Bowes Environmental, LLC

December 27, 2016 via E-mail

Bryan Harrington
Indirect Discharge Section
Drinking Water and Groundwater Protection Division Department of Environmental Conservation
1 National Life Drive-Main 2
Montpelier, Vermont 05620-3521

Re: Agri-Mark Inc. (dba Cabot Creamery) Indirect Discharge Permit
ID 9-0043: Report on the September-October 2016 Soil Sampling
Bowes Environmental Project VT 001-01.

Dear Mr. Harrington:

The following includes the results of the September-October 2016 Indirect Discharge Permit (IDP) soil monitoring performed by Bowes Environmental, LLC for Agri-Mark Inc. (dba Cabot Creamery).

1.0 INTRODUCTION

This soil report is being forwarded to the Vermont IDP Section in accordance with Part II, Section J.7 of the referenced IDP. An overall assessment of the results of the sampling is provided in a Memorandum from Stone Environmental dated November 21, 2016; a copy of which is included as Attachment 1. The actual soil reports generated by the Agricultural and Environmental Testing Laboratory at University of Vermont (UVM Ag Lab) were submitted to the Vermont IDP on October 28, 2016 by Bowes Environmental on behalf of Cabot and as such, have not been included with this document.

2.0 PROCEDURE

The sampling was performed by Bowes Environmental from September 28 – October 5, 2016 in accord with the April 2016 Soil Sampling Work Plan dated March 28, 2016 and the amended field list dated April 19, 2016 with the following exceptions: Field 25B was replaced by Field 95E; Field 131A was replaced by Field 116A, and Field 62D was not sampled. These exceptions have been previously discussed in the October 28th submittal of the soil results. The list of fields sampled September-October 2016 is provided in Table 1.

For those fields greater than 20 acres, two samples were collected. Table 1 presents the area, annual capacity, and loading data associated with each sub-sample as ½ the actual acreage, capacity and loading data for the entire field. In the event separate seasonal areas were sampled within the same field, then the actual area, capacity and loading data are listed.

Upon completion of sample collection, the samples were specified for analyses of the parameters listed on the April 2016 Work Plan and delivered by Cabot to the UVM Ag Lab on October 6th. The results were received from October 21-27th.

3.0 RESULTS

3.1 ALL FIELDS

A detailed discussion of the results of sampling and analysis is provided in Stone Environmental's Memorandum dated November 21, 2016 (Attachment 1). Stone Environmental's assessment found that in general, the soil quality is consistent with Vermont agricultural soils, for those parameters where baseline or average concentrations have been determined. Soil pH ranged from 5.3-7.1 Standard Units (S.U.), consistent with Vermont soils. Regarding macronutrients (phosphorus, calcium, magnesium, potassium, sulfur) phosphorus levels reported in Cabot soils were slightly lower than levels reported in a 2008 report on the quality of soils in Lake Champlain Basin (Attachment 1). Of the 36 fields, only one was reported at a level higher than 20 parts per million (ppm). During site work in summer 2016, this field (11A in Hardwick) was observed by Bowes Environmental and Cabot to have received at least two separate spray applications of manure-pit waste. These applications were done prior to the September- October soil sampling, and may be the likely cause of elevated phosphorus (see more discussion below). If soil sampling is repeated in future terms, fields included in the Soil Sampling Work Plan that are observed to receive manure, fertilizer, or lime in advance of sample collection will not be sampled, and will be replaced with alternate fields. No other manure-pit applications were observed or indicated in any of the other fields sampled. Calcium levels ranged from 440-2,093 ppm in the Cabot fields. Levels of calcium vary considerably depending on soil type and parent geologic formation (Attachment 1). Magnesium levels in the Cabot fields ranged from 21-144 ppm. Stone noted that although several fields were reported with magnesium levels higher than 100 ppm, their magnesium base saturation levels ranged well below the 20% level where adverse impacts could be possible (Attachment 1). Except for three fields (Attachment 1), potassium levels in the Cabot fields ranged from 22-127 ppm placing them in the "Low" to "Optimum" soil categories.

Results reported for the micronutrients (iron, manganese, boron, copper, zinc) in Cabot field soils were lower than listed Vermont average levels for zinc, boron and manganese; higher for iron, and identical for copper (Attachment 1).

The sodium levels in the Cabot fields ranged from 16-155 ppm, with an average of 52 ppm, which is greater than the Vermont average of 20 ppm. However, Stone calculated the base saturation level for sodium and determined it to range in the Cabot fields from 0.9-5.4%, which is well below the acceptable base saturation limit of 15% (Attachment 1).

3.2 FIELDS REPORTED WITH 'HIGH' NUTRIENT CONTENT

Of the 36 fields, six were reported by UVM Ag Lab with a "High" nutrient content designation, i.e., UVM Ag Lab listed high phosphorus as greater than 10 ppm, and/or magnesium greater than 100 ppm. Table 2 lists the sample results of all fields, with the two Non-applied fields highlighted in gray, the six "High" content fields highlighted in orange, and fields designated "Optimum" or lower non- shaded. The two Non-applied fields (50C-NON and 48A-NON) were collected from non-application areas and represent typical Vermont agricultural field soils. Table 2 demonstrates except for phosphorus and sodium content, there is little variability between the average nutrient concentrations in Non-applied, High, and Optimum-or-lower rated fields, further suggesting that the soil quality reported by the fall sampling is typical for normal Vermont agricultural practices as discussed in Section 3.1. The average extractable phosphorus concentration is higher in the “High” content fields than the Non-applied and Optimum fields. Sodium is higher in both the “High” and “Optimum-or-lower” group fields compared to the Non-applied fields.

The loading rate information in Table 1 demonstrates that over the past year, these six fields were loaded with washwater volumes at a percentage rate ranging from 46.0 – 99.8% of their annual capacities. The lowest amount went to 48A and the highest went to 142A-1. Available phosphorus content in these soils ranged from 4.9 – 21.8 ppm (24.3 – 50.0 ppm as P2O5) and magnesium ranged from 71 – 130 ppm. The field reported with the highest soil phosphorus concentration (Field 11A) was observed on two occasions to have received manure-pit applications prior to the September-October soil sampling. None of the other fields sampled were observed directly or indirectly (evidence of spraying on the field) to have received manure pit applications prior to sampling. As such, the higher phosphorus in Field 11A may be attributable to the manure-pit applications. As described above, although magnesium levels were over 100 ppm in four fields, the magnesium base saturation content was well below the 20% base saturation level where adverse soil impacts could occur (Mg Base Saturation range = 7.9-12.9 %).

Of note is that four of the six fields with “High” reported nutrient content (50C, 11A, 113A and 142A) and eight of the 30 fields designated with ‘Optimum’ or lower nutrient content were recently instrumented for surface and groundwater sampling as part of Cabot’s IDP Renewal. Two rounds of sampling were conducted in August and September 2016, respectively. Although the very dry conditions experienced over the past year combined with negligible snowpack last winter precluded sampling groundwater from the full network of monitoring wells, samples collected from the receiving surface waters for each of the four “High nutrient content” fields and the eight ‘Optimum’ or lower fields demonstrated water quality in compliance with the Vermont Water Quality Standards. Continued water quality monitoring will be conducted at these fields which should enable a more thorough assessment of impacts from washwater applications to these fields with time.

