16
March
2020

Final Report
Prairie Creek
Testing Program

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1. Introduction

This document reports on Prairie Creek testing programme completed up to 16th of March 2020.

It includes the results of the characterization of tailings (particle size distribution, specific gravity, XRD and XRF), pH level measurements, as well as the rheological tests together with the Uniaxial Compressive Strength (UCS) tests results of 7, 14, 21, 28 and 56 day cured samples.

This project was a collaborative work of United Geo Test Inc. and McGill University.

2. Disclaimer

These results are relevant to the samples as received and processed only. The report authors or their establishments (United Geo Test Inc. and McGill University) do not hold any responsibility and liability for how this information is used by AMC or/and Prairie Creek Mine, or/and their subsidiaries or clients.

3. Tailing types

On November 27, 2019, 11 buckets (20-liter) of Prairie Creek tailings. the buckets were not labelled. The photos of buckets are presented in Appendix 1. The materials in buckets were submerged in water. AMC advised that 11 buckets of Prairie Creek tailings were identical tailings samples. Therefore, 11 buckets of Prairie Creek Tailings thoroughly mixed using a ribbon drill mixer attached to a power drill and one homogenous representative sample was prepared.

4. Binder

In this project three types of binder were used. These binder samples are:

- GU cement
- GUL cement (with limestone)
- T90 Terraflow

GUL cement and T90 Terraflow binders were obtained from Lafarge Inc. and GU cement was obtained from a Home Depot outlet located in Montreal.

5. Sample preparation

All tailings were homogenized and mixed using a mixer and riffle splitter.

Three 50-gram representative samples from tailings were carefully prepared and sent for XRD, XRF and particle size analysis.

The homogenised samples were carefully stored to prepare UCS samples in the next step.

24 batches of samples will be prepared and cast according to the mixing design provided by AMC and presented in Table 1.

i. Mixing Method

Initially, the required amount of tailings, binders and water were measured separately. Then, tailings and binders were poured into a 5-quart, stainless steel bowl and mixed for one minute at a stirrer rate of 75 RPM. Consequently, the measured water was introduced to the materials and mixed for 5 min.

ii. Casting

Mixtures were poured into cylindrical polyvinyl chloride (PVC) moulds. The dimensions of the PVC moulds are 10 cm long and 5 cm diameter. The moulds were capped and sealed.

iii. Curing

The capped samples were stored in a humidity chamber to cure. The relative dimensions of the chamber are 3×3×2.5 metres. The humidity and temperature in the chamber are controlled and adjusted by a digital control board. The relative humidity was kept constant at 90 ± 4% and the temperature was adjusted to 22 ± 2 °C.

iv. Trimming

Before conducting the tests, the specimens were removed from the moulds and the top and bottom of the samples were trimmed to reach a ratio of 2:1 height to diameter and making sure the top and bottom surfaces are parallel.

v. Uniaxial compression machine

The tests were conducted by a 50 KN compression testing machine according to the ASTM D 2166-16 Standard Test Method for Unconfined Compressive Strength of Cohesive Soil (ASTM, 2016d). The press is equipped with a 50 kN load cell and a Linear Variable Displacement Transducer sensor (LVDT). A normal loading rate under displacement control of 1 mm/min was applied by the press control panel. A computer setup and digital data acquisition was employed to obtain and store the data in a computer.

Table 1: Binder mixtures characteristics and mixing design of Prairie Creek samples prepared for UCS tests

