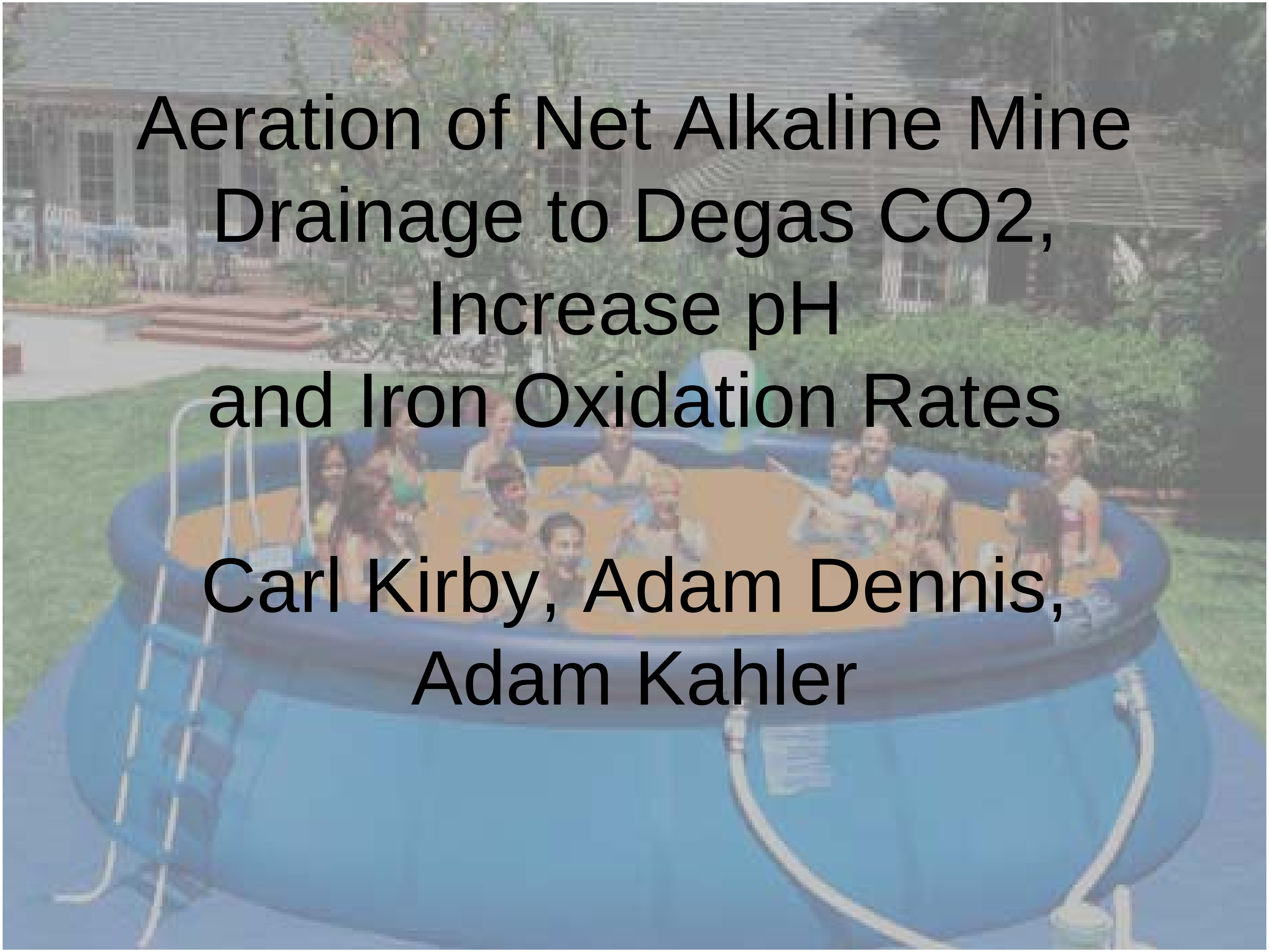


Aeration of Net Alkaline Mine Drainage to Degas CO2, Increase pH and Iron Oxidation Rates

Carl Kirby, Adam Dennis, Adam Kahler

Objectives

- Aerate Net Alkaline Mine Drainage
  - Degas CO_2
  - Increase pH
  - Increase Fe(II) Oxidation Rates
  - Model Fe(II) concentrations, pH, alkalinity, CO_2 to predict pond size

- Compare to area required for passive treatment (no aeration)

