Management of Acid Producing Materials for the Route 220 Project in Virginia

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Topics for Today

- **Quick review of issues with acid forming materials (AFM) in Virginia road corridors.**
- **Describe the Route 220 Project (2016 to 2023) and procedures employed to mitigate potential AFM impacts**
- **Review a new detailed field procedure developed for field ID and AFM characterization**
- **Present water quality monitoring data for project**

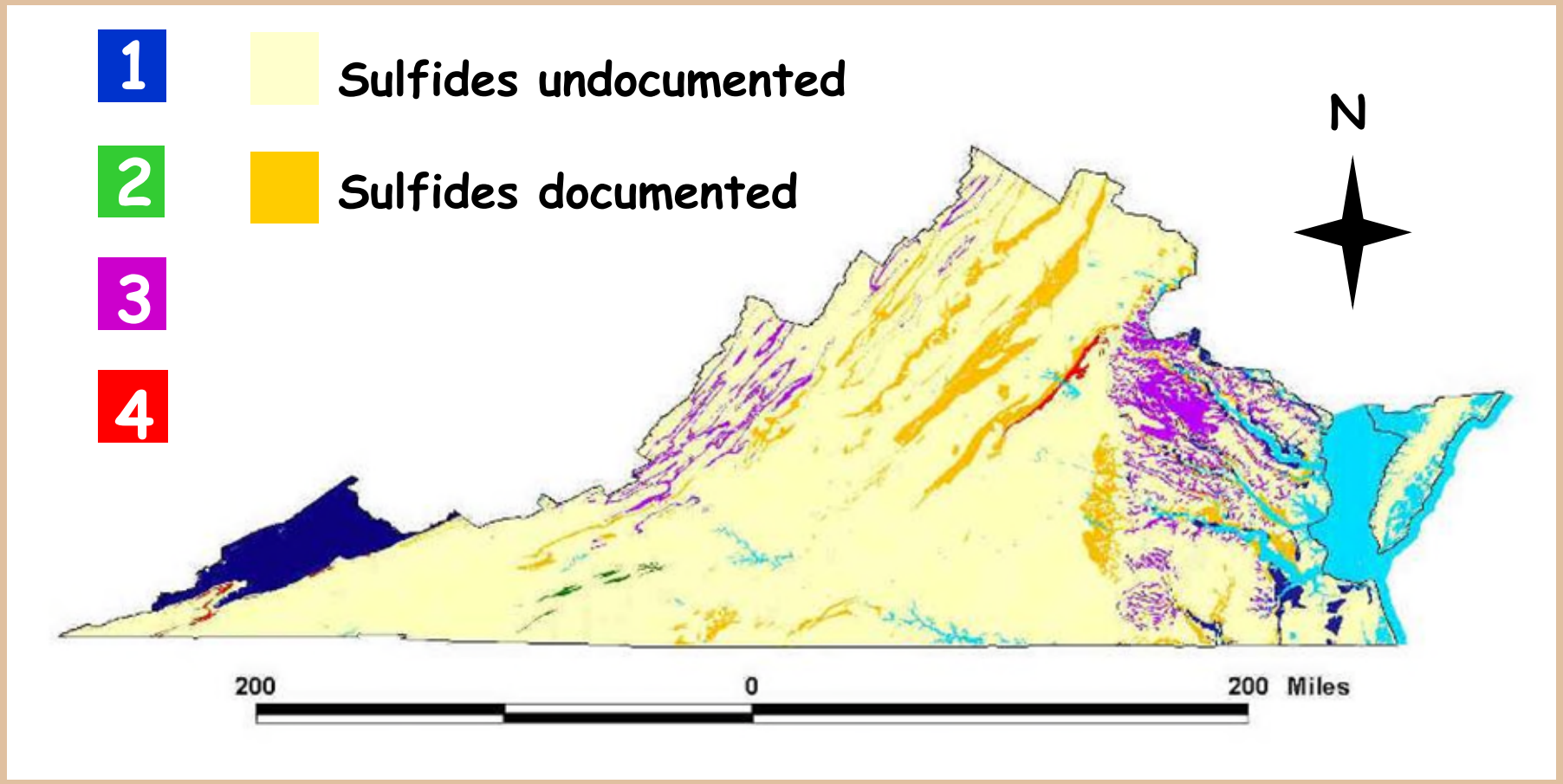
Background/Rationale

Accurate and rapid prediction of the acid-forming potential of geologic materials in a field setting is challenging and most projects and their analysts rely on conventional acid base accounting (ABA) lab procedures to determine relative risk and appropriate liming requirements.

Road improvements for Route 220 in Botetourt County, Virginia, will cut and fill large volumes of soil/saprolite/rock materials derived from potentially acid-forming Devonian black shales.

VDOT permit requirements mandate separating all handled materials into four different categories of acid formation risk with differing liming and/or placement procedures.

Orndorff (2001) -Compiling a state-wide sulfide hazard map for Virginia: the final map.



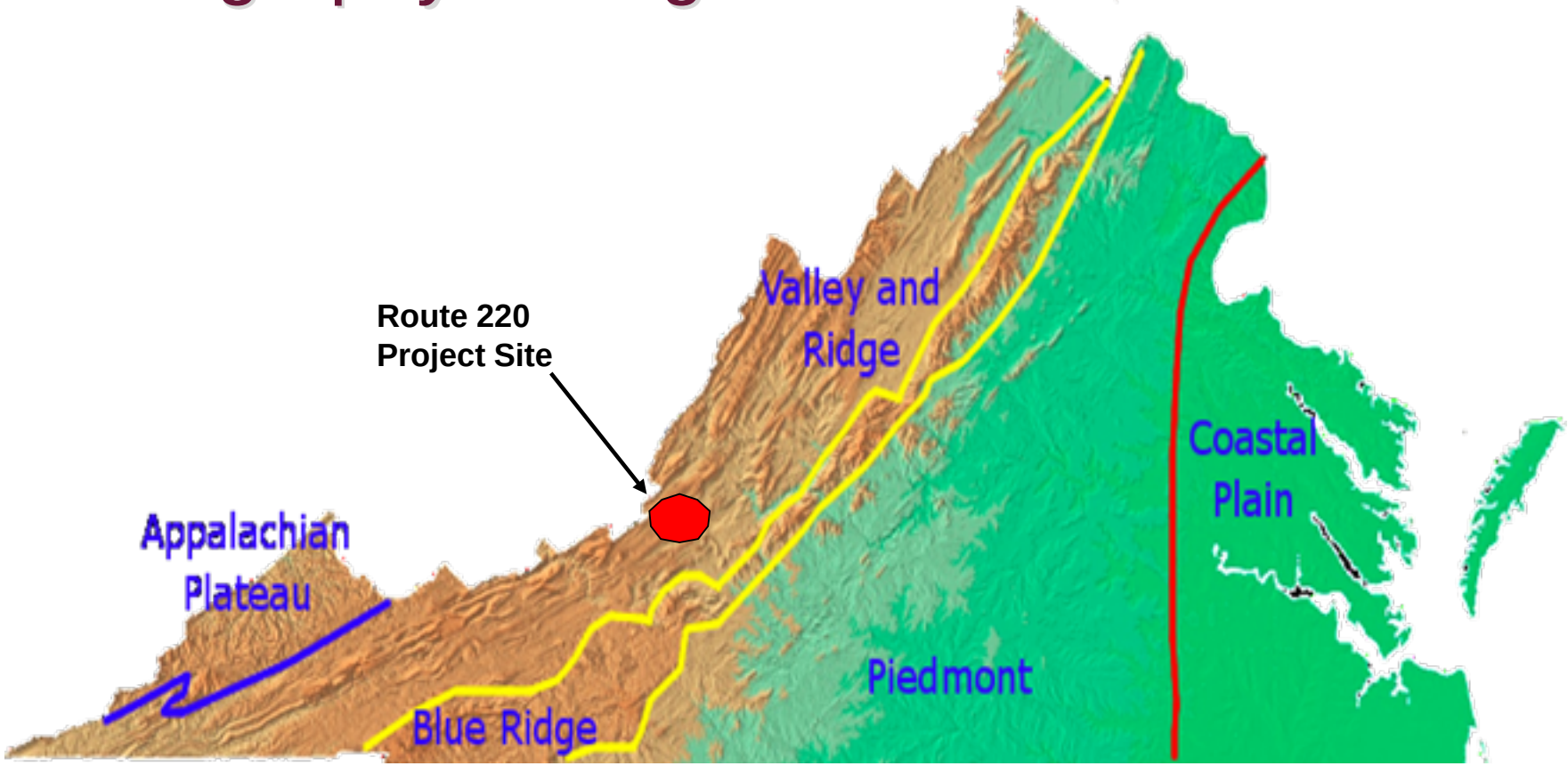
Compiling a state-wide sulfide hazard map for Virginia: Devonian black shales.

Culvert beneath I-64 in Clifton Forge

Compiling a state-wide sulfide hazard map for Virginia: Devonian black shales.

Inside the culvert at Clifton Forge.

Geography of Virginia



http://www.virginiaplaces.org/regions/ and
http://www.virginiaplaces.org/regions/physio.html

Image and water sample location map for Route 220 project in Botetourt County, Virginia.

Entire section between points 1 and 11 involves excavations to 15 m or more into Devonian “black shales” that are locally sulfide rich, but highly folded and variable in spatial distribution of sulfides.

