HIGH ALTITUDE REVEGETATION TEST PLOTS ON THE BEARTOOTH PLATEAU

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The Federal Highway Administration (FHWA) is proposing to reconstruct a portion of the Beartooth Highway in Wyoming. During this process, FHWA identified revegetation as a major concern. As a result, the FHWA is investigating revegetation techniques for use in alpine portions of the Beartooth Plateau. The Beartooth Highway traverses a spectacular alpine plateau in the Shoshone National Forest near the Northeast entrance to Yellowstone National Park. FHWA strives to preserve the pristine nature of this area and to pioneer technology for revegetation of potential impacts along the highway using the best revegetation techniques available.

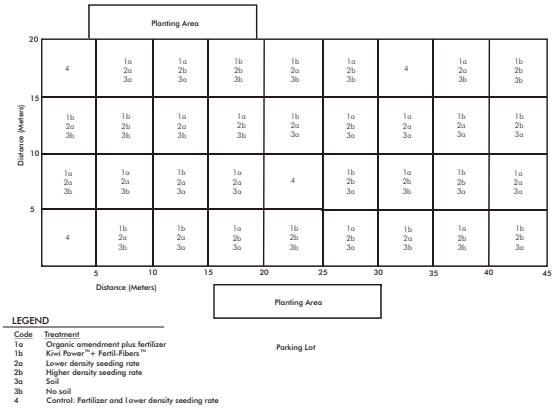
The FHWA is conducting revegetation tests on the Beartooth Plateau to assist in evaluating relative effectiveness of different revegetation techniques along U.S. 212, the Beartooth Highway. The road traverses alpine areas of the Beartooth Plateau between Red Lodge and Cooke City, Montana, near the northeast entrance to Yellowstone National Park. ERO Resources Corporation (ERO) is conducting the revegetation tests for FHWA. Revegetation tests have been conducted over 3 years to identify revegetation techniques applicable for revegetating alpine areas. This paper presents the findings of the first year of annual monitoring on these test plots.

In September 1999, ERO placed revegetation tests plots in an existing gravel borrow area along the Beartooth Highway. The test plots were designed based on studies of revegetated disturbances in Rocky Mountain alpine environments. Three variables were tested: soil salvaging, seeding rates, and soil amendments. Additional revegetation test areas were created to determine the feasibility and cost effectiveness of planting greenhouse-grown seedling plant materials from locally collected seed. Native seed was collected on the Plateau and used for direct seeding of the revegetation test plots and for production of plant materials. ERO completed statistical analysis on the fall 2000 monitoring data, and is analyzing the fall 2001 monitoring data. Monitoring data included vegetation cover, species richness, and soil nutrients. Monitoring data for 2001 also includes soil moisture.

Results are preliminary because only the first year's data has been analyzed statistically. From the analysis of the first year's data, it appears that vegetation cover was higher on plots where organic amendments were used. There was no apparent effect of seeding density, and the effect of topsoil was not apparent.

Three variables were tested on the revegetation test plots-

- Topsoil salvaging (S) versus no topsoil (N)
- Lower seeding rate (L) versus higher seeding rate (H)
- Organic amendments plus fertilizer (O) versus surface application of Kiwi Power™ and Fertil-Fibers NutriMulch™ (K)



Wind River Seed of Manderson, Wyoming, collected seed from the Beartooth Plateau for the revegetation test plots.

Scientific Name	Common Name
Deschampsia caespitosa	Tufted hairgrass
Poa alpina	Alpine bluegrass
Phleum alpinum	Alpine timothy
Festuca ovina	Sheep fescue
Trisetum spicatum	Spike trisetum
Antennaria lanata	Wooly pussytoes
Artemisia scopulorum	Rocky Mountain sage
Lupinus argentea	Lupine
	Total

Native species used to seed revegetation test plots

Revegetation test plots in September 2000, after one growing season.

Revegetation test plots in September 2001, after two growing seasons.

The Beartooth Plateau contains the largest area above timberline in the continental U.S. There is a rich tradition of the study of vegetation, wildlife, and revegetation on the Beartooth Plateau.

