DEFINING SOURCE TERMS FOR BACKFILL COMPONENTS IN THE SELBAIE MINE PIT

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Objective/Scope

- Provide estimates of zinc source terms (or functions) that can be applied to the waste materials in order to estimate loadings to the Selbaie Pit lake water.

- The source term functions used by Lorax in modeling future water quality.

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Project Components

- Field Work
  - Sample Collection
  - Data Collection
- Laboratory Testing
  - Shake Flask Tests
  - “Column” Tests
- Source Term Modeling

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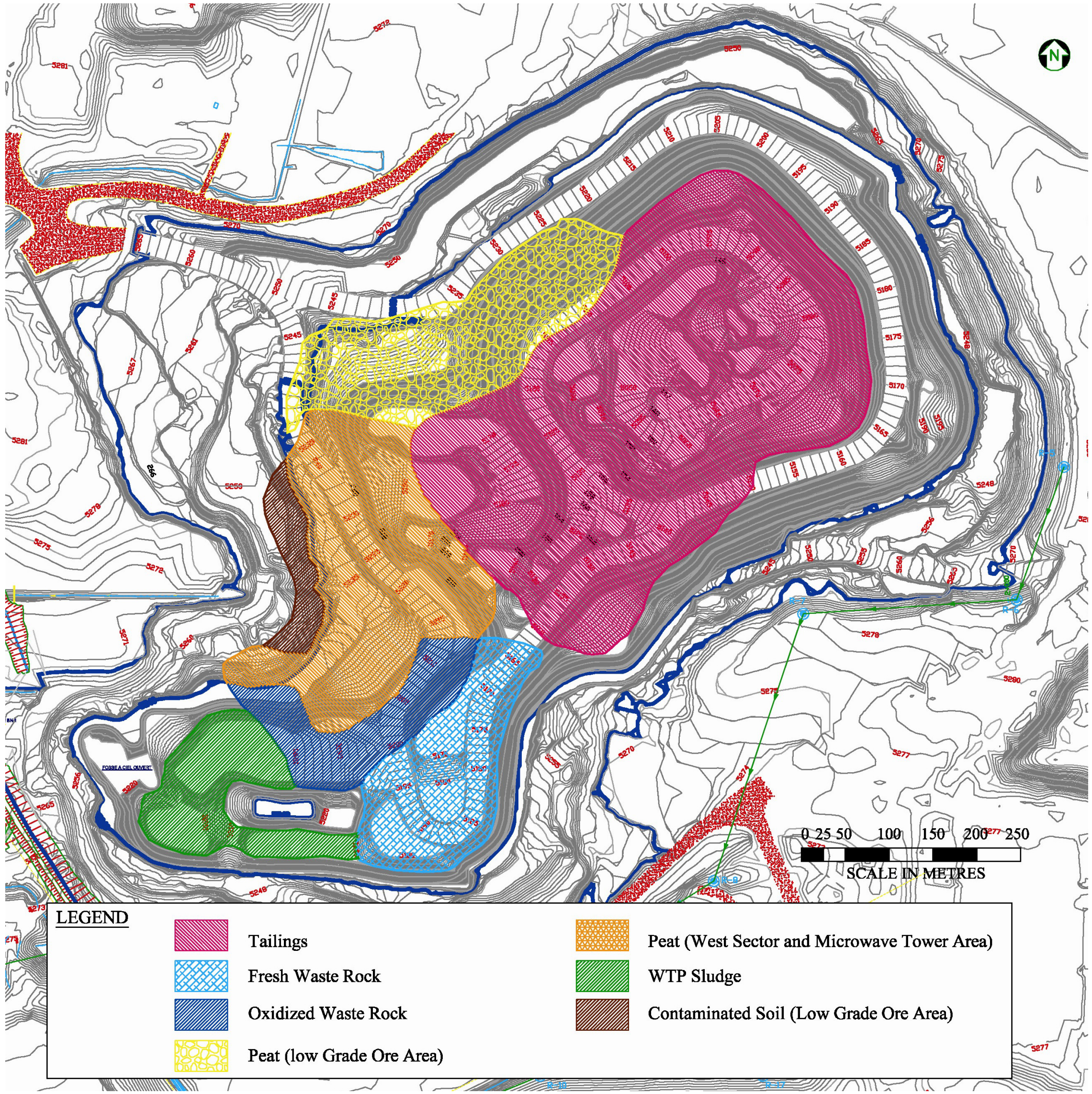

0 25 50 100 150 200 250
SCALE IN METRES
LEGEND
Tailings
Fresh Waste Rock
Oxidized Waste Rock
Peat (low Grade Ore Area)
Peat (West Sector and Microwave Tower Area)
WTP Sludge
Contaminated Soil (Low Grade Ore Area)

Laboratory Testing

- Evaluated :
  - Contaminated Peat
  - Contaminated Soils
  - Oxidized Waste Rock
- Did not Evaluate:
  - Tailings
  - Treatment Sludges
  - Unoxidized (fresh) Waste Rock

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Laboratory Testing

- Previous Investigations (SNC-Lavalin)
  - Tailings and Treatment Sludges:
    - Liquid Phase Zinc Inventory <0.5 mg/L
    - Leaching at pH 7 = Zinc concentration <0.5 mg/L
  - Unoxidized (Fresh) Waste Rock
    - >2 yrs for significant oxidation to occur
    - Fresh WR deposited in pit within 2 yrs
    - No significant increase in aqueous Zinc concentrations during flooding of this waste

