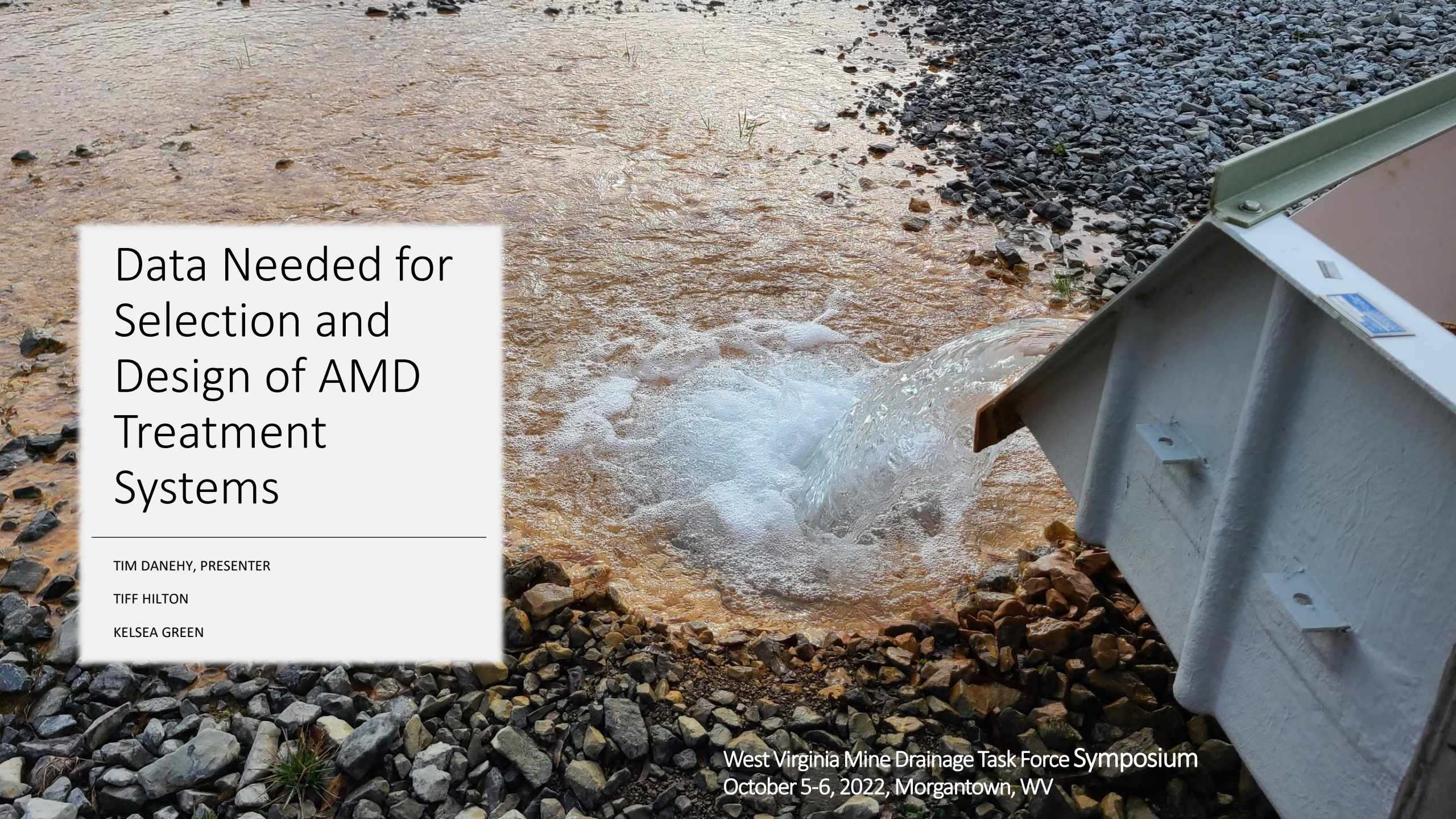


Data Needed for Selection and Design of AMD Treatment Systems

TIM DANEHY, PRESENTER

TIFF HILTON

KELSEA GREEN

West Virginia Mine Drainage Task Force Symposium
October 5-6, 2022, Morgantown, WV

Goal: AMD Treatment based on Good Science

Objectives

- Communicate the importance of good **flow** data
- Help design a solid sampling plan
- Provide a list of essential data
  - This includes good **flow** measurements
- Review why data is critical to design

