Using iron oxidation and decarbonation to enhance inorganic carbon removal in coal mine drainage

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Objectives

* Briefly review acidity;
* Review Total Inorganic Carbon (TIC) and its aqueous species
* Explain Enhanced Decarbonation
* Review results of full scale implementation

$$Fe^{3+} + 3H_2O = Fe(OH)_3(s) + 3H^+$$

Acid

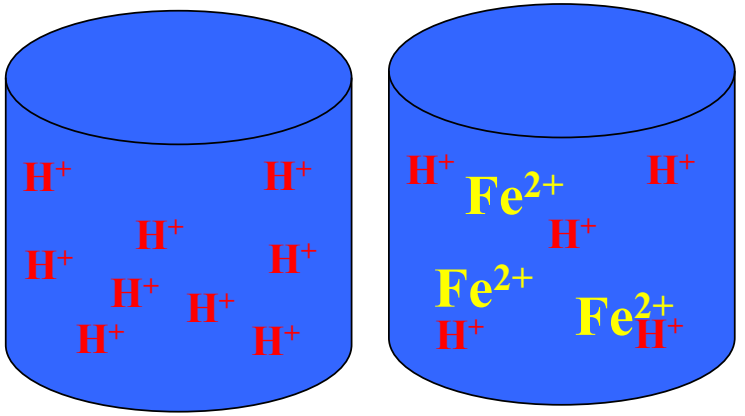
$pH = -\log[H^+]$

Caustic Soda

$$NaOH + H^+ = Na^{2+} + H_2O$$

Base Acid

* Bases prevent H^+ from increasing in concentration and causing the pH to drop



Three CO_2 Species in Water (Total Inorganic Carbon)

$$O_{2(g)} + H_2O = H_2O + O_{2(aq)}$$

$$CO_{2(g)} + H_2O = H_2CO_3$$

$$H_2CO_3 = H^+ + HCO_3^-$$

$$HCO_3^- = H^+ + CO_3^{2-}$$

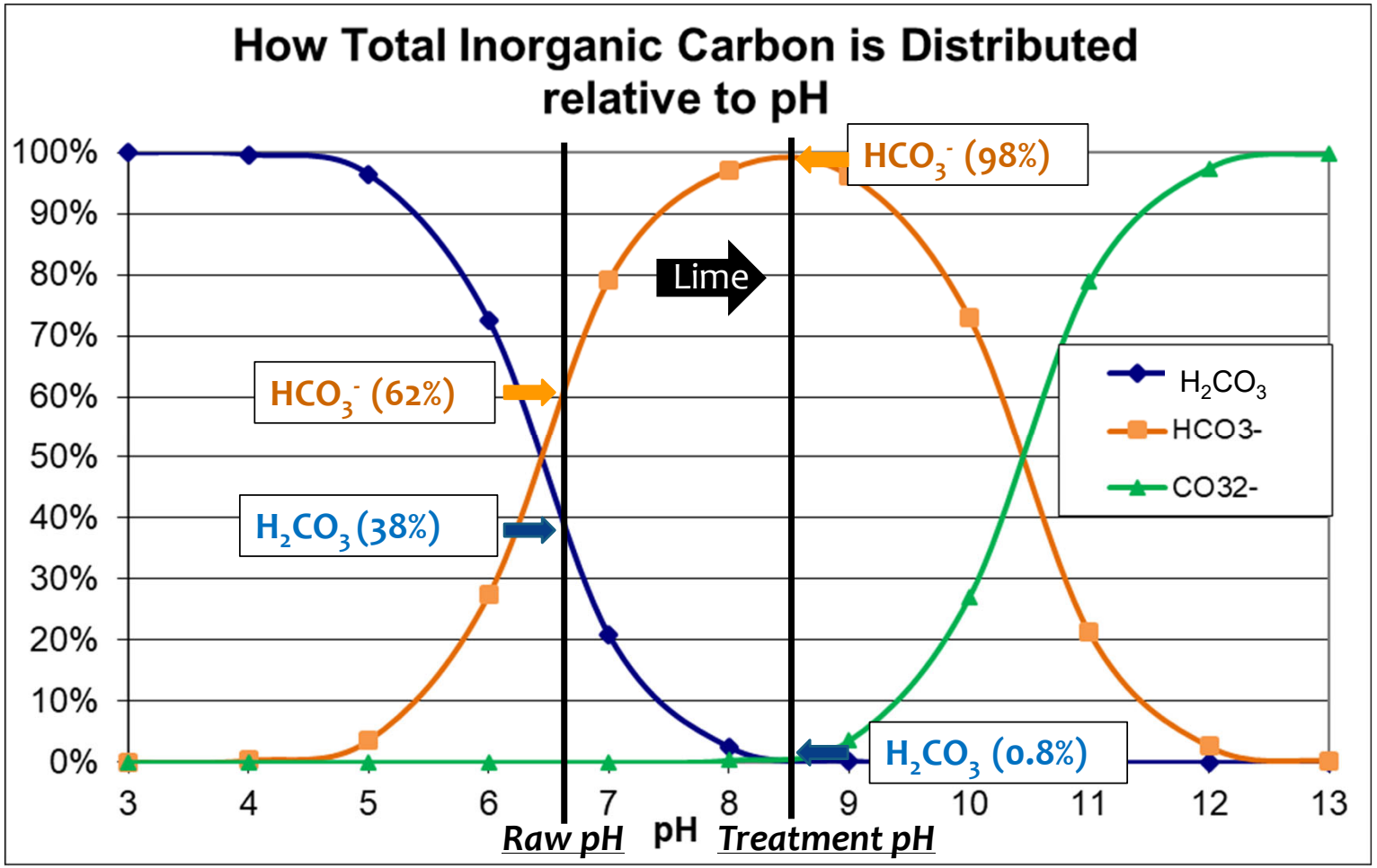
Solid Water (Ice)

