50TH EASTERN SNOW CONFERENCE
61ST WESTERN SNOW CONFERENCE
Quebec City 1993

Cost Analysis of Snow Control Structures in Ontario

M.S. PERCHANOK AND A. BACCHUS
Research and Development Branch
Ontario Ministry of Transportation
1201 Wilson Avenue
Downsview, Ontario M3M 1J8 Canada

ABSTRACT

The number of snow fences used along Ontario highways has declined as highway maintenance resources have diminished. This study was undertaken to compare alternative windbreak technologies to control drifting snow.

Four principal types of windbreaks suitable for controlling snow were identified:

- temporary snow fence
- permanent snow fence
- snow hedge
- standing corn stalks when corn is planted in rotation, alternating with temporary snow fence in other years.

Material, labour and land costs associated with each type were estimated, and compared on the basis of equivalent annual cost of the net present value, for periods of use ranging from 1 to 50 years.

Where practical, corn stalks with temporary snow fence was the lowest cost alternative for periods from 1 to 6 years. Permanent snow fence was the lowest cost alternative for longer periods. The study showed that permanent snow fence or snow hedge are more cost effective than temporary snow fence in controlling drifting snow and should be considered for installation where land use conditions are suitable.

INTRODUCTION

The Ontario Ministry of Transportation (MTO) uses windbreaks to control drifting snow at susceptible sites on provincial highways (MTO, 1981). The standard form of windbreaks are temporary snow fences comprised of vertical wooden slats bound together with flexible wire and supported on steel posts (MTO, 1977). They are erected each fall in fields outside the highway right-of-way, and removed to storage at MTO patrol yards at the end of the winter.

Government fiscal restraints have restricted the availability of personnel for snow fence installation. This has contributed to a reduction in the length of fence erected in southwestern Ontario from 104,372 metres in 1988/89 to 82,405 metres in 1990/91. The cost of annual erection and removal of temporary snow fence is approximately $3.20 per lineal metre (Brubacher, 1992), for an annual operating cost of $256,000 in this region. This does not include materials or administrative costs.

This study was undertaken to compare the costs and benefits of alternative windbreak technologies to prevent drifting snow from reaching the highway.

METHODOLOGY

The study was undertaken through three principal tasks:

1. establish functional requirements,
2. define cost components, and
3. compare costs on a common basis.

The objective of the first task was to ensure that each alternative considered would perform with equal effectiveness. The functional requirements included material properties and snow trapping capacity. The material properties requirements related primarily to durability, and were investigated through field trials over a 12 year period as well as through laboratory tests (Perchanok, 1990).

The snow trapping requirement was determined experimentally by measuring the seasonal maximum cross-sectional area of snow drifts at 31 windbreak test sites, over a six-season study (Perchanok, 1990, 1992).

The second task involved the development

of dimensioned designs, materials lists, and labour schedules for installation and annual maintenance which allowed each alternative windbreak type to meet the functional requirements. These were based on manufacturers' recommendations, published information, and experience gained with all windbreak types during the field trials program.

For analysis periods ranging from 1 to 50 years, costs incurred in each year were summed and converted to 1993 present value dollars (PV),

$$PV_m = \frac{Total_m}{(1 + i)^m}$$

where m is the year (0 to 50), $Total_m$ is the sum of costs incurred during year m, and i is the interest rate net of inflation expressed as a decimal fraction, assumed to be .05.

Net present value (NPV) is the sum of PV_m over the period of analysis,

$$NPV_n = \sum_{m=0}^{n-1} PV_m$$

where n is the period of analysis (1 to 50).

The equivalent annual cost (EAC) in 1993 dollars was obtained by multiplying the NPV_n by an appropriate capital recovery factor, (Grant, Ireson and Leavenworth, 1990) where

$$EAC_n = NPV_n \left(\frac{i(1 + i)^n}{(1 + i)^{n-1}} \right).$$

EAC was provided for each windbreak type for analysis periods ranging from 1 to 50 years. No salvage value was assumed where the component life expectancy exceeded the installation period.

