Outline

- **Introduction**
- **Objective**
- **Project Tasks**
  - Task 1 – Literature Review and State of Practice
  - Task 2 – Field Evaluation
  - Task 3 – Development of Methodology for Legal and Safety Issues
  - Task 4 – Analysis Method for Determination of Critical Site Parameters
  - Task 5 – Effect of Level of Service and Cost/Benefit Analysis
  - Task 6 – Match Analysis Methodology
  - Task 7 – Construction of Snow Barriers for Evaluation
  - Task 8 – Evaluation of Barrier Performance at Test Sites
  - Task 9 – Implementation Plan
  - Task 10 – Research Reports
- **Conclusions**
- **Acknowledgments**
Snow fences are used to reduce the velocity of the wind on the leeward side of the fence, causing the precipitation of the snow and the formation of a drift close to the fence.
Motivation for the Research

New Mexico Department of Transportation (NMDOT) Maintenance Crew has reported that, although effective in most places, 4ft vertical slat snow fences are reaching their capacity and losing their effectiveness at several locations.

To prevent snow accumulation on the roadway at these locations, crews are required to repeatedly clear these sites, significantly increasing maintenance costs.
The objective of this research project is to provide the NMDOT with recommendations for appropriate snow barrier technology to mitigate problems associated with accumulation of snow along the Department’s roadways.
Project Tasks

1. Literature Review and State of Practice
2. Field Evaluation
3. Development of Methodology for Legal and Safety
4. Analysis Method for Determination of Critical Site Parameters
5. Effect of Level of Service and Cost/Benefit Analyses
6. Match Analysis Methodology
7. Construction of Snow Barriers for Evaluation
8. Evaluation of Barrier Performance at Test Sites
9. Implementation Plan
10. Research Reports
The objective of this task was to perform a comprehensive literature search and state-of-the-practice survey to assess and ascertain best practices for addressing the problem of traffic hazards presented by snow accumulation along the right-of-way.

This task should include:

- a compilation of published research in snow barrier technology
- research into criteria affecting snow barrier design
- a phone survey of state Departments of Transportation with similar environmental conditions
Common Types of Snow Fence

- **Wyoming Barrier**
- **Vertical Wood Fences**
- **Living Snow Fences**
- **Polymer Fences**

Claudia Wilson

Winter Research

Barbara Budek-Schmeisser
Factors Affecting Snow Fence Capacity

- **Height**
  - Higher fences have a higher capacity (although relationship is not linear)
- **Porosity**
  - Ideally 50%
  - Influences shape and length of drift
- **Bottom Gap**
  - Approximately 10% of total height
  - Prevents burying of the fence

Efficiency of Bottom Gap on Fences with Horizontal Slats vs. Fences with Vertical Slats (Tabler 2003)
More Factors Affecting Snow Fence Capacity

- **Placement**
  - Perpendicular to prevailing wind
  - Place fence approximately 35H from roadway
- **Length**
  - Extend fence 12H on each end to account for end-effect

(End Effect) Tabler 2003
## Phone Survey

<table>
<thead>
<tr>
<th>State</th>
<th>Fences Used</th>
<th>Living Fences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iowa</td>
<td>Vertical lath fences</td>
<td>Corn rows and soybeans</td>
</tr>
<tr>
<td>Idaho</td>
<td>Plastic horizontal rail fences</td>
<td>Do not like them</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Plastic horizontal rail fences</td>
<td>Extensively used</td>
</tr>
<tr>
<td>Montana</td>
<td>- Wyoming fences&lt;br&gt;- Plastic rail fences&lt;br&gt;- Wyoming fences with fiber reinforced polymer (FRP) rails</td>
<td>Trees and shrubs</td>
</tr>
<tr>
<td>South Dakota</td>
<td>- Temporary rollout fences&lt;br&gt;- Wyoming fences</td>
<td>Pleased with results for over 20 years</td>
</tr>
<tr>
<td>Wyoming</td>
<td>- Wyoming fences&lt;br&gt;- Plastic rail fences&lt;br&gt;- Wooden rail fences&lt;br&gt;- Wood lath fences</td>
<td>Used</td>
</tr>
<tr>
<td>Utah</td>
<td>- Wyoming fences&lt;br&gt;- Plastic horizontal rail fences&lt;br&gt;- Metal horizontal rail fences (old guardrails)</td>
<td>Sage, rabbitbush, and one ridgetop location with trees as a test</td>
</tr>
</tbody>
</table>
Project Tasks