Field Sampling / Lab Testing

- **VDOT/Cardno/ECS ran ABA on 56 samples before design/build RFP was released and used those data to approximate potential volumes of acid-forming materials.**

- **Used PA DOT criteria for developing liming recommendations. Based largely on Bald Eagle Mountain APM problems.**

Acid Base Accounting (ABA)

- **Conventional EPA x WV ABA procedures, but with Skousen et al. modified method for siderite.**
- **MPA = maximum potential acidity based on total-S**
- **NP = neutralization potential via titration**
- **NNP = net neutralization potential (NP minus MPA)**

- **Units given in ppt net CCE (or mg/kg) = tons of CCE ag lime needed per thousand tons material (or AFS)**
- **General coal mining threshold for potentially toxic materials is – 5 tons/1000.**
- **NPR = ratio of NP to MPA; > 2.0 supposedly indicates minimal risk of long-term acid generation (Skousen et al. 2002).**

Original VDOT RFP Criteria

- **Category 1: All materials with S > 0.2% and NNP < -5 ppt; Isolate and/or *lime to NNP of +24 ppt*.**

- **Category 2: Materials with S < 0.2%, pH < 5.0 and NNP between -5 and +5 ppt. *Lime to NNP of +24 ppt.***

- **Category 3: NNP between +5 and +30; slight HCL fizz. No treatment needed.**

- **Category 4: NNP > +30 ppt; can be used to mix with/treat Category 2 materials.**

Approximate Volumes (Original RFP Criteria)

- Approximately 450,000 m^3 of total cut/fill materials
- Approximately 60,000 m^3 of Category 1
- Approximately 100,000 m^3 of Category 2
- No apparent Category 3
- Approximately 55,000 m^3 of “unknown”

Field Sampling / Lab Testing

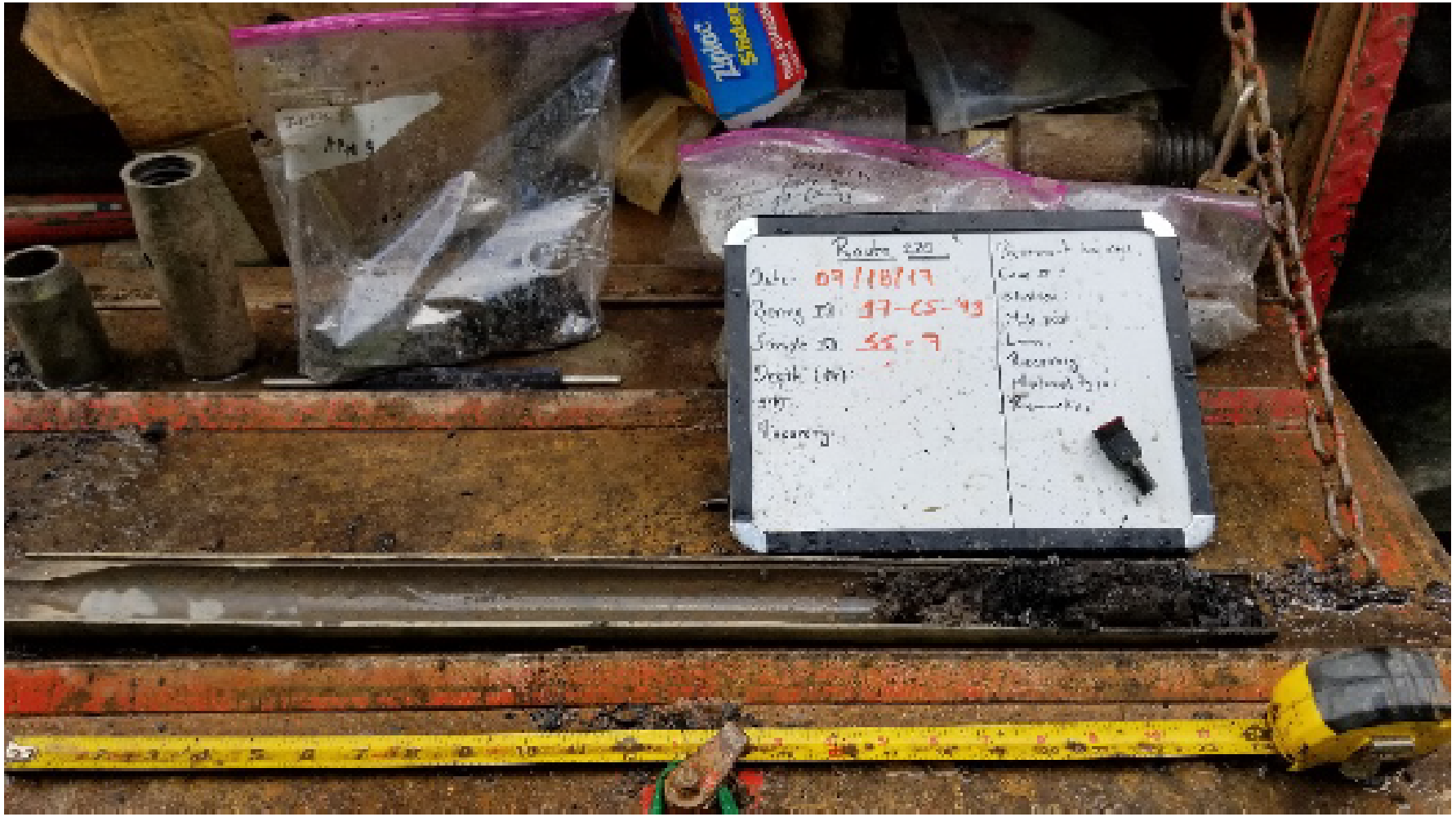
- **CH2M/Jacobs and Faulconer (contractor) won design/build bid competition in 2017.**

- **CH2M/Jacobs advanced 90 additional bore holes with multiple samples taken of soil, weathered and hard rock zones with depth. VT trained the field crew for soil descriptions, color, hardness, etc.**

- **Virginia Tech ran ABA on > 340 samples along with 30% H_2O_2 and HCl fizz and color determinations.**

New drill cores were taken every 30 m in an offset pattern up and down slope to better define location of acid producing materials (APMS).

APM, CATEGORY 1 - TYPICAL



17-CS-43 (0 - 22 feet)

17-CS-39 (23 – 29 feet)

