INVESTIGATIONS OF NEW ECONOMICAL DESIGNS OF "THICK SNOW FENCES" TO PRESERVE SNOW FOR MAXIMUM WATER CONSERVATION

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ABSTRACT: What are effects of snow fences on interception of snow? Snow is a vital consideration as potential water conservation method during drought. Dense drifted snow melts more slowly and sublimates less; therefore, development of economical methods to intercept windblown snow into dense drifts is of major concern.

The project extended over two winters. During the first winter, one meter tall snow fences were used in a field setting to test effects of changing horizontal board thickness on wind patterns and snow drift geometry, and to validate results of small scale models previously tested in a wind tunnel.

All snow fence design hypotheses were tested. As board thickness increased, wind speed decreased further upwind, drift apex occurred further upwind, and total volume increased. Snow fences tested in field conditions did create similar relationships between wind patterns and snow drift geometry to those of small scale models tested in a wind tunnel, thus validating results of previous models.

The second winter expanded the "Thick Fence" investigations to develop a more economical design, which would still produce short length, high volume drifts. Two designs, an Angles and a 3-Piece fence, decreased material while still generating high levels of turbulence. A cross-sectional analysis was conducted by digging a snow pit at the apex of the drift, which allowed study of grain types and densities throughout the snowpack. The 3-Piece Fence was more economical and retained the drift characteristics of short length, and high volume. The Angles Fence was similar to the Control-Thick Fence, while the 3-Piece Fence was the least expensive, enhanced drift characteristics earlier during winter, and had higher density with more distribution of rounded particles.

These results will help scientists and land managers use various snow fence designs to more economically manipulate snow for enhanced water supply for conservation during drought.

KEYWORDS: blowing snow, interception, drifting snow, snow fences, water conservation

1. INTRODUCTION

Snow is a vital consideration as potential water supply during drought. The snow in a windblown snow drift is far denser than loose snow, thus sublimates less, melts more slowly, and is retained longer in the spring; therefore, development of economical methods to intercept windblown snow into dense drifts is of major concern. The use of variable types of snow fences allows specific design and placement of snow drifts for the targeted results of protection and water supply (Figure 1).

Figure 1. Interception and retention of snow in dense drifts is affected by snow fence design.

The first winter's project used one-meter tall, snow fences in a field setting to test effects of changing the horizontal board thickness on wind patterns and snow drift geometry, and to validate results of previous small scale models.

The second winter continued with the one-meter tall snow fences to develop a more economical version of the previously tested Thick Fence, which produced short length, high volume drifts

These two investigations are the third and fourth winters of research projects about drifting snow and snow fence design. Year 1 tested various household products to determine which closely replicated wind blown snow in small scale models, and proved that Cascade dish detergent is a close replica. Year 2 used Cascade as the snow medium in small scale model testing of snow fence variables, and concluded that porosity and horizontal board thickness greatly influence the resultant wind patterns and drift geometry.

The results can be used to more economically design and position snow fences for specific intents for protection and water supply.

The first winter's research addressed two questions/hypotheses:

1A. Does the thickness of the horizontal boards of a snow fence affect the resultant wind pattern and snow drift geometry? It was hypothesized that as the thickness of the horizontal boards increases, the wind speed will decrease further upwind, the deepest part of the collected drift will occur further upwind, and the total volume of the collected drift will increase.

1B. Do snow fences tested in field conditions result in wind patterns and snow drift geometry similar to those of small scale models tested in a wind tunnel? It was hypothesized that snow fences tested in field conditions will create similar relationships between wind patterns and snow drift geometry to those of small scale models tested in a wind tunnel.

The second winter's research addressed three questions/hypotheses:

2A. Can a more economical version of the Control-Thick Fence be designed that still produces a short length, high volume drift? It was hypothesized that a more economical version of the Control-Thick Fence can be designed that still produces the Control-Thick Fence's drift characteristics of short length and high volume, that the Control-Thick Fence will be most expensive to construct, followed by the 3-Piece Fence, while the Angles Fence will be least expensive, and that the 3-Piece Fence will retain drift characteristics of the Control-Thick Fence, the Angles Fence will enhance drift characteristics.

2B. Are there similar stages of drift development of Control-Thick, Angles, and 3-Piece fences? It was hypothesized that 3-Piece Fence drifts will develop similarly to Control-Thick Fence drifts, while Angles Fence drifts will accumulate more depth and volume earlier in the winter.

2C. Does cross-sectional analysis of the drifts expose similar grains and densities for Control-Thick, Angles, and 3-Piece fences? It was hypothesized that 3-Piece Fence drifts will have grains and density similar to those of the Control-Thick Fence, while Angles Fence drifts will have more prominently rounded crystals throughout the cross-section, and a higher density.

2. METHODS

2.1 Research in First Winter:

Preparation of Snow Fences for First Winter:

Construction Note: Because building materials are purchased locally, lumber measurements are not in System International units. Data measurements are made in S.I. units.