Mine Drainage Chemistry

Formation:

- $FeS_2 + H_2O + 7/2O_2 = Fe^{2+} + 2SO_4^{2-} + 2H^+$

  or
- $FeS_2 + 7/2H_2O + 15/4O_2 = Fe(OH)_{3,s} + 2SO_4^{2-} + 4H^+$

- $Fe^{2+} + 1/4O_2 + H^+ = Fe^{3+} + 1/2H_2O$

- $Fe^{3+} + 3H_2O = Fe(OH)_{3,s} + 3H^+$

Net Alkalinity

From Kirby and Cravotta (2005)

- Either
  - If "hot acidity" < 0 (***with negative values reported***)

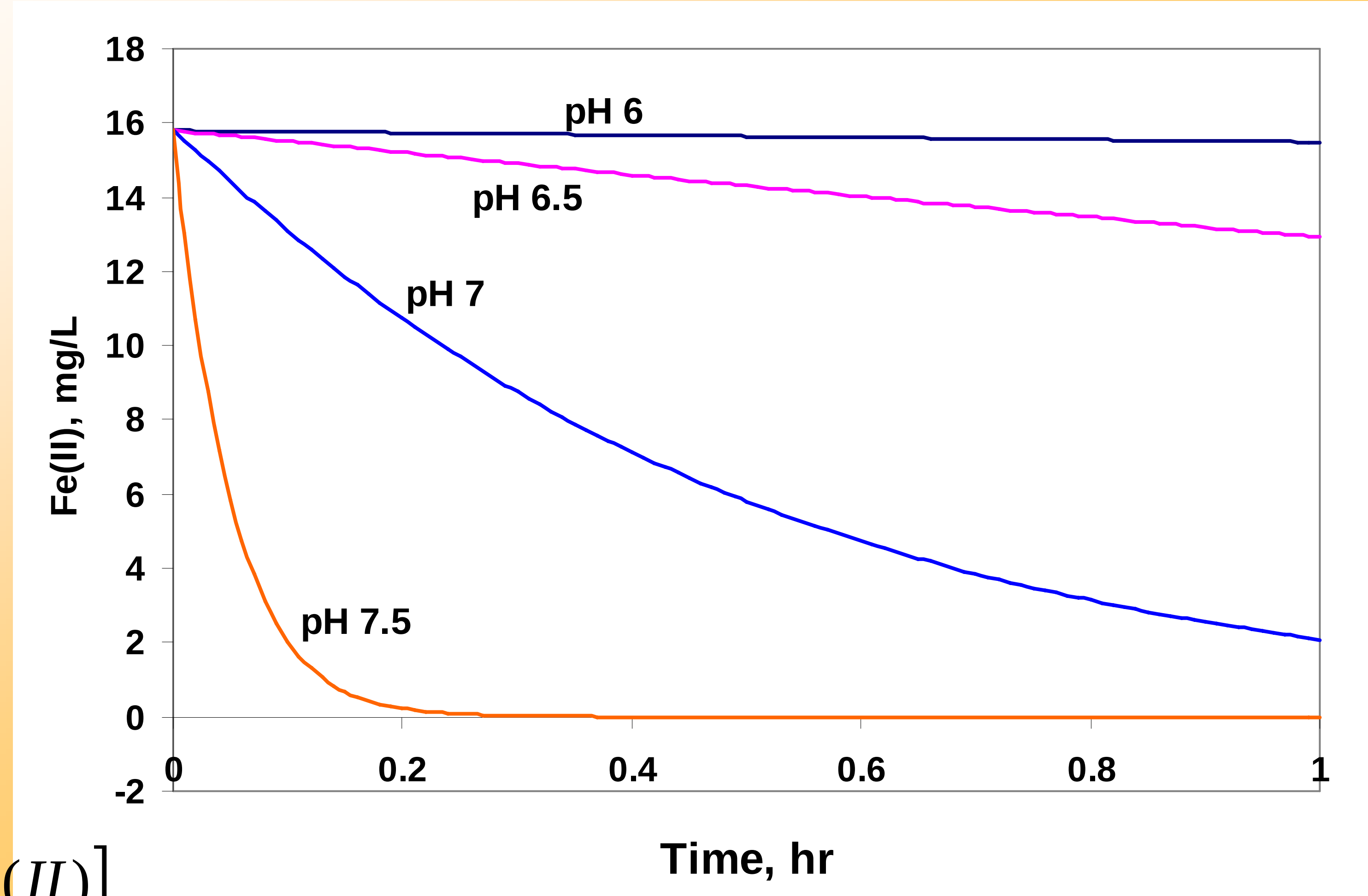
  or

  - measured alkalinity – calculated acidity > 0
    - Where calc. acidity, mg/L $CaCO_3$

