Passive Treatment using Drainable Limestone Beds: Lessons from 14 years of Design and Maintenance

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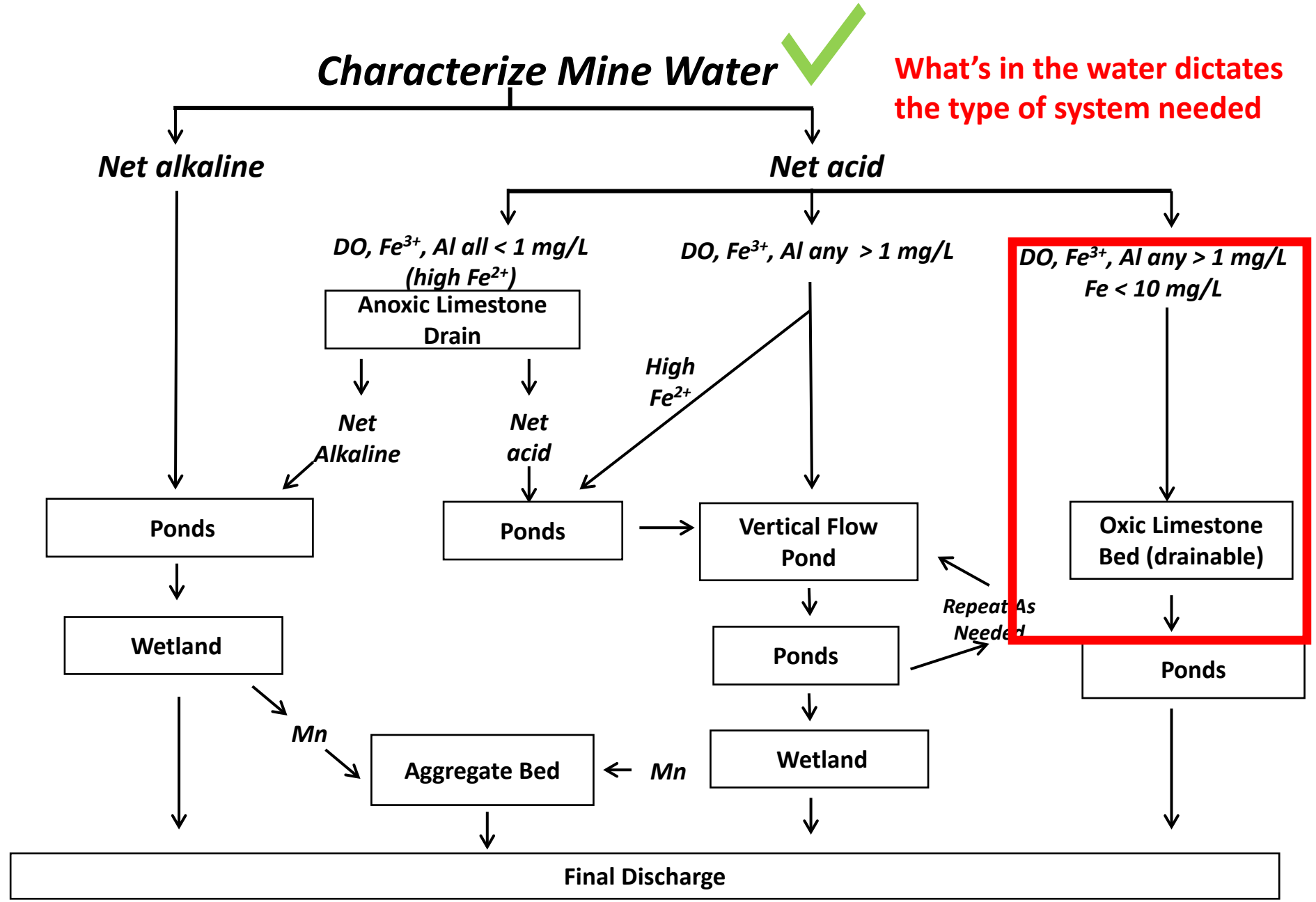
HedinEnvironmental

Passive Treatment Philosophy

Passive treatment attempts to create environments that mimic those found in nature where the desired geochemical reactions occur

- Biologically active areas (wetlands)
- Water bodies (ponds)
- Carbonate aquifers (limestone beds)

The goal of passive treatment is to provide “hands-off” water treatment that is sustainable over years to decades with minimal intervention