Liquid Water (Fluid)

Water Vapor (Gas)

$TIC = H_2CO_{3(aq)} + HCO_3^- + CO_3^{2-}$ Total Water= Ice + Liquid + Vapor

Total Inorganic Carbon (TIC) is a summation of the three CO_2 species dissolved in water



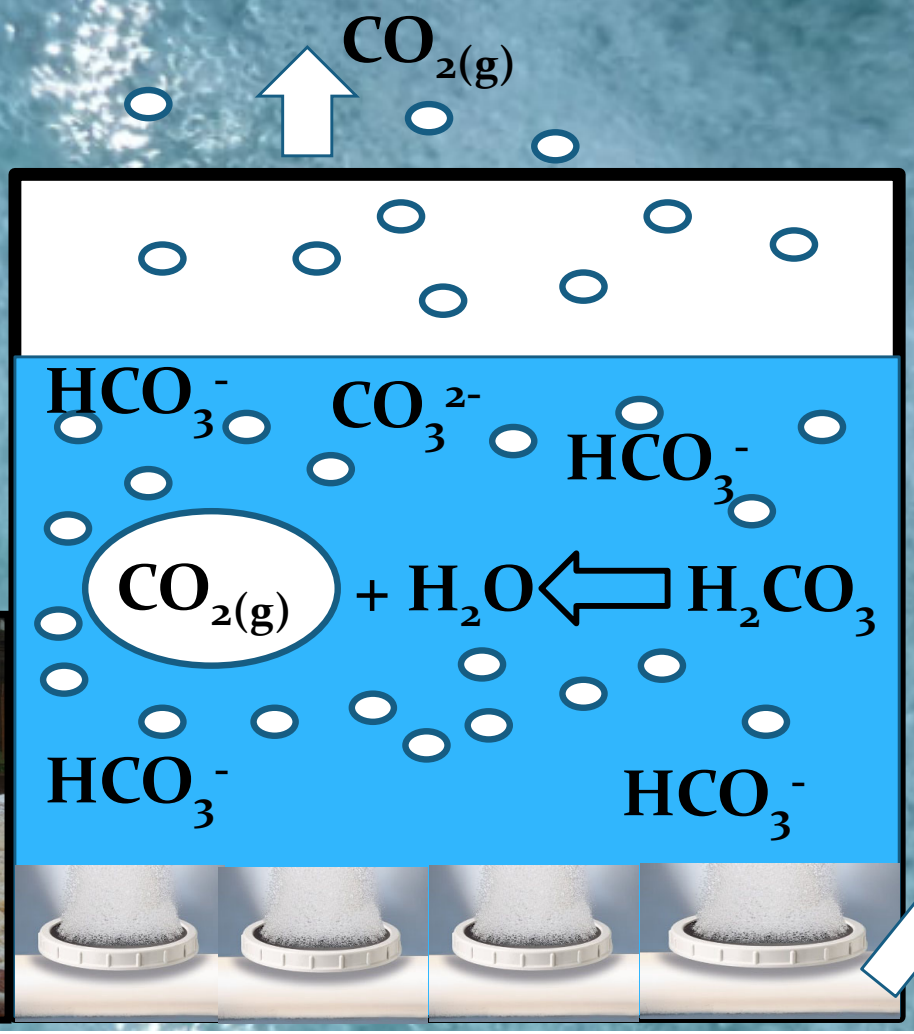
$H_2CO_3 = H^+ + HCO_3^-$

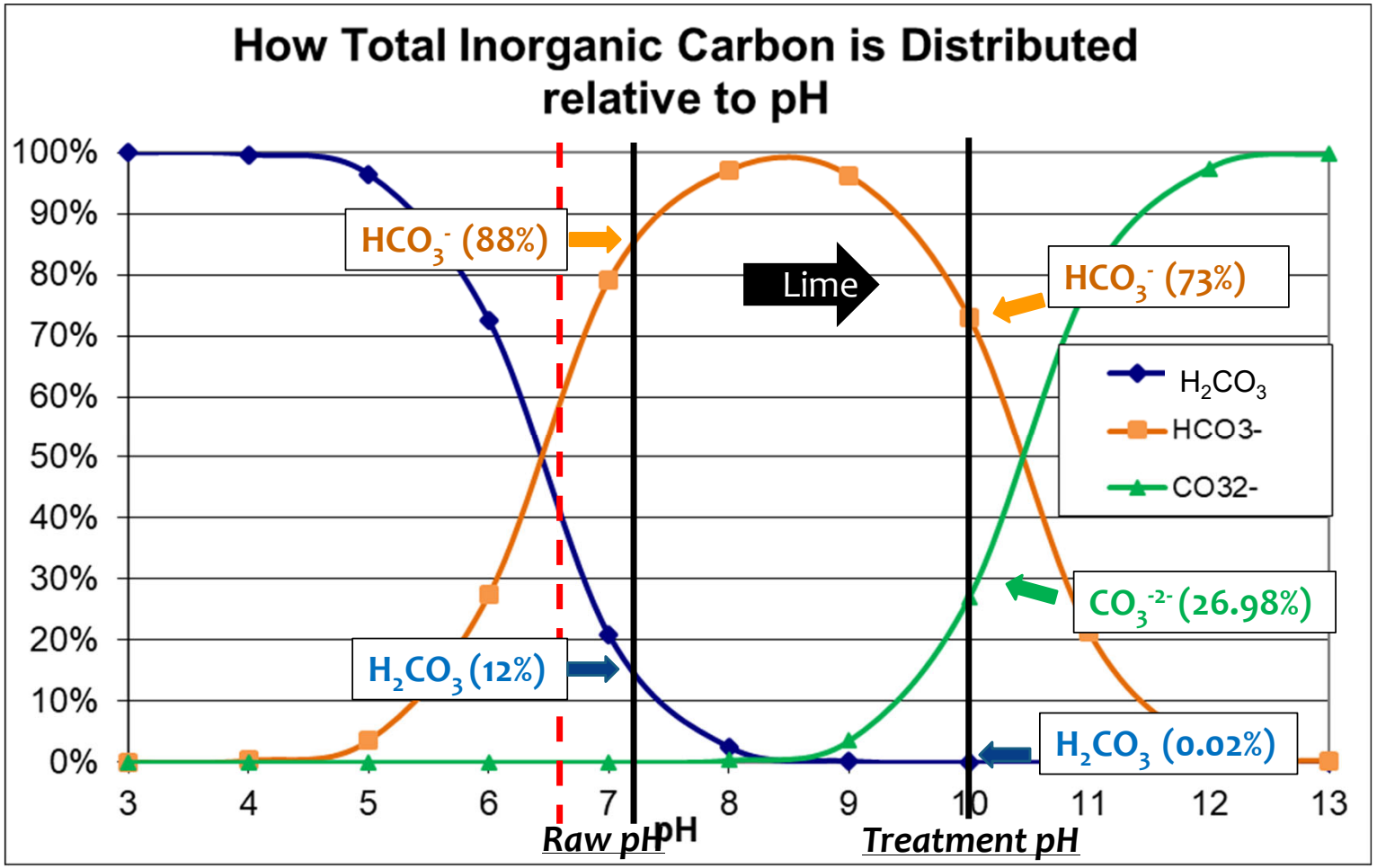
$H^+ = Acid$

$2H^+ + Ca(OH)_2 = Ca^{2+} + 2H_2O + \$$

Q: How do we get rid of H_2CO_3?

