reach retained 75-100% of an intact forest then it was categorized it as Intact. Each reach was manually labeled in the layer properties according to its degree of riparian zone removal in the attributes table. Each reach was colour coded as red (severe), orange (Moderate), yellow (Low) and green (Intact) on a map to represent the degree of riparian zone removal found therein (see Figure 3.1). If a stream intersected a wetland it was stated as Y/N. The channel type of each stream reach was also noted as Headwater, Mid (Alluvial) or Delta.

Beginning where the Sackville River enters the Halifax Harbour, I moved upstream following the eastern branches (the Little Sackville River sub watershed) and then moving into north and west, adding the following data to the attributes table in ArcGIS (Table 3.1). Streams were broken down into reaches of uniform riparian impact or vegetation removal. I categorized the riparian zones as belonging to the Left or Right bank of the stream. As I progressed up a stream, every new degree of riparian zone removal and land use category was labeled as a reach in the ArcGIS attributes table (severe, moderate, low and agriculture, industrial, forestry etc). Alternately, if two degree of impact categories were found within the same land use category then this was considered a new reach. For example, if a residential reach had both low and severe degrees of buffer removal it was categorized as two discrete reaches. The length of every reach was calculated using the summary statistics function in ArcGIS. The total length of all streams was calculated by using the statistics function in the attributes table.

Table 3.2 Example of GIS Attributes Table								
Stream Reach ID (FID)	**Impact (L)**	**Impact (R)**	**Land Use (L)**	**Land Use (R)**	**Wetland (Y/N)**	**Channel Type (Headwater, Mid, Delta)**	**Comments**	**Length (m)**
1	S	M	Comm	Rec	N	Delta	Old Gravel Mine	25
2	L	M	Res	Util	Y	Mid	Partial Buffer Maintained	89
3	M	S	Trans	Hist	Y	Headwater	New residential	14

The stream ID is generated automatically by ArcGIS. The Impact (L)/Impact (R) columns refer to the degree of riparian zone removal on the left bank or right bank of the stream being examined. The Land Use (L)/Land Use (R) columns contain the land use category attributable to each discrete reach. The left and right banks of stream were coded and analyzed separately because many stream reaches have different land uses and degree and extent of impacts on either side of the stream. The length of the reach (determined by the land use or degree of impact on one side of a stream) is generated using the Calculate Geometry tool. The degree of impact is categorized as Severe(S), Moderate (M), Low (L) or Intact (I). The land use category for each reach is listed using the following abbreviations:

- **Agri** = Agriculture (croplands, industrial or pastoral livestock operations)
- **For** = Forestry Operation
- **Res** = Residential Development
- **HDRes** = High Density Residential
- **Rec** = Recreational Space
- **Comm**= Commercial/ Industrial Development
- **Trans** = Transportation Infrastructure (roads, railroads, airport)
- **Util** = Energy related infrastructure (power lines)
- **Hist** = Historical Use (old deforestation)
- **Mun** = Public Services (cemeteries, schools, hospitals, churches, community centres)
- **Wild** = Undisturbed Forest

When a stream intersects a wetland it is noted as Yes (Y) or No (N). Wetlands are areas delineated by the Service Nova Scotia Municipal Relations lakes layer but which are vegetated (i.e.: not visible water bodies). The channel type (morphology) is listed as a Headwater, Mid (Alluvial) or Delta.

A 20m buffer width (delineated based on the Service Nova Scotia Municipal Relations stream layer, generally from the centre of a stream) was chosen for its compatibility with the *Wildlife Habitat and Watercourses Protection Regulations* which require forestry operations to maintain a 20m buffer on either side of a stream (NS DNR 2002). The motivation for using the same buffer width is that if the government of Nova Scotia chose to create new regulations for land uses other than forestry operations, it is assumed that the same buffer width would be used in order to create a unified policy approach. This would simplify the implementation of buffers from one land use category to the next.

For the purposes of this study a stream was coded for if it appeared in the Service Nova Scotia Municipal Relations GIS stream layer; in many cases the width of streams was unknown and may have been quite small, down to 50cm. This delineation of streams and lakes is appropriate as this research will primarily benefit the provincial government. Lakes narrower than 20m and linear in form were considered streams. This study focuses on streams rather than on all water body types therefore streams flowing through lakes were not included in the analysis. Lakes are defined as such if they were present in the Service Nova Scotia Municipal Relations lakes layer, if they were minimum 20m wide and were visible water bodies. Google Street View and stereoscopic imagery were used to validate reaches that were unclear in the digital aerial photos in GIS. Trees were used as the primary indicator of intact forests.

3.5 Sources of Error & Limitations

The land use shown in the GIS data may not be responsible for the current degree of riparian zone removal if it were caused by a previous land use. For example, the land use may have changed before the air photo was taken and after the riparian area was removed as is often the case with historical forestry operations. Land uses are not always homogenous and the delineated reaches may contain a mixture of land uses. In such cases, I used my discretion to assign a land use category based on 75% land use in a single category. In some cases the resolution (1:10,000) of the digital aerial photos limited my ability to assess the land use adjacent to a stream. This study is also limited in its applicability to other watersheds in Nova Scotia. While the methods are broadly applicable, the results of this study will be watershed specific and cannot be extrapolated to other watersheds because development in the Sackville River watershed may differ significantly from the land uses in other Nova Scotian watersheds.

Land uses and degree of riparian zone removal were only examined within a 20m buffer in accordance with the existing *Wildlife Habitat and Watercourses Protection Regulations* (NS DNR 2002). While a 20m buffer was chosen because it is the current minimum riparian buffer width standard in Nova Scotia, it does not necessarily represent an adequate width to maintain riparian ecosystem functioning or habitat.