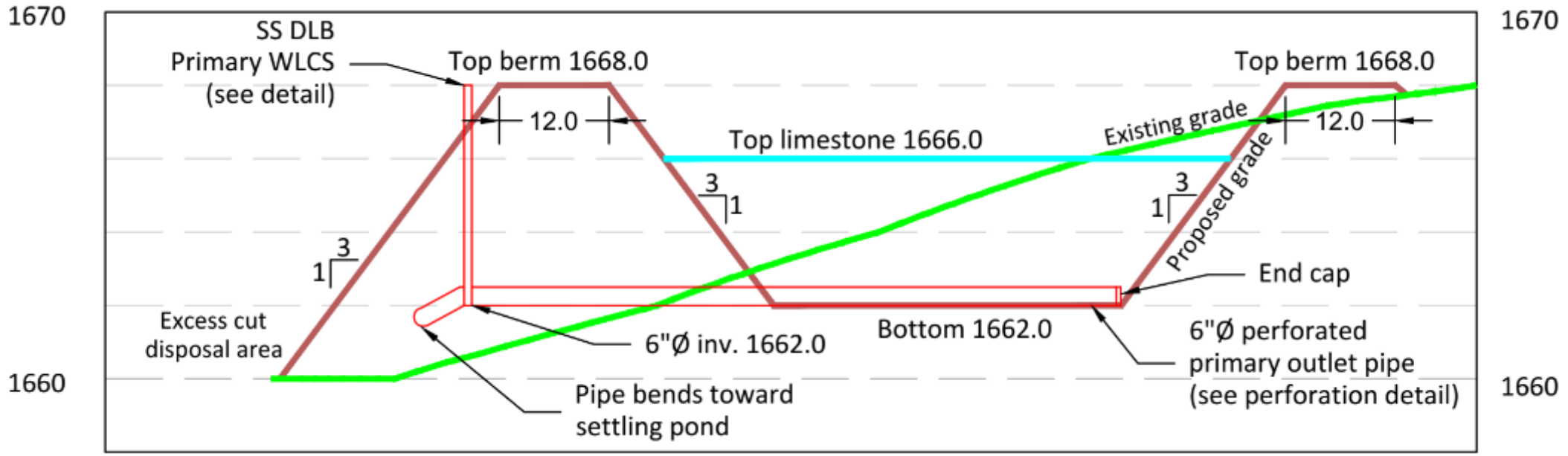

Characterize Mine Water
What's in the water dictates the type of system needed
Net alkaline
Net acid
DO, Fe3+, Al all < 1 mg/L (high Fe2+)
DO, Fe3+, Al any > 1 mg/L
DO, Fe3+, Al any > 1 mg/L Fe < 10 mg/L
Anoxic Limestone Drain
Net Alkaline
Net acid
High Fe2+
Ponds
Ponds
Vertical Flow Pond
Oxic Limestone Bed (drainable)
Repeat As Needed
Wetland
Ponds
Ponds
Mn
Aggregate Bed
Mn
Wetland
Final Discharge

A Quick Aside….

MEASURE FLOW RATE!