3.3 POTENTIAL FOR NUTRIENT LEACHING

Nutrient leaching potential would be considered higher in those fields with coarse soil texture (especially sand to loamy sand), low soil pH (below 5.5 S.U.), low soil organic matter and higher exchangeable acidity relative to the soil’s total exchange capacity (more than 50% of total exchange capacity consisting of exchangeable acidity rather than exchangeable base cations; Attachment 1). The six fields with ‘high’ reported nutrient content (Section 3.2) generally do not exhibit any of these characteristics. The soil textures in these fields range from sand loam to silt loam, and so generally contain sand-size particles at 70% or less compared to silt or clay (Table 1). Soil pH in these fields is above 6.0 S.U., and soil organic matter content is 4% or higher (Table 2). Exchangeable acidity in the fields with ‘high’ reported nutrient content accounts for 32% or less of the soils’ total exchange capacity (Table 2).

Several fields that did not have ‘high’ reported nutrient content exhibited one or more characteristics that have the potential to promote nutrient leaching. Soil samples from two fields (73C-2 and 98B) had reported soil pH lower than 5.5 S.U. (Table 2). In addition, five fields (73C-1, 73C-2, 17B, 99B-SF, and 98B) had 50% or more of the total exchange capacity consisting of exchangeable acidity rather than exchangeable base cations (Table 2). None of these fields had other characteristics that may indicate particular vulnerability to nutrient leaching; soil textures were reported as sand loam or finer, and soil organic matter in these five fields ranged from 5.1-8.7%. One of the fields in this grouping (73C-1) was recently instrumented for surface and groundwater sampling. As discussed above (Section 3.2), surface and ground water quality monitoring will continue to be conducted at this field, eventually enabling a more thorough assessment of the potential impacts from washwater applications over time.

4.0 SUMMARY AND CONCLUSIONS

Results of the fall 2016 soil sampling reported that in general, the soil quality of the Cabot fields sampled in September-October 2016 are within the optimum range of calcium saturation, and in the lower end or below the optimum range for potassium and magnesium saturation (Attachment 1). Regarding phosphorus, as a group, the Cabot fields tested lower than phosphorus levels in Lake Champlain Basin soils (Attachment 1). One isolated occurrence of elevated phosphorus greater than 20 ppm is likely the result of manure-pit spray applications. The sodium concentrations in the Cabot fields were on average higher than expected Vermont-wide concentrations, however the base saturation levels calculated for sodium (0.9-5.4%) were far less than the 15% limit where adverse impacts could result (Attachment 1).

Nutrient leaching potential was evaluated for both the fields designated with ‘High” reported nutrient content as well as those designated with lower nutrient content. Of the six fields designated with ‘High’ content, none of them exhibit the characteristics of high nutrient leaching potential (Section 3.3). For those designated with lower nutrient content, two fields had reported low soil pH and five had higher exchangeable acidity content when compared to exchangeable base content. Continued surface and ground water quality monitoring will be conducted at twelve of the sampled fields which should enable a more thorough assessment of the potential impact(s) from washwater applications over time.

The September-October 2016 soil sampling marks the first ever program under Cabot’s IDP for soil testing. Overall, the results in general demonstrate soil quality is in accord with Vermont agricultural soils. Bowes Environmental recommends no further soil testing necessary regarding the September- October 2016 soil sampling results.

Please contact me at (802) 839-9241 with questions or comments or if you need more information.

Sincerely,

BOWES ENVIRONMENTAL, LLC

By: Jim Bowes

James R. Bowes, P.G.

Principal

Attachments

C: Aaron Page, Ed Pcolar, Marcel Gravel and Jed Davis, Cabot Creamery via e- mail.

Warren Coleman, Esq. MMR Legal Services, LLC via e-mail.

Amy Macrellis, and Julie Moore, P.E., Stone Environmental via e-mail.

TABLES

TABLE 1 AGRI-MARK, INC
IDP ID 9-0043
LIST OF SOIL SAMPLING FIELDS WITH
ANNUAL LOADING AND UVM AG LAB SOIL
NUTRIENT CONTENT RESULTS

FIELD	OWNER	TOWN	AREA	ANNUAL CAPACITY	PREDOM.SOIL TYPE	Annual Average 5 years (Gallons per year) 1/1/2011 – 12/31/2015	Most Recent Years' Loading (Gallons per Year) 10/1/2015 - 9/30/2016	UVM Lab Soil Report Nutrient Content Category		
								Phosphorus (P)	Potassium (K)	Magnesium (Mg)
103B	BRUNETTO	DANVILLE	3.4	92,317	SAND LOAM	90,000	92,000	LOW	LOW	OPTIMUM
17B	CHANDLER	PEACHAM	17.5	475,160	SAND LOAM	337,680	404,000	LOW	LOW	LOW
17A	CHANDLER	PEACHAM	8.2	222,646	SAND LOAM	144,480	164,000	MEDIUM	LOW	OPTIMUM
98B	DEMERRITT	CRAFTSBURY	11.1	301,387	SAND LOAM	278,560	280,000	MEDIUM	LOW	LOW
113A	DIMICK	HARDWICK	12.7	344,830	SAND LOAM	245,700	208,000	OPTIMUM	LOW	HIGH
132A-1	KOPECKY	MARSHFIELD	12.8	347,546	SAND LOAM	302,040	338,000	MEDIUM	MEDIUM	OPTIMUM
132A-2	KOPECKY	MARSHFIELD	12.8	347,546	SAND LOAM	302,040	338,000	LOW	MEDIUM	MEDIUM
132B	KOPECKY	MARSHFIELD	8.9	241,653	SAND LOAM	178,960	215,990	LOW	LOW	OPTIMUM
50C-YR	LAGGIS	HARDWICK	8.2	222,646	SAND LOAM	168,200	164,000	HIGH	MEDIUM	OPTIMUM
50C-NON	LAGGIS	HARDWICK	2.7	-	SAND LOAM	-	-	OPTIMUM	MEDIUM	OPTIMUM
48A	LAGGIS	HARDWICK	6.4	173,773	SILT LOAM	170,800	80,000	HIGH	OPTIMUM	OPTIMUM
48A-NON	LAGGIS	HARDWICK	6.4	-	SILT LOAM	-	-	MEDIUM	MEDIUM	OPTIMUM
11F -SF	LAGGIS	HARDWICK	11.3	306,818	SAND LOAM	239,352	180,000	OPTIMUM	OPTIMUM	OPTIMUM
100A-SF	PETERSON	CALAIS	14.9	404,565	SILT LOAM	246,414	192,000	MEDIUM	MEDIUM	MEDIUM
100A-S	PETERSON	CALAIS	10.6	287,811	SILT LOAM	141,676	248,000	LOW	LOW	MEDIUM
100B-S	PETERSON	CALAIS	16.7	453,438	SILT LOAM	213,505	428,000	OPTIMUM	MEDIUM	OPTIMUM
100B-SFYR	PETERSON	CALAIS	10.6	287,812	SILT LOAM	221,275	248,000	LOW	LOW	MEDIUM
142A-1	SHATNEY	GREENSBORO	9.0	244,368	SAND LOAM	69,453	244,000	OPTIMUM	LOW	HIGH
142A-2	SHATNEY	GREENSBORO	11.8	320,394	SAND LOAM	311,212	320,000	OPTIMUM	LOW	OPTIMUM
54D	SHERRY	DANVILLE	18.4	499,597	SAND/SILT LOAM	302,000	276,000	LOW	LOW	MEDIUM
54F	SHERRY	DANVILLE	22.4	608,205	SAND/SILT LOAM	460,640	499,950	LOW	LOW	MEDIUM
99B-SF	WRIGHT	WHEELOCK	3.8	103,177	SAND LOAM	59,200	56,000	MEDIUM	LOW	LOW
127A	YOUNG	CRAFTSBURY	13.9	377,413	SAND LOAM	260,000	352,000	OPTIMUM	MEDIUM	OPTIMUM
116A	LYON	BARTON	23.0	551,185	SAND LOAM	301,570	476,000	MEDIUM	LOW	OPTIMUM
110A-YR	SPRAUGES	BROOKFIELD	15.7	426,286	SAND LOAM	177,000	248,400	HIGH	LOW	OPTIMUM
110B-YR	SPRAUGES	BROOKFIELD	29.1	790,123	SAND LOAM	605,200	556,000	OPTIMUM	MEDIUM	OPTIMUM
105C-YR	JAQUISH	BARTON	16.1	437,147	SAND LOAM	393,280	432,000	OPTIMUM	LOW	OPTIMUM
11A - YR	LAGGIS	HARDWICK	7.9	214,501	SAND LOAM	146,960	212,000	HIGH	MEDIUM	HIGH
73A-YR	LAGGIS	HARDWICK	15.4	418,141	SILT LOAM	308,240	416,000	OPTIMUM	MEDIUM	OPTIMUM
73C-1	LAGGIS	HARDWICK	16.1	435,790	SILT LOAM	392,000	434,000	MEDIUM	LOW	OPTIMUM
73C-2	LAGGIS	HARDWICK	16.1	435,790	SILT LOAM	392,000	434,000	OPTIMUM	MEDIUM	MEDIUM
73E- YR	LAGGIS	HARDWICK	11.8	320,394	SILT LOAM	214,240	312,000	OPTIMUM	MEDIUM	OPTIMUM
73K V-YR	LAGGIS	HARDWICK	18.4	249,798	SILT LOAM	246,240	248,000	MEDIUM	LOW	MEDIUM
95E-1	GEORGE	CALAIS	16.7	291,884	SILT LOAM	258,880	288,000	LOW	LOW	LOW
95E-2	GEORGE	CALAIS	16.7	291,884	SILT LOAM	258,880	288,000	LOW	LOW	LOW