Arrowhead Reclamation of Whitehall, MT, installed all of the revegetation test plots in the fall of 1999.

Scientific Name	Common Name
Grasses and Sedges	
Carex paysonis	Payson's sedge
Carex scirpoidea	Downy sedge
Deschampsia caespitosa	Tufted hairgrass
Festuca ovina	Sheep fescue
Phleum alpinum	Alpine timothy
Poa alpina	Alpine bluegrass
Trisetum spicatum	Spike trisetum
	Total Grass Survival
Forbs	
Antennaria lanata	Woolly pussytoes
Artemesia scopulorum	Rocky Mountain sage
Geum rossii	Alpine avens
Lupinus argenteus	Silvery lupine
Sibbaldia procumbens	Sibbaldia
Trifolium parryii	Parry's clover
	Total Forb Survival
	Total

Transplant species planted in planting areas.

Bitterroot Restoration of Corvallis, Montana grew transplants from seed collected from the Beartooth Plateau by Wind River Seed. Transplants were placed in planting areas in the fall of 1999.

Plots were treated with Big Butte compost (dark brown), topsoil (medium brown), and subsoil (light brown).

Transplants were planted by cutting holes in the erosion control blanket.

Kiwi Power™ was applied to the revegetation test plots.

Planting test plots in September 2000, after one growing season.

Following incorporation of soil amendments and seeding, a 70:30 straw:coconut fiber erosion control blanket was placed on the revegetation test plots.

Planting test plots in September 2001, after two growing seasons.

Vegetation cover analysis: all treatment

Treatment (Mean % Vegetation Cover)	C	KLS	KHS	KLN	KHN	OLS	OHS	OLN	OHN
C (14.55%)				Y	Y	Y	Y		
KLS (17.75%)							Y		
KHS (17.15%)							Y		
KLN (22.05%)	Y								
KHN (21.45%)	Y								
OLS (21.80%)	Y								
OHS (23.50%)	Y	Y	Y						
OLN (18.85%)									
OHN (19.20%)									

Y = significant difference (P=0.05)

Vegetation cover analysis: groped by soil treatments.

Treatment (Median % Vegetation Cover)	C	S	N
C (15.50%)		Y	Y
S (19.00%)	Y		
N (20.00%)	Y		

Y = significant difference (P=0.05)

Vegetation cover analysis: grouped by organic amendment treatments.

Treatment (Median % Vegetation Cover)	C	K	O
C (15.50%)		Y	Y
K (18.50%)	Y		
O (20.00%)	Y		

Y = significant difference (P=0.05)

Vegetation cover analysis: grouped by seeding treatments.

Treatment (Median % Vegetation Cover)	C	L	H
C (15.50%)		Y	Y
L (19.00%)	Y		
H (20.00%)	Y		

Y = significant difference (P=0.05)

Soil laboratory analysis: organic matter

Treatment (Mean % Organic Matter)	C	KLS	KHS	KLN	KHN	OLS	OHS	OLN	OHN
C (3.38%)		Y	Y			Y		Y	Y
KLS (7.78%)	Y			Y	Y				
KHS (6.98%)	Y			Y	Y				
KLN (3.15%)		Y	Y			Y		Y	Y
KHN (3.40%)		Y	Y			Y		Y	Y
OLS (6.63%)	Y			Y	Y				
OHS (5.5%)									
OLN (8.00%)	Y			Y	Y				
OHN (6.05%)	Y			Y	Y				

Y = significant difference (P=0.05)

Soil laboratory analysis and vegetation cover.

Treatment	Veg. Cover (Mean %)	OM (Mean %)	NO3 ppm*	K (Median ppm)	P (Median ppm)
C	14.6	3.4	19.3	381.3	33.4
KLS	17.8	7.8	241.5	273.5	8.8
KHS	17.2	7.0	214.0	255.5	6.8
KLN	22.1	3.2	38.5	253.0	27.8
KHN	19.1	3.4	11.8	276.3	12.2
OLS	18.7	6.6	87	670.8	74.0
OHS	23.5	5.5	187.5	845.5	78.0
OLN	18.9	8.0	48.2	866.8	130.0
OHN	21.5	6.1	119.5	879.5	132.0

*The laboratory results for nitrates varied widely and may not be accurate.