Alternative designs were developed for each type, taking into consideration different dimensions, number of rows, installation methods and materials with different life expectancies. The designs were compared to illustrate the sensitivity to different cost components, and the lowest cost design of each principal type which met the functional requirement, was selected for overall comparison.

RESULTS

Functional Requirements

Earlier studies (Perchanok, 1990) showed that snow fence materials must be capable of; withstanding lateral tensioning during erection, wind and snow loads imposed over long periods of service, constant vibration and abrasion. Field trials indicated that these requirements can be met by most available products if suitable installation and maintenance procedures are followed, and if suitable component life-cycles are used and therefore, few products were eliminated on the basis of material properties. Instead, differences in material properties affected the cost of using a particular product.

Snow trapping capacity was based on the largest snowdrift measured over a six year study period at 31 test windbreaks in the snowbelt of southwestern Ontario. The largest drift was 38 m^2 in cross-sectional area. It was accumulated during the winter of 1993 by a 4 metre tall snow hedge, and had geometric characteristics of a drift in the early stages of development as defined by Tabler (1992). This indicates that the drift was far below the saturation volume for that windbreak, and the windbreak was trapping snow at a high efficiency level. The drift volume was therefore a reliable indicator of the snow storage requirement for that location and year. Total snowfall at the nearest weather station for 1992/93 was 308 mm water equivalent, compared with a normal of 280 mm (AES, 1981, 1993). This suggests that the cross-sectional area measured in 1992/93 is a reasonable design value.

Following Tabler (1992), windbreaks were designed with an excess capacity in this study, to compensate for the decrease in trapping efficiency as saturation level increases. An excess capacity of 20% was used, giving a total snow storage requirement of 46 m^2 in cross-sectional area, and resulting in a snow-trapping efficiency of 55% at the measured snow storage requirement of 38 m^2.

Table 1

Cost Components (1000 m installation)

Windbreak Type	Temporary Fence			Permanent Fence	Hedge	Corn & Temp. Fence
	wood picket	plastic lattice	horizontal strip	plastic lattice		
Component Life (yrs)	7	7;12	7	7;12	35	1;9
Number of Rows	1;2	2	2	1	3	7;1
Post/tree Spacing (m)	5	5	5	5	2	1,5
Set-back from ROW	15	15	15	15	15	7
Annual Labour (hrs/m)	0.11	0.10	0.20	0.01	0.002	0;0.11
Post/tree ($ each)	12	12	12	45	18	0;12
Fabric ($/m)	2	5	6	7	0	0;2
One-time Costs ($/m or tree)	0	0	0	3	20	0
Land Purchase;Rent	0	0	0	2000;350	2000;350	0;350

; indicates alternatives included in analysis

Cost Components

Cost components used in the analysis are listed in Table 1.

Four principal types of windbreak were identified in the literature and included in the cost analysis:

1. temporary snow fence
2. permanent snow fence
3. snow hedge
4. corn stalks.

Temporary fence consists of a porous fabric, vertical support posts, devices for attaching the fabric to the posts, and guy wires or other anchoring and lateral support devices. It is normally erected on private land during the winter season and removed in the spring. It does not interfere with agricultural land use and the highway authority is generally not charged for use of the land.

Permanent fence requires components similar to temporary fence, but is erected permanently and not removed during the summer. It may interfere with agricultural or other land use and therefore, land costs are included in the analysis for permanent fence.

Three types of fence fabric were considered; vertical wood picket, plastic lattice, and plastic horizontal strips. The MTO standard fence consists of 1.2 metre high, vertical wood pickets mounted on steel T-posts (MTO, 1977). This type of material lasts an average of 7 years. Plastic lattice and horizontal plastic strips are available in a variety of geometries, material strengths and porosities (Perchanok, 1993). Manufacturers of these fabrics claim material lifespans of up to 12 years, but MTO experience suggests that most will become unserviceable due to abrasion, tearing, and stretching within 7 years. Calculations are provided for both cases in the analysis.