Populate the Dataset

Date	Flow	F .Cond.	Cond.	F.pH	pH	Alk.	Acid.	Fe	D. Fe	Mn	D. Mn	Al	D. Al	Sulfate	TSS	Acid	T.Fe	D.Fe	T.Mn	D.Mn	T.Al.	D.Al.
	gpm	umho/cm	umho/cm	s.u.	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day
01/01/21	32			3.6	4.19	ND	166	0.3	0.3	3.9	3.8	38.6	36.8	919	6	64	0.1	0.1	1.5	1.5	14.8	14.2
02/12/21	60	1512	1500	4.3	4.08	10	90	0.1	0.1	1.0	1.0	11.8	12.2	840	1	65	0.1	0.1	0.7	0.7	8.5	8.8
03/17/21	50	824	1700	4.3	4.24	10	92	0.1	0.1	1.1	1.1	13.3	13.3	920	1	55	0.1	0.1	0.6	0.6	8.0	8.0
04/01/21	60	1560	1600	4.2	4.14	10	96	0.1	0.2	1.1	1.1	13.7	13.4	910	1	69	0.1	0.1	0.8	0.8	9.9	9.7
05/16/21	100	1341	1400	4.4	4.21	10	64	1.8	0.4	0.9	0.9	9.2	8.4	760	204	77	2.2	0.5	1.1	1.1	11.0	10.1
06/19/21	100	1469	1500	4.3	4.24	10	64	0.1	0.1	1.0	1.0	11.0	11.1	880	17	77	0.2	0.1	1.1	1.2	13.2	13.3
07/04/21	86	1764	1800	4.3	4.15	10	120	0.1	0.1	1.4	1.4	16.6	16.7	1100	2	124	0.1	0.1	1.4	1.4	17.1	17.2
08/04/21	75	1858	1800	4.3	4.07	10	120	0.1	0.1	1.5	1.5	19.4	18.0	1100	3	108	0.1	0.1	1.3	1.3	17.5	16.2
09/05/21	100	1585	1700	4.2	4.14	10	100	0.1	0.1	1.3	1.3	17.5	18.0	1000	1	120	0.1	0.1	1.6	1.6	21.0	21.6
10/31/21	60	1597	1800	4.2	4.51	10	140	0.1	0.1	1.4	1.4	18.1	18.8	1000	1	101	0.1	0.1	1.0	1.0	13.1	13.6
11/11/21	75	1532	1500	4.6	4.17	10	190	0.1	0.1	1.2	1.2	15.1	14.0	1200	1	171	0.1	0.1	1.0	1.0	13.6	12.6
12/21/21	60	1742	1900	4.2	4.37	10	220	2.2	0.2	1.6	1.6	18.8	23.6	1700	44	159	1.6	0.1	1.2	1.2	13.6	17.0
Average	71	1526	1655	4.2	4.21	10	122	0.4	0.2	1.4	1.4	16.9	17.0	1027	24	99	0.4	0.1	1.1	1.1	13.4	13.5
Median	68	1560	1700	4.3	4.18	10	110	0.1	0.1	1.2	1.2	15.9	15.4	960	2	89	0.1	0.1	1.1	1.1	13.4	13.5
Minimum	32	824	1400	3.6	4.07	10	64	0.1	0.1	0.9	0.9	9.2	8.4	760	1	55	0.1	0.1	0.6	0.6	8.0	8.0
Maximum	100	1858	1900	4.6	4.51	10	220	2.2	0.4	3.9	3.8	38.6	36.8	1700	204	171	2.2	0.5	1.6	1.6	21.0	21.6

Where should I collect the sample?

