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Attachment J.

Lyons Quarry Revegetation Study – Germination Bench Test

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Technical Memo

Date: **February 24, 2021**

Project: **Aggregate Industries** – **LYONS QUARRY RECLAMATION PROJECT**

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Subject: **Revegetation Study – Germination Bench Test**

Project Description

Aggregate Industries (Aggregate) is proposing to reclaim and restore the Lyons Quarry (**Figure 1**), which is located about 2 miles southwest of Lyons, Colorado, in Boulder County [Section 25 and 26, Township 3N, Range 72W]. The quarry is currently inactive but is in the process of closure and reclamation by following compliance standards set forth in the Colorado Division of Reclamation, Mining and Safety (DRMS) mineral rules and regulations for the extraction of construction materials. Project restoration will meet the slope stability and surrounding topography requirements by excavating, processing, and either backfilling or exporting the overburden material from the site. **Figure 2** shows the layout of Quarry 1 and Quarry 2 where overburden material will be stripped from the top of the highwalls and placed at the base. The dacite highwalls will be stabilized by scaling and using rock bolt anchors to allow for appropriately distanced and protected public viewing of this unique geologic formation as well as to provide suitable habitat for avian and bat nesting areas. The Project will require blasting and excavation of more than 245,000 cubic yards of material; soil conditioning and revegetation of approximately 40 acres; and installation of stormwater drainage and erosion control infrastructure.

The mining permit for the quarry is still under active status with DRMS. Aggregate has been coordinating reclamation with the current property owner since 2011 and with Boulder County Parks and Open Space (BCPOS). Aggregate intends to initiate Project construction activities (Phase 1 Quarry Area) in fall 2021 and conclude before March 2022.

Figure 1 – Lyons Quarry Project Location

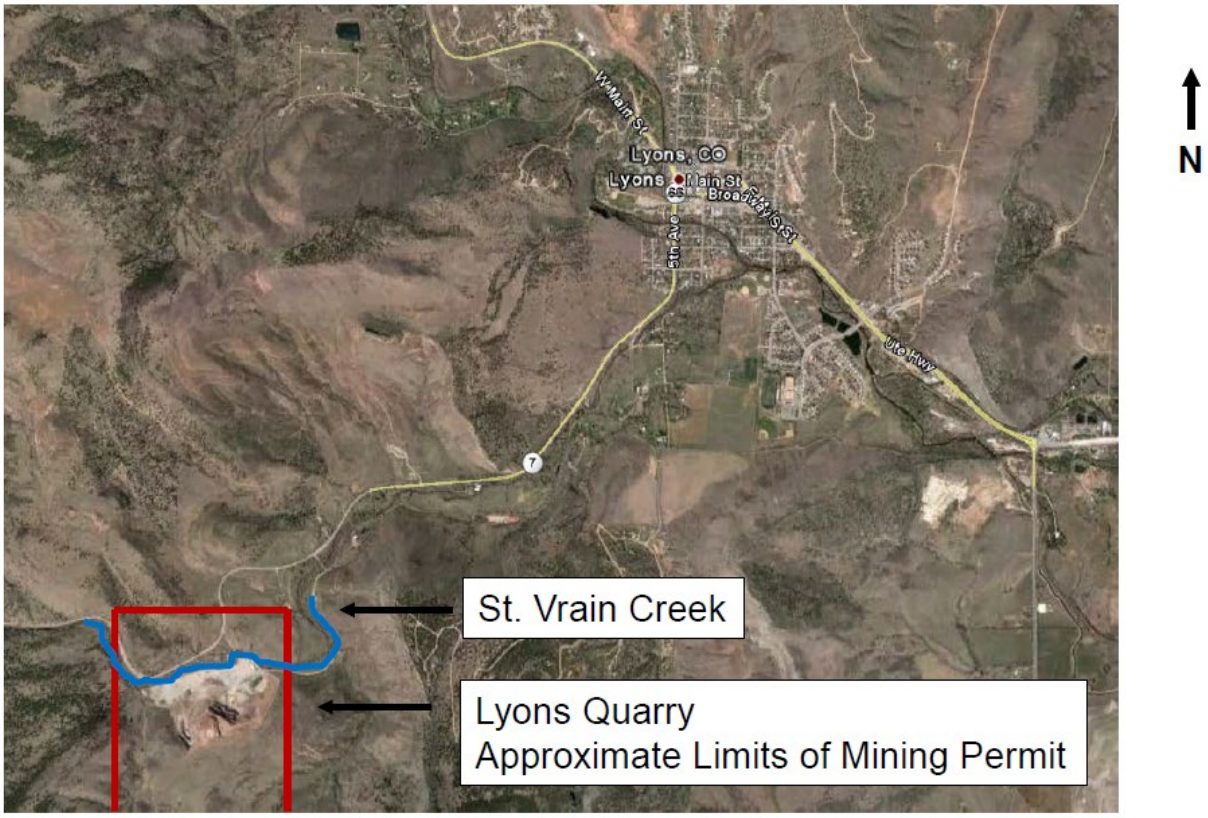


Figure 2 – Overview of Lyons Quarry Project Area

Purpose and Need

Native topsoil for the approximately 55 acres of disturbed area was not stockpiled during mining operations and has been mixed with inorganic sandstone overburden materials throughout the site. As a result, organic material will need to be imported to promote growth of revegetation following site re-grading. Before Aggregate can be released from their reclamation bond with DRMS, the site must meet the following Colorado Mined Land Reclamation Board 2019 requirements:

Rule 3.1.10(1): *In those areas where revegetation is part of the Reclamation Plan, land shall be revegetated in such a way as to establish a diverse, effective, and long-lasting vegetative cover that is capable of self-regeneration without continued dependence on irrigation, soil amendments or fertilizer, and is at least equal in extent of cover to the natural vegetation of the surrounding area.*

In 2017, a plan was developed to perform a revegetation test-plot study at the site with the goal of determining a successful strategy for reclamation of the mine site. The main objectives of the study would be:

1. Assess growth medium materials by evaluating success in establishing vegetation;
2. Assess soil chemistry for each growth media and determine need for fertilizers and/or other amendments; and
3. Develop recommendations for full-scale reclamation based on pilot study results.

Due to the timing of the start for the revegetation study in late fall 2021, an onsite revegetation test-plot study would be impractical and would not show results until the following spring when revegetation is scheduled to begin. Aggregate and their subconsultant HDR Engineering, Inc. (HDR) worked with Boulder County to scale down the study into a bench study that could be performed in climate-controlled conditions through the winter. While conditions would not completely replicate the site (e.g., grade orientation, UV exposure, temperature, and relative humidity), the warehouse for HDR in Englewood, Colorado, was chosen as the site for the bench study. A large glass garage door will provide available sunlight for the bench test and the warehouse location provides the ability to closely monitor and irrigate the study as needed.

The purpose of this bench test will be to evaluate the germination ability of the site soils with various amendments and rates used. While the warehouse conditions and small sample size may impact the overall growth of vegetation, the actual germination of the various species proposed in the Boulder County-provided seed mix will be the focus.

Methods

The proposed test-plot approach provided for the revegetation study is included as Attachment A to this technical memorandum. To scale the study down to a bench test level, several adjustments were made. The following describes the process and methodology for setting up the Lyons Quarry – Germination Bench Test.

