

PHYTOSTABILIZATION STUDIES AT THE KEATING TAILINGS SITE

2005 REPORT

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TABLE OF CONTENTS

	Page
INTRODUCTION.....	1
General Comments Regarding the Site in July 2005	1
Canopy Cover	2
Species List	2
Rooting Patterns	3
Treated Tailings Plots.....	3
Un-Treated Tailings Plot.....	6
Above Ground Biomass	6
Metal Levels in Vegetation	6
Arsenic in Vegetation	7
Cadmium in Vegetation	9
Lead in Vegetation	9
Copper in Vegetation.....	9
Zinc in Vegetation.....	9
Mercury in Vegetation	10
REFERENCES CITED	10
APPENDIX A – Selected Images	11
APPENDIX B – Canopy Cover of Vegetation.....	16
APPENDIX C – Above Ground Biomass.....	29
APPENDIX D – Arsenic and Metal Levels in Vegetation.....	34

LIST OF FIGURES

	Page
Figure 1. Mean percent canopy cover of live vegetation in 2005	3
Figure 2. Mean aboveground biomass of vegetation in 2005.	7
Figure 3. Mean concentrations of arsenic, cadmium, and lead in grass samples	8
Figure 4. Mean concentrations of copper and zinc in grass samples.....	8

LIST OF IMAGES

	Page
Image A-1. Overview of experimental plots on Keating Tailings, July 6, 2005	12
Image A-2. The treated tailings plots.....	12
Image A-3. Treated plot with yarrow in flower along the plot edge and the stand Dominated by the seeded wheatgrasses	13
Image A-4. Un-treated (control) tailings plots	13
Image A-5. Off-site experimental plots on native soils.....	14
Image A-6. Treated tailings pit face and roots sprayed with Hellige pH indicator solution	14
Image A-7. Un-treated (control) pit face and roots sprayed with Hellige pH indicator Solution.....	15

LIST OF TABLES

		Page
Table 1.	Species occurring on each experimental plot – Keating Tailings Project 2005.....	4
Table B-1.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 1: Off site native range site	17
Table B-2.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 2: Off site native range site	18
Table B-3.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 3: Off site native range site	19
Table B-4.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 4: Off site native range site	20
Table B-5.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 5: On site treated with lime and organic matter	21
Table B-6.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 6: On site treated with lime and organic matter	22
Table B-7.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 7: On site control.....	23
Table B-8.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 8: On site control.....	24
Table B-9.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 9: On site treated with lime and organic matter.....	25
Table B-10.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 10: On site control.....	26
Table B-11.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 11: On site treated with lime and organic matter.....	27
Table B-12.	Vegetation cover at Keating Tailings, July 7, 2005 – Plot 12: On site control.....	28
Table C-1.	Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 1: Off site native range site.....	31

LIST OF TABLES - Continued

	Page
Table C-2. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 2: Off site native range site.	30
Table C-3. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 3: Off site native range site.	30
Table C-4. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 4: Off site native range site.	31
Table C-5. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 5: On site treated with lime and organic matter.....	31
Table C-6. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 6: On site treated with lime and organic matter.....	31
Table C-7. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 7: On site control.....	32
Table C-8. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 8: On site control.....	32
Table C-9. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 9: On site treated with lime and organic matter.....	32
Table C-10. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 10: On site control.....	32
Table C-11. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 11: On site treated with lime and organic matter.....	33
Table C-12. Vegetation above ground biomass at Keating Tailings, July 7, 2005–Plot 12: On site control.....	33
Table D-1. Arsenic and metal levels in vegetation collected from experimental plots at Keating Tailings, July 7, 2005	35

INTRODUCTION

The Keating Tailings site is located in Broadwater County, Montana on land administered by the Bureau of Land Management. These low pH (4 standard units) wastes resulting from historic gold and copper mining operations contain phytotoxic levels of several metals and are generally devoid of vegetation. With an estimated volume of 110,100 m³, these tailings represent unacceptable risk to the environment and human health.

The objective of conducting a phytostabilization study at the Keating Tailings Site was to provide BLM managers and decision makers with site specific information and data relating to the implementation, and effectiveness of phytostabilization so that it may be applied to other similar acid metalliferous mine tailings sites administered by the Bureau. In 2003, replicated experimental plots were implemented using soil amendments, lime and organic matter, designed to ameliorate the plant inhibiting chemical characteristics of the tailings. The plots were seeded with a mix of indigenous native plant species. Vegetation performance of plants grown in the amended or phytostabilized tailings was compared to results for plants seeded into tailings that were not amended, and performance of plants seeded in an adjacent off-site, but non-impacted area.

Response variables evaluated in the first growing season, 2004, included emergence and establishment, density, and canopy cover. Concentrations of metals in vegetation were evaluated in terms of plant sufficiency/excess, and in terms of maximum allowable dietary levels for cattle. Changes in soil rootzone pH, conductivity, and soluble metal concentrations before and after treatment were also determined. Results for these data were presented by Neuman et al. (2005).

In July 2005, the vegetation growing on the twelve experimental plots at the Keating Tailings Pond was evaluated. Canopy cover by species within each plot was determined using the Daubenmire's cover class method. Samples of above ground plant material were collected by clipping, drying and weighing. Rooting patterns were evaluated by developing excavation pits with selected plots. Digital images were collected, and field notes were written. Samples of dried vegetation were submitted to BLM for determinations of metal (cadmium, copper, lead, mercury, and zinc) and arsenic concentrations. This 2005 Report is a summary and interpretation of the collected data.

General Comments Regarding the Site in July 2005

Heavy spring rains in 2005 stimulated excellent plant growth on the treated tailings plots (refer to Images A-1 & A-2 in Appendix A). Slender (*Agropyron trachycaulum*) and Western (*Agropyron smithii*) wheatgrasses were approximately 48" tall (Image A-3). All seeded species, except American vetch (*Vicia Americana*) were found on all of the treated plots. The vetch was noticeably absent and occurred as an

incidental species in one treated plot. Several non-seeded plant species have established in the treated plots.

The on-site untreated tailings plots (controls) had sparse vegetation (Image A-4) limited to three of the seeded species, Western wheatgrass, Slender wheatgrass, and Big bluegrass (*Poa ampla*).

Evidence of rodent activity, most likely meadow voles (*Microtus pennsylvanicus*) and/or white footed deer mice (*Peromyscus maniculatus*), was present in the treated tailings plots, but not on the control plots.

The off-site plots developed on native soils supported very good plant growth (Image A-5). Many species were present that were not in the seed mix, but the plots were dominated by Slender wheatgrass. Many other native species were also present.

Yellow sweetclover (*Melilotus officinalis*) was very prevalent on the surrounding hillsides (Image A-1), but absent from all experimental plots. Images obtained during the July field trip are exhibited in Appendix A.

Canopy Cover

Canopy cover by plant species was estimated using Daubenmire's cover class method (Daubenmire 1959). Five 20 x 50 cm frames were placed along a diagonal transect on each plot. Cover class for each individual species within the frame was recorded. The complete data set is provided in Appendix B. The mean percent canopy cover of live vegetation, by life form – perennial grasses, perennial forbs, and shrubs/subshrubs - is displayed in Figure 1.