VDOT Project No. 0220-011-786, UPC 105543

blk = 2.5YR 2.5/1, 5YR 2.5/1, 7.5YR 2.5/1, and 10YR 2/1

Acid-Base Accounting Results for All Cut Borings

Number	Station	Boring	Sample ID	Sample Depth (ft)	Test Above Cut	Type of Material	Color	Munsell Soil Color (moist)	Munsell Soil Color (dry)	NP	% S	MPA	NNP	NP/MPA	pH	EC	H2O2 Fizz #	Sobek Fizz #	Collection Date	RFP Categorization	NPR Categorization	Required Neutralization Potential-NPR Method (ppt)
1	373+82	17-CS-01	APM 1	0.0-3	Y	CL-ML	orange	7.5YR 5/6 (<5% 10YR 6/4)	7.5YR 6/6	-0.49	0.038	1.19	-1.68	-0.41	6.89	0.03	1.00	0.00	6/28/2017	Category 2	Category 2	4.05
2	373+82	17-CS-01	APM 2	3.0-8.2	Y	CL	tan and gy	7.5YR 5/6, 7/4 (<5% 7.5YR 3/0)	10YR 7/6, 8/1 (<5% 7.5YR 4/6)	2.86	0.022	0.69	2.17	4.16	5.07	0.04	0.00	0.00	6/28/2017	Category 2	Category 2	2.00
3	373+82	17-CS-01	APM 3	8.2-14	Y	ML	dk gy	5YR 3/1 (10%2.5YR 4/6)	10YR 5/1 (10%5YR 5/6)	2.7	0.041	1.28	1.42	2.11	4.85	0.08	2.00	0.00	6/28/2017	Category 2	Category 2	2.00
4	373+82	17-CS-01	APM 5	14-19	Y	SHL	dk gy	7.5YR 3/0	10YR 3/1 (<5% 10YR 6/6)	2.94	0.413	12.91	-9.97	0.23	3.63	2.45	3.00	0.00	6/28/2017	Category 1	Category 1	35.78
5	373+97	17-CS-02	APM 1	0.7-4	Y	ML/SM	dk brwn	10YR 6/4, 5/3, 3/1 (5% 7.5YR 5/6)	10YR 7/2, 6/1, 7/3 (5% 7.5YR 5/8)	2.45	0.035	1.09	1.36	2.24	5.39	0.05	3.00	0.00	6/28/2017	Category 2	Category 2	2.00
6	373+97	17-CS-02	APM 2	4.0-10	Y	IGM, SHL	dk brwn	10YR 6/4, 5/6, 3/3	10YR 7/6, 6/3, 5/2	4.81	0.032	1.00	3.81	4.81	5.66	0.04	3.00	0.00	6/28/2017	Category 2	Category 3	0.00
7	373+97	17-CS-02	APM 5	25	Y	SHL	gy	10YR 3/1	7.5YR 4/0 (20% 10YR 5/4)	6.41	0.126	3.94	2.47	1.63	5.02	0.46	3.00	0.00	6/28/2017	Category 2	Category 2	5.40
8	377+42	17-CS-03	APM 1	0.4-10	Y	SC	orange	10YR 6/4, 7.5YR 5/6 (<5% 10YR 3/1)	10YR 7/3, 6/1	3.64	0.023	0.72	2.92	5.06	5.54	0.04	3.00	0.00	6/28/2017	Category 2	Category 3	0.00
9	377+42	17-CS-03	APM 2	11-15	Y	SM/IGM, SHL	dk gy	10YR 3/1 (20% 10YR 5/8)	10YR 3/1 (<20% 10YR 6/2)	5.04	0.032	1.00	4.04	5.04	5.78	0.05	3.00	0.00	6/28/2017	Category 2	Category 3	0.00
10	378+50	17-CS-04	APM 1	1.0-3.5	Y	CL	orange-brwn	10YR 5/4,5/2	10YR 7/3, 7/1	2.53	0.027	0.84	1.69	3.00	4.43	0.12	1.00	0.00	6/28/2017	Category 2	Category 2	2.00
11	378+50	17-CS-04	APM 2	3.5-23	Y	SM	gy-brwn	10YR 5/4	10YR 8/2	2.98	0.023	0.72	2.26	4.15	4.95	0.05	2.00	0.00	6/28/2017	Category 2	Category 2	2.00
12	378+50	17-CS-04	APM 3	23-33	Y	SM	dk gy	10YR 5/4, 3/1	10YR 5/2, 5/4	0.59	0.027	0.84	-0.25	0.70	4.42	0.04	2.00	0.00	6/28/2017	Category 2	Category 2	2.00
13	378+50	17-CS-04	APM 4	33-40	N	IGM, SHL	dk gy	10YR 4/1 (20% 10YR 5/4)	10YR 4/1 (20% 10YR 7/1)	0.59	0.601	18.78	-18.19	0.03	4.00	0.37	3.00	0.00	6/28/2017	Category 1	Category 1	
14	382+37	17-CS-05	APM 1	0.5-3.3	Y	CL-ML	tan-brwn	10YR 5/4, 5/6 (5% 10YR 3/1)	10YR 7/6, 6/2	0.32	0.033	1.03	-0.71	0.31	5.00	0.07	2.00	0.00	6/28/2017	Category 2	Category 2	2.77
15	382+37	17-CS-05	APM 2	3.3-15	Y	IGM, SM	gy-brwn	7.5YR 6/6, 4/2, 10YR 5/3	10YR 7/6, 5/3	0.86	0.038	1.19	-0.33	0.72	4.73	0.04	1.00	0.00	6/28/2017	Category 2	Category 2	2.70
16	382+37	17-CS-05	APM 3	18-30	Y	IGM, ML	brwn	10YR 4/3, 3/2 (<5% 7.5YR 5/6)	10YR 5/3, 5/8 (<5% 10YR 7/4)	1.13	0.033	1.03	0.10	1.10	5.61	0.03	1.00	0.00	6/28/2017	Category 2	Category 2	2.00
17	383+59	17-CS-06	APM 1	1.0-6	Y	CL-ML	orange-brwn	10YR 6/6, 5/4, 7/4	10YR 6/3, 6/4, 6/5	0.32	0.025	0.78	-0.46	0.41	5.00	0.06	1.00	0.00	6/28/2017	Category 2	Category 2	2.02
18	383+59	17-CS-06	APM 2	6.0-20	N	IGM, ML	dk brwn	7.5YR 3/0 (20% 7.5YR 5/6)	10YR 3/1, 6/1, 6/2	-0.22	0.025	0.78	-1.00	-0.28	5.38	0.04	1.00	0.00	6/28/2017	Category 2	Category 2	
19	387+00	17-CS-07	APM 1	1.0-7.5	Y	CL	orange-brwn	7.5YR 5/6, 10YR 5/8, 6/3	10YR 7/4, 6/3	1.67	0.024	0.75	0.92	2.23	5.86	0.03	2.00	0.00	6/30/2017	Category 2	Category 2	2.00
20	387+00	17-CS-07	APM 2	7.5-9	Y	CL	orange-brwn	10YR 6/8, 6/3	10YR 7/4, 8/2	3.56	0.013	0.41	3.15	8.76	5.49	0.05	2.00	0.00	6/30/2017	Category 2	Category 2	2.00
21	387+00	17-CS-07	APM 3	9.0-10	N	IGM, SHL	dk brwn-gy	10YR 6/4	10YR 6/3	7.35	0.01	0.31	7.04	23.52	6.03	0.06	3.00	0.00	6/30/2017	Category 3	Category 3	
22	388+27	17-CS-08	APM 1	0.2-6	Y	CL	tan-orange	7.5YR 5/6 (20% 10YR 5/8, 5YR 5/8)	10YR 7/4 (20% 10YR 7/6, 7.5YR 5/6)	0.05	0.015	0.47	-0.42	0.11	5.30	0.03	2.00	0.00	6/30/2017	Category 2	Category 2	2.00
23	388+27	17-CS-08	APM 2	6.0-9.7	Y	ML	brwn	10YR 5/4, 6/4, 7/4	10YR 6/3, 7/2, 7/3	4.64	0.023	0.72	3.92	6.46	4.56	0.16	3.00	0.00	6/30/2017	Category 2	Category 2	2.00
24	388+27	17-CS-08	APM 3	9.7-15	Y	IGM/ML	gy-brwn	10YR 4/3 (20% 10YR 8/4, 5/4)	10YR 5/2 (20% 10YR 7/2, 7.5YR 5/8)	6	0.052	1.63	4.38	3.69	5.17	0.26	3.00	0.00	6/30/2017	Category 2	Category 2	2.00
25	390+39	17-CS-09	APM 2-1	1.0-5	Y	CL	brwn	10YR 6/8, 7/4 (<5% 10YR 3/3)	10YR 7/4, 7/8, 7/2	3.02	0.046	1.44	1.58	2.10	6.15	0.03	1.00	0.00	7/12/2017	Category 2	Category 2	2.00
26	390+39	17-CS-09	APM 2-2	5.0-12	Y	CL	dk brwn	7.5YR 5/2, 6/8, 2.5 YR 5/8	7.5YR 6/2 (20% 5YR 6/8, 2.5 YR 6/8)	0.29	0.111	3.47	-3.18	0.08	4.37	0.31	1.00	0.00	7/12/2017	Category 2	Category 2	10.12
27	392+20	17-CS-10	APM 2	1.0-4	Y	ML	tan-gy	7.5YR 5/4 (10% 2.5YR 5/8)	7.5YR 7/4 (10% 2.5YR 6/8)	0.56	0.031	0.97	-0.41	0.58	5.68	0.04	2.00	0.00	7/12/2017	Category 2	Category 2	2.35
28	392+20	17-CS-10	APM 2-2	6.75-8	Y	IGM, SM	brwn	10YR 5/8, 7.5YR 5/6 (20% 10YR 3/0)	10YR 6/4, 7.5YR 6/6	1.09	0.056	1.75	-0.66	0.62	5.07	0.05	3.00	0.00	7/12/2017	Category 2	Category 2	4.16
29	392+20	17-CS-10	APM 3	4.0-6.75	Y	IGM, SM	dk gy	10YR 5/2 (<5% 10YR 8/4, 2.5 YR 5/6)	10YR 6/2 (<5% 5YR 7/6, 7.5YR 7/2)	1.9	0.033	1.03	0.87	1.84	5.04	0.05	3.00	0.00	7/12/2017	Category 2	Category 2	2.00
30	392+20	17-CS-10	APM 3-2	8.0-10	Y	IGM, SM	brwn	10YR 6/3	10YR 7/2, 7/4	1.35	0.03	0.94	0.41	1.44	5.07	0.09	3.00	0.00	7/12/2017	Category 2	Category 2	2.00
31	392+20	17-CS-10	APM 3-3	13-15	Y	IGM, SM	brwn	10YR 5/3 (<10% 7.5YR 5/8, 10YR 3/1)	10YR 6/2 (<10% 7.5YR 5/8, 10YR 3/1)	0.82	0.082	2.56	-1.74	0.32	4.39	0.19	1.00	0.00	7/12/2017	Category 2	Category 2	6.87
32	394+24	17-CS-11	APM 1	1.0-6	Y	CL	orange and gy	5YR 5/6, 10YR 6/4	7.5YR 6/6, 10YR 7/4	1.36	0.019	0.59	0.77	2.29	4.86	0.04	2.00	0.00	7/7/2017	Category 2	Category 2	2.00
33	394+24	17-CS-11	APM 2	6.0-10	Y	SC	dk brwn	10YR 3/0, 3/2, 4/3	10YR 6/4, 6/3	16.89	0.032	1.00	15.89	16.89	7.89	0.34	3+	0.00	7/7/2017	Category 3	Category 3	0.00
34	394+24	17-CS-11	APM 3	13-13.2	Y	IGM, SHL	gy	10YR 4/1, 6/2	10YR 6/3, 6/1 (<10% 10YR 5/6)	275.3	0.03	0.94	274.36	293.65	8.42		3.00	Strong	7/7/2017	Category 4	Category 4	0.00
35	394+24	17-CS-11	APM 5	14.5	Y	SHL	gy	7.5YR 3/0	7.5YR 5/0, 6/0	478.7	0.051	1.59	477.11	300.36	5.51		1.00	Strong	7/7/2017	Category 4	Category 4	0.00
36	395+04	17-CS-12	APM 2	1.0-2.3	Y	CL	tan-brwn	10YR 4/1, 5/4	10YR 6/4, 7/3	26.8	0.059	1.84	24.96	14.54	8.21	0.62	3+	0.00	7/7/2017	Category 3	Category 3	0.00
37	395+04	17-CS-12	APM 3	2.3-4.5	Y	IGM, SHL	gy	10YR 5/3, 6/3	10YR 5/2, 6/3	323.6	0.024	0.75	322.85	431.47	8.20	0.24	3+	Strong	7/7/2017	Category 4	Category 4	0.00
38	395+04	17-CS-12	APM 4	4.5-14.5	Y	SHL	gy	10YR 3/1, 5/3 (<10% 7.5YR 4/4)	10YR 4/1, 6/4 (<10% 10YR 6/6)	162.3	0.023	0.72	161.58	225.81	8.24	0.28	3+	Strong	7/7/2017	Category 4	Category 4	0.00
39	395+04	17-CS-12	APM 5	14.5-24.5	Y	SHL	gy	10YR 4/1, 6/3, 4/3 (<5% 10YR 6/6)	10YR 4/2, 6/4 (10% 7.5YR 5/6)	133	0.019	0.59	132.41	224.00	8.34	0.23	3.00	Strong	7/7/2017	Category 4	Category 4	0.00
40	396+14	17-CS-13	APM 2	0-0.8	Y	CL	brwn-tan	10YR 6/4, 3/3, 3/1	10YR 5/3, 6/4, 5/2	1.1	0.018	0.56	0.54	1.96	5.03	0.10	2.00	0.00	7/7/2017	Category 2	Category 2	2.00
41	396+14	17-CS-13	APM 3	0.8-9	Y	ML	gy and brwn	10YR 3/1, 6/4 (10% 10YR 7/6)	10YR 6/4, 5/2 (10% 10YR 7/6)	-0.69	0.022	0.69	-1.38	-1.00	4.94	0.07	3.00	0.00	7/7/2017	Category 2	Category 2	2.75
42	396+14	17-CS-13	APM 3-2	9-14.5	Y	CL	orange and gy	10YR 6/4 (10% 10YR 6/1, 3/2)	10YR 7/3 (10% 5YR 5/8, 10YR 6/2)	-0.94	0.027	0.84	-1.78	-1.11	5.79	0.03	3.00	0.00	7/7/2017	Category 2	Category 2	3.47
43	396+14	17-CS-13	APM 4	14.5-30	N	CL	dk gy	10YR 3/1, 4/2 (<5% 10YR 6/8)	10YR 5/1, 5/2 (<5% 7.5YR 6/8)	-1.96	0.036	1.13	-3.09	-1.74	5.61	0.04	1.00	0.00	7/7/2017	Category 2	Category 2	
44	404+31	17-CS-14	APM 1	0-10	Y	CL	brwn	10YR 5/4 (10% 10YR 4/1)	7.5YR 6/4 (<10% 10YR 5/1)	-1.96	0.059	1.84	-3.80	-1.06	4.93	0.04	3.00	0.00	7/12/2017	Category 2	Category 2	7.49
45	404+31	17-CS-14	APM 2	11-15	Y	CH	gy-tan	10YR 5/4 (20% 10YR 5/8, 6/1)	10YR 6/4 (<20% 10YR 7/2, 5/8)	1.72	0.113	3.53	-1.81	0.49	5.65	0.04	1.00	0.00	7/12/2017	Category 2	Category 2	8.87
46	405+44	17-CS-15	APM 1	0-5	Y	CL	brwn	7.5YR 5/4 (10% 10YR 6/1)	7.5YR 7/4 (10% 10YR 7/1)	2.91	0.164	5.13	-2.22	0.57	4.86	0.05	3.00	0.00	7/12/2017	Category 2	Category 2	12.47
47	405+44	17-CS-15	APM 2	5-10	Y	CH	brwn-orange	5YR 5/6, 7.5YR 5/6, 3/0	5YR 5/8, 7.5YR 5/6, 6/2	2.91	0.181	5.66	-2.75	0.51	4.24	0.14	1.00	0.00	7/12/2017	Category 2	Category 2	14.06
48	409+58	17-CS-16	APM 1	0.3-3.8	Y	CL	orange	10YR 5/4, 6/6, 6/8	10YR 6/4, 6/8	7.42	0.072	2.25	5.17	3.30	4.93	0.15	3.00	0.00	7/12/2017	Category 3	Category 3	2.00
49	409+58	17-CS-16	APM 2	4-6	Y	CL-ML	brwn	10YR 3/1	10YR 4/1 (10% 7.5YR 4/6)	9.08	0.094	2.94	6.14	3.09	7.53	0.35	3.00	0.00	7/12/2017	Category 3	Category 3	0.00
50	409+58	17-CS-16	APM 3	6.5-10	N	IGM, SHL	vdk gy	7.5YR 3/0	7.5YR 4/0	7.18	1.224	38.25	-31.07	0.19	6.98	1.80	3.00	0.00	7/12/2017	Category 1	Category 1	
51	410+93	17-CS-17	APM 1	0-9	Y	CL	orange-brwn	7.5YR 5/4, 5/6, 7/4	7.5YR 6/4, 6/6	25.51	0.066	2.06	23.45	12.37	7.66	0.45	3.00	Slight	7/12/2017	Category 3	Category 3	0.00
52	410+93	17-CS-17	APM 2	9-10	Y	IGM, SHL	brwn	10YR 5/3, 6/6	10YR 6/2, 6/8	109	0.04	1.25	107.75	87.20	8.06	0.47	3+	Moderate	7/12/2017	Category 4	Category 4	0.00
53	410+93	17-CS-17	APM 3	10-14	N	IGM, SHL	vdk gy	10YR 3/1 (10% 7.5YR 5/8)	10YR 4/1 (<10% 7.5YR 5/8)	14.78	0.111	3.47	11.31	4.26	8.24	0.65	3+	0.00	7/12/2017	Category 3	Category 3	
54	412+25	17-CS-18	APM 1	0-2.5	Y	CL	orange-brwn	7.5YR 5/6	7.5YR 6/4	3.75	0.0	0.6	3.19	6.67	4.82	0.06	2.00	0.00	8/4/2017	Category 2	Category 2	2.00
55	412+25	17-CS-18	APM 2	2.5-14	Y	SM	gy	10YR 4/2, 3/1 (10% 7.5YR 5/6)	10YR 6/2, 5/1 (10% 7.5YR 7.6)	15.48	0.01	0.41	15.07	38.10	8.15	0.51	3.00	0.00	8/4/2017	Category 3	Category 3	0.00
56	413+20	17-CS-19	APM 1	0-3	Y	CL	brwn	10YR 6/4, 5/6 (<10% 10YR 4/1)	7.5YR 7/2 (<10% 10YR 4/1)	3.15	0.031	0.97	2.18	3.25	4.81	0.06	2.00	0.00	7/14/2017	Category 2	Category 2	2.00
57	413+20	17-CS-19	APM 2	3-10	Y	SC/IGM, SHL	dk brwn	10YR 5/3, 4/3, 5/4	10YR 6/4 (<10% 10YR 5/1)	118.4	0.04	1.25	117.15	94.72	8.17	0.57	3.00	Moderate	7/14/2017	Category 4	Category 4	0.00
58	413+20	17-CS-19	APM 3	13-15	N	IGM, SHL	dk gy	10 YR 5/1, 5/3	10 YR 5/1, 5/3	285.2	0.702	21.94	263.26	13.00	7.94		3.00	Strong	7/14/2017	Category 4	Category 4	
59	415+34	17-CS-20	APM 1	0-7	Y	CL	orange	7.5YR 5/6, 10YR 5/4 (< 10% 10YR 4/1)	7.5YR 6/6, 10YR 5/4	1.48	0.033	1.03	0.45	1.44	4.69	0.06	2.00	0.00	7/14/2017	Category 2	Category 2	2.00
60	415+34	17-CS-20	APM 2	7-12	N	SC-SM	dk brwn and gy	10YR 5/3 (<10% 10YR 4/1)	10YR 5/4 (<10% 10YR 4/1)	7.66	0.053	1.66	6.00	4.62	6.97	0.22	3.00	0.00	7/14/2017	Category 3	Category 3	
61	416+26	17-CS-21	APM 1	0-3	Y	CL	brwn	10YR 5/4, 5/6 (<10% 10YR 4/1)	7.5YR 6/2, 10YR 6/3	1.96	0.053	1.66	0.30	1.18	5.35	0.04	2.00	0.00	7/14/2017	Category 2	Category 2	3.01
62	416+26	17-CS-21	APM 2	3-10	Y	CL	dk brwn	7.5YR 4/4, 5/4 (<10% 10YR 4/1)	7.5YR 6/4, 5/4 (<10% 10YR 5/1)	1.96	0.059	1.84	0.12	1.06	4.84	0.05	1.00	0.00	7/14/2017	Category 2	Category 2	3.57
63	416+26	17-CS-21	APM 3	13-20	Y	IGM, SHL	dk gy	10YR 3/1 (<10% 7.5YR 5/8)	10YR 3/1, 4/1 (<10% 7.5YR 5/8)	1.48	0.08	2.47	-0.99	0.60	4.07	0.13	1.00	0.00	7/14/2017	Category 2	Category 2	5.93
64	417+39	17-CS-22	APM 1	0.5-4	Y	CL	brwn	7.5YR 7/3, 6/2 (<10% 10YR 3/1)	7.5YR 7/4, 7/3 (<10% 10YR 3/1)	-0.73	0.05	1.56	-2.29	-0.47	4.99	0.05	2.00	0.00	7/14/2017	Category 2	Category 2	5.42
65	417+39	17-CS-22	APM 2	4-6	Y	CL	dk brwn	10YR 6/4 (10% 10YR 6/8, 7/1)	10YR 6/3, 7/3, 5YR 5/6	0.49	0.083	2.59	-2.10	0.19	5.32	0.03	2.00	0.00	7/14/2017	Category 2	Category 2	7.29
66	417+39	17-CS-22	APM 3	6-9.2	Y	CL	dk brwn	10YR 5/4, 4/2 (<10% 10YR 4/1)	10YR 4/3, 7/3 (<10% 10YR 4/1)	-0.24	0.428	13.38	-13.62	-0.02	5.85	0.03	3.00	0.00	7/14/2017	Category 1	Category 1	40.37
67	417+39	17-CS-22	APM 3-2	9.2-10	Y	ML	dk brwn	7.5YR 4/6 (<10% 7.5YR 5/8)	7.5YR 5/4 (<5% 7.5YR 5/8)	-0.08	0.29	8.94	-0.92	-0.11	5.00	0.03	3.00	0.00	7/14/2017	Category 1	Category 1	27.79
68	417+39	17-CS-22	APM 3-3	13-20	Y	SC-SM	gy and brwn	10YR 4/3 (<10% 10YR 4/1, 7.5YR 6/6)	10YR 5/3 (<10% 10YR 4/1)	1.96	0.09	2.69	-0.73	0.73	4.76	0.05	3.00	0.00	7/14/2017	Category 2	Category 2	6.30
69	417+39	17-CS-22	APM 4	23-25	Y	IGM, SHL	gy-blk	10YR 3/1 (<10% 7.5YR 5/6)	10YR 4/1, 4/2 (<5% 7.5 YR 5/6)	1.96	0.12	3.75	-1.79	0.52	4.81	0.07	1.00	0.00	7/14/2017	Category 2	Category 2	9.29
70	418+57	17-CS-23	APM 1	0-6	Y	CL/SC	tan-brwn	10YR 5/3 (10% 7.5YR 5/6)	10YR 6/2 (10% 7.5YR 5/6)	-0.98	0.067	2.09	-3.07	-0.47	5.21	0.04	1.00	0.00	7/19/2017	Category 2	Category 2	7.26
71	418+57	17-CS-23	APM 2	6-15	Y	SM	dk gy	10YR 3/1, 4/2, 4/3	10YR 5/1, 5/2	-0.98	0.07	2.19	-3.17	-0.45	4.35	0.04	1.00	0.00	7/19/2017	Category 2	Category 2	7.54

