Yukon University

Revegetation research at Minto Mine

Year 1 Progress Report | November 2021

UNIVERSITY OF ALBERTA

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Introduction

Revegetation is a key process in reclamation as it ultimately determines future land uses by people and wildlife (Guittony 2020). The majority of boreal reclamation research focuses on oil sands mining in the Boreal Plains Ecoregion of Alberta with a strong emphasis on soil amendments of peat and forest floor materials, as well as extensive tree planting (Dhar et al. 2018). Forest floor salvage and peat amendments can reintroduce plant propagules and improve soil characteristics; tree planting reduces the time to canopy closure and can limit establishment of weedy species (Macdonald et al. 2015). In the Yukon, most mines are in remote locations without significant peat or topsoil resources. Access to locally sourced tree seedlings is also limited. Best practice in revegetation is to optimize the use of local resources (Guittony 2020) and thus exploring alternative techniques for northern regions is warranted.

Facilitation by woody shrubs in restoration projects has been documented in dry, arid climates, but not tested in northern systems (Gómez et al 2004; Castro et al. 2004; Gómez -Aparacio et al. 2005). Research studying shrub encroachment in arctic and alpine tundra provides evidence that tall shrubs have a strong, year-round influence on northern non-forested community dynamics (review by Myers-Smith et al. 2011). Plants can facilitate the survival and growth of their neighbors by providing more favorable environmental conditions such as reduced soil and air temperature extremes, nitrogen fixation, attracting pollinators and providing physical protection from herbivory (Castro et al. 2004 Baraza et al. 2006; Padilla and Pugnaire 2006; Dona and Galen 2007; Brooker et al. 2008). In cold climates, vertical structure such as a shrub canopy can increase the capture of snow which dramatically alters both summer and winter soil conditions (Kreyling 2019). Vertical structure can also reduce the loss of soil and seeds to wind erosion (Peterson 2001).

Facilitation between plants is most common in harsh environments, especially during the establishment and early growth life stages (Maestre et al. 2009). Growth of shrubs alters abiotic and biotic conditions in non-forested northern ecosystems; in a reclamation setting, the presence of shrubs may facilitate establishment and growth of other species. The strength of facilitation effects from the physical characteristics of vertical structure versus biological characteristics of shrubs is unclear.

Figure 1. Green alder seedling facilitating the “capture” of windblown seeds.

The main objectives of this study are to evaluate the usefulness of vertical structure in facilitating the arrival, establishment and growth of northern plants and compare the effects of living vs. non-living structure.

More specifically, the hypothesizes investigated in this study are:

1) Vertical structures improve growing season soil moisture by increased wind protection, snow capture and soil shading.
    a. The magnitude of effect is proportional to structure height and distance from structure
    b. Living structures increase soil moisture more than inert structures as litter increases soil organic matter and thus water holding capacity
2) Living vertical structures improve growing season plant available nitrogen by nitrogen fixation and litter deposition
    a. The magnitude of effect is species specific
    b. The magnitude of effect is proportional to structure height and distance from structure
3) Increases in soil moisture and plant available nitrogen provided by woody shrubs improves plant growth under harsh, northern conditions
    a. Facilitation by woody shrubs is stronger than competition during establishment and early growth of target species
4) Vertical structure increases natural deposition of seeds
    a. From animal/bird dispersal using the perches/cover
    b. From wind dispersal, slowing wind currents to deposit seeds

Experimental design

The study design is a randomized complete block experiment with biotic and abiotic structures of three different heights for a total of four blocks of six treatments (Table 1.). Treatments are in rows perpendicular to the dominant wind direction. Spacing between rows is based on the tallest treatment in each row to avoid interference between treatments; main effects of treatments are expected between two and seven times structure height (AAFC 2010). See the Experiment Layout Section for more details on actual site layout.

Table 1. Summary of experiment treatments

Treatment Height	Biotic Structure	Abiotic Structure
Tall	Green alder	0.65 m snow fence
Medium	Soapberry	0.35 m snow fence
Short	Smooth-leaf mountain avens	0 m control

To determine whether vertical structure facilitates seed capture, three 0.25 m wide transects with a smooth, uniform seedbed will be installed straddling each treatment from -1 to 7x the treatment height (Figure 2.). In Blocks 1-3, soil moisture and temperature sensors will also be installed along the centre transect at -1, 1, 3, and 7x the treatment height.

