Research Project C-06-09

Designing, Developing and Implementing a Living Snow Fence Program for New York State

Task 3-C, 3-C1 & 3C2

Protocol for Field Measurements of Effectiveness of Operationally Mature Living Snow Fences

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State University of New York College of Environmental Science and Forestry



Justin P. Heavey Dr. Timothy Volk Dr. Lawrence Abrahamson

State University of New York College of Environmental Science & Forestry

John Rowen New York State Department of Transportation

Background

The structure of living snow fences, and the manner in which they hold snow, change over time as plants grow. This document provides protocols for a complete assessment of living snow fence structure and function that can be applied at any point during the life cycle of a living snow fence. The two primary vegetation characteristics affecting the snow trapping function of living snow fences are the fence height (**H**) and optical porosity (**P**). Height and porosity combine to create the snow storage capacity of the fence (**Q**_c). Vegetation characteristics are measured in the field to estimate the level of functionality of living snow fences. Site characteristics that influence the quantity of annual snow transport (**Q**), such as the fetch distance (**F**), can be measured in the field with surveying equipment or measured remotely using a geographic information system (GIS). Vegetation and site characteristics can then be modeled using the snow fence equations developed by R. Tabler (2000 and 2003) to determine the snow trapping function of the fence.

Tabler's models of snow trapping function are formulated using metric units. To use the models, data must be collected in, or converted to, metric units. Estimates of snow trapping function can be verified using the protocol provided in this document for measuring snow depth and density.

Undertaking winter field measurements raises safety issues because of the season and because snow and ice work by transportation agencies may limit access to the right of way. Before making a field visit, the user of this protocol must contact the agency maintaining the highway to ensure it is safe to work on the roadside.

1. Examine Aerial Photos of the Snow Fence Site

Examining aerial photos of a living snow fence and the surrounding land assists in field measurement by providing an overview of the site and context of the landscape around the fence, including the area *upwind* of the fence that contributes to the blowing snow problem known as the fetch distance. The distance from the *downwind* edge of the fence to the edge of the roadway is known as the setback distance. Looking at aerial photos before a field visit can help in determining the best parking and access route to the fence for field measurements. Aerial photos provide a bird's eye view of the site. They can show things that may not be readily visible from the ground but may be important to the analysis of the snow fence and site. An example of an aerial photo of a living snow fence site is provided in Figure 1.



Figure 1: Aerial photo of a living snow fence site from Google Earth software. The living snow fence is the row of dark green vegetation indicated by the tree icon, located on New York Route 167, Town of Manheim, Herkimer County.

The Google Earth software program is a free, user-friendly GIS program that often has the most up-to-date aerial photos. Living snow fence sites can be easily viewed from multiple angles and resolutions in this software and site locations can be "bookmarked" for easy identification and further analysis. Distances and elevations can also be quickly and easily measured in Google Earth and shapes can be marked on the landscape and printed as aerial maps that can assist in the next steps of evaluating living snow fence structure and function. Examining aerial photos of living snow fences also helps to frame the snow fence in the context of the important site characteristics that contribute to the blowing snow problem. A diagram illustrating the basic elements of a snow fence site is provided in Figure 2. From top to bottom, this diagram shows the following:

- A row of houses that indicates an obstruction to the wind where snow transport is assumed to start
- The fetch distance, that is the open area upwind where snow is lifted off the ground and transported by the wind toward the fence,
- The living snow fence which disrupts the wind and causes snow deposition around the fence,
- The setback distance between the roadway and the fence, and the roadway protected by the fence.

Note that a 100-meter sampling plot and a minimum 7.5-meter buffer on either side of the fence is included in this diagram and explained in the next step, "Establishing a Sampling Plot".



Figure 2: Diagram of living snow fence site showing the basic elements that influence snow control

2. Establish a Sampling Plot

Living snow fences vary in length and can be several hundred meters/feet long or more. For fences up to 100 meters long, it should be possible to take measurements along the full length of the fence. For fences over 100 meters long, it is useful to establish a sampling plot or plots across a portion of the fence and take all measurements within the sampling plot/plots. Living snow fences of consistent age, species makeup, planting pattern, soil conditions and management practices across the entire length

of the fence generally will grow to a height and porosity that is relatively consistent from end to end. Measurements taken within a sampling plot of a living snow fence of relatively consistent growth characterize a subsection of the entire fence that is representative of the entire fence, just as a biological study samples a subset of a population to determine the structure of the larger population.