A: Decarbonation





$$HCO_3^- = H^+ + CO_3^{2-}$$

$$H^+ = Acid$$

$$2H^+ + Ca(OH)_2 = Ca^{2+} + 2H_2O + \$$

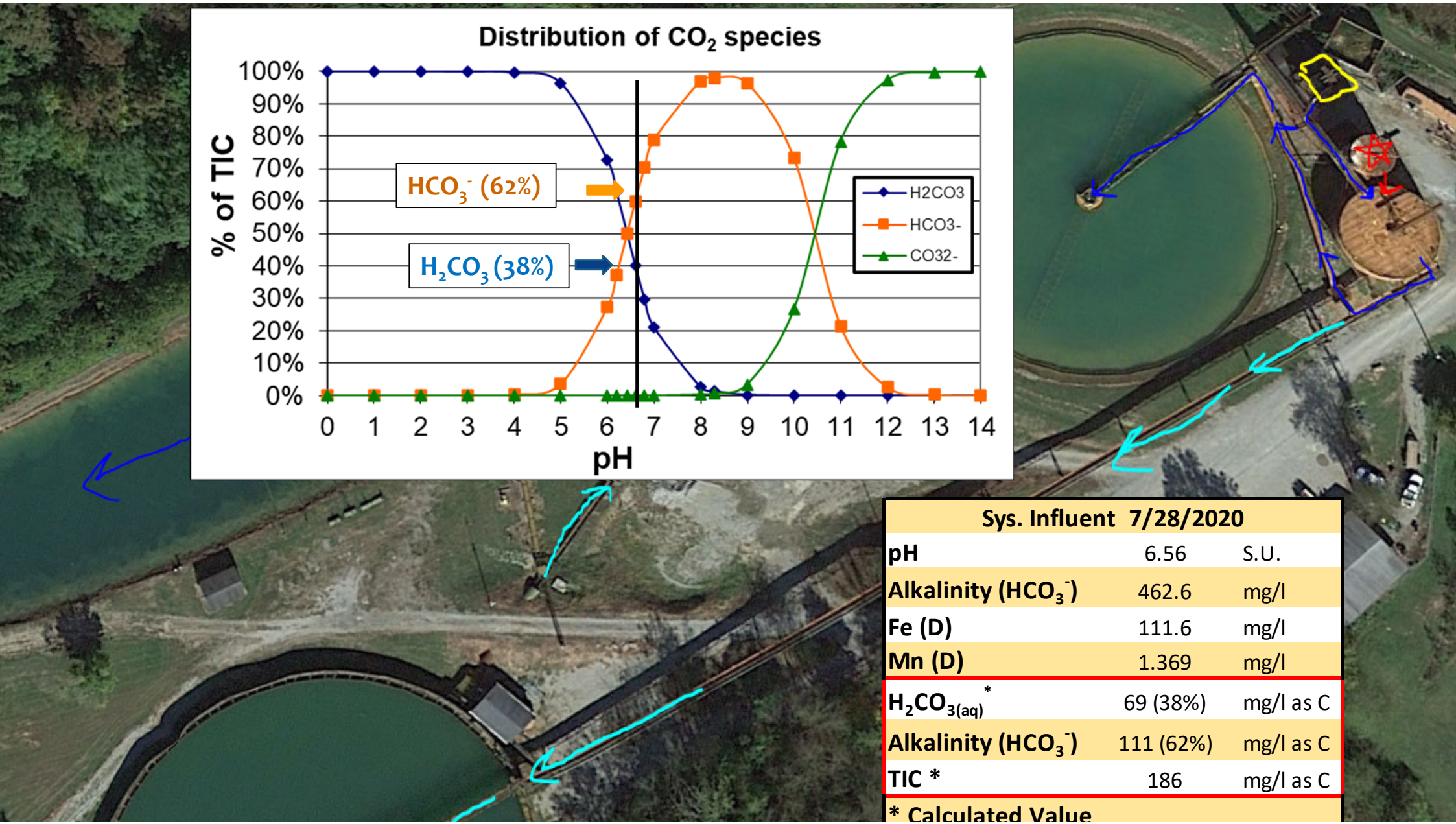
Enhanced Decarbonation

* Decarbonation is focused on reducing H_2CO_3 concentration by outgassing as $CO_{2\,(gas)}$
