Seasonal Recovery of an Appalachian Stream Affected by Acid Mine Drainage and Municipal Wastewater

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What's Being Studied?

Where Did We Study?

Chemistry Data

Macroinvertebrate Data

Conclusion

Co-Treatment

- Municipal Wastewater Treatment Plant Effluent (MWW)
- Acid Mine Drainage (AMD)

What is in MWW?

Raw Influent

- Contains
  - Elevated Phosphorus
  - Elevated Nitrogen
  - Pathogens
  - Organic Carbon
  - Other contaminants of emerging concern (CECs) e.g. Pharmaceuticals
  - Alkalinity

Our “Treated” MWW Effluent

- Contains
  - **Elevated Phosphorus & Nitrogen**
  - **Residual Organics**
  - CECs?
  - **Alkalinity**

Inadvertent Treatment?

AMD provides

- Coagulants
  - Fe
  - Al
- Disinfectant
  - pH
  - Metals

MWW provides

- Reactant
  - Phosphorus
- pH Buffer
  - Alkalinity
- Sorbent
  - Residual Organics

What happens in co-treatment of AMD & MWW?

AMD: Al^{3+}, Fe^{3+}, SO_4^{2-} & H^+

MWW: Nutrients (NO_3^-, PO_4^{3-}), Organic matter & Alkalinity ($CaCO_3$)

Focus on rapid reactions

$$Al^{3+}_{(aq)} + PO_4^{3-}_{(aq)} \longrightarrow AlPO_{4(s)} \qquad pH = 5\text{-}6$$

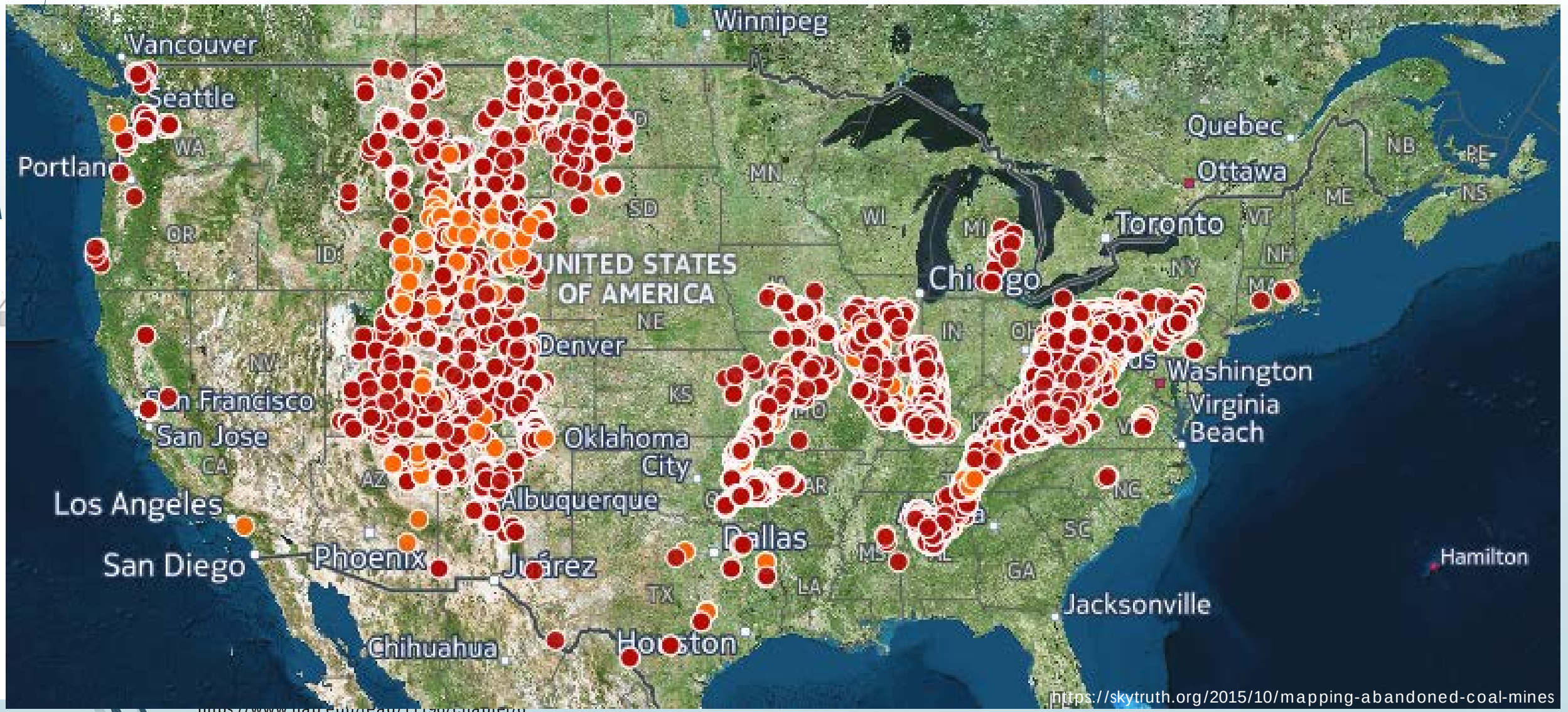
$$Fe^{3+}_{(aq)} + PO_4^{3-}_{(aq)} \longrightarrow FePO_{4(s)} \qquad pH = \sim 3.5\text{-}6$$

$$Al^{3+}_{(aq)} + H_2O_{(aq)} \longrightarrow Al(OH)_{3(s)} + H^+ \qquad pH = 5.2\text{-}8.8$$

$$Fe^{3+}_{(aq)} + H_2O_{(aq)} \longrightarrow Fe(OH)_{3(s)} + H^+ \qquad pH > 3$$

Sorption: Phosphorus will sorb to the Al and Fe hydroxides

Why is this Important?



https://skytruth.org/2015/10/mapping-abandoned-coal-mines

https://www.nap.edu/read/11196/chapter/6

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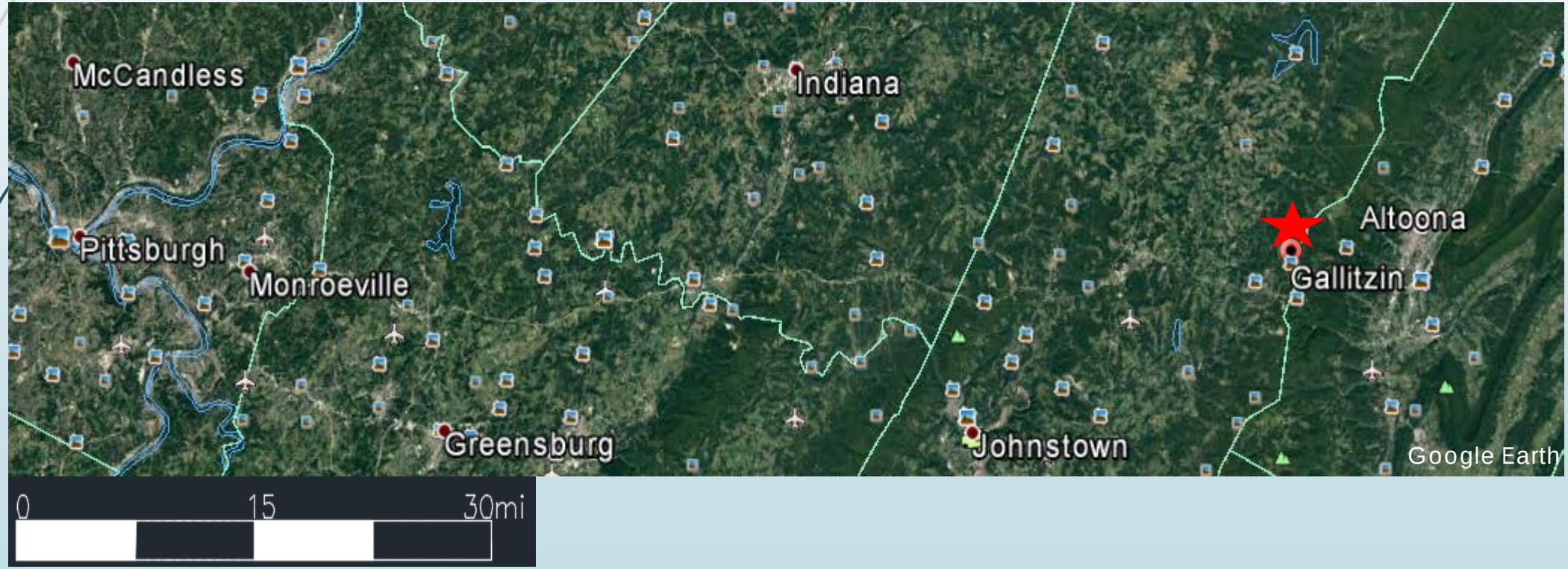
http://www.myonlinemaps.com/pennsylvania-counties-map.php