Further testing may yield more accurate results.

Soil laboratory analysis: phosphorous.

Treatment (Median ppm Phosphorous)	C	KLS	KHS	KLN	KHN	OLS	OHS	OLN	OHN
C (33.40)									
KLS (8.75)								Y	Y
KHS (6.80)								Y	Y
KLN (27.75)									
KHN (12.20)									
OLS (74.00)									
OHS (78.00)									
OLN (130.00)		Y	Y						
OHN (132.00)		Y	Y						

Y = significant difference (P=0.05)

Soil laboratory analysis: potassium.

Treatment (Median ppm Potassium)	C	KLS	KHS	KLN	KHN	OLS	OHS	OLN	OHN
C (381.25)						Y	Y	Y	Y
KLS (273.50)									
KHS (255.50)						Y	Y	Y	Y
KLN (253.00)						Y	Y	Y	Y
KHN (276.25)						Y	Y	Y	Y
OLS (670.75)	Y		Y	Y	Y				
OHS (845.50)	Y		Y	Y	Y				
OLN (866.75)	Y		Y	Y	Y				
OHN (879.50)	Y		Y	Y	Y				

Y = significant difference (P=0.05)

Percent survival in planting area 1 (north of revegetation plots, south-facing slope).

Scientific Name	Common Name	No. Planted	No. Live*	% Survival
	Grasses and Sedges			
Carex paysonis	Payson's sedge	20	4	20
Carex scirpoidea	Downy sedge	17	13	76
Deschampsia caespitosa	Tufted hairgrass	20	20	100
Festuca ovina	Sheep fescue	20	14	70
Phleum alpinum	Alpine timothy	20	10	50
Poa alpina	Alpine bluegrass	20	15	75
Trisetum spicatum	Spike trisetum	20	6	30
	Total Grass Survival	**137**	**82**	**60**
	Forbs			
Antennaria lanata	Woolly pussytoes	20	2	10
Artemesia scopulorum	Rocky Mountain sage	20	5	25
Geum rossii	Alpine avens	20	5	25
Lupinus argenteus	Silvery lupine	20	4	20
Sibbaldia procumbens	Sibbaldia	20	8	40
Trifolium parryii	Parry's clover	20	3	15
	Total Forb Survival	**120**	**27**	**23**
	Total	**257**	**109**	**42**

*Note: Because most grass and sedge species did not produce seed heads in 2000, differentiation between species was difficult, especially in the case of *C. scirpoidea* and *C. paysonis.*

Percent survival in planting area 2 (south of revegetation plots, north-facing slope).

Scientific Name	Common Name	No. Planted	No. Live*	% Survival
	Grasses and Sedges			
Carex paysonis	Payson's sedge	20	7	35
Carex scirpoidea	Downy sedge	18	17	94
Deschampsia caespitosa	Tufted hairgrass	20	20	100
Festuca ovina	Sheep fescue	20	17	85
Phleum alpinum	Alpine timothy	20	16	80
Poa alpina	Alpine bluegrass	20	18	90
Trisetum spicatum	Spike trisetum	20	5	25
	Total Grass Survival	**138**	**100**	**72**
	Forbs			
Antennaria lanata	Woolly pussytoes	20	5	25
Artemesia scopulorum	Rocky Mountain sage	20	6	30
Geum rossii	Alpine avens	20	8	40
Lupinus argenteus	Silvery lupine	20	3	15
Sibbaldia procumbens	Sibbaldia	20	16	80
Trifolium parryii	Parry's clover	20	3	15
	Total Forb Survival	120	41	34
	Total	**258**	**141**	**55**

*Note: Because most grass and sedge species did not produce seed heads in 2000, differentiation between species was difficult, especially in the case of *C. scirpoidea* and *C. paysonis.*

Conclusions

Vegetation Cover Analyses

The ANOVA on all treatments revealed that there half of the experimental treatments yielded higher vegetation cover than the control plots, but the ANOVA did not show any conclusions about which organic amendment, soil, or seeding treatment yielded higher cover. Because 2000 was only the first year of monitoring, the results only indicate the germination and emergence success of the plots. Revegetation generally takes from 3 to 5 years, so the effects of the treatments may not be evident for a few more years. Also, the lack of statistical differences detected by this ANOVA could be related experimental variability. For example, there may be experimental variability related to the site topography or microsites created by rocks and general drainage patterns. Seven plots apparently held more moisture than other plots (Plot 3-OHS, 4-KHN, 5-KLN, 17-KLS, 23-C, 32-KHN, and 34-KHN).

