INTEGRATING SPATIAL MODELING AND FIELD FEASIBILITY ASSESSMENTS TO PRIORITIZE ECOPASSAGE SITES FOR TURTLES AT RISK ACROSS THE LAND BETWEEN, ONTARIO

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ABSTRACT

Freshwater turtles are among the vertebrate groups most vulnerable to road mortality, and effective mitigation requires integrating spatial analysis with field-based feasibility assessment. This study applied GIS-based wetland adjacency modeling and on-the-ground verification across The Land Between region of Ontario to identify and prioritize road–wetland intersections for potential ecopassage development. A total of 1,439 potential sites were mapped using remote sensing on primary roads, including county roads and secondary provincial highways alone, and 119 were subsequently evaluated in the field for ecological priority and engineering feasibility. Approximately 14% of assessed sites were classified as high priority, 9% as structurally feasible, and only 2.5% as both high-priority and feasible. Spatial patterns revealed that Haliburton and Hastings Counties contained the greatest densities of candidate crossings. Results emphasize the importance of integrating remote sensing, mortality evidence, and engineering constraints to guide strategic investments in turtle road mitigation and conservation connectivity across mixed rural–shield landscapes.

Ecopassage Prioritization and Feasibility Across The Land Between

1. Introduction

Road networks represent one of the most pervasive threats to freshwater turtle populations worldwide. Because turtles exhibit slow movement, delayed maturity, and strong site fidelity, roads fragment habitat, disrupt seasonal migration routes, and cause direct mortality that can exceed natural recruitment (Aresco 2005; Steen et al. 2006; Gibbs & Shriver 2002). Among vertebrates, turtles experience some of the highest road-related mortality rates; even a few adult deaths per year can drive long-term population decline (Beaudry et al. 2008; Patrick & Schwartz 2004). In Ontario, where most native turtle species are listed as Species at Risk, road mortality has been identified as the single largest ongoing threat to population persistence (Ontario Ministry of Natural Resources and Forestry [OMNRF] 2018; Crowley & Brooks 2005).

Road-ecology research has therefore emphasized the need to identify mortality 'hotspots' and to implement mitigation structures, such as exclusion fencing, under-road culverts, and ecopassages, that restore connectivity between wetlands and reduce collision risk (Clevenger & Huijser 2011; Baxter-Gilbert et al. 2015). However, the effectiveness of these interventions depends heavily on accurate spatial targeting and engineering feasibility.

To address this gap, The Land Between and its Turtle Guardians program undertook a region-wide initiative to map and assess potential ecopassage locations on arterial roads across the ecoregion in southcentral Ontario. The purpose of this project was to highlight those sites with the greatest ecological need and structural feasibility, providing a scientifically defensible basis for prioritizing investment in mitigation, retrofitting, and long-term monitoring. By combining GIS-based spatial modeling with field validation and feasibility scoring, this initiative establishes a framework for focusing road-ecology action where it will yield the greatest conservation benefit for turtle populations at risk.

2. Methods Summary

Wetlands located on both sides of road segments across The Land Between were identified using GIS and remote-sensing datasets. This analysis included hydrological layers, digital elevation models, and verified Species at Risk (SAR) occurrences from the Turtle Guardians monitoring network and provincial databases. These were intersected with the road network to identify potential wetland-to-wetland crossing points where ecological connectivity is most likely to be impeded by road infrastructure. The resulting layer represented 1,439 potential ecopassage locations. From this regional inventory, 119 sites were visited between 2018 and 2022 for on-the-ground assessment of ecological priority and engineering feasibility.

2.1. Methods for Feasibility and Priority Assessment

Feasibility assessments were conducted through both desktop analysis and field reconnaissance to determine the structural practicality of implementing ecopassage mitigation at each site. Field teams recorded parameters related to the physical context of the road corridor, hydrology, and adjacent infrastructure. A key indicator of feasibility was the openness ratio, defined as the product of structure height and width divided by its length, which reflects the degree to which wildlife can perceive light and move freely through a passage. Sites with higher openness ratios or existing culvert infrastructure conducive to retrofitting were rated as more feasible.

