FINAL REPORT

FHWA-WY-09/01F

State of Wyoming
Department of
Transportation

Snow Snake Performance Monitoring

December 2008

By:
PMPC
P.O. Box 370
Saratoga, WY 82331
(307) 326-8301

Notice

Quality Assurance Statement

Technical Report Documentation Page

Report No. FHWA-WY-09/01F	Government Accession No.	Recipients Catalog No.
Title and Subtitle Snow Snake Performance Monitoring		Report Date December 2008 Performing Organization Code
Author(s) Paul McCarthy, Keith Haskins		Performing Organization Report No.
Performing Organization Name and Address PMPC POB 370 Saratoga, WY 82331-0370		Work Unit No. RS07(207) Job No. RS07207 Contact or Grant No.
Sponsoring Agency Name and Address Wyoming Department of Transportation 5300 Bishop Blvd. Cheyenne, WY 82009-3340 WYDOT Research Center (307) 777-4182		Type of Report and Period Covered Final Report January 2007– December 2008 Sponsoring Agency Code
Supplementary Notes WYDOT Technical Contact: Cliff Spoonemore, P.E., Winter Research Services		

Abstract: A recent study, "Three-Dimensional Roughness Elements for Snow Retention" (FHWA-WY-06/04F) (Tabler 2006), demonstrated positive evidence for the effectiveness of Snow Snakes, a new type of snow fence suitable for use within the highway right-of-way. Snow Snakes are wire frames covered with a continuous extruded plastic fabric and aptly named for their reptilian appearance.

This study evaluates the effectiveness of using Snow Snakes as a viable means to reduce road ice formed by blowing snow originating within the highway right-of-way. The study was initially scheduled for completion by the fall of 2007. Mild winter conditions necessitated a contract extension through the fall of 2008. Mild conditions continued allowing only three site observations with blowing snow observed only during the February 6, 2008 observation.

Snow drift depths and lengths were measured along transects intersecting various snow fence types and configuration; this data was used to calculate trapped snow volumes and water equivalents. During the December 31, 2007 to February 6, 2008 observation period, Snow Snakes trapped and prevented approximately 622 tons of snow from potentially interacting with the roadway surface to form slush and ice.

Due to insufficient field data, obtaining conclusive evidence of the effectiveness of using Snow Snakes as a viable means to reduce road ice formed by blowing snow originating within the highway right-of-way will require additional study.

Key Words Wyoming, Snow Snake, snow retention, blowing snow, near snow, far snow, icy roads, road ice, solar radiant heat.		Distribution Statement Unlimited	
Security Classif. (of this report) Unclassified	Security Classif. (of this page) Unclassified	No. of Pages 61	Price

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized.

SI* (Modern Metric) Conversion Factors

Approximate Conversions from SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
Area				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
Volume				
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
Mass				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lbs)	T
Temperature (exact)				
^{0}C	Centigrade temperature	1.8C + 32	Fahrenheit temperature	^{0}F
Illumination				
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
Force and Pressure or Stress				
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

Approximate Conversions to SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
Area				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
Volume				
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
Mass				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lbs)	0.907	megagrams	Mg
Temperature (exact)				
^{0}F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	^{0}C
Illumination				
fc	foot candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
Force and Pressure or Stress				
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

ACKNOWLEDGEMENTS

PMPC acknowledges Dr. Ronald D. Tabler, Tabler and Associates, for his valuable assistance in this research. The work Dr. Tabler has accomplished throughout his career in the blowing snow research and design field is of a level we can only aspire to attain. Dr. Tabler has been extremely helpful in developing our background, giving us direction, answering questions and reviewing our results. We are very grateful for his energy and lifelong dedication to this field.

The Wyoming Department of Transportation (WYDOT), Rock Springs maintenance staff installed the Snow Snakes. James Montuoro, P.E., District Maintenance Engineer and the Rock Springs staff observed daily conditions and helped to determine which blowing snow events were most valuable for collecting information.

Clifford Spoonemore, P.E., WYDOT Project Development, was the study sponsor and provided weather forecast updates and technical review.

John F. Samson, M.S./CCA, Agronomist, WYDOT Environmental Services, conducted field inspections and provided his observations of the Snow Snake's effects on the study site revegetation.

EXECUTIVE SUMMARY

A recent study, *Three-Dimensional Roughness Elements for Snow Retention* (Tabler 2006) demonstrated positive evidence of the effectiveness of Snow Snakes, a new type of snow fence suitable for use within the highway right-of-way. Snow Snakes are wire frames covered with a continuous extruded plastic fabric and aptly named for their reptilian appearance.

This study evaluates the effectiveness of using Snow Snakes as a viable means to reduce road ice formed by blowing snow originating within the highway right-of-way. In particular, this study focused on a geometrically complex section of interstate highway. The study area chosen has limited topsoil, severe wind exposure, limited precipitation and was stripped of vegetation during construction activities in 2005, thus providing an apparently ideal location to evaluate the potential secondary benefits of using Snow Snakes to aid in revegetation efforts in areas of high wind exposure and limited revegetation potential.

Figure 1 - 30-inch Snow Snakes

Sixteen 30-in Snow Snakes were installed in three locations at the Interstate 80 – College Drive Interchange in Rock Springs, Wyoming as part of this study. The 85-ft downwind drift formed by a 30-in Snow Snake is 50-ft (37%) shorter that the downwind drift formed by the commonly used 4-ft vertical lath snow fence thereby providing an alternate snow control structure for use in areas with restricted snow storage.

The study site is geometrically and topographically complex. The eastbound and westbound lanes are superelevated giving the sun a greater angle of incidence on the roadway increasing the amount of available solar radiant heat; the intersection ramps are not superelevated. The College Drive bridge and approach embankments are upwind of the study area and influence the wind and snow deposition patterns in the western end of the study area; two 4-ft vertical snow fences are also present which additionally affect wind and snow deposition patterns. The eastern portion of the study area is shadowed by an upwind 8-ft Wyoming type snow fence with some of the Snow Snakes located in a drainage channel and in a roadway cut section which affects wind and snow deposition patterns.

The study was initially scheduled for completion by fall of 2007. Due to mild winter conditions during the 2006-2007 winter season, the study was extended to the fall of 2008. Mild winter conditions continued into the 2007-2008 winter season allowing opportunities for only three site observations with blowing snow observed during only the February 6, 2008 observation.

Snow drift depths and lengths were measured along transects intersecting various snow fence types and configurations; this data was used to calculate trapped snow volumes and water equivalents. During the December 31, 2007 to February 6, 2008 observation period the study area Snow Snakes trapped and prevented approximately 622 tons of snow from potentially interacting with the roadway surface to form slush and ice.

Road surface temperature profiles were conducted on two site visits. Insufficient field data prevented development of a valid correlation between roadway surface temperatures and the presence of Snow Snakes. The study site complexity, insufficient data, and inconclusive results dictate that this study be considered site specific and not be used to estimate snow storage, roadway protection, or revegetation benefits of using Snow Snakes in other areas.

Obtaining conclusive evidence of the effectiveness of using Snow Snakes as a viable means to reduce road ice formed by blowing snow originating within the highway right-of-way will require additional study. If an additional study is conducted, it is recommended that a different study site be selected which is within the right-of-way on a geometrically simple section of road with consistent terrain. This would reduce errant data due to roadway and terrain features. Stripping vegetation in the study area and planting selected plant species in Snow Snake areas with control plots outside the snow snake protection but in similar terrain would provide more useful data. A north-south highway would be best for prevailing winds, and a location with higher snowfall averages would be beneficial.

The results of this study are inconclusive and do not warrant the development of an implementation plan.

Study site revegetation was evaluated by John F. Sampson, M.S./CCA, Agronomist, WYDOT Environmental Services. His Executive Summary and monitoring reports are included in Appendices A, B, and C.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
PROBLEM DESCRIPTION

Blowing snow is the primary cause of road ice due to the ability of melting snow to extract stored solar radiant heat from the roadway. The key to inhibiting the formation of slush and ice on roadways is to reduce the contact between snow and the roadway. Direct snowfall cannot be prevented, but the installation of snow fences has proven to significantly reduce the interaction of blowing snow on the roadway.

Previous efforts have focused mainly on installation of snow fences outside of the highway right-of-ways to catch "far snow" (Figure 2). This is due in part to the limited configurations of snow fence. Standard heights of Wyoming snow fence are 8-ft, 10-ft, 12-ft, and 14-ft. Fully formed drifts behind these snow fences on flat terrain with 50 percent porosity extend downwind approximately 272-ft, 340-ft, 408-ft, and 476-ft, respectively. This significantly limits the use of standard Wyoming snow fences to trap "near snow" (Figure 2) without encroaching onto the roadway. Even 50 percent porosity, 4-ft vertical lath fence can produce a drift 136-ft downwind. Additionally, the above mentioned snow fences could increase accident severity if impacted by an errant vehicle. There is currently no standard manmade solution effective within 100-ft upwind of highway shoulders.

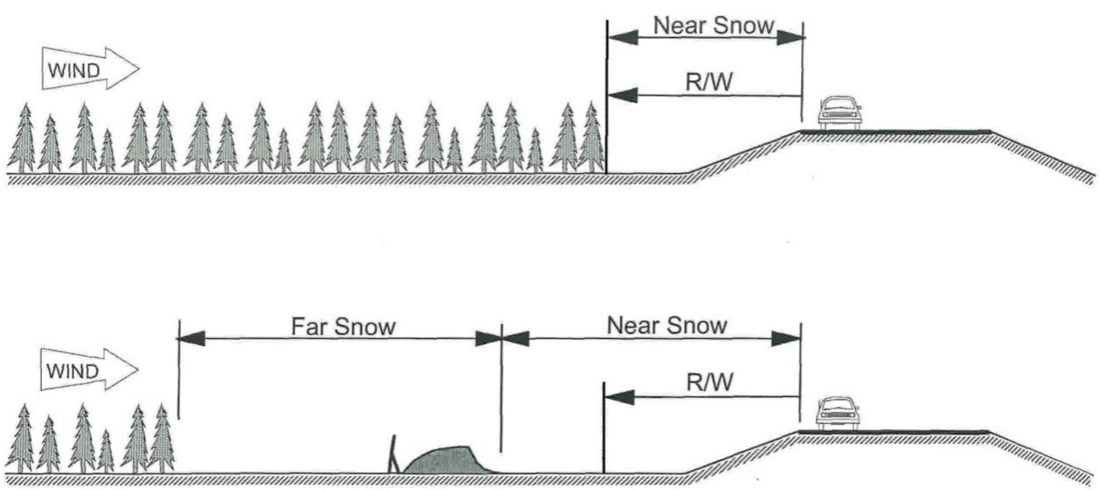


Figure 2 - Distinction Between "Near Snow" And "Far Snow" (Tabler 2003)

A recent study, *Three-Dimensional Roughness Elements for Snow Retention* (Tabler 2006) demonstrated positive evidence of the effectiveness of Snow Snakes, a new type of snow fence for use within the highway right-of-way. Snow Snakes are wire frames covered with a continuous extruded plastic fabric and aptly named for their reptilian appearance.

This study evaluates the effectiveness of using Snow Snakes as a viable means to reduce road ice formed by blowing snow originating within the highway right-of-way. In particular, this study focused on a geometrically complicated section of interstate highway. The study area chosen has limited topsoil, severe wind exposure, limited precipitation and was stripped of vegetation during construction activities in 2005, thus providing an apparently ideal location to evaluate the potential secondary benefits of using Snow Snakes to aid revegetation efforts in areas of high wind exposure and limited revegetation potential.

Figure 3 - Snow Snake Installation

Sixteen 30-in Snow Snakes were installed in three locations at the Interstate 80 – College Drive Interchange in Rock Springs, Wyoming as part of this study. Snow Snakes are either 24 or 30-in tall and will produce fully formed downwind drifts of approximately 68-ft and 85-ft, respectively. The 85-ft downwind drift formed by a 30-in Snow Snake is 50-ft (37%) shorter that the downwind drift formed by the commonly used 4-ft vertical lath snow fence (Figure 4).

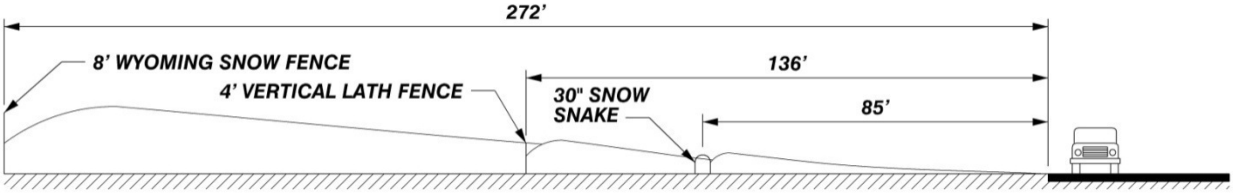


Figure 4 - Graphical Comparison Of Offsets For Three Snow Fences

CHAPTER 2
STUDY OBJECTIVE

The primary study objective is to evaluate the effectiveness of Snow Snakes as a viable means for reducing road ice formed when snow deposited within the highway right-of-way is blown across the roadway surface. In particular, this study evaluates the use of Snow Snakes in areas where vegetation has been stripped during construction.

A secondary study objective is to evaluate the impact of Snow Snakes to facilitate the establishment of revegetation growth in construction disturbed areas. John F. Samson, M.S./CCA, Agronomist, WYDOT Environmental Services, conducted field inspections and provided his observations of the Snow Snake's effects on the study site revegetation. Mr. Sampson's work is included in Appendices A, B, and C.

CHAPTER 3
TASK DESCRIPTION

The research plan consisted of direct observations of Snow Snake installations near the College Drive Interchange (RM 103.82) on I-80 in Rock Springs. Three observation trips were conducted on December 31, 2007, January 11, 2008, and February 6, 2008. The January 11, 2008 and the February 6, 2008 observations incorporated the use of a specialized vehicle equipped with compatible video, air and pavement temperature measurement equipment, and mapping software to record and log the pavement conditions present at the time of the site visit.

Drifts formed by the snow fences were measured along permanently established transects to determine the snow storage. Data from local weather stations was used to determine the precipitation at the site to quantify the amount of snow transport captured by the Snow Snakes.

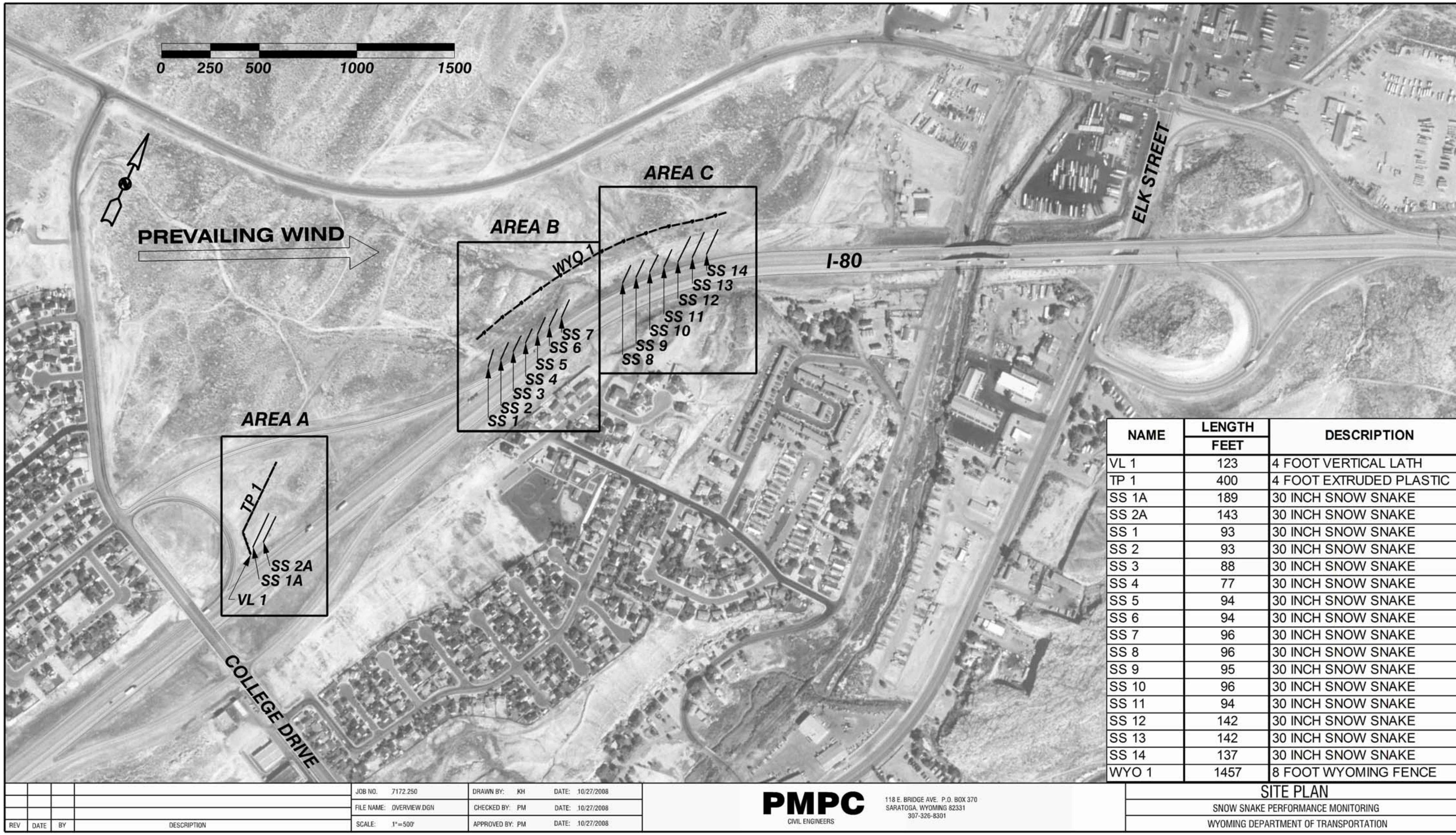
3.1 SITE DESCRIPTION

The study area is located in the I-80 corridor east of College Drive, west of Elk Street and on the north side of I-80. The study area contains three separate snow fence areas defined by prevailing wind direction (Figure 6). All three areas were stripped of vegetation, reseeded and mulched during I-80 reconstruction in 2005.