Growth Medium

- Overburden material: HDR observed vegetation growing directly in the weathered fine-grain sedimentary overburden material at the site. If this material can support re-vegetation, then it might be possible to avoid or minimize importing material.
- Compost or biosolids (organic source): A local source of compost or biosolids will be used and blended with overburden material. Several rates will be evaluated.
- Topsoil and fill: Little topsoil exists onsite. One important objective of the test plots is to evaluate the ability of the overburden material to support vegetation and to determine if an organic source is needed to support plant growth.

The overburden material or organic/overburden mix will be placed in plastic bins to simulate the placement of such material during reclamation.

Location of Test Soils

Soils were collected for performing a complete nutrient analysis at the Colorado Analytical lab in Commerce City. A total of 5 composite samples were collected on October 1, 2021, from various disturbed areas along the base of the quarry. The upper areas of the quarry highwall were inaccessible and covered with vegetation at the time of collection. The five locations included the following:

- Site staging area (surface sample of floodplain with andesite/sandstone mix)
- Processing area near sediment pond (andesite crusher fines)
- East Borrow Pit (fine-grained sandstone)
- East Slope 0-2 ft below ground surface (bgs) (fine-grained sandstone & organics)
- East Slope 2-4 ft bgs (fine-grained sandstone)

The 1 quart-size samples were allowed to dry indoors for one week prior to shipment to the lab. Results for the soils analysis were received November 5, 2021, and are provided in the results section below. Based on the fertilizer and compost recommendations from the laboratory and from the Boulder County ecologist, the amendments for the bench test were selected.

An HDR environmental scientist and ecologist mobilized to the site November 5, 2021, to collect the soils for the test. For the four tests to run in triplicate, a total of 12 clear plastic tubs were filled with fine-grained sandstone overburden soils. Prior to soils placement, a layer of washed pea gravel was placed at the bottom of each tub to provide a drainage layer for water if needed. Rocks greater than 2-inches in diameter were removed from the sandstone material as it was placed in the tubs. This would be replicated on a large scale by heavy equipment (bulldozer/excavator) crushing the larger sandstone rocks or raking them from the top few inches during soil conditioning.

To gain a representative sample of the overburden material two of the three plots (Tx-A & Tx-B) per test were collected at the base of the quarry while the third plot (Tx-C) was filled with soil from the constructed soil berm at the top of the highwall.

Number of Test Plots and Setup

Four test plots with two subplots per test plot (8 total subplots) were established (**Table 1**). Proposed treatments are listed below:

- Treatment 1 (T1) – 6 inches of overburden only with 1 gram (g) seed (23 pounds [lb] of pure live seed [PLS]/acre)—placement of onsite overburden was representative of material to be generated during reclamation and consistent with the material observed supporting vegetation at the site.
- Treatment 2 (T2) – 6 inches of overburden with 23 (g) fertilizer (1,650 lb/acre)—fertilizer was mixed in to the top 1 inch of soils. For large scale, fertilizer would be stabilized by adding to hydromulch mix. No mulch is proposed for the bench test.
- Treatment 3 (T3) – 6 inches of overburden with fertilizer and 5 percent volume organic compost—overburden and organic source was mixed throughout. This equates to a full-scale compost application rate of 81 cubic yards (CY)/acre.
- Treatment 4 (T4) – 6 inches of overburden with 10 percent volume organic compost—overburden and organic source was mixed throughout. A 10 percent compost application rate would comply with recommendations from Boulder County and the analytical lab for compost application of 3-4 CY/1,000 ft^2 (130–160 CY/acre).

The inorganic fertilizer addition, Biosol Forte, was selected based on soil (overburden material) test recommendations from Colorado Analytical lab, which recommended 130 lb/acre nitrogen and 80 lb/acre phosphorous for the amendment. Biosol Forte is a 7:2:1 fertilizer that has been proven successful for mine reclamation projects in Colorado. It contains greater than75 percent organic material, provides a slow release of nitrogen, and has a neutral pH of 7.1. Biosol Forte contains less phosphorous and potassium than the Richlawn 3:6:3 proposed by Boulder County but, based on the results, more nitrogen was needed and there is sufficient potassium available at the site.

The lab results also proposed adding sulfur at a rate of 40 to 60 lb/acre. HDR will monitor the results of the bench test to see if this is needed, for sulfur can have drastic impacts on pH if not metered correctly.

The organic source will be EcoGro compost from A-1 Organics in Eaton, Colorado, which was used on the downstream South St. Vrain Creek restoration project and would be available in bulk quantity for full-scale reclamation. EcoGro is a Class 1 compost made from tree trimmings, food waste, yard waste, leaves, etc. A stable organic matter, it is a good source of nitrogen, phosphorous, potassium, sulfur, and other nutrients essential for plant growth. These nutrients are made available to the plant roots in a slow-release form.

See **Table 1** below for the full setup and unit conversions of the bench test.

Table 1. Bench Test Plot Set-up

	L	W	H	CF	CY	Quart (US)	Gallon (US)
Tub Dimensions	**15**	**13**	**6**	**0.68**	**0.03**	**20.34**	**5.09**
	SF per plo	**1.35**		**Total SF**	**16.25**		
Compost	Placed in uniform layer and mixed into top 6 inches					**Full-Size Scale**	
Each Test Plot	**0.68**	**Cubic Fe**	**Cups**	**CY/acre**		**Total Import CY**	**Trucks**
5% Compost	1.02	Qt.	4.068	80.67	=	2581	103
10% Compost	2.03	Qt.	8.136	161.33	=	5163	207
15% Compost	3.05	Qt.	12.204	242.00	=	7744	310
Total Organic Vol.	9.153	Qt.					
Seed	Seedbed prep top 1/2 inch with light compaction, watering, seed spead, and cover soil						
Each Test Plot	1.35	Square Feet				Seed (#pls/acre)	28.16
Each Test Plot	3.1E-05	Acres				Total Acreage	31
Upland Seed Mix	23.16	#PLS/acre				Total Seed (#pls)	872.96
Upland Seed Mix	10505.2	grams/acre					
Seed per plot	0.33	grams	Seed tripled to get representative mix per plot				
Seed per plot @ 3x rate	1.00	grams					
Total seed	3.92	grams					
Total seed @ 3x rate	12.00	grams					
Fertilizer	Fertilizer applied to top 1inch of soil following compost and prior to seed placement						
			lbs/acre	**lbs/1k sf**	**lbs/plot**	**total lbs**	**g/plot**
Biosol (6-1-1, 90% OM, 4. pH)			1650	37	0.05	0.45	22.68
Biosol Forte (7-2-1, 75% OM, 7.1 pH)			1650	37	0.05	0.45	22.68
Water	16 oz applied to each plot every 48 hours for first week						
Avg. Climate	**March**	**April**	**May**	**June**		**Average**	
Temp (High)	46.2	52.3	61.5	76.6		59.15	
Temp (Low)	25.9	30	37.9	49.6		35.85	
Humidity %	61	59	58	46		56	
Rain	1.26	1.85	2.72	1.85		1.92	
Snow	7.17	8.39	2.09	0		4.41	
Rain + SWE	1.98	2.69	2.93	1.85		2.36	
Sunlight (hrs)	8.8	10.4	10.7	11.7		10.4	
Ounce per SF	13.3	13.3	13.3	13.3			
Inches per SF	3.30	4.48	4.88	3.08			
Oz per SF per month	26	36	39	25	**Oz/Gal**	**Gal/SF**	**Gal/acre**
Oz per plot per month	36	48	53	33	128	0.092	4021
Oz per plot biweekly	18	24	26	17	**Total gal/31 acre**		124,649
Selected amendment for test							

Site Preparation and Seeding

Following placement of overburden and organics, the surface will be lightly scarified (for the bench test-plots, this meant removing top ½ inch of soil, firming soil by hand packing, and wetting surface) to allow for suitable surface bed for receiving seeds. A native upland seed mix will be used composed of the species and mixtures recommended by Boulder County Ecologist. The actual mix for the test, provided by Granite Seed in Denver, Colorado, is provided in **Table 2** below.