In some cases the GIS stream layer did not match the actual boundaries seen in the digital aerial photos. In these cases discrepancies were noted (see Appendix A) .The GIS data would benefit from being validated by GPS readings at various points along the watershed. Another limitation of the study arises from the fact that both the digital and hard copy aerial photos used are somewhat dated (2003 and 2005, pre and post 2004 hurricane Juan respectively) and may not reflect the most current land uses and may add a degree of uncertainty surrounding land cover changes occurring between 2003 and 2005. In addition, seasonal differences between the aerial photos may also make it difficult to identify the degree of impact in riparian zones. The resolution of the aerial photos makes it difficult to assess riparian conditions at scales smaller than 1:1,000; however, the ability to use the zoom function in ArcGIS aids in addressing this issue. The zoom function is not applicable to the hard copy aerial photos and discrepancies in the analysis may have occurred as a result. It is also difficult to detect thinning within riparian zones so reaches that appear to be intact may in fact have been thinned. Likewise it can be difficult to tell if a reach is naturally moderately forested or because of anthropogenic thinning.

The length of each reach may be underestimated because reaches were not always joined precisely and gaps may occur between reaches. When GIS stream layer date did not match the digital aerial photos reach lengths tended to be underestimated. For reasons unknown, in some location the 20m buffer polygon was not symmetrical and buffer width was over estimated on side and underestimated on the other. The author's judgment was used to assign riparian zone removal and land use categories.

3.6 Analysis

Once the extent and degree of impact and land use drivers were mapped in ArcGIS, the extent and degree of riparian area removal and land use associated with riparian area removal were determined.

3.6.1 Extent and Degree of Riparian Area Removal in Sackville Watershed

The total combined length of all streams attributable to each degree category was calculated using ArcGIS Summary Statistics. As there may be different impact classification on either side of the bank in the reach, the reach was classified according to the highest impact category on either bank. Any reaches categorized as wild were removed from each degree category and added into the intact category in order to isolate anthropogenic riparian deforestation to produce the total area of severely impacted riparian zones in the watershed. This figure is also summarized as a percentage per category of the watershed. This process was repeated for each degree category (see Table 4.1). These combined lengths are the basis for the maps included in this study (see Figures 4.1 -4.3).

3.6.2 Land Use Associated with Riparian Area Removal in Sackville Watershed

The total combined length of all streams attributable to each land use category was calculated using Microsoft Excel. The total area of severely deforested land was broken down according to land use and represented in a pie chart as a percentage of the total riparian area removal. The reaches categorized as wild remained in the intact category for this level of analysis. This process was repeated for each degree of removal category (see Figures 4.4 – 4.9). The results of the severe and moderate land use categories were combined to identify the land uses causing 50% or more of the riparian deforestation in the Sackville River watershed (Figure 4.6).

4. Results

4.1 Extent of Riparian Area Removal

My findings show that there has been extensive removal of riparian vegetation in the Sackville watershed. 21% of the total riparian area in the Sackville River watershed has been severely deforested. 12% has been removed in the moderate and low categories and 55% is intact or has naturally low levels of vegetation (see Table 4.1) totaling 82.2%, the average of the impacted length between the right and left banks. Wild reaches (regardless of the degree of riparian vegetation removal) were removed from the results to identify anthropogenic deforestation. For example, many reaches categorized as wild occur in wetlands which have naturally have floating mats of vegetation rather than mature trees which were the basis for assessing riparian integrity. Information on stream reaches without riparian vegetation for natural reasons was collected. For example many wetlands have floating mats of vegetation rather than mature trees. When we combine the severe and moderate categories, approximately one third of the total stream length (~48km) has lost at least 50% riparian forest constituting approximately 1km^2 of riparian area.

Table 4.1. Extent and Degree of Riparian Deforestation in Sackville Watershed

Degree of impact	Length (m)	% of Watershed
Severe	30,393	21
Moderate	17,323	12
Low	17,092	12
Intact/Natural	78,909	55
Total	**143,716**	**100**