Analysis of variance indicated that the percent cover of perennial grasses growing on the treated tailings is significantly ($P < 0.05$) greater than percent canopy cover of perennial grasses growing on the un-treated tailings. Canopy cover of vegetation on the treated tailings was not statistically distinct from perennial grasses growing on the off-site experimental plots. Percent canopy cover of perennial forbs growing on the treated tailings and the off-site control were also statistically equivalent. Data tables exhibiting cover percentages by species for each plot are provided in Appendix B.

Species List

A species list of all plants found within each of the twelve experimental plots was developed (Table 1). Species are distinguished by whether they were part of the seed mix or naturally established within the plot. The detailed vegetation cover data were used to designate major species, those with mean cover percentages for the plot greater than 0.5%, and those that contribute little to the overall vegetation cover of the plot, but were present during the July survey.

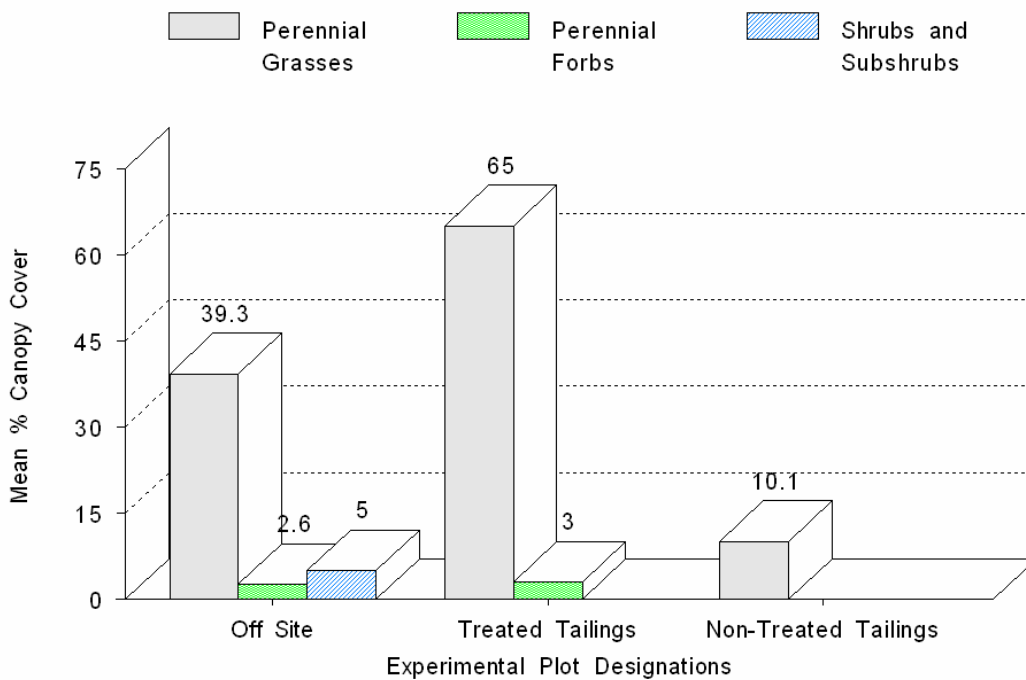


Figure 1. Mean percent canopy cover of live vegetation in 2005.

Rooting Patterns

A sharpshooter and a regular shovel were used to excavate soils from representative (vegetation) locations with several experimental plots. The depth of each excavation was approximately 22 to 24 inches. Rooting patterns and depths were recorded.

Treated Tailings Plots

Plot 5 – No pit was developed on this plot due to standing water on the surface of the plot as a result of recent precipitation.

Plot 6 – Copious roots were visible to a depth of 8 to 10 inches, with fewer roots visible below. The maximum rooting depth was measured at 18 inches. Plant species were common yarrow, slender wheatgrass and western wheatgrass. The pH of the rooting media (treated tailings) was 7 to 8 using the Hellige triplex pH indicator solution (Image A-6).

Table 1. Species occurring on each experimental plot - Keating Tailings Project 2005.

M = Major species with > 0.5% cover, X = Other species occurring in the plot
 Plots 1-4 are off-site native soils; Plots 5, 6, 9, and 11 are on-site treated tailings, Plots 7, 8, 10, 12 are on-site control

<u>Scientific Name</u>	<u>Common Name</u>	<u>Seeded Species (Y/N)</u>	<u>Off-site Native Soils</u>				<u>Treated Tailings</u>				<u>Non-treated Tailings</u>			
			1	2	3	4	5	6	9	11	7	8	10	12
<i>Achillea millefolium</i>	Common yarrow	Y	M	X	M	M	M	M	M	M		X		X
<i>Achnatherum hymenoides</i>	Indian ricegrass	Y	M	M	M	M	X	X	X	M				X
<i>Agropyron smithii</i>	Western wheatgrass	Y	M	M	M	M	M	M	M	M	M	M	M	M
<i>Agropyron trachycaulum</i>	Slender wheatgrass	Y	M	M	M	M	M	M	M	M	M	M	M	M
<i>Artemisia frigida</i>	Fringed sagewort	Y	M	M	M	M		X	X	X	X			
<i>Artemisia ludoviciana</i>	Cudweed sagewort	Y	M	M	M	M	X	X	X	X				
<i>Artemisia tridentata</i>	Big sagebrush	N					X	X	X	X				
<i>Astragalus spp.</i>	Milkvetch	N				M								
<i>Brassica nigra</i>	Black mustard	N		X	X									
<i>Chenopodium berlandieri</i>	Goosefoot	N						X		X				
<i>Chrysothamnus nauseosus</i>	Rubber rabbitbrush	N								X				
<i>Cinquefoil spp.</i>	Cinquefoil	N												X
<i>Fescue spp.</i>	Fescue	N			M									
ground lichen	Unknown	N				X								
<i>Gutierrezia sarothrae</i>	Broom snakeweed	N	X	X	X	X								
<i>Hordeum jubatum</i>	Foxtail barley	N	X		X	M	X	X	X	X				
<i>Hordeum L.</i>	Barley	N	X	X	X	X								X
<i>Lepidium densiflorum</i>	Common pepperweed	N		X		M								
<i>Opuntia polyacantha</i>	Pricklypear	N	M			X								
<i>Plantago patagonica</i>	Woolly plantain	N				X								
<i>Poa ampla</i>	Big bluegrass	Y	M	M		M	M	X			M	M	X	M
<i>Poa spp.</i>	Bluegrass	N							X			X	X	
<i>Polygonum aviculare</i>	Prostrate knotweed	N						X	X	X				

Table 1. Species occurring on each experimental plot - Keating Tailings Project 2005.

M = Major species with > 0.5% cover, X = Other species occurring in the plot
 Plots 1-4 are off-site native soils; Plots 5, 6, 9, and 11 are on-site treated tailings, Plots 7, 8, 10, 12 are on-site control

<u>Scientific Name</u>	<u>Common Name</u>	<u>Seeded Species (Y/N)</u>	<u>Off-site Native Soils</u>				<u>Treated Tailings</u>				<u>Non-treated Tailings</u>			
			1	2	3	4	5	6	9	11	7	8	10	12
<i>Polygonum lapathifolium</i>	Curlytop knotweed	N						X	X	X				
<i>Populus tremuloides</i>	Quaking aspen	N					X				X	X	X	
<i>Sphaeralcea coccinea</i>	Scarlet globemallow	N		M		X		X						
<i>Stipa comata</i>	Needle and thread	N	M	M	M	M		X	X					
<i>Stipa viridula</i>	Green needle grass	Y	M	M	M	M	X	M	M	M				
<i>Tragopogon dubious</i>	Yellow salsify	N			X			X	X					
<i>Verbena bracteata</i>	Bigbract verbena	N									X			
<i>Vicia americana</i>	American vetch	Y		X										X
Number of Species			13	15	14	18	10	16	15	14	4	6	5	8

Plot 9 – Copious roots to 10 to 12 inches with many fine root hairs. Organic matter was clearly visible to 18 to 20 inches, indicating the depth of the treatment in this plot. Few roots were evident at the bottom of the pit, unable to determine if the roots penetrated below the treated zone. The pH of the soil (tailings) profile was 7 to 8 using the Hellige indicator solution.

