Applied Research and Innovation Branch

ASSESSMENT AND PLACEMENT OF LIVING SNOW FENCES TO REDUCE HIGHWAY MAINTENANCE COSTS AND IMPROVE SAFETY (LIVING SNOW FENCES) STUDY NO: 047-10

Greg Sundstrom

Report No. CDOT-2015-01
May 2015

1. Report No. CDOT-2015-01	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle ASSESSMENT AND PLACEMENT OF LIVING SNOW FENCES TO REDUCE HIGHWAY MAINTENANCE COSTS AND IMPROVE SAFETY (LIVING SNOW FENCES) Study No: 047-10		5. Report Date May 2015 6. Performing Organization Code	
7. Author(s) Greg Sundstrom		8. Performing Organization Report No.	
9. Performing Organization Name and Address Colorado State Forest Service 5060 Campus Delivery Fort Collins, CO 80523-5060		10. Work Unit No. (TRAIS) 11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Colorado Department of Transportation - Research 4201 E. Arkansas Ave. Denver, CO 80222		13. Type of Report and Period Covered Final, research and report-writing spanned from 1/1/13 – 12/31/14 14. Sponsoring Agency Code	
15. Supplementary Notes Prepared in cooperation with the US Department of Transportation, Federal Highway Administration			
16. Abstract: Living snow fences (LSF) are designed plantings of trees and/or shrubs and native grasses along highways, roads and ditches that create a vegetative buffer that traps and controls blowing and drifting snow. These strategically placed fences have been shown to be cost effective in reducing highway maintenance associated with blowing and drifting snow conditions. The objective of the study is to equip Colorado Department of Transportation (CDOT) with the tools and knowledge to expand the use of living snow fences. These tools should provide a roadmap for local CDOT maintenance staff which includes: Identifying the best locations, Identifying land owners and securing their cooperation, Engaging resource agency support of the design and establishment, Insuring initial maintenance, Tracking these assets over time and documenting the benefits Implementation: To initiate the study the Colorado State Forest Service (CSFS) conducted an informal survey of Colorado Natural Resources Conservation Districts, CDOT Maintenance supervisors, and CSFS field offices to inventory existing LSFs along Colorado state highways. The inventory identified approximately 177 existing LSFs along state highways. Training sessions designed to meet the study objectives were held for CDOT staff in each of five CDOT Regional Offices. A notebook entitled "Colorado Living Snow Fence Guidelines and Short Course" was prepared and provided to attendees at these sessions. The notebook contained a PowerPoint training presentation with notes along with all reference material used for the training. The training sessions were attended by 60 CDOT employees and 7 CSFS foresters. Three methods for CDOT to implement a LSF program at either a local or state wide basis were provided: Conduct a program entirely within CDOT; involve other partners in an interagency cooperative program; or for CDOT to provide funding for another agency to manage and implement a program with this being the preferred alternative due to expertise and landowner relationship needs.			
17. Keywords: CDOT, CSFS, energy efficiency, snow control, winter maintenance, snow fence, living snow fence, windbreak design and establishment, highway safety, windbreak benefits, snow fence location		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service 5825 Port Royal Road Springfield, VA 22161	
19. Security Classif. (of this report) None	20. Security Classif. (of this page) None	23. No. of Pages 20	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ASSESSMENT AND PLACEMENT OF LIVING SNOW FENCES TO REDUCE HIGHWAY MAINTENANCE COSTS AND IMPROVE SAFETY (LIVING SNOW FENCES)
STUDY NO: 047-10

Report No. CDOT-2015-01

Prepared by:

Greg Sundstrom, Forester
Colorado State Forest Service
5060 Campus Delivery
Fort Collins, CO 80523-5060

Sponsored by:

Colorado Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

Colorado Department of Transportation
Research Branch
4201 E. Arkansas Avenue
Denver, CO 80222
(303) 757-9506

May 4, 2015

Acknowledgements

The members of the Colorado Department of Transportation Study Panel members for this project are acknowledged for their cooperation and leadership. Panel members are:

Study Manager: Bryan Roeder, CDOT Research Branch
4201 E. Arkansas Avenue, Shumate Bldg.
Denver, CO 80222
(303) 512-4420

Study Panel Leaders: Mike Banovich, CDOT Environmental Programs Branch
(303) 757-9542

David Vialpando, CDOT Region 5 Maintenance
(719) 587-6400

Study Panel Members/Area of Employment:

Jan Klaetsch, CDOT Landscape Architect, Region 3
Jeff Peterson, CDOT Wildlife Program, Environmental Programs Branch
Basil Ryer, CDOT Landscape Specialist, Environmental Programs Branch
Greg Fischer, CDOT Landscape Specialist, Environmental Programs Branch
Mark Harrington, CDOT DTD-Information Management Branch

Individuals within several Natural Resources Conservation Districts, Colorado State Forest Service District Offices and Colorado Department of Transportation maintenance staff contributed to the inventory of existing Living Snow Fences along state highways that was conducted as part of this project. Their contributions are appreciated.

The individuals whose photographs are used in the training presentation and guidelines developed for the training sessions and those agencies and authors of reference materials based on a huge volume of research and information on Living Snow Fences are also deserving of acknowledgement.

Executive Summary

Living snow fence utilization is one of the most sustainable engineering actions CDOT can do along highway corridors. Living snow fences are designed plantings of trees and/or shrubs and native grasses along highways, roads and ditches that create a vegetative buffer that traps and controls blowing and drifting snow. These strategically placed fences have been shown to be cost effective in reducing highway maintenance associated with blowing and drifting snow conditions. This is especially important during a time in which maintenance budgets are extremely tight. In addition improved traffic safety can be realized by less snow drifting upon the highway surface.

The National Resource Conservation Service of USDA, Colorado State Forest Service, Colorado Soil Conservation Board and affiliated natural resources conservation districts, Colorado Division of Wildlife, CDOT, non-profits such as Pheasants Forever, and others were involved in establishing living snow fences on both public and private lands under a previous interagency cooperative program. USDA has conservation financial assistance programs, Continuous Conservation Reserve Program - CCRP, and Environmental Quality Incentives Program - EQIP, which can provide cost share to private landowners for living snow fences on private lands. CCRP can provide up to 90% of the cost of installation on crop land, along with other incentives for landowners. These programs put the onus of establishment and maintenance of the LSFs on the private landowners which can dissuade them from providing them primarily for the benefit of the public. Livestock shelter, improved habitat for wildlife species they enjoy, and improved soil and crop protection are a few of the benefits that enhance the value of LSFs to landowners.

In many respects, CDOT Maintenance already knows where blowing snow is a problem and has worked with adjacent land owners to install slatted snow fences. In some locations the land owners require that the fences be removed during the summer. Such locations would not be conducive for living snow fences; however,

land owners may be more willing to allow a permanent living snow fence, than a permanent artificial snow fence. A program to promote the potential multiple benefits provided by a LSF would improve this situation.

CDOT Region 5 has recently worked with local state agencies to establish a living snow fence near Villa Grove. At the local level eastern Colorado CDOT occasionally works with local conservation districts to establish living snow fences. Wyoming DOT is replacing many of their wood snow fences with living snow fences working in conjunction with local conservation districts and Wyoming State Forest Service which greatly assists in gaining landowner acceptance.

Colorado State Forest Service has researched and identified the best weed-control materials and developed a highly efficient placement device. They have also created design guidelines and hosted workshops. A detailed training notebook for transportation professionals or others interested in LSF installation and maintenance was developed as a result of this research and is available at the CDOT Applied Research and Innovation Branch Library.

Implementation Statement

To initiate the study the Colorado State Forest Service (CSFS) conducted an informal survey of Colorado Natural Resources Conservation Districts, CDOT Maintenance supervisors, and CSFS field offices to inventory existing LSFs along Colorado state highways. There was some redundancy in locations reported but after review a consolidated summary report (Appendix A) was created. The inventory identified approximately 177 existing LSFs along state highways, but it should be understood that there may be some inaccuracies in the report.

Training sessions designed to meet the study objectives were held for CDOT staff in each of five CDOT Regional Offices. A notebook entitled "Colorado Living Snow Fence Guidelines and Short Course" was prepared and provided to attendees at these sessions. The notebook contained a PowerPoint training presentation with notes (Appendix B) along with all reference material used for the training.

The Training presentation and notebook was broken into sections entitled:

- Why Windbreaks?
- Windbreak Function and Design
- Where Are Living Snow Fences Needed?
- Living Snow Fence Program Set Up Options – Potential Partners
- Installation and Maintenance
- Proper Pruning

Each of the training sessions consisted of ½ day classroom discussion and ½ day field tour of existing or potential LSF sites to visualize and discuss information provided in the classroom discussions and guidebook. The training sessions were attended by 60 CDOT employees and seven CSFS foresters. Three methods for CDOT to implement a LSF program at either a local or state wide basis were provided: conduct a program entirely within CDOT; involve other partners in an interagency cooperative program; or for CDOT to provide funding for another

agency to manage and implement a program with this being the preferred alternative due to expertise and landowner relationship needs.

Information gathered will assist CDOT in setting up a LSF program thus reducing snow control costs and improving public safety on Colorado highways.

Table of Contents

1.0 Introduction

Living snow fences (LSFs) are designed plantings of trees and/or shrubs and native grasses along highways, roads and ditches that create a vegetative buffer that traps and controls blowing and drifting snow. These strategically placed fences have been shown to be cost effective in reducing highway maintenance associated with blowing and drifting snow conditions.

LSFs for snow control is not a new concept. As early as 1905 railroad companies planted trees as barriers to control blowing snow along rights of way. By 1915, the Great Northern Railway Company had planted over a million trees. In North Dakota over 96,000 trees and shrubs were established. This action reduced snow drifting, line closure and helped maintain an expected level of service along the rail line.

Years past, the Colorado Department of Transportation (CDOT) was party to an interagency agreement which provided $10,000 per year to the State Conservation Board (SCB) to coordinate locating and installing LSFs. This was part of a Colorado Interagency Cooperative LSF Program where a steering committee reviewed applications for resources and assistance and agreed which proposed LSF projects would receive state level program assistance. The Colorado State Forest Service (CSFS) provided seedlings and some funds for planting materials such as plastic mulches for the state wide program. Dale Shaw did coordination work for the CSFS. The Colorado Division of Wildlife (CDOW) contributed materials valued at approximate $10,000 each year. This effort along with other cooperative programs with the SCB, local conservation entities, and the CSFS installed over 300 living snow fences statewide. These were on county as well as state highways. The CDOT dropped the cooperative agreement because they perceived that they were getting little assistance from the SCB and chose to rely on local coordination. CDOW and CSFS all did the same on a state wide basis; therefore the program was left up to local entities and resources to carry it out at the local level. Some local areas such as in El Paso County still have active LSF programs installing LSFs on an interagency cooperative effort which includes CDOT in some cases. The statewide interagency cooperative program, though very successful at the time it was running, took a huge amount of coordination due to the number of contributors. This program was evaluated as part of this study.

In 1998, the Wyoming State Forestry Division and the Wyoming Association of Conservation Districts approached the leadership of Wyoming Department of Transportation to initiate a statewide living snow fence program. This effort was successful and today all three agencies work under an agreement to fund and implement living snow fence projects. To date, 57 projects have been installed and will protect 55,529 feet of public roadway upon establishment in Wyoming. This model was also examined and evaluated for this study.

Many Highway road system designs do not take into account the potential of using LSFs. While LSF have a higher initial cost, they provide a long term cost benefit over traditional snow fencing, as well as other benefits described below.

2.0 Background

Many DOTs, including CDOT, use wooden and plastic slat fencing in areas with large open areas. These are expensive to purchase, install and maintain. The implementation of a LSF program is a highly sustainable transportation action for CDOT. The LSF concept incorporates many components associated with sustainable actions such as environmental condition improvements, consideration of financial resources and cooperation with the local landowners/community. The following summarizes the main advantages of living snow fencing along highway corridors:

1. The service life of LSFs is 50-75 years in comparison to the 20-25 year life of a slat fence.
2. Living mature trees can capture up to 12 times more snow than slat fences.
3. LSFs can be installed to address tree mitigation from highway construction projects.
4. Trees and shrubs sequester carbon that can reduce a DOTs overall carbon footprint.
5. Wildlife habitat can be enhanced.
6. Maintenance plowing activities and the potential of road closures are reduced.
7. Reduced soil erosion along the right of way.
8. Reduced amount of snow plowing thus minimizing fuel consumption and costs, and greenhouse gas emissions.
9. Increased vegetation provides enhanced aesthetic features along the highway corridor.
10. Maintenance is free after trees are established.
11. LSFs can provide winter livestock protection and improved crops for landowners.

The design and implementation of LSFs requires acceptance and cooperation of stakeholders. Generally, for large open areas LSFs need to be 150-200 feet away from the road surface which many times requires planting off the DOT right of way. Coordination with the following stakeholders may make the planning process more rewarding: 1) the local landowner, 2) county commissioners, 3) resource conservation districts, 4) state and federal forest services, 5) land management agencies and 6) local environmental organizations. Cooperation among stakeholders is critical to the success of a living snow fencing in regards to the following:

- Site access which may include easements
- Tree planting, site preparation, seedlings, planting supplies
- Irrigation water and systems
- Fencing from livestock or wildlife
- Maintenance – monitoring, weed control, replacement planting
- Aesthetics
- Erosion control

The challenges to LSFs are that they require more space than the wooden slat fencing, plantings need to be protected from livestock and wildlife and it takes five to seven years to provide effective snow control and, if improperly designed, can take up to 20 years to become fully functional. Many sites where LSFs are needed are on private lands. Gaining access and agreements with owners of these sites can be difficult. There may be site conditions such as shallow soils, arid climate and soil pH issues that may challenge plant establishment. The cost of monitoring and performing maintenance during the first three to five years to insure adequate seedling survival is offset by the long term life of these live structures compared to wooden slat fences.

Overall, LSFs can be a win/win for both the DOT and landowner by increasing the number of planted trees to sequester carbon, improving soil stability, improve aesthetics, improve wildlife habitat, and protect livestock and crops, all in addition to saving highway maintenance costs and improving highway safety for the citizens of Colorado.

The objective of this study is to equip CDOT with the tools and knowledge to expand the use of LSFs. These tools should provide a roadmap for local CDOT maintenance staff which includes: identifying the best locations; identifying land owners and securing their cooperation; engaging

resource agency support of the design and establishment; insuring initial maintenance; tracking these assets over time and documenting the benefits.

3.0 Living Snow Fence Inventory

LSFs can be considered assets for the entity that funded and maintained them over time. Tracking them and documenting the benefits they provide can improve their validity for future funding. An inventory of existing LSFs on state highways for reference and to be used as study points for training of CDOT employees and partners was completed as part of this study. The Study Panel determined it would be impractical to drive the roughly 9,000 miles of state highways to get global positioning system information for the existing LSFs so an informal survey of those entities that might provide information was the method used for the inventory.

Due to there having been a coordinated LSF program in Colorado at one time there were expectations that records of many existing LSFs might have been kept by CSFS, the Natural Resources Conservation Service (NRCS) state office or the SCB office. None of these agencies were able to locate such records when asked if they had them. To help implement the inventory of existing LSFs, David Valiapando, one of the Study Panel Leaders, provided a list gathered from the CDOT regions' maintenance sections. CSFS District Foresters were asked to review that list and add any LSFs that they were aware of. In some cases they requested LSF location information from resource conservation districts. In addition, Cindy Lair, State Conservation Program Manager with the SCB was asked to request information from the resource conservation districts as well. This resulted in several LSFs being reported multiple times. The information in the various reports was compared and consolidated into one report. There are 177 LSFs along state highways listed. They were identified with the highway number, mile-marker, length and travel direction being protected in most entries. It should be understood that there may be LSFs that were not reported and that some may be included more than once due to a variety of information provided. The Summary Report of Existing Living Snow Fences is included in Appendix A.

4.0 Living Snow Fence Short Course Training

One hundred notebooks entitled "Colorado Living Snow Fence Guidelines and Short Course" (Appendix B) were prepared to be provided to participants attending one of five training sessions

held across the state. Excess notebooks were given to participants who wanted extras to provide to others within their agency who would have a need for them.

Valiapondo and Roeder coordinated the scheduling and logistical arrangements to hold a training session in each of the CDOT Region Offices. The arrangements were as follows:

2/4 - 2/5, Poncha Springs, CO	Poncha Springs Conference Room
2/18 - 2/19, Pueblo, CO	902 Eerie Basement Conference Room
3/25 - 3/26, Greeley, CO	Platte Room
4/2 - 4/3, Denver, CO	Mt. Evans Conference Rooms A & B at HQ
4/16 - 4/17, Craig, CO	Black Mountain Conference Room (Main Conference Room)

The notebook contained a PowerPoint training presentation with notes along with all reference material used for the training. Each of these sessions consisted of ½ day classroom discussion and ½ day field tour of existing or potential LSF sites to visualize and discuss information provided in the classroom discussions and notebook. The pre-site visit was made to each training location to locate exiting or potential snow fence locations for the training participants to visit during the tours. Sixty CDOT employees and seven CSFS foresters attended the training sessions.

Notebook Organization

The Power Point presentation is organized in tabbed topic sections within the notebook. Supporting, reference and informational material for each section was included in a second set of Supplemental Tabs which are similarly numbered and follow Power Point sections.

The tabbed sections and material provided for each topic are as follows:

1. *Introduction* – Introduction, Notebook Organization and Acknowledgements - A Supplemental Tab is not included for this topic.

2. *Why Living Snow Fences*?

Additional information in the Supplemental Tab (second tab numbered 2):

Living Snow Fences: Protection That Just Keeps Growing (booklet)

Economics of living snow fences in the Intermountain West (research paper)
LSF Coordinator for Colorado letter to the CDOT (letter)
Working Trees- Living Snow Fence (National Agroforestry Center Publication)
Windbreaks and Wildlife (University of Nebraska Cooperative Extension Publication)
Windbreaks for Livestock Operations (University of Nebraska Cooperative Extension Publication)
Field Windbreaks (University of Nebraska Cooperative Extension Publication)

3. *Windbreaks Function and Design*
Additional information in the Supplemental Tab (second tab numbered 3):
Windbreak Suitability Groups (Natural Resources Conservation Service technical guide)
Trees for Conservation – a buyer's guide (Colorado State Forest Service publication)
Wind Rose Data site information (printed from Natural Resources Conservation Service web site)
Prevailing Wind Direction (printed from Western Regional Climate Center web site)
Windbreak/Shelterbelt Establishment - Code 380 (Natural Resources Conservation Service Practice Standard and Specification)
How Windbreaks Work (University of Nebraska Cooperative Extension Publication)
Windbreaks: An Agroforestry Practice (Agroforestry Notes - National Agroforestry Center Publication)
Windbreaks for Snow Management (University of Nebraska Cooperative Extension Publication)
Living Snow Fence Planting Plan (Colorado State Forest Service form)
Windbreak / Shelterbelt Establishment CO-ECS-1(Natural Resources Conservation Service Practice planning form and cost estimator)

4. *Where Are Living Snow Fences Needed?* - A Supplemental Tab is not included for this topic.