The snow storage capacity for a fabric of given porosity is related to windbreak height, for a given porosity such that:

$$A=23.25H^2$$

where A is snowdrift cross-sectional area and H is height of a 60% porous, vertical fence (Tabler, 1991). A 46 m^2 snow storage capacity therefore requires a fence height of 1.4 metres. This is in agreement with experience in Ontario, where 1.2 m high picket fences are observed to have insufficient capacity.

Several fabrics are available in more than one height to allow the desired storage capacity with a single lift. All can be installed in more than one lift to achieve the same effect, but logistical considerations restrict the use of more than one lift in a temporary installation. Costs of a single lift of the standard wood picket fence are presented for illustrative purposes, but all other analyses of temporary fence are based on two rows. The analysis for permanent fence assumes that a single row of appropriate height can be installed.

The relationship between height and capacity is different for snow hedge than for fence fabrics because hedge has different aerodynamic properties. The capacity of a snow hedge can be adjusted through species selection, number of rows and height. A three row, cedar hedge which was shown to be effective in field tests (Perchanok, 1992), was used as the basis for the cost analysis. It was assumed that a hedge will grow to an effective height and crown width within five years of planting, and that a single row of picket fence is installed to protect the seedlings and provide snow control during this period. The fence is removed at the end of five years. A 35 year life expectancy was assumed for the cedar hedge.

Protection from drifting snow can also be achieved using seven to ten rows of standing corn stalks (Brubacher, 1992). This method may be feasible only one year in three due to crop rotation requirements, and the analysis therefore included the cost of seven rows of corn in the first year, and the cost of two rows of temporary fence in the second and third years of a three-year cycle. The seven year expected component life for temporary snow fence was extended to nine years to account for the reduced exposure of the fabric to installation and environmental loads in the years when corn is used.

Post, tree and crop spacing for all of the windbreak options were based on current practice in Ontario.

All of the windbreaks must be installed some distance from the highway to ensure that the accumulated snow drift does not encroach on it. A set-back distance of 15 metres from the right-of-way was used for snow fence and snow hedge, and 7 metres for standing corn. These provide adequate snow storage area when additional area of at least 10 metres is available between the right-of-way edge and the road shoulder.

Fabric and post or tree costs (Perchanok, 1990), and land prices (McCaw, 1992), are based on current market rates in Ontario. Annual labour refers to recurring maintenance and repair and not to installation costs. Post/tree, fabric and one-time costs occur at the beginning of each component lifespan. These costs are spread out over the component lifespan up to the period of analysis.

Cost Comparison

The equivalent annual costs of the net present values for 1000 meter long sections of alternative windbreaks, are shown in Figures 1 through 6. Figures 1 through 5 provide a breakdown of alternative methods and component costs for each type of windbreak, while Figure 6 and Table 2 compare the lowest cost option of each type meeting the functional requirements. Values are given for installation periods ranging from 1 to 50 years.

Table 2 Lowest Annual Cost

Windbreak Type	Analysis Period	
	15 yrs	50 yrs
Temporary Fence	6500	6200
Permanent Fence	4600	3700
Hedge	6600	4400
Corn & Temp. Fence	4400	4200

Total costs of five types of temporary fence are shown in Figure 1. One row picket fence with a seven year component life is shown for comparative purposes only. It is commonly used but does not meet the snow storage requirement for Ontario. Two row lattice fence with a 12 year component life is also shown although it does not meet the durability requirement.

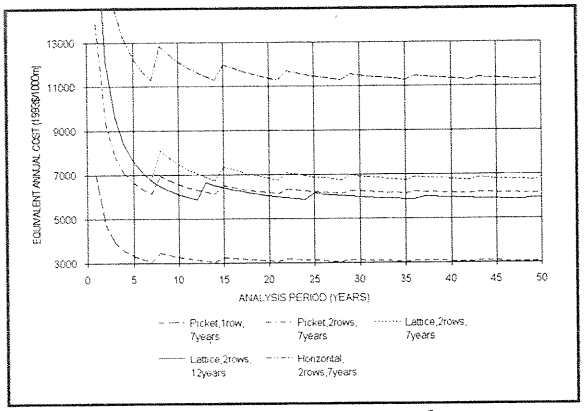

Figure 1. Cost comparison of temporary snow fence.

