LARGE NATURAL AREAS: A LITERATURE REVIEW
MUSKOKA WATERSHED COUNCIL

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RiverStone
ENVIRONMENTAL SOLUTIONS INC.

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Judi Brouse
via e-mail to jbrouse@muskokaheritage.org

SUBJECT: Large Natural Areas Review

Dear Ms. Brouse:

RiverStone Environmental Solutions Inc. is pleased to provide you with the attached report.

Please contact us if there are any questions regarding the report, or if further information is required.

Best regards,

RiverStone Environmental Solutions Inc.

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INTRODUCTION

The need to conserve natural areas is well recognized throughout the world. The reason(s) to conserve a natural area were historically relatively straightforward; areas that were easily recognized as having features that humans could benefit from were protected. Current interest in the size of natural areas, as a measure of relative isolation from human activity, still has a reasonably long history in nature conservation science (Kapos et al. 2000). De Candolle (1874) as cited in Orians [1993]) noted that the link between human-induced division of large natural areas and the extinction of species has been recognized for more than 120 years. As summarized by Kapos et al. (2000), the importance of size in natural areas has been promoted most strongly by island biogeography theory (MacArthur and Wilson 1963) and the species-area relationships of Preston (1962). These concepts hold that larger areas typically support a greater diversity of habitats and contain more species and larger populations of individual species than smaller areas. Similarly, reviews by Peterson et al. (1998) and Elmqvist et al. (2003) determined that larger natural areas are more resilient to change, that is they have greater capacity to accommodate change or absorb disturbance. Based on the principles of landscape ecology, the core of a large natural area will be less exposed to human activity than the core of a small natural area; therefore, the exposure of a natural area to human activity is largely related to its size (Kapos et al. 2000). In addition to the aforementioned reasons to maintain large natural areas, recent scientific publications have emphasized the need to maintain a full suite of ecosystems, ecological processes, and biodiversity within these areas (Soule et al. 2004, Mackey et al. 2008). Because ecological processes, as well as structural and functional connectivity, may work over large distances (Soule et al. 2004), larger areas that encompass these processes are likely required. Finally, larger natural areas are also likely to be more robust in a number of ways to a changing climate.

The intent of this report is as follows:

1. Describe the current state of the science with respect to the benefits, and value of Large Natural Areas.

2. Evaluate these concepts in the context of the Muskoka River watershed.

3. Provide preliminary recommendations on how Muskoka could work to protect large natural areas (how much, benchmarks, methodologies, etc.)

1 BENEFITS OF LARGE NATURAL AREAS

1.1 Protection of Biodiversity

One of the most recognized approaches to conserving biodiversity focuses on the establishment and preservation of large natural areas (Timonen et al. 2011). Biodiversity refers to the variety of species and ecosystems in a given area and includes the ecological processes of which these organisms are a part. The three most commonly accepted components of biodiversity are ecosystem, species, and genetic diversity.

Benefits of biodiversity in a general sense are numerous. It is an essential part of healthy ecosystems, human health, prosperity, security, and wellbeing. Diversity of natural landscapes and species is also a source of emotional, artistic, and spiritual inspiration and cultural identity in Canada (Government of Canada 2003). Many Canadians recognize that biodiversity is the foundation for Canada's natural resource sectors and the key to continued growth in other sectors such as ecotourism and recreation (Government of Canada 2003). Many ecologically important regions of the world have hundreds of vertebrate species and tens of thousands of insect and plant species (Holloway et al. 2004), as such, a species-by-species approach to the conservation of biodiversity is nearly impossible (OMNR 2010).

1.1.1 Landcover

By virtue of their size alone, large natural areas are more likely to contain more types of landcover than smaller areas. There is evidence in the scientific literature that the amount and diversity of natural land cover in an area usually has the largest effect on biodiversity. Natural land cover functions as habitat for species, and it is known that habitat loss is the single most important factor contributing to the global biodiversity crisis (Pimm et al. 1995, Fahrig 1999). Furthermore, there is a positive relationship between species richness and area for nearly every taxon. Considerable evidence has been collected that shows that the amount of habitat in an area has a much greater effect on biodiversity than the configuration of this habitat (Andren 1994, Fahrig 2001, Fahrig 2003).

Ecosystems are composed of a diverse array of components (i.e., they are inherently heterogeneous). Heterogeneous land cover may arise from disturbances (e.g., fire, high winds) (Lindenmayer et al. 2006), or in many cases environmental gradients reflect the natural condition of a landscape. For example, in forested systems, landscape heterogeneity corresponds to a mosaic of patches that differ in species composition and age class (Lindenmayer et al. 2006). Species have evolved to exploit different environmental conditions within a landscape; therefore, the diversity, size, and spatial arrangement of habitat patches strongly influences species richness and abundance in an area (Hanski 1994, Saab 1999, Debinski et al. 2001, Lindenmayer et al. 2006).

Structural complexity is an inherent feature of all natural forests throughout the world (Berg et al. 1994). The structural complexity of forest stands can be attributed to several factors, including species composition and the way in which species are spatially arranged within and between stands (Lindenmayer et al. 2006). Additional factors influencing structural complexity within a forest include trees from multiple age cohorts, large living trees and snags, large diameter logs on the forest floor, vertical heterogeneity created by multiple or continuous canopy layers, and horizontal heterogeneity (e.g. canopy gaps) (Lindenmayer et al. 2006). As recognized by Lindenmayer et al. (2008), maintaining structural complexity within a forest stand is important for biodiversity conservation for several reasons: (1) it may allow organisms to persist in areas from which they would otherwise be eliminated; (2) it may promote the return of logged and regenerated stands to suitable habitat for species that have been displaced; (3) the dispersal of some animals in a cutover area may be enhanced because of increased habitat connectivity; and (4),within-stand habitat heterogeneity in the form of structure complexity may be a key element required by a species.