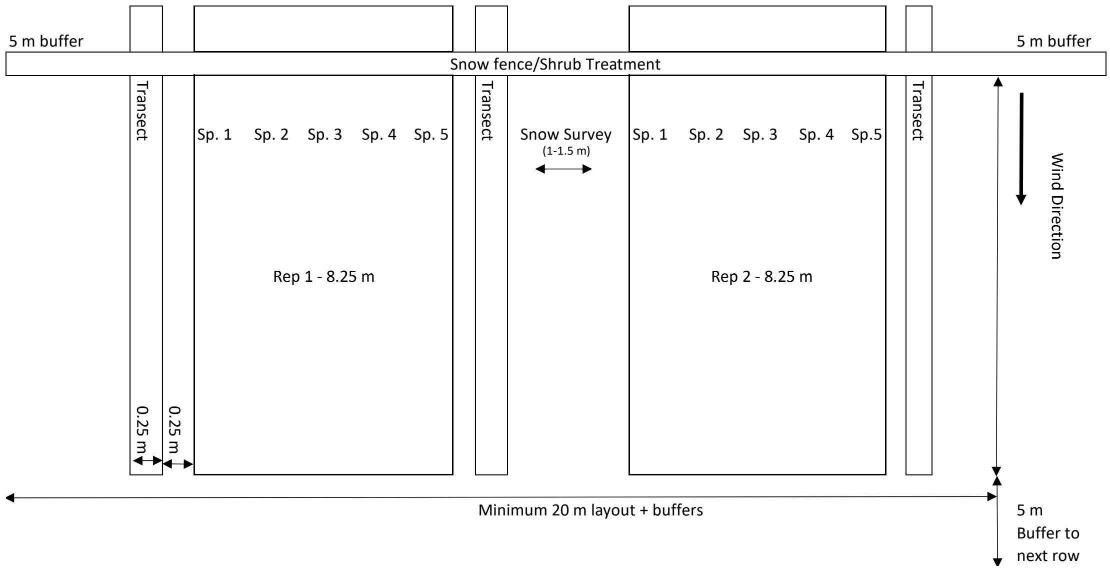

Figure 2. Within block layout of transects and germination/seedling plot replicates. See Figure 3. for detailed layout of each replicate.

In Year 3 (2023), small plots will be established at -1, 1, 3, and 7x the height of the shelter to evaluate the effect of vertical structure on the germination, establishment and growth of target northern plants (Figure 3.). Shrub heights in each treatment will be averaged from measurements in Year 3 to determine the treatment height. For each target species, paired comparisons of spring vs. fall seeding/planting will be tested. Germination trials of 100 seeds will be installed in 0.15 m^2 plots; protection from herbivory will be provided if required. Plant performance will be tested by planting six seedlings in 0.5 x 0.15 m plots. A minimum distance of 0.25 m between plots will be maintained. Germination percentages, seedling survival, seedling height will be sampled in September of Year 4 (2024).