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Zinc Inventory in Materials

Waste Material	Zinc Concentration Range (mg/kg)	Zinc Concentration Average (mg/kg)
Contaminated Soils (8 Samples)	134 – 3,150	1,413
Oxidized Waste (11 Samples)	243 – 8,250	**3,897**
Peat (11 Samples)	211 – 8,130	2,327

Note : Oxidized Waste has 2.8x greater Zn concentration relative to Contaminated Soils

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Shake Flask Tests

- Estimate initial porewater concentrations available for release to overlying pit lake through diffusion processes over time
  - 3:1 Water:Solids Ratio (125g Solid:375mL water)
  - Constant Agitation for 24 hour

Shake Flask Tests - Results

Waste Material	Estimated Porewater pH	Estimated Zinc Concentration (mg/L)
Contaminated Soils	4.1	**1658**
Oxidized Waste	6.2	**19**
Peat from Low Grade Ore Stockpile	5.1	317
Peat from West Sector	5.6	6.0

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“Column” Tests

- Determine the rate of metal flux to overlying water column under different pH conditions

- Allows for assessment of physics (diffusion) and geochemistry (e.g., precipitation reactions).

- Evaluated (in duplicate):
    - pH 7
    - pH 9
    - Unadjusted pH (generally ranged between pH 6-7)

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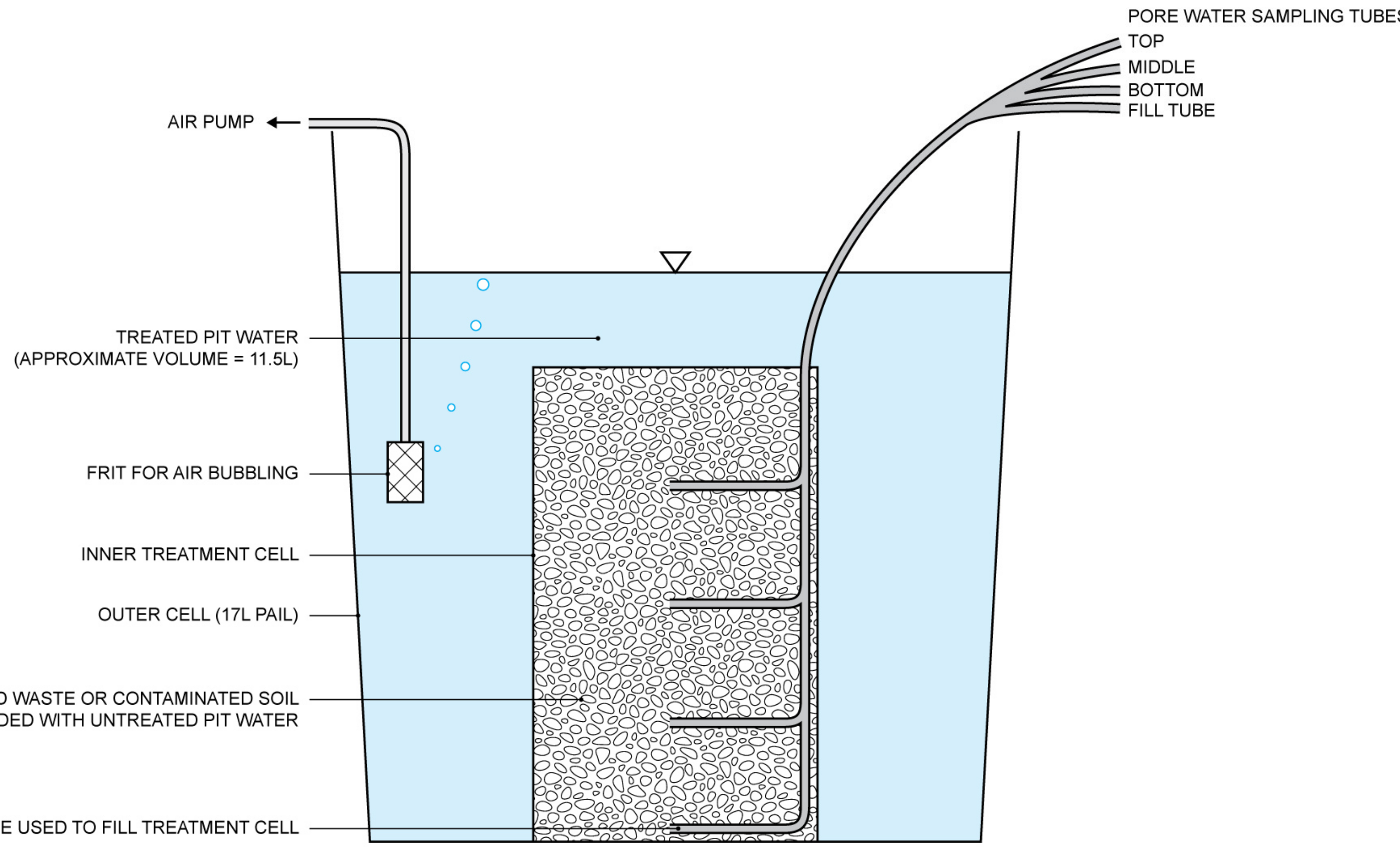
Test Cell Set-up