Issues and Modifications

- **Essentially all native soils and weathered rock in the project would be Category 2 and demand liming up to +24 NNP. Not rational?**

- **Many/most category 2 materials had very low S content and NPR values > 2.0.**

- **Proposed modified categories based on alternative lab/field criteria, NPR data, and important subdivisions of Category 2.**

Table 1: Categorization of Acid Producing Material (APM) and Treatment Criteria				
RFP Categorization	**NPR**	**pH**	**NEW Categorization**	**Treatment**
Category 1	NPR<3	Any pH	Category 1	Dispose without treatment or shall be encapsulated and mixed with Agriculture Limestone to elevate the NPR to more than 3 with minimum 2 tons of alkaline amendment per 1000 tons
Category 2	NPR ≤ 3.0	Any pH	Category 2a	Mixed with Alkaline to elevate the NPR to more than 3 with minimum 2 tons of alkaline amendment per 1000 tons
	NPR > 3.0	pH ≤4.5	Category 2b	Treat with minimum 2 tons of alkaline amendment per 1000 tons
		4.5 < pH ≤5.5	Category 2c	No treatment is required, however, recommend placing such material with Category 3 and 4 materials
		pH> 5.5	Category 3&4	Can be placed as is without treatment.
Category 3	NPR > 3.0	Any pH	Category 3&4	Can be placed as is without treatment.
Category 4	NPR > 3.0	Any pH	Category 3$4	Can be placed as is without treatment.

