APPENDIX E.10

Reclamation Research Studies

RECLAMATION PILOT STUDY
Mary River Mine Project

Revegetation Survey & Preliminary Reclamation Trial

REV.1

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19Y0005:2008
March 2020

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Down to Earth Biology

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1 INTRODUCTION

The Mary River Mine Project (the Project) refers to an open-pit iron ore mine and its ancillary features located in the Qikiqtani Region of North Baffin Island, Nunavut. The Project has been under construction since 2013 and operational since 2014 by Baffinland Iron Mine Corporation (Baffinland). Under the Project's Terms and Conditions, Baffinland is committed to timely and effective reclamation during appropriate phases of the Life-of-Mine to ensure post-disturbance landscapes that are safe, stable and non-polluting, and align with a suitable aesthetic and self-sustaining land use(s). In this respect, Baffinland recognizes that reclamation research and field trials should be undertaken to inform and refine reclamation practices onsite and, thereby, meet these reclamation objectives.

EDI Environmental Dynamics Inc. (EDI) was retained to review recent advances in Arctic mine reclamation in Canada and the USA, and examine strategies (i.e., to the extent possible and practical) that are expected to promote natural revegetation at the Project (EDI 2019). Building from this desktop investigation, a reclamation pilot study was designed with the objectives to:

1) Document the status of opportunistic post-disturbance revegetation at the Project;
2) Initiate preliminary reclamation trials that examine methods and approaches that are considered appropriate and adaptable to the inherent challenges of the Arctic environment; and,
3) Identify pathways and opportunities for future research.

The field program was conducted 17–24 July 2019 and focused on siting and establishing a preliminary trial design that could, ultimately, be expanded and further developed based on the Project's reclamation research findings. This report summarizes the rationale, methods and outcomes of the reclamation pilot study. Collectively, this preliminary investigation (and any/all subsequent initiatives) are intended to advance reclamation success in the Arctic and guide future reclamation activities that support the environmental compliance and sustainability of the Project.

2 POST-DISTURBANCE REVEGETATION SURVEY

2.1 SURVEY DESIGN

The first part of the reclamation pilot study focused on documenting the status of opportunistic revegetation at the Project. In consultation with Baffinland's Sustainable Development and Site Environment teams, EDI field-scouted areas within or along the Project footprint that had been developed, disturbed and/or temporarily decommissioned. As shown on Map 1, two sites along the Tote Road (KM52 and KM16) were selected for preliminary survey of post-disturbance revegetation status and species composition. Given that the Project has been under construction since 2013, the Tote Road has also been subject to ongoing re-alignment and maintenance activities including surface earthworks and regrading. Survey site KM52 was selected as it represented approximately 1-year post-disturbance and KM16 represented approximately 5-years post-disturbance (i.e., from the time of field survey). Road re-alignment activities at each location were discussed onsite with Road and Maintenance personnel.

At each site, cover transects (100 m in length at KM52; 150 m at KM16) and survey plots (1x1 m vegetation quadrats and 30x30x30 cm soil survey pits at each survey marker) were surveyed to document if/where opportunistic natural revegetation may have occurred and how site conditions (e.g., soil and terrain) and revegetation development (e.g., surface cover and species composition) compared to undisturbed locations. Survey plots were distributed at the start, middle and end of the 100 m or 150 m segment bordering the existing Tote Road (Figure 1), all within a 25 m buffer from the centreline of the right of way [ROW]. Control survey markers were distributed 30 m away from each corresponding survey marker (i.e., outside of the ROW boundaries) in areas deemed representative of pre-development/undisturbed site conditions.

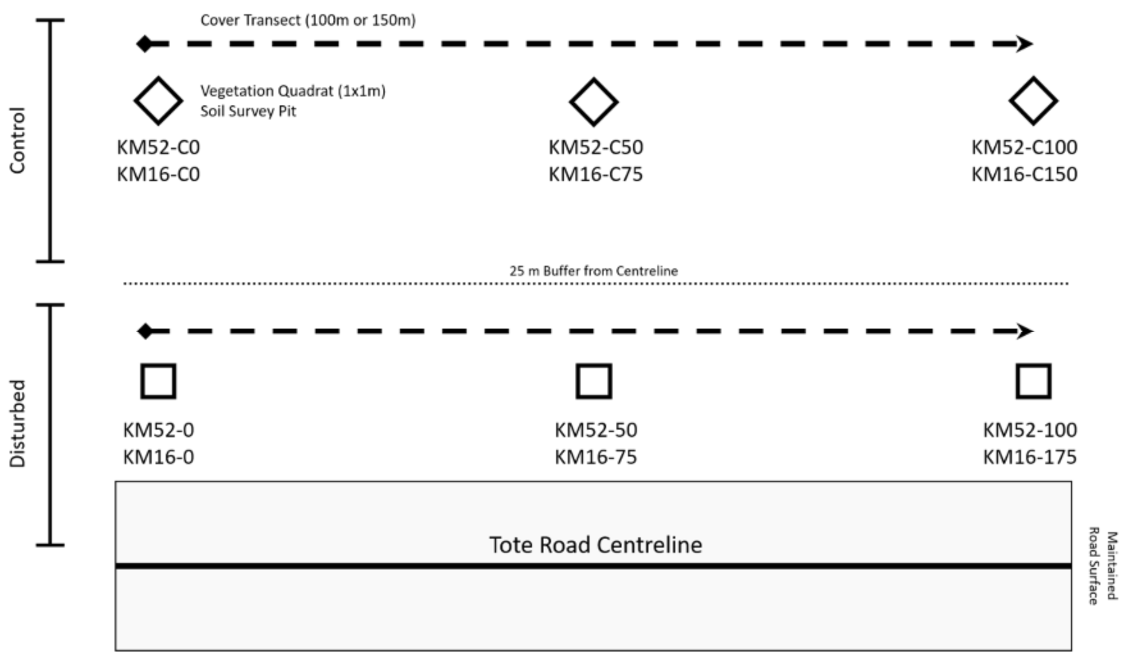

Figure 1. SCHEMA — Survey layout and sampling design.

Tote Road Overview
Survey Locations

Baffinland

Legend

- KM 16
- KM 52
- Tote Road
- Port
- Mine

0 5 10 15 20
Kilometers

N

Map Scale = 1:270,000 (printed on 11 x 17)
Map Projection: NAD 1983 UTM Zone 17N

Data Sources

- Main map. Baffinland Iron Mines Corporation Imagery. 2019
- Inset map. National Geographic World Map.

Disclaimer
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Drawn: Y. Navarro	Checked: P. Audet	Map 1	Date: 2019-08-28

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2.2 METHODS & ANALYSES

Landscape, Terrain and Soil

Survey procedures for characterizing landscape, terrain and soil were based on methods described in the *Field Manual for Describing Terrestrial Ecosystems — Land Management Handbook No. 25* (BC Ministry of Forests and Range and BC Ministry of Environment 2010) and *The Canadian System of Soil Classification, 3rd Edition* (Soil Classification Working Group 1998). Landscape features and terrain (e.g., slope grade, aspect, geomorphological process) were addressed at transect-scale; soils were addressed at plot-scale. At each soil survey point (Photo 1a) a shovel and hand trowel were used to expose a 30x30 cm area and dig up to 30 cm (being mindful not to disturb permafrost) to access the subsoil layers (B or C horizons). Documented soil profile information included parent material, horizon depths, texture, colour, and structure. Soil samples were collected from each soil pit for analysis of textural and nutritional attributes by ALS Environmental Laboratories.

Vegetation Surface Cover and Composition

Survey procedures for characterizing vegetation surface cover and composition were based on methods that are used in Baffinland's existing vegetation monitoring program, and described in the *Canadian Tundra and Taiga Experiment (CANTTEX) — Field Manual* (Bean and Henry 2003, Bean et al. 2003). Vegetation species lists within and adjacent to the survey areas were recorded using various taxonomic reference guides (Bean and Henry 2003, Aiken et al. 2011, Mallory and Aiken 2012); bryophytes and lichen taxons were not characterized at the species level and only recorded in terms of presence or absence. Vegetation cover and structural composition were addressed at the *transect*- and *plot*-scale. Surface projective cover[1] was calculated based on measurements at 1 m intervals along the 100 m or 150 m transect (Photo 1b). Surface projective cover within the 1x1 m vegetation quadrats was recorded at two basal strata (i.e., due to overlapping structural cover components) and calculated based on 100–200 measurements within the point-frame grid (Photo 1c).

Data Collection and Analysis

Field data collection sheets (as an example for future data collection) are provided in Appendix A. Since the present revegetation survey is still at a preliminary stage, field data summaries are strictly descriptive and only means or data ranges are provided. Some survey sites had sparse cover vegetation; therefore, field data were commonly consolidated into coarse structural groupings. No statistical analyses were applied due to small/limiting sample size.

[1] Referring to the % presence or absence of exposed rock and bare soil, bryophytes, lichen, graminoids, forbs and shrubs.

Photo 1. SURVEY METHODS — Soil survey pit (a), cover transect (b), and vegetation quadrat (c).

2.3 RESULTS SUMMARY

2.3.1 KM52 — 1-YEAR POST-DISTURBANCE

Map 2 shows the sampling layout at KM52. Table 1 summarizes landscape, terrain and soil attributes. Table 2 lists observed vegetation species within and adjacent to the study area. Table 3 summarizes mean surface projective cover within vegetation survey quadrats. Figure 2 shows total projective cover along the survey transect. Supporting information (e.g., georeferencing and lab analysis) is provided in Appendix B.

<u>*Landscape, Terrain and Soil*</u>

Located near Katitkok Lake, the study area occurs within a glaciofluvial and periglacial landform characterized by an undulating surface expression with nearly level to very gentle slopes with intermittent soils and frost-weathered bedrock (Photos 2a–b). Native (control) soils were deemed to be Regosolic Turbic Cryosols as defined by an Om and Cy/Cgy/Cz sequence[2]. Soil profiles (KM52-C0, -C50, -C100) were characterized by a discontinuous surface organic layer (Om, 0-2 cm in depth) and a sandy loam textured C horizon. If/where soils were present, the high incorporation of coarse parent materials (i.e., till and frost-weathered bedrock at surface) resulted in a restrictive layer at 25–30cm in depth. The soil moisture regime was xeric (dry); no mottling or gleying[3] was observed within any of the soil profiles. Disturbed soils (KM52-0, -50, -100) had no surface organic layer, a similarly textured sandy loam C horizon with a high incorporation of coarse parent materials, but no discernible subsoil structure as a result of the site's disturbance history.

Laboratory analysis determined that both control and disturbed sites had poor fertility [as indicated by low available nutrients, low electrical conductivity (EC) and adsorption potential] and very little incorporated organic matter for both control and disturbed soils.

<u>*Vegetation Surface Cover and Composition*</u>

Given the landform attributes and soil conditions described above, vegetation cover in control areas was sparse (29% along the transect; 66% within quadrats) but still composed of graminoids, forbs/perennial herbs, shrubs, bryophytes and lichen (Photos 3 a–c). Whereas, disturbed areas exhibited scarce cover vegetation (4% along the transect; <2% within quadrats) and was primarily composed of small/juvenile graminoids and forbs (Photo 3 d–f) if/where present.

Short-leaved sedge (*Carex fuliginosa* subsp. *misandra*), mountain avens (*Dryas integrifolia*), purple saxifrage (*Saxifraga oppositifolia*), yellow saxifrage (*S. aizoides*), arctic bladderpod (*Physaria arctica*) and net-veined willow (*Salix reticulata*) were commonly observed within the study site — primarily in control areas. No exotic and/or non-native species were recorded. The presence and abundance of these species was generally consistent with known habitat descriptors for dry, rocky areas on plains and slopes that are characterized by imperfectly drained substrates composed of rocks, gravel, sand, silt, clay and/or till (Aiken et al. 2011).

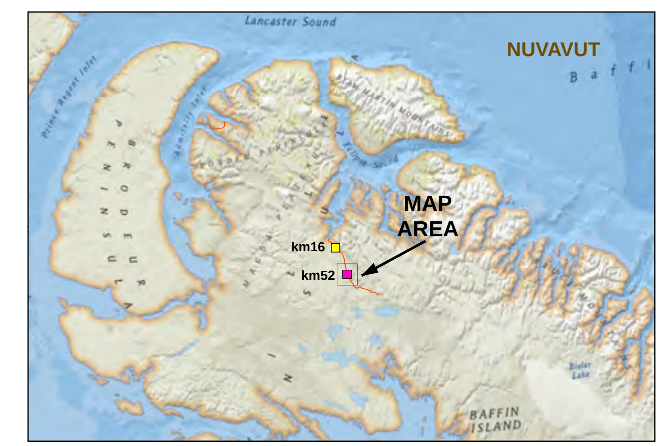
[2] Om = Organic-mesic; Cy = C horizon with cryoturbation; Cgy = Cy with gleying; Cz = C horizon that frozen due to permafrost.

[3] Referring to secondary soil colors in the soil profile not associated with compositional properties.

KM-52
Post-Disturbance Revegetation Survey

Legend

- Tote Road
- Tote Road (25m Buffer)
- Soil
- Vegetation
- Survey Marker
- Cover Transect



0 25 50 75 100
Meters

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Map Scale = 1:2,000 (printed on 11 x 17)
Map Projection: NAD 1983 UTM Zone 17N

Data Sources

• Main map. Baffinland Iron Mines Corporation Imagery. 2019
• Inset map. National Geographic World Map.

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Photo 2. KM52 — Landscape overview southeast (a) and northwest (b).

Photo 3. KM52 — Cover vegetation at KM52-C0, -C50 and -C100 (a-c) and KM52-0, -50 and -100 (d-f).

Table 1. KM52 — Summary of landscape, terrain and soil attributes.

	Survey Site	**KM52 — Disturbed**	**KM52 — Control**
	Survey Marker ID	**KM52-0, -50, -100**	**KM52-C0, -C50, -C100**
	Landscape Attributes		
	Geomorphological Process	Glaciofluvial and Cryoturbation	
	Parent Material	Glacial Till and Bedrock	
	Surface Expression	Undulating	
	Slope Class Description	Nearly Level (Class 2: 0.5–2%) to Very Gentle Slopes (Class 3: 2–5%)	
	Aspect	South	
	Drainage	Well Drained	
	Soil Moisture Regime	Xeric (Dry)	
	Soil Attributes		
*	Organic Matter Content	1.3% (±1.0 SD)	1.8% (±3.9 SD)
*	pH	8.7 (±0.2 SD)	7.7 (±0.4 SD)
*	Texture/Particle Size	Sandy Loam	Sandy Loam
	Surface Organic Depth	*<None>*	*<Discontinuous>*
	Rooting Depth	<1 cm	8–15 cm
	Restrictive Layer	20-25 cm (Till)	23–29cm (Till)
	Nutritional Profile		
*	Available Nitrate-N	1.8 ppm (±0.6 SD)	1.5 ppm (±0.9 SD)
*	Available Phosphate-P	*<Below Detection Limit>*	*<Below Detection Limit>*
*	Available Potassium-K	33.3 ppm (±3.5 SD)	24.7 ppm (±0.6 SD)
*	Available Sulfate-S	*<Below Detection Limit>*	*<Below Detection Limit>*
*	Electrical Conductivity	0.5 dS/m (±0.2 SD)	0.6 dS/m (±0.4 SD)
*	Sodium Adsorption Ratio	0.4 (±0.1 SD)	0.3 (±0.0 SD)
*	Saline Classification	Non-Saline	Non-Saline

SD: Standard Deviation

*Mean values; Based on laboratory analyses of soil samples

Table 2. KM52 — Summary of observed vegetation.

Growth Form	Taxon	Common Name	Control	Disturbed	Environs*
Graminoid	***Carex fuliginosa* subsp. *misandra***	**Short-Leaved Sedge**	✓	✓	
Forb/ Perennial Herb	***Dryas integrifolia***	**Mountain Avens**	✓	✓	
	Pedicularis lanata	Woolly Lousewort			✓
	Erysimum pallasii	Arctic Wallflower		✓	
	Saxifraga oppositifolia	**Purple Saxifrage**	✓		
	Saxifraga aizoides	**Yellow Saxifrage**	✓		
	Physaria arctica	**Arctic Bladderpod**	✓	✓	
Shrub/Ericaceae	***Salix reticulata***	**Net-Veined Willow**	✓		
Exotic Weeds	—	—	*<None Recorded>*		

*Recorded adjacent to study area // <**Bold**> Refers to high/predominant abundance.

Table 3. KM52 — Mean surface projective cover (%) within vegetation quadrats.