5. *Living Snow Fence Program Set Up Options* – Potential Partners
Additional information in the Supplemental Tab (second tab numbered 5):
Your Local CSFS District (Colorado State Forest Service field office directory)
Natural Resources Conservation Service Colorado (web links to Main Page and local offices directory)
USDA Service Center Locator (Colorado Counties map and link)
Colorado

Colorado Department of Agriculture, Colorado State Conservation Board (web link and Conservation Districts' directory)
Living Snow Fence planning Checklist for partners and Living Snow Fence Program partners Working Agreement (sample forms)
Report Summaries of previous Interagency Cooperative Living Snow Fence Program 1983-1999
Wyoming Living Snow Fence Program Procedure (document)

6. *Installation and Maintenance*
Additional information in the Supplemental Tab (second tab numbered 6):
Living Snow Fence Survival and Evaluation Sheet (form used in previous program)
Windbreak Establishment (University of Nebraska Cooperative Extension Publication)
Windbreak Management (University of Nebraska Cooperative Extension Publication)

7. *Proper Pruning* - A Supplemental Tab is not included for this topic.

8. *Conclusion and Contact Information* - A Supplemental Tab is not included for this topic.

4.1 Why Living Snow Fences?

Winds can carry small particles such as soil and snow. Reducing the speed of the wind with barriers reduces its capability to carry these particles causing the particles to be deposited on the leeward or downwind side of a barrier. Constructing barriers at strategic locations along highways can help control where drifting snow gets deposited.

The following was stated in a 1999 study: "Efficiency gains from living snow fences, evaluated using the annualized cost approach, demonstrate that the benefits to society outweigh the costs. An example is presented using an average sized, 1040-ft-long, 3 row snow fence, and a discount rate of 8%. To offset snow fence costs over a 50 year expected life, the fence need only reduce traffic accidents by as little as one every 23 years, or reduce snow plowing by about 6hr/yr. Other likely but less quantifiable benefits make the benefits of living snow fences even more economical to society."

In 1995 the LSF Coordinator for Colorado wrote the following in a letter to the CDOT, ”The DOT Foreman at Arriba has reported that the Department realizes a benefit of $600 per living snow fence per storm along I-70 in snow removal costs. He also estimates they spend $8,000-$9,000 in snow removal costs on Highway 71 where there are no Living Snow Fences. Safety, aesthetics and wildlife benefits are over and above the actual dollar benefits. ….”.

While snow fences can keep snow from causing problems on roads, they can also reduce maintenance costs and time required to remove snow drifts around public facilities such as rest areas and ports of entry.

A critical consideration in barrier storage capacity is height. Other factors being equal, storage capacity increases more than four times when height is doubled. For example, mature living fences have the potential to store over 12 times more snow than a single row of picket fence.

Living snow fences provide a home for many wildlife species. A combination of trees, shrubs and grasses provide excellent wildlife habitat. Landowners and program supporters value this benefit. Be aware that tall trees on the plains may attract avian predators that can impact ground dwelling animals. If this is a concern, design the LSF using shrubs and short trees. Windbreaks have potential to attract wildlife to areas near roads which can create hazards for both wildlife and vehicles. However, the safety benefits provided by a LSF may outweigh the resulting negative consequences.

Living snow fences improve landscape aesthetics and provide alternative crop and income potential for landowners. Fruit such as plums are good to eat, and living snow fences are a good source of easy to gather tree and shrub seed. LSF are aesthetically pleasing to highway travelers and provide a break in the monotony of a flat landscape. According to the Minnesota Department of Agriculture, LSF can sequester carbon and reduce spring flooding

A good selling point for landowners to allow LSFs on grazing lands is that livestock can be protected during blizzards. LSFs can be designed specifically for livestock protection resulting in better survival,

and up to ten percent increased weight gains, and 8-20% improved milk production. Driveway maintenance efforts may also be reduced.

Protecting crops from wind allows for an increase in crop yield. LSFs allow more snow to land behind the windbreak, thus maintaining adequate soil moisture for longer periods. Increased yields behind LSFs can compensate for the area taken out of production. Wildlife attracted by windbreaks may be able to assist in controlling insects that may impact crops.

4.2 Windbreaks Function and Design

Snow storage capacity and area of protection behind a LSF is determined by the height of the tallest tree/shrub row, the density of the barrier created and the length of the barrier.

A common rule of thumb (10H Rule) for windbreak design is that wind velocity is decreased by 50% at ten times the height (H) of a barrier such as a LSF. The area within 10H of the tallest component of a barrier is provided fair protection and particles being carried by the wind are commonly deposited within this area. A 20 foot tree gives 200 feet of protection. Storage capacity increases four times when height is doubled. For windbreaks, this distance is measured from the expected mature (20 years) height of the tallest component.

The soils on a given site determine which, if any, trees and shrubs may grow there. Species selected should be adapted to the site and not on the Colorado noxious weed list .The NRCS has developed a guide called "Windbreak Suitability Groups" to assist in species selection for given soils. The guide provides potential height of both coniferous and deciduous tree and shrub species at 20 years of age within given precipitation ranges. The guide is located at:

http://efotg.sc.egov.usda.gov/references/public/CO/WINDBREAK_SUITABILITY_GROUPS.doc

The NRCS has mapped soils across the United States. They also have soils specialists in nearly every county, co-located with natural resources conservation district offices. The NRCS web site has a tool with mapping capabilities to assist in determining soils. That tool is located at:

http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Once the soil name is found a planner can go to the "Windbreak Suitability Groups" to determine which species and their potential heights under different precipitation ranges may be planted.

Density of a wind barrier refers to the ratio of solid area to the total frontal area of the barrier. A solid barrier has 100% density. Extreme turbulence behind a solid barrier results in limited snow storage behind them. Research indicates that barriers with 50% density store the most snow. That is the reason that slat fences are constructed with the areas between the slats the same width as the slats. Density of a LSF can be controlled by varying in-row and between-row spacing and species selection. Evergreen species provide density year around. CSFS has booklet called "Trees for Conservation - a Buyer's Guide" that can assist in species selection. It contains descriptions and photos of common species along with wildlife value, insect and disease, and type of soil conditions required for those species. The booklet can be found online at: http://csfs.colostate.edu/pdfs/08byrgd-www.pdf

A dense LSF can be planted with Rocky Mt. juniper in two rows with ten feet or less between rows and in- row spacing of eight feet – Twin row high density design. Not only can this design create a dense barrier, having trees planted closely in these twin rows will result in canopy closure quicker, making the snow fence functional at an earlier age. Most windbreaks are designed to be fully functional at twenty years of age. This means they will be of the proper density and height to provide protection of the area they were intended to protect at 20 years of age. Multiple twin row high density rows of trees can significantly increase snow storage capacity.

The area of protection is also determined by the length of a barrier such as LSF. The longer the LSF, the greater the stretch of road that will be protected. Wind does not always blow from a single direction. It is common for it to vary 45 degrees from what might be considered the prevailing wind direction. With this in mind, to protect an area 300 feet long, which is a fairly short distance along a road, extending LSF 150 feet on each end past this 300 feet long area will compensate for the varying winds to better protect the 300 feet length. End effect results in a loss of storage capacity due to rounding and shortening of drifts. It is recommended that the minimum length of a LSF should be 600 feet to compensate for variations in wind direction and end effect.

For maximum snow storage, LSFs should be located perpendicular to the troublesome wind at the time protection is needed. Data to determine wind direction at given times of the year for given locations is available at:

http://www.wcc.nrcs.usda.gov/climate/windrose.html

http://www.wrcc.dri.edu/htmlfiles/westwinddir.html

While it could be advantageous to develop formulas to provide guidance on potential LSF design and layout in a given location based on wind direction and speed, snow fall amounts, slopes, ground roughness and cover and other factors, the variability in climate, weather and topography across Colorado makes this impractical. A more practical approach has been the standard for LSFs previously installed in Colorado.

LSFs should be designed so that they have adequate snow storage within and downwind from them to avoid piling snow on roads. Shaw states in the Living Snow Fences: Protection that Keeps Growing publication, "The living snow fence should be placed as close to the road as possible yet far enough away so that the leeward drift edges do not touch the road." On level topography, using the 10H rule to determine the distance away from the road generally meets the needs of controlling snow deposition and storage for the snow event that would block a highway on a regular basis. Should more snow storage be needed, adding rows upwind of the LSF or a slat fence will add to the capacity.

The NRCS specification for their "Windbreak /Shelterbelt Establishment", Code 380, practice in Colorado states "Where a living snow fence will be the only structure or factor keeping snow off a road, the windward row or the living snow fence should be located at least 200 feet from the center line of the road being protected". Keeping LSFs back from a highway far enough to avoid capturing snow on the highway usually dictates planting the LSF on adjacent lands, rather in Right of Ways. Other guidance indicates distances of 100 feet to 300 feet back from the highway are appropriate. In situations where a road cut is causing snow to be deposited on a road, placing a LSF upwind 100 to 300 hundred feet of the cut will capture the snow before it reaches the cut.

In some instances snow sifting across a road does not necessarily create a drift which blocks it. This drifting snow may stick to the road surface and create icy conditions. A LSF consisting of a low growing shrub species planted near the road can stop the sifting snow in the barrow ditch. The 10H rule should be utilized for this type LSF to prevent it from causing a drift to form on the road. This design is planned for a section of Pena Boulevard approaching Denver International Airport where shrub rows will be planted in the median and to the windward side of the highway.

LSFs can be planted in a variety of designs, depending on storage capacity needs, space available, available funding, soils types, geography, etc. Designs vary from single row, single twin row high density, and multiple twin row high density rows to multiple single rows or combinations of single rows and twin row high density rows. Shrubs are often included in designs for wildlife benefits. Designs are often influenced by what a land owner might want as a benefit of the project and the space he/she may be willing to provide.

Once the design of a LSF is determined a planting plan should be developed to show how it will be laid out and installed. A planting plan will show project location and distances from the road and other features, species to be planted, spacing between trees within rows and spacing between rows. Planting method, drip supplies and mulch material needed and any other information that could aid in insuring the project is planted as planned will assist in completing the LSF. The plan should include a drawing of the project along with future maintenance needs. Estimated costs may also be included. Plans can be developed using forms or electronically.

4.3 Where Are Living Snow Fences Needed?

To determine where a LSF is needed along existing roads it is suggested to ask the snow plow operators, school bus drivers, local mail carriers, and local conservation district supervisors. People who work and live in the local area are the ones who travel the highways the most during all seasons of the year. They are the most impacted when roads are blocked by snow so are probably the best resource for determining where the major problem areas are. Another method is to observe where slat fences are already located. A long term solution to having an existing snow fence which has been requiring continual maintenance is to replace it with a living snow fence which can be designed to be more functional and require less maintenance when established.

Seldom are snow control structures included in the design phases of highway construction though doing so can assist in financing and gaining right of way on adjacent lands. Potential sites to consider LSFs are on the windward side of road cuts, upwind of long curves, where traffic barriers such as guard rails may cause snow accumulation on the road, adjacent to highway access areas and where continual drifting may cause ice buildup when snow sticks to the road surface. Controlling snow accumulation around maintenance facilities, ports of entry and rest areas can reduce maintenance needs as well.

A given site may not support trees and shrubs due to soils and lack of precipitation. Will a site support trees and shrubs without long term maintenance needs in the form of supplemental watering and/or continual replacement of dead trees? If not, slat fencing is probably more economical that a LSF.

Some high altitude areas of Colorado normally receive high amounts of snow and roads require almost daily snow plowing whether there are snow drifts or not. Consider whether a snow fence will reduce the snow removal activities in these areas before installing snow control structures. The structures themselves often become buried in these areas.

4.4 Living Snow Fence Program Set Up Options

There are basically 3 options for setting up a LSF program in Colorado. These options could be set up on a state wide basis or on a regional basis. Regardless of how a program is set up, success will require an individual within each area or agency be designated as coordinator.

Landowners are a critical partner for any LSF project that needs to be placed on non CDOT ROW sites. They may provide assistance in a variety of means, even to the point of participating in various cost share programs that can provide financial assistance for LSF installations. These programs may change at any time due to political decisions. An example is the Continuous Conservation Reserve Program with the Farm Services Agency. That program has sign up incentive payments and land payments for up to 15 years for LSF installations on crop land. That program may provide up to 90% of the cost of the installation. The Environmental Incentives Program with the NRCS may provide 50% cost share for LSFs in certain parts of the state. Some conservation districts also have financial incentives for LSFs in their areas. It must be kept in mind that these programs' agreements are with the landowner and ties them to certain expectations which they may not wish to take on.

One option is that CDOT could develop and implement a program within their agency keeping in mind that they may not have the skilled personnel and specialized equipment to do all that is needed for a successful LSF program. There is potential assistance from other agencies that could assist CDOT if willing to do so. CSFS and NRCS have expertise for technical assistance in design. Conservation districts and CSFS have regular contacts with landowners which could facilitate getting access for sites. CSFS and conservation districts may be available to provide LSF installation, monitoring and maintenance services as contractors. They also have lists of vendors who might provide these services. As in all options, landowners are important contributors by providing sites whether through easements or

a less formal agreement process. CDOT would need a statewide LSF coordinator to insure all steps needed for each LSF installation are completed. If done on a regional basis, a regional coordinator would be needed as well.

The second option is to set up an interagency cooperative LSF program like in the past. This requires extensive coordination and commitment from a number of partners/contributors. A state wide coordinator and steering committee made up of contributors would be needed to select sites to be supported. Examples of past partners and contributors and their contributions were as follows: CSFS - cash, seedlings, materials, labor, equipment, technical assistance, coordination; Colorado Parks and Wildlife - cash, materials, labor, equipment, technical assistance; NRCS - labor, technical assistance; SCB - labor, technical assistance; CDOT - cash, materials, labor, equipment; County Commissioners - cash, materials, labor, equipment;; Conservation Districts - materials, labor, equipment; Landowners - materials, labor, equipment, planting sites; Private Industry – materials; USDA Forest Service - planting sites, labor, technical assistance; School Districts - labor; Extension Service – labor; State Land Boards - planting sites, transplants; Youth Organizations - labor; Bureau of Land Management – planting sites, labor, materials; Pheasants Forever – materials; Colorado Wildlife Federation – labor. An agreement signed by all partners and contributors is necessary to insure all components of an individual LSF are in place and all involved knows who is doing what. Easements were not used in this program. If anyone did not do what they agreed to do, there was huge potential for failure of the LSF. This method is still used on a local basis in some areas with local entities including local CDOT offices making contributions. The program demonstrated the value of living snow fences and protected miles of roads, but was dissolved as contributor funds and agency priorities changed.

The third option is for CDOT to provide funding for another agency to coordinate and implement a program. This option could be patterned after the successful Wyoming Living Snow Fence Program which is a cooperative effort between the Wyoming Department of Transportation (WYDOT), Wyoming State Forestry Division (WSFD), local conservation districts (CD) and private landowners to implement windbreak plantings for the purpose of snow catchment along State highways. WSFD coordinates the program. The WYDOT provides funds to cover the costs of planting and maintaining LSF projects. The states 34 CDs initiate site proposals in cooperation with local WYDOT maintenance personnel. These proposals are reviewed for technical aspects and site characteristics related to tree growth by the state living snow fence committee and contracts are signed identifying project installation and maintenance requirements.

General requirements for the WYDOT funded program are as follows:

1. Proposed sites must be located along state maintained highways (includes interstates)

2. Land ownership can be private, state or federal

3. Local Conservation District must be contacted for proposal development

4. All proposals must be pre-approved by WYDOT District office.

5. 30 year easements and maintenance agreements are generally required.

6. Proposals are due by September 1 of each year.

A program similar to this in Colorado with CSFS as coordinator would capitalize on the skills and knowledge of personnel with extensive experience in LSF implementation and project administration and coordination. Colorado State Forest Service is an agency within Colorado State University. There are 17 district offices located across the state, and a conservation seedling nursery located in Fort Collins. A directory of their district offices can be found at: http://csfs.colostate.edu

4.5 Installation and Maintenance

A well planned and laid out LSF will prevent snow from being deposited on a road during normal snow fall events. Using your design plan, mark or flag distances before any site preparation or planting begins. Flag row length, width, spacing between rows, and distances from the road. Global positioning system technology can aid in this process. Straight rows aid in maintenance activities.

Proper site preparation to remove competing vegetation and prepare the soil for ease in seedling root development is one of the most important steps for successful plantings. Plowing the site in the fall is ideal for heavier soils. This breaks up and aerates the soil for easier root growth. Rough soil captures and stores winter moisture. Disking in the spring further prepares the site by breaking the clods than remain from plowing. On sandy soils preparation in the spring prevents potential soil erosion that may occur if tilled in the fall. Simply mowing the competing vegetation is not an

option for effective site preparation and weed control. Prepare eight feet wide strips if weed barrier mulches are to be used to assist in weed control and moisture conservation.

While simply digging or drilling planting holes and planting seedlings by hand may be necessary in rocky soils, it is much more efficient to use tree planters which are pulled by tractors when installing LSFs. A crew of three consisting of a tractor driver, someone on the planter and another person following up for quality control is needed for mechanical planting. Mechanical planters leave a furrow which is good for watering the seedlings when needed.

The planting furrow can also help gather precipitation closer to the seedlings when weed barrier is used. It is most efficient to plant mechanically, then lay the weed barrier over the rows.

Regular monitoring is required to detect maintenance needs before extreme damage occurs. Responsibility for maintenance needs to be determined during planning. Maintenance needed varies with the site and season of the year.

Weed/grass control – spring and summer

Supplemental water – as needed

Replanting – spring time is best

Animal protection – year around

Pest protection - seasonal

Survival check - conduct each fall so replacements can be ordered

Fabric mulch can assist in weed & water management.

Providing water immediately after planting and for a period of three to five years afterword helps young seedlings survive the shock of being transplanted and gives them a better chance of becoming established. Drip irrigation is an effective means of providing supplemental water slowly and right to each seedling. This results in less waste and fewer weeds.

