Society for Range Management
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The "Hollow Frame Fence" – Year 7: Investigations of Innovative Snow Fence Designs to Maximize Snow Capture for Water Conservation and Reclamation in Industrial Settings

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1. INTRODUCTION

Recently, natural gas development has become a major part of the domestic economy and emphasis in natural resource studies. Reclamation of areas disturbed by this rapidly expanding development is of high ecological importance, yet extremely challenging in the high desert sage community. In this area, high desert native plants such as sagebrush, various forbs, and grasses are targeted in the reclamation process. However, water supply, volume, and timing of application are critical variables for the success of the new vegetation. Furthermore, this area is also home to the nation's largest intact pronghorn migratory route and habitat for sage grouse, which recently have been considered for the endangered species list.

The aerial view shows the nation's largest natural gas field, home to 1,500 well sites and recently approved for 4,000 more (Figure 1). Each well site disturbs approximately five acres of land, including construction of roads, heavy machinery, and large storage tanks (Figure 2).

Figure 1. Aerial view of road and well pad matrix of the natural gas field (17).

Figure 2. Extensive natural gas development activity includes roads, bare sites, buildings, tanks, drilling rigs, and machinery. (All photos by student unless noted.)

Reclamation specialists' largest issue in restoring disturbed sites to their natural condition is maintaining a consistent water supply through the late spring and early summer germination periods (Figures 3 and 4). The project objective for the current research was to develop guidelines for utilizing snow fences as a novel and innovative tool for increased water conservation in a reclamation setting.

Figure 3. Disturbed site showing bare soil ready for reclamation.

Figure 4. Natural condition targeted in reclamation.

1.1 Literature Review

The present investigation is the sixth in a series of research projects about drifting snow, snow fence design, snow interception, and their implications in water conservation and reclamation. This research series has produced a new and innovative design of snow fence that greatly increases the fence efficiency and economic viability for this new use. This design, the Hollow Frame Fence, lays the foundation for use of snow fences for industrial applications in the reclamation phases of natural gas exploration and development.

Historically, the study of snow fences was initiated to protect transportation corridors. According to past research studies (15), the earliest known written reference to snow fences was in Norway in 1852. The first U.S. snow fences were rows of stone blocks used during construction of the first transcontinental railroad in 1868. Various versions of wooden slat designs were used along railroads and highways into the 1970's. A highway government commission reported in 1930 that "intelligent use of snow fences in windy districts accomplishes more per dollar expended than any other feature in maintaining the highways free from snow" (15).

A new surge in snow fence design in 1970 was prompted by consistently severe snow issues on the re-routed Interstate 80. The team of researchers (5, 14, 15) extensively investigated variables of snow fence design such as material, height, porosity, bottom gap, orientation, evaporative loss, and fetch. From their cumulative work, an ideal fence for snow capture and area protection was developed and is used still today, the WY Design Board Snow Fence (15). These researchers' ongoing work has resulted in Snow Snake Fences, a porous tubular design that intercepts smaller amounts of snow in highway protection (16). This group's comprehensive work stands to date as the major reference of snow fence design and implementation.

Additional research concerning vegetation and soil moisture has been conducted by a multitude of authors in an effort to improve reclamation practices. Prior research highlights vegetation interception and snow sublimation (4, 12). The work concluded that conifers do respond to changes in ambient air temperature, and that intercepted snow is lost as a potential soil moisture supply due to sublimation (13). Other investigations concerning living snow fences concluded that trees, shrubs, and standing crops can be manipulated to serve as effective snow control (2, 6, 11). Soil moisture researchers (1, 3) presented traditional techniques and views of soil moisture infiltration and percolation, yet were limited in investigations of midwinter and early spring subsurface sublimation loss.

Regional teams of scientists, agencies, and industry are striving for successful reclamation of native conditions in this region's exploration and development of natural gas reserves. Consensus has been reached for highly desirable shrubs, forbs, and grasses, and for stages of reclamation (7, 8). Soil moisture patterns greatly influence germination and growth of these targeted and desirable native plants, with early spring moisture availability a key factor (9, 10). This background work served as a basis for vegetation, soil moisture, and sublimation studies conducted throughout the current research.