Survey Site (Survey Marker ID)	KM52 — Disturbed (KM52-0, -50, -100)	KM52 — Control (KM52-C0, -C50, -C100)
*Bare Soil/Rock	98.7% (±0.6 SD)	66.0% (±4.2 SD)
*Bryophytes/Lichen	*<None>*	16.3% (±2.2 SD)
*Litter	*<None>*	*<None>*
*Graminoids	*<None>*	6.2% (±0.4 SD)
*Forbs	1.3% (±0.6 SD)	9.6% (±3.7 SD)
*Shrubs/Ericaceae	*<None>*	1.9% (±3.3 SD)

*Means values // SD: Standard Deviation

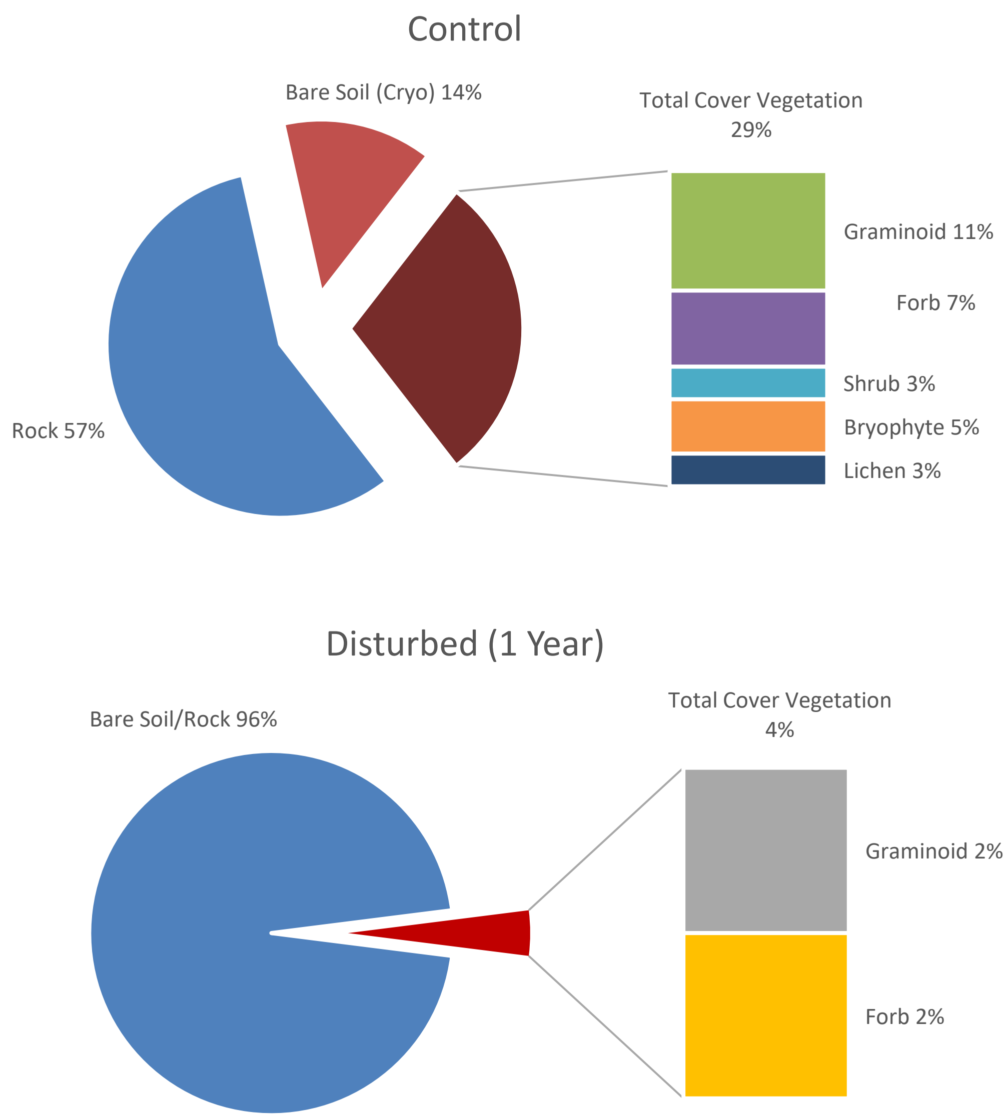


Figure 2. KM52 — Surface projective cover (%) along vegetation transect.

2.3.2 KM16 — 5-YEARS POST-DISTURBANCE

Map 3 shows sampling layout at KM16. Table 4 summarizes landscape, terrain and soil attributes. Table 5 lists observed vegetation species within and adjacent to the study area. Table 6 summarizes mean surface projective cover within the vegetation survey quadrats. Figure 3 shows total projective cover along the survey transect. Supporting information (e.g., georeferencing and lab analysis) is provided in Appendix C.

Landscape, Terrain and Soil

Located near Phillips Creek, the study area occurs on an upland plateau with near-level slopes (Photos 4 a–b). The landscape is characterized by low-centred polygons (i.e., patterned-ground caused by permafrost) resulting in an abundance of small hummocks and shallow depressions. Native (control) soils were deemed to be Brunisolic Turbic Cryosols as defined by an Om and Bm/Bmy sequence[4]. Soil survey profiles (KM16-C0, -C75, -C150) were characterized by a thin surface organic layer (Om, 4–6 cm in depth) followed by a sandy loam textured B horizon. The moderate incorporation of coarse parent materials (i.e., till) resulted in a restrictive layer at ~25 cm in depth. The soil moisture regime was subxeric (dry); faint mottling[5] was observed in the soil profile. Disturbed soils (KM16-0, -75, -150) were characterized by a discontinuous surface organic layer (Om, up to 2 cm in depth — where present), a similar sandy loam B horizon with incorporation of coarse parent materials and some discernible horizons or structure, but no mottling or gleying. Subsoils were intact which suggests that the area had only been superficially disturbed.

Laboratory analysis determined that both control and disturbed soils had poor fertility [as indicated by low available nutrients, low EC and adsorption potential] and little incorporated organic matter.

Vegetation Surface Cover and Composition

Vegetation cover in control areas was abundant (83% along the transect; 92% within quadrats) with representation by graminoids, forbs/perennial herbs, shrubs, bryophytes and lichen (Photo 5a–c). Disturbed areas were characterized by a discontinuous, but still moderately abundant cover vegetation (51% along the transect; 40 within quadrats) that was primarily composed of graminoids and forbs/perennial herbs and few bryophytes or lichen species (Photo 5 d–f).

Short-leaved sedge, membranous sedge (*C. membranacea*), mountain avens, dwarf fireweed (*Chamerion latifolium*), yellow oxytropis (*Oxytropis maydelliana* subsp. *melanocephala*), Arctic blueberry (*Vaccinium uliginosum* subsp. *microphyllum*), net-veined willow, and white mountain heather (*Cassiope tetragona*) were commonly observed within the study area both in control and disturbed areas. No exotic and/or non-native species were recorded. The presence and abundance of these species was generally consistent with known habitat descriptors for tundra heath that is characterized by imperfectly drained to moderately well-drained dry-to-moist substrates characterized by rocks, gravel, sand, silt and clay (Aiken et al. 2011).

[4] Om = Organic-mesic; Bm = B horizon affected by chemical alteration and/or weathering; Bmy = Bm with cryoturbation.

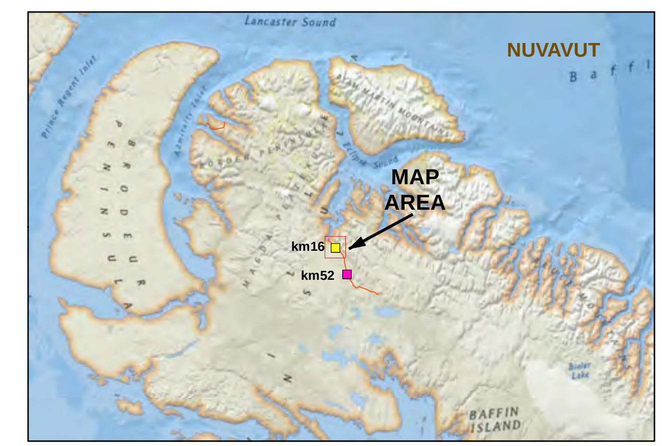
[5] This characteristic results from oxidizing and reducing conditions associated with a fluctuating water table and/or presence of an impermeable subsoil layer.

KM-16
Post-Disturbance Revegetation Survey

Baffinland

Legend

- Tote Road
- Tote Road (25m Buffer)
- Soil
- Vegetation
- Survey Marker
- Cover transect



0 25 50 75 100

Meters

N

Map Scale = 1:1,500 (printed on 11 x 17)
Map Projection: NAD 1983 UTM Zone 17N

Data Sources

• Main map. Baffinland Iron Mines Corporation Imagery. 2019
• Inset map. National Geographic World Map.

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Drawn:	Checked:		
Y. Navarro	P. Audet	Map 3	Date: 2019-08-28

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Photo 4. KM16 — Landscape overview southwest (a) and northeast (b).

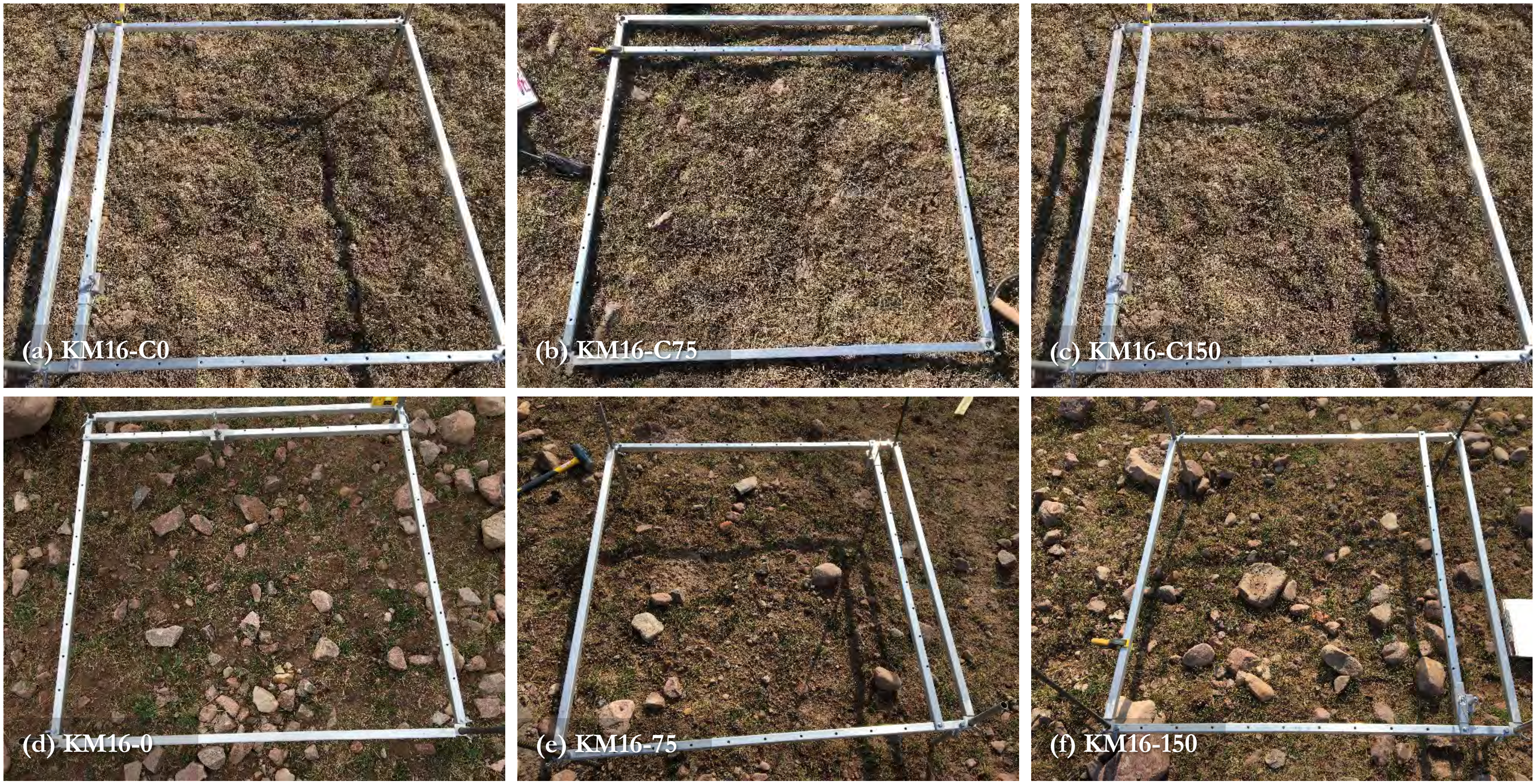

Photo 5. KM16 — Cover vegetation at KM16-C0, -C75 and -C150 (a-c) and KM16-0, -75 and -150 (d-f).

Table 4. KM16 — Summary of landscape, terrain and soil attributes.

	Survey Area Survey Marker ID	KM16 — Disturbed KM16-0, -75, -100	KM16 — Control KM16-C0, -C75, -C100
Landscape Attributes			
	Geomorphological Process	Glaciation and Cryoturbation	
	Parent Material	Morainal	
	Surface Expression	Level	
	Slope Class Description	Nearly Level (Class 2: 0.5–2%)	
	Aspect	West-Southwest	
	Drainage	Moderately Well Drained	
	Soil Moisture Regime	Subxeric (Dry)	
Soil Attributes			
*	Organic Matter Content	3.9% (±1.8 SD)	6.1% (±3.8 SD)
*	pH	7.2 (±0.4 SD)	7.4 (±0.5 SD)
*	Texture/Particle Size	Sandy Loam	Sandy Loam
	Surface Organic Depth	*<Discontinuous>*	Om/Oh = 4-6 cm
	Rooting Depth	13–17 cm	12-14 cm
	Restrictive Layer	15–23 cm (Till)	26 cm (Till)
Nutritional Profile			
*	Available Nitrate -N	1.4 ppm (±0.4 SD)	1.3 ppm (±0.6 SD)
*	Available Phosphate-P	*<Below Detection Limit>*	*<Below Detection Limit>*
*	Available Potassium-K	25.0 ppm (±2.6 SD)	29.3 ppm (±9.7 SD)
*	Available Sulfate-S	*<Below Detection Limit>*	*<Below Detection Limit>*
*	Electrical Conductivity	1.1 dS/m (±0.4 SD)	0.4 dS/m (±0.2 SD)
*	Sodium Adsorption Ratio	0.2 (±0.0 SD)	0.2 (±0.0 SD)
*	Saline Classification	Non-Saline	Non-Saline

SD: Standard Deviation
Om: Organic-mesic; Oh: Organic-humic.
*Mean values; Based on laboratory analyses of soil samples

Table 5. KM16 — Summary of observed vegetation.

Growth Form	Taxon	Common Name	Control	Disturbed	Environs*
Graminoid	***Carex membranacea***	**Membranous Sedge**	✓	✓	
	Carex fuliginosa* subsp. *misandra	**Short-Leaved Sedge**	✓	✓	
Forb/ Perennial Herb	*Bistorta vivipara*	Alpine Bistort		✓	
	Dryas integrifolia	**Mountain Avens**	✓	✓	
	Pedicularis lanata	Woolly Lousewort			✓
	Chamerion latifolium	**Dwarf Fireweed**			✓
	Oxytropis maydelliana* subsp. *melanocephala	**Yellow Oxytropis**	✓	✓	
	Saxifraga oppositifolia	Purple Saxifrage	✓	✓	
	Saxifraga aizoides	Yellow Saxifrage	✓	✓	
	Potentilla hyparctica	Arctic Cinquefoil		✓	
Shrub/ Ericaceae	***Vaccinium uliginosum* subsp. *microphyllum***	**Arctic Blueberry**	✓	✓	
	Salix reticulata	**Net-Veined Willow**	✓		
	Cassiope tetragona	**White Mountain Heather**	✓		
Exotic Weeds	—	—	*<None Recorded>*		

*Recorded adjacent to study areas // **Bold**> Refers to high/predominant abundance.

Table 6. KM16 — Mean surface projective cover (%) within vegetation survey quadrats.

