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Innovation in Transportation

Snow Barrier Effectiveness

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SNOW BARRIER EFFECTIVENESS

Field Guide

by

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PREFACE

This Field Guide is part of the Implementation Plan developed for the Snow Barrier Effectiveness Research Project conducted by the New Mexico Institute of Mining and Technology (New Mexico Tech, NMT) for the New Mexico Department of Transportation (NMDOT) in cooperation with the U.S. Department of Transportation Federal Highway Administration. It aims to assist NMDOT personnel in the design and placement of snow fences, hence reducing snow accumulation on roadways, risks to motorists, and snow plowing costs. This guidebook was developed based on (1) a comprehensive review of the literature addressing the state-of-the-practice, (2) consulting with the Wyoming Department of Transportation Winter Research Team, in particular, Ms. Kathy Ahlenius, (3) field visits in New Mexico and in Wyoming, and (4) the construction and evaluation of snow fences on two test sites.

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This report presents the results of research conducted by the authors and does not necessarily reflect the views of the New Mexico Department of Transportation. This report does not constitute a standard or specification.
ABSTRACT

Although snow fences have been successful in reducing snow drifts and consequently the risks to motorists, New Mexico Department of Transportation (NMDOT) maintenance crew reported that the capacity of these structures has been exceeded at several locations. As a result, snow has accumulated on the roadway at these sites, requiring repeated clearing and significantly increasing plowing costs. The objective of this Field Guide is to assist NMDOT personnel in the design and placement of snow fences. It aims to serve as a practical guide that can be used in field operations. It contains a summary of the factors affecting the effectiveness of snow fences and a recommended procedure for their design. It discusses site identification, data acquisition, fence capacity, location, orientation, and effects on wildlife. Finally, it addresses the required steps to acquire land and the surveys required prior to construction. Readers desiring additional information on these topics are referred to the Final Report generated for this project.
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This research would not have been possible without the assistance and proficiency of Keli Daniell, project manager for this contract and Deirdre Billingsley, contract administrator. The author is very thankful for the help and support received from members of the Technical Panel who carefully reviewed all reports, offered invaluable suggestions, and answered numerous questions: Steve Briggs, Consuelo Chavez, Paul Gray, John McElroy, Elias Sanchez, Chris Vigil, and especially Mark Anaya, Scott Kirksey, and Mary Pacheco.

Thanks are also extended to Ms. Kathy Ahlenius from the Wyoming Department of Transportation (WyDOT) Winter Research Services who gracefully answered our numerous questions, introduced us to the WyDOT Winter Research Program, provided us with various documents essential to the completion of this project, kindly conducted our visit to the WyDOT offices and several snow fences field sites.

Finally, the author would like to acknowledge the involvement of Dr. Andrew Budek-Schmeisser and Mrs. Barbara Budek-Schmeisser in nearly all phases of this project. They were essential members of the research team and this project could not have been completed without their valuable and extensive contribution.
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INTRODUCTION

The purpose of this Field Guide is to provide New Mexico Department of Transportation (NMDOT) maintenance crew a practical guide for the design of snow fences. Recommendations provided herein are a result of the research conducted by the New Mexico Institute of Mining and Technology (NMT) for the NMDOT Research Bureau which included an extensive literature survey of state-of-the-art snow barrier systems, consulting with the Wyoming Department of Transportation Winter Research Team, in particular, Mrs. Kathy Ahlenius, field visits to sites in both New Mexico and Wyoming, and the construction and monitoring of snow fences on two test sites. Because of the successful results of the work conducted in Wyoming by Dr. Ron Tabler for over 40 years, the design procedure recommended in this document relies extensively on the papers and reports he published and especially on the “Snow Fence Guide” he prepared in 1991 for the Strategic Highway Research Program, National Research Council (1). Also noteworthy are the “Guidelines for Controlling Snowdrifting on Canadian Highways” prepared in 1990 by Rowan Williams Davies & Irwin Inc. for the Transportation Development Center Policy and Co-ordination Group of Transport Canada (2).

This Field Guide takes a step-by-step approach to the design and placement of snow fences. It discusses site identification, data acquisition, fence capacity, location, orientation, and effects on wildlife. In addition, it addresses the required steps to acquire land and obtain necessary permits. Finally, it lists surveys required prior to construction. Readers desiring additional information on these topics are referred to the Final Report generated as part of this research project.