Browsing by wildlife will occur and should be monitored so that protective measures can be taken. No plant is resistant. There are various means to protect seedlings from wildlife. Fencing livestock out of LSFs until trees can withstand them is essential to prevent damage to trees and shrubs.

Some plant species survive better in shade rather than being in the open sun. There are various ways to provide shade and protection from high winds.

4.6 Proper Pruning – Snow Damage

Seldom do trees in LSFs need pruning. A LSF that has been damaged due to snow demonstrates that the living snow fence has done its job – it captured snow. The damaged trees will generally recover. Even dead trees can act as a barrier. If pruning is needed, there are some steps in proper pruning to avoid further damage.

Should the top of a tree be severely damaged, the trunk can be pruned down to a branch rather than removing the whole tree. Pruning large branches from the main trunk can result in ripping of the bark down the trunk so should be done in three steps. The branch can be partially under cut a few inches from the trunk. A second cut can be made next to the first cut to remove the branch and lessen the weight leaving a short stub. The third cut is made to remove the stub. It is commonly recommended that when pruning back a branch, prune back to another branch that is at least 1/3 the width of the branch being removed.

5.0 Discussion

Each LSF training workshop consisted of a ½ day classroom session followed by a ½ day field tour to observe and discuss principles presented during the classroom session. Open discussion was encouraged during both parts of the workshop but was best during the field tour when participants could view installed LSFs, slat fences and potential sites for LSFs. If a snow fence was not functioning properly due to improper location and/or orientation, poor design, or lack of maintenance, solutions to the problems were discussed. Where there were potential sites for a LSF, the participants discussed how a LSF might be designed for that location.

In one location a LSF was installed in conjunction with a slat fence at the top of a road cut. Though the LSF had not become taller that the slat fence at this time, when the trees grow to their potential height it will increase the amount of snow to be captured on the road. Adding more rows upwind of the current snow fences (slat and LSF) was suggested as a means to prevent that.

In some locations it was observed that existing slat fences had captured snow to their fullest capacity. Dozers or snow cats had been used to pile up the snow to increase the height of the barrier

and create snow berms to increase the snow stored by these "snow traps." It was agreed that this is probably more costly than it would be to increase the number of rows of snow fences to increase snow storage capacity, and if the site was suitable for trees, these would be good locations to plant LSFs to decrease the need for using equipment to create snow fences. Pushing snow for equipment operator training may not be the most efficient means of training.

Many existing snow fences are located parallel to roads. If they were arranged perpendicular to winds they would capture more snow. Slat fences are placed with right-of-way fences in many areas. This also results in snow fences being placed more parallel than perpendicular to a road in those locations. These were too close to the road in some instances. Snow fences along long stretches of roads can be broken into sections, each section placed perpendicular to the wind, rather than parallel to the road. Snow fences broken into sections also assist in wildlife and livestock movement. Landowners may be more willing to allow LSFs over slat fences to overcome some of these situations.

After visiting a rest area which was located in an open area one tour group agreed it would be a good site for a LSF. It would improve the aesthetics of the area and decrease the need for snow removal around the building itself.

The tours and associated discussions should result in better designs and locations for future snow fence installations and actions to improve those that already exist.

6.0 Conclusion and Recommendations

An informal inventory identified approximately 177 existing LSFs along state highways, but it should be understood that there may be some inaccuracies in the report (Appendix A) due to redundancies in reporting. Locations were identified by mile markers. Length measurements of the LSFs were estimated.

Though the inventory conducted in this project did not assess the LSFs for condition nor functionality, the inventory could be used to help in assessing the existing LSFs. There are some that need maintenance, added rows, or renovation as was discussed during the workshop tours. . Others may need to be abandoned and removed due to their condition depending on landowners' desires. An assessment protocol would need to be developed to guide the process. CDOT could

then use the information to evaluate their future involvement in assisting in the long term stewardship of existing LSFs.

The desire by CDOT to place easements for installation and future access to locations where future LSFs might be planted could be a hindrance to getting LSFs onto lands adjoining highway right of ways. It was mentioned that if federal funding is used to pay for a LSF that an easement would be required. Part of the success of the previous LSF program was that the landowners provided the sites on a voluntary basis. This potential hindrance and landowner relation impacts should be considered if CDOT develops a LSF program.

Should CDOT become a major funding source and/or an easement holder for future LSF installations it would be advantageous to provide location and layout information using Global Positioning System technologies.

There are three potential methods for CDOT to implement a LSF program at either a local or on a state wide basis: conduct a program entirely within CDOT; involve other partners in an interagency cooperative program; or for CDOT to provide funding for another agency to manage and implement a program. Details of these options are provided in Section "4.4 Living Snow Fence Program Set Up Options" above. Due to expertise and specialized tree planting equipment which CDOT may not have, the option of providing funding for another agency to manage and implement a state wide program is the recommended alternative. It should be looked into whether or not this arrangement might eliminate the need for easements which, if required, would result in fewer landowners being willing to have a LSF located on their property.

7.0 References

Colorado State Forest Service. *Trees for Conservation: A Buyers Guide*. Fort Collins, Co: Colorado State Forest Service, 2008. Print.

Conservation Trees: For Your Farm, Family & Future. *Living Snow Fences*. Nebraska City: Conservation Trees: For Your Farm, Family & Future, n.d. Print.

Crisp, John. "Living Snow Fences." Interview. *Wyoming Forestry Division*. Wyoming State Lands, n.d. Web. <http://lands.state.wy.us/>.

Kelson, Aaron R; Lillieholm, Robert J.; Kuhns, Michael R. Economics of living snow fences in the Intermountain West. Western Journal of Applied Forestry. Vol. 14, no. 3 (July 1999) p. 132-136

Shaw, Dale L. *Living Snow Fences: Protection That Just Keeps Growing*. Fort Collins, Co: Colorado State University, 1991. Print.

"Living Snow Fences." *Colorado State Conservation Board*. Department of Agriculture, n.d. Web.(xxx)

University of Nebraska Cooperative Extension. *Field Windbreaks*. Lincoln: University of Nebraska Cooperative Extension, n.d. Print.

University of Nebraska Cooperative Extension. *How Windbreaks Work*. Lincoln: University of Nebraska Cooperative Extension, n.d. Print.

University of Nebraska Cooperative Extension. *Windbreak Establishment*. Lincoln: University of Nebraska Cooperative Extension, n.d. Print.

University of Nebraska Cooperative Extension. *Windbreaks for Livestock Operations*. Lincoln: University of Nebraska Cooperative Extension, n.d. Print.

University of Nebraska Cooperative Extension. *Windbreaks for Snow Management*. Lincoln: University of Nebraska Cooperative Extension, n.d. Print.

University of Nebraska Cooperative Extension. *Windbreaks and Wildlife*. Lincoln: University of Nebraska Cooperative Extension, n.d. Print.

University of Nebraska Cooperative Extension. *Windbreak Management*. Lincoln: University of Nebraska Cooperative Extension, n.d. Print.

USDA National Agroforestry Center. *Working Trees: Living Snow Fence*. Lincoln, NE: USDA National Agroforestry Center, 2011. Print.

Appendix A – Summary Report of Existing Living Snow Fences

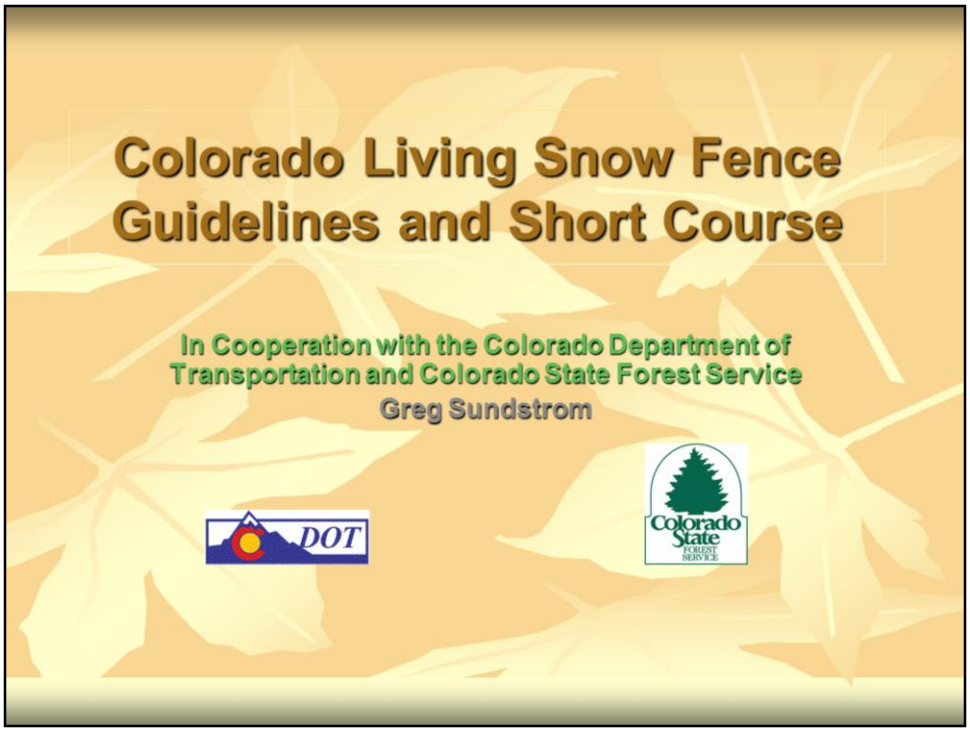
Colorado Living Snow Fence				Colorado Living Snow Fence			
Highway	**Mile Marker**	**Length**	**Travel direction**	**Highway**	**Mile Marker**	**Length (FT)**	**Travel direction**
CO 12	3	1600	East Bound	CO 52	33.1	2,600	West Bound
CO109	11.9	2640	West Bound	CO 52	43.5	1,000	West Bound
CO109	12	5480		CO 52	54	1,000	West Bound
CO109	53	2259		CO 52	56.1	2,700	West Bound
CO149	47.8	100	South Bound	CO 52	56.6	2,600	West Bound
CO17	117.215	5729	South Bound	CO 52	58.6	1,000	West Bound
CO194	10.5	500	West Bound	CO14	160.5	3,778	West Bound
CO194	19	1320		CO14	161.2	619	West Bound
CO194	10.5	968		CO14	161.4	636	West Bound
CO194	10.5	1300		CO14	162.5	623	West Bound
CO86	20.3	2750	West Bound	CO14	163.5	1,664	West Bound
CO86	36.7	1267	West Bound	CO14	166.1	173	West Bound
CO86	37.65	750	West Bound	CO14	167	1,537	West Bound
CO86	38.1	500	West Bound	CO14	167.3	2,193	West Bound
CO86	43.4	2675	West Bound	CO14	168.3	1,072	West Bound
CO86	47.6	1268	West Bound	CO14	169.7	544	West Bound
CO86	49.4	1880	West Bound	CO14	171.7	2,436	West Bound
CO86	55.8	2000	West Bound	CO14	174	1,023	West Bound
CO94	24.2	1056	West Bound	CO14	174.3	801	West Bound
CO94	29.5	1056	West Bound	CO14	175	1,986	West Bound
I-25	165.8	6336	South Bound	CO14	178.1	500	West Bound

Colorado Living Snow Fence				Colorado Living Snow Fence			
Highway	Mile Marker	Length	Travel direction	Highway	Mile Marker	Length (FT)	Travel direction
I-70	298.9	300	West Bound	CO14	187.1	500	West Bound
I-70	299.1	600	East Bound	CO14	215.5	500	West Bound
I-70	322.5	2683	West Bound	I-25	292.316	755	South Bound
I-70	327.1	2228	East Bound	I-25	293.295	2120	South Bound
I-70	350			I-25	297.601	2227	South Bound
I-70	407		East Bound	I-76	62.4	1,500	South Bound
I-70	403		West Bound	I-76	66.4	1,000	South Bound
I-70	404		West Bound	I-76	172.3	500	West Bound
I-70	405		West Bound	I-76	174.5	500	West Bound
I-70	406		East Bound	US287	365	1560	South Bound
I-70	410		East Bound	US287	373.5	2080	South Bound
I-70	398		East Bound	US287	374.8	2600	South Bound
US160	208.974	540	East Bound	US287	59.5	800	
US160	277.7	2000	East Bound	US287	47	1000	
US160	414.7	500	East Bound	US287	57.7	800	
US160	420.2	2640	East Bound	US287	57.7	800	
US160	430.9	500	East Bound	US34	239.3	2071	West Bound
US160	431.25	500	East Bound	US34	239.8	516	West Bound
US160	431.4	500	East Bound	US34	240	436	West Bound
US160	437.5	4200	East Bound	US34	240.5	465	West Bound
US160	444.5	500	East Bound	US34	241.2	559	West Bound
US160	446.3	1150	East Bound	US34	241.4	799	West Bound
US160	447.4	2640	East Bound	US34	242.8	451	West Bound

Colorado Living Snow Fence				Colorado Living Snow Fence			
Highway	Mile Marker	Length	Travel direction	Highway	Mile Marker	Length (FT)	Travel direction
US160	449	4200	East Bound	US34	243.2	515	West Bound
US160	451.3	800	East Bound	US34	243.5	509	West Bound
US160	460.1	800	East Bound	US34	243.9	430	West Bound
US160	460.8	800	East Bound	US34	244	336	West Bound
US160	470.15	500	East Bound	US34	245.5	1000	West Bound
US160	470.3	1056	East Bound	US36	30.5	1365	East Bound
US160	460.7	1320		US36	135.5	800	West Bound
US160	451.8	600		US36	135.5	800	West Bound
US160	447.5	2600		US36	142.2	400	West Bound
US160	449	1650		US36	142.2	400	West Bound
US160	470.15	1100		US36	165.8	1100	West Bound
US160	438	3900		US36	165.8	1100	West Bound
US160	460.35	200		US36	192.8	700	West Bound
US160	28.79	470		US36	196.1	850	West Bound
US160	464.5	2750		US36	210.5	2700	West Bound
US160	482	2500		US36	213.8	600	West Bound
US160	445	5280		US385	271.04	2,115	South Bound
US160	446.4	2640		US385	271.684	4,000	South Bound
US160	422.3	1518		US385	272.661	1,850	South Bound
US160	431.5	330		US385	273.213	775	South Bound
US160	431.3	330		US385	307-308	5280	South/West Bound
US160	431	330		US 385	304		South/West Bound
US160	415	630		US 385	124	5280	

Colorado Living Snow Fence				Colorado Living Snow Fence			
Highway	Mile Marker	Length	Travel direction	Highway	Mile Marker	Length (FT)	Travel direction
US24	203.75	1450	West Bound	US6	419.1	525	West Bound
US24	207.65	1035	West Bound	US6	419.3	150	West Bound
US24	223.6	1035	West Bound	US85	298.6	1,280	South Bound
US24	244.5	330	East Bound	US85	308.4	1,368	South Bound
US24	352.3	2100	West Bound	US85	309.1	1,600	South Bound
US24	362	30,000	West Bound	CO71	40	10560	
US24	364.5		West Bound	CO71	20	1600	
US24	365.2		West Bound	CO71	20.4	880	
US24	367		West Bound	CO71	20.7	480	
US24	367.7		West Bound	US 350	59.5	1320	
US24	368.3		West Bound	US285	100.114	127	South Bound
US24	432.9	3700	West Bound	US285	100.187	929	South Bound
US24	434	5280	West Bound	US285	105.1	18140	South Bound
US24	439	1580	West Bound	US287	59.4	1600	South Bound
US24	440.5	500	West Bound	US287	96	1600	South Bound
US24	441.3	2100	West Bound	US50	461.4	3700	West Bound
US285	99.795	211	South Bound	CO 13	20.9	500	South Bound
US285	100.114	797	South Bound	CO 13	52.3	500	South Bound
CO 125	72	600	South Bound	CO 59	29		South Bound
CR 3 & CO 138			West Bound	CO 59	23		North Bound
CO 138 & CR 11			West Bound	CO 59	19		North Bound
CO 59	38		South Bound				

Appendix B. - Colorado Living Snow Fence Guidelines and Short Course PowerPoint Training Presentation

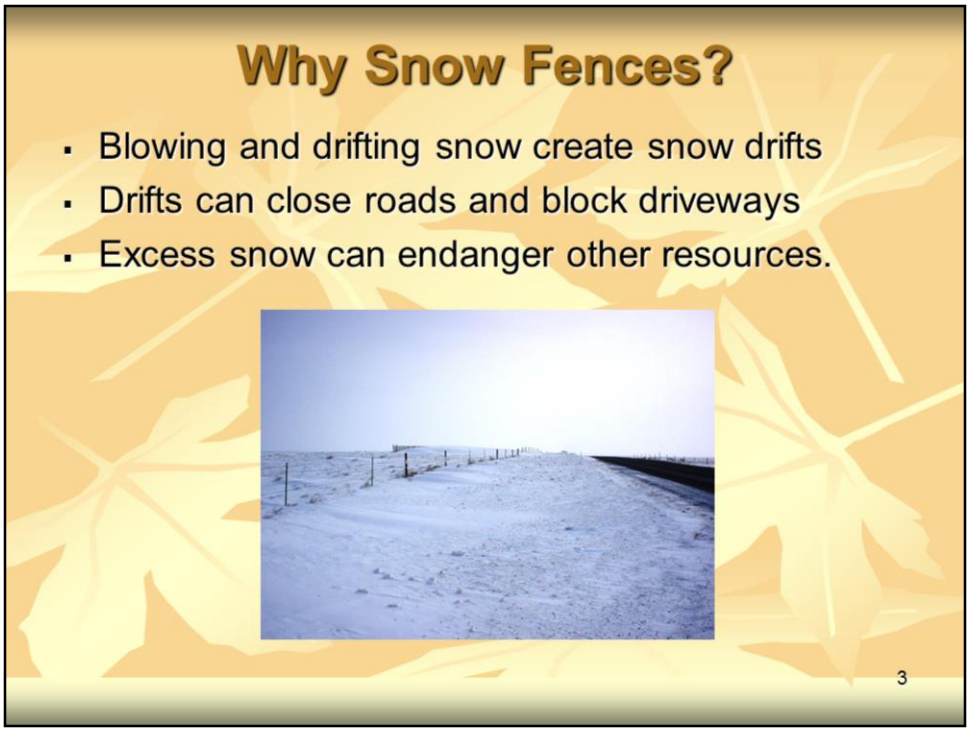


This presentation and training notebook presented by Greg Sundstrom to CDOT staff, as part of CDOT Applied Research and Innovation Branch's Living Snow Fence research project 2014.