3.1.1. AREA A

Area A is the west snow fence installation containing four snow fences and is located in the gore area (Figure 6) between the westbound College Drive off ramp and westbound I-80. The College Drive bridge and approach embankments are upwind of the study area. The snow fences include a 4-ft vertical wood lath snow fence (VL 1), a 4-ft extruded plastic (Vexar® L-300) snow fence (TP 1) and two 30-in Snow Snakes (SS 1A and SS 2A) (Figure 9). With the exception of VL 1, which has a northwest-southeast orientation, all the snow fences in this area are oriented north-south. The terrain drains easterly towards the interstate.

Figure 5 - Area A Snow Fences



NAME	LENGTH FEET	DESCRIPTION
VL 1	123	4 FOOT VERTICAL LATH
TP 1	400	4 FOOT EXTRUDED PLASTIC
SS 1A	189	30 INCH SNOW SNAKE
SS 2A	143	30 INCH SNOW SNAKE
SS 1	93	30 INCH SNOW SNAKE
SS 2	93	30 INCH SNOW SNAKE
SS 3	88	30 INCH SNOW SNAKE
SS 4	77	30 INCH SNOW SNAKE
SS 5	94	30 INCH SNOW SNAKE
SS 6	94	30 INCH SNOW SNAKE
SS 7	96	30 INCH SNOW SNAKE
SS 8	96	30 INCH SNOW SNAKE
SS 9	95	30 INCH SNOW SNAKE
SS 10	96	30 INCH SNOW SNAKE
SS 11	94	30 INCH SNOW SNAKE
SS 12	142	30 INCH SNOW SNAKE
SS 13	142	30 INCH SNOW SNAKE
SS 14	137	30 INCH SNOW SNAKE
WYO 1	1457	8 FOOT WYOMING FENCE

Figure 6 - College Drive Study Area Site Plan

3.1.2. AREA B

Figure 7 - Area B Snow Snakes SS 5 and SS 6 Looking Along Transect T 3 Located By Red Flagging At The Top Of The Snow Snakes

Area B contains the center snow fence installation (SS 1 – SS 7) and lies north of I-80 and east of Area A (Figure 6). Area B contains seven 30-in Snow Snakes oriented north-south (Figure 10). The terrain drains to the northeast away from the interstate to a drainage swale. The higher areas east and west of the drainage are devoid of vegetation, while the drainage swale is vegetated with native grasses and sage brush established prior to the 2005 construction. An 8-ft Wyoming snow fence (WYO 1) is located north of Area B and parallels Interstate 80.

3.1.3. AREA C

Figure 8 - Area C Snow Fences

Area C contains the east snow fence installation and lies north of I-80 and east of Area B (Figure 6). Area C contains seven 30-in Snow Snakes (SS 8 – SS 14) oriented north-south (Figure 11). Area B and Area C are divided by a drainage swale entering the right of way from the west and discharging to a culvert crossing under the interstate (Figure 6). The Snow Snakes are located in a cut section which drains southeast towards the interstate. An 8-ft Wyoming snow fence (WYO 1) is located north of Area C and parallels I-80.

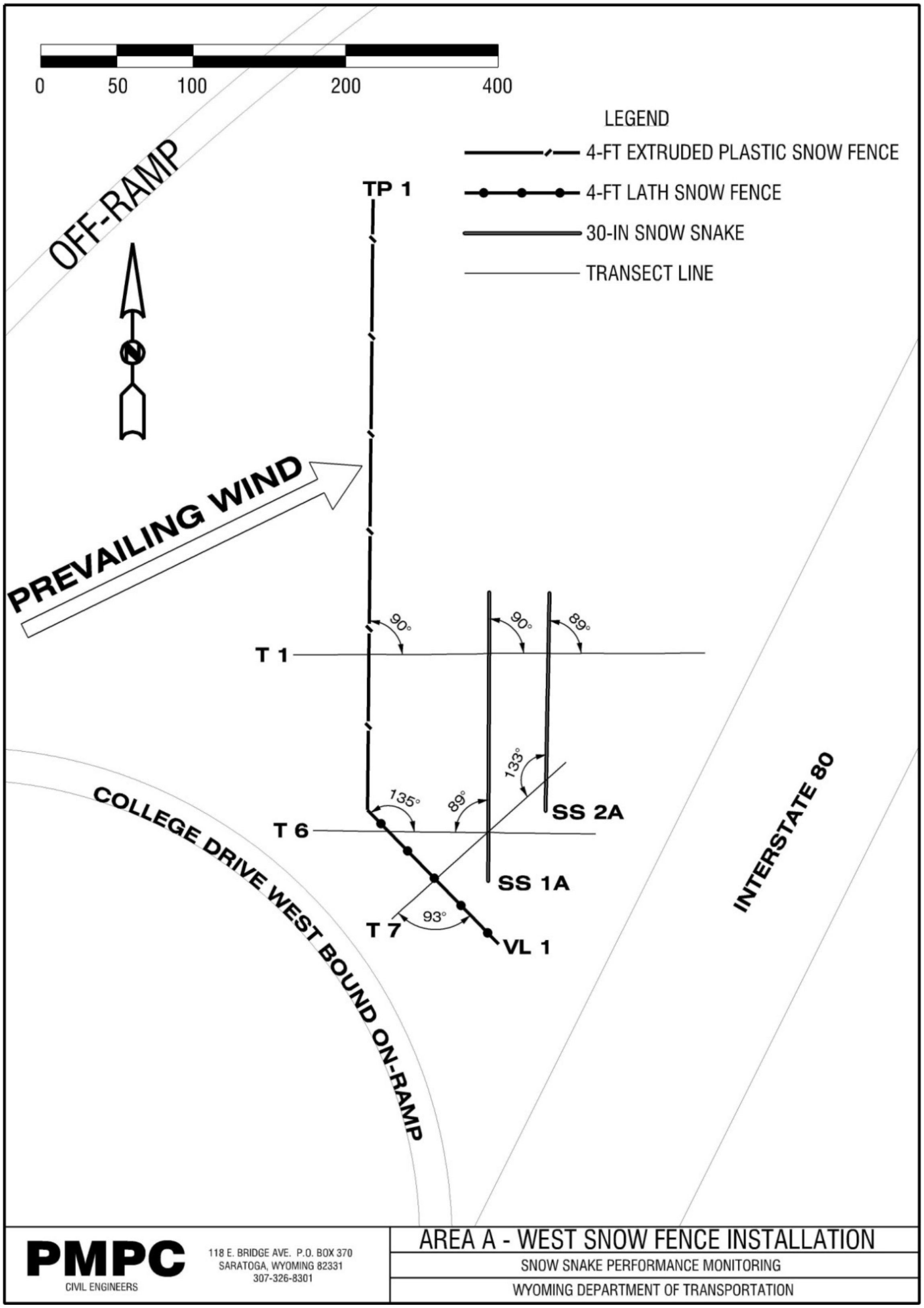


Figure 9 - Area A - West Snow Fence Installation

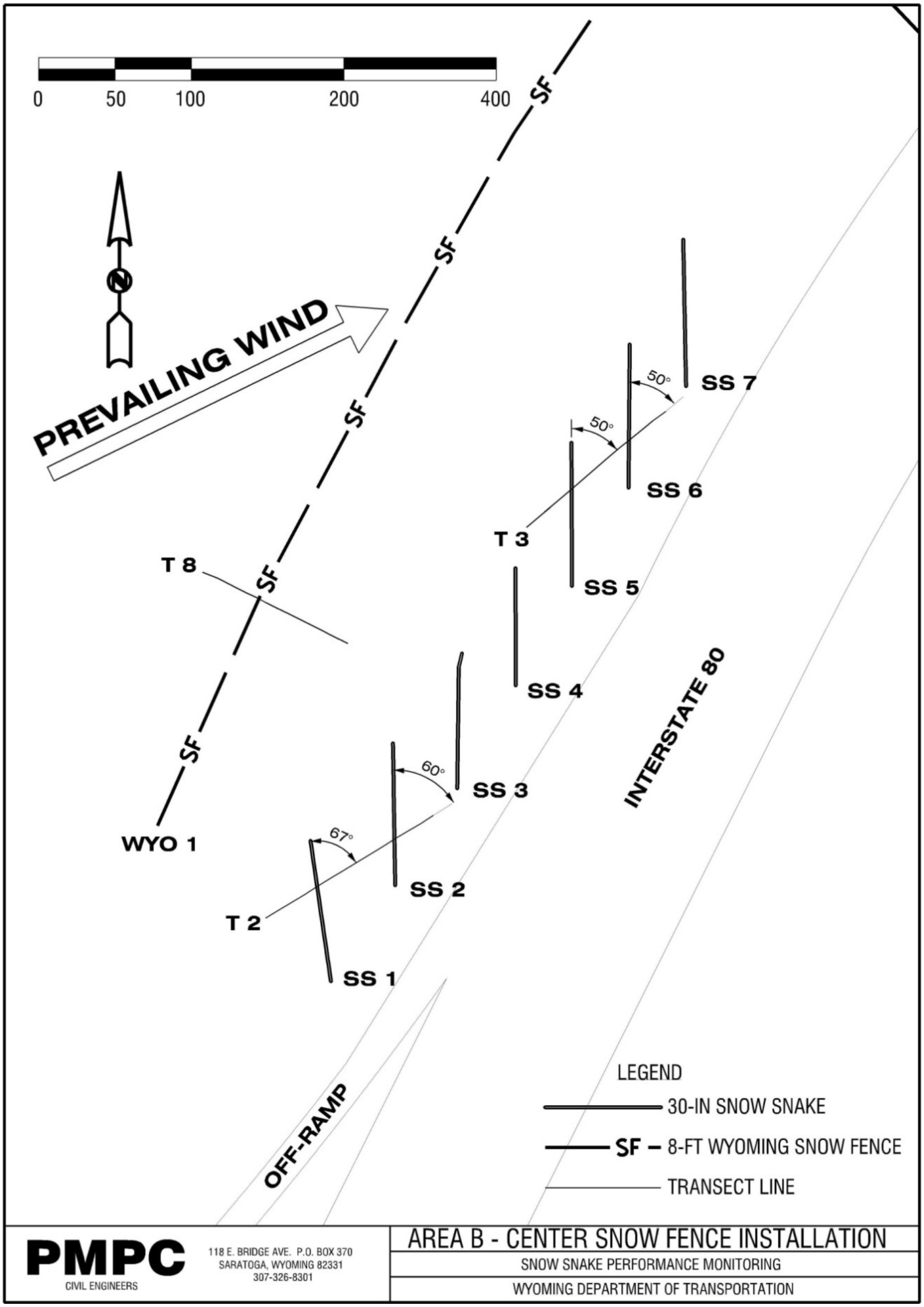


Figure 10 - Area B - Center Snow Fence Installation

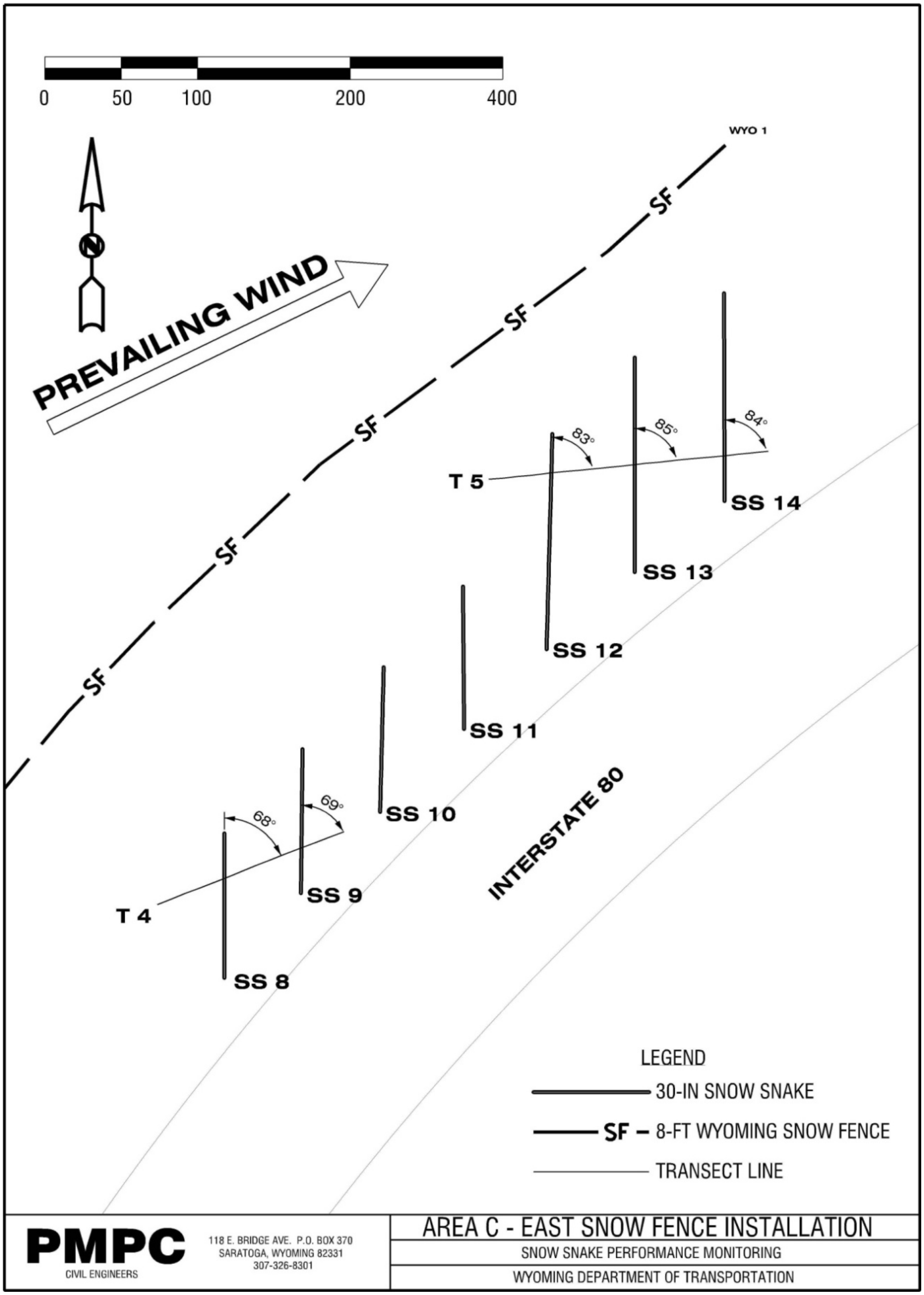


Figure 11 - Area C - East Snow Fence Installation

3.2 FIELD OBSERVATION PROCEDURES

3.2.1. ROADWAY DATA

Field observations and photographs were recorded December 31, 2007, January 11, 2008, and February 6, 2008. Temperature profiles and video images were recorded in the eastbound and westbound lanes and on all ramps of College Drive interchange during the last two site visits, with blowing snow present only during the last site visit.

