Executive Summary

Living snow fences (LSF) are a form of passive snow control designed to mitigate blowing and drifting snow problems on roadways. Blowing and drifting snow can increase the cost of highway maintenance and create hazardous driving conditions when snow is lifted off the ground by wind and transported toward a road without disruption. LSF disrupt wind patterns, causing blowing snow to be deposited in drifts in designated areas around the fence and away from the road. LSF are rows of vegetation (trees, shrubs, standing corn rows) that perform the same function as structural (wooden, plastic, metal) snow fences with potentially longer life cycles and better returns on investment.

This project provided technology transfer for LSF through the creation and dissemination of training materials, and combined classroom and field training workshops on LSF design and installation/maintenance held at four New York State Department of Transportation (NYSDOT) residencies around the state. Four willow LSF were installed at known blowing snow problem areas as part of the training workshops. Protocols to assess potential sites and operational LSF were created and applied to the four demonstration sites. These protocols were further applied in an original research study that measured structural characteristics and snow trapping potential of 18 LSF of various ages and vegetation types in locations across New York State.

Based on the literature review conducted at the start of this project, this new research is the most comprehensive study on LSF to date and provides new understanding on the structure and snow trapping potential of LSF over time. Study findings identified key factors for successful LSF that have important implications related to the design, feasibility and effectiveness of LSF. This new information has been incorporated into LSF guidelines and protocols during the course of this project. A benefit-cost tool for LSF was also created, tested and revised as part of this project. Example scenarios modeled using the tool have shown that willow LSF and LSF of other vegetation types can have positive net present values and other metrics of financial analysis by reducing snow and ice control costs. The benefit-cost tool also demonstrated that LSF can produce large amounts of other public benefits (that can be quantified in economic values) such as reduced accidents rates and avoidance of reduced travel speeds. LSF can also provide environmental benefits that increase the sustainability of transportation projects consistent with the standards of the NYSDOT GreenLITES environmental certification program.

Introduction

LSF have been used for decades or longer to prevent blowing snow problems on roads around the world, as well as to protect other areas such as railroad tracks or houses. Blowing snow problems typically occur next to large open areas where no or limited obstructions to blowing snow exist, such as agricultural fields that have been cleared of vegetation or large frozen lakes. In New York, blowing and drifting snow problems occur most frequently around large open agricultural fields adjacent to roadways with little or no vegetation or other obstructions between the road and field. Blowing and drifting problems often occur in remote rural locations and can create the need for frequent plowing, salting, de-icing, snow blowing and other methods of snow and ice control. These problems can occur consistently and repeatedly in problem areas as the wind continues to blow and transport snow for days or even

weeks after a snow event. This often requires frequent and costly trips to remote locations and sometimes leads to road closures, automobile accidents and other severe situations.

LSF are planted in such areas to mitigate these situations by acting as an obstruction to the wind and blowing snow. This disruption of blowing snow creates wind turbulence and eddies (swirling winds) around fence, causing blowing snow to be deposited in drifts on both the upwind and downwind side of the fence, away from the road.

LSF have been used for decades in New York and are considered a best practice. But previous research on LSF is limited and design standards have been loosely adapted from structural snow fences. LSF and structural snow fences trap snow in the same manner and produce essentially the same result, with one important (but often overlooked) difference. LSF grow over time, which changes the fence's snow holding capacity and snow drift shape as plants mature. This critical factor has not been fully accounted for in previous research studies and has not been incorporated into LSF design protocols and educational publications. Several NYSDOT residencies have engaged in LSF to various degrees before this project started, with varying degrees of success. In the early 2000's, workshops were held in NYSDOT Region 5 and facilitated by the late Ronald Tabler, whose work continues to be the most extensive engineering study and design standards for structural snow fences and provides important insights into LSF. An engineering design tool for LSF --"Snowman" (Snow management) -- was created by NYSDOT and researchers from these workshops, but the use and functionality of this tool for LSF design has been limited. Tabler focused on structural snow fences. The nuances of his work on LSF are often not transferred correctly into simplified LSF protocols or educational publications. One of the main areas where this is most evident - and related to the changing nature of LSF over time - is lack of emphasis in the literature on the potential for excess storage capacity of mature LSF and the impact excess storage capacity can have on downwind drift length.