Batch	Test Mixing Design					
	PC Tailings (%)	T90 Terraflow (%)	GU Cement (%)	GUL Cement (%)	Solid Concentration (%)	Required Yield Stress (Pa)
1	99.0	1.0	0	0	78.3	250
2	98.0	2.0	0	0	78.3	250
3	95.0	5.0	0	0	78.3	250
4	93.0	7.0	0	0	78.3	250
5	90.0	10.0	0	0	78.3	250
6	96.5	3.5	0	0	77.0	100
7	96.5	3.5	0	0	78.3	250
8	96.5	3.5	0	0	78.8	350
9	99.0	0	1.0	0	78.3	250
10	98.0	0	2.0	0	78.3	250
11	95.0	0	5.0	0	78.3	250
12	93.0	0	7.0	0	78.3	250
13	90.0	0	10.0	0	78.3	250
14	96.5	0	3.5	0	77.0	100
15	96.5	0	3.5	0	78.3	250
16	96.5	0	3.5	0	78.8	350
17	99.0	0	0	1.0	78.3	250
18	98.0	0	0	2.0	78.3	250
19	95.0	0	0	5.0	78.3	250
20	93.0	0	0	7.0	78.3	250
21	90.0	0	0	10.0	78.3	250
22	96.5	0	0	3.5	77.0	100
23	96.5	0	0	3.5	78.3	250
24	96.5	0	0	3.5	78.8	350

6. Results

6.1. Tailings Physical Properties

The specific gravity of the tailings was measured using a pycnometer (ASTM D 854 – 10). The tests results are presented in Table 2.

Table 2: The physical properties of the Prairie Creek tailings

Material	Colour	Specific Gravity
Prairie Creek Tailings	Bright gray	2.70

6.2. Tailings Particle Size

The particle size distribution of tailings was investigated by conducting the sieve analysis and the laser diffraction particle sizing technique. For these tests, two 500-gram representative samples were carefully selected and prepared using a riffle sample splitter from Prairie Creek Tailings. The size distribution of particles and the results are shown in Figure 1.

