LIVING SNOW FENCES: PROTECTION THAT JUST KEEPS GROWING

Colorado State University

Living Snow Fences: Protection That Just Keeps Growing

History, Characteristics, and Design Of Living Snow Fences

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Contents

To The Reader

This is not intended as a scientific publication. Instead, it is a combination of observation and research plus experience gained by the author over six years of involvement in establishing and maintaining living snow fences in an arid climate. Our purpose is to share this experience along with what we've learned from reading and from associating with many who are involved in blowing snow control.

A major message we wish to convey is that yes, snow barriers do work. Even the lowly picket or slat fence does its best to capture and store relocated snow. The Wyoming design structure is certainly effective and efficient. However, our vote goes to the living fence for its snow control effectiveness, beauty, and multiple benefits for both man and creatures of the wild.

Acknowledgement

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Dedication

This publication is dedicated to all those who make the Colorado Interagency Living Snow Fence Program a success. Special appreciation goes to Jim Hubbard, Colorado's State Forester, who from the Program's outset, provided encouragement and resources far beyond reasonable expectation. And to Gordon East of the Colorado Division of Wildlife who early on recognized the Program's potential as a major contributor to Colorado's wildlife and has been a steadfast source of help and encouragement.

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The success experienced by the Colorado program is due to those mentioned above.

Living Snow Fences: Protection That Just Keeps Growing

Living snow fences are rows of trees and shrubs planted to control deposition of wind-transported snow and to provide other benefits.

A 13-year-old Rocky Mountain juniper living snow fence near Ord, Nebraska.

History

Railroad companies were among the first in the United States to use living barriers to control blowing snow. In 1905, the Great Northern Railway Company planted trees for snowdrift control along rights-of-way in North Dakota (Finney, 1934). By 1909, this company reported that over 96,000 trees and shrubs had been planted and survival exceeded 80 percent. By 1915, 500,000 seedlings were in the ground. Extreme droughts from 1929-33 caused severe mortality; however, some plantings survived and still provide protection.

Finney also stated that in 1914, the Minneapolis, St. Paul, and Saulte St. Marie Railway Company began experimenting with tree plantings for snow control in North Dakota and Montana. Buffalo berry, buckthorn, and willows were used. By 1916, the Company decided against further plantings because "The soil and climate of western prairies are not suitable for natural tree growing conditions and the expense of properly watering, cultivating, etc. is too great and results discouraging."

By 1916, the Canadian Pacific Railway Company was in the tree planting business. Cedars from nearby fields and nursery-grown pine and spruce were planted. Efforts were so successful that by 1934, a considerable mileage of living fences was in place. It is interesting to note that company policy decreed that in no instance were trees allowed to exceed eight feet in height. Possibly this was due to limited right-of-way planting distances.

During the winter of 1925-26, the Wyoming State Highway Department made an attempt to keep roads open state-wide (Walter, 1984). Because of difficulties encountered, a decision was made to install living fence plantings. Installation was initiated in the spring of 1927. Using WWI surplus equipment for watering, efforts were made to keep plantings alive during the early 1930s drought. This task proved too difficult and tree mortality was high. However, remnants of some plantings remain today and provide a surprising degree of snow control. Almost 50 years were to pass before the living fence program was revived in Wyoming.

Recent photo of living snow fence planting established in the early 1900s along a railroad in North Dakota. Approximately 27 miles of such plantings still exist.

At about the time that Wyoming initiated their first living fence plantings, the Michigan State Highway Department began studies of relationships between drifting snow and variables affecting drifting (Finney, 1934). In 1928, the Department began planting trees for snow control and highway beautification. By 1934, over a million seedlings had been planted at a cost of 6¢ to 10¢ per tree. In addition, along northern roads, the state purchased strips of timber to be preserved as snow barriers. The Michigan Highway Department continues to establish living fences.

In 1929, Pennsylvania's legislature authorized planting of evergreen snowbreaks adjacent to highways. The objective was "To facilitate public travel and avoid danger and inconvenience to the traveling public" (Finney, 1934). Living fence establishment continues to be encouraged in Pennsylvania (Amos, 1986).

In 1963, the Iowa Department of Transportation began experimenting with varieties of honeysuckle obtained from the USDA Soil Conservation Service Plant Materials Center in Elsberry, Missouri. After three years of testing, these plants were deemed satisfactory for living snow barriers. This was followed by installation of a number of shrub-type plants which, along with honeysuckle, proved to be cost effective. Cost comparisons revealed that living barriers became cost effective after four years when compared to picket or vertical slat fences (Dolling, 1986).

About 30 miles of living fences were established along Iowa's interstate highways. Current average contract cost of installation, which includes mulching and watering, is about $21,000 per mile.

A few snow control plantings were tried along Minnesota highways in the 1940s. In the 1970s, a larger, more coordinated effort was made, primarily by the Minnesota Department of Transportation (Heng, 1986). Over 17 miles of plantings were installed along interstate systems. Site preparation and planting were contracted to private operators and financed largely from Federal Highway Administration funds.

Personnel from Minnesota's Lyons Soil and Water Conservation District began promoting living fence plantings in 1984. Three demonstration plantings were established in 1985. Funding came primarily from the Minnesota Department of Transportation and the Agricultural Stabilization and Conservation Service (Shelito, 1986).

Minnesota's legislature, in 1986, adopted the "Reinvest in Minnesota" (RIM) program designed to retire certain agricultural lands from crop production. The program's objectives are to establish permanent vegetative cover, restore altered wetlands, or establish tree plantings adjacent to highways. Approximately $500,000 became available for the latter.

A number of requirements were set forth concerning establishing RIM living snow fences. Plantings must be a minimum of six rows, be within 300 feet of a county or state road, and landowners must grant perpetual easements. Annual payments of \$300-\$1000 per acre are paid depending on land production capabilities and other factors. Landowners must establish plantings and maintain them for a specified time; cost-sharing is available on this.

Limited landowner interest has been shown because of no tax breaks on enrolled land, too many rows are required, and per-acre payments are perceived as being too low. Efforts are underway to achieve changes which will make plantings more acceptable to landowners (Dwight, 1989).