Table 2. Native Upland Seed Mix Composition

Table 2 - Lyons Quarry Upland Seed Mix			BCPOS Proposed		Granite Seed Supplied	
Common Name	**Latin name**	**Variety (Granite Seed)**	**% of mix**	**# PLS/Acre**	**% of mix**	**#PLS**
Side Oats Grama	*Bouteloua curtipendula*	Vaughn	10	1.82	7	0.07
Blue Grama	*Bouteloua gracilis*	Hachita	15	0.63	2	0.02
Mountain Mahogany*	*Cercocarpus montana*	VNS	5	3.68	19	0.18
Griffith's Wheatgrass*	*Elymus albicans*	Trailhead	12	2.72	10	0.1
Canada Wildrye	*Elymus canadensis*	Mandan	10	3.03	13	0.12
Squirreltail	*Elymus elymoides*	Pueblo	14	2.72	11	0.11
Slender Wheatgrass	*Elymus trachycaulus*	San Luis	9	4.38	19	0.18
Rabbitbrush	*Ericameria nauseousus*	VNS	8	0.38	2	0.02
Little Bluestem	*Schizachyrium scoparium*	Cimarron	8	1.07	4	0.04
Needle and Thread Grass	*Stipa comata*	VNS	9	2.73	11	0.11
		Totals	**100**	**23.16**	**99**	**1.0**
Rates are for broadcasting. If using a seed drill, reduce rates by half. PLS = Pure Live Seed * - Local sourced seed may be provided by BCPOS for full scale reclamation						

Seeds were planned to be broadcast evenly throughout bench test-plots and applied at the recommended rate of 23.16 lb pls/acre. This equated to approximately 0.33 g per plot, which was tripled due to its extremely small amount to 1 g per plot. This was measured by splitting up a total of 12 g of seed, as measured by a cooking scale, into 12 separate 1 g amounts. Once the seed was placed in each plot, it was lightly covered with ½ inch of soil.

Because the test is occurring in a climate-controlled warehouse, mulch was not included in the test plots but would be needed for full-scale revegetation. Humidity and temperature levels within the warehouse were tracked on an hourly basis using a Bluetooth datalogger.

Irrigation

No irrigation was proposed for the original test-plot program to be conducted onsite assuming the seeding was done in fall. However, because the test occurred indoors, irrigation was provided according to recommendations from the Mile High Flood District for newly revegetated areas.

At the start of the test, each plot received 16 ounces (oz) of water (equivalent to roughly 2 weeks of precipitation at site during April/May). This was enough to moisten the surface and up to 1 inch of soil below for each plot. Upon observation one day later, the soil had formed a ½ inch crust and sealed a layer of moisture below the surface. Mud cracking was evident in all plots. To promote early germination, the plots were watered every other day for the first week of the test with 16 oz of water (1.5 gallons/16.25 ft^2). This would be replicated on a large scale (up

to 31 acres) when revegetation is being completed with hydromulching and a water truck in addition to precipitation. Total volume needed for this would be approximately 4,021 gallons/acre or 124,649 gallons for the entire 31-acre site.

To replicate seasonal precipitation for the site, HDR evaluated the average precipitation rates for Lyons, Colorado, for the months of April and May when revegetation is likely to occur. As shown in **Attachment B**, the rain and snow water equivalents for April and May average 2.69 and 2.93 inches, respectively. This equates to roughly 4.48–4.88 inches of water per ft^2 per month during this time. Converting this to fluid ounces for the months of April and May, results in 36 and 39 oz of water per ft^2 per month, respectively. When adjusted for the size of the 1.35 ft^2 plots, the watering application rates for each plot were between 48 and 53 oz per month. Note that other site factors such as overnight freezing, evapotranspiration, sheet runoff, and evaporation rates were not considered in these calculations. HDR applied water on a weekly basis to replicate this precipitation in the field.

HDR oversaw the bench test and monitored soil and atmospheric conditions every two weeks. A soil multimeter probe was used to measure pH, moisture %, and ambient light of each of the 12 test plots. In addition, ambient temperature and % relative humidity were recorded every hour by a Bluetooth data logger. These parameters as well as visual observations by the HDR scientists were recorded and updated on a technical memorandum each month to track performance.

Results

Soils analysis results for the samples collected from the quarry in October 2021, as well as the floodplain area test pits in April 2021, are provided in **Table 3** below. Observations from the soils analysis shows very low organic content in the native soils, as was expected. The pH is also relatively high for Colorado, and areas with andesite crusher fines indicated high levels of manganese. Areas where the overburden samples for the bench test were taken show slightly above average levels of copper. Results are similar and even more pronounced for high pH, manganese, and copper levels, as well as low organic content levels, in the floodplain test pit soils analysis from April 2021.

Table 3 also includes manufacturer provided data on the specifications for the Biosol Forte fertilizer and the A-1 Organics EcoGro compost. The combined application rate of these amendments proposed in the bench test provides:

- 138 lb nitrogen (lab recommended 130 lb/acre);
- 56 lb phosphorous (lab recommended 80 lb/acre); and
- 25 lb potassium per acre (lab recommended 0 lb/acre).

The EcoGro compost will also provide a source of sulfur which may help bring down the high pH and supply the 40-60 lb/acre lab recommendation. The 7.1 pH of the Biosol Forte fertilizer may also help bring down the high pH of the native soils.

Table 4 provides the baseline and biweekly parameters and observations from the bench test study. This table will be updated monthly during the bench test study to evaluate the performance of each test and sub-plot. Table 5 displays the general observations made during the first 12 weeks of the bench test, including the time of day and weather conditions (affecting luminosity), ambient humidity/temperature prior to adding water, germination monitoring, and other notes from observing the soil conditions.