Additional feasibility factors included potential obstacles to establishing continuous exclusion fencing or other passage systems. Obstacles commonly observed included driveways, multiple lane divisions, rock cuts, utility corridors, and islands that would prevent effective enclosure. These features were documented to identify where engineering modifications would be necessary to close a system. Hydrological connectivity, gradient stability, and proximity to watercourses were also considered in determining practical feasibility.

Priority ratings were assigned based on ecological significance and evidence of turtle activity or mortality. In most counties, priority was derived remotely using known occurrences of Threatened or Endangered turtle species from provincial datasets, supplemented by historical road-mortality data. In Parry Sound County, however, direct field observations of dead-on-road turtles, shell fragments, and nesting evidence were incorporated. Reconnaissance-level verification included identifying shell fragments, depressed nest sites, or other physical indicators of turtle presence along shoulders and embankments. Sites with multiple confirmed records of SAR species or physical evidence of mortality were classified as high priority.

This dual-tiered approach, combining remotely derived data layers with field-based validation, ensured that both regional habitat modeling and on-the-ground evidence informed final prioritization. The integration of ecological value with engineering practicality provides a replicable model for targeting mitigation investment in other mixed-ecoregion contexts where infrastructure intersects critical turtle habitat.

3. Results

3.1 GIS-Identified Potential Sites

The GIS-based analysis identified 1,439 potential road–wetland crossing locations across The Land Between. These represent areas where turtle movement is most likely to intersect with transportation corridors. They collectively form a regional framework for prioritizing mitigation planning and infrastructure retrofits.

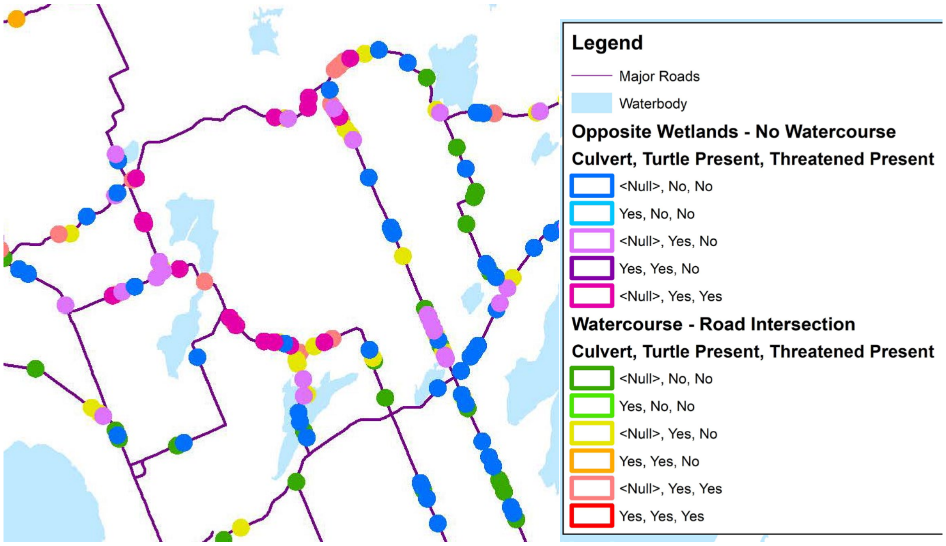

FIGURE 1: POTENTIAL ECOPASSAGE LOCATIONS

FIGURE 2: REFINED-REMOTE ASSESSMENT OF POTENTIAL ECOPASSAGE SITES

3.2 Field-Assessed Sites

A total of 119 potential sites were visited between 2018 and 2020. Each was evaluated for ecological priority (based on species presence, mortality risk, and habitat connectivity) and engineering feasibility (based on hydrology, structural condition, and access constraints). The results of these assessments are summarized below.