As seen above, a large body of work has been developed on the use of snow fences for protection of critical areas from blowing and drifting snow. However, little research exists concerning the use of snow fences in water conservation and reclamation of disturbed sites. The present work evaluated and developed the potential for utilizing snow captured by snow fences as a viable water supply for improved success of targeted native vegetation.
Snow fences are optimal water conservation tools because of their ability to capture snow in dense smooth snow drifts, which persevere as a water supply longer in the spring. A snow fence is a mechanism used to catch windblown snow by creating aerodynamic drag and altering the structure of the turbulence which slows the velocity of the wind and diminishes its capacity to carry snow (15) (Figure 5). The resultant dense drift melts more slowly, providing more spring water supply (12). The present series of investigations has proven that using snow fences allows specific placement of snow drifts for targeted results of water conservation and reclamation.

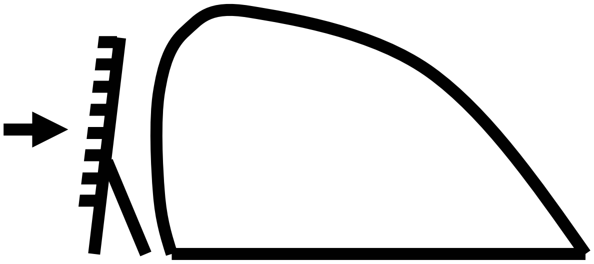


Figure 5. Windblown snow is deposited in a drift downwind of the fence.

1.2 Previous Years' Work

Other research examined snow interception and snow fence characteristics extensively, yet a detailed investigation of effects of the thickness of the horizontal boards had not been undertaken. The primary thread throughout this seven year study was to develop the variable of horizontal board thickness to attribute to increased efficiency of snow interception.

Year One tested household products to determine which replicated wind blown snow in small scale models, proving Cascade dish detergent to be a close replica. Year Two used Cascade as snow medium in small scale model testing of snow fence variables, concluding that porosity and horizontal board thickness greatly influence wind patterns and drift geometry. The increased thickness was a valuable variable in shaping and placing drifts and customizing the water supply.

Year Three tested relationships between conifer branch resistance and ambient temperature, as well as effects of density and surface area on sublimation of snow. Year Four used full size snow fences in field settings to test effects of changing horizontal board thickness on wind patterns and drift geometry, validated results of previous small scale models, and evaluated retention of intercepted snow by conifers in drought versus those with full water supply.

Year Five developed more economical versions of the previous years' Thick Fence, resulting in the Hollow Frame Fence, a far more financially efficient version that also enhanced all drift characteristics. The Hollow Frame Fence created an extremely condensed, high volume drift, which was also exceptionally dense throughout its snow pack. Furthermore, this fence stood out from a monetary aspect, as a highly applicable, economical design. To create a concentrated supply of stored water, the Hollow Frame Fence proved to be the most valuable by shortening the drift length and increasing its depth. Additionally, Year Five investigated sagebrush interception of snow finding a significant correlation between maturity, ambient air temperature, and resultant intercepted snow, concluding that sagebrush areas developed in a mosaic pattern would be most efficient to preserve snow as a water supply.

1.3 Current Research

The sixth year's study, discussed in this paper, was a multivariate investigation with the overall objective to develop guidelines for utilization of Hollow Frame and Snow Snake Fences to improve water conservation for reclamation. Various snow fence systems, installed on several natural gas reclamation sites with varying terrain, were evaluated. The investigation analyzed drift development and recession, soil moisture patterns, and vegetation germination and density.

1.4 Questions and Hypotheses

To address the above aspects, several questions (Q) were asked, each of which is followed by the responding hypothesis (H).

Project Objective: Q: Develop guidelines for the most effective snow fence system for water conservation for reclamation. H: The most effective snow fence system will be Intensive Snow Snakes, followed by Dispersed Snow Snakes, then by the Hollow Frame Fence.

Drift Profiles: Q1: What are effects of fence variations on the depth profiles, volumes, and snow pack profiles of the resultant drifts during accumulation and recession periods? H1A. The Hollow Frame Fence will produce the short length, high volume, and high density drift, while the Snow Snake Fence will produce a longer, shallower, and lower density drift. H1B. The Intensive Snow Snake System will produce the highest volume and highest density snow pack, followed by the Hollow Frame Fence System, then by the Dispersed Snow Snake System. H1C. The Intensive Snow Snake System drifts will recede the slowest, followed by the Hollow Frame Fence System drifts, while the Dispersed Snow Snake System drifts will recede the fastest.

Soil Moisture: Q2: What are effects of drift depth and density on the resultant soil moisture profiles? H2A. During thawing periods, the resultant soil moisture increases will correlate directly with increases in snow drift depth and density. H2B. During subzero temperatures, the soil moisture percentages will not change. Q3: What are effects of drift depth and density on timing and duration of soil moisture changes? H3A. During thawing periods, the shallower and lower density snow areas will melt faster, and the resultant soil moisture increases will occur more quickly, yet with shorter duration than the deeper and higher density snow areas.