Table 3 – Lyons Quarry Soils and Amendment Analytical Data

			Field Texture	pH	Salts	CEC	Lime	OM	Organic N	Sodium	Available Nutrient (ppm)											Fertilizer Rcommendations (lbs/acre)					Compost	
Sample	**Coordinates (Lat/Long)**	**Date Collected**	**EST**		MMHOS/CM	MEQ/100g	Qual.	%	lbs/acre	meq/100g	N	P	K	Ca	Mg	S	B	Zn	Fe	Mn	Cu	N	P	K	Sulfur	Lime	CY/1000 sf	CY/acre
Stockpile Staging	40.200154, 105.298570	10/1/2021	Sandy Loam	8.7	0.2	6	High	0.4	11	0.24	2.1	1.5	54.3	1866.8	69.3	0.8	0.4	1.1	1.9	2.6	0.5	130	80	0	60	0	3.5	152.46
Andesite Crusher Fines	40.200672, 105.297249	10/1/2021	Sandy Loam	8.6	0.3	6.5	High	0.6	18.5	0.13	1.7	1.9	85	1718.3	66	3.8	0.5	1	2.1	6.5	0.8	130	80	0	60	0	3.5	152.46
East Borrow NW Pile	40.200472, 105.297343	10/1/2021	Sandy Loam	8.9	0.4	6.7	High	0.7	22	0.2	1.7	1.8	109.5	1926.8	290.8	12.1	0.3	0.7	0.7	0.9	1.9	130	80	0	40	0	3.5	152.46
East Slope 0-2 ft bgs	40.200779, 105.296715	10/1/2021	Sandy Loam	8.9	0.2	6.8	High	0.8	23.8	0.13	<0.1	1.5	113.3	1250.3	187.4	0.7	0.4	0.4	0.8	1	0.9	130	80	0	60	0	3.5	152.46
East Slope 2-4 ft bgs	40.200779, 105.296715	10/1/2021	Sandy Loam	8.9	0.3	6.7	High	0.7	22.1	0.16	<0.1	0.3	117.1	1929.8	261	1.5	0.2	0.6	1.1	0.9	1.7	130	80	0	60	0	3.5	152.46
Average				8.80	0.28	6.54		0.64	19.48	0.17	1.8	1.4	95.8	1738.4	174.9	3.8	0.4	0.8	1.3	2.4	1.2	130.0	80.0	0.0	56.0	0.0	3.5	152.5
																						62%	38%	0%				
														NPK% Ratio and suggested amendments								2	1	0			3.5	152.5
														D. Hirt proposed amendments								3	6	3			3	131.0
Biolsol Forte				7.1				75			7%	2%	1%									115.5	33	16.5				
EcoGro Analysis				8.89	2.6			26.8			1.4%	1.4%	0.5%	1.5	0.36							23.1	23.1	8.415			3	131.0
																			Bench Test Total			138.6	56.1	24.915			5%/10%	81/161

Floodplain Soil Analysis	**Coordinates (Lat/Long)**	**Date Collected**	**Field Texture**	**pH**	**Salts**	**CEC**	**Lime**	**OM**	**Organic N**	**Sodium**	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**B**	**Zn**	**Fe**	**Mn**	**Cu**
SH7 TST7 (West end?)	Unknown	4/28/2021	Sandy Loam	8.5	0.22	14.8		0.5		17	1.1	3	115	2547	199	7.5	0.1	4.1	20.5	26.7	5.9
SH7 TST1 (East end)	Unknown	4/28/2021	Sandy Loam	8.1	0.21	14.3		0.4		10	2	3	81	2504	179	5.2	0.1	1.8	11.9	13.8	5.7
SH7 TST6 (Central?)	Unknown	4/28/2021	Sandy Loam	8.4	0.26	16.1		0.5		48	1.1	3	80	2928	120	8.6	0.1	2.7	21.2	32.1	7.5
Above Average for CO																					

Table 4 – Germination Bench Test Monitoring Log

Parameter (Ideal Range)	Moisture (2-5 scale reading)														# Sprouts					pH (7-9)											
Week	**Base**	**W0**	**W2**	**W2**	**W4**	**W4**	**W6**	**W6**	**W8**	**W8**	**W10**	**W10**	**W12**	**W12**	**W4**	**W6**	**W8**	**W10**	**W12**	**Base**	**W0**	**W2**		**W4**		**W6**		**W8**		**W10**		**W12**	
Probe	**A**	**A**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**#**	**#**	**#**	**#**	**#**	**A**	**A**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**	**A**	**D**
T1-A	1.0	1.8	3.6	4.0	2.8	4.0	3.8	6.0	6.5	6.0	6.2	8.0	8.0	6.0	7	14	44	60	96	7.5	7.5	7.0	6.0	7.2	6.5	6.8	7.0	7.0	7.0	7.0	7.0	6.5	6.5
T1-B	1.0	1.8	1.5	4.0	4.0	4.0	3.0	6.0	5.5	6.0	6.0	8.0	7.5	6.0	2	39	69	76	108	7.8	7.2	7.0	6.0	6.8	7.0	6.8	6.5	6.6	6.5	7.2	6.0	6.2	6.0
T1-C	1.0	1.8	3.0	4.0	2.0	4.0	3.5	4.0	6.0	4.0	7.0	6.0	6.8	6.0	2	8	13	38	56	7.8	7.8	7.0	6.5	7.5	6.5	7.2	7.0	7.0	7.0	6.0	7.0	6.0	6.5
T1 Average	**1.0**	**1.8**	**2.7**	**4.0**	**2.9**	**4.0**	**3.4**	**5.3**	**6.0**	**5.3**	**6.4**	**7.3**	**7.4**	**6.0**	**3.7**	**20.3**	**42.0**	**58.0**	**86.7**	**7.7**	**7.5**	**7.0**	**6.2**	**7.2**	**6.7**	**6.9**	**6.8**	**6.9**	**6.8**	**6.7**	**6.7**	**6.2**	**6.3**
T2-A	1.0	1.0	1.4	4.0	5.2	4.0	5.0	2.0	2.8	4.0	5.2	6.0	4.5	6.0	2	2	1	16	25	7.8	7.8	6.8	6.5	7.4	6.5	7.5	6.5	7.6	6.5	7.5	6.0	7.2	6.0
T2-B	1.0	1.5	2.8	4.0	3.5	4.0	4.2	4.0	3.5	4.0	5.0	4.0	4.8	6.0	1	1	4	16	30	7.5	7.0	6.5	6.0	7.0	7.0	7.2	6.5	7.2	6.0	6.8	6.5	7.0	6.5
T2-C	1.0	2.2	2.2	4.0	2.6	6.0	3.5	2.0	5.0	4.0	8.5	6.0	9.2	10.0	0	7	21	29	45	7.8	7.2	6.5	6.0	7.2	6.0	7.2	6.5	6.8	6.5	6.2	6.5	6.2	5.5
T2 Average	**1.0**	**1.6**	**2.1**	**4.0**	**3.8**	**4.7**	**4.2**	**2.7**	**3.8**	**4.0**	**6.2**	**5.3**	**6.2**	**7.3**	**1.0**	**3.3**	**8.7**	**20.3**	**33.3**	**7.7**	**7.3**	**6.6**	**6.2**	**7.2**	**6.5**	**7.3**	**6.5**	**7.2**	**6.3**	**6.8**	**6.3**	**6.8**	**6.0**
T3-A	1.0	1.8	2.0	4.0	4.0	4.0	4.5	4.0	3.2	4.0	6.5	6.0	4.0	6.0	0	1	1	1	15	7.8	7.2	7.0	5.5	7.0	6.8	7.0	7.0	7.4	6.5	7.5	6.0	7.4	6.5
T3-B	2.0	2.0	3.6	4.0	4.6	6.0	2.6	6.0	3.6	4.0	3.6	6.0	7.5	6.0	0	1	1	6	16	7.5	7.4	7.0	6.0	7.2	6.5	7.4	6.5	7.0	6.5	7.5	6.5	6.8	6.0
T3-C	1.2	1.2	4.0	4.0	3.0	4.0	2.0	4.0	4.0	4.0	5.2	6.0	8.0	6.0	0	1	6	14	27	7.8	7.6	6.8	6.0	6.8	7.0	7.5	7.0	7.0	6.5	7.0	6.5	7.0	7.0
T3 Average	**1.4**	**1.7**	**3.2**	**4.0**	**3.9**	**4.7**	**3.0**	**4.7**	**3.6**	**4.0**	**5.1**	**6.0**	**6.5**	**6.0**	**0.0**	**1.0**	**2.7**	**7.0**	**19.3**	**7.7**	**7.4**	**6.9**	**5.8**	**7.0**	**6.8**	**7.3**	**6.8**	**7.1**	**6.5**	**7.3**	**6.3**	**7.1**	**6.5**
T4-A	1.2	1.2	1.8	6.0	3.5	6.0	4.5	4.0	6.8	4.0	2.0	2.0	4.4	6.0	0	0	0	0	10	7.8	7.4	7.0	6.5	7.0	6.0	7.0	6.0	7.0	6.5	7.6	6.5	7.2	7.0
T4-B	1.2	2.8	2.8	4.0	3.5	4.0	4.5	4.0	4.5	6.0	2.0	5.0	6.8	8.0	5	6	5	7	15	7.5	6.8	6.8	6.0	7.0	6.0	7.0	7.0	7.0	6.0	7.4	6.5	7.2	6.0
T4-C	1.0	1.5	2.2	5.0	2.5	4.0	1.5	2.0	3.5	4.0	1.8	4.0	5.6	10.0	0	0	0	0	1	7.8	7.2	6.5	6.0	7.0	6.5	7.4	6.5	7.2	6.5	7.4	6.5	7.2	7.0
T4 Average	**1.1**	**1.8**	**2.3**	**5.0**	**3.2**	**4.7**	**3.5**	**3.3**	**4.9**	**4.7**	**1.9**	**3.7**	**5.6**	**8.0**	**1.7**	**2.0**	**1.7**	**2.3**	**8.7**	**7.7**	**7.1**	**6.8**	**6.2**	**7.0**	**6.2**	**7.1**	**6.5**	**7.1**	**6.3**	**7.5**	**6.5**	**7.2**	**6.7**
Average	**1.1**	**1.7**	**2.6**	**4.3**	**3.4**	**4.5**	**3.6**	**4.0**	**4.6**	**4.5**	**4.9**	**5.6**	**6.4**	**6.8**	**1.6**	**6.7**	**13.8**	**21.9**	**37.0**	**7.7**	**7.3**	**6.8**	**6.1**	**7.1**	**6.5**	**7.2**	**6.7**	**7.1**	**6.5**	**7.1**	**6.5**	**6.8**	**6.4**
% Delta		51%	50%		33%	6%	3%	-11%	29%	13%	7%	24%	31%	22%		321%	106%	59%	69%		-5%	-7%		4%	7%	1%	2%	-1%	-3%	0%	-1%	-4%	-1%