Dates for training follow:

- 2/4/14 - 2/5/14 Poncha Springs, CO — Region 5 Poncha Springs Conference Room
- 2/18/14 - 2/19/14 Pueblo, CO — Region 2 902 Eerie Basement Conference Room
- 3/25/14 - 3/26/14 Greeley, CO — Region 4 Platte Room
- 4/2/14 - 4/3/14 Denver, CO — Region 1 and HQ Mt. Evans Conf Rooms A & B at HQ
- 4/16/14 - 4/17/14 Craig, CO — Region 3 Black Mountain Conference Room (Maint Conf Room)

Training Short Course schedule and topics



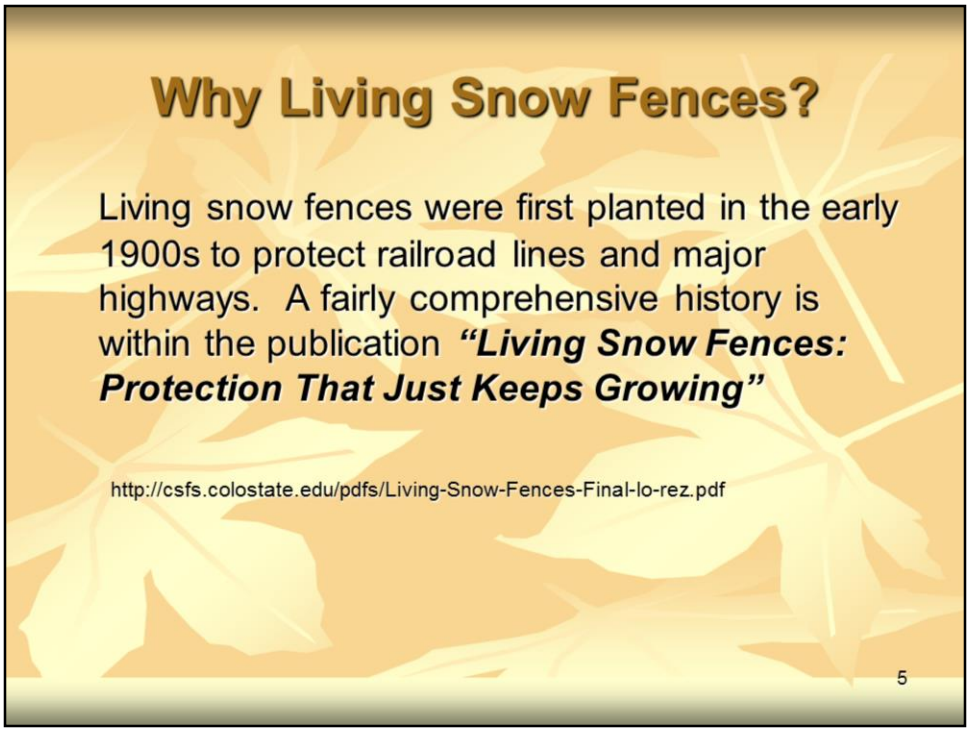
Winds can carry small particles such as soil and snow. Reducing the speed of the wind with barriers reduces its capability to carry these particles causing the particles to be deposited on the leeward or down wind side of a barrier. Constructing barriers at strategic locations along highways can help control where drifting snow gets deposited.

Even though this slatted snow fence captured a lot of snow, the road still needed to be plowed after a blizzard. Snow fences can fail to keep all the snow off a road if not properly designed and located. Even then, there will be times when the road protected during normal snow fall situations will need to have snow removed during the weather extremes we often experience in Colorado.

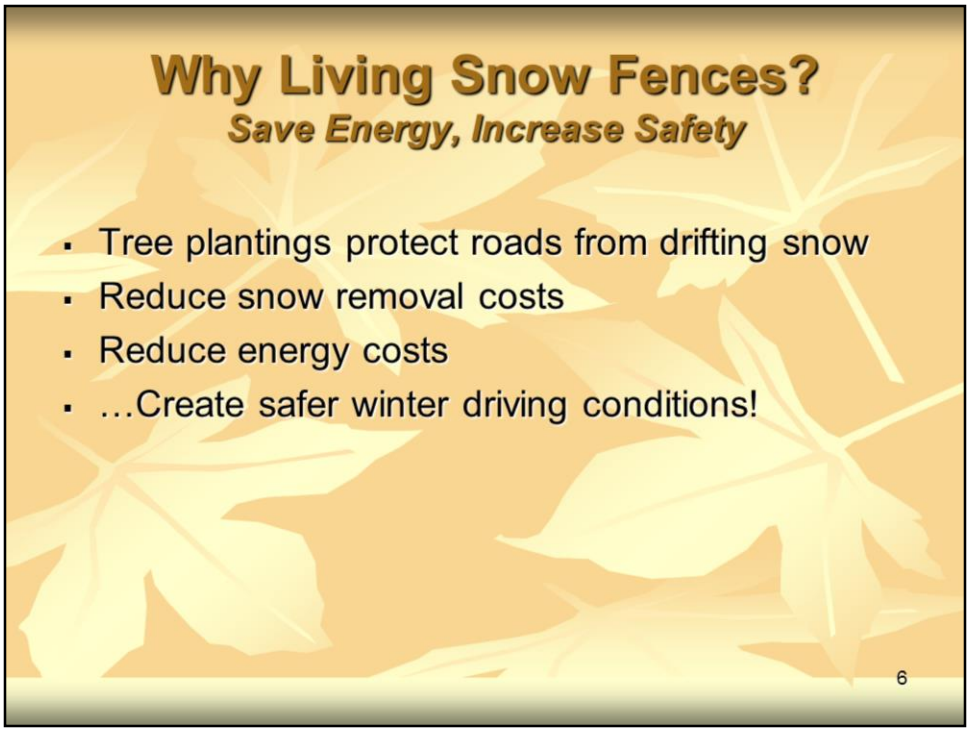
Photo – NRCS

Slat fences and living snow fences are commonly installed to act as barriers to snow movement.

Photo – NRCS



A copy of this publication is included in the course notebook.



The following was stated in a 1999 study: "Efficiency gains from living snow fences, evaluated using the annualized cost approach, demonstrate that the benefits to society outweigh the costs. An example is presented using an average sized, 1040-ft-long, 3 row snow fence, and a discount rate of 8%. To offset snow fence costs over a 50 year expected life, the fence need only reduce traffic accidents by as little as one every 23 yr, or reduce snow plowing by about 6hr/yr. Other likely but less quantifiable benefits make the benefits of living snow fences even more economical to society.

Kelson, Aaron R; Lillieholm, Robert J.; Kuhns, Michael R. Economics of living snow fences in the Intermountain West. Western journal of applied forestry. Vol. 14, no. 3 (July 1999) p. 132-136

In 1995 the LSF Coordinator for Colorado wrote the following in a letter to the CDOT.

"The DOT Foreman at Arriba has reported that the Department realizes a benefit of $600 per living snow fence per storm along I-70 in snow removal costs. He also estimates they spend $8,000-$9,000 in snow removal costs on Highway 71 where there are no Living Snow Fences. Safety, aesthetics and wildlife benefits are over and above the actual dollar benefits. ……."

These documents are included in the notebook.

This snow fence was planted in 1987. It is fully functional and has had minimal maintenance in 26 years.

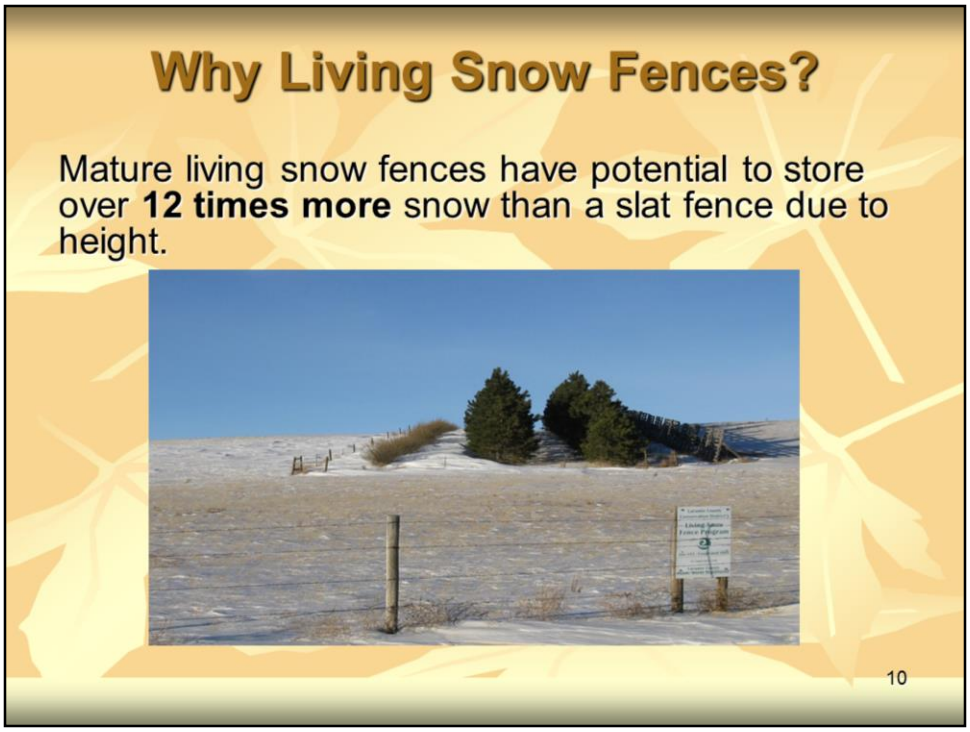
Photo – Amy L Inskeep-Wonch

This Wyoming snow fence is in need of repair.

Photo – Amy L Inskeep-Wonch

While snow fences can keep snow from causing problems on roads, they can also reduce maintenance costs and time required to remove snow drifts around public facilities such as rest areas and ports of entry. A living snow fence to the windward side of this rest area keeps snow from piling around the rest area entrance and parking area.

Photo – Amy L Inskeep-Wonch



A critical consideration in barrier storage capacity is height. Other factors being equal , storage capacity increases more than four times when height is doubled. For example, mature living fences have the potential to store over 12 times more snow than a single row of picket fence.

Photo – Dennis Kemmer

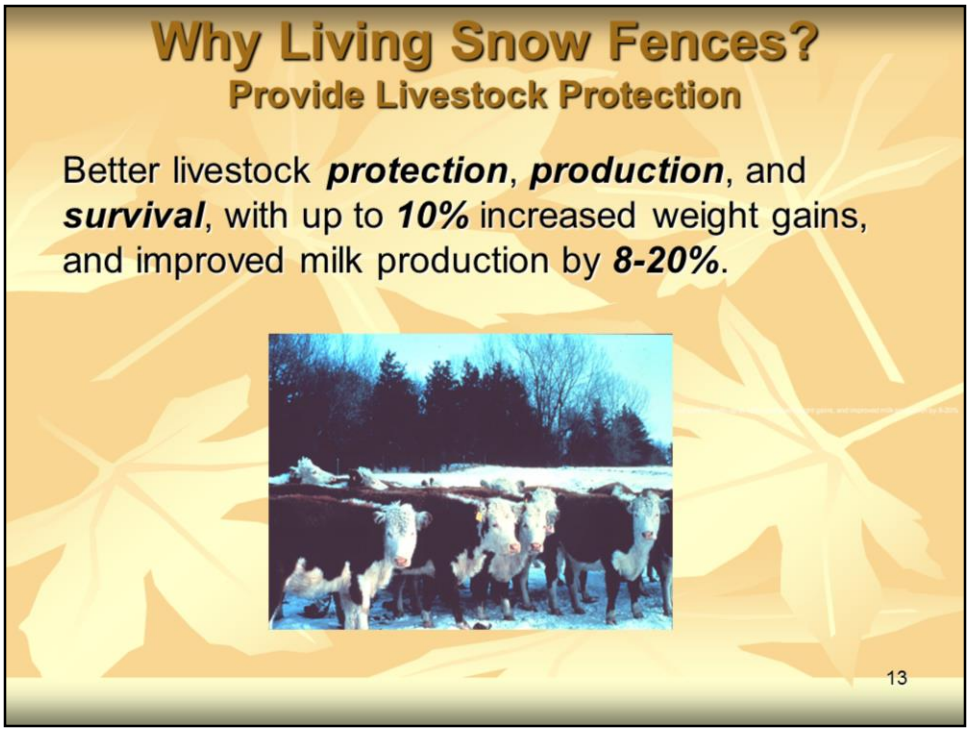
Landowners and program supporters value this benefit.

Be aware that tall trees on the plains may attract avian predators that can impact ground dwelling animals. If this is a concern, design the LSF using shrubs and short trees. Windbreaks have potential to attract wildlife to areas near roads which can create hazards for both wildlife and vehicles. Are these potential negative consequences higher priority than the positive safety benefits provided by a Living Snow Fence?"

Photos – Pheasants, Jerry Miller; Deer - Amy L Inskeep-Wonch

Fruit such as these plums are good to eat, and living snow fences are a good source of easy to gather tree and shrub seed. A break in the monotony of a flat landscape can have eye appeal to highway travelers.

Photos – Top, Amy L Inskeep-Wonch; Bottom - CSFS

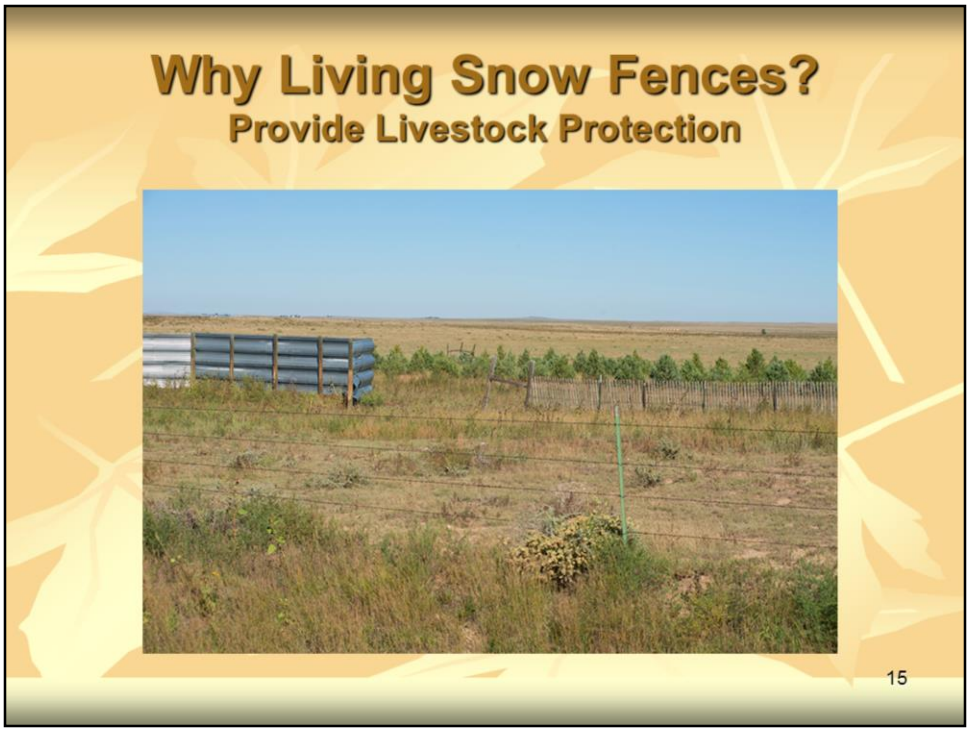


A good selling point for landowners to allow LSFs on grazing lands.

Phot0 - USDA

This snow fence was planted in the corner of a pivot system at the junction of a county road and a state highway. The snow fence was laid out and fenced so that cattle that graze the crop aftermath in the field may have shelter behind it should a severe snow storm cause them to drift. The intersection is on a school bus route and commonly had snow blocking it prior to the LSF becoming functional.

Photo – Amy L Inskeep-Wonch



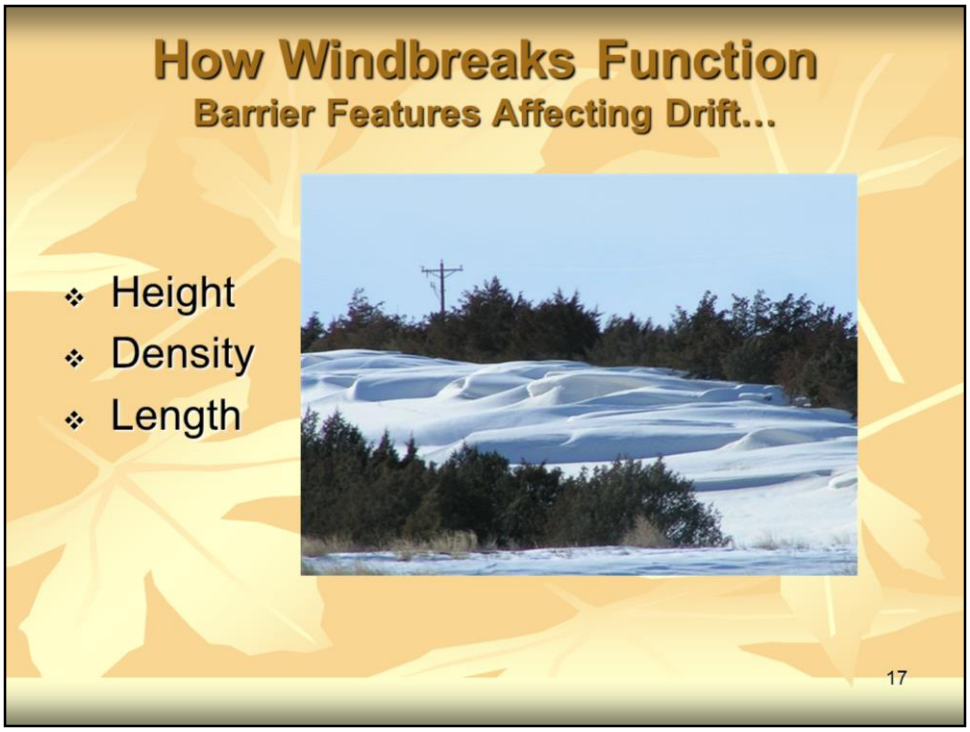
This steel livestock shelter has limited area behind it for livestock protection. The trees in the living snow fence expands this area and will be there long after the steel structure has fallen down. Note the existing slat fence which served a single purpose of controlling snow. Living snow fences often are planned to serve multiple benefits.