The study site is geometrically and topographically complex. The eastbound and westbound lanes are superelevated giving the sun a greater angle of incidence on the roadway increasing the amount of available solar radiant heat; the intersection ramps are not superelevated. The College Drive bridge and approach embankments are upwind of the study area and influence the wind and snow deposition patterns in the western end of the study area; two 4-ft vertical snow fences are also present which additionally affect wind and snow deposition patterns. The eastern portion of the study area is shadowed by an upwind 8-ft Wyoming type snow fence with some of the Snow Snakes located in a drainage channel and in a roadway cut section which affects wind and snow deposition patterns.

3.2.2. SNOW MEASUREMENT METHODOLOGY

Permanent transect locations were established intersecting various snow fence types and configurations prior to the winter season. Snow drifts were measured along all transects during each winter observation event using a snow probe. Each observation event occurred after snow events large enough to warrant a site visit. These trips were first discussed with regional WYDOT staff to ensure suitable conditions. Drifts were not measured prior to snow precipitation events, necessitating the use of a drift melt equation to determine the amount of snow drift melt between field measurements, ensuring a more accurate accounting of snow storage on the site. This data was used to calculate trapped snow volumes, weights and water equivalents that were prevented from coming into contact with the roadway surface.

Figure 12 - Snow Pit Showing Current And Previous Deposition Layers Downwind of Snow Snake SS 1A

3.3 DATA SOURCES

Climate data from four local weather stations was used in this study (Figure 13). Prevailing wind and temperature data used in this report are based on data from weather station CW5688. Snow precipitation depths are the average of data obtained from weather stations RSFD, WY-SW-1 and WY-SW-10.

3.3.1. NATIONAL CLIMATIC DATA CENTER

The National Climatic Data Center logs climate data from the Rock Springs Fire Department weather station RSFD. Snow precipitation depths and water equivalents are reported in inches every 24 hours; this data was complete for the study period and used in preparation of this report.

3.3.2. MESOWEST

The University of Utah's Mesowest website (http://www.met.utah.edu/mesowest) logs climate data from weather station CW5688 (Figure 13). CW5688 is the weather station closest to the study area and wind data from this station was used to determine the prevailing wind direction. Temperature data from this site was used to determine drift melt. CW5688 station does not report precipitation data.

3.3.3. COMMUNITY COLLABORATIVE RAIN, HAIL, AND SNOW NETWORK

The Community Collaborative Rain, Hail, and Snow Network (Co Co Ra HS) website (http://www.cocorahs.org) collects data from WY-SW-1 and WY-SW-10 weather stations (Figure 13). Snow precipitation depths and water equivalents are reported every 24 hours; this data was complete for the study period and used in preparation of this report.

Table 1 - Field Inspection Summary

FIELD INSPECTION SUMMARY

DATE	NEW SNOWFALL (inches)	TEMPERATURE (°F)	WEATHER	WIND SPEED (MPH)	WIND DIRECTION (Azimuth)	BLOWING SNOW
12/31/2007	11.5	12	Clear	17	250°	NO
1/11/2008	2.2	29	Clear	17	270°	NO
2/6/2008	11.6	25	Overcast	20	250°	YES

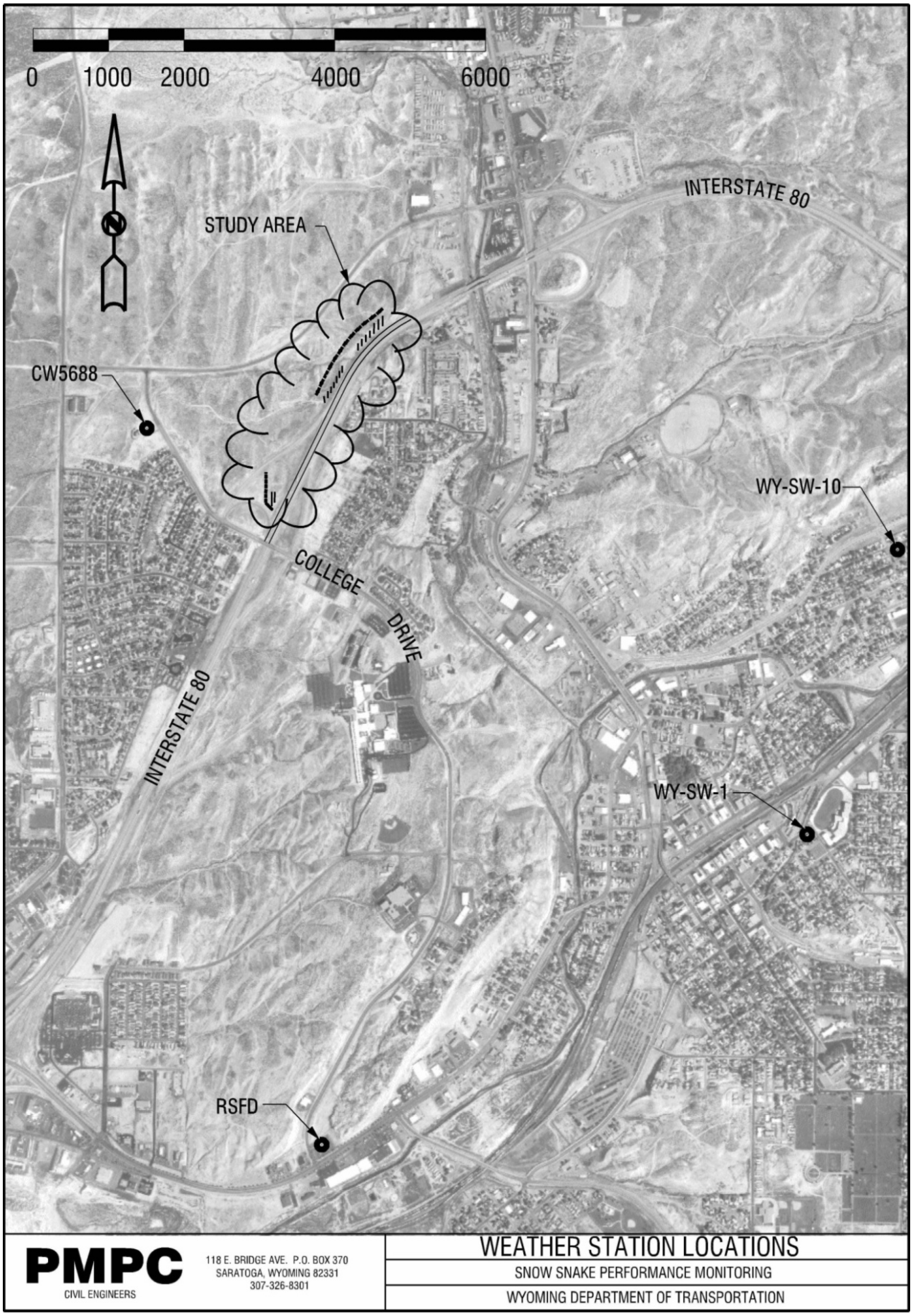


Figure 13 - Weather Station Location Vicinity Map

3.4 SNOW SNAKE ANALYSIS METHODOLOGY

3.4.1. SITE PREPARATIONS

All snow fences were marked with identification tags attached to the snow fence end nearest I-80. Eight permanent transects were established intersecting various snow fence types and configurations (Figure 9 through Figure 11). Transects were located a minimum of 30-ft (12H) from the Snow Snake ends to minimize erroneous data caused by end effects. Each transect was marked with a stake at the begin point and flagging was tied to the Snow Snakes at crossing points. The ends of each snow fence were located using GPS survey equipment. Each transect was also surveyed to obtain ground elevations and alignment data.

3.4.2. TOTAL SNOW SNAKE STORAGE

The volumes of snow collected by the Snow Snake installations were determined from field observation data. The total snow depth was measured along each transect. Drift volumes were determined by the average end area method. Respective drift depth measurements were averaged and multiplied by the distance between the readings (in the prevailing wind direction), this average area was then multiplied by the length of the snow fence to determine the incremental drift volume between two contiguous measurements. The incremental volumes were multiplied by the incremental snow density (based on drift depth) to determine the total weight of the drift. Weights were adjusted to account for the end effects of the snow drifts. Two Snow Snakes (SS 4 and SS 5) were corrected for length because their northern ends extended into vegetation rendering them ineffective until the vegetation filled with snow, which did not occur. When snow fence drifts were transected multiple times, their drift weights were averaged for the tables and graphs. Snow Snakes SS 3, SS 4, SS 7, SS 10 and SS 11 were not intersected by transects. Snow storage quantities were estimated for these Snow Snakes using information developed for adjacent transected Snow Snakes.

The densities of the transected snow drifts were calculated using the standard relationship for drifted snow (Tabler 1985).

Equation 1 - Snow Drift Density ρ_s (kg/m^3) As A Function Of Depth Y (m)

$$\boldsymbol{\rho_s = 522 - \left(\frac{304}{1.485Y}\right)\left(1 - e^{-1.485Y}\right)}$$

The density of stored snow increases with drift depth. The stored snow weight of each drift was determined by multiplying the incremental volumes by the incremental densities along the drift transects, and summing the products.

The end effects of the drifts were calculated using the relationship for drift cross sectional area as a function of the unaffected cross sectional area and the distance from the end of the fence (Tabler 1980)

Equation 2 - Cross-Sectional Drift Area A As A Function Of The Uneffected Cross-Sectional Area A_{inf} And Distance From End Of Snow Fence X_e And Fence Height H

$$\frac{A}{A_{inf}} = 0.23 + \frac{X_e}{5.2} - \frac{\left(\frac{X_e}{H}\right)^2}{59.5} + \frac{\left(\frac{X_e}{H}\right)^3}{1961} , \frac{X_e}{H} \leq 12$$

End effect areas were calculated at 1-ft intervals from the fence end for a distance of 12H, where H is the height of the snow fence. Using the incremental area calculations based on the cross-sectional area unaffected by end effects (transects), the total volume and weight of the drift within 12H from the end of the drift was calculated. Drift weights were then adjusted to reflect snow drift end effects.

Drift melt occurred between site visits and was estimated using the equation for the melt rate of snow drifts (Tabler 1985)

Equation 3 - Melt Rate Of Snow Drifts

$$\frac{1\ cm\ depth}{℃\ day}$$

Temperature data was taken from the CW5688 weather station for snow melt calculations. The weather station records the temperature every 15-minutes. The total volume of snow replacing drift melt occurring since the previous measurements was included in the storage calculations for the site visits on 01/11/08 and 02/06/2008.

3.5 SNOW SNAKE EFFECTS ON REVEGETATION

3.5.1. VEGETATION PERFORMANCE AT SITE

The effects of Snow Snakes on the revegetation of the study site were evaluated by John F. Samson, M.S./CCA, Agronomist, WYDOT Environmental Services. He conducted field inspections on August 16, 2007 and June 25, 2008; his Executive Summary and inspection reports are included in Appendices A, B, and C.

3.5.2. DRIFT WATER DETENTION

Vegetation removal commonly occurs during construction operations in borrow areas, realignments, road cuts, road fills, drainage areas, and other graded areas. This was the case in the College Drive study area. In addition to protecting the roadway from winter ice formation, an additional perceived benefit of Snow Snakes is to provide additional water later in the growing season to improve vegetation establishment in construction disturbed areas. Drifts formed by snow fences provide denser snow pack than the surrounding unprotected areas. When blanketed snow has receded in surrounding areas, snow fence drifts still provide a source for water as was witnessed at the study site (Figure 14). This later season water source may be significant in the high desert areas of Wyoming subject to drought conditions and evaporative winds.

Figure 14 - Drift Water Detention Behind Snow Snake SS 2A

3.5.3. OTHER RECENT SNOW FENCE STUDIES

With limited site specific information from the College Drive study area, other recent studies and site observations are worthy of discussion.

3.5.3.1. ECOLOGICAL ASSESSMENT AND EVALUATION OF SNOWFENCE AREAS AND SNOWFENCE MITIGATIONS (FHWA-WY-02/06F)

This report evaluated the impacts of snow drifts from Wyoming type snow fences on soils and determined which seed species were best suited to be planted behind these snow fences. The report indicates drifts behind Wyoming type snow fences actually increase the mortality rate of sagebrush. However, several species of wheatgrass (pubescent, western, thickspike and slender) and two species of wildrye (altai and Russian) may be well suited for planting behind these fences.

Snow Snakes are much shorter than the Wyoming type snow fences, producing short lived drifts. Therefore, the findings of the above referenced report may or may not pertain to Snow Snakes.

3.5.3.2. THE HOLLOW FRAME FENCE – YEAR 7

This report, written by Erika David of Pinedale, Wyoming, focuses on reclamation of well sites located in Wyoming's Jonah Field. The study objective was to "develop guidelines for utilizing new snow fence design as a novel and innovative tool for increased water conservation in a reclamation setting." The study recognizes a problem with "maintaining a consistent water supply through the late spring and early summer germination periods." It compares three types of snow fence installations: hollow frame, dispersed Snow Snake, and intensive Snow Snake. The intensive Snow Snake configuration produced the highest percentages of desirable and lowest percentage of undesirable targeted plants.

Figure 15 - Hollow Frame Snow Fence

CHAPTER 4
FINDINGS AND CONCLUSIONS

4.1. DRIFT PROFILES

Depths along each of eight transects (Figure 16 through Figure 23) were measured during three site visits and plotted by date to show the snow drift profile for each field investigation.

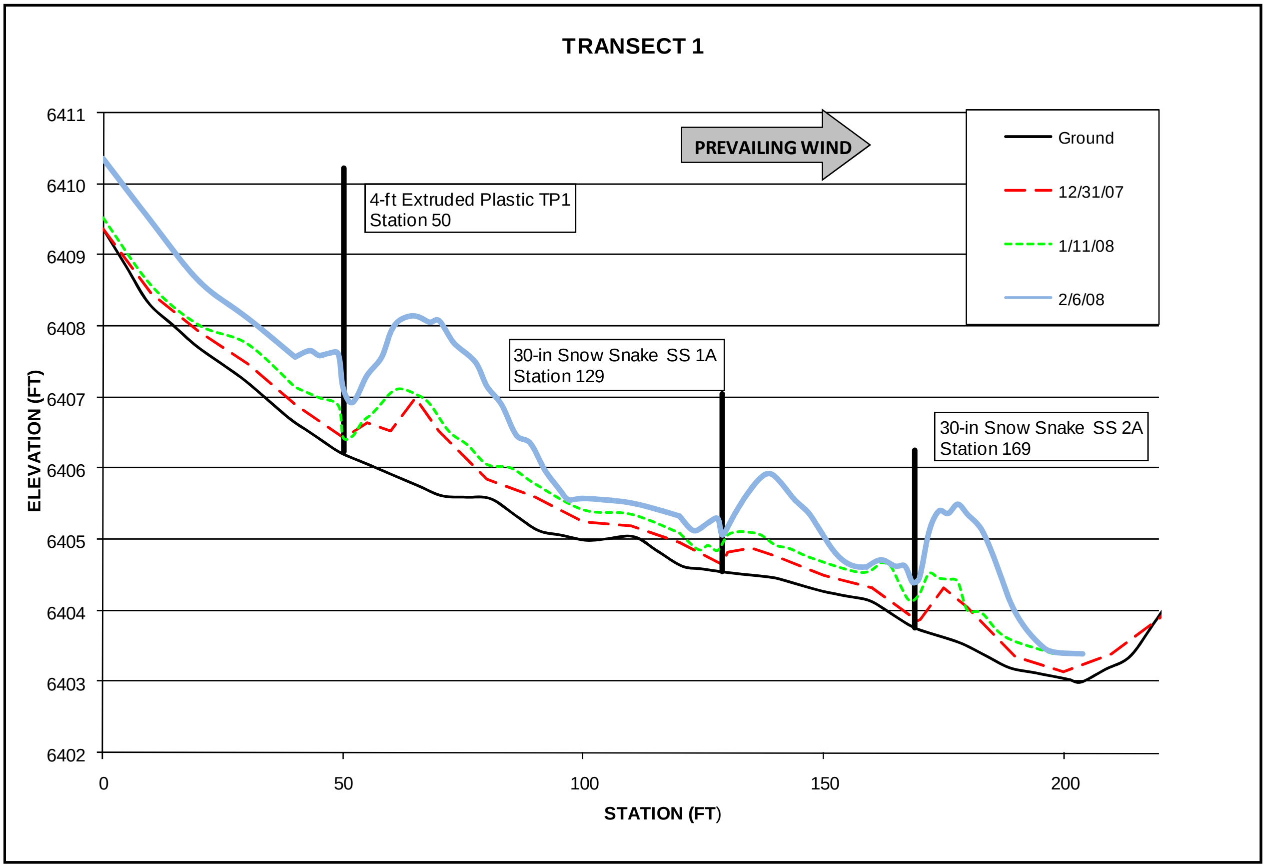


Figure 16 - Transect 1 Observed Data

Transect 1 (T 1), in Area A, intersects the 4 foot extruded plastic fence TP 1 first, then passes through Snow Snakes SS 1A and SS 2A. TP 1 has a much larger downwind drift than either of the Snow Snakes as expected due to the height of the fence and that this fence is first in line to receive blowing snow in the prevailing wind direction.