1.1.2 Habitat Loss and Fragmentation

Large natural areas preserve considerable amounts of contiguous habitat for multiple species and therefore aid in the preservation of biodiversity. Recent studies have provided a better understanding of how species react when natural areas are lost in the landscape. The loss of natural areas is often viewed in terms of habitat loss (**Figure 1**); the largest factor contributing to species declines and extinctions (Fahrig 1999). Recent increases in habitat loss can be traced primarily to the growth of the human population leading to expansion of human activities into formerly natural areas (Sisk et al. 1994). The effects of losing habitat is often obvious, with individual species that rely on the habitat within the landscape becoming displaced, resulting in a population decline or loss (Bender et al. 1998). Habitat loss usually occurs in small increments (Fahrig 2003); which is more problematic because losses often occur continuously, thereby making it difficult to stop. In the case of many wildlife populations, large portions of contiguous habitat must be preserved to avoid drastic population declines or massive species loss (Rompre et al. 2010).

There is strong evidence that habitat loss has large, consistently negative effects on biodiversity. Therefore, conservation of all species in a given region requires identifying which species in that region are most vulnerable to habitat loss (Fahrig 2001, Fahrig 2003, Fischer and Lindenmayer 2007).

Trzcinski et al. (1999) determined that for forest birds the amount of forest cover is positively correlated to the number of species present, more so than the effects of habitat fragmentation in agricultural regions; the conclusion of the study was that the “primary focus should be on preventing a decrease in forest cover. ” With respect to aquatic systems and their associated features, large natural areas that facilitate the function of these ecosystems are critically important, particularly because in addition to the aquatic species that these features support, a large proportion of the biodiversity found in terrestrial landscapes are associated in some respect with aquatic ecosystems (Mac Nally et al. 2000). Loss of biodiversity is predominantly driven by habitat loss (Fahrig 2003); therefore, preservation of large natural areas should prevent habitat loss and maintain biodiversity.

1.1.3 Connectivity

Large natural areas help to ensure connectivity between habitats and thereby help to preserve biodiversity. Connectivity is best thought of as the opposite of fragmentation: it is the linkage of habitats, ecological communities, and ecological processes at multiple spatial and temporal scales. Key biodiversity processes such as population persistence and recovery after disturbance are strongly influenced by connectivity in a landscape (Lamberson et al. 1994). Additional processes, such as the exchange of individuals and genes within a population (Saccheri et al. 1998), and the occupancy of habitat patches (Villard and Taylor 1994) are affected by the levels of connectivity present in a system.

Two of the key land uses that disrupt connectivity in natural systems are roads and urbanization. The number of studies that demonstrate adverse effects of roads on wildlife is considerable. For example, adverse effects of roads have been demonstrated for amphibians (Fahrig et al. 1995, Eigenbrod et al. 2008), turtles (Steen et al. 2006), badgers (Clarke et al. 1998), small mammals (Oxley et al. 1974), bobcats and coyotes (Riley et al. 2006), deer (Kuehn et al. 2007) and grizzly bears (Mace et al. 1996). Although terrestrial taxa are most affected, roads can also disrupt connectivity of aquatic habitats for fish, i.e., when culverts are not appropriately sized or placed, and birds that are killed by motor vehicles. The negative effects of urbanization on biodiversity are also well documented (Trzcinski et al. 1999, Gagne and Fahrig 2007). For example, the urbanized areas within Canada were more than double in 1996 as compared to 1971 (Canadian Biodiveristy Information Network 2004).

1.2 <u>Ecosystem Stability</u>

Large natural areas support higher levels of biodiversity than smaller areas. The insurance hypothesis suggests that ecosystems with higher biodiversity are more stable (Tilman 1999, Yachi and Loreau

1999, Leary and Petchey 2009). This increased stability is based on the idea that if an event resulting in a negative impact were to occur, not all species within an ecosystem would be affected in the same way. In an ecosystem with high species richness, a change in the population level of an individual species is not as likely to result in overall negative impacts on the entire ecosystem (Yachi and Loreau 1999, Caldeira et al. 2005, Leary and Petchey 2009). This is because high species diversity increases the likelihood that another species already found within the ecosystem is capable of filling the function of the declining species (Tilman 1999). In this way, an ecosystem can be said to exhibit resistance and resilience. The insurance hypothesis brings together two key ideas: Ecosystem Resistance and Ecosystem Resilience.

1.2.1 Ecosystem Resilience and Resistance

Ecosystem resistance, as defined by Vinebrooke et al. (2003), "...[is] to the capacity of an ecosystem to withstand having its ecological processes displaced by a perturbation." Resistance differs from resilience, in that ecosystem resistance is the ability of a given ecosystem to withstand negative impacts, while ecosystem resilience is the ability of the ecosystem to recover from negative impacts. The loss of species from an ecosystem has been found to reduce ecosystem resistance (Vinebrooke et al. 2003). Some studies have suggested that there is a positive relationship between high species diversity (and therefore high biodiversity) and ecosystem resistance (Yachi and Loreau 1999).

Similar to ecosystem resistance is the concept of ecosystem resilience. Resilience in this context can be defined as the amount of disturbance a system can absorb and remain stable (Holling 1973). Essentially, it can be thought of as the amount of disturbance an ecosystem can absorb before the services rendered by that system (e.g., nutrient cycling, wildlife habitat) are compromised. It has been demonstrated that increased species richness (the number of different species) within a given area increases the stability and resiliency of ecosystem functions (Peterson et al. 1998). Therefore, ecosystem resilience is influenced by biodiversity and in the majority of cases, resilience is increased by higher biodiversity levels (Peterson et al. 1998, Elmqvist et al. 2003). When species are lost from an ecosystem, or are substantially reduced in number, the impacts are often not immediately apparent; however, a number of studies have demonstrated that ecological resilience to disturbance is subsequently impaired.

The ability of an ecosystem to resist negative impacts and quickly recovery from impacts is directly linked to its biodiversity (Tilman 1999, Caldeira et al. 2005, Leary and Petchey 2009). Higher biodiversity helps to insure an ecosystem against the influence of human impacts as well as increase the ability of the ecosystem to recover after such an event. No single action can guarantee that ecosystems will exhibit high resistance or resilience; however, maintaining large natural areas that promote biodiversity is consistent with the Insurance Hypothesis and represents an excellent approach.