- Task 1: Literature Review and State of Practice
- Task 2: Field Evaluation
- Task 3: Development of Methodology for Legal and Safety
- Task 4: Analysis Method for Determination of Critical Site Parameters
- Task 5: Effect of Level of Service and Cost/Benefit Analyses
- Task 6: Match Analysis Methodology
- Task 7: Construction of Snow Barriers for Evaluation
- Task 8: Evaluation of Barrier Performance at Test Sites
- Task 9: Implementation Plan
- Task 10: Research Reports
Field Evaluation

The objective of this task was to visit the sites selected by the Technical Panel to document existing snow barriers and to evaluate their effectiveness.

- Two test sites were selected by members of the Technical Panel: one in the Clines Corners area and one in the Eagle Nest area.
- Site visits were conducted in the summer of 2009 to evaluate site conditions.
- The sites were visited again in the winter of 2009-2010 to:
  - assess the performance of the existing snow fences
  - understand the magnitude of the problems encountered
  - become familiar with the sites under wintery conditions
Summer Visit to Clines Corners Site

Test Site is located on US 285, less than a mile south of the I-40 intersection.

It was selected due to the recurring problems with snow drifts on the road.

Northwest view of test site and existing 4ft snow fence

July 23, 2009
Winter Visit to Clines Corners Site

Southwest view of snow drift along existing fence on US285

January 31, 2010
Test Site is located on US Hwy 64, immediately across from the Mountain View Cabins located at 28386 US Hwy 64.

West view of test site. Existing 4ft snow fence and right-of-way fence

July 30, 2009
Winter Visit to Eagle Nest Site

Snow drift and snow walls created by NMDOT Maintenance Crew to increase storage capacity of existing snow fences

January 29, 2010
Project Tasks

**Task 1**  Literature Review and State of Practice

**Task 2**  Field Evaluation

**Task 3**  Development of Methodology for Legal and Safety

**Task 4**  Analysis Method for Determination of Critical Site Parameters

**Task 5**  Effect of Level of Service and Cost/Benefit Analyses

**Task 6**  Match Analysis Methodology

**Task 7**  Construction of Snow Barriers for Evaluation

**Task 8**  Evaluation of Barrier Performance at Test Sites

**Task 9**  Implementation Plan

**Task 10**  Research Reports
The objective of this task was to research and document legal precedent for the placement of safety structures such as snow fences on private land.

Although extreme measures such as easement condemnation should be avoided, precedent for such action is also to be investigated.

Because snow fences have been shown to improve public safety by effectively reduce drift formation on the roadways the majority of the time, their adoption is highly recommended by the research team.
Opposition to the placement of snow fences on private land is not uncommon.

In these cases, landowners’ cooperation is sought by showcasing the benefits of the structures:

- Improved traffic safety
- Shade for cattle and wildlife during summer
- Shelter for cattle and wildlife during winter
- Melting of trapped snow assists with the watering of rangeland

Minnesota is the only state that has had to resort to condemning land for the construction of snow fences (State of Minnesota v. David Dorow et al).

Most states contacted during the phone survey avoided the use of eminent domain.