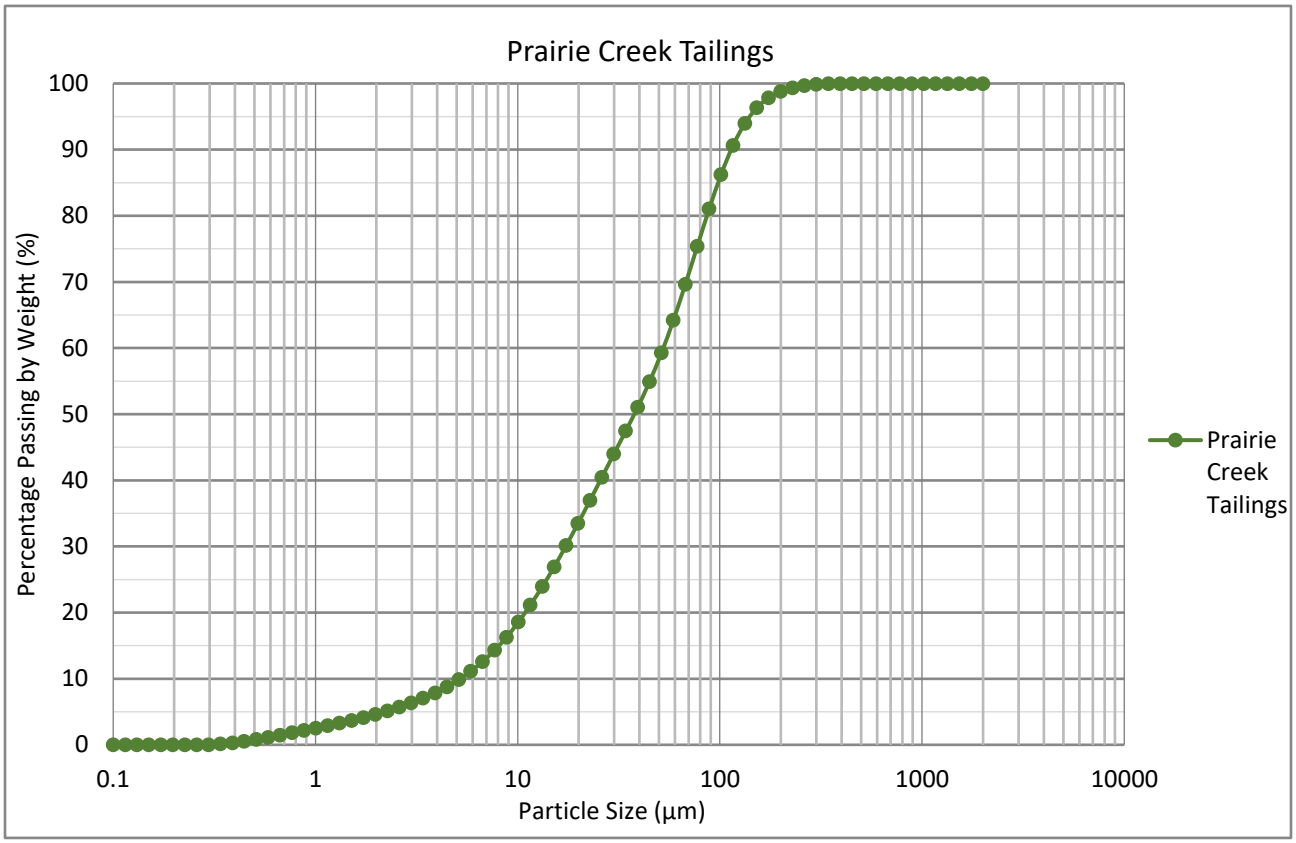


Figure 1: The particle size distribution graph of the Prairie Creek tailings

The coefficient of uniformity and curvature were calculated and presented in Table 3.

Table 4 presents the Percentage of Sand, Silt and Clay based on MIT soil classification system. It can be seen that the majority of Prairie Creek tailings particles are within the range of silt. Additionally, there is a considerable amount of sand and clay-sized particles in the Prairie Creek tailings, so considering the M.I.T. classification system Prairie Creek tailings can be classified as Sandy-Silt with some Clay.

It is also observed that 34% of tailings particles are smaller than 20 microns.

Table 3: Coefficients of uniformity and curvature of the Prairie Creek tailings.

	Tailings
D_{10} (microns)	5.15
D_{30} (microns)	17.35
D_{50} (microns)	38.85
D_{60} (microns)	51.67
D_{90} (microns)	116.21
Cu $C_u = \frac{D_{60}}{D_{10}}$	10.03
Cc $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$	1.13

Table 4: Percentage of Sand, Silt and Clay base on MIT soil classification system

	Prairie Creek Tailings
Sand (% passing 2 mm-%passing 0.06mm)	34.50%
Silt (% passing 0.06 mm-%passing 0.002mm)	60.50%
Clay (% 0.00 2mm)	5.00%

6.3. Tailings Mineralogy

The mineralogy of the Prairie Creek tailings was studied using the x-ray diffraction (XRD) method and presented in Appendixes 2. The XRD results are summarized in Table 5. The results indicate that the tailing samples consisted predominantly of Quartz, Calcium Magnesium Carbonate and Calcium Carbonate. The elemental composition of Prairie Creek tailings was analysed using the X-ray fluorescence (XRF) method and presented in Table 6.

Table 5: Prairie Creek tailings mineralogy

	Phase	Mineral	Chemical	Formula
Prairie Creek Tailings	**Major**	Quartz		SiO_2
	Major	Dolomite	Calcium Magnesium Carbonate	$CaMg(CO_3)_2$
	Minor	Calcite	Calcium Carbonate	$Ca\ CO_3$

Table 6: Prairie Creek tailings XRF result

Formula	Concentration (%)
SiO2	31.82
Al2O3	26.56
Fe2O3	17.05
MgO	15.44
CaO	2.94
Na2O	1.59
K2O	1.34
TiO2	0.77
P2O5	0.75
MnO	0.34
Cr2O3	0.32
V2O5	0.0798
LOI	0.0596
Co	< 0.01
Ni	< 0.01
Cu	0.03
Zn	0.028
Mo	< 0.01
Pb	0.53
Sum	98.3

6.4. Rheological Characterisation

In order to measure the rheological properties of the materials and yield stress of the samples a rotational desktop shear vane rheometer was used. Table 7 shows the rheometer specifications.