Table 5 – Germination Bench Test General Observations

General Observations							
	Day	**Date**	**Time**	**Weather**	**Temp**	**% RH**	
Test start	1	11/9/2021	1200	Sunny, clear	77.2	21.0	Added 16 oz water to all plots. Enough to moisten top 1" of soil
W0	2	11/10/2021	1210	Sunny, clear	75.7	15.2	Surface crust ~1/2" thick covering all plots. Some mud cracks observed in all but T1-A. Datalogger shows min temp 65 and max 83 over past 24 hours. Sunlight/temp peak at 8-9 am MST.
W0	3	11/11/2021	1300	Sunny, clear	76.1	13.6	Added 16 oz water to all plots. Enough to moisten top 1-2" of soil
W0	5	11/13/2021	1630	Sunny, clear	77.9	18.4	Added 16 oz water to all plots. Enough to moisten top 1-2" of soil. Some preferential pathways to bottom observed.
W1	7	11/15/2021	1700	Sunny-partly cloudy	76.1	16.4	Added 16 oz water to all plots. Enough to moisten top 1-2" of soil. More preferential pathways to bottom observed. After one week observed that RH% in warehouse (~15-17%) is well below average site conditions (30-50%). To further replicate field conditions plastic tops were loosely placed on top of each bin to help hold in moisture. RH% immediately increased with logger inside of T1-3 bin from 16% up to 52% after bin had been watered.
W1	11	11/19/2021	930	Sunny, clear	82.5	39.4	Added 16 oz to all plots. Most went to bottom at corners but did saturate surface. T4 soils holding more water on surface than others. Moved humidity/temp logger to T2-B to be more representative of all plots. Humidity being held in much better with lids loosely placed on. RH% ranging from 20-90% since 11/15.
W2	14	11/23/2021	1030	Sunny, clear	79.8	18.65	Added 16 oz to all plots. Humidity not held as well after lids were moved to allow more air flow on 11/19. RH% ranging from 12-34% since 11/19. Will go back to loosely placing over top with minimal gaps. First sign of growth with ~1" sprout in T1-C (sp. unknown). ~2-6 white mold spheres ~1/4" diameter on surface and ~1" below surface in about half of plots. Humidity holding better 30-50% range on 11/25. Sprouts observed in T1-A. T2-A, T2-C, T4-B.
W2	20	11/29/2021	900	Sunny, clear	84.38	23.95	Added 16 oz to all plots. Humidity held for a couple days since last watering but has been around 20% since. Some sprouts have desiccated since last observation. Some new sprouts observed and mold has not spread since last watering.
W3	24	12/3/2021	1600	Sunny, clear	80.62	12.16	To better represent sunlight exposure to all plots, plots were switched up on rack. T1 was moved to the bottom shelf and T4 was moved to top rack. T2 and T3 were also switched. Plots were placed in CBA order instead of ABC order.
W4	30	12/9/2021	1115	Sunny-partly cloudy	78.37	70.89	Added 16 oz to all plots and replaced lids as plants were desiccating due to low humidity levels. To date half of the plots have sprouts, 25% have low levels of mold. T1-A has most sprouts, could be due to broken up surface being easier to penetrate.
W5		12/17/2021	1300	Sunny, clear	77.9	23.1	Added 16 oz to all plots
W6		12/23/2021	1600	Sunny, clear	74.05	44.74	Added 16 oz water to all plots on 12/21. Heater at office was out 12/18-12/20 and is reflected on temperature logger (50-60 degree temps). T1 showing a lot more growth since W4 check (avg. up from 3.7 to 20). All other tests showing minimal change. Rotated all tests to have sunlight hit back half of plot as most growth is on front half.
W8		1/3/2022	1545	Sunny, clear	72.8	56.0	Added 16 oz water to all plots. Rotated pots from top to bottom so they are back their position on rack from November.
W10		1/19/2022	1100	Sunny, clear	53.01	63.06	Added 16 oz water to all plots. Scarified soils in A test plots for T2, T3 and T4. This scarification is similar to setup for T1-A which showed the highest potential for growth early on. A scarified surface seems to allow germination more easily as a crust is not as uniform as it would be in a flat/folded seedbed. This theory will compare against "B plots" for each test which maintaining a flat seed bed for the same soil source.
W12		2/2/2022	1120	Sunny, clear	66.7	64.08	Added 16 oz water to all plots.