1. Build a wooden one-meter tall scaled-down version of 7 foot Wyoming Design Board Snow Fence as the Control, 50% porosity, 1 in horizontal board thickness, 24 ft length, in three 8 ft sections (Figure 2)
2. Build variable fences, scaled equally to the Control, with following variations:
   - Thick Fence: Horizontal board thickness of 4 in (Figure 3)
   - Thin Fence: Horizontal board thickness of 0.25 in (Figure 4)

Figure 2. First Winter Control Fence, 1 in thick

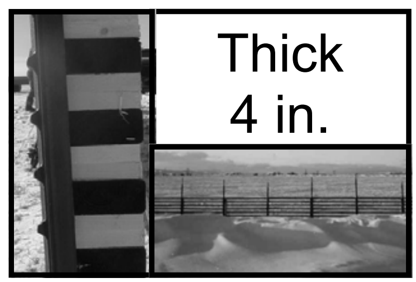

Figure 3. First Winter Thick Variable, 4 in thick, and Second Winter Control-Thick Fence

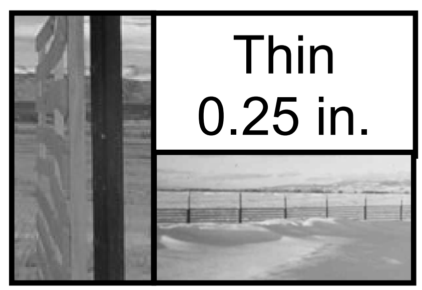

Figure 4. First Winter Thin Variable, 0.25 in thick

3. Select two field test sites with generally even terrain and vegetation, and uninterrupted fetch (minimum 200 m) and downwind (minimum 100 m) areas
4. Secure fences to steel fence posts at 4 ft intervals in field test sites, perpendicular to prevailing wind, arranging control and test fences end to end, with 24 ft of plastic commercial snow fence at both ends to prevent "end effect" influencing test fence results (Figure 5).

Figure 5. Securing fences in test areas (left) and measuring wind speeds (right)

5. Build 4 instrument towers, to stabilize center of wind gauges' sensor propellers 50 cm above ground level, at center of fences' height and perpendicular to wind flow (Figure 5).

<u>Collection of Wind Pattern Data:</u>

1. Collect data on days with wind speed minimum 10 kph in the non-obstructed area.
2. To gather data from test areas simultaneously, place one instrument tower with wind gauge along center line of each test area, set to measure the 1 minute average wind speed at 5 min intervals.
3. Begin data collection from all test areas at 9 m upwind of fence line. During each 5 minute interval, move wind gauges downwind 2 m along center line. Continue to 39 m downwind.
4. Repeat at both field sites on two days

<u>Drift Geometry (Depth Profile and Volume):</u>

1. Collect data after each snow and wind storm has caused drift development
2. Measure drift depths in cm, every 0.5 m along drift center line for longitudinal profile, from 10 m upwind to 40 m downwind (Figure 6).

Figure 6. Measuring drift depth along center line.

<u>2.1 Research in Second Winter:</u>

<u>Preparation of Snow Fences for Second Winter:</u>

1. Build a wooden 1-meter tall fence identical to previous Thick Fence as this winter's Control: 50% porosity, 4 in thick horizontal boards, 24 ft length, in three 8 ft sections (Figure 3).
2. Build variable fences, scaled equally to Control-Thick, with the following variations:
   - Angles Fence: 0.5 in thick horizontal boards, at alternating 72° angles, for 4 in thickness (Figure 7)
   - 3-Piece Fence: 3-piece frame for 4 in horizontal thickness (Figure 8).

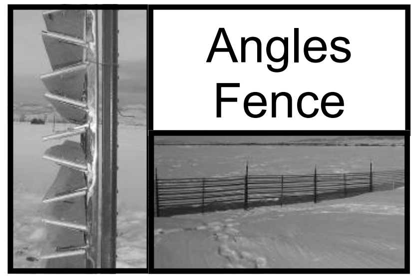

Figure 7. Second Winter Variable Fence: Angles

Figure 8. Second Winter Variable Fence: 3-Piece

3. Set up field test sites, fences, and wind instrument towers identical to first winter (see above, Figure 5).

<u>Collection of Wind Pattern Data and Drift Geometry Data in Second Winter:</u>

1. Collect wind and drift geometry data the same as in first winter, with the exceptions of using 2-minute intervals in wind data collection, and measuring drift depth to 20 m downwind of fences (Figures 5 and 6).

<u>Collection of Drift Cross-Sectional Profile Data:</u>

1. Evaluate cross-sectional profile of each drift with a snow pit at the end of drift measurement season.
2. Mark snow pits at each drift's apex along drift center line; dig to ground, with a straight vertical wall in shadow as the study face.
3. Establish snow pack layer boundaries by grain and resistance differences. Within each layer, measure layer depth, use a 10x magnifier and crystal card to identify grain type and size, and use fist resistance technique to measure resistance.
4. At center of each 10 cm layer of snow pack, use a snow cutter and spring scale to measure density of a 200 cm^3 block, from which water content is calculated (Figure 9)

Figure 9. Conducting a cross-sectional analysis of snowpack at drift apex.

3. DISCUSSION OF RESULTS

3.1 Summary of Results

This investigation of snow fence design, over two winters, studied effects of horizontal board thickness of snow fences on resultant wind patterns and drift geometry, and as a comparison to previous small scale modeling work. All of the hypotheses were supported. As board thickness increased, wind speed decreased further upwind, thus the apex of the resultant drift occurred further upwind. As board thickness increased, the resultant drifts' total volume also increased. Snow fences tested in field conditions did create similar relationships between wind patterns and drift geometry to those created by small scale models tested in a wind tunnel. This validates the results of previous small scale modeling.