Survey Area (Survey Marker ID)	KM16 — Disturbed (KM16-0, -75, -100)	KM16 — Control (KM16-C0, -C75, -C100)
*Bare Soil/Rock	60.3% (±5.0 SD)	8.1% (±4.7 SD)
*Bryophytes/Lichen	2.3% (±3.2 SD)	54.1% (±7.7 SD)
*Litter	3.3% (±1.5 SD)	2.7% (±3.0 SD)
*Graminoids	20.0% (±5.3 SD)	12.9% (±8.9 SD)
*Forbs	10.0% (±1.7 SD)	14.0% (±7.9 SD)
*Shrubs/Ericaceae	4.0% (±2.0 SD)	8.3% (±10.5 SD)

*Mean values; SD: Standard Deviation

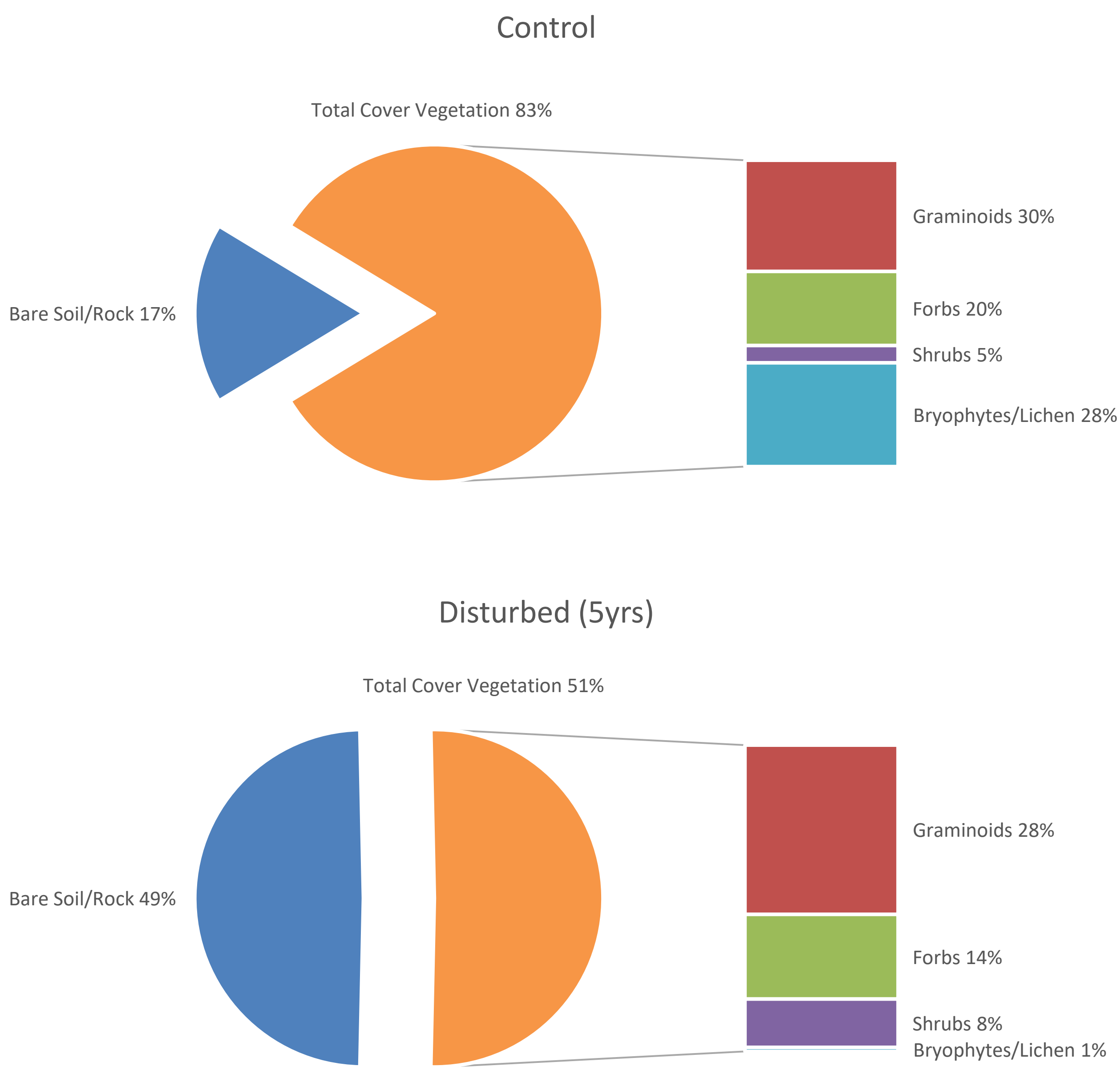

Figure 3. KM16 — Surface projective cover (%) along vegetation transect.

2.4 PRELIMINARY CONCLUSIONS

The purpose of this revegetation survey was to examine and document opportunistic post-disturdance revegetation within the Project footprint. Rates of natural revegetation in the Arctic are characteristically slow in part due to the region' extreme climate and narrow growing season, but also its challenging site conditions and terrain. At KM52 and KM16, soils and terrain were defined by xeric or subxeric conditions (respectively) and characterized by restrictive growth substrates (comprised of coarse parent materials) and poor fertility. Consistent with the notion that natural revegetation should be low, KM52 (1-year post-disturbance) indicated a high level of soil/substrate disturbance that corresponded with low/scarce cover vegetation composed primarily of graminoids and perennial herbs and forbs. On the other hand, KM16 indicated less severe soil/substrate disturbance corresponding with only moderately low cover vegetation comprised of graminoids and perennial herbs and forbs, and even some shrubs, bryophytes and lichen. Given uncertainties regarding disturbance histories at both study locations, survey observations suggest that KM16 may not have been significantly disturbed and/or only at a surficial level. Many factors may have contributed to these divergent site conditions. However, a key limitation is that the survey's small sample size (n=2 sites) is currently insufficient to draw any meaningful conclusions. Nevertheless, recommendations pertaining to future reclamation research activities can still be advanced to improve data capture:

Recommendations

1. **Identify Revegetation Indicators**

   At both KM52 and KM16, revegetation status appeared to be closely correlated with the level of soil/substrate disturbance. Still, vegetation within disturbed areas at both sites was predominantly characterized by the early establishment of graminoids and forbs/perennial herbs; whereas shrubs were much less abundant, and bryophytes and lichen were nearly absent. When investigating revegetation indicators, it is preferable to target early-succession species that may represent a desired structural trajectory — in this case, selection of 'faster' growing graminoids and forbs/perennial herbs is preferred. That said, species selection will depend on the predominant target ecosystem(s) and site-specific growth conditions. Consequently, a wider characterization and more in-depth study of potential/desired reclamation endpoints (described below) in relation to the level of soil/substrate disturbance will help refine a shortlist of suitable revegetation indicator species.

2. **Increase Revegetation Survey Sites / Increase Site Replication and Diversification**

   A gap in this pilot study's experimental design and data capture is that landscape diversity and terrain encountered along the Project footprint are not entirely represented. Therefore, the study design should increase its survey replication and diversification by (1) increasing the total number of baseline survey sites and (2) broadening the range of landscapes, terrain and ecosites affected by the Project. If/where possible, the expanded data capture should seek to populate a chronosequence of early plant re-establishment and potentially even succession patterning. A first step toward closing this gap is to review the range of different landscape features affected by the Project and how they can be grouped as reclamation endpoints. The second step is to conduct a statistical power analysis to determine the optimal number of survey sites to establish a basic statistical threshold to differentiate statistical trends.

3 RECLAMATION TRIAL

3.1 TRIAL DESIGN

Site Layout

The second portion of the reclamation pilot study focused on initiating preliminary reclamation trials at the Project. The locations of the reclamation trials correspond with the KM52 and KM16 post-disturbance revegetation survey areas (described in Section 2). Reclamation trial design and layout at KM52 and KM16 are shown on Maps 4 and 5, respectively. At each trial location, a 100x10 m (at KM52) or 150x10 m trial strip (at KM16) was delineated all within the 25m buffer from the centreline of the ROW. This buffer corresponds with the permissible Project area for earthworks and maintenance along the Tote Road.

Surface Configurations

Drawing from reclamation best management practices and land management approaches used in mining, pipeline development and transportation — and having applications across a wide range of environments and terrain including coarse textured substrates, xeric landscapes and exposed slopes — two surface configurations were applied: (1) 'rough and loose' and (2) 'track-packing'. Rough and loose refers to the use of a digging bucket to open small holes and generate mounds within a given landscape (Polster 2013). This method creates surface heterogeneity and micro-site conditions favorable to seed germination (especially in the absence of direct seeding) and facilitates soil decompaction conditions conducive to root proliferation and water infiltration. Track-packing (aka. surface imprinting) refers to the use of tracked earthwork equipment to create surface roughness (Neville 2003). This method is typically used to reduce the erosion potential of exposed soils by enhancing surface stability and provide micro-site conditions for seed germination. Either of these methods are technically feasible and can be used extensively for the Mary River Project's reclamation activities. The 'rough and loose' surface configuration was applied to the entire reclamation test strip at KM52 and KM16. At this time, the operators were instructed to tie-in all earthworks in a manner consistent with the predominant landscape and terrain to maintain surface drainage patterns. Thereafter, 'track-packing' was applied to half (1/2) of each test strip. The final surface preparations were then inspected to verify the stability of surface materials and ensure that they would not increase risk of erosion and sedimentation. All earthworks were carefully monitored to limit maximum excavation depths (<35 cm) to prevent potential adverse effects on permafrost. Surface configurations were photo-documented (Photos 6a–b and Photos 7a–b) and geo-referenced (refer to Appendix C and D) for follow-up monitoring to be determined at a later time.

Logistical Parameters

All surficial earthworks were completed by a qualified and experienced operator using a CAT 345D Excavator[6] equipped with a standard-sized 122 cm wide, 4-toothed bucket. The excavator was 'floated' (or mobilized) to each site 12h prior to site preparation. All earthworks (i.e., from start to finish — including pre-work communications and post-work inspections) required approximately 4h per test strip.

[6] The CAT 345D has a maximum digging depth of 8.9 m and a bucket capacity up to 3.8 m^3 maximum volume.

KM-52
Reclamation Pilot Study

Baffinland

Legend

- Survey Marker
- Tote Road
- Excavation Boundary
- Tote Road (25m Buffer)

0 25 50 75 100
Meters

N

Map Scale = 1:2,000 (printed on 11 x 17)
Map Projection: NAD 1983 UTM Zone 17N

Data Sources

- Main map. Baffinland Iron Mines Corporation Imagery. 2019
- Inset map. National Geographic World Map.

Disclaimer
EDI Environmental Dynamics Inc. has made every effort to ensure this map is free of errors. Data has been derived from a variety of digital sources and, as such, EDI does not warrant the accuracy, completeness, or reliability of this map or its data.

Drawn: Y. Navarro	Checked: P. Audet	Map 4	Date: 2019-08-28

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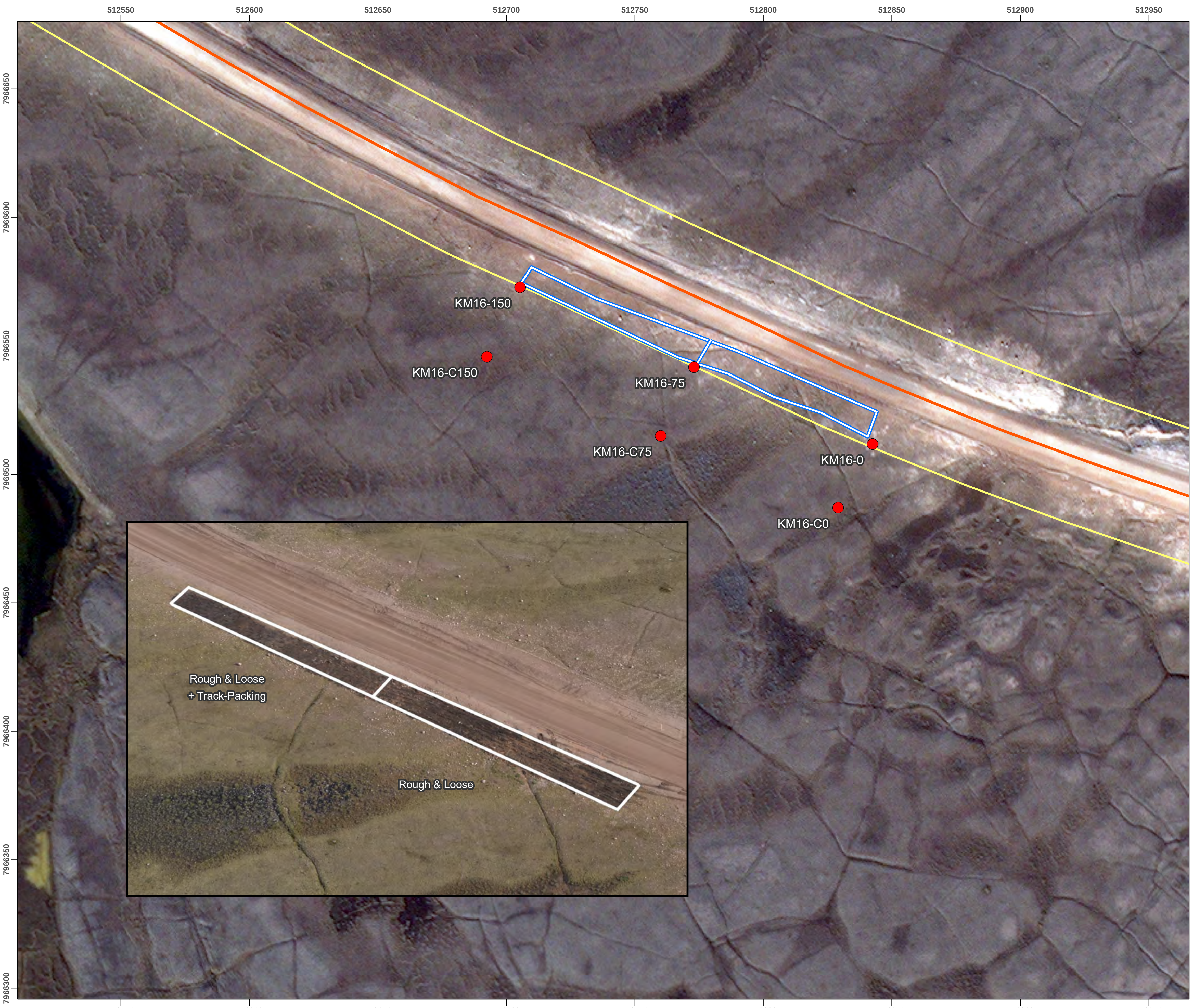
Path: L:\PROJECTS\2019\19Y0005_Baffinland\Mapping\Report\19Y0005_km52_Reclamation_Pilot_Study.mxd

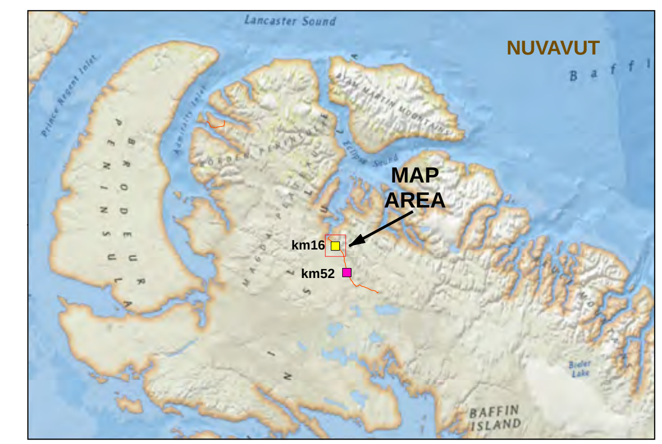
KM-16
Reclamation Pilot Study

Baffinland



Legend

- Survey Marker
- Tote Road
- Reclamation Treatment Boundary
- Tote Road (25m Buffer)



0 25 50 75 100
Meters

Map Scale = 1:1,500 (printed on 11 x 17)
Map Projection: NAD 1983 UTM Zone 17N

N

Data Sources

- Main map. Baffinland Iron Mines Corporation Imagery. 2019
- Inset map. National Geographic World Map.

Disclaimer
EDI Environmental Dynamics Inc. has made every effort to ensure this map is free of errors. Data has been derived from a variety of digital sources and, as such, EDI does not warrant the accuracy, completeness, or reliability of this map or its data.

Drawn: Y. Navarro	Checked: P. Audet	Map 5	Date: 2019-08-28

EDI
ENVIRONMENTAL DYNAMICS INC.

Photo 6. KM52 — Rough and loose (a) and track-packing (b).

Photo 7. KM16 — Rough and loose (a) and Track-Packing (b).

3.2 MONITORING COMMITMENT AND PROJECT EXPANSION

The preliminary reclamation trials described here are intended as a starting point for research and development to examine revegetation strategies that are appropriate for, and adaptable to, the Project and the Arctic environment. The reclamation trial sites at KM52 and KM16 will require periodic monitoring to determine revegetation status and development. Since natural revegetation patterns and processes in the Arctic are characteristically slow, annual or biannual survey[7] should be reasonable to assess the long-term performance of surface configurations and characterize rates of revegetation by early succession species at these sites. That said, consistent with preliminary conclusions outlined in Section 2.4, the reclamation trial's sample size (n=2) is too small to draw any meaningful conclusions at this time. Expansion of reclamation trials at the Project will be necessary to improve data capture and support more in depth analysis.

