PROTECTED B

NRC·CNRC

Technology Verification for Extracting Lithium from Brine
Final Report

Report No.: A1-018878
Date: April 14th, 2021
Authors: Christopher Baxter and Ben Yu

Energy, Mining and Environment

National Research Council Canada
Conseil national de recherches Canada

Canada

1. Introduction

Summit Nanotech (Summit) is developing sorbent technology to extract lithium from brine. NRC was contracted to manage and perform a verification of the Client's process, including:

i) Testing and Sample Collection
ii) Analytical Testing
iii) Mass Balancing and Reporting

Due to travel constraints surrounding the Covid-19 pandemic, NRC contracted InnoTech Alberta (InnoTech) to a) perform a site visit to Summit and observe their process and b) collect and analyze samples. InnoTech's Dr. Julius Pretorius visited Summit's facilities in Calgary, Alberta from 1 to 5 March 2021 to witness the execution of the process. Assay certificates received from InnoTech are attached in Appendix A.

2. Summit Nanotech Process

Summit provided a Block Flow Diagram (BFD) of the process to NRC (see Figure 1). Broadly, Li-containing raw brine is first passed through Summit's proprietary sorbent material, contained in columns, to selectively adsorb lithium. Depleted brine is collected and removed. Next, lithium is eluted by passing eluent solution through the columns. Then, the lithium-bearing solution is concentrated by evaporation. Polishing for removal of remaining calcium and magnesium is performed by addition of sodium hydroxide and oxalic acid. Finally, lithium carbonate is precipitated by carbonating the softened lithium-bearing liquor at 90 °C, filtered, washed, and dried.

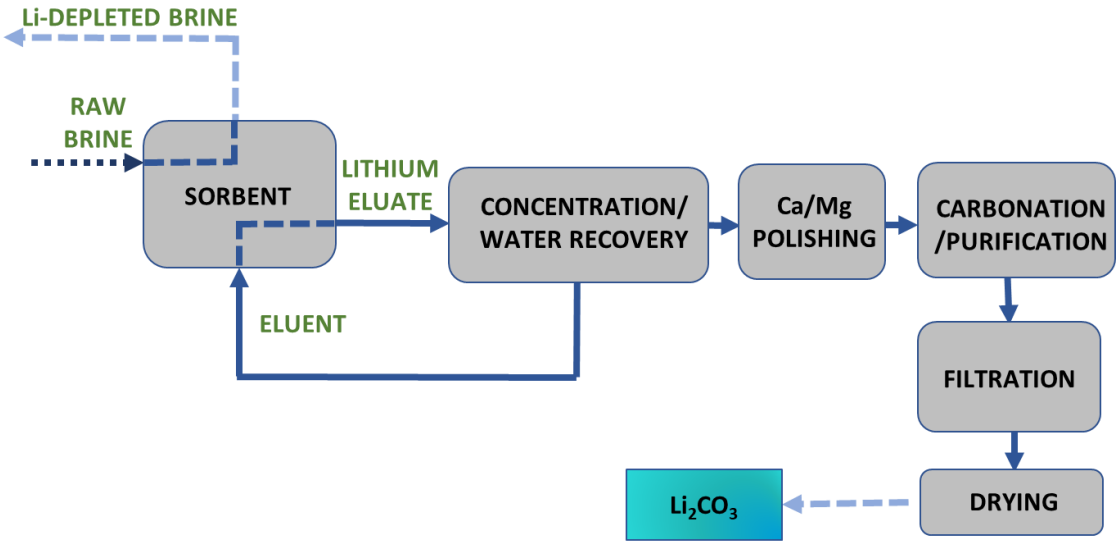

Figure 1: Block Flow Diagram for Lithium Recovery as Supplied to NRC by Summit

The current process was demonstrated as a series of individual batch operations, of which the following were presently observed:

a) Li adsorption from raw brine
b) Li desorption from adsorbent
c) Eluate concentration by evaporation
d) Ca and Mg removal
e) Lithium carbonate formation, precipitation, and recovery

3. Batch Testing

Dr. Julius Pretorius of InnoTech witnessed the running of batch test work on behalf of NRC and supervised the collection of required samples. The following section provides a description of the test campaign as observed.

3.1. Adsorption

Adsorbent was contained in two parallel columns (2.6 kg and 2.8 kg, for column 1 and 2, respectively). Brine was fed to the top of each unit using peristaltic pumps. Pre-heating to 60 °C was achieved by spiraling the feed lines between the columns and the heating jackets (see Figure 2). Depleted solution was collected from the bottom in 20 L pails.

An initial volume of 2 L was discarded from the test as the columns were pre-filled with brine from a previous run. The flowrate into the columns was approximately 40 cm^3/min during the flush, reduced to 20 cm^3/min afterwards. A summary of test conditions can be found in Table 1.