For living snow fences of up to 300 meters, one sampling plot, approximately 100 meters (328 feet) in length, established across the linear center of a fence, will be sufficient. For very long fences 300 meters or longer, one or more additional sampling plots can be established along the length of the fence at equidistant spacing. Multiple plots should be approximately equal in length and long enough (generally between 50 and 100 meters) to collectively total approximately one-third of the total fence length. The measurements of each plot can be averaged together for a final value of each structural variable of the fence. Sampling plots can be measured and marked on aerial photos by remotely using GIS, then established in the field using an aerial map printout. Alternatively, sampling plots can be established with at least 7.5 meters (25 feet) on either side of the plot to provide a buffer against "edge-effects" where the structure and function of the fence may differ due to aerodynamic effects that are created by wind at the end of the fence.



Figure 3: Aerial photo of a living snow fence from geographic information software showing the measurement of fence length, linear center point and 100-meter sampling plot established around the center point. This snow fence is on New York Route 60 in the town of Pomfret, Chautauqua County.

Protocol for Establishing a Sampling Plot

- A. Using GIS software or field surveying equipment, measure and record the total fence length in meters (Figure 3).
- B. If the total fence length is between 100 and 300 meters, determine the linear center point of the fence and establish a 100-meter sampling plot around the center of the fence.
- C. If the total fence length is greater than 300 meters, divide the length by 3. That is the total length to be tested in multiple plots. Divide this length into two or more plots of equal size, each a minimum of 50 meters and a maximum of 100 meters long. Divide the total length of the fence into the number of equal-length segments needed to locate the center point of the required number of sample plots and establish a sampling plot around the center of each point.
- D. Mark the beginning, center and end of the sampling plot with flagging tape tied to the fence vegetation, stakes or other appropriate marking techniques

3. Measure Setback Distance

The length of setback distance is an important variable in the function of snow fences. Setback should be large enough to accommodate the entire length of the downwind drift, but not so large that the wind regains speed and creates snow transport between the fence and the roadway. Measure setback distance by following the steps below and refer to Figure 4.

*Note: The protocol below is a methodology for measuring the setback distance on existing living snow fences, not for calculating an appropriate setback distance for the design of new living snow fences.

Protocol for Measuring Setback

- A. Using GIS software or field surveying equipment, measure and record the setback distance in units of meters as follows.
- B. Measure the distance from the fence vegetation, at the angle of the prevailing wind, to the edge of roadway pavement.
- C. Take four measurements of setback distance within the established 100-meter sampling (or within each sampling area of multiple-plot fence) at approximately equidistant spacing as shown in Figure 4.
- D. Compute the average of all measurements and round the final value to the nearest meter to calculate the setback distance value of the fence.



Figure 4: Sampling diagram for measuring setback distance and fetch distance, as described in Steps 3 and 4

4. Measure Fetch Distance

Fetch distance is an important variable in the analysis of living snow fences. Fetch distance is used in the model of snow transport to determine the quantity of blowing snow at a site in an average year.

Protocol for Measuring Fetch Distance

- A. Using GIS software or field surveying equipment, measure and record the fetch distance in units of meters as follows.
- B. If the predominant winter wind angle is not known, start at the fence vegetation and measure at a perpendicular angle to the first obstruction upwind that is assumed to disrupt wind patterns and to cause snow deposition such as houses, forests or groups of trees. If the predominant winter wind angle is known from climatologic analysis, measure from the fence to the first obstruction at that angle.
- C. Take four measurements of fetch distance within the established 100-meter sampling at approximately equidistant spacing, as shown in Figure 4.
- D. Compute the average of the four measurements and round the final value to the nearest meter to calculate the fetch value of the fence.

5. Measure Fence Height

Height (**H**) of living snow fences is measured with a telescoping height pole as follows, a range finder (such as a Nikon Forestry Pro) or other device. Two people will make height measurements easier, with one person to operate the height pole and call out measurements, and one to record the height values and to act as a spotter to align the top of the pole with fence, if needed.