Study Site: Bradley Run

- Location: Gallitzin, Pennsylvania (20 minutes SW of Altoona, 90 minutes E of Pittsburgh)



Bradley Run Sampling Sites

Bradley Run Sampling Sites

Upstream (un-impacted) Site

Bridge

Poleline

Culvert

AMD

MWW

Upstream

0 500 1000ft

Gallitzin Rd

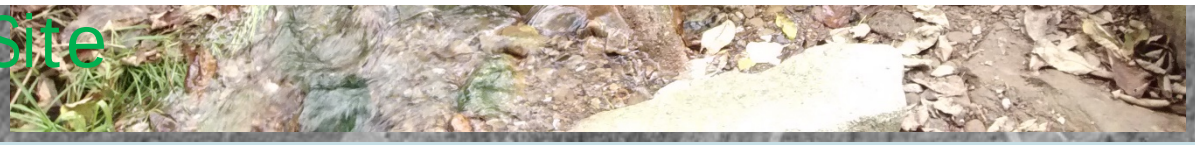
53

Commercial Ln

Google Earth

Bradley Run Sampling Sites

Municipal Wastewater (MWW) Site



Bridge

Poleline

Culvert

MWW

Upstream

0 500 1000ft

Vampire Rd

Gallitzin Rd

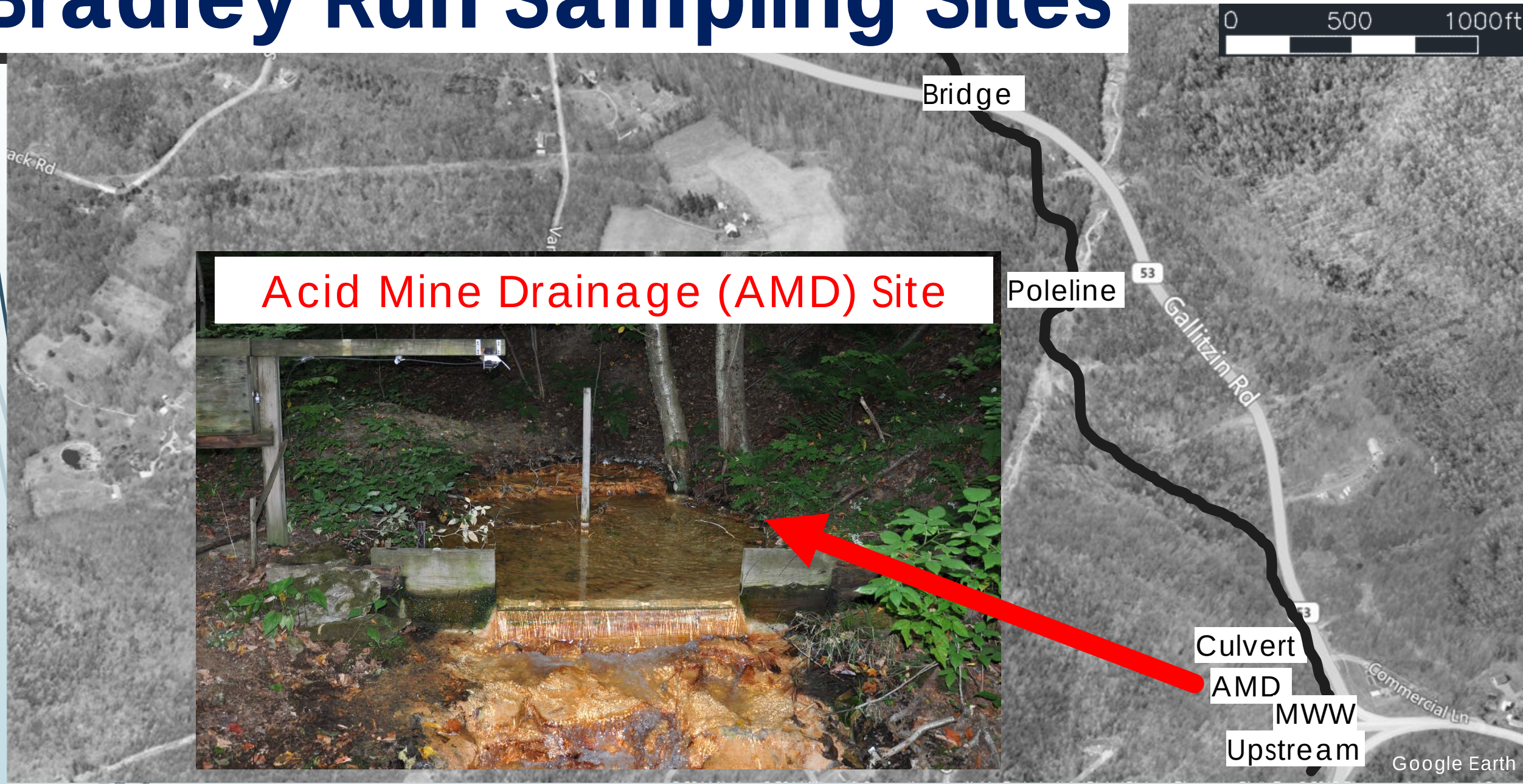
53

Cherry Ln

Commercial Ln

Google Earth

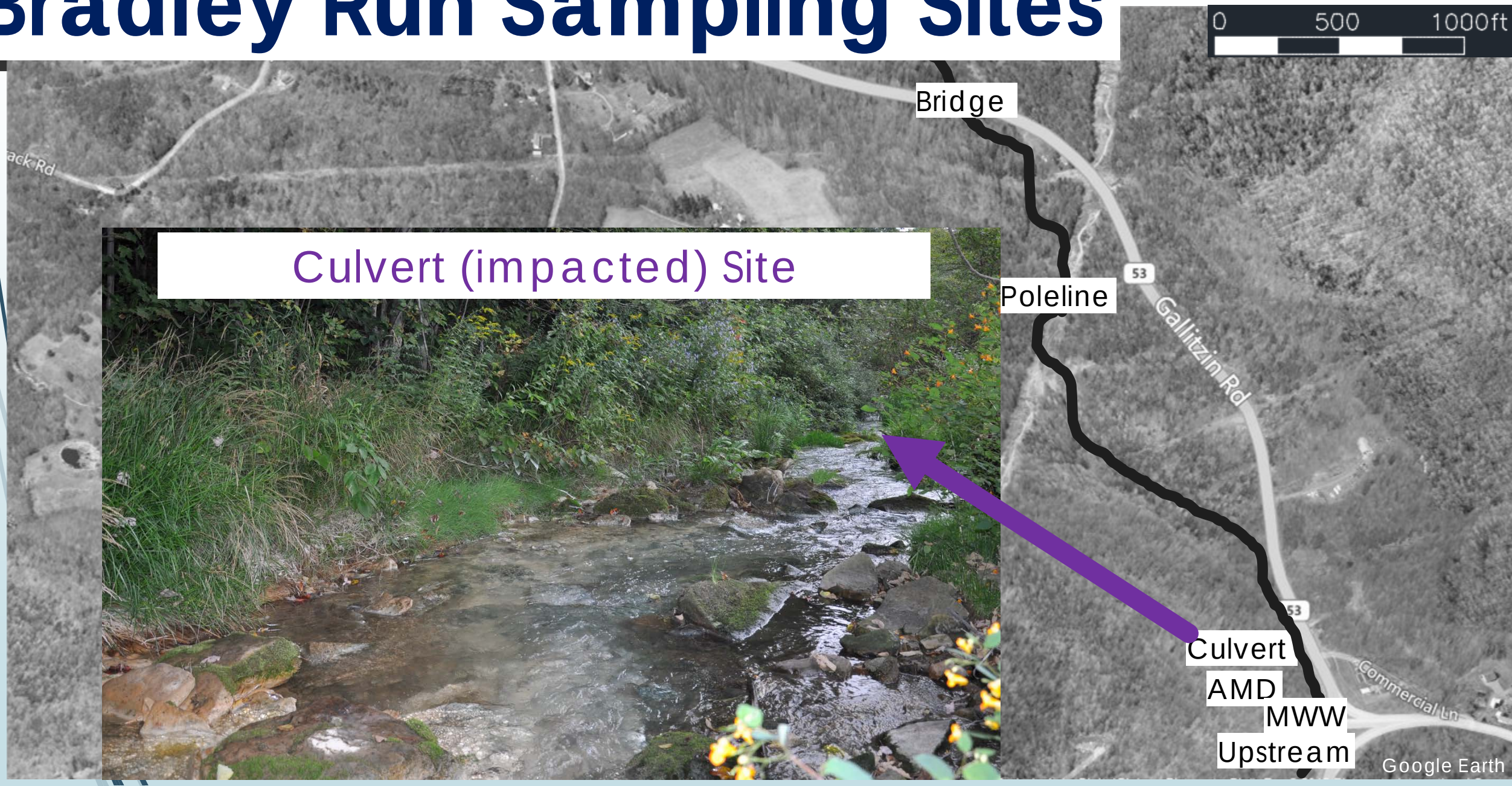
Bradley Run Sampling Sites



Acid Mine Drainage (AMD) Site

Bradley Run Sampling Sites

Culvert (impacted) Site



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0 500 1000ft

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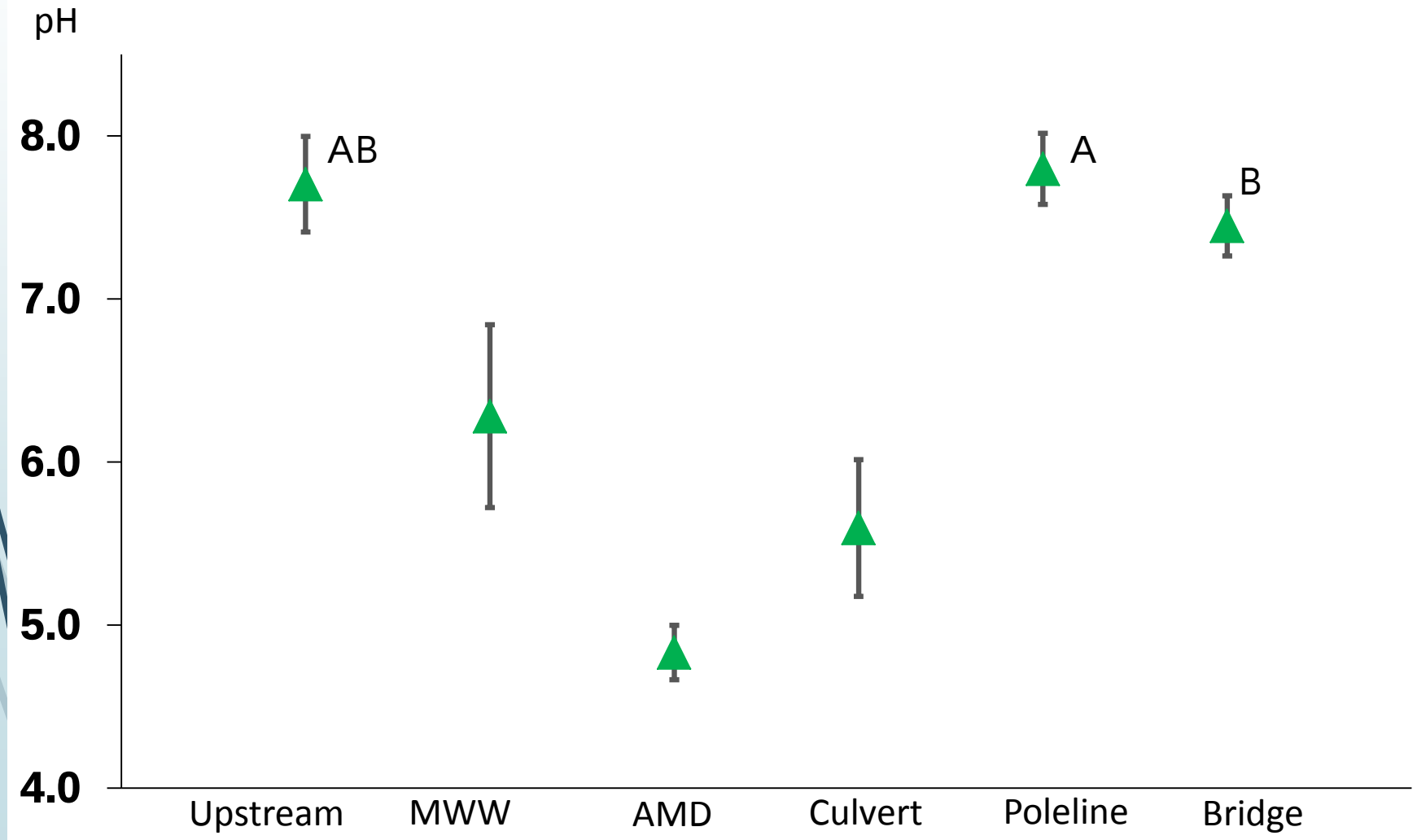
Chemistry Methods