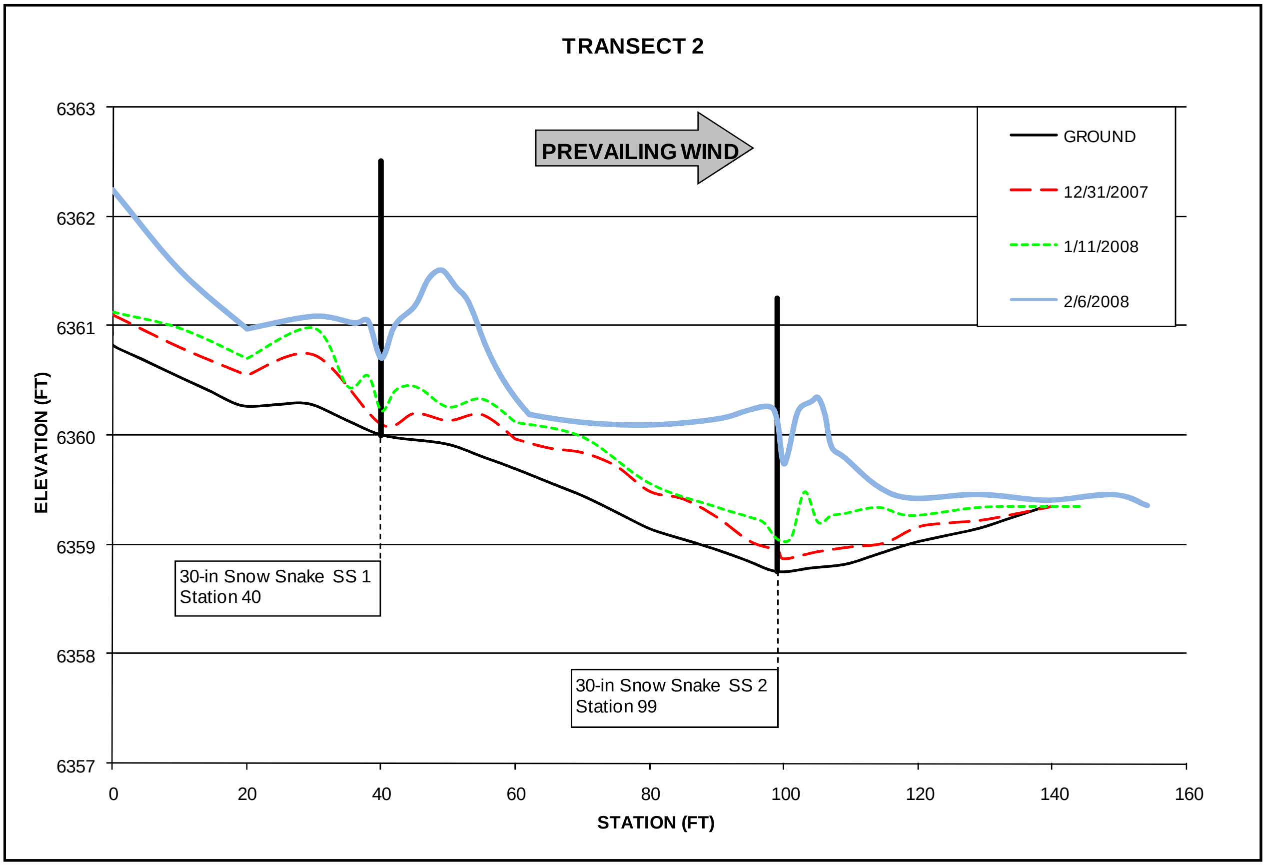


Figure 17 - Transect 2 Observed Data

Transect 2 (T 2), in Area B, starts in vegetation (vegetation stops in first 20 feet), slopes slightly downhill and passes through a small depression. As seen in Figure 17, the roadside drainage channel encourages snow storage. Additionally, snow storage seen at the beginning of the transect is due to the vegetation (mostly grasses) upwind of the Snow Snakes.

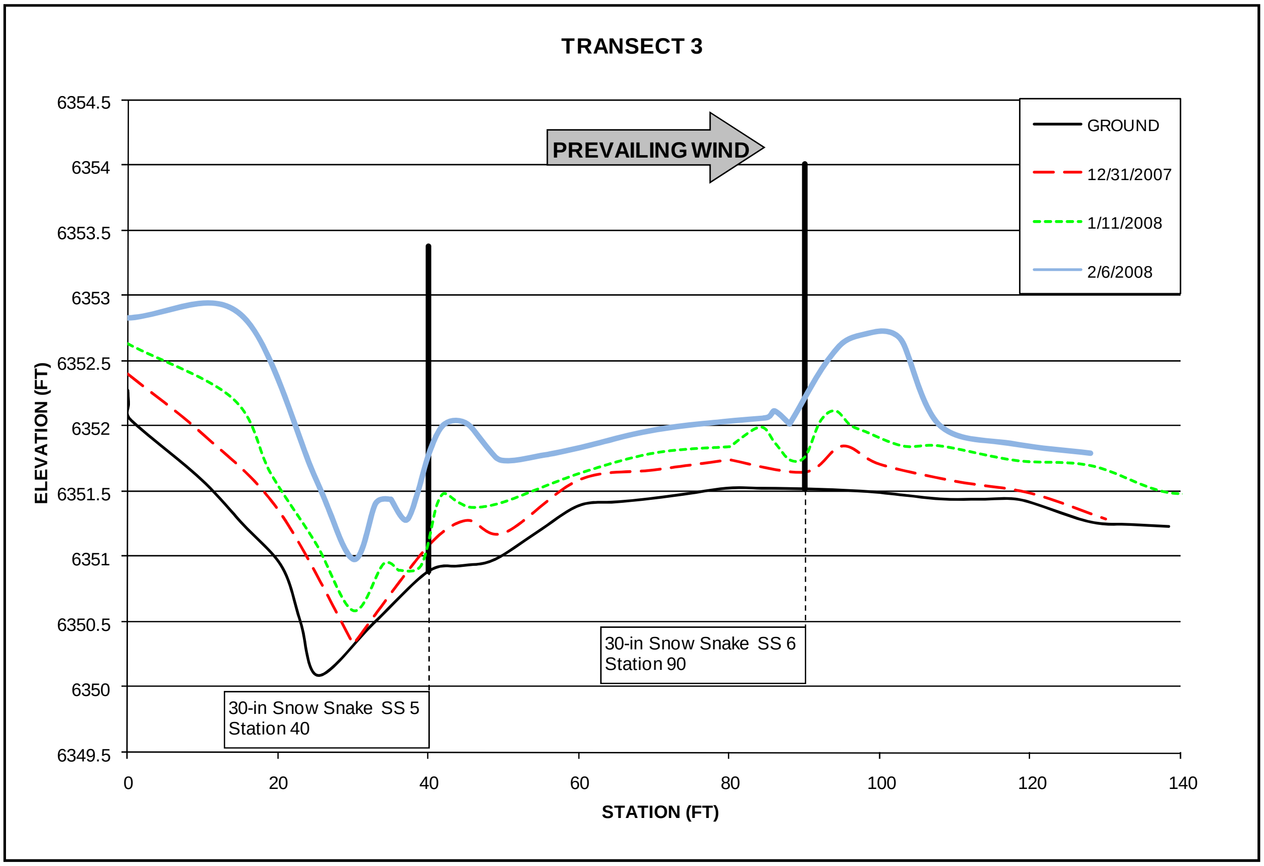


Figure 18 - Transect 3 Observed Data

Transect 3 (T 3), in Area B, starts in vegetation (sagebrush and grasses), passes through a drainage swale and then through Snow Snakes SS 5 and SS 6. The existing vegetation at the beginning of the transect causes a drift on the windward side of SS 5 which would be reduced in the absence of the vegetation.

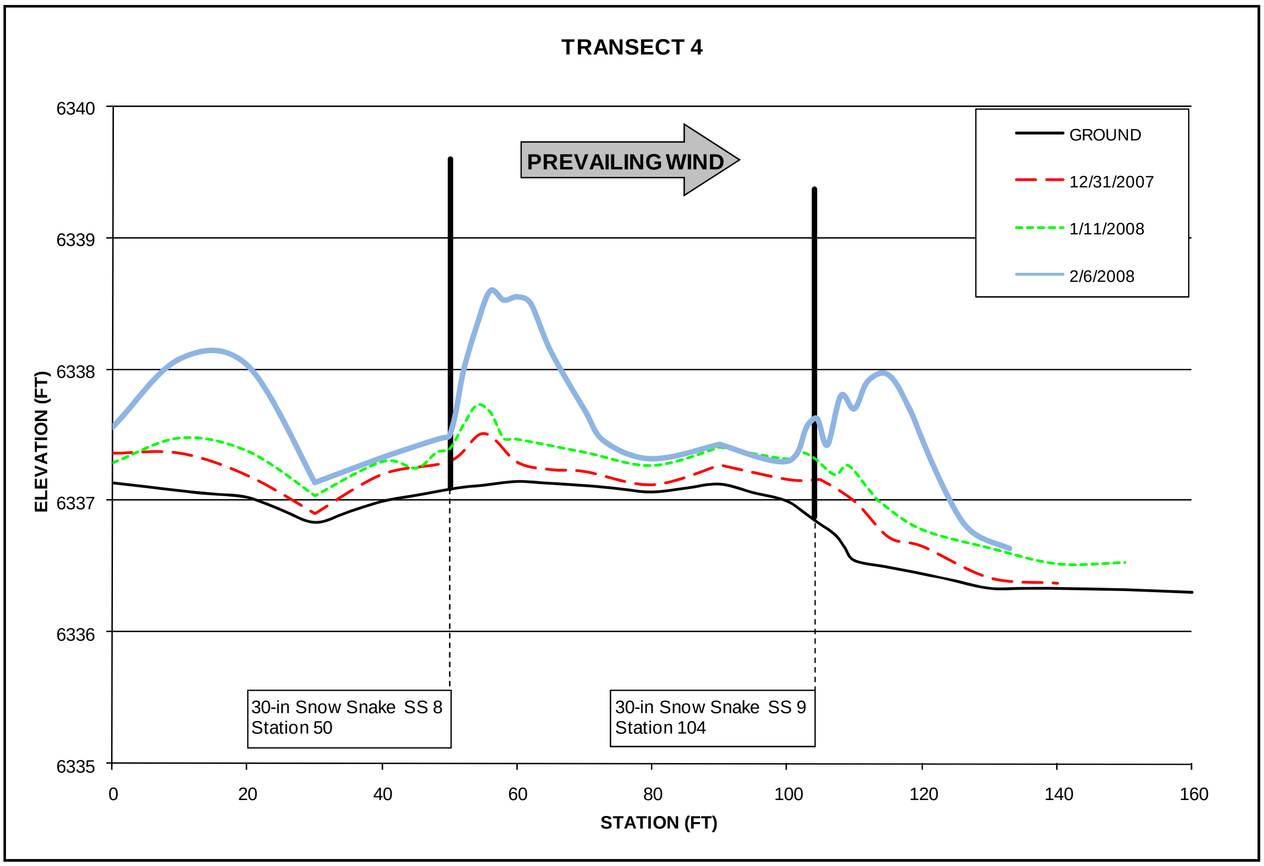


Figure 19 - Transect 4 Observed Data

Transect 4 (T 4), in Area C, passes through Snow Snakes SS 8 and SS 9. Snow Snake SS 8 is the first Snow Snake in line to receive drifting snow in Area C. The drift at the beginning of the transect is due to a short swath of vegetation which lies at the top of the hill downwind from the drainage between Areas B and C. Even with vegetation upwind of these Snow Snakes, they still trapped significant amounts of blowing snow.

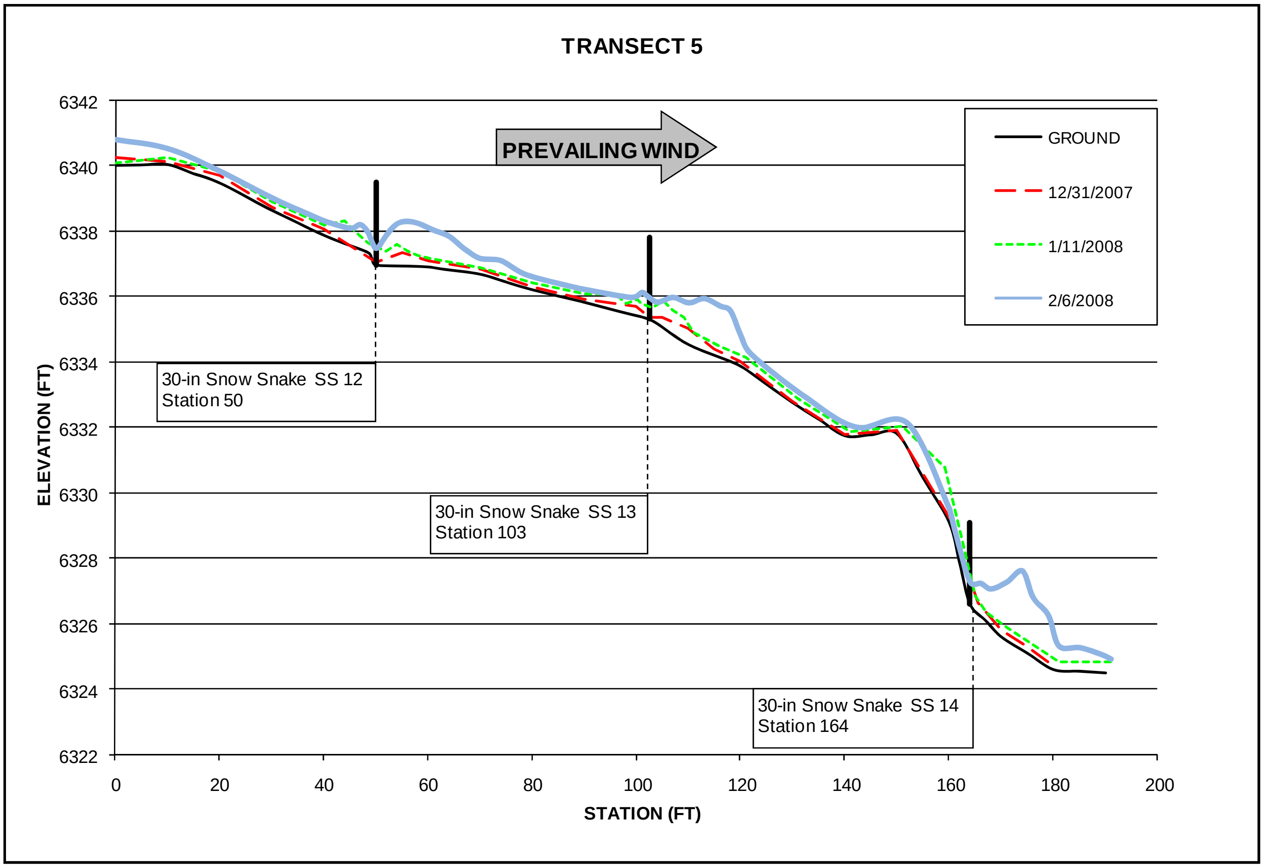


Figure 20 - Transect 5 Observed Data

Transect 5 (T 5), in Area C, begins just south of the chain link right-of-way fence in patchy vegetation (mostly grasses) and passes through Snow Snakes SS 12, SS 13, and SS 14 near the bottom of the hillside cut.