Vegetation cover data were analyzed according to only one treatment (soil treatment, organic amendment treatment, or seed treatment) to test the effect of the one treatment. The results showed that plots with any organic or soil treatment had statistically higher vegetation cover than the control plots (to which fertilizer and seed, at the lower seeding rate, were applied).

Soil Treatments. There was no statistically significant difference in vegetation cover between the plots treated with topsoil than those that were not. Plots treated with organic matter and those treated with Kiwi™ products had statistically higher vegetation cover than the control plots.

Organic Amendment Treatments. When vegetation cover data were analyzed according to organic amendment treatment, the plots treated with organic matter had significantly higher vegetation cover than those treated with Kiwi™ products. Plots treated with Kiwi™ products had significantly higher vegetation cover than control plots.

Seeding Rate Treatments. There was no significant effect of seeding rate, which probably indicates that a lower seeding rate is sufficient. The lower rate used on the plots is representative of a standard seeding rate used in reclamation. Alpine revegetation researchers, however, have speculated that higher seeding rates may be appropriate in revegetating alpine disturbances where extreme environmental conditions are limiting to vegetation establishment, and plant competition may be a less important variable. However, there may be a threshold beyond which higher seeding rates have diminishing returns and beyond which competition increases, potentially lowering diversity.

Soil Laboratory Analyses

Organic Matter. Topsoil and organic material (compost) are important sources of organic matter. Because organic matter is known to reduce bulk density and increase available water holding capacity, treatments that increase percent organic matter may be important for increasing soil moisture content. The soil moisture tests that will be analyzed in future monitoring will examine this. The topsoil used in this experiment was obtained from a borrow site about 100 meters (300 feet) south of the revegetation test plots. This topsoil was probably higher in organic matter and nutrients than most topsoil sources on the Beartooth Highway. Topsoil sampling throughout the study area was conducted in 2001, and the depth and quality of this topsoil borrow source is probably superior to the depths and quality of topsoil available on the Beartooth Highway (ERO 2001).

Phosphorous. The data regarding phosphorous are difficult to interpret. Plots to which Kiwi™ products were applied along with topsoil had significantly lower phosphorous than those where organic material was applied to plots without topsoil.

Potassium. Potassium was higher on plots with organic matter, regardless of topsoil treatment. The plots with the lowest potassium concentrations were plots to which Kiwi™ products and topsoil were applied. Lower levels of both phosphorous and potassium were found on plots with Kiwi™ products and topsoil. It is possible that the microbes present in the Kiwi™ products deplete these nutrients from topsoil; however, the microbes potentially also deplete phosphorous and potassium from plots on which topsoil was not applied.

Apparent Soil Moisture

Several plots appeared to retain more moisture than others. The plots that retained moisture had significantly higher vegetation cover than the others. This demonstrates that available water is potentially more important than any soil amendment, topsoil salvaging, or seeding rate. While it is not practical to irrigate disturbances at this elevation, water appears to be the limiting factor in establishing vegetation in these revegetation plots, and surface mulches and organic amendments that retain soil moisture may be important in alpine areas.

Transplant Survival

On the south-facing test plot, 60% of the grass plugs planted survived, 23% of the forbs survived, and a total of 42% of the transplants survived. On the north-facing slope, 72% of the grass plugs planted survived, 34% of the forbs planted survived, and a total of 55% of the transplants survived the first growing season. These results are preliminary, and much higher success was recorded during fall 2001 monitoring.

Species Richness

There was no significant treatment effect on species richness. This may be due to the limited number of species capable of colonizing the plots or because of the high variability within treatments.