Protocol for Measuring Fence Height

- A. In the field, measure the fence height within the sampling plot(s).
- B. Note: if using a height pole, place it on level ground at the base of the fence vegetation, as close to the stool/stump (for shrubs) or main stem (for trees) as possible. Hold the pole at a perpendicular angle to the ground and extend the pole until it is even with the height on the

vegetation where the vegetation is acting as a continuous, uniform fence. Record the height of the fence, then lower the pole to a height where it can be moved to the next measurement.

- C. Take equidistant measurements across the length of each sampling plot at approximately 12.5 meters (e.g. eight measurements for a 100-meter sampling plot as shown in Figure 5).
- D. Compute the average of all measurements and round the final value to the nearest meter to calculate the height value of the fence



Figure 5: Sampling diagram showing height and porosity measurements for living snow fence 100 meter sampling plots shown and as described in Steps 5 and 6.

6. Measure Fence Optical Porosity

Optical porosity (P) is an important characteristic of living snow fences that influences the snow storage capacity of the fence and the length of the downwind drift. The porosity of a fence is the percentage of

visible open space not occupied by vegetation when the fence is viewed at a perpendicular angle in winter (after leaf fall). The percent porosity of a fence is the inverse of the vegetation density. For example, a fence with 75 percent porosity has a 25 percent density and has more open (porous space) than space that has filled in with vegetation. A fence with 50 percent porosity is half open and half closed by vegetation and provides the highest amount of storage capacity. Two protocols for measuring optical porosity of living snow fences are provided here, based on two primary vegetation types of living snow fences: shrubs and evergreen trees.

Protocol for Measuring Fence Porosity Using the Chroma-key Backdrop Technique (shrubs)

- A. Use a backdrop at least 1 meter wide by 3 (three feet by nine feet) meters tall for a sufficiently large sample of porosity. The backdrop should be made of a synthetic fabric, such as "weblon," that is durable, opaque, smooth and red in color. A red backdrop provides a distinct and consistent color contrast between fence vegetation and porous (open) space in the fence. The backdrop should be collapsible for transporting and framed with sturdy aluminum or wooden pole, so the backdrop can be stretched flat by one or two people. An example of a suitable chroma-key backdrop held in front of a shrub-willow living snow fences is provided in Figure 6.
- B. Hold the backdrop perpendicular to the ground, as close to the vegetation as possible. Photograph the backdrop from the opposite side of the fence (with the fence vegetation between the camera and the backdrop), at a distance of approximately 2.5 meters downwind, or at whatever distance is necessary to capture the entire backdrop area with as little space on the top and bottom of the backdrop in the photo as possible. Use the highest resolution setting on the camera and the "auto mode" setting if you are not familiar with advanced digital photography techniques.
- C. Repeat Step B at equidistant locations along the length of the sampling plot(s), at the same locations where the height measurements were taken (e.g. eight measurements for a 100 meter sampling plot, as shown in Figure 5).



Figure 6: Chroma-key backdrop held in front of a shrub-willow living snow fence to create a contrast between fence vegetation and open space to photograph the fence and to measure the optical porosity

Protocol for Measuring Fence Porosity Using the High-Contrast Technique (evergreen trees)

If the fence cannot be accurately measured using the chroma-key backdrop technique due to large height, large widths and/or low porosities, as is often the case with mature evergreen fences, proceed with the high-contrast technique as follows.

A. Photograph the fence at a distance of approximately 2.5 meters upwind or downwind at a perpendicular angle. If possible, try to photograph the fence in the early morning or late evening when the fence can be photographed with the sun behind one side. This increases light infiltration through the open space (porosity) of the fence and improves the contrast between porous space and vegetation. If possible, increase the contrast setting on the camera to further accentuate the open space versus vegetation. The photo contrast can also be increased in the next step of processing the photos with photo editing software. An example of a photo taken on an evergreen living snow fence is provided in Figure 7. When comparing the optical porosity results with other fences that were sampled using the chroma-key technique, it is advisable to photograph approximately the same size area that appears in front of the backdrop. Otherwise, a larger area of fence can be captured. In either case, one complete replication of the planting pattern of the fence should be captured in the photo(s) if possible. For example, if the fence is planted in a double off-set row pattern with Norway

spruce in the front row and white spruce in back row, capture the entirety of both rows (front row and back row) in one photo, or in multiple side-by-side photos.