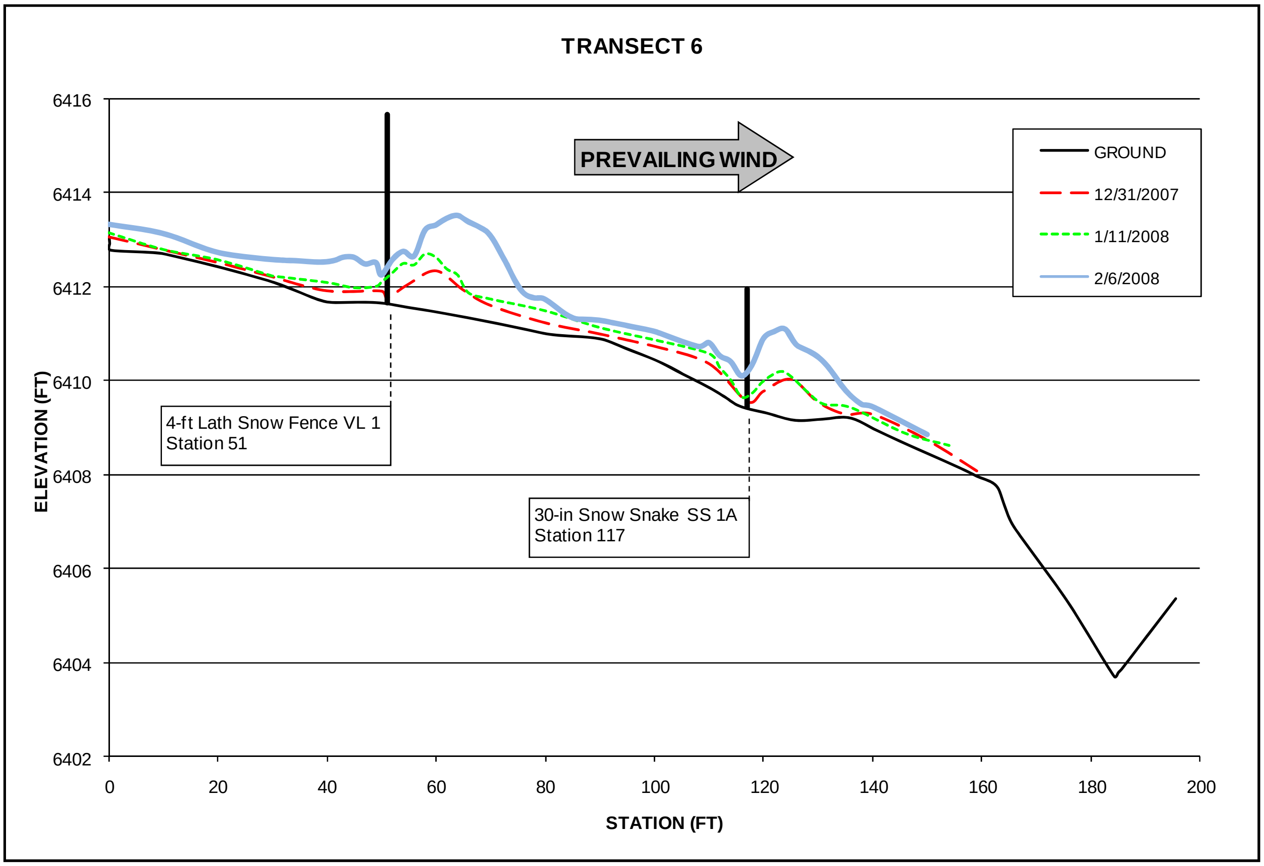


Figure 21 - Transect 6 Observed Data

Transect 6 (T 6), in Area A, passes through VL 1 and SS 1A. This transect was located to be perpendicular to Snow Snakes SS 1A and SS 2A. The transect begins just east of the west bound I-80 on-ramp from College Drive. The drift formed by VL 1 is larger than the drift formed by SS 1A due to its height and being first in line to receive blowing snow in the predominant wind direction.

The VL 1 drift is smaller than the TP 1 drift due to their different orientations. VL 1 is more perpendicular to the prevailing wind than the other fences in Area A, but is sheltered from blowing snow by the upwind bridge embankment.

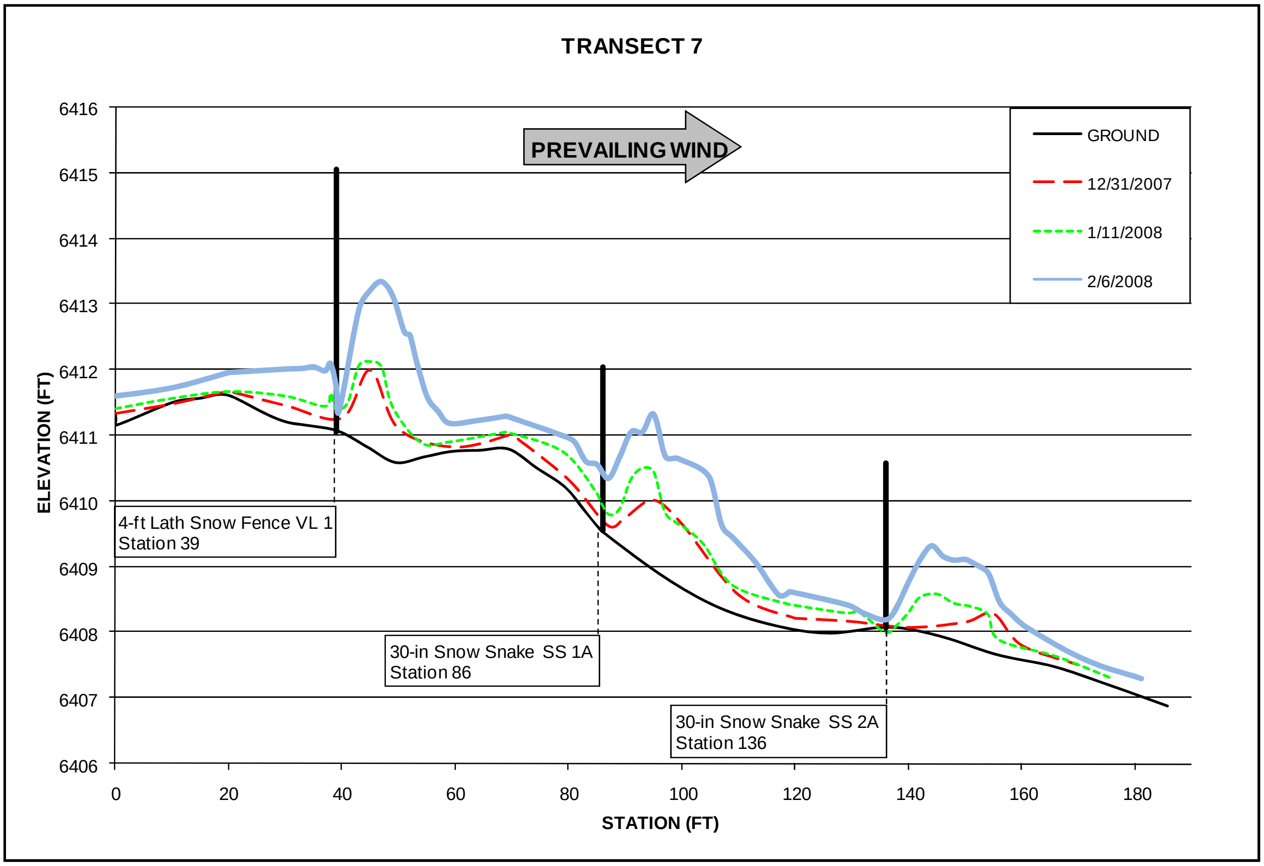


Figure 22 - Transect 7 Observed Data

Transect 7 (T 7), in Area A, passes nearly perpendicular through snow fence VL 1 and on a skew through SS 1A and SS 2A.

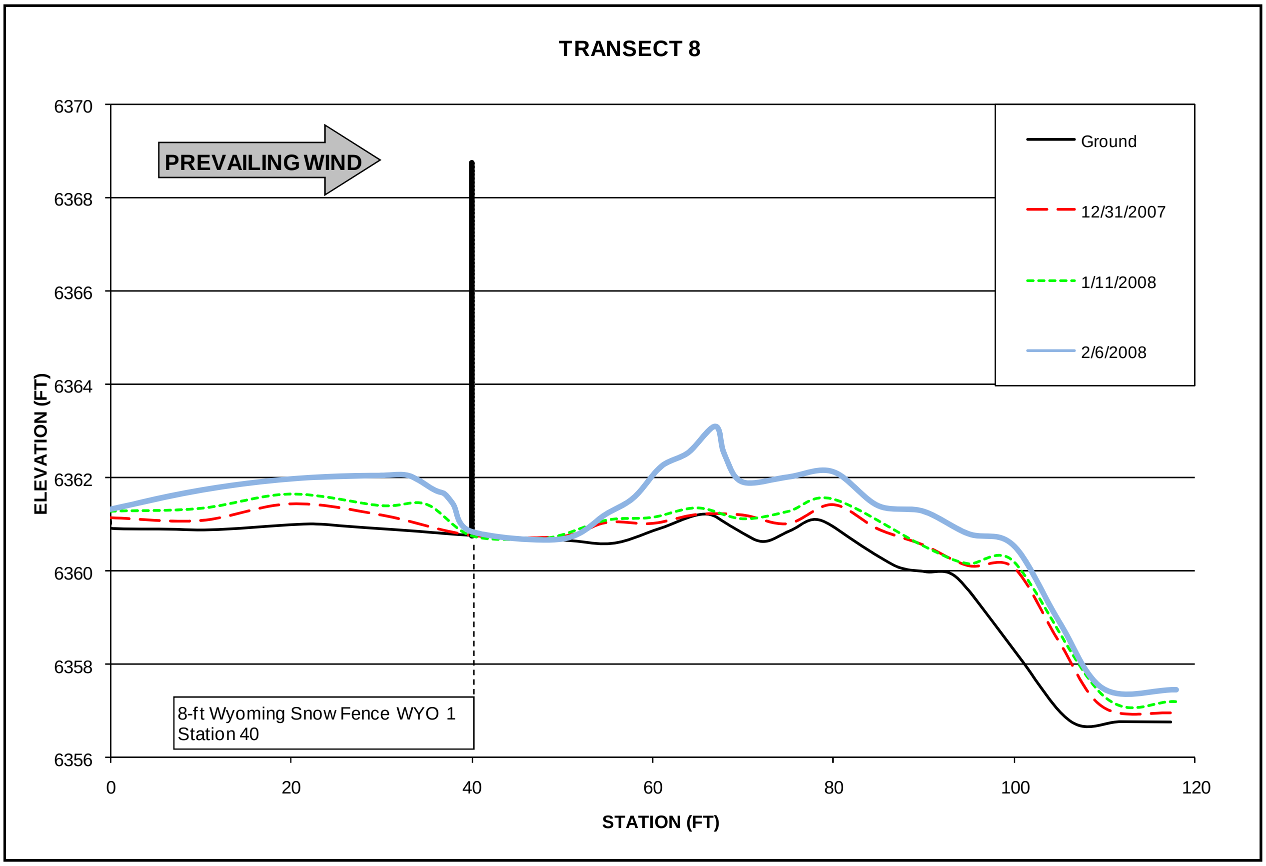


Figure 23 - Transect 8 Observed Data

Transect 8 (T 8), in Area B, passes through the 8-ft Wyoming snow fence, WYO 1, located outside of the right-of-way with sage brush and grasses both upwind and downwind from the fence. During the study, the vegetation never completely filled with snow. The bare area at the fence structure is the result of increased wind velocities through the snow fence bottom gap.

4.2. SNOW STORAGE

The quantity of snow stored and corresponding water equivalent were determined for observation dates for each snow fence intersected by a measurement transect using procedures discussed in Section 3.4.2. Snow storage for non-transect intersected snow fences was estimated from field data obtained for adjacent snow fences. To determine the new storage total for each snow fence, the melt occurring since the previous observation was added to the measured total for the observation date and then the previous measured snow storage was subtracted.

During the 2007-2008 winter, the study area Snow Snakes trapped and prevented approximately 622 tons of snow from potentially interacting with the roadway surface to form slush and ice. This total does not include snow storage behind snow fences TP 1, VL 1, or WYO 1.

To determine the amount of water detained in each drift as shown in the seventh and eighth columns of Tables 2, 3, and 4, the weight of the drift in tons was converted into gallons of water detained using the density of water equal to 62.4 lb/ft^3 and the volumetric relationship of 7.48 gal/ft^3. The water detention quantity should not be seen as an attempt to determine the total amount of water available to seeded plants because a portion of the snow will sublimate and a portion of the snow melt may flow across frozen ground not yet able to accept the moisture.

4.2.1. AREA A

By December 31, 2008 in Area A, the two Snow Snakes (SS 1A and SS 2A) prevented a combined total of nearly 24 tons of blowing snow from crossing the roadway which is approximately 20 percent of the total storage in Area A. Combined, the two Snow Snakes detained 5,730 gallons of water. By January 11, 2008, the same Snow Snakes prevented 22 tons of additional snow from crossing the roadway, and detained nearly 5,300 gallons of additional water in the form of snow pack. By February 6, 2008, the same Snow Snakes prevented an additional 78 tons of snow from crossing the roadway, detaining about 18,800 gallons of additional water. If TP 1 and VL 1 were removed, the quantity of snow trapped by the Snow Snakes would be expected to increase.

During the 2007 – 2008 winter, the two Snow Snakes in Area A prevented 124 tons of snow from crossing the roadway, accounting for approximately 23 percent of the total storage in Area A. They also detained more than 29,800 gallons of water in snow pack. No estimate could be made as to how much ice was prevented on the roadway.

Snow storage amounts are shown in Table 2. A graphical distribution of the snow storage amounts for Area A is shown in Figure 24. A graphical distribution of the detained water amounts for Area A is shown in Figure 25.

Table 2 - Area A Storage Summary

AREA A

12/31/2007

SNOW FENCE	SNOW STORAGE					WATER DETENTION	
	MEASURED	MELT	PREVIOUS	NEW		TO DATE	NEW
	(tons)	(tons)	(tons)	(tons)	(%)	(gallons)	(gallons)
TP 1	82.0	0.0	0.0	82.0	69.3%	19,659	19,659
VL 1	12.5	0.0	0.0	12.5	10.6%	2,997	2,997
SS 1A	14.9	0.0	0.0	14.9	12.6%	3,572	3,572
SS 2A	9.0	0.0	0.0	9.0	7.6%	2,158	2,158
TOTALS	**118.4**	**0.0**	**0.0**	**118.4**	**100.0%**	**28,386**	**28,386**

1/11/2008

SNOW FENCE	SNOW STORAGE					WATER DETENTION	
	MEASURED	MELT	PREVIOUS	NEW		TO DATE	NEW
	(tons)	(tons)	(tons)	(tons)	(%)	(gallons)	(gallons)
TP 1	132.9	9.1	82.0	60.0	59.5%	34,044	14,385
VL 1	28.5	2.8	12.5	18.8	18.6%	7,504	4,507
SS 1A	24.5	3.2	14.9	12.8	12.7%	6,641	3,069
SS 2A	16.1	2.2	9.0	9.3	9.2%	4,388	2,230
TOTALS	**202.0**	**17.3**	**118.4**	**100.9**	**100.0%**	**52,577**	**24,191**

2/6/2008

SNOW FENCE	SNOW STORAGE					WATER DETENTION	
	MEASURED	MELT	PREVIOUS	NEW		TO DATE	NEW
	(tons)	(tons)	(tons)	(tons)	(%)	(gallons)	(gallons)
TP 1	338.6	16.3	132.9	222.0	67.2%	87,267	53,223
VL 1	53.8	4.7	28.5	30.0	9.1%	14,696	7,192
SS 1A	66.1	5.2	24.5	46.8	14.2%	17,861	11,220
SS 2A	43.7	4.0	16.1	31.6	9.6%	11,964	7,576
TOTALS	**502.2**	**30.2**	**202.0**	**330.4**	**100.0%**	**131,788**	**79,211**