MOTIVATION FOR RESEARCH

In northern New Mexico, 4ft (1.22m) vertical slat snow fences are commonly used to help reduce snow drifts on the roadways. Although effective in most places, they were found to reach their capacity and lose their effectiveness at several locations. In some instances, prolonged low temperatures prevented the snow from melting throughout the winter, resulting in excessive snow accumulation by the fence. Because these locations also experienced high volumes of snowfall early in the winter, the fences would often reach their capacity early in the season and snow blown by the wind would continuously accumulate on the road throughout the remaining winter months, requiring constant plowing. In other locations, snow was observed to melt a reasonably short period after the storm, making problems related to snow accumulation on the roadways temporary, but just as worrisome. At these locations, high winds, sustained for long periods of time after snow storms, were responsible for the large volume of snow that accumulated by the fences and often buried the structures, rendering them ineffective.

Because other states and countries have reported the successful use of these structures, a search of the literature was conducted to determine best practices, different types of fences available, existing design methodologies, and factors affecting snow barrier effectiveness. Detailed results of the literature review are presented in the Final Report, while a summary of the factors affecting fence effectiveness is presented herein along with the design methodology considered most effective.
CRITICAL PARAMETERS AFFECTING SNOW FENCE CAPACITY

Snow fences function by reducing the velocity of the wind on the leeward side of the fence, hence reducing its carrying capacity and causing the precipitation of the snow and the formation of a drift close to the fence. Figure 1 illustrates this process where Y denotes the height of the drift, H the height of the fence above the ground cover and X the horizontal distance from the fence. If placed at an adequate distance from the sides of the roads, these fences can be used to protect them from snow accumulation, helping improve road safety and reducing the need, or at least the frequency of plowing. However, if designed or placed incorrectly, they may become buried by the snow and drifts larger than those obtained without the presence of the fences may form on the roads (3).

FIGURE 1 Progressive Formation of Snowdrift by a 12.4ft (3.8m) 50% Porous Horizontal-Board Fence (4)

Research has shown that the main factors affecting the efficiency of snow fences are (in no particular order): (1) height, (2) length, (3) porosity, (4) gap at the bottom of the fence, and (5) placement. The effects of these variables on the capacity of the snow fences are presented below.

Height

The height of the fence is one of the most influential variables in design because of its effect on the fence’s storage capacity. According to Tabler (4), for fences with 50% porosity, the maximum height of the downwind drift will be 1.0 to 1.2 times the height of the fence. As shown in Figure 1, this maximum height is achieved during stage 3 of the snowdrift formation sequence. After the maximum height is achieved, the drift starts to stretch downwind as its relatively sharp slope is filled. At this point, the trapping efficiency of the fence declines and snow deposition from stages 4 to 7 is slow (4).

However, Tabler (4) observed that the airflow over fences shorter than 4.5ft (1.5m) tall, was different than that of the taller structures studied. In fact, he often observed that these short
fences would be partially buried before the drift behind them would cease to grow. As shown in Figure 2, this reduces the fence’s height above the snow cover (effective height), and renders it less effective.

**FIGURE 2 Effect of Partial Burial of a Snow Fence on Drift Formation (5)**

The height of snow fences not only affects the height achieved by the drift, but it is also important when one considers the fact that snow transported by the wind usually travels close to the surface. In fact, for a wind speed of 26mph (41.84km/h), 95% of the snow is transported within the first 4ft (1.22m) above the ground and 99% within 12ft (3.66m), while for 50mph (80.47km/h) winds, 77% of the snow is transported within the first 4ft (1.22m) and 95% within the first 12ft (3.66m) (6). Therefore, where high winds are expected, fences of approximately 12ft (3.66m) would be desirable. Yet, it is important to note that the relationship between snow transport and wind speed is not linear (4).

Finally, because taller fences require less space than multiple rows of smaller fences (7) and because one row of 8ft (2.44m) fence can trap as much snow as five rows of 4ft (1.22m) fence (1, 8, 9), when possible, a single row of tall fences should be used.

**Length**

The length of the fence is also an important design factor because rounding of the drifts occurs near the ends of these structures (Figure 3), reducing their storage capacity (1, 3, 4, 6). Hurlbut (6) recommends that fences be constructed with lengths of at least 30 times the height of the fence, and that they be extended at least a distance of 13 times the height of the fence beyond the
area to be protected to allow for wind direction variations. To compensate for the observed diminished storage capacity near the ends of a barrier compared to more centralized regions of the fence, the USDA Natural Resources Conservation Service (10) requires snow fences to be extended at least 100ft (30.48m) beyond the area to be protected, Tabler (4) recommends an extension of 12 times the height of the fence, and the Iowa Department of Transportation (8, 9) recommends an extension of the ends approximately 30 degrees beyond the desired protection limits to allow for wind variability (Figure 4).