Figure 2: Experimental Setup for Lithium Adsorption

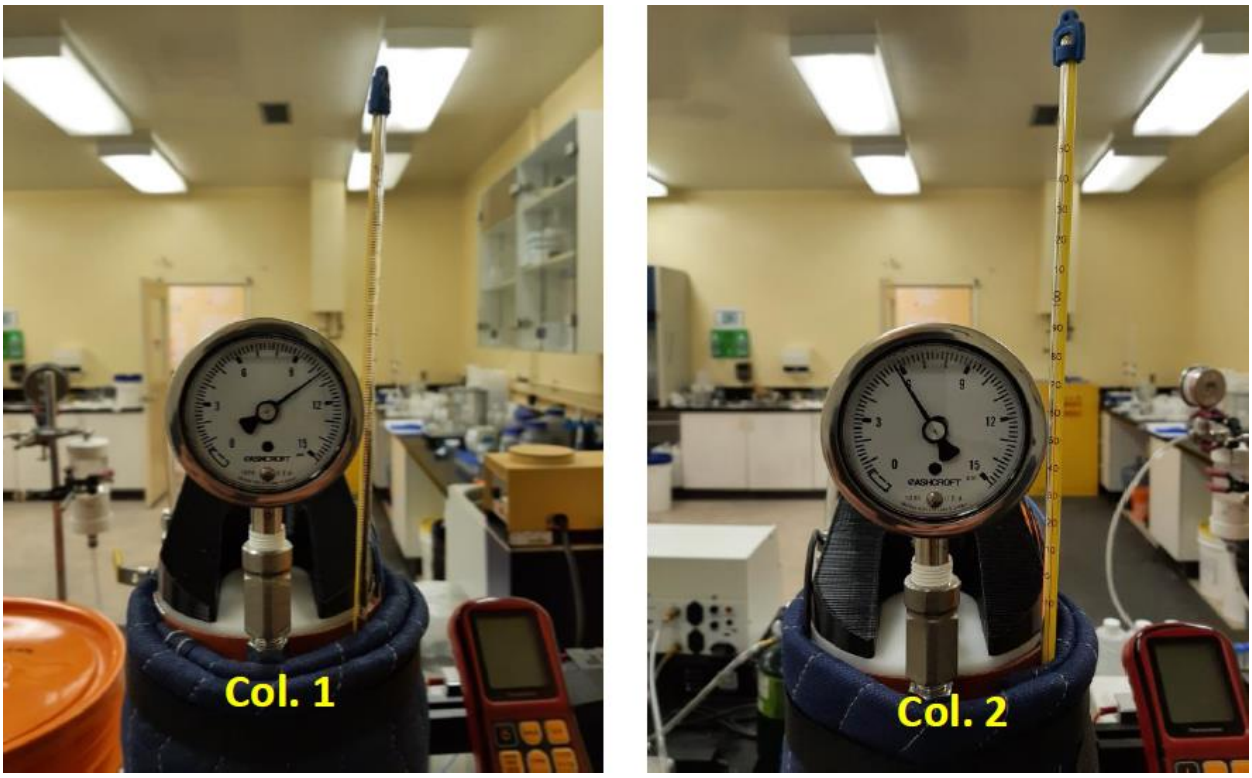

Figure 3: Column Pressures Observed during Adsorption

Table 1: Adsorption Test Parameters

Parameter	Units	Column 1	Column 2
Pressure	psi_g	6-12	
Temperature	°C	60	
Column Dimensions (height x internal diameter)	cm	45 x 9.37	
Adsorbent Mass	kg	2.6	2.8
Feed Volume	L	9.92	6.97
Waste Volume	L	2	2
Depleted Solution Volume	L	7.81	4.99

3.2. Elution

Column flushing and elution were performed in a single step by passing eluent over the columns. Initial eluate with an electrical conductivity greater than 75 mS/cm was collected for recycling while eluate with conductivity less than 75 mS/cm was retained for further processing. A summary of test conditions is presented in Table 2. Eluate from both columns was combined for subsequent test work.

Table 2: Elution Test Parameters

Parameter	Units	Column 1	Column 2
Eluent Flow Rate	cm^3/min	~ 20	
Eluent Feed Volume	L	10.6	8.93
Initial Reject/Flush Volume	L	2.93	1.96
Eluate Volume	L	7.52	6.88

3.3. Concentration

The lithium-enriched eluate was concentrated using two Büchi laboratory scale rotary evaporators (Figure 4). Concentrated eluate and condensed reject water were collected (Table 3). Note, the total volume of products was 200 cm^3 less than the volume of initial eluate. It is assumed this is due to inefficient condensers in the rotary evaporators which resulted in a loss of water vapour. Note, only a portion of the eluate obtained from elution was used.

Figure 4: Rotary Evaporators used for Eluate Concentration

Table 3: Concentration Test Stream Volumes

Parameter	Units	Value
Eluate Volume	L	11.0
Condensed Water Volume	L	10.1
Concentrated Eluate Volume	L	0.6172

3.4. Polishing

The concentrated eluate was polished for removal of calcium and magnesium impurities by the addition of caustic and oxalic acid. Reagent dosage was dictated by observed levels of Ca and Mg during titrimetric analysis. The resulting solution had a milky-white appearance and a pH of 11.5. Following 30 minutes of stirring, the solution was centrifuged at 4,000 rpm. Clear supernatant was decanted from a dense white precipitate (Figure 5). Test conditions are listed in Table 4.