The investigation further developed a more economical version of the previously tested Thick Fence, which produced short length, high volume drifts. The 3-Piece Fence was a more economical version which retained the drift characteristics of short length, high volume drifts, therefore supporting the first part of Hypothesis 1A. All other snow fence design hypotheses were not supported. The Angles Fence was similar to the Control-Thick Fence, while the 3-Piece Fence was least expensive, enhanced drift characteristics earlier during winter, and had higher density with more distribution of rounded particles.

These results can be used to emphasize the need to capture snow in a dense snow pack wherever additional stored moisture is needed in the spring. The research will help scientists and land managers use snow fence designs and placements to more economically manipulate snow for enhanced water supply during drought.

3.2 First Winter Result of Thin versus Thick Fences, and Validation of Models:

Wind Pattern Results of Thin versus Thick:

The Control-1 inch (in) thick fence, caused the wind to gradually decrease from an average of 20 kph upon entering the testing area, to an average of 11 kph directly upwind of the fence. One m downwind of the fence, wind speed rapidly decreased to an average of 7.5 kph. Then wind speed began to increase to a laminar flow at 16 kph at 22.5 m downwind of the fence (Figure 10).

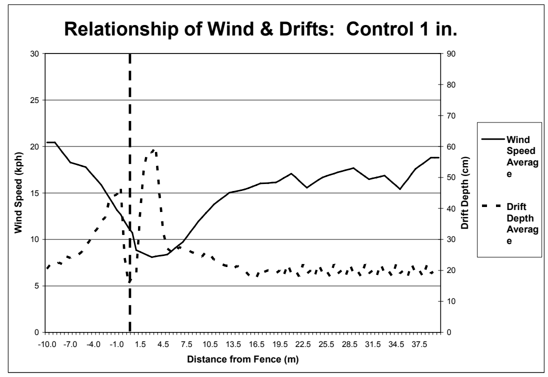

Figure 10. Relationship of Control Wind & Drifts

The Thick-4 in thick fence, created a wind pattern very different from that of the Control. Upon entering the testing area at 19 kph, the wind stayed at a steady speed until five m upwind when it dropped to 12 kph one m upwind of the fence. Directly downwind of the fence, wind accelerated due to the compression of the moving air across the thick boards, yet then decreased to 10.5 kph at 2 m downwind of the fence. The wind speed gradually increased to reach laminar flow at 16 kph at 7.5 m downwind of the fence (Figure 11).

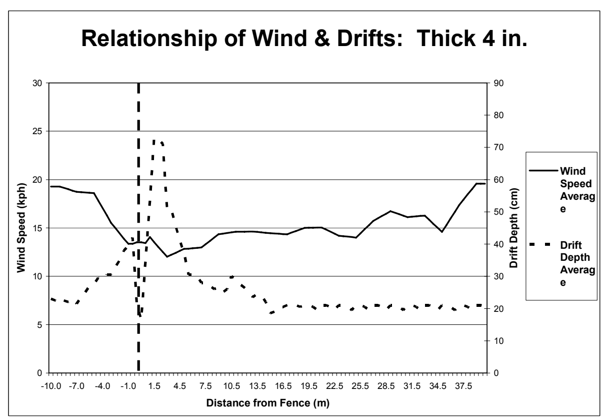

Figure 11. Relationship of Thick Fence Wind & Drifts

The Thin-0.25 in thick fence, also created a unique wind speed profile. The wind entered the testing area at 19 kph, and then steadily decreased to 7.5 kph in between 0 m and 4.5 m downwind of the fence. At 4.5 m the wind began to gradually increase to laminar flow of 17 kph at 13.5 m downwind of the fence (Figure 12).

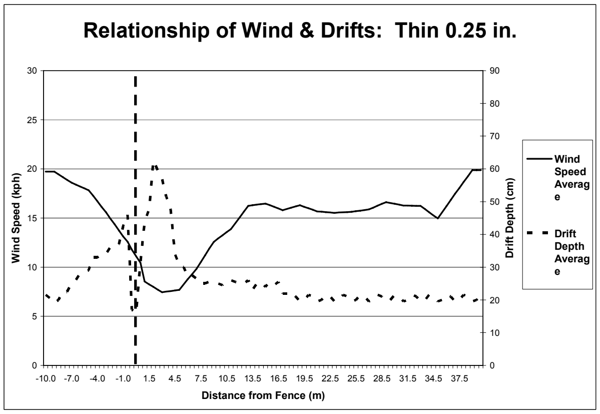

Figure 12. Relationship of Thin Fence Wind & Drifts

An unobstructed area, 72 m beyond the test fence line, was also measured. The wind speed ranged widely due to gusting, from 15 to 29 kph.

Drift Geometry Results of Thin versus Thick:

The Control-1 in thick fence, created a typical lens shaped drift with the majority of the snow slightly downwind of the fence. The upwind drift began at 8 m upwind of the fence, and had a fairly steep front, reaching a depth of 50 cm one m upwind of the fence. The downwind drift began one m downwind of the fence, with a steep incline to the apex of 60 cm, at two m downwind of the fence. The downwind drift then tapered off to a depth of 20 cm, ending at 17 m downwind of the fence. Total volume collected by the Control Fence averaged at 91 m^3 (Figure 10).