![End Effect](image)

**FIGURE 3 End Effect (11 cited in 5)**

![Snow Fence Ends](image)

**FIGURE 4 Iowa Department of Transportation (8, 9) Recommends that Snow Fences’ Ends Should Extend Approximately 30° beyond the Desired Protection Limits**

**Porosity**

Performance of a snow fence is also affected by the porosity of the fence or the “solidity ratio” which Williams (12) defines as the area actually covered by fencing material divided by the total frontal area of the fence, and gives an idea of the fence’s permeability. A “porosity ratio” has
also been used to measure the permeability of the fence, and has been defined by Hurlbut (6) as the ratio of open area to total fence area.

The effect of the fence’s porosity has been extensively analyzed because it affects the size of the vortices that create the turbulence behind the fence (6). The large vortex produced by solid fences was found to reduce their trapping and storage capacities compared to porous fences which generated small eddies. In the case of solid fences, the snow was initially deposited very close to the fence, eventually burying it and preventing the collection of additional drifting snow (6, 12). The collecting capacity of solid snow fences was found to be approximately one third that of fences with 50% porosity and a bottom gap (3, 6, 13). Although researchers such as Williams (12) and Shelquist (14) have claimed that fences with a porosity ratio of 0.5 would collect the largest volume of drifting snow, Hurlbut (6) believes that the size of the apertures should also be considered. If these openings are too small, they will restrict air movement through the fence which will behave as a solid fence, even if its porosity ratio is 0.5. It is also important to note that the conclusion that fences with a porosity ratio of 0.5 collect the largest amount of snow is not shared by all researchers. Brugnot (15), for example, compared 7 different types of snow fences and observed that the effectiveness of the snow barriers increased with increasing porosity and that the barrier with a porosity ratio of 0.7 (the only one with a porosity ratio larger than 0.5) was the one that accumulated the largest amount of snow. This researcher observed that the change in porosity strongly affected the shape of the drift: increasing porosity resulted in an elongation of the drift, a shortening of its height, and an increase of the amount of snow stocked. These findings agree with research conducted by Tabler (4) presented in Figure 5.

![Figure 5: Effect of Fence Porosity on Shape of Snowdrifts (4)](image)

**FIGURE 5** Effect of Fence Porosity on Shape of Snowdrifts (4)

**Bottom Gap**

Another factor that was found to considerably affect the performance of a snow fence is the gap beneath the structure. Because the bottom gap forces the wind to speed up under the fence, it prevents snow deposition close to the toe of the fence, hence preventing the fence from being
buried in snow (3, 6, 15). This problem seemed more critical in barriers with horizontal slats than in those that used vertical slats (15).

The gap beneath snow fences impacted by wind at a 90° angle was found to control the position of the drift. For instance, if a very small gap or if no gap is present beneath the fence, the drift will form very close to the fence, and often cover the bottom portion of the fence. On the other hand, a larger gap will cause the drift to form further away from the fence. Hurlbut (6) and Tabler (16, cited in 3) recommend a gap of 0.10 (for fences with vertical slats) and 0.15 (for fences with horizontal slats) times the height of the fence. Larger gaps should be used when terrain is sloping downward in the direction of the wind (6).

Finally, Tabler (4) found that the bottom gap was more effective in fences with horizontal slats than those with vertical slats. This is because snow tended to deposit closer to the toe of fences with vertical slats, as shown in Figure 6. In addition, fences with horizontal slats have the advantage of having the space between rails function as a bottom gap in the event that their toe becomes buried.

FIGURE 6 Efficiency of Bottom Gap on Fences with Horizontal Slats vs. Fences with Vertical Slats (4)

Fence Placement

The placement of the fence will also strongly affect its performance. To effectively protect a road or any other area of interest, the length of the drifts relative to the height of the fence should
first be estimated and the fence should evidently be placed no closer to the protected area than this estimated distance. In some instances, this distance will be quite large and a fetch area can be created between the fence and the road. In these cases a row of smaller fences may be placed between the larger fence and the area to be protected. When using multiple rows of fences, care should be taken not to place them too close together for it may cause the burial of adjacent rows.

Recommendations on the distance from the road to the snow fence vary slightly depending on the type of fence used. For Tensar™ fences, a distance of at least 35 times their height is recommended between the road and the fence, while a distance of at least 25 times their height is recommended between rows (6). For plastic fences such as the ones used in Iowa, a distance of 30 times the height of the fence is suggested between the road and the fence, assuming level terrain and absence of trees and buildings (14). These results were confirmed by Brugnot (15) who compared the drifts obtained with 7 different fences made of synthetic material or wood, heights ranging from 5 to 7ft (1.52 to 2.13m), with or without bottom gaps, and also considering different slat orientations (horizontal or vertical). Drift lengths obtained for these structures ranged from 16 to 23 times the height of the fence. Finally, although fences should be placed perpendicular to the prevailing wind direction, Hurlbut (6) observed that departures of up to 20° did not seriously affect their performance. Finally, Tabler (1, 4, 5) concurred with most of these findings, recommending a general setback distance of 35 times the height of the fence for fences with 50% porosity and bottom gap and reporting no serious effect on storage capacity for winds deviating up to 30° from the prevailing wind direction.