Plot 11 – Roots and organic matter clearly visible to 12 to 13 inches, with fewer roots visible below this depth. The roots have many fine root hairs, but do not appear to occupy the entire depth of treatment.

Un-treated Tailings Plots

Plot 7 – Maximum root depth was about 6 inches, with nearly all roots restricted to the upper 2 to 3 inches. The pH of the soil (tailings) profile was 4 to 4.5 (Image A-7).

Plot 8 - Maximum root depth was about 8 inches, with nearly all roots restricted to the upper 2 to 3 inches. The pH of the soil (tailings) profile was 4 to 4.5.

Plot 10 – No pit developed.

Plot 12 – No pit developed.

Above Ground Biomass

A 25 x 25 cm frame was placed in the same location as the cover frame and vegetation with each frame was clipped and segregated by plant species and placed into separate labeled paper bags for transport to the RRU labs. The samples were oven dried (70° C) for 24 to 36 hours. The vegetation mass in each bag was weighed to the nearest 0.01 gram. The complete data set is provided in Appendix C. Mean above ground biomass in grams/m² of live vegetation is displayed in the Figure 2. Analysis of variance indicated significant differences ($P < 0.05$) among the three mean values, with the treated tailings supporting the greatest above ground plant biomass, followed by the native range soils.

The untreated tailings did support some plant growth, but significantly less than the treated tailings and the native range soils. Two grasses, western wheatgrass (*Agropyron smithii*) and slender wheatgrass (*Agropyron trachycaulum*) contributed most to the biomass on all plots and treatments (refer to Appendix C for biomass data for each species and plot).

Metal Levels in Vegetation

Vegetation samples collected for biomass determinations were submitted to BLM/Denver for determinations of concentrations of selected elements, including arsenic, cadmium, copper, lead, mercury, and zinc. Mean levels of these elements

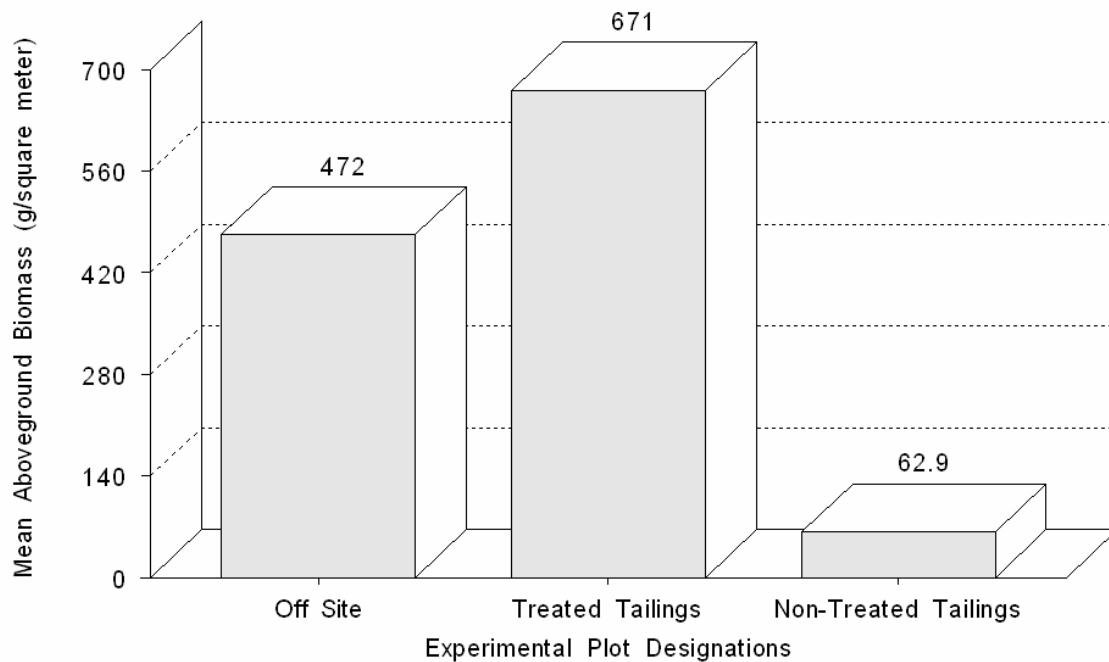


Figure 2. Mean aboveground biomass of vegetation in 2005.

in grass samples [(Western wheatgrass, Slender wheatgrass, Indian wheatgrass (*Achnatherum hymenoides*) and Big blue grass (*Poa ampla*)] collected from the experimental plots are provided in Figures 3 and 4. Complete data set of elemental levels in vegetation is provided in Appendix D.

Arsenic in Vegetation

Analysis of variance indicated that the mean arsenic level in grasses collected from the untreated tailings (2.60 mg/kg) was significantly greater than mean concentrations for grasses growing on treated tailings (1.09 mg/kg). Grasses growing on the native range soils revealed the least arsenic, with a mean of 0.36 mg/kg. For these statistical tests, any arsenic value reported at the detection limit were multiplied by 0.7, with the resulting valued used to calculate mean concentrations.

Based on a review of the scientific literature (Kabata-Pendias and Pendias [1992]), normal or sufficient levels of arsenic in mature leaf tissue range from 1 to 1.7 mg/kg; excessive or toxic levels for plants range from 5 to 20 mg/kg. None of the individual grass samples collected from the experimental plots had arsenic levels in the excessive range. The maximum tolerable dietary level of arsenic for cattle and horses (NRC 1980) is 50 mg/kg. The arsenic concentrations in grasses growing on the Keating Tailings do not pose a threat to grazing animals.

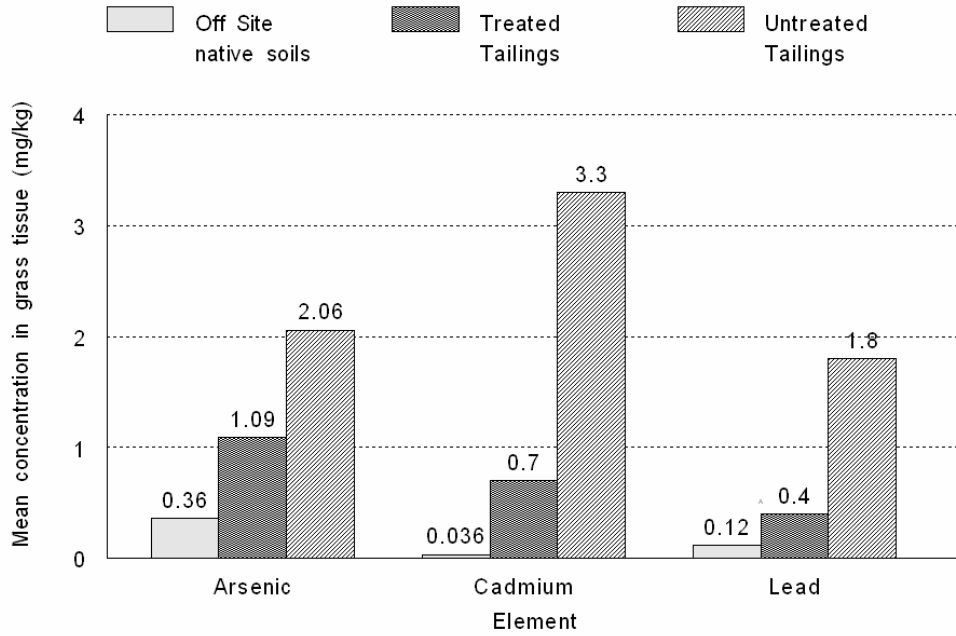


Figure 3. Mean concentrations of arsenic, cadmium, and lead in grass samples.