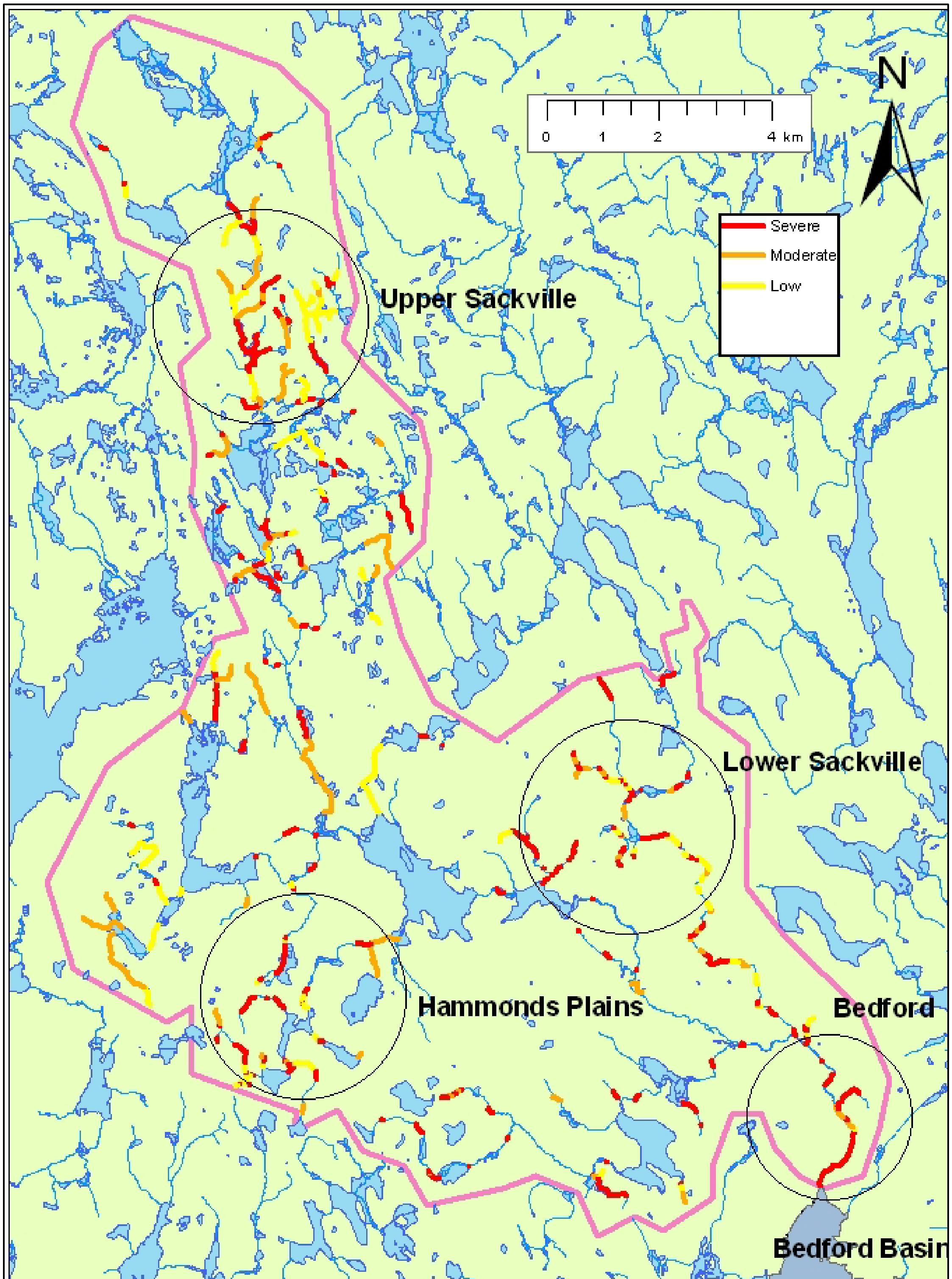

Figure 4.1 Severe, Moderate and Low Riparian Area Removal in the Sackville River Watershed (Left Bank Only). Circles indicate Intensive Buffer Removal Hot Spots