- Sampling Protocol
  - 1-2 times per week
    - August – October 2014 & 2015
    - May – June 2016
  - Water Samples
  - YSI Professional Plus Probe
- What was measured?
  - Measured Metal concentrations
    - Aluminum & Iron
  - Anion concentrations
    - Phosphate & Nitrate
  - Water quality parameters

pH shows recovery downstream

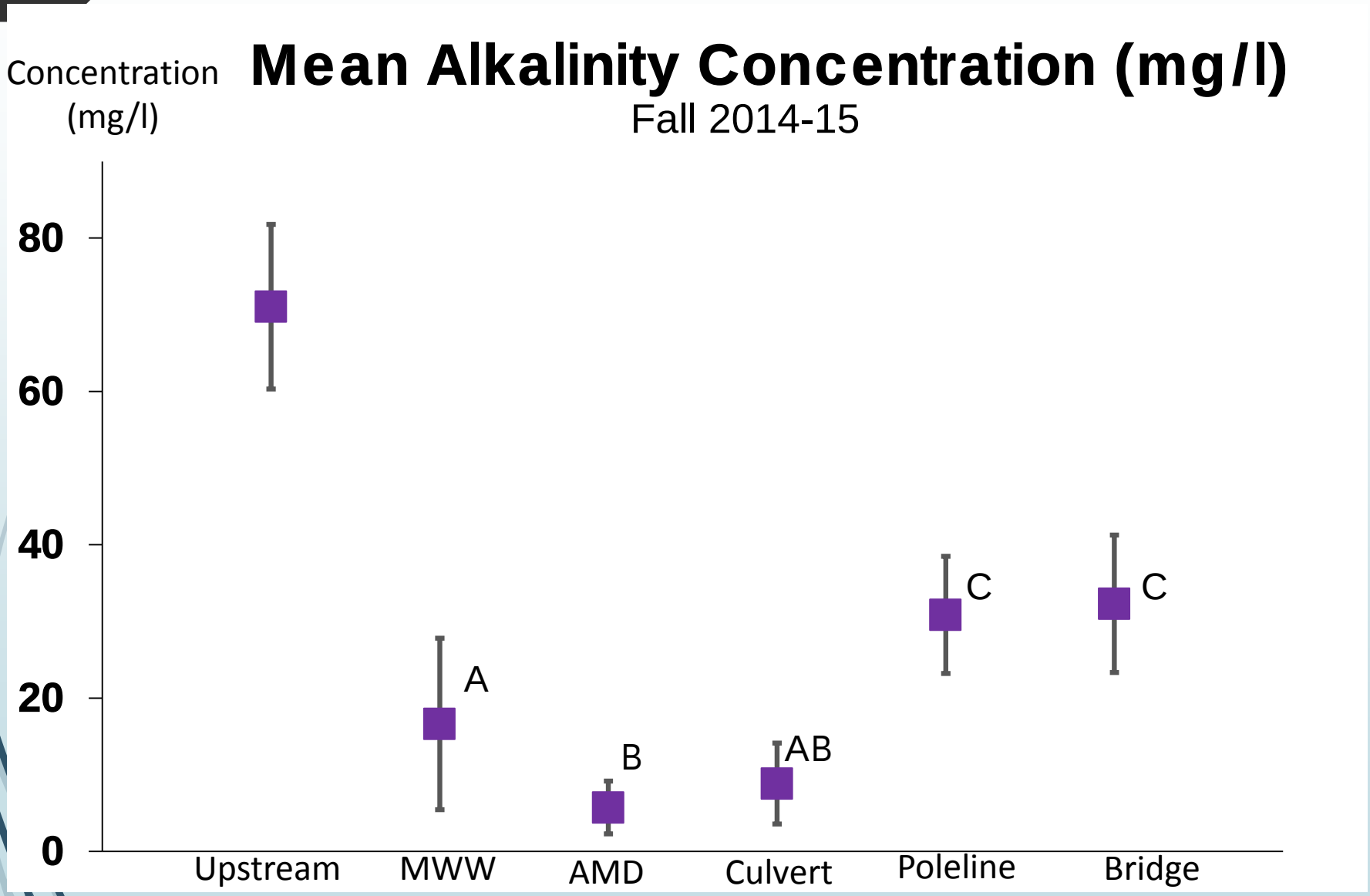
Mean pH – Fall 2014-15



Sites sharing a letter are not significantly different from each other (1-way ANOVA, Tukey's HSD, $p < 0.05$)

n = 20-21/site

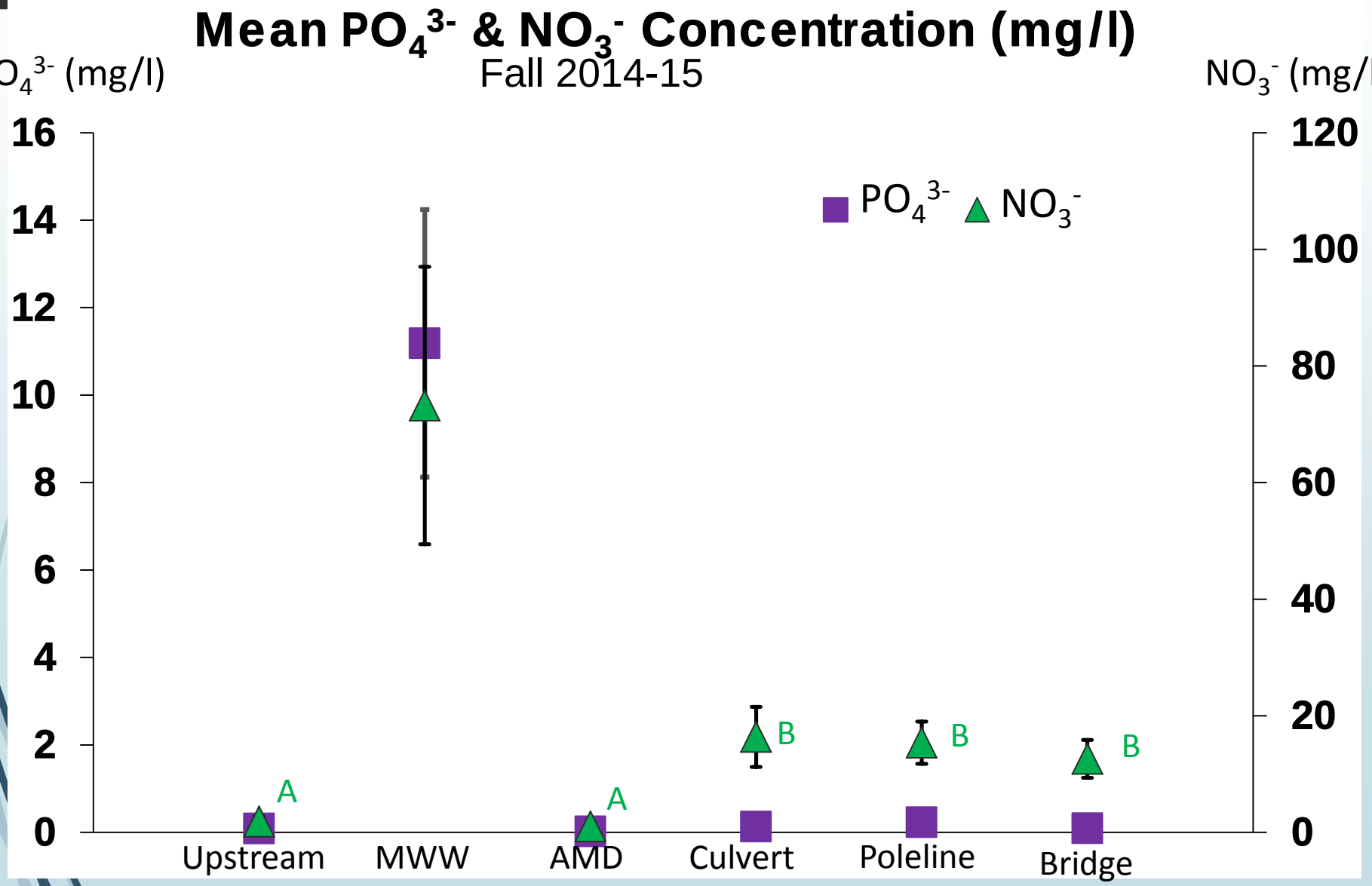
Only slight recovery of alkalinity downstream