      $= 50000(2*Fe/56 + 3*Al/27 + 2*Mn/55 + 10^3*10^{-pH})$

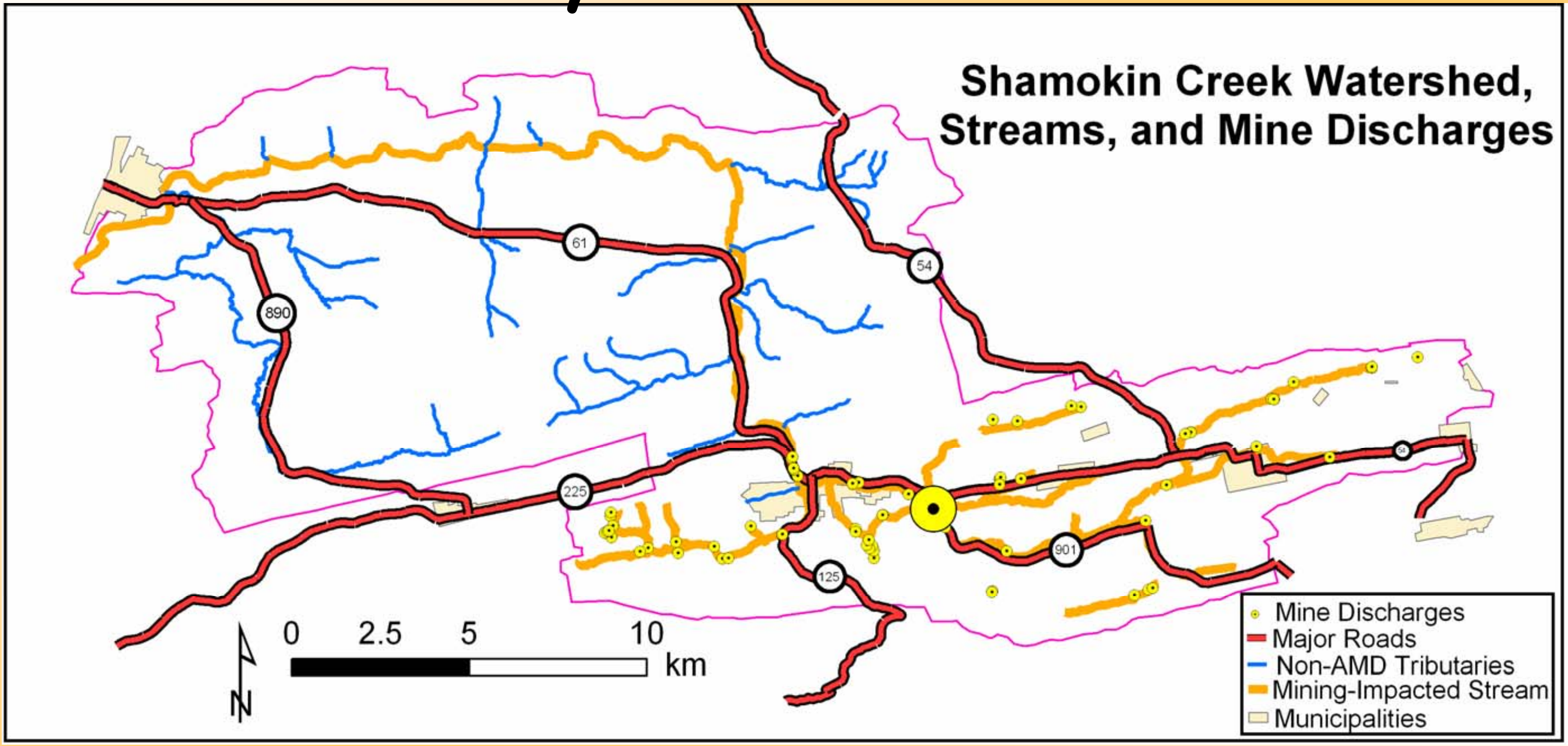
- In practice, water with metals removed will have pH ≥ 6.3