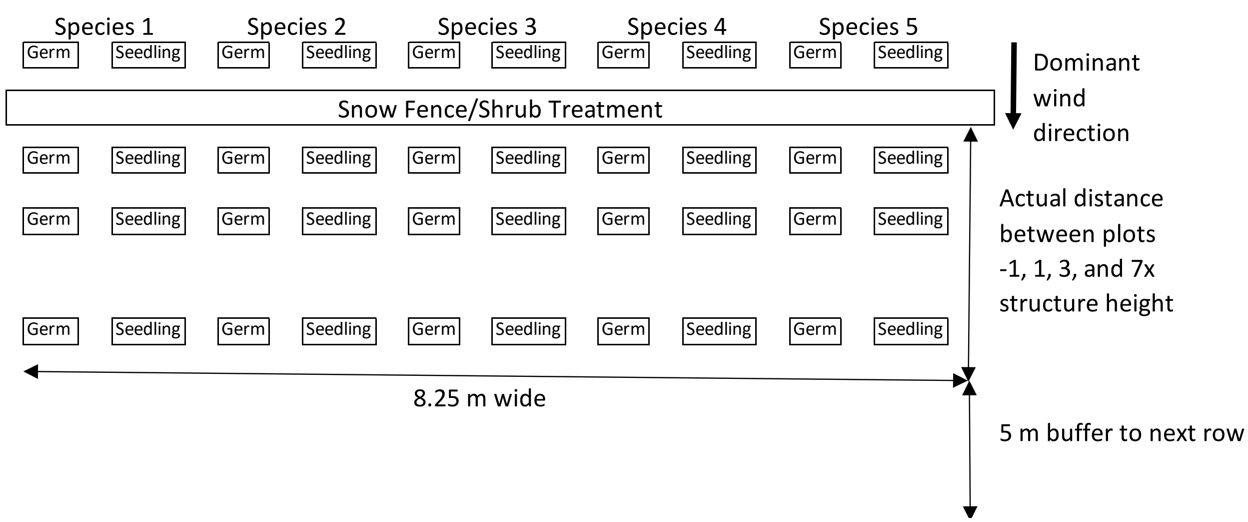

Figure 3. Replicate layout for germination/seedling plots. Target species will be selected in 2022.

Experiment set-up in 2021

Project area description

The research will be located at the Minto Mine in central Yukon, Canada (62.620097°N, 137.276705°W). The site is within the Yukon Plateau-Central Ecoregion of the Boreal Cordillera Ecozone and is characterized by long, cold winters and short, warm summers (Smith et al. 2004). The ecoregion was almost entirely glaciated three million years ago, but the Minto Mine site remained unglaciated during the last glacial maximum (Smith et al. 2004). The northernmost Holocene volcano in Canada, Nelruna (Volcano Mountain), is located about 30 km northeast of the mine and last erupted between 5,000-10,000 years ago (name from Ritter et al. 1977; Smith et al. 2004). Historical annual average temperature was -4°C, though average temperatures in Yukon have risen by 2°C in the past 50 years and increased precipitation is expected in the future (Streiker 2016). Currently, Minto Mine has limited precipitation (<300 mm/year) due to the rain shadow effect of the St. Elias-Coast Mountains (Smith et al. 2004). Wildfire is common due to low precipitation and has resulted in various successional stages of plant communities surrounding the mine (Access Consulting 2013).

The mine footprint is within the Boreal Low Bioclimate Zone-Yukon Plateau North Subzone, with potential for Boreal High Bioclimate Zones at the uppermost elevations (McKenna and Flynn 2017). Most of the surrounding area is forested with pure or mixed stands of trembling aspen (*Populus tremuloides*), white spruce (*Picea glauca*) and lodgepole pine (*Pinus contorta*) depending on drainage, aspect and fire history. Black spruce (*Picea mariana*) forests are found on cool, north facing slopes that have not burned within the last 100 years (Access Consulting 2013). Shrub dominated plant communities (*Salix* spp. and *Betula glandulosa*) are found on the edges of wetlands and riparian areas, and grassland communities are located on dry, warm and nutrient-poor slopes (Access Consulting 2013).

The mine is located within the Traditional Territory of the Selkirk First Nation: Northern Tutchone peoples who share a language and close ties with the First Nation of Na-cho Nyäk Dun and Little Salmon Carmacks First Nation. The majority of Yukon-based citizens live in the community of Pelly Crossing (TPWG 2021), on the banks of Ts'ékí Netú (Pelly River), about 60 km upstream of the confluence with Tagé Cho (Yukon River) (Ritter et al. 1977). The Minto Mine area is about 40 km southwest of Pelly Crossing and, prior to the mine, was known as Marten Hill due to a high marten population in the area (Selkirk First Nation 2018).

The mine is also close to Łútsäw Dachäk (Minto Landing), an important gathering and harvesting site beside Tagé Cho and at one point a small settlement (Selkirk First Nation 2018). Łútsäw Dachäk is actively used and the location where Selkirk First Nation representatives signed Self-Government and Final Agreements with the Governments of Canada and Yukon in July of 1997. Included in these agreements was 4,740 km^2 Category A and B Settlement Lands. Minto Explorations Ltd. was in the process of developing the Minto Mine prior to the Final Agreement and is situated in Category A Settlement Land Parcel R-6A. Selkirk First Nation owns the land though the mine is regulated under federal and territorial legislation through special conditions in the Final Agreement (GC, SFN and YG 1997).