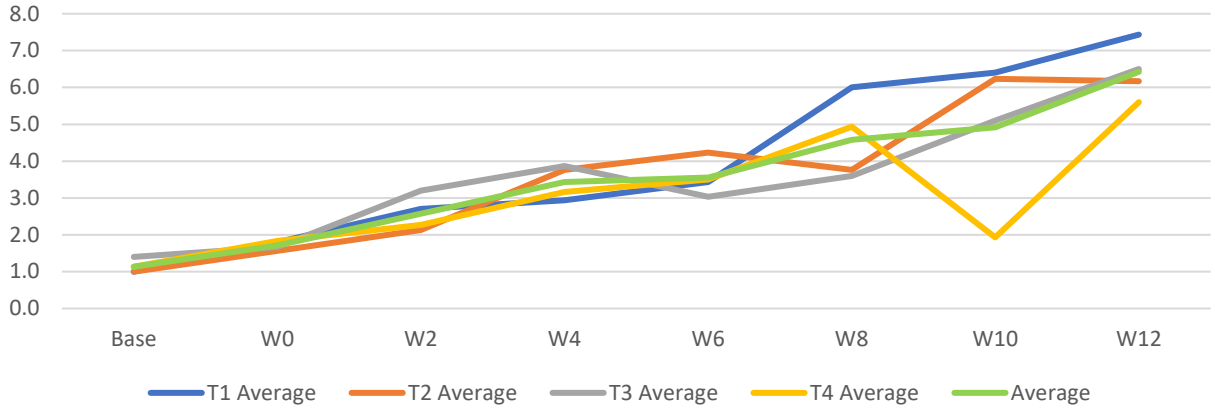
Quarter 1 Monitoring Results:

Quarter 1 of the bench test monitoring concluded in Week 12 on February 2, 2022. Photos of the bench test setup and progress of germination are in the **Photo Log** at the end of this document. During Quarter 1, the test plots were rotated on the four-shelf rack every four weeks and rotated front to back facing the windowed garage door of the warehouse to evenly distribute sunlight across each plot. Another modification to the test occurred in Week 10 when the top ½ inch of soil in "A test plots" for T2, T3, and T4 was scarified to break up the hardened crust that had formed from consistent watering of the alkaline soils (see **Image 3** of **Photo Log**). This scarification is similar to the setup for T1-A, which showed the highest potential for growth early on. A scarified surface seems to allow germination more easily as a crust is not as uniform as it would be in a flat/folded seedbed. This theory will compare against "B" test plots for each test that maintains a flat seed bed for the same soil source. The following is a summary of observations for the moisture, number of sprouts per test plot, and changes in pH throughout the first 3 months of the test.

MOISTURE ANALOG READINGS-

As shown in **Figure 3**, relative moisture in the soil has been steadily increasing in all test plots throughout the test. Moisture is measured approximately 24 hours after weekly watering (16 oz per test plot) is performed. Readings for moisture have been taken by an analog soil probe since the start of the test. All readings started out very dry (1-2 on a scale of 1 to 10) with only the soil moisture captured from the site in the covered plastic bins. A redundant digital moisture probe began being used in Week 2 and has shown similar changes in readings week-over-week to the analog gauge even though it has only five different units (2-Very Dry, 4-Dry, 6-Normal, 8-Wet, 10-Very Wet) as shown in **Table 4**. Moisture across all tests was consistent for roughly the first six weeks of the test. As germination has progressed, however, tests with higher sprout counts have consistently shown higher moisture content as vegetation is able to store water rather than having it evaporate in the air-conditioned atmosphere of the warehouse.

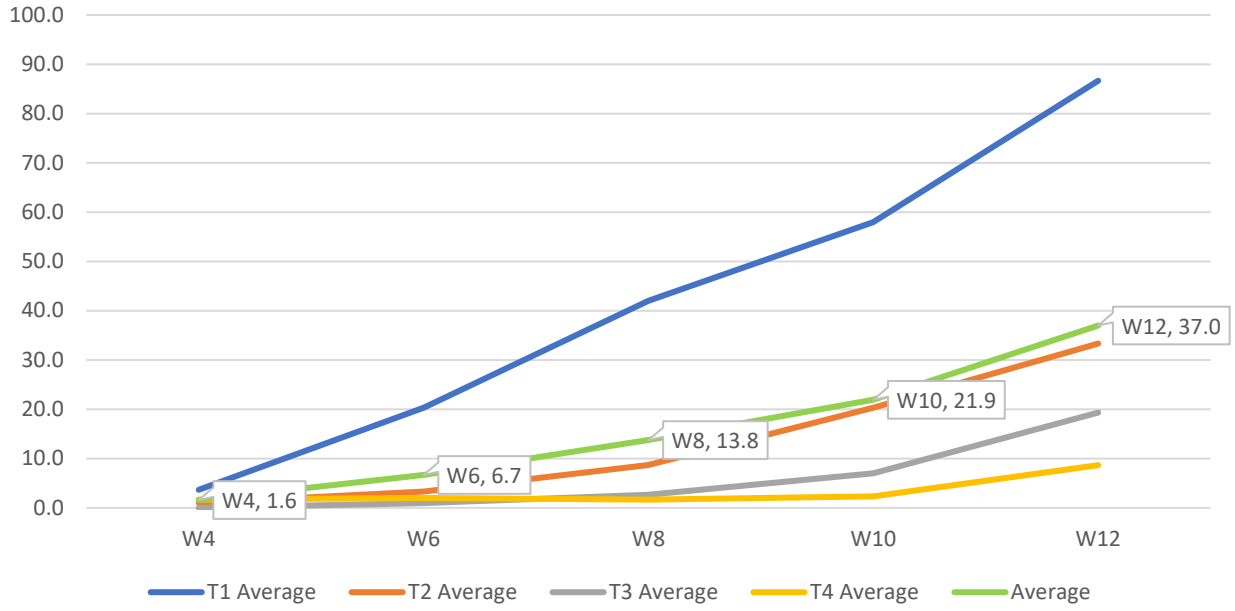
Figure 3 – Moisture



SPROUTING

Sprouting of seedlings was first tracked in Week 4 of the bench test and has continued since. As shown in **Figure 4,** all test plots are showing signs of sprouting grasses as of Week 12. Test plot T1 (no organic amendments) has shown a considerably higher rate of growth (86.7 sprouts per plot on average as of Week 12) compared to the other tests. Even with regular rotating of the test plots and consistent watering between each test, the rate of germination seems to decrease as more amendments are added, with test plot T4 producing an average of less than 10 sprouts per plot after 12 weeks. Sprouting in general has increased by at least 59 percent between biweekly monitoring events since Week 4.