The two row picket fence is the lowest cost temporary fence meeting the functional requirements when a seven year installation period is considered. The cost of a long-term installation is about $6200.00 per 1000 metres per year. The long-term cost for two row lattice fence is $6900.00, and for two row horizontal strip fence is more than $11,000.00.

Plastic lattice fabric which is available in a range of heights, was used for the analysis of permanent fence, as it can be designed to meet the snow storage requirement in a single row and a single lift. Component and total costs for a permanent, plastic lattice snow fence are shown in Figure 2. Costs include the purchase of a 15 metre wide strip of land between the fence and the highway, and assume a 7 year fabric life. The annual cost for long-term installations is $3700.00, with materials and one-time costs constituting the major component for any installation period.

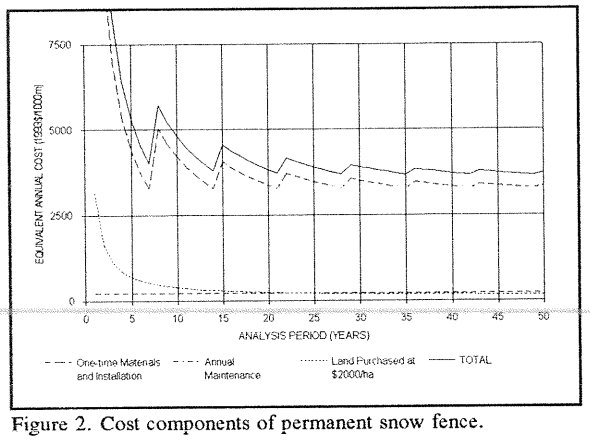

Figure 2. Cost components of permanent snow fence.

Figure 3 compares the cost of a permanent fence when land is purchased, and Figure 4 compares the cost when land is rented for a variety of land values. Typical values in southwestern Ontario are $2000/ha for land purchase and $350/ha for rental (McCaw, 1992). A precise analysis of the relative merits of purchasing vs renting land is sensitive to particular land values at the site in question, but the analysis suggests that land purchase is relatively less expensive than land rental in a typical case.

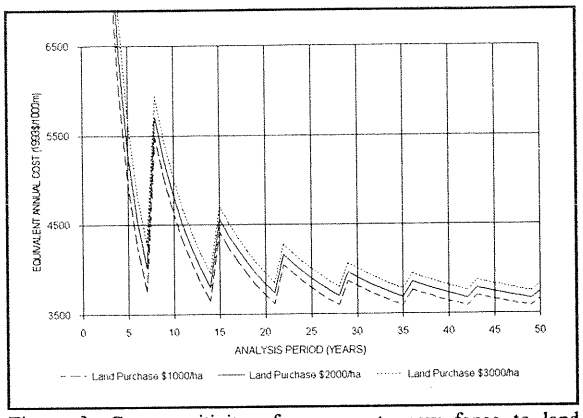

Figure 3. Cost sensitivity of permanent snow fence to land purchase price.

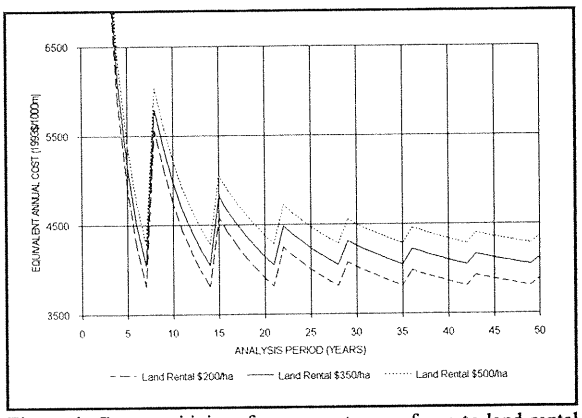

Figure 4. Cost sensitivity of permanent snow fence to land rental price.