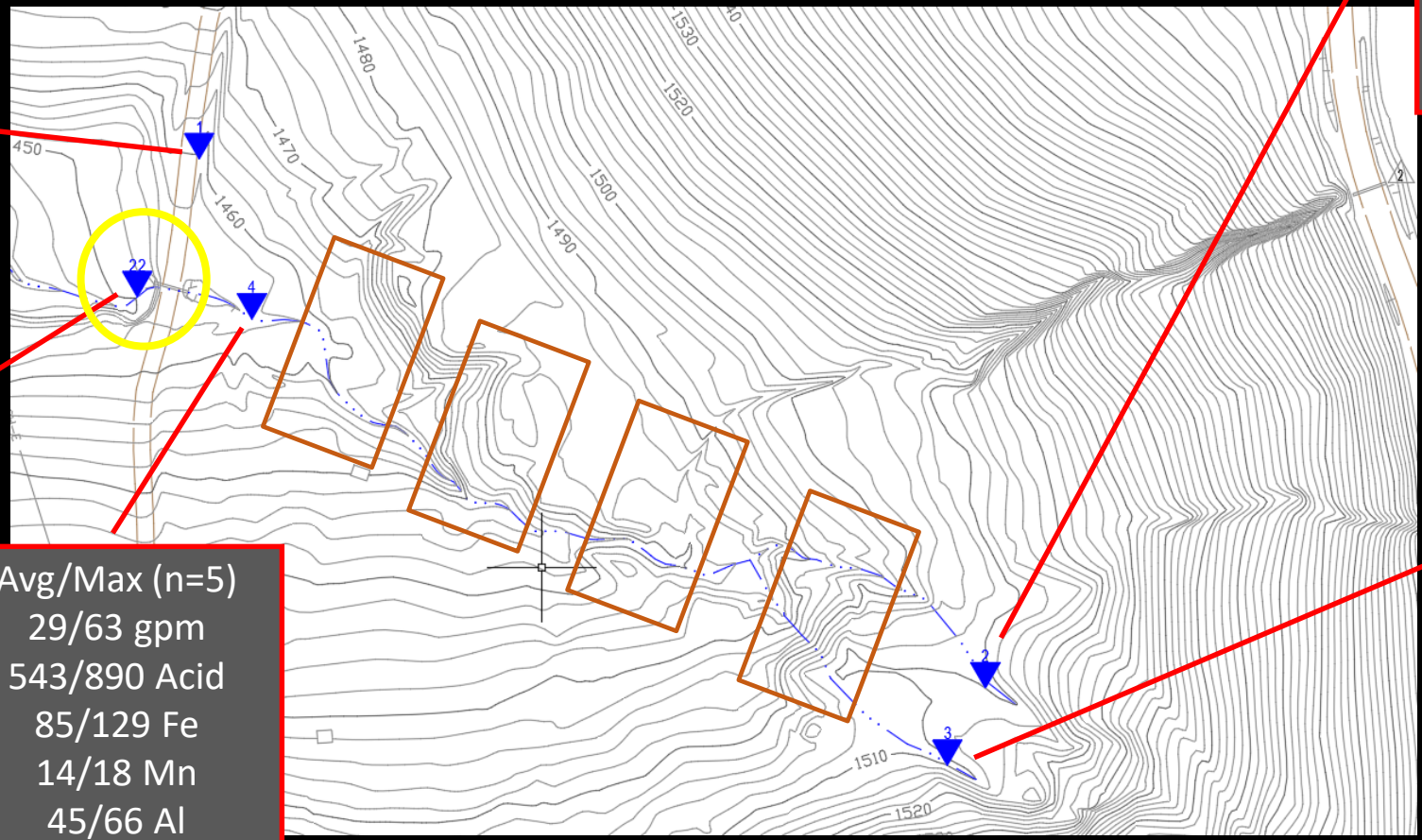
Measure the Flow

Sample Location

- The most convenient location may not provide the best information

Avg/Max (n=4)
36/85 gpm
-117/-97 Acid
0.4/0.7 Fe
1/1Mn
0/0 Al

70%tile (n=13)
31 gpm
783 Acid
105 Fe
26 Mn
66 Al



Avg/Max (n=5)
29/63 gpm
543/890 Acid
85/129 Fe
14/18 Mn
45/66 Al

Avg/Max (n=24)
5/6 gpm
2251/2990 Acid
438/645 Fe
22/28 Mn
152/207 Al

Avg/Max (n=25)
10/11 gpm
1658/2696 Acid
314/553 Fe
21/28 Mn
113/198 Al

Investigate the Entire Site

- There can be clues – is low pH iron removal happening?

How Location & Low pH Fe Can Impact Design

Parameter	Data Collected ~100 ft from Source	At Source
pH	3.4	3.7
Acid (mg/L)	159	177
Fe (mg/L)	2	30
Mn (mg/L)	39	68
Al (mg/L)	20	5