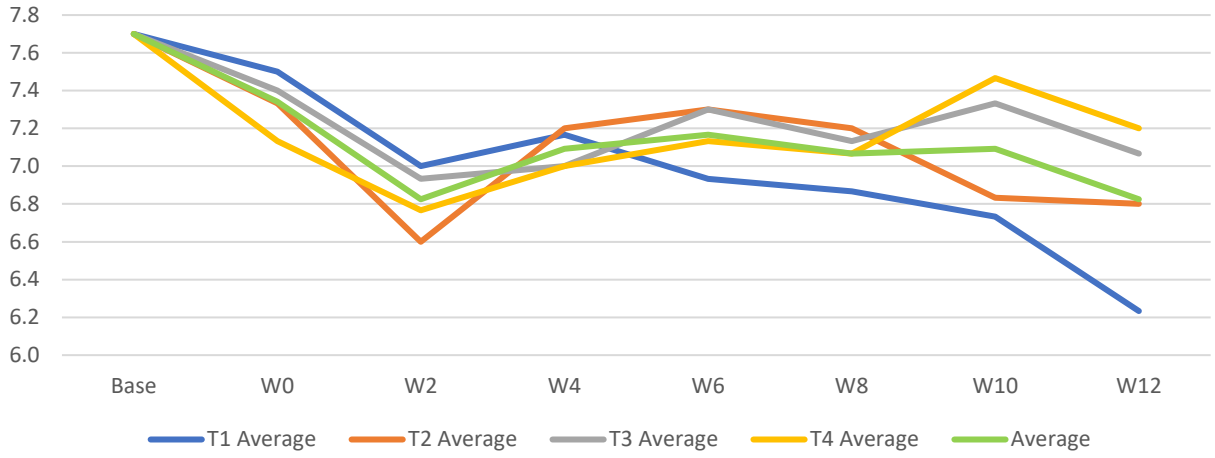
Figure 4 – Sprouts



PH ANALOG READINGS

Readings for pH, as shown in **Figure 5**, have been taken by an analog soil probe since the start of the bench test. All readings started out at a uniform 7.6 to 7.8 pH, which is indicative of the calcium-rich alkaline soils of the Lyons Quarry. A redundant digital pH probe began being used in Week 2 and has shown similar changes in readings week-over-week to the analog gauge even though it has an accuracy of 0.5 pH units. Once amendments were added to test plots T2, T3, and T4, pH immediately started dropping down to a more neutral range. Test plots T3 and T4 saw the largest decrease, possibly due to the sulfur content of the EcoGro compost. Coincidently, T1 also saw a drop in pH during this time though not as drastically as the other tests. After Week 2, pH has a discernable leveling off and even increase of pH. Since Week 4, test plot T1 has seen a decrease in pH week-over-week, which could be due to the rate of germination producing humic acids.

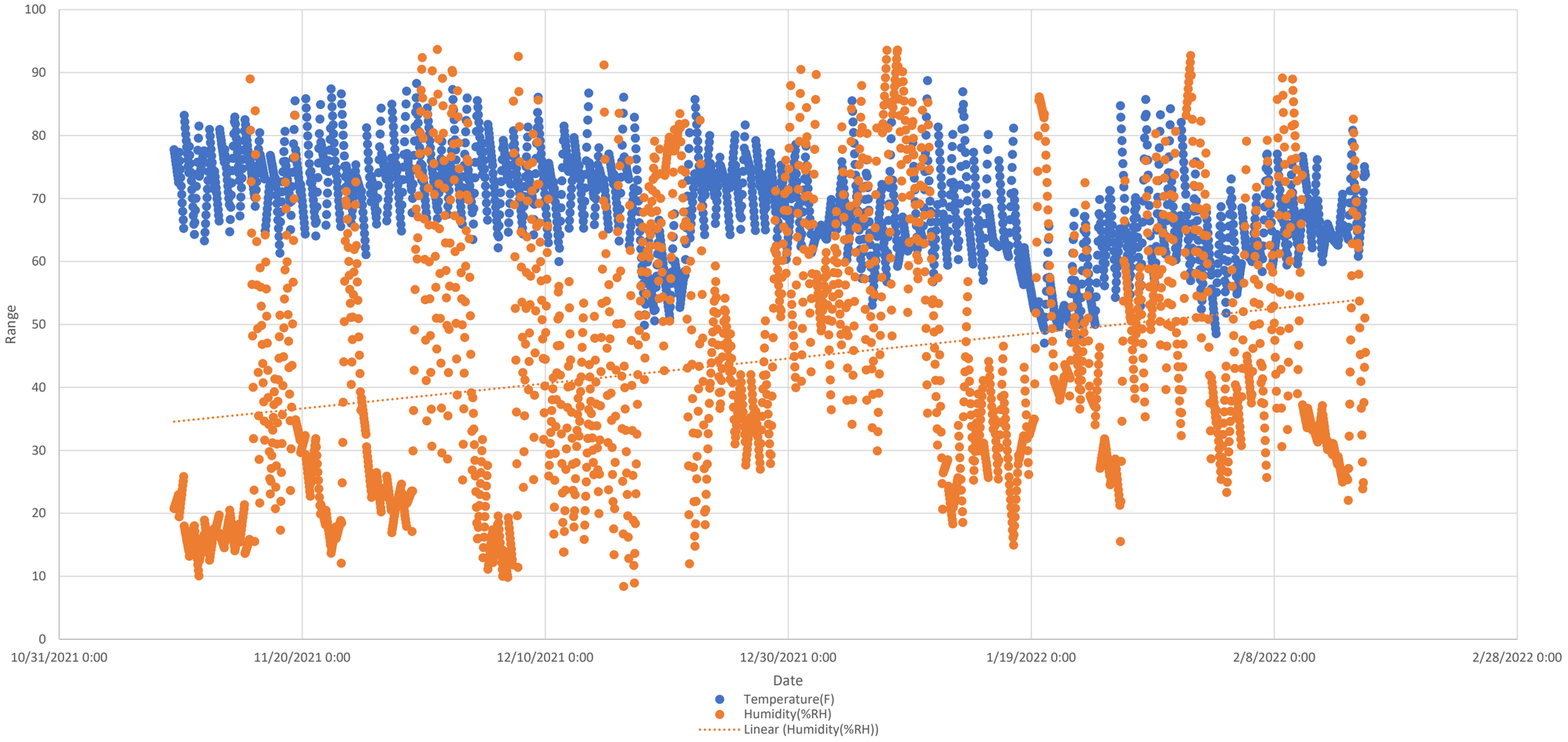
Figure 5 – pH Range (Analog)



TEMPERATURE AND HUMIDITY READINGS

Temperature and percent humidity readings were collected hourly with the continuous data logger setup in the one of the central test plots on the rack. As shown in **Figure 6**, temperature has been maintained at ranges similar to Lyons Quarry during spring conditions with diurnal fluctuations of 80-degree Fahrenheit (F) highs (daytime) and lower 60s to upper 50s F at night. Humidity has also been maintained within the test plots by laying the plastic cover lightly across the top to allow for air flow while holding in moisture. Lower humidity readings (10 to 20 percent) at the start of the test are indicative of times when the cover was either removed completely or barely covering the test plot. Since approximately Week 4, humidity has been fluctuating greatly between 20 to 90 percent depending on relative atmospheric pressure along with temperature. This keeps the mean somewhere in the 35 to 55 percent range, which is similar to conditions seen at the site during springtime.

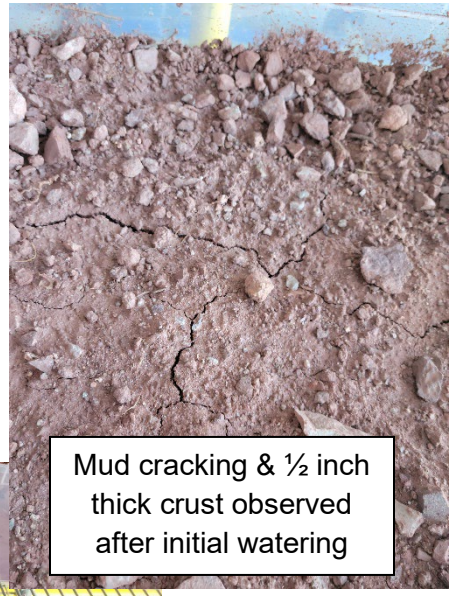
Figure 6 – Temperature and Humidity Readings - Lyons Bench Test