Recommendations

1. **Increase Reclamation Trial Sites / Increase Range of Reclamation Endpoints**

   Different landscapes and landscape features will require potentially different and perhaps even a combination of reclamation strategies and surface configurations to ensure safe, stable and desirable end-landscapes. For example, areas with more pronounced slopes or landscapes characterized by unconsolidated surface materials may require additional or site-specific mitigation. For this reason, it would be beneficial to (1) review the range of different landscape features affected by the Project, (2) examine how they can be grouped as reclamation/revegetation endpoints, and — most importantly — (3) determine what reclamation strategies and surface configurations can be applied to optimize revegetation outcomes. Increase of reclamation trial sites would be most readily achieved along the Tote Road, but (to the extent practicable) it may be valuable to examine sites within/along other Project components such as the Mine Site, Milne Port and their ancillary features. The study approach presented here provides an initial template and investigative strategy to identify candidate sites, initiate reclamation trials and apply consistent survey methods to document revegetation patterns and processes onsite. Of course, increase of reclamation trial sites to increase the range of reclamation endpoints should be conducted with direct input from Baffinland's Sustainable Development and Site Environment teams

2. **Examine Medium- and Large-Scale Reclamation Trials**

   During appropriate phases of the Life-of-Mine cycle, it would be beneficial — i.e., as a long-term objective — to evaluate Project features that could be decommissioned and/or reclaimed to reduce the Project's disturbance footprint. For example, discontinued laydowns, access roads or other features associated with the Mine Site, the Milne Port and/or Tote Road. These features could provide a ready-landscape for planning, designing and implementing medium- and even large-scale reclamation trials to examine the scalability of reclamation approaches and calibrate the time, effort and cost of reclamation onsite. This will require further consultation with and input from Baffinland's Sustainable Development and Site Environment teams to identify and select suitable sites/locations within or along the Project footprint that could serve to expand the reclamation/revegetation activities onsite.

[7] For continuity, the same survey methods as defined in this report should be applied during follow-up site surveys.

4 CLOSURE

EDI was retained by Baffinland to design and initiate a reclamation pilot study at the Mary River Mine Site. This report summarizes the rationale, methods and outcomes of the study as well as recommendations to expand the study's scope.

The following EDI Environmental Dynamics Inc. personnel who contributed to this project:

Patrick Audet, Ph.D., R.P.Bio...Project Team Lead/Report Author
Jordyn Renaud, B.Sc., A.Ag. ....Field Technician
Brett Pagacz, B.Sc., P.Biol. ....Project Advisor
Yolanda Navarro, B.Tech. (GIS)..GIS/Mapping
Daryl Johannesen, M.Sc., P.Bio...Senior Review
Mike Setterington, M.Sc., R.P.Bio., C.W.B. ....Senior Project Advisor

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APPENDIX A. EXEMPLAR — DATA COLLECTION SHEETS

GROUND INSPECTION FORM

BRITISH COLUMBIA

G ☐ VS V ☐	PHOTO	X:	Y:	DATE

PROJECT ID.	SURV.	
MAP SHEET	PLOT #	POLY. #
UTM ZONE	LAT. / NORTH	LONG. / EAST
ASPECT º	ELEVATION m	
SLOPE %	SMR	SNR

MESO SLOPE POSTION
☐ Crest ☐ Upper slope ☐ Mid slope ☐ Lower slope ☐ Toe ☐ Depression ☐ Level

DRAINAGE - MINERAL SOILS
☐ Very rapidly ☐ Rapidly ☐ Well ☐ Mod. well ☐ Imperfectly ☐ Poorly ☐ Very poorly

MOISTURE SUBCLASSES - ORGANIC SOILS
☐ Aqueous ☐ Peraquic ☐ Aquic ☐ Subaquic ☐ Perhumid ☐ Humid

MINERAL SOIL TEXTURE
☐ Sandy (LS,S) ☐ Loamy (SL,L,SCL,FSL) ☐ Silty (SiL,Si) ☐ Clayey (SiCL,CL,SC,SiC,C)

ORGANIC SOIL TEXTURE
☐ Fibric ☐ Mesic ☐ Humic

SURF. ORGANIC HORIZON THICKNESS
☐ 0–40 cm ☐ > 40 cm

HUMUS FORM
☐ Mor ☐ Moder ☐ Mull

ROOT RESTRICTING LAYER
Depth __________ cm Type ______________

COARSE FRAGMENT CONTENT
☐ < 20% ☐ 20–35% ☐ 35–70% ☐ > 70%

TERRAIN

COMPONENT: TC1 ☐ TC2 ☐ TC3 ☐

TERRAIN TEXTURE	SURFICIAL MATERIAL	SURFACE EXPRESSION	GEOMORPH PROCESS
1	1	1	1
2	2	2	2

ECOSYSTEM

COMPONENT: EC1 ☐ EC2 ☐ EC3 ☐

BGC UNIT	ECOSECTION
SITE SERIES	SITE MODIFIERS
STRUCTURAL STAGE	CROWN CLOSURE %

ECOSYSTEM POLYGON SUMMARY

	%	SS	SM	ST
EC1				
EC2				
EC3				

TERRAIN POLYGON SUMMARY

	%	Classification
TC1		
TC2		
TC3		

DOMINANT / INDICATOR PLANT SPECIES

Total %	A:	B:	C:	D:

L.	Species	%	L.	Species	%	L.	Species	%

Complete ☐ Partial ☐

Tree Mensuration

Spp.	DBH	Ht. Calculation to DBH						Ht. to DBH	Total HT	BH Age	Path Y/N
		Top	Bot	SD	SL	HD	HT				

NOTES (site diagram, exposure, gleying, etc.)

ECOSYSTEM FIELD FORM

BRITISH COLUMBIA

MINISTRY OF FORESTS
BC ENVIRONMENT

DATE	Y	M	D	PLOT NO.
PROJECT ID.				FIELD NO. / SURVEYOR(S)

SITE DESCRIPTION

LOCATION

GENERAL LOCATION				
FOREST REGION	MAPSHEET	UTM ZONE	LAT./ NORTH.	LONG./ EAST.
AIRPHOTO NO.	X CO-ORD.	Y CO-ORD.	MAP UNIT	

SITE INFORMATION

PLOT REPRESENTING				
BGC UNIT	SITE SERIES	TRANS./ DISTRIB.	ECOSECTION	
MOISTURE REGIME	NUTRIENT REGIME	SUCCESS. STATUS	STRUCT. STAGE	REALM/ CLASS
ELEV. m.	SLOPE %	ASPECT °	MESO SLOPE POS.	SURFACE TOPOG.

SITE DIAGRAM

SITE DISTURB.	PHOTO ROLL
EXPOS. TYPE	FRAME NOS.

NOTES

SUBSTRATE (%)

ORG. MATTER		ROCKS	
DEC. WOOD		MINERAL SOIL	
BEDROCK		WATER	

FS882 (1) HRE 98/5

FS882 (3) HRE 98/5

VEGETATION

NOTES:

TREES	A1	A2	A3	A	B1	B2	B	HERB LAYER (C)	%	MOSS / LICHEN / SEEDLING (D)	%

SHRUBS	B1	B2	B	ADDITIONAL SPECIES	LAYER	%

SPP. LIST	COMP. PART.	% COVER BY LAYER	TREE (A)	SHRUB (B)	HERB (C)	MOSS / LICHEN (D)	SURVEYOR(S)	PLOT NO.	PAGE OF

SOIL DESCRIPTION

GEOLOGY BEDROCK	C. F. LITH.	**SURVEYOR(S)**	**PLOT NO.**

TERRAIN TEXTURE 1 / 2	SURFICIAL MATERIAL 1 / 2	SURFACE EXPR. 1 / 2	GEOMORPH. PROCESS 1 / 2	**PROFILE DIAGRAM**

SOIL CLASS.	**HUMUS FORM**	**HYDROGEO.**

ROOTING DEPTH cm	ROOT RESTRICT. LAYER	TYPE	WATER SOURCE	DRAINAGE
R. Z. PART. SIZE		DEPTH cm	SEEPAGE cm	FLOOD RG.

ORGANIC HORIZONS/LAYERS

HOR/ LAYER	DEPTH	FABRIC STRUCTURE	FABRIC vPOST	MYCEL. AB.	FECAL AB.	ROOTS AB.	ROOTS SIZE	pH	COMMENTS (consistency, character, fauna, etc):

MINERAL HORIZONS/LAYERS

HOR/ LAYER	DEPTH	COLOUR	ASP.	TEXT.	% COARSE FRAGMENTS G	C	S	TOTAL	SHAPE	ROOTS AB.	ROOTS SIZE	STRUCTURE CLASS	STRUCTURE KIND	pH	COMMENTS (mottles, clay films, effervesc., etc):

NOTES: ______

FS882 (2) HRE 98/5

MENSURATION FORM

SURVEYOR(S):

TREE#	SPP.	DBH	HEIGHT CALCULATIONS TOP	BOT.	SD	SL.	HD	HT.	HT. TO DBH	TOTAL HT.	BH AGE	SI	SUP.	CONK	BL. CONK	SCAR.	F. OR C.	F. CRACK	MISTLE.	R. BRAN.	D. OR B. TOP	DAMAGE TYPE	DAMAGE SEV.	SITE SERIES

NOTES

TREE DIAMETER TALLY

TREE #	SPP.	DBH	TREE #	SPP.	DBH

MENSURATION

FS 882 (4) HRE 98/5

Vegetation Abundance Monitoring Program 2018 | **Point-Quadrat Data** | Baffinland Iron Mines Corporation

Page: of

Year:		Frame Ht (cm): start @thick, go counter clockwise	
Site ID:		Thick:	
Treatment:	Exclosure	Temp:	
	Non-Exclosure	Thin:	
Plot:	A B X	Temp:	

5 cm CANOPY		15 cm CANOPY		25 cm CANOPY		35 cm CANOPY		45 cm CANOPY		55 cm CANOPY	
A5:		A15:		A25:		A35:		A45:		A55:	
B5:		B15:		B25:		B35:		B45:		B55:	
C5:		C15:		C25:		C35:		C45:		C55:	
D5:		D15:		D25:		D35:		D45:		D55:	
E5:		E15:		E25:		E35:		E45:		E55:	
F5:		F15:		F25:		F35:		F45:		F55:	
G5:		G15:		G25:		G35:		G45:		G55:	
H5:		H15:		H25:		H35:		H45:		H55:	
I5:		I15:		I25:		I35:		I45:		I55:	
J5:		J15:		J25:		J35:		J45:		J55:	
5 cm GROUND		**15 cm GROUND**		**25 cm GROUND**		**35 cm GROUND**		**45 cm GROUND**		**55 cm GROUND**	
A5:		A15:		A25:		A35:		A45:		A55:	
B5:		B15:		B25:		B35:		B45:		B55:	
C5:		C15:		C25:		C35:		C45:		C55:	
D5:		D15:		D25:		D35:		D45:		D55:	
E5:		E15:		E25:		E35:		E45:		E55:	
F5:		F15:		F25:		F35:		F45:		F55:	
G5:		G15:		G25:		G35:		G45:		G55:	
H5:		H15:		H25:		H35:		H45:		H55:	
I5:		I15:		I25:		I35:		I45:		I55:	
J5:		J15:		J25:		J35:		J45:		J55:	

Notes:

Vegetation Abundance Monitoring Program 2018   Point-Quadrat Data

Baffinland
Iron Mines Corporation

Page: of

65 cm CANOPY		75 cm CANOPY		85 cm CANOPY		95 cm CANOPY	
A65:		A75:		A85:		A95:	
B65:		B75:		B85:		B95:	
C65:		C75:		C85:		C95:	
D65:		D75:		D85:		D95:	
E65:		E75:		E85:		E95:	
F65:		F75:		F85:		F95:	
G65:		G75:		G85:		G95:	
H65:		H75:		H85:		H95:	
I65:		I75:		I85:		I95:	
J65:		J75:		J85:		J95:	
65 cm GROUND		75 cm GROUND		85 cm GROUND		95 cm GROUND	
A65:		A75:		A85:		A95:	
B65:		B75:		B85:		B95:	
C65:		C75:		C85:		C95:	
D65:		D75:		D85:		D95:	
E65:		E75:		E85:		E95:	
F65:		F75:		F85:		F95:	
G65:		G75:		G85:		G95:	
H65:		H75:		H85:		H95:	
I65:		I75:		I85:		I95:	
J65:		J75:		J85:		J95:	

APPENDIX B. KM52 — SUPPORTING INFORMATION

Appendix B: Table 1. KM52 — Vegetation Survey — Georeferencing (NAD1983 UTM Zone 17N).

Survey Area	Survey Location	Identifier/Activity	Northing	Easting
		Survey Marker	7936125.03	525984.6437
	KM52-0	Soil Pit	7936124.492	525986.242
		Vegetation Quadrat	7936128.389	525985.664
		Survey Marker	7936174.073	525981.6067
Disturbed	KM52-50	Soil Pit	7936175.986	525982.9982
		Vegetation Quadrat	7936172.624	525981.6597
		Survey Marker	7936223.046	525972.8407
	KM52-100	Soil Pit	7936220.833	525974.2824
		Vegetation Quadrat	7936222.379	525973.0256
		Survey Marker	7936118.877	525955.6433
	KM52-C0	Soil Pit	7936123.059	525960.12
		Vegetation Quadrat	7936124.695	525957.0582
		Survey Marker	7936168.669	525949.9803
Control	KM52-C50	Soil Pit	7936173.391	525953.0002
		Vegetation Quadrat	7936165.329	525950.5161
		Survey Marker	7936220.338	525942.7386
	KM52-C100	Soil Pit	7936217.381	525947.2311
		Vegetation Quadrat	7936214.865	525942.133

Appendix B: Table 2. KM52 —Reclamation Trial — Georeferencing (NAD1983 UTM Zone 17N).

7936125.699N 525984.6356E		7936174.904N 525985.6995E		7936222.712N 525972.8447E
South	Rough & Loose		Rough & Loose + Track Packing	**North**
7936124.011N 525992.5439E		**Tote Road**		7936224.378N 525981.4547E

Baffinland Iron Mine's Corporation
(Oakville)
ATTN: William Bowden/Connor Devereaux
2275 Upper Middle Rd. E.
Suite #300
Oakville ON L6H 0C3

Date Received: 29-JUL-19
Report Date: 08-AUG-19 13:50 (MT)
Version: FINAL

Client Phone: 647-253-0596

Certificate of Analysis

Lab Work Order #: L2318743

Project P.O. #: 4500057496
Job Reference: 19Y0005:08
C of C Numbers: 17-706508
Legal Site Desc:

Maria De Leon
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-7 KM52-0 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	18.2		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	0.82		0.10	%	07-AUG-19	08-AUG-19	R4743748
pH (1:2 soil:water)	8.83		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	7.96		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	56.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	37.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	7.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	2.1		1.0	mg/kg	01-AUG-19	01-AUG-19	R4738808
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Potassium	30		20	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4740489
Saturated Paste Extractables							
SAR	0.53		0.10	SAR		07-AUG-19	
Calcium (Ca)	80.6		5.0	mg/L		06-AUG-19	R4739873
Calcium (Ca)	14.6		0.91	mg/kg		07-AUG-19	
Chloride (Cl)	141		5.0	mg/L	06-AUG-19	06-AUG-19	R4739939
Chloride (Cl)	25.6		0.91	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.701		0.040	dS/m	06-AUG-19	06-AUG-19	R4739817
Magnesium (Mg)	26.0		5.0	mg/L		06-AUG-19	R4739873
Magnesium (Mg)	4.73		0.91	mg/kg		07-AUG-19	
Potassium (K)	6.5		5.0	mg/L		06-AUG-19	R4739873
Potassium (K)	1.18		0.91	mg/kg		07-AUG-19	
Sodium (Na)	21.4		5.0	mg/L		06-AUG-19	R4739873
Sodium (Na)	3.90		0.91	mg/kg		07-AUG-19	
Sulfate (SO4)	6.4		1.1	mg/kg		07-AUG-19	
Sulfate (SO4)	35.2		6.0	mg/L	06-AUG-19	06-AUG-19	R4739939
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-8 KM52-50 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	25.5		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	2.45		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	8.56		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	7.77		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	74.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	20.0		1.0	%	02-AUG-19	06-AUG-19	R4740289

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-8 KM52-50 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Particle Size							
% Clay	6.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	2.2		1.0	mg/kg	01-AUG-19	01-AUG-19	R4738808
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Potassium	37		20	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4740489
Saturated Paste Extractables							
SAR	0.25		0.10	SAR		07-AUG-19	
Calcium (Ca)	62.3		5.0	mg/L		06-AUG-19	R4739873
Calcium (Ca)	15.9		1.3	mg/kg		07-AUG-19	
Chloride (Cl)	42.3		5.0	mg/L	06-AUG-19	06-AUG-19	R4739939
Chloride (Cl)	10.8		1.3	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.414		0.040	dS/m	06-AUG-19	06-AUG-19	R4739817
Magnesium (Mg)	12.8		5.0	mg/L		06-AUG-19	R4739873
Magnesium (Mg)	3.3		1.3	mg/kg		07-AUG-19	
Potassium (K)	9.0		5.0	mg/L		06-AUG-19	R4739873
Potassium (K)	2.3		1.3	mg/kg		07-AUG-19	
Sodium (Na)	8.4		5.0	mg/L		06-AUG-19	R4739873
Sodium (Na)	2.2		1.3	mg/kg		07-AUG-19	
Sulfate (SO4)	3.7		1.5	mg/kg		07-AUG-19	
Sulfate (SO4)	14.6		6.0	mg/L	06-AUG-19	06-AUG-19	R4739939
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-9 KM52-100 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	17.8		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	0.59		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	8.84		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	8.03		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	84.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	11.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	5.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	1.2		1.0	mg/kg	02-AUG-19	02-AUG-19	R4739959
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Potassium	33		20	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4739093