In Nebraska, a living fence program was started on the Lower Loup Natural Resource District in 1975. This was a cooperative effort involving the District, county road department, USDA Soil Conservation Service, Game, Fish, and Parks Department, and the state forestry agency. This effort produced several very impressive fences resulting in other states using Nebraska's program as a model.

Using Nebraska's experience as a springboard, a living fence effort was launched in Colorado in the fall of 1982. The objective was to establish five demonstration plantings. To overcome a lack of funding, a cooperative program was forged involving private landowners, private industry, youth groups, sportsmen's organizations, state and county road departments, soil conservation districts, and local, state, and federal natural resource agencies. In addition, support was obtained from the Governor's office.

The concept was for everyone involved to contribute a relatively small amount to a "common pot" from which plantings could be established and maintained. Response was so positive that by the spring of 1989, almost 150 plantings were in the ground with an average length of one-quarter mile per planting. With plantings averaging three rows each, this represents over 112 miles of trees and shrubs.

The Wyoming State Forestry Division, in cooperation with that state's highway department, established experimental living snow fence plantings in 1983. Two plantings are north of Cheyenne along I-25 and the other borders U.S. Highway 85 northeast of Cheyenne. Later, state and federal natural resource agencies, in cooperation with soil conservation districts, private industry, and private landowners, established additional plantings (Perko, 1989).

Recent photo of a living fence established in Wyoming in the late 1920s.

Efforts have been initiated to establish a living fence program in Montana. This is a cooperative venture involving the state's Division of Forestry, Extension Service, county road departments, and others (Bergmeier, 1989).

Following a period of discussions and organizations, three demonstration living snow fences were established in Kansas in 1988. Two are along I-70 west of Goodland and the other borders State Highway 36 east of Atwood. Cooperators on these include the Kansas State Forestry Division, USDA Soil Conservation Service, Extension Service, Department of Wildlife and Parks, and Kansas Department of Transportation. In the spring of 1989, two additional plantings were established along I-70 west of Goodland.

As part of the organizational effort, a Living Snow Fence Committee was formed recently in Kansas. Represented are the Kansas State Forestry Division, Department of Wildlife and Parks, Kansas Wildlife Federation, Department of Transportation, USDA Soil Conservation Service, and Department of Corrections. A basic objective is to develop guidelines for living fence establishment and maintenance. Current plans call for the Department of Transportation to locate sites and provide some materials; Wildlife and Parks will plant trees and provide 50 percent of their cost; the State Forestry Division will provide 50 percent of tree cost, make contacts and formulate planting plans; landowners will furnish planting sites and do site preparation; the Soil Conservation Service will contact landowners and help with planting design; and the Department of Corrections will provide labor.

A four-year-old living snow fence on the Alan Pizel property northeast of Burlington, Colorado. Rows from left to right are American plum, Russian olive, Austrian pine, and Rocky Mountain juniper.

Living snow fence on the Lower Loup Natural Resource District in central Nebraska.

Tree and shrub species commonly used in Kansas for living fence plantings include eastern redcedar *(Juniperus virginiana),* Rocky Mountain juniper *(Juniperus scopulorum),* American plum *(Prunus Americana),* and sandhill plum *(Prunus angustifolia)* (Strine, 1989).

Desirable Features of Living Fences

Multiple Benefits — A major feature of living snow fences is that multiple benefits are obtained for resources expended. Included are snow control, economic advantages, permanent and high-quality wildlife habitat, and environmental beautification. In some instances, landowners use living fences for winter cattle protection and spring calving areas. Where this occurs, the area planted must be fenced.

Costs — The following are data related to cost comparisons involving picket (slat), Wyoming design, and living snow fences. Living fence data is for arid-land plantings where supplements such as weed barrier, plastic mulch, drip irrigation, and potted planting stock may be used.

Table 1. Comparison of installation costs for structural and living snow fences.*

Fence Type	Height	Snow Storage When Full	Service Life	Installation Cost	Cost Per Unit Snow Storage Per Year
	-ft-	-tons/ft-	-yrs.-	-$/mile-	-$/mile/year-
Picket	4.5	5.4	7	7,000	185
Wyoming	13.8	67	35	47,520	20
3-row Living	20	68	75	16,000	3

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It should be remembered that the above data are for installation costs only. Because maintenance costs may vary considerably on both structures and live plantings, no attempt will be made to generalize on these costs.

Long Service Life — As indicated in Table 1, service life is a major factor in the economics of snow barriers. The relatively long life of living fences is a distinct advantage as frequent barrier replacement adds up to high costs. In addition, living barriers require little maintenance following the period needed to establish satisfactory root development and above-ground growth, especially where mulching is used.

Storage Capacity — 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 will a single row of picket fence.

An indication that living barriers have considerable snow storage capacity is reflected by heights reached by evergreens commonly used in the Great Plains. Site capability studies show average heights of Rocky Mountain juniper and eastern redcedar to be near 20 feet and ponderosa pine *(Pinus ponderosa)* about 23 feet at 20 years of age in Colorado (Olmsted, 1985). These data are for varying land classifications with irrigation of plantings during early years of growth. Multiple rows of these species with adequate between-row spacing should provide snow drift protection in the most severe of winter storms.

A major fault of low barriers such as slat or picket fence is that equilibrium (capacity) is quickly reached in major storms. Relocated snow then sweeps across the saturated barrier causing drifting and visibility problems for drivers. To further compound the problem, winds often continue after snowfall ceases. With barriers already full, visibility continues to be impaired and repeated drift removal may be necessary. With tall, wide barriers such as living fences can provide, these problems are largely eliminated.

This Wyoming Design structure is 13.8 feet in height. With a porosity of 50 percent, it is very efficient in capturing and storing blowing snow.

Disadvantages of Living Barriers

Seedling trees and shrubs commonly used to establish living fences take time to become effective. An estimated average time needed for sufficient height growth and crown closure in the Great Plains is 5-7 years with proper location, design, and maintenance. In-row spacing to achieve relatively rapid crown closure is important as described later under Location and Design.