Revised and accepted classification categories based on NPR, field pH and certain other field indicators.

Field Assessment/Classification Criteria

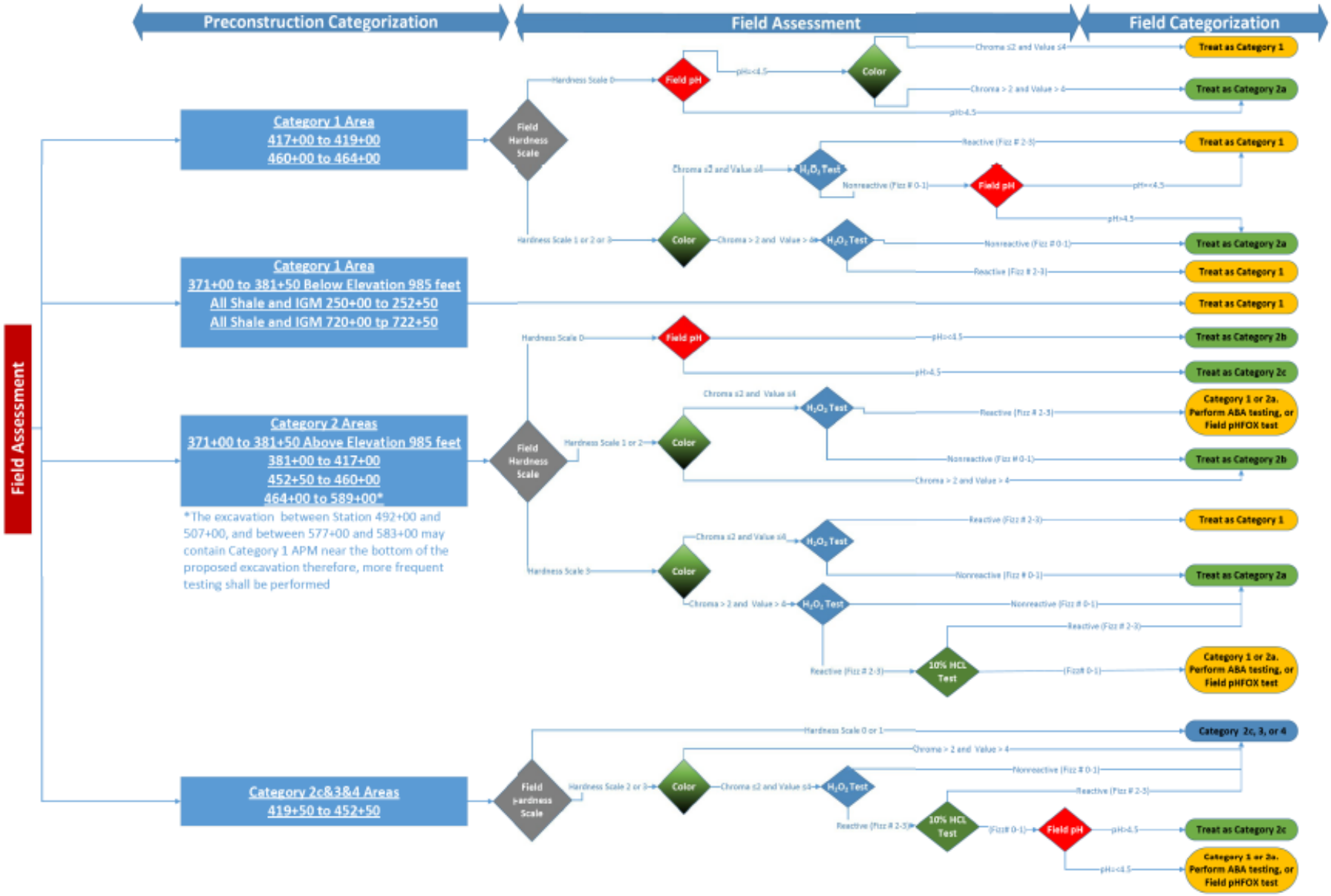
- **Vary by preconstruction assessment/ranking of relative probability of Category 1 being present.**
- **Field Hardness (e.g. is it weathered?)**
- **Munsell color (particularly value $\geq$ 4.0)**
- **Reaction/fizz to 30% H_20_2 (sulfides)**
- **Reaction/fizz to 10 HCl (carbonates)**
- **pHfox test for questionable materials**

Examples of potentially problematic materials and weathering indicators from upper partially weathered zone.

APM FIELD ASSESSMENT

CH2M Richmond, Virginia	CH2M Richmond, Virginia MATERIALS ENGINEER

DESIGN FEATU
OR TO REGULA
MAY BE SUBJE
NECESSARY BY



Color Scale for Category 1 Material		
Munsell Color	**Value**	**chroma**
5YR	2.5, 3	1, 2
7.5 YR	2.5, 3, 4	1,2,3
10 YR	2.5, 3, 4	1,2,3

Example of hand sample from May 30, 2019. This material is clearly oxidized, but soft and had an H_2O_2 fizz of 2 and an HCL fizz of 1. pH was 5.6 and pre-drill information indicates carbonates immediately below. This is 2C, but obviously still has some reactive sulfide component.

APM Hardness Scale

Scale	Type	Description
0	Friable	weathered soil-like material; crushes readily between fingers when moistened (soil)
1	Firm	weathered soil-like to saprolite material with oxidized (brown/red) coloration; original rock type readily determined (saprolite). Moistened sample crushes or shatters with moderate to strong pressure in hand
2	Very firm rock saprolite	Saprolite to Weathered bedrock materials with limited oxidized (brown/red) coloration. Material will cut with a shovel or auger with moderate to strong effort.
3	Intact	hard unweathered rock with no evidence of oxidation or weathering. Refuses shovel or auger penetration.

H_2O_2 'Fizz' tests Scale

H_2O_2 Fizz Number	Reaction	Category
0	no reaction	Not Category 1
1	slight vapor/bubbling	Unlikely to be Category 1
2	moderate vapor/bubbling	May be Category 1
3	violent reaction/frothing	Most likely Category 1

pH Scale Test

pH	Category
<4.5	Higher likely Category 1 when combined with other field tests that indicate Category 1
4.5-5.5	May be Category 1 when combined with other field tests that indicate Category 1
>5.5	Less likely Category 1 when combined with other field tests that does not indicate Category 1