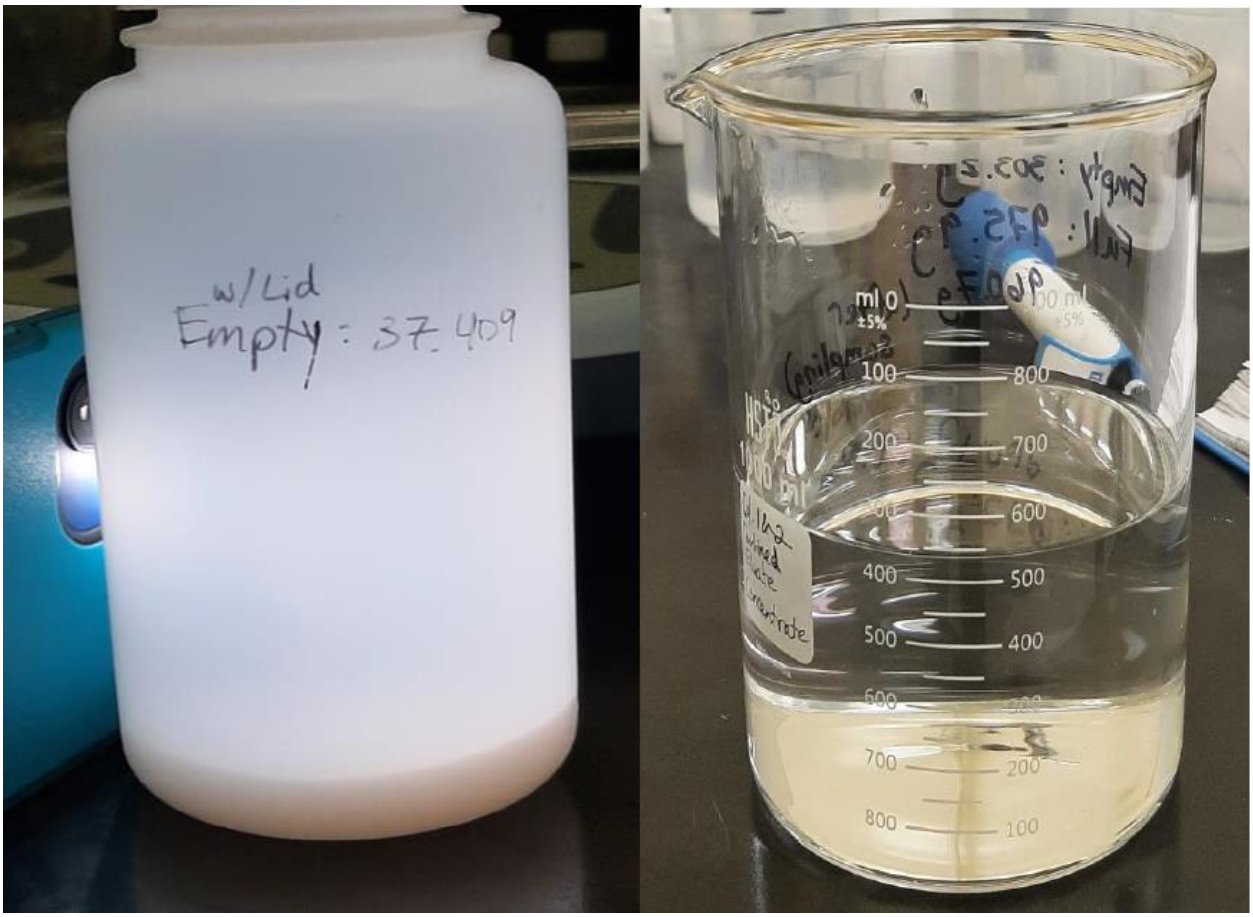

Figure 5: Polished Solution with Dense White Precipitate (Left) and Decanted Clear Supernatant Solution (Right)

Table 4: Polishing Test Parameters

Parameter	Units	Value
Solution pH	n/a	11.5
Mixing Time	min	30
Enriched Lithium Solution Volume	mL	603.2
Polished Solution Volume	mL	552.1
Precipitate Mass	g	14.5

3.5. Carbonation

For lithium recovery, the polished lithium-bearing liquor was preheated to 90 °C and solid Na_2CO_3 was added under constant stirring at 700 rpm. Immediate formation of a precipitate was observed (see Figure 6) and continued for 30 minutes (constant stirring increased to 1,100 rpm). The temperature of the solution was maintained and the beaker was covered to minimize evaporation. The precipitate was vacuum filtered, washed using 241 cm^3 of hot deionized water, and dried overnight at 105 °C.

Figure 6: (Top Left) Precipitate Formation, (Top Right) Filtration, and (Bottom Left) Filter Cake Washing

4. Results

During adsorption and elution, samples were taken from the feed solution, depleted brine, eluent, initial flush, and eluate. Volumes were calculated from the measured mass and the density of the corresponding samples. Densities were obtained by weighing a known volume of sample. Results are shown in Table 5 (Column 1), Table 6 (Column 2), and Table 7 (Column 1 + 2). The following observations are noted:

- The balance around lithium suggests a contribution from a previous test in the column.
- Lithium in the fresh eluent accounts for between 16-19% of lithium mass in. Concentration of non-lithium ions was lower in the Column 2 eluent.