1 BLUE shaded entries indicate fields are instrumented with groundwater monitoring wells and surface water sampling.
2 GREEN shaded entries are soil samples collected from NON-application areas.

TABLE 2

				SU	%	ppm												meq/100g		%		
LabID	**CustSampName**	**OrderNo**	**Date**	**pH**	**OM_Pct**	**Avail_P**	**K**	**Ca**	**Mg**	**Zn**	**B**	**Mn**	**Cu**	**Fe**	**Al**	**Na**	**S**	**Exch_Acid**	**ECEC**	**CA_Base_Sat**	**MG_Base_Sat**	**K_Base_Sat**
S16-03649	48A-NON	3499	10/6/2016	6.04	7.514	3.85	51	1391	106	2.6	0.15	7.5	0.7	19.1	53	24	17	2.78	7.97	64.71	8.22	1.22
S16-03651	50C-NON	3499	10/6/2016	6.51	3.237	6.8	67	1108	101	2	0.2	5.2	0.8	6.3	39	37	15	0.36	6.55	80.15	12.18	2.49
			Max	**6.5**	**7.5**	**6.8**	**67**	**1391**	**106**	**2.6**	**0.2**	**7.5**	**0.8**	**19**	**53**	**37**	**17**	**2.8**	**8.0**	**80.2**	**12.2**	**2.5**
			Min	**6.0**	**3.2**	**3.9**	**51**	**1108**	**101**	**2.0**	**0.2**	**5.2**	**0.7**	**6**	**39**	**24**	**15**	**0.4**	**6.6**	**64.7**	**8.2**	**1.2**
			Avg	**6.3**	**5.4**	**5.3**	**59**	**1250**	**104**	**2.3**	**0.2**	**6.4**	**0.8**	**13**	**46**	**31**	**16**	**1.6**	**7.3**	**72.4**	**10.2**	**1.9**
S16-03648	48A	3499	10/6/2016	6.02	5.057	**14.55**	111	1065	97	3.65	0.15	6.1	0.45	7.1	50	19	11	2.31	6.42	60.99	9.26	3.26
S16-03650	50C-YR	3499	10/6/2016	6.44	3.965	**10.55**	67	1065	**110**	2.55	0.2	4.2	0.65	4.7	32	24	11	0.70	6.41	74.86	12.89	2.42
S16-03655	11A-YR	3499	10/6/2016	6.25	9.607	**21.8**	69	1780	**130**	2.85	0.25	6.6	0.2	5.6	29	155	11	2.47	10.16	70.49	8.58	1.40
S16-03670	113A	3499	10/6/2016	6.55	7.15	4.9	48	1496	144	3.15	0.2	3.7	0.7	6.4	63	53	8	1.15	8.80	75.14	12.05	1.24
S16-03674	110A-YR	3499	10/6/2016	6.53	4.602	**10.05**	48	1893	71	1.95	0.2	5	1.15	6.4	55	36	13	0.64	10.18	87.44	5.47	1.14
S16-03675	142A-1	3499	10/6/2016	6.18	8.97	7	36	1833	**123**	1.9	0.25	6.3	0.15	10.8	72	50	10	2.72	10.28	70.48	7.88	0.71
			Max	**6.6**	**9.6**	**22**	**111**	**1893**	**144**	**3.7**	**0.3**	**6.6**	**1.2**	**11**	**72**	**155**	**13**	**2.7**	**10.3**	**87.4**	**12.9**	**3.3**
			Min	**6.0**	**4.0**	**5**	**36**	**1065**	**71**	**1.9**	**0.2**	**3.7**	**0.2**	**5**	**29**	**19**	**8**	**0.6**	**6.4**	**61.0**	**5.5**	**0.7**
			Avg	**6.3**	**6.6**	**11.5**	**63**	**1522**	**113**	**2.7**	**0.2**	**5.3**	**0.6**	**6.8**	**50**	**56**	**11**	**1.7**	**8.7**	**73.2**	**9.4**	**1.7**
S16-03646	132B	3499	10/6/2016	6.78	8.242	2	42	2040	59	0.25	0.15	3.3	0.1	3.8	57	113	7	0.64	10.80	89.19	4.30	0.94
S16-03647	103B-YR	3499	10/6/2016	7.12	4.238	1.6	47	1152	116	0.15	0.2	2.1	0.1	3.3	49	33	8	0.00	6.85	84.12	14.12	1.76
S16-03652	73A-YR	3499	10/6/2016	6.05	5.33	5	62	972	58	1.35	0.15	4.4	0.3	6.2	98	70	13	2.47	5.50	60.98	6.06	1.99
S16-03653	73C-1	3499	10/6/2016	5.62	5.057	3.6	36	672	55	1.65	0.1	6	0.3	10.7	146	32	16	3.94	3.91	42.78	5.84	1.18
S16-03654	73C-2	3499	10/6/2016	5.43	5.785	5	60	525	49	1.85	0.1	6.9	0.45	17.8	183	27	20	4.84	3.19	32.71	5.09	1.92
S16-03656	11F-SF	3499	10/6/2016	6.09	4.966	5.3	127	857	72	1.6	0.15	3.4	0.5	5.7	110	35	14	2.31	5.21	56.95	7.97	4.33
S16-03657	17A-S	3499	10/6/2016	5.86	6.422	2.45	46	761	52	1.05	0.1	7.7	0.1	5.9	104	98	7	3.31	4.36	49.61	5.65	1.54
S16-03658	17B	3499	10/6/2016	5.73	6.695	1.95	43	591	33	0.9	0.05	6.3	0.15	8.1	142	66	8	3.93	3.34	40.64	3.78	1.52
S16-03659	54F	3499	10/6/2016	5.9	7.605	1.2	41	1012	47	0.55	0.1	6.4	0.1	6.6	122	95	10	3.51	5.56	55.81	4.32	1.16
S16-03660	54D	3499	10/6/2016	5.8	6.786	1.55	33	925	38	0.4	0.1	5.7	0.1	6.9	142	37	7	3.73	5.03	52.82	3.62	0.97
S16-03661	95E-1	3499	10/6/2016	6.1	6.24	2	29	1275	22	0.3	0.1	4.7	0.1	6.4	59	41	5	2.35	6.63	71.00	2.04	0.83
S16-03662	95E-2	3499	10/6/2016	6.54	6.786	1.35	26	1499	34	0.25	0.2	3.7	0.1	5.5	57	68	7	1.08	7.85	83.96	3.17	0.75