1.3 Preservation of Water Quality

Large natural areas aid in the maintenance of water quality. Reductions in the amount of natural landcover adjacent to water bodies has been linked to reductions in water quality (Patric 1973, Huntington 2006).Traditionally, intact vegetated areas have been suggested as methods for minimizing the impacts of adjacent land uses on water quality. These vegetated buffers are typically recommended to be between 15 and 30m wide (Ontario Ministry of Natural Resources 2010). After conducting an extensive literature review, Desbonnet et al. (1994) concluded that vegetated buffers of 30m remove 70% of sediment and pollutants from runoff before it enters the adjacent water body (**Table 1**). In fact, to remove 99% of sediment and pollutants would require a vegetated buffer to be 600m in width (Desbonnet et al. 1994). As such, watercourses that are greater than 600m from human development are likely not significantly impacted by point source pollution. The preservation of large natural areas is likely to provide for the conservation of areas that are greater than 600m from human development and therefore provide protection of water quality in that area.

2 INFLUENCE OF CLIMATE CHANGE

Climate change represents one of the major perceived long-term disturbances within natural ecosystems. There is now considerable evidence that changes in climate are occurring at higher rates than background levels. As previously mentioned, large natural areas have a greater capacity to resist change and are more resilient to negative impacts of disturbances. Therefore, large natural areas are more likely to be able to maintain ecosystem services and functionality in the face of climate change.

These high rates of change in climate present a challenge to those tasked with preserving biodiversity because managers must plan for a myriad of potential outcomes, now they must do so more quickly while at the same time planning for substantial uncertainty. For example, predicting future forest condition is difficult even in systems suspected of being stable. Thompson et al. (1998) predicted that the forest landscape will undergo significant homogenization under global warming. Pyrophilic (fire-loving) species such as jack pine and aspen will increase substantially throughout the boreal forest, reducing forest complexity and structure because of large patch size and reduced species composition. In areas where fires have been suppressed, and white and red pine removed by selective logging, aspen forest will dominate over tolerant hardwoods, simplifying forest systems over much of central Ontario. Furthermore, climate change in Ontario is likely to result in larger mean patch size, less old growth forest, reduced diversity over much of Ontario (greater homogeneity), and lower mean shape (defined as area/perimeter) (Thompson et al. (1998). Temperature change alone will result in new forest landscapes. Plant species adapted to warmer climates are expected to move north with disturbances and the transition zone between boreal and Great Lakes forest types will shift north. Generalist species will succeed over species with more narrow ecological tolerances. For example, poplar and balsam poplar species that thrive in disturbed areas and reproduce by suckering after fire will become more widespread, especially in central Ontario.

Animals are much more capable of adapting rapidly to changes in habitat and climate. Most animals with a body size greater than 500 g are capable of moving many kilometers in a short period. As climate changes and vegetation ultimately responds, animal distributions across landscapes also change. Concerns have been expressed that altered forest landscapes, reduced diversity, decreased amount of old forest, and reduction in tree species distributions will have significant consequences for animals that operate at the ecosystem level and above (i.e., moose and white-tailed deer) (Thompson et al. 1998, Thompson et al. 2009). Both deer and moose require a mixture of young forest for food and older forest, particularly dense mature conifers for shelter from deep snow. Deer carry a parasite *Paralaphostrongylus tenuis* that is fatal in moose. Currently, the overlapping zone between the two species is limited and they tend to separate spatially in common areas, but under increased temperatures, there may be substantial overlap between the two species in central Ontario. Despite the inherent ability of animals to respond to changes in climate more ably than plants, the habitat must be present for them to move to when conditions change sufficiently to render an area unsuitable. Therefore, it is vital that management plans include guidelines for protection of enough large natural areas so that species are capable of withstanding changes associated with climate modifications.

3 HUMAN VALUATION OF LARGE NATURAL AREAS

Humans are dependent on the natural environment to supply everything from oxygen for respiration to food and health. The supplies of these elements essential to human existence are dependent on the biological cycles and processes within the local ecosystems. Although we rely upon the direct extraction of ecosystem elements for our daily needs (e.g. food, water, etc.), the true value of ecosystems lies in the services that they provide.

Indirectly, ecosystems provide humanity with numerous “free” essential services, such as clean air and water, the hydrological cycle, and buffering effects to reduce the impacts of extreme flood and drought. Vegetative cover plays an important for the maintenance of water and humidity levels. These environmental variables are crucial for the maintenance of the oxygen/carbon dioxide balance in the atmosphere. Loss of natural landcover has been shown to have effects on erosion and water quality (Patric 1973, Huntington 2006), loss of habitats for fish (Wang et al. 2001, Foley et al. 2005) and wildlife (Foley et al. 2005), as well as many other environmental disruptions. Forests help to maintain rainfall by recycling water vapour into the atmosphere from the forest canopy (Huntington 2006).

Natural ecosystems help to absorb the wastes we create and render them nontoxic. Wetlands act as large filters, purifying freshwater, removing heavy metals and other contaminants (Munger et al. 1995). We often depend on rivers to flush away and break down the sewage and effluents that we put into them, which requires a diverse array of organisms that actively decompose and transform wastes in water (Barber et al. 1995). Soil organisms act to decompose food items and other waste produced by human activities (Smith 2009).

The role of biodiversity in natural systems is intrinsically complex and environmental degradation can affect many other components of the ecosystem. The preservation of large natural areas contributes to biodiversity and therefore, the associated beneficial ecosystem services.

Although ecological services are essential to life on earth, there are additional philosophical and social arguments for the value of natural areas. Natural areas are said to have intrinsic value because they currently exist and have existed for a long time (Alho 2008). Humans have also applied economic, aesthetic and recreational value to natural areas.

3.1 Intrinsic Value

Intrinsic value is a philosophic concept in which an object in and of its self has value (Alho 2008). The intrinsic value of nature then is the idea that nature and natural areas have value because they are and not simply because of what they can provide for us has humans. In his book “Conserving Life on Earth” (1972), David Ehrenfeld states that "The non-humanistic value of communities and species is the simplest of all to state: they should be conserved because they exist and because this existence is itself but the present expression of a continuing historical process of immense antiquity and majesty. Long standing existence in Nature is deemed to carry with it the unimpeachable right to continued existence." If the above statement is correct, then the right to a continued existence for life forms and natural processes is based in morality and the valuation of natural areas is an ethical disposition. To be consistent with the concept of intrinsic value, if we identify that protecting natural areas is morally good then the continuation of human activities and disturbances that result in the destruction of biodiversity loss cannot be considered ethical on a broad scale.