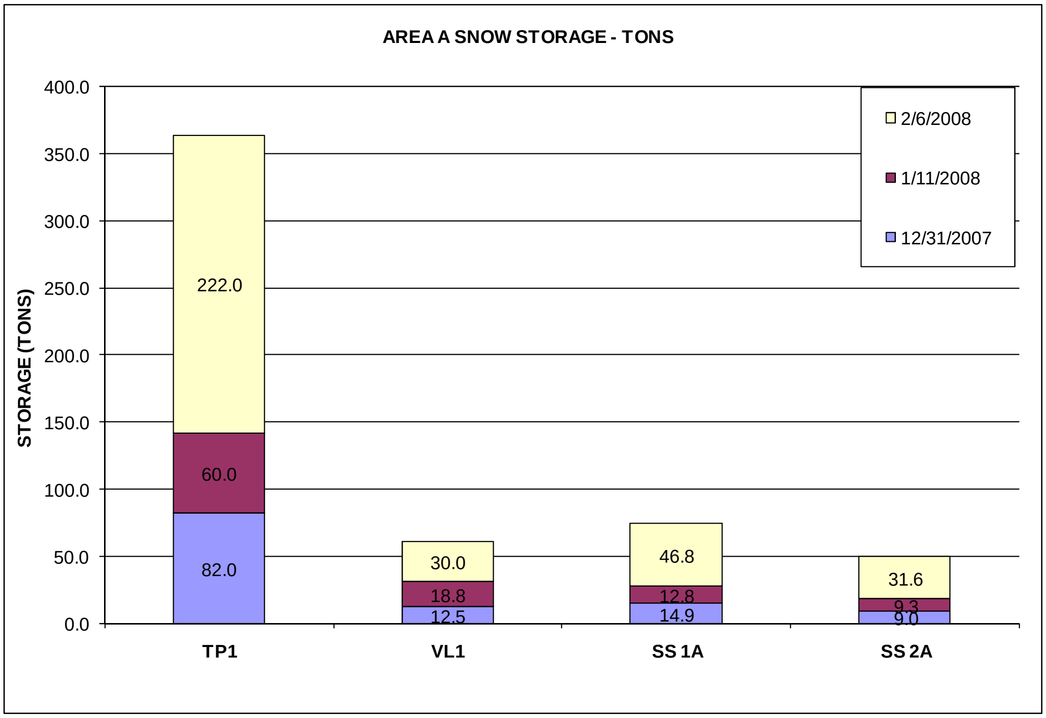


Figure 24 - Area A - Snow Storage Distribution

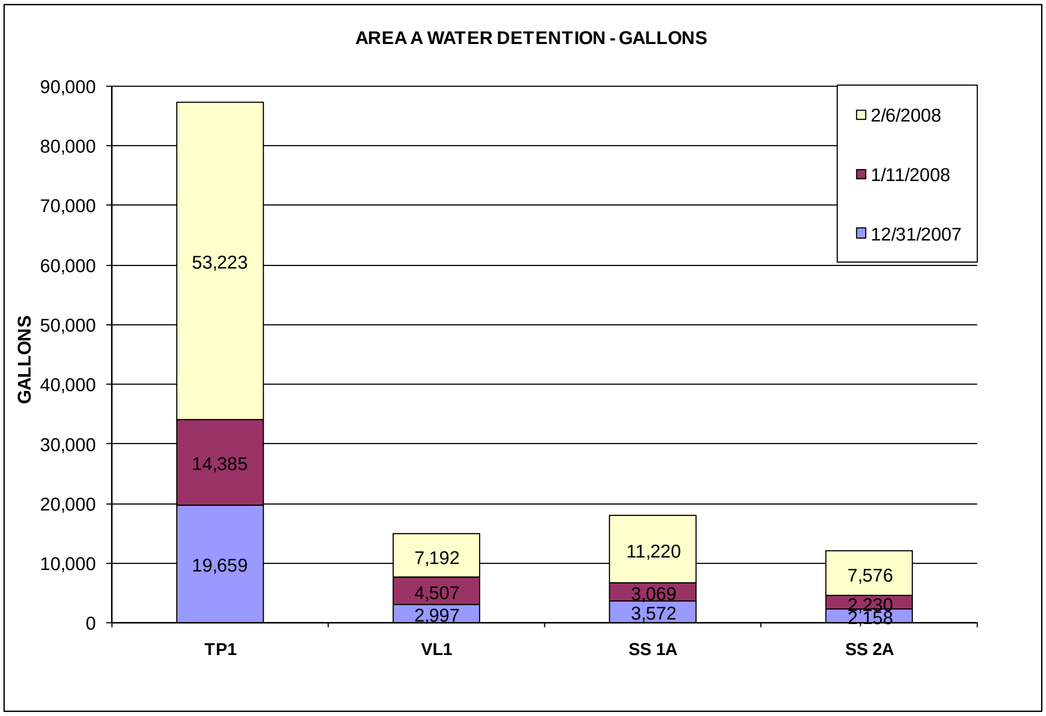


Figure 25 - Area A - Water Detention Distribution

4.2.2. AREA B

By December 31, 2008 in Area B, the seven Snow Snakes (SS 1 through SS 7) prevented a combined total of approximately 43 tons of blowing snow from crossing the roadway and detained over 10,300 gallons of water in snow pack. By January 11, 2008, the Snow Snakes prevented nearly 60 tons of additional snow from crossing the roadway, and detained more than 14,300 gallons of additional water in the form of snow pack. By February 6, 2008, the same Snow Snakes prevented over 129 tons of additional snow from crossing the roadway, detaining over 31,000 gallons of additional water.

Overall, the Snow Snakes in Area B prevented over 232 tons of snow from crossing the roadway and detained nearly 56,000 gallons of water in snow pack. These results are shown in Table 3. A graphical distribution of the snow storage amounts for Area B is shown in Figure 27. A graphical distribution of water detained for Area B is shown in Figure 28.

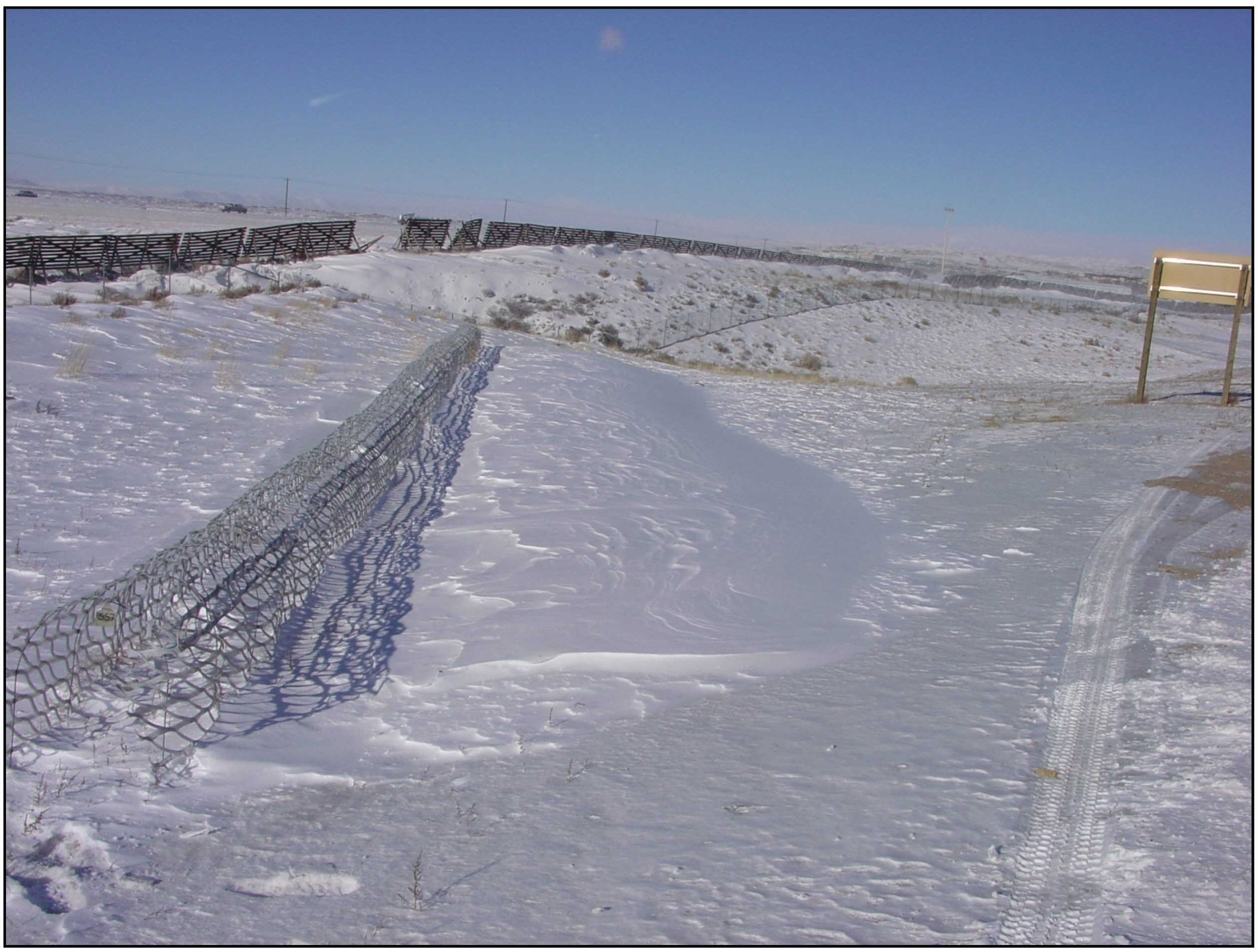


Figure 26 - Drift Behind Snow Snake SS 7 On 02/06/08

Table 3 - Area B Storage Summary

AREA B

12/31/2007

SNOW FENCE	SNOW STORAGE					WATER DETENTION	
	MEASURED	MELT	PREVIOUS	NEW		TO DATE	NEW
	(tons)	(tons)	(tons)	(tons)	(%)	(gallons)	(gallons)
SS 1	6.2	0.0	0.0	6.2	14.4%	1,486	1,486
SS 2	7.5	0.0	0.0	7.5	17.4%	1,798	1,798
SS 3*	7.1	0.0	0.0	7.1	16.4%	1,702	1,702
SS 4*	6.1	0.0	0.0	6.1	14.1%	1,462	1,462
SS 5	7.4	0.0	0.0	7.4	17.1%	1,774	1,774
SS 6	4.4	0.0	0.0	4.4	10.2%	1,055	1,055
SS 7*	4.5	0.0	0.0	4.5	10.4%	1,079	1,079
TOTALS	**43.2**	**0.0**	**0.0**	**43.2**	**100.0%**	**10,356**	**10,356**

1/11/2008

SNOW FENCE	SNOW STORAGE					WATER DETENTION	
	MEASURED	MELT	PREVIOUS	NEW		TO DATE	NEW
	(tons)	(tons)	(tons)	(tons)	(%)	(gallons)	(gallons)
SS 1	10.8	1.2	6.2	5.8	9.7%	2,877	1,391
SS 2	17.4	2.4	7.5	12.3	20.6%	4,747	2,949
SS 3*	16.5	1.8	7.1	11.2	18.8%	4,387	2,685
SS 4*	12.3	1.7	6.1	7.9	13.2%	3,356	1,894
SS 5	11.3	1.4	7.4	5.3	8.9%	3,045	1,271
SS 6	11.3	1.5	4.4	8.4	14.1%	3,069	2,014
SS 7*	11.6	1.7	4.5	8.8	14.7%	3,189	2,110
TOTALS	**91.2**	**11.7**	**43.2**	**59.7**	**100.0%**	**24,670**	**14,314**

2/6/2008

SNOW FENCE	SNOW STORAGE					WATER DETENTION	
	MEASURED	MELT	PREVIOUS	NEW		TO DATE	NEW
	(tons)	(tons)	(tons)	(tons)	(%)	(gallons)	(gallons)
SS 1	27.9	2.3	10.8	19.4	15.0%	7,528	4,651
SS 2	41.2	4.1	17.4	27.9	21.5%	11,436	6,689
SS 3*	37.8	5.6	16.5	26.9	20.8%	10,836	6,449
SS 4*	28.1	6.4	12.3	22.2	17.1%	8,678	5,322
SS 5	25.8	2.9	11.3	17.4	13.4%	7,217	4,172
SS 6	20.1	2.2	11.3	11.0	8.5%	5,706	2,637
SS 7*	14.8	1.5	11.6	4.7	3.6%	4,316	1,127
TOTALS	**195.7**	**25.0**	**91.2**	**129.5**	**100.0%**	**55,717**	**31,047**

Note:

* Denotes snow snakes without transects. The storage volumes were estimated by adjacent snow snakes. Estimated storage volumes were multiplied by the fence lengths to obtain storage values.

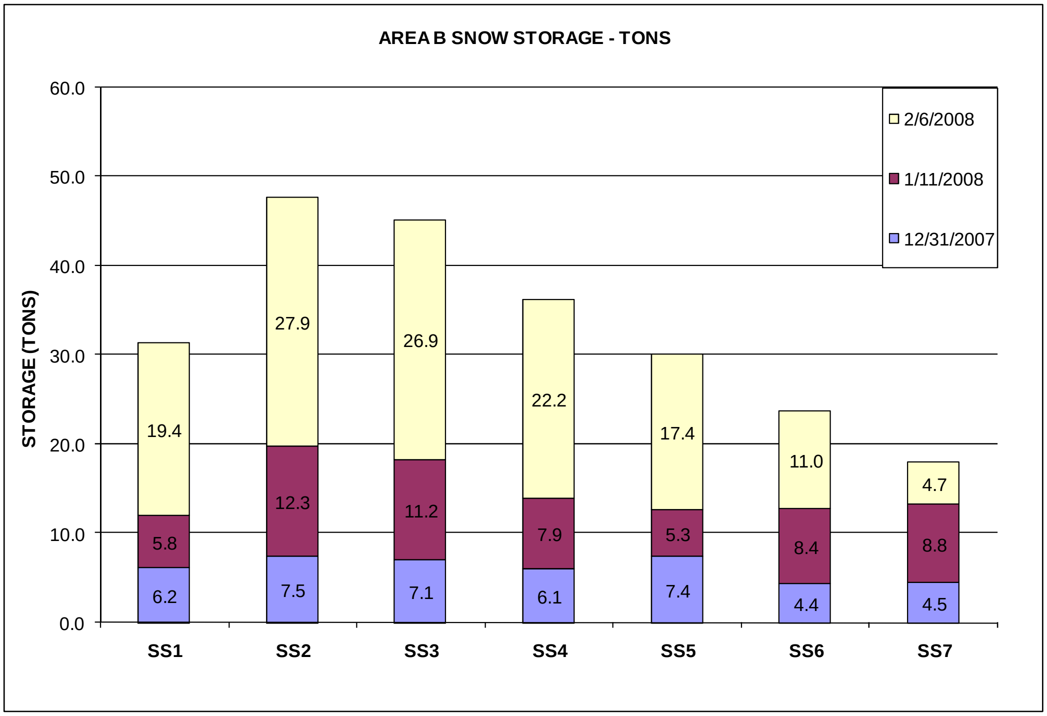


Figure 27 - Area B - Snow Storage Distribution

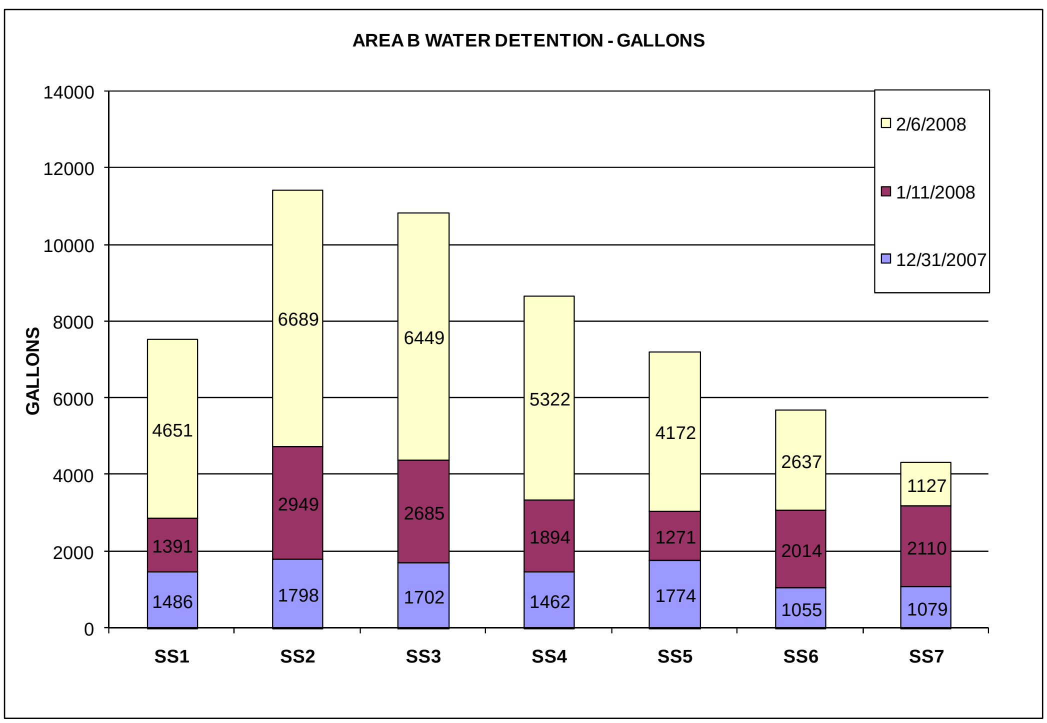


Figure 28 - Area B - Water Detention Distribution

4.2.3. AREA C

By December 31, 2008 in Area C, the seven Snow Snakes (SS 8 through SS 14) prevented a combined total of approximately 36 tons of blowing snow from crossing the roadway and detained over 8,600 gallons of water in snow pack. By January 11, 2008, the Snow Snakes prevented nearly 53 tons of new snow from crossing the roadway, and detained more than 12,600 gallons of additional water in the form of snow pack. By February 6, 2008, the same Snow Snakes prevented 176 tons of additional snow from crossing the roadway, approximately 42,300 gallons of additional water.