S16-03663	132A-1	3499	10/6/2016	6.55	8.515	2.5	52	2093	59	0.5	0.25	3.4	0.1	4.2	69	27	6	1.46	11.09	83.39	3.92	1.06
S16-03664	132A-2	3499	10/6/2016	6.11	9.607	1.1	58	1514	45	0.4	0.1	3.6	0.1	8.1	161	50	9	3.43	8.09	65.69	3.25	1.29
S16-03665	73E-YR	3499	10/6/2016	6.16	5.876	6.55	69	1242	76	1.05	0.15	3.3	0.25	8.7	107	31	12	2.27	7.02	66.81	6.81	1.90
S16-03666	100B-S	3499	10/6/2016	6.09	5.239	4.95	78	1067	63	1.1	0.1	5.8	0.1	6.7	64	83	8	2.19	6.06	64.67	6.36	2.42
S16-03667	100B-SFYR	3499	10/6/2016	5.88	6.331	1.95	36	1127	40	0.9	0.1	10.6	0.1	6.3	65	46	6	3.08	6.06	61.66	3.65	1.01
S16-03668	73K-VYR	3499	10/6/2016	5.74	6.149	4.05	33	753	51	1.65	0.1	8.3	0.4	14.7	113	30	14	3.67	4.27	47.41	5.35	1.07
S16-03669	116A-YR	3499	10/6/2016	6.16	4.056	3.7	27	1074	59	1.15	0.1	4	0.15	13.2	20	93	5	1.54	5.93	71.84	6.58	0.93
S16-03671	100A-SF	3499	10/6/2016	5.66	5.694	2.45	66	780	47	1.35	0.1	7.5	0.2	9.5	108	18	9	3.80	4.46	47.20	4.74	2.05
S16-03672	110B-YR	3499	10/6/2016	6.87	5.239	7.5	91	1908	97	4	0.35	5.7	0.6	6	61	45	15	0.00	10.58	90.16	7.64	2.21
S16-03673	110B-SF	3499	10/6/2016	6.98	4.784	7.75	117	1817	99	4.35	0.25	5.8	0.6	6.1	47	39	21	0.00	10.21	88.98	8.08	2.94
S16-03676	142A-2	3499	10/6/2016	5.85	6.604	4.1	22	1002	78	1.7	0.1	6.1	0.1	9.9	119	22	7	3.44	5.72	54.70	7.10	0.62
S16-03677	99B-SF	3499	10/6/2016	5.62	8.697	2.15	40	544	25	0.55	0.05	5	0.1	9.6	264	107	15	5.18	3.03	33.12	2.54	1.25
S16-03678	98B	3499	10/6/2016	5.27	7.969	2.05	29	440	21	0.4	0.05	4	0.15	28	245	81	8	6.05	2.45	25.90	2.06	0.88
S16-03679	100A-S	3499	10/6/2016	6	3.146	1.35	40	803	43	0.4	0.1	3.7	0.1	5.8	114	16	8	2.23	4.48	59.87	5.34	1.53
S16-03680	100A-SF (127A-YR on bag)	3499	10/6/2016	6.4	4.784	8.45	68	1418	94	1.9	0.2	3.2	0.4	6.1	60	33	10	1.11	8.05	77.43	8.56	1.90
S16-03681	105C	3499	10/6/2016	5.91	4.966	4.6	41	1169	67	1.55	0.15	3.2	0.15	10.6	122	32	12	2.92	6.51	61.97	5.92	1.11
			Max	**7.1**	**9.6**	**8.5**	**127**	**2093**	**116**	**4.4**	**0.4**	**10.6**	**0.6**	**28**	**264**	**113**	**21**	**6.0**	**11.1**	**90.2**	**14.1**	**4.3**
			Min	**5.3**	**3.1**	**1.1**	**22**	**440**	**21**	**0.2**	**0.1**	**2.1**	**0.1**	**3**	**20**	**16**	**5**	**0.0**	**2.4**	**25.9**	**2.0**	**0.6**
			Avg	**6.1**	**6.1**	**3.5**	**52**	**1108**	**57**	**1.2**	**0.1**	**5.1**	**0.2**	**9**	**107**	**52**	**10**	**2.7**	**6.2**	**61.5**	**5.5**	**1.5**

Gray shading = Non-application area Field

Orange shading = Field with a 'High' nutrient content designation

Unshaded = Fields designated as "Optimum-or-lower" nutrient content

ATTACHMENT 1

NOVEMBER 21, 2016

MEMORANDUM FROM STONE ENVIRONMENTAL, INC.

TO

JIM BOWES, BOWES ENVIRONMENTAL, LLC

STONE ENVIRONMENTAL
535 Stone Cutters Way / Montpelier / VT / 05602 / USA
802.229.4541 / info@stone-env.com / www.stone-env.com

November 21, 2016

MEMO

To: Jim Bowes

From: Amy Macrellis, Julie Moore

Stone Project No. 15-216
Subject: Cabot IDP – ID-9-0043, Condition J7 Soil Sampling – Results Interpretation Support

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Soil sampling was conducted September 28-October 5, 2016 in accordance with the April 2016 Soil Sampling Work Plan dated March 28, 2016 and amended field list dated April 19, 2016 (as further amended in the memo submitting soil sampling results to the Indirect Discharge Section on October 28, 2016).

According to condition J7 of Cabot's Indirect Discharge Permit ID-9-0043, the soil samples were required to be analyzed, at minimum, for "total exchange capacity, pH, percent organic matter, sulfur, phosphorus (as P_2O_5), calcium, magnesium, potassium, sodium, exchangeable hydrogen and the minor elements".