Populate the Dataset

Date	Flow	F .Cond.	Cond.	F.pH	pH	Alk.	Acid.	Fe	D. Fe	Mn	D. Mn	Al	D. Al	Sulfate	TSS	Acid	T.Fe	D.Fe	T.Mn	D.Mn	T.Al.	D.Al.
	gpm	umho/cm	umho/cm	s.u.	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day
01/01/21	32			3.6	4.19	ND	166	0.3	0.3	3.9	3.8	38.6	36.8	919	6	64	0.1	0.1	1.5	1.5	14.8	14.2
02/12/21	60	1512	1500	4.3	4.08	10	90	0.1	0.1	1.0	1.0	11.8	12.2	840	1	65	0.1	0.1	0.7	0.7	8.5	8.8
03/17/21	50	824	1700	4.3	4.24	10	92	0.1	0.1	1.1	1.1	13.3	13.3	920	1	55	0.1	0.1	0.6	0.6	8.0	8.0
04/01/21	60	1560	1600	4.2	4.14	10	96	0.1	0.2	1.1	1.1	13.7	13.4	910	1	69	0.1	0.1	0.8	0.8	9.9	9.7
05/16/21	100	1341	1400	4.4	4.21	10	64	1.8	0.4	0.9	0.9	9.2	8.4	760	204	77	2.2	0.5	1.1	1.1	11.0	10.1
06/19/21	100	1469	1500	4.3	4.24	10	64	0.1	0.1	1.0	1.0	11.0	11.1	880	17	77	0.2	0.1	1.1	1.2	13.2	13.3
07/04/21	86	1764	1800	4.3	4.15	10	120	0.1	0.1	1.4	1.4	16.6	16.7	1100	2	124	0.1	0.1	1.4	1.4	17.1	17.2
08/04/21	75	1858	1800	4.3	4.07	10	120	0.1	0.1	1.5	1.5	19.4	18.0	1100	3	108	0.1	0.1	1.3	1.3	17.5	16.2
09/05/21	100	1585	1700	4.2	4.14	10	100	0.1	0.1	1.3	1.3	17.5	18.0	1000	1	120	0.1	0.1	1.6	1.6	21.0	21.6
10/31/21	60	1597	1800	4.2	4.51	10	140	0.1	0.1	1.4	1.4	18.1	18.8	1000	1	101	0.1	0.1	1.0	1.0	13.1	13.6
11/11/21	75	1532	1500	4.6	4.17	10	190	0.1	0.1	1.2	1.2	15.1	14.0	1200	1	171	0.1	0.1	1.0	1.0	13.6	12.6
12/21/21	60	1742	1900	4.2	4.37	10	220	2.2	0.2	1.6	1.6	18.8	23.6	1700	44	159	1.6	0.1	1.2	1.2	13.6	17.0
Average	71	1526	1655	4.2	4.21	10	122	0.4	0.2	1.4	1.4	16.9	17.0	1027	24	99	0.4	0.1	1.1	1.1	13.4	13.5
Median	68	1560	1700	4.3	4.18	10	110	0.1	0.1	1.2	1.2	15.9	15.4	960	2	89	0.1	0.1	1.1	1.1	13.4	13.5
Minimum	32	824	1400	3.6	4.07	10	64	0.1	0.1	0.9	0.9	9.2	8.4	760	1	55	0.1	0.1	0.6	0.6	8.0	8.0
Maximum	100	1858	1900	4.6	4.51	10	220	2.2	0.4	3.9	3.8	38.6	36.8	1700	204	171	2.2	0.5	1.6	1.6	21.0	21.6

Measure the Flow

DATE: How Long Should I Sample?

- Preferred: Monthly for 1 Year
  - 12 samples
- Better: Bimonthly for 1 Year
  - 24 Samples
- Adequate: Monthly During High Flow
  - January through June
  - 6 Samples
  - You may miss the late summer/early fall “Hurricane Rains”
- More data is better (must have **FLOW**)
- (**Only** the flow measurement from treated samples can be helpful)