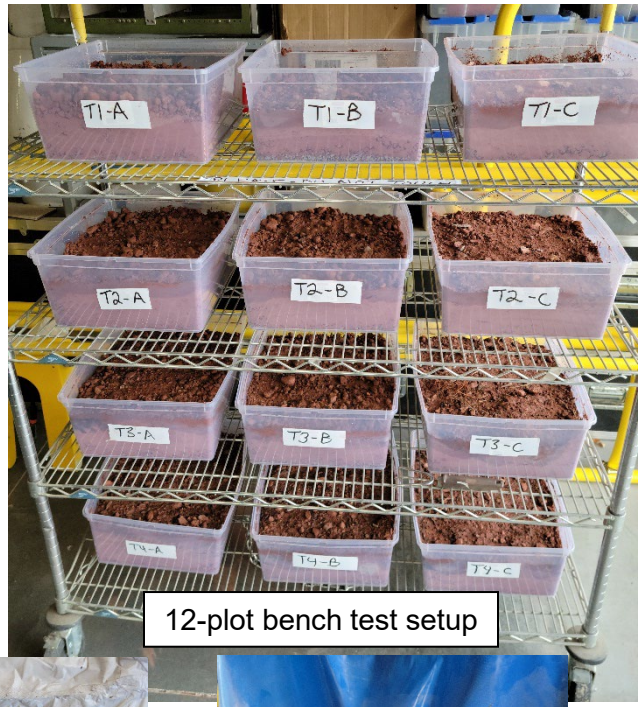


Summary and Recommendations

A full summary and recommendations based on the results of the germination bench test will be provided at the conclusion of the test, which is scheduled at the 16-week mark (approximately March 1, 2022). At that point, the potential for the bench test to run additional time will be based off the results to date. If a delay in construction may lead to revegetation occurring later than April/May 2022, a site revegetation test-plot study may still be considered to test the feasibility of revegetation onsite. Lessons learned from the bench test study would be incorporated into the setup of an onsite test-plot study.

Photo Log





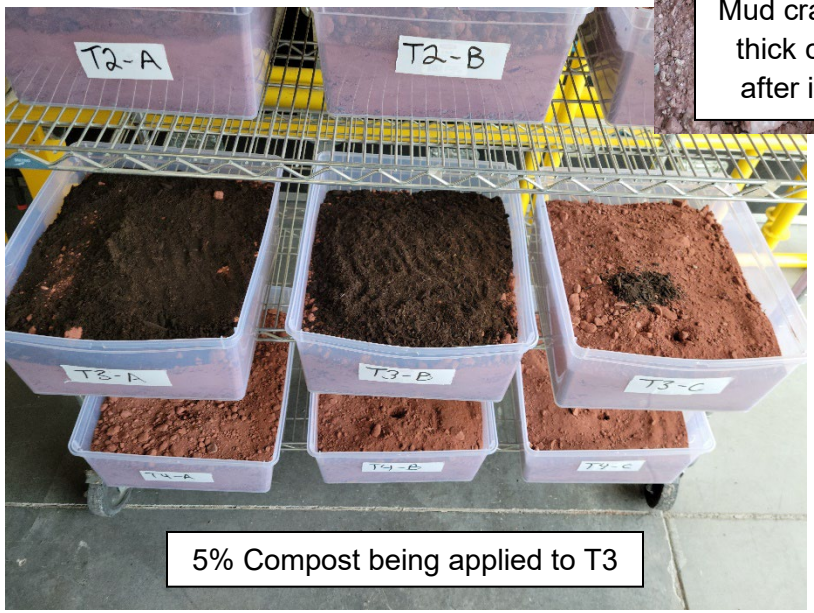


Image 1. Bench Test Initial Setup Photos

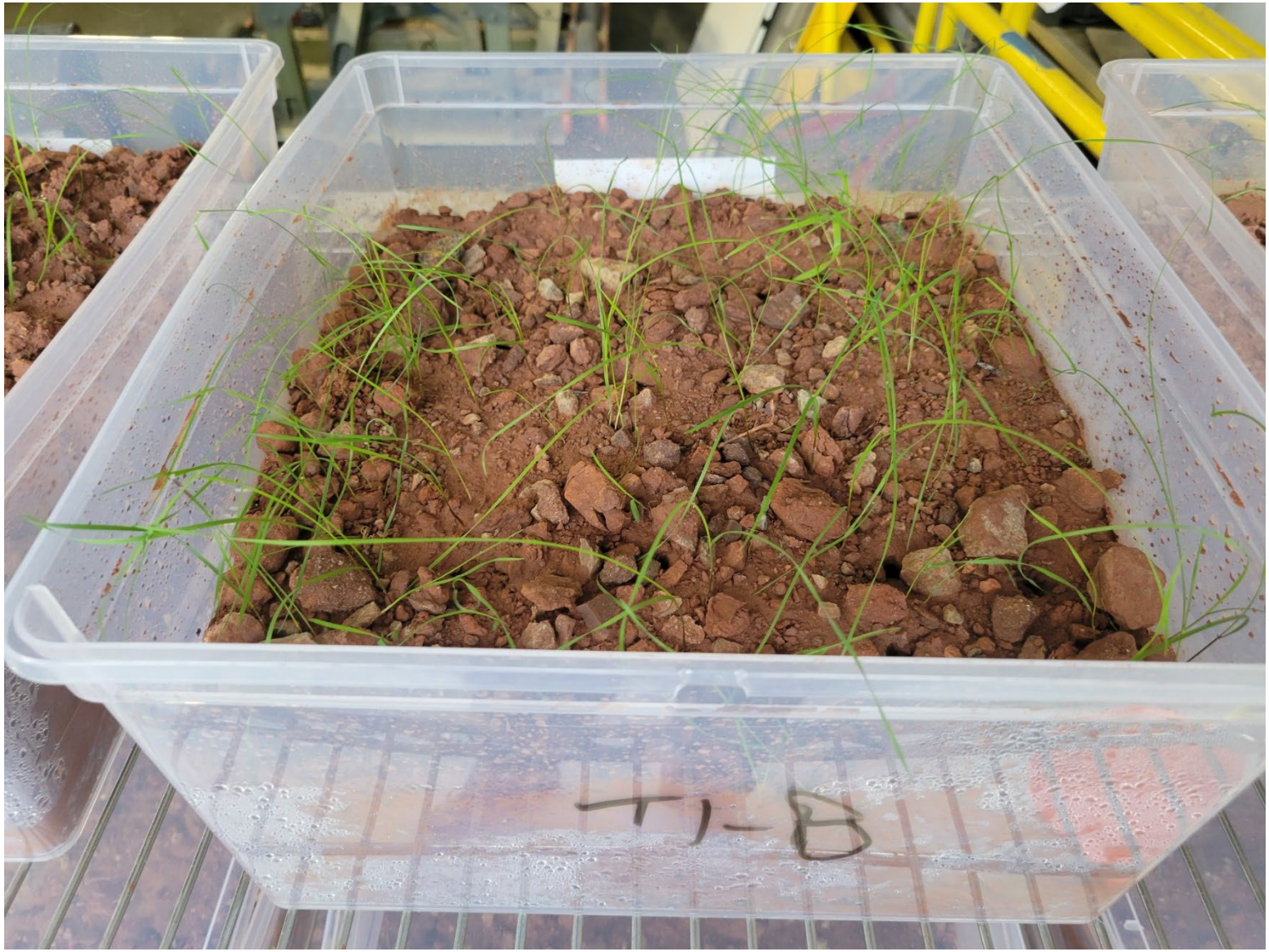


Image 2. Bench Test Interim Photo – Test Plot T1-B (10 weeks)

Image 3. Bench Test Interim Photos – Scarified Test Plot T4-A versus T4-B (Week 10)