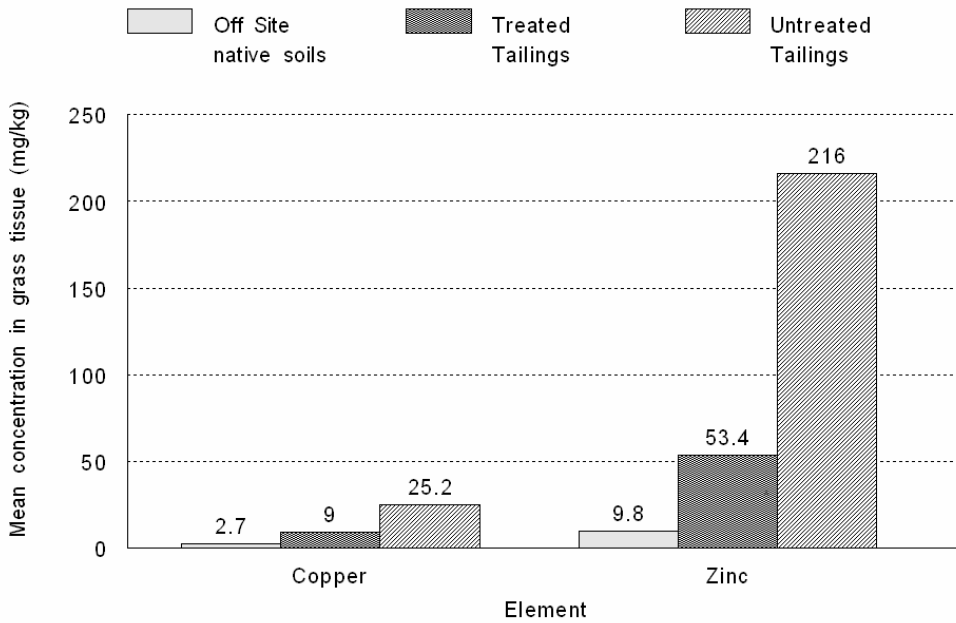


Figure 4. Mean concentrations of copper and zinc in grass samples.

Cadmium in Vegetation

Mean concentration of cadmium in samples collected from the untreated tailing was 3.3 mg/kg, which was not statistically distinct from the mean cadmium concentration of grasses collected from the treated plots (0.70 mg/kg). A significantly lower mean concentration of cadmium was found in grasses growing on the native soils.

The maximum tolerable dietary level of cadmium for cattle and horses is 0.50 mg/kg (NRC 1980). Of the eight individual grass samples (refer to Appendix D) from the treated tailings, one sample of Indian wheatgrass was found to have a cadmium concentration of 2.13 mg/kg, while the other samples had cadmium concentrations ranging from 0.21 to 0.80 mg/kg. The dietary level of cadmium for domesticated animals is based on human food residue considerations (NRC 1980), and the need to avoid increases of cadmium in the US food supply. Higher residue levels (>0.50 mg/kg) for a short period of time would not be expected to be harmful to animal health or to human food use, particularly if the animals were slaughtered at a young age (NRC 1980).

Lead in Vegetation

Lead levels in vegetation samples were relatively low. Analysis of variance indicated that concentration of lead in grasses growing on the untreated tailings (mean of 1.8 mg/kg) was significantly elevated compared to mean levels in plants growing on the treated tailings or native range soils. All concentrations were less than the maximum tolerable dietary level for cattle and horses of 30 mg/kg. Normal concentrations of lead in mature leaf tissue range from 5 to 10 mg/kg (Kabata-Pendias and Pendias [1992]). All lead data were less than this range (refer to Appendix D). The lead concentrations in grasses growing on the Keating Tailings do not pose a threat to grazing animals.

Copper in Vegetation

Mean concentrations of copper in grass samples collected from the site (Figure 4) were significantly different across the three treatments. The grasses growing in native range soils had a mean copper level of 2.7 mg/kg. This level would be considered in the deficient range for this essential element. Mean levels of copper in grasses growing on treated and untreated tailings, 9.0 and 25.2 respectively, are statistically different ($P < 0.05$), but within the sufficient or normal range of 5 to 30 mg/kg provided by (Kabata-Pendias and Pendias [1992]). The National Research Council (1980) provided a maximum tolerable dietary level of copper for cattle and horses at 100 mg/kg. The copper concentrations in grasses growing on the Keating Tailings do not pose a threat to grazing animals.

Zinc in Vegetation

Mean zinc concentrations (Figure 4) were quite variable, and analysis of variance found that they were statistically distinct. The maximum dietary level for zinc for cattle and horses is 500 mg/kg; no sample concentration exceeded this value. The zinc

concentrations in grasses growing on the Keating Tailings do not pose a threat to grazing animals.

Mercury in Vegetation

All of the mercury values were reported as < 0.1 mg/kg (refer to Appendix D). No interpretation of the data is appropriate.

REFERENCES CITED

- Daubenmire, Rexford. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-64.
- Kabata-Pendias, A. and H. Pendias. 1992. Trace Elements in Soils and Plants. CRC Press, Boca Raton, FL. 365 p.
- NRC. 1980. Mineral Tolerance of Domestic Animals. National Research Council, National Academy of Sciences, Washington, DC. 577 p.
- Neuman, D.R., G.S. Vandeberg, P.B. Blicher, J.D. Goering, S.R. Jennings, and K. Ford. 2005. Phytostabilization of Acid Metalliferous Mine Tailings at the Keating Site in Montana, In: Proc. of 2005 National Meeting of the Amer. Soc. of Mining and Reclamation, Breckenridge, CO. Published by ASMR, 3134 Montavesta Road, Lexington, KY 40502.

APPENDIX A – Selected Images



Image A-1. Overview of experimental plots on Keating Tailings, July 6, 2005. Note apparent difference between treated tailings and un-treated tailings.



Image A-2. The treated tailings plots.



Image A-3. Treated plot with yarrow in flower along the plot edge and the stand dominated by the seeded wheatgrasses.



Image A-4. Un-treated (control) tailings plots.



Image A-5. Off-site experimental plots on native soils.