Sites sharing a letter are not significantly different from each other (1-way ANOVA, Tukey's HSD, $p < 0.05$)

n = 16/site

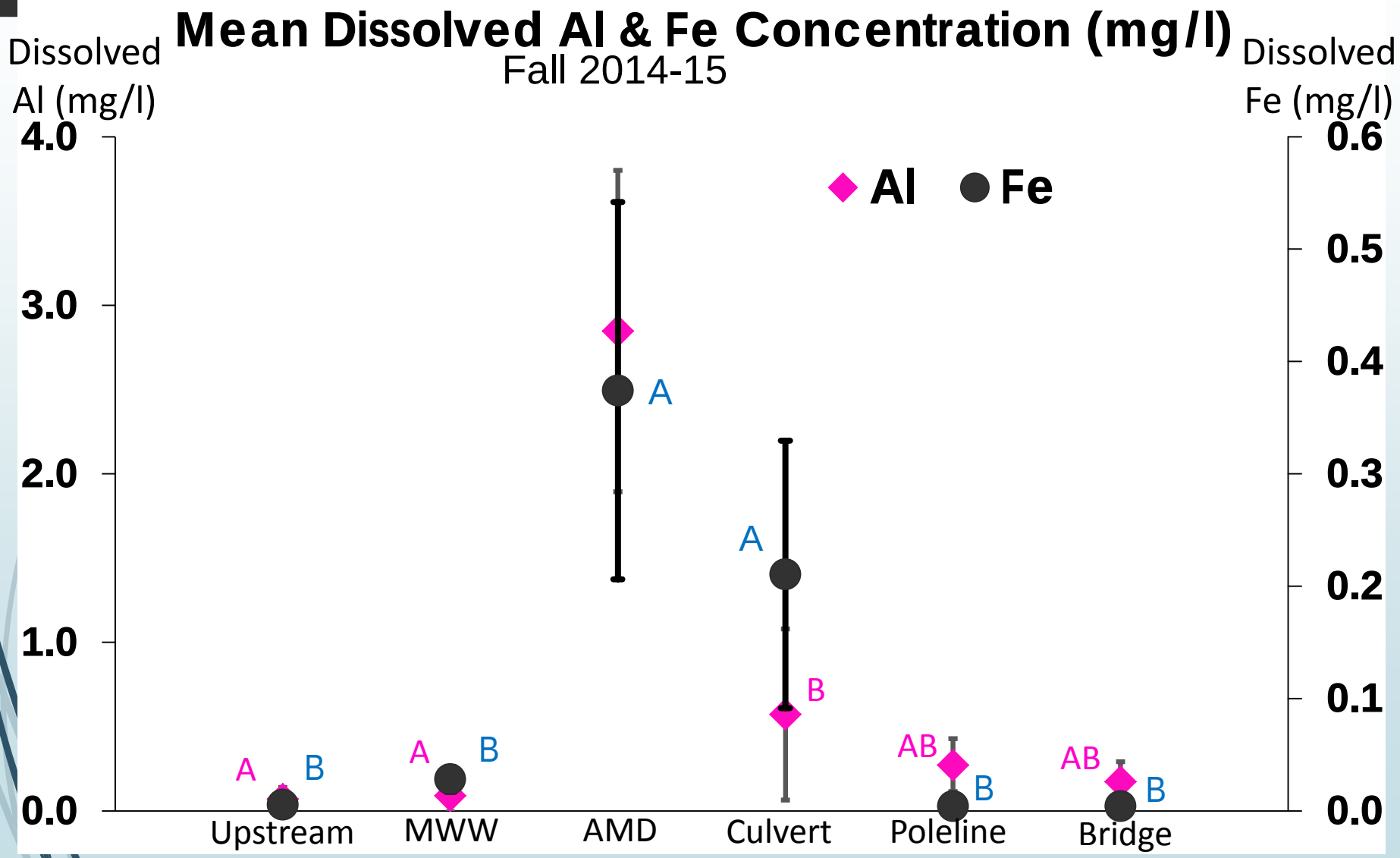
Phosphate is rapidly removed while nitrate is conserved downstream



Sites sharing a letter are not significantly different from each other (1-way ANOVA, Tukey's HSD, $p < 0.05$)

