Use of Biochar in Yukon Mine Revegetation / Reclamation
Field Studies 2013- 2014

Yukon Technology Innovation Centre

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1.0 Contents

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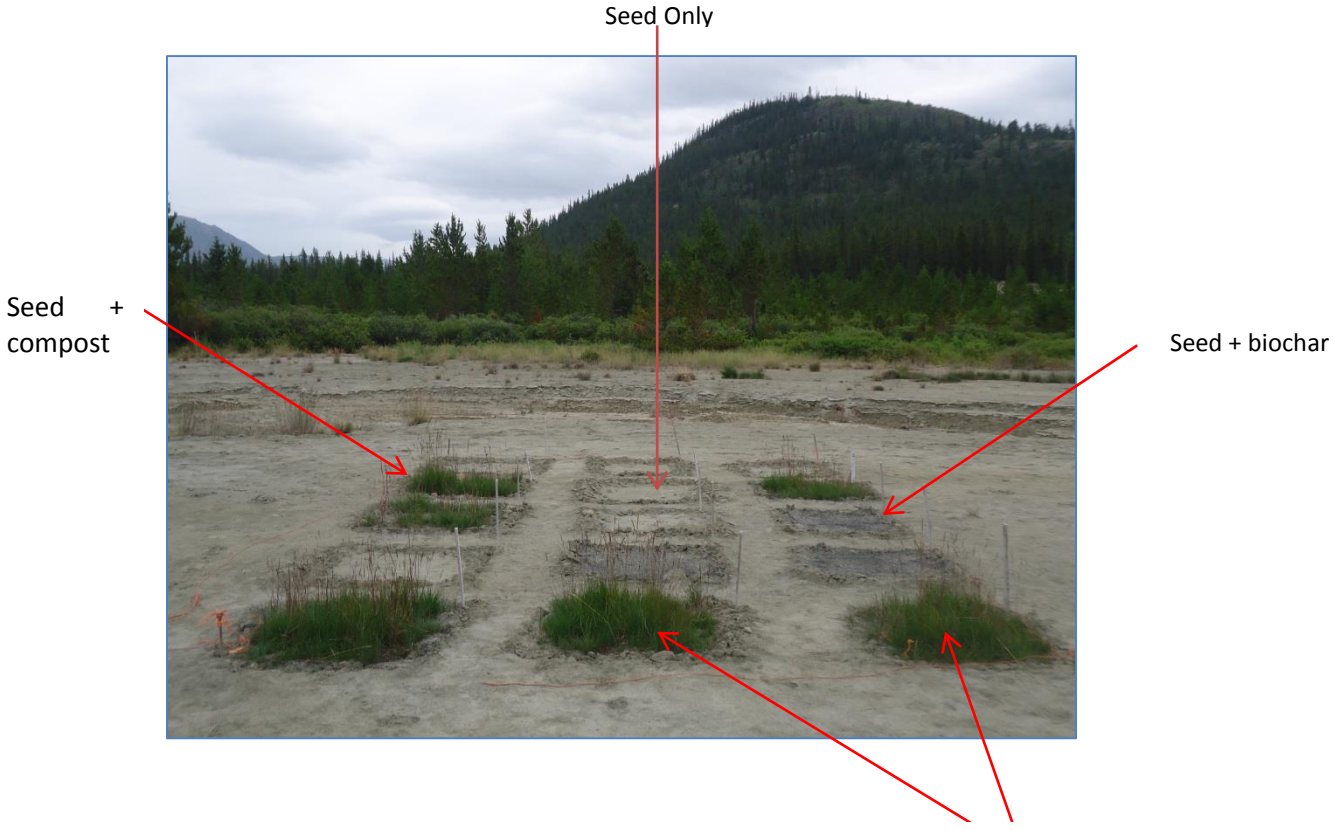
EXECUTIVE SUMMARY

The use of biochar as a soil amendment for mine affected soil revegetation was established as a field experiment in 2012. While the objective of the present report is to synthesize data collected over the past two years of the program, some general conclusions and recommendations for further research are also supplied.

The field plots were established on three different mine tailings sites within a 100 km radius of Whitehorse, Yukon Territory; the Whitehorse Copper Mine Tailings, Mount Skukum Gold Mine (MSGM) tailings and the Arctic Gold and Silver (AG&S) tailings cover. The tailings and tailings cover present different characteristics but share the same challenge for successful revegetation; mineral soils which do not support plant growth without soil amendments.

The overall findings of the research are perhaps best illustrated by the image below, from the MSGM site. With some minor variability among sites, the plots that achieved the highest cover class of native grass species were those that were treated with compost and biochar. The second ranked cover class was with compost only and the third ranked cover class was biochar alone. Biochar when combined with a secondary soil amendment (compost) achieved excellent plant growth compared with the Null (seed only) plots. As expected from previous research, use of biochar alone as the only soil amendment was not as effective as combining it with compost.

Further research should consider varying the application rates of the soil amendments to achieve the most economical blend possible for the given mine-affected soil problem. The research has the potential to enhance the mine closure and reclamation process using local materials and expertise.



1.0 BACKGROUND AND STUDY DESIGN

In 2010, Laberge Environmental Services (LES) made an application to the Mine and Petroleum Environment Research Group (MPERG) to investigate the use of biochar in mine reclamation. In early 2011 Yukon College assumed control over the MPERG and LES again submitted a proposal to investigate the role of biochar in mine reclamation, resulting in a funding agreement between the Yukon Research Centre as represented by Cold Climate Innovation. The 2012 results were summarized in a technical report (Laberge Environmental Services. *Technical Report – Use of Biochar in Yukon Mine Revegetation – Field Trials 2012*). The present report compiles the results of the 2013 and 2014 field seasons.