Table 7: Rheometer Specification

Rheometer	HAAKE Viscotester 550
Vane	FL 100
Vane Diameter (mm)	22
Vane Height (mm)	16
Rotation Rate (deg/min)	75
Rate of Shear (1/s)	0.04355
Room Temperature (°C)	22

Two batches of samples were prepared according to the mixing design provided by AMC and presented in Table 8. For the preparation of the samples, initially two 3-Kg representative samples were carefully selected and prepared using a riffle sample splitter from Prairie Creek tailings. One of the 3 Kg-tailing samples was mixed with 3.5% of GU cement by total dry weight of the sample. Water was added to the mixtures in order to make a thick paste. The samples were sheared with the rheometer and the yield stress and solid concentration were measured. A small amount of water was added to the mixture and the test repeated until the yields shear stress dropped below 70 Pa. The shear yield stress profiles of the samples are presented in Figure 2.

As expected, it was observed that the yield shear stress of the samples was increased exponentially with solids concentration. The yield stress versus solids concentration curves were developed by fitting exponential trendlines to the data and presented in Figure 2. The equations for these curves are presented in Table 9. The solid concentrations of material corresponding to 100 Pa, 150 Pa, 250 Pa and 350 Pa yield stresses are presented in Table 10.

Table 8: Sample mixture characteristics and mixing design of backfill samples prepared for rheology tests

Batch	Test Mixing Design	
	Prairie Creek Tailings	GU Cement
Prairie Creek No Binder	100.0%	0.0%
Prairie Creek 3.5% GU Cement	96.5%	3.5%

Figure 2: Shear yield stress vs. solids concentration of the Prairie Creek tailings

Table 9: The yield stress versus solids concentration curve equations

Batch	Equations	Range
Prairie Creek No Binder	$\tau_y = 3.46E-21e^{6.67E+01x}$	$0.770 < x < 0.795$
Prairie Creek 3.5% GU cement	$\tau_y = 5.05\text{E}-22e^{6.97\text{E}+01x}$	$0.770 < x < 0.795$

τ_y is the yield stress (Pa) and x is the solid concentration.

Table 10: The solid concentrations of paste corresponding to 100 Pa, 150 Pa, 250 Pa and 350Pa yield stresses

Batch	Test Mixing Design		Solid Concentration at 100 Pa yield stress (%)	Solid Concentration at 150 Pa yield stress (%)	Solid Concentration at 250 Pa yield stress (%)	Solid Concentration at 350 Pa yield stress (%)
	Prairie Creek Tailings	GU cement				
Prairie Creek No Binder	100.0%	0.0%	77.6	78.2	78.9	79.4
Prairie Creek 3.5% GU cement	96.5%	3.5%	77.0	77.6	78.3	78.8

The Boger slump test conducted with 78mm Boger stainless cylinder and the results presented in Figure 3, and Appendix 3.