Photo – Amy L Inskeep-Wonch

Increased yields behind living snow fences can compensate for the area taken out of production. Runoff from melting snow increases soil moisture and improves crop yields. A publication entitled “Field Windbreaks” is included in the notebook .

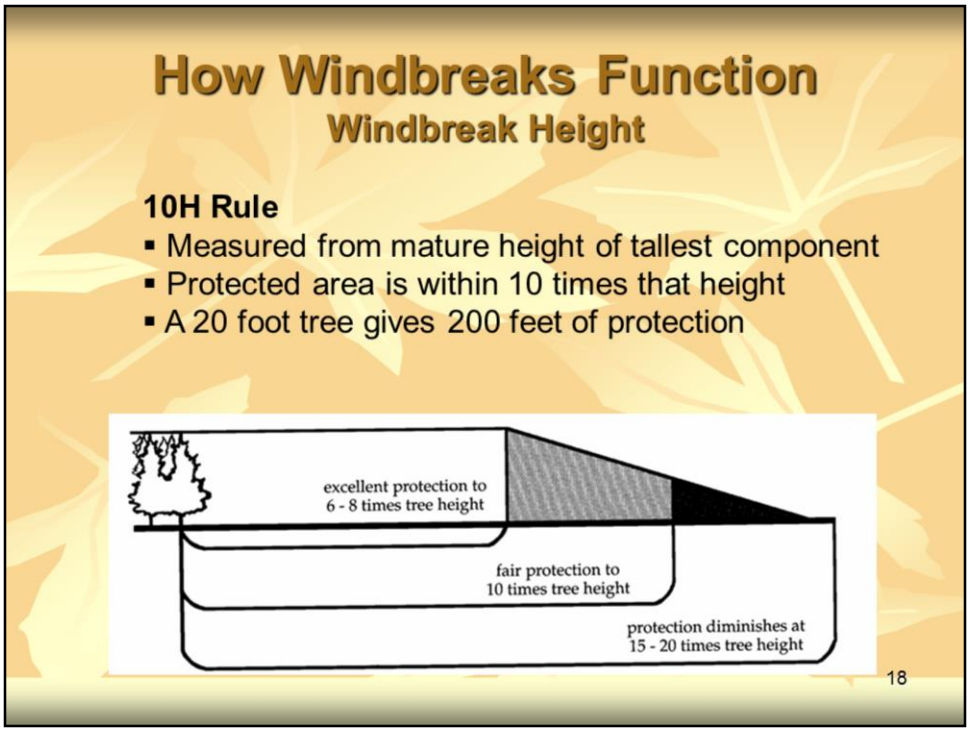
Wildlife attracted by windbreaks can assist in controlling insects that may impact crops.

Photo – Amy L Inskeep-Wonch

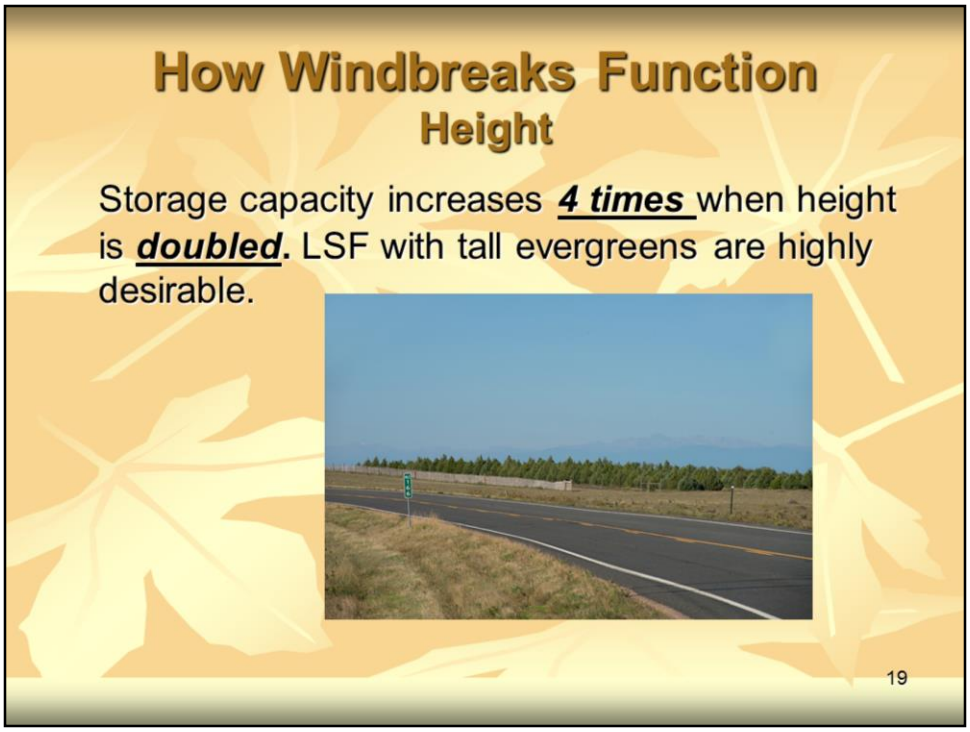


Snow storage capacity and area of protection behind a living snow fence is determined by the height of the tallest row, the density of the barrier created and the length of the barrier.

Photo – Larry Brachtenbach

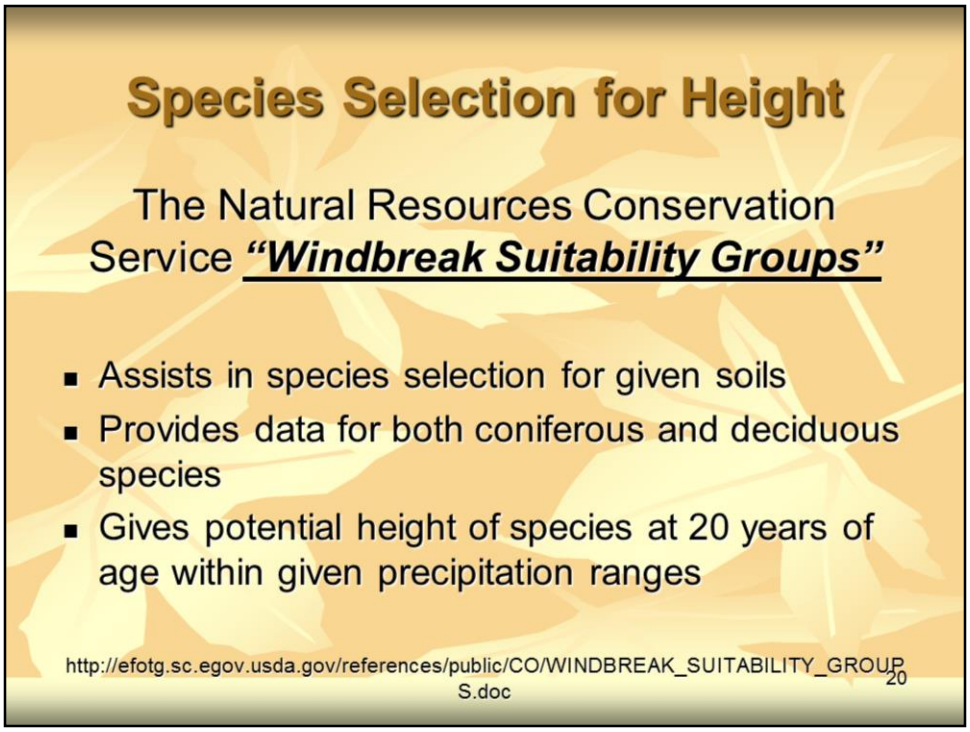


A common rule of thumb is that wind velocity is reduced to 50% at ten times the height a windbreak.

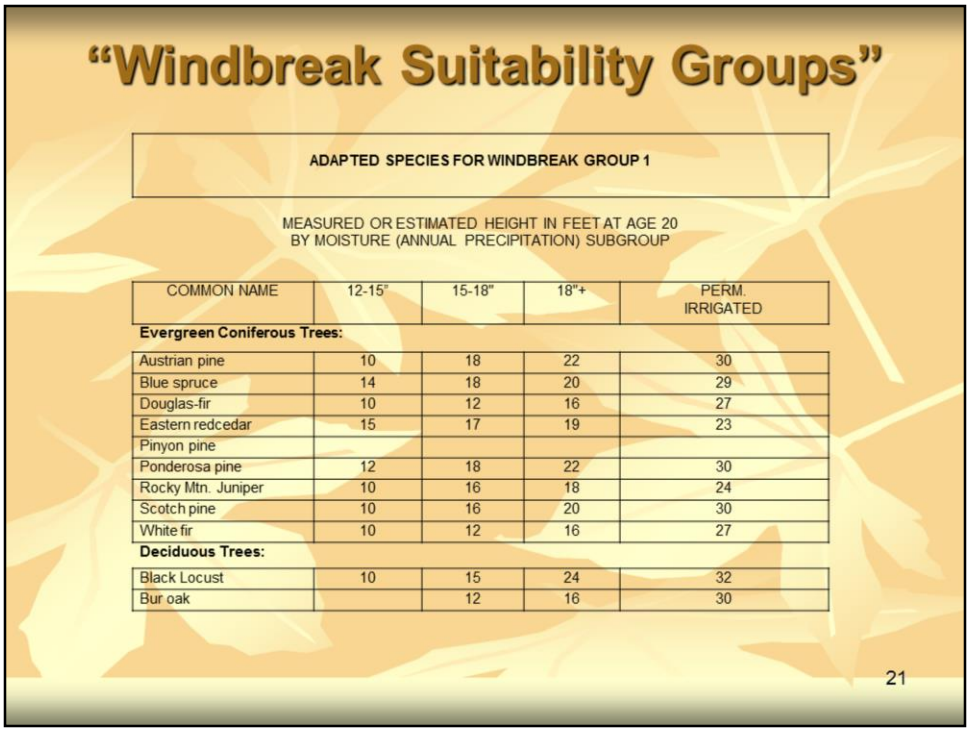


This curve in the road is protected by multiple rows of Rocky Mountain juniper. Note the height of the trees compared to the previously installed slat fence.

Photo – Amy L Inskeep-Wonch



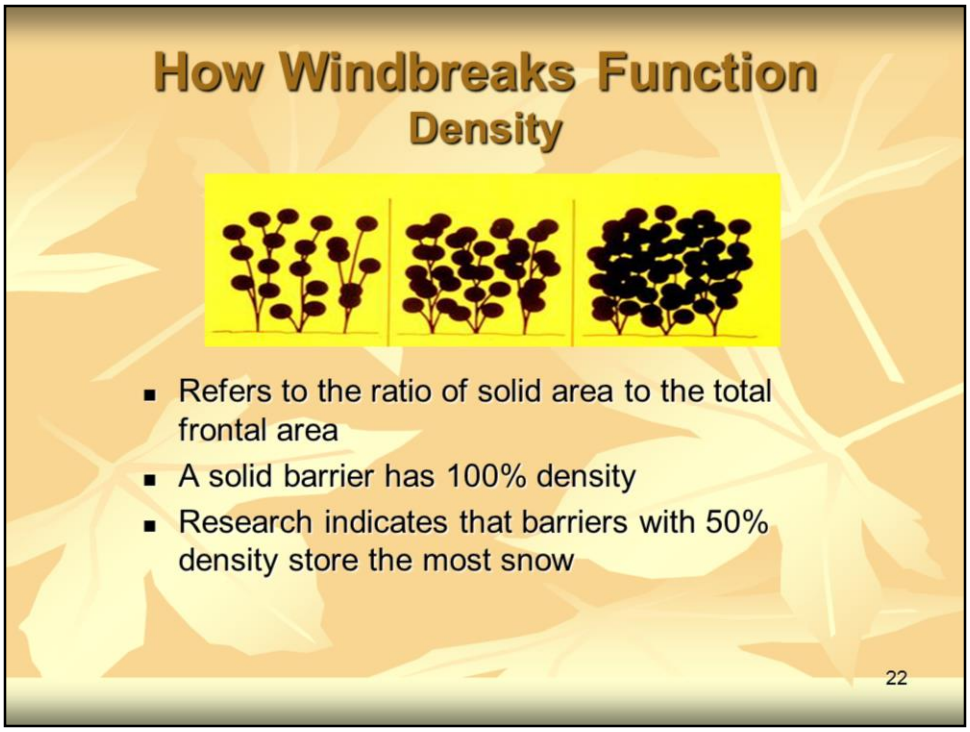
A copy of this document is included in the notebook.



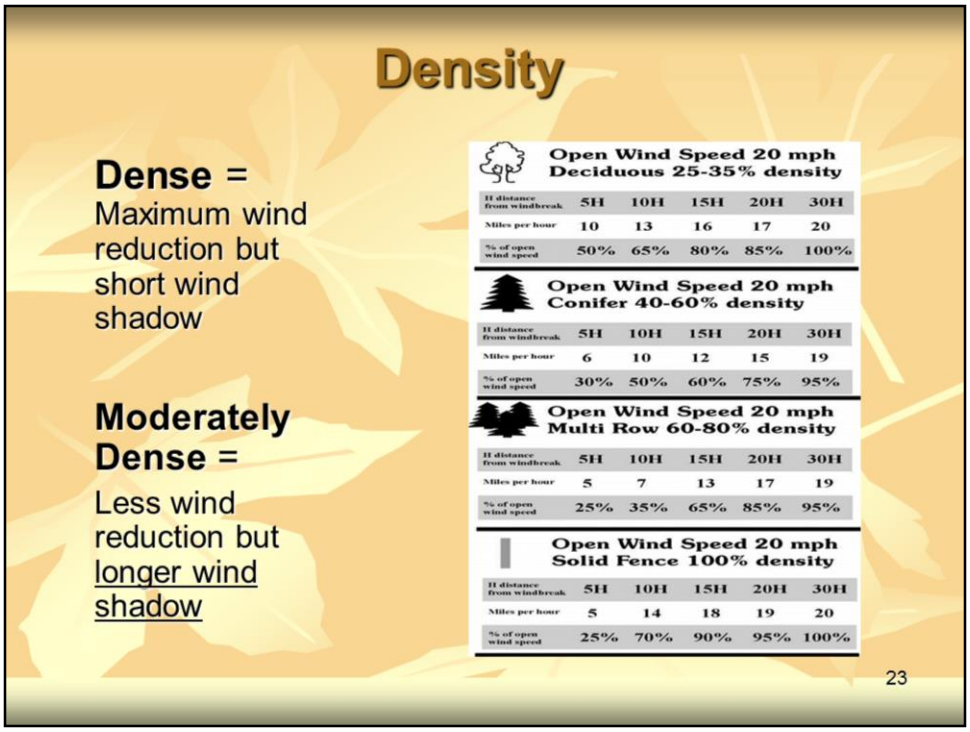
The soils on a given site determine which, if any, trees and shrubs may grow there. The Natural Resources Service has mapped soils across the United States. They also have soils specialists in nearly every county, co-located with natural resources conservation district offices. The NRCS web site has a tool with mapping capabilities to assist in determining soils. That tool is located at: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Once the soil name is found a planner can go to the Windbreak Suitability Groups to determine which species and their potential heights under different precipitation ranges may be planted. The full "Windbreak Suitability Groups" document for Colorado is included in the notebook.

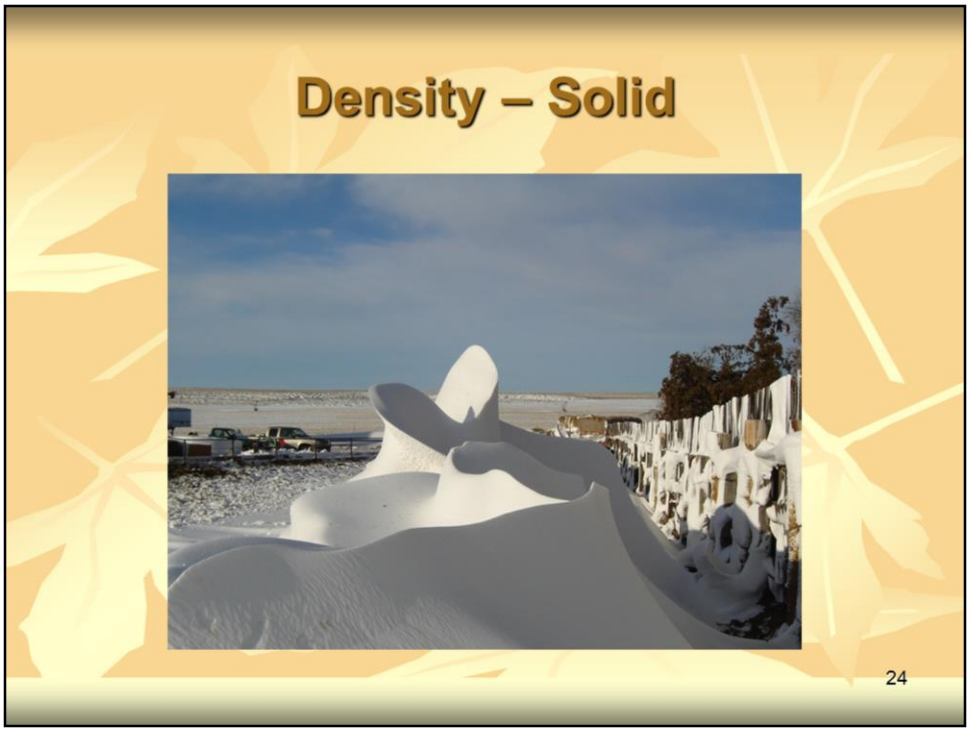
Species selected should be adapted to the site and not on the Colorado noxious weed list .



The opposite of density is porosity. Most slatted snow fences are built with 50% density.