Vegetation: Q4: What is the effect of various snow fence systems on the germination of newly seeded reclamation sites? H4A. The Intensive Snow Snake System will encourage the most germination of targeted plants, followed by the Hollow Frame Fence System, then by the Dispersed Snow Snake System.

Industry standards for reclamation have been limited to summer water supply such as rainfall and irrigation, and little research exists that attempts to correlate winter stored water to improved reclamation tactics. This research provided a better understanding of manipulating snow for maximum water conservation for reclamation. By initiating the link between snow fencing and reclamation success, this study demonstrates the potential for industry to reclaim disturbed land with increased efficiency and success.

2. METHODOLOGY

2.1 Plan Study Sites

* Select 4 field sites with generally even terrain, uninterrupted fetch (minimum 200 m) and downwind area (minimum 100 m), and with similar soils, reclamation status, and winds.
* Plan layout of each site, including locations of various snow fence systems and data transects for soil moisture points, drift profiles, and vegetation study (Figures 6, 7, and 8).
* Site SHB 9-33: A flat site to compare fence systems to the sloped sites, including Hollow Frame Fence to compare to the Snow Snake sections, Intensive Snow Snakes and a Single Snow Snake to evaluate effect of fence density on drifts, Single Snow Snake to compare to the Hollow Frame Fence drift development, and Control Area outside of the influence of snow fences.
* Sites SHB 7-26 and SHB 8-33: Sloped sites on windward aspect, to compare fence systems, with similar fence configuration to flat site SHB 9-33.
* For each fence section, lay out a data transect at the center of the fences' width, perpendicular to the fence line, extending from 10 m upwind of the fence line through the fence lines, on to 20 m downwind of the last fence in the series.

Figure 6. Constructing Snow Snake Fences.

Figure 7. Hollow Frame Fence Line.

Figure 8. Study Site with Intensive and Dispersed Snow Snake Systems, left to right.

2.2 Fence Construction

* Note - Fence construction: Because building materials are purchased domestically, lumber measurements are not in System International units. All data measurements are in S.I. units.
* Build Hollow Frame Fences following the 2006 design: 50% porosity, 4 in thick horizontal boards as a hollow frame, 24 ft length, consisting of three 8 ft panels (Figure 7).
* Secure Hollow Frame Fences to steel fence posts at 8 ft intervals on site fence lines, perpendicular to prevailing wind according to fence system plans for each site.
* Secure Snow Snake Fences to steel hoops staked at 3 ft intervals, following Snow Snake Fence design, perpendicular to prevailing wind according to fence system plans for each site (Figure 6).
* At both ends of all test sections, add 12 ft of plastic commercial snow fence to prevent "end effect" influencing test fence results.

2.3 Drift Geometry

* Collect data after snow and wind storms have initiated or altered drift development.
* Along each data transect, measure drift depth at every 0.5 m along drift center line, for longitudinal profile, 10 m upwind to 20 m downwind, with Control outside of fence influence.

2.4 Cross-Sectional Analysis of Drifts

* Evaluate the cross-sectional profile at each drift apex with a snow pit during drift measurement; dig pit 1 m north of data transect line.
* Establish snow pack layer boundaries according to differences in grains and resistance. Measure each layer's depth. Identify grain type and size using a 10x magnification loop.
* For every 10 cm layer of the snow-pack, use a snow cutter and spring scale to measure density of a 250 cm^3 block, from which water content is calculated (Figure 9).

2.5 Soil Moisture

* Install DeltaT PR2 soil moisture access tubes, extending 1 meter below the surface, every 8 m along each data transect. Install with a truck-mounted Giddings probe (Figure 10-11).
* Use a DeltaT PR2 Probe/HH2 Moisture Meter in each access tube to take soil moisture readings at 100, 200, 300, 400, 600, and 1000 mm below the surface (Figure 12).
* If snow has accumulated over cap, use a 50 cm ring and flat scoop to remove adjacent snow with minimal disruption to snow-pack layers above the tube. Replace snow section after reading.
* Repeat readings during periods of sub-zero temperature and melting periods.

2.6 Vegetation Germination

* Count germinated individual plants within a 0.5 m^2 Daubenmire Frame every 8 m along the transect, aligned to access tubes.
* Classify vegetation by species, and categorize as Targeted, Desirable, or Undesirable according to industry reclamation standards (Figure 13).


Figure 9. Conducting Cross Sectional Drift Analysis.


Figure 10. Soil Moisture Access Tubes Installation.