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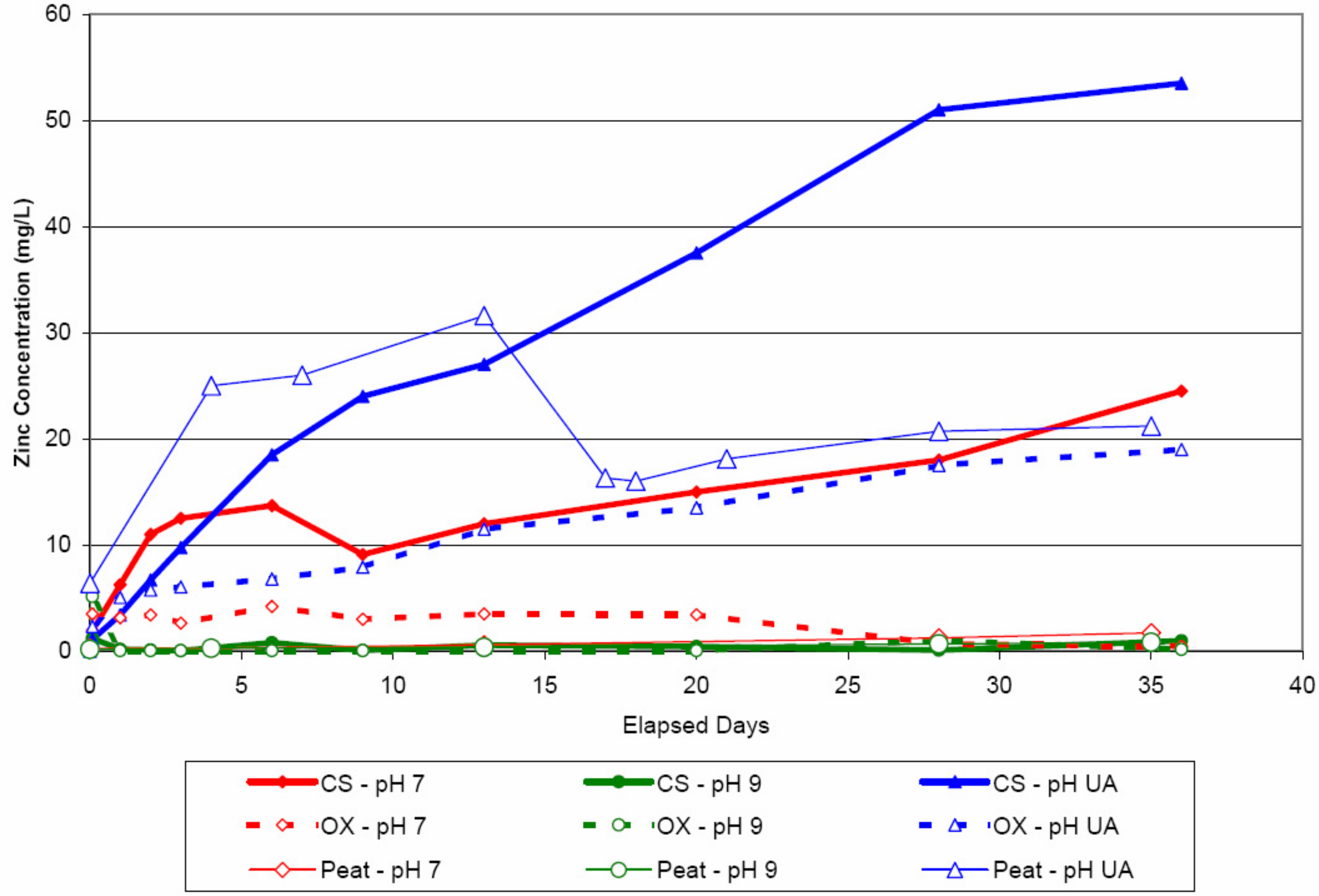
Column Test Results-Overlying Water