Site selection and preparation

A site visit to Minto Mine was completed May 27th, 2021 to identify a location for the research. Site criteria were a 1.5 ha area with minimal slope, final soil cover in place, minimal existing vegetation, and significant wind exposure. The site would need to remain undisturbed for a minimum of four years. A suitable site was identified on the Southwest Waste Dump (see Figure 4.). The waste rock was capped with 0.5 m of overburden in 2014-2015 and the overburden ripped east-west to 30 cm by a Caterpillar 16G grader in early June of 2021.

Figure 4. Minto Mine revegetation research location on the Southwest Waste Dump.

Experiment layout

The dominant wind direction (300° W/NW) was determined from Minto Exploration Ltd.'s 2020 weather data. Treatments were laid out in rows along a bearing of 120° with one to three treatments per row. Rows with tall treatments were spaced at 15 m, medium treatments at 10 m and short treatments at 7.5 m (Figure 5.). Treatments were 25-35 m long depending on the length of each row with two exceptions: control treatments in block two (18.5 m) and block four (23.5 m).

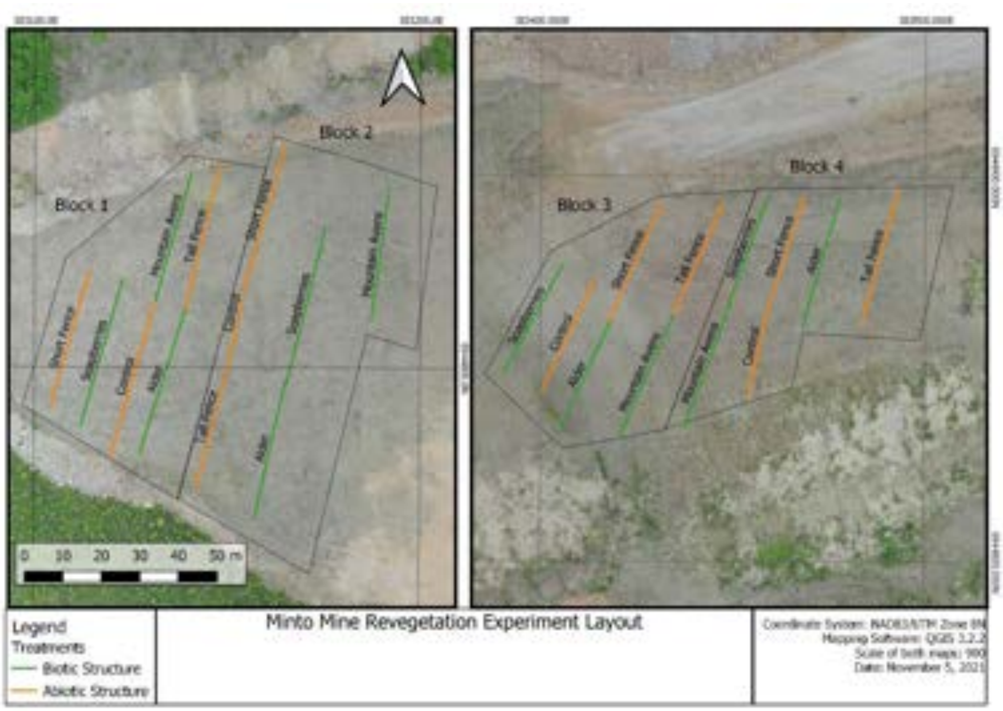

Figure 5. Minto Mine revegetation experiment layout

Biotic structure establishment

Species selection for shrub shelters

Green alder (*Alnus viridis* subsp. *crispa*), soapberry (*Shepherdia canadensis*) and smooth-leaf mountain avens (*Dryas integrifolia*) were selected for tall, medium and short biotic structures. Primary succession processes in northern systems indicate shrubs, especially nitrogen fixers, have a prominent role. Nitrogen fixation by shrubs in early seral stages is a primary determinant of total nitrogen within the climax system though legumes can also contribute (Jacobson and Birks 1980; Chapin et al. 2006; Buma et al. 2017). Green alder and soapberry are well known nitrogen fixers; the evidence is inconclusive for smooth-leaf mountain avens though yellow mountain avens (*D. drummondii*) are capable (Kohls et al. 1994; Rhoades et al. 2008; Callender et al. 2016). Mat-forming shrubs, especially *Dryas* spp., and erect shrubs also capture wind-blown soil fines which stimulates soil development on glacial moraines and outwash (Viereck 1966; Birks 1980; Buma et al. 2017). These species are native to the Yukon and tolerate poorly developed soils and harsh conditions associated with mine sites.