A special application of eminent domain relates to the condemnation of easements which considers land use instead of land ownership.
• Snow fences often need to be placed on private land.
• Because NMDOT personnel need access to the fence easements have been granted: landowner receives compensation and retains the title of the land, while NMDOT personnel are granted permission to work in a specified area of the property.
• This agreement is often reached once the landowner understands the advantages of the snow fences to public safety, with the added bonus of providing shade and shelter for cattle, and increasing snow storage and hence soil moisture for the growth of forage for livestock.
Placing Snow Fences on Private Land

- Determine area needed for construction and maintenance of the structures
- Contact the Right-of-Way Bureau Chief requesting a Title Report
- Contact the Right-of-Way Bureau and provide:
  - Information on snow fences to be constructed,
  - Maps with proposed location of fences and easements,
  - Title of the land,
  - Final maps and legal descriptions,
  - Appraisal of the land.
- A meeting will be set up with the landowner or lessee to discuss the possibility of an agreement.

Details in Right-of-Way Handbook:
http://dot.state.nm.us/Infrastructure/ROW_Handbook.pdf
Project Tasks

1. Literature Review and State of Practice
2. Field Evaluation
3. Development of Methodology for Legal and Safety
4. Analysis Method for Determination of Critical Site Parameters
5. Effect of Level of Service and Cost/Benefit Analyses
6. Match Analysis Methodology
7. Construction of Snow Barriers for Evaluation
8. Evaluation of Barrier Performance at Test Sites
9. Implementation Plan
10. Research Reports
The goal of this task was to examine and prioritize site parameters that influence the selection of snow barriers.

Since snow fences can only capture snow blown by the wind, only sites that with a fetch upwind of the problematic road section should be considered.
Critical Site Parameters

The following parameters can be used to prioritize the candidate sites:

- accident records for previous 5 years;
- road closure history for previous 5 years;
- plowing records for previous 5 years;
- route’s importance to the region;
- average daily traffic (ADT).

Priority should be given based on the seriousness of the problem, that is, number and severity of accidents, frequency and duration of road closures, and extent of plowing requirements, while considering the importance of the roadway to the region and the ADT in the area.
Snow Fence Selection

Parameters dictating snow fences’ effectiveness include:
- height
- orientation
- placement
- porosity
- length
- bottom gap

The New Mexico Tech Research Team recommends polymer fences with horizontal rails, 50% porosity and bottom gap of 15% of the fence height.

If initial costs for these fences render their use prohibitive, wood fences with horizontal rails, 50% porosity and bottom gap of 15% of the fence height 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.
Project Tasks

**Task 1**: Literature Review and State of Practice

**Task 2**: Field Evaluation

**Task 3**: Development of Methodology for Legal and Safety

**Task 4**: Analysis Method for Determination of Critical Site Parameters

**Task 5**: Effect of Level of Service and Cost/Benefit Analyses

**Task 6**: Match Analysis Methodology

**Task 7**: Construction of Snow Barriers for Evaluation

**Task 8**: Evaluation of Barrier Performance at Test Sites

**Task 9**: Implementation Plan

**Task 10**: Research Reports
Task 5 aims to investigate:

- the effect of level of service on snow barrier efficiency
- costs and benefits of snow fences
Effect of Level of Service

• Intuitively: the larger the volume of vehicles and the higher their speed, the larger the amount of drifted snow dissipated.

• To accurately determine the effects of level of service on snow barrier performance, field experiments would have to be conducted. At this time, these experiments are cost-prohibitive.

• The author believes that even if the amount of snow dissipated by traffic could be quantified and related to a certain level of service, these values should NOT be used in design because levels of service vary significantly within a 24-hour period.
# Installation and Maintenance Costs

To allow for comparison, costs reported were converted to present value (October 2011) using historical cost indices provided by RS Means.