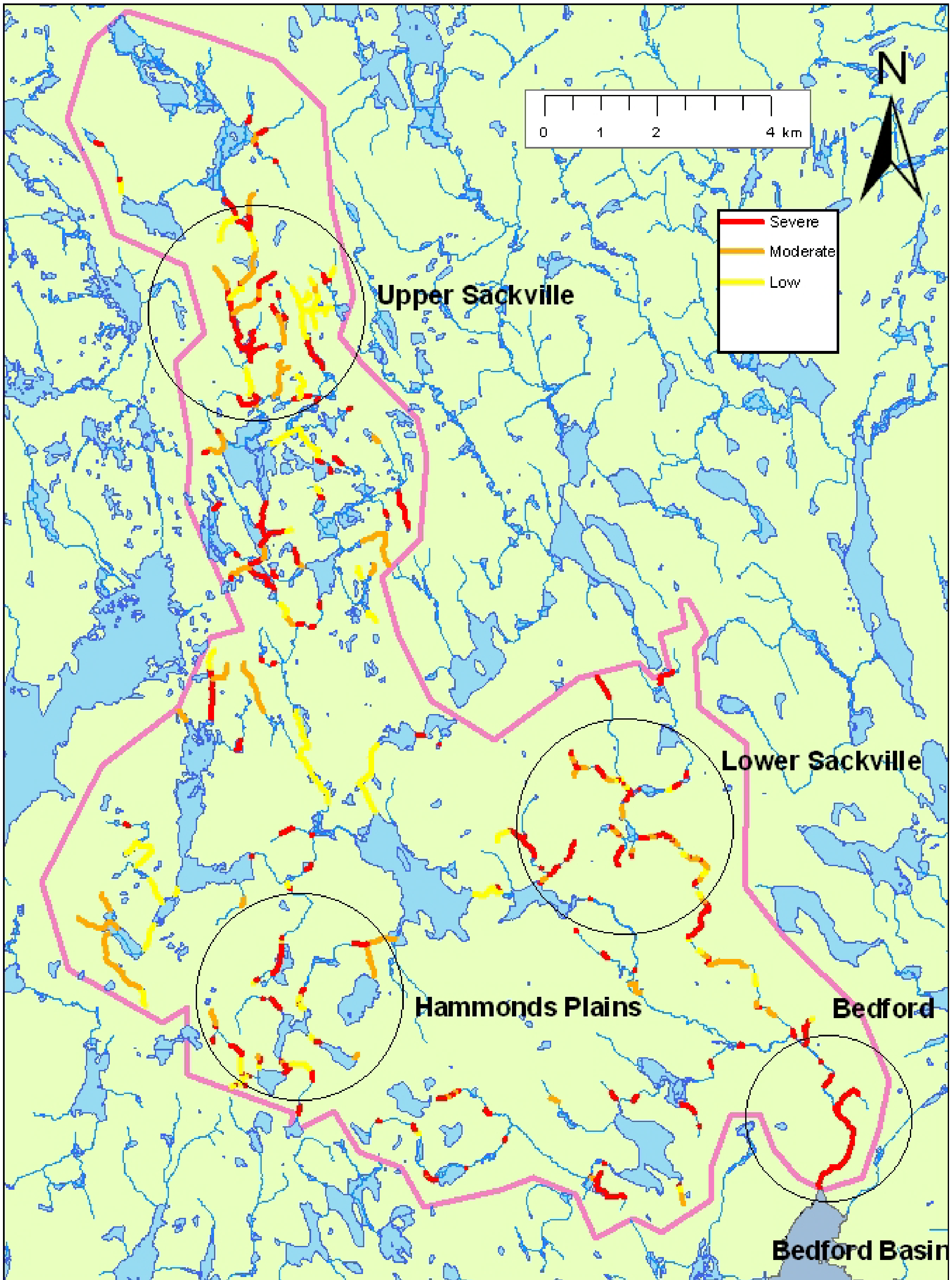

Figure 4.2 Severe, Moderate and Low Riparian Area Removal in the Sackville River Watershed (Right Bank Only). Circles indicate Intensive Buffer Removal Hot Spots

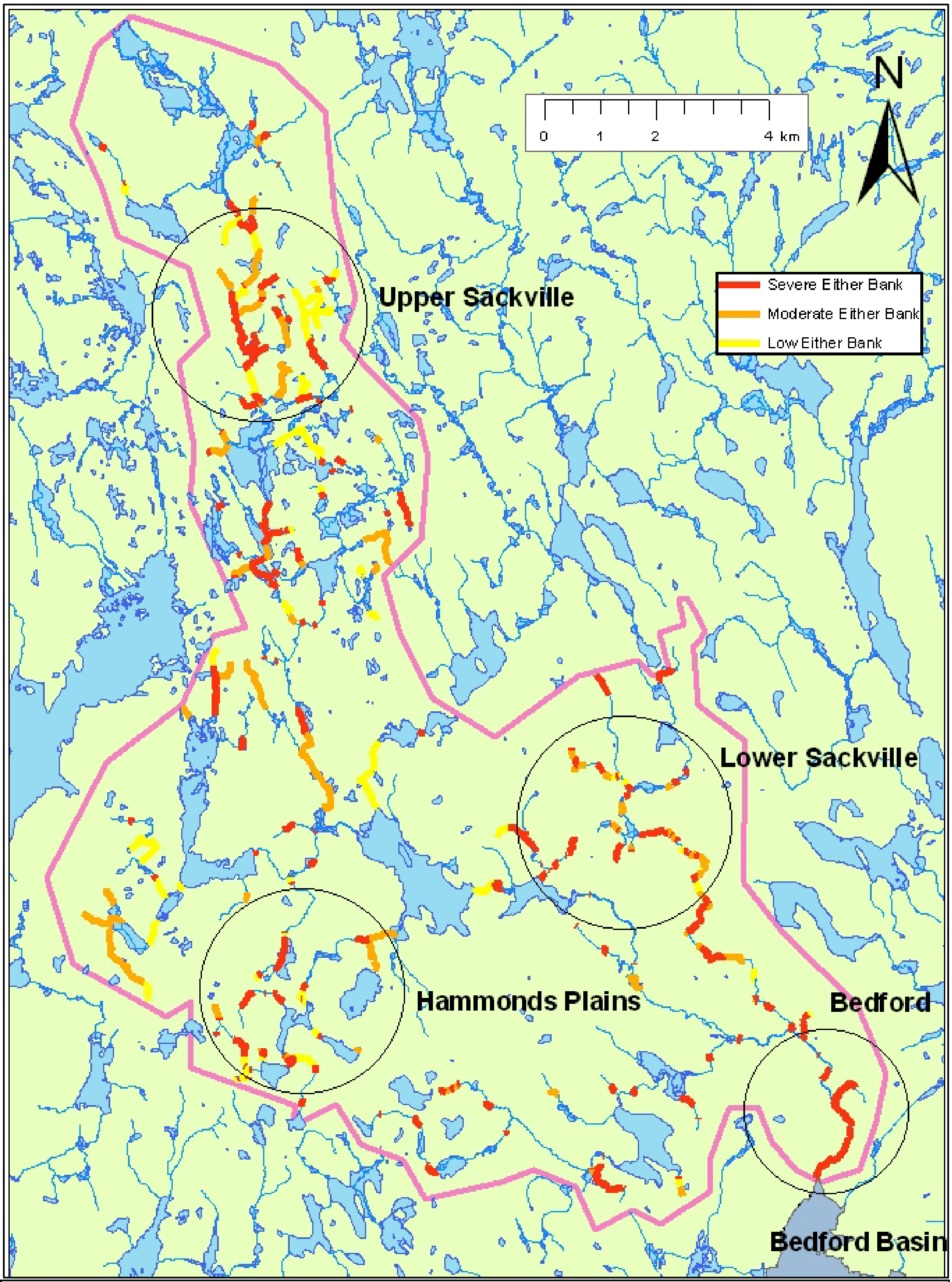

Figure 4.3 Severe, Moderate and Low Riparian Area Removal in the Sackville River Watershed (Left & Right Bank Combined). Circles indicate Intensive Buffer Removal Hot Spots

Figures 4.1 - 4.3 show the extent of severe and moderate riparian area removal for the entire watershed. The most intensive areas of riparian removal were found in along the lower reaches of the Sackville River in Bedford (a densely developed urban community in the HRM) associated primarily with commercial and residential land uses, and in Lower Sackville, Upper Sackville and Hammonds Plains (small but extensively developed suburban communities in the HRM) associated with primarily residential land uses.