Living snow fences, as do structures, require some degree of maintenance. With living barriers, little maintenance is required where weed barrier or plastic and mulching is used. If these materials are not used, considerable maintenance may be needed. For example, if drip or trickle irrigation is employed, lines and emitters must be tended, weeds controlled, and a watering schedule followed.

Living fences may be difficult to establish on sites with rocky and shallow soils. Also, at elevations over 7000 feet, seedling growth rate may be slow (Sturges, 1983).

Major Barrier Features Which Affect Drifting

Height — As described in an earlier section, barrier height is a critical feature as doubling of height more than quadruples snow storage potential with other factors being equal. Barriers provided by living fences containing tall evergreens are highly desirable when large amounts of relocated snow need to be captured and stored.

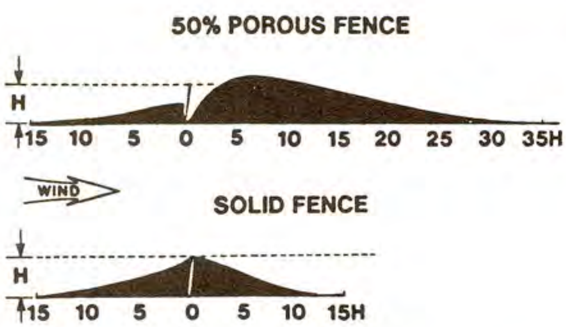

Fig. 1. Drift profiles with porous and solid barriers. From "Snow Control Course Notes" by R.D. Tabler (1988).

Density — This term, as used here, refers to the ratio of solid area to total frontal area. A barrier with no openings (solid) has a 100 percent density and zero porosity. Density and porosity are equal at 50 percent. As indicated by Figure 1, solid fences form much shorter leeward drifts than porous barriers and have proportionately less snow storage capacity.

Variation in drift lengths with barriers of differing densities. Barrier nearest camera has a density of 50 percent; the far barrier has a density of about 85 percent.

Research indicates that barriers with a density of 50 percent store the most snow when other factors are equal (Tabler, 1988). Studies done in Wyoming indicate that barriers with densities varying from 77 to 92 percent cast drifts averaging nine times barrier height (H). Average drift length downwind with a barrier of 64 percent density was 12H. When density was 50 percent, drift length increased to 25-30H (Peterson and Schmidt, 1984).

The drift formed on the windward side of solid barriers extends upwind for a distance of 10-12 times H and when mature, has a maximum depth equal to barrier height. Drifts on the windward side of 50 percent density fences extend to about 15H and have a maximum depth equal to about half of barrier height (Tabler, 1988).

Barrier density is most important when determining fence location in relation to distance from the road. Density is also critical in location of winter wildlife habitat in relation to relative position in a planting. These elements are discussed in the Design and Wildlife sections.

Density control in living snow fences is more limited than with structures. However, living fence density can be controlled to some degree through species selection and by varying in-row and between-row spacing. For example, a very dense barrier can be created by planting two rows of Rocky Mountain juniper or similar species with a spacing of 10 feet or less between rows and with an in-row spacing of not more than eight feet. Such arrangements are termed twin-row high-density plantings.

Length — Snow storage near the end of a barrier is significantly less than toward the center. This is called "end effect" and is due to generation of turbulent eddies at a fence boundary, an acceleration of converging air flow at the fence's ends, and response of air flow to lateral pressure gradients developed behind the barrier (Tabler, 1973).

A twin-row high-density living snow fence planting.

End effect results in a loss of storage due to rounding and shortening of the drift. This rounding may extend toward the barrier's center for a distance of 12H. The significance of this is that barriers should extend at least 100 feet beyond the ends of areas needing protection. Tabler (1973) recommends that minimum barrier length be at least 30 times H. It is important that barriers extend far enough beyond the protected area to intercept winds from at least 25 degrees on either side of the prevailing direction (Tabler, 1988). For example, the minimum length for Great Plains living fences where evergreens such as Rocky Mountain juniper and eastern redcedar are used is 600 feet.

Bottom gap — Barriers with an opening or bottom gap at ground level perform differently than when no gap exists. A bottom gap permits relocated snow to move under the barrier reducing the proportion of snow deposited to windward. A bottom gap of 10-15 percent of H displaces drifts downwind, increases drift length, and enhances storage capacity (Tabler and Schmidt, 1986).

The recommendation for living fences is that they be of high density and with no bottom gap to increase upwind drifting and decrease the length of the downwind drift.

End effect means that considerably less snow is stored at the ends of a barrier.

The barrier nearest the camera has a bottom gap while the other does not.

Location and Design

Location refers to distance from the area needing protection to the leeward or nearest tree or shrub row. Design deals with tree and shrub species selection and their placement within a planting.

Location — The living snow fence should be placed as close to the road as possible yet far enough away so that leeward drift edges do not touch the road.

Factors influencing proper location include fetch distance, upwind ground cover, annual snowfall, barrier height, number of rows, spacing between rows, and barrier density. The first three determine the volume of snow for which storage must be provided.

The *fetch or contributing distance* is the distance contributing relocated snow to a given location. Its dimension is determined solely by the distance to an upwind barrier and can be essentially infinite. The *maximum transport distance* is the distance determined by evaporation rate and can be less or greater than fetch distance depending on weather conditions. When relative humidity is 100 percent, evaporation rate is zero. In other words, snow transport is limited by evaporation of blowing snow particles (Tabler, 1975). This author reports that estimated maximum transport distance for open areas in Colorado and Wyoming is about 10,000 feet.

Other factors being equal, long fetch distances call for barriers to be placed well away from road edges. A rule of thumb for open prairie conditions is that the leeward row should be no closer to the road than 200 feet.

Amount and height of wintertime vegetation or other surface roughness immediately upwind from the living fence planting site influences snow storage needed and thus barrier location. Vegetation creates surface roughness that retains snow. In general, surface roughness is filled with snow before appreciable amounts move into the barrier. For example, snow plow operators report that significantly less highway snow removal is required downwind from wheat stubble as compared to adjacent bare ground.