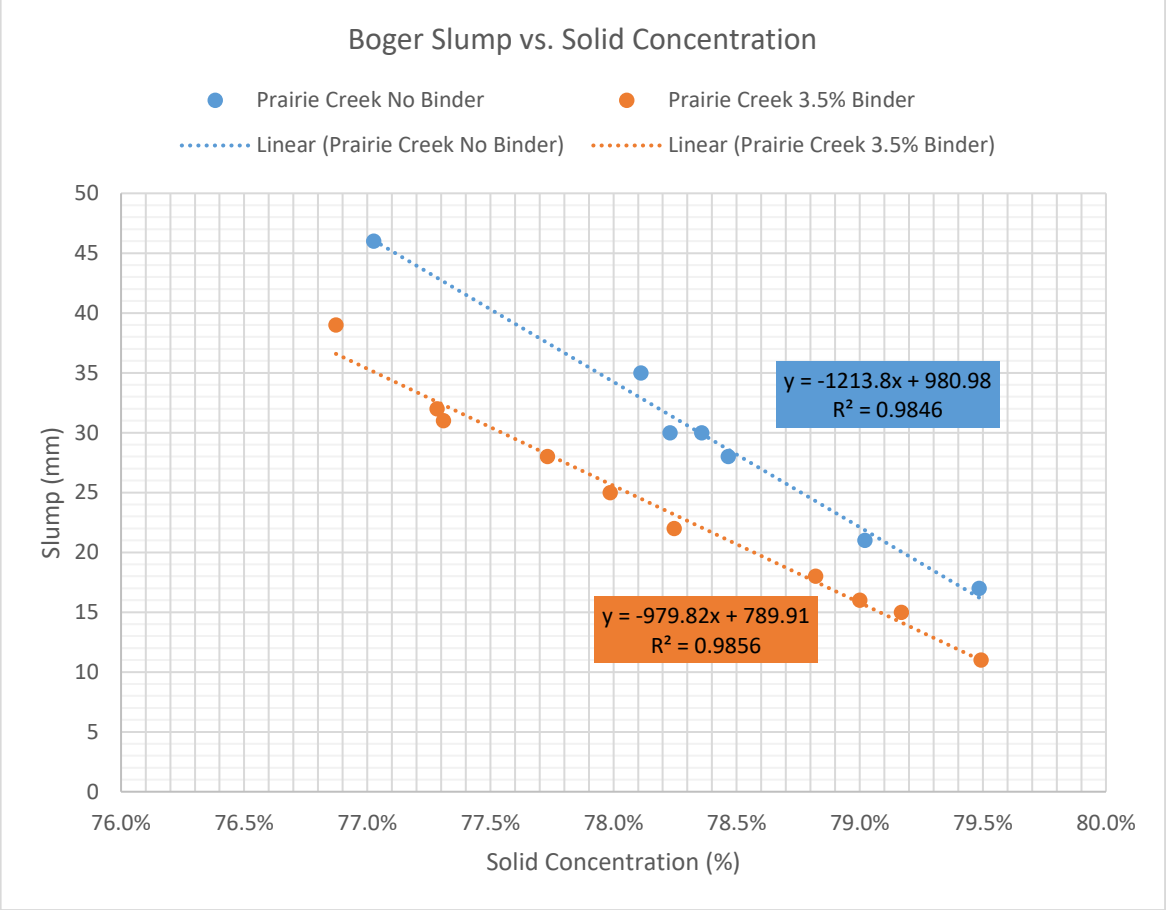


Figure 3: Boger Slump vs solid concentration

6.5. pH Measurements

The pH levels of materials were measured according to ASTM, Standard Test Methods for pH of Soils, D4972-01. The pH levels of the tailing sample mixed with GU Portland Cement at 5 different percentages (0%, 2%, 5%, 8%, and 10%) were measured and presented in Table 11 and presented in Figure 4.

Table 11: pH level of tailings prepared with GU Portland Cement

Batch	Test Mixing Design		
	Prairie Creek Tailings (%)	GU Cement (%)	pH
1	98.0	2.0	11.6
2	95.0	5.0	12.1
3	92.0	8.0	12.4
4	90.0	10.0	12.5
Prairie Creek Tailings	100.0	0.0	7.6