In the 2012 field trails, six blocks containing 15 test plots each were set up at three mines sites. In 2013 six replicate blocks were established at the same sites in close proximity. The difference in 2013 was that there were three extra soil amendments resulting in up to 24 test plots per block. Also, locally generated biochar was used in 2013 as opposed to the commercial biochar purchased from Colorado used in the 2012. Again in 2013 the plots were set up to minimize in-site variability; all plots faced the same way, were on the same level and had the same exposure and drainage. Each plot measured 1 x 1 m with a 0.5 m buffer around all plots. The soil amendments were as follows:

2012

Plot Number	Soil amendment
1, 2, 3	NULL
4,5,6	Seed only
7,8,9	Seed + Compost 15 L/m^2
10,11,12	Seed + Biochar 2.28 kg/m^2
13,14,15	Seed + Biochar 2.28 kg/m^2 + Compost 15 L/m^2

2013

Plot Number	Soil amendment
1, 2, 3	NULL
4,5,6	Seed only
7,8,9	Seed + Compost 15 L/m^2
10,11,12	Seed + Biochar 2.28 kg/m^2
13,14,15	Seed + Biochar 2.28 kg/m^2 + Compost 15 L/m^2
16,17,18	Seed + Leonardite Pellets 50g/m^2
19,20,21	Seed + Leonardite Pellets 150g/m^2
22,23,24	Seed + Biochar 2.28 kg/m^2 + Compost 7.5 L/m^2 (1/2 compost)

For all blocks in 2013 the plots were randomized using randomizing software available on the internet. Each plot was labelled with a stake, with the tag facing towards the plot and with the block facing North, except at Whitehorse Copper Block C which faced East.

1.1 SEED MIX

The seed mix common to both years was as follows:

2. Slender wheatgrass (*Agropyron trachycaulum*) 30% by weight,
3. Tufted hairgrass (*Deschampsia caespitosa*) 30% by weight,
4. Creeping red fescue (*Festuca rubra* var. *rubra*) 30% by weight and
5. Hairy vetch (*Vicia villosa*) 10% by weight, or Hediserum

Those plots receiving seed were seeded with 0.9 g of each grass and 0.3 g of hairy vetch. In order to scarify the seed coats, the vetch seeds were soaked in liquid humic acid for 24 hours prior to application.

1.2 SOIL AMENDMENTS

1.2.3 BIOCHAR APPLICATION

In 2013 the biochar was supplied locally by Warren Zakus. The raw biochar chips were ground in a steel-blade seed grinder to produce a fine, almost powdery mix prior to application. To arrive at the application rate, the bulk density of biochar was obtained, and 2.28 kg/m^2 was applied to plots receiving biochar. This was meant to represent roughly 15% by volume of the top 5 cm of soil.

1.2.4 COMPOST APPLICATION

The co-operative project at the Whitehorse Solid Waste Facility which produces commercial quantities of high quality compost was the source of the compost for the field trials. 15 L/m^2 of Black Gold compost was incorporated into plots receiving compost. Compost was applied on top of the biochar in plots receiving both amendments. In 2013 six plots were tested with ½ the compost rate to see if cost savings could be achieved.

1.2.5 PHYSICAL MANIPULATION

In an attempt to mimic real-life scenarios for re-vegetation, all plots were scarified first with long-tined (tine length 10 cm) rake or hand-cultivator, and then raked with a fine-toothed rake. After the application of soil amendments, seed and water, each plot was tamped gently but firmly with the back of a rake to create micro-sites and achieve good seed placement.

1.2.6 WATER APPLICATION

Each plot was supplied with 8 litres of water when installed. During subsequent monitoring events, 8 litres of water were also applied to each plot unless it was obvious that rainfall was sufficient.

2.0 FIELD STUDY SITES

2.1 WHITEHORSE COPPER MINE TAILINGS

The Whitehorse Copper Mine, in the City of Whitehorse, shut down in 1982 after 15 years of steady production of copper and gold. The mine left behind significant tailings – about ten million tons. The tailings are strongly alkaline and present a hard saline evaporite crust which severely inhibits plant growth. The pH of the tailings is around 8.5. Manganese is slightly elevated at around 800 mg/kg and copper concentration is around 2,400 mg/kg. Markedly high is Iron at 143,000 mg/kg. The latter, in the form of magnetite, is the reason why the tailings are slated for re-processing by the current operator Imperial Metals, who graciously consented to allow access to their leased property.

The Whitehorse Copper Tailings were subjected to a revegetation research project conducted for Hudson Bay Mining and Smelting between 1994 and 1997 by Dr. Doug Craig and his wife Joan Craig. The vegetation program was very intense and involved irrigation and application of several soil amendments on plots within a 1 hectare test area on the “old tailings” near the Little Chief Mine. The project was a success, with the best results achieved with application of locally derived compost made from grass cuttings, sawdust and coffee grounds collected from government offices. Thus the site presented several advantages for the current study; it is in the city limits of Whitehorse, it has been successfully re-vegetated in test plots using locally made compost and it is representative of real-life challenges in re-vegetating mine-affected soil.

Although the tailings are currently slated for re-processing, the current field trials should still provide insight into the revegetation of similar sites.

Two blocks of 15 plots each were laid out on the Whitehorse Copper tailings on July 13, 2012, with three replicates of each treatment. Each plot was 1 X 1 m^2 with a buffer zone of 0.5 m between plots.