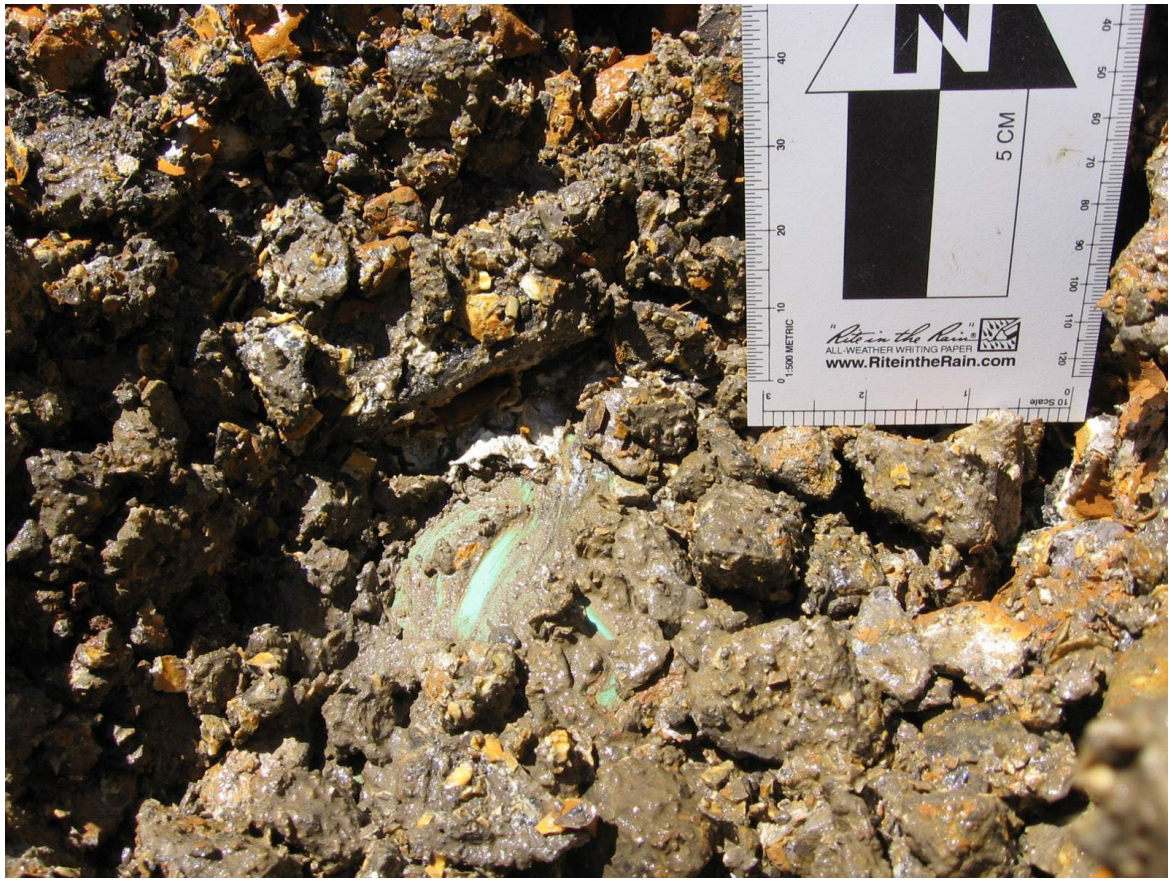
Oxic Limestone Beds (OLBs)

- Utilize calcite-rich aggregate (limestone) to treat acidic mine water
- Typically used for removal of Fe, Al, Mn



Oxic Limestone Beds

Limestone aggregate neutralizes acidity



Metals solids foul limestone

Limestone Fouling

- Metals solids accumulate in limestone aggregate beds degrading performance
- Typically Fe and Al
- Sometimes Mn

Iron

Aluminum

Manganese

Limestone Fouling

- Managing metals solids is a significant challenge
- There are two primary types of metals solids:

Scale

Suspended solids

Flushing Study

- Research project funded by PA DEP BAMR and others in 2006
- Experimental test units constructed to evaluate and optimize oxic limestone treatment cell operation and design
- Results presented at IMWA 2010: *Sustained Treatment of AMD Containing Al and Fe^{3+} with Limestone Aggregate*

Drainable Limestone Bed Design

- OLBs can be designed to accommodate metals solids accumulation
- Prevent plugging but also maximize retention time
- Draining to empty maintains permeability (Drainable Limestone Beds, DLBs)
- Proper sizing – acidity loading ~20 g/t/d
- Chemistry influences design - Fe, Al, and Mn precipitate at different rates so are deposited in different locations in the aggregate bed
- Raw pCO_2 – more pCO_2 = more aggressive dissolution, more volume created