Figure 11. Fully Installed Access Tube.

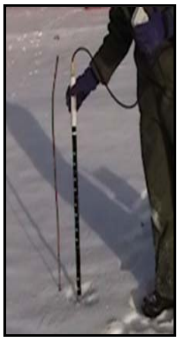


Figure 12. Soil Moisture Data in Midwinter.


Figure 13. Daubenmire Frame Used in Conducting Germination Counts.

3. DISCUSSION OF RESULTS

3.1 Summary of Results

The results indicate the Intensive Snow Snake System as the most effective approach to retain windblown snow, enhance soil moisture, and encourage germination of targeted vegetation. This research will provide reclamation specialists with tools to manipulate snow for maximum water conservation for reclamation.

More specifically, the Hollow Frame Fence created a shorter length, higher volume, and higher density drift than the Single Snow Snake. The Intensive Snow Snake System deposited higher volume snow pack, yet the Dispersed Snow Snake System had higher density drifts. Intensive Snow Snake System drifts receded more slowly, however Dispersed Snow Snake System drifts receded more slowly than Hollow Frame Fence System drifts. Soil moisture did decrease during subzero temperatures. During thawing, shallower, lower density areas melted more quickly and resultant soil moisture increased more quickly.

3.2 Drift Depth Profile Results

Drift profile data was analyzed for every transect, meter by meter, as in the following detailed example. The Hollow Frame Fence System (Figure 14) created a short, compact drift, with the majority of snow located directly downwind of the fence. On the SHB 7-26 site, the storm resulted in an upwind drift that began 2 m upwind of the fence, and had a steep front, reaching a depth of 13 cm at 1 m upwind. The downwind drift began 2.5 m downwind of the fence, with a rapid incline to the apex of 19 cm, located 5 m downwind. The downwind drift then decreased to a depth of 3 cm, ending at 9.5 m downwind. Specific depths according to the fence system axes are as follows: 10 m upwind, at the start of the testing area, snow depth averaged 3 cm. Snow depth stayed level until 41 m downwind, where the first upwind drift began. Here, the depth increased rapidly to 13 cm at 1 m upwind of the fence. The depth then dropped sharply to 2 cm, then gradually increased to 4 cm, displaying a distinct scour zone directly behind the Hollow Frame Fence. At 45 m, the depth immediately began to increase again to form the downwind drift, reaching 19 cm. The drift then gradually decreased to 12 cm at 49.5 m downwind. Then, the depth dropped sharply to 3 cm at 52.5 m downwind, and remained at approximately this depth for the remainder of the testing area. The SHB 8-33 site was extremely similar in resultant depth profile, yet displayed less development through shallower depths throughout the profile. Total length of the Hollow Frame Fence drift was 11 m, and total volume of maximum drifts collected by the Hollow Frame Fence System, averaged over two field sites was 2270 cm^3. After warm temperatures caused drift recession, total length of the Hollow frame Fence drift was 2.5 m, and total recession volume, averaged over two field sites, was 92 cm^3.

In a summary explanation of the remaining fences, the Dispersed Snow Snake Fence System (Figure 15) created three distinctive drifts, with the majority of snow located directly downwind of the furthest upwind Snow Snake. Total volume collected by the Dispersed Snow Snake System for the maximum drift, averaged over two field sites was 3532 cm^3. These drifts receded less than the Hollow Frame System drifts, averaging to a recession volume of 656 cm^3.

The Intensive Snow Snake Fence System (Figure 16) created five distinctive drifts, with the majority of snow located directly downwind of the most upwind Snow Snake. On the SHB 7-26 site, a large amount of snow was captured, resulting in a drift downwind of the Hollow Frame Fence not seen in corresponding drifts at the SHB 8-33 site. The overall pattern showed that the Snow Snakes' resultant drift series steadily decreased in depth downwind along the system's transect. Total volume for maximum drifts collected by the Intensive Snow Snake System, averaged over two field sites was 3693 cm^3, with recession volume drifts averaging to 904 cm^3.

The Single Snow Snake Fence (Figure 17) created a moderately compact drift, with the majority of snow located slightly downwind. Total drift length was 13.5 m, and total volume for maximum drift collected by the Single Snow Snake Fence was 1364 cm^3. The Single Snow Snake drift did not recede as much as other drifts, averaging total volume at 352 cm^3.