Soil samples were analyzed by the Agricultural & Environmental Testing Laboratory at the University of Vermont for the following parameters:

- pH
- Macronutrients (phosphorus, calcium, magnesium, potassium, sulfur)
- Micronutrients or "minor elements" (iron, manganese, boron, copper, zinc), along with sodium (required by permit) and aluminum (not required)
- Soil Organic Matter % ("percent organic matter")
- Effective Cation Exchange Capacity (ECEC)
- Exchangeable Acidity ("exchangeable hydrogen")
- Total Exchange Capacity (sum of Effective CEC and Exchangeable Acidity)
- Base Saturation (%) was also reported for calcium, potassium, and magnesium

Each of the parameters, its importance for overall soil health and agricultural fertility, and typical values or ranges are described below, along with a brief assessment of where the soils in the fields tested fall with regard to each of the parameters assessed.

1. Soil pH

Soil pH is derived by measuring the concentration of hydrogen ions in a soil solution (in this case, a mixture of 2 parts soil to 1 part water). The pH scale ranges from 0 (very acid) to 14 (very alkaline), with a pH of 7.0 being neutral (neither acidic nor alkaline). An optimum range or average value for soil pH is not provided in the UVM laboratory's Soil Test Report. Most agricultural soils in Vermont are in the range of pH 5 to pH 7, and most agronomic crops prefer soil pH between 6 and 7 (Darby et al. 2009).

Soil pH has a great effect on the solubility of minerals or nutrients. Fourteen of the seventeen essential plant nutrients are obtained from the soil, and before a nutrient can be used by plants, it must be dissolved in the soil solution (Bickelhaupt, n.d.). Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils.

The 36 fields sampled for this assessment had soil pH ranging from 5.3-7.1, consistent with the typical range of soil pH for Vermont agricultural soils reported above.

2. Macronutrients

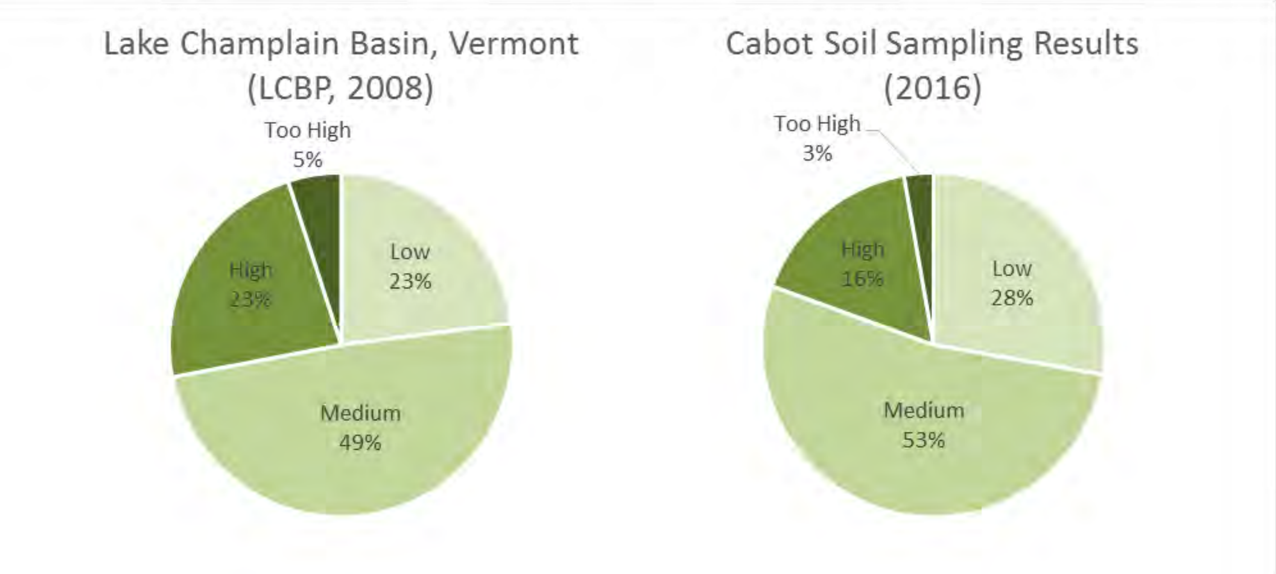
Analysis for macronutrients and micronutrients at the UVM Agricultural & Environmental Testing is completed using a modified-Morgan's solution to extract nutrients from soil for further analysis. Research in Vermont, New York, and other New England states has shown it to be a good indicator of plant availability (Jokela et al. 2004). This method results in a reasonable assessment of plant-available soil nutrients, as well as the potential for nutrients to be leached from the soil. It does not represent the total amounts of macro- and micro-nutrients present in soil. Measurements of total nutrient content are not useful indicators of sufficiency for plant growth, because only a small portion of the nutrients are plant-available.

2.1 Phosphorus

Phosphorus provides plants with a means of using the energy harnessed by photosynthesis to drive its metabolism. A deficiency of this nutrient can lead to impaired vegetative growth, weak root systems, poor fruit and seed quality, and low yield; however, excessive soil phosphorus levels are a concern due to the potential negative impact on surface water quality (Spargo et al. 2013).

Some phosphorus is present as part of soil organic matter and becomes available to plants as the organic matter decomposes. Most inorganic soil phosphorus is bound tightly to the surface of soil minerals (e.g., iron and aluminum oxides). Warm, moist, well-aerated soils at a pH of about 6.5 optimize the release of both of these forms. Optimum ranges for available phosphorus are provided in the UVM laboratory's Soil Test Report. When a soil test indicates that phosphorus is low (less than 2.0 ppm) or medium (2.1-4.0 ppm), fertilizer application is recommended at rates intended to satisfy immediate crop needs and begin to build soil phosphorus levels to the optimum range (i.e., build and maintain). Once soil test levels are in the optimum range (4.1-7.0 ppm), only a small amount of phosphorus is needed to replace removal and maintain soil levels. If soil test results indicate levels are higher than optimum (7.1-20 ppm), phosphorus application is unnecessary and should be limited. Where soil phosphorus levels are excessive (greater than 20 ppm), phosphorus application is required to be eliminated under Vermont's proposed Required Agricultural Practices (VT AAFM, 2016).

The 36 fields sampled for this assessment had extractable soil P ranging from 1.1-21.8 ppm. The overall distribution of soil test P values was somewhat lower than those reported in the Lake Champlain Basin Program's "State of the Lake" report from 2008, with 81% of the results having P values of 7.0 ppm or less (see the pie charts below). Only one of the fields assessed had soil test P higher than 20 ppm, where no further P application will be allowed under the proposed RAPs.



Note that the RAPs regulate soil test P as reported in ppm, but IDP permit condition J7 requires phosphorus to be reported as P_2O_5. To convert to P_2O_5, multiply P (ppm) by 2.2915.

2.2 Calcium

Calcium is a major nutrient cation, and is essential for proper functioning of plant cell walls and membranes (Spargo et al. 2013). Levels of extractable calcium in soils vary substantially depending on soil type and parent geologic materials, as well as on the history of crop rotation and lime application on each individual field. Optimum ranges for calcium also vary by crop, and so no optimum range or average value was provided with the soil test results. Soils with lower pH will tend to have lower calcium levels, and may require amendment with lime to supply sufficient calcium to plants. The 36 fields sampled for this assessment had extractable soil calcium ranging from 440-2,093 ppm.