Seedling procurement

Green alder seeds were collected from five populations in late September and early October of 2019 (Table 2.). Seeds were air dried and shipped to NATS Nursery in Abbotsford, BC. Seedlings were grown over the summer of 2020, hardened and frozen for overwinter storage. Alder was shipped frozen by air in February 2021. Soapberry and smooth-leaf mountain aven seeds were each collected from a single population near Whitehorse. Aven seeds were air dried and soapberries kept moist in the fridge until shipping to NATS Nursery in August. Both aven and soapberry seedlings were grown over the summer of 2021, however delayed germination of soapberries meant they were not ready for outplanting in September. Soapberries are expected to be ready in the spring of 2022.

Table 2. Seed source locations for shelter species

Species	Ecoregion	Landmark	Coordinates
Green alder	Yukon Plateau Central	Cabin Gulch	62°16'26"N, 137°9'32"W
Green alder	Yukon Plateau Central	Freegold Road	62°20' 46"N, 137°14'10"W
Green alder	Pelly Mountains	Little Salmon Lake	62°12'21"N, 134°47'24"W
Green alder	Yukon Southern Lakes	Copper Haul Road	60°42'44"N, 135°10'7"W
Green alder	Yukon Southern Lakes	Grey Mountain	60°39'50"N, 134°54'26"W
Soapberries	Yukon Southern Lakes	Deep Creek	61° 4'34"N, 135°12'30"W
Mountain avens	Yukon Southern Lakes	Grey Mountain	60°39'34"N, 134°53.81"W

Green alder seedlings were removed from freezer storage June 13th and planted 0.3 m apart on June 14-16th, 2021 (Figure 6.). Boxes of seedlings were kept in the adjacent forest for shade and covered with a Silvicool Tarp (Bushpro) until planting. Each replicate received 100 L of water the day of planting and another 100 L of water 24 hrs after planting. Alder replicates received 50 L of water June 24th and 70 L of water July 1st. An additional 20 L mixed with 30 mL of soluble 10-40-25 fertilizer (GardenPRO Water Soluble Superbloom) was applied to each alder replicate June 24th and July 20th.

Twenty alder seedlings were randomly selected during planting to determine seedling characteristics (Table 3.). Alder height, root collar, shoot count and presence of nodules was determined in the field. Seedlings were kept cool during transport and frozen at the Yukon Research Centre Lab.

Root to shoot ratios were determined by separating the root and shoot at the root collar, washing the roots thoroughly and drying samples at 70°C for 24 hrs before weighing to the nearest 0.1 mg.

Table 3. Alder seedling characteristics from twenty randomly selected seedlings.

Characteristic	Mean	SE (n=20)	Min	Max
Height (cm)	1.28	± 0.92	1	16.8
Root Collar Diameter (mm)	0.98	± 0.14	2.54	4.65
Shoot #	1.11	± 0.39	2	9
R:S Ratio (g)	1.22	± 0.13	1.02	3.38

Avens were hardened at NATS Nursery, shipped by air to Whitehorse, and planted September 14-16th, 2021. Boxes of seedlings were stored at the research site and covered with a Silvicool tarp (Bushpro) until planting. Avens were planted 0.1 m apart and each replicate was watered with 20 L to improve seedling-soil contact. Twenty-five seedlings were randomly selected for characterization. Seedlings are currently in the freezer and will be processed this winter following the same procedure as the alders.

Soapberries will be planted in spring 2022 at 0.2 m apart.

Abiotic structure installation

Orange snow fencing with 50% porosity was cut into 0.6 and 0.3 m strips. Medium duty steel T-rails were cut into 1.4 m and 0.75 m posts. The tall and medium snow fencing was installed June 12-17, 2021. Posts were spaced at 2 m and pounded in with a mallet or post pounder to the height of the treatment. Snow fencing was installed with the factory edge up, raised 5 cm above the ground to account for variation in microtopography for a final height of 0.65 and 0.35 m respectively. Controls were marked with a wooden stake at each end, but no further structure added.

Figure 6. Planting rows of alder along a stringline in Block 2. The short fence (left) and tall fence (right) are already installed.

Transect Installation

Figure 7. Seedbed preparation with a hand-held cultivator along a transect.