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-9 KM52-100 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Plant Available Nutrients							
Saturated Paste Extractables							
SAR	0.30		0.10	SAR		07-AUG-19	
Calcium (Ca)	55.2		5.0	mg/L		06-AUG-19	R4739873
Calcium (Ca)	9.84		0.89	mg/kg		07-AUG-19	
Chloride (Cl)	30.6		5.0	mg/L	06-AUG-19	06-AUG-19	R4739939
Chloride (Cl)	5.46		0.89	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.373		0.040	dS/m	06-AUG-19	06-AUG-19	R4739817
Magnesium (Mg)	9.0		5.0	mg/L		06-AUG-19	R4739873
Magnesium (Mg)	1.61		0.89	mg/kg		07-AUG-19	
Potassium (K)	11.4		5.0	mg/L		06-AUG-19	R4739873
Potassium (K)	2.03		0.89	mg/kg		07-AUG-19	
Sodium (Na)	9.1		5.0	mg/L		06-AUG-19	R4739873
Sodium (Na)	1.63		0.89	mg/kg		07-AUG-19	
Sulfate (SO4)	2.4		1.1	mg/kg		07-AUG-19	
Sulfate (SO4)	13.7		6.0	mg/L	06-AUG-19	06-AUG-19	R4739939
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-10 KM52-C0 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	16.9		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	0.49		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	8.85		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	8.11		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	53.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	39.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	8.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	<1.0		1.0	mg/kg	02-AUG-19	02-AUG-19	R4739959
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Potassium	21		20	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4739093
Saturated Paste Extractables							
SAR	0.17		0.10	SAR		07-AUG-19	
Calcium (Ca)	88.8		5.0	mg/L		02-AUG-19	R4738634
Calcium (Ca)	15.0		0.85	mg/kg		07-AUG-19	
Chloride (Cl)	199		5.0	mg/L	02-AUG-19	02-AUG-19	R4738667
Chloride (Cl)	33.7		0.85	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.995		0.040	dS/m	02-AUG-19	02-AUG-19	R4737628

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-10 KM52-C0 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Saturated Paste Extractables							
Magnesium (Mg)	44.3		5.0	mg/L		02-AUG-19	R4738634
Magnesium (Mg)	7.49		0.85	mg/kg		07-AUG-19	
Potassium (K)	8.0		5.0	mg/L		02-AUG-19	R4738634
Potassium (K)	1.36		0.85	mg/kg		07-AUG-19	
Sodium (Na)	7.9		5.0	mg/L		02-AUG-19	R4738634
Sodium (Na)	1.34		0.85	mg/kg		07-AUG-19	
Sulfate (SO4)	5.4		1.0	mg/kg		07-AUG-19	
Sulfate (SO4)	32.0		6.0	mg/L	02-AUG-19	02-AUG-19	R4738667
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-11 KM52-C50 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	15.6		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	0.28		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	9.04		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	8.24		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	56.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	38.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	6.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	<1.0		1.0	mg/kg	02-AUG-19	02-AUG-19	R4739959
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Potassium	<20		20	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4739093
Saturated Paste Extractables							
SAR	0.15		0.10	SAR		07-AUG-19	
Calcium (Ca)	94.1		5.0	mg/L		02-AUG-19	R4738634
Calcium (Ca)	14.7		0.78	mg/kg		07-AUG-19	
Chloride (Cl)	242		5.0	mg/L	02-AUG-19	02-AUG-19	R4738667
Chloride (Cl)	37.9		0.78	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.988		0.040	dS/m	02-AUG-19	02-AUG-19	R4737628
Magnesium (Mg)	43.6		5.0	mg/L		02-AUG-19	R4738634
Magnesium (Mg)	6.83		0.78	mg/kg		07-AUG-19	
Potassium (K)	5.6		5.0	mg/L		02-AUG-19	R4738634
Potassium (K)	0.88		0.78	mg/kg		07-AUG-19	
Sodium (Na)	6.9		5.0	mg/L		02-AUG-19	R4738634
Sodium (Na)	1.07		0.78	mg/kg		07-AUG-19	
Sulfate (SO4)	2.67		0.94	mg/kg		07-AUG-19	

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-11 KM52-C50 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Saturated Paste Extractables							
Sulfate (SO4)	17.0		6.0	mg/L	02-AUG-19	02-AUG-19	R4738667
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-12 KM52-C100 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	48.2		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	7.22		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	8.24		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	7.60		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	75.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	21.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	4.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	2.5		1.0	mg/kg	02-AUG-19	02-AUG-19	R4739959
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Potassium	<20		20	mg/kg	02-AUG-19	02-AUG-19	R4740509
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4739093
Saturated Paste Extractables							
SAR	<0.20	SAR:DL	0.20	SAR		07-AUG-19	
Calcium (Ca)	59.9		5.0	mg/L		02-AUG-19	R4738634
Calcium (Ca)	28.8		2.4	mg/kg		07-AUG-19	
Chloride (Cl)	32.7		5.0	mg/L	02-AUG-19	02-AUG-19	R4738667
Chloride (Cl)	15.8		2.4	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.381		0.040	dS/m	02-AUG-19	02-AUG-19	R4737628
Magnesium (Mg)	9.0		5.0	mg/L		02-AUG-19	R4738634
Magnesium (Mg)	4.3		2.4	mg/kg		07-AUG-19	
Potassium (K)	<5.0		5.0	mg/L		02-AUG-19	R4738634
Potassium (K)	<2.4		2.4	mg/kg		07-AUG-19	
Sodium (Na)	<5.0		5.0	mg/L		02-AUG-19	R4738634
Sodium (Na)	<2.4		2.4	mg/kg		07-AUG-19	
Sulfate (SO4)	<2.9		2.9	mg/kg		07-AUG-19	
Sulfate (SO4)	<6.0		6.0	mg/L	02-AUG-19	02-AUG-19	R4738667
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Calcium (Ca)	MS-B	L2318743-1, -10, -11, -12, -2, -3, -4, -6
Matrix Spike	Magnesium (Mg)	MS-B	L2318743-1, -10, -11, -12, -2, -3, -4, -6
Matrix Spike	Sodium (Na)	MS-B	L2318743-1, -10, -11, -12, -2, -3, -4, -6

Sample Parameter Qualifier key listed:

Qualifier	Description
DLA	Detection Limit adjusted for required dilution
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
SAR:DL	SAR is incalculable due to undetectable Na. Detection Limit represents maximum possible SAR value.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
CL-PASTE-IC-GP	Soil	Chloride in Soil (Paste) by IC	Carter-CSSS/EPA 300.1 Modified

A soil extract produced by the saturated paste extraction procedure is analyzed for Chloride by IC (Ion Chromatography)..

ALS Test Code	Matrix	Test Description	Method Reference**
EC-PASTE-GP	Soil	Conductivity (Saturated Paste)	CSSS 15.3.1 2ND ED.

Electrical conductivity of sample extracts is measured using a conductivity meter, which essentially consists of a conductance cell and a Wheatstone bridge.

ALS Test Code	Matrix	Test Description	Method Reference**
MET-PASTE-ICP-GP	Soil	Salinity Metals By ICPOES (Sat. Paste)	CSSS CH15/EPA 6010B

A soil extract produced by the saturated paste extraction procedure is analyzed for Calcium, Magnesium, Potassium, Sodium by ICPOES.

ALS Test Code	Matrix	Test Description	Method Reference**
NO3-AVAIL-SK	Soil	Available Nitrate-N	Alberta Ag (1988)

Available Nitrate and Nitrite are extracted from the soil using a dilute calcium chloride solution.
Nitrate is quantitatively reduced to nitrite by passage of the sample through a copperized cadmium column. The nitrite (reduced nitrate plus original nitrite) is then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. The resulting water soluble dye has a magenta color which is measured at colorimetrically at 520nm.

ALS Test Code	Matrix	Test Description	Method Reference**
ORGANIC MATTER-GP	Soil	Organic Matter (LOI)	AAFC 1984 84-045

Weight loss between 105 C and 550 C is approximately equal to the amount of organic matter in a sample.

ALS Test Code	Matrix	Test Description	Method Reference**
PH-1:2 CACL2-GP	Soil	pH (1:2 CaCl2)	CSSS 16.3 - 1:2 Extraction w/0.01M CaCl2

pH 1:2 Soil: 1:2 CaCl2 Extract; The pH is determined in the laboratory using a pH electrode. Field Measurement is recommended where accurate pH measurements are required, due to the 15 minute recommended hold time.

ALS Test Code	Matrix	Test Description	Method Reference**
PH-1:2-GP	Soil	pH in Soil (1:2 Soil:Water Extraction)	CSSS 16.2 - pH of 1:2 water extract

pH 1:2 Soil: Water Extract; The pH is determined in the laboratory using a pH electrode. Field Measurement is recommended where accurate pH measurements are required, due to the 15 minute recommended hold time.

ALS Test Code	Matrix	Test Description	Method Reference**
PO4/K-AVAIL-SK	Soil	Plant Available Phosphorus and Potassium	Comm. Soil Sci. Plant Anal, 25 (5&6)

Plant available phosphorus and potassium are extracted from the soil usng Modified Kelowna solution. Phosphorous in the soil extract is determined colorimetrically at 880 nm, while potassiumis determined by flame emission at 770 nm.

ALS Test Code	Matrix	Test Description	Method Reference**
PSA-1-GP	Soil	Particle Size by Hydrometer	CSSS 55.3 - Hydrometer (modified)

Soil samples oven dried, grinded, and soaked in Calgon solution for 16 hours; soil suspensions measured for their particle size by distribution using a hydrometer after various times of settling.

ALS Test Code	Matrix	Test Description	Method Reference**
SAL-MG/KG-CALC-GP	Soil	Detailed Salinity Calculation (mg/kg)	CALCULATION
SALINITY-INTCHECK-GP	Soil		CALCULATION
SAR-PASTE-CALC-GP	Soil	Sodium Adsorption Ratio (Sat. Paste)	CSSS 15.4.4-Calculation

A soil extract produced by the saturated paste extraction procedure is analyzed for Sodium, Calcium, and Magnesium by ICPOES. Sodium Adsorption Ratio (SAR) is calculated as per "Soil Sampling and Methods of Analysis" by M. Carter.

ALS Test Code	Matrix	Test Description	Method Reference**
SAT-PCNT-GP	Soil	% Saturation	AER D50

As received samples are pasted to saturation. A sub-sample is weighed, oven dried and re-weighed to determine % saturation.

ALS Test Code	Matrix	Test Description	Method Reference**
SO4-AVAIL-SK	Soil	Available Sulfate-S	REC METH SOIL ANAL - AB. AG(1988)

Plant available sulfate in the soil is extracted using a weak calcium chloride solution. Sulfate in the extract is determined by ICP-OES. This extraction may also produce organic sulfur in the extracts when organic soils are analyzed.

ALS Test Code	Matrix	Test Description	Method Reference**
SO4-PASTE-IC-GP	Soil	Sulfate by IC (Saturated Paste)	CSSS CH15/EPA 300.1

A soil extract produced by the saturated paste extraction procedure is analyzed by Ion Chromatography with conductivity or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
TGR2-CALC-GP	Soil	Theoretical Gypsum Requirement	J. Ashworth et al (1999)

Reference Information

Theoretical Gypsum Requirement is an estimate of the gypsum amendment required to remediate brine-contaminated or sodic soils, and is provided in units of tonnes per hectare (t/ha) for a treatment depth of 15cm. TGR(brine), intended for brine-contaminated soils, is calculated using Method A from "A Comparison of Methods for Gypsum Requirement of Brine-Contaminated Soils", by J. Ashworth (Cdn J. of Soil Science, 1999), available at www.alsglobal.com. TGR(sodic), intended for naturally sodic soils, uses the Oster and Frenkel method (Method B) from the same paper. Reported TGR values are capped at 50 t/ha, considered the maximum practical gypsum amendment. To convert TGR from t/ha to tons/acre, multiply by 0.446. To determine a TGR value for an alternate treatment depth, multiply by [desired treatment depth (cm) / 15 cm].

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
GP	ALS ENVIRONMENTAL - GRANDE PRAIRIE, ALBERTA, CANADA

Chain of Custody Numbers:

17-706508

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid weight of sample
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

APPENDIX C. KM16 — SUPPORTING INFORMATION

Appendix C: Table 1. KM16 — Georeferencing (NAD1983 UTM Zone 17N).

Survey Area	Survey Location	Identifier/Activity	Northing	Easting
Disturbed	KM16-0	Survey Marker	7966511.786	512842.5098
		Soil Pit	7966515.018	512841.9323
		Vegetation Quadrat	7966518.521	512831.1031
	KM16-75	Survey Marker	7966541.702	512773.019
		Soil Pit	7966543.502	512775.4485
		Vegetation Quadrat	7966545.804	512768.8105
	KM16-150	Survey Marker	7966572.859	512705.3704
		Soil Pit	7966574.11	512709.4418
		Vegetation Quadrat	7966571.42	512707.1571
Control	KM16-C0	Survey Marker	7966487.054	512829.1336
		Soil Pit	7966491.622	512828.3038
		Vegetation Quadrat	7966487.935	512827.2455
	KM16-C75	Survey Marker	7966514.965	512760.0727
		Soil Pit	7966517.305	512759.675
		Vegetation Quadrat	7966518.74	512757.1561
	KM16-C150	Survey Marker	7966545.787	512692.3557
		Soil Pit	7966552.833	512695.4509
		Vegetation Quadrat	7966550.487	512694.8375

Appendix B: Table 2. KM16 —Reclamation Trial — Georeferencing (NAD1983 UTM Zone 17N).

7966513.451N 512841.14E	7966543.84N 512776.0391E		7966573.199N 512706.2748E
Southeast	Rough & Loose	Rough & Loose + Track Packing	Northwest
7966523.175N 512844.288E	**Tote Road**		7966579.021N 512709.8653E

Baffinland Iron Mine's Corporation
(Oakville)
ATTN: William Bowden/Connor Devereaux
2275 Upper Middle Rd. E.
Suite #300
Oakville ON L6H 0C3

Date Received: 29-JUL-19
Report Date: 08-AUG-19 13:50 (MT)
Version: FINAL

Client Phone: 647-253-0596

Certificate of Analysis

Lab Work Order #: L2318743

Project P.O. #: 4500057496
Job Reference: 19Y0005:08
C of C Numbers: 17-706508
Legal Site Desc:

Maria De Leon
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-1 KM16-0 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	46.3		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	4.29		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	7.45		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	6.83		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	88.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	8.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	4.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	LOAMY SAND				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	1.6		1.0	mg/kg	01-AUG-19	01-AUG-19	R4738808
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Potassium	26		20	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4740489
Saturated Paste Extractables							
SAR	0.25		0.10	SAR		07-AUG-19	
Calcium (Ca)	165		5.0	mg/L		02-AUG-19	R4738634
Calcium (Ca)	76.4		2.3	mg/kg		07-AUG-19	
Chloride (Cl)	471	DLA	10	mg/L	02-AUG-19	02-AUG-19	R4738667
Chloride (Cl)	218	DLA	4.6	mg/kg		07-AUG-19	
Conductivity Sat. Paste	1.60		0.040	dS/m	02-AUG-19	02-AUG-19	R4737628
Magnesium (Mg)	57.5		5.0	mg/L		02-AUG-19	R4738634
Magnesium (Mg)	26.6		2.3	mg/kg		07-AUG-19	
Potassium (K)	11.2		5.0	mg/L		02-AUG-19	R4738634
Potassium (K)	5.2		2.3	mg/kg		07-AUG-19	
Sodium (Na)	14.5		5.0	mg/L		02-AUG-19	R4738634
Sodium (Na)	6.7		2.3	mg/kg		07-AUG-19	
Sulfate (SO4)	<5.6	DLA	5.6	mg/kg		07-AUG-19	
Sulfate (SO4)	<12	DLA	12	mg/L	02-AUG-19	02-AUG-19	R4738667
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-2 KM16-75 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	29.0		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	2.03		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	7.34		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	6.71		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	89.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	6.0		1.0	%	02-AUG-19	06-AUG-19	R4740289