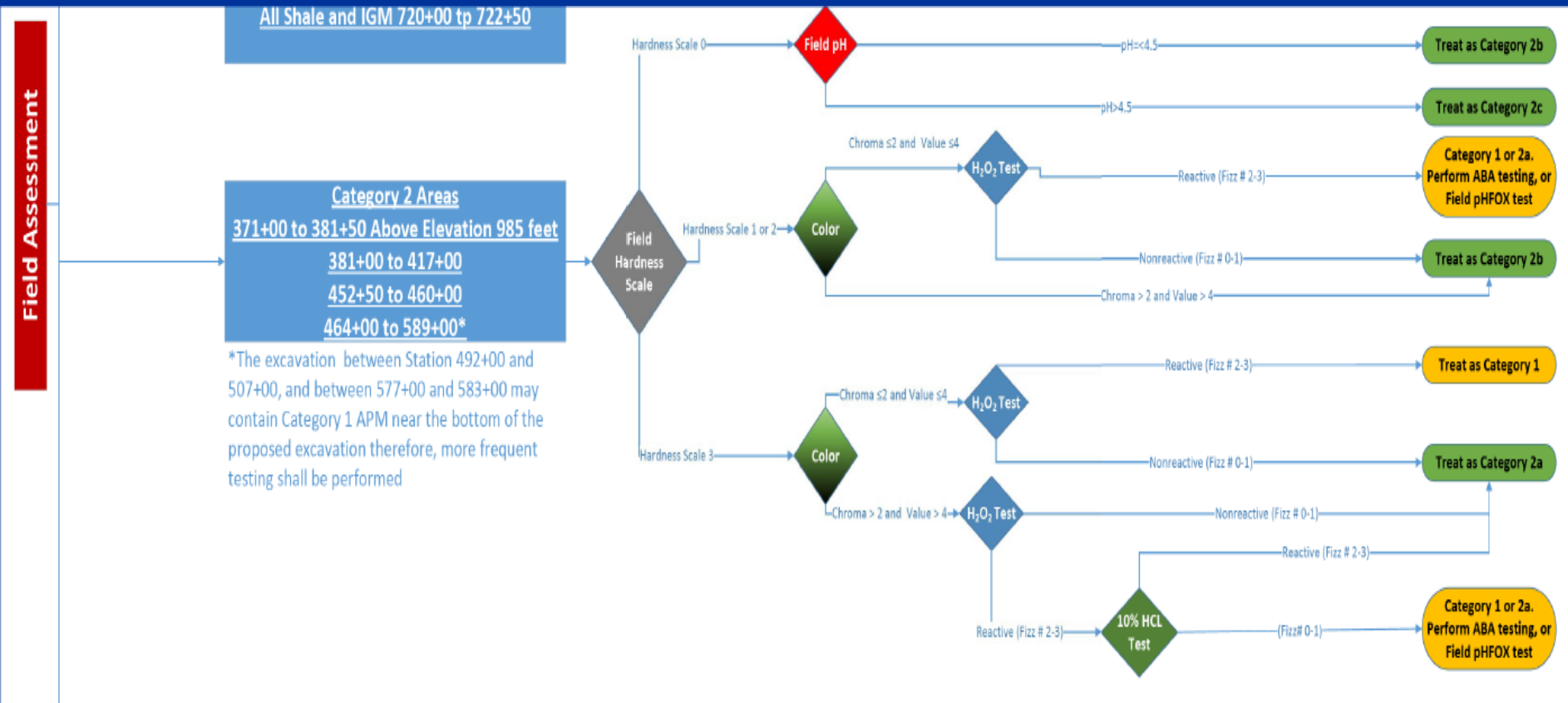
Sobek HCL 'Fizz' tests Scale

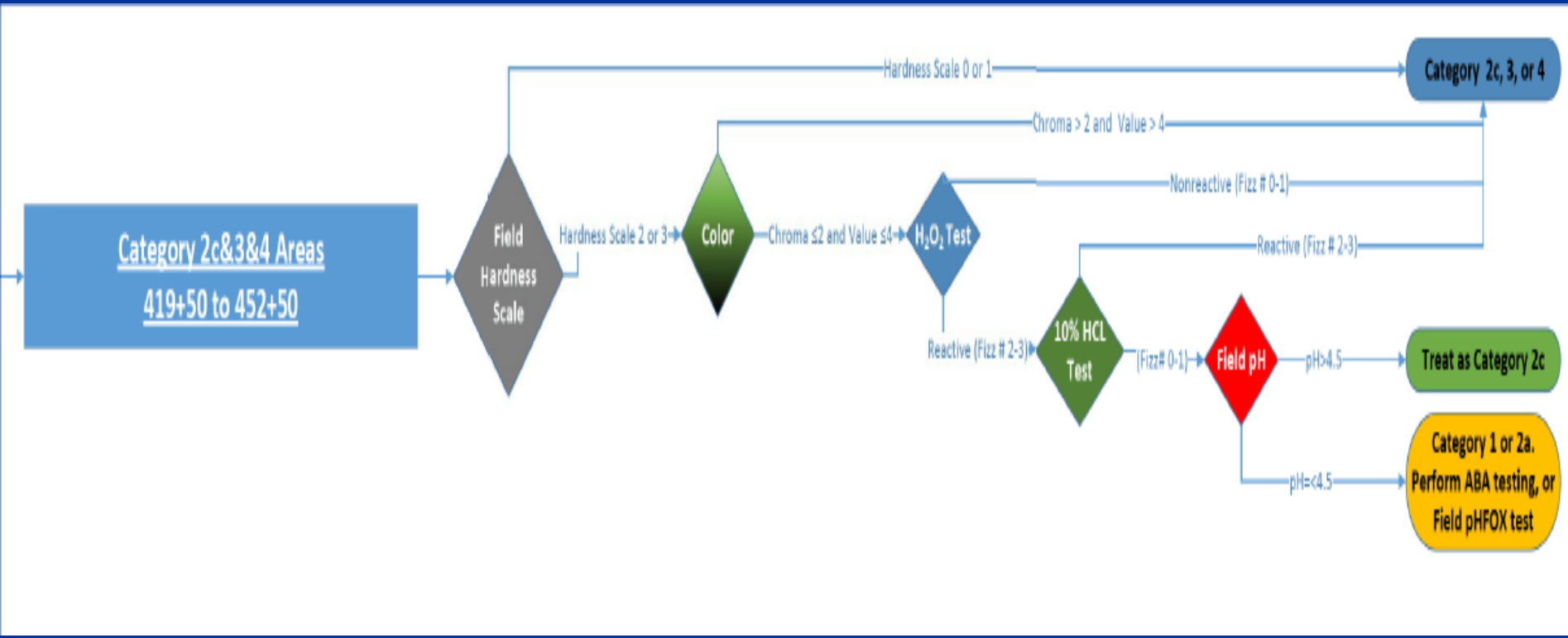
Fizz Rating	Reaction	Category
0	no reaction	May Be Category 1 or 2- See Chart
1	slight vapor/bubbling	May Be Category 1 or 2- See Chart
2	moderate vapor/bubbling	Not Category 1- See Chart
3	Strong reaction/frothing	Not Category 1- See Chart

If drilling data predetermine probability of Category 1, any material meeting color and hardness criteria are assumed to be APM.

Category 2 classes based on flow chart below and periodic supporting/confirming lab analyses.

Full time geotechnical engineer trained by VT assesses materials daily and performs testing/classification on every 10 truck loads or more often if indicated.



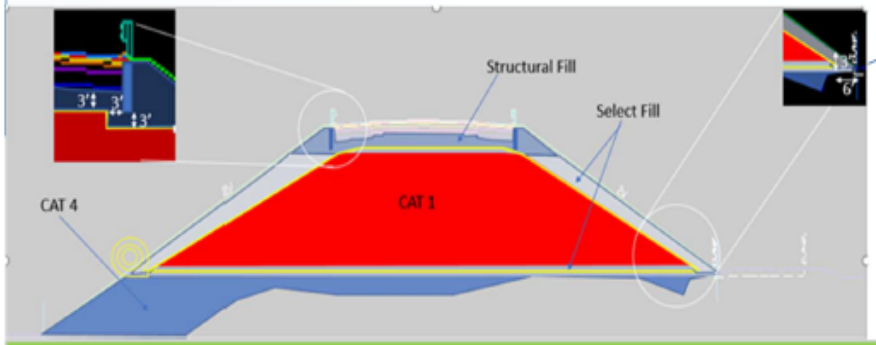


Detail of flow chart for decisions for areas that are presumed likely to be non-acid forming based on preconstruction drilling and lab ABA data.

Example of highly reactive (NNP = - 30 T/1000) black shale (Category 1) at depth with weathered oxidized pH 4.5 materials (Category 2) above.

Excavated Material

- All the excavated material in Area 1 below elevation 985 feet and all Category 1 material in Areas 3 and 5 will be transported within 72 hours during dry days or 24 hours during rainy days to a designated encapsulation site or directly to a landfill. Any excavated materials that are not within the preconstruction categorization station ranges, which are classified as Category 1 materials based on the field assessment, will also be transported to a designated encapsulation site or directly to a landfill.
- The trucks hauling this material shall be covered to minimize any spill during transportation.
- If not disposed to a landfill, the material shall be treated with agricultural limestone and shall be processed to meet the requirements of the Project Special Provisions for Processing and Placement of Shale Fill. This will require crushing such material to maximum size of 6 inches.
- In the final alkaline-blending encapsulation sites, APM Category 1 material shall be thoroughly blended per the requirements in Table 2.
- Site 1 is the proposed embankment between Station 425+00 and 428+00, and Site 2 is the proposed embankment between 396+50 and 400+50.
- Before placing Category 1 APM, the encapsulation site shall be prepared by placing at least 5.5 feet of Category 3 or 4 material above the native ground as shown in Figure 1.
- The base and side of the APM will be lined and covered by impervious membrane that will prevent water table wicking to the APM; the APM material will be fully encapsulated from bottom, side, and top.
- Before placing Category 1 material, the membrane will be installed directly on top of a 12-inch select bedding material with maximum size of 3/8-inch and will be covered with at least 6-inch of same material to protect the membrane from puncturing during compacting and blending of the Category 1 APM. The sides on the APM will be also backfilled with select material to minimize the compaction effort and protect the membrane;
- A low berm may be installed around the base of the site to prevent any localized runoff from contacting the APM encapsulation during construction. This low berm will also be used to focus and capture any potential runoff that might come from the APM encapsulation, keeping it isolated from stormwater runoff.
- Once the Category 1 material is placed on the membrane, amended with lime, disked and blended, and then compacted, it will be temporarily covered with an impervious liner material that is tied into the encapsulation berm to keep it isolated from precipitation and runoff while waiting to add the next layer of Category 1 material or prior to a major forecast rain event.
- The blended material will then be shaped to the required lift thickness of 8 inches and properly compacted per the standard specifications.
- The encapsulation site will be then covered with at least 3 feet of select and self-compacted material that is geotechnically stable against the membrane and 2 inches of topsoil and vegetated or covered with roadway pavement.
- If placed below proposed roadway pavement, the material shall have minimum CBR value of 4-5 as specified in the pavement design report.



Exposed Slope Faces

1. Apply 10 tons of agriculture limestone per acre of slope face for all exposed faces except between station 422+00 and 44+00
2. Apply 6" of Topsoil and cover the face with EC-2.
3. Construct the limestone enhanced ditches with the station in Table 3 as shown in the Figure
4. Construct settling basin to provide final settling, filtration and neutralization before release to wetland or stream for the discharge between station 414+50 and 422+00.
5. For the discharge between Station 371+50 and 381, it will go through 2000-foot long channel that can work as a settling basing to collect any solid. The use of a wide flat bottom grassed swale with check dams will mimic the characteristics of a settling basin by providing adequate storage volume behind each check dam

JACOBS

Acid Producing Material Inspection Form

Project Name:	Route 220 Safety Improvement, Phase 1, 2, and 3	Contractor:	Faulconer Construction Company
Project No.:	0220-011-786	Superintendent:	M. Butler
Location Phase/ Station :	PH1 / 444+00±	APM Field Engineer (APME):	P. Gilmore
Truck Tracking Number:		APM Specialist (APMS):	W.L. Daniels

General Information

Truck Type:	Tandem Axle Dump Truck	Preconstruction APM Area and Station:	☐ 1 ☐ 2 ☐ 3 ☑ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9
Truck Size:		Preconstruction APM Category:	☐ 1 ☐ 2a, 2b ☐ 2c ☑ 3 or 4
Truck Plate Number:	257 676	Approximate Depth / Elevation:	1040±
Truck Driver:	Harlow's	Date / Time @ Excavation:	5/31/19 1020
Weather Condition:	P. Cloudy	Date / Time @ Hauling:	5/31/19 1030
Temperature:	78	Date / Time @ Transporting:	

Visual Inspection

Color of Excavated Material	☐ Grey ☐ Dk Grey ☐ Black ☑ Other Brown
Munsell Color	☑ 5YR ☐ 7.5YR ☐ 10YR ☐ Other
Munsell Color Value	☐ 2.5 ☐ 3 ☑ 4 ☐ Other
Munsell Color Chroma	☐ 1 ☑ 2 ☐ 3 ☐ Other
Hardness Scale	☐ 0 ☑ 1 ☐ 2 ☐ 3
Material Classification	☐ CL ☐ ML ☐ CH ☐ MH ☐ SM-SC ☑ SW-GW ☐ Shale ☐ Limestone
Geological Origin	☐ Fill ☐ Alluvial ☑ Residual ☑ ISM ☐ Bedrock
Moisture Condition	☐ Dry ☑ Moist ☐ Wet
Can be Categorized?	☑ Yes ☐ No
Basis of Categorization	Hardness
Final Category	☐ 1 ☐ 2a, 2b ☑ 2c ☐ 3 or 4

Field Testing Inspection

pH Reading	
H2O2 'Fizz' index	☐ 0 ☐ 1 ☑ 2 ☐ 3 1-2
10% HCL 'Fizz' index	☐ 0 ☐ 1 ☐ 2 ☑ 3 3
Can be Categorized?	☐ Yes ☐ No
If No, Bulk Sample Taken to the Lab?	☐ Yes ☐ No
Basis of Categorization	
Final Category	☐ 1 ☐ 2a, 2b ☐ 2c ☐ 3 or 4

Observations / Problems during Excavation and Assessment: No problems observed

Example of field data sheet for analyses performed at a minimum of every 10 truck loads or "as needed" based on field monitor.