Leeward drift length depends in part on barrier height. Because a dense evergreen barrier functions like a solid fence, the downwind drift extends to 12-15H. When at equilibrium or capacity, a 20-foot-tall living fence would form a drift up to 300 feet in length. Drifts behind barriers having a 50 percent density could be up to three times as long. However, there are few if any locations where there would be sufficient relocated snow to fill such a barrier.

Barriers placed too close to the road result in excess drifting over the area needing protection.

Number of tree and shrub rows is a factor in fence location. Other conditions being equal, the more rows, the closer the planting can be to the road. If unlimited space and resources are available, it is safe to plant a dozen or more widely-spaced rows with the leeward row next to the road. This type of planting, known as a snow forest, is done in Japan (Tabler, 1988).

Spacing between rows is another important consideration in living fence location. Wide between-row spacing allows for maximum snow storage while close spacing does not. In areas where large amounts of relocated snow must be stored and where rows are closely spaced, the leeward row or rows becomes nonfunctional in major storms. Under Great Plains conditions, the recommendation is that rows, either twin or single, be spaced at least 50-75 feet apart.

Another factor to consider in spacing rows too close together is increased potential for snow breakage to evergreen trees. Observations over six years in Colorado show breakage to be minimal where between-row spacing is 50 feet or more.

The effect of barrier density is discussed in an earlier section titled "Major Barrier Features Which Affect Drifting."

Design — Design, or species selection and placement, is based primarily on planning objectives, snow volume to be stored, species adaptability and longevity, soil type, soil PH and fertility, and species resistance to snow breakage.

The portion of this barrier nearest the camera consists of two closely-spaced rows. Essentially, the leeward row becomes nonfunctional except to increase barrier density. In this instance, rows were about 20 feet apart.

The recommended basic living fence design consists of twin rows of juniper or cedar to the windward and a spacing of 50-75 feet between this and the next leeward row or wildlife component. If shrubs or other wildlife components are placed upwind from the twin row, these should be well out of the anticipated windward drift zone which could be more than 10H.

Where snowdrift control is the only objective, one species adapted to local soil and climatic conditions may suffice.

Where large amounts of drifting snow need to be stored and storage is the only objective, two or more rows of tall, dense evergreens can perform satisfactorily. Where snow control is the only interest and where fetch distance is 1000 feet or less, one or two rows of tall shrubs may be all that is needed. Under some conditions in Montana, for example, one or more rows of caragana *(Caragana arborescens)* make up the total barrier (Bergmeier, 1989).

Where short fetch distances or other conditions exist which limit amounts of relocated snow, one row may suffice.

A condition commonly encountered in Great Plains states is snow blowing across a road during or following a storm. Under severe conditions, these "white outs" or ground blizzards diminish visibility to near zero. In addition, slush and ice may form on the road and intensify driving hazards. One or two rows of tall shrubs or dense evergreens placed to windward can help ease these situations.

A planting with multiple objectives normally calls for two or more tree and shrub species. Where wildlife habitat is involved, shrubs and trees beneficial to targeted wildlife species should be included. For the Great Plains, shrubs or shrubby trees could include American plum *(Prunus americana),* sandhill plum *(Prunus angustifolia),* cotoneaster *(Cotoneaster acutifolia),* Russian olive *(Elaeagnus angustifolia),* chokecherry *(Prunus virginiana),* and sand cherry *(Prunus besseyi).* Some planters object to the latter because of its relatively short life. Caragana *(caragana arborescens)* is also recommended in areas where grasshoppers are not abundant; these insects devour leaves, bark, and twigs. Caragana is also satisfactory for high-altitude plantings.

According to Snyder (1982), a major value of American plum for wildlife is that this species provides cover close to the ground in contrast to the open understory often associated with trees. Further, American plum will reach heights of 10-12 feet, form thickets, and is not crushed by heavy snow loads. In addition, this and other suitable shrubs provide food for the wildlife table.

Shrub species commonly used in Minnesota include caragana and honeysuckle *(Omoena arnoldiana).* This particular species of honeysuckle is used because of its resistance to aphids. Trees used include ponderosa pine *(Pinus ponderosa),* Colorado blue spruce *(Picea pungens),* Black Hills spruce *(picea glauca),* and green ash *(Fraxinus pennsylvanica)* (Dwight, 1989).

Where shrubs or other wildlife habitat components are included, it is critical that these be placed outside the drift zone created by upwind barriers or by upwind drifting near dense evergreens. If not, these components will be covered by drifts and thus rendered useless when needed most by wildlife. In open prairies, for example, wildlife shrub rows planted upwind from dense evergreens should be no closer than 75 feet. Downwind distance should be at least 150 feet. In-row distance between shrubs is normally 4-6 feet.

Volume of snow that must be stored is a major factor in determining tree and shrub species selection and placement. In general, where large volumes of snow are to be stored, taller evergreens with a spacing of 75 or more feet between single or twin rows is recommended.

The following sketches (see Fig. 2) indicate recommended *minimum* living snow fence plantings for open prairie country where