<table>
<thead>
<tr>
<th>Snow Fence Type</th>
<th>Height (ft)</th>
<th>Initial Cost/ft ($)</th>
<th>Service Life (years)</th>
<th>Maintenance</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyoming fences (wood)</td>
<td>6</td>
<td>29.08</td>
<td></td>
<td></td>
<td>Tabler and Furnish (1982)</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>35.65</td>
<td></td>
<td></td>
<td>Tabler and Furnish (1982)</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>17.92</td>
<td>25</td>
<td></td>
<td>Jairell and Schmidt (1991)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>41.54</td>
<td></td>
<td></td>
<td>Tabler and Furnish (1982)</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>53.48</td>
<td></td>
<td></td>
<td>Tabler and Furnish (1982)</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>19.35*</td>
<td>20-25</td>
<td>Maintenance costs are estimated at $6428.40/mi/year.</td>
<td>Laramie County Conservation District</td>
</tr>
<tr>
<td>6 - 14</td>
<td></td>
<td></td>
<td></td>
<td>Annual maintenance costs are estimated at 5% of the initial cost.</td>
<td>Tabler and Meena (2006)</td>
</tr>
<tr>
<td>10</td>
<td>18.90**</td>
<td></td>
<td></td>
<td>Very labor intensive and required on an yearly. Example: 3 months were required for a crew of 3 to 4 men to check anchors, tighten bolts and repair fences on a 13-mi stretch of roadway.</td>
<td>Alhenius, pers. com. (2010)</td>
</tr>
</tbody>
</table>

* Year in which cost was incurred is not known
** Bid price – does not include additional costs due to change orders
## Installation and Maintenance Costs (cont.)

To allow for comparison, costs reported were converted to present value (October 2011) using historical cost indices provided by RS Means.

<table>
<thead>
<tr>
<th>Snow Fence Type</th>
<th>Height (ft)</th>
<th>Initial Cost/ft ($)</th>
<th>Service Life (years)</th>
<th>Maintenance</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical wood</td>
<td>10</td>
<td>29.38**</td>
<td></td>
<td>Annual maintenance is required and includes checking of the anchors, tightening of the bolts, and repairs in general.</td>
<td>Alhenius, pers. com. (2010)</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>46.05**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>15.87</td>
<td></td>
<td>Maintenance costs in a 40-mi road stretch in the state of Washington are estimated at $5,000/mi/year.</td>
<td>Schroeder (2010)</td>
</tr>
<tr>
<td>Polymer</td>
<td></td>
<td>60.49**</td>
<td></td>
<td>Require very little maintenance. These structures have been in place for 3 years and so far only tightening of the straps have been necessary. Tightening of the bolts is anticipated in the future.</td>
<td>Alhenius, pers. com. (2010)</td>
</tr>
<tr>
<td>Vertical lath fences</td>
<td>4</td>
<td>2.01**</td>
<td></td>
<td></td>
<td>Alhenius, pers. com. (2010)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5 – 7</td>
<td></td>
<td></td>
<td>USDA (1999)</td>
</tr>
<tr>
<td>Living fences</td>
<td>3 rows</td>
<td>4.36*</td>
<td>50-75</td>
<td>Maintenance costs are estimated at $1029.60/mi/year.</td>
<td>Laramie County Conservation District</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maintenance costs are expected to be very low and consist of only weed control and replanting during the first few years.</td>
<td>Schroeder (2010)</td>
</tr>
</tbody>
</table>

* Year in which cost was incurred is not known

** Bid price – does not include additional costs due to change orders
Benefits

Reports on the benefits of snow fences varied, but fell into three categories: savings in snow removal costs, reduction in crash rates and road closures.

Tabler (1997 in Josiah and Majeski 2009) reported that savings from snow removal alone yielded benefit/cost ratios ranging from 9:1 to 46:1.

Tabler (1991) reported more than $\frac{1}{3}$ reduction in plowing costs. Plowing costs were estimated 100 times higher than snow fence installation costs.

Tabler and Furnish (1982) showed that:

- snow fences reduced costs of snow and ice removal by at least a third
- snow fences did not affect road closures because these can occur even if poor visibility is observed in only a small unprotected section of the highway
- highways need to be completely protected by snow fences before reductions in road closure time are observed.