Interpretative Issues?

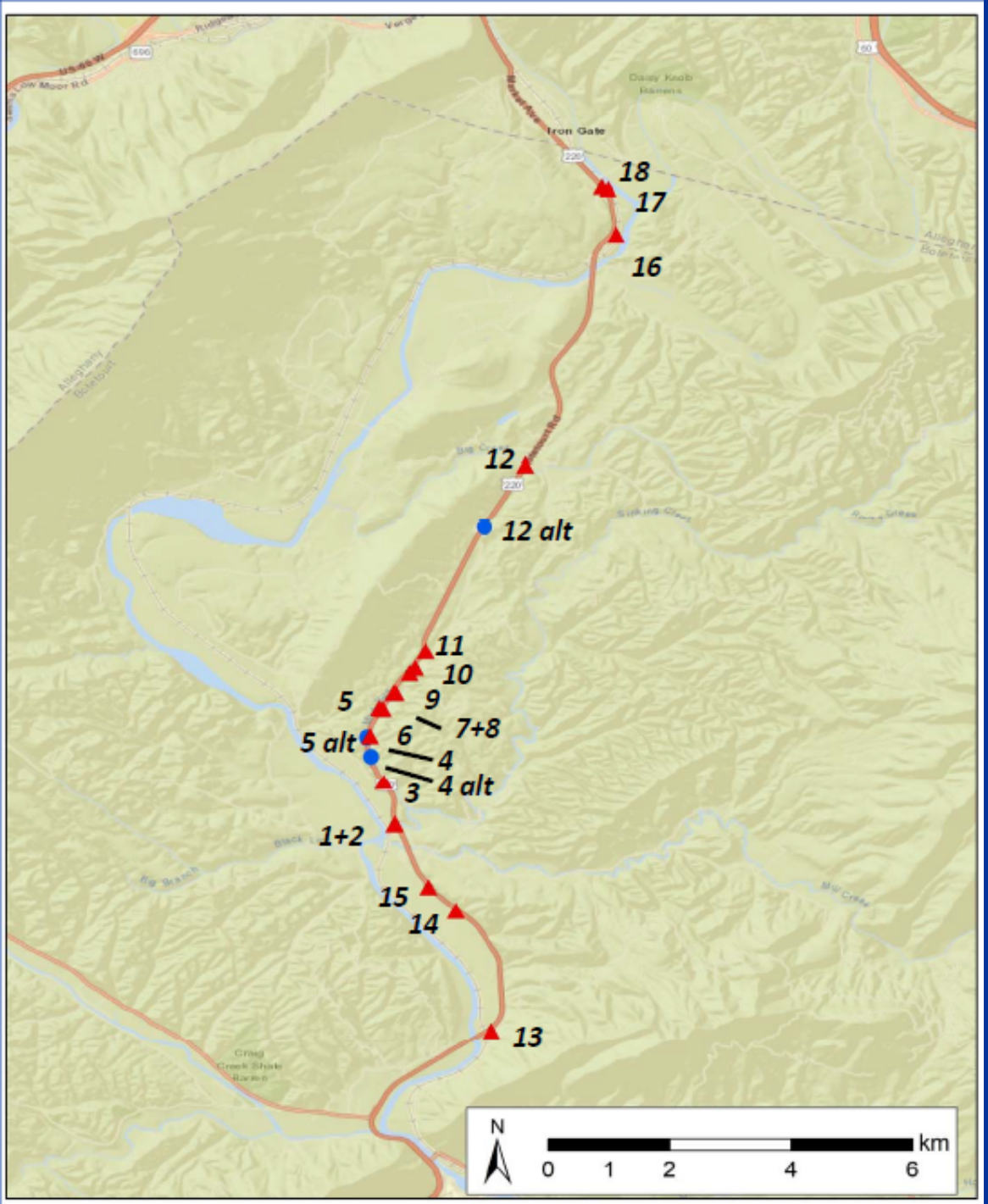
- **Relatively thin weathered saprolite zones appear fully oxidized but still contain a mix of reactive sulfides and traces of carbonates (as shown in earlier image).**

- **False positives: Mn coatings on some rocks make them appear black and they have a vigorous peroxide fizz. Internally, these are often red/yellow and/or carbonates.**

- **Intact hard black shales often have visible very fine pyrite crystals coupled with strong H_2O_2 and HCl fizz. Back-up ABA lab analyses on many such samples indicated NNP of > + 40. Lots of siderite nodules and masses!**

Final AFM Categorization & Placement

- ~ 25,000 m^3 was strongly acid forming Category 1 and was hauled offsite for disposal in a landfill in WV.
- ~100,000 m^3 was Category 2A or 2B and was bulk-blended with agricultural lime in fills and compacted. Lime rate was added to assure NPR > 3.0, but not +24 NNP. Most lime rates were less than 10 T/1000 as applied.
- The balance of the material (~325,000 m^3) did not require special management.



Water quality sampling locations. BL 12 was considered to be above the majority of AFM impact and BL 5 was a pre-existing perennial seep with obvious Fe-floc.

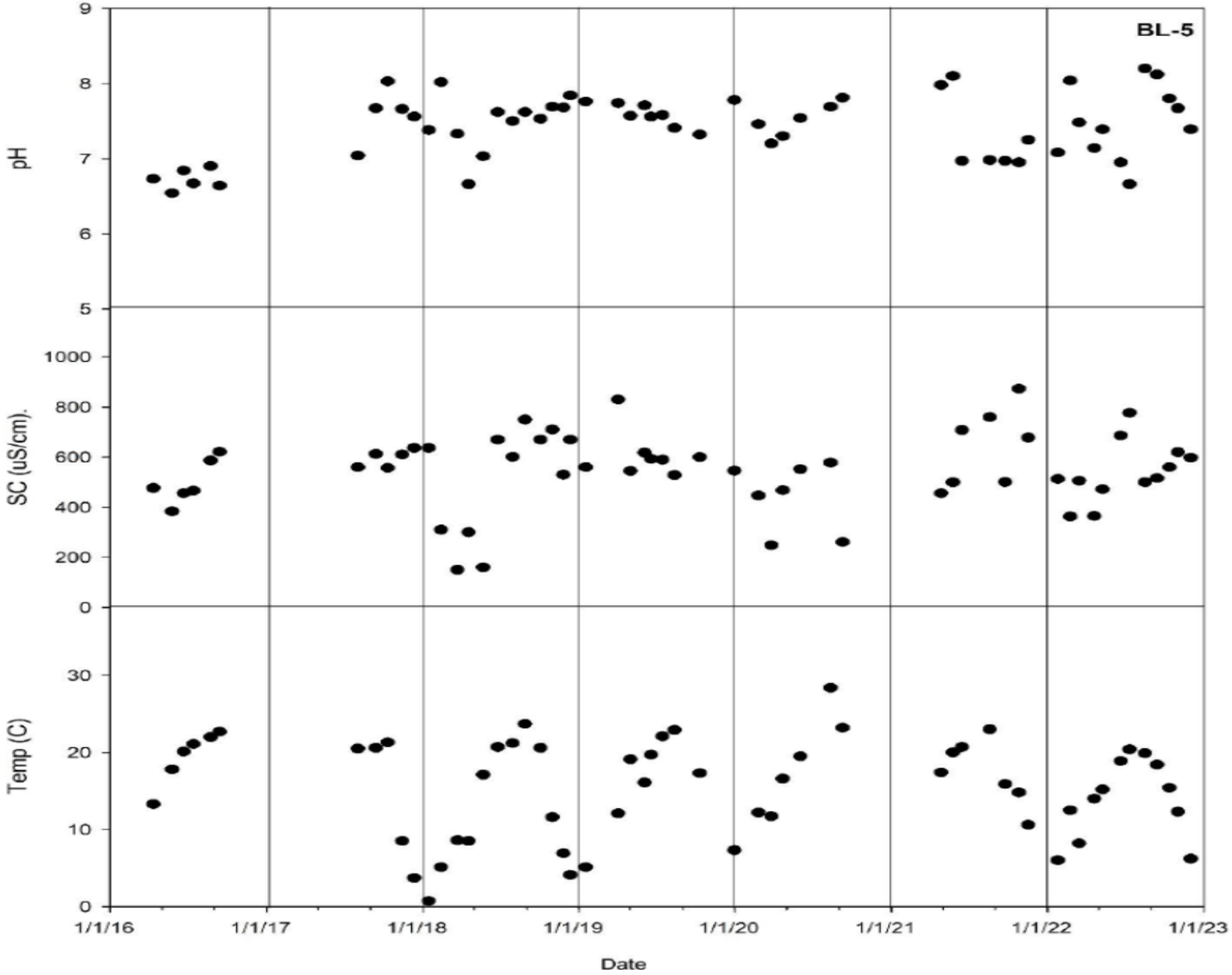
BL 4 was instream below major AFM cut/fill zones. Points 1 and 2 were at the local stream discharge point with the James River.