B. Repeat step B eight times at equidistant locations along the length of the 100-meter sampling plot as shown in Figure 5, at the same locations that the height measurements were taken.



Figure 7: Photographic sample of optical porosity of an evergreen living snow fence using the high contrast technique

Protocol for Processing Porosity Photos from the Chroma-key and High-Contrast Techniques

After photos have been taken in the field, they must be processed to determine the optical porosity. Use a photo editing software program to accomplish this as outlined in the steps below.

- A. Begin by opening a copy of the first photo to be processed in the photo editing program and maximize the program and the picture window to occupy the entire computer screen
- B. If necessary, rotate the image so it is right side up (as it would appear naturally)
- C. Repeat step B to maximize the photo on screen again if necessary
- D. Carefully crop around the red backdrop area or the desired sample area. Capture as much of the red area (or sample) as possible. The remaining area after the crop should contain only red backdrop (or sample area) and vegetation
- E. Repeat step B to maximize the photo on screen again if necessary

- F. Use the "magic wand" or equivalent selection tool to select to the red or open area (the porosity) in the photo
- G. Clear the selected area to verify an accurate selection and confirm that there is very little or no red (or background color) left in the picture and none of the vegetation has been cleared. It may be necessary to zoom in on the image to verify that small stems or edges of the stems have not been cleared. If necessary, redo step F with different settings. Several attempts and adjustments may be necessary to accurately clear all open space without clearing any vegetation. It is important to precisely clear all the open space and no vegetation to get an accurate measurement.
- H. Once the open space in the photo has been cleared successfully, use the selection to tool to select all the open space that has been cleared, making sure all the white space is selected and none of the stems are selected. The total white space represents the optical porosity.
- I. Use the histogram or equivalent tool to count the number of cleared white "pixels" shown in the histogram window in a corresponding data sheet in a column labeled "blank pixels."
- J. Select the entire cropped photo and use the histogram tool to count the total pixels in the image, then enter this number in the corresponding data sheet in a second column labeled "total pixels"
- K. Dividing the value in the "blank pixels" column by the value in the "total pixels" column in the data sheet gives the optical porosity that can be expressed as a decimal or percent
- L. Save the photo file as a copy to retain the original unprocessed image
- M. Repeat steps "A" through "L" for each of the porosity photos taken at each site. Average all porosity photos together to calculate the final optical porosity value of the snow fence.



Figure 8: Example of a cropped photo in photo editing software

7. Estimate The Snow Trapping Function

Average Annual Snow Transport (Q)

Snow transport (**Q**) can be estimated using the following model from Tabler's (2000) report *Climatologic Analysis for Snow Mitigation in New York State*: $\mathbf{Q} = 1500(0.17)(\mathbf{S_{we,AS}})(1-0.14^{\mathrm{F/3000}})$

Equation 1

Where:

Q is average annual snow transport quantity in units of t/m (metric tons per linear meter) (0.17) is the assumed snow relocation coefficient (C_r) of snowfall (S_r to) is the water equivalent of snowfall over the drift accumulation season in meters.

 $(S_{we,AS})$ is the water equivalent of snowfall over the drift accumulation season in meters ${f F}$ is the fetch distance in meters

The assumed C_r value of 0.17 represents a statewide average provided and described by Tabler (2000) as the recommended value for designing snow fences in New York State when a more precise value is not known or measured for the site in question. A more precise value for the snow fence site can be used for the C_r value if known. Snow transport (**Q**) and snow fence capacity (**Q**_c) are measured in units of t/m, or metric tons of snow water equivalent (SWE) per linear meter of fence

Snowfall water equivalent over the drift accumulation season ($S_{we,AS}$) in the above model (Equation 1) can be estimated using the following model from Tabler (2000):

 $S_{we,AS} = (-695.4 + 0.076*Elev + 17.108*Lat)(0.10)$

Equation 2

Where:

Swe,AS is the water equivalent of snowfall over the drift accumulation season in inches^A Elev is the elevation of the snow fence site in meters Lat is the degrees north latitude of the snow fence site (0.10) is the assumed water equivalent of snowfall in New York State (Tabler 2000)

Note: The output of Equation 2 must be converted from inches into meters to be used in Equation 1.