Tabler and Meena (2006) observed a reduction in road closure by an average of 8 days per year, with 73% of the roadway protected by snow fences. Crash rates were also assessed over the 34-year life of the structures and a decrease in the frequency of accidents was observed.
Project Tasks

Task 1: Literature Review and State of Practice
Task 2: Field Evaluation
Task 3: Development of Methodology for Legal and Safety
Task 4: Analysis Method for Determination of Critical Site Parameters
Task 5: Effect of Level of Service and Cost/Benefit Analyses
Task 6: Match Analysis Methodology
Task 7: Construction of Snow Barriers for Evaluation
Task 8: Evaluation of Barrier Performance at Test Sites
Task 9: Implementation Plan
Task 10: Research Reports
Task 6 consisted in the development of a match analysis methodology to be presented in a Field Guide that provides NMDOT Maintenance crew a practical guide for the design of snow barriers.
The Field Guide developed includes:

- an introduction to snow fences’ operation
- factors affecting their performance
- a step-by-step approach to their design and placement
- effects of snow fences on livestock and wildlife
- required steps for land acquisition

The design process is broken down into four main steps:

Site Identification ➔ Data Acquisition ➔ Required Fence Capacity ➔ Snow Fence Location and Orientation

Because of the successful results of the work conducted for over 40 years by Dr. Ron Tabler in Wyoming, the design procedure recommended in the Field Guide relies extensively on the papers and reports he published.
Project Tasks

Task 1: Literature Review and State of Practice
Task 2: Field Evaluation
Task 3: Development of Methodology for Legal and Safety
Task 4: Analysis Method for Determination of Critical Site Parameters
Task 5: Effect of Level of Service and Cost/Benefit Analyses
Task 6: Match Analysis Methodology
Task 7: Construction of Snow Barriers for Evaluation
Task 8: Evaluation of Barrier Performance at Test Sites
Task 9: Implementation Plan
Task 10: Research Reports
The objective of Task 7 was to use the design methodology presented in Task 6 to design and construct two snow fences for field evaluation.
Construction at the Clines Corners Test Site

**Design Specifications:**
- Required fence height: 8ft
- Porosity: 50%
- Setback distance: 240-280ft (30 to 35 times fence height)
- Orientation: parallel to road

The New Mexico Tech Research Team selected an 8.5ft tall polyethylene fence because of its reported performance and low maintenance.

Budget available for this fence limited its length to 300ft.
Details of Clines Corners’ Fence

Details of the pre-manufactured polyethylene snow fence placed in the Clines Corners site

Placement of polyethylene rails and coated wire-stays to minimize movement of the rails between posts

Rail attachment to end posts
- Top: secured connection
- Bottom: ratchet
Construction at the Eagle Nest Test Site

Design Specifications:
- Required fence height: 10-12ft
- Porosity: 50%
- Setback distance: 350-420ft (35 times fence height)
- Orientation: parallel to road

Lack of landowner’s cooperation prevented New Mexico Tech from placing the snow fence at the proper location. Even if porosity was reduced to shorten drift length, and a solid was used, part of the drift would still be formed over the roadway.

A custom 8ft wooden fence with vertical slats was built at the edge of the right-of-way (75ft from roadway). Although this short setback will still cause part of the drift to form on the road, it is believed that more snow will be stored close to the fence than with the existing 4ft fence.

Scott Kirksey, NMDOT
Details of the custom snow fence placed in the Eagle Nest test site

Foundations were extended above ground to ensure an 8in bottom gap.