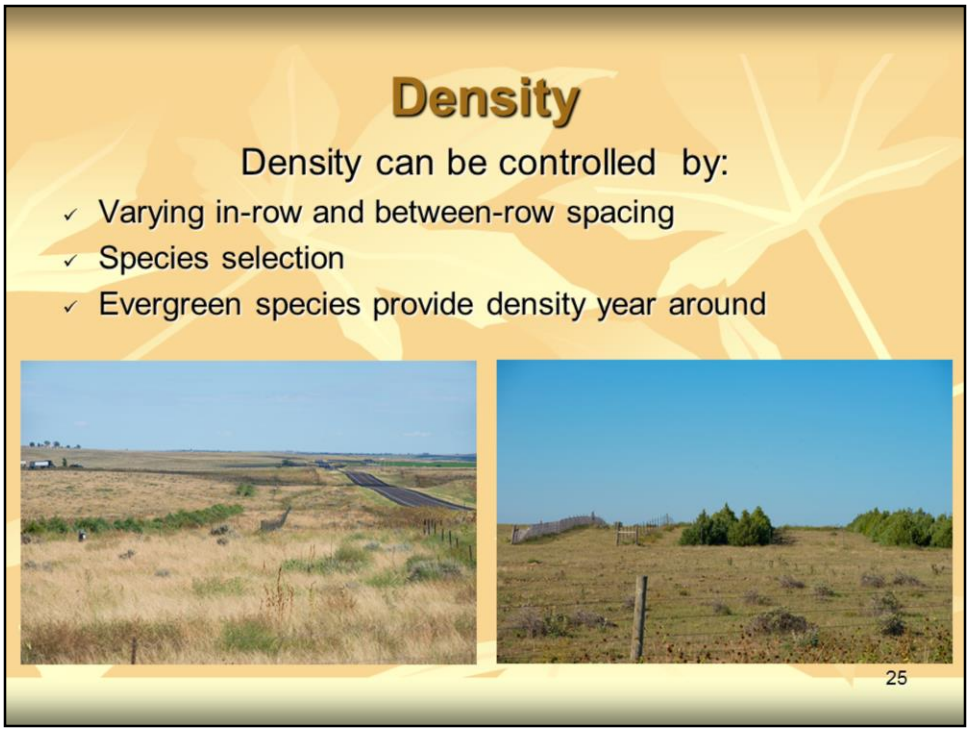


This chart shows percent of reduction in wind speed at various distances behind various barriers of differing densities.



There can be extreme wind turbulence behind solid barriers resulting in little snow storage. The drift in this photo is a good indication of how such turbulence can impact snow deposition.

Photo – Larry Brachtenbach



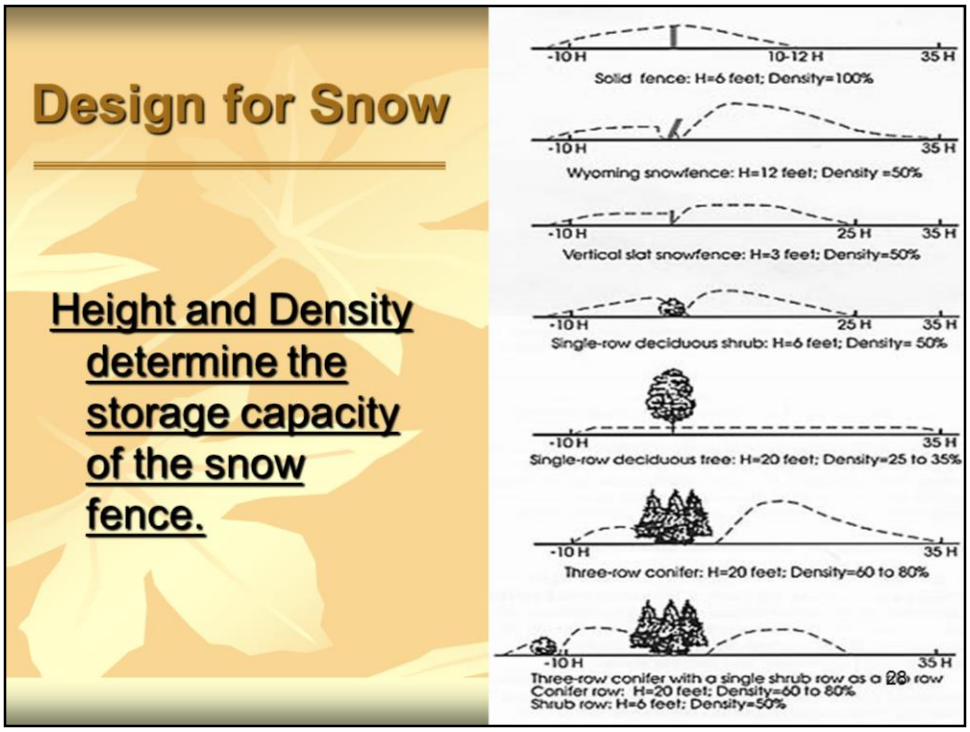
A very dense LSF can be planted with Rocky Mt. juniper in 2 rows with 10 feet or less between rows and in-row spacing of 8 feet – Twin row high density design.

Not only can this design create a dense barrier, having trees planted closely in these twin rows will result in canopy closure quicker, making the snow fence functional at an earlier age. Most windbreaks are designed to be fully functional at twenty years of age. This means they will be of the proper density and height to provide protection of the area they were intended to protect at 20 years of age. Multiple twin row high density rows of trees can significantly increase snow storage capacity.

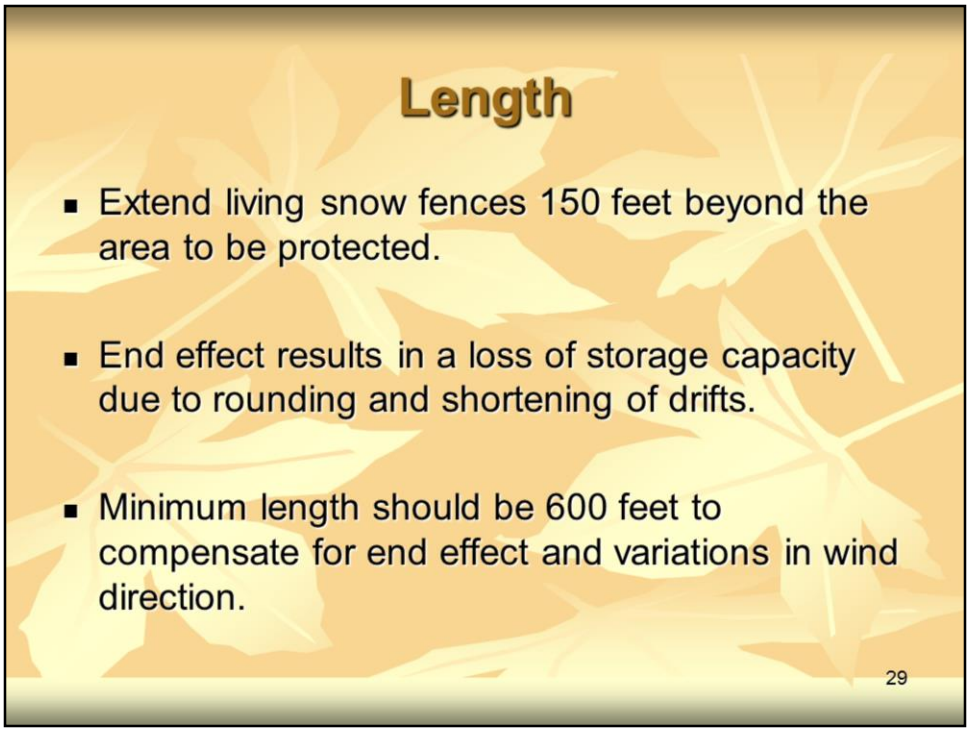
Photos – Amy L Inskeep-Wonch

This guide is included in the notebook.

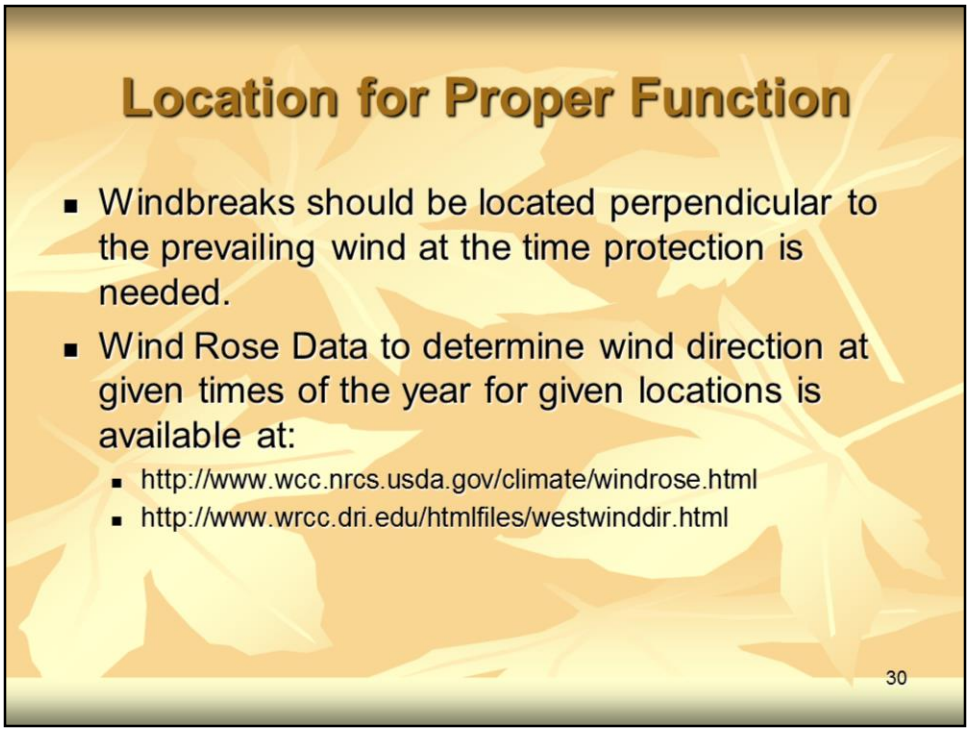
Species are selected based on fencing goals, and requirements of each site



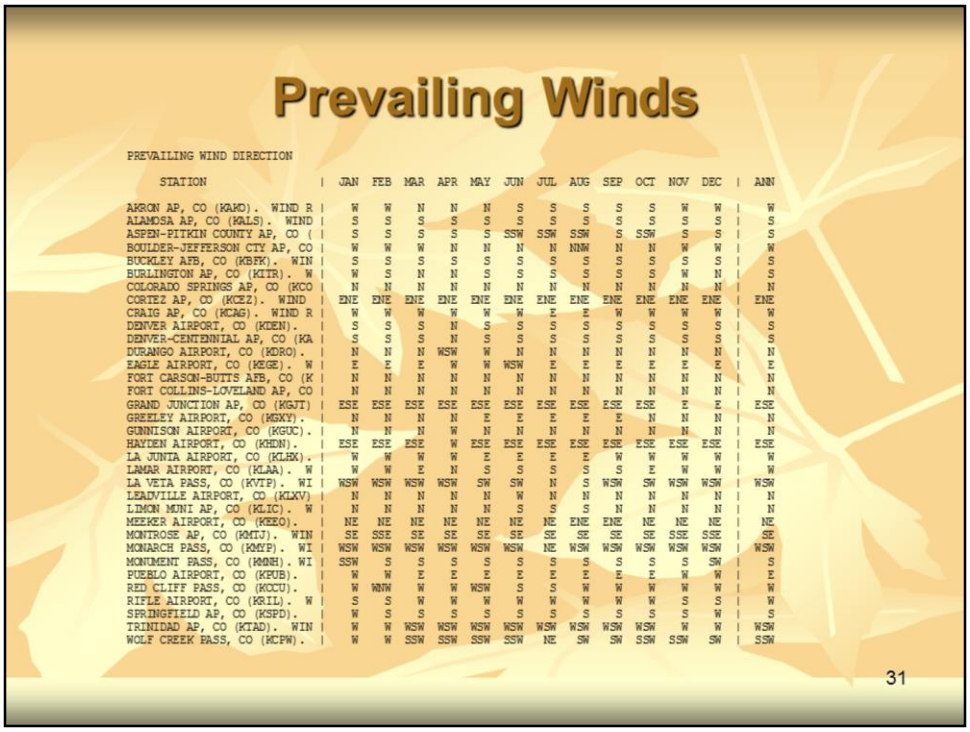
This chart shows snow storage area at various densities and heights of different types of snow fences.



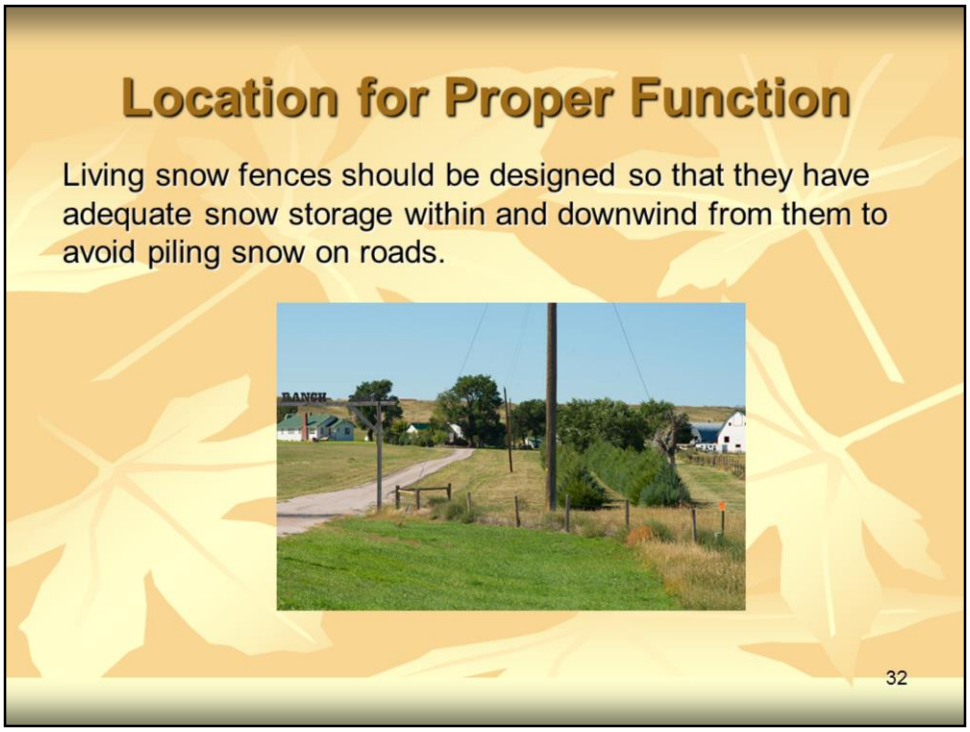
Wind does not always blow from a single direction. It is common for it to vary 45 degrees from what might be considered the prevailing wind direction. With this in mind, to protect an area 300 feet long, which is a fairly short distance along a road, extending a windbreak 150 feet on each end past this 300 feet long area will compensate for the varying winds to better protect the 300 feet length.



Information about wind roses and local weather station data is included in the note book. The publication “Living Snow Fences: Protection That Just Keeps Growing” which is included in the notebook has excellent guidance on locating living snow fences.



This is a table that is located at: http://www.wrcc.dri.edu/htmlfiles/westwinddir.html and is in the notebook. Note the different wind directions depending on what time of the year it is for various locations.



This windbreak along a private road is located perpendicular to the prevailing wind in this area. While very attractive, it has huge potential to pile snow on the road in the winter when the trees reach their full growth.

Shaw states in the Living Snow Fences: Protection that Keeps Growing publication, “The living snow fence should be placed as close to the road as possible yet far enough away so that the leeward drift edges do not touch the road.”

The Natural Resource Conservation Service specification for their “Windbreak /Shelterbelt Establishment”, Code 380 practice in Colorado states “Where a living snow fence will be the only structure or factor keeping snow off a road, the windward row or the living snow fence should be located at least 200 feet from the center line of the road being protected”. A copy of the standard and specification is included in the notebook. Keeping LSFs back from a highway far enough to avoid capturing snow on the highway usually dictates planting the LSF on adjacent lands, rather in Right of Ways. Other guidance indicates distances of 100 feet to 300 feet back from the highway are appropriate.

Photo – Amy L Inskeep-Wonch

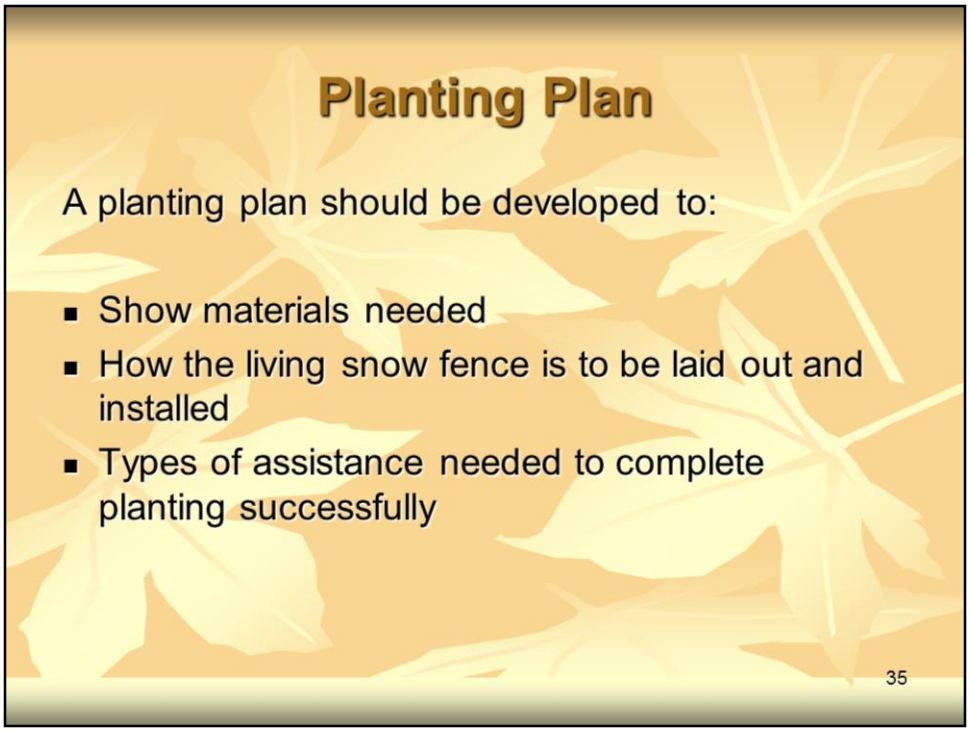
Living snow fences can be planted in a variety of designs, depending on storage capacity needs, space available, available funding, soils types, geography, Etc. The design in the left photo has 4 rows spaced at 20 feet between the rows, planted to replace the Wyoming slatted snow fence. There has been two phases of planting, with the younger phase being planted along the slope of the hill, probably to compensate for end affect around the older phase.

The right photo show a 2 row high density twin-row with a third row of shrubs design, which, not having an existing slatted fence in place, should have become functional at a younger age than the other design where the trees were space wider apart.