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-2 KM16-75 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Particle Size							
% Clay	5.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	1.0		1.0	mg/kg	01-AUG-19	01-AUG-19	R4738808
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Potassium	22		20	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4740489
Saturated Paste Extractables							
SAR	0.17		0.10	SAR		07-AUG-19	
Calcium (Ca)	79.8		5.0	mg/L		02-AUG-19	R4738634
Calcium (Ca)	23.2		1.5	mg/kg		07-AUG-19	
Chloride (Cl)	180		5.0	mg/L	02-AUG-19	02-AUG-19	R4738667
Chloride (Cl)	52.2		1.5	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.831		0.040	dS/m	02-AUG-19	02-AUG-19	R4737628
Magnesium (Mg)	23.1		5.0	mg/L		02-AUG-19	R4738634
Magnesium (Mg)	6.7		1.5	mg/kg		07-AUG-19	
Potassium (K)	7.2		5.0	mg/L		02-AUG-19	R4738634
Potassium (K)	2.1		1.5	mg/kg		07-AUG-19	
Sodium (Na)	6.5		5.0	mg/L		02-AUG-19	R4738634
Sodium (Na)	1.9		1.5	mg/kg		07-AUG-19	
Sulfate (SO4)	<1.7		1.7	mg/kg		07-AUG-19	
Sulfate (SO4)	<6.0		6.0	mg/L	02-AUG-19	02-AUG-19	R4738667
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-3 KM16-150 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	40.6		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	5.48		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	6.78		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	6.37		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	88.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	7.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	5.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	1.7		1.0	mg/kg	01-AUG-19	01-AUG-19	R4738808
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Potassium	27		20	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4740489

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-3 KM16-150							
Sampled By: CLIENT on 24-JUL-19							
Matrix: SOIL							
Plant Available Nutrients							
Saturated Paste Extractables							
SAR	0.23		0.10	SAR		07-AUG-19	
Calcium (Ca)	100		5.0	mg/L		02-AUG-19	R4738634
Calcium (Ca)	40.6		2.0	mg/kg		07-AUG-19	
Chloride (Cl)	269		5.0	mg/L	02-AUG-19	02-AUG-19	R4738667
Chloride (Cl)	109		2.0	mg/kg		07-AUG-19	
Conductivity Sat. Paste	1.00		0.040	dS/m	02-AUG-19	02-AUG-19	R4737628
Magnesium (Mg)	31.9		5.0	mg/L		02-AUG-19	R4738634
Magnesium (Mg)	13.0		2.0	mg/kg		07-AUG-19	
Potassium (K)	9.8		5.0	mg/L		02-AUG-19	R4738634
Potassium (K)	4.0		2.0	mg/kg		07-AUG-19	
Sodium (Na)	10.4		5.0	mg/L		02-AUG-19	R4738634
Sodium (Na)	4.2		2.0	mg/kg		07-AUG-19	
Sulfate (SO4)	<2.4		2.4	mg/kg		07-AUG-19	
Sulfate (SO4)	<6.0		6.0	mg/L	02-AUG-19	02-AUG-19	R4738667
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-4 KM16-C0							
Sampled By: CLIENT on 24-JUL-19							
Matrix: SOIL							
Physical Tests							
% Saturation	30.7		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	2.75		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	7.89		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	7.08		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	89.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	6.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	5.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	<1.0		1.0	mg/kg	01-AUG-19	01-AUG-19	R4738808
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Potassium	21		20	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4740489
Saturated Paste Extractables							
SAR	0.26		0.10	SAR		07-AUG-19	
Calcium (Ca)	55.0		5.0	mg/L		02-AUG-19	R4738634
Calcium (Ca)	16.9		1.5	mg/kg		07-AUG-19	
Chloride (Cl)	32.8		5.0	mg/L	02-AUG-19	02-AUG-19	R4738667
Chloride (Cl)	10.1		1.5	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.508		0.040	dS/m	02-AUG-19	02-AUG-19	R4737628

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-4 KM16-C0 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Saturated Paste Extractables							
Magnesium (Mg)	22.3		5.0	mg/L		02-AUG-19	R4738634
Magnesium (Mg)	6.8		1.5	mg/kg		07-AUG-19	
Potassium (K)	6.9		5.0	mg/L		02-AUG-19	R4738634
Potassium (K)	2.1		1.5	mg/kg		07-AUG-19	
Sodium (Na)	9.0		5.0	mg/L		02-AUG-19	R4738634
Sodium (Na)	2.7		1.5	mg/kg		07-AUG-19	
Sulfate (SO4)	<1.8		1.8	mg/kg		07-AUG-19	
Sulfate (SO4)	<6.0		6.0	mg/L	02-AUG-19	02-AUG-19	R4738667
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-5 KM16-C75 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	45.6		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	5.36		0.10	%	06-AUG-19	07-AUG-19	R4742549
pH (1:2 soil:water)	7.52		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	6.54		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	87.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	7.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	6.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	<1.0		1.0	mg/kg	01-AUG-19	01-AUG-19	R4738808
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Potassium	27		20	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4740489
Saturated Paste Extractables							
SAR	<0.20	SAR:DL	0.20	SAR		07-AUG-19	
Calcium (Ca)	29.7		5.0	mg/L		06-AUG-19	R4739873
Calcium (Ca)	13.5		2.3	mg/kg		07-AUG-19	
Chloride (Cl)	36.1		5.0	mg/L	06-AUG-19	06-AUG-19	R4739939
Chloride (Cl)	16.5		2.3	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.261		0.040	dS/m	06-AUG-19	06-AUG-19	R4739817
Magnesium (Mg)	11.9		5.0	mg/L		06-AUG-19	R4739873
Magnesium (Mg)	5.4		2.3	mg/kg		07-AUG-19	
Potassium (K)	<5.0		5.0	mg/L		06-AUG-19	R4739873
Potassium (K)	<2.3		2.3	mg/kg		07-AUG-19	
Sodium (Na)	<5.0		5.0	mg/L		06-AUG-19	R4739873
Sodium (Na)	<2.3		2.3	mg/kg		07-AUG-19	
Sulfate (SO4)	5.0		2.7	mg/kg		07-AUG-19	

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2318743-5 KM16-C75 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Saturated Paste Extractables							
Sulfate (SO4)	11.0		6.0	mg/L	06-AUG-19	06-AUG-19	R4739939
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	
L2318743-6 KM16-C150 Sampled By: CLIENT on 24-JUL-19 Matrix: SOIL							
Physical Tests							
% Saturation	91.6		1.0	%	02-AUG-19	02-AUG-19	R4738712
Organic Matter (LOI)	10.2		0.10	%	07-AUG-19	08-AUG-19	R4743748
pH (1:2 soil:water)	6.90		0.10	pH	06-AUG-19	06-AUG-19	R4739814
pH (1:2 CaCl2)	6.23		0.10	pH	02-AUG-19	02-AUG-19	R4739805
Particle Size							
% Sand	85.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Silt	9.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
% Clay	6.0		1.0	%	02-AUG-19	06-AUG-19	R4740289
Texture	SANDY LOAM				02-AUG-19	06-AUG-19	R4740289
Plant Available Nutrients							
Available Nitrate-N	2.0		1.0	mg/kg	01-AUG-19	01-AUG-19	R4738808
Available Phosphate-P	<2.0		2.0	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Potassium	40		20	mg/kg	02-AUG-19	02-AUG-19	R4739152
Available Sulfate-S	<4.0		4.0	mg/kg	02-AUG-19	02-AUG-19	R4740489
Saturated Paste Extractables							
SAR	0.22		0.10	SAR		07-AUG-19	
Calcium (Ca)	45.8		5.0	mg/L		02-AUG-19	R4738634
Calcium (Ca)	41.9		4.6	mg/kg		07-AUG-19	
Chloride (Cl)	101		5.0	mg/L	02-AUG-19	02-AUG-19	R4738667
Chloride (Cl)	92.4		4.6	mg/kg		07-AUG-19	
Conductivity Sat. Paste	0.538		0.040	dS/m	02-AUG-19	02-AUG-19	R4737628
Magnesium (Mg)	16.9		5.0	mg/L		02-AUG-19	R4738634
Magnesium (Mg)	15.4		4.6	mg/kg		07-AUG-19	
Potassium (K)	9.0		5.0	mg/L		02-AUG-19	R4738634
Potassium (K)	8.2		4.6	mg/kg		07-AUG-19	
Sodium (Na)	7.0		5.0	mg/L		02-AUG-19	R4738634
Sodium (Na)	6.4		4.6	mg/kg		07-AUG-19	
Sulfate (SO4)	6.6		5.5	mg/kg		07-AUG-19	
Sulfate (SO4)	7.2		6.0	mg/L	02-AUG-19	02-AUG-19	R4738667
TGR(sodic)	<0.10		0.10	t/ha		07-AUG-19	
TGR(brine)	<0.10		0.10	t/ha		07-AUG-19	

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Calcium (Ca)	MS-B	L2318743-1, -10, -11, -12, -2, -3, -4, -6
Matrix Spike	Magnesium (Mg)	MS-B	L2318743-1, -10, -11, -12, -2, -3, -4, -6
Matrix Spike	Sodium (Na)	MS-B	L2318743-1, -10, -11, -12, -2, -3, -4, -6

Sample Parameter Qualifier key listed:

Qualifier	Description
DLA	Detection Limit adjusted for required dilution
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
SAR:DL	SAR is incalculable due to undetectable Na. Detection Limit represents maximum possible SAR value.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
CL-PASTE-IC-GP	Soil	Chloride in Soil (Paste) by IC	Carter-CSSS/EPA 300.1 Modified

A soil extract produced by the saturated paste extraction procedure is analyzed for Chloride by IC (Ion Chromatography)..

EC-PASTE-GP	Soil	Conductivity (Saturated Paste)	CSSS 15.3.1 2ND ED.

Electrical conductivity of sample extracts is measured using a conductivity meter, which essentially consists of a conductance cell and a Wheatstone bridge.

MET-PASTE-ICP-GP	Soil	Salinity Metals By ICPOES (Sat. Paste)	CSSS CH15/EPA 6010B

A soil extract produced by the saturated paste extraction procedure is analyzed for Calcium, Magnesium, Potassium, Sodium by ICPOES.

NO3-AVAIL-SK	Soil	Available Nitrate-N	Alberta Ag (1988)

Available Nitrate and Nitrite are extracted from the soil using a dilute calcium chloride solution.
Nitrate is quantitatively reduced to nitrite by passage of the sample through a copperized cadmium column. The nitrite (reduced nitrate plus original nitrite) is then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. The resulting water soluble dye has a magenta color which is measured at colorimetrically at 520nm.

ORGANIC MATTER-GP	Soil	Organic Matter (LOI)	AAFC 1984 84-045

Weight loss between 105 C and 550 C is approximately equal to the amount of organic matter in a sample.

PH-1:2 CACL2-GP	Soil	pH (1:2 CaCl2)	CSSS 16.3 - 1:2 Extraction w/0.01M CaCl2

pH 1:2 Soil: 1:2 CaCl2 Extract; The pH is determined in the laboratory using a pH electrode. Field Measurement is recommended where accurate pH measurements are required, due to the 15 minute recommended hold time.

PH-1:2-GP	Soil	pH in Soil (1:2 Soil:Water Extraction)	CSSS 16.2 - pH of 1:2 water extract

pH 1:2 Soil: Water Extract; The pH is determined in the laboratory using a pH electrode. Field Measurement is recommended where accurate pH measurements are required, due to the 15 minute recommended hold time.

PO4/K-AVAIL-SK	Soil	Plant Available Phosphorus and Potassium	Comm. Soil Sci. Plant Anal, 25 (5&6)

Plant available phosphorus and potassium are extracted from the soil usng Modified Kelowna solution. Phosphorous in the soil extract is determined colorimetrically at 880 nm, while potassiumis determined by flame emission at 770 nm.

PSA-1-GP	Soil	Particle Size by Hydrometer	CSSS 55.3 - Hydrometer (modified)

Soil samples oven dried, grinded, and soaked in Calgon solution for 16 hours; soil suspensions measured for their particle size by distribution using a hydrometer after various times of settling.

SAL-MG/KG-CALC-GP	Soil	Detailed Salinity Calculation (mg/kg)	CALCULATION
SALINITY-INTCHECK-GP	Soil		CALCULATION
SAR-PASTE-CALC-GP	Soil	Sodium Adsorption Ratio (Sat. Paste)	CSSS 15.4.4-Calculation

A soil extract produced by the saturated paste extraction procedure is analyzed for Sodium, Calcium, and Magnesium by ICPOES. Sodium Adsorption Ratio (SAR) is calculated as per "Soil Sampling and Methods of Analysis" by M. Carter.

SAT-PCNT-GP	Soil	% Saturation	AER D50

As received samples are pasted to saturation. A sub-sample is weighed, oven dried and re-weighed to determine % saturation.

SO4-AVAIL-SK	Soil	Available Sulfate-S	REC METH SOIL ANAL - AB. AG(1988)

Plant available sulfate in the soil is extracted using a weak calcium chloride solution. Sulfate in the extract is determined by ICP-OES. This extraction may also produce organic sulfur in the extracts when organic soils are analyzed.

SO4-PASTE-IC-GP	Soil	Sulfate by IC (Saturated Paste)	CSSS CH15/EPA 300.1

A soil extract produced by the saturated paste extraction procedure is analyzed by Ion Chromatography with conductivity or UV detection.

TGR2-CALC-GP	Soil	Theoretical Gypsum Requirement	J. Ashworth et al (1999)

Reference Information

Theoretical Gypsum Requirement is an estimate of the gypsum amendment required to remediate brine-contaminated or sodic soils, and is provided in units of tonnes per hectare (t/ha) for a treatment depth of 15cm. TGR(brine), intended for brine-contaminated soils, is calculated using Method A from "A Comparison of Methods for Gypsum Requirement of Brine-Contaminated Soils", by J. Ashworth (Cdn J. of Soil Science, 1999), available at www.alsglobal.com. TGR(sodic), intended for naturally sodic soils, uses the Oster and Frenkel method (Method B) from the same paper. Reported TGR values are capped at 50 t/ha, considered the maximum practical gypsum amendment. To convert TGR from t/ha to tons/acre, multiply by 0.446. To determine a TGR value for an alternate treatment depth, multiply by [desired treatment depth (cm) / 15 cm].

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
GP	ALS ENVIRONMENTAL - GRANDE PRAIRIE, ALBERTA, CANADA

Chain of Custody Numbers:

17-706508

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid weight of sample
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

RESEARCH REVIEW
ADVANCES IN ARCTIC RECLAMATION

Implications for Reclamation Practices & Trials at the Mary River Mine Project

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ENVIRONMENTAL DYNAMICS INC.
Down to Earth Biology

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1 INTRODUCTION

The Mary River Project (the Project) refers to the construction, operation, closure and reclamation of an open-pit iron ore mine (and its ancillary features) located in the Qikiqtaaluk Region of North Baffin Island, Nunavut (Map 1). The Project — under construction since 2013 and operational since 2014 — has an anticipated life-of-mine of 21 years at an average production rate of 22.2 million tonnes per annum (mtpa). Project approval was granted by the Nunavut Impact Review Board (NIRB) to Baffinland Iron Mines Corporation (Baffinland) under the Terms and Conditions outlined in Project Certification #005 (Nunavut Impact Review Board 2014). Additional commitments related to Project closure and reclamation are listed in NIRB's Final Hearing Report for the Project, Appendix A (Nunavut Impact Review Board 2012).

Notably, under Project Term and Condition #39:

> *The Proponent shall develop a progressive revegetation program for disturbed areas that are no longer required for operations, such program to incorporate measures for the use of test plots, reseeding and replanting of native plants as necessary. It is further recommended that this program be directly associated with the management plans for erosion control established for the Project.*

To which Project Commitment #39 states:

> *Baffinland is committed to investigating and exploring the potential for native species of flora to be used for re-vegetating areas disturbed within the Project area.*

Baffinland developed a Preliminary Closure and Reclamation Plan (PCRP) for the Project (Baffinland Iron Mines Corporation 2012a). They recently updated their Interim Closure and Reclamation Plan (ICRP; (Baffinland Iron Mines Corporation 2016) with intentions of documenting progressive reclamation activities to inform the Final Closure and Reclamation Plan (FCRP). As per Project Commitment #39, it is recognized that reclamation research and field trials should be undertaken to "*[reduce] uncertainties to an acceptable level and provide [beneficial] information that can lead to the development of additional appropriate closure criteria*".

The purpose of this investigation is to review and summarize available research and recent advances from Arctic mine reclamation in Canada's northern territories and in Alaska (USA), and examine strategies that will promote natural revegetation onsite to the extent possible and practical. Field trials will then help guide and refine Baffinland's proposed reclamation practices at the Project.

LEGEND

- Community
- Mary River Project
- Approved - Current Development Area
- Approved - Future Development Area
- Phase 2 - Proposed Development Area

NOTES

PDA provided by KP, July 11, 2017.

Map Projection: Canada Albers Equal Area Conic.

Scale 0 10 20 40 60 80 100 Km

Baffinland

Mary River Project Overview Map

EDI

Date: 10/6/2017

MAP 1

RECLAMATION PRINCIPLES, GOALS & OBJECTIVES

The Project's closure and reclamation principles and site-specific objectives for major infrastructure features[1] are presented in Table 1. Unifying principles are to achieve a safe, stable, and non-polluting landscape that aligns with an agreed-upon end land-use and aesthetic. As stated in the ICRP, Baffinland is committed "*to return disturbed areas to viable and (wherever practicable) self-sustaining ecosystems that are compatible with a healthy environment and with human activities in as minimal duration as reasonably practical*" (Baffinland Iron Mines Corporation 2016). To meet stated reclamation goals and objectives, Baffinland will recontour and regrade their disturbance footprint to tie-in to the predominant landscape. Where possible and practical, site preparation techniques integrating available salvaged soils/overburden materials will seek to promote natural revegetation of species identified onsite.