Table 5: Mass, Volume, and Elemental Concentration for Column 1 Streams

Stream	Mass	Volume	Sample No.	Ca	K	Li	Mg	Na	Cl
	kg	L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Feed	12.01	9.92	SN-01	396	23,800	554	9,440	95,700	194,000
Depleted Brine	9.43	7.81	SN-02	390	23,500	3.06	9,180	94,200	188,000
Eluent	10.68	10.6	SN-03	5.55	268	99.9	111	1,030	2,690
Initial Flush	3.26	2.93	SN-07	258	14,800	470.1	6,360	57,200	124,000
Eluate	7.684	7.52	SN-08	10.8	585	831	271	2,050	8,830
Mass Balance, %				97.4	96.8	116.7	97.4	95.7	97.2

Table 6: Mass, Volume, and Elemental Concentration for Column 2 Streams

Stream	Mass	Volume	Sample No.	Ca	K	Li	Mg	Na	Cl
	kg	L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Feed	8.43	6.97	SN-01	396	23,800	554	9,440	95,700	194,000
Depleted Brine	6.02	4.99	SN-04	397	23,300	4.29	9,480	94,000	190,000
Eluent	9.01	8.93	SN-05	0.33	1.41	100	0.61	5.86	528
Initial Flush	2.29	1.96	SN-06	310	18,800	124	7,860	75,700	156,000
Eluate	7.017	6.88	SN-09	2.11	209	756	144	308	4,920
Mass Balance, %				94.2	93.2	115.0	96.8	92.9	94.9

Table 7: Observed Adsorption and Elution Recoveries

Parameter	Recovery, % (Col 1 / Col 2 / Overall)					
	Ca	K	Li	Mg	Na	Cl
Adsorption	22.5 / 28.2 / **24.8**	22.3 / 29.9 / **25.4**	99.6 / 99.4 / **99.5**	23.4 / 28.1 / **25.4**	22.5 / 29.7 / **25.5**	23.7 / 29.9 / **26.3**
Elution	8.6 / 1.9 / **5.6**	7.9 / 2.9 / **5.6**	95.7 / 109.9 / **101.7**	8.8 / 5.4 / **7.3**	6.9 / 1.1 / **4.1**	13.7 / 8.3 / **11.2**
Overall	2 / 0.5 / **1.4**	1.8 / 0.9 / **1.4**	95.3 / 109.4 / **101.3**	2.1 / 1.5 / **1.9**	1.6 / 0.3 / **1.1**	3.4 / 2.5 / **3**

The results of concentration are shown in Table 8. Samples were taken from the combined eluate, condensed vapour, and concentrated solution. Volume was reduced by a factor of 17.8 without loss of lithium.

Table 8: Volume and Elemental Concentrations during Evaporation

Stream	Volume	Sample No.	Ca	K	Li	Mg	Na	Cl
	L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Combined Eluate	11	SN-10	4.69	289	795	162	778	6,060
Condensed Vapour	10.1	SN-11	<0.001	<0.02	<0.006	<0.002	0.03	0.097
Concentrated Solution	0.6172	SN-12	78.3	5,030	14,300	2,690	13,600	107,000
Mass Balance, %			93.7	97.7	100.9	93.2	98.1	99.1

Observations for polishing and carbonation are shown in Table 9 and Table 10, respectively. Polishing removed 86.8% of Ca and >99.9% of Mg with lithium losses of 11%. Carbonation resulted in lithium recovery of 88.5% into 34.6 g of final product assaying 19.2 wt.% Li.

Table 9: Mass, Volume, Elemental Concentration, and Recovery during Polishing

Stream	Volume *Mass*	Sample No.	Ca	K	Li	Mg	Na	Cl
	mL *g*		mg/L *ppm*	mg/L *ppm*	mg/L *ppm*	mg/L *ppm*	mg/L *ppm*	mg/L *ppm*
Concentrated Solution	603.2	SN-12	78.3	5,030	14,300	2,690	13,600	107,000
30 wt.% NaOH	13.9	SN-13	<0.01	138	<0.06	<0.02	275,000	N.D.[1]
90 g/L Oxalic Acid Solution	1.4	SN-14	0.09	<0.2	0.11	<0.02	0.43	N.D.[1]
Precipitate, (s)	14.5	SN-16	2,530	20,500	61,500	115,000	89,100	480,000
Polished Li Solution	552.1	SN-15	11.3	4,890	13,900	0.31	19,300	104,000
Mass Balance, %			93.7	97.7	100.9	93.2	98.1	99.1
Recovery, %			13.2	88.9	89.0	0.0	88.6	89.0

[1]Not determined.
[2]Reported liquid stream values are volume in mL and concentration in mg/L. Solid stream values, marked by "(s)", are mass in g and concentration in ppm.