3.2 Aesthetic Value

Aesthetic value is commonly assigned to natural areas by humans seeking contact with nature. Over the past century, humans have become disengaged from the natural environment (Maller et al. 2009). The foundation of the aesthetic value of natural areas is that they are visually appealing and provide opportunities to escape increasingly polluted, densely populated, human-dominated landscapes. Natural areas have high aesthetic value as they provide numerous opportunities for wilderness recreation and solitude (Ehrlich and Ehrlich 1992). In fact, the highly lucrative Ecotourism industry has emerged to provide opportunities for solitude, health and recreation by allowing individuals to embrace the aesthetic value of natural areas (Maller et al. 2009).

3.3 Economic Value

There are different views on the valuation of the natural environment from an economic perspective. Market prices can be applied to goods provided by the natural environment, such as aggregate or timber; however, it is difficult to assign market values to the services natural areas provide to humans (Costanza et al. 1987). Services provided by the natural environment represent a significant portion of the total economic value of the planet. Efforts by Costanza et al. (1987) to quantify the economic value of ecosystem services at a global scale, estimated that humans receive an average of $33 trillion per year of ‘free’ services from the ecosystems in which they reside.

If the role of natural areas in economic and social wellbeing can be grasped, economic and social values will in turn reinforce biodiversity conservation (Maller et al. 2009). Within the Muskoka River Watershed, increases in the popularity of nature-based tourism and the use of parks and large natural can have significant impacts on the local economy.

3.4 Quality of Life

Public health and social welfare experience significant benefit from the preservation of existing natural areas. Proximity to natural areas has been shown to have positive effects on psychological well-being (Kaplan 2001). The amount of green space within a radius of 1 km of a residence is positively related to perceived general health (De Vries et al. 2003, Maas et al. 2006). The introduction of outdoor recreational opportunities to maintain active living and enhance public health increases the attractiveness of a community. The presence of natural areas help boost the local economy as individuals are increasingly seeking rural communities for retirement or a second home (Poudyal et al. 2009). Studies linking the relationship between natural areas and human health provide a compelling argument for the conservation of those spaces. Use of natural areas can be a component of preventive treatment and, at the same time, a means for increasing civic environmentalism (Poudyal et al. 2009). Maas et al. (2006) indicated that few general health practitioners advise their patients about the benefits of performing their physical activities in natural environments instead of urban or artificial settings. Poudyal et al. (2009) suggested that encouraging individuals to interact with, or exercise in, natural areas could result in significant economic savings on health expenses within the public and private sectors.

4 APPLICATION TO THE MUSKOKA RIVER WATERSHED

The Muskoka River watershed is situated on the Canadian Shield in central Ontario and contains over 500,000 hectares of forest, wetland, settlement, and agricultural areas (Tran 2007). A total of 36 different landcover types were determined to occur within the watershed (Tran 2007). At the time the Muskoka River Watershed Inventory Project (MRWIP) was completed, approximately 68% of the watershed was covered by forest and other natural vegetation types (Tran 2007). The MRWIP was a "… landscape level analysis of terrestrial ecological systems (ecosystems)…" (Tran 2007), and is the most comprehensive evaluation of land cover in the watershed to date. Although the MRWIP analyses did not directly address questions regarding large natural areas, the data and analytical results of that project have been considered for their potential to assess these questions. One of the characteristics that makes Muskoka different from portions of Ontario to the south is that it contains a large proportion of natural landcover; in a different way it also diverges from areas of Ontario to the north because it has higher levels of biodiversity (i.e., latitudinal diversity gradients), particularly the southwestern portion of the watershed. Because of these differences, it makes good sense to commission projects such as the MRWIP so that land use strategies and decisions can be tailored specifically to the Muskoka region. Similarly, the large natural areas evaluation being presented here takes into account the uniqueness of the Muskoka River watershed.

The previous sections describe the documented benefits and values associated with large natural areas; specifically, (1) protection of biodiversity, (2) ecosystem stability, (3) preservation of water quality, and (4) human values (intrinsic, aesthetic, and economic). Based on the information presented, it is evident that large natural areas should be an important component of any Natural Heritage Strategy or system, particularly in light of the potential for cumulative negative impacts, including climate change.

Assuming then that maintaining or creating large natural areas is deemed important within the Muskoka River watershed, the following questions need to be addressed:

- How should the boundaries of a large natural area be determined?
- How large does an area need to be to qualify as a large natural area?
- Where are the large natural areas within the watershed?
- What percentage of the landscape should large natural areas cover to maintain acceptable levels of biodiversity, stability, resilience, water quality, and human values?

5 APPROACH

Based on our understanding of (1) the ecological and land use data available for the Muskoka River watershed (e.g., MRWIP datasets, orthophotography, more recent datasets), (2) methodologies used to measure biodiversity and model landscapes, and (3) land uses most detrimental to water quality and biodiversity, we contend that the best approach would be to use the road network to address the primary question: "What determines the boundaries and spatial scale of large natural areas in Muskoka?"

Using Muskoka's road network to delineate and define natural areas is logical for several reasons. First, roads are typically reflective of development patterns (i.e., more roads usually equals more development); thus, it is an effective measure to gauge the extent of human encroachment into an area. Second, the development of roads is inherently related to a variety of negative impacts on otherwise natural conditions. Third, because it has been amply demonstrated that roads have numerous adverse effects on a multitude of species (Fahrig et al. 1995, Forman 1998, 2000, Clevenger et al. 2001, Gibbs and Shriver 2005, Fahrig and Rytwinski 2009), it is logical that roads will form part of the boundaries of what would be considered large natural areas in the majority of cases. Large natural areas without roads have been shown to be important for maintaining population distributions and for facilitating adequate levels of space use by many species (MacArthur and Wilson 1963, Bender et al. 1998, Fahrig 2001, Fahrig 2003, Brodeur et al. 2008, Obbard et al. 2010). Additionally, areas farther from roads and human development are known to have higher water quality, provide high quality wildlife habitat, and support diverse ecological communities (Desbonnet et al. 1994). Relative to other digital datasets, the road "layers" available are regularly updated and the 2008 orthophotography available for the District of Muskoka would allow for identification of any inaccuracies. **Figure 2** shows the road network used for the MRWIP analyses.

