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## **STRATEGIES FOR RESTORING ECOLOGICAL CONNECTIVITY AND ESTABLISHING WILDLIFE PASSAGE FOR THE UPGRADE OF ROUTE 78 IN SWANTON, VERMONT: AN OVERVIEW**

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**Abstract:** Vermont Route 78 travels through one of the largest and most significant wetland complexes in the State of Vermont. This fact is exemplified by the presence of the Missisquoi National Wildlife Refuge and the Carmens Marsh State Wildlife Management Area as the primary landowners of this large wetland system. This mosaic of wetlands offers outstanding wildlife habitat for a myriad of resident and migratory species ranging from waterfowl (e.g., black ducks, wood ducks, goldeneyes) and wading birds (e.g., great blue herons, American bitterns, Virginia rail – the state's largest colony of nesting great blue herons occurs in this wetland system), to rare, threatened and endangered species, such as the black tern and spiny softshell turtle. Although black bear and moose are not the common species in this part of the state, vehicle collisions with those species have occurred in the project area. Each year, many white-tailed deer are killed by vehicle collisions in one area of this roadway alone. Numerous other species of mammals, birds, reptiles and amphibians are killed by traffic in this area each year.

Route 78 is a relatively narrow, winding road with an increasing volume of traffic, most notably commercial truck traffic coming from and going to Canada. Public safety concerns regarding the high traffic volume and poor road conditions have caused the Vermont Agency of Transportation to pursue upgrade of the road along the Missisquoi River and through the Missisquoi wetland system and Missisquoi National Wildlife Refuge. In order to address safety issues related to the road conditions and the wildlife habitat and associated environmental concerns, a collaborative process was developed to identify issues and solutions. The Vermont Department of Fish and Wildlife in coordination with the Missisquoi National Wildlife Refuge and the Vermont Agency of Transportation identified impacts to wetland habitat, effects of traffic on sensitive wetland-dependent wildlife, and the barrier effect of the existing road conditions as primary concerns related to this project. In order to address those concerns, we evaluated landscape and habitat conditions along the road project corridor, distribution of road-related wildlife mortality, animal movement information based on evidence of animal movements and activity in habitats near the road (e.g., tracks, observations of animals), and local knowledge of animal movements and animal vehicle collision areas from Missisquoi National Wildlife Refuge biologists and Vermont Department of Fish and Wildlife Game Wardens.

Landscape analysis of this segment of Route 78 indicates an isolated area of upland habitat surrounded by wetland habitat associated with an S-curve in the road known as Louis Landing. Road-related wildlife mortality information indicates a high proportion of animal-vehicle collisions along the S-curve by Louis Landing suggesting that the upland habitat is serving as a primary travel corridor for many species of wildlife. Species that cross, or are likely to cross, within the wetland/upland complex along Route 78, such as deer, moose, black bear, mink, otter, beaver, muskrat, raccoon, coyotes, red fox, gray fox, other small mammals, amphibians, reptiles, and some birds, would utilize a transition zone between wetland and upland habitat which is provided by this area. As mentioned earlier, this is the only area where black bear and moose have tried to cross Route 78. In Vermont, we have found black bears are selective in their preference for locations to cross roads. This is a primary location where birds are struck by vehicles, including hawks, owls, waterfowl and songbirds.

Additionally, we identified several other important wildlife linkage areas that traverse Route 78 as well as an important amphibian breeding area that requires large migrations of frogs to cross the road each year during spring spawning season.

Based on this evaluation, we developed a "Route 78 Permeability Plan for Fish, Wildlife, and Ecosystem Functions." The purpose of this plan is to identify the most significant wildlife habitat linkage areas along the road project corridor and identify measures for resolving road-related conflicts with those areas. The plan proposes the following measures for restoring and mitigating wildlife movement and ecological functions within the Missisquoi wetland system:

A. Construction of a 500-foot-long span bridge in an area identified as Louis Landing. This is the primary linkage area. The dimensions of the underpass have been designed to accommodate spanning the entire linkage area to accommodate the needs of a variety of taxa and species. We believe that this strategy will reduce the risk that the structure would fail to serve the needs and interests of some of the species and/or taxonomic groups that require unrestricted movement in this wetland system.