This data supported Hypothesis 1A because the Hollow Frame Fence did create a shorter length, and higher volume drift than the Single Snow Snake. The Intensive Snow Snake System created higher volume snow pack than the Dispersed Snow Snake System, supporting only the first part of Hypothesis 1B. Intensive Snow Snake System drifts did recede more slowly, partially supporting Hypothesis 1C; however Dispersed Snow Snake System drifts receded more slowly than Hollow Frame System drifts, not supporting the remainder of 1C.

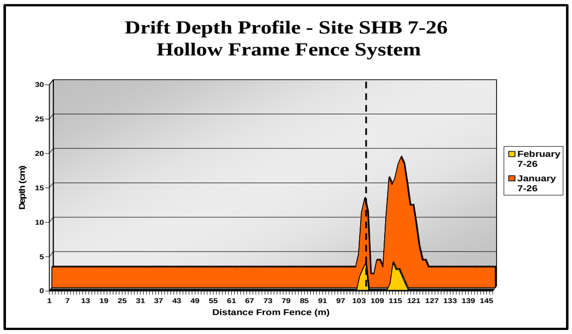


Figure 14. Drift Depth Profiles for Hollow Frame Fence System on Site 7-26 showing Recession during February.

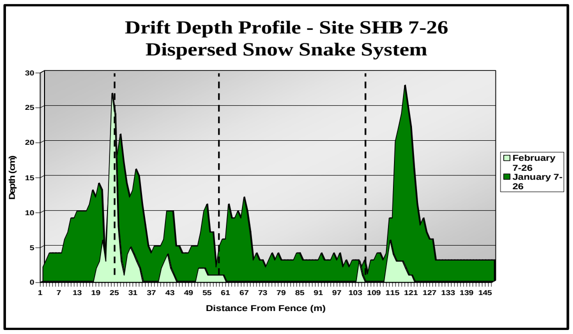


Figure 15. Drift Depth Profiles for Dispersed Snow Snake System on Site 7-26 showing Recession during February.

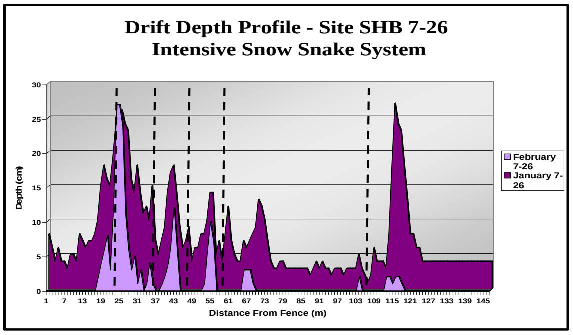


Figure 16. Drift Depth Profiles for Intensive Snow Snake System on Site 7-26 showing Recession during February.

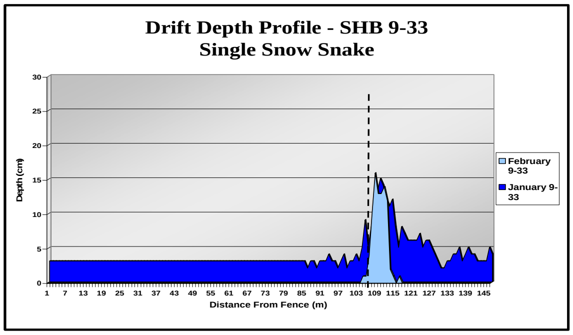


Figure 17. Drift Depth Profile for Single Snow Snake on Site 9-33 showing Recession during February.

3.3 Statistical Analysis for Drift Profile

A regression analysis was conducted on the mean volumes of the three fence systems at both maximum drift volume and recession stages (Figure 18). The slope of the resultant trend line was 711.5. The y-intercept was 1742, and R^2 value was 0.8336. The regression analysis was run again following the recession period. The slope of the resultant trend line was 141.4, the y-intercept was -21, and R^2 value was 0.721. This supports Hypothesis 1A because the Hollow Frame Fence did have a higher volume drift than the Single Snow Snake. The Intensive Snow

Snake System created higher volume snow pack than the Dispersed Snow Snake System, supporting the first part of Hypothesis 1B.