Two more blocks (Block C and Block D), were installed in June 2013.

Whitehorse Copper Block C Installed June, 2013:

E

15	18	8	4
11	2	17	16
5	12	9	20
19	3	13	14
1	10	7	6
24 seed + BC + ½ rate Compost	23 seed + BC + ½ rate Compost	22 seed + BC + ½ rate Compost	21 seed + 150g Leonardite Pellets

Whitehorse Copper Block D Installed June, 2013:

N

5	8	15	20
7	2	11	14
6	17	16	12
13	9	3	19
10	18	1	4
24 seed + BC + ½ rate Compost	23 seed + BC + ½ rate Compost	22 seed + BC + ½ rate Compost	21 seed + 150g Leonardite Pellets

2.2 MOUNT SKUKUM GOLD MINE TAILINGS

The mine tailings at this site, in the Wheaton River Valley, have been undisturbed since the mine closed in 1988. Decommissioning work and recent environmental baseline studies have shown that the tailing no longer host cyanide. Earlier revegetation studies had taken place on these tailings from 2003 to 2006. These were revisited in 2009 and reported in 2010 (Hutchison and Hayward MPERG Report 2010-5). The results of the revegetation studies indicated that Whitehorse compost was very effective at sustaining plant growth on the tailings. The current field trials are situated in close proximity to the existing test plots.

Two blocks of 15 plots each were laid out on the Mount Skukum tailings on July 24, 2012, with three replicates of each treatment. Each plot was 1 X 1 m^2 with a buffer zone of 0.5 m between plots.

Two new blocks were installed in June, 2013.

MSGM Block C Installed June, 2013

N

12	8	13	17
20	19	7	9
18	16	11	6
5	1	10	15
4	2	3	14

MSGM Block D Installed June, 2013

N

4	13	18	6
15	3	16	14
12	7	19	11
1	2	5	10
9	17	8	20

2.3 ARCTIC GOLD AND SILVER MINE (AG&S) TAILINGS

The mine tailings at this site near Carcross were provided with a till cover (fine silt and clay sized particles obtained from a borrow pit at the Carcross landfill) over the tailings pond in 1999. The underlying tailings are strongly acidic. The cover was re-vegetated in 2000 using clover, and re-done in 2008 due to poor results. Presently there are still significant areas where revegetation has not taken hold. Drainage from the covered tailings pond is concentrated in a ditch from the till cover to an unnamed lake and thence to Tank Creek. It is thought that pore water from the tailings is day lighting in this ditch because it is presenting symptoms typical of acid rock drainage (ARD). These include metal precipitates, pH as low 3 and vegetation die-off.

In 2012 tTwo blocks of 15 plots each were laid out on the Arctic Gold and Silver tailings cover on July 20, 2012, with three replicates of each treatment. Each plot was 1 X 1 m^2 with a buffer zone of 0.5 m between plots. It should be noted that these two plots are not representative of revegetation of tailings, rather they are meant to demonstrate revegetation of a tailings cover comprised of fine-grained till. The cover itself is designed to inhibit acid mine drainage by shutting off the supply of water and oxygen to the highly acidic tailings buried below.

In 2012 an additional block of ten plots was established downslope from the tailings in the area with acid mine drainage (AMD) on July 21, 2012. Each plot was 1m^2 with buffer zones between plots. Five of the plots were treated with S+C and five with S+B+C. These plots were improvised in the field to suit the site micro topography. They are circular in shape and bordered by stones.

In 2013 replicate blocks D and E were established on the till cover proximal to the Blocks A and B installed in 2012. No further work was done at the acid-drainage affected site due to flooding.

AG&S Block D Installed June, 2013

N

1	20	15	13
14	10	19	3
8	2	12	11
7	16	9	17
4	6	5	18

AG&S Block E Installed June, 2013

N

1	20	15	13
14	10	19	3
8	2	12	11
7	16	9	17
4	6	5	18

3.0 2013 FIELD TRIAL RESULTS

The field sites were monitored periodically in 2013 from when the new plots were established in June until early September. During these site visits, besides the application of water when required (as described above), the plots were examined and the following observations were made:

- Estimated number of grasses that have emerged (all species)
- Number of vetches that have emerged
- Average plant height - all species (cm)
- Plant health (general description of foliage)
- Soil state (moisture, compaction, disturbance)

The complete results of the field monitoring have been tabulated in an excel workbook supplied under separate cover. The vegetative cover at each site, reported as the counted number of emerging vetch plants and the estimated number of grasses (all species combined), is summarized as follows:

3.1 WHITEHORSE COPPER MINE TAILINGS

The Whitehorse Copper test plots were monitored on July 5, July 16, July 23, July 29, August 7, August 16, August 22, August 28 and September 3.

Table 3.1.1 Whitehorse Copper Test Plots Established in 2012 (average of pooled data for six plots receiving each treatment)

Date	Null		Seed		Seed+Compost		Seed+Biochar		Seed+Compost+ Biochar	
	Vetch	Grass	Vetch	Grass	Vetch	Grass	Vetch	Grass	Vetch	Grass
July 5	0.0	0	0.0	21	0.0	81	0.0	8	0.0	53
July 16	0.0	0	0.0	100	0.0	304	0.0	71	0.0	225
July 23	0.0	0	0.0	111	0.0	224	0.0	39	0.0	148
July 29	0.0	0	0.0	65	0.0	228	0.0	17	0.0	171
Aug 7	0.0	0	0.0	59	0.0	255	0.0	43	0.0	269
Aug 16	0.0	0	0.0	61	0.0	212	0.0	29	0.0	172
Aug 22	0.0	1	0.0	26	0.0	41	0.0	23	0.0	29
Sept 3	0.0	0	0.0	81	0.0	173	0.0	37	0.0	247