2.3 Magnesium

Magnesium is also a major nutrient cation. Magnesium acts together with phosphorus to drive plant metabolism and is part of chlorophyll, a vital substance for photosynthesis. Finer-textured soil types, and especially some clays, can have naturally higher magnesium levels. Like calcium, if levels of magnesium in the soil are low, amendments are ordinarily supplied through application of lime or Epsom salts (Spargo et al. 2013). The optimum range for magnesium provided in the UVM laboratory's Soil Test Report is 50-120 ppm. When a soil test indicates that magnesium is low (less than 35 ppm) or medium (36-50 ppm), fertilizer application is recommended at rates intended to satisfy crop needs and begin to build magnesium levels to the optimum range. Once soil test levels are in the optimum range (51-100 ppm), only small amounts are needed to maintain soil levels. If soil test results indicate levels are higher than optimum (>100 ppm), further amendment is not needed.

The 36 fields sampled for this assessment had extractable soil magnesium ranging from 21-144 ppm. Seven of the tested fields had magnesium concentrations higher than 100 ppm, and three of these had concentrations higher than120 ppm. While excessively high soil magnesium can result in soils that tend towards surface compaction or poor internal drainage, these conditions only tend to occur when magnesium accounts for more than 20% of base saturation levels (Midwest Laboratories, n.d.). For soil tests with magnesium concentrations higher than 100 ppm, magnesium base saturation levels ranged from 7.9-14.1%, well below the 20% threshold.

2.4 Potassium

Potassium is responsible for the regulation of water usage in plants, disease resistance, stem strength, photosynthesis, and protein synthesis (Darby et al. 2009). Potassium rivals nitrogen as the nutrient absorbed in greatest amounts by plants and, as with nitrogen, crops take up a relatively large proportion of plant-available potassium each growing season (Spargo et al. 2013). Most available potassium exists in soil as an exchangeable cation. The slow release of potassium from native soil minerals and from fixed forms in clays can replenish some of the potassium lost by crop removal and leaching, but this ability is limited and variable. Sandy soils with very low cation exchange capacity tend to lose substantial quantities of potassium due to leaching.

The optimum range for potassium provided in the UVM laboratory's Soil Test Report is 100-160 ppm. When a soil test indicates that potassium is low (less than 50 ppm) or medium (51-100 ppm), fertilizer application is recommended at rates intended to satisfy crop needs and begin to build potassium levels to the optimum range. Once soil test levels are in the optimum range (101-130 ppm), only small amounts are needed to maintain soil levels. If soil test results indicate levels are higher than optimum (>131-160 ppm), or are excessive (>160 ppm), further amendment is not needed.

The 36 fields sampled for this assessment had extractable soil magnesium ranging from 22-127 ppm, corresponding with the "low" to "optimum" ranges identified above. All but three of the fields had exchangeable potassium levels lower than 100 ppm.

2.5 Sulfur

The vast majority of sulfur in soil is stored in soil organic matter and is converted to available mineral form by the action of soil microorganisms (Spargo et al. 2013). In New England, atmospheric deposition resulting from combustion of fossil fuels has historically contributed significant amounts of sulfur to soil each year; however, with improved emissions control and the use of cleaner fuels, sulfur deposition has been reduced.

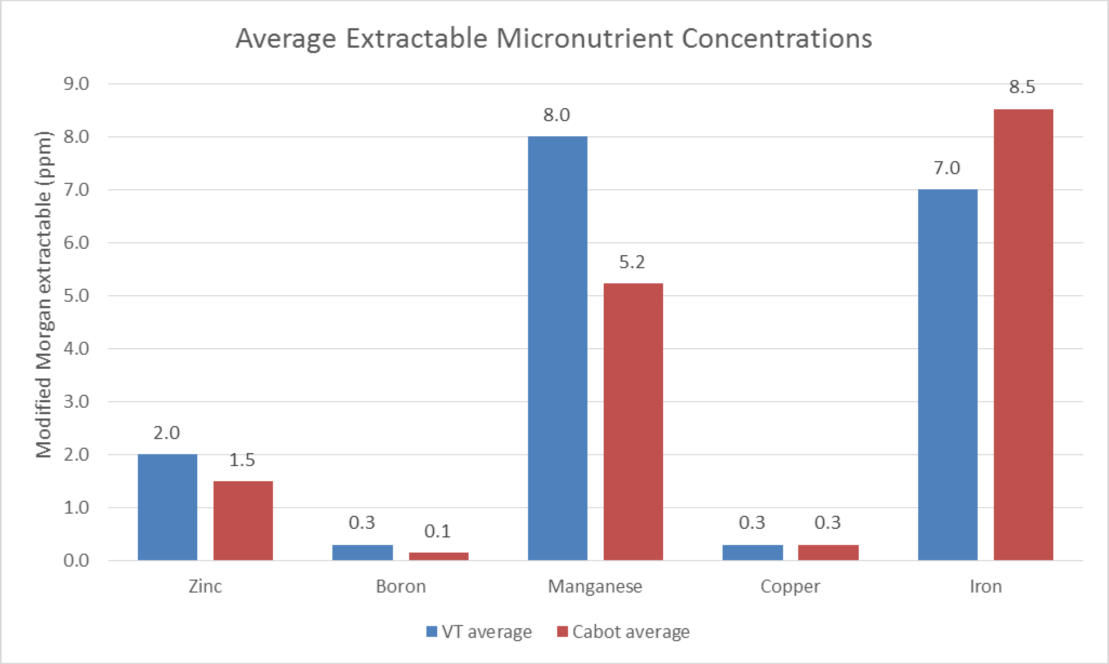
Sulfur deficiencies are rare in Vermont and optimum ranges are not defined. Instead, the average value provided in the UVM laboratory's Soil Test Report is 11 ppm. The 36 fields sampled for this assessment had extractable soil sulfur ranging from 5-21 ppm, and the average across the fields was 10.6 ppm.

2.6 Nitrogen

Nitrogen an essential macronutrient for nearly every aspect of plant growth. Nitrogen is absorbed by plants as nitrate (NO_3^-) and ammonium (NH_4^+), but levels of these dissolved nitrogen compounds fluctuate widely with soil and weather conditions over very short periods of time (Spargo et al. 2013). Soil nitrogen testing was not required under condition J7 of Cabot's IDP. In any case, this analysis would be not be completed until shortly before fertilizer application in the spring, as for the pre-sidedress nitrate test (PSNT) where annual sampling is required because soil nitrate levels can vary greatly from one year to the next, depending on soil and weather conditions (Jokela et al. 2004).

3. Micronutrients / "Minor Elements"

Micronutrients are elements essential to plants that are required in very small amounts. Five of these (iron, manganese, boron, copper, zinc) are tested routinely. Micronutrient deficiencies are most likely to occur in sandy, low organic matter soils (Spargo et al. 2013). High soil pH may also bring about micronutrient deficiencies, especially in sandy soils. Micronutrient deficiencies are rarely observed in Vermont field and forage crops, likely due to historical and present practices with regard to manure application on agricultural soils (Darby et al. 2009). There limited exceptions, for example, occasional zinc deficiency in corn, and boron deficiency in alfalfa and bird's-foot trefoil as Vermont soils tend to be low in boron (Darby et al. 2009). For this reason, optimum ranges have not been defined. Instead, average values for Vermont soils are provided in the UVM laboratory's Soil Test Reports. The bar chart below compares the average values across Vermont provided in the laboratory soil test reports with the average values from the 36 fields tested for this assessment. The fields tested for this assessment tended to have lower extractable zinc, boron, and manganese concentrations; higher iron concentrations; and identical copper concentrations when compared to Vermont-wide averages.