Table 10: Mass, Volume, Elemental Concentration, and Recovery during Carbonation

Stream	Volume *Mass*	Sample No.	Ca	K	Li	Mg	Na	Cl
	mL *g*		mg/L *ppm*	mg/L *ppm*	mg/L *ppm*	mg/L *ppm*	mg/L *ppm*	mg/L *ppm*
Polished Li Solution	539.9	SN-15	11.3	4,890	13,900	0.31	19,300	104,000
DI Water	241	SN-17	<0.001	0.02	<0.006	<0.002	0.05	0.044
Na_2CO_3, (s)	61.7	SN-18	28.9	28	3	14	488,000	461
Filtrate Solution	476	SN-19	0.42	5,180	1,410	0.02	71,700	108,000
Rinse Filtrate Solution	236	SN-20	1.16	926	1,750	0.31	13,100	20,200
Li_2CO_3(s) Product, (s)	34.6	SN-21	295	96	192,000	33	739	558
Mass Balance, %			135.5	101.7	103.0	118.7	91.9	100.0
Recovery, %			129.5	0.1	88.5	110.7	0.1	0.0

[1]Reported liquid stream values are volume in mL and concentration in mg/L. Solid stream values, marked by "(s)", are mass in g and concentration in ppm.

5. Recovery

The cumulative sequential recovery of lithium observed in the present test work was 78%. However, further study at a continuous pilot scale is strongly recommended to refine this estimate, as several factors contribute to current uncertainty:

a) In a continuous operation, some of the lithium lost in the present test work is typically returned to the process in recycle loops (e.g. process water). This should be considered especially for the final carbonation step, as the once-through recovery of lithium carbonate will be solubility-limited. A pilot scale incorporating recycling would be necessary to determine overall recovery (vs. accumulation of impurities) in this case.
b) Batch scale test work may not capture full-scale unit operation efficiencies (e.g. mixing, settling).
c) Evaporation alone for the concentration of the lithium-bearing eluate stream may be considered unlikely to be sufficient at scale (i.e. cost, speed). Depending on the method selected, lithium losses at this step could be observed.

Appendix A

InnoTech Sample Test Report

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

RESULTS: Julius Pretorius
InnoTech Alberta Inc

INVOICE: Julius Pretorius

CLIENT SAMPLE ID: SN-01

Matrix: Water

CANISTER ID:

PRIORITY: Normal

DESCRIPTION: Feed brine into column 1

DATE SAMPLED: 01-Mar-21 08:25

DATE RECEIVED: 10-Mar-21

REPORT CREATED: 18-Mar-21

REPORT NUMBER: 21030078

REPORT REVISED: 21-Mar-21

VERSION: Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-001	Calcium, Dissolved		396	mg/L	0.100	Research	10-Mar-21
21030078-001	Lithium, Dissolved		554	mg/L	0.600	Research	10-Mar-21
21030078-001	Magnesium, Dissolved		9440	mg/L	0.200	Research	10-Mar-21
21030078-001	Potassium, Dissolved		23800	mg/L	20.0	Research	10-Mar-21
21030078-001	Sodium, Dissolved		95700	mg/L	5.00	Research	10-Mar-21
21030078-001	Chloride, Dissolved		194000	mg/L	40.0	AC-026	13-Mar-21

Report certified by: Rebecca Holgate, Account Coordinator On behalf of: PJ Pretorius, Manager, Analysis and Testing Services

Date: March 21, 2021

Inquiries: (780) 632 8455 E-mail: EAS.Results@innotechalberta.ca

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-02		Water	02-Mar-21 08:20

DESCRIPTION: Depleted brine from column 1

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-002	Calcium, Dissolved		390	mg/L	0.100	Research	10-Mar-21
21030078-002	Lithium, Dissolved		3.06	mg/L	0.060	Research	10-Mar-21
21030078-002	Magnesium, Dissolved		9180	mg/L	0.200	Research	10-Mar-21
21030078-002	Potassium, Dissolved		23500	mg/L	20.0	Research	10-Mar-21
21030078-002	Sodium, Dissolved		94200	mg/L	5.00	Research	10-Mar-21
21030078-002	Chloride, Dissolved		188000	mg/L	40.0	AC-026	13-Mar-21

Report certified by: Rebecca Holgate, Account Coordinator On behalf of: PJ Pretorius, Manager, Analysis and Testing Services

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-03		Water	02-Mar-21 08:30

DESCRIPTION: Eluent for column 1

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-003	Calcium, Dissolved		5.55	mg/L	0.010	Research	10-Mar-21
21030078-003	Lithium, Dissolved		99.9	mg/L	0.600	Research	10-Mar-21
21030078-003	Magnesium, Dissolved		111	mg/L	0.200	Research	10-Mar-21
21030078-003	Potassium, Dissolved		268	mg/L	2.00	Research	10-Mar-21
21030078-003	Sodium, Dissolved		1030	mg/L	0.500	Research	10-Mar-21
21030078-003	Chloride, Dissolved		2690	mg/L	4.00	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-04		Water	02-Mar-21 13:57