Note that "snowfall over the drift accumulation season" is different from the total annual snowfall for a location. The former is/includes being delimited by snowfall that does not contribute to the sustained growth of the snow drift around the fence (i.e., snow that falls and melts before the drift achieves sustained growth or snow that falls after the drift has started to permanently melt in the spring). Elevation and latitude values can be measured at the linear center of each fence in Google Earth. The 0.10 value for the water equivalent of snowfall is assumed to be an accurate statewide assumption based on Tabler (2000). If a more precise value at each site is known, it can be substituted for 0.10 in Equation 2.

Snow Storage Capacity (Qc)

Snow storage capacity (Q_c) of the snow fence can be estimated using the observed height and porosity values from each fence and the following model from Tabler (2003):

$$Q_c = (3 + 4P + 44P^2 - 60P^3) H^{2.2}$$

Equation 3

Where:

 Q_c is the snow storage capacity of the fence in units of t/m (metric tons per linear meter) **P** is the observed optical porosity value of the fence **H** is the observed height of the fence in meters

8. Measure the shape and quantity of the snowdrift

The quantity of snow in the snowdrift around a living snow fence can be measured using the following protocol: Snowdrifts can be measured at the end of a drift accumulation season in the late winter or early spring or over the course of a snow season. The quantity and shape of a snow drift around a living snow fence is estimated by probing and measuring the snow depth and density of snow pack around the fence. Four transects that extend upwind and downwind of the fence are established and measurements are taken along each transect (Figure 9). The mean snow depth along the four transects is calculated to determine the average cross-sectional profile of the drift across the length of the fence (Figure 10). Once the cross-sectional profile of the drift has been measured, the

quantity of snow deposition can be estimated by calculating the area of the drift and multiplying the area by the measured snow density.

Appendix A is a worksheet that can be taken out to the field to tally snowdrift measures.



Figure 9: Sampling diagram showing four transects established at equidistant spacing across the 100-meter sampling plot for measuring snow depth and density as described in Step 8.



Figure 10: Diagram illustrating the cross-sectional profile of an equilibrium (full-capacity) snowdrift around a 50 percent porous structural snow fence. (Diagram from Tabler 2003)

Protocol for Establishing Transects and Measuring Snow Depth and Density

- A. At the beginning of the 100 meter sampling plot, establish the first transect on the downwind side of the fence by staking a metric tape measure into the snow at the base of the fence. Suspend the tape above the highest point of snow drift if possible to get the most accurate measurements, or lay the tape on top of the snow surface.
- B. Extend the tape at a perpendicular angle from the fence to the near edge of the roadway, or until the snow depth is negligible. In general, snow depths less than 0.10 meter can be considered negligible.
- C. Use a specialized snow depth probe, or other measuring stick capable measuring snow drift depths, to measure the snow depth at a series of intervals along the transect, such as 1 meter, 2 meters, 3 meters and so on.

The majority of snow deposition and slope of the drift will likely occur in close proximity to the fence. It is, therefore, logical to space measurements closer together while probing in close proximity to the fence, and space measurements more widely as you move away from the fence. For example, measure the depth every one meter over the first 10 meters of the transect, every two meters from 12 through 20 meters of the transect and every five meters thereafter (Table 1). Record each measurement, and the distance from the fence each measurement was recorded at on a spreadsheet, such as the one provided in the Table 1 on the last page of this document. Repeat steps A through B on the upwind of the fence at a perpendicular angle to the fence, in alignment with the downwind transect.

D. Now sample snow density on the upwind side of Transect 1 using a metric federal (mount rose) snow tube. Begin by taking a core of the snow at a distance of one meter upwind by inserting the cutting end of the tube directly down into the snowdrift. Turn the tube one half turn and pull the tube up and examine the bottom of the tube for dirt or grass. There should be some dirt or grass on the end of the tube to indicate that the bottom of the tube reached the ground. Wipe off all dirt and grass from the tube.