It is important to note that snow fences are designed for prevailing wind direction and anticipated snow accumulation and as such, they are expected to be effective most of the time, not all of the time. In the instances where wind direction and/or snow accumulation vary from the norm, they may not only be ineffective in trapping snow, but they may also cause the formation of drifts in unexpected directions. Because snow fences reduce drift formation on the roadways the majority of the time and such occurrences are expected to be rare, their adoption is recommended by the New Mexico Tech research team.
SNOW FENCE DESIGN

Because of the successful results of the work conducted for over 40 years by Dr. Ron Tabler in Wyoming, the design procedure recommended in this document relies extensively on the papers and reports he published and especially on the “Snow Fence Guide” he prepared in 1991 for the Strategic Highway Research Program, National Research Council (1). Figure 7 shows the main steps required for the design of a snow fence. Each step will be addressed in detail in the sections below.

FIGURE 7 Main Steps in the Design of a Snow Fence

SITE IDENTIFICATION

Snow fences are designed to retain blown snow by causing deposition short distances downwind from their bases and forming snow drifts at these locations. Therefore, if properly designed and placed, they can be used in the protection of road sections. The identification of problematic sites that may be improved by the placement of snow fences often simply begins with the recurring observation of snowdrifts in a particular section of a road. Poor visibility and/or loss of traction are also good indicators that a problem exists and may be addressed by the placement of snow fences. Also of interest are areas where existing snow fences are being buried by snow because when this happens, the fences cease to be functional.

Although snow fences can generally be used to solve the problems listed above, they are not always the only or the most effective solution. Therefore, alternative solutions may also be considered. For example, Figures 8 to 12, from a very practical guide to common problems related to snowdrifts prepared for Transport Canada (2), show that drifts created due to the accumulation of snow in the upwind cut region of a roadway cross section can be reduced by the addition of snow fences (living or structural) or by changes to the embankment. Recommendations on modifications to terrain profile to reduce or relocate snow drifts can be found in Tabler (4, 5).

FIGURE 8 Snow Accumulation in Upwind Cut Region of a Roadway Section, Creating a Drift on the Roadway (2)
FIGURE 9 First Possible Solution: Regrading of Backslope to 7:1 or Less to Prevent Snow Accumulation in the Upwind Cut Region (2)

FIGURE 10 Second Possible Solution: Creation of Terraces to Provide Snow Storage Upwind from the Roadway (2)

FIGURE 11 Third Possible Solution: Installation of Snow Fences to Increase Storage Capacity of the System Upwind from the Roadway (2)

FIGURE 12 Fourth Possible Solution: Landscaping – Adding Vegetation to Increase Storage Capacity of the System Upwind from Roadway (2)
Once the site has been identified as a prospective candidate for the placement of snow fences, weather data and a field examination should be conducted to determine the feasibility of this plan and the potential effectiveness of these structures.

DATA ACQUISITION

Meteorological Data

Ideally, historical weather data for the site in question should be collected. It should include prevailing wind direction, wind speed, and snowfall. If such data is not available, at a minimum, prevailing wind direction should be determined on site because it is essential to the proper placement of the snow fence. The improper placement of snow fences can lead to the formation of drifts in unexpected directions and the creation of unnecessary problems.

If prevailing wind direction is to be determined on site, a portable weather station can be used to gather such information, but when not available, wind direction can be determined on site by observing the orientation of snowdrifts. Since weather systems may cause temporary wind shifts, to determine the most common drift orientation, several observations should be made throughout the winter.

Topographical Data

The topography of the surrounding area is also essential to the design of effective snow fences. Terrain profile upwind from the fence will determine the amount of snow that needs to be stored. Also affecting the capacity of the fence are the ground cover and the presence of obstacles such as fences, structures, ditches, etc. Therefore, the first step in this section is to determine the fetch, that is, the length of the open area adjacent to the roadway, from which snow will be picked up and transported to the site. It can be measured on site or on aerial photographs as the distance from the roadway to the nearest physical boundary. Examples of boundaries are: rows of trees, ditches, valleys, large buildings, rows of structures, stream channels, open water, etc (1, 2). Tabler (1) recommends an upper limit of 4mi (6.4km) for the fetch because most of the snow evaporates before traveling such distance.