The Thick-4 in fence, created a shorter, more compact drift than the Control, with the majority of the snow located directly downwind of the fence. The upwind drift began at 6 m upwind of the fence, and gradually increased to an apex of 45 cm directly upwind of the fence. The downwind drift began directly downwind of the fence, where depth increased suddenly to an apex of 72 cm. The apex was located 1.5 m downwind of the fence. From the apex, drift depth tapered to a depth of 20 cm, ending the drift 19.5 m downwind. Total volume collected by the Thick Fence was 98 m^3 (Figure 11).

The Thin-0.25 in thick fence created a long, lens-shaped drift. The majority of the snow was located 1 m downwind of the fence. The upwind drift began at 9 m upwind of the fence. The depth gradually increased to a depth of 47 cm, one m upwind of the fence. The downwind drift began 0.5 m downwind of the fence, and increased to an apex of 63 cm by 1 m downwind of the fence. From the apex, the drift gradually tapered off to a depth of 25 cm. The drift ended at 16.5 m downwind of the fence. The total volume collected by the Thin Fence averaged at 95 m^3 (Figure 12).

The Outside of Fence test area had a generally flat drift profile. The total volume averaged 70 m^3

Statistical Analysis Results for Wind Speed and Drift Geometry of Thin versus Thick:

Average volume for the outside area was 72 m^3. The average volumes for the Control Fence, Thin Fence, and Thick Fence were 91 m^3, 95 m^3, and 98 m^3, respectively. The regression analysis of average volumes of 4 areas resulted in a slope of 7.2909, with R^2 value at 0.6162. As thickness of the horizontal boards increased, total volume of the collected drift did increase (Figure 13).

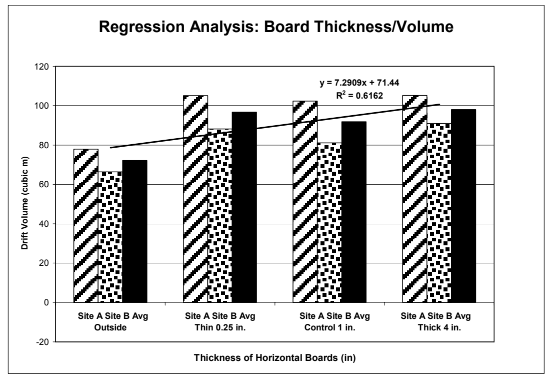

Figure 13. Regression Analysis Board Thickness versus Volume

T-tests were run on average volumes of the collected drifts. At confidence levels of 90%, total volumes of the Control versus Thin fences, the Control vs Thick, and Thin versus Thick fences were not significantly different. Yet, as these were early stage drifts, it can be assumed that the difference in the means (0.048) would accumulate as the drifts developed, causing the drift volumes to eventually become significantly different.

A correlation was run between wind speed and drift depth. The results showed that as board thickness increased, the correlation decreased. (Figure 14).

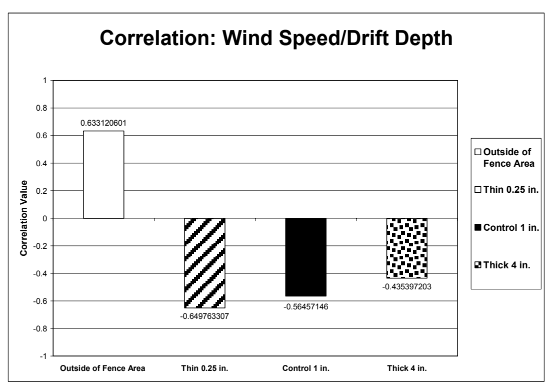

Figure 14. Correlation of Wind Speed and Drift Depths

Ranges of lowest wind speed and deepest drift depth were charted. The results showed that the Thick fence's low wind speed range began furthest upwind. The Thin and Control fences' low wind speed range began further downwind. When the deepest drift depth ranges were evaluated, it was found that the Thick fence's apex began furthest upwind, while the Thin and Control fences' drift apexes began slightly downwind of the Thick fence's apex. As thickness of horizontal boards increased, there was greater interference with incoming wind, therefore the deepest part of the collected drift did occur further upwind.

A regression analysis was run comparing wind speed to drift depth for all test areas. All fences created a trend with a negative slope, while the outside area created a trend with positive slope. The trend line for the Control-1 in Fence had a slope of -1.6254, indicating that for every 1 kph that wind speed increases, drift depth will decrease 1.6254 cm. The trend line the Thin Fence showed a slope of -1.8156, indicating that the Thin Fence demonstrates that for every 1 kph that wind speed increases, drift depth will decrease 1.8156 cm. The trend line for the Thick Fence had a slope of -2.3929, showing that for every 1 kph that wind speed increases, drift depth will decrease 2.3929 cm, due to higher influence on the wind/snow deposition of thicker boards.

<u>Validation of Models and Field Tests</u>:

A correlation was run with the previous year's modeling work between wind speed and drift depth. The results showed that all three fence types' models had close correlation values to the field test fences. The snow fences tested in field conditions did create similar relationships between wind patterns and snow drift geometry to those of small scale models tested in a wind tunnel. Use of small scale models was validated in this comparison to field tests (Figure 15).