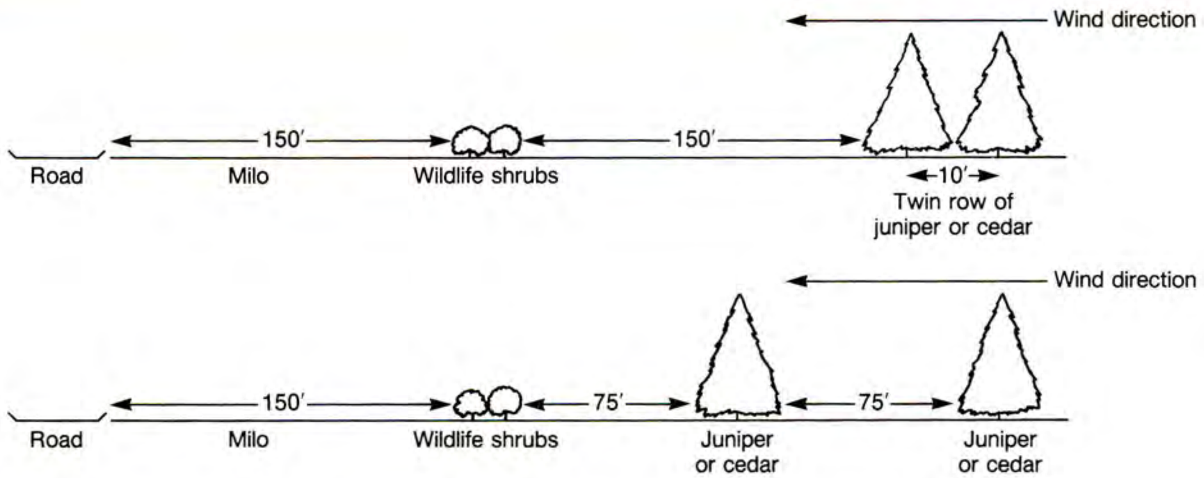

Fig. 2: Minimum living snow fence components where wildlife habitat is an objective.

large volumes of relocated snow are anticipated. Additional components may be added if desired. In areas where tumbleweeds are prevalent, a single shrub row to the windward can serve to catch and store these weeds.

The twin row of evergreens in the top sketch of Fig. 2 is designed to form a barrier dense enough to cause upwind drifting about equal to that downwind. Thus, enough snow should be stored to keep the wildlife shrub rows relatively free of drifts. Milo or other food and cover can be established between rows in either planting to enhance wildlife values. For winter food plots, milo should be sown between the road and shrub rows away from the drift zone.

When spacing evergreens in the row, do not place them so far apart that crown closure is slow to occur. Recommended in-row spacing for juniper and cedar in the Great Plains is 6-8 feet.

In-row spacing of juniper and cedar should be such that complete crown closure is attained in a relatively short time.

The importance of tree and shrub species adaptability and longevity are largely self-explanatory. The primary concept is to establish a living barrier that not only survives and grows fast, but also remains effective over a long period. Maintenance and replacement costs are at a minimum in such plantings. In addition, aesthetic appeal remains constant in a vigorous, long-lasting living snow fence.

Species selection and growth rate depend to a degree on soil type and fertility. Some soils may be so shallow that tree planting is not practical. Other soils may exhibit high salt content or alkalinity. Sandy soils may limit options in species selection. On the other hand, most species do well on deep, fertile soils where enough moisture is available. If there is doubt, consult a soils specialist. In the United States this is usually personnel of the USDA Soil Conservation Service. Another option is to observe which trees and shrubs are doing well in the area.

Deep snowdrifts exert powerful downward pressures that can cause breakage to any barrier. Species selection, especially with evergreens, should take this into consideration. Local experience and observations following major storms are the best guides to choosing species resistant to breakage.

Wildlife Components

A significant characteristic of living snow fences in many locations is their ability to enhance wildlife habitat. Such fences, when properly designed, offer nesting, roosting, loafing, food, and escape cover for a variety

Living fences can be of great help in sustaining wildlife populations, especially in the Great Plains.

of avian species (Hintz, 1984). Many animals, including deer, reside and raise young in living fences. Such fences provide habitat stability, the key to attracting and holding wildlife.

Wildlife components, especially for pheasants, can include milo or other sorghums, tall grasses, alfalfa, or similar plants adjacent to or between tree and shrub rows. Block plantings of a shrub such as American plum may be established downwind and beyond the drift zone. Block plantings can greatly reduce adverse impacts on wildlife resulting from winter storms (Snyder, 1982).

American plum has a growth form and other characteristics highly suitable for thicket-type plantings. One of these characteristics is spreading by natural reproduction about three years after seedlings are planted. With heights of eight to 10 feet, this species is not readily inundated by snow, has a closed, protective canopy, yet is open enough to allow access by animals as large as deer (Snyder, 1982). The importance of such plantings is evidenced by the fact that in winter, species such as pheasants will attempt to use inadequate food supplies near good cover rather than adequate food near cover which provides little protection (Stormer and Valentine, 1981).

Another addition to living fence plantings that benefits wildlife is a provision for surface water. One landowner built small concrete basins at the ends of tree rows and allowed water from drip irrigation emitters to supply these small basins.

Living snow fences in locations surrounded by grassland have lower wildlife values than those near cropland. This is especially true of avian species because seeds provided by annual crops or annual weeds are an important part of the diet. Where such a food base is lacking, milo, other sorghums, or other grains can provide food. Where conditions permit, another technique is to disk between rows in early spring to promote wild herbaceous annuals as a substitute for cultivated crops (Snyder, 1989).

In locations adjacent to cropland, between-row food sources may not be as critical to wildlife. Where soil-moisture conditions are suitable, switchgrass *(Paniceum virgatum)* is recommended because it grows tall and stands well in winter to provide night roosting cover, nesting cover, and also collects and holds a great amount of snow.

Milo sown between rows (upper photo) and American plum (lower photo) make excellent wildlife components in open prairie living fence plantings.

On sites immediately adjacent to the road where snow collection isn't wanted, the Ranger variety of alfalfa can be used. The alfalfa provides green succulents and nesting cover but doesn't stand over winter to cause drifting (Snyder, 1989).

An added bonus from wildlife components is such additions usually increase the barrier's capacity to catch and store relocated snow. Further, addition of wildlife cover between rows in young living fence plantings encourages more complete site preparation, catches and stores snow for added soil moisture, and aids in weed control near tree and shrub rows (Shaw, 1985).

The concept that arid-land tree plantings must be clean cultivated is open to question. Observations on approximately 100 living fence plantings in Colorado indicate little or no difference in tree and shrub survival and growth between clean cultivation and where

Winter scene of young living fence where milo was established between rows. Over 5 million cubic feet of snow was captured and held by the milo.

moisture conservation and weed control were practiced four to six feet on either side of rows. Weeds and other vegetation were allowed to develop for wildlife cover between rows in the latter. Because of no observed difference in survival and growth of seedlings, the recommendation is to permit vegetative growth between rows (East, 1989). Again, note that weed control and soil moisture conservation were practiced in a strip on either side of rows. Moisture conservation techniques are described in sections which follow.