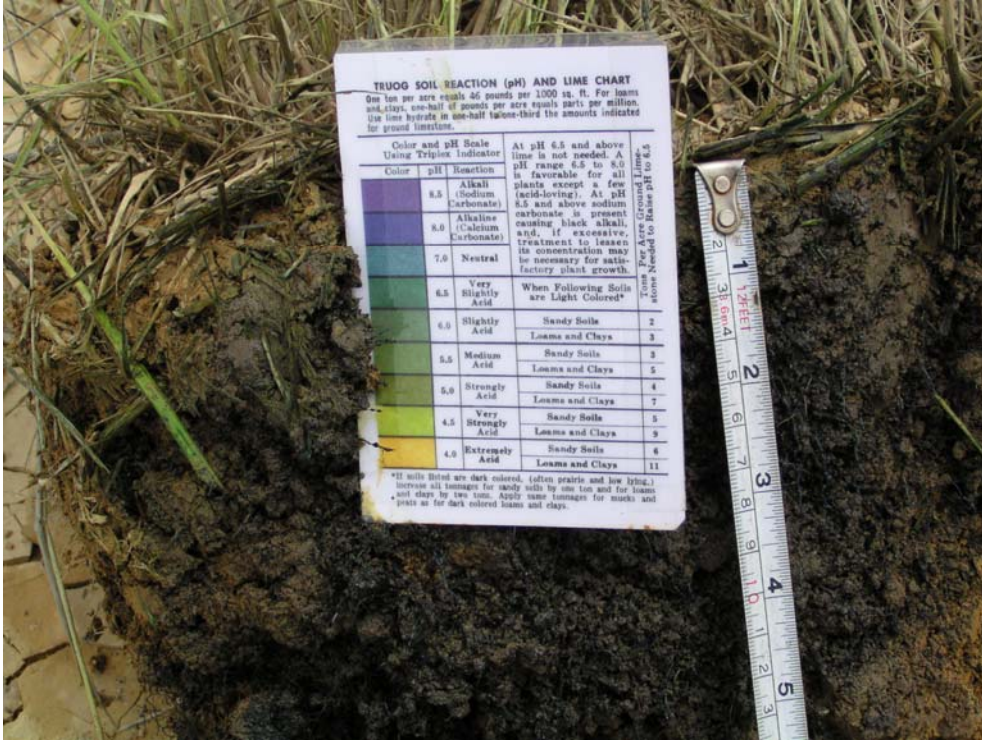


Image A-6. Treated tailings pit face and roots sprayed with Hellige pH indicator solution. The pH of the tailings is approximately 7 to 8.

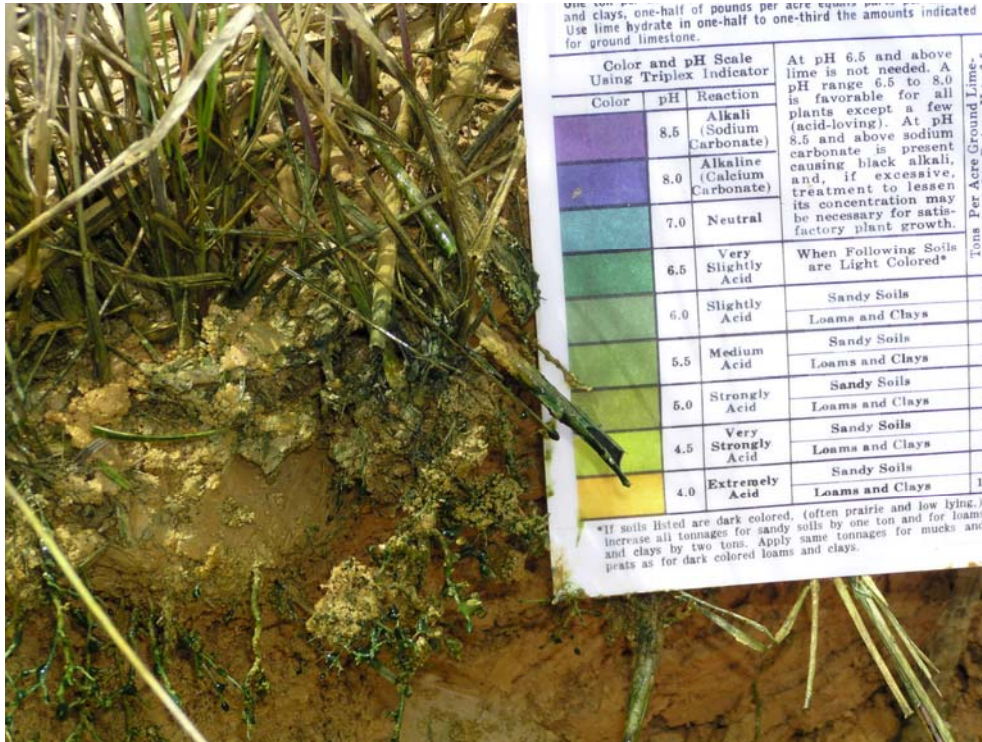


Image A-7. Un-treated (control) pit face and roots sprayed with Hellige pH indicator solution. The pH of the tailings is approximately 4.5.

APPENDIX B – Canopy Cover of Vegetation

Table B-1. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 1 - Off Site Native Range Site											
Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover per plot
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	
Perennial Grasses											
Stipa Comata	1	2.5			1	2.5					1
Poa ampla	1	2.5	1	2.5					1	2.5	1.5
Agropyron smithii	1	2.5	2	15.0	1	2.5	1	2.5	1	2.5	5
Agropyron trachycaulum	2	15.0	3	37.5	2	15.0	3	37.5	3	37.5	28.5
Stipa viridula							1	2.5			0.5
Achnatherum hymenoides									1	2.5	0.5
Total Perennial Grasses		22.5		55.0		20.0		42.5		45.0	37.0
Perennial Forbs											
Artemisia ludoviciana			1	2.5	1	2.5					1
Achillea millefolium			1	2.5							0.5
Total Perennial Forbs		0.0		5.0		2.5		0.0		0.0	1.5
Shrubs & Subshrubs											
Artemisia frigida	2	15.0	1	2.5	2	15.0	1	2.5			7
Opuntia polyacantha	1	2.5									0.5
Total Shrubs & Subshrubs		17.5		2.5		15.0		2.5		0.0	7.5
Sum of Species Cover		40.0		62.5		37.5		45.0		45.0	46
Total Live Vegetation Cover		40.0		62.5		37.5		45.0		45.0	46
Litter	1	2.5	2	15.0	2	15.0	2	15.0	2	15.0	12.5
Mulch	1	2.5	1	2.5	3	37.5	2	15.0	3	37.5	19
Bare ground	2	15.0	1	2.5	1	2.5	1	2.5	1	2.5	5
Total Ground Cover		45.0		80.0		90.0		75.0		97.5	77.5

Table B-2. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 2 - Off Site Native Range Site

Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover per plot
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	
Perennial Grasses											
Stipa Comata					1	2.5			1	2.5	1
Poa ampla					1	2.5			1	2.5	1
Agropyron smithii	1	2.5	1	2.5	1	2.5	1	2.5	1	2.5	2.5
Agropyron trachycaulum	3	37.5	3	37.5	2	15.0	3	37.5	2	15.0	28.5
Stipa viridula			1	2.5							0.5
Achnatherum hymenoides			1	2.5	1	2.5			1	2.5	1.5
Total Perennial Grasses		40.0		45.0		25.0		40.0		25.0	35.0
Perennial Forbs											
Artemisia ludoviciana	1	2.5	2	15.0	1	2.5					4.0
Total Perennial Forbs		2.5		15.0		2.5		0.0		0.0	4.0
Shrubs & Subshrubs											
Artemisia frigida	1	2.5	2	15.0					2	15.0	6.5
Sphaeralcea coccinea							1	2.5			0.5
Total Shrubs & Subshrubs		2.5		15.0		0.0		2.5		15.0	7.0
Sum of Species Cover		45.0		75.0		27.5		42.5		40.0	46
Total Live Vegetation Cover		45.0		75.0		27.5		42.5		40.0	46
Litter	2	15.0	2	15.0	2	15.0	2	15.0	1	2.5	12.5
Mulch	2	15.0	2	15.0	2	15.0	3	37.5	2	15.0	19.5
Bare ground	1	2.5	1	2.5	0		0		2	15.0	4
Total Ground Cover		75.0		105.0		57.5		95.0		57.5	78

Table B-3. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 3 - Off Site Native Range Site											
Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	per plot
Perennial Grasses											
Stipa Comata	1	2.5	1	2.5							1
Agropyron smithii	1	2.5	1	2.5	2	15.0	1	2.5	1	2.5	5
Agropyron trachycaulum	2	15.0	3	37.5	4	62.5	3	37.5	2	15.0	33.5
Stipa viridula	1	2.5									0.5
Achnatherum hymenoides			1	2.5							0.5
Fescue spp.	1	2.5									0.5
Total Perennial Grasses		25.0		45.0		77.5		40.0		17.5	41.0
Annual Grasses											
Hordeum spp			1	2.5							
Perennial Forbs											
Artemisia ludoviciana	1	2.5					1	2.5	1	2.5	1.5
Achillea millefolium							1	2.5			0.5
Total Perennial Forbs		2.5		0		0.0		5.0		2.5	2.0
Shrubs & Subshrubs											
Artemisia frigida	1	2.5							1	2.5	1
Total Shrubs & Subshrubs		2.5		0		0.0		0.0		2.5	1
Sum of Species Cover		30.0		45.0		77.5		45.0		22.5	44
Total Live Vegetation Cover		30.0		47.5		77.5		45.0		22.5	44.5
Litter	1	2.5	2	15	2	15.0	2	15.0	1	2.5	10
Mulch	1	2.5	2	15	2	15.0	2	15.0	2	15.0	12.5
Bare ground	3	37.5	1	2.5	0		1	2.5	3	37.5	16
Total Ground Cover		35.0		77.5		107.5		75.0		40.0	67

Table B-4. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 4 - Off Site Native Range Site											
Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover per plot
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	
Perennial Grasses											
Stipa Comata	1	2.5			1	2.5					1
Poa ampla	1	2.5	2	15.0	1	2.5			1	2.5	4.5
Agropyron smithii	2	15.0	1	2.5	1	2.5	2	15.0	1	2.5	7.5
Agropyron trachycaulum	3	37.5	2	15.0	3	37.5	3	37.5	2	15.0	28.5
Stipa viridula			1	2.5					1	2.5	1
Achnatherum hymenoides			1	2.5	1	2.5					1
Hordeum jubatum					1	2.5					0.5
Total Perennial Grasses		57.5		37.5		50.0		52.5		22.5	44.0
Perennial Forbs											
Artemisia ludoviciana			1	2.5	1	2.5	1	2.5			1.5
Achillea millefolium									1	2.5	0.5
Lepidium densiflorum	1	2.5									0.5
Astragalus spp					1	2.5					0.5
Total Perennial Forbs		2.5		2.5		5.0		2.5		2.5	3.0
Shrubs & Subshrubs											
Artemisia frigida	1	2.5	1	2.5	1	2.5			2	15.0	4.5
Total Shrubs & Subshrubs		2.5		2.5		2.5		0.0		15.0	4.5
Sum of Species Cover		62.5		42.5		57.5		55.0		40.0	51.5
Total Live Vegetation Cover		62.5		42.5		57.5		55.0		40.0	51.5
Litter	2	15.0	2	15.0	2	15.0	2	15.0	2	15.0	15
Mulch	2	15.0	2	15.0	2	15.0	2	15.0	3	37.5	19.5
Bare ground	2	15.0	1	2.5	1	2.5	1	2.5	1	2.5	5
Total Ground Cover		92.5		72.5		87.5		85.0		92.5	86

Table B-5. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 5 - On Site Treated with Lime and Organic Matter											
Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	per plot
Perennial Grasses											
Poa ampla									1	2.5	0.5
Agropyron smithii	3	37.5	1	2.5	1	2.5	2	15.0	3	37.5	19
Agropyron trachycaulum	3	37.5	4	62.5	1	2.5	2	15.0	3	37.5	31
Total Perennial Grasses		75.0		67.5		5.0		30.0		77.5	50.5
Perennial Forbs											
Achillea millefolium			1	2.5					2	15.0	3.5
Total Perennial Forbs		0.0		2.5		0.0		0.0		15.0	3.5
Shrubs & Subshrubs											
Total Shrubs & Subshrubs		0.0		0.0		0.0		0.0		0.0	
Sum of Species Cover		75.0		70.0		5.0		30.0		92.5	54.5
Total Live Vegetation Cover		75.0		70.0		5.0		30.0		92.5	54.5
Litter	2	15.0	2	15.0	4	62.5	2	15.0	2	15.0	24.5
Mulch	0		0		0		1	2.5	1	2.5	1
Bare ground	2	15.0	2	15.0	1	2.5	2	15.0	1	2.5	10
Total Ground Cover		90.0		85.0		67.5		47.5		110.0	80

Table B-6. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 6 - On Site Treated with Lime and Organic Matter

Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover per plot
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	
Perennial Grasses											
Poa ampla									1	2.5	0.5
Agropyron smithii	2	15.0	2	15.0	1	2.5	2	15.0	1	2.5	10
Agropyron trachycaulum	4	62.5	4	62.5	4	62.5	4	62.5	4	62.5	62.5
Stipa viridula			1	2.5					1	2.5	1
Total Perennial Grasses		77.5		82.5		65.0		77.5		70.0	74.0
Perennial Forbs											
Achillea millefolium			1	2.5	2	15.0	2	15.0	1	2.5	7
Total Perennial Forbs		0.0		2.5		15.0		15.0		2.5	7.0
Shrubs & Subshrubs											
Total Shrubs & Subshrubs		0.0		0.0		0.0		0.0		0.0	
Sum of Species Cover		77.5		85.0		80.0		92.5		72.5	81.5
Total Live Vegetation Cover		77.5		85.0		80.0		92.5		72.5	81.5
Litter	2	15.0	2	15.0	2	15.0	2	15.0	2	15.0	15
Mulch	1	2.5	1	2.5	1	2.5	1	2.5	1	2.5	2.5
Bare ground	0		0		0		0		0		0
Total Ground Cover		95.0		102.5		97.5		110.0		90.0	99