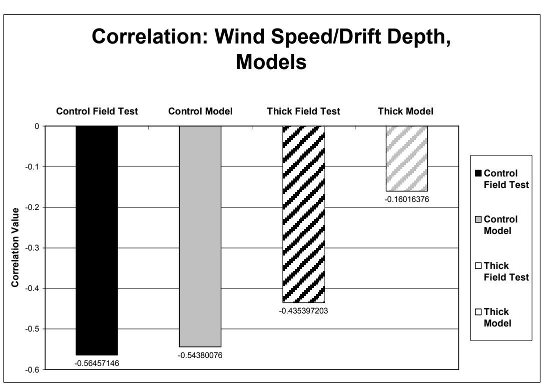

Figure 15. Correlation of Models and Field Test Fences

3.3 <u>Second Winter Result of Variations of Thick Fence Designs:</u>

<u>Wind Pattern Results:</u>

The Control-Thick Fence caused the wind to sharply decrease from an average of 23 kph at 2 m upwind, to an average of 12.5 kph directly upwind of the fence. 2 m downwind of the fence, the wind accelerated a large amount to a wind speed of 23 kph. This 'blip' in the wind speed is unique to the Thick Fence, due to compression of moving air across the thick boards.

The Angles Fence, a fence designed with boards set at alternating angles, caused the wind to sharply decrease from an average of 27 kph at 3 m upwind, to approximately 16.5 kph directly upwind of the fence. 2 m downwind of the fence, the wind accelerated a slight amount due to the increased turbulence through the angled boards to a wind speed of 18 kph, yet then decreased to 13 kph at 6.5 m downwind of the fence. Then wind speed rapidly increased to 21 kph at 8 m downwind of the fence and remained approximately 21 kph.

The 3-Piece Fence, a fence designed with a 4 in thick, open framework, caused the wind to sharply decrease from an average of 25 kph at 1 m upwind of the fence, to approximately 14 kph directly upwind of the fence. 2 m downwind of the fence, the wind continued a sharp declination, reaching a wind speed of 7 kph. Then the wind speed began to gradually increase in speed, reaching 21 kph at 14 m downwind of the fence.

<u>Drift Geometry Results:</u>

The Control-Thick Fence, created a short, compact drift, with the majority of the snow located directly downwind of the fence. The drift developed by adding length and depth in similar proportions after each storm. Total average length and volume of the final drifts were 18 m and 82,588,608 cm^3 (Figure 16).

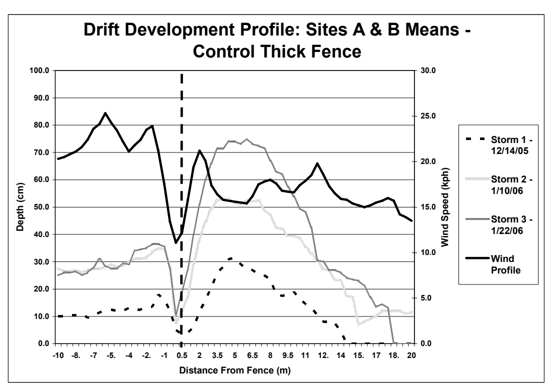

Figure 16. Wind/Drift Development - Control Fence

The Angles Fence created an elongated, round drift, with the majority of the snow spread evenly throughout the downwind area of the fence. The drift developed by adding extensive length and only moderate depth after each storm. Total average length and volume of the final drifts were 19 m and 84,380,832 cm^3 (Figure 17).

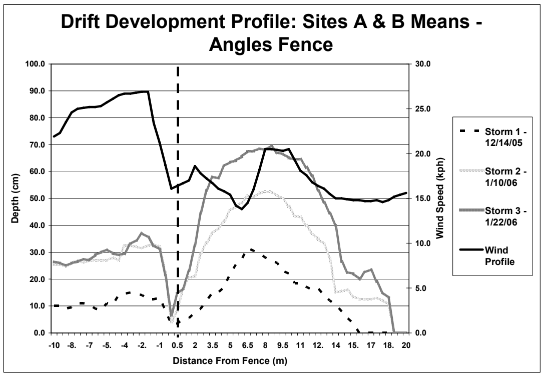

Figure 17. Wind/Drift Development - Angles Fence

The 3-Piece Fence created an extremely short, highly compact drift, with the majority of snow located immediately downwind of the fence. The drift developed by decreasing in length and vastly increasing in depth after each storm. Total average length and volume of final drifts were 16 m and 85,130,640 cm^3. This supported Hypothesis 1A because the 3-Piece Fence did enhance the Control-Thick Fence's drift characteristics of short length and high volume. (Figure 18)

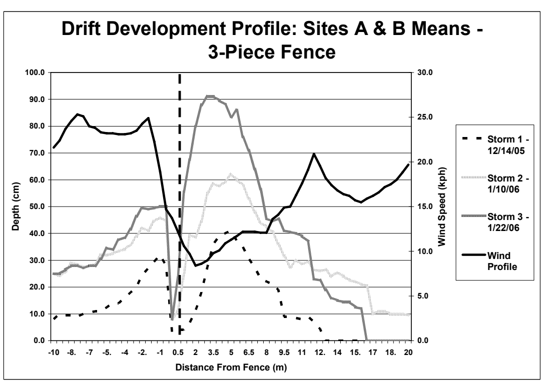

Figure 18. Wind/Drift Development – 3-Piece Fence

Statistical Analysis Results for Drift Geometry:

To examine the development patterns of each drift, a stacked column graph was created. This showed that for all fences, the majority of the drift accumulated in the third stage, probably in result of a larger storm (Figure 19).