B. Shifting of the existing road at least 100 feet away from the edge of the Missisquoi River and restore that area to functional riparian habitat.

C. Construction of at least 4 amphibian passage structures along a segment of the corridor to reduce amphibian road mortality and restore amphibian access to spawning habitat.

D. Construction of at least 3 large box culverts in the Carmens' Marsh area of the road corridor to restore hydrology in that part of the wetland system and allow for wetland dependent furbearers (muskrat, beaver, otter) to move within that wetland system.

E. Conserve through application of a conservation easement lands on the south side of Carmens Marsh to restore wetlands affected by the disruption in hydrology due to the road, and improve wildlife habitat condition and connectivity in that area.

Agreements related to this project will ensure that future research will be funded to explore the efficacy of this strategy and learn more regarding the effects of highways through biologically rich wetland systems. This project serves as an outstanding example of how collaborative efforts between natural resource and transportation agencies can achieve public safety, transportation, wildlife, and habitat interests in a meaningful and expeditious manner. This paper will explain further the process used to evaluate linkage area conditions, wildlife movement, and development of restoration and mitigation measures.

## **Introduction**

Vermont Route 78 travels through one of the largest and most significant wetland complexes in the State of Vermont. This fact is exemplified by the presence of the Missisquoi National Wildlife Refuge and the Carmens Marsh State Wildlife Management Area as the primary landowners of this large wetland system. This mosaic of wetlands offers outstanding wildlife habitat for a myriad of resident and migratory species ranging from waterfowl (e.g., black ducks, wood ducks, goldeneyes) and wading birds (e.g., great blue herons, American bitterns, Virginia rail – the state's largest colony of nesting great blue herons occurs in this wetland system), to rare, threatened and endangered species such as the black tern and spiny softshell turtle. Although black bear and moose are not common species in this part of the state, vehicle collisions with those species have occurred in the project area. Each year, many white-tailed deer are killed by vehicle collisions in one area of this roadway alone. Numerous other species of mammals, birds, reptiles and amphibians are killed by traffic in this area each year. In addition, the potential displacement effect of traffic on sensitive wetland-dependant wildlife may be significant (Jackson 2000).

The Missisquoi River is one of several major river systems that flow through Vermont into Lake Champlain. The Missisquoi River creates the lakeshore wetland system comprising thousands of acres. This is the second largest wetland system in the State of Vermont and possibly the most biologically diverse. Vermont Route 78 parallels approximately three miles of this river without any buffer. The lack of separation between the road and river precludes movement along the river by wildlife, creates water quality problems, and presents a serious public safety hazard.

Route 78 is a narrow, rural arterial state highway with an increasing volume of traffic, most notably commercial truck traffic coming from and going to Canada. In 1996, Route 78 was designated a national highway. Public safety concerns regarding the high traffic volume and poor road conditions have caused the Vermont Agency of Transportation to pursue upgrade of the road along the Missisquoi River and through the Missisquoi wetland system and Missisquoi National Wildlife Refuge. In order to address safety issues related to the road conditions and wildlife habitat and associated environmental concerns, a collaborative process was developed to identify issues and solutions. The Vermont Department of Fish and Wildlife in coordination with the Missisquoi National Wildlife Refuge, the Vermont Agency of Transportation and other government organizations (e.g., EPA, ACOE) identified impacts to wetland habitat, effects of traffic on sensitive wetland dependent wildlife, and the barrier effect of the existing road conditions as primary concerns related to this project. In order to address those concerns, we evaluated landscape and habitat conditions along the road project corridor, distribution of road-related wildlife mortality, animal movement information based on evidence of animal presence and activity in habitats near the road (e.g., tracks, observations of animals), and local knowledge of animal movements and areas where there has been a high frequency of animal/vehicle collisions from Missisquoi National Wildlife Refuge biologists and Vermont Department of Fish and Wildlife Game Wardens (Trombulak and Frissell 2000; Wagner et. al. 1998).