Solids Management – Flow distribution

- Maximizes retention time
- Spreads solids over wider area

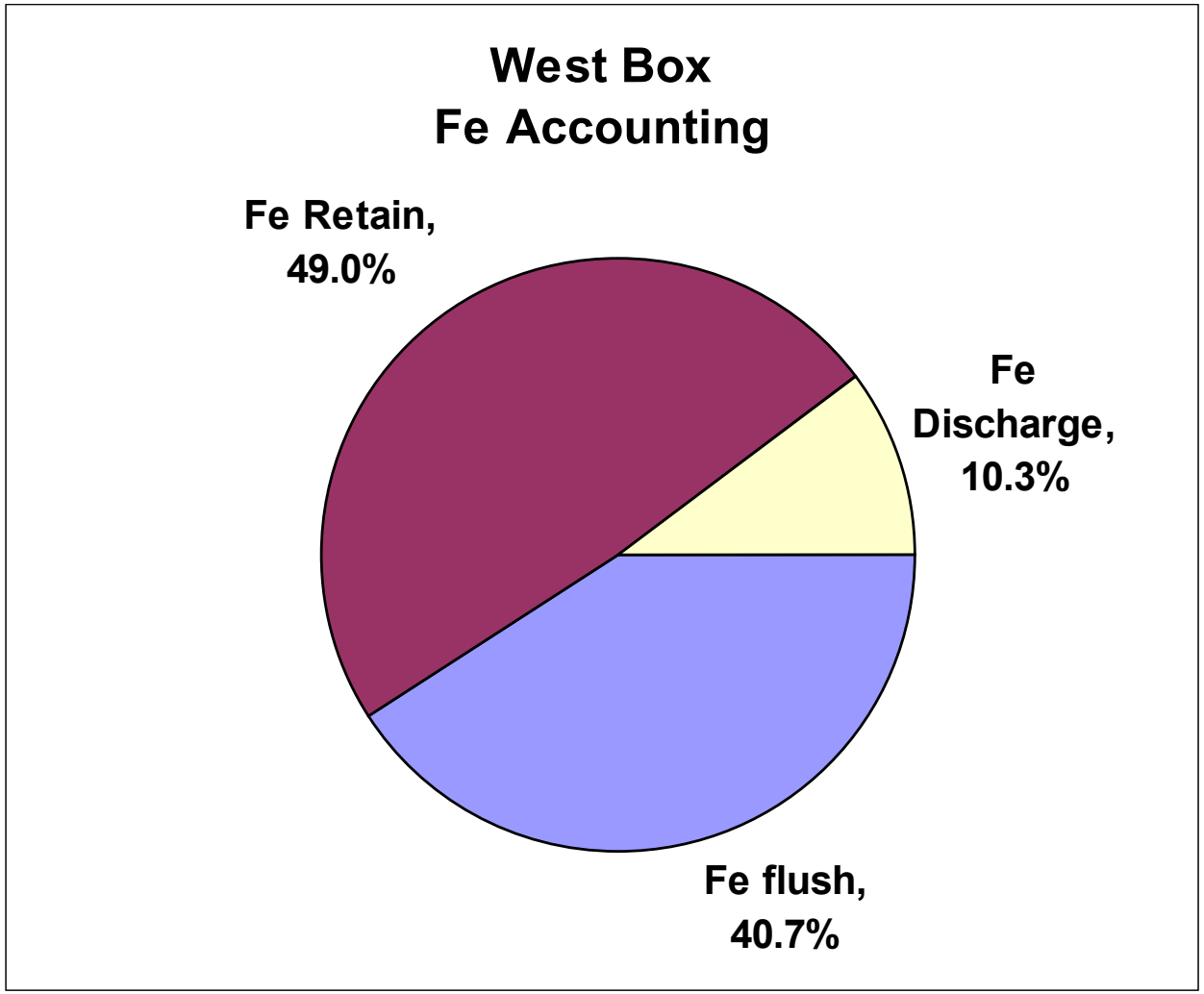
Solids Management - Flushing

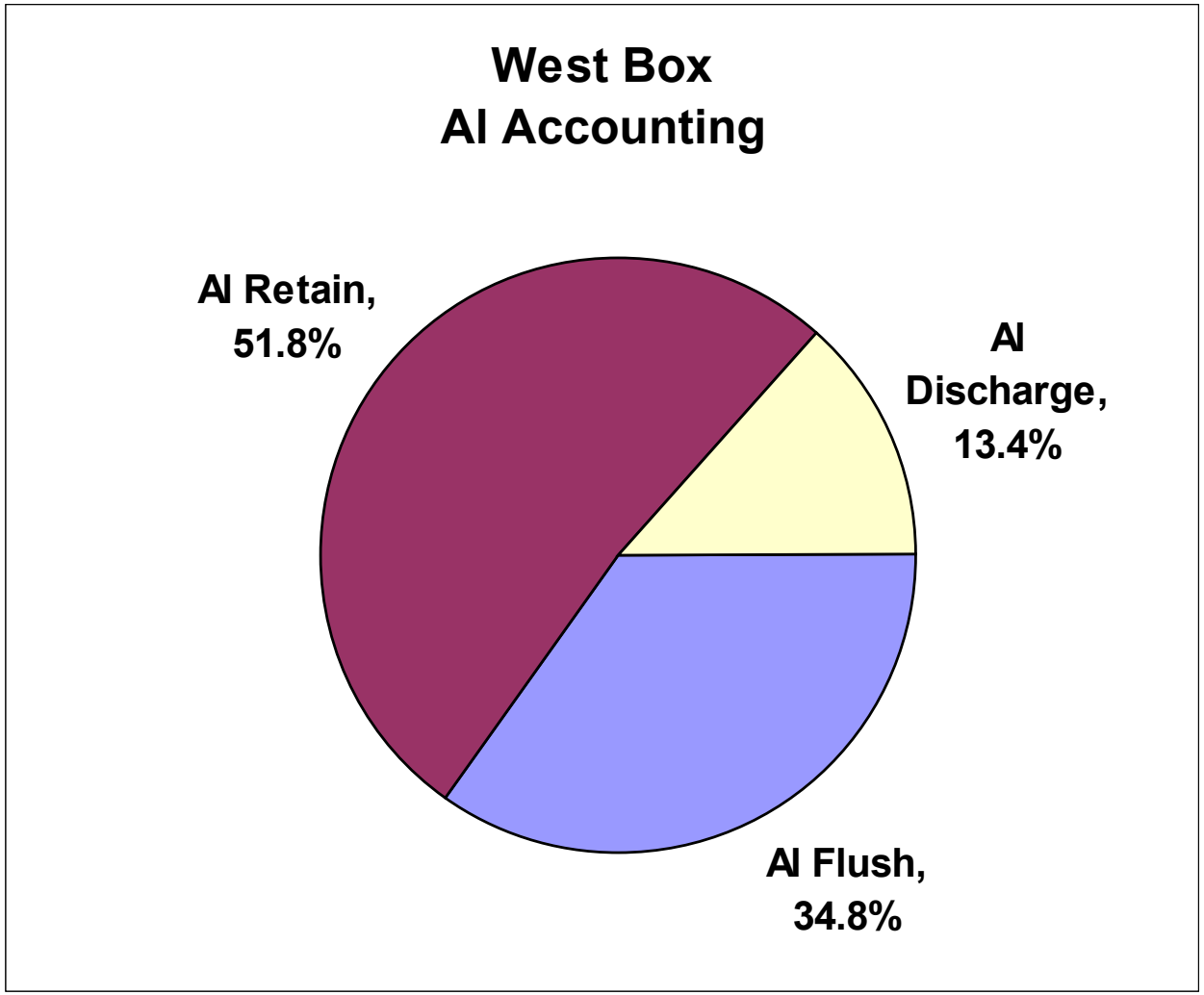
- Removes suspended solids but NOT scale
- Draining to empty is best (DLB)

Solids Management - Flushing

- Manual flushing – low loading sites, monthly or less
- Automated flushing – high loading sites, weekly

Solids Management - Flushing





- Mn removal by flushing is negligible

Aggregate Gradation

- Uniform gradation important
- Larger aggregate = less plugging but less surface area
- Smaller aggregate = more plugging and more surface area
- Better design is allowing for smaller aggregate to be used
  - More compact footprint
- Washed, no fines
- Avoid tracking mud into bed during installation

Preferred gradation 0.5” to 1.0” (13-25 mm)