* Enhanced Decarbonation is focused on lowering the concentration of **both** H_2CO_3 and HCO_3^-
* Two Step Process
  1. Transform HCO_3^- to H_2CO_3
  2. Decarbonate H_2CO_3

$$CO_{2(g)} + H_2O = H_2CO_3$$

$$H_2CO_3 = H^+ + HCO_3^-$$

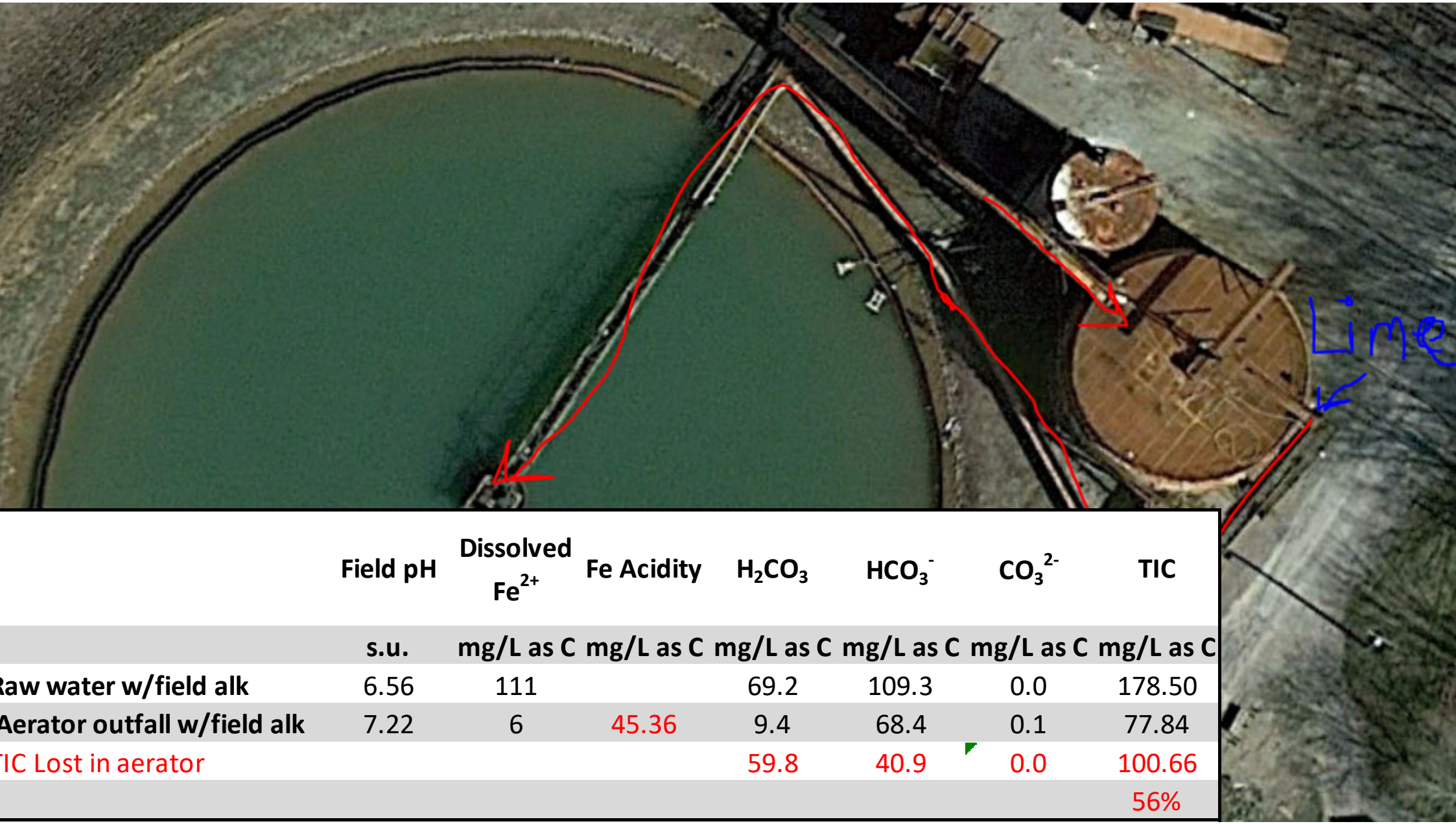
$$Fe^{2+} + 2.5H_2O + .25O_2 + \ = Fe(OH)_3 + 2H^+$$