Populate The Dataset

Date	Flow	F .Cond.	Cond.	F.pH	pH	Alk.	Acid.	Fe	D. Fe	Mn	D. Mn	Al	D. Al	Sulfate	TSS	Acid	T.Fe	D.Fe	T.Mn	D.Mn	T.Al.	D.Al.
	gpm	umho/cm	umho/cm	s.u.	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day
01/01/21	32			3.6	4.19	ND	166	0.3	0.3	3.9	3.8	38.6	36.8	919	6	64	0.1	0.1	1.5	1.5	14.8	14.2
02/12/21	60	1512	1500	4.3	4.08	10	90	0.1	0.1	1.0	1.0	11.8	12.2	840	1	65	0.1	0.1	0.7	0.7	8.5	8.8
03/17/21	50	824	1700	4.3	4.24	10	92	0.1	0.1	1.1	1.1	13.3	13.3	920	1	55	0.1	0.1	0.6	0.6	8.0	8.0
04/01/21	60	1560	1600	4.2	4.14	10	96	0.1	0.2	1.1	1.1	13.7	13.4	910	1	69	0.1	0.1	0.8	0.8	9.9	9.7
05/16/21	100	1341	1400	4.4	4.21	10	64	1.8	0.4	0.9	0.9	9.2	8.4	760	204	77	2.2	0.5	1.1	1.1	11.0	10.1
06/19/21	100	1469	1500	4.3	4.24	10	64	0.1	0.1	1.0	1.0	11.0	11.1	880	17	77	0.2	0.1	1.1	1.2	13.2	13.3
07/04/21	86	1764	1800	4.3	4.15	10	120	0.1	0.1	1.4	1.4	16.6	16.7	1100	2	124	0.1	0.1	1.4	1.4	17.1	17.2
08/04/21	75	1858	1800	4.3	4.07	10	120	0.1	0.1	1.5	1.5	19.4	18.0	1100	3	108	0.1	0.1	1.3	1.3	17.5	16.2
09/05/21	100	1585	1700	4.2	4.14	10	100	0.1	0.1	1.3	1.3	17.5	18.0	1000	1	120	0.1	0.1	1.6	1.6	21.0	21.6
10/31/21	60	1597	1800	4.2	4.51	10	140	0.1	0.1	1.4	1.4	18.1	18.8	1000	1	101	0.1	0.1	1.0	1.0	13.1	13.6
11/11/21	75	1532	1500	4.6	4.17	10	190	0.1	0.1	1.2	1.2	15.1	14.0	1200	1	171	0.1	0.1	1.0	1.0	13.6	12.6
12/21/21	60	1742	1900	4.2	4.37	10	220	2.2	0.2	1.6	1.6	18.8	23.6	1700	44	159	1.6	0.1	1.2	1.2	13.6	17.0
Average	71	1526	1655	4.2	4.21	10	122	0.4	0.2	1.4	1.4	16.9	17.0	1027	24	99	0.4	0.1	1.1	1.1	13.4	13.5
Median	68	1560	1700	4.3	4.18	10	110	0.1	0.1	1.2	1.2	15.9	15.4	960	2	89	0.1	0.1	1.1	1.1	13.4	13.5
Minimum	32	824	1400	3.6	4.07	10	64	0.1	0.1	0.9	0.9	9.2	8.4	760	1	55	0.1	0.1	0.6	0.6	8.0	8.0
Maximum	100	1858	1900	4.6	4.51	10	220	2.2	0.4	3.9	3.8	38.6	36.8	1700	204	171	2.2	0.5	1.6	1.6	21.0	21.6

Measure the Flow

FLOW: Should I Measure the Flow?

- YES!

How Do I Measure Flow?

- Bucket and Stopwatch
- Flume
- Weir
- Flow Meter

Measure the Flow

Bucket & Stopwatch

- Set a pipe
- Calibrated Bucket
- Stopwatch

Calibrated Buckets

Standard 5-Gallon Bucket Calibration	
Feet from Bottom	US Gal.
1.070	5.0
0.965	4.5
0.865	4.0
0.765	3.5
0.660	3.0
0.550	2.5
0.450	2.0
0.340	1.5
0.235	1.0
0.170	0.5
Bottom	0.0

Measuring Flow: A Solid Investment

- Prevent Under-Sizing
- Avoid Over-Sizing

Populate The Dataset

Date	Flow	F .Cond.	Cond.	F.pH	pH	Alk.	Acid.	Fe	D. Fe	Mn	D. Mn	Al	D. Al	Sulfate	TSS	Acid	T.Fe	D.Fe	T.Mn	D.Mn	T.Al.	D.Al.
	gpm	umho/cm	umho/cm	s.u.	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day
01/01/21	32			3.6	4.19	ND	166	0.3	0.3	3.9	3.8	38.6	36.8	919	6	64	0.1	0.1	1.5	1.5	14.8	14.2
02/12/21	60	1512	1500	4.3	4.08	10	90	0.1	0.1	1.0	1.0	11.8	12.2	840	1	65	0.1	0.1	0.7	0.7	8.5	8.8
03/17/21	50	824	1700	4.3	4.24	10	92	0.1	0.1	1.1	1.1	13.3	13.3	920	1	55	0.1	0.1	0.6	0.6	8.0	8.0
04/01/21	60	1560	1600	4.2	4.14	10	96	0.1	0.2	1.1	1.1	13.7	13.4	910	1	69	0.1	0.1	0.8	0.8	9.9	9.7
05/16/21	100	1341	1400	4.4	4.21	10	64	1.8	0.4	0.9	0.9	9.2	8.4	760	204	77	2.2	0.5	1.1	1.1	11.0	10.1
06/19/21	100	1469	1500	4.3	4.24	10	64	0.1	0.1	1.0	1.0	11.0	11.1	880	17	77	0.2	0.1	1.1	1.2	13.2	13.3
07/04/21	86	1764	1800	4.3	4.15	10	120	0.1	0.1	1.4	1.4	16.6	16.7	1100	2	124	0.1	0.1	1.4	1.4	17.1	17.2
08/04/21	75	1858	1800	4.3	4.07	10	120	0.1	0.1	1.5	1.5	19.4	18.0	1100	3	108	0.1	0.1	1.3	1.3	17.5	16.2
09/05/21	100	1585	1700	4.2	4.14	10	100	0.1	0.1	1.3	1.3	17.5	18.0	1000	1	120	0.1	0.1	1.6	1.6	21.0	21.6
10/31/21	60	1597	1800	4.2	4.51	10	140	0.1	0.1	1.4	1.4	18.1	18.8	1000	1	101	0.1	0.1	1.0	1.0	13.1	13.6
11/11/21	75	1532	1500	4.6	4.17	10	190	0.1	0.1	1.2	1.2	15.1	14.0	1200	1	171	0.1	0.1	1.0	1.0	13.6	12.6
12/21/21	60	1742	1900	4.2	4.37	10	220	2.2	0.2	1.6	1.6	18.8	23.6	1700	44	159	1.6	0.1	1.2	1.2	13.6	17.0
Average	71	1526	1655	4.2	4.21	10	122	0.4	0.2	1.4	1.4	16.9	17.0	1027	24	99	0.4	0.1	1.1	1.1	13.4	13.5
Median	68	1560	1700	4.3	4.18	10	110	0.1	0.1	1.2	1.2	15.9	15.4	960	2	89	0.1	0.1	1.1	1.1	13.4	13.5
Minimum	32	824	1400	3.6	4.07	10	64	0.1	0.1	0.9	0.9	9.2	8.4	760	1	55	0.1	0.1	0.6	0.6	8.0	8.0
Maximum	100	1858	1900	4.6	4.51	10	220	2.2	0.4	3.9	3.8	38.6	36.8	1700	204	171	2.2	0.5	1.6	1.6	21.0	21.6