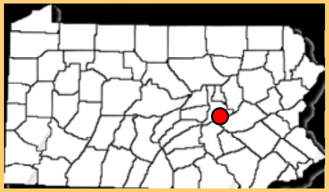
Increasing pH dramatically increases Fe(II) oxidation rates



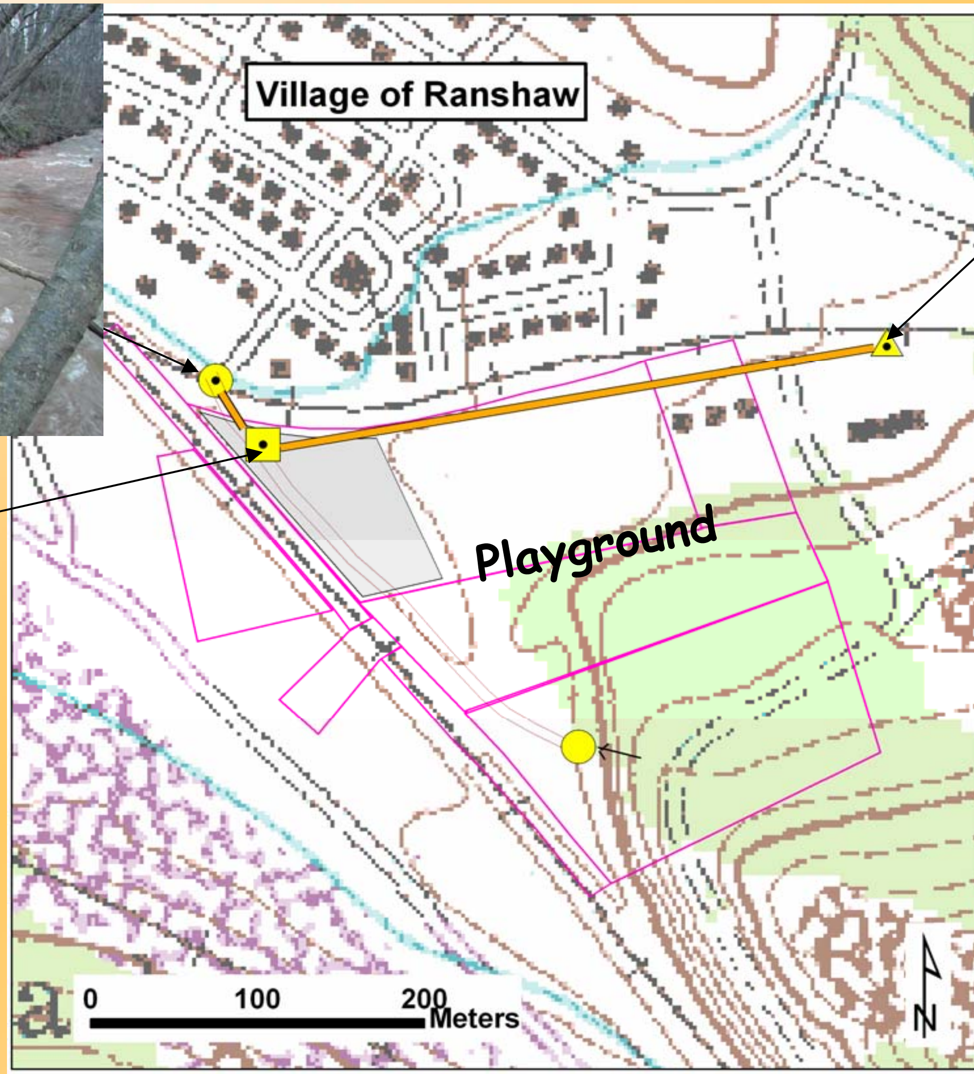
$$\frac{d[Fe(II)]}{dt} = -k[Fe(II)][O_2][H^+]^{-2}$$