5.1 Identify Boundaries of Natural Areas

The first step in developing a plan to preserve large natural areas in Muskoka is the identification of the boundaries of "natural areas". Based on our review of the literature there is no ready-made approach that is applicable for the Muskoka Watershed. Many of the models that have been developed for other areas are both field intensive studies and are very specific to the areas in which the work has been undertaken. For this reason, we have not suggested the use of these models in Muskoka. Instead, we have developed the framework for a method that makes use of currently available data for Muskoka as well as accepted concepts that support the identification of boundaries of areas that could be considered Natural Areas.

Based on this rationale, RiverStone would recommend the following approach to the identification of Natural Area boundaries.

- Use roads as a surrogate measure of human impacts in the watershed (**Figure 3**[*]).
- To delineate and define the Natural Areas, decide on what distances from a road should be excluded; for example, within distance X of high volume road X, negative impacts on mobile animals are high; therefore, the extent of the Natural Area is reduced considerably because of its proximity to a road with high traffic volume (see **Table 1**, **Figure 3**, and **Figure 4*** as conceptual examples). The distance-from-road values can be based on the level of impact determined to acceptable in a Natural Area in Muskoka.

5.2 Determine What is "Large" for Muskoka

At this stage, we will have identified the areas in the watershed that are not impacted or that are minimally impacted by humans. These areas can then be classified according to size; this will establish a baseline for how many areas there are in each size category. Thus, the next step in the process would be as follows:

- Use the range of sizes of the Natural Areas within the watershed to define what is "Large" (**Figure 5**[*]).

5.3 Identify Locations of Large Natural Areas in Muskoka

Once the size and abundance of the natural areas have been established and a benchmark has been determined with respect to "what is large", a detailed examination of the locations and spatial arrangement of the large natural areas is required. The analysis of the data in a GIS environment, could allow for the consideration of landcover types, proximity to surface water features, distributions of species of conservation interest, distance to urban centres, potential for connectivity, etc. Using this approach the next steps in the process would be as follows:

- Develop criteria for determining ranks for the existing large natural areas in terms of their value for conservation as well as identify areas that should be the target of mitigation and/or rehabilitation efforts.

5.4 Management and Prioritization of Large Natural Areas in Muskoka

The first three steps of our recommended approach involve the identification of all the Natural Areas (as described in Section 5.1), and the determination of what a large natural area (or range of areas) is in Muskoka. The final step is to determine the extent and percent coverage required or desired to maintain biodiversity, as well as the other positive ecosystem services or values identified in this review, in the Muskoka watershed. To complete this step RiverStone recommends the following approach:

- Set targets for large natural areas based on we currently have in the watershed (as identified in the previous steps).
- Additionally, the analysis outlined in Sections 5.1–5.3 could be repeated on the Muskoka road network from 10, 20, 30, etc. years ago. This would allow us to evaluate any changes in the extent of large natural areas in the Muskoka River watershed over time. Targets could then be adjusted according to conservation goals.

Regardless of how the benchmarks and targets are established, the final step would involve:

- Prioritizing the protection of the large natural areas based on the best species representation, diversity of land cover types or ecological communities.

[*]Note: Figures 3, 4, and 5 are intended to provide rough examples of the product of such an analysis and are in no way intended to represent final analytical results.

6 SUMMARY

The scientific literature clearly outlines the ecological value of large natural areas. Large natural areas maintain biodiversity by allowing for contiguous areas of habitat that species rely on. In turn, these biologically diverse areas result in stable and resilient ecosystems that can absorb both human and natural stressors. Large natural areas can have intrinsic and aesthetic value, and contribute to public health and social welfare. These same areas provide the features and functions necessary to support humanity's daily needs, while contributing numerous free services that humans rely on for their very existence such as clean air and water. The prescriptions provided within the scientific literature for identifying the boundaries and spatial scale of what constitutes "Large" in a natural areas context are highly site- and situation-specific. Consequently, RiverStone is proposing a cost-effective, Muskoka-specific approach to identify the boundaries and spatial scale of large natural areas by making use of readily available data, and methodologies and concepts that are well supported within the scientific literature.

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Table 1. Summary of pollutant removal effectiveness and wildlife habitat value of vegetated buffers according to width (adapted from Desbonnet et al. 1994).

Buffer Width (m)	Pollutant Removal Effectiveness	Wildlife Habitat Value
5	Approximately 50% or greater sediment and pollution removal	Poor habitat value, useful for temporary activities of wildlife
10	Approximately 60% of greater sediment and pollution removal	Minimally protects stream habitat; poor habitat value, useful for temporary activities of wildlife
15	Greater than 60% sediment and pollutant removal	Minimal general wildlife and avian habitat value
30	Approximately 70% of greater sediment and pollution removal	Minimal wildlife habitat value; some value as avian habitat
40	Approximately 70% of greater sediment and pollution removal	May have use as a wildlife travel corridor as well as general avian habitat
50	Approximately 75% of greater sediment and pollution removal	Minimal general wildlife habitat value
75	Approximately 80% of greater sediment and pollution removal	Fair-to good general wildlife and avian habitat value
100	Approximately 80% of greater sediment and pollution removal	Good general wildlife habitat value; may protect significant wildlife habitat
200	Approximately 90% of greater sediment and pollution removal	Excellent general wildlife value; likely to support a diverse community
600	Approximately 99% of greater sediment and pollution removal	Excellent general wildlife value; supports a diverse community; protection of significant species