Measure the Flow

Essential Parameters

Field Parameters

- Flow
- pH
- Temperature

Laboratory Analysis

- Conductivity
- Alkalinity
- Acidity (Hot Peroxide Method +/-)
- Iron
- Manganese
- Aluminum
- Sulfate
- Total Suspended Solids

Measure the Flow

Preferred Parameters

Field Parameters

- Flow
- pH
- Temperature
- Alkalinity
- Dissolved Oxygen (Luminescent)
- ORP

Measure the Flow

Laboratory Analysis

- Conductivity
- Alkalinity
- Acidity (Hot Peroxide Method +/-)
- Iron (Total & Dissolved)
- Manganese (Total & Dissolved)
- Aluminum (Total & Dissolved)
- Magnesium (Total & Dissolved)
- Calcium (Total & Dissolved)
- Sulfate
- Total Suspended Solids
- Total Dissolved Solids
- Osmotic Pressure

Dissolved metals are to be filtered in the field with 0.45-micron filter

The Complete Dataset

Field Parameters

- Flow
- pH
- Temperature
- Alkalinity
- Conductivity
- Dissolved Oxygen (Luminescent)
- Carbon Dioxide (Cold Acidity)
- ORP

Measure the Flow

Laboratory Analysis

- Conductivity
- Alkalinity
- Acidity (Hot Peroxide Method +/-)
- Bicarbonate
- Chloride
- Sulfate
- Total Inorganic Carbon (Carbon Dioxide)
- Total & Dissolved:
  - Fe (Ferrous/Ferric), Mn, Al, Mg, Ca, K
- Total & Dissolved (if needed):
  - Cu, Pb, Cd, Ni, Zn, etc.
- Treatment Titration