Metric	Result
Total field-assessed sites	119
High-priority sites	14.3 %
Medium-priority sites	0.0 %
Feasible sites (engineeringly practical)	9.2 %
High-priority + feasible	2.5 %
High + medium + feasible	2.5 %

TABLE 1: RESULTS OF ECOPASSAGE POTENTIAL FROM FIELD ASSESSMENTS

3.3 Spatial Distribution and Site Density

The 119 field-assessed sites were distributed across multiple counties within The Land Between, including Haliburton, Hastings, Parry Sound, Peterborough, Kawartha Lakes, and Frontenac. The proportional distribution of assessments varied by accessibility and wetland-road density, with an average of approximately 11 sites per county and 3 to 4 sites per township. Haliburton County accounted for approximately one-fifth of all assessed sites, reflecting its extensive network of secondary roads intersecting beaver-influenced wetlands. Hastings County represented roughly 15% of assessments, while Parry Sound and Kawartha Lakes together comprised around 25%, due to their combination of high turtle species richness and existing road-mortality records. Northern counties such as Parry Sound and Frontenac generally contained fewer feasible sites overall due to the rugged topography and prevalence of narrow or elevated road corridors that limit potential for cost-effective mitigation. These findings underscore the importance of localized prioritization, directing resources where wetland density, turtle movement, and engineering feasibility most strongly converge.

3.4 County-Level Distribution of Assessed Sites

Spatially, site densities corresponded with regions where road infrastructure coincides with large wetland complexes, particularly in central and eastern Haliburton, northern Hastings, and southern Parry Sound. Areas with lower densities tended to include shield terrain, deep rock cuts, or limited road access. These distributional trends reinforce that ecopassage planning must consider both biological need and physical opportunity across the heterogeneous landscapes of The Land Between.

4. Interpretation

Across the 119 assessed sites, approximately 14% were classified as high ecological priority, but only 9% were considered structurally feasible for mitigation. Overall, only 2.5% of all sites met both criteria, representing the most strategic opportunities for ecopassage or culvert retrofitting to reduce turtle road mortality and restore wetland connectivity. These findings confirm that while many potential road–wetland intersections exist regionally, practical mitigation opportunities are limited. Strategic focus on these high-priority, high-feasibility sites is essential to maximize conservation outcomes and infrastructure efficiency.

5. Discussion

Over the past seven years, Turtle Guardians staff have conducted standardized road patrols and mortality monitoring across The Land Between region, surveying hundreds of kilometres of municipal, county, and provincial roads each field season. These patrols, carried out under consistent protocols by trained staff, have generated one of the most comprehensive and continuous turtle road-mortality and occurrence datasets in Ontario. The dataset captures long-term patterns across multiple counties.

Integration of these long-term patrol data with the spatial-feasibility modeling presented here strengthens the conclusion that road mortality is both spatially predictable and persistent. Many of the GIS-identified hotspots align closely with sites repeatedly documented by Turtle Guardians staff, confirming that predictive modeling and field evidence converge on the same critical areas. Although feasible mitigation opportunities comprise only a small proportion of all potential crossings (approximately 2.5%), this alignment highlights the reliability of combining spatial modeling with empirical mortality data to guide mitigation investment.

Concentrations of mortality at unmitigated priority sites, particularly those adjoining large wetland basins and beaver-influenced corridors, illustrate the magnitude of the remaining risk across The Land Between. These findings echo broader road-ecology research demonstrating that even low levels of adult mortality can precipitate long-term population decline (*Beaudry et al.*, 2008; *Gibbs & Shriver*, 2002; *Steen et al.*, 2006).

The current phase of Turtle Guardians research is using this seven-year dataset to examine changes in turtle population indices. By comparing demographic composition and biomass in areas over time, this analysis will help determine whether sustained mortality correlates with reductions in population density and recruitment. The outcome of this work is expected to reinforce the urgent need for targeted, durable, and strategically placed mitigation structures, ensuring that investments are directed where they will yield the greatest conservation benefit.

By integrating spatial modeling, feasibility assessment, and multi-year empirical monitoring, this project provides a defensible and replicable framework for prioritizing road-mitigation across mixed rural–shield landscapes. Together, these results confirm both the persistence of threat and the need for well-maintained mitigation.

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