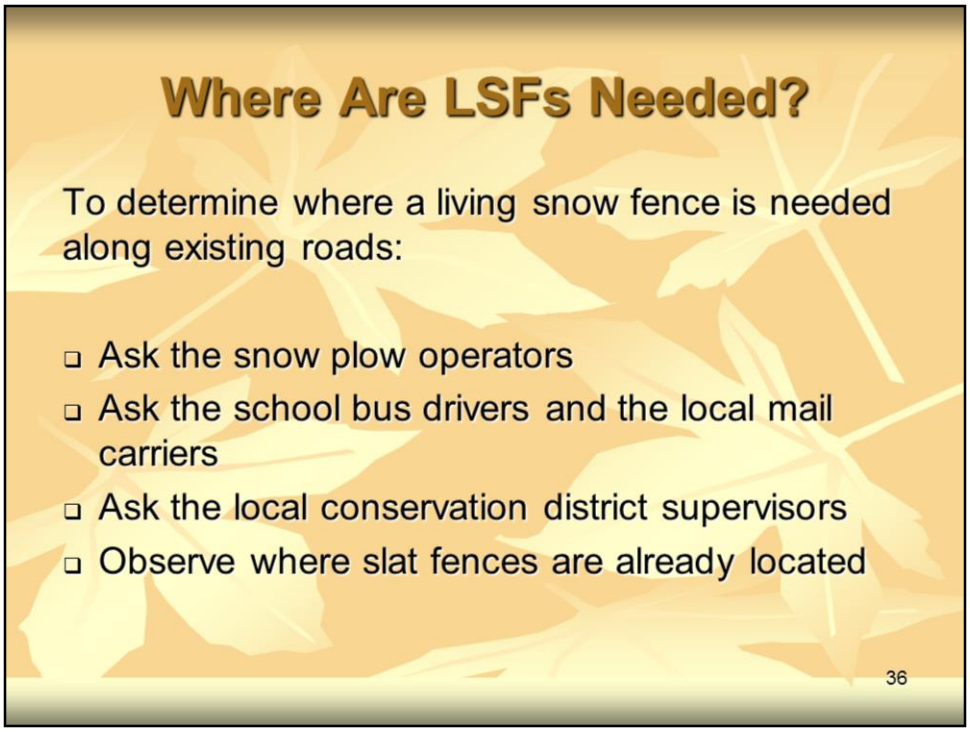
Photos – Amy L Inskeep-Wonch

Designs vary from single twin row high density plantings to multiple row living snow fences. Shrubs are often included in designs for wildlife benefits. Design often is influenced by what a land owner might want as a benefit of the project and the space he/she may be willing to provide.

Photo – Amy L Inskeep-Wonch



A planting plan will show project location and distances from the road and other features, species to be planted, spacing between trees within rows and spacing between rows. Installation method, drip supplies and mulch material needed and any other information that could aid in insuring the project is planted as planned will assist in completing the living snow fence. The plan should include a drawing of the project. A examples of planting plan forms are in the notebook.



People who work and live in the local area are the ones who travel the highways the most during all seasons of the year. They are the most impacted when roads are blocked by snow. They are probably the best resource for determining where the major problem areas are. A long term solution to having an existing snow fence which has been requiring continual maintenance is to replace it with a living snow fence which can be designed to be more functional and require less maintenance when established.

Note that the road is lower than the adjacent land surface. Also note that this living snow fence has 3 rows – one row of shrubs on the windward side and 2 rows of Rocky Mountain juniper. This is a very common design in Colorado.

Photo – Amy L Inskeep-Wonch

This living snow fence was installed to solve the problem of snow sifting across and sticking to the road surface creating dangerous icy road conditions on this curve. The multiple row twin-row high density planting with a row of shrubs for wildlife included in it is one of the most effective designs for storing large volumes of snow and providing wildlife habitat.

Photo – Amy L Inskeep-Wonch

While the road along this cut is being protected by a living snow fence just over and on top of the hill, a living snow fence was installed on this slope perpendicular to the prevailing wind to stop snow from blowing across the road where this traffic barrier could cause it to accumulate on the road.

Photo – Amy L Inskeep-Wonch

Slatted snow fences were located along this highway entrance to keep snow from drifting across the road causing icy conditions on the access road and highway. A living snow fence was planted in the same location for longer term and more effective snow control. When snow removal from access roads is secondary in priority to getting a main road opened, living snow fences can be planted to reduce the amount of snow that may drift and accumulate on the access road. A few years ago, west of Fort Morgan, an exit from I-76 was redone and a living snow fence was included in the project design specifically for this reason.

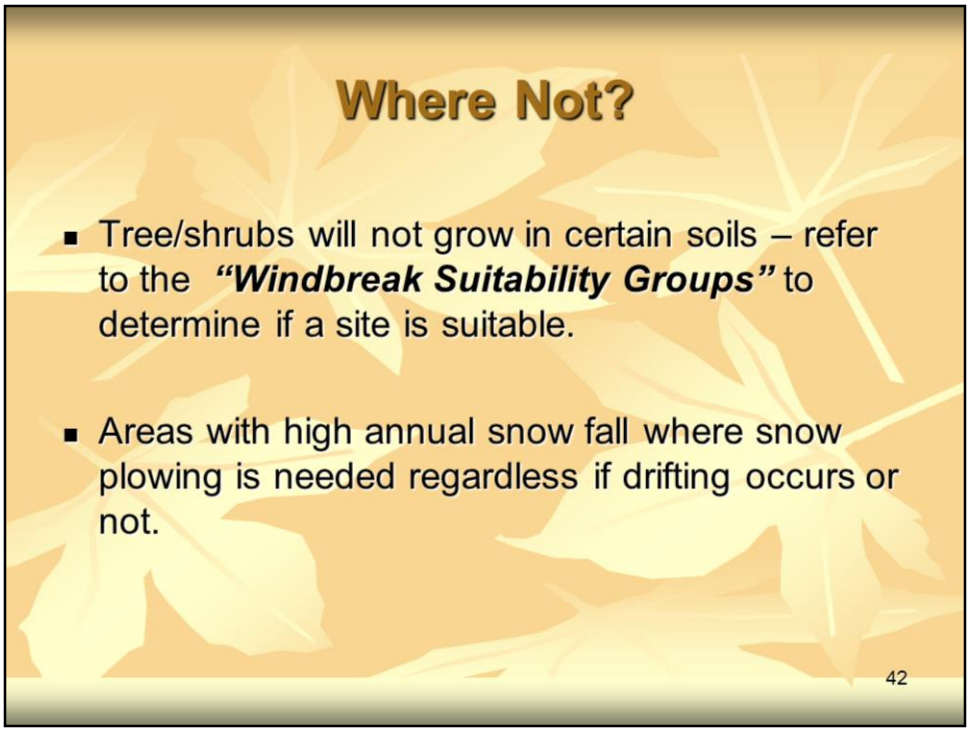
Photo – Amy L Inskeep-Wonch

Note that the road surface in this location is actually higher than the upwind area. The slatted snow fence had been installed along this road to stop continual drifting which created icy conditions along this stretch. Rocky Mt. juniper have been planted to provide this function for a longer period which will reduce long term maintenance needs and is more attractive to look at.

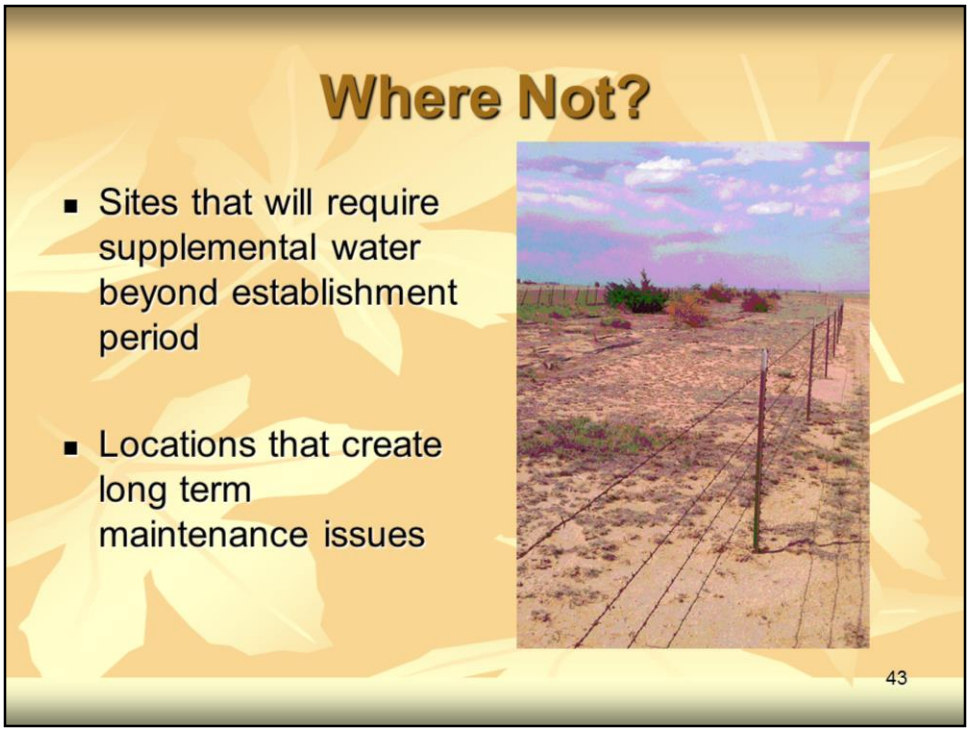
A rebuild project of Pena Boulevard going to Denver International Airport has a living snow fence of low growing shrubs included in the project design. Rows of shrubs will be planted on the windward side of the two lane road and in the median to stop snow from drifting across the road. Drifting snow sticking to the road surface has been causing dangerous icy conditions on this important road.

Photo – Amy L Inskeep-Wonch

.



A given site may not support trees and shrubs due to soils and precipitation. Will a site support trees and shrubs without long term maintenance needs in the form of watering and/or continual replacement of dead trees? Many areas of Colorado normally receive high amounts of snow and require almost daily snow plowing whether it drifted onto the road or not.



This site appears to be too dry to support trees and shrubs with out long term supplemental watering. This long term need specific to growing trees and shrubs on this site raises doubt to the economic feasibility of trying to have a living snow fence on a site like this. Where drought is a common occurrence, let's stick with slated snow fences.

Photo – Greg Sundstrom

There are basically 3 options in setting up a living snow fence program in Colorado. Regardless of how a program is set up, success will require individuals within each area or agency be designated as a coordinator.

Colorado State Forest Service is an agency within Colorado State University. There are 17 district offices located across the state, and a conservation seedling nursery located in Fort Collins. A directory of their district offices is in the notebook. http://csfs.colostate.edu/pages/your-local-forester.html

Seedlings for conservation can be purchased from the CSFS Nursery. http://csfs.colostate.edu/pages/seedling-tree-nursery.html

The Natural Resources Conservation Service is an agency within the United States Department of Agriculture. The NRCS has an office in nearly every county of the state. An office locator map is in the notebook.

http://offices.sc.egov.usda.gov/locator/app?service=page/CountyMap&state=CO&stateName=Colorado&stateCode=08

Colorado's Conservation Districts represent private landowners' interests in "local governments", they fall under the statutory guidance of the State. conservation planning and practices. They have led this charge since they were created by the Colorado State Legislature in 1937. While Conservation Districts are technically considered

The **State Conservation Board** is comprised of Conservation District representatives from Colorado's 10 watersheds and provides guidance to the Department of Agriculture for:

Disperses state grant funds and direct assistance to the Conservation Districts

Develops training tools for long and short term planning, budgeting, and laws pertaining to local governance

Performs as a board of appeals for landowners appealing Conservation District activities

Helps facilitate local conservation programs

Colorado's seventy-six conservation districts are dedicated to conserving natural resources. Districts are generally co-located with NRCS offices. Board members are local landowners. A map and directory of conservation districts is in the notebook.

Landowners are a critical partner for any LSF project that needs to be placed on non CDOT ROW sites. They may provide assistance in a variety of means, even to the point of participating in various cost share programs that can provide financial assistance for LSF installations. These programs may change at any time due to political decisions. An example is the Continuous Conservation Reserve Program with the Farm Services Agency . That program has sign up payments and land payments for up to 15 years for LSF installations on crop land. That program may provide up to 90% of the cost of the installation. The Environmental Incentives Program with the

Natural Resources Conservation Service may provide 50% cost share for LSFs in certain parts of the state. Some conservation districts also have financial incentives for LSFs in their areas. It must be kept in mind that these programs agreements are for with the landowner and ties them to certain expectations which they may not wish to take on.

Landowners are a critical partner for any LSF project that needs to be placed on non CDOT ROW sites. They may provide assistance in a variety of means, even to the point of participating in various cost share programs that can provide financial assistance for LSF installations. These programs may change at any time due to political decisions. An example is the Continuous Conservation Reserve Program with the Farm Services Agency . That program has sign up payments and land payments for up to 15 years for LSF installations on crop land. That program may provide up to 90% of the cost of the installation. The Environmental Incentives Program with the Natural Resources Conservation Service may provide 50% cost share for LSFs in certain parts of the state. Some conservation districts also have financial incentives for LSFs in their areas. It must be kept in mind that these programs agreements are for with the landowner and ties them to certain expectations which they may not wish to take on.

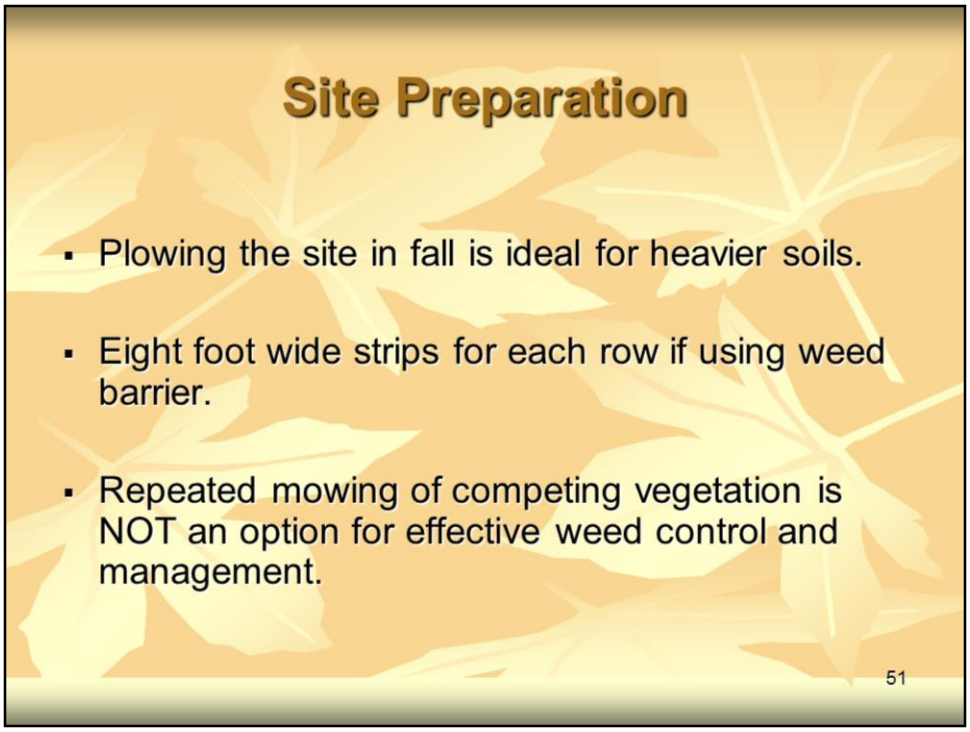
The Interagency Cooperative Living Snow Fence had an extensive list of partners and contributors. This arrangement took a huge amount of coordination and process. Over 300 living snow fences were installed on county roads and state highways. The program demonstrated the value of living snow fences and protected miles of roads, but was dissolved as contributor funds and agency priorities changed. There are various reports about the program in the notebook.

This option could be patterned after the successful Wyoming Living Snow Fence Program which is a cooperative effort between the Wyoming Department of Transportation (WYDOT), Wyoming State Forestry Division (WSFD), local conservation districts (CD) and private landowners to implement windbreak plantings for the purpose of snow catchment along State highways. The program provides funds to cover the costs of planting and maintaining LSF projects. A copy of the "Wyoming Living Snow Fence Program Procedure" is included in the notebook.

A well planned and laid out living snow fence will prevent snow from being deposited on a road during normal snow fall events.

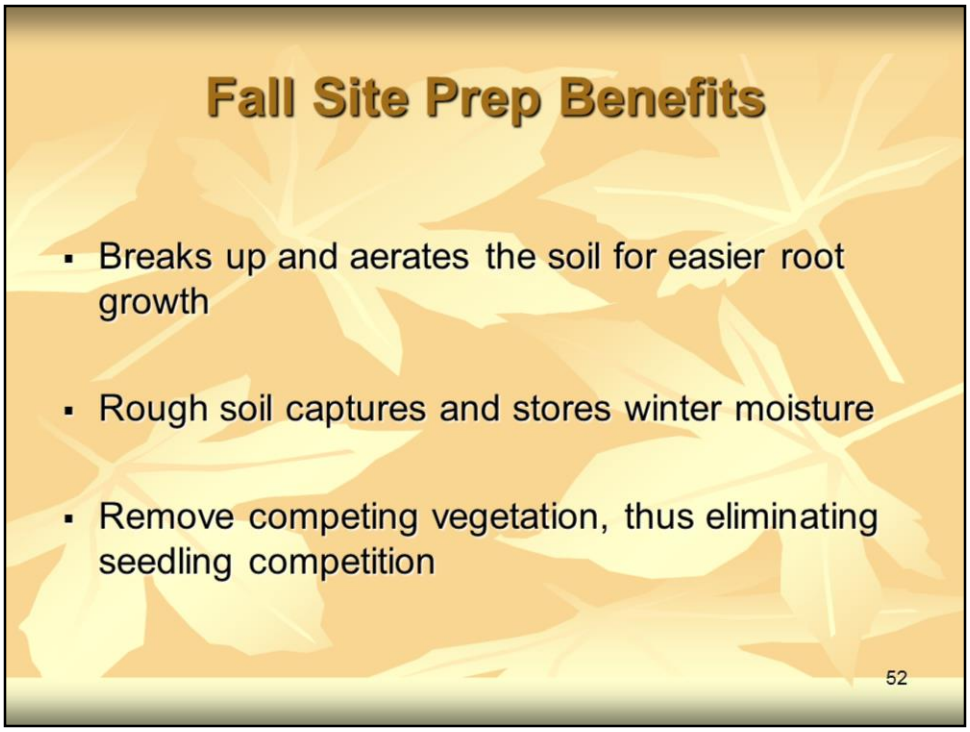
Straight rows aid in mowing and other maintenance activities.