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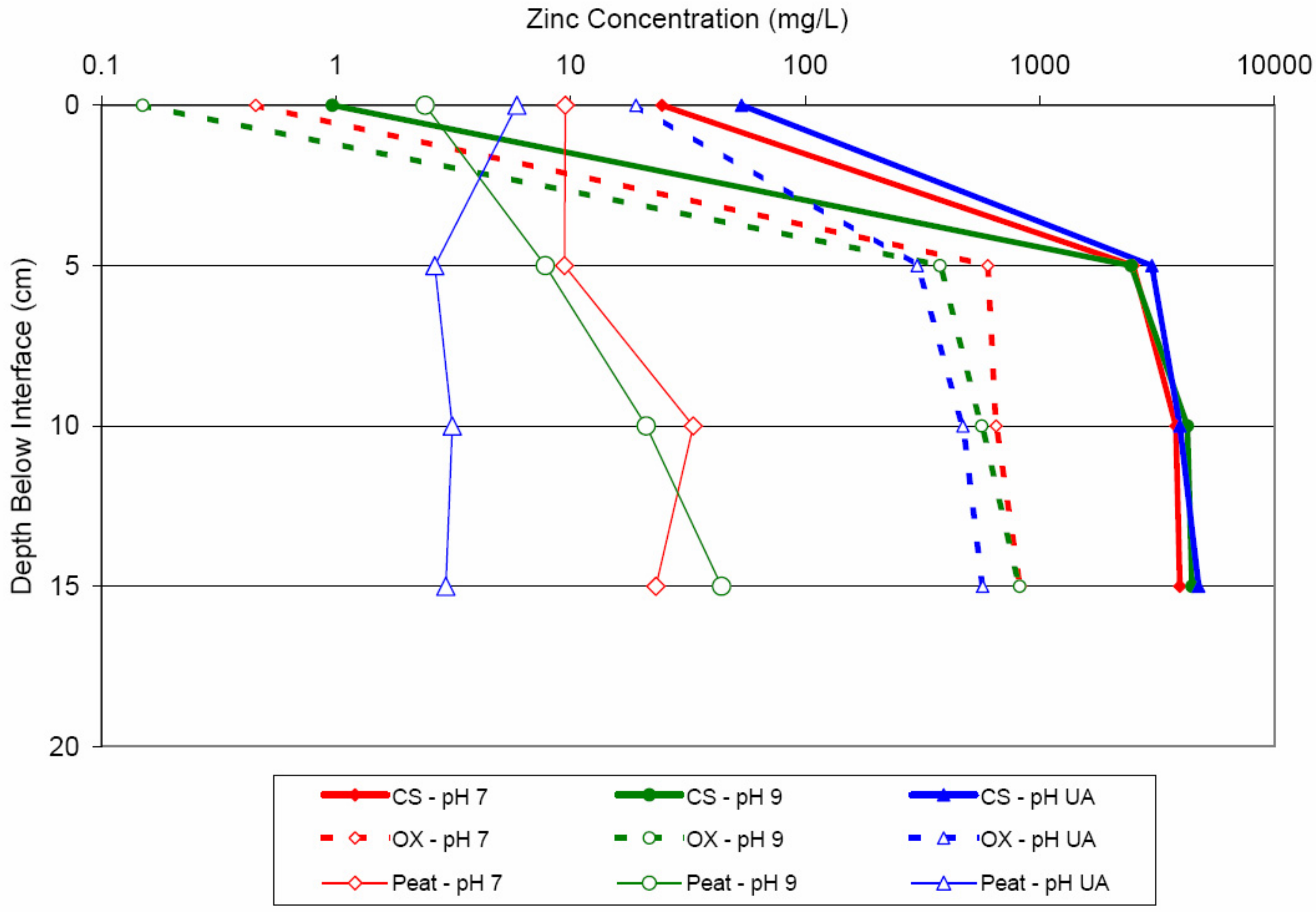
Column Test Results-Porewater