REQUIRED FENCE CAPACITY

To determine the required fence capacity, one must first estimate the amount of relocated precipitation, that is, the amount of snow (in water equivalent) that is expected to be transported by the wind and reach the snow fence. Because a portion of the snow will melt or harden, not all precipitation will be transported by the wind and reach the fence (4). The relocated precipitation is estimated by subtracting the portion of the snow that is lost to evaporation from the total precipitation (Figure 13). Several factors affect evaporation rate: air temperature, humidity, atmospheric pressure, solar radiation, wind speed, among others. Estimating the annual volume of snow lost to evaporation is therefore a challenging task. For practical purposes, the following
recommendations are made based on experimental work: (1) total precipitation, in water-equivalent, can be approximated by 10% of the average annual snowfall in inches and (2) relocated precipitation can be conservatively assumed to be 70% of that value (I).

![Figure 13 Illustration of the Concept of Snow Transport (I)](image1)

**FIGURE 13 Illustration of the Concept of Snow Transport (I)**

Once the fetch and the relocated precipitation have been determined, Figure 14 can be used to obtain the total seasonal snow transport. If this value is considered to be the required storage capacity of the fence, that is, if it is assumed that snow stored by the fence will not melt throughout the winter, Figure 15 can be used to determine the required fence height. Although multiple rows of shorter snow fences could also provide the required storage capacity, because the relationship between fence height and storage capacity is nonlinear, a very large number of rows may be required in most instances. For example, 5 rows of 4ft (1.22m) fence are required to provide the same storage capacity as 1 row of 8ft (2.44m) fence. Additional advantages of taller fences are improved driver visibility, less land requirements, and reduced costs (I).

![Figure 14 Total Seasonal Snow Transport as a Function of Fetch and Relocated Precipitation (I)](image2)

**FIGURE 14 Total Seasonal Snow Transport as a Function of Fetch and Relocated Precipitation (I)**
Although several types of snow fence are available, the New Mexico Tech research team recommends the use of polymer fences with horizontal rails, approximately 50% porosity and a bottom gap of 15% of the height of the fence. While these structures have shown to have a higher initial cost, their installation is relatively simple and their maintenance cost is very low. If initial costs for these fences render their use prohibitive, wood fences should be selected. Living fences are not recommended because of the large number of sites not conducive for tree planting in New Mexico, as well as the long period of time required for trees to mature and the fence to become fully functional.

**SNOW FENCE LOCATION AND ORIENTATION**

Ideally, snow fences should be placed perpendicular to the prevailing wind direction. However, little change in capacity was observed with angles of attack ranging between 55° and 90° (4), where the angle of attack is defined as the angle the prevailing wind direction makes with the road. Therefore, for these cases, the fence should be placed parallel to road, as shown in Figure 16. To account for wind direction fluctuations, snow fences should extend beyond the area to be protected. Tabler (5) recommends that they be designed to intercept winds that deviate 30° from the prevailing wind direction, as illustrated in Figure 16. For angles of attack smaller than 55°, fences should be placed perpendicular to the wind direction, as shown in Figure 17.
FIGURE 16 Angle of Attack and Recommended Fence Extension Beyond Road Section to be Protected (Adapted from illustrations in (5))

FIGURE 17 Placement of Oblique Snow Fences Recommended for Attack Angles Smaller than 55° (Adapted from illustrations in (1) and (5))
Fences with 50% porosity on flat terrain should be placed a distance equal to at least 35 times the height of the fence from the edge of the road. Because this distance corresponds to the expected length of the drift when fence capacity is reached, it should be measured along the prevailing wind direction instead of perpendicular to the road. However, if wind direction is expected to fluctuate, the worst case scenario should be considered, which, in the set-up presented in Figure 16, would be to measure the setback distance perpendicular to the road. For fences of different porosity, the following equation can be used to determine the minimum setback distance ($D_{min}$):

$$D_{min} = (\sin \alpha)(12 + 49P + 7P^2 - 37P^3)H$$

where $D_{min}$ is the minimum setback distance, $\alpha$ is the attack angle, $P$ is the fence porosity, and $H$ is the fence height. Because required setback distance may not always be available, denser fences, that is, fences with porosity lower than the recommended 50% may be selected. However, with the reduction in drift length shown in Figure 5 also comes a reduced storage capacity, and hence a less effective system.