Study Area Location

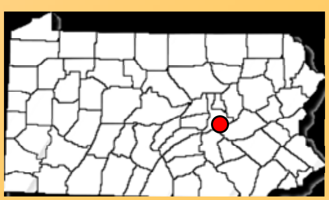




Field Setting



Grate



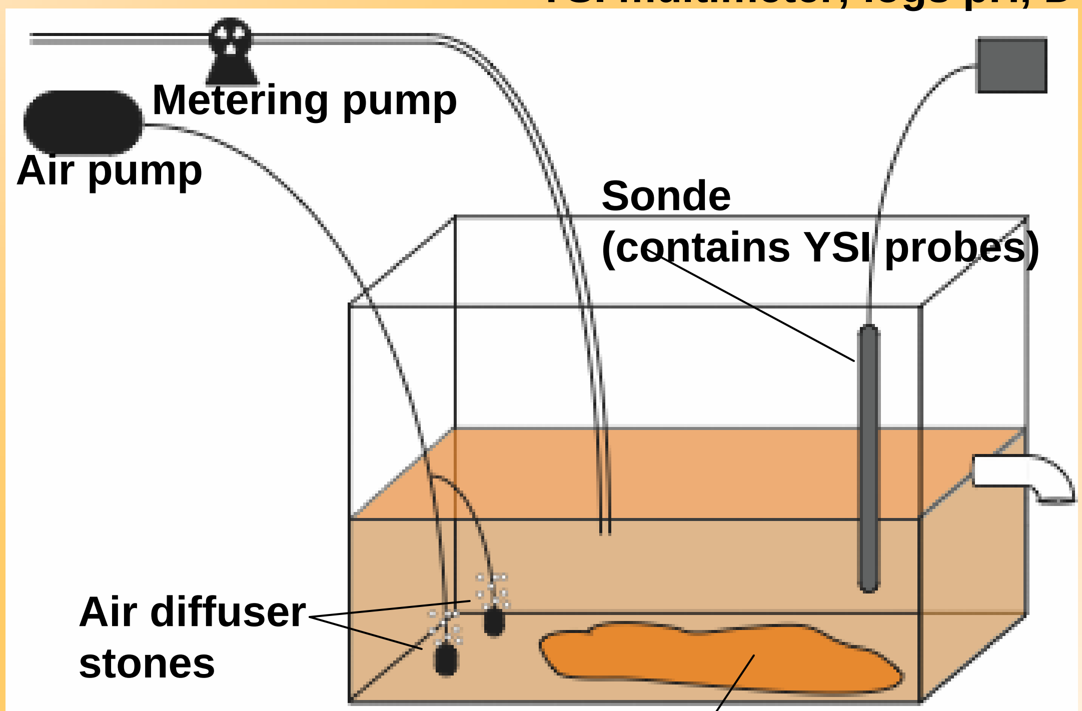
Photos courtesy of S. Kirby and Jim Koharski .

Figure courtesy USGS 7.5" Shamokin Quad.

Field Setup

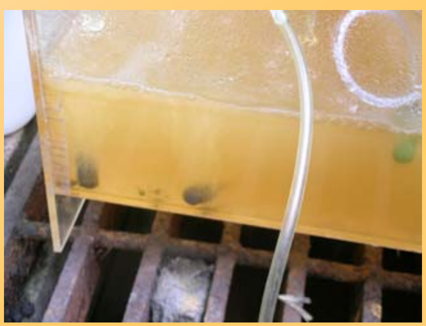
Influent from mine drainage

YSI multimeter; logs pH, DO, T



Outflow for sample collection

Iron hydroxide “sludge”



Field Sites

Fe(II) = 16 mg/L
Al < 0.5 mg/L
pH 5.7
Alk = 117 mg/L $CaCO_3$

Flow = 2000 L/min
scaled to reactor

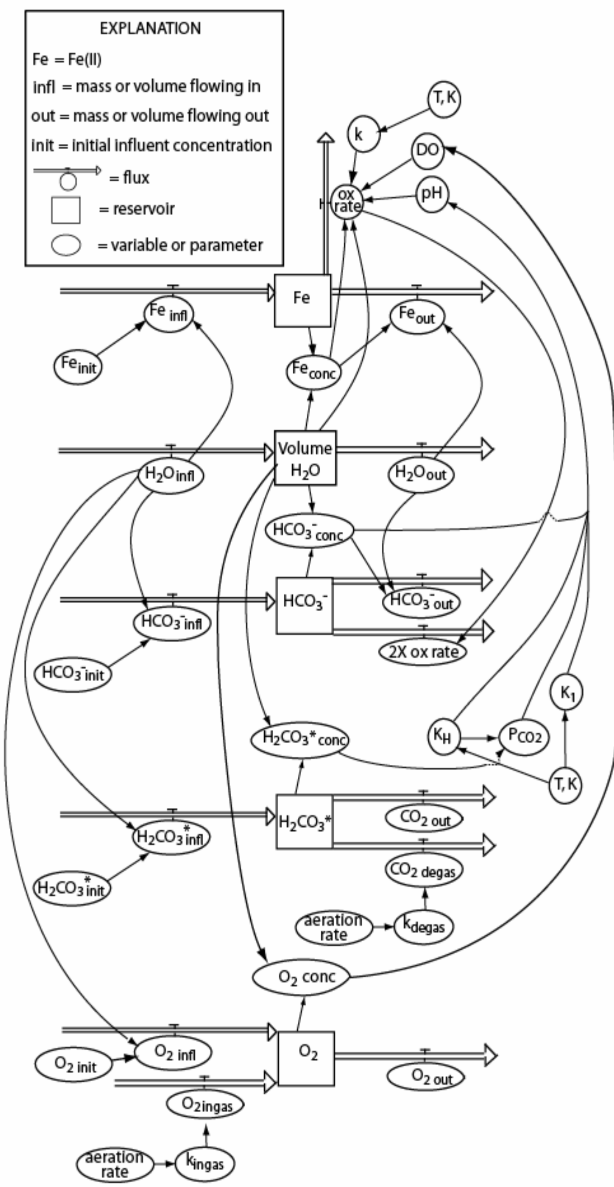
Fe(II) = 16 mg/L
Al < 0.5 mg/L
pH 6.1
Alk = 170 mg/L $CaCO_3$