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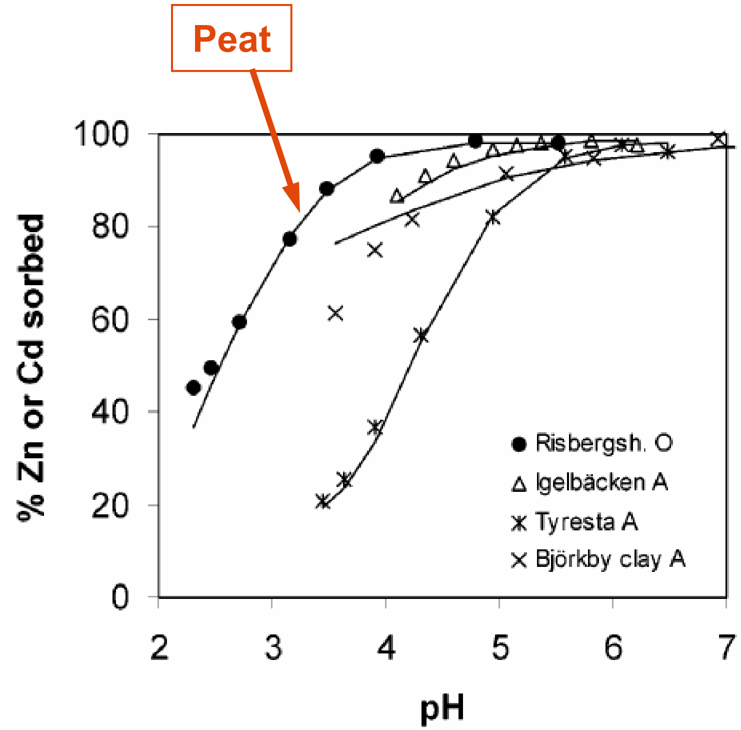
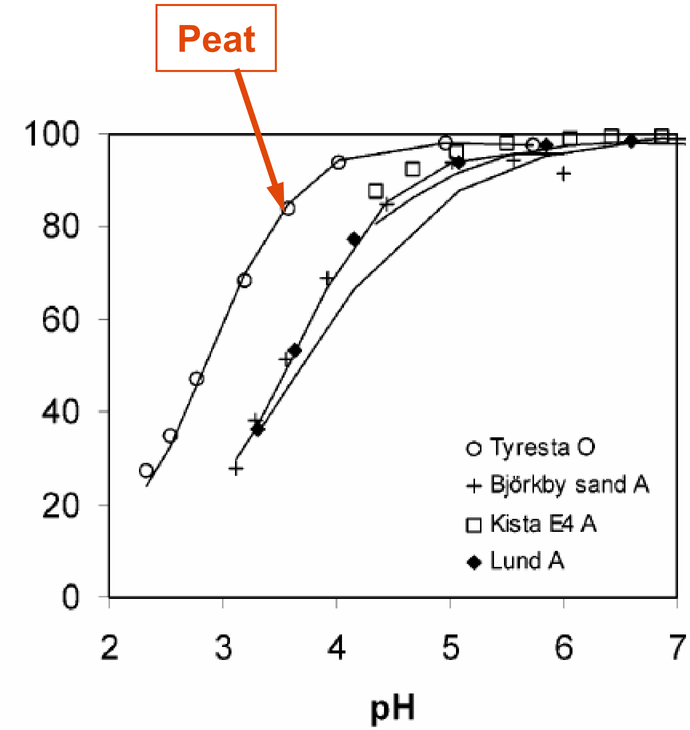
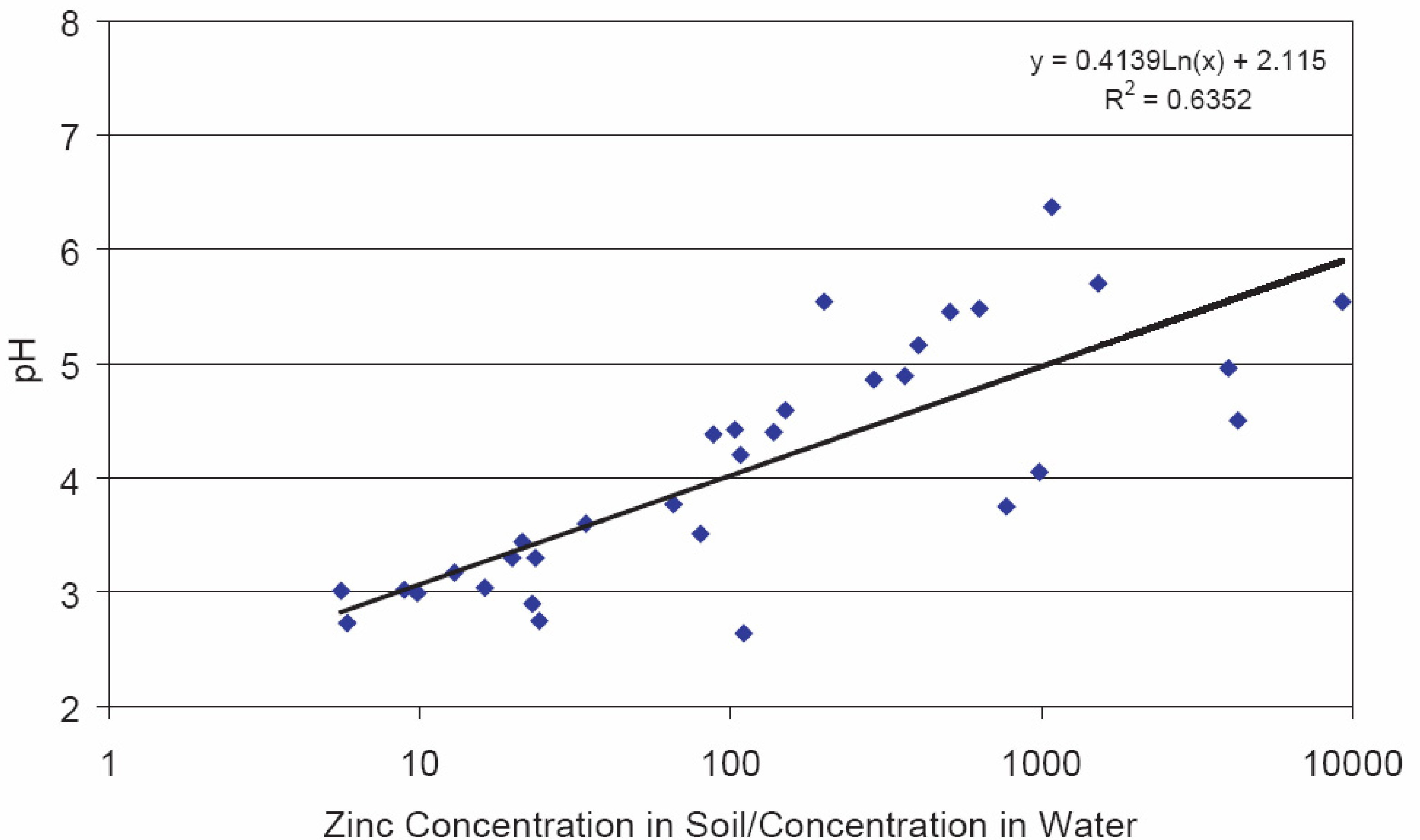
Dependence of Zinc Sorption on pH for Peat





Source: Gustafsson et al., 2003. Modeling Metal Binding to Soils; The Role of Natural Organic Matter. Environmental Science and Technology, 37, pp.2767.