A Closure Working Group organized by Baffinland will be tasked in selecting these methods and reclamation techniques based on best available information and reclamation research. In accordance with the ICRP, results of reclamation research will be reported on an annual basis in the Nunavut Impact Review Board (NIRB) Annual Report. Project objectives for reclamation research are to:

(a) Identify methods for successful reclamation and revegetation;
(b) Enhance physical stability of reclaimed features; and
(c) Incorporate principles of landscape aesthetics.

Table 1. Closure and Reclamation Principles and Site-Specific Objectives.

Closure and Reclamation Principles	Site-Specific Closure and Reclamation Objectives*
• Ensure that Project sites are safe for wildlife and human users; • Ensure physical stability of Project sites and remaining physical features (e.g., open pit, waste rock stockpile, quarries, road and railway embankments, stream crossings); • Ensure chemical stability of the open pit, waste rock stockpile, quarries, and other Project disturbed areas; • Implement reclamation in a progressive, on-going manner during the life of the Project and restore sites as soon as an area is no longer required for operations to limit the need for long term maintenance and monitoring. • Consider future land use of Project sites in final closure planning; and • Achieve the status of a "Recognized Closed Mine" in as minimal duration as reasonably practical and ensure there are no requirements for long-term active care.	• Re-establish sites that are physically and geotechnically stable; • Reinstate pre-disturbed surface conditions (incl. drainage patterns have been re-established to the extent possible); • Ensure site preparation that promotes natural revegetation; • Sites facilitate wildlife movement; • Sites are safe for humans and wildlife; • Dust levels are safe for humans, vegetation, aquatic life and wildlife; • Landscape features are contoured and revegetated as necessary to blend with the natural surrounding environment for aesthetic purposes; • Contaminated soils are to be remediated to ensure they do not pose an unacceptable environmental risk; and • No long-term active care is required.

*For major infrastructure components.

[1] Referring to the Mine Site, Milne Port, and Tote Road (including the road alignment, water withdrawal access areas, and water crossings such as bridges and culverts).

2 ARCTIC RECLAMATION

Reclamation is the process of returning a disturbed site to a condition that is safe, stable and non-polluting: i.e., that prevents or minimizes adverse effects on the environment or threats to human health and safety (Baffinland Iron Mines Corporation 2016). The end land-use should align with a desired and pre-determined (or agreed-upon) land use. This typically means achieving site conditions similar to or on a trajectory toward the pre-disturbance environment; alternatively, end land-use can be another productive environment that aligns with accepted bioregional land uses. In this regard, it is necessary to frame the ecological context to establish end land-use objectives, but also identify limitations and constraints that may affect a given reclamation strategy. For example, such as those related to biogeoclimatic conditions and plant eco-physiological responses to these conditions.

BIOREGIONAL CONTEXT

The Project is located on northern Baffin Island in Canada's Northern Arctic terrestrial ecozone (Ecological Stratification Working Group 1995): one of the largest ecosystems in the world encompassing approximately 1.5 million square kilometres (equivalent to one-seventh the size of Canada). The climate is characterized as cold and dry (i.e., low average/seasonal temperatures and low seasonal/annual precipitation) with high winds and shallow soil (typically poor fertility and low organic content) resulting in sparse vegetation cover. Vegetation is characteristically stunted or low-lying, slow-growing and devoid of woody species (Ecological Stratification Working Group 1995). Permafrost is continuous within the Northern Arctic and surficial snow cover usually persists from September to June (the annual snow-free period is approximately 60 days). The Northern Arctic ecozone is further delineated[2] into three ecoregions: (1) the Borden Peninsula Plateau (2) the Baffin Island Uplands and (3) the Melville Peninsula Plateau. Most of the Project area falls within the Melville Peninsula Plateau ecoregion that is characterized by non-mountainous terrain, including rugged uplands, rolling plains, and lowland features with some standing water. The area is underlain by continuous permafrost; vegetation is composed of dwarf shrubs, forbs, grasses and sedges, mosses, and lichens. Lesser portions of the Project coincide with the Borden Peninsula Plateau (northwestern tip of the Project area, near Milne Inlet) and the Baffin Island Uplands (eastern periphery of the Project area).

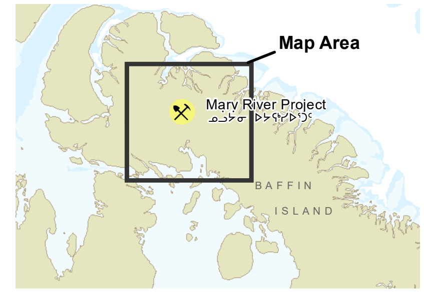
Based on ecosystem mapping using Northern Land Cover (NLC) classes (Map 2, Olthof et al. 2009), most of the Project coincides with sparsely vegetated bedrock cover type characterized by 2–10% vegetation cover comprised of graminoids (grasses) and prostrate dwarf shrubs (FEIS; Russell 2012). Remaining portions of the Project primarily coincide with prostrate dwarf shrub cover type characterized by > 25% vegetation cover comprised of prostrate dwarf shrubs, graminoids, and < 10% lichen and moss (FEIS; Russell 2012). The Project also coincides discontinuously with other similar variants of these NLC classes identified/described in the Mary River Regional Study Area (Baffinland Iron Mines Corporation 2012b). Native plant species found colonizing previously disturbed areas at the Mary River Project are presented in Table 2.

[2] Based on climate, topography, vegetation, soil, water, wildlife, and land use.

Table 2. Plants Observed Naturally Revegetating Disturbed Sites in the Project Area.

Common Name	Taxon	Location*		
		Mine Site	Milne Inlet	Tote Road
Alpine fescue	*Festuca brachyphylla*	✓		
Arctic bladderpod	*Physaria arctica*		✓	✓
Arctic mouse-ear chickweed	*Cerastium arcticum*	✓	✓	
Glaucous bluegrass	*Poa glauca*	✓	✓	
Long-stalked starwort	*Stellaria longipes*	✓		✓
Mountain sorrel	*Oxyria digyna*	✓	✓	
Polar grass	*Arctagrostis latifolia*			✓
Purple saxifrage	*Saxifraga oppositifolia*		✓	✓
Snow whitlow grass	*Draba nivalis*		✓	✓
Spiked trisetum	*Trisetum spicatum*	✓		

*Observed during 2014 Operations Monitoring



LEGEND

- Community
- Mary River Project
- Potential Development Area

Northern Landcover Classes

- Tussock graminoid tundra
- Wet sedge
- Moist to dry non-tussock graminoid/Dwarf shrub tundra: 50-70% cover
- Dry graminoid prostrate dwarf shrub tundra: 70-100% cover
- Prostrate dwarf shrub - Dryas/heath, usually on bedrock
- Sparsely vegetated bedrock
- Sparsely vegetated colluvium
- Bare soil with cryptogam crust
- Wetlands
- Barren
- Ice/snow
- Unclassified

NOTES

Updated PDA provided by Hatch (25 April 2013).

Map Projection: Canada Albers Equal Area Conic.

Scale 0 5 10 20 30 40 50 Km

Baffinland Iron Mines Corporation

Northern Land Cover Classes Distributed in the Mary River RSA

EDI

Date: 4/27/2017

MAP 2

ENVIRONMENTAL LIMITATIONS AND CONSTRAINTS

Arctic Growing Conditions

The Arctic is characterized by a cold and dry climate resulting in a short growing season and low water availability (Ecological Stratification Working Group 1995). Topsoils are typically shallow (< 5cm in depth, if/where present), nutrient poor (i.e., having low bioavailable nitrogen and phosphorus) and have low organic and moisture content (Shaver and Chapin 1980, Mallory and Aiken 2012, Naeth and Wilkinson 2014). Permafrost further impacts soil nutrient availability and slows-down nutrient cycling (i.e., organic decomposition) and thereby limits the below-ground rooting zone (Reid and Naeth 2005a, b, Miller and Naeth 2017). High winds commonly cause abrasion and desiccation of aboveground vegetative tissues. Combined, these conditions impose a significant selective pressure on plants that slows down plant establishment/colonization, productivity and turn-over. Consequently, the native Arctic flora has evolved unique adaptations to the harsh Arctic climate.

Plant Adaptations

As summarized by Mallory and Aiken (2012), most species are perennial (i.e., having a life-cycle of three or more years) and grow low to the ground (e.g., spreading laterally and/or forming a tight tussock or cushion) to minimize wind abrasion and desiccation. Plants develop trichomes (specialized hairs or fur) that insulate and protect exposed/aboveground vegetative tissues to optimize heat retention and ensure metabolic function. Flowering plants commonly have radial symmetry (i.e., star-shapes – Photos 1-2) that optimize sunlight capture and track diurnal rhythms, such as the Arctic poppy (*Papaver nudicaule*) and mountain avens (*Dryas integrifolia*). Herbaceous shrubs develop leaves that stay on the plant (even when withered and senesced) to provide insulation during the winter and thatch around the base of the plant to release nutrients and improve water holding capacity. Although the Arctic growing season is very narrow, Arctic plants may rapidly self-propagate asexually via seed and/or clonal reproduction (e.g., in the absence of pollination) to increase their survival.

Ecosystem Recovery

Ecological succession (referring to natural/progressive changes in plant community structure and composition) and pedogenesis (referring to the process of soil formation/development) occurs very slowly in the Arctic (Cargill and Chapin III 1987). For example, where sites have suitable water availability (e.g., wet-site), revegetation of by herbaceous shrubs is projected to require 50 or more years to re-establish toward an intermediate or climax succession state and where sites do not have suitable water availability (e.g., dry site), revegetation can be much longer (Shaver and Chapin 1980, Cargill and Chapin III 1987).

As summarized by Kearns et al. (2015) early patterns of plant colonization and growth affect the final plant community composition. Permafrost also impacts plant colonization due to effects on soil moisture and nutrient availability. Erosion by wind or water can slow the process of natural succession by removing soil nutrients and cover. For these reasons, it is necessary to identify site-specific conditions that may impose barriers or obstacles that can significantly affect plant colonization and early development.

Photo 1. Mountain avens (*Dryas integrifolia*).
Photograph by Jacob W. Frank, distributed under a CC-BY 2.0 license.

Photo 2. Arctic poppy (*Papaver nudicaule*).
Photograph by Derek Ramsey, distributed under a CC-BY 2.0 license.

3 REVIEW OF RECLAMATION PRACTICES AND PERFORMANCE

A literature review of reclamation programs was completed for northern mines in Canada and the USA. Subject matter experts were also consulted for additional perspectives on reclamation practices in the Canadian Arctic. The reclamation activities and approaches from the following mines were reviewed to compare/contrast practices and outcomes relevant to the Project:

- Polaris Mine
- Nanisivik Mine
- Red Dog Mine
- Hope Bay Doris North Mine
- Meadowbank Mine
- Diavik Diamond Mine
- Ekati Diamond Mine
- Gahcho Kué Mine
- Con Mine

A summary of closure and reclamation of the mines listed above is presented in Table 3. A summary of reclamation/revegetation approaches and outcomes is presented in Table 4. Highlights are described in paragraphs below.

Lessons Learned from Northern Mine Reclamation Projects

Upon review of the available information, common themes are that the Arctic environment imposes significant constraints on reclamation and revegetation that are consistent with those described in Section 2. Natural patterns of cover vegetation are commonly sparse and/or intermittent, and patterns of revegetation succession and associated soil forming processes are slow. Of course, these conditions directly impact reclamation performance.

At some mine sites — Polaris Mine and Nanisivik Mine (both closed); Hope Bay Doris North Mine and Meadowbank Mine (both currently operating) — no reclamation trials were conducted and post-reclamation monitoring focused only on the physical and chemical stability of waste materials (i.e., recontouring, backfilling and/or capping of disturbed areas). Therefore, no methods for revegetation were explored and natural revegetation was expected to occur without further management input. At all other mine sites — Red Dog Mine, Diavik Diamond Mine, Ekati Diamond Mine, Gahcho Kué Mine and Con Mine (all currently operating) — reclamation trials and even progressive reclamation activities were either ongoing or under development. Field trials (and sometimes greenhouse studies) were designed to support surface preparation, substrate composition, soil handing and amendment, and planting/seeding techniques using native species.

Overall, key take-aways were that sites where soils were not salvaged/stockpiled (i.e., due to legacy management practices) prior to development necessarily focused their reclamation approach toward preparation techniques that would be conducive to natural revegetation (i.e., to ensure safe, stable and non-polluting end-landscapes). Where possible (given site circumstances and conditions) reclamation and revegetation performance benefitted from appropriate soil salvage and handling. Where appropriate, soil amendments and/or supplementary seeding/planting were beneficial to revegetation development. It remains to be determined what combination of these approaches is best for Arctic reclamation, and how they may be applied to the Mary River Project.

Table 3. Summary of Closure and Reclamation Goals at Northern Mines in Canada and Alaska.

Mine Status	Mine / Proponent	Ecozone	Location	Resource	Closure & Reclamation Goal(s)
Closed	Polaris Mine / Teck Cominco[1]	Northern Arctic	75º North Little Cornwallis Island, NU.	Underground Lead, Zinc	• Ensure conditions such that public health and safety, and the environment are protected. • Provide a working document that addresses the concerns and requirements of all stakeholders during the consultation and implementation stages. • Identify the activities required to return the site to an aesthetically acceptable condition. • Ensure that planned activities during decommissioning minimize and/or eliminate requirements for long term care and maintenance
	Nanisivik Mine / Breakwater Resources[2]	Northern Arctic	73º North Baffin Island, NU.	Underground Lead, Zinc	
Operating	Red Dog Mine / Teck Cominco[3]	Southern Arctic	68º North Northwest, AK.	Zinc, Lead, Silver	• Establish plant communities (where appropriate) that are self-sustaining. • Assist in protecting water quality by controlling erosion and preventing acid rock drainage. • Contribute to the proposed land use(s) of the mine after closure.
	Hope Bay Doris North Mine / TMAC Resources Inc.[4]	Northern Arctic	67º North Western, NU.	Gold	• Establish stable landforms; Protect water resources in the local area. • Facilitate natural recovery of areas affected by mining and mining-related activities at the project site. • Re-establish productive use of the land and water in the vicinity of the mine site for future generations in a manner that is consistent with the pre-development (incl. wildlife habitat and traditional activities as practised by the local communities and Inuit prior to the development of the mine).

Table 3. Continued (1).

Mine Status	Mine / Proponent	Ecozone	Location	Resource	Closure & Reclamation Goal(s)
Operating	Meadowbank Mine / Agnico-Eagle Mines Ltd.[5]	Northern Arctic	65° North Baker Lake Region, NU.	Gold	• Minimize the area of surface disturbance, stabilize disturbed land surfaces against erosion, and return the land to a suitable condition for post-mining uses such as traditional pursuits and wildlife habitat. • Operate and close the mine responsibly, leaving behind a positive community and environmental legacy.
	Diavik Mine / Diavik Diamond Mines Inc.[6]	Southern Arctic	64° North North Slave Region, NWT.	Diamond	
	Ekati Mine / Dominion Diamond Mines[7]	Southern Arctic	64° North North Slave Region, NWT.	Diamond	• Return the Ekati mine site to viable, and wherever practicable, self-sustaining ecosystems that are compatible with a healthy environment, human activities, and the surrounding environment.
	Gahcho Kué / De Beers[8]	Taiga Shield	63° North Kennady Lake, NWT.	Diamond	• Return the site and affected areas around the mine to technically viable and, where practicable, self-sustaining ecosystems that are compatible with a healthy environment and with human activities.
	Con Mine / Miramar Northern Mining Ltd.[9]	Taiga Shield	62° North Yellowknife, NWT.	Gold	• Meet the approved end land use goal for open areas with a potential for light recreational use, supported by the establishment of a self-sustaining vegetative cover over the entire surface of the tailing areas.

Note: Ecozone (and its equivalent) is based on the national ecological framework for Canada (Ecological Stratification Working Group 1995).

[1] (Donald 2004); [2] (Cassie and Eng 2015); [3] (ABR Inc. 2007, SRK Consulting 2009); [4] (Miramar Hope Bay Ltd. 2006);[5] (Golder Associates 2014); [6] (Rio Tinto 2017); [7] (BHP Billiton Canada Inc. 2010); [8] (De Beers Canada Inc. 2016a, b, 2017); [9] (Miramar Northern Mining Ltd. 2014).

Table 4. Summary of Reclamation/Revegetation Approaches and Outcomes at Northern Mines in Canada and Alaska.