Table 3.1.2 Whitehorse Copper Test Plots Established in 2013 - Vetch Count (average of pooled data for six plots receiving each treatment)

Site Visit Date	Null	Seed	Seed + 15 L Compost	Seed + Biochar	Seed + Biochar + 15 L Compost	Seed + Biochar + 7.5 L Compost	Seed + 50 g Humic Acid	Seed + 150 g Humic Acid
July 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
July 16	0.0	0.6	0.6	0.5	0.0	0.2	0.6	0.0
July 23	0.0	0.0	0.8	0.5	0.7	0.3	1.3	0.2
July 29	0.0	3.0	2.5	3.8	2.3	2.2	3.7	2.0
Aug 7	0.0	3.7	3.0	4.3	3.2	2.8	4.3	2.8
Aug 16	0.0	3.3	2.8	4.2	2.8	3.2	4.3	1.8
Aug 22	0.0	3.8	3.0	4.0	3.2	3.2	4.2	3.2
Aug 28	0.0	3.3	3.0	4.3	3.2	3.3	3.7	3.3

* on Sept 3 Whitehorse Copper Site C was reported, but not Site D, so not included in Table 3.1.2

Table 3.1.3 Whitehorse Copper Test Plots Established in 2013 - All Species Grass Count (average of pooled data for six plots receiving each treatment)

Site Visit Date	Null	Seed	Seed + 15 L Compost	Seed + Biochar	Seed + Biochar + 15 L Compost	Seed + Biochar + 7.5 L Compost	Seed + 50 g Humic Acid	Seed + 150 g Humic Acid
July 5	0	0	0	0	0	0	0	0
July 16	0	0	2	5	0	0	0	0
July 23	0	1	2	1	1	2	0	3
July 29	0	92	97	121	94	133	144	152
Aug 7	0	117	233	209	162	203	199	168
Aug 16	0	103	187	126	137	128	164	128
Aug 22	0	50	88	61	115	81	69	70
Aug 28	0	46	89	67	98	200	58	84

* on Sept 3 Whitehorse Copper Site C was reported, but not Site D, so not included in Table 3.1.3

3.2 MOUNT SKUKUM MINE TAILINGS

The Mount Skukum test plots were monitored on July 17, July 24, July 30, August 6, August 14, August 21 and August 27.

Table 3.2.1 Mount Skukum Test Plots Established in 2012 (average of pooled data for six plots receiving each treatment)

Date	Null		Seed		Seed+Compost		Seed+Biochar		Seed+Compost+Biochar	
	Vetch	Grass	Vetch	Grass	Vetch	Grass	Vetch	Grass	Vetch	Grass
July 17	0.0	0	0.0	61	0.0	213	0.0	50	0.0	162
July 24	0.0	0	0.0	49	0.0	155	0.3	82	0.0	99
July 30	0.0	0	0.0	50	0.3	107	0.0	115	0.0	120
Aug 6	0.0	1	0.0	31	0.2	57	0.0	47	0.0	77
Aug 14	0.0	0	0.0	41	0.0	124	0.2	82	0.0	121
Aug 21	0.0	1	0.0	43	0.0	151	0.0	88	0.0	105
Aug 27	0.0	0	0.0	67	0.0	203	0.0	125	0.0	145

Table 3.2.2 Mount Skukum Test Plots Established in 2013 - Vetch Count (average of pooled data for six plots receiving each treatment)

Site Visit Date	Null	Seed	Seed + 15 L Compost	Seed + Biochar	Seed + Biochar + 15 L Compost	Seed + Biochar + 7.5 L Compost	Seed + 50 g Humic Acid	Seed + 150 g Humic Acid
July 17	0.0	1.0	1.0	0.3	0.2	0.7	0.2	1.3
July 24	0.0	1.3	1.7	1.5	0.3	1.0	1.5	2.2
July 30	0.0	6.8	4.8	6.0	5.3	6.7	7.0	8.5
Aug 6	0.0	2.7	0.7	0.7	2.0	2.0	3.2	0.8
Aug 14	0.0	7.0	4.8	5.0	2.3	2.3	6.8	6.0
Aug 21	0.0	6.8	2.5	4.2	4	4.2	7.3	5.8
Aug 27	0.0	1.3	1.3	3.0	1.0	1.0	6.7	6.0

Table 3.2.3 Mount Skukum Test Plots Established in 2013 - All Species Grass Count (average of pooled data for six plots receiving each treatment)

Site Visit Date	Null	Seed	Seed + 15 L Compost	Seed + Biochar	Seed + Biochar + 15 L Compost	Seed + Biochar + 7.5 L Compost	Seed + 50 g Humic Acid	Seed + 150 g Humic Acid
July 17	2	0	0	0	0	0	1	2
July 24	5	0	0	0	0	0	3	0
July 30	2	254	191	165	143	188	220	223
Aug 6	2	179	165	146	100	177	188	167
Aug 14	8	240	221	187	153	192	287	185
Aug 21	3	162	157	123	142	181	116	161
Aug 27	10	119	280	170	203	233	233	300

3.3 ARCTIC GOLD AND SILVER MINE TAILINGS

The Arctic Gold and Silver test plots were monitored on August 1, August 8, August 13, August 23 and August 30.