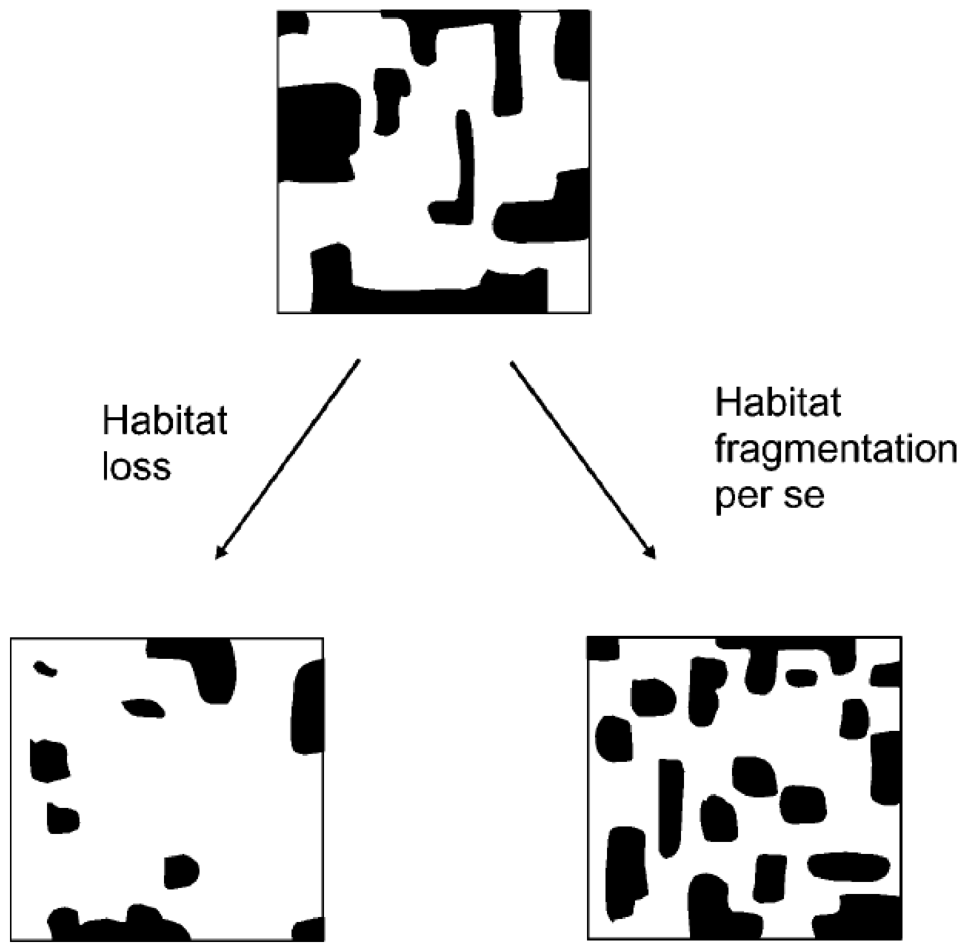

Figure 1. Visual representation of the difference between habitat loss and habitat fragmentation (adapted from Fahrig 2003).

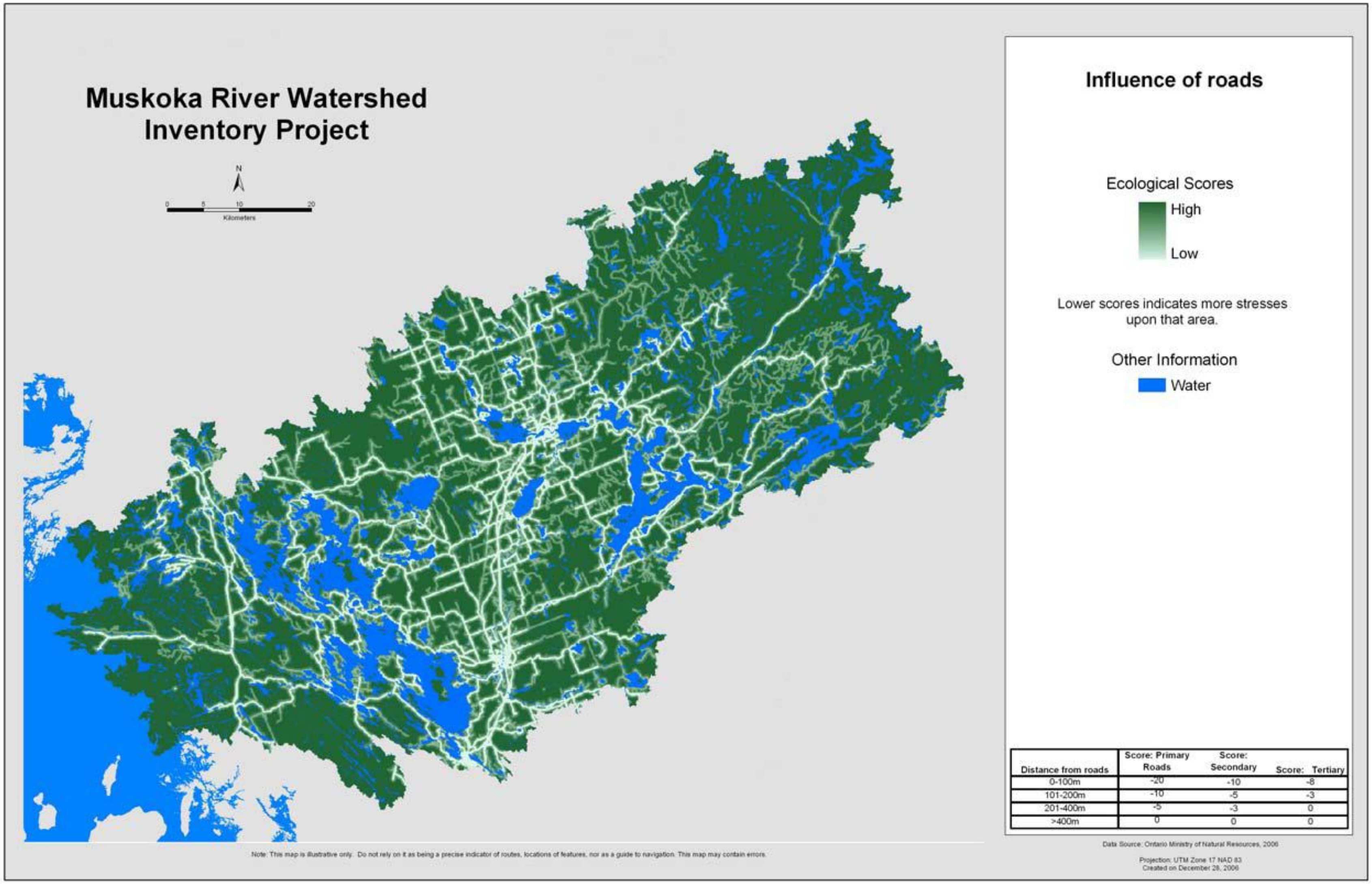

Figure 2. Locations of roads within the Muskoka River watershed (from Tran 2007).