Topography also has a serious effect on drift shape and size. The estimated length (35 times the height of the fence) and height (1.0 to 1.2 times the height of the fence) of the drifts recommended above are valid for fences placed on level terrains, that is, where the slope is less than 15°. Fences placed on a ridge or in areas upwind of a depression will provide additional storage because their drifts will not only be higher, but also more elongated (Figure 18). Drifts of fences placed on sloping terrain will also have their shape and size affected by the terrain. According to Tabler (4), for downward slopes (steeper than 15%), more snow will accumulate on the upwind side of the fence, leading to burial of the fence. The drift on the downwind side of the fence will be elongated, as shown in Figure 18. Fences placed on upward slopes greater than 15% will cause the formation of shorter and shallower drifts on the downwind side of the fence and little or no snow accumulation on the upwind side of the fence.
FIGURE 18 Influence of Topography on the Shapes of Drifts (*11 cited in 4 and 5*)
EFFECT OF SNOW FENCE ON LIVESTOCK OR WILDLIFE

To allow for the passage of wildlife, the Wyoming Department of Transportation provides openings in the snow fences every 660ft (201m). However, Ronald Tabler has shown his disapproval for such practice due to the reduced effectiveness of the fences at these locations, as illustrated in Figure 19 (1, 4). To accommodate landowners and wildlife officials’ requests for openings to allow the passage of livestock or wildlife, three configurations were proposed in Tabler (4) and are presented in Figure 20. The first type of opening (Type A), which is also the preferred type, consists in overlapping two lines of fences. While it provides continuous coverage along the entire length of the roadway, the opening does not allow for vehicular traffic during the winter months. If the opening through the fence must be kept free of snow to allow the passage of vehicles year round, Tabler (4) presents two solutions: Types B and C in Figure 20. Type B only offers off-road access through the narrow openings (16ft or 5m) that are left between snow fence panels. Because the opening is quite narrow, the wind passing through it will accelerate and scour a path through the drift. Type C is recommended for roads that intersect the snow fence and must be kept open year-round. For these locations, the snow fence should be set a distance of 5H (where H is the height of the fence) from either side of the shoulders of the intersecting road.

FIGURE 19 Model of a 6ft Wyoming Fence Demonstrating Reduced Effectiveness at the Location of the 6in (15cm) Gaps between Panels (4)

In New Mexico, landowners and ranchers have contacted NMDOT personnel and expressed their need for periodic access through snow fences with 4 wheelers or pickup trucks. For this reason, the Department of Transportation has been using Type A access configuration (Figure 20) with a width of 10 to 12ft (3 to 3.7m) and 12ft (3.7m) overlap. Each fence section has been no longer than 1320ft (402.3m), and to accommodate the overlap, they have been angled so that the distance from the fence to the pavement is 12ft (3.7m) further at the end of the fence than at the
beginning of the structure. Since this procedure has accommodated landowners’ needs while keeping the fences functioning without interruption, it should be continued as new fences are designed and installed. However, if vehicular access must be ensured throughout the winter, Type A configuration cannot guarantee that the overlapping region will be kept entirely free of snow, especially if fences 8ft (2.4m) or taller are used. In these cases, it is advisable to place openings as far apart as possible and use configuration Type B, even though it will create an unprotected section on the roadway.

![Diagram of fence configurations](image)

**FIGURE 20 Configurations for Access through Snow Fences Panels (4)**

Unfortunately, no studies have been found on the effects of structural snow fences on wildlife behavior or migration patterns. However, several documents have been published on the effect of wildlife exclusion fences (also known as deer fences) on the reduction of accidents involving vehicles and animals (21, 22, 23, 24). In addition, in one of these documents, wildlife officers of the Colorado Division of Wildlife Officers mention that they do not believe that the fences are adversely affecting deer and elk in the area. One of them even mentions that these animals do not need access to open water because they can obtain it from snow and aliments (24). Therefore, because, like the wildlife exclusion fences, 8ft (2.4m) or higher snow fences will prevent the passage of larger animals, similar conclusions can be drawn. In fact, the most commonly used height for exclusion fences is 6 to 7ft (1.8 to 2.1m), although barriers as high as 15ft (4.6m) are also available (25, 26, 27). This is because reports show that although deer are capable of jumping as high as 15ft (4.6m), they do not usually do so unless threatened (25, 26).
For this reason, the NMT research team believes that the placement of 8ft (2.4m) or higher snow fences along the study sections will probably lead to a reduction in accidents involving elk or deer. However, there is a chance that these types of accidents become clustered at the ends of the fences. If that is the case, the construction of wildlife underpasses or the installation of animal-triggered alarms may be necessary at these locations. It is also important to note that the gap at the bottom of the fence may allow the passage of some species of deer. Falk et al. (28), Palmer et al. (29), and Feldhamer et al. (30) cited in VerCauteren et al. (31) reported that adult white-tailed deer were able to crawl through gaps of 10in (25cm), while Ward (32), also cited in VerCauteren et al. (31), found that mule deer manage to pass through gaps of only 6in (15cm). Since Tabler (1) recommends a bottom gap of 10 to 12% the height of the snow fence, measured from the top of the existing vegetation or the anticipated snow cover, an 8ft (2.4m) fence would require a gap of 9.6 to 11.5in (24 to 29cm), which, according to the studies mentioned above, could allow the passage of certain deer species.