- E. Record the depth of the snow core at the distance from the fence that it was sampled.
- F. Weigh the snow core with the mount rose scale and cradle and record the mass of the core plus the tube. Later, when calculations are performed, the percent density of the snow water equivalent is determined by dividing the weight of the snow core (minus the weight of the snow tube) by the snow depth.
- G. Repeat steps D through F at 3-5 locations on the downwind side of the fence and three to five locations on the upwind side of the fence along transect 1. Density measurements can generally be taken less frequently and at larger spacing than depth measurements, such as 1, 3, 5, 10, and 20 meters from the fence (Table 1). Larger drifts with steeper slopes may require more than five density samples on each side of transect 1 to accurately characterize average density of the drift or changes in density at different snow depths. Refer to the National Resources Conservation Services (NRCS) Snow Survey Sampling Guide for more detailed instructions on how to sample snow density using a mount rose tube http://www.wcc.nrcs.usda.gov/factpub/ah169/ah169.htm
- H. Repeat steps A through C to sample the snow depth profile for each of the remaining three transects. Be sure to make the distances from the fence at which measurements are taken as consistent as possible at each transect. For example if you measure snow depth at 1, 3, and 9 meters on transect 1, measure depth at 1, 3 and 9 meters or as close as possible to these intervals on all the other transects.

9. Calculate the shape and water equivalent of the drift

After measuring snow depths and density in the field, calculate the cross-sectional profile of the drift and water equivalent of snow as follows.

Protocol for Calculating the Drift Profile and Quantity of Snow Water Equivalent

- A. Enter the snow depths distances from the fence at which each measurement was taken into a spreadsheet. Calculate the mean depth at each distance from the fence by averaging the four measurements from the four transects at each distance. For example, average the recorded snow depth at 5 meters downwind from the fence on transects 1 through 4 to calculate the mean snow depth across the snow fence 5 meters downwind from the fence.
- B. Create a cross-sectional profile of the drift by inputting the mean depths across the four transects into one column and the distance from the fence in another column, with the upwind distances as negative numbers and the downwind distances as positive number (Table 1). Create a dotted line plot from the two columns with the distance from the fence plotted on the X-axis and snow depth plotted on the Y-axis as shown in Figure 11.
- C. Estimate the cross-sectional area of the drift by overlaying triangles or other geometric shapes for which the sides and areas can be easily calculated as show in Figure 12. In most cases, two right triangles will sufficiently encompass the area of the upwind and downwind drift, based on

standard drift geometry dictated by the aerodynamics and deposition patterns of wind transported snow particles encountering a porous barrier (i.e. snow fence). In some cases, the drift may need to be broken up into smaller sections when overlaying shapes to determine the area, such as irregularly shaped drifts or large drifts in which the density of snow varied substantially across the length of the drift. Alternately, a calculus function can be created to calculate the area under the curve based on the slope of the drift profile.

- D. Calculate the average density of snow in the fence using the snow core data. Calculate the snow water content in each sample by subtracting the known mass of the empty snow tube from the measured mass of the core. Divide the water content by the measured depth of the core to give the snow density at each sampling point. If density varies less than 10 percent across all measurements, all density measurements can be averaged and one value can be used for the mean density value of the entire fence. If the variation is greater than 10 percent, analysis of the fence should be broken down into sections, using the average of two consecutive density measurements along a transect as the average density for the snow area in between those two points.
- E. Once the cross-sectional area and the average snow density of the fence is determined, calculate the snow water equivalent (SWE) of the drift by multiplying the area by the percent density. This will give the square meters of m^2 of snow water equivalent in the drift. If the cross-sectional profile is theoretically expanded to one linear meter of fence, the value of snow water equivalent does not change, but the unit of snow water equivalent becomes cubic meters m^3 . One cubic meter of water has a mass of 1000 kg in mass, or one metric ton. Therefore, the value of cubic meters of snow water equivalent is synonymous with the standard unit of snow fence transport and capacity of t/m (metric tons of snow water equivalent per linear meter of fence). This provides an observed value of snow *deposition* around the fence in units of tons per meter, than compared with the estimated values of snow fence capacity (\mathbf{Q}_c) and average annual snow transport (\mathbf{Q})



Figure 11: Cross-sectional drift profile of a living snow fence created from mean snow depths measured along four transects upwind and downwind of the fence