Populate The Dataset

Date	Flow	F .Cond.	Cond.	F.pH	pH	Alk.	Acid.	Fe	D. Fe	Mn	D. Mn	Al	D. Al	Sulfate	TSS	Acid	T.Fe	D.Fe	T.Mn	D.Mn	T.Al.	D.Al.
	gpm	umho/cm	umho/cm	s.u.	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day
01/01/21	32			3.6	4.19	ND	166	0.3	0.3	3.9	3.8	38.6	36.8	919	6	64	0.1	0.1	1.5	1.5	14.8	14.2
02/12/21	60	1512	1500	4.3	4.08	10	90	0.1	0.1	1.0	1.0	11.8	12.2	840	1	65	0.1	0.1	0.7	0.7	8.5	8.8
03/17/21	50	824	1700	4.3	4.24	10	92	0.1	0.1	1.1	1.1	13.3	13.3	920	1	55	0.1	0.1	0.6	0.6	8.0	8.0
04/01/21	60	1560	1600	4.2	4.14	10	96	0.1	0.2	1.1	1.1	13.7	13.4	910	1	69	0.1	0.1	0.8	0.8	9.9	9.7
05/16/21	100	1341	1400	4.4	4.21	10	64	1.8	0.4	0.9	0.9	9.2	8.4	760	204	77	2.2	0.5	1.1	1.1	11.0	10.1
06/19/21	100	1469	1500	4.3	4.24	10	64	0.1	0.1	1.0	1.0	11.0	11.1	880	17	77	0.2	0.1	1.1	1.2	13.2	13.3
07/04/21	86	1764	1800	4.3	4.15	10	120	0.1	0.1	1.4	1.4	16.6	16.7	1100	2	124	0.1	0.1	1.4	1.4	17.1	17.2
08/04/21	75	1858	1800	4.3	4.07	10	120	0.1	0.1	1.5	1.5	19.4	18.0	1100	3	108	0.1	0.1	1.3	1.3	17.5	16.2
09/05/21	100	1585	1700	4.2	4.14	10	100	0.1	0.1	1.3	1.3	17.5	18.0	1000	1	120	0.1	0.1	1.6	1.6	21.0	21.6
10/31/21	60	1597	1800	4.2	4.51	10	140	0.1	0.1	1.4	1.4	18.1	18.8	1000	1	101	0.1	0.1	1.0	1.0	13.1	13.6
11/11/21	75	1532	1500	4.6	4.17	10	190	0.1	0.1	1.2	1.2	15.1	14.0	1200	1	171	0.1	0.1	1.0	1.0	13.6	12.6
12/21/21	60	1742	1900	4.2	4.37	10	220	2.2	0.2	1.6	1.6	18.8	23.6	1700	44	159	1.6	0.1	1.2	1.2	13.6	17.0
Average	71	1526	1655	4.2	4.21	10	122	0.4	0.2	1.4	1.4	16.9	17.0	1027	24	99	0.4	0.1	1.1	1.1	13.4	13.5
Median	68	1560	1700	4.3	4.18	10	110	0.1	0.1	1.2	1.2	15.9	15.4	960	2	89	0.1	0.1	1.1	1.1	13.4	13.5
Minimum	32	824	1400	3.6	4.07	10	64	0.1	0.1	0.9	0.9	9.2	8.4	760	1	55	0.1	0.1	0.6	0.6	8.0	8.0
Maximum	100	1858	1900	4.6	4.51	10	220	2.2	0.4	3.9	3.8	38.6	36.8	1700	204	171	2.2	0.5	1.6	1.6	21.0	21.6

Calculate the Load

Load Calculation

Flow (gpm) x Concentration (mg/L) x 0.01202 = lb/day

- Used to size aerobic wetlands
- Can be used to size manganese removal beds
- Helps to estimate sludge volumes
- Used to estimate chemical consumption
- Used to project environmental benefit
  - Stream Impact, TMDLs, etc.