Table B-7. Vegetation Cover at Keating Tailings, July 7, 2005.											
PLOT 7 - On Site Control											
Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	per plot
Perennial Grasses											
Poa ampla					1	2.5					0.5
Agropyron smithii	1	2.5	1	2.5	1	2.5	1	2.5			2
Agropyron trachycaulum	1	2.5	1	2.5	1	2.5	1	2.5	1	2.5	2.5
Total Perennial Grasses		5.0		5.0		7.5		5.0		2.5	5.0
Perennial Forbs											
Total Perennial Forbs		0.0		0.0		0.0		0.0		0.0	0.0
Shrubs & Subshrubs											
Total Shrubs & Subshrubs		0.0		0.0		0.0		0.0		0.0	0.0
Sum of Species Cover		5.0		5.0		7.5		5.0		2.5	5.0
Total Live Vegetation Cover		5.0		5.0		7.5		5.0		2.5	5.0
Litter	0		0		0	0	0	0	0		
Mulch	4	62.5	3	37.5	3	37.5	3	37.5	4	62.5	47.5
Bare ground	2	15.0	4	62.5	3	37.5	3	37.5	2	15	33.5
Total Ground Cover		67.5		42.5		45.0		42.5		65.0	52.5

Table B-8. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 8 - On Site Control

Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover per plot
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	
Perennial Grasses											
Poa ampla	2	15.0	1	2.5	1	2.5	2	15.0			7
Agropyron smithii	1	2.5	1	2.5	1	2.5	1	2.5	1	2.5	2.5
Agropyron trachycaulum	1	2.5	2		2	15.0	1	2.5			4
Total Perennial Grasses		20.0		5.0		20.0		20.0		2.5	13.5
Perennial Forbs											
Total Perennial Forbs		0.0		0.0		0.0		0.0		0.0	0.0
Shrubs & Subshrubs											
Total Shrubs & Subshrubs		0.0		0.0		0.0		0.0		0.0	0.0
Trees											
Populus tremuloides			1	2.5							0.5
Sum of Species Cover		20.0		7.5		20.0		20.0		2.5	14.0
Total Live Vegetation Cover		20.0		7.5		20.0		20.0		2.5	14
											0
Litter	0		0		0		0		0		0
Mulch	3	37.5	3	37.5	2	15.0	3	37.5	2	15.0	28.5
Bare ground	1	2.5	2	15.0	3	37.5	2	15.0	5	85.0	31
											0
Total Ground Cover		57.5		45.0		35.0		57.5		17.5	42.5

Table B-9. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 9 - On Site Treated with Lime and Organic Matter

Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover per plot
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	
Perennial Grasses											
Poa ampla	1	2.5									
Agropyron smithii	3	37.5	1	2.5	1	2.5	2	15	3	37.5	19
Agropyron trachycaulum	4	62.5	3	37.5	3	37.5	3	37.5	4	62.5	47.5
Stipa viridula									1	2.5	
Total Perennial Grasses		102.5		40		40		52.5		102.5	67.0
Perennial Forbs											
Achillea millefolium									1	2.5	0.5
Total Perennial Forbs		0		0		0		0		2.5	0.5
Shrubs & Subshrubs											
Total Shrubs & Subshrubs		0		0		0		0		0	
Sum of Species Cover		102.5		40		40		52.5		105	68
Total Live Vegetation Cover		102.5		40		40		52.5		105	68
Litter	2	15	2	15	3	37.5	2	15	2	15	19.5
Mulch	0	0	3	37.5	2	15	1	2.5	1	2.5	11.5
Bare ground	0	0	1	2.5	1	2.5	1	2.5	1	2.5	2
Total Ground Cover		117.5		92.5		92.5		70		122.5	99

Table B-10. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 10 - On Site Control											
Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	per plot
Perennial Grasses											
Agropyron smithii	2	15	1	2.5			1	2.5			4
Agropyron trachycaulum	2	15	2	15	1	2.5	1	2.5	1	2.5	7.5
Total Perennial Grasses		30		17.5		2.5		5		2.5	11.5
Perennial Forbs											
Total Perennial Forbs		0		0		0		0		0	0
Shrubs & Subshrubs											
Total Shrubs & Subshrubs		0		0		0		0		0	0
Sum of Species Cover		30		17.5		2.5		5		2.5	11.5
Total Live Vegetation Cover		30		17.5		2.5		5		2.5	11.5
Litter	0		0		0		0		0		
Mulch	2	15	4	62.5	3	37.5	3	37.5	5	85	47.5
Bare ground	2	15	1	2.5	4	62.5	2	15	1	2.5	19.5
Total Ground Cover		45		80		40		42.5		87.5	59

Table B-11. Vegetation Cover at Keating Tailings, July 7, 2005.											
PLOT 11 - On Site Treated with Lime and Organic Matter											
Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover per plot
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	
Perennial Grasses											
Agropyron smithii	2	15	2	15	1	2.5	1	2.5	3	37.5	14.5
Agropyron trachycaulum	4	62.5	4	62.5	2	15	4	62.5	4	62.5	53
Stipa viridula									1	2.5	0.5
Achnatherum hymenoides							1	2.5			0.5
Total Perennial Grasses		77.5		77.5		17.5		67.5		102.5	68.5
Perennial Forbs											
Achillea millefolium					1	2.5	1	2.5			1
Total Perennial Forbs		0		0		2.5		2.5		0	1
Shrubs & Subshrubs											
Total Shrubs & Subshrubs		0		0		0		0		0	0
Sum of Species Cover		77.5		77.5		20		70		102.5	69.5
Total Live Vegetation Cover		77.5		77.5		20		70		102.5	69.5
Litter	2	15	2	15	2	15	2	15	2	15	15
Mulch	1	2.5	1	2.5	4	62.5	2	15	1	2.5	17
Bare ground	0		0		1	2.5	1	2.5	0	0	1
Total Ground Cover		95		95		97.5		100		120	101.5

Table B-12. Vegetation Cover at Keating Tailings, July 7, 2005.

PLOT 12 - On Site Control											
Life Form and Species	Frame 1	midpoint	Frame 2	midpoint	Frame 3	midpoint	Frame 4	midpoint	Frame 5	midpoint	Mean cover
	Class	Percent	Class	Percent	Class	Percent	Class	Percent	Class	Percent	per plot
Perennial Grasses											
Poa ampla	1	2.5									0.5
Agropyron smithii	1	2.5	1	2.5	1	2.5	1	2.5	1	2.5	2.5
Agropyron trachycaulum	2	15	2	15	1	2.5	1	2.5	1	2.5	7.5
Total Perennial Grasses		20		17.5		5		5		5	10.5
Annual Grasses											
Hordeum spp					1	2.5					0.5
Perennial Forbs											
Total Perennial Forbs		0		0		0		0		0	
Shrubs and Subshrubs											
Total Shrubs & Subshrubs		0		0		0		0		0	
Sum of Species Cover		20		17.5		7.5		5		5	11
Total Live Vegetation Cover		20		17.5		7.5		5		5	11
Litter	0		0		0		0		0		
Mulch	3	37.5	2	15	5	85	3	37.5	5	85	52
Bare ground	3	37.5	3	37.5	1	2.5	2	15	2	15	21.5
Total Ground Cover		57.5		32.5		92.5		42.5		90	63

APPENDIX C – Above Ground Biomass

Table C-1. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.

PLOT 1 - Off Site Native Range Site (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Mean biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Achillea millefolium				0.03		0.03	
Agropyron smithii	2.34		1.52		2.77	6.63	
Agropyron trachycaulum	12.46	34.48	28.06	18.40	40.85	134.25	
Artemisia frigida	1.00					1.00	
Artemisia ludoviciana			0.52			0.52	
Opuntia polyacantha	0.39					0.39	
Poa ampla		0.73			3.66	4.39	
Stipa comata	2.07				0.39	2.46	
Stipa viridula	3.74	2.37		0.77		6.88	
							500.96

Table C-2. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.