n = 20-21/site

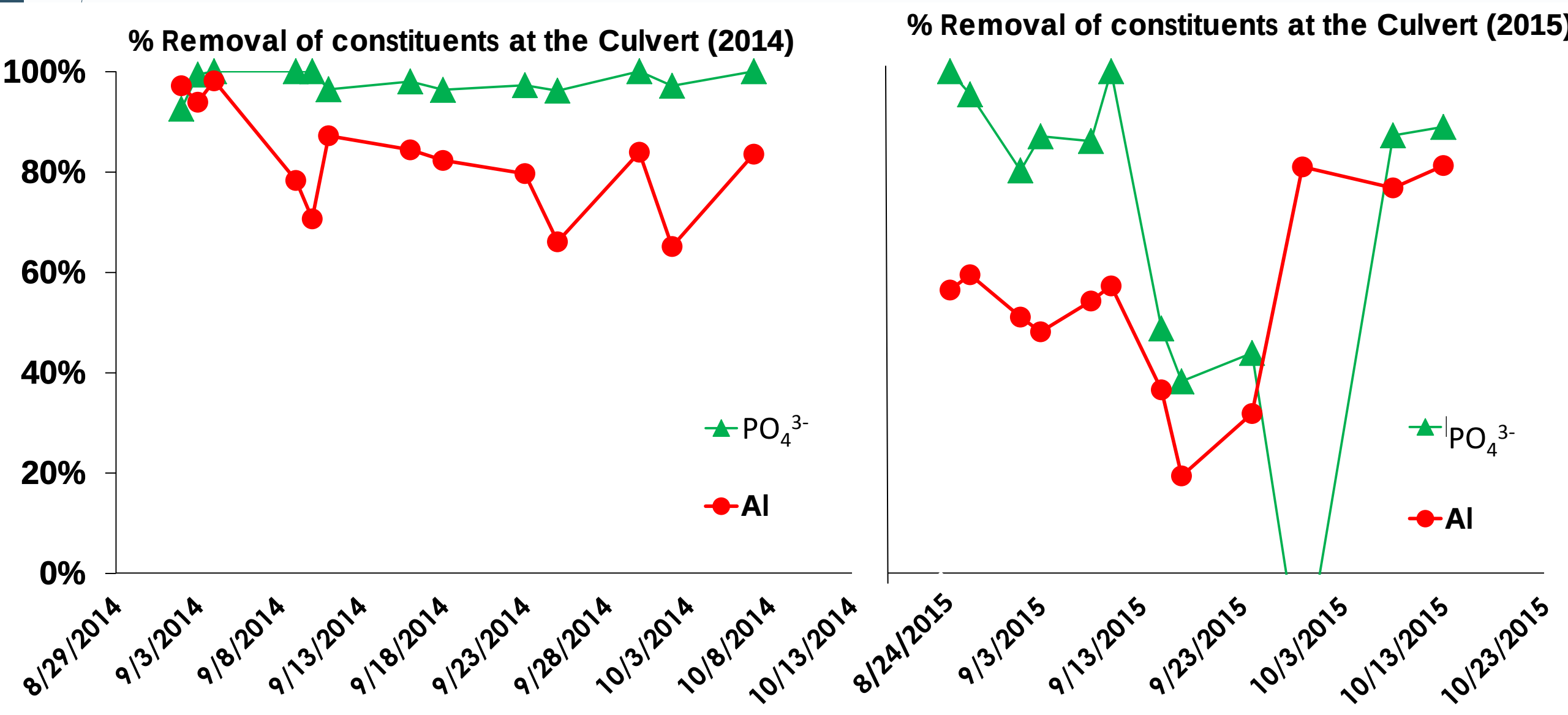
Al & Fe are removed downstream



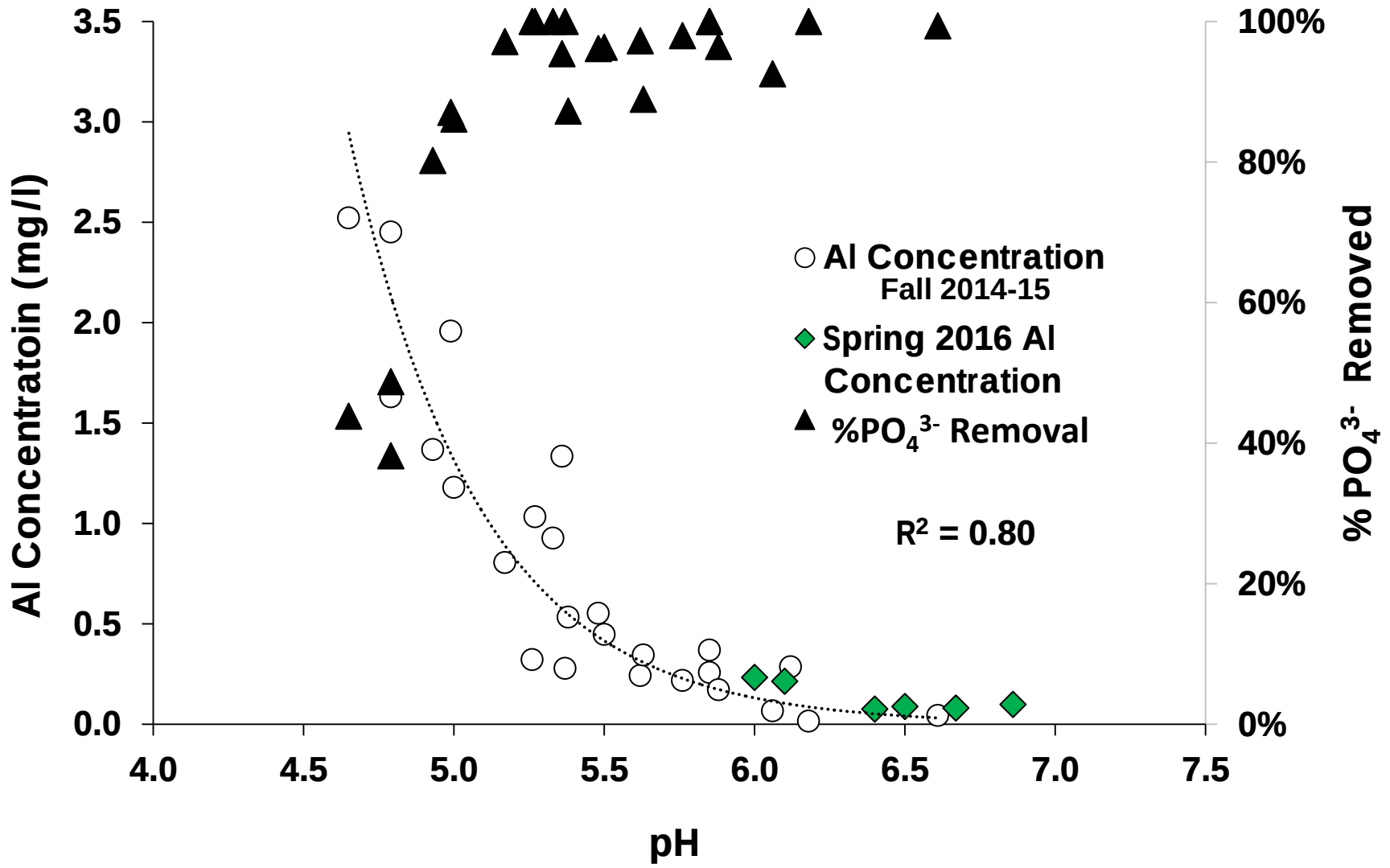
Sites sharing a letter are not significantly different from each other (1-way ANOVA, Tukey's HSD, $p < 0.05$)

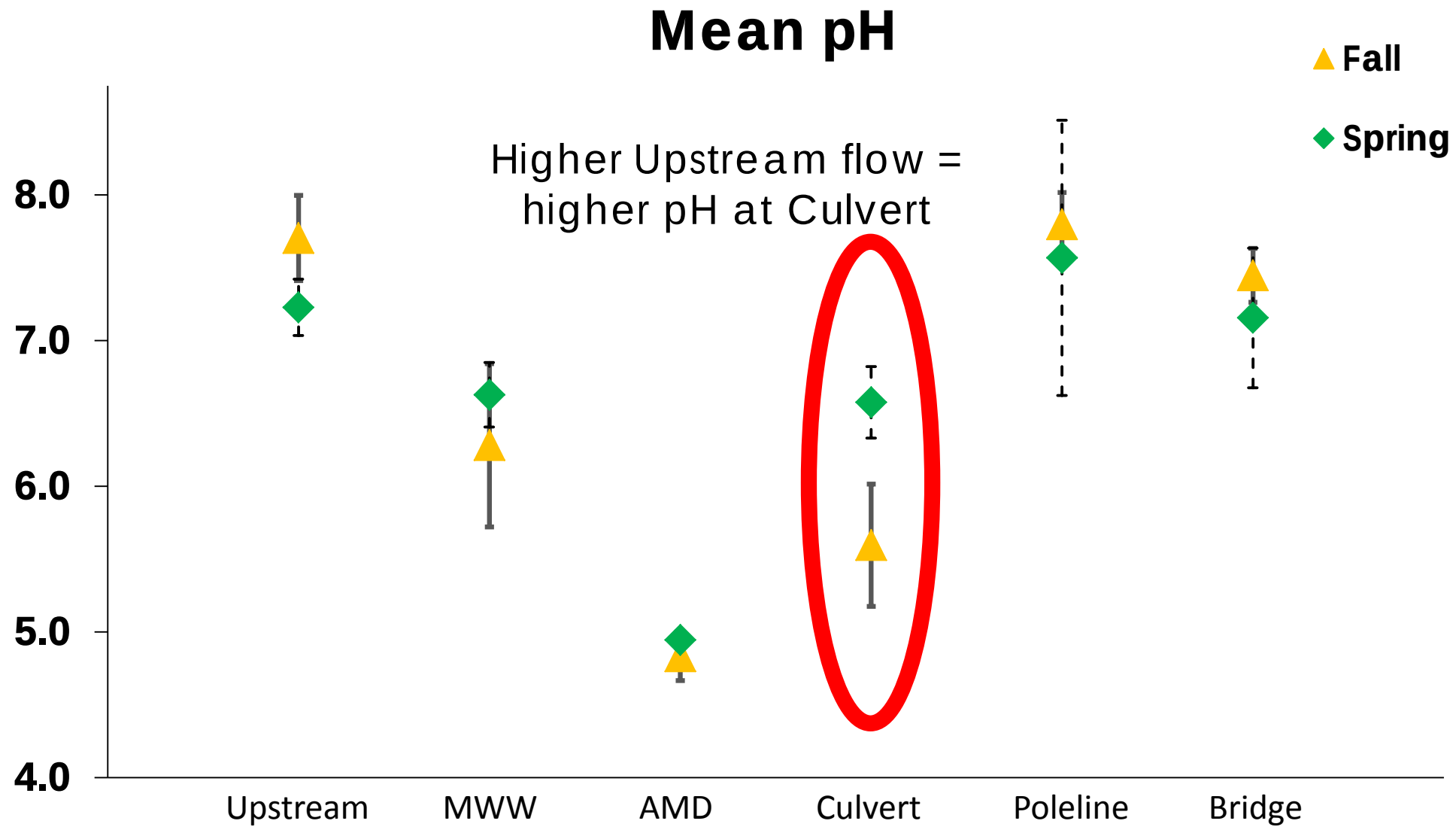
n = 20-21/site

Good PO_4^{3-} removal; moderate Al removal; variability



Al concentration & % PO_4 removal at the Culvert as a function of pH




Mean pH
Fall
Spring
Higher Upstream flow = higher pH at Culvert
8.0
7.0
6.0
5.0
4.0
Upstream
MWW
AMD
Culvert
Poleline
Bridge