Partition Coefficient (Kd) for Zn in Peat vs pH



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Contaminated Soils
pH 9

Oxidized Waste
pH 9

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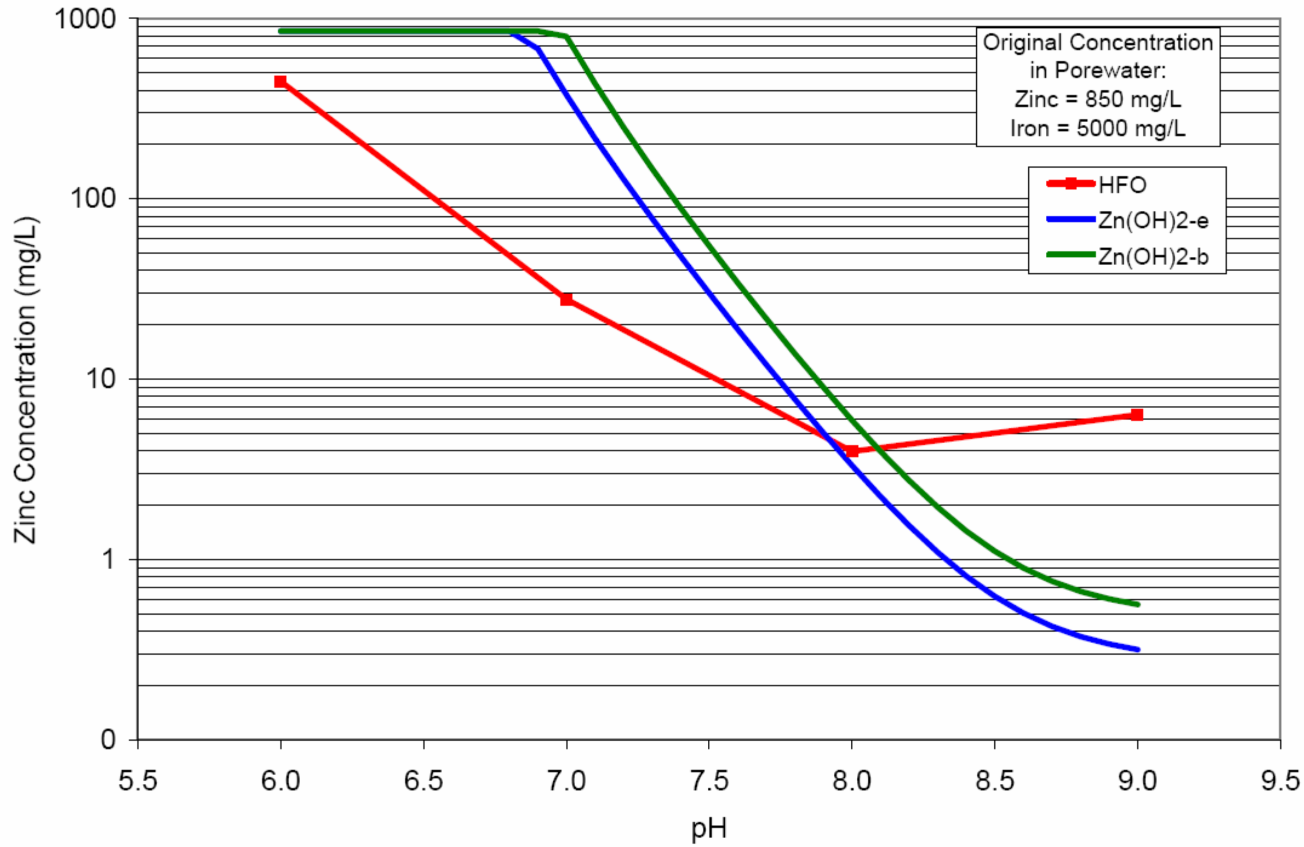
Hydrous Ferric Oxides

$$Fe\text{-}OH + Me^{2+} = Fe\text{-}O\text{-}Me^{2+} + H^+$$



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Source Modeling

- Predict unit areal flux over time
- Solved numerically using Finite Difference Technique

$$F = -D_z \frac{dC_{pw}}{dz}$$

$$f = 1 - \frac{C_{pw} \cdot \eta}{C_T}$$

$$K_d = \frac{f}{1-f} \cdot \frac{\eta}{\rho_b}$$

$$\frac{dC_{pw}}{dt} = \frac{d}{dz}\left(D_z \frac{dC_{pw}}{dz}\right)$$

C_{pw} = concentration of zinc in the porewater (mg/L);
C_T = total concentration of zinc (mg/kg);
F = mass flux (source loading) (g/m^2/day);
dt = time differential (s);
dz = depth differential (m);
η = porosity;
ρ_b = dry bulk density of material (kg/L);
f = adsorbed fraction;
K_d = distribution coefficient (L/kg);

Dz = vertical diffusion coefficient (m^2/s)