Table 3.3.1 Arctic Gold and Silver Test Plots Established in 2012 (average of pooled data for six plots receiving each treatment)

Date	Null		Seed		Seed+Compost		Seed+Biochar		Seed+Compost+Biochar	
	Vetch	Grass	Vetch	Grass	Vetch	Grass	Vetch	Grass	Vetch	Grass
Aug 1	1.0	10	0.0	48	0.3	66	0.0	16	0.0	12
Aug 8	0.8	7	0.0	54	0.0	179	0.0	88	0.0	178
Aug 13	0.0	3	0.0	78	0.0	243	0.0	109	0.0	133
Aug 23	0.0	5	0.0	69	0.3	198	0.0	86	0.0	149
Aug 30	0.0	9	0.0	113	0.0	308	0.0	116	0.0	172

Table 3.3.2 Arctic Gold and Silver AMD Test Plots Established in 2012 (average of pooled data for five plots receiving each treatment)

Date	Seed+Biochar		Seed+Compost+Biochar	
	Vetch	Grasses	Vetch	Grasses
Aug 1	0.0	36	0.0	39
Aug 8	0.0	78	0.0	89
Aug 13	0.0	82	0.0	104
Aug 23	0.0	60	0.0	69
Aug 30	0.0	74	0.0	76

Table 3.3.3 Arctic Gold and Silver Test Plots Established in 2013 - Vetch Count (average of pooled data for six plots receiving each treatment)

Site Visit Date	Null	Seed	Seed + 15 L Compost	Seed + Biochar	Seed + Biochar + 15 L Compost	Seed + Biochar + 7.5 L Compost	Seed + 50 g Humic Acid	Seed + 150 g Humic Acid
Aug 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 8	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Aug 13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug 23	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Aug 30	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0

Table 3.3.4 Arctic Gold and Silver Test Plots Established in 2013 - All Species Grass Count (average of pooled data for six plots receiving each treatment)

Site Visit Date	Null	Seed	Seed + 15 L Compost	Seed + Biochar	Seed + Biochar + 15 L Compost	Seed + Biochar + 7.5 L Compost	Seed + 50 g Humic Acid	Seed + 150 g Humic Acid
Aug 1	0	0	1	2	1	1	1	0
Aug 8	0	0	1	0	1	1	1	0
Aug 13	0	0	0	0	0	0	0	1
Aug 23	0	0	2	2	0	0	0	1
Aug 30	0	0	3	1	2	2	0	1

4.0 2014 MONITORING RESULTS

In 2014 the monitoring protocol was simplified to include observations of cover class instead of the grass count used in 2012 and 2013. The field sites were monitored periodically in 2014 from mid-June until mid-September. During these site visits, besides the application of water when required the plots were examined and the following observations were made:

- Cover class for all grass species that had emerged (all species combined). Cover classes include:
  - 1 0-5%
  - 2 5-25%
  - 3 25-50%
  - 4 50-75%
  - 5 75-95%
  - 6 95-100%
- average plant height of each grass species (cm)
- whether or not each grass species was in flower/seed
- soil state (moisture, compaction, disturbance)
- evidence of invading species
- rain gauge reading for each site (mm)

The complete results of the field monitoring have been tabulated in an excel workbook supplied under separate cover. The vegetative cover class at each site is summarized as follows.

4.1 WHITEHORSE COPPER MINE TAILINGS

In 2014, the Whitehorse Copper test plots were monitored on June 11, June 20, June 24/25, July 2, July 9, July 16, July 24, August 4, August 11, September 3, September 9 and September 16.

Table 4.1.1 Cover Class for Whitehorse Copper Test Plots Established in 2012

Date	Null	Seed	Seed+Compost	Seed+Biochar	Seed+Compost+B
June 11	1.0	1.2	3.5	1.0	2.2
June 20	1.0	1.2	3.5	1.0	3.0
June 25	1.0	1.0	3.7	1.0	2.8
July 2	1.0	1.0	3.8	1.0	2.8
July 9	1.0	1.0	2.3	1.0	2.3
July 16	1.0	1.0	3.5	1.0	2.6
July	1.0	1.0	3.0	1.0	2.3
Aug 4	1.0	1.0	3.3	1.0	3.2
Aug 11	1.0	1.0	4.0	1.0	3.0
Sept 3	1.0	1.0	3.5	1.0	2.8
Sept 9	1.0	1.0	3.0	1.0	2.3
Sept 16	1.0	1.2	3.3	1.0	2.8

Note: these are the average of pooled data for six plots receiving each treatment in Blocks A and B, except for July 9, July 24 and Sept 9 when only the three plots receiving each treatment in Block A were monitored, and August 11 when only the three plots receiving each treatment in Block B were monitored.

Table 4.1.2 Cover Class for Whitehorse Copper Test Plots Established in 2013

Site Visit Date	Null	Seed	Seed + 15 L Compost	Seed + Biochar	Seed + Biochar + 15 L Compost	Seed + Biochar + 7.5 L Compost	Seed + 50 g Humic Acid	Seed + 150 g Humic Acid
June 11	1.0	1.3	2.5	1.5	2.8	2.3	1.0	1.2
June 20	1.0	1.3	2.7	1.7	3.0	2.3	1.5	1.3
June 24	1.0	1.5	3.2	2.3	3.3	2.8	1.5	1.2
July 2	1.0	1.3	3.3	1.7	3.2	2.2	1.5	1.3
July 9	1.0	1.3	2.7	1.7	3.2	2.4	1.3	1.2
July 16	1.0	1.3	2.7	1.5	3.0	2.5	1.0	1.0
July 24	1.0	1.0	3.0	1.0	2.7	2.0	1.0	1.0
July 30	1.0	1.0	2.7	1.0	2.7	2.7	1.0	1.0
Aug 4	1.0	1.0	2.8	1.8	3.2	2.8	1.3	1.2
Aug 11	1.0	1.2	2.7	1.7	3.2	2.5	1.3	1.2
Sept 3	1.0	1.0	2.7	2.0	3.7	2.7	1.0	1.0
Sept 16	1.0	1.3	2.7	1.8	3.3	2.8	1.3	1.3

Note: Average of pooled data for six plots receiving each treatment in Blocks C and D, except for Sept 3 when only the three plots receiving each treatment in Block C were monitored, and July 24 and 30 when only the three plots receiving each treatment in Block D were monitored.