Stream Recovery Based on Chemistry

- Coincidental removal of Al & PO_4^{3-}
- AMD masks PO_4^{3-} inputs from MWW in Bradley Run
- Spring “recovery” of stream relative to Fall

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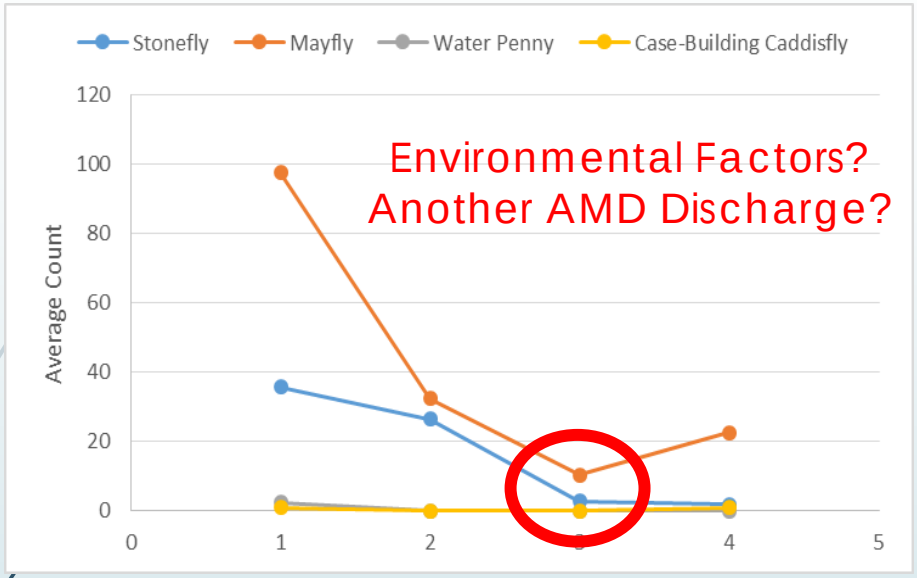
The Macroinvertebrate Data

- Methods
  - Sampled
    - September 2015: 2 dates
    - May – June 2016: 5 dates
  - Adaptation of the US EPA Rapid Bio-assessment Protocol
    - 4 Sites: Upstream, Culvert, Poleline, & Bridge
- Identification
  - 3 Group
  - Water quality score determined
  - Percent EPT

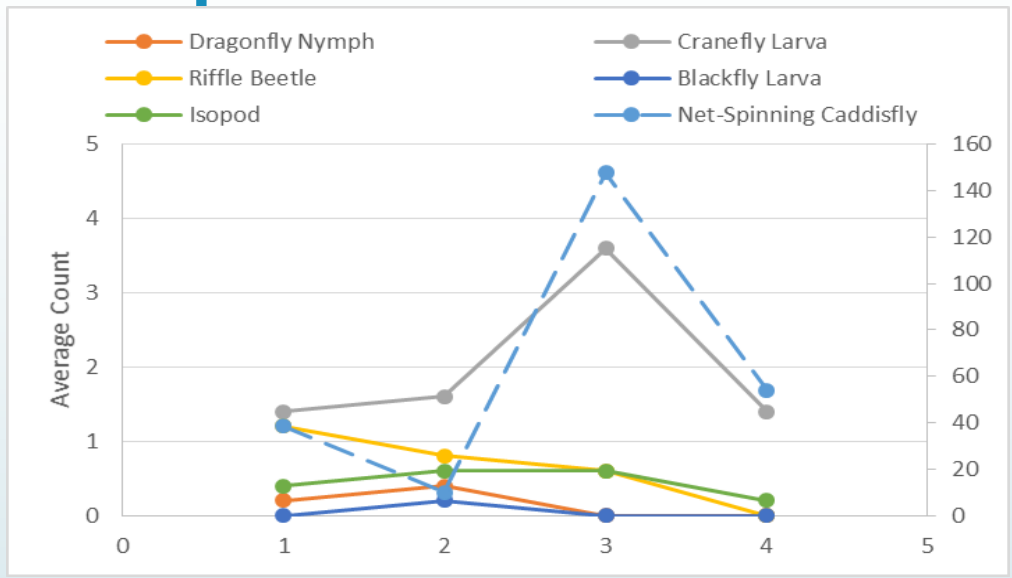
Amount of Each	Group 1	Group 2	Group 3
Rare	X 5.0	X 3.2	X 1.2
Common	X 5.6	X 3.4	X 1.1
Dominant	X 5.3	X 3.0	X 1.0
	Water Quality Score		
	Poor	Fair	Good
	<20	20 to 40	>40