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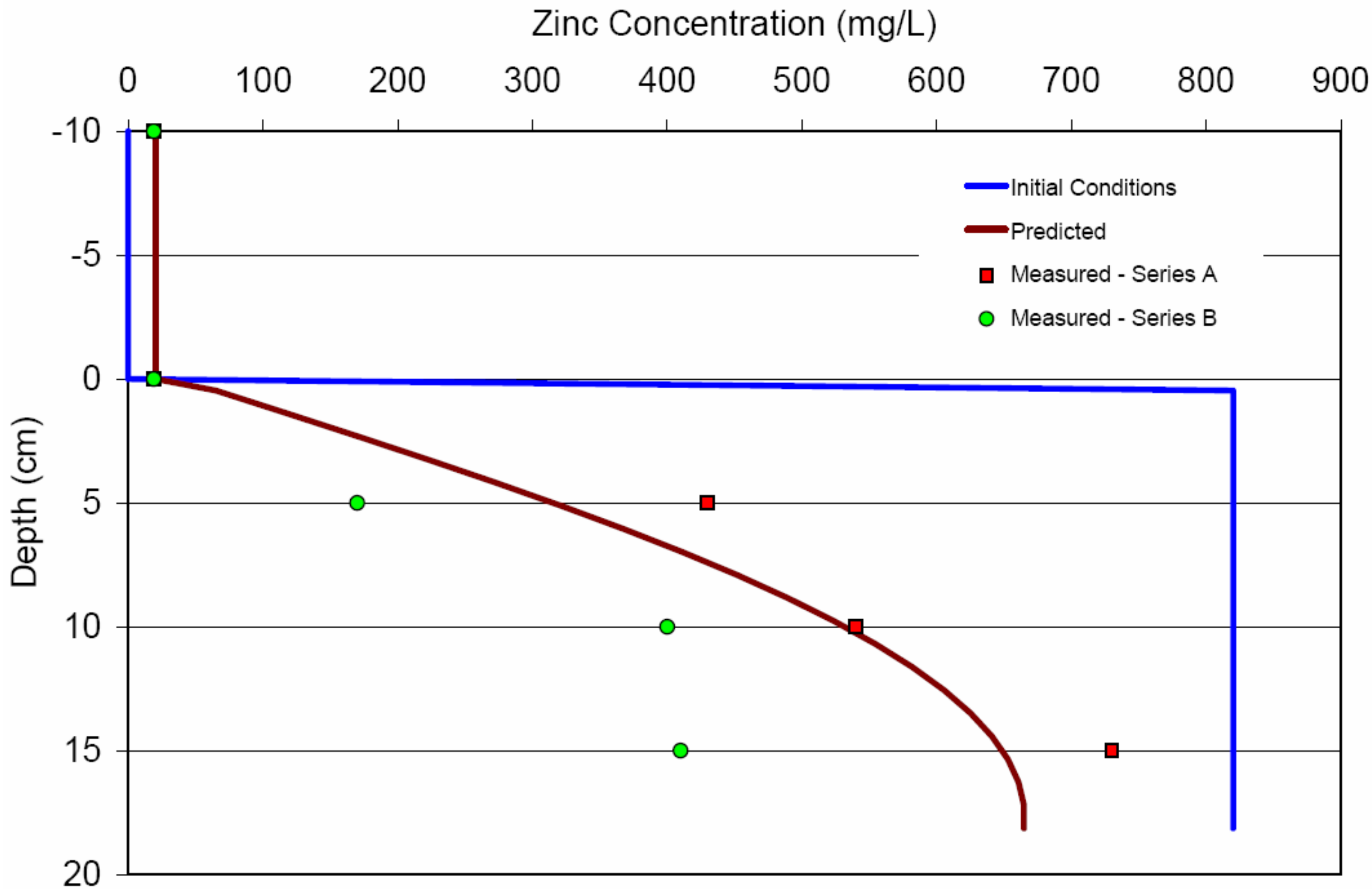
Calibration Results – Oxidized Waste



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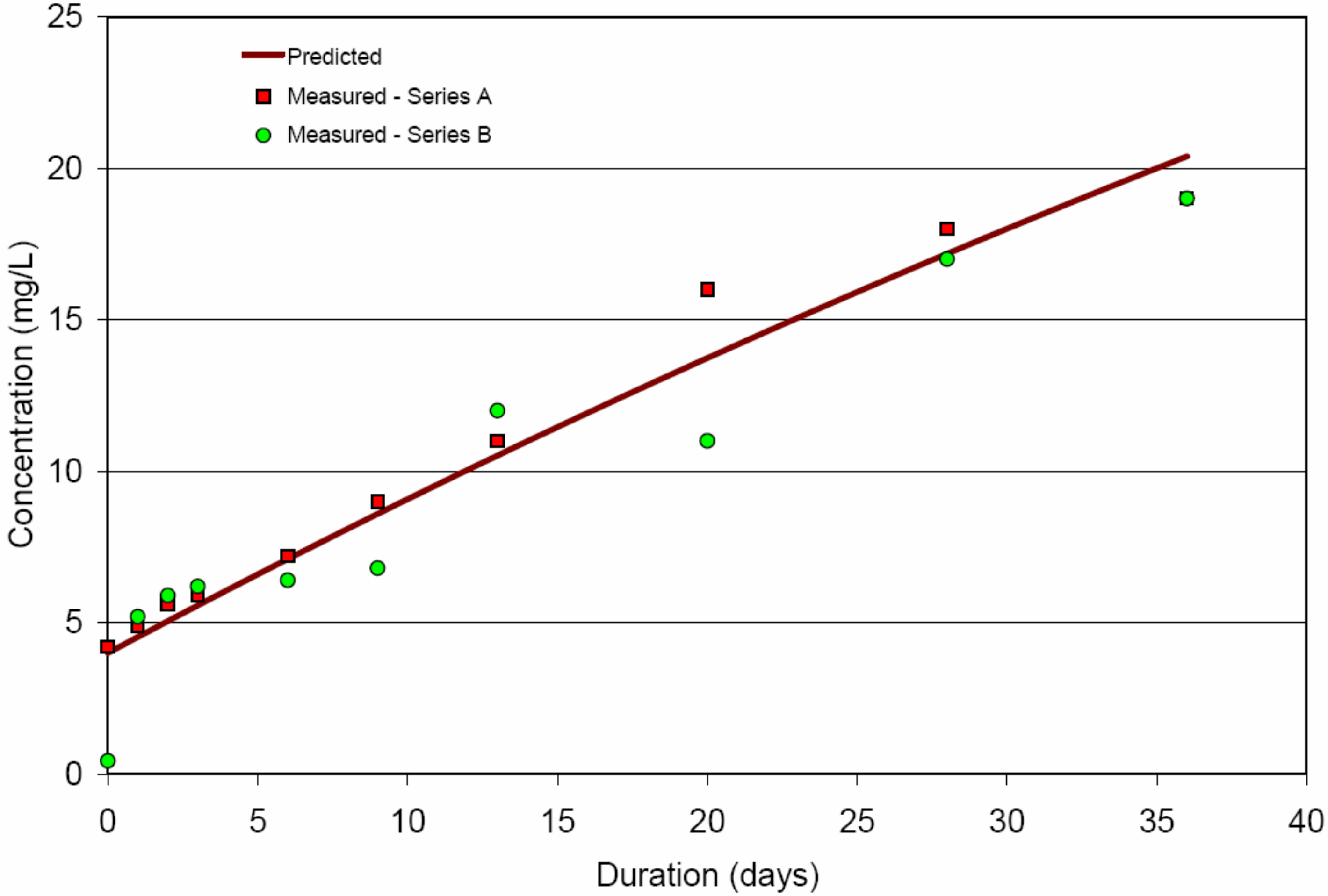