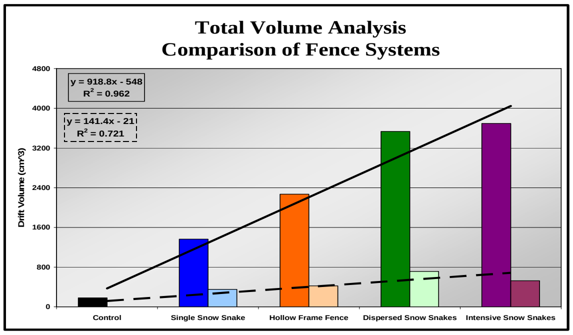
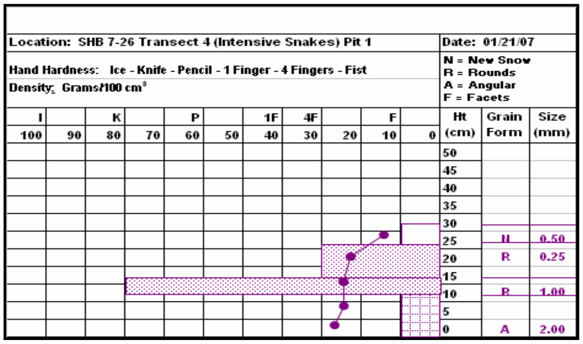


Figure 18. Total Volume Analysis to Compare all Fence Systems During January and February.

3.4 Cross-sectional Analysis Results

The drifts were analyzed in standard snow pit profiles, as in the detailed example of a cross-sectional analysis (Figures 19). In Pit 1 of the Hollow Frame Fence System at SHB 9-33, total depth was 19 cm. Layer depths were as follows: Layer 1, 0-4.5 cm, layer 2, 4.5-10.5 cm, layer 3, 10.5-16 cm, and layer 4, 16-19 cm. Layer 1 consisted of 3 mm facets, with a resistance of fist. Layer 2 consisted of 1 mm angular grains, with a resistance of pencil. Layer 3 consisted of 0.5 mm angular grains, with a resistance of knife. Layer 4 consisted of 0.25 mm rounds, with a resistance of fist. Density was as follows: 0-6=16.8g/100 cm^3, 6-12=29.2g/100 cm^3, 12-18=20g/100 cm^3.

The Hollow Frame Fence created higher density drifts than the Single Snow Snake, supporting Hypothesis 1A (Figure 20). The Dispersed Snow Snake System had higher density drifts than the Intensive Snow Snake System, not supporting the first part of Hypothesis 1B.


Location: SHB 7-26 Transect 4 (Intensive Snakes) Pit 1

Date: 01/21/07

Hand Hardness: Ice - Knife - Pencil - 1 Finger - 4 Fingers - Fist

Density: Grams/100 cm^3

N = New Snow
R = Rounds
A = Angular
F = Facets

Figure 19. Cross Sectional Analysis Profile for Pit 1 of Intensive Snow Snake System.

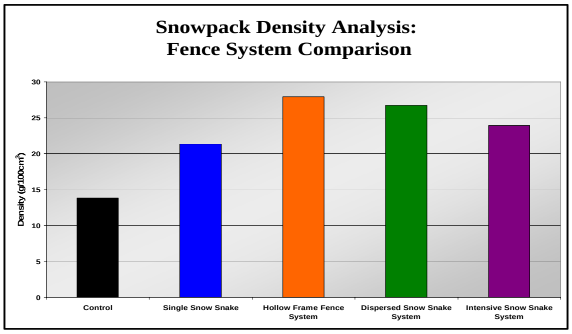


Figure 20. Snow-pack Density Analysis to Compare all Snow Fence Systems.

3.5 Soil Moisture Results

Vertical soil moisture profiles were assembled to visualize the range of moisture levels throughout varying depths of soil. For each transect, the Upper and Lower Bounds were plotted to define the range of soil moisture in that area (Figure 21).

Transect 2, Hollow Frame Fence, of the SHB 9-33 site, will serve as the detailed example of soil moisture data analysis that was actually conducted for every access tube on every transect. In February and March, for Transect 2, Hollow Frame Fence, of the SHB 9-33 site, soil moisture ranges were as follows: 100 mm below surface ranged from 5.8 % to 13.3 %. 200 mm ranged from 12.3 % to 19.2 %. 300 mm ranged from 7.6 % to 20.6 %. 400 mm ranged from 15.4 % to 9.4 %. 600 mm ranged from 12.1 % to 18.6 %. 1000 mm below surface ranged from 9 % to 24.4 %. General patterns showed an increase in the range of % V, with an increase in depth below surface, and a slight trend towards an increase in % V with an increase in depth. Additionally, in comparison to the baseline data, the February range was narrower, had higher soil moisture readings near the surface, and further emphasized the previously stated trends.

All testing areas did decrease soil moisture readings during subzero temperatures (Figure 22), so Hypothesis 2B was not supported. This decrease would most likely be due to sublimation during the subzero temperatures. Hypothesis 2A was not able to be conclusively addressed as slope and surface tillage variations affected accurate data collection. Nevertheless, Hypothesis 3A was supported, because during thawing periods, the shallower and lower density areas did melt faster, and the resultant soil moisture increases did occur more quickly.