DESCRIPTION: Depleted brine from column 2

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-004	Calcium, Dissolved		397	mg/L	0.100	Research	10-Mar-21
21030078-004	Lithium, Dissolved		4.29	mg/L	0.060	Research	10-Mar-21
21030078-004	Magnesium, Dissolved		9480	mg/L	0.200	Research	10-Mar-21
21030078-004	Potassium, Dissolved		23300	mg/L	20.0	Research	10-Mar-21
21030078-004	Sodium, Dissolved		94000	mg/L	5.00	Research	10-Mar-21
21030078-004	Chloride, Dissolved		190000	mg/L	40.0	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-05		Water	02-Mar-21 14:00

DESCRIPTION: Eluent for column 2

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-005	Calcium, Dissolved		0.330	mg/L	0.010	Research	11-Mar-21
21030078-005	Lithium, Dissolved		100	mg/L	0.600	Research	11-Mar-21
21030078-005	Magnesium, Dissolved		0.610	mg/L	0.020	Research	11-Mar-21
21030078-005	Potassium, Dissolved		1.41	mg/L	0.20	Research	11-Mar-21
21030078-005	Sodium, Dissolved		5.86	mg/L	0.050	Research	11-Mar-21
21030078-005	Chloride, Dissolved		528	mg/L	0.400	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-06		Water	02-Mar-21 16:00

DESCRIPTION: Initial flush column 2

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-006	Calcium, Dissolved		310	mg/L	0.100	Research	10-Mar-21
21030078-006	Lithium, Dissolved		124	mg/L	0.600	Research	10-Mar-21
21030078-006	Magnesium, Dissolved		7860	mg/L	0.200	Research	10-Mar-21
21030078-006	Potassium, Dissolved		18800	mg/L	20.0	Research	10-Mar-21
21030078-006	Sodium, Dissolved		75700	mg/L	5.00	Research	10-Mar-21
21030078-006	Chloride, Dissolved		156000	mg/L	40.0	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-07		Water	02-Mar-21 16:21

DESCRIPTION: Initial flush column 1

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-007	Calcium, Dissolved		258	mg/L	0.100	Research	10-Mar-21
21030078-007	Lithium, Dissolved		470	mg/L	0.600	Research	10-Mar-21
21030078-007	Magnesium, Dissolved		6360	mg/L	0.200	Research	10-Mar-21
21030078-007	Potassium, Dissolved		14800	mg/L	20.0	Research	10-Mar-21
21030078-007	Sodium, Dissolved		57200	mg/L	5.00	Research	10-Mar-21
21030078-007	Chloride, Dissolved		124000	mg/L	40.0	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-08		Water	03-Mar-21 08:20

DESCRIPTION: Eluent column 1

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-008	Calcium, Dissolved		10.8	mg/L	0.010	Research	10-Mar-21
21030078-008	Lithium, Dissolved		831	mg/L	0.600	Research	10-Mar-21
21030078-008	Magnesium, Dissolved		271	mg/L	0.200	Research	10-Mar-21
21030078-008	Potassium, Dissolved		585	mg/L	2.00	Research	10-Mar-21
21030078-008	Sodium, Dissolved		2050	mg/L	0.500	Research	10-Mar-21
21030078-008	Chloride, Dissolved		8830	mg/L	4.00	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-09		Water	03-Mar-21 08:25

DESCRIPTION: Eluent column 2

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-009	Calcium, Dissolved		2.11	mg/L	0.010	Research	10-Mar-21
21030078-009	Lithium, Dissolved		756	mg/L	0.600	Research	10-Mar-21
21030078-009	Magnesium, Dissolved		144	mg/L	0.200	Research	10-Mar-21
21030078-009	Potassium, Dissolved		209	mg/L	2.00	Research	10-Mar-21
21030078-009	Sodium, Dissolved		308	mg/L	0.500	Research	10-Mar-21
21030078-009	Chloride, Dissolved		4920	mg/L	4.00	AC-026	13-Mar-21

Report certified by: Rebecca Holgate, Account Coordinator On behalf of: PJ Pretorius, Manager, Analysis and Testing Services

Date: March 21, 2021

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-10		Water	03-Mar-21 08:35

DESCRIPTION: Combine eluate (1+2)

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-010	Calcium, Dissolved		4.69	mg/L	0.010	Research	10-Mar-21
21030078-010	Lithium, Dissolved		795	mg/L	0.600	Research	10-Mar-21
21030078-010	Magnesium, Dissolved		162	mg/L	0.200	Research	10-Mar-21
21030078-010	Potassium, Dissolved		289	mg/L	2.00	Research	10-Mar-21
21030078-010	Sodium, Dissolved		778	mg/L	0.500	Research	10-Mar-21
21030078-010	Chloride, Dissolved		6060	mg/L	4.00	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-11		Water	04-Mar-21 11:00

DESCRIPTION: Reject water from Rotovap

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-011	Calcium, Dissolved	K, T, U	< 0.001	mg/L	0.001	Research	11-Mar-21
21030078-011	Lithium, Dissolved	K, T, U	< 0.006	mg/L	0.006	Research	11-Mar-21
21030078-011	Magnesium, Dissolved	K, T, U	< 0.002	mg/L	0.002	Research	11-Mar-21
21030078-011	Potassium, Dissolved	K, T, U	< 0.02	mg/L	0.02	Research	11-Mar-21
21030078-011	Sodium, Dissolved		0.030	mg/L	0.005	Research	11-Mar-21
21030078-011	Chloride, Dissolved		0.097	mg/L	0.004	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-12		Water	04-Mar-21 11:30