3.1 Sodium

Sodium is a cation that is sometimes adsorbed onto soils, and is part of the cation exchange capacity of the soil. Unlike the other base cations (calcium, magnesium and potassium), sodium is not an essential element for all plants. Soils that contain high levels of sodium can develop salinity problems, primarily in areas where crops are routinely irrigated with saline irrigation water. Excessive sodium in soils may also become a concern where biosolids or food processing waste-streams are land-applied over long time periods (Clemson University 2015). The acceptable base saturation limit for sodium is 15%--meaning that where sodium ions make up more than 15% of a soil's total cation exchange capacity (see below), impacts such as soil dispersion, poor water infiltration, and possible sodium toxicity to plants may result (Pearson 2003, Clemson University 2015).

Testing for sodium was required under condition J7 of Cabot's IDP. The 36 fields sampled for this assessment had extractable sodium concentrations ranging from 16-155 ppm with an average of 52 ppm, which is higher than the Vermont-wide average of 20 ppm reported in the UVM laboratory's Soil Test Reports. Sodium is present in the washwater land-applied to fields under Cabot's program (see the Stone memo titled "Summary of Washwater Characteristics and Chemical Product Use at Cabot", dated January 22, 2016). As discussed further below, however, exchangeable sodium makes up only 0.9-5.4% of the cation exchange capacity across all tested fields. While extractable sodium in the fields tested is somewhat elevated relative to the average exchangeable sodium reported across all Vermont soils, this parameter is not elevated to a level that may be cause for concern.

3.2 Aluminum

Aluminum is not a plant nutrient, but it is a major component of soils. The aluminum content of soil is predominantly driven by the mineralogy of the parent geologic material, weathering history, and soil pH, rather than by amendment or agricultural use of the soil. In soil solution, aluminum is an acidic cation, and thus is included with hydrogen in the calculation of a soil's exchangeable acidity (see below). At elevated levels it can be toxic to plant roots and limit the ability of plants to take up phosphorus by reducing phosphorus solubility (Spargo et al. 2013). Aluminum sensitivity varies greatly with plant type. Extractable aluminum increases somewhat at soil pH below 5.5, and increases dramatically at soil pH below 5.0 (Spargo et al. 2013). Proper liming can lower aluminum solubility to acceptable levels.

Testing for aluminum was not required under condition J7 of Cabot's IDP. It is included in the soil test results because phosphorus recommendations for agronomic crops in Vermont are based on a combination of the available phosphorus soil test (P extracted with Modified Morgan's solution) and reactive aluminum (Al in the same extractant) (Jokela et al. 2004). Reactive aluminum is an indicator of a soil's ability to fix, or tie up, added phosphorus. Thus, low P-testing soils with high aluminum levels require greater amounts of added P to provide an adequate P supply to the crop and to raise soil test P (Jokela et al. 2004).

The 36 fields sampled for this assessment had extractable aluminum concentrations ranging from 20-264 ppm with an average of 95 ppm, which is substantially higher than the Vermont-wide average of 35 ppm reported in the UVM laboratory's Soil Test Reports. Aluminum is included in the toxic scan analysis (condition J9 of the Cabot's IDP), and was not detected at levels above laboratory reporting limits (see the Stone memo titled "Summary of Washwater Characteristics and Chemical Product Use at Cabot", dated January 22, 2016). The elevated aluminum levels observed on fields included in this testing program are more likely the product of generally acidic soil pH and parent material geology than of washwater application. None of the fields sampled had soil pH below 5.0, indicating that issues related to excessive aluminum, if any, are minor.

4. Soil Organic Matter % ("percent organic matter")

Soil organic matter (SOM) is composed of materials containing carbon—plant and animal remains including bacteria and fungi in various stages of decomposition, root and microbial exudates, and humus (the end-product of decay, which is resistant to further decomposition). Native soil organic matter content of most cultivated or developed areas of New England is almost always less than 8% and typically in the 2 to 4%

range (Spargo et al. 2013). Despite the low SOM content of many New England soils, it is an important component of soil for nutrient supply, water holding capacity, cation exchange capacity, and soil structure.

The optimum range for SOM varies with soil type and crop, and thus an optimum range is not offered in the UVM laboratory's Soil Test Reports. Generally, lower levels of SOM are sufficient, and practical to achieve, in coarse textured, sandy soils as compared to finer soils with more clay content. For example, 2.5% SOM in a loamy sand soil might be considered ideal, while 2.5% could be considered marginal in a silt loam soil where 3 to 5% is more common (Spargo et al. 2013).

The 36 fields sampled for this assessment had SOM percentages ranging from 3.1-9.6% with an average of 6.2%. This is a slightly higher range of SOM content than commonly expected for New England soils, which is a positive result from the perspective of soil health and the soil's overall ability to retain exchangeable nutrients and limit nutrient leaching.

5. Effective Cation Exchange Capacity

Mineral cations within the soil have either a positive or negative charge. The cations with a positive charge are held by negatively charged clay particles and organic matter. The main exchangeable cations in soil are calcium, magnesium, potassium and to a lesser extent ammonium (which are nutrients) added to sodium, aluminum, and hydrogen. "Exchangeable" means that they are held loosely enough in the minerals which make up soils, and the organic matter in soils, so that they can be used by plants.

Cation exchange capacity (CEC) refers to a soil's ability to retain these nutrients, rather than having them leached away (Darby et al. 2009). The more clay and organic matter in a soil, at near neutral pH, the higher the soil's CEC. If there are too many non-nutrients (for example, in irrigation water), these can displace nutrient cations. Soils with higher clay and silt content tend to have higher levels of exchangeable calcium and magnesium, and lower levels of acidity (hydrogen ions) and aluminum. Soils which are sandier tend to be more acidic, and thus to contain more exchangeable hydrogen and aluminum, and less calcium and magnesium. Low CEC soils are more susceptible to cation nutrient loss through leaching.

The effective CEC reported by the UVM laboratory was calculated by summing only the millequivalents per 100 grams of soil (meq/100g) for the major basic nutrient cations (exchangeable potassium, magnesium, and calcium) extracted in the soil analysis. In most soils in humid regions such as in New England, sodium is not present in sufficient quantities to occupy a significant amount of the CEC (Ketterings et al. 2007). However, if excessive sodium is of concern, then exchangeable sodium should be included in the calculation of effective CEC. The effective CEC was therefore re-calculated to include exchangeable sodium (see table on the following page). This change affects calculation of the total exchange capacity and the reported base