Sys. Influent 7/28/2020		
pH	6.56	S.U.
Alkalinity (HCO_3^-)	462.6	mg/l
Fe (D)	111.6	mg/l
Mn (D)	1.369	mg/l
$H_2CO_{3(aq)}$ *	69 (38%)	mg/l as C
Alkalinity (HCO_3^-)	111 (62%)	mg/l as C
TIC *	186	mg/l as C

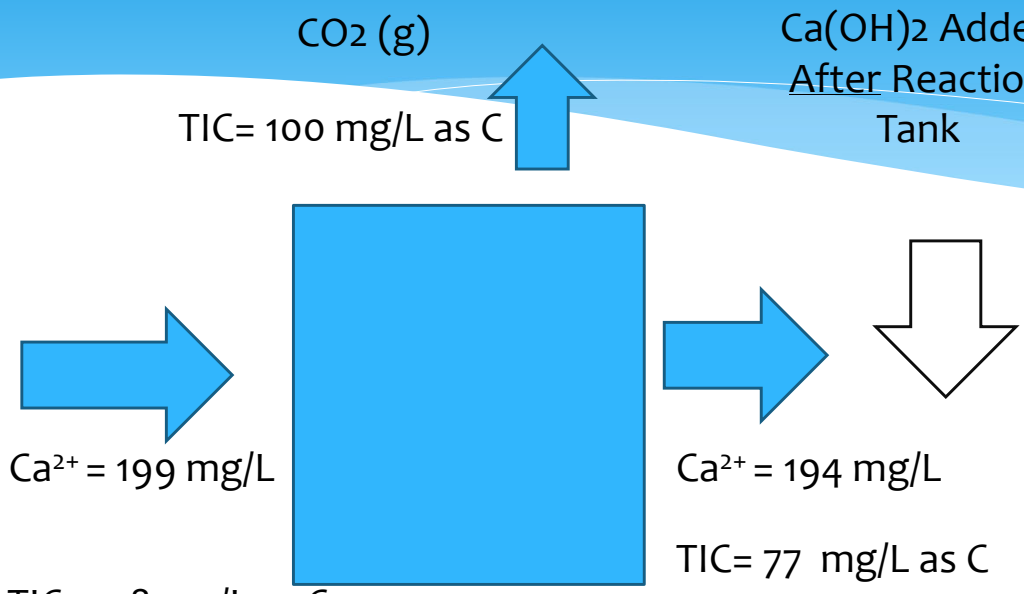
*** Calculated Value**

Existing Tank for Enhanced Decarbonation



	Field pH	Dissolved Fe^{2+}	Fe Acidity	H_2CO_3	HCO_3^-	CO_3^{2-}	TIC
	s.u.	mg/L as C	mg/L as C	mg/L as C	mg/L as C	mg/L as C	mg/L as C
Raw water w/field alk	6.56	111		69.2	109.3	0.0	178.50
Aerator outfall w/field alk	7.22	6	45.36	9.4	68.4	0.1	77.84
TIC Lost in aerator				59.8	40.9	0.0	100.66
							56%