DESCRIPTION: Concentrateed lithium-enriched solution

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-012	Calcium, Dissolved		78.3	mg/L	0.100	Research	11-Mar-21
21030078-012	Lithium, Dissolved		14300	mg/L	6.00	Research	11-Mar-21
21030078-012	Magnesium, Dissolved		2690	mg/L	0.200	Research	11-Mar-21
21030078-012	Potassium, Dissolved		5030	mg/L	2.00	Research	11-Mar-21
21030078-012	Sodium, Dissolved		13600	mg/L	5.00	Research	11-Mar-21
21030078-012	Chloride, Dissolved		107000	mg/L	40.0	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-13		Water	04-Mar-21 12:35

DESCRIPTION: NaOH reagent used in Polishing step

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-013	Calcium, Dissolved	K, T, U	< 0.010	mg/L	0.010	Research	11-Mar-21
21030078-013	Lithium, Dissolved	K, T, U	< 0.060	mg/L	0.060	Research	11-Mar-21
21030078-013	Magnesium, Dissolved	K, T, U	< 0.020	mg/L	0.020	Research	11-Mar-21
21030078-013	Potassium, Dissolved		138	mg/L	2.00	Research	11-Mar-21
21030078-013	Sodium, Dissolved		275000	mg/L	50.0	Research	11-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-14		Water	04-Mar-21 12:35

DESCRIPTION: Oxalic acid solution used in polishing step

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-014	Calcium, Dissolved		0.090	mg/L	0.010	Research	11-Mar-21
21030078-014	Lithium, Dissolved	I	0.110	mg/L	0.060	Research	11-Mar-21
21030078-014	Magnesium, Dissolved	K, T, U	< 0.020	mg/L	0.020	Research	11-Mar-21
21030078-014	Potassium, Dissolved	K, T, U	< 0.20	mg/L	0.20	Research	11-Mar-21
21030078-014	Sodium, Dissolved		0.430	mg/L	0.050	Research	11-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-15		Water	04-Mar-21 14:35

DESCRIPTION: Polished Li-enriched solution

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-015	Calcium, Dissolved		11.3	mg/L	0.010	Research	11-Mar-21
21030078-015	Lithium, Dissolved		13900	mg/L	6.00	Research	11-Mar-21
21030078-015	Magnesium, Dissolved		0.310	mg/L	0.020	Research	11-Mar-21
21030078-015	Potassium, Dissolved		4890	mg/L	2.00	Research	11-Mar-21
21030078-015	Sodium, Dissolved		19300	mg/L	5.00	Research	11-Mar-21
21030078-015	Chloride, Dissolved		104000	mg/L	40.0	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-16		Solid	05-Mar-21 09:50

DESCRIPTION: Solid waste collected from centrifuge (Dry)

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-016	Calcium, Total		2530	ug/g	5.0	Research	17-Mar-21
21030078-016	Lithium, Total		61500	ug/g	300	Research	17-Mar-21
21030078-016	Magnesium, Total		115000	ug/g	100	Research	17-Mar-21
21030078-016	Potassium, Total		20500	ug/g	100	Research	17-Mar-21
21030078-016	Sodium, Total		89100	ug/g	300	Research	17-Mar-21
21030078-016	Chloride		480000	mg/kg	0.1	Research	16-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-17		Water	04-Mar-21 15:07

DESCRIPTION: DI water used as rinse water

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-017	Calcium, Dissolved	K, T, U	< 0.001	mg/L	0.001	Research	17-Mar-21
21030078-017	Lithium, Dissolved	K, T, U	< 0.006	mg/L	0.006	Research	17-Mar-21
21030078-017	Magnesium, Dissolved	K, T, U	< 0.002	mg/L	0.002	Research	17-Mar-21
21030078-017	Potassium, Dissolved	I	0.02	mg/L	0.02	Research	17-Mar-21
21030078-017	Sodium, Dissolved		0.050	mg/L	0.005	Research	17-Mar-21
21030078-017	Chloride, Dissolved		0.044	mg/L	0.004	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-18		Solid	04-Mar-21 15:20

DESCRIPTION: Na2CO3 used for carbonation

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-018	Calcium, Total		28.9	ug/g	0.5	Research	16-Mar-21
21030078-018	Lithium, Total	I	3	ug/g	3	Research	16-Mar-21
21030078-018	Magnesium, Total		14	ug/g	1	Research	16-Mar-21
21030078-018	Potassium, Total	I	28	ug/g	10	Research	16-Mar-21
21030078-018	Sodium, Total		488000	ug/g	30	Research	16-Mar-21
21030078-018	Chloride		461	mg/kg	0.1	Research	16-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-19		Water	05-Mar-21 09:15