When LSF snow trapping capacity (driven by height growth over time) exceeds the annual quantity of blowing snow at a site, the length of the downwind drift is reduced, or does not reach the maximum possible drift length during the snow season. Estimating when this reduced drift length will occur in the life cycle of LSF and consequently how much drift length will be reduced is of critical importance when designing LSF in regards to the chosen setback distance, or distance between fence and the road.

Not accounting for excess storage capacity of large, mature LSF and using the standard design assumption for structural snow fences of setback distance being set equal to 35H (or 35 times the height of the fence) will generally result in setbacks that are far larger than necessary. This excessive setback distance can lead to "near-snow problems" of blowing snow between the fence and the road, or the inability to install LSF beyond the right of way boundary on privately held land, limiting the effectiveness and feasibility of LSF. Also critically important to the success of LSF is the use of best practices for site assessment, design, installation and maintenance. These and other issues related to the structure, function, analysis and design of LSF are addressed in this study and have been incorporated into training materials, workshops, and protocols.

Research Method

Training materials, including a series of seven fact sheets and two PowerPoint presentations, were prepared to assist in the design and installation classes. Training materials were created from an extensive literature review of LSF, previous research and development efforts conducted by SUNY- ESF, and improved methods and protocols developed in this project. Five classes were held during the project. The first four classes were held at four different NYSDOT residencies in Onondaga, Erie, Delaware and Oneida Counties. Each class had two sessions.

In the first session, generally held in the fall, participants learned about basics of blowing snow problems, addressing problems with LSF, site assessment and fence design. In the field component of the fall session, students visited a site identified by residency staff as having a blowing snow problem and addressing the factors for site assessment as a group, including talking through potential challenges to fence installation and possible solutions.

The following spring, the class reconvened for a one- or two-day long session. The classroom aspect of the spring session covered LSF design, installation, maintenance and best practices. In the field component of the second session, participants observed and assisted in site preparation and installation of a living snow fence on the site. Shrub willow LSF were used in the field sessions, as this vegetation type is recognized as a best practice for LSF due to the rapid growth rate of willow, the ease of propagation from dormant stem cuttings, tolerance of high planting density, consistent porosity, etc. Protocols to assess and measure LSF sites were developed and applied at each site and these methods and findings were presented and applied in each of the classes as part of the comprehensive demonstrations of site identification, analysis, design, installation and maintenance of LSF. Methods of site assessment included using geographic information systems (GIS) to assess and measure the site, soil sampling and interpretation of results, assessing vegetation and land use history, assessing the blowing snow problem, developing strategies to overcome site challenges (ditches, trees, utilities), etc.

The fifth and final class was planned to be a winter workshop to observe and discuss functional LSF in the landscape. Scheduling of this tour so participants from multiple residencies across the state could participate proved difficult amongst competing and uncertain demands on NYSDOT staff for snow and ice control during the winter. A summer class to observe mature LSF was held instead to accommodate previous participants from various residences attending. The workshop, held in NYSDOT Region 2, consisted of a brief classroom training in the morning, followed by site visits to four LSF in Region 2 of various ages and vegetation types including willow, evergreen trees and shrubs. Instruction and discussion at each stop focused on the original research conducted as part of this project and how the dynamics of maturing LSF affect snow trapping function over time. This dynamic was illustrated by visiting LSF with a range of ages, plant types, heights and snow storage capacities and explaining how these factors affected the length of the downwind drift and selection of setback distance and other design factors.

Protocols in this project were developed to measure and evaluate LSF based on work by Ronald Tabler and previous efforts by the Willow Project Research Group at SUNY-ESF. These protocols included methods for taking accurate measurements and developing sampling

designs to evaluate key vegetation characteristics of plant height and optical porosity, as well as gathering other information on site characteristics using GIS. These protocols were applied to a comprehensive study of 18 living snow fences of various vegetation types and ages across the state. Data on plant characteristics were used to model snow trapping capacity of the fences and downwind drift length based on the engineering equations of Ronald Tabler. The range of ages from three to eleven years after planting allowed plant height, porosity and the resulting snow storage capacity and down drift length to be modeled over time.

The benefit-cost tool for this project was created by itemizing costs associated with LSF installation and maintenance, and the machinery/logistics of snow and ice control by NYSDOT. Other variables were included in the model based on transportation industry standards to quantify benefits from LSF related to value travel time savings (VTTS) and accident reduction factor (ARF). The model was presented to NYSDOT staff via a webinar and improvements were made to the model based on comments and discussions from the project's technical working group.