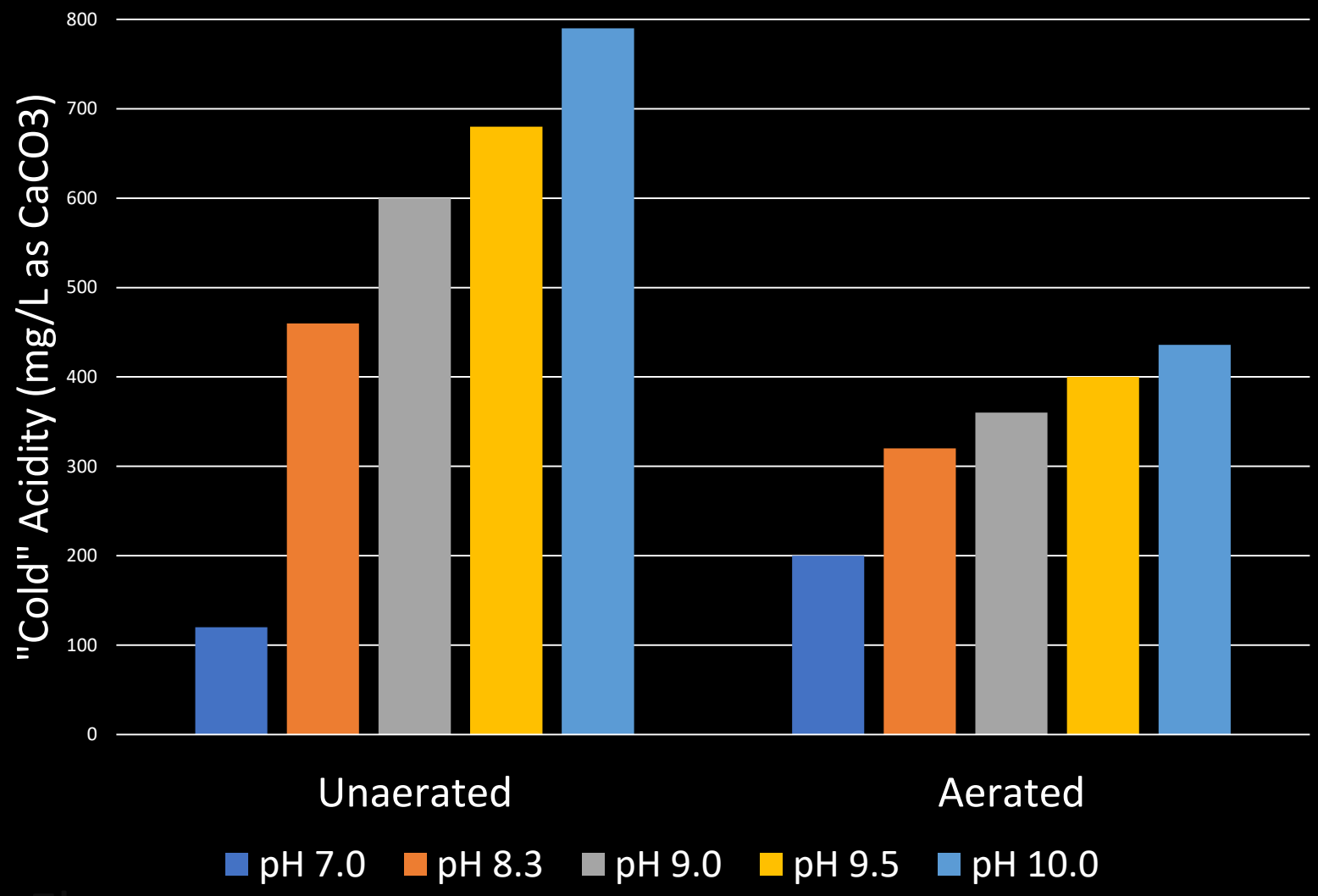
Measure the Flow

Quick Tip

The Shucka-Shucka Test

- Use pH to check for CO_2
  - Measure pH
  - Shake sample
  - Does pH go up?

Why Carbon Dioxide Matters



You can waste A LOT of money!

Field vs. Lab: What's the Difference?

Point	Flow gpm	Field pH	Lab pH	Field Alk. mg/L $CaCO_3$	Lab Alk. mg/L $CaCO_3$	(Hot) Acidity mg/L $CaCO_3$
VFP-West	61	6.5	5.77	108	53	-4
VFP-East	81	6.7	5.67	121	43	2
Wetland	228	6.2	5.08	33	3	96

Measure the Flow

Field vs. Lab and Total vs. Dissolved

Point	Field pH	Lab pH	Field Alk. mg/L $CaCO_3$	Lab Alk. mg/L $CaCO_3$	Total Fe mg/L	Diss. Fe mg/L	Total Mn mg/L	Diss. Mn mg/L	Total Al mg/L	Diss. Al mg/L
2	6.29	6.08	191	113	275	238	7	6	1	1
3	3.35	3.14	0	0	177	148	12	12	3	3

Calculated & Treatment Acidity

Calculated Acidity

$50{,}000 \times 10^{-pH} + 1.79(Fe^{2+}) + 2.83(Fe^{3+}) + 1.82(Mn) + 5.56(Al) - Alk$

(field pH, subtract field alkalinity)

$+ 4.34(Mg) + 2.50(Ca) + 1.53(Zn) + 1.57(Cu) + 1.70(Ni)$

- *Used dissolved metals*
- *Not all Mn may precipitate in Hot Acidity Test*
- ***Treatment acidity** may differ as Mg, Ca, may precipitate at high pH, + other metals*

Treatment Acidity

Read Paper by Brent Means & Tiff Hilton:

"Comparison of Three Methods to Measure Acidity of Coal-Mine Drainage"

Available from the American Society of Reclamation Sciences (www.asrs.us)

asrs.us/past-asrs-meetings/2004-morgantown-wv-member/

It has a great Literature Cited Section

Great References for the AMD Practitioner

Great Reference for Passive Treatment of AMD:

“Review of Passive Systems for Acid Mine Drainage Treatment”

(J.Skousen, C.Zipper, A.Rose, P.Ziemkiewicz, R.Nairn, L.McDonald, R.Kleinman)

link.springer.com/article/10.1007/s10230-016-0417-1

Mind-blowing knowledge of AMD Chemistry and Awesome Literature Cited:

“Interactive PHREEQ-N-AMDTreat water-quality modeling tools to evaluate performance and design of treatment systems for acid mine drainage”

(Charles Cravotta)

sciencedirect.com/science/article/pii/S0883292720303371

Flow: Expectations vs. Reality

Measure the Flow

Thank you! Questions?