## **Permeability Design for Route 78**

### **Assessment Process**

The assessment of wildlife movement and linkage habitat associated with the Route 78 project area consisted of: (1) wildlife species inventories; (2) significant habitat inventories; (3) landscape and vegetative cover data; (4) evidence of animal movement along Route 78 (track data); and (5) road mortality data for wildlife. Aerial and ortho photography was used to identify habitat features within the road corridor (Fahrig and Merriam 1985; Singleton et. al. 2001). Areas reviewed for evidence of wildlife movement were within 300 feet on either

side of the road edge. Due to the fact that much of the project area is in public ownership for conservation purposes by the U.S. Fish and Wildlife Service and the Vermont Department of Fish and Wildlife a great deal of institutional knowledge was available to identify important wildlife species, habitats, and road crossing locations without extensive field inventory work (Clevenger et. al. 2002).

Road-related wildlife mortality was evaluated in a systematic fashion for 1.5 years by refuge biologists, Vermont Department of Fish and Wildlife biologists and game wardens. Standard information was recorded opportunistically while conducting regular field responsibilities, including the location of the road mortality, species, date, time of day. The process was designed to be simple in order to maximize the likelihood of receiving data from volunteer field staff.

A general landscape analysis of the area around the Route 78 corridor illustrates a long linear component of mature flood plain and upland forest within a large deep rush marsh. This area represents the only segment of Route 78 where forest habitat abuts both sides of the road. It also represents the only area of forested habitat within the western segment of the wetland system. This is a critical component to accommodating the movement of most mammals in a large wetland system (Clevenger and Waltho 2000; Hammond 2002).

Animals known to cross Route 78 in this area include: white-tailed deer, moose, black bear, American beaver, mink, muskrat, otter, numerous species of small mammals, snapping turtles, numerous amphibian species, a variety of waterfowl species, wading birds, song birds, owls, raccoons, skunk (this list does not necessarily represent all species that utilize this area for crossing Route 78).

During 2001, we confirmed concentrated use of this habitat zone on both sides of Route 78 by deer. Based on the landscape analysis of the habitat and land conditions as well as limited road mortality data and the history of professional knowledge by wildlife experts familiar with this area, many taxonomic groups and species of wildlife appear to be using this area to move across Route 78 to access habitats to the north and south. As an example, deer migrate from the habitat to the north of Route 78 to winter habitat on the south side of the road during early winter periods. We measured the area along the existing alignment of Route 78 that demonstrated the greatest concentration of animal activity as well as the best habitat conditions of transitional upland and wetland. This area measured 500 feet along the road.

## **Results and Discussion**

### **Overall Fish and Wildlife Permeability Plan**

Based on the results of the linkage area and wildlife movement assessment, a road permeability plan for restoring connectivity for fish, wildlife and related ecosystem functions was developed for the project area. This plan consists of five primary elements that are discussed below including: (1) construct a wildlife underpass that is 500-foot-long and spans a significant area of linkage habitat; (2) shift a 1.5-mile segment of the road away from the Missisquoi River and establish riparian habitat in the former road location; (3) install tunnels that will allow amphibians to access important reproduction habitat; (4) install multiple, large box culverts in strategic locations throughout the marsh habitat; and (5) conserve an important area of wetland habitat near the road that will be connected to other conserved habitat by large box culverts.