Overall, the Snow Snakes in Area C prevented nearly 266 tons of snow from crossing the roadway and detained nearly 63,700 gallons of water in snow pack. These results are shown in Table 4. A graphical distribution of the snow storage amounts for Area C is shown in Figure 30. A graphical distribution of water detained for Area C is shown in Figure 31.

Figure 29 - Drift Behind Snow Snake SS 13 On 02/06/08

Table 4 - Area C Storage Summary

AREA C

12/31/2007

SNOW FENCE	SNOW STORAGE					WATER DETENTION	
	MEASURED	MELT	PREVIOUS	STORAGE		TO DATE	NEW
	(tons)	(tons)	(tons)	(tons)	(%)	(gallons)	(gallons)
SS 8	5.7	0.0	0.0	5.7	15.8%	1,367	1,367
SS 9	5.5	0.0	0.0	5.5	15.2%	1,319	1,319
SS 10*	5.2	0.0	0.0	5.2	14.4%	1,247	1,247
SS 11*	4.7	0.0	0.0	4.7	13.0%	1,127	1,127
SS 12	6.6	0.0	0.0	6.6	18.3%	1,582	1,582
SS 13	5.7	0.0	0.0	5.7	15.8%	1,367	1,367
SS 14	2.7	0.0	0.0	2.7	7.5%	647	647
TOTALS	**36.1**	**0.0**	**0.0**	**36.1**	**100.0%**	**8,656**	**8,656**

1/11/2008

SNOW FENCE	SNOW STORAGE					WATER DETENTION	
	MEASURED	MELT	PREVIOUS	NEW STORAGE		TO DATE	NEW
	(tons)	(tons)	(tons)	(tons)	(%)	(gallons)	(gallons)
SS 8	11.0	1.8	5.7	7.1	13.4%	3,069	1,702
SS 9	11.0	1.5	5.5	7.0	13.2%	2,997	1,678
SS 10*	10.6	1.2	5.2	6.6	12.5%	2,829	1,582
SS 11*	10.1	0.9	4.7	6.3	11.9%	2,637	1,510
SS 12	14.7	2.4	6.6	10.5	19.8%	4,099	2,517
SS 13	12.3	2.0	5.7	8.6	16.3%	3,429	2,062
SS 14	8.0	1.5	2.7	6.8	12.9%	2,277	1,630
TOTALS	**77.7**	**11.3**	**36.1**	**52.9**	**100.0%**	**21,337**	**12,681**

2/6/2008

SNOW FENCE	SNOW STORAGE					WATER DETENTION	
	MEASURED	MELT	PREVIOUS	NEW STORAGE		TO DATE	NEW
	(tons)	(tons)	(tons)	(tons)	(%)	(gallons)	(gallons)
SS 8	24.5	3.2	11.0	16.7	9.5%	7,073	4,004
SS 9	41.6	2.3	11.0	32.9	18.6%	10,885	7,888
SS 10*	35.5	1.7	10.6	26.6	15.1%	9,206	6,377
SS 11*	29.0	0.5	10.1	19.4	11.0%	7,288	4,651
SS 12	34.7	4.1	14.7	24.1	13.7%	9,877	5,778
SS 13	34.5	3.7	12.3	25.9	14.7%	9,638	6,209
SS 14	36.2	2.7	8.0	30.9	17.5%	9,685	7,408
TOTALS	**236.0**	**18.2**	**77.7**	**176.5**	**100.0%**	**63,652**	**42,315**

Note:

* Denotes snow snakes without transects. The storage volumes were estimated by adjacent snow snakes. Estimated storage volumes were multiplied by the fence lengths to obtain storage values.

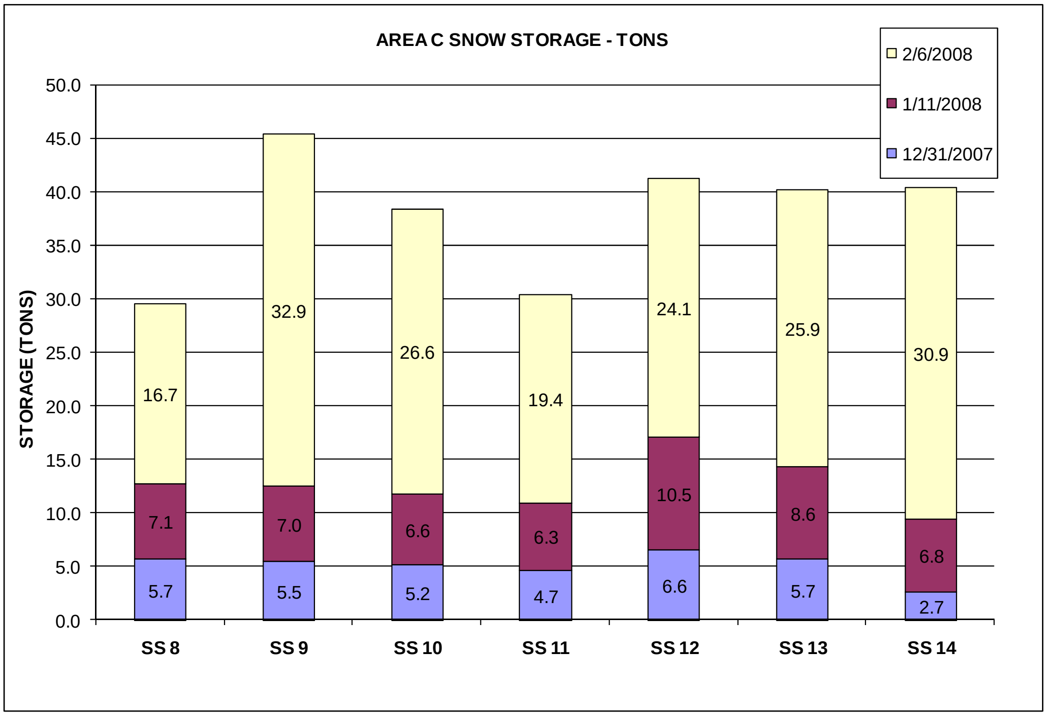


Figure 30 - Area C Snow Storage Distribution

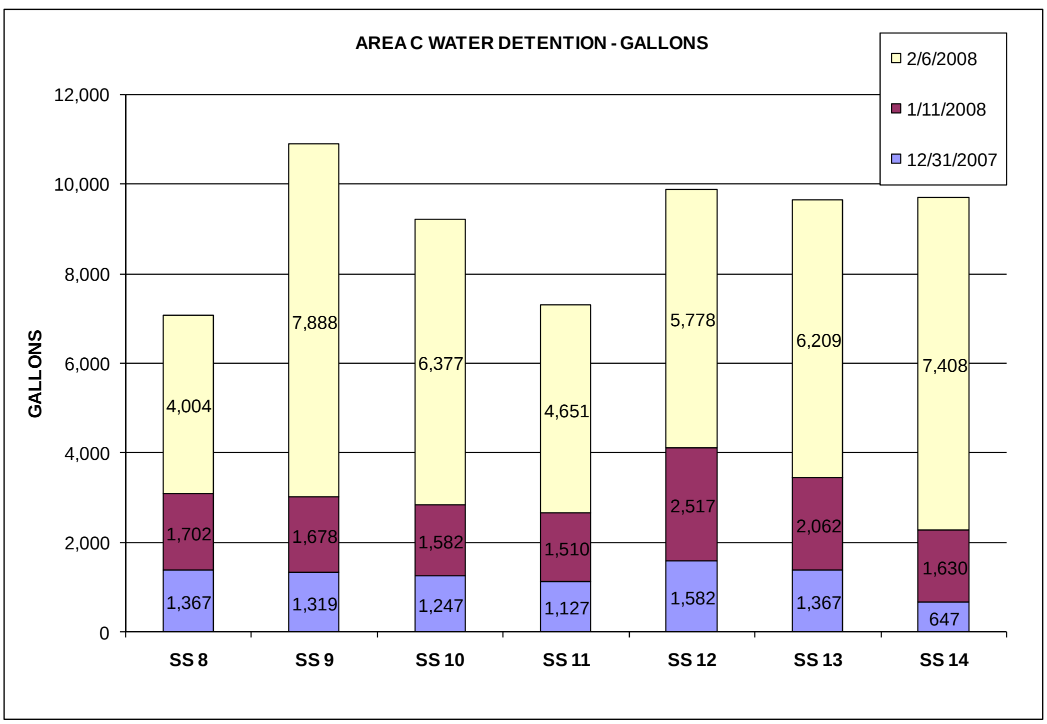


Figure 31 - Area C Water Detention Distribution

CHAPTER 5
CONCLUSIONS AND IMPLEMENTATION

5.1. ROADWAY PROTECTION

Mild winter conditions limited the opportunities for field observations. Three visits to the site provided sufficient information to verify the ability of Snow Snakes to trap blowing snow. However, not enough data was available to determine the effects of Snow Snakes on roadway temperatures in preventing road ice formation. Temperature profiles were run on the roadway during the January 11, 2008 and February 6, 2008 site visits; blowing snow was only present during the February 6, 2008 site visit. Insufficient field data prevented development of a valid correlation between roadway surface temperatures and the presence of Snow Snakes.

The study site is geometrically and topographically complex. The eastbound and westbound lanes are superelevated giving the sun a greater angle of incidence on the roadway increasing the amount of available solar radiant heat; the intersection ramps are not superelevated. The College Drive bridge and approach embankments are upwind of the study area and influence the wind and snow deposition patterns in the western end of the study area; two 4-ft vertical snow fences are also present which additionally affect wind and snow deposition patterns. The eastern portion of the study area is shadowed by an upwind 8-ft Wyoming type snow fence with some of the Snow Snakes located in a drainage channel and in a roadway cut section which affects wind and snow deposition patterns.

Obtaining conclusive evidence of the effectiveness of using Snow Snakes as a viable means to reduce road ice formed by blowing snow originating within the highway right-of-way will require additional study. If an additional study is conducted, it is recommended that a different study site be selected which is within the right-of-way on a geometrically simple section of road. This would reduce errant data due to terrain features and roadway geometries. Stripping vegetation in the study area and planting selected plant species in Snow Snake areas with control plots outside the snow snake protection but in similar terrain would provide more useful data. A north-south highway would be best for prevailing winds, and a location with higher snowfall averages would be beneficial.

5.1.1. SNOW STORAGE

The previously demonstrated ability of Snow Snakes to capture blowing snow (Tabler 2006) was verified during this study. Even during smaller precipitation events, snow drifts were obvious behind the Snow Snakes. During the 2007 – 2008 observation period, the Snow Snakes in Areas A, B, and C stored 124 tons, 232 tons, and 266 tons respectively, a combined total of nearly 622 tons of blowing snow.

5.2. REVEGETATION

5.2.1. WATER DETENTION

One of the advantages of snow fence is the ability to provide a source for water beyond the average snow melt. The drifts behind snow fences have a higher density than undrifted snow and provide a large localized volume of snow. When blanketed snow has already melted, drifts can provide a slow release of water that may encourage vegetation growth in newly seeded areas.

Figure 32 - Water Release From Snow Snake Drift

5.2.2. VEGETATION MONITORING

Vegetation at the site was evaluated by WYDOT Agronomist, John F. Sampson, M.S./ CCA. His Executive Summary, monitoring reports from September 2007 and July 2008 are included in Appendix A, B, and C respectively.

5.3. IMPLEMENTATION PLAN

The results of this study are inconclusive and do not warrant the development of an implementation plan.

APPENDIX A

Executive Summary, "Snow Snakes" Vegetative Performance

Material reprinted in Appendix A is as received from John F. Samson, Agronomist, Wyoming Department of Transportation

EXECUTIVE SUMMARY– "Snow Snakes" Vegetative Performance

Submitted by: John F. Samson, Agronomist, M.S.-CCA, WY Dept. Of Transportation (WYDOT)

Test sites were revegetated as part of WYDOT Project, I080-2(173), Rock Springs Marginal, July-November 2005 prior to structure installation. A standard High Desert seed mix utilizing native grasses, forbs and a shrub was drill seeded, fertilized and surface protected with crimped straw and organic tackifier into placed topsoil. Planned establishment period was four growing seasons(2006-2009) in this arid climate undergoing severe drought.

Growing Season Two, the initial monitoring conducted August 2007. The annual precipitation-to-date(7 mo.) was 4.8-inches(2007 NOAA data). The "snow snakes" were ineffective since very little moisture was received in form of snow, Winter 2006-7 to stockpile extra moisture leeward. Resulted in <5% seeded plant cover, ~35% weedy cover of kochia and halogeton helped protect seedbed from further soil evaporation and wind erosion.

Growing Season Three, follow-up monitoring repeated June 2008. Annual precipitation-to-date(6 mo.) was 4.0-inches(2008 NOAA data). Three significant snow storms Winter 2008 were transected by PMPC and later observed in vegetative emergence at 6-8(h) leeward of the "snow snakes" with little vegetative change further downwind. Within the moisture stockpile zone, seeded cover doubled to 10% and weedy cover dropped to ~20%, drill rows visible.

The Control Point graded cut slope(land shaping), no added structures, was the most effective treatment for snow storage and moisture retention(i.e., erosion blankets) given north facing solar aspect. Here established, seeded cover of 20% matched background rangeland cover with < 3% weedy cover after three growing seasons. Further work with "snow snakes" oriented with land shaping(rounded, variable graded slopes) and moisture retentive blankets are recommended under extreme Evapotranspiration(ET) climates.

APPENDIX B

"Sno-Snakes" Performance - Veg. Monitoring, September 2007

Material reprinted in Appendix B is as received from John F. Samson, Agronomist, Wyoming Department of Transportation

"SNO-SNAKES" PERFORMANCE - VEG. MONITORING
Rock Springs Marginal
Killpecker Creek Sec.
I080-02(173)

Date: 9-11-07

INTRODUCTION

Vegetation recovery was inspected 8/16/07 on I-80 Killpecker Ck. Section. Reclamation occurred July - November 2005 along this Section. Therefore, due to High Desert climate, the first growing season actually began June 2006 with vegetation monitoring at ~1.5 growing seasons. Historically, the current severe drought since 1999 has delayed native vegetation recovery to 3-4 growing seasons in this exceptional arid region. Rock Springs Airport, to-the-inspection date for 2007 currently at 4.88-inches annual precipitation(NOAA data). The 2006 total annual precipitation, measured 6.65-inches and 2005 total annual moisture totaled 8.49-inches with 5.04-inches of that occurring prior to seedbed preparation or just 3.45-inches following seedbed tillage in 2005. The Grand total precipitation since project seedbed tillage disturbance now stands at 14.98-inches over the past three years.

The annual mean annual Class A pan evaporation (wet soil) at Rock Springs Airport = 46.2-inches/yr. (J. Curtis & K. Grimes, WYO Climate Atlas, 2004) or since seedbed tillage potential total evaporation estimated at 92.4-inches. This means a running deficit of -77.42-inches since seedbed tillage on any bare soil(5X of the measured precipitation). This desert climate was mitigated somewhat, through use of mechanically crimped straw plus organic tackifer over flatter soils and the use of temporary straw blankets on steeper slopes to reduce potential surface evaporation. The August 2007 inspection found < 5% of original crimped straw cover remains at the Sno-Snake sites. Luckily, volunteer plant cover of kochia(*K. scoparia*) and halogeton(*H. glomeratus*) now occupy trial sites at ~ 35% cover level which serve to currently abate soil evaporation.

DATA COLLECTION

Plot #1A –
Hospital sign exit(MP 104.4, I-80 WBL) --
Windward of 30" sno-snake #SS-8: seeded plants +/- 5% grd. cover(< 0.5/LF drill row) = Ind. ricegrass + Bluebunch wheatgrass + Thickspike wheatgrass + globemallow @ trace; vol. plants = kochia 35% cover + halogeton 15% cover + Douglas rabbitbrush @ trace.
Note: Super-elevation runoff negative, away from WBL ditch & sno-snakes; Eastern-facing aspect.