Solids Management - Stone Cleaning

- In theory very simple
- Start with dirty stone
- End with clean stone

Easy

Clean stone

Oh no

Solids

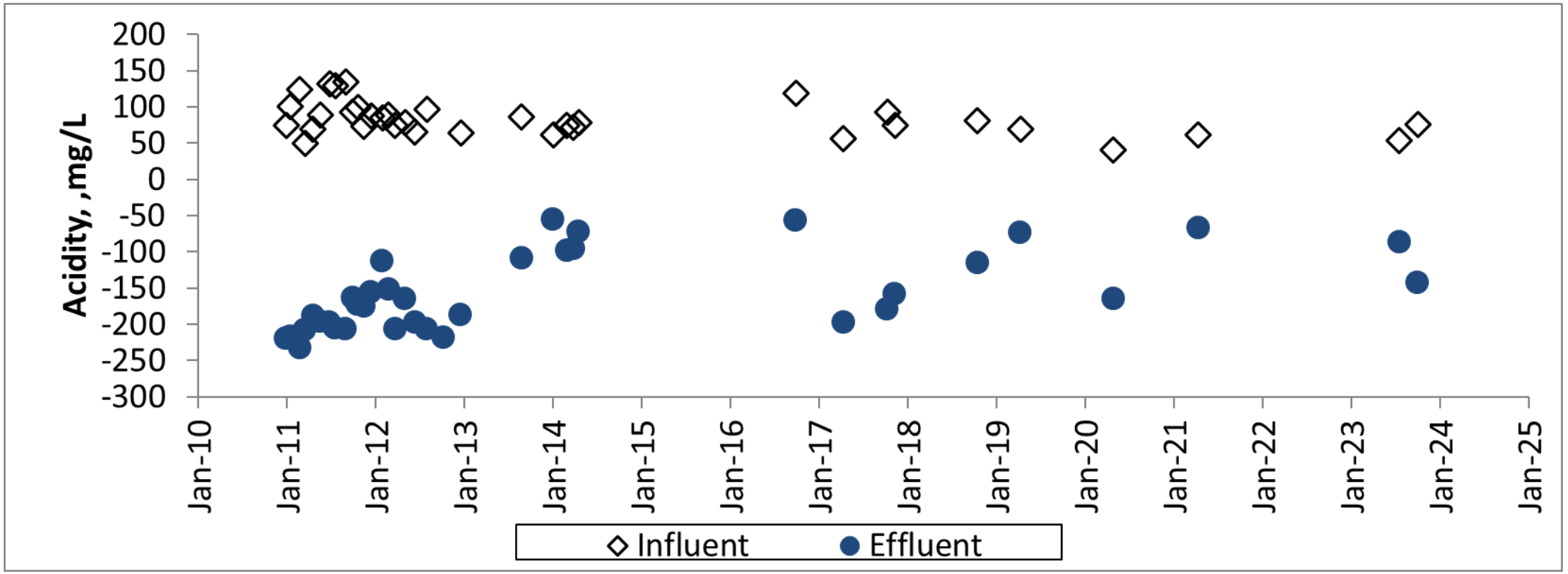
Cleaning Methods Evaluation Ongoing

- Mechanical methods only
- Chemical methods possible but….

Scootac Site - 2010

- First full-scale implementation of flushing study findings
- 1,000-ton drainable limestone bed

Scootac Site



Site	Flow	pH	Alk.	Acid	Fe	Mn	Al
	gpm	s.u.	mg/L $CaCO_3$		mg/L	mg/L	mg/L
DLB in	na	3.6	0	93	<0.1	17.3	9.3
DLB out	42	7.3	186	-179	<0.1	<0.02	<0.1

PBG Woodlands - 2013

PBG Woodlands

	Flow	pH	Alk	Acid	Fe	Mn	Al
	gpm	s.u.	mg/L $CaCO_3$		mg/L	mg/L	mg/L
DLB in	na	3.3	0	144	0.6	0.9	17.9
DLB out	9	6.7	204	-193	0.1	0.2	0.6

Greene Site - 2015

- Regulated site meeting effluent standards
- Field trip destination on Wednesday

Greene Site

- 4 DLBs in parallel followed by a settling pond
- 4,122 tons total

Site	Flow	pH	Alk.	Acid	Fe	Mn	Al
	gpm	s.u.	mg/L $CaCO_3$		mg/L	mg/L	mg/L
Raw	na	3.6	0	93	<0.1	17.3	9.3
Final	83	7.3	186	-179	<0.1	<0.02	<0.1

Conclusions

- Oxic Limestone Beds can provide reliable treatment of Fe, Al, and Mn
- Design elements can improve performance
  - Flow distribution
  - Draining to empty (flushing)
  - Accommodate maintenance (no elaborate plumbing)
- Stone can be cleaned to extend service life
- Single step removal of metals, including Mn

In Memoriam

- Mitchell West Box 2007-2023
- 6-month experiment that lasted 16 years
- Metal container failed before treatment stopped
- More than 1/3 of the original limestone had dissolved

About Hedin Environmental

- Specializes in assessing and remediating mine drainage for stream restoration and compliance
- Over 80 passive treatment systems at mine sites in the US and around the world
- Incorporated in 1994 – many treatment systems in operation for 20+ years
- Flows of 5 to 2,000 gpm.
- Removing Fe, Al, Mn, and Cu from both acidic and alkaline waters.

Cherry Run passive mine water treatment system (Elk County, PA)