4.2 MOUNT SKUKUM MINE TAILINGS

In 2014, the Mount Skukum test plots were monitored on June 18, June 26, July 3, August 13, September 5, September 12 and September 19.

Table 4.2.1 Cover Class for Mount Skukum Test Plots Established in 2012

Da	Null	Seed	Seed+Compost	Seed+Biochar	Seed+Compost+Bio
June 18	1.0	1.0	3.0	1.0	2.5
June 26	1.0	1.2	4.5	1.8	3.8
July 3	1.0	1.0	3.2	1.0	2.7
Aug 13	1.0	1.0	4.0	1.3	3.3
Sept 5	1.0	1.0	4.0	1.7	5.2
Sept 12	1.0	1.0	3.3	1.0	4.0
Sept 19	1.0	1.0	4.2	1.0	4.2

Note: (average of pooled data for six plots receiving each treatment in Blocks A and B, except for Sept 12 when only the three plots receiving each treatment in Block B were monitored)

Table 4.2.2 Cover Class for Mount Skukum Test Plots Established in 2013

Date	Null	Seed	Seed + 15 L Compost	Seed + Biochar	Seed + Biochar + 15 L Compost	Seed + Biochar + 7.5 L Compost	Seed + 50 g Humic Acid	Seed + 150 g Humic Acid
June 18	1.0	1.0	2.2	1.5	1.8	2.2	1.3	1.6
June 26	1.0	1.3	1.2	1.3	1.5	1.5	1.0	1.2
July 3	1.0	1.2	1.2	1.0	1.5	1.3	1.0	1.0
Aug 13	1.0	1.7	2.2	1.5	2.3	2.2	1.3	2.0
Sept 5	1.0	1.3	2.3	1.7	2.0	2.0	1.3	2.0
Sept 12	1.0	1.6	1.2	1.0	3.0	2.3	1.3	1.7
Sept 19	1.0	1.3	1.0	1.3	3.3	1.0	1.0	1.0

Note: (average of pooled data for six plots receiving each treatment in Blocks C and D, except for Sept 5 when only the three plots receiving each treatment in Block D were monitored and Sept 12 and Sept 19 when only the three plots receiving each treatment in Block C were monitored)

4.3 ARCTIC GOLD AND SILVER MINE TAILINGS

In 2014, the Arctic Gold and Silver test plots were monitored on June 17, June 23, June 30, July 8, July 14, July 23, July 31, August 6, August 12, September 4, September 11 and September 18.

Table 4.3.1 Cover Class for Arctic Gold and Silver Test Plots Established in 2012

Date	Null	Seed	Seed+Compost	Seed+Biochar	Seed+Compost+Bioc
June 17	1.0	1.3	2.3	1.5	2.3
June 23	1.0	1.8	2.8	1.5	2.8
June 30	1.0	2.0	3.6	2.7	3.7
July 8	1.0	1.8	2.8	1.7	2.3
July 14	1.0	2.0	2.8	1.3	2.3
July 23	1.0	2.2	3.5	2.3	3.3
Sept 4	1.0	2.0	3.0	1.3	3.3
Sept 11	1.0	2.0	3.0	2.0	3.0
Sept 18	1.0	2.0	2.3	1.7	3.0

Note: (average of pooled data for six plots receiving each treatment in Blocks A and B, except for Sept 4, September 11 and September 18 when only the three plots receiving each treatment in Block B were monitored)

Table 4.3.2 Cover Class for Arctic Gold and Silver Test Plots Established in 2013

Site Visit Date	Null	Seed	Seed + 15 L Compost	Seed + Biochar	Seed + Biochar + 15 L Compost	Seed + Biochar + 7.5 L Compost	Seed + 50 g Humic Acid	Seed + 150 g Humic Acid
June 17	1.0	1.2	1.8	1.0	1.2	1.3	1.2	1.2
June 23	1.0	1.2	1.8	1.3	1.2	2.0	1.3	1.3
June 30	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July 8	1.0	1.0	1.3	1.0	1.2	1.2	1.0	1.0
July 14	1.0	1.2	1.3	1.0	1.2	1.2	1.2	1.2
July 23	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July 31	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Aug 6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Aug 12	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sept 4	1.0	1.3	1.7	1.2	1.5	1.8	1.3	1.5
Sept 11	1.0	1.0	1.7	1.0	1.7	1.3	1.0	1.0
Sept 18	1.0	1.0	1.5	1.0	1.3	1.3	1.2	1.0

Note: (average of pooled data for six plots receiving each treatment in Blocks D and E, except for June 30, July 23, July 31, August 6, August 12, and September 11 when only the three plots receiving each treatment in Block D were monitored)

5.0 SOIL ANALYTICS

In 2012 a series of baseline composite samples were collected from the footprint of each of the proposed test blocks at each of the three mine sites prior to installation of the 1 x 1 m test plots and prior to any soil amendments. In the fall of 2013, composite samples were collected from each of the soil amendment groups at each block at each site. In 2013, the blocks were duplicated using locally produced biochar (as opposed to biochar imported from Colorado used in 2012). These blocks were sampled in 2014 using identical techniques and parameters as in 2013.