Mine Status	Mine / Proponent	Status of Reclamation Activities	Revegetation Methods	Conclusions
Closed	Polaris Mine / Teck Cominco[1] Nanisivik Mine / Breakwater Resources[2]	• Post-reclamation performance monitoring for physical and chemical stability only	• Reclamation activities included recontouring, backfilling and/or capping of disturbed areas. • No other methods for revegetation were explored.	• Natural vegetation patterns were low/sparse within the project area; therefore, no effort was made to revegetate/re-establish pre-disturbance conditions • Post-reclamation monitoring does not include measures for revegetation.

Operating	Red Dog Mine/ Teck Cominco[3]	• Active/Ongoing Progressive Reclamation
		• Monitoring & Evaluation of Active/Ongoing Revegetation Plots (Est. 1987, 2004, and 2007).
			• Greenhouse and field trials in support of revegetation, focussing on:
			– **Surface preparation**: contouring, raking or grading, scarifying and surface roughening of compacted surface soils.
			– **Substrate type:** mine waste materials such as shale from the quarry; talus and sand/gravel mixes from nearby slopes and associated floodplains.
			– **Soil manipulation:** topsoil; inorganic fertilizer.
			– **Planting technique:** native species seed mixes; native species seed collection, cuttings and sprigs, and vegetative mat transplants.
				• Topsoil very limited on-site; where present/available, plant growth and vegetation cover were significantly increased.
				  • Trials for topsoils amended with sewage sludge from mine camp facilities; native grasses performed better with amendments; ongoing evaluations for potential adverse impacts (e.g., pathogens, heavy metals, and nitrates)
				• 20 Year Revegetation Monitoring
				  • Initial/primary focus on agronomic cultivars
				  • Ongoing study focus on native species and revegetation; ongoing focus on the collection of indigenous seeds and plant propagules (currently insufficient sources for seeding/propagation)
				  • Engagement of commercial grower (Alaska Seed Growers Inc.) to supplement seed supply; reclaimed landscape could serve as source material for future revegetation efforts.
				• Ongoing transplantation studies
				  • Arctic pendant grass (*Arctaphila fulva*) identified as a successful candidate; local populations being evaluated for subsequent seed viability

	Hope Bay Doris North Mine / TMAC Resources Inc.[4]	• Reclamation trials under review/to be confirmed.	• Revegetation is currently limited to natural revegetation (ingress) due to insufficient topsoil/growth substrate
			• Prospective reclamation trials will focus on site preparation
				• Methods of revegetation are limited to backfilling and capping of disturbed areas using local materials.
				  • No other techniques are being used to promote revegetation.
				  • No effort is being made to revegetate rock quarries.

Table 4. Continued (1).

Mine Status	Mine / Proponent	Status of Reclamation Activities	Revegetation Methods	Conclusions
Operating	Meadowbank Mine / Agnico-Eagle Mines Ltd.[5]	• Active/Ongoing Progressive Reclamation	• Revegetation is currently limited to recontouring and capping of disturbed areas; open-pits to be converted to pit lakes. • Large scale revegetation considered not feasible due to site conditions.	• Methods of revegetation are limited to backfilling and capping of disturbed areas using local materials. • No other techniques are being used to promote revegetation. • No effort is being made to revegetate rock quarries. • Insufficient native seed sources; insufficient topsoil/growth substrate for revegetation
	Diavik Mine / Diavik Diamond Mines Inc.[6]	• Active/Ongoing Progressive Reclamation • Monitoring & Evaluation of Active/Ongoing Revegetation Plots (Est. 2004).	• Greenhouse and field trials in support of revegetation method re-establish, focussing on: – **Surface preparation**: contouring, raking or grading, scarifying and surface roughening of compacted surface soils. – **Substrate type:** mine waste materials such as crushed rock, gravel, till, and processed kimberlite mine tailings. – **Soil manipulation:** sewage sludge, salvaged topsoil, biochar; inorganic fertilizer. – **Planting technique:** native species seed mixes; native species seed collection and vegetative mat transplants.	• Ongoing trials and data gathering • Limited available/salvaged topsoil onsite; native soil preferred for revegetation; soil stripping/salvage found to reduce indigenous seed viability – Soil amendment trials to improve the physical and chemical nature of the soil (e.g., coarse vs. fine till waste materials combined with organic matter) – Sewage sludge found to be favourable/beneficial for initiating plant growth and early establishment. (increased water content and micro/macro-nutrient content) – Biochar found to be less effective amendment. • Limited/available plant cultivars (i.e., seeds and tubestock) for revegetation; Reliance on local plant populations (e.g., native grasses and legumes); Ongoing transplantation studies – Polar grass (*Arctagrostis latifolia*) identified as a successful candidate, even where organic matter was low; transplantation of vegetative mats also successful. – Plants benefit from micro sites with protection from wind and erosion resulting in higher germination rates. – Incorporating several types of plant functional groups is more beneficial than including a higher number of species.

Table 4. Continued (2).

Mine Status	Mine / Proponent	Status of Reclamation Activities	Revegetation Methods	Conclusions

Operating	Ekati Mine / Dominion Diamond Mines[7]	• Active/Ongoing Progressive Reclamation
		• Monitoring & Evaluation of Active/Ongoing Revegetation Plots (Est. 2000).
			• Greenhouse and field trials in support of revegetation method re-establish, focussing on:
			– **Surface preparation**: contouring, raking or grading, scarifying and surface roughening of compacted surface soils.
			– **Substrate type:** mine waste materials such as processed kimberlite mine tailings.
			– **Soil manipulation:** sewage sludge, lake sediment, peat moss, and papermill sludge, inorganic fertilizer, rock phosphate, calcium carbonate, gypsum.
			– **Planting technique:** native species seed mixes and vegetative mat transplants.
				***Similar trials/study outcomes as Diavik Mine (above)**
				• Trials for topsoils amended with sewage sludge from mine camp facilities; ongoing evaluations for potential adverse impacts (e.g., pathogens, heavy metals, and nitrates)
				  • Winter application of sewage sludge significantly reduced the health risk associated with using a biosolid waste material as a soil amendment to 0.02% of the original fecal coliform (*Streptococcus*) and Salmonella levels.
				• Limited/available plant cultivars (i.e., seeds and tubestock) for revegetation; Reliance on local plant populations (e.g., native grasses and legumes); Ongoing transplantation studies
				  • Site/substrate preparation linked to the success of vegetation re-establishment.
				  • Wherever possible, islands of undisturbed vegetation should be left/maintained undisturbed to provide a seed source for revegetation.
				  • Hulten Bering's tufted hairgrass (*Deschampsia beringensis*; 53%), creeping red fescue (*Festuca rubra*; 33%), tufted hairgrass (*Deschampsia caespitosa*; 16%), and alpine bluegrass (*Poa alpina*; 11%) were successful candidates.

	Gahcho Kué Mine / De Beers[8]	• Research/Revegetation Trials Planned (specific to project features — vegetation at the mine site, roads, pads and the airstrip)	• Greenhouse and field trials in support of revegetation method re-establish, focussing on:
			– **Surface preparation**: contouring, raking or grading, scarifying and surface roughening of compacted surface soils; focus on erosion and sediment control measures.
				***Gahcho Kué Mine is at a similar operational stage to the Mary River Mine in its reclamation planning process.**
				• Scoping based on a desktop review of reclamation/revegetation practices (2016–19)
				  • Revegetation research is being initiated and is projected to occur over the next 10 years.
				  • DeBeers organized workshops to identify closure and reclamation goals and objectives.

Table 4. Continued (3).

Mine Status	Mine / Proponent	Status of Reclamation Activities	Revegetation Methods	Conclusions
Operating	Con Mine / Miramar Northern Mining Ltd.[9]	• Active/Ongoing Progressive Reclamation • Monitoring and Evaluation of Active/Ongoing Revegetation Plots (Est. 1970, 1980, and 2002).	• Greenhouse and field trials in support of revegetation method re-establish, focussing on: – **Substrate type:** mine waste material of blasted rock (coarse and fine grain mixture). – **Soil manipulation:** peat/organic soil, inorganic fertilizer. – **Planting technique:** agronomic seed mixes; native shrub/tree planting.	• Presently, no unifying criteria for determining reclamation success onsite. • Soil amendment trials using organics (1977) on Neil Lake tailings found to be favourable/beneficial for initiating plant growth and early establishment. • Soil additive (inorganic fertilizer) enhanced plant early-development; additives favoured agronomic species rather than native species; an influx of agronomic species altered natural succession patterns. • Supplemental planting necessary to facilitate the establishment of woody/shrubby species; woody species indicated slow re-establishment.

[1] (Donald 2004); [2] (Cassie and Eng 2015); [3] (ABR Inc. 2007, SRK Consulting 2009); [4] (Miramar Hope Bay Ltd. 2006, Nunavut Impact Review Board 2018);[5] (Golder Associates 2014, Paquin Bilodeau et al. 2018, Agnico Eagle Mines Limited et al. 2018); [6] (Naeth and Wilkinson 2004, 2014, Naeth et al. 2004, 2014, Drozdowski et al. 2012, Miller and Naeth 2017, Rio Tinto 2017); [7] (Reid and Naeth 2005b, a, BHP Billiton Canada Inc. 2010, Harvey Martens & Associates Inc. 2013); [8] (De Beers Canada Inc. 2016a, b, 2017); [9] (C.E. Jones & Associated Ltd. 2009, Miramar Northern Mining Ltd. 2014).

SUMMARY OF RECLAMATION AND REVEGETATION MECHANISMS

The following sections summarize site preparation approaches and mechanisms relevant to Arctic reclamation and revegetation. Due to the inherent environmental constraints imposed by the Arctic environment, the most critical issues identified by these investigations refer to the availability of organic topsoil and the ability of topsoil to retain moisture. Consequently, most preparation techniques, approaches and mechanisms are focused on enhancing soil water retention and nutrient bioavailability to then provide suitable micro-habitats conducive to plant early-establishment. Secondary approaches focused on amendments to the growth substrate to improve these starting conditions and, lastly, the subsequent effects of biodiversity (i.e., plants and soil microbes) on these conditions.

1. Surface Preparations

Site Preparation and Landscape Engineering

Contouring, raking or grading, scarifying and surface roughening of compacted surface soils have been found to improve soil moisture infiltration and retention. These actions create suitable micro-sites that are conducive to plant early establishment and development. Predictably, studies by Kidd et al. (2004, 2006) who investigated plant growth on gravel suggest that creating substrate conditions similar to adjacent undisturbed environment (i.e., ensuring similar size and composition) facilitates water infiltration and retention. Any site preparations should aim to reinstate similar starting conditions to control sites; here, it is critical to restore hydrologic function without initiating permafrost thaw.

Berm and Basin Construction

Berm and basin construction refer to the technique of constructing ridges and troughs to shelter plants and capture drifting snow. Jorgenson and Joyce (1994) have shown that small berms (up to 50 cm high) are effective in increasing plant-available soil moisture (via snowmelt) which then improved plant growth and plant re-establishment. These effects were especially beneficial in areas composed of organic soils and amended with fertilizer. Similar findings (as above) suggesting that these micro-sites shelter plant growth from wind/exposure and facilitate water/nutrient capture were reported by Rausch and Kershaw (2007) and later by Boulanger-Lapoint et al. (2016).

Installation of Snow fences

Similar to the construction of ridges and troughs to shelter plants during early-establishment (as above) studies by Lemay et al. (2018) investigated the use of snow fences as a novel approach to encourage/facilitate plant growth. Snow fences were erected to reduce wind-injury as well as capture/accumulate snow in winter to increase soil moisture (via snowmelt) in summer. Preliminary findings indicated that snow fencing increased average soil temperature in winter (>-10ºC) compared to a control, which was then correlated with greater soil microbial activity and an observed stimulation of plant growth.

Topsoil Handling and Amendments

In the Arctic, topsoils are typically shallow, nutrient poor and have low organic and moisture content. If/where present, appropriate conservation procedures including topsoil stripping/salvage and handling are necessary to ensure soil viability and growing capability. In the absence of soil, plant establishment is hampered due to the lack of organic substrate which limits the quantity and quality of colonizable environments. Therefore, conservation of native topsoil (i.e., containing indigenous seed and nutrient profiles) is preferred and deemed beneficial for reclamation (Cargill and Chapin III 1987). Where topsoil is limited and/or low in organic content, amendments such as the application of fertilizer and/or sewage sludge benefit revegetation (Jorgenson and Joyce 1994). However, determining appropriate soil amendment application rates and composition is necessary to address/calibrate site-specific requirements.

2. Biodiversity Effects

Re-Establishment of Surface Cover

Re-establishment of cover vegetation represents a critical feedback mechanism to facilitate and enhance soil forming processes, moisture retention, etc. described above. Although some reclamation programs relied on natural revegetation (i.e., species ingress and volunteer colonization), seeding/planting and transplantation of vegetative mats are known to increase plant re-establishment. The later approach should emphasize species representative of native biodiversity since they are best adapted to bioregional conditions. Wherever possible, undisturbed vegetation should be left undisturbed areas to provide seed sources for natural revegetation.

Nitrogen-Fixing Plants

Incorporating native nitrogen-fixing plants (i.e., via seeding and/or transplantation) in the initial composition of the reclaimed landscape can improve soil macronutrient content (Jorgenson and Joyce 1994) and, over time, enhance natural revegetation. Mountain avens (*Dryas integrifolia*) are woody shrubs commonly found on North Baffin Island that are adapted to Arctic growth conditions and nutrient-poor soils (Mallory and Aiken 2012); this species fosters an active association (or symbiosis) with nitrogen-fixing bacteria in its root (Kohn and Stasovski 1990, Rausch and Kershaw 2007). Likewise, certain Arctic lichens have also been identified as forming associations with nitrogen-fixing bacteria (Stewart 1973, Crittenden and Kershaw 1978). These adaptations contribute to enriching soil macronutrient conditions by converting inorganic (and otherwise unavailable) nitrogen into its organic form which can then be metabolized by plants.

Biological Soil Crusts

Biological soil crusts (BSCs) are natural surface crusts typically occurring in arid or semi-arid environments. They are composed of a diverse array of bacteria, cyanobacteria/algae, mosses, and/or fungi and lichens. Albeit slow-forming, BSCs stabilize surface soils and improve water infiltration and soil moisture retention. These characteristics provide bio-active micro-sites for plant colonization and early-development (Stewart and Siciliano 2015).

4 RECLAMATION AND REVEGETATION TRIALS AT BAFFINLAND

PATH FORWARD AND RECOMMENDATIONS FOR WORKPLAN

Based on the review of reclamation practices and performance for Northern mines (Section 3), the following components are recommended for inclusion in reclamation and revegetation trials at Baffinland. Ultimately, the Closure Working Group will be tasked of selecting appropriate methods and reclamation techniques. Over the life of the Project, it is expected that these methods will be adapted with changes to the understanding of the Project site, stakeholder's views, and technologies for cost-effective and practical reclamation in northern conditions (Baffinland Iron Mines Corporation 2016). Therefore, planning for mine site closure and reclamation will be flexible to incorporate ongoing study outcomes and best practices for the Project's site-specific conditions.

1. Identify Site Preparation Techniques Best Suited/Tailored for Natural Revegetation

It is beneficial to determine/classify the composition of soil substrate on-site (if/where present) to identify constraints and limitations to the colonization and early establishment of plants. Thereafter, site preparation techniques such as surface recontouring and construction of micro-sites (e.g., berms, troughs and snow fences) should be investigated to enhance capture/retention of soil moisture and nutrient availability. These findings and observations will contribute in refining techniques that are best suited for natural revegetation.

Recommended Actions and Objectives:

a. Characterize control/undisturbed landscape conditions as a template for reclaimed environments.
b. Examine landscape preparation approaches that will increase the availability of micro-habitats conducive to plant early-establishment.
c. Determine timelines and measurables for reclamation success.

2. Identify Indicator Species Best Suited for Natural Revegetation

A list of suitable plant species with potential for revegetation should be identified/refined — including the proximity of local populations and the viability of sources of seed and/or biological materials. Observations of natural revegetation were made during operations in the Project area as part of vegetation monitoring programs (2014–18). These observations will contribute in identifying indicator species best suited for natural revegetation. NLC classes should also be used to guide species selection. Where applicable, Inuit should be consulted to incorporate and align with traditional knowledge and land use objectives.

Recommended Actions and Objectives:

a. Characterize control/undisturbed vegetation conditions as a template for reclaimed environments.
b. Examine landscape preparation approaches that will increase the suitability of micro-habitats for plant early-establishment and development of cover vegetation.
c. Determine timelines and measurables for reclamation success.

3. Examine the Viability and Applicability of Seeding/Planting and Soil Amendments

As stated in the ICRP, Baffinland will recontour and regrade their disturbance footprint to tie-in to the predominant landscape. They will rely on initial site preparation to promote natural revegetation of species identified on-site. No extrinsic seeding/planting and/or soil amendments are planned. Unrelated to any prospective field reclamation trials (described above), it is recommended to examine the viability and applicability of seeding/planting and/or soil amendment in support of the ICRP's approach and identify potential opportunities if/where applicable.

5 CLOSURE

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