A fear is sometimes expressed that living fence plantings will concentrate wildlife populations near roads and increase road kill and driving risks. An Indiana study indicates that road kill is not increased by roadside plantings (Roach and Kirkpatrick, 1985). A study of pheasant movement by Hartman, Sheffer, and Kriz (1971) indicates that pheasants may move from five to 10 miles from winter range to breeding areas. In areas with extensive road systems, as much as 12 to 20 percent of the wintering population may fall victim to automobiles and other vehicles during such migrations.

Techniques for Seedling Survival and Growth on Arid Lands

Maintenance, or the effort required to obtain satisfactory tree and shrub survival and growth following planting, presents few problems where climate permits natural forest growth (Willeveen, 1986). However, where climate is harsh as in the Great Plains, plantings have little chance without attention to soil moisture, weed growth, and other factors.

Supplemental watering or soil moisture conservation are needed in the Great Plains in areas where annual precipitation is less than 22-25 inches. This is due not only to limited soil moisture, but also because precipitation may be poorly distributed in that most may arrive in winter. In many cases, soil moisture problems are compounded by dry, hot summer winds.

Drip Systems — An efficient method of supplying supplemental water is by drip or trickle irrigation.

A young living snow fence with a drip system. Dark circles on the soil's surface indicate areas receiving water.

Advantages of a drip system include (1) requires relatively little water, (2) takes a minimum of time and labor to apply water, (3) permits close control over rate and amount of water applied, (4) maintains soil moisture at an optimum level, and (5) allows irrigation on uneven topography (Thomas et al, 1981). Disadvantages include (1) relatively high initial cost, (2) potential for overwatering, (3) filters, emitters, and lines may require frequent checking, (4) is subject to rodent and other damage, (5) encourages weed growth near trees and shrubs, and (6) may be an obstacle to cultivation.

Water for drip systems may be supplied from household taps, storage tanks, or mobile water tankers.

When irrigating with drip, soak the soil thoroughly and then let it partially dry. In arid regions, the rule of thumb is to water new plantings once each week with moisture penetration to about 18-24 inches. This takes about one gallon of water per plant per week during the first year, two gallons per plant per week the second year, and about five gallons per plant per week thereafter (Thomas, 1981). If irrigation is continued after about three years, emitters may be added at the drip line of trees and shrubs to increase area watered and speed of application.

A concern sometimes expressed is that one emitter per tree or shrub, especially following the first year after planting, may concentrate water in an area too small to encourage lateral root development. One practice that may be beneficial is to begin adding emitters a distance from seedlings the second year after planting.

The best emitters available should be used. Pressure compensating and self-flushing emitters are recommended.

Another recommendation is to not bury lateral lines below the soil surface. When buried, it is difficult to check emitters and for breaks in the line. Also, damage by rodents such as gophers and kangaroo rats seems to increase when lines are buried.

The author's recommendation where drip systems are used is to continue watering new plantings for at least five years. Gradually decrease the amount of water applied during the last two of these years.

Plastic and Polypropylene Mulches — Experimentation with sheet plastic as a mulch for arid-land tree and shrub plantings in Colorado was initiated by Warren

The drip system on this planting is fed from a 3000-gallon storage tank. The tank is elevated by placing it on a mound of earth.

Living snow fence planting mulched with plastic and gravel.

Snyder, research biologist for the Colorado Division of Wildlife. Testing was conducted with both plastic and herbicides to evaluate weed control and seedling survival and growth. Four-mil black plastic strips were placed immediately adjacent to and on both sides of shrub rows and covered with wood chips or corn cobs. This covering held plastic in place, stabilized soil temperatures, and served as a barrier to prevent plastic deterioration by ultraviolet rays from the sun. Tests revealed that plastic and mulch treatments were the most effective in eliminating competing weeds and in increasing survival and growth rates (Snyder, 1982). Since then, plastic has been used quite successfully in establishing dryland wildlife habitat plantings.

Based on Snyder's work and starting in 1983, 6-mil plastic covered with gravel was used on 45 living snow fence plantings in Colorado. Most plantings are on dry rangeland with an average annual precipitation of 15-17 inches. No supplemental water was provided except at planting time if soils were dry. Seedling survival rates average near 95 percent and growth rates equal those where drip irrigation is used (Shaw, 1986).

Major advantages of plastic mulching are weed control adjacent to and between seedlings in the row plus soil moisture retention. Further, it appears that the growing season is extended with use of plastic as soil warms earlier in the spring and stays warm later in the fall. Experience indicates that almost no planting maintenance is needed when plastic is used.

One question sometimes raised is root development under plastic. A concern is that soil moisture under plastic stays near the surface and thus roots do the same. Rocky Mountain juniper planted seven

Living fence with plastic and gravel mulch (top). Same planting after two year's growth (bottom).

years earlier were dug from a plastic-covered planting in northeastern Colorado. Root development was normal. Also, as indicated earlier, survival and growth rates over a period of years have been excellent under plastic in both wildlife habitat and living fence plantings.

Ultraviolet-resistant plastic is available but is normally more expensive than "regular" plastic. Though the entire surface of the former may not require covering for protection against the sun's rays, uncovered plastic is subject to damage by hail and by the hooves of deer where these animals are present.

In Colorado, plastic is purchased in boxes containing 8′ by 100′ folded material if the plastic is to be laid by hand. If machine-laid, plastic is purchased in 6′ by 200′ flat material rolled on tubes. Thickness is six mils. When plastic is used, the ground should slope toward tree or shrub seedlings from both sides so precipitation collected will move to the seedlings. Also, if soil is dry at planting time, watering should be done immediately after planting.

One method of site preparation of rangeland or areas subject to wind erosion is scalping a strip 10′-12′ wide. A road grader is a good tool for this. Follow by ripping a 2′-3′ strip in the center of the scalped area where planting will take place. Ripping should be done to a depth of 16″-18″. Site preparation should be done the fall before spring planting.