While environmental impact analyses are necessary to clearly define the impacts of the snow fences on the animals inhabiting each of the sites, general preliminary conclusions can be drawn based on the studies cited above: (1) larger animals such as elk, and deer probably will not be seriously affected by the fences since, according to a wildlife officer of the Colorado Division of Wildlife Officers (24), they do not need access to open water, (2) smaller animals such as coyotes and foxes will probably not be affected either since they will be able to pass under the fences. However, if providing wildlife with open water access is desired, snow fences strategically placed may also be used to improve or even create water supplies (33).

Finally, to determine the effects of the snow fences on migration patterns of larger animals inhabiting the two study sites, environmental impact analyses would be necessary. In fact, researchers have reported that exclusion fences can hinder, not only migration of such animals, but also their daily movements (34 and 35 cited in 31).
LAND ACQUISITION

Even though snow fences have been shown to improve public safety by effectively reducing drift formation on the roadways the majority of the time, landowners’ opposition to the placement of these structures on their land is not uncommon. In these cases, the best approach is to seek landowners’ endorsement by stressing the additional advantages of these structures: shelter and shade for cattle and wildlife and increased watering of rangeland for cattle feed due to the accumulated snow.

After snow fences have been selected as the best solution for a problematic site and their design has been completed, the following steps should be taken for acquiring the land necessary for their placement:

1. Determine the area necessary for construction of the fences and for access and maintenance of the structures. Because construction of the barriers requires the use of a larger area than their general maintenance, an agreement could be made to grant temporary access to a predetermined area for storing construction material and maneuvering vehicles, while a smaller, more permanent easement could be obtained for maintenance purposes. The latter would include access from the roadway to the fences as well as a small area surrounding the structures to give maintenance crew enough room to work.

2. Contact the Right-of-Way Bureau Chief requesting a Title Report.

3. Contact the Right-of-Way Bureau and provide:
   a. Detailed information on the snow fences to be constructed,
   b. Maps showing the location of the proposed fences and easements required,
   c. Title of the land,
   d. Final maps and legal descriptions or Plats,
   e. Appraisal of the land.

A meeting will be set up with the landowner or lessee to discuss the possibility of an agreement. Details of the process are presented in the Right-of-Way Handbook available online at the NMDOT website (http://dot.state.nm.us/Infrastructure/ROW_Handbook.pdf)
DESIGN EXAMPLE – CLINES CORNERS REGION

SITE IDENTIFICATION

The site selected in the Clines Corners region is located on US 285, less than a mile south of the I-40 intersection, as indicated on Figure 21. It was selected as a test site for this project due to the recurring problems with snow drifts on the road observed by NMDOT personnel.

DATA ACQUISITION

Meteorological Data

Because weather conditions are essential in determining snow fence dimensions and placement, they should be as specific to the site as possible; the presence of microclimates caused by changes in the terrain and in land use may significantly affect snow transport, deposition, and accumulation. Historical weather data for the region of Clines Corners was obtained from three different sources. Data presented in Table 1 was obtained from World Climate (18) and represents the average temperatures and monthly precipitation over the following years: 1971 to 2000. Average wind speeds are shown in Table 2 and are based on data collected by the Western Regional Climate Center of the Desert Research Institute, Nevada System of Higher Education (19) from 1996 to 2006.

FIGURE 21 Study Site - Clines Corners Region
TABLE 1 Average Temperature and Monthly Precipitation for the Clines Corners Region (18) Conversion: 1in = 2.54cm; °F = 1.8 °C + 32.

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The most comprehensive data set was obtained from MesoWest (20), which is a partnership between researchers from the Atmospheric Sciences Department of the University of Utah, and forecasters from the Salt Lake City National Weather Service Office, the National Weather Service Western Region Headquarters, as well as from other agencies, commercial firms and universities. Records obtained for the Clines Corners region only range from 2007 to 2010, but include maximum and minimum temperatures, relative humidity, total precipitation (rain and/or melted snow), wind speed, wind direction, and wind gusts, all measured several times a day. A summary of the data is presented in Table 3. This data was also used to create histograms for wind speed (Figures 22 and 23) and wind direction (Figure 24), so that prevailing conditions could be observed. From these figures, it can be concluded that predominant winds are around 10 to 12mi/h (16.09 to 19.31km/h), that the 85th percentile is approximately 20mi/h (32.19km/h), while the 95th percentile is approximately 27mi/h (43.45km/h). With respect to wind direction, it can be seen that winds of approximately 300°, that is, northwest winds, predominate. In addition, it is important to note that east winds of approximately 87 to 90° also occur frequently.