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Expected and Upper Bound

- Model Prediction using Expected (50th Percentile) and Upper Bound (90th Percentile)

Waste Material	**Expected** Zinc Concentration (mg/kg) (50th Percentile)	**Upper Bound** Zinc Concentration (mg/kg) (90th Percentile)
Contaminated Soils	1,315	8,223
Oxidized Waste	1,555	2,485
Peat	1,080	6,610

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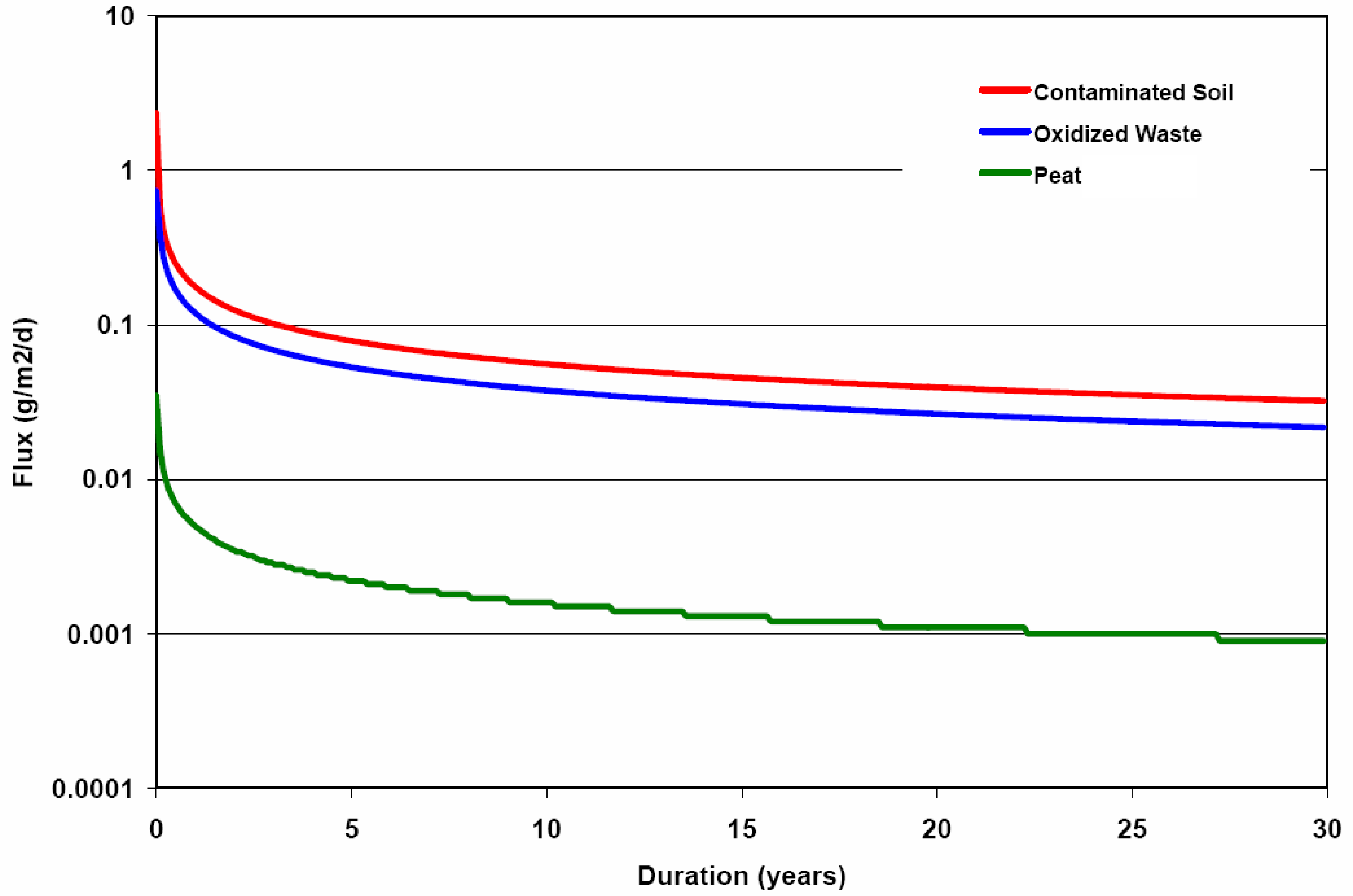