4.2 Land Use Drivers

Residential land use is associated with the greatest length of riparian zone removed (to severe or moderate extent) (9.6km), followed by historical (8.9km), transportation (7.7km), utilities (7.1km), and forestry (7.5km) (see Figure 4.6).

Table 4.2 Land Uses Driving Riparian Deforestation in the Sackville River Watershed as a Percentage of Total Watershed

	Degree of Riparian Removal			
Land Use	**Severe**	**Moderate**	**Low**	**Intact**
Residential	19.1%	22.1%	27.2%	10.5%
Transportation	22.9%	4.4%	8.2%	1.4%
Energy infrastructure	20.7%	4.8%	1.2%	0.1%
Historical	8.8%	36.1%	46.4%	13.5%
Forestry	11.7%	22.9%	7.8%	1.8%
Recreation	5.5%	4.0%	3.9%	0%
Commercial/ Industrial	9.3%	5.4%	3.7%	0.3%
Total	**98%**	**99.7%**	**98.4%**	**27.6%**

Here I analyze the impact footprint for land uses that impact more than 1% of the riparian zone length of the Sackville River watershed. Using this metric, agriculture, high density residential and municipal land uses are excluded as they account for only 0.3%, 0.1% and 0.8% respectively of the total length. The wild reaches have also been excluded to isolate anthropogenic riparian deforestation. The exclusion of the three land uses listed above and wild reaches results in totals for each degree of removal category equaling less than 100%.

Residential land use featured prominently in each degree of removal category, particularly when the severe and moderate categories are combined.

I found that energy infrastructure and transportation were driving the most severe riparian removal whereas they are minor drivers in terms of moderate, low and intact riparian removal categories. This is due to the fact that these land uses by nature must completely remove the riparian area when they intersect watercourses as they are linear land use features. Historical land uses featured prominently in the healthier riparian zones (low and moderate).

Similarities in riparian area removal characteristics (land uses show a range of degrees of riparian area removal) can be seen when I compare forestry, commercial/industrial, historical and recreation. Transportation and energy infrastructure land uses are also comparable as they both completely remove vegetation in the riparian area. Similarities between agriculture, high density residential and municipal land uses can be seen based on their relatively minor contribution to riparian deforestation in the Sackville River watershed.

When I combine severe and moderate categories (see Figure 4.6), residential land use is the single largest land use driving riparian vegetation removal at 20.1% of the total buffer length of the Sackville River watershed.

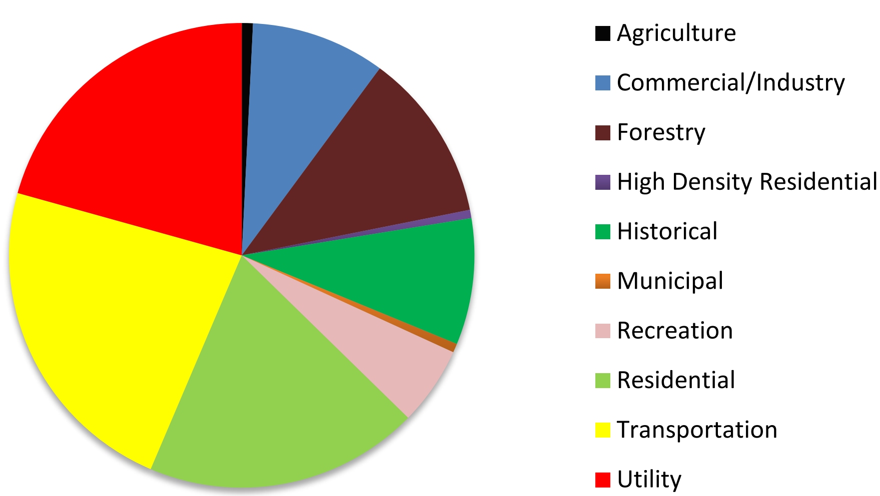

Figure 4.4 Land Use Associated with Severe Riparian Buffer Removal in Sackville Watershed as a Percentage of Total Length of Stream with Buffer Removal

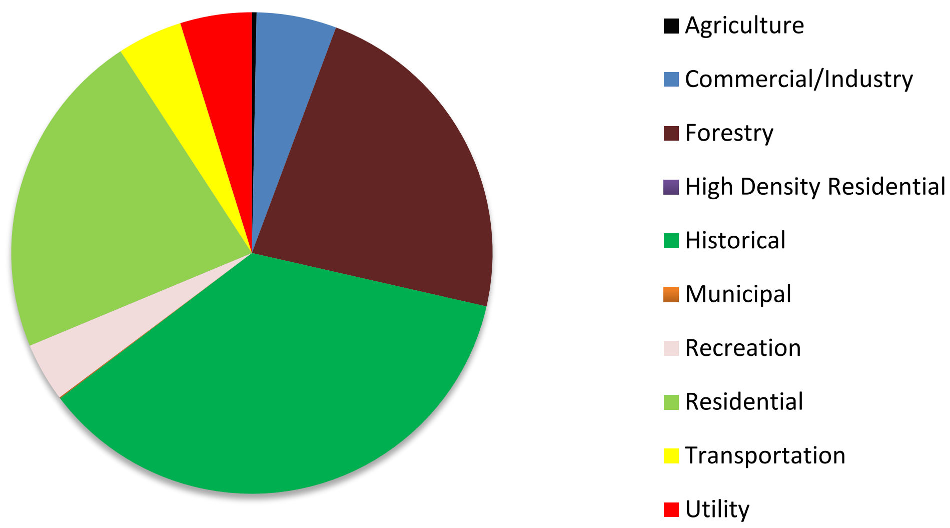

Figure 4.5 Land Use Associated with Moderate Riparian Buffer Removal in the Sackville Watershed as a Percentage of Total Length of Stream with Buffer Removal