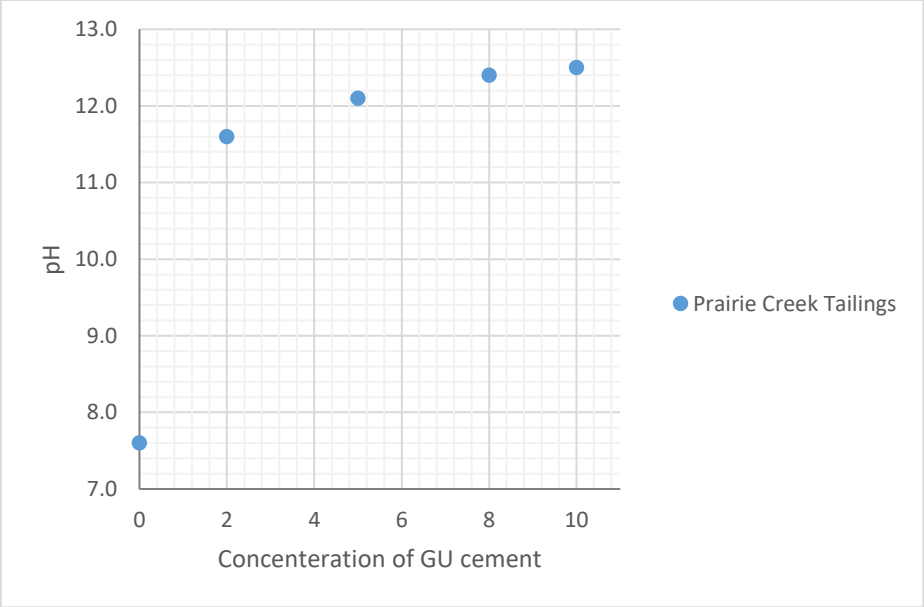


Figure 4: pH vs binder concentration

6.6. UCS Results

It is important to note that two samples of the same kind for each parameter were tested for 7, 14 and 21 day cured samples, and an average result has been presented here in the sample labels and their corresponded UCS results are shown in Table 12.

Table 12: UCS Results

Batch #	Prairie Creek Tailings (%)	T90 Terraflow (%)	GU Cement (%)	GUL Cement (%)	Solid Concentration (%)	Required Yield Stress (Pa)	7 days (MPa)	14 days (MPa)	21 days (MPa)	28 days (MPa)	56 days (MPa)
1	99.0	1.0	0	0	78.3	250	*N.M.*	*N.M.*	*N.M.*	*N.M.*	*N.M.*
2	98.0	2.0	0	0	78.3	250	*N.M.*	*N.M.*	*N.M.*	*N.M.*	*N.M.*
3	95.0	5.0	0	0	78.3	250	*N.M.*	*N.M.*	*N.M.*	*N.M.*	*N.M.*
4	93.0	7.0	0	0	78.3	250	*N.A.*	*N.A.*	*N.A.*	*N.M.*	0.31
5	90.0	10.0	0	0	78.3	250	*N.A.*	*N.A.*	*N.A.*	*N.M.*	3.7
6	96.5	3.5	0	0	77.0	100	*N.M.*	*N.M.*	*N.M.*	*N.M.*	*N.M.*
7	96.5	3.5	0	0	78.3	250	*N.M.*	*N.M.*	*N.M.*	*N.M.*	*N.M.*
8	96.5	3.5	0	0	78.8	350	*N.M.*	*N.M.*	*N.M.*	*N.M.*	*N.A.*.
9	99.0	0	1.0	0	78.3	250	*N.M.*	*N.M.*	*N.M.*	*N.M.*	0.08
10	98.0	0	2.0	0	78.3	250	*N.M.*	0.08	0.21	0.26	*N.A.*
11	95.0	0	5.0	0	78.3	250	0.04	0.53	0.63	0.69	0.75
12	93.0	0	7.0	0	78.3	250	*N.A.*	*N.A.*	*N.A.*	1.15	*N.A.*
13	90.0	0	10.0	0	78.3	250	*N.A.*	*N.A.*	*N.A.*	1.98	2.27
14	96.5	0	3.5	0	77.0	100	*N.M.*	0.27	0.36	0.40	*N.A.*
15	96.5	0	3.5	0	78.3	250	*N.M.*	0.32	0.44	0.47	0.54
16	96.5	0	3.5	0	78.8	350	*N.M.*	0.37	0.51	0.55	*N.A.*
17	99.0	0	0	1.0	78.3	250	*N.M.*	*N.M.*	*N.M.*	*N.M.*	*N.M.*
18	98.0	0	0	2.0	78.3	250	*N.M.*	*N.M.*	*N.M.*	0.06	*N.A.*
19	95.0	0	0	5.0	78.3	250	*N.M.*	0.35	0.51	0.55	0.61
20	93.0	0	0	7.0	78.3	250	*N.A.*	*N.A.*	*N.A.*	0.99	*N.A.*
21	90.0	0	0	10.0	78.3	250	*N.A.*	*N.A.*	*N.A.*	1.71	1.91
22	96.5	0	0	3.5	77.0	100	*N.M.*	0.20	0.30	0.36	*N.A.*
23	96.5	0	0	3.5	78.3	250	*N.M.*	0.29	0.36	0.42	0.51
24	96.5	0	0	3.5	78.8	350	*N.M.*	0.35	0.45	0.49	*N.A.*