Three uniform seedbeds perpendicular to each abiotic treatment replicate were established July 20-24th, 2021 (Figure 7.). Smooth 0.35 m wide belt transects were created with shovels, mattocks and Fiskars Extended Reach Cultivators. Transect lengths straddled the centerline and were based on the height of the treatment: -0.65 to 4.55 m (tall), -0.35 to 2.45 m (medium) and -0.25 to 1.75 m (short) (Figure 7.). Four Hobo EC-5 Soil Moisture Smart Sensor or Decagon 5TM Soil Moisture Sensors and four Maxim Integrated iButton Thermochron F5 temperature data loggers were installed at intervals along the centre transect in each replicate based on treatment height. Soil moisture sensors log hourly and temperature sensors log every three hours. Seedbeds at biotic treatments will be established in 2023 once the final shrub heights for the experiment are known.

Baseline sampling and environmental monitoring

A weather station was installed in June 2021 near Block 2 to monitor climate conditions (Figure 8.). Data is logged by a HOBO USB Microstation outfitted with an Onset Photosythetic Light Smart Sensor, Davis Wind Speed and Direction Smart Sensor, Davis Rain Gauge Smart Sensor, Decagon EC-5 Soil Moisture Sensor and Onset Smart Temperature Sensor. An additional HOBO External Temperature and Relative Humidity logger was also installed. Two Reconyx HP2X Hyperfire 2 Professional Covert IR Cameras were set up overlooking the site to monitor overall conditions with a daily photo at 1 pm.

Figure 8. Amanda and Taylor celebrating successful weather station installation.

A vegetation inventory of the waste dump surrounding the research site was conducted June 16th and confirmed July 24th (Appendix 1.). Baseline soil samples were collected June 15-16th. Three composite samples were collected in each block and treatment for a total of 12 samples. A separate composite sample was taken of the red residuum material that occurs around the research site and sporadically in Block 3. Each sample was analyzed for pH, electrical conductivity, soil texture, total carbon, total organic carbon, total nitrogen, % organic matter, plant available NPK and trace metals. Copper was the only metal above CCME guidelines and only in Block 3 replicate; the red residuum sample confirmed this material as the source. Select soil sample results are summarized in Table 4.

Table 4. Mean soil characteristics and standard error (n=3) from baseline sampling in June 2021 and single red residuum sample results. TOC=total organic carbon and TIN=total inorganic nitrogen.

Block	pH	Texture	TOC (w/w%)	TIN mg/kg	PO4-P mg/kg	K mg/kg	Cu mg/kg
B1	8.43 ± 0.05	Clay Loam	0.27 ± 0.03	2.83 ± 0.47	0.66 ± 0.08	64.84 ± 6.56	40.12 ± 1.11
B2	8.47 ± 0.05	Clay Loam	0.35 ± 0.09	2.33 ± 0.38	0.69 ± 0.16	60.90 ± 3.83	40.38 ± 2.32
B3	8.73 ± 0.09	Loam	0.17 ± 0.05	1.50 ± 0.19	0.66 ± 0.16	51.14 ± 2.83	92.85 ± 2.56
B4	8.67 ± 0.02	Clay Loam	0.17 ± 0.01	2.07 ± 0.03	1.05 ± 0.31	68.52 ± 2.19	52.63 ± 0.54
Resi-duum	8.7	Sandy Clay Loam	0.12	2.40	0.68	62.9	214.8

The above ground structure and biomass of green alders were sampled July 20-24th, 2021, following the Tall Shrub Monitoring Protocol for Arctic Canada and Alaska (Myers-Smith et al. 2012). Ten randomly selected alders within each replicate were tagged and sampled for stem count, stem diameter, annual growth, maximum canopy height, and canopy area.

Heights of 10 randomly selected mountain avens and previously tagged alders in each replicate were measured September 14th-17th, 2021 (Table 5.). Weather station, transect sensors and time lapse photo data were also downloaded at this time. A full series of photopoints was taken September 16th, 2021 (Appendix 2.).

Table 5. Shrub seedling heights (n=10) in September 2021

	Alder		Mountain Avens	
Block	Mean Height (cm)	SE	Mean Height (cm)	SE
B1	25.29	± 2.17	4.33	± 0.42
B2	12.5	± 0.80	4.96	± 0.28
B3	13.14	± 1.23	4.66	± 0.46
B4	13.48	± 1.54	4.31	± 0.39

Remaining experiment set-up activities

Characterization of mountain avens

Twenty-five seedlings are currently frozen and seedling height, root collar diameter, presence of nodules and root to shoot ratio will be measured over the winter.