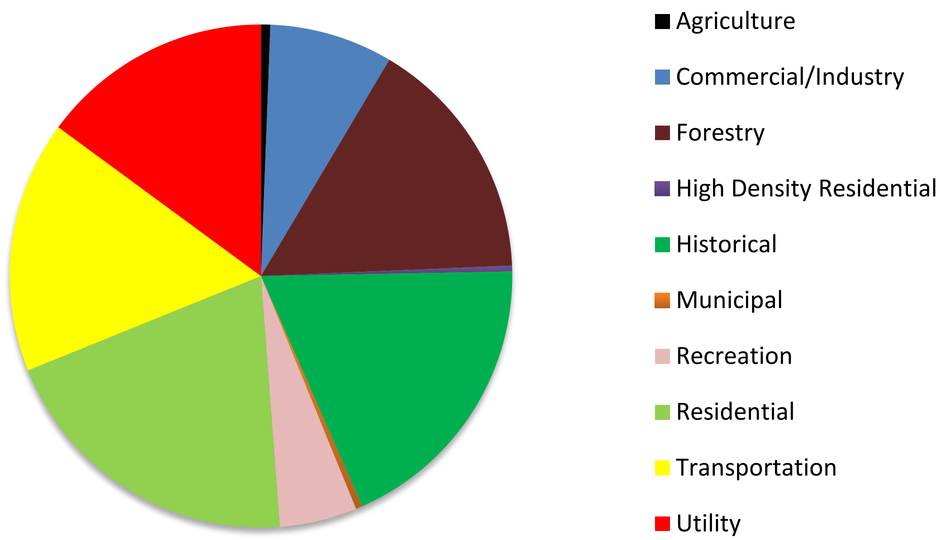

Figure 4.6 Land Use Associated with Severe & Moderate (Combined) Riparian Buffer Removal in the Sackville Watershed as a Percentage of Total Length of Stream with Buffer Removal

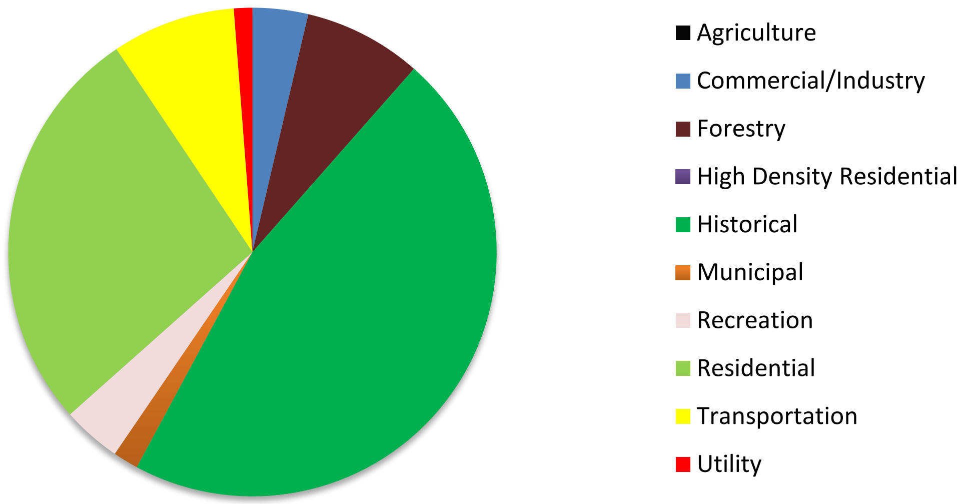

Figure 4.7 Land Use Associated with Low Riparian Buffer Removal in the Sackville River Watershed as a Percentage of Total Length of Stream with Buffer Removal

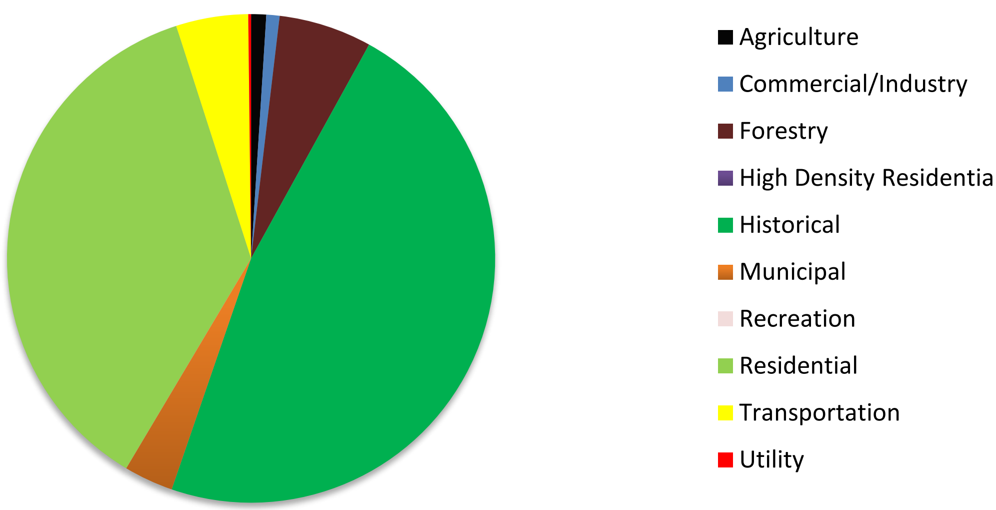

Figure 4.8 Land Use Associated with Intact Riparian Buffers (No Removal) in the Sackville River Watershed as a Percentage of Total Length of Stream with Buffer Removal