Component costs for snow hedge fall in the same relative order as those for permanent fence, with one-time costs constituting the major component (Figure 5). The annual cost of a long-term snow hedge installation is $4400.00, including installation of a picket fence for the first five years of operation, and the purchase of a 15 metre strip of land.

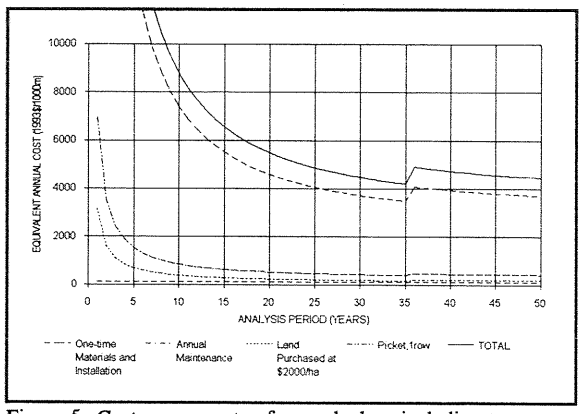

Figure 5. Cost components of snow hedge, including temporary fence.

The annual cost for corn stalks alone is assumed to be equal to the net market value for corn. This was $350.00 per hectare in 1992. However, this method is feasible only in years when corn is planted, approximately one year in three. Standing corn meets the functional requirement only when used in conjunction with temporary snow fence. Costs for the combined use of standing corn and temporary snow fence in a three-year cycle is $4200.00 for long-term use (Figure 6).

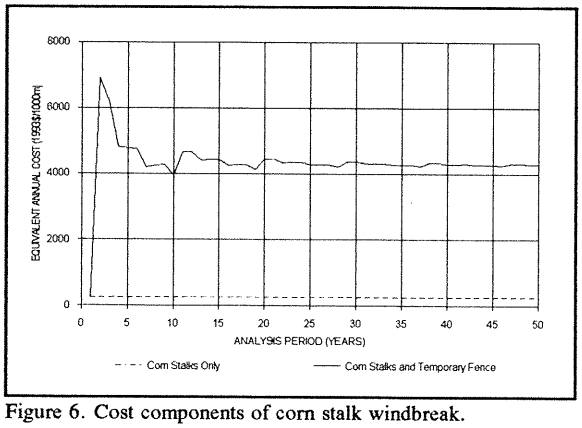

Figure 6. Cost components of corn stalk windbreak.

As illustrated in Figure 7, the standing corn system provides the lowest overall cost for periods of 1 to 6 years and is lowest for most periods up to 15 years. Where corn is not available, temporary fence provides the lowest cost option for periods of 1 to 3 years. Permanent snow fence provides the lowest cost for longer periods. Snow hedge is effective at lower cost than temporary fence for periods of 15 years or more.

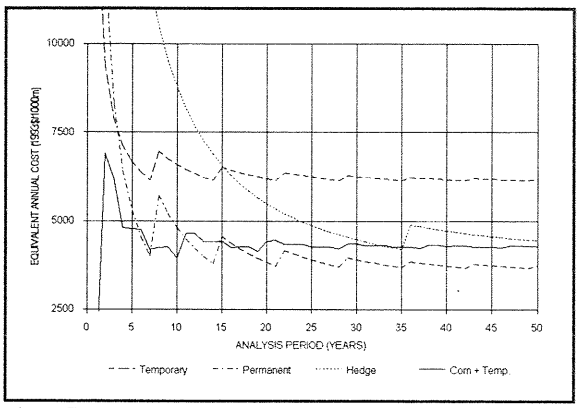

Figure 7. Overall cost comparison of windbreaks for snow control.

Overall, permanent, plastic lattice snow fence is the least expensive method of controlling drifting snow under most operational circumstances.

Other Considerations

While this analysis shows clearly that permanent fence has the lowest annual cost, other factors may affect the selection of a snow control system.

Temporary snow fence is the most flexible method in that it can be moved from year to year or eliminated entirely if changes to roadside land use reduce the severity of drifting snow. It also has the least effect on roadside land use. Its drawbacks are that installation may be prevented by uncooperative roadside land owners or by changes to government spending priorities.