Soapberry establishment

Soapberry seedlings are growing at NATS Nursery in Abbotsford, BC and will be shipped frozen to Whitehorse in the spring of 2022. Seedlings will be planted with 0.2 m spacing shortly after receipt.

Transects for living shelters

Transects along alder, soapberry and mountain aven treatments will be established in 2023 once final height for the experiment is known.

Species selection for target species

Species selection for the target species remains unknown. The plan is to follow up with the Mining Manager at Selkirk First Nation about whether there is interest in collaborating on species selection. Seeds need to be collected in 2022. If there's either limited interest or Covid prevents engagement, species selection can be done with existing written material. Selkirk First Nation has published several in-depth heritage reports and Minto Mine's Reclamation and Closure Plan does include Selkirk First Nation's high level reclamation objectives (Minto Exploration Ltd. 2020).

Once species are selected, seeds will be collected from wild populations in Yukon, cleaned and either stored at the Yukon Research Centre or shipped to NATS Nursery for propagation.

Figure 9. Examining freshly prepared Blocks 3 and 4, looking east.

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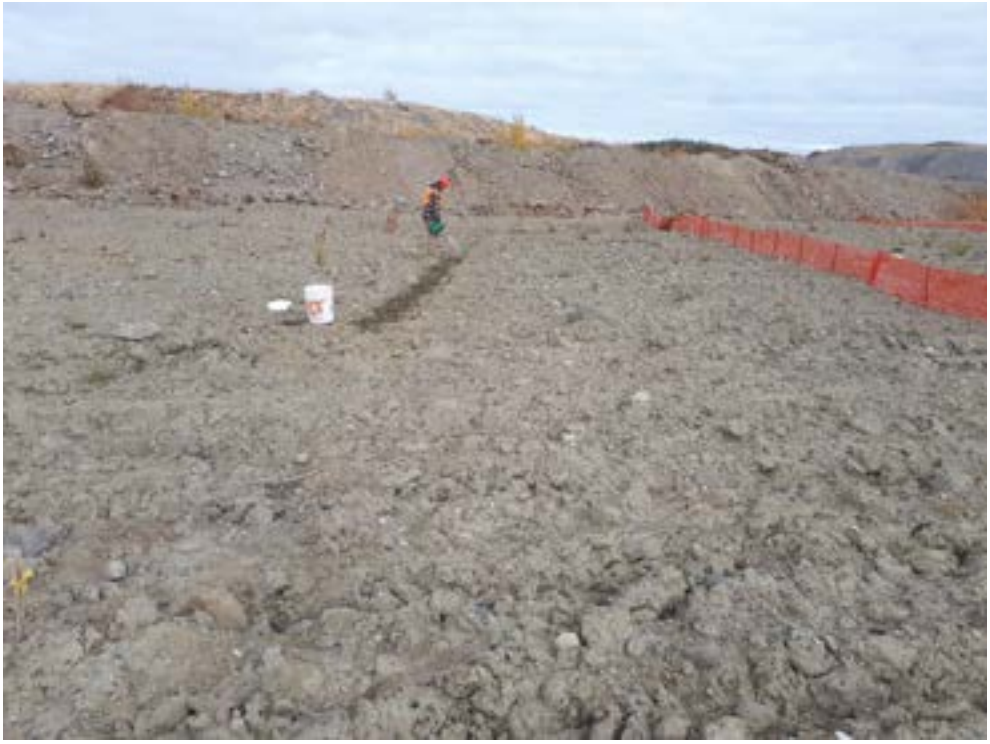
Appendix 1. June 16th and July 24th vascular plant species list from Southwest Waste Dump

Achillea millefolium
Agrostis scabra
Alnus viridis subsp. *crispa*
Arctagrostis latifolia
Boechera sp.
Calamagrostis canadensis
Caryophyllaceae sp.
Chamerion angustifolium
Chamerion latifolium
Crepis elegans
Crepis tectorum
Deschampsia cespitosa
Descurainia sp.
Elymus trachycaulus
Equisetum arvense
Equisetum sylvaticum
Erigeron acris
Festuca altaica
Festuca saximontana
Hordeum jubatum
Lepidium sp.
Mertensia paniculata
Pinus contorta
Polemonium acutiflorum
Polygonum alaskanum
Populus balsamifera
Rorippa sp.
Rubus idaeus
Salix alaxensis
Salix arbusculoides
Salix bebbiana
Salix glauca
Salix sp.
Stelleria longipes