5. Discussion

5.1 Extent of Riparian Area Removal

Figure 2.1 demonstrates the relationship between riparian area removal and negative ecological effects such as declining salmon populations. Given that riparian area removal causes negative riparian impacts, combined with the large degree of riparian area removal due to development found in the area, this watershed is facing heightened risks from flooding, and significant future development and would benefit considerably from riparian buffer management regulations.

As previously mentioned, the most drastic areas of riparian area removal were found along the lower reaches of the Sackville River in Bedford and in Lower Sackville, Upper Sackville and Hammonds Plains. The highly developed urban/suburban nature of these areas is likely contributing to this drastic riparian area removal. The effects of development and riparian vegetation removal in these areas may have watershed-wide impacts including increased sedimentation, loss of habitat (which puts additional pressure on other intact riparian habitats in the watershed) and decreased water quality. These areas are in need of immediate protection and rehabilitation.

The most intact reaches were found in the region between McCabe Lake and Tomahawk Lake in the central western region of the watershed North West of the Bedford Basin. These areas contain primarily historical and wild land uses. These areas are in need of long term protection and rehabilitation.

Moderate and low degree categories were found throughout the watershed. These areas are in need of midterm protection and rehabilitation.

5.2 Land Use Drivers

Figure 2.1 showed the relationship between land use and impact on riparian systems. Impact to riparian areas is a function of the extent of the riparian area removal, severity of initial disturbance, time since initial disturbance and whether or not forest cover has been permitted to recover or if it is continually removed. Impacts on the riparian area increases linearly with the area of riparian removal increase; a reduction in riparian area will result in negative ecological impacts. Likewise the severity of the initial disturbance is linearly related to the impacts upon the riparian area. A modifying factor (is the riparian area permitted to recover?) is added depending on the regenerative capacity of the riparian area. This modifier is useful in determining impact from land uses in which regrowth is not permitted (for example energy infrastructure and transportation land uses) and for land uses in which it is permitted to grow back such as residential or forestry operations.

Table 5.1. Riparian Area Removal Parameters by Land Use Category

	Land Use Category										
Parameters	**Res**	**Util**	**Trans**	**Agri**	**Rec**	**For**	**HD Res**	**Comm**	**Mun**	**Hist**	**Wild**
Are Property Setbacks Possible?	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A
Is Recovery Possible After Initial Disturbance?	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A
Is a Lower Initial Impact Possible?	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A
Are There Regulations?	No	No	No	No	No	Yes	No	No	No	No	No
Government Jurisdiction	Mun	Prov	Prov	Mun /Prov	Mun	Prov	Mun	Mun/ Prov	Mun	N/A	N/A

* Mun = Municipal Government
Prov = Provincial Government
Fed = Federal Government

If riparian buffer regulations were implemented, they would only be relevant to selected land use categories. Energy infrastructure and transportation land uses necessarily remove the entire riparian area where they intersect streams. Alternately, regulations would only apply to wild/natural land cover only once they had been slated for development. Regulations would be relevant to agriculture, residential, high density residential, recreation, municipal and commercial land uses. Regulation for forestry operations already exists (NS DNR 2002).

As shown in Table 5.1, different land use categories display a range of riparian area removal parameters and flexibility around the maintenance of riparian area. For all land use categories mitigatory measures are possible when initially developing the land. For example, roads (or any type of development) can be designed to avoid streams rather than moving streams to accommodate roads. Roads can be built at right angles to streams in order to minimize the extent of riparian area removal, and riparian zones can be maintained (whole or in part). Once the initial riparian area removal has taken place, the area can be permitted to regenerate. The majority of the land use categories permit regeneration after the initial disturbance with the exception of energy infrastructure and transportation. The current practice used when creating energy infrastructure corridors is to completely remove all vegetation within the 60m wide strip. Conceivably, a small riparian zone could be retained along all streams that traverse these corridors when they are initially cleared.

5.3 Policy Implications

As the principle driver of pooled severe and moderate deforestation, residential development clearly requires legislation. Forestry is the only land use category tested for that is regulated (requires a 20m buffer be maintained) and the Service Nova Scotia & Municipal Relations (2003 & 2005) aerial photos have shown this regulation to be effective.

Hypothetically speaking, if 20m riparian buffer regulations had been continually in place for all land uses in Nova Scotia, then approximately 69% of the riparian area in the watershed would have been retained (when I combine severe and moderate riparian area removal categories). My research shows that even with the most stringent buffer zone setback regulations possible, 31% would not be protected because the removal is associated with linear land uses (transportation and utilities), which cannot have setbacks from the stream. This is a significant amount, and identifies the need for planning and regulations to mitigate and to changes in location and orientation of these linear land uses so that impact on riparian areas is reduced.