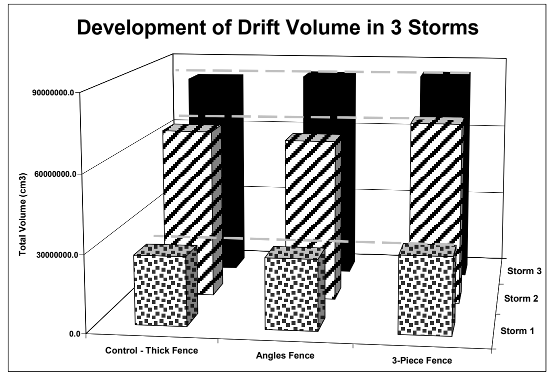

Figure 19. Development of Drift Volume over 3 Winter Storms

Total volume of the drifts was calculated through incremental measurements of length, width, and depth. The 3-Piece Fence increased total volume of collected drifts over the Control, but the Angles Fence did not. T-test showed that when comparing the Control-Thick vs Angles Fences, the Control-Thick vs 3-Piece Fences, and Angles vs 3-Piece Fences at 95% confidence level, total drift volumes were not significantly different. Yet, as these were intermediate stage drifts, it can be assumed that differences in means will accumulate as drifts develop, causing volumes to eventually become significantly different.

Cross-sectional Analysis Results:

A cross-sectional analysis of each drift's snowpack was conducted at the apex of each drift, which included distinguishing the snowpack layers, layer depth, grain type and size, resistance, and density, and displaying the results in a pit profile (Figures 20, 21, 22).

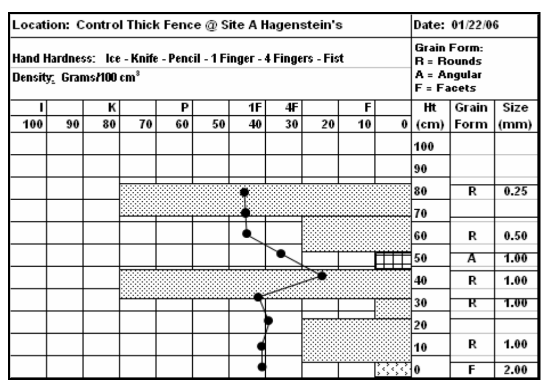

Figure 20. Pit Profile Control Fence Drift

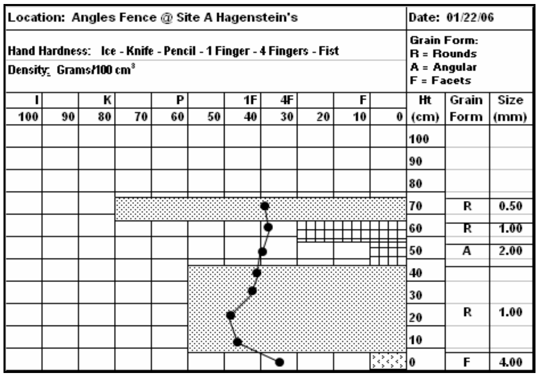

Figure 21. Pit Profile Angles Fence Drift

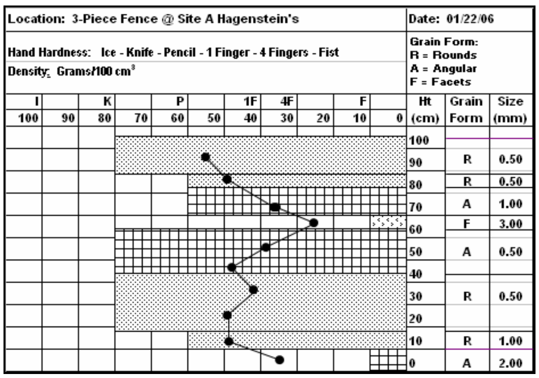

Figure 22. Pit Profile 3-Piece Fence Drift

A sample data set: For the Control-Thick Fences at Site A, total depth was 88 cm. Layer depths were as follows: Layer 1, 0-8 cm, layer 2, 8-27 cm, layer 3, 27-35 cm, layer 4, 35-48 cm, layer 5, 48-56 cm, layer 6, 56-73 cm, and layer 7-73-88 cm. Layer 1 = 2 mm faceted grains, with a resistance of fist. Layer 2 = 1 mm rounds, with a resistance of 4 finger. Layer 3 = 1 mm rounds, with a resistance of fist. Layer 4 = 1 mm rounds, with a resistance of knife. Layer 5 = 1 mm angular grains, with a resistance of fist. Layer 6 = 0.5 mm rounds, with a resistance of 4 finger. Layer 7 = 0.25 mm rounds, with a resistance of knife. Density was as follows: 0-10=41g/100 cm^3, 10-20=41g/100 cm^3, 20-30=39g/100 cm^3, 30-40=41g/100 cm^3, 40-50=25g/100 cm^3, 50-60=34g/100 cm^3, 60-70=45g/100 cm^3, 70-80=45g/100 cm^3 (Figure 20).