Appendix 2. September 2021 photopoints

B1T1 – Alders: September 17, 2021

B1T2 – No soapberries yet: September 17, 2021



B1T3 – Mountain avens: September 17, 2021

B1T4 – Tall Fence: September 17, 2021

B1T5 – Short fence: September 17, 2021

B1T6 – Control: September 17, 2021

B2T1 – Alders: September 17, 2021

B2T2 – No soapberries yet: September 17, 2021

B2T3 – Mountain avens: September 17, 2021

B2T4 – Tall fence: September 17, 2021


B2T5 – Short fence: September 17, 2021

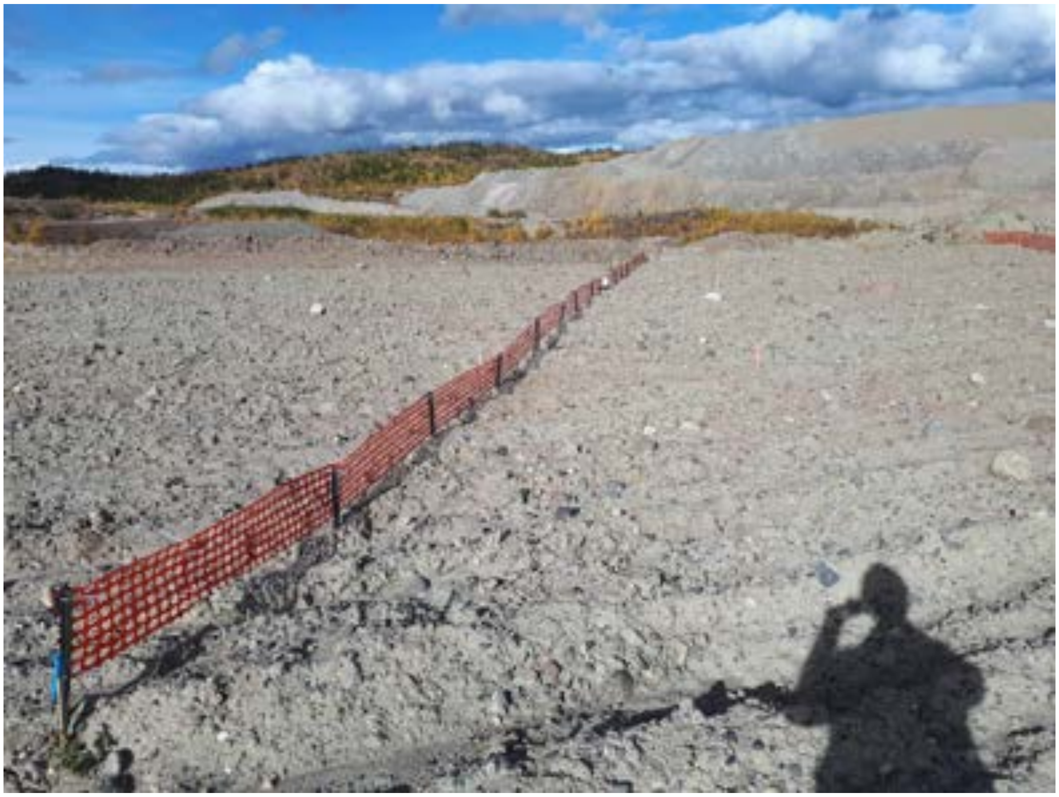

B2T6 – Control: September 17, 2021

B3T1 – Alders: September 17, 2021

B3T2 – No soapberries yet: September 17, 2021

B3T3 – Mountain Avens: September 17, 2021

B3T4 – Tall fence: September 17, 2021



B3T5 – Short fence: September 17, 2021

B3T6 – Control: September 17, 2021

B4T1 – Alders: September 17, 2021

B4T2 – No soapberries yet: September 17, 2021

B4T3 – Mountain avens: September 17, 2021

B4T4 – Tall fence: September 17, 2021

B4T5 – Short fence: September 17, 2021

B4T6 – Control: September 17, 2021