An additional wildlife component to this project that is not directly discussed in this paper involves the geometric design of the road to avoid critical nesting habitat for the state threatened black tern. The black tern is extremely rare in Vermont and northern New England. Its population in Vermont has declined drastically in recent years for causes that are not certain. At this time, the only remaining nesting population of black terns in Vermont is adjacent to the project site. Therefore, in accordance with Vermont's Threatened and Endangered Species Law, the participants in this collaborative process have gone to great lengths to ensure that this critical nesting habitat is properly protected.

### **Wildlife Underpass**

A 500-foot-long span bridge has been designed for the area identified in figure 1 (the primary linkage habitat for wildlife movement in the project area) in order to restore ecological connectivity within the Missisquoi delta wetland complex, to provide wildlife passage in an area identified as an important wildlife movement corridor, and to improve public safety by reducing the risk of vehicle collisions with wildlife.

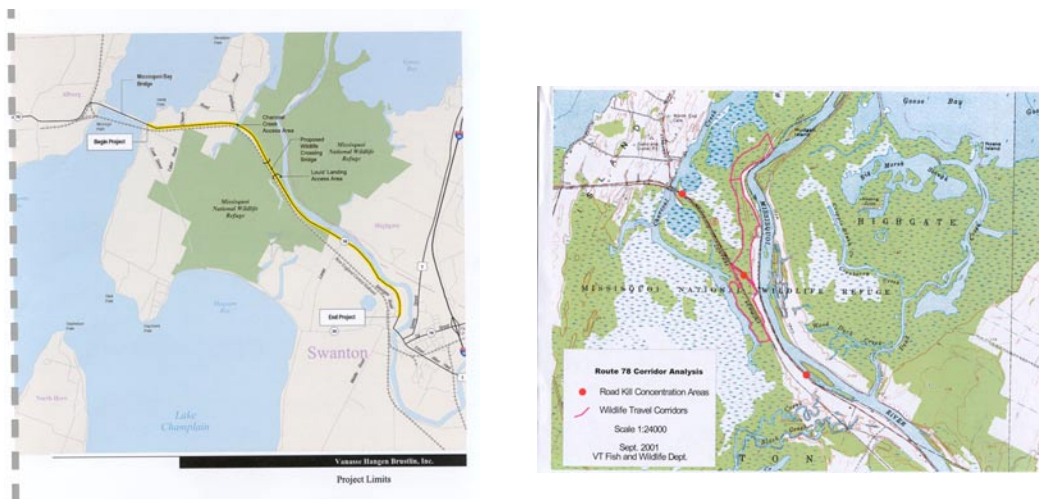


Fig. 1. Maps of the project area identifying the linkage habitat, road mortality hot spots, and location of the wildlife underpass.

Based on an assessment of the linkage area, and given the unique and significant environmental contributions to the state associated with the MNWR and the wetland system, a decision was made to span the entire width of the linkage area. This design is intended to avoid the risk that the structure will not serve the passage needs of the myriad fish and wildlife species that require mobility within this system of habitats (Ruediger 2001). The design of the structure represents an attempt to address the affects of a major state highway on an overall ecosystem rather than a single species of wildlife. A secondary benefit of spanning the entire area of linkage habitat is that it avoids additional wetland impacts and, therefore, reduces the need for off-site wetland compensation. Finally, raising the road over the linkage habitat allows the extreme curvature in the roadway to be reduced, thereby adding an additional level of safety to the traveling public.

In addition to the structure itself, the former roadbed will be reclaimed to functional wetland habitat similar in character to the surrounding forested swamp. Habitat will also be established within the wildlife passage structure by planting appropriate vegetation and incorporating course woody debris, large rocks/boulders, and other organic material that will provide cover for migrating animals.

While fencing may be necessary to direct animals, particularly large mammals such as deer, to the passage structure, the natural funneling affect of the habitat lends itself to focusing animal movements in the area of the proposed bridge. Future monitoring and evaluation of this area may examine the efficacy of the passage structure both with and without fencing. The type and length of fencing necessary to ensure the proper function of this structure for wildlife is not yet determined. It is possible that given the significant funneling effect that this habitat has on animal movement, fencing requirements may be limited.