N.M. = Not Measurable (UCS value of the sample was too low and cannot be measurable)
N.A. = Not Available (The sample was not requested and prepared)

Appendix 1: Photos of the Prairie Creek samples

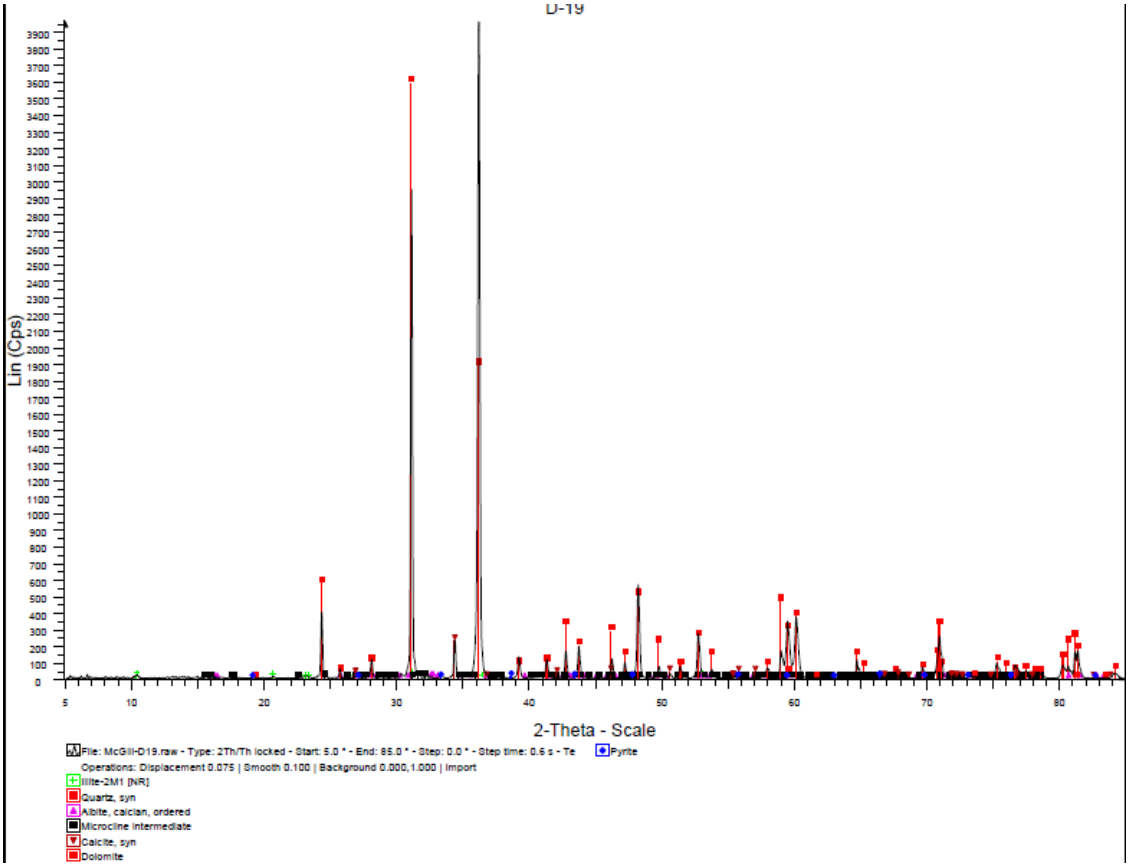
Appendix 2: Prairie Creek tailings XRD analysis result