Mean densities for each fence were calculated: Control-Thick = 38.21g/100 cm^3, Angles = 38.78g/100 cm^3, and 3-Piece = 42.10g/100 cm^3. All Site A drifts had higher densities than the Site B drifts, nevertheless, at both sites, the Control-Thick Fence had the lowest density, while the 3-Piece had the highest density. A regression analysis was run in relation to the mean densities, which resulted in a trend line with a slope of 1.9449, a y-intercept of 35.804, and a R^2 value of 0.8566. The Angles Fence had similar densities to the Control, while the 3-Piece had a far higher density (Figure 23).

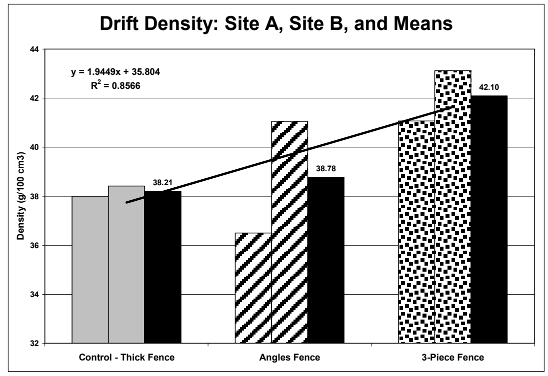

Figure 23. Snow Pack Densities in Drifts

The average percentage of rounded and angular grain distribution throughout the snowpack for each fence drift was calculated. Average results: Control-Thick = 89%, Angles = 88%, and 3-Piece = 93%. The regression analysis run in relation to average percentages for each fence resulted in a trend line with a slope of 0.0222, a y-intercept of 0.852, and R^2 value of 0.8402. The Angles Fence had similar grain distribution to the Control, yet the 3-Piece had a far higher distribution percentage of rounded and angular grains (Figure 24).

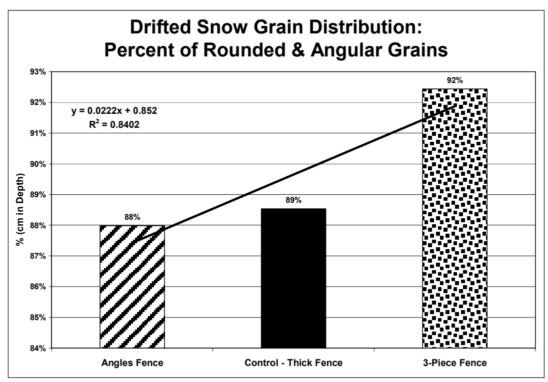

Figure 24. Drifted Snow Grain Distribution as Percent of Rounded and Angular Grains

A percent coefficient was generated that described the amount for every 1% increase in rounded and angular grain distribution that the density would increase on a percentage basis. This was generated by running a regression analysis of a scatter plot with grain distribution charted on the x axis and density charted on the y axis. The resultant trend line had a slope of 16.193, a y intercept of 25.177, and a R^2 value of 0.0408. When the slope and y intercept were used in a % coefficient equation, the result was that for every 1% of increase in rounded grain distribution, the density would increase 0.64%.

The distribution of snow density was graphed with density in 10 g blocks on the x axis, and cm of distribution on the y-axis. Trends were displayed by the density distribution graph. Most outstanding was the recognition that only the 3-Piece Fence had densities in the 50-60g/100 cm^3 density range. The peaks were distributed into the 30-50g/100 cm^3 ranges and were displayed by the 3-Piece Fence's Site A drift and the Angles Fence's Site A drift, both reaching 50 cm of distribution. Tails were displayed by lower distribution in the extremely high and low density ranges (Figure 25).

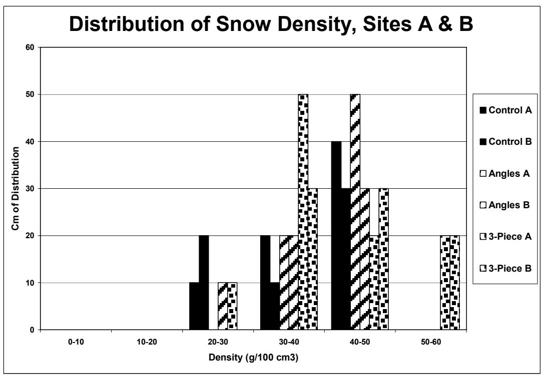

Figure 25. Distribution of Snow Pack Densities

<u>Construction Expense and Water Equivalent:</u>

Fences were all constructed from wood material, excluding the uprights to the Angles Fence, which were metal to allow the angled brackets to be attached through welds. All material was purchased at retail prices. Because materials were purchased domestically, materials are not measured in System International units.

Cost was calculated for 24 feet of fence for each fence type at each field site. The Control-Thick Fence cost a total of $234.60, the Angles Fence, $239.37, and the 3-Piece, $135.15 (Figure 26).