In order to ensure that this and other elements of the Route 78 fish and wildlife permeability plan function properly it is necessary to create openings in the adjacent railroad bed that parallels the road to the south. The railroad serves as a parallel barrier along Route 78; however, the train traffic in this area is infrequent (1 train trip per day). While it is likely that many large- and medium-sized mammals successfully negotiate this barrier due to infrequent train traffic, it is necessary to perforate that barrier for other small wildlife as well as to allow fish free movement within the wetland system during periods of high water, typically during the spawning season for many resident species (e.g., northern pike). Additionally, the wildlife underpass may increase the volume and frequency of wildlife movement in the area, thus requiring a greater level of permeability for both barriers in order to maximize the benefit of the substantial investment in the bridge. No openings are required in the railroad bed along the Missisquoi River segment of the project since two bridge openings already exist in that area.

### **Restoration of Riparian Habitat and Associated Wildlife Mobility Along the Missisquoi River**

Roughly 1.5 miles of the Route 78 upgrade runs directly along the Missisquoi River. In this area, the road will be removed from its current location and shifted approximately 100 feet to the west of the river, thus affording the opportunity to restore valuable riparian habitat. Over time, and following appropriate riparian vegetation restoration, this area should serve myriad important ecological, recreational, educational, and public safety functions including: (1) reduction in driving hazards; (2) wildlife movement along that portion of the Missisquoi

River; (3) nesting habitat for songbirds; (4) habitat for reptiles and amphibians; (5) angler access; (6) nature hikes and bird watching; and (7) improved water quality.

### **Movement for Amphibians to Access Important Reproduction Habitat**

The wet meadow and shrub wetland habitat to the west of Route 78 serves important breeding functions for many species of amphibians. In order to accommodate and improve access to and from this important spawning habitat, amphibian tunnels will be installed along this segment of roadway (Carr and Fahrig 2000; Jackson 1997). Since the habitat on both sides of the road is relatively homogenous, four amphibian tunnels will be placed equidistant throughout the segment of road identified in figure 2. The intent is to establish a high frequency of passage structures in concert with concrete barrier to direct amphibian movement, such that there is a probability of frogs and other amphibians, reptiles and small mammals finding a tunnel and attempting to cross.



Figure 2. Area of amphibian spawning habitat and Route 78 adjacent to Missisquoi River.

In order to ensure that the tunnels function properly, permanent fencing will be required to direct amphibians to tunnel openings (Jackson 1997). Permanent fencing in the form of metal or concrete barriers will be necessary since less permanent fencing will require a great deal of annual maintenance. Additional research is necessary to determine the length of fencing necessary to capture and direct most migrating amphibians. If culverts are also used to drain water along this segment of roadway, future monitoring could be used to evaluate the disparity of use by amphibians between the amphibian tunnels (open grate, trapezoidal cast concrete) and conventional culverts (round metal corrugated pipe). Given the cost of the amphibian tunnels and their open grate component, maintenance will likely be required to ensure proper long-term functioning.

### **Other Crossing Structures and Habitat Acquisition**

Wetland habitats on both the north and south sides of Route 78 at Carmen's Marsh include outstanding examples of deep rush marsh, forested swamp, and wet meadow habitat. These habitats serve outstanding functions for spawning fish (e.g., northern pike), migratory waterfowl and wading birds, breeding and feeding habitat for reptiles and amphibians, among many other important functions. This is an area where, during spring migration, it is not uncommon to see hundreds of ducks resting and feeding, including many species which are not otherwise seen in Vermont.