Sample ID	Exchangeable Acidity (meq/100g)	Effective CEC (meq/100g) Reported by	Effective CEC (meq/100g) Including Exchangeable Na	Total Exchange Capacity (meq/100g)	Calcium Saturation (%)	Magnesium Saturation (%)	Potassium Saturation (%)	Sodium Saturation (%)	Total Base Saturation (%)
132B	0.64	10.80	11.29	11.93	85.51	4.12	0.90	4.12	95
103B-YR	0.00	6.85	6.99	6.99	82.40	13.83	1.72	2.05	100
48A	2.31	6.42	6.50	8.81	60.41	9.17	3.23	0.94	74
48A-NON	2.78	7.97	8.07	10.85	64.09	8.14	1.20	0.96	74
50C-YR	0.70	6.41	6.52	7.22	73.78	12.70	2.38	1.45	90
50C-NON	0.36	6.55	6.71	7.07	78.33	11.90	2.43	2.27	95
73A-YR	2.47	5.50	5.81	8.27	58.74	5.84	1.92	3.68	70
73C-1	3.94	3.91	4.05	7.99	42.03	5.73	1.15	1.74	51
73C-2	4.84	3.19	3.30	8.14	32.24	5.02	1.89	1.44	41
11A-YR	2.47	10.16	10.83	13.30	66.92	8.15	1.33	5.07	81
11F-SF	2.31	5.21	5.36	7.68	55.82	7.82	4.24	1.98	70
17A-S	3.31	4.36	4.78	8.10	47.00	5.35	1.46	5.26	59
17B	3.93	3.34	3.63	7.56	39.10	3.64	1.46	3.80	48
54F	3.51	5.56	5.97	9.48	53.38	4.13	1.11	4.36	63
54D	3.73	5.03	5.19	8.92	51.87	3.55	0.95	1.80	58
95E-1	2.35	6.63	6.81	9.16	69.62	2.00	0.81	1.95	74
95E-2	1.08	7.85	8.14	9.22	81.27	3.07	0.72	3.21	88
132A-1	1.46	11.09	11.21	12.67	82.61	3.88	1.05	0.93	88
132A-2	3.43	8.09	8.31	11.74	64.47	3.19	1.27	1.85	71
73E-YR	2.27	7.02	7.16	9.43	65.86	6.72	1.88	1.43	76
100B-S	2.19	6.06	6.42	8.61	61.96	6.10	2.32	4.19	75
100B-SFYR	3.08	6.06	6.26	9.34	60.34	3.57	0.99	2.14	67
73K-VYR	3.67	4.27	4.41	8.07	46.65	5.27	1.05	1.62	55
116A-YR	1.54	5.93	6.34	7.88	68.15	6.24	0.88	5.13	80
113A	1.15	8.80	9.03	10.19	73.44	11.78	1.21	2.26	89
100A-SF	3.80	4.46	4.54	8.34	46.75	4.70	2.03	0.94	54
110B-YR	0.00	10.58	10.78	10.78	88.52	7.50	2.17	1.82	100
110B-SF	0.00	10.21	10.38	10.38	87.53	7.95	2.89	1.63	100
110A-YR	0.64	10.18	10.34	10.98	86.19	5.39	1.12	1.43	94
142A-1	2.72	10.28	10.50	13.22	69.32	7.75	0.70	1.64	79
142A-2	3.44	5.72	5.81	9.25	54.13	7.02	0.61	1.03	63
99B-SF	5.18	3.03	3.50	8.68	31.34	2.40	1.18	5.36	40
98B	6.05	2.45	2.80	8.85	24.87	1.98	0.84	3.98	32
100A-S	2.23	4.48	4.55	6.78	59.25	5.29	1.51	1.03	67
127A-YR	1.11	8.05	8.19	9.30	76.24	8.42	1.87	1.54	88
105C	2.92	6.51	6.65	9.57	61.07	5.83	1.10	1.45	69

saturation percentages for calcium, magnesium, and potassium, which are also re-calculated and reported in the table.

The 36 fields sampled for this assessment had effective CEC ranging from 2.8-11.3 meq/100g with an average of 6.9 meq/100g. As with soil organic matter and exchangeable calcium, optimum ranges for effective CEC vary with soil type and crop, and thus a desired range is not offered in the UVM laboratory's Soil Test Reports for comparative purposes.

6. Exchangeable Acidity ("exchangeable hydrogen")

Exchangeable acidity is a measurement of the amount of the soil's total exchange capacity occupied by major acidic cations (hydrogen and aluminum). The acidity, like the effective CEC, is expressed as meq/100g of soil. Finer-textured soils such as clays, as well as those high in organic matter, tend to have higher pH, a high cation exchange capacity (CEC) and a potential for lesser amounts of exchangeable acidity (Spargo et al. 2013). These soils are said to be well buffered. If the soil is acidic (pH less than 7.0) and exchangeable acidity represents a large proportion of the soil's total exchange capacity, the availability of nitrogen, phosphorus, and potassium may be reduced, and there are usually low amounts of calcium and magnesium in the soil (Spargo et al. 2013). The more acidic a soil is and the lower the soil pH value, the closer the exchangeable acidity value will be to the total exchange capacity.

The 36 fields sampled for this assessment had exchangeable acidity ranging from 0.0-6.0 meq/100g with an average of 2.4 meq/100g. Exchangeable acidity is a supplemental analysis, and so although it is used in the calculation of percent base saturation on the Soil Test Reports, an optimum range or average value is not offered by the laboratory for comparative purposes.

7. Total Exchange Capacity

Total exchange capacity is calculated by adding together the meq% values for calcium, magnesium, potassium, sodium and exchangeable acidity for a given soil sample. The total exchange capacity is utilized when calculating percent base saturation for the major basic cations (see below). Total exchange capacity values as calculated for each of the fields sampled for this assessment are included in the table on the previous page. Total exchange capacity values ranged from 6.8-11.3 meq/100g, with an average of 9.3 meq/100g.

8. Percent Base Saturation

The concept of base saturation is a useful indicator, because the relative proportion of acids and bases on the exchange sites determines a soil's pH. As the number of calcium and magnesium ions decreases and the number of hydrogen and aluminum ions increases, the pH drops. Adding lime to a soil replaces acidic hydrogen and aluminum cations with basic calcium and magnesium cations, which increases base saturation and raises the pH. Soils having a high CEC and high buffer capacity change pH much more slowly under normal management than low-CEC soils. On low-CEC soils, some leaching of cations can occur, and so fall fertilizer applications, especially of ammonium N and potassium, could result in some leaching below the root zone, particularly in the case of sandy soils (Clemson University, 2015).

The Percent Base Saturation is calculated by dividing the milliequivalents of each of the exchangeable basic cations (calcium, magnesium, potassium, and sodium) but the total exchange capacity for the soil sample. Note that, in the Soil Test Reports provided by the UVM laboratory, the percent base saturation values do not account for exchangeable sodium, and thus are slightly lower across the entire dataset. The table below compares minimum, maximum, and average percent base saturation values across the 36 fields sampled for this assessment with the ranges of calcium, magnesium and potassium base saturation provided for soils across Vermont on the Soil Test Reports.

	UVM optimum range	UVM Average Percent Saturation (not including sodium)	Cabot Soils Range	Cabot Soils Average
Calcium Saturation (%)	40-80	64	25-89	63
Potassium Saturation (%)	2.0-7.0	1.6	0.6-4.2	1.5
Magnesium Saturation (%)	10-30	6.4	2.0-13.8	6.3
Sodium Saturation (%)	n/a	n/a	0.9-5.4	2.4

Overall, the fields sampled tend fall within the optimum range of calcium saturation provided on the UVM Soil Test Reports for Vermont soils, and to fall towards the low end of or below the optimum range with regard to potassium and magnesium saturation. As discussed in Section 5 above, sodium saturation falls well below the 15% saturation threshold where negative impacts from excessive exchangeable sodium might be anticipated. A few of the fields included in this testing program, those with soil pH below 5.5 and total base saturation less than 50%, may be particularly vulnerable to nutrient leaching.

9. References

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