American plum with plastic and gravel. Top photo is after one growing season and the other after two growing seasons. The site is dry rangeland.

Plastic and mulch covering can be placed first if hand planting is done. When planting by machine, plant first, lay plastic, cut slits and pull seedlings through, spread gravel or other covering, then uncover any buried seedlings. Gravel covering should be to a depth of 3"-4". This material, if dry, can be spread from conventional dump trucks by opening the tail gate about three inches, tilting the bed, and driving astraddle of rows. Small gravel, when wet, tends to lodge in the tail gate opening. In areas of high winds, sand should not be used as a mulch as it tends to blow from the plastic.

A second method of enhancing survival and growth on arid-land plantings is use of polypropylene weed barrier as a mulch. In Colorado, DeWitt SunBelt weed barrier is used because of its high resistance to ultraviolet rays and thus does not require covering. This material, commonly used in landscaping, is purchased in 6' by 300' rolls.

As indicated, a major advantage of weed barrier over plastic is the former does not require complete covering because of its resistance to ultraviolet rays and also because it is more sturdy and far less subject to ripping and animal damage. A convenient method of holding this material in place when not laid by machine is by throwing a plow berm along the barrer's margins.

To the author's knowledge, no field testing has been done to compare the relative merits of plastic and weed barrier. To date, both have proved quite satisfactory for weed control and soil moisture retention.

Snow Breakage From Upwind Structures — A common practice is to place picket (slat) fencing immediately upwind from new plantings for wind protection and to cause drifting for additional soil moisture. These structures should be removed after two-three years to prevent snow breakage on evergreens.

Polyacrylamide — This substance, commonly referred to as polymer, may be placed in the soil with newly-planted seedlings to attract and hold moisture. When hydrated, this polymer, sometimes called hydrogel, will then release moisture when needed by plant roots. Recharge occurs when more moisture becomes available.

The physical appearance of polymer is white powder, crystals, or granules. These can absorb water at the rate of from 40-400 times their dry weight. Placed in water, or

After seedlings are planted (top photo), plastic is laid and covered with gravel.

hydrated, crystals or granules form a gel with a bead-like or bubbly appearance.

Polyacrylamide is a petroleum-based plastic or acrylic with cross-linking agents used for bonding. By definition, polyacrylamide is a polymide of acrylic acid. Polymer is a chemical compound or mixture of compounds formed by polymerization and consisting of repeating structural units. Polymerization is a chemical reaction in which two or more small molecules combine to form a larger molecule that contains repeating structural units of original molecules.

Polymer was used as an absorbent in baby diapers, feminine hygiene aids, and similar products before use in horticulture. In 1979, polymer was used in plantings in the Sahara Desert; reports are that the material used is still functional (Curry, 1989). Another report is that polymer placed in soil eight years ago remains active (Wolford, 1988).

Some research on horticultural use of polymer exists; much of this involves greenhouse-type studies. One example is a test involving spider plants to determine effect on growth and water use (Wang and Boogher, 1987). Polymer with a 1:40 absorption rate improved quality and increased water use efficiency with this particular plant. Erazo (1987) maintains that polymers can increase water-holding capacity, improve soil aeration and drainage, reduce irrigation frequency, and maintain moisture equilibrium. He recommends this product for root dipping of bareroot seedlings and as a soil additive in containerized seedlings.

In yet another experiment, polymer was tested as an amendment to sand. Here, significantly less water was required to produce tomatos and kidney beans in the amended sand as compared to no amendment. Fresh weight of tomato transplants was as much as 106 percent greater than with non-amended sand. Beans growing in amended sand withstood a six-day induced drought without showing signs of wilting; those in sand alone died (Jensen, et al, 1971).

A high-absorbency polymer has been used for three years in many Colorado living fence plantings in the belief that this helps in collecting and holding soil moisture around the roots of young seedlings. The common practice is to hydrate polymer and place a cupful or so around roots at planting time. Unanswered questions include whether high- or low-absorbency polymer should be used, whether polymer should be applied hydrated or dry, whether root development is restricted by concentrating polymer in a small area immediately adjacent to roots, and how tree and shrub seedlings respond in a particular location with and without polymer.

In inquiries made by the author, no record of long-term field testing of polymer was found which involved this substance and arid-land tree and shrub plantings. Such tests are needed involving a number of controlled and measured variables and conducted for a minimum of five years.

A living snow fence mulched with plastic and wood chips. Chips may be used in areas where winds are not strong enough to blow them off the plastic.

Living snow fence planted in a wheat field and mulched with plastic and gravel. Twin-row high-density plantings such as this removes very little land from crop production. Added soil moisture provided by snowdrifts can increase net crop yields.

Weed barrier machine in operation. The person riding the machine cuts slits to pull seedlings through. Seedlings are planted before the weed barrier is put down.

Research Status

Research directly related to living snow fence location, design, and performance is practically nonexistent. Although this condition was pointed out almost 50 years ago by Bates and Stoeckeler (1941), apparently little has been done. Sturges (1984) found that studies of snow storage by shelterbelt-type plantings suffer from a universal deficiency in that barriers examined were not at equilibrium. Yet, in determining proper living snow fence location, knowing specifics of fence performance at equilibrium or capacity is vital. In a windbreak bibliography compiled by Loucks (1983), only nine of 1583 titles mentioned living snow fence.

Efforts to gain knowledge relative to living fence performance have been primarily with

Machine for laying weed barrier. Slanted disks just behind the tractor wheels open a small furrow, barrier feeds from the bar behind the disks, the small, round wheels press the barrier into the furrow, and the plow turns a berm of soil over the barrier's edges. The machine is attached to the tractor with a 3-point hitch.

Drifting downwind from this picket fence covers a row of evergreen seedlings. Such drifts can cause significant breakage when seedlings are two-three years old and older.