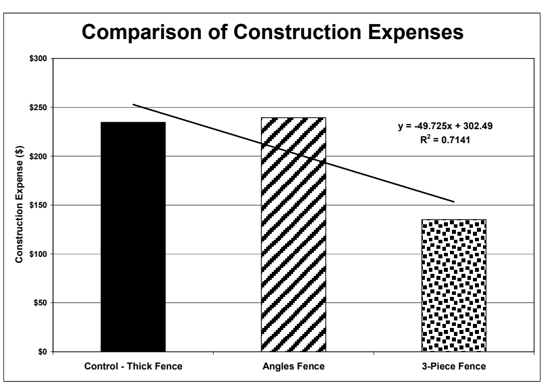

Figure 26. Comparison of Construction Expenses

As the income figure for the economic analysis, water equivalent (WE) of each fence type became extremely important. This figure was calculated by multiplying total volume (cm^3) by average snowpack density (g/100 cm^3) (Figure 27).

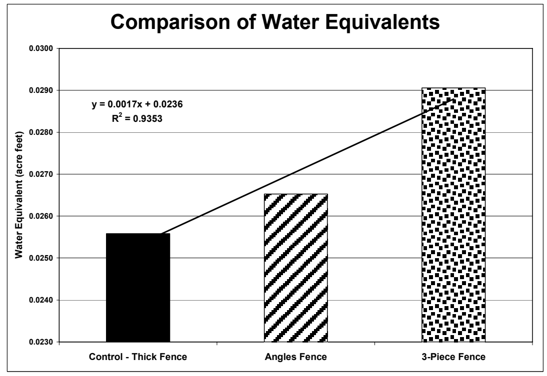

Figure 27. Comparison of Total Water Equivalent

T-tests were run on each drift's WE at 95% confidence levels. The total water equivalents of the drifts of the Control, Angles Fences, and 3-Piece Fences were not significantly different. Yet, as these were intermediate stage drifts, it can be assumed that as the drifts developed the water equivalents would become significantly different.

To calculate the economic worth, the income value of this water, the current bid from California for Green River Basin water, $6,000/acre-foot was used (Wyoming Water Plan, 2002). The total acre-feet of water equivalent was multiplied by $6000/acre-foot resulting in the total water income for 0.5 of a snow season for 24 ft of snow fencing. This research was only conducted through December and January, half of the potential snow season. A typical water preservation project would cover 240 ft of snow fence; therefore the total income per 1 ft was multiplied by 240 to generate the total income for a typical water preservation project. The expenses to construct the fence were then subtracted from the total income to produce the net profit value. This value was then expanded to one and ten years to show the profit gained over time. Expense figures for building the snow fences were not factored into the cost after the initial construction. When the figures for the 3-Piece Fence are expanded out over a period of 1 and 10 years, the net profit could be $2,135.21 and $33,515.64, respectively.

5. CONCLUSION

The applications of the current research focus on the need to preserve water in drought. Today much of the Western United States is still in a drought, which is predicted to continue. The use of snow as a water resource, or 'snow harvesting' is becoming very popular.

The first year research investigated the use of horizontal board thickness of snow fences to alter the wind patterns and resultant drift geometry. It was found that horizontal board thickness did make a major difference in the geometry of the resultant drift, which leads to several specific suggestions for application of the results. Water supply spread over a large area, such as a hay field, could be increased by using a Control-1 in thick fence directly on the upwind edge of the area. The Control fence creates a long, deep drift, effective for retaining water over a large area. Water supply concentrated into a small area, such a small reservoir or gully, could be increased by using a Thick-4 in fence placed directly on the upwind edge of the area. Increasing board thickness decreases the length of the drift, increases depth, and moves the apex further upwind, creating a short condensed drift effective for storing water in small areas. Other situations, such as buildings, terrain, landscaping, land ownership, can be addressed by changing thickness and placement of fences.

The research also validated previous modeling work, allowing the models to be used as an effective lab test for drift placement. Using the models will allow the effective planning of a strategic placement of the fences for the maximum results, saving much cost, labor, and research time related to testing with full size fences.

The second winter's research looked into the development of a more economical version of the previously tested Thick Fence, to produce short length, high volume drifts. It was found that the 3-Piece Fence created an extremely condensed, high volume drift, which was also exceptionally dense throughout its snowpack. From a monetary aspect, the 3-Piece Fence stands out as a highly applicable, reasonable design. To create a concentrated supply of stored water, the 3-Piece Fence will be the most valuable by shortening the drift length and increasing its depth. Placing the 3-Piece Fence directly upwind of the collection area would be ideal as a concentrated water supply, such a small reservoir or gully..

This current research can be used to emphasize the need to capture snow in a dense snow pack wherever additional stored moisture is needed in the spring. These results will help scientists and land managers use snow fences to more economically manipulate snow for protection and enhanced water supply during drought.

5. ACKNOWLEDGEMENTS

First, I'd like to acknowledge my mentors throughout this project. R.D. Tabler, R.A. Schmidt, and Bob Jairell have spent hours in the field, in person, and over the phone with assistance They have encouraged me in all aspects of science research and sharing my findings.

Second, I'd like to thank landowners who supported my project: Circle 9 Ranch, Sally Swift and Phelps Swift, owners, and Randy Bolgiano, foreman, and Paul and Bette Hagenstein, owners, for use of their large hayfields for two years as field sites for snow fences.

Very especially, I want to thank my family, who helped me construct fences and gather equipment for both of the experiments and fed my animals during my hours of fieldwork.

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