Spring Counts Per Group

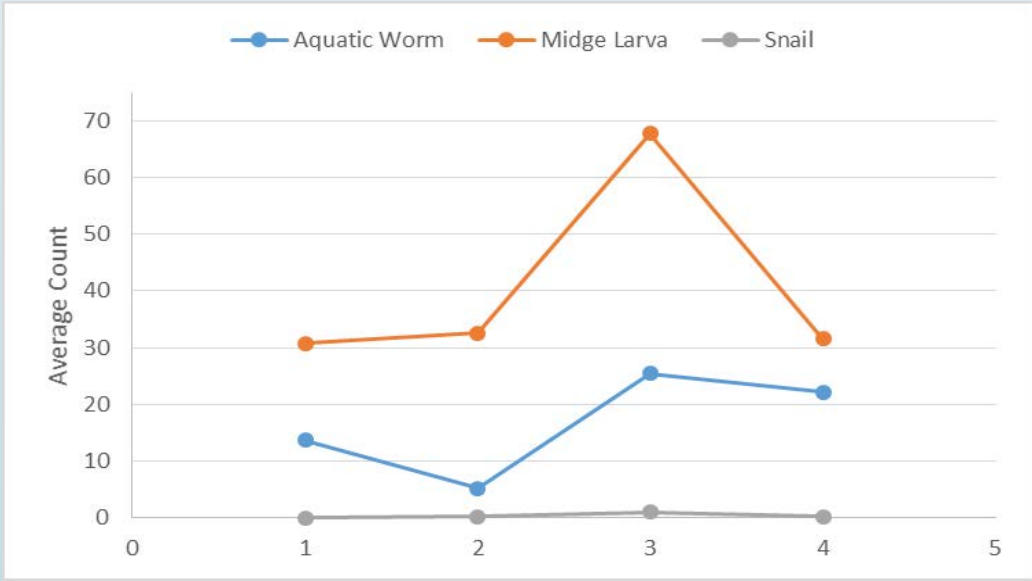
Group 1



Group 2



Group 3



Sites By Number
1 = Upstream
2 = Culvert
3 = Poleline
4 = Bridge

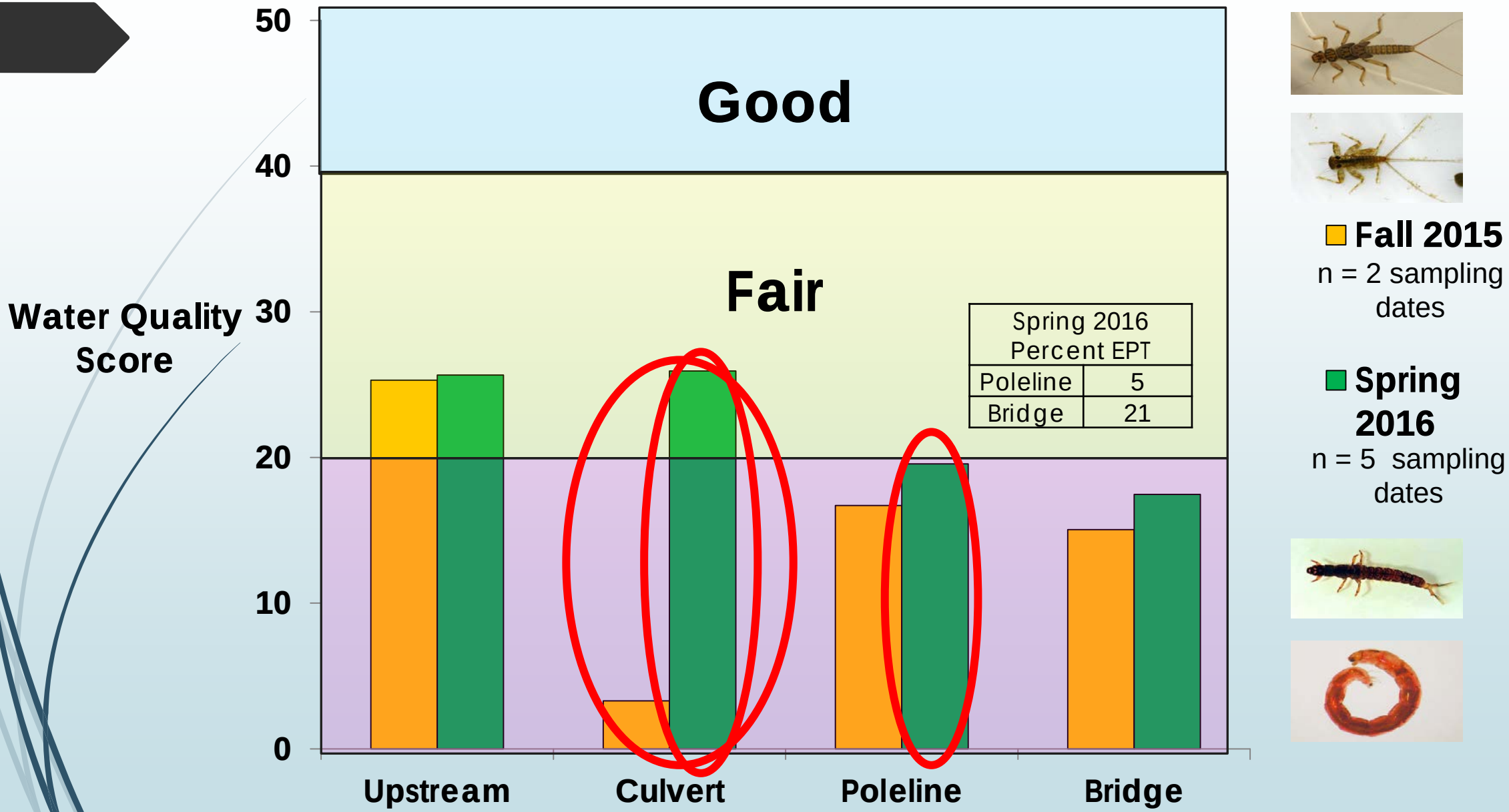
Group 1 Percentage (EPT)

- Ephemeroptera (Mayflies)
- Plecoptera (Stoneflies)
- Trichoptera (Case-building Caddisflies)

Fall 2015 Percent EPT			
Sampling Site	9/8/2015	9/10/2015	Average
Upstream	52	50	51
Culvert	0	0	0
Poleline	2	6	4
Bridge	12	7	9

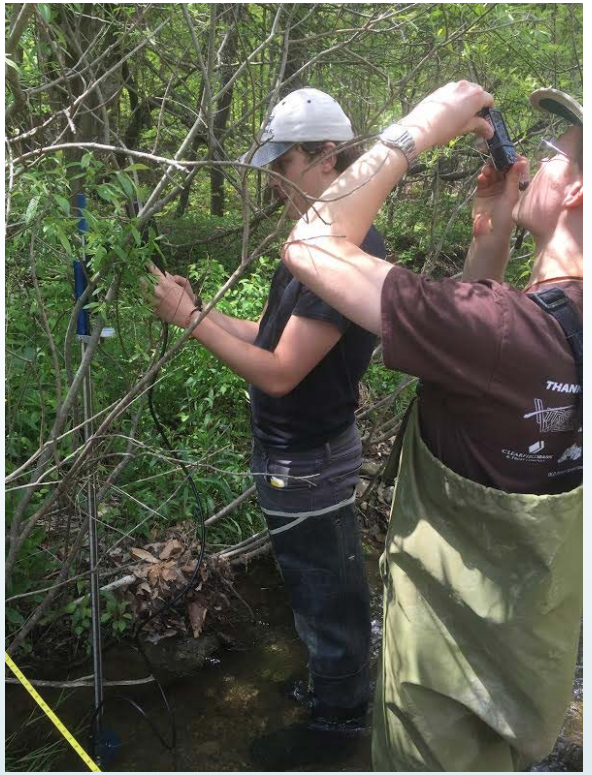
Spring 2016 Percent EPT						
Sampling Site	5/17/2016	5/19/2016	5/24/2016	5/26/2016	5/31/2016	Average
Upstream	80	67	76	41	57	64
Culvert	68	38	55	59	58	55
Poleline	0	3	4	11	10	5
Bridge	6	4	10	39	46	21

Bradley Run Macroinvertebrate-based Water Quality Score



What Does This Mean?

- Fall data
  - Shows water quality score drops at the Culvert
    - Lower flows
    - MMW pH ~ 3
  - Begins to rise again at Poleline
- Spring Data
  - Quick recovery at Culvert
    - Higher flows
    - WWTP Update
  - Scores drop at Poleline
    - Other possible AMD sources
    - Poor habitat



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Does Bradley Run Show Recovery?

- Spring "recovery" is relative to the Fall
- Inadvertent removal of Al and PO_4^{3-}
- Water Quality Score
  - Fall indicates slight recovery at the Poleline
  - Spring indicates recovery by Culvert
    - Scores drop off at Poleline and Bridge

Spring 2016 Percent EPT	
Poleline	5
Bridge	21

What's Next?

- Continued monitoring
- Macroinvertebrate
  - Stream Visual Assessment Protocol
  - Comparison
    - Riffle to Riffle
    - Pool to Pool
- Identify other sources of impact
- New MWW treatment system
- Future AMD treatment system

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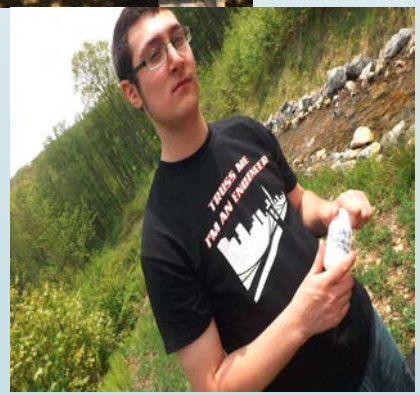

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