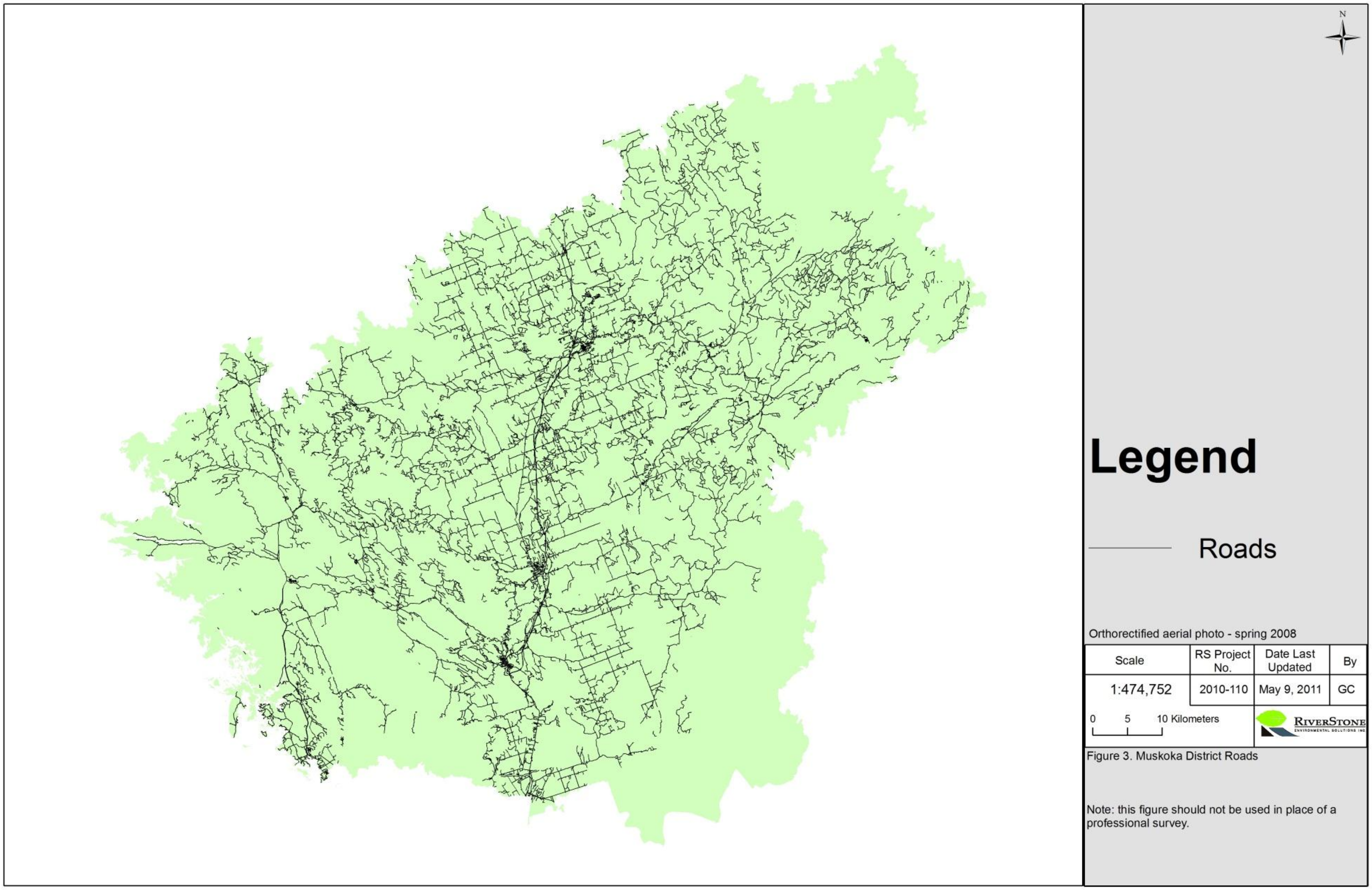

Figure 3. Muskoka District road network.