Currently, only two small (approximately 18-inch diameter) culverts exist in this area and do not function properly. In order to accommodate and improve wildlife movement within this outstanding wetland system along Route 78, three large (minimum 4-foot wide) concrete box culverts will be installed (Clevenger and Waltho 1999). Figure 3 identifies the segment of road planned for perforation. Unless future observations provide cause for adjusting this strategy, one culvert will be placed in the middle of the area; one will be placed near the western edge and one near the eastern edge. The height of the box culverts should be designed such that there is open air space during periods of high water (e.g., spring flooding). In order to improve the efficacy of fish and wildlife use of these passages, it will be useful to establish shrub vegetation around the openings of the culverts. This will provide valuable cover for traveling animals.



Fig. 3. Aerial view of the segment planned for installation of box culverts and land conservation. The yellow points indicate the proposed locations for box culvert placement.

In order to ensure that these improvements for animal and fish passage are maximized, it is necessary to conserve an area of forested swamp and wet meadow habitat on the south side of Route 78. A conservation easement or fee acquisition of this habitat is a requirement of the permeability plan and settlement agreement.

Parallel crossing structures in the railroad bed will be necessary at Carmen's Marsh in order to ensure animal and fish passage through the box culverts. It is not certain whether a corresponding structure in the railroad bed will be necessary for each roadway box culvert or whether something less than that will suffice. This will be determined collaboratively between Vermont Agency of Transportation, Vermont Agency of Natural Resources, and other interested government agencies, as well as the railway company. Vegetation will be incorporated into the design of openings along the railroad bed, similar to that proposed for the roadway openings.

### **Future Research and Monitoring**

Given the unique nature of this project and considerable opportunities for learning the extent to which the road conditions and associated traffic are influencing wildlife movement, behavior, survival and mortality, research will examine the upgraded conditions. In particular, research efforts will focus on the efficacy of the overall permeability plan to understand the extent to which it has affected ecological connectivity, wildlife movement, mortality, and possibly population isolation. The University of Vermont or other appropriate academic institution will be employed to conduct this research in a rigorous fashion. The structures themselves will be monitored for no less than two years following construction to understand their functions and values for wildlife movement. This is another provision of the permeability and road upgrade plan. The collaborative process provided the opportunity to identify this as an important need for the success of the project and to secure a guarantee for research funding in the associated agreement.

### **Conclusions and Recommendations**

The habitat conditions and environmental circumstances associated with the Route 78 upgrade project are unique in several respects that influence conclusions. The fact that much of the project area is owned and controlled by the United States Fish and Wildlife Service as a National Wildlife Refuge had a significant influence on the outcome of this project design and permeability plan. Several conclusions arise from this preliminary phase of the project.

- a. The primary area of wildlife movement across Route 78 is discrete and easily identified. Rather than studying the precise location of wildlife movement within this linkage habitat, and given the objective to restore ecological connectivity for the entire wetland system, a decision was made to raise the road above the entire area of linkage habitat. This was possible due to the dimensions of the linkage habitat. The area itself is rather narrow and made it possible to consider this option. This strategy reduced the time necessary to reach a conclusion on the design of the project by reducing the time necessary to identify the location of a more narrow crossing structure. To the extent similar linkage habitat conditions are found elsewhere, this may be an advisable approach.

b. Given the diverse system of habitats and the broad array of fish and wildlife species that required consideration for passage in this area, it was necessary to apply multiple strategies for establishing effective connectivity throughout the project area. This seems to be an important point in that many road permeability strategies focus on single species or single taxonomic groups. Taking an ecosystems approach towards road permeability may prove effective for this set of circumstances.

c. As part of the collaborative process that was used to address these and other project-related issues, a settlement agreement was established to memorialize the myriad mitigation and enhancement measures. The settlement agreement and associated permeability plan for the project includes a provision to fund research to understand the efficacy and effects of the permeability measures and future road conditions on wildlife and ecosystem functions. This is a critical component to any mitigation or enhancement plan since projects like this can yield a wealth of useful information and scientific knowledge to better understand what works for wildlife movement and what does not.

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