Findings and Conclusions

Nearly 110 people attended the classes. NYSDOT staff who attended were a diverse group from all parts of the agency, including Highway Maintenance Workers, Landscape Architects, engineers and environmental specialists. Students also included staff from the New York State Thruway Authority and local governments. Class instructors, content and format received high evaluations from students.

Several students have since applied this training to LSF projects in their home region. The training materials developed are comprehensive and cover every aspect of LSF from site assessment through maintenance of installed fences. These training materials include best practice guidelines for site assessment, design, installation and maintenance that will improve the chance of survival, growth rates, functionality and returns on investment for LSF implemented using these guidelines. The benefit-cost tool created is user friendly and customizable to NYSDOT operations and a variety of installation and maintenance variables for LSF. All of these materials are available for download in convenient fashion on the SUNY-ESF hosted website which will remain active indefinitely. A recent assessment of website traffic using Google analytics showed that this site is being accessed at rate of approximately 500 – 600 times per year.

This study found that LSF of various vegetation types can create snow trapping potential equal to the annual quantity of blowing snow at an average site in NYS as early as three years after planting, much earlier than the seven to twenty years or longer often described in the literature. Related to this, as LSF grow and increase in height, they continue to add snow storage capacity. As fence snow storage capacity continues to exceed the quantity of blowing snow at the site by larger and larger amounts, this reduces the length of the downwind drift that forms around the fence during the snow season.

These findings show LSF can be effective much sooner than previously assumed and can be safely situated nearer the road than previously assumed, due to reduced setback requirements resulting from reduced drift lengths caused by large storage snow capacity. Applying these design standards along with installation and maintenance best practices

developed in this project can increase LSF feasibility and effectiveness. Well designed and managed LSF yield economic, safety and environmental benefits to transportation agencies and the public.

Many areas of potential future research exist around LSF. A comprehensive study of LSF snow drift formations, comparing predicted values of snow load and drift shape to observed values in the field throughout single and across multiple snow seasons and fences, would further inform the LSF design and functionality. Case studies of specific locations with snow problems before and after LSF installations, including documented reductions in road maintenance costs and accident rates, would improve understanding of the financial returns on investment and offer the opportunity to apply and improve the benefit-cost tool created in this study. Additional research could be conducted to further quantify LSF's environmental benefits and their application the NYSDOT's GreenLITES program for environmental sustainability and multiple benefits including the production of renewable woody biomass, erosion control and other environmental services. LSF best practices can continue to be improved and evaluated in more detail, examining the tradeoffs of implementing certain practices at higher or lower initial costs versus long term impacts. The 18 LSF identified and evaluated in this study could be studied in more detail and could also be expanded to include a broader range of sites, vegetation types and fence ages. Other efforts could focus on statewide initiatives such as cataloging and prioritizing blowing snow problem areas and documenting the effectiveness of existing LSF. More decision analysis tools can be developed including online LSF design tools and benefit-cost modules such as those being developed in other states. More advanced studies of snow hydrology around LSF could be conducted in the field and in aerodynamic simulations in order to refine site and fence design standards. Additional development of support systems for the adoption of LSF could also be developed such as more comprehensive outreach programs for working with landowners to adopt LSF.

Statement on Implementation

Much of this project was focused on training and technology transfer. With the training, the intention was that class participants could use the protocols and best practices developed and disseminated to address blowing snow problems in various locations around the state. The technology transfer included consultations with NYSDOT staff outside the training and overview presentations to groups such as the Cornell Local Roads program.

While training helped participants better understand LSF, it appears that only participants who engaged in multiple trainings or had prior awareness of or experience with LSF were comfortable enough to implement these ideas. Providing ongoing support for LSF design and installation could encourage wider use of LSF across the state. There is no comprehensive living snow fence program within NYSDOT however, so tracking and supporting these projects on a statewide level will be challenging, but would be useful to continue advancing the technology and implementation. LSF, especially willow LSF are now a well-developed technology but there is still room to improve these systems and increase awareness about the benefits they produce. With training materials now completed, numerous LSF around the state identified and studied, and these results fed back into development of best practices and design standards, future projects will have a much stronger foundation to build upon to advance LSF science and implementation even further.