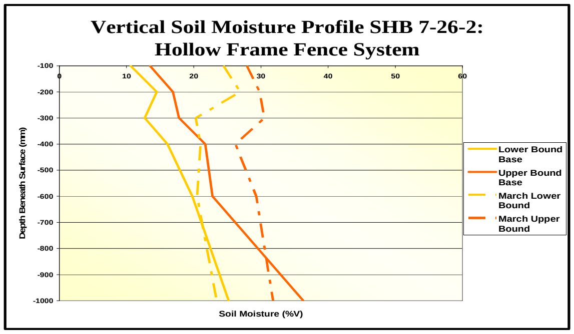


Figure 21. Vertical Soil Moisture Profile of Hollow Frame Fence System.

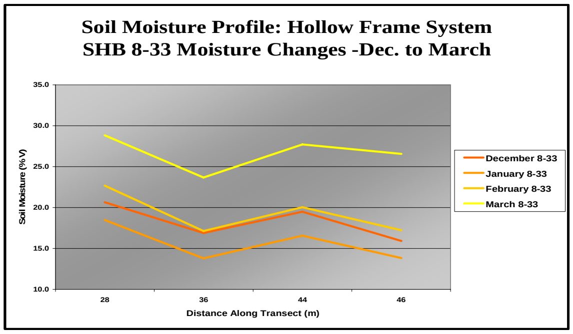


Figure 22. Soil Moisture Changes December to March for Hollow Frame Fence System.

3.7 Statistical Analyses of Soil Moisture Patterns

A percent coefficient was generated that described the amount that the soil moisture would increase on a percentage basis for every 100 mm increase in distance beneath the surface (Figure 23). This was generated by conducting a regression analysis of a scatter plot with distance beneath the surface charted on the x axis and soil moisture in % V charted on the y axis. The resultant trend line had a slope of 0.0115, a y intercept of 13.685, and a R^2 value of 0.7445. When slope and y intercept were used in a percent coefficient equation, the result was, for every 100 mm of increase in distance beneath the surface, the soil moisture would increase 8.4 %.

The rates of change in soil moisture were calculated using a regression analysis which charted the average soil moisture per transect over time in months (Figure 24). Many unique trends were exhibited from this calculation. Most importantly, all soil moistures, across all sites, were extremely similar; having only a 4 % difference on average. This set an outstanding baseline for upcoming phases of study. The rates of decrease were calculated for a three month period (Dec-Mar) as the slope of the regression analysis trend line. The results were as follows: For the Control, the rate of change was – 0.2242, and the y intercept was 18.537. For the Hollow Frame Fence System, the rate of change was 7.208, and the y intercept was 16.917. For the Dispersed Snow Snake System, the rate of change was 0.6861, and the y intercept was 18.474. For the Intensive Snow Snake System, the rate of change was 0.546, and the y intercept was 18.17. This data supported Hypothesis 3A, as the shallower Control area decreased in soil moisture while the other snow fence areas increased in soil moisture over the three month period.

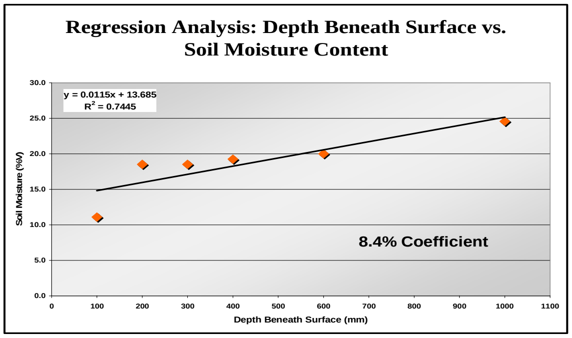


Figure 23. Percent Coefficient for Depth Beneath Surface vs. Soil Moisture Content.

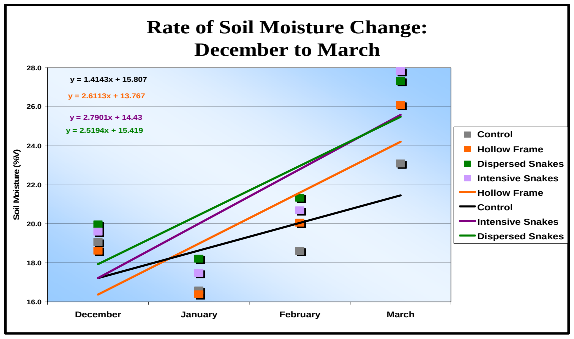


Figure 24. Rate of Change in Soil Moisture from December to March for all Fence Systems.