Posts were notched and sealed to help rail connections.
Project Tasks

Task 1: Literature Review and State of Practice
Task 2: Field Evaluation
Task 3: Development of Methodology for Legal and Safety
Task 4: Analysis Method for Determination of Critical Site Parameters
Task 5: Effect of Level of Service and Cost/Benefit Analyses
Task 6: Match Analysis Methodology
Task 7: Construction of Snow Barriers for Evaluation
Task 8: Evaluation of Barrier Performance at Test Sites
Task 9: Implementation Plan
Task 10: Research Reports
Task 8 consists in the monitoring of the snow fences designed and built for this project over a snow season.

Unfortunately, the winters of 2010-2011 and 2011-2012 did not bring a significant amount of snow to the Eagle Nest and the Clines Corners sites.

Visits to Eagle Nest site:  
• February 5, 2011  
• January 7, 2012

Visits to Clines Corners site:  
• December 26, 2011  
• Since the snow fence at the Clines Corners site was not completed until the end of March 2011, no visits to the site were conducted during the first winter.
Field Evaluation of Eagle Nest Site
Winter 2010-2011

Visit conducted on February 5, 2011, immediately after the January 31 to February 4, 2011 winter storm.

Although up to 2ft of snow fell in some regions of the Sangre de Cristo Mountains during this storm, a snow cover ranging from only 1 to 2in was measured at the test site.
Negligible snow accumulation observed around the snow fence on February 05, 2011.

However, it was interesting to notice the lack of snow cover in the immediate vicinity of the fences, indicating that the gap under the fence was preventing the accumulation of snow at the toe of the structure.
January 7, 2012
Drifts formed reached a height of 11in and a length of 28ft
The difference in drift formation and the effect of the bottom gap can be seen on the figure in the right, where part of the 4ft fence is buried on the foreground while the toe of the larger wood fence is clear of snow.

Lack of snow in immediate vicinity of fence showing that bottom gap is preventing snow accumulation against the fence.
Visit conducted on December 26, 2011, after the winter storm of December 23, 2011

Snow cover was approximately 10in and drifts were observed by the polymer snow fences, while the 4ft vertical slat wood fence (on the foreground) was buried in most places.
Snow drifts downwind from polymer fence extended for 44ft, and reached a maximum height of 47in, a distance of 20ft from the toe of the fence.
The bottom of the fence remained clear of snow accumulation, allowing the fence to remain functional.
Project Tasks

Task 1: Literature Review and State of Practice
Task 2: Field Evaluation
Task 3: Development of Methodology for Legal and Safety
Task 4: Analysis Method for Determination of Critical Site Parameters
Task 5: Effect of Level of Service and Cost/Benefit Analyses
Task 6: Match Analysis Methodology
Task 7: Construction of Snow Barriers for Evaluation
Task 8: Evaluation of Barrier Performance at Test Sites
Task 9: Implementation Plan
Task 10: Research Reports
Implementation Plan

In this task, an implementation plan was developed to assist the NMDOT in the employment of the findings and recommendations of the research project.
Project Tasks

- **Task 1**: Literature Review and State of Practice
- **Task 2**: Field Evaluation
- **Task 3**: Development of Methodology for Legal and Safety Analysis
- **Task 4**: Analysis Method for Determination of Critical Site Parameters
- **Task 5**: Effect of Level of Service and Cost/Benefit Analyses
- **Task 6**: Match Analysis Methodology
- **Task 7**: Construction of Snow Barriers for Evaluation
- **Task 8**: Evaluation of Barrier Performance at Test Sites
- **Task 9**: Implementation Plan
- **Task 10**: Research Reports
Documents produced as part of this project include:

- Final Report
- Field Guide
- Implementation Plan
- Multimedia Presentation
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.
Acknowledgments

The author would like to express her gratitude to the US Department of Transportation Federal Highway Administration and the NMDOT Research Bureau for providing the funding for this research project.

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 Mrs. Kathy Ahlenius from the Wyoming Department of Transportation Winter Research Services who gracefully answered numerous questions, provided us with various documents essential to the completion of this project, kindly conducted our visit to the WyDOT and several 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.
References