Plot 2 - Off Site Native Range Site (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Mean biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Achillea millefolium	0.07					0.07	
Achnatherum hymenoides					0.86	0.86	
Agropyron smithii	2.66	6.1	3.45	3.36	3.75	19.32	
Agropyron trachycaulum	23.09	25	24.37	25.4	5.1	102.96	
Artemisia frigida	0.29	0.72			0.76	1.77	
Artemisia ludoviciana	0.43	0.37				0.80	
Poa ampla		0.61			2.38	2.99	
Stipa comata		0.45			7	7.45	
Stipa viridula		0.92			2.57	3.49	
							447.07

Table C-3. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.

Plot 3 - Off Site Native Range Site (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Agropyron smithii	2.61	5.06	5.05	2.19	2.89	17.80	
Agropyron trachycaulum	13.03	31.59	38.39	42.88	7.48	133.37	
Artemisia frigida	0.49				3.48	3.97	
Artemisia ludoviciana					0.82	0.82	
Festuca spp.	0.25					0.25	
Stipa viridula		2.23				2.23	
							505.60

Table C-4. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.							
Plot 4 - Off Site Native Range Site (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Achillea millefolium		0.12					0.12
Agropyron smithii		3.37	3.76	9.48	1.89		18.50
Agropyron trachycaulum	11.56	27.71	6.72	19.58	36.15		101.72
Artemisia frigida	0.46	0.84					1.30
Artemisia ludoviciana		0.12					0.12
Poa ampla		6.46			1.19		7.65
Stipa comata	2.36						2.36
Stipa viridula				2.56	1.28		3.84
							433.95

Table C-5. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.							
PLOT 5 - On Site Treated with Lime and Organic Matter (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Achillea millefolium				0.2			0.20
Agropyron smithii	10.23	0.76			5.47		16.46
Agropyron trachycaulum	49.27	61.11	12.45	29.17	43.05		195.05
Hordeum jubatum		1.01					1.01
Stipa viridula	0.46	0.92			0.43		1.81
							686.50

Table C-6. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.							
PLOT 6 - On Site Treated with Lime and Organic Matter (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Achillea millefolium				3.25	1		4.25
Agropyron smithii	4.49	7.68	3.67	2.05			17.89
Agropyron trachycaulum	55.78	22.59	3.92	28.56	79.49		190.34
Artemisia ludoviciana					3.14		3.14
Poa ampla					1.55		1.55
							694.94

Table C-7. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.							
PLOT 7 - On Site Control (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Agropyron smithii	0.94	0.15	1.06	0.64	0.34	3.13	
Agropyron trachycaulum		0.71	1.7	1.39		3.80	
							22.18

Table C-8. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.							
PLOT 8 - On Site Control (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Agropyron smithii	3.33	2.35	1	3.06	0.32	10.06	
Agropyron trachycaulum	1.84	5.36	2.08	4.09		13.37	
Poa ampla	3.74	3.18		1.18		8.10	
Populus tremuloides		0.17				0.17	
							101.44

Table C-9. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.							
PLOT 9 - On Site Treated with Lime and Organic Matter (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Agropyron smithii		0.45	7.96	1.56	2.92	12.89	
Agropyron trachycaulum	76.19	13.51	15.51	21.86	36.7	163.77	
Stipa viridula					3.30	3.30	
							575.81

Table C-10. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.							
PLOT 10 - On Site Control (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Agropyron smithii	1.74	1.65	2.13	0.4	0.33	6.25	
Agropyron trachycaulum	12.45	2.45		0.6		15.50	
Poa ampla			1.28			1.28	
							73.70

Table C-11. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.							
PLOT 11 - On Site Treated with Lime and Organic Matter (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Achillea millefolium			0.17	1.58		1.75	
Achnatherum hymenoides				2.24		2.24	
Agropyron smithii	4.2	2.93	1.55	15.38	6.39	30.45	
Agropyron trachycaulum	25.12	42.82	10.55	71.16	42.37	192.02	
Poa ampla				1.19		1.19	
							728.48

Table C-12. Vegetation Above ground Biomass at Keating Tailings, July 7, 2005.							
PLOT 12 - On Site Control (Frame size is 25 cm x 25 cm)							
Species	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5		Total biomass
	(g)	(g)	(g)	(g)	(g)		(g/m ²) per plot
Agropyron smithii	0.59	2.41	2.08	0.09	0.6	5.77	
Agropyron trachycaulum	0.89	5.18	2.26	2.26	0.54	11.13	
Astragalus spp.					0.03	0.03	
							54.18

APPENDIX D – Arsenic and Metal Levels in Vegetation

Appendix D-1. Arsenic and metal levels (mg/kg) in vegetation collected from experimental plots at Keating Tailings Site.							
		Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
Offsite Control							
VEG1	western wheatgrass	0.4	<0.05	3	0.2	<0.1	11
VEG2	western wheatgrass	0.3	<0.05	2.8	0.11	<0.1	11
VEG3	western wheatgrass	<0.3	<0.05	2.5	0.06	<0.1	12
VEG4	western wheatgrass	<0.3	<0.05	2.5	0.07	<0.1	11
VEG 13	slender wheatgrass	<0.3	<0.05	2.5	<0.11	<0.1	9
VEG 14	slender wheatgrass	<0.3	<0.05	2.6	0.21	<0.1	10
VEG 15	slender wheatgrass	<0.3	<0.05	2.1	0.08	<0.1	9
VEG 16	slender wheatgrass	<0.3	<0.05	2.2	0.06	<0.1	7
VEG 30	big bluegrass	0.7	<0.05	3.4	0.23	<0.1	9
VEG 31	big bluegrass	0.8	0.05	3.5	0.14	<0.1	9
VEG 39	fringed sage	7.8	1.32	19	9.2	<0.1	57
Treated Tailings							
VEG5	western wheatgrass	3.3	0.21	7.8	0.47	<0.1	34
VEG9	western wheatgrass	0.6	0.8	11.4	0.81	<0.1	84
VEG11	western wheatgrass	0.3	0.66	8.1	0.09	<0.1	71
VEG 17	slender wheatgrass	0.9	0.28	6.1	0.3	<0.1	24
VEG 18	slender wheatgrass	0.7	0.55	8.8	0.37	<0.1	47
VEG 21	slender wheatgrass	0.8	0.34	10.1	0.25	<0.1	56
VEG 23	slender wheatgrass	1.3	0.66	8.9	0.65	<0.1	67
VEG 41	indian ricegrass	0.8	2.13	10.4	0.23	<0.1	44
VEG 40	cudweed sagewort	2.6	3.62	27.5	1.62	<0.1	69
Untreated Tailings							
VEG7	western wheatgrass	3.8	5.01	40.7	2.75	<0.1	319
VEG8	western wheatgrass	1.8	3.3	16.5	1.26	<0.1	201
VEG 12	western wheatgrass	2.9	1.98	23.1	1.86	<0.1	129
VEG 19	slender wheatgrass	2.7	4.14	26.9	2	<0.1	289
VEG 20	slender wheatgrass	3.3	3.64	26.7	2.33	<0.1	240
VEG 22	slender wheatgrass	1.6	2.66	22.2	1.16	<0.1	176
VEG 34	big bluegrass	2.1	1.87	20	1.25	<0.1	163