To aid in review of these data, the soil amendments and baseline sample locations are repeated below. The 2012 samples represent the baseline case. The samples collected in 2013 represent the effect of each soil amendment upon the baseline after one growing season. The samples collected in 2014 represent the effect of each soil amendment upon the baseline case after one growing season in the blocks installed in 2013. Note that the 2013 blocks used locally made biochar, and that new soil amendments were added to the experiment (Plots 16, 17 and 18 represent addition of Leonardite pellets at a rate of 50g/m^2, plots 19, 20 and 21 represent the addition of Leonardite pellets at 150/g/m^2 and plots 22, 23, and 24 represent a 50% reduction in compost).

The excel workbook ***Biochar_Soil_Analytics_2012-2013-2014.xlsx*** is supplied with this report. A pivot table has been created with the analytical data to allow easy comparison of various parameters to baseline data. The data suggest that soil quality was enhanced by the soil amendments. Organic matter was increased and metalloids were reduced.

A comprehensive interpretation of the soil analytical data is beyond the scope of this report, however the data have been supplied in two formats allowing for review by Yukon College students or others interested in the research.

2012 Baseline Samples

Plot Number	comment
WHC A,B,C	Whitehorse Copper Tailings Composite samples taken from the footprints of Blocks A and B
MSGM A,B,C	Mount Skukum Gold Mine Tailings Composite sample taken from the footprint of Blocks A and B
AG&S TILL	Arctic Gold and Silver (also referred to as Montana Mountain, or MTM in subsequent sampling) composite sample taken from the till cover in the footprint of Blocks A and B
AG&S DS	Arctic Gold and Silver composite sample taken from the acid drainage pathway downstream of the tailings till cover in the footprint of Block C

Plots Installed in 2012 and sampled in September 2013

Plot Number	Soil amendment
1, 2, 3	NULL
4,5,6	Seed only
7,8,9	Seed + Compost 15 L/m^2
10,11,12	Seed + Biochar 2.28 kg/m^2
13,14,15	Seed + Biochar 2.28 kg/m^2 + Compost 15 L/m^2

Plots Installed in 2013 and sampled in September 2014

Plot Number	Soil amendment
1, 2, 3	NULL
4,5,6	Seed only
7,8,9	Seed + Compost 15 L/m^2
10,11,12	Seed + Biochar 2.28 kg/m^2
13,14,15	Seed + Biochar 2.28 kg/m^2 + Compost 15 L/m^2
16,17,18	Seed + Leonardite Pellets 50g/m^2
19,20,21	Seed + Leonardite Pellets 150g/m^2
22,23,24	Seed + Biochar 2.28 kg/m^2 + Compost 7.5 L/m^2 (1/2 compost)

6.0 CONCLUSIONS AND RECOMMENDATIONS

Following is a brief summary of the 2013 field observations of the test plots established in 2012:

- At all three sites, compost has been the most effective of the three soil amendments. This conclusion is based solely on the number of grass plants (all species combined) found on the test plots. The next most effective soil amendment has been the combination of compost + biochar, followed by biochar alone.

- The data set from the ARD plots at AG&S suggests that the combination of compost + biochar is a more effective soil amendment than biochar alone.

- The near-zero survival of the vetch plants (hairy vetch or Vicia villosa, a legume species non-native to North America) over the winter of 2012-13 ascertains that this species will be of no use in the multi-year evaluation of soil amendments in the Yukon.

Following is a brief summary of the field observations of the test plots established in 2013:

- Preliminary monitoring data from the Whitehorse Copper and Mt. Skukum sites (the late seeding of the plots at the Arctic Gold & Silver site rendered the data from there inconsistent with that from the other two sites), indicates that compost has been a more effective soil amendment than biochar. This conclusion is based solely on the number of grass plants (all species combined) found on the test plots.

- Humic acid also appears to be an effective soil amendment. The preliminary monitoring data is inconclusive as to whether the higher application rate (150 g compared to 50 g) is beneficial.

- The monitoring data is also inconclusive as to whether a higher application rate of compost (15 L compared to 7.5 L) in combination with biochar is beneficial.

The 2014 monitoring results (cover class only) are summarized as follows:

Whitehorse Copper

Test Plots Established in 2012

The plots receiving the treatment of compost only resulted in the highest observed cover class (maximum average cover class of 4.0), followed by those treated with compost and biochar (maximum average 3.2) and those treated with biochar only (maximum average 1.0).

Test Plots Established in 2013

The plots receiving the treatment of biochar and 15 litres of compost resulted in the highest observed cover class (maximum average cover class of 3.7), followed by those treated with compost only (maximum average 3.3), those treated with biochar and 7.5 litres of compost (maximum average 2.8) and those treated with biochar only (maximum average 2.3). There was little difference between the cover classes on the plots treated with 50 grams of humic acid and those treated with 150 grams of humic acid - both very similar to the untreated plots (seed only).

Mount Skukum

Test Plots Established in 2012

The plots receiving the treatment of biochar and compost resulted in the highest observed cover class (maximum average cover class of 5.2), followed by those treated with compost only (maximum average 4.5) and those treated with biochar only (maximum average 1.8).