3.7 Vegetation Germination Analysis

Vegetation was classified by species, but also by Targeted, Desirable, and Undesirable, and analyzed as in the following detailed example. The Control transects totaled 1003 Undesirable, 159 Desirable, and 0 Targeted plants. The Hollow Frame Fence totaled 1108 Undesirable, 163 Desirable, and 0 Targeted plants. The Dispersed Snow Snake System totaled 919 Undesirable, 82 Desirable, and 0 Targeted plants. The Intensive Snow Snake System totaled 897 Undesirable, 137 Desirable, and 18 Targeted plants. In summary, the percentage of Undesirable plants was greatly decreased in the Intensive Snow Snake System as compared to other systems, additionally, the Desirable and Targeted numbers greatly increased. The appearance of Targeted plants strictly within the Intensive Snow Snake System supports Hypothesis 4A.

4. 2007-2008 RESEARCH

Research is continuing throughout the present year, with an emphasis on finalizing the prior work into a packaged, marketable product. Progressing into the Year Seven Fall Phase, site layouts have been revised to maximize beneficial effects for reclamation by expanding on the most beneficial fence system supported by previous year's findings. To progress from the prior year's three sites, the 2007-2008 research year will include seven sites to more comprehensively analyze specific aspects and variables.

The three sites used previously will continue to analyze vegetation growth and rollover effect to evaluate the long term benefits of the snow fence systems. In addition, these sites will compare the Intensive Snow Snake System to the new design, which replaces the Snow Snake lines with 2007-Design Hollow Frame Fence lines. Revisions of the Hollow Frame Fences for the 2007-Design include, reducing the height to 24 in to more adequately match the snow load of the area, removing the second upright to save material cost, and removing the bottom gap to prevent scour of soil by accelerated wind under the fence (Figure 25). A patent is being pursued on this design.

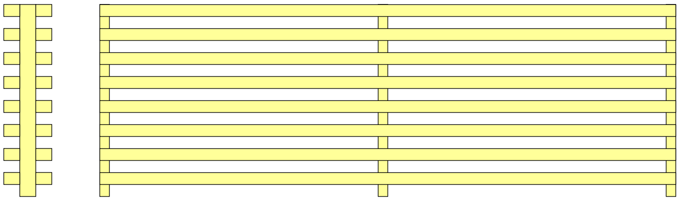


Figure 25. Cross section and front views of the 2007-Design Hollow Frame Fence.

Two new sites will investigate vegetation germination and growth in a more controlled setting. Each of these sites will be hand seeded, so that a known number of each desired plant is seeded per square meter. Each site will be fenced to prevent grazing. Therefore, germination and growth data in the spring can be accurately correlated to drift development and increased soil moisture. All five above sites are being analyzed for drift development and recession, soil moisture patterns, moisture retention, and vegetation analysis.

Two final sites include snow fence systems constructed to fully cover the site, as the sites would be covered upon industrial use of the Hollow Frame Fence. This provides conclusions concerning economic benefits in comparison to other presently used methods (i.e. sprinklers), as well as a large scale view of the application of the Hollow Frame Fence.
The ultimate goal is to initiate the implementation of snow-fence systems on reclamation sites. By producing new and innovative designs of snow fences that greatly increases the fence efficiency and economic viability, the Hollow Frame Fence lays the foundation for use of snow fences for industrial applications in the reclamation phases of natural gas development

5. CONCLUSION

Reclamation of areas disturbed by rapidly expanding natural resource development is of high ecological importance. This demand for rapid and effective reclamation is under additional pressure due to the overlay of major natural gas fields with vital wildlife habitat and scenery. The current work builds a cornerstone to greatly improve tactics of water conservation for reclamation of targeted plants such as big sage, various forbs, and grasses. The research further emphasizes that blowing snow captured in a drift is far denser than loose snow, thus melts more slowly, and is retained longer in the spring (Figure 26 and 27). The use of snow fences allows specific placement of snow drifts for targeted results of water conservation and reclamation. Due to the fact that water supply, volume, and timing of water application are critical variables for the success of the new vegetation, the application of the Hollow Frame Fence System is expected to significantly improve reclamation success.

Figure 26. During the spring, only the dense drifted snow remains, providing early moisture for germination.

Figure 27. The tail edge of a drift, surrounded by moisture saturated soil, outside of which the soil is already dry and cracking.

By compiling the links between snow fencing and reclamation success, this study, and the Hollow Frame Fence, instigates the potential for industry to reclaim disturbed land with increased efficiency and success.

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