Plot #1B –
Leeward & mid-point of 30" sno-snakes #SS-8 & #SS-9: seeded plants <1% grd. cover(<0.3/LF drill row) = Gardner saltbush + Ind. Ricegrass @ trace; vol. plants = kochia 20% cover + halogeton 5% cover.

<u>Plot #2A –</u>
College Drive Exit #103(MP 103.8, I-80 Int. NW quad) --
Leeward of Maintenance Guy type 4-foot plastic fence,#CTP-1: seeded plants +/- 10% grd. cover(2/LF drill row) = Thickspike wheatgrass + Ind. Ricegrass +Bluebunch wheatgrass + Sandberg bluegrass + Bottlebrush squirrel @ trace + Gardner saltbush @ trace; vol. plants = kochia 5% cover + halogeton 5% cover.
Note: flat graded topography.

<u>Plot #2B –</u>
Leeward & mid-point of 30" sno-snakes #SS1A & #SS2A: seeded plants <1% grd. cover(<0.2/LF drill row) = Ind. Ricegrass @ trace; vol. plants = halogeton 35% cover + Russian thistle 5% cover.

<u>Plot #2C –</u>
Maintenance Guy type slated 4-foot crib fence #VC-1. Note: no evaluation since very short run with different wind orientation and on-ramp interference than plastic fences, above. Revegetation trend more like #CTR-1 than 30" height fence.

<u>Plot #3(baseline control) –</u>
Elk Street Exit #104(MP 104.7, I-80 EBL) --
Leeward of north-facing 1:2 graded cut, mid-slope. No snow control structures: seeded plants 20% baseline grd. cover(3-4/SF) = Ind. Ricegrass + Bluebunch wheatgrass + Thickspike wheatgrass + Sandberg bluegrass + Garner saltbush; vol. plants = crested wheatgrass 5% + halogeton 5% cover + kochia 2% cover. Note: Erosion control blanket deteriorated(nets gone w/ +/- 2% straw cover remaining). No apparent gullies or rill runoff channels, no contour runoff diversion above the cut.

<u>COMMENTS</u>

* A majority of observed grass seedlings 2-leaf to 8" headed stage with majority 3-leaf. This would indicate germination Fall '06 and Spring '07 considering native species dormancy characteristics.

* Surface soils very dry at monitoring date(8/16/07). Annual kochia 4-6" height versus ditch run-in areas at +24" as indication of 2007 moisture stress. The high carbonate soils crusted at all observed locations.

* Expect another 1.5-2 growing season for all dormant seeded species to germinate, given severe drought in the Rock Springs area. The cover data collected so far is only preliminary estimate.

* Initial observation that the 30" Sno-snakes encourage sublimation(vaporization) of snow moisture instead of desired soil infiltration as documented with the higher WY board fences. This trend was represented by improved growth of seeded species leeward of the 4-foot plastic sno-fence(#CTP-1) on this project. Sublimation of winter snowfall is typical of Great Basin in Nevada versus the vivid contrast of surrounding wooded Foothills. A similar effect is visible in Green River Basin but maybe not as drastic in wet cycles.

* The control slope(i.e., without snow structures but with evaporation restriction using blankets, reduced solar aspect and graded runoff) demonstrated the validity of the actual revegetation protocol given a reduction of negative evapo-transpiration common to Green River Basin climate. It would be interesting to see how interaction of 30" Sno-snakes' shallow snow deposition could be conserved by use of leeward erosion control blankets or longer life composite turf reinforcement mats(C-TRM's). Thereby, improving revegetation potential, downwind, a technique successful on WYDOT Living Snow fences. Although, the living snow fence protocol calls for tightly woven geotextile which would inhibit grass and forb growth desired in this application. A C-TRM typical is bid item #216.03955-Coconut Ditch Liner for a more porous matrix function.

* Another potential explanation maybe that the Sno-snakes by encouraging water sublimation setup repeated wet-drying cycles that are known to induce repeat seed dormancy in species adapted to xeric zones. A physiological adaptation of desert species that enhances drought survival. If this is the case, time will tell in follow-up vegetation monitoring and hopefully, long-term average rainfall within this decade solving the delayed revegetation leeward of the Sno-snakes.

John F. Samson,
Agronomist, M.S./CCA
Environmental Services
(307)777-4416

Enc.
cc: Jim Montuoro, WYDOT Dist. Maint. Engr., Rk. Spgs.
Clint Lockman, WYDOT Resident Engr., Rk. Spgs.
Tim Stark, WYDOT Environ. Services Engr., Cheyenne
Cliff Spoonemore, WYDOT Blowing Snow Team Engr., Cheyenne
Jim Arnold, Forest Stewardship Specialist, WY State Forest, Cheyenne
Paul McCarthy, Principal, PMPC Consulting, Box 370, Saratoga, WY 82331

PHOTO #1
I080-2(173) Sno-snake Trial

August 16, 2007
Plot #1B, MP 104.4 WBL
Mid-point #SS-8 & 9 lower photo, stunted weeds, <1% grass

PHOTO #2
I080-2(173) Sno-snake Trial

August 16, 2007
Plot #1A, windward grass RH, stunted weeds LH of photo

PHOTO #3
I080-2(173) Sno-snake Trial

August 16, 2007
Plot #2A, MP 103.8, NW Quad
#CTP leeward grass growth

PHOTO #4
I080-2(173) Sno-snake Trial

August 16, 2007
Plot #2A, seeded grass in drill rows

PHOTO #5
I080-2(173) Sno-snake Trial

August 16, 2007
Plot #2B, MP 103.8, NW Quad
Mid-point #SS-1A & 2A photo RH, stunted weeds <1% grass

PHOTO #6
I080-2(173)

August 16, 2007
Plot #3, baseline grass cover 20%, 1:2 cut w/ erosion blanket

APPENDIX C

"Sno-Snakes" Performance - Veg. Monitoring Report, July 2008

Material reprinted in Appendix C is as received from John F. Samson, Agronomist, Wyoming Department of Transportation

"SNO-SNAKES" PERFORMANCE - VEG. MONITORING REPORT
Rock Springs Marginal
Killpecker Creek Sec.
I080-02(173)

Date: 7/22/08

INTRODUCTION

Vegetation recovery was again, re-inspected 6/25/08 on I-80 Killpecker Ck. Section, Rock Springs Marginal. Reclamation occurred July - November 2005 along this Section. Therefore, due to High Desert climate, the first growing season actually began June 2006 with second vegetation monitoring at ~2.2 growing seasons. Historically, the current severe drought since 1999 has delayed native vegetation recovery to 3-4 growing seasons in this exceptional arid region. Rock Springs Airport, to-the-inspection date for first half of 2008, currently at 3.95-inches annual precipitation(NOAA data). Total precipitation for 2007 was 9.16-inches. The 2006 total annual precipitation, measured 6.65-inches and 2005 total annual moisture totaled 8.49-inches with 5.04-inches of that occurring prior to seedbed preparation or just 3.45-inches following seedbed tillage in 2005. The Grand total precipitation since the project seedbed tillage disturbance now stands at 23.21-inches over the past four years.

The annual mean annual Class A pan evaporation (wet soil) at Rock Springs Airport = 46.2-inches/yr. (J. Curtis & K. Grimes, WYO Climate Atlas, 2004) or since seedbed tillage potential total evaporation estimated at 138.6-inches. This means a running deficit of -115.39-inches since seedbed tillage on bare soil(5X of any measured precipitation). This desert climate was mitigated somewhat, through use of mechanically crimped straw plus organic tackifer over flatter soils(location of Sno-snakes) and the use of temporary straw blankets on steeper slopes(baseline control plot) to reduce potential surface evaporation. The recent June 2008 inspection found < 3% of original crimped straw cover remains at the Sno-Snake sites. Luckily, volunteer plant cover of weedy kochia(*K. scoparia*) and halogeton(*H. glomeratus*) occupies trial sites at ~ 30% ground cover level which serves to currently reduce the intense soil evaporation.

DATA COLLECTION

Plot #1B –
Hospital sign exit(MP 104.4, I-80 WBL) --
Leeward & midpoint of 30" Sno-snake #SS-9: seeded plants +/- 10% grd. cover(one plant/LF drill row) = Sandberg bluegrass + Thickspike wheatgrass + Bluebunch wheatgrass + Globemallow + Ind. ricegrass & Gardner saltbush @ trace; vol. plants = kochia 20% veg. cover + halogeton 10% veg. cover + Cheatgrass 5% veg. cover + Douglas rabbitbrush & crested wheatgrass @ trace.
Note: Super-elevation runoff negative, away from WBL ditch & Sno-snakes; slight Eastern-facing aspect.

Plot #1C –
Leeward & midpoint of 30" sno-snake #SS-6: seeded plants +/-10% grd. cover(1.5 plants/LF drill row) = Sandberg bluegrass + Thickspike wheatgrass + Bluebunch wheatgrass + Ind. Ricegrass + Globemallow + Gardner saltbush @ trace; vol. plants = kochia 15% veg. cover + halogeton & cheatgrass & crested wheatgrass @ trace.
Note: Normal two lane 2% crown, fore slope runoff location, slight west facing aspect.

Plot #2A –
College Drive Exit #103(MP 103.8, I-80 Int. NW quad) --
Leeward of Maintenance Guy type 4-foot plastic fence, #CTP-1: seeded plants +/- 10% grd. cover(1.5 plants/LF drill row) = Sandberg bluegrass + Thickspike wheatgrass + Bluebunch wheatgrass + Globemallow + Ind. Ricegrass + Gardner saltbush; vol. plants = kochia 10% veg. cover + halogeton 5% veg. cover + cheatgrass & crested wheatgrass @ trace.
Note: Flat graded topography, slight north facing aspect.

Plot #2B –
Leeward & midpoint of 30" sno-snake #SS1A: seeded plants <1% grd. cover(<0.2/LF drill row) = Ind. Ricegrass @ trace; vol. plants = halogeton 35% cover + Russian thistle 5% cover.
Note: No change from 2007.

Plot #2C –
Maintenance Guy type slated 4-foot crib fence #VC-1. Note: no evaluation since very short run with different wind orientation and on-ramp interference than plastic fences, above. Mature Douglas rabbitbrush and sagebrush, only partially seeded. Good response from existing wheatgrasses.

Plot #3(baseline control) –
Elk Street Exit #104(MP 104.8, I-80 EBL) --
Leeward of north-facing 1:2.5 graded cut, mid-slope. No snow control(storage) structures, just land shaping & surface protection(water conservation): seeded plants 20% baseline grd. cover(3 plants/SF broadcast method) = Thickspike wheatgrass + Sandberg bluegrass + Bluebunch wheatgrass + Ind. ricegrass; vol. plants = crested wheatgrass @ trace. Note: Erosion control blanket deteriorated(nets gone with +/- 2% straw cover remaining), no apparent gullies or rill runoff channels, no contour runoff diversion above the cut.

DISCUSSION

* Expect another 0.8-1 additional growing season for all dormant seeded species to germinate, given continuing & predicted long term severe drought(NOAA July, 2008) in the Rock Springs area. The cover data collected so far are only midpoint estimates of native species planted.

* My initial 2007 observation that the 30" Sno-snakes encourage sublimation (vaporization) of snow moisture instead of desired soil infiltration. This is tempered somewhat

by PMPC snow drift cross-sections of three storms, Winter 2007-8. The snow profile of later 2/8/08 storm leeward of #SS-8 at maximum peak ~20 ft. downwind, 8-h (PMPC Transect 4). The vegetation response(Photo #1) 6/25/08 demonstrates growth response with plot 15 ft. leeward(with range pole).

The prior storm(1/11/08) provided ~2" depth spread across the entire area with less wind. The 12/31/07 storm dropped ~1" depth with minimal peaking. It is surmised that majority of these two storm amounts were lost to atmospheric evaporation due to low humidity and frozen soil. Photo #1 shows very poor vegetative response in non-peaked zone past 20-25 ft. downwind.

Similarly, PMPC Transect 3 cross-sections of #SS-6 leeward(Plot #1C) show vegetative response to 2/8/08 storm peak of ~ 15 ft. downwind(6-h). Reduced vegetative growth further downwind (Photos not attached).

PMPC Transect 1 of 2/8/08 storm show's maximum peak leeward of #CTP-1 of ~35 ft. downwind(8.8-h). The vegetative response(Photo #3) at about this extent. Plot #2A(with range pole) is 25 ft. leeward. The low production storms 1/11/08 & 12/31/07 provided 2-3" depth levels past 35 ft. leeward also thought lost to sublimation from poor vegetative response.

* The baseline control slope(i.e., without snow structures but with evaporation restriction using blankets, reduced solar aspect and land shaping validates the actual revegetation protocol given a reduction of negative evapo-transpiration common to Green River Basin climate(See attached Photo #6). I recommend 30" Sno-snakes' shallow snow deposition moisture conserved more by use of leeward 16-feet wide erosion control blankets or longer life composite turf reinforcement mats(C-TRM's). Thereby, improving revegetation potential, downwind, a technique successful on WYDOT Living Snow fences. A new Living Snowfence was recently installed on Dewar Drive Interchange, MP 102.4 using both land shaping(berms) plus tree height = (h) and Living sno-snakes(e.g.. native four-wing saltbush and rabbitbrush) to aid tree survival.

* The baseline control plot demonstrates potential for more work on land shaping to reduce solar heating impacts like "broken back" cut slope grades or slope rounding/warping like at Elk Street Interchange cuts. The use of 4-foot slatted snow fence or contour diversions 'top-of-cut" another approach to peak snow depositions downwind of prevailing winds. Storage of winter moisture thru use of erosion control blankets proven in number of arid, western U.S. studies and construction projects including WYDOT's.

John F. Samson,
Agronomist, M.S./CCA
Environmental Services
(307)777-4416

Enc.

cc: Jim Montuoro, WYDOT Dist. Maint. Engr., Rock Spgs.
Clint Lockman, WYDOT Resident Engr., Rock Spgs.
Tim Stark, WYDOT Environ. Services Engr., Cheyenne

Cliff Spoonemore, WYDOT Blowing Snow Team Engr., Cheyenne
John Crisp, Resource Forester, WY State Forest, Cheyenne
Paul McCarthy, President, PMPC Consulting, Box 370, Saratoga, WY 82331

RECEIVED
JUL 24 2008
RECEIVED

PHOTO #1
I080-2(173) Sno-Snake Trial
June 25, 2008
Plot #1-B, MP 104.4 WBL
Mid-point #SS-9 & 10, RH, 10% seeded cover

PHOTO #2
I080-2(173) Sno-Snake Trial
June 25, 2008
Plot #1-B, mid-point leeward @ 1seeded plant/LF row

PHOTO #3
I080-2(173) Sno-Snake Trial
June 25, 2008
Plot 2-A, MP 103.8, NW Quad
#CTP-1 leeward , 10% seeded cover

PHOTO #4
I080-2(173) Sno-Snake Trial
June 25, 2008
Plot #2-A, leeward @ 1.5 seeded plants/LF row

PHOTO #5
I080-2(173) Sno-Snake Trial
June 25,2008
#CTP-1 windward LH stand vs. leeward stand RH

PHOTO #6
I080-2(173), MP 104.8 EBL
June 25, 2008
Plot #3, baseline, NW 1:2.5 cut w/ erosion blkt., seeded cover 20%

BIBLIOGRAPHY

David, Erica. *The "Hollow Frame Fence" - Year 7.* (307) 537-5666 : Pinedale High School.

Peter D. Stahl and Justin. Shirley, 2002. *Ecological Assessment and Evaluation of Snowfence Areas and Snowfence Mitigations.* Wyoming Department of Transportation, 2002.

R. D. Tabler and R. L. Jairell, 1980. *Studying snowdrifting problems with smale-scale models outdoors.* Western Snow Conference (Laramie, Wyo.; April 15-17, 1980) Proceedings 48:1-13, 1980.

Ronald D. Tabler, Ph.D. 1985. *Ablation rates of snow fence drifts at 2300-meters elevation in Wyoming.* Western Snow Conference (Boulder, Colo.; April 16-18, 1985) Proceedings 53: 1-12, 1985.

—. 2003. *Controlling Blowing and Drifting Snow with Snow Fences and Road Design.* National Cooperative Highway Research Program Transportation Research Board of the National Academies, 2003.

—. 2006. *Three-Dimensional Roughness Elements for Snow Retention.* Wyoming Department of Transportation, 2006.