**Topographical Data**

The land in the study area was observed to be gently rolling, with very low vegetation, consisting mainly of grass on both sides of the road. The existing snow fences were made of vertical wood slats and were approximately 4ft (1.22m) tall. They had no gap at the bottom and a porosity of approximately 60%. The distance from the fences to the edge of the pavement was approximately 56ft (17.07m). As mentioned previously, short fences tend to behave a little differently than their taller counterpart, becoming partially buried before the drift behind them ceases to grow (4). Nonetheless, a distance of approximately 35 times the height of the fence is in general desired for storage of a downwind drift. Therefore, the fences were found to be too
close to the road, not providing enough storage area for optimal performance. Figure 25 depicts the region investigated with and without snow cover.

**TABLE 3 Summary of Historical Data from MesoWest (20).**

Conversion: 1\text{ln} = 2.54\text{cm}; \ 1\text{°F} = 1.8 \ \text{°C} + 32; \ 1\text{mi/h} = 1.61\text{km/h}

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<td>15.02</td>
<td>42.58</td>
<td>54.09</td>
</tr>
</tbody>
</table>
FIGURE 22 Histograms Showing Frequency and Cumulative Frequency of Wind Speed in the Clines Corners Region from 2007 to 2009. (1mi/h = 1.61km/h).
FIGURE 23 Histograms Showing Frequency and Cumulative Frequency of Wind Speed in the Clines Corners Region from January 2010 to March 2010. (1mi/h = 1.61km/h).

FIGURE 24 Histograms Showing Frequency and Cumulative Frequency of Wind Direction in the Clines Corners Region from 2007 to 2010. (1mi/h = 1.61km/h).
Snow transport should first be estimated based on the size of the fetch. Aerial photograph of the site considered was used to determine the length of the fetch. Figure 26 depicts the fetch measured along the prevailing wind direction, which in this area is at most 16000ft (4877m).

The next step requires the determination of the relocated precipitation, which is generally taken as 70% of the water-equivalent precipitation over the entire season, a value considered conservative for design purposes. Considering average temperatures as well as average high and average low temperatures for the Clines Corners region, it was assumed that all precipitation from November to March was snow, giving a total of 4.15in (10.5cm) of water-equivalent precipitation for the season. Therefore, the relocated precipitation for this area was initially determined as 2.91 in (7.4cm). However, this value was considered to be too conservative because temperatures at Clines Corners during the winter months usually allow for the melting of some or all of the snow that accumulates in the region. A total precipitation of 2in (5cm) of water-equivalent, corresponding to roughly the total precipitation in two consecutive winter months, was deemed more reasonable. Thus, the resulting relocated precipitation was estimated at 1.4in (3.6cm).

Seasonal snow transport is then determined based on the relocated precipitation and the length of the fetch (Figure 14). For Clines Corners, if no snow were to melt between November and March, the relocated precipitation would be 2.91in (7.4cm) and with a fetch of approximately16000ft (4877m), the seasonal snow transport would be approximately 35ton/ft (104t/m). However, as mentioned previously, a relocated precipitation of 1.4 in (3.6cm) was considered to be a more realistic value. With fetches of no more than 16000ft (4877m), the seasonal snow transport would be approximately 18tons/ft (54t/m).

The required fence height is determined using Figure 15 and the amount of snow transport determined previously. For the study site, if no snowmelt is assumed between November and
March (seasonal snow transport of 35ton/ft or 104t/m), a 10ft snow fence would be necessary. However, if snow is assumed to melt throughout the winter, an 8ft fence would be sufficient for that site.

**SNOW FENCE LOCATION AND ORIENTATION**

Because the prevailing for the study site was determined to be 300° (northwest winds), the angle of attack is 60°. Therefore, the fence should be placed parallel to the road. The setback distance should be 35 times the height of the fence, that is, 280ft (85.3m) if the 8ft (2.4m) fence is selected or 350ft (106.7m) if the 10ft (3m) fence is used.

**FIGURE 26** Fetch on the Proposed Study Site in the Clines Corners Region Measured in the Northwest-Southeast Direction
REFERENCES


(8) Iowa Department of Transportation. Iowa's Cooperative Snow Fence Program. Des Moines, Iowa. 2002.

(9) Iowa Department of Transportation. Iowa's Cooperative Snow Fence Program. Des Moines, Iowa. 2005.