Weed barrier on a living snow fence planting in Colorado. Although this fabric is somewhat porous, it is a good idea to have it sloping from the edges to the tree row in the center.

wind tunnels or were observations of a few established plantings. Finney (1934) was the first to publish results of wind tunnel studies. In these, he used sawdust and mica to simulate snowdrifts. Finney, as have others since, found some difficulty in obtaining valid results because snow has specific properties which make it difficult to duplicate. These properties include changes in surface stress, moisture content, variations in particle size, and drifting tendencies altered by temperature variations.

An example of observations is given by Worthington (1966) and reported by Dronen (1984) where a three-row barrier located 120 feet from a road allowed drifts to accumulate on that road. Nearby, a barrier placed 180 feet from the road permitted no highway drifting.

To conduct field research on living snow fence location and design can require years and an expenditure of considerable money. There is, however, a technique to accomplish desired results with a relatively small expenditure of time and money. This involves using scale models under the right conditions and in the right place.

Tabler and Jairell (1980) present and summarize a basis for and results from employing small-scale models to duplicate or at least closely simulate full-size snow fences. These authors discuss the scientific basis, procedures, site selection, and general

Research on living fence location, design, and performance is largely lacking.

Drifting patterns and profiles can be quickly and inexpensively studied with models.

An ideal modeling surface is the center of an ice-covered lake with upwind flat, open areas.

modeling requirements. Because surface roughness should be minimal, the suggested ideal location for modeling is the center of an ice-covered lake with relatively low topographic relief upwind for a considerable distance.

This location should also feature frequent winds with blowing snow and temperatures well below freezing. Ice must be of a thickness to support the weight of personnel and equipment. All snow should be removed from the modeling site in an area about 40 feet on a side. Ideal wind speeds for modeling are around 15-25 miles per hour with an air temperature of near 15° Fahrenheit above zero. When models are in the desired configuration, they should be allowed to reach equilibrium before measurements are taken. Equilibrium is reached when drift length and height remains relatively constant.

Summary

Living snow fences, when properly designed and located, can assist with control of relocated snow, provide stable and high-quality wildlife habitat, enhance environmental aesthetics, furnish winter protection for domestic livestock, and reduce highway snow control costs.

Living barriers take time to reach effective heights and densities following establishment. Some sites may not support living fences. In arid climates, effort is required to establish trees and shrubs. However, by using certain techniques, establishment can be accomplished.

Barrier features which affect drifting should be known and understood when designing living fences. Such features include height, density, length, and bottom gap.

Location and design of living fences are not necessarily the same as for farmstead, livestock, or field wind and snow barriers. Density, distances, species, and wildlife components commonly used in the latter may need to be altered to meet snow storage and other objectives of living fences.

A number of materials and techniques can aid in living fence establishment and growth on arid sites. Other than drip systems, plastic, polypropylene fabric, and polyacrylamide can aid dryland plantings.

Little or no research on living fence location, design, and performance has been conducted.

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Appendix

Living Snow Fence Planning Checklist

1. Site location ______________________________

____

2. Who owns the land? ______________________________
3. Present land use ______________________________
4. Site prep needed ______________________________
5. Who will do site prep and when? ______________________________
6. List planting stock needed by species and number ______________________________

____

7. Who will obtain planting stock? ______________________________
8. Who will do planting? ______________________________
9. Who will provide drip or other irrigation? ______________________________
10. Who will install irrigation system? ______________________________
11. Who will operate system, check emitters, etc.? ______________________________
12. Who will provide plastic or weed barrier? ______________________________
13. How much plastic or weed barrier is needed? ______________________________
14. If plastic is used, who will provide mulch? ______________________________
15. Who will transport and spread mulch? ______________________________
16. If weed barrier used, who will install it? ______________________________
17. Who will provide livestock fencing? ______________________________
18. Who will install and maintain fence? ______________________________
19. When will fence be installed? ______________________________
20. Who will provide fertilizer tablets? ______________________________
21. How many fertilizer tablets are needed? ______________________________
22. Who will provide rabbit guards? ______________ How many needed? ______________
23. Who will provide weed control? ______________________________
24. How will weed control be accomplished? ______________________________
25. Who will provide shingles or other wind protection? ______________________________
26. Will cover crop be planted between rows? ________ If so, what kind? ______________
27. Who will plant cover crop? ______________ When? ______________
28. Will wildlife cover such as plum thickets be established? ______________________________
29. Who will establish wildlife cover? ______________ When? ______________
30. If clean cultivation is practiced, who will do it? ______________________________
31. Who will inspect and evaluate plantings for survival and maintenance needs? ______________

____

32. Who will report or take care of maintenance? ______________________________
33. Who will plant replacement seedlings? ______________________________
34. Other considerations ______________________________

____

Living Snow Fence Survival and Evaluation Sheet

1. Landowner ______________________________ Date checked ______________
2. Checked by ______________________________
3. Location from nearest town ____________________ County ______________
4. State highway No. ________ County road No. ________ Interstate No. ______________
5. Planting length ________ Site prep: when & how ______________________________
6. Date planted __________ How planted ______________________________
7. Species information (row 1 is windward row)

Row No.	Species	In-Row Spacing	Potted (P) or bareroot (B)	No. planted	Percent survival	Number replacements needed
1.						
2.						
3.						
4.						
5.						
6.						

8. Spacing between row 1&2____ 2&3____ 3&4____ 4&5____ 5&6____
9. Cause of mortality ______________________________
10. Tree/shrub condition on day checked: Good____ Medium____ Poor____
11. Planting clean cultivated? Yes____ No____ Weedy in the row? Yes____ No____
12. Cover crop used? Yes____ No____ If yes, what kind? ______________________________
13. Drip system? Yes____ No____ Is irrigation adequate? Yes____ No____ If no, what's the problem? ______________________________

    ____
14. Specific maintenance needs ______________________________

    ____
15. Height growth satisfactory? Yes____ No____ Rodent damage? Yes____ No____
    Other damage? Yes____ No____ If yes, what kind? ______________________________

    ____
16. Other comments ______________________________

    ____

    ____

    ____

Black & white photos should be obtained during each evaluation and attached to back of sheet.