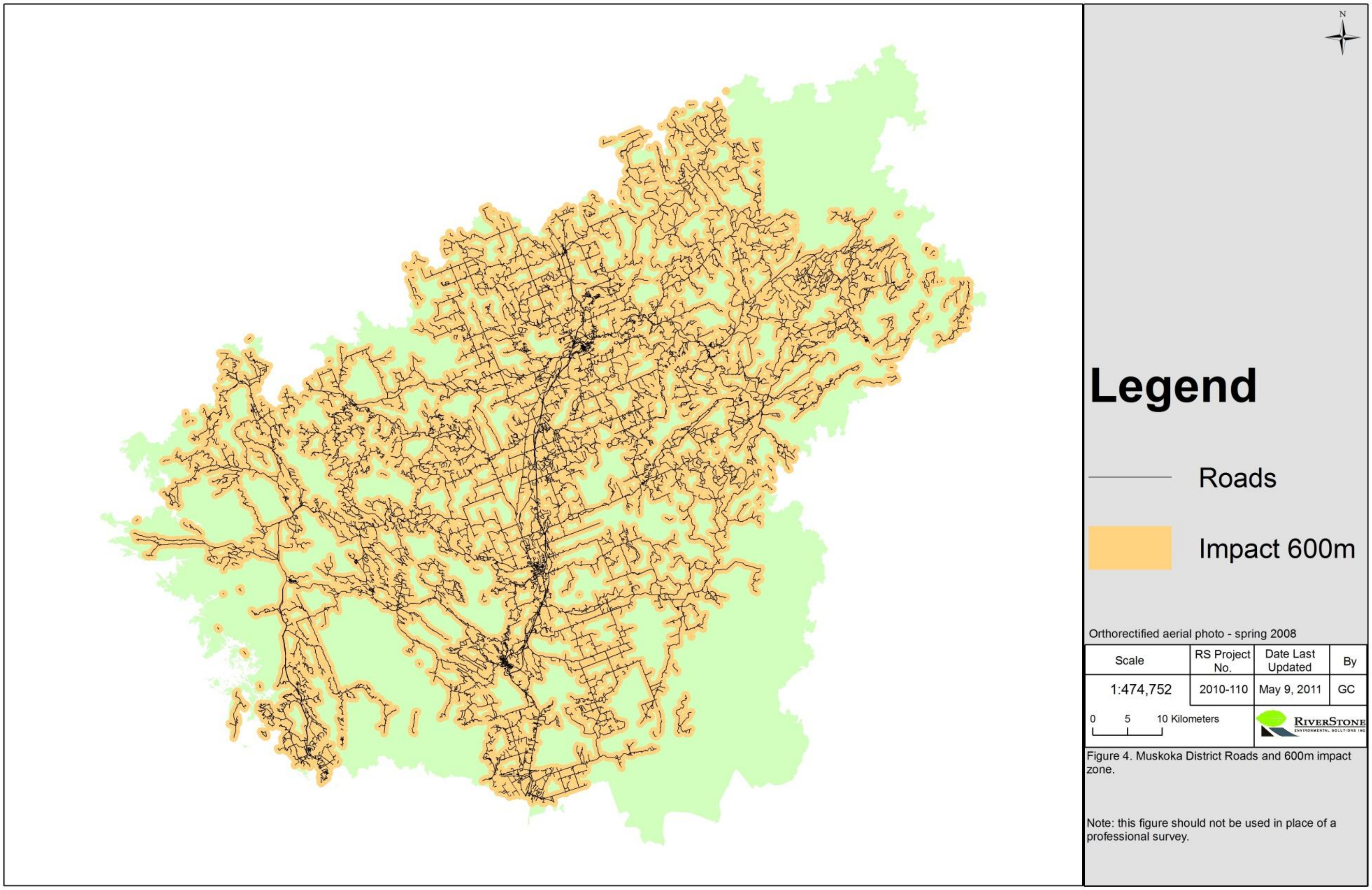

Figure 4. Muskoka District area of human impact (600 m around roads).

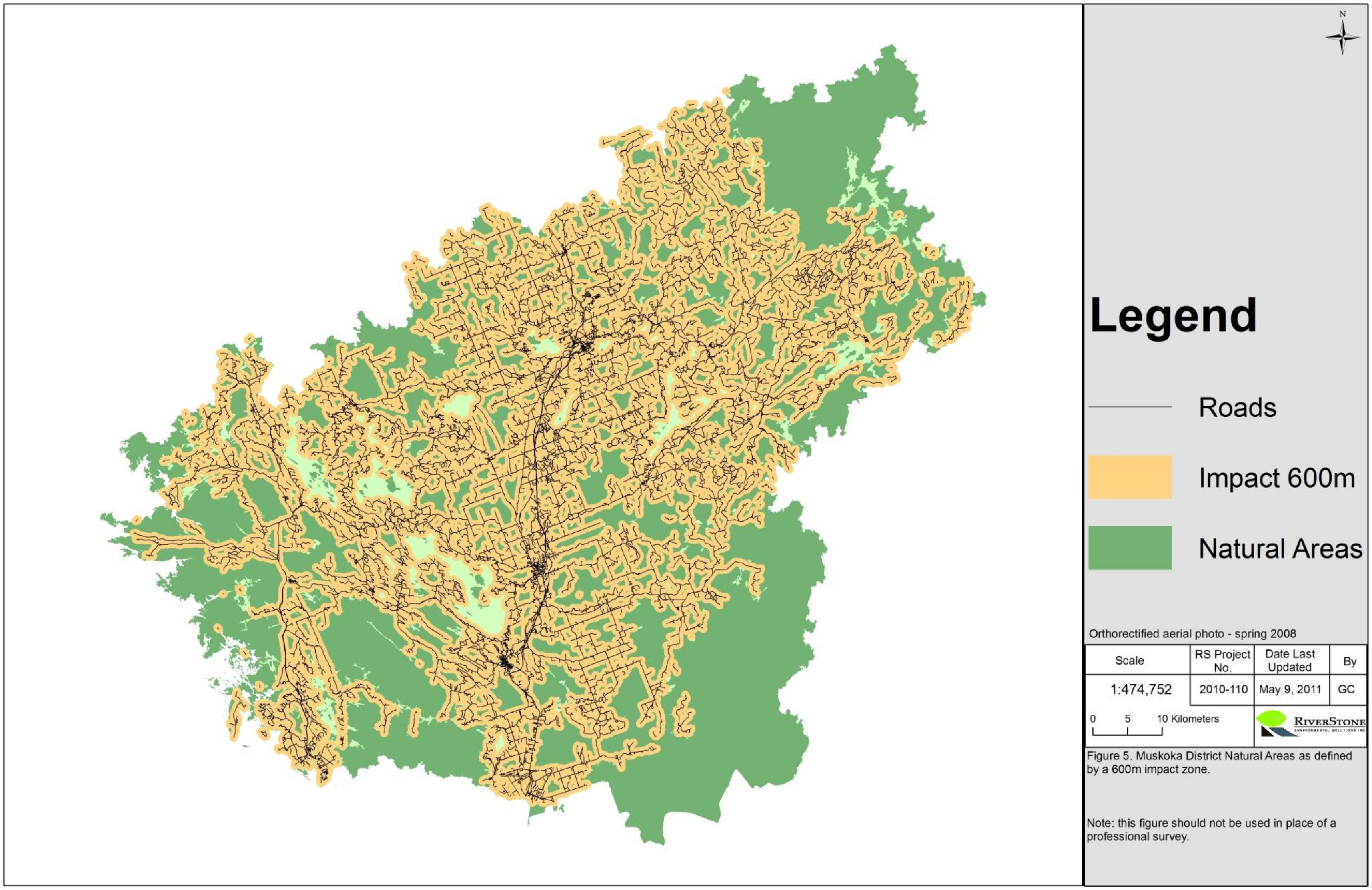

Figure 5. Muskoka District Natural Areas as defined by a 600 m area of human impact.