Figure 12: Simple geometric shapes transposed over the plotted drift profile to estimate the area

Conclusion

The preceding protocols can be followed to conduct a thorough analysis of living snow fences of any age and species. Geographic information systems are useful in the preliminary analysis of living snow fences to: examine aerial photos of the site; measure site characteristics, such as fetch and setback distances; and create site maps that can assist in establishing measurement plots and field data collection. Establishing a sampling plot creates a subsection representing the entire fence that can be more easily sampled. The key variables of fence height (**H**) and optical porosity (**P**) can be accurately sampled through measurements within the sampling plot. These variables can be modeled, along with measurements or assumptions of climatic variables, to estimate the snow-trapping function of fences using the models of Tabler (2000, 2003). Key functional variables are the average annual snow transport at the site (**Q**) and the snow storage capacity of the fence (**Q**_c). Estimates of these models can be validated with empirical data collected on snowdrifts and analyzed with the protocols above. In aggregate these protocols provide a complete methodology for measuring, modeling and validating the structure and function of living snow fences.

References

Tabler, R.D. 2000. *Climatological analysis for snow mitigation in New York State*. Tabler and Associates. Niwot, CO.

Tabler, R.D. 2003. *Controlling blowing and drifting snow with snow fences and road design*. Tabler and Associates. Niwot, CO.

	Transect 1					Transect 2			Transect 3			Transect 4	
	Distance from Fence	Snow Depth	Snow Core Depth	Snow Core Mass		Distance from Fence	Snow Depth		Distance from Fence	Snow Depth		Distance from Fence	Snow Depth
	(m)	(m)	(m)	(kg)		(m)	(m)		(m)	(m)	1	(m)	(m)
	-40					-40			-40			-40	
ow Drift \rightarrow	-35					-35			-35			-35	
	-30					-30			-30			-30	
	-25					-25			-25			-25	
	-20					-20			-20			-20	
	-18					-18			-18			-18	
	-16					-16			-16			-16	
	-14					-14			-14			-14	
	-12				_	-12			-12			-12	
	-10					-10			-10			-10	
	-9					-9			-9			-9	
	-8					-8			-8			-8	
	-7					-7			-7			-7	
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	-5					-5			-5			-5	
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Upwind	-3					-3			-3			-3	
	-2					-2			-2			-2	
	-1					-1			-1			-1	
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	16					16			16			16	
	18					18			18			18	
	20]	20			20			20	
	25]	25			25			25	
	30				1	30			30			30	
	35				1	35			35			35	
	40					40			40			40	
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		Transe			Transect 2		Transect 3		Transect 4		
	Distance from Fence	Snow Depth	Snow Core Depth	Snow Core Mass		Distance from Fence	Snow Depth	Distance from Fence	Snow Depth	Distance from Fence	Snow Depth
	(ft)	(ft)	(ft)	(lb)		(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
	-130					-130		-130		-130	
	-110					-110		-110		-110	
	-90					-90		-90		-90	
	-80					-80		-80		-80	
	-70					-70		-70		-70	
	-60					-60		-60		-60	
	-50					-50		-50		-50	
	-45					-45		-45		-45	
	-40					-40		-40		-40	
	-35					-35		-35		-35	
	-30					-30		-30		-30	
	-25					-25		-25		-25	
	-21					-21		-21		-21	
	-18					-18		-18		-18	
;	-15					-15		-15		-15	
;	-12					-12		-12		-12	
	-9					-9		-9		-9	
	-6					-6		-6		-6	
2	-3					-3		-3		-3	
	3					3		3		3	
	6					6		6		6	
	9					9		9		9	
	12				-	12		12		12	
	15				-	15		15		15	
	18					18		18		18	
	21				-	21		21		21	
	25					25		25		25	
	30		-		-	30		30		30	
	35					35		35		35	
	40					40		40		40	
	45					45		45		45	
	50				-	50		50		50	
	60				1	60		60		60	
	70				1	70		70		70	
	80				1	80		80		80	
	90					90		90		90	
	110				1	110		110		110	
	130					130		130		130	

Note: All English measurements must be converted into metric units before applying snow load equations. It is recommended that all measurements be taken in metric units whenever possible.

Upwind Snow Drift →

Downwind Snow Drift \rightarrow