Considering that energy infrastructure and transportation land uses necessarily remove the entire riparian zone at the stream/land use intersection which regulations may not be able to address, it is inevitable that some impact to riparian areas will occur. If the government of Nova Scotia chooses to implement riparian buffer regulations for all land uses excluding energy infrastructure and transportation, then mitigatory and/or restorative measures that may be included in an effective watershed approach to riparian buffer management include: retaining a standardized minimum buffer width in provincial legislation and in municipal land use bylaws, minimizing riparian area removal through selective harvesting (thinning), replanting deforested riparian areas following the initial riparian zone removal during development and incenting watercourse-adjacent land owners to retain or replant zones. Incentives could include a tax exemption for land owners proportional to the amount of riparian area that is maintained.

One issue in terms of policy implications stems from the fact that minimum buffer zone regulations have been examined primarily at the provincial level but the dominant land use category driving riparian zone removal (residential development) is regulated at the municipal level. The provincial government may not be able to act effectively on this issue because it is unable to intervene in matters relating to the modification to Land Use Bylaws which fall under municipal jurisdiction. A best case scenario would involve the provincial government producing policy recommendations and funding for reforestation efforts for the HRM. Opportunities exist to address energy infrastructure and transportation driven riparian zone removal. This study may also be of interest to the Halifax Regional Municipality.

The scope of this paper and the debate in the literature are such that I have been unable to state whether a 20 m wide riparian buffer zone is adequately wide to sustain ecological functioning of riparian areas. Policy makers should create minimum riparian buffer regulations in accordance with the literature and with which riparian functions they aim to protect.

There is an urgent need for regulation for residential, transportation and energy infrastructure land which contribute the most to severe buffer removal in the Sackville River watershed. Since so much riparian area has been impacted, an opportunity exists to restore salmon habitat in this severely damaged salmon run through reforestation efforts, particularly in the lower reaches of the Sackville River in Bedford, in Lower Sackville, Upper Sackville and Hammonds Plains. Future research could be undertaken to assess the condition of the channel morphology or instances of decreased water quality in this watershed. These parameters could then be correlated with the data presented here to provide a picture of the effects on riparian area removal and riparian ecosystem functions (for example, water quality or bank stability). Correlative research could provide a stronger argument for the creation of standardized riparian buffer management regulations for all land uses excluding transportation and energy infrastructure.

6. Conclusion

This study found that riparian zones in the Sackville River watershed have been impacted to a large extent over the years; fully one third of the total riparian area length has had approximately 50% or greater of its vegetation removed. The land use driving the most severe deforestation are energy infrastructure, transportation and residential development, and the land uses driving the most moderate deforestation are forestry operations, unknown historical uses and residential development. Overall (when I combine severe and moderate effects from land uses) I show that residential development is the single most important driver of riparian deforestation.

My analysis has shown that a correlation exists between land uses (and therefore land use regulations) and the degree and extent of riparian area removal in this watershed. A review of the literature showed that there is a marked absence of legislation in Nova Scotia ensuring that buffer zones are maintained with the exception of forestry operations. Without legislation ensuring the protection of buffer zones for new development, riparian buffer removal and its associated threats to ecosystems will continue apace. I have shown that further research is urgently needed to identify best practices for riparian buffer protection legislation and opportunities to create new policies around maintaining buffer zones during new development.

This study shows conclusively that riparian zones in the Sackville River watershed have been significantly deforested. The Sackville watershed contains one of few remaining salmon runs in NS, though it has been severely depleted in the past two decades. It is likely that the degree of riparian area removal found in this study will impact terrestrial and aquatic habitat and biodiversity, putting already stressed salmonid populations and water quality at further risk. Because of the large impacts noted in this pilot study, there is a great need for a concerted effort to assess the state of riparian in watersheds across Nova Scotia. These results support the need for more research of best practices and policies regarding the protection of riparian zones from new development as well as the replanting of damaged riparian zones caused by past/existing development.

A tangible outcome of this research is a map of impacted riparian "hot spots" which may inform protective policies under the Nova Scotia water strategy or other legislation. I also present summaries of riparian impact by degree of riparian zone removal and by land use. This model could be replicated for all watersheds in Nova Scotia to create a better understanding of the land uses driving riparian zone removal in other watersheds with different land use composition. By identifying the most impacted riparian zones, government or community watershed groups can act to protect and/or rehabilitate them in order to preserve the health of the watershed as a whole.

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9. Appendices

Appendix A

Table A.1. Data Errors from Digital Aerial Photos (2005 – Post Hurricane Juan)	
FID	**Data Error**
79	Streams layer does not match aerial stream
70	Streams layer does not match aerial stream
307	Streams layer does not match aerial stream by a significant margin
94	Streams layer does not match aerial stream by a significant margin – underestimates length
104	Streams layer does not match aerial stream
105	Streams layer does not match aerial stream - underestimates length
106	Streams layer does not match aerial stream
108	Streams layer does not match aerial stream
155	Streams layer does not match aerial stream
161	Unusual delineation of stream layer (wetland?)
164	Unusual delineation of stream layer (wetland?)
197	Streams layer does not match aerial stream - underestimates length
554	Wetland from aerials missing from GIS, through an energy infrastructure corridor
555	Wetland from aerials missing from GIS, through an energy infrastructure corridor

Appendix B

Table A.2 Gantt Chart Timeline for Study								
Objectives & Tasks	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Assess which rivers have the highest degree of riparian zone removal								
Assemble the required aerial photographs and GIS base maps								
Classify riparian zones according to degree of impact								
Create a map of impacted areas								
Assess which land uses are primarily driving riparian zone removal								
Assign likely cause of riparian loss based upon adjacent land use category								
Identify land use categories responsible for the most riparian zone removal in watershed								
Create riparian buffer management recommendations that address these drivers								
Explore the effects of riparian zone removal on Sackville watershed								
Maintain a record of inaccuracies in existing data								