Permanent fence has an intermediate effect on roadside land use. It interferes with cropping to the extent that farm machinery must work around it, and it constitutes a barrier to animals and people. It may also affect crop growth by shading. It may have beneficial effects by reducing soil erosion and evaporative losses from crops.

Snow hedge has more effect on roadside land use than other methods. As well as shading adjacent crops, it may compete for soil nutrients and moisture. The width of affected area is also larger for a hedge than for a fence. It has positive effects in reducing soil erosion and evaporation, providing wildlife habitat, exchanging atmospheric carbon dioxide, and is aesthetically pleasing. It also allows the passage of animals and people.

Corn stalk windbreak may affect agricultural land use through the growth of volunteer corn which may interfere with the harvesting of rotation crops the following summer.

All of the windbreaks may result in excess soil moisture within the snow storage area during spring snowmelt.

The cost analysis assumes that land must be purchased where windbreaks are installed permanently, but not where temporary fence is used. The cost advantages of permanent windbreaks will be increased if the land can be used at no charge.

Calculations in this study are based on land and material prices; labour, interest and inflation rates; methods of windbreak installation; and snow storage requirements typical in the Province of Ontario. Different values may be appropriate for other geographical areas.

CONCLUSIONS

This study shows the benefit of continued use of temporary snow fence only in areas where protection is required for less than 3 years where corn is not grown, or less than 6 years where corn is grown in rotation. Where protection is needed for longer periods, permanent snow fence is the lowest cost alternative. Snow hedge is the highest cost method for periods less than 15 years, and is intermediate between permanent and temporary fence for longer periods.

This study suggests that permanent snow fences or snow hedges may be more cost effective in Ontario than the commonly used temporary fences. They should be considered for installation where land-use conditions are suitable.

ACKNOWLEDGEMENT

The authors thank Mr. Chris Falchuk, Department of Civil Engineering, University of Waterloo, for technical support in the cost analysis. The work was conducted with support and assistance from the Research and Development Branch and the Maintenance Branch, Ontario Ministry of Transportation.

REFERENCES

AES, 1981. "Canadian Climate Normals: Temperature and Precipitation", Atmospheric Environment Service, Environment Canada, Downsview.

AES, 1993. Data provided by Ontario Climate Centre, Atmospheric Environment Service, for Barrier, Ontario.

Brubacher, P., et al, 1992. "Feasibility of Co-operative Snow Control Initiatives:, Report MAT 92-05, Research and Development Branch, Ontario Ministry of Transportation, Downsview.

Grant, E. L., W. G. Ireson and R. S. Leavenworth, 1990. Principles of Engineering Economy, John Wiley and Sons, Toronto.

McCaw, G., 1992. Personal Communication, Policy Analysis Branch, Ontario Ministry of Agriculture and Food, Ridgetown.

MTO, 1977. "Standard J2244, Snow Fence", Purchasing, Sales and Distribution Office, Ontario Ministry of Transportation, Downsview.

MTO, 1981. "Operating Instructions; Winter Maintenance Standards, Series M-700, Vol. 4; Maintenance Manual", Highway Engineering Division, Ontario Ministry of Transportation, Downsview.

Perchanok, 1990. "What Makes a Good Snow Fence? Results from 12 Years of Testing at the Ontario Ministry of Transportation", Proceedings, Eastern Snow Conference, Bangor, 1990.

Perchanok, 1992. "Snow Hedge Design Guidelines; Preliminary Results and Implications", Proceedings, Eastern Snow Conference, Oswego, 1992.

Perchanok, M., 1993. (In Press), "Investigation of Fabric Properties for Highway Snow Fence", Report MAT-92-15, Research and Development Branch, Ontario Ministry of Transportation, Downsview.

Tabler, R.D., 1991. "Snow Control Course Notes", Tabler and Associates, Niwot, Colorado.

Tabler, R.D., 1992. "Drifting Snow Control", in: Instructor's Guide, Snow and Ice Control Seminar, Strategic Highway Research Program, Federal Highway Administration, Chicago.