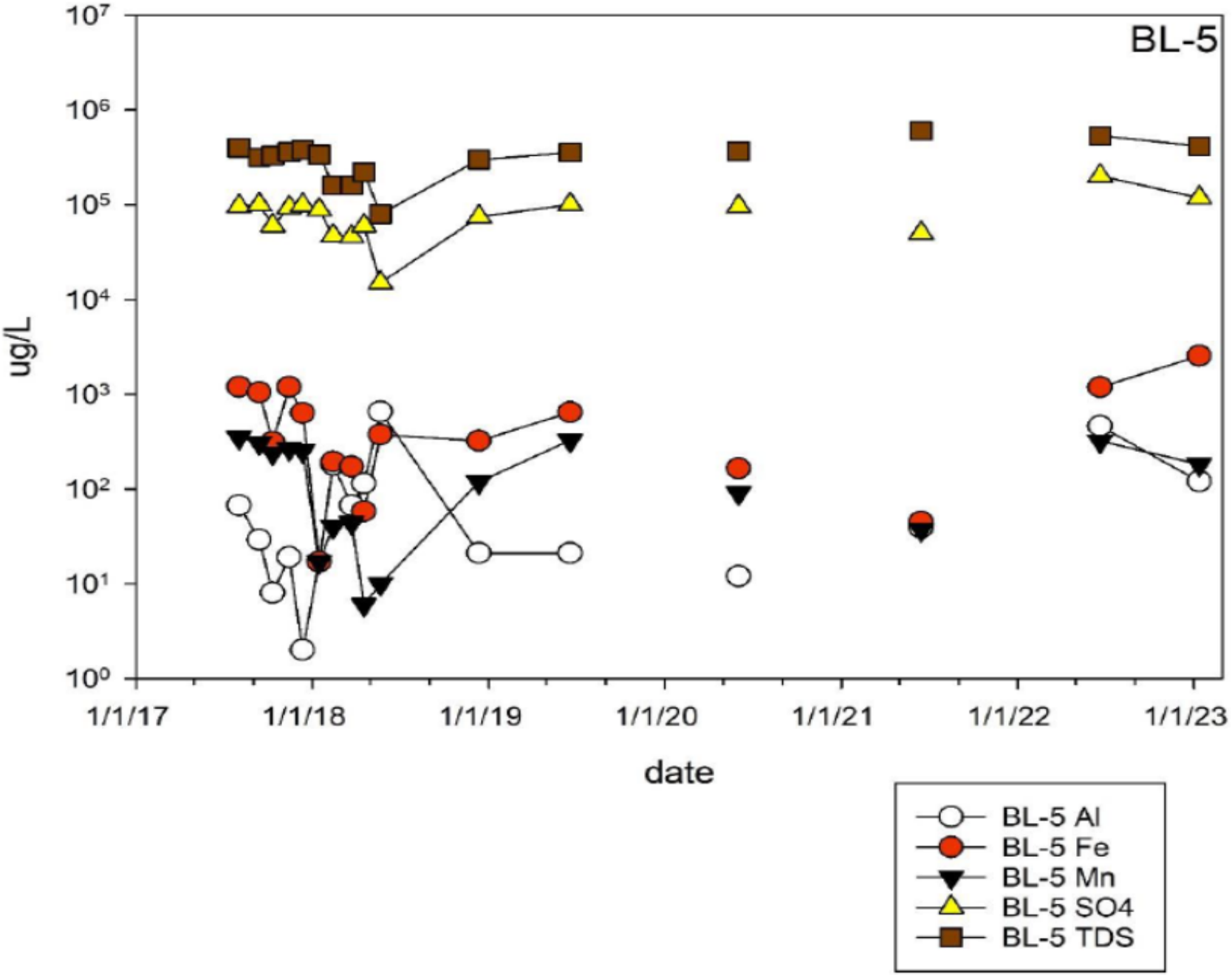
Close up of critical impact reach

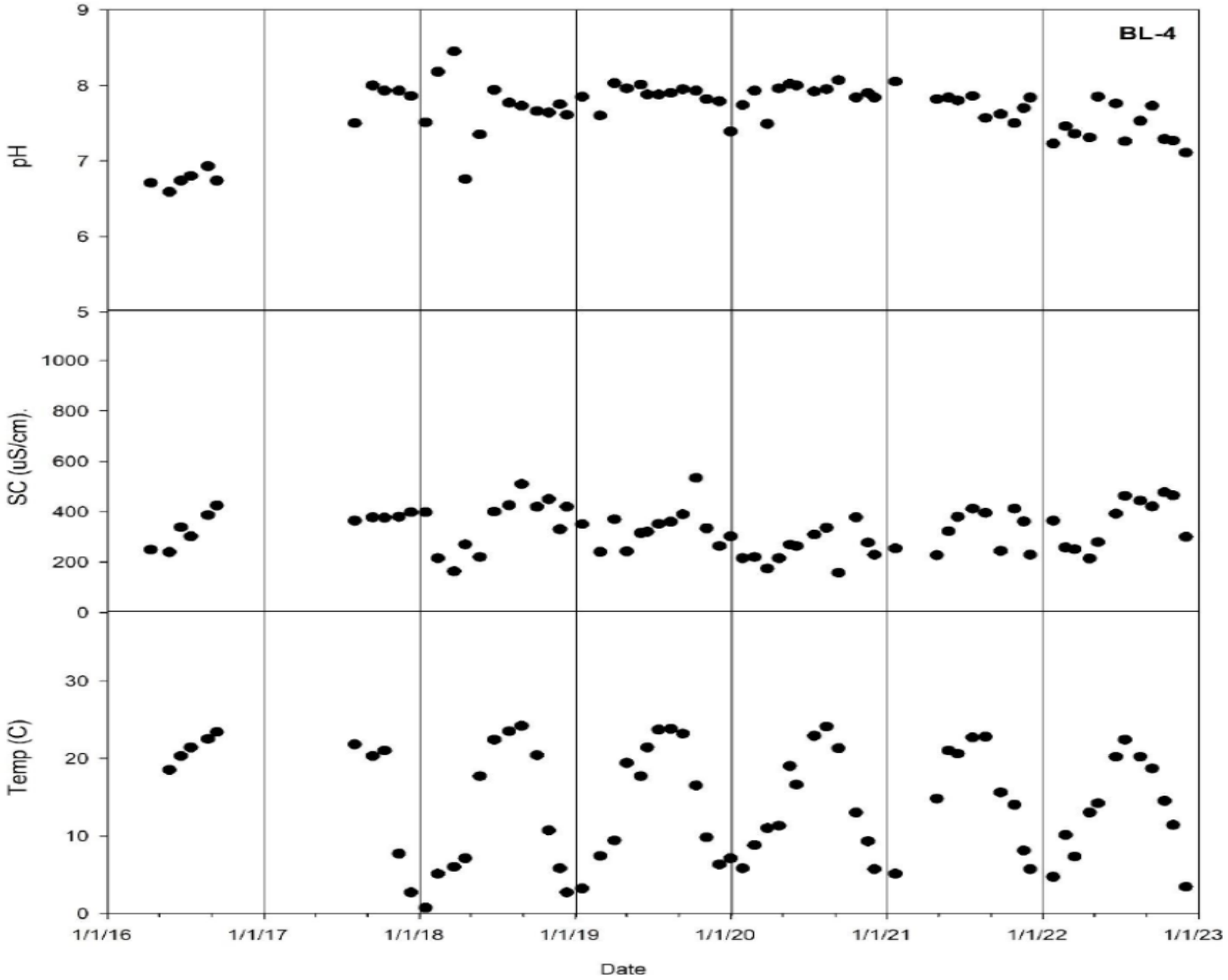

2016

Main stream sampling at BL 12 at culvert below Route 220 under low base flow conditions. Note sediment and yellow Fe-floc.

Culvert collecting and discharging drainage near former BL-5 seep location.


BL-5
pH
9
8
7
6
5
SC (uS/cm).
1000
800
600
400
200
0
Temp (C)
30
20
10
0
1/1/16
1/1/17
1/1/18
1/1/19
1/1/20
1/1/21
1/1/22
1/1/23
Date


BL-5
ug/L
date
1/1/17
1/1/18
1/1/19
1/1/20
1/1/21
1/1/22
1/1/23
BL-5 Al
BL-5 Fe
BL-5 Mn
BL-5 SO4
BL-5 TDS


BL-4
pH
9
8
7
6
5
SC (uS/cm).
1000
800
600
400
200
0
Temp (C)
30
20
10
0
1/1/16
1/1/17
1/1/18
1/1/19
1/1/20
1/1/21
1/1/22
1/1/23
Date

Site	Time Period	pH		SC		Temp	
		average	median	average	median	average	median
				------ µS/cm ------		-------- °C--------	
BL-1	08/2017 – 07/2018	6.68	6.83	73	85	12.7	12.5
	08/2021 – 07/2022	7.08	7.23	94	78	13.4	12.8
BL-4	08/2017 – 07/2018	7.77	7.90	329	370	13.0	12.7
	08/2021 – 07/2022	7.54	7.54	322	320	13.2	13.5
BL-5	08/2017 – 07/2018	7.46	7.53	475	559	13.0	12.9
	08/2021 – 07/2022	7.17	7.08	590	513	14.5	14.8
BL-8	08/2017 – 07/2018	7.91	8.01	324	358	12.5	8.1
	08/2021 – 07/2022	7.75	7.72	296	286	13.0	13.9
BL-12	08/2017 – 07/2018	7.08	7.15	160	141	13.4	10.2
	08/2021 – 07/2022	7.16	7.25	89	81	14.7	14.9

Conclusions

- **Meta-analysis of our large (> 300 samples) data set for all field parameters vs. ABA lab data indicated that the "flow chart system" was ≥ 90% accurate *if applied correctly.***

- **Actual field application confirmed efficacy of the approach, but pointed out a number of interpretative challenges that were resolved via periodic lab confirmation. However, that takes days to weeks and the operation defaulted to "worse case" in many instances out of caution.**

- **In most instances, we feel that errors will be "false positives" and be conservative in terms of treatment.**

- **The system is designed to categorize materials in the field for management; it is *not* intended to predict actual NNP or lime requirements.**

Conclusions

- **Overall, the project was successful at accurately identifying the vast majority of AFM and protecting local water quality.**

- **Short-term spikes in SC and Fe were seen occasionally at several small discharge locations directly under or in contact with recently placed/limed AFM fills, but no impacts to the main stem of the draining creek were noted.**

- **The success of this project was due to the skill and training of the on-site engineer and his ability to interact with the contractor staff on a daily basis for the ID of the AFM.**

Acknowledgments

- Thanks to Julie Burger, Joe Buckwalter and Athena Tilley for help in the field and lab on this project.

- Thanks to Jacobs and Faulconer Construction, particularly to Stephanie Hart for project/contract management and Phillip Gilmore for field AFM ID and tracking.