Photo - Boyd Labeda



Plow site in fall for prep.

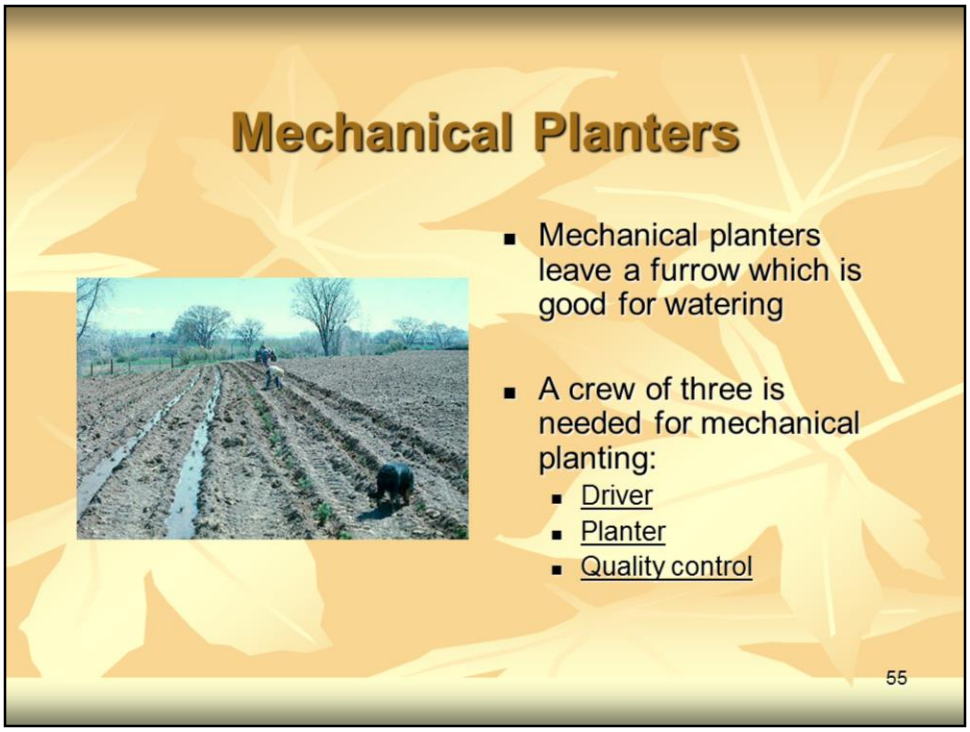
Weeds cannot be controlled simply thru repeated mowing



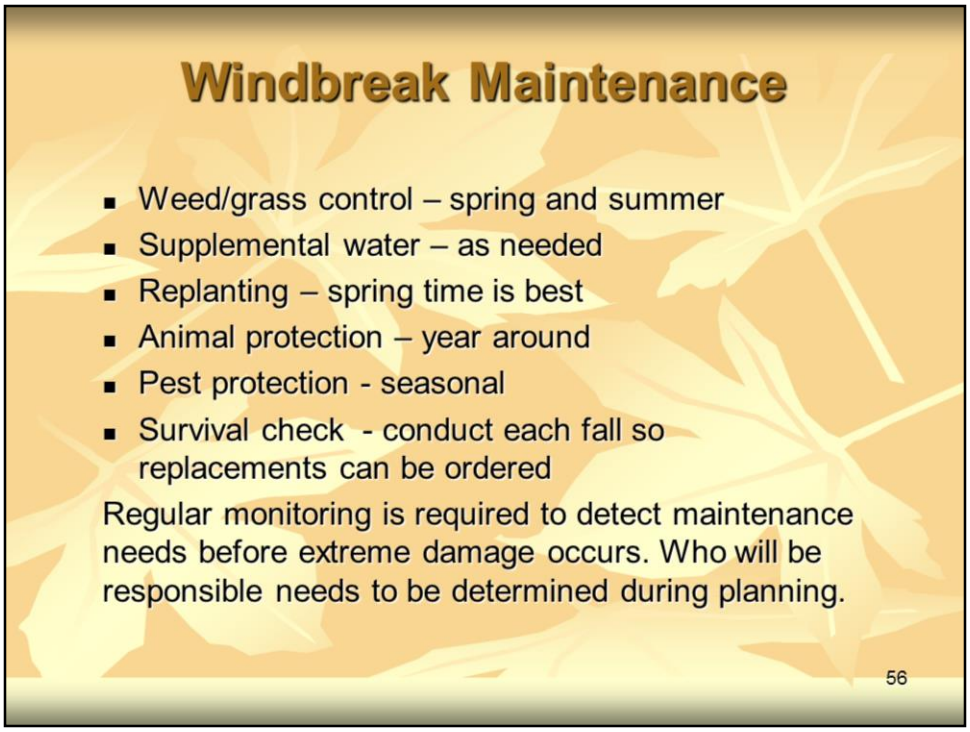
Prep work during the Fall helps by aerating soil and assisting in capture of winter moisture.

Disking can be done in early Spring

Planting approach



Most efficient to plant mechanically, then lay the weed barrier over the rows. The planting furrow can help gather precipitation closer to the seedlings when weed barrier is used.



A sample “Living Snow Fence Survival and Evaluation Sheet” is included in the notebook.

Avoid drift of herbicides onto trees when controlling weeds in road ditches.

Fabric Mulch

Cut an X shaped hole; Walk the fabric down because lethal heat can develop in air pockets under fabric; Examine and enlarge holes as seedlings grow because girdling can happen

Providing water immediately after planting and for a period of 3 to 5 years afterword helps young seedlings survive the shock of being transplanted and gives them a better chance of becoming established. The living snow fence on the right has a water tank which feeds a drip irrigation system.

Photos – left, CSFS; right, Amy L Inskeep-Wonch

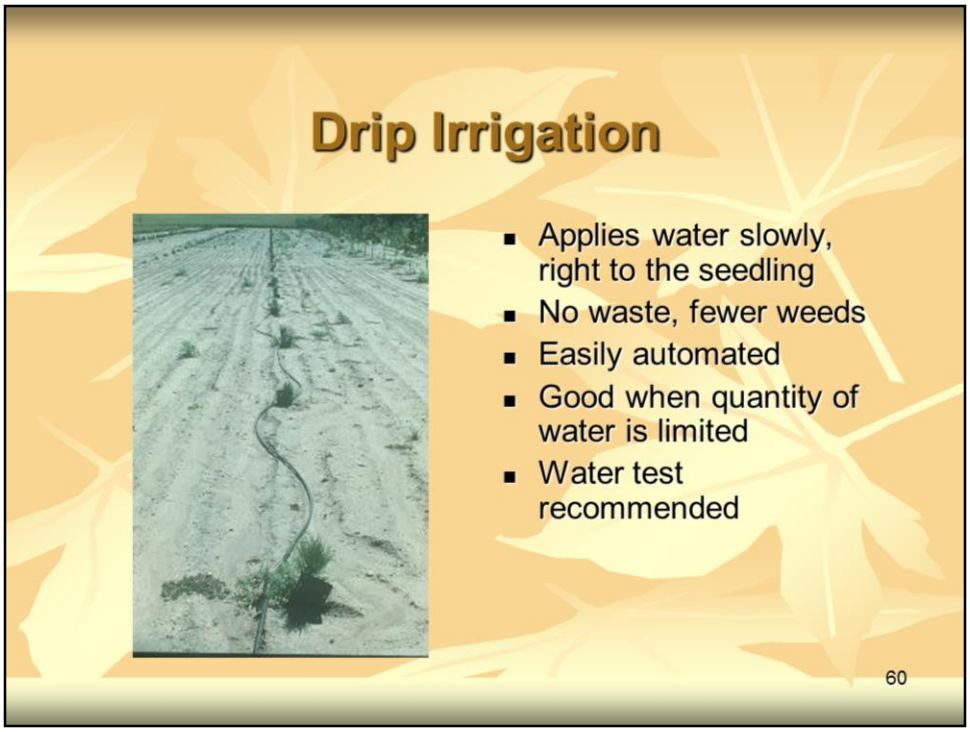

Drip Irrigation
Applies water slowly, right to the seedling
No waste, fewer weeds
Easily automated
Good when quantity of water is limited
Water test recommended
60

Photo - CSFS


Dealing With Wildlife
Fencing essential with livestock
Browsing will happen
No plant is resistant
61

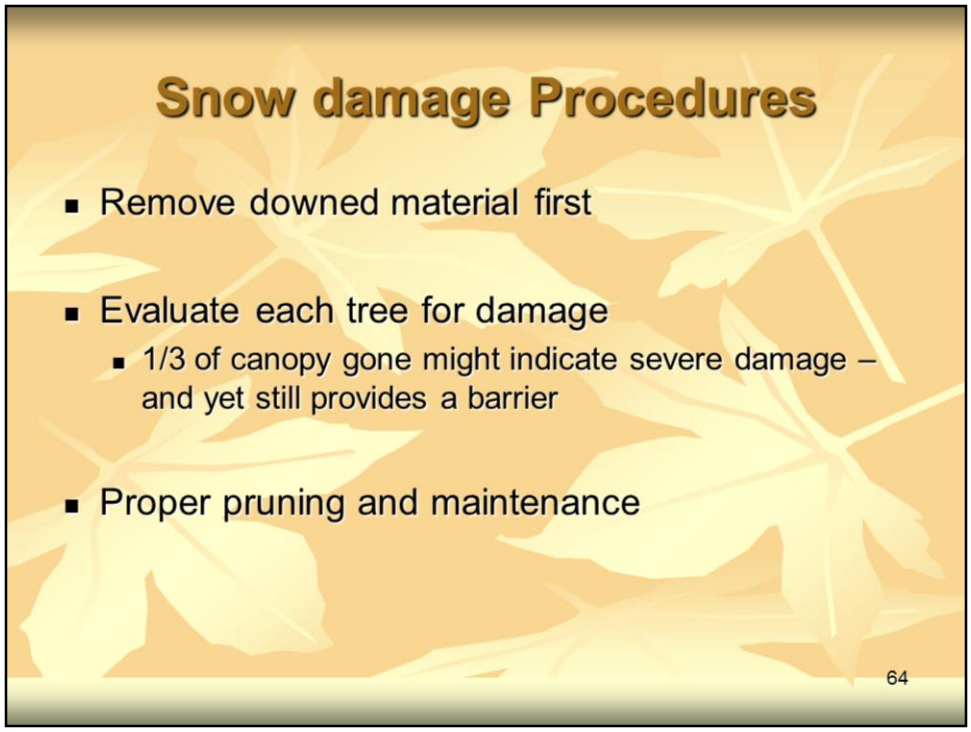
Photo - CSFS

There are various means to protect seedlings from wildlife.

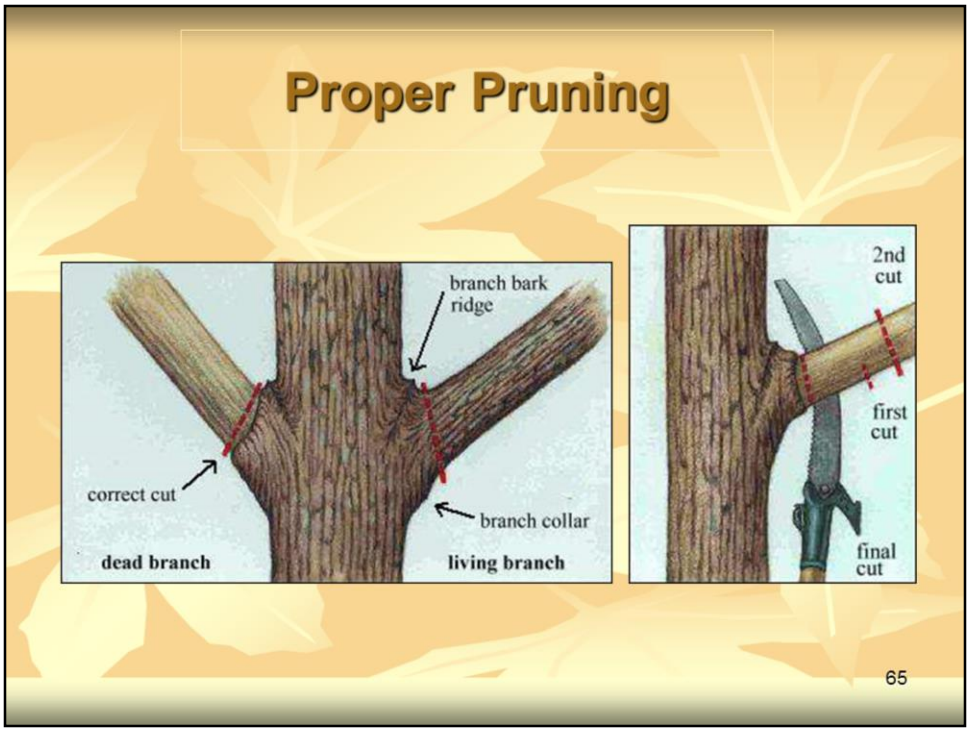
Photos - CSFS

Some species survive better in shade rather that being in the open sun. There are various ways to provide shade and protection from high winds.

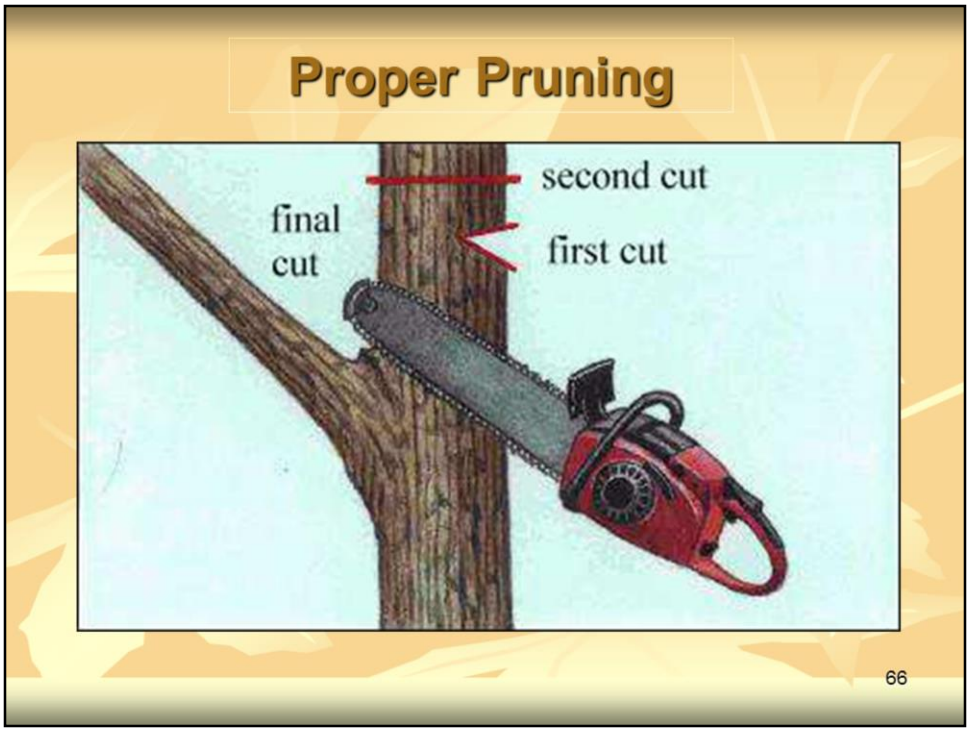
Photos - CSFS



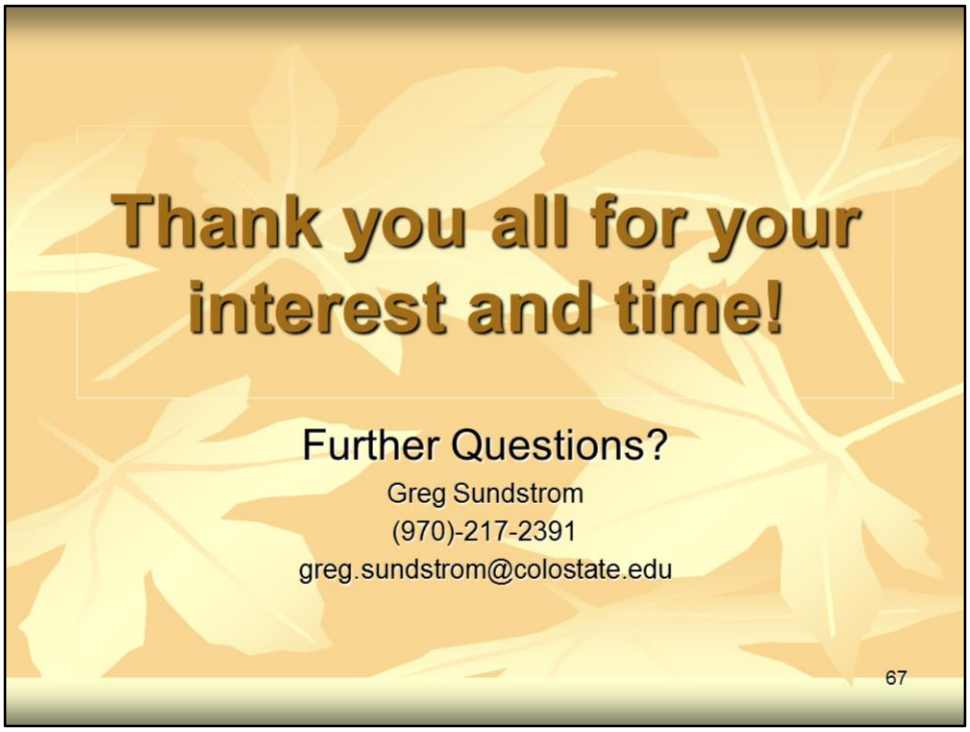
A living snow fence that has been damaged due to snow demonstrates that the living snow fence has done its job – it captured snow. The damaged trees will generally recover. Even dead trees can act as a barrier. If pruning is needed, there are some steps in proper pruning to avoid further damage.



Pruning large branches from the main trunk can result in ripping of the bark down the trunk. The photo on the right shows the technique used to avoid damaging of the trunk.



Should the top of a tree be severely damaged, the trunk can be pruned down to a branch rather than removing the whole tree. It is commonly recommended that when pruning back a branch, prune back to another branch that is at least 1/3 the size of the branch being removed.



Or contact CDOT Landscape Architects