Test Plots Established in 2013

The plots receiving the treatment of biochar and 15 litres of compost resulted in the highest observed cover class (maximum average cover class of 3.3), followed by those treated with biochar and 7.5 litres of compost (maximum average 2.3), those treated with compost only (maximum average 2.3) and those treated with biochar only (maximum average 1.7). The cover class on the plots treated with 150 grams of humic acid was higher (maximum average 2.0) than those treated with 50 grams of humic acid (maximum average 1.3).

Arctic Gold and Silver

Test Plots Established in 2012

The plots receiving the treatment of biochar and compost resulted in the highest observed cover class (maximum average cover class of 3.7), followed by those treated with compost only (maximum average 3.6) and those treated with biochar only (maximum average 2.7).

Test Plots Established in 2013

The plots receiving the treatment of biochar and 7.5 litres of compost resulted in the highest observed cover class (maximum average cover class of 2.0), followed by those treated with compost only (maximum average 1.8), those treated with biochar and 15 litres of compost (maximum average 1.7) and those treated with biochar only (maximum average 1.3). There was little difference between the cover classes on the plots treated with 50 grams of humic acid and those treated with 150 grams of humic acid - both very similar to the untreated plots (seed only).

Based solely on the cover class data from the 2014 observations of the 15 test plots established in 2012 at each of the three sites, and the 24 test plots established in 2013 at each of the three sites, the following preliminary conclusions can be reached:

- After one and two years since the plots were established, compost remains the most effective soil amendment. The addition of biochar has also been beneficial in most cases. As expected, biochar treatment alone has been less effective. The monitoring data is insufficient to show whether or not a reduced rate of compost application (7 L/m^2 compared to 15 L/m^2) in combination with biochar provides comparable benefits. Data from the Whitehorse Copper and Mt. Skukum sites show a slight improvement with the higher application rate but growth was still robust with the lower rate.

- Humic acid appears to have limited benefits as a soil amendment. The preliminary monitoring data is inconclusive as to whether the higher application rate (150 g compared to 50 g) is beneficial.

Following are recommendations for the 2015 growing season:

- Monitoring should carried out routinely from mid-June to mid-September.

- Standard watering protocols should be continued.

- The monitoring protocols used in 2014 should be continued.

Appendix A Pictures

Image 1 – Whitehorse Copper Block D July 2013

2 - Whitehorse Copper Block D May 11 2014

Image 2 – Arctic Gold and Silver (AG&S) Block D, 2013

Image 3 – AG&S Block D May 23 2014

Image 4 – AG&S, 2013

Image 5 – AG&S Block E May 23 2014

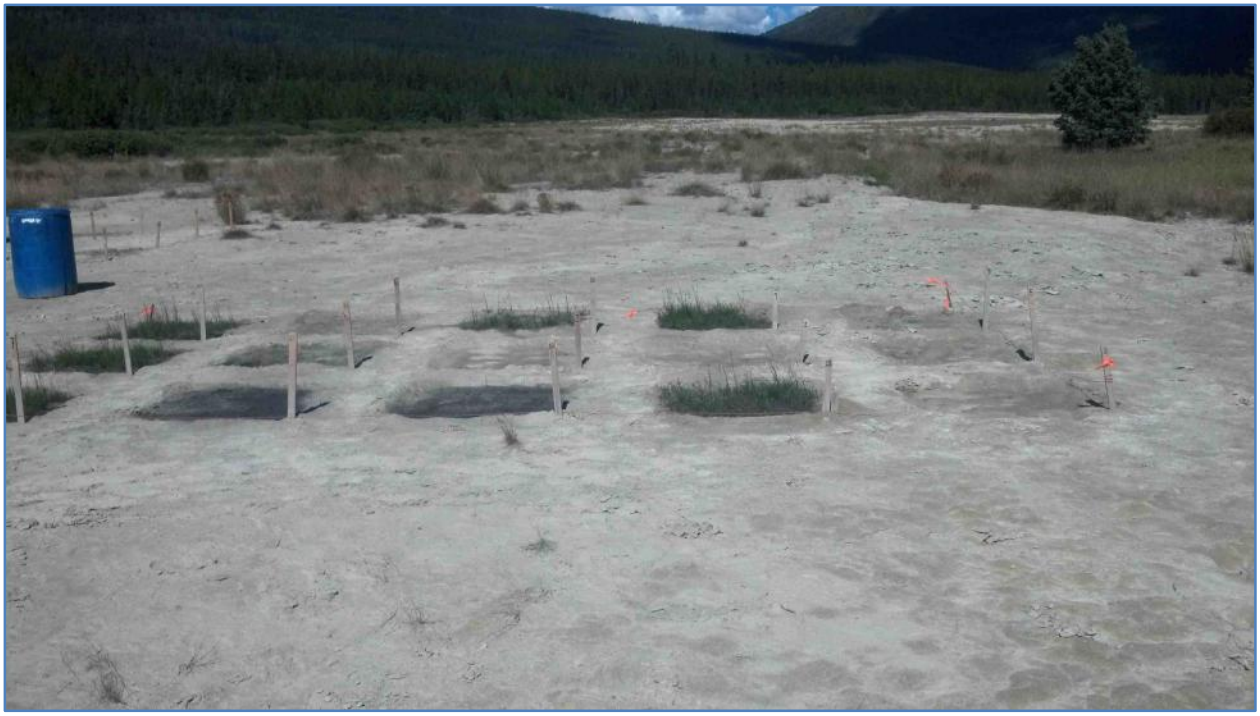


Image 4 – Mount Skukum 2012 Block B (note growth)

Image 5 MSGM Block B May 26 2014

Image 5 – Mount Skukum Block C installed 2013

Mount Skukum Block A July 13 2014