Calcium Mass Balance to determine Hydrated Lime Reduction



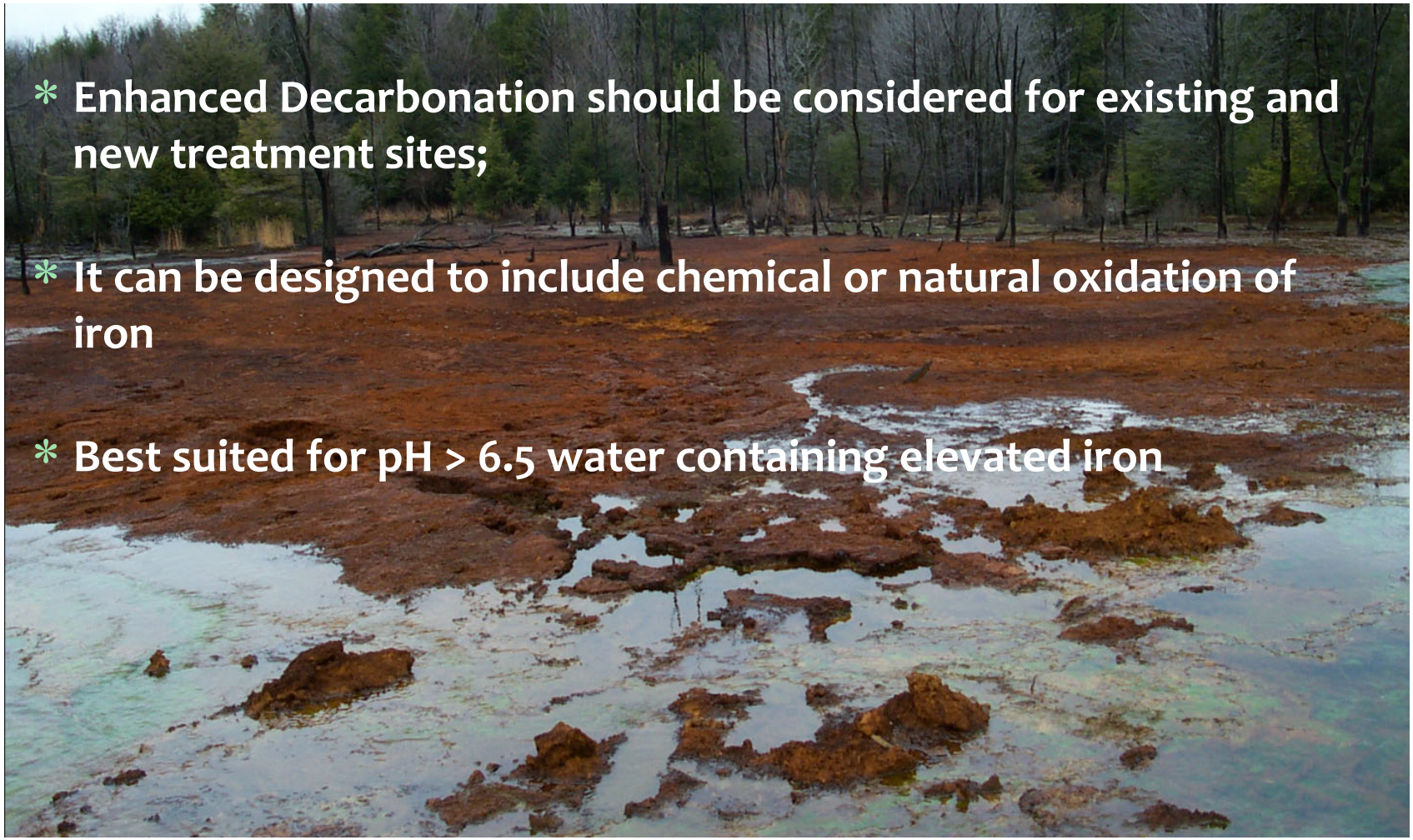
Ca^{2+} Mass Balance

286.7 – 194 = 92.2 mg/L Ca^{2+} added

92.2 mg/L Ca^{2+} = 167 mg/L Ca(OH)2 Added

~2.36 tons/day (30% reduction/annual cost savings of 60K)

Conclusion



* Enhanced Decarbonation should be considered for existing and new treatment sites;
* It can be designed to include chemical or natural oxidation of iron
* Best suited for pH > 6.5 water containing elevated iron