Flow = 17400 L/min

Site 21 Field Setup

Packer 5 Site

Modeling



GOVERNING EQUATIONS

$$\frac{dm_{Fe(II)}}{dt} = -k[Fe(II)][O_2]a_{H+}^{-2}$$

where

k = temperature-dependent Fe(II) oxidation rate constant

$$\frac{dm_{HCO_3^-}}{dt} = -2(\text{Fe(II) oxidation rate})$$

$$\frac{dm_{CO_2}}{dt} = -k_l(A)([CO_2, t] - [CO_2, eq])$$

where

k_l = mass transfer coefficient

A = surface area of aeration bubbles

$$\frac{dm_{O_2}}{dt} = -k_l(A)([O_2, eq] - [O_2, t])$$

where

k_l = mass transfer coefficient

A = surface area of aeration bubbles

Figure X. Schematic diagram representing the mathematical relationships in Model 2. Arrowheads point to parameter that is a function of the parameter at the initial end.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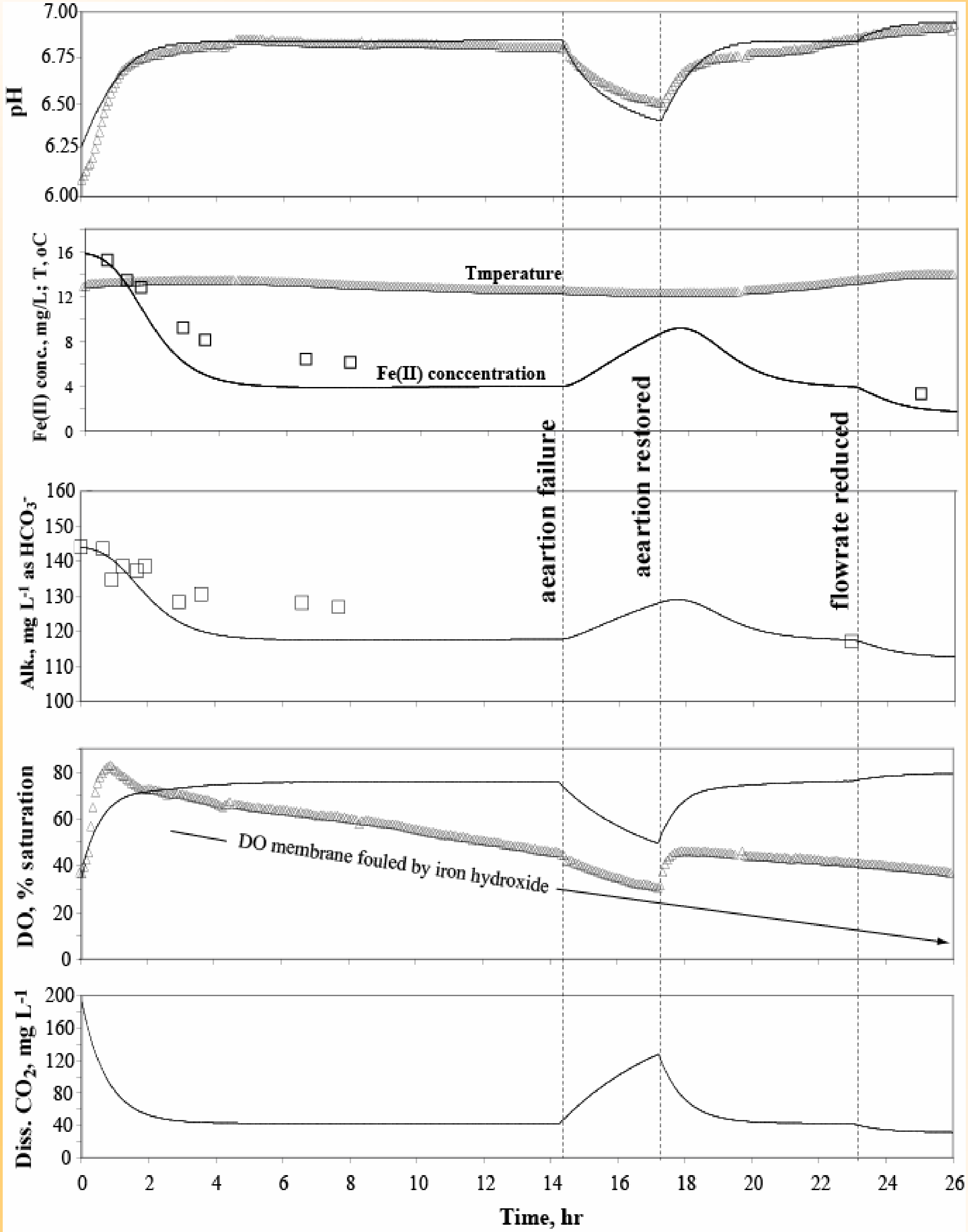

pH
Fe(II) conc., mg/L; T, oC
Tmperature
Fe(II) conccentration
Alk., mg L-1 as HCO3-
aeartion failure
aeartion restored
flowrate reduced
DO, % saturation
DO membrane fouled by iron hydroxide
Diss. CO2, mg L-1
Time, hr


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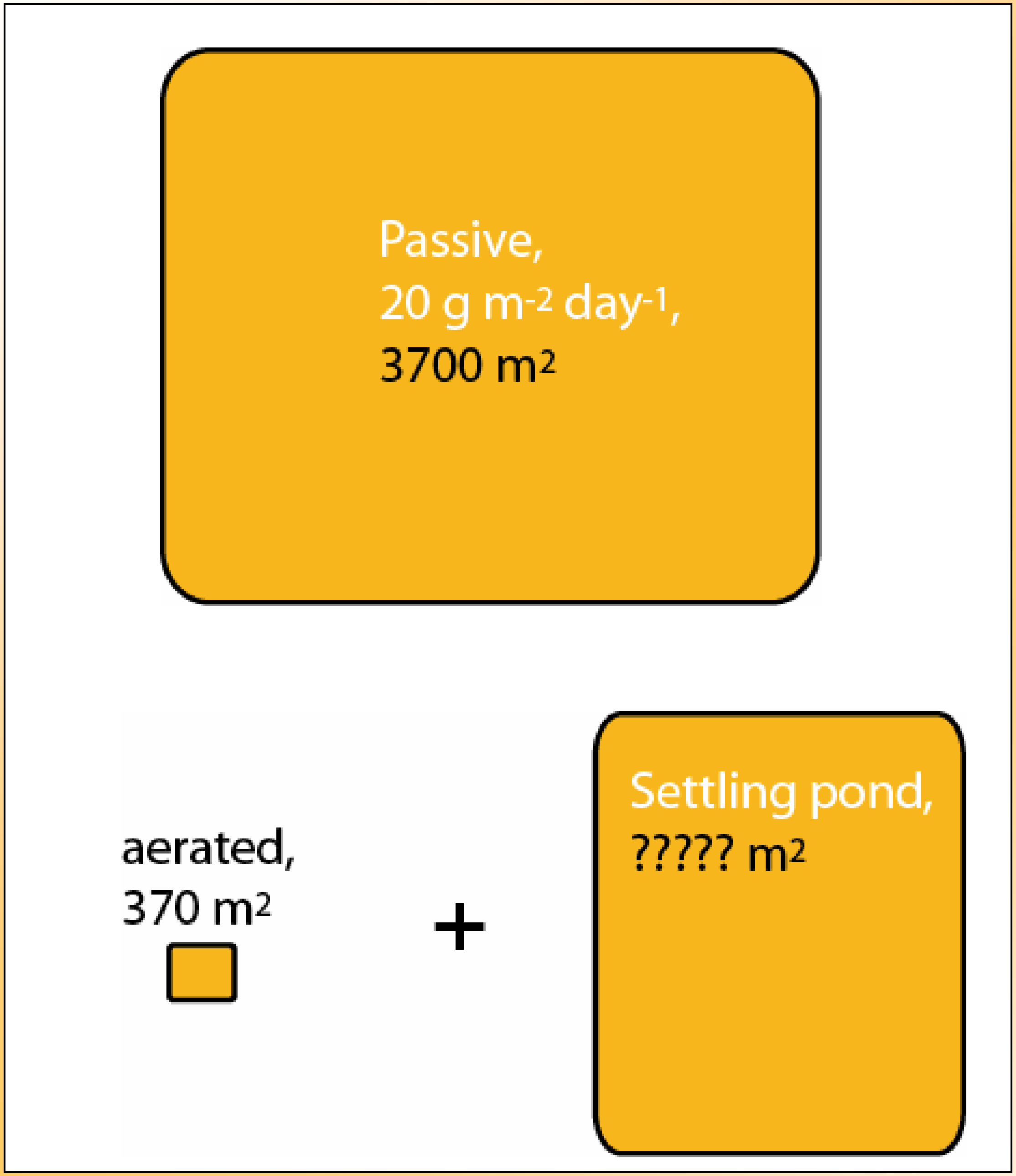
Compare to Hedin et al. (1994) Estimate - $\left(\frac{20g}{m^2}\right)\Big/ day$

Winter (5 °C), 1 m deep

Site	Acres Hedin	Acres Model 2	HP Model 2
Site 21	1	0.1	15
Packer 5	5	0.5	50

Summer (20 °C), 1 m deep

Site	Acres Hedin	Acres Model 2	HP Model 2
Site 21	1	0.1	8
Packer 5	5	0.5	25



10X smaller pond with aeration.....

...but what about the settling pond?

Conclusions

- Aeration method very effective for net alkaline, high-CO_2 waters
  - pH increase promotes rapid Fe(II) oxidation
- With aeration treatment ponds at least **10x smaller** than passive treatment
- Can apply to effluent from ALD's
- Settling pond of unknown size would need to follow oxidation pond

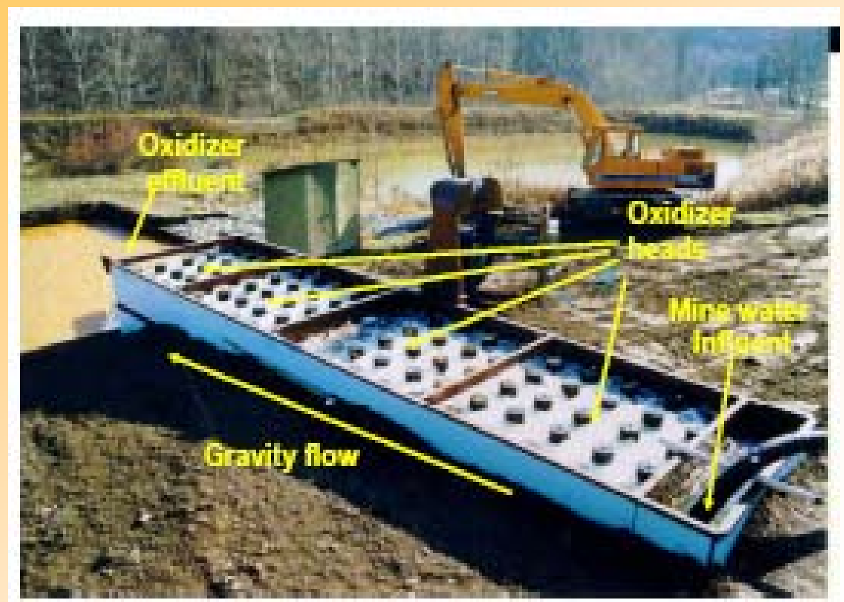
Future Research

Estimate costs of a building/running a treatment system

Investigate aeration methods

FlexLine™ Nonbuoyant Tubular Fine Bubble Diffuser

Environmental Solutions LLC "Maelstrom Oxidizer"



Future Research

Investigate aeration methods

Aeration Solutions Inc.
Diffuser grid and blower

Future Research

Characterize sediment for pigment quality

Acknowledgments:

Shamokin Creek Restoration Alliance

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Michael Dennis

Questions?