DESCRIPTION: Filtrate from carbonation step

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-019	Calcium, Dissolved		0.420	mg/L	0.010	Research	11-Mar-21
21030078-019	Lithium, Dissolved		1410	mg/L	0.600	Research	11-Mar-21
21030078-019	Magnesium, Dissolved	I	0.020	mg/L	0.020	Research	11-Mar-21
21030078-019	Potassium, Dissolved		5180	mg/L	2.00	Research	11-Mar-21
21030078-019	Sodium, Dissolved		71700	mg/L	5.00	Research	11-Mar-21
21030078-019	Chloride, Dissolved		108000	mg/L	40.0	AC-026	15-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-20		Water	05-Mar-21 09:20

DESCRIPTION: Rinse filtrate from carbonation step

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-020	Calcium, Dissolved		1.16	mg/L	0.010	Research	11-Mar-21
21030078-020	Lithium, Dissolved		1750	mg/L	0.600	Research	11-Mar-21
21030078-020	Magnesium, Dissolved		0.310	mg/L	0.020	Research	11-Mar-21
21030078-020	Potassium, Dissolved		926	mg/L	2.00	Research	11-Mar-21
21030078-020	Sodium, Dissolved		13100	mg/L	5.00	Research	11-Mar-21
21030078-020	Chloride, Dissolved		20200	mg/L	4.00	AC-026	13-Mar-21

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ENVIRONMENTAL ANALYTICAL SERVICES

TEST REPORT

CLIENT SAMPLE ID	CANISTER ID	Matrix	DATE SAMPLED
SN-21		Solid	05-Mar-21 09:35

DESCRIPTION: Final product (Li2CO3)

REPORT NUMBER: 21030078 **REPORT CREATED:** 18-Mar-21 **REPORT REVISED:** 21-Mar-21 **VERSION:** Version 02

Lab ID	Parameter	Qualifier	Result	Units	RDL	Method	Analysis Date
21030078-021	Calcium, Total		295	ug/g	0.5	Research	16-Mar-21
21030078-021	Lithium, Total		192000	ug/g	30	Research	16-Mar-21
21030078-021	Magnesium, Total		33	ug/g	1	Research	16-Mar-21
21030078-021	Potassium, Total		96	ug/g	10	Research	16-Mar-21
21030078-021	Sodium, Total		739	ug/g	3	Research	16-Mar-21
21030078-021	Chloride		558	mg/kg	0.1	Research	16-Mar-21

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Revision History

Order ID	Ver	Date	Reason
21030078	01	18-Mar-21	Report created
21030078	02	21-Mar-21	Cation results for 21030078-001 were entered incorrectly. Results from data collected on 10 March 2021 were used. Duplicate analysis of this sample had an RPD value for lithium of 2.4%. Sample was repeated on 15 March 2021 and an RPD of less than 1% was

21030078-021	Chloride	Research	Sample extracted at 100mg due to high carbonate. No matrix interference.

Methods

Method	Description
AC-026	Ion Chromatographic Procedures using the Dionex ICS 3000 and 5000 Systems
Research	Research method

Qualifiers

Data Qualifier	Translation
B	Blank contamination; Analyte detected above the method reporting limit in an associated blank
I	The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit
J1	Reported value is estimated; Surrogate recoveries limits were exceeded
J2	Reported value is estimated; No known QC criteria for this component
J3	Reported value is estimated; The value failed to meet QC criteria for either precision or accuracy
J4	Reported value is estimated; The sample matrix interfered with the analysis
K	Off-scale low. Actual value is known to be less than the value given
L	Off-scale high. Actual value is known to be greater than value given
N	Non-target analyte; Tentatively identified compound (using mass spectroscopy)
Q	Sample held beyond the accepted holding time
R	Rejected data; Not suitable for the projects intended use
T	Value reported is less than the laboratory method detection limit
U	Compound was analyzed for but not detected
V	Analyte was detected in both the sample and the associated method blank

Order Comments

21030078

Pre-login. Project ID: Summit Nanotechnology

Sample Comments

21030078-001

Did not sample feed into column 2. Feed for both columns originate from same stock solution. Expected concentrations (ppm): Li: 600; Na: 91,000; K: 26,500; Ca: 4,500; Mg: 9,650; Cl:196,268.

21030078-002

Depleted in Li. Other constituents should remain high.

21030078-004

Depleted in Li. Other constituents should remain high.

21030078-006

Could be high in all constituents.

21030078-007

Could be high in all constituents.

21030078-008

Enriched in Li. Ca and Mg concentrations also important.

21030078-009

Enriched in Li. Ca and Mg concentrations also important.

21030078-010

Enriched in Li. Ca and Mg concentrations also important.

21030078-011

Should be low in all constituents.

21030078-012

High in Li. Ca and Mg important.

21030078-013

Should be low except in Na.

21030078-014

Should be low.

21030078-015

High in Li, except low Ca and Mg. Ca and Mg conc important.

21030078-016

Wet product was dried overnight at 100°C. Moisture content = 80.17%

Result Comments

Note:

1. Results relate only to items tested and apply to the sample as received.

2. This report shall not be reproduced, except in full, without the explicit approval of the laboratory.

21030078-016 IC-Chloride

Sample extracted at 100mg/L, no matrix interference.

21030078-018 IC-Chloride

Sample extracted at 100mg/L due to high carbonate, no matrix interference.

21030078-021 IC-Chloride

Sample extracted at 100mg due to high carbonate. No matrix interference.