Prairie Creek tailings

Anchor Scan Parameters

Dataset Name:	PCI_01_exported
File name: Geo Test United	C:\LHS\PCI\PCI_01_exported.raw
Comment:	Scan Mode: Step scan mode Scan Type: Detector Scan Goniometer Stage: Standard stage Goniometer Control: Diffractometer Controller only Sample Changer: Unknown Sample Changer Measurement Flag: Already measured Sync. Axis: Unknown Sync Axis Beam Optics: Unknown Beam Optics Flag Monochromator: Unknown Monochromator Analyzer: Unknown Analyzer
Measurement Date / Time:	16/12/2019
Raw Data Origin:	BRUKER-binary V4 (.RAW)
Scan Axis:	Gonio
Start Position [°2Th.]:	3.1850

	Prairie Creek Tailings	Chemical Formula
Illite (mica)	0.8	(K;H3O)Al2Si3AlO10(OH)2
Quartz	53.2	SiO2
Albite	0.5	(Na;Ca)Al(Si;Al)3O8
Microcline	1.2	K(Si0.75Al0.25)4O8
Calcite	5.8	CaCO3
Dolomite	37.8	CaMg(CO3)2
Pyrite	0.7	FeS2
Total	100	
sample has also some minerals, like smectite		


D-19
Lin (Cps)
2-Theta - Scale
File: McGill-D19.raw - Type: 2Th/Th locked - Start: 5.0 ° - End: 85.0 ° - Step: 0.0 ° - Step time: 0.6 s - Te
Operations: Displacement 0.075 | Smooth 0.100 | Background 0.000,1.000 | Import
Pyrite
Illite-2M1 [NR]
Quartz, syn
Albite, calcian, ordered
Microcline intermediate
Calcite, syn
Dolomite

Appendix 3: Boger Slump vs Yield stress

Slump Yield Stress No Binder

Test	Cylinder Height (mm)	Slump Height (mm)	Solid (%)	SG solid	SG water	YS Measured (Pa)	pH
Prairie Creek -NO_BINDER_1	76	17	79.5	2.7	1	366	7.6
Prairie Creek -NO_BINDER_2	76	21	79	2.7	1	265	7.6
Prairie Creek -NO_BINDER_3	76	28	78.5	2.7	1	182	7.6
Prairie Creek_NO_BINDER_4	76	30	78.4	2.7	1	180	7.6
Prairie Creek -NO_BINDER_5	76	30	78.2	2.7	1	170	7.6
Prairie Creek -NO_BINDER_6	76	35	78.1	2.7	1	118	7.6
Prairie Creek -NO_BINDER_7	76	46	77	2.7	1	73	7.6

Slump Yield Stress 3.5% Binder

Test	Cylinder Height (mm)	Slump Height (mm)	Solid (%)	SG solid	SG water	YS Measured (Pa)	pH
Prairie Creek _3.5%BINDER_1	76	11	79.5	2.7	1	576	11.9
Prairie Creek _3.5%BINDER_2	76	15	79.2	2.7	1	465	11.9
Prairie Creek _3.5%BINDER_3	76	16	79	2.7	1	375	11.9
Prairie Creek _3.5%BINDER_4	76	18	78.8	2.7	1	320	11.9
Prairie Creek _3.5%BINDER_5	76	22	78.2	2.7	1	280	11.9
Prairie Creek _3.5%BINDER_6	76	25	78	2.7	1	203	11.9
Prairie Creek _3.5%BINDER_7	76	28	77.7	2.7	1	176	11.9
Prairie Creek _3.5%BINDER_8	76	31	77.3	2.7	1	130	11.9
Prairie Creek _3.5%BINDER_9	76	32	77.3	2.7	1	122	11.9
Prairie Creek _3.5%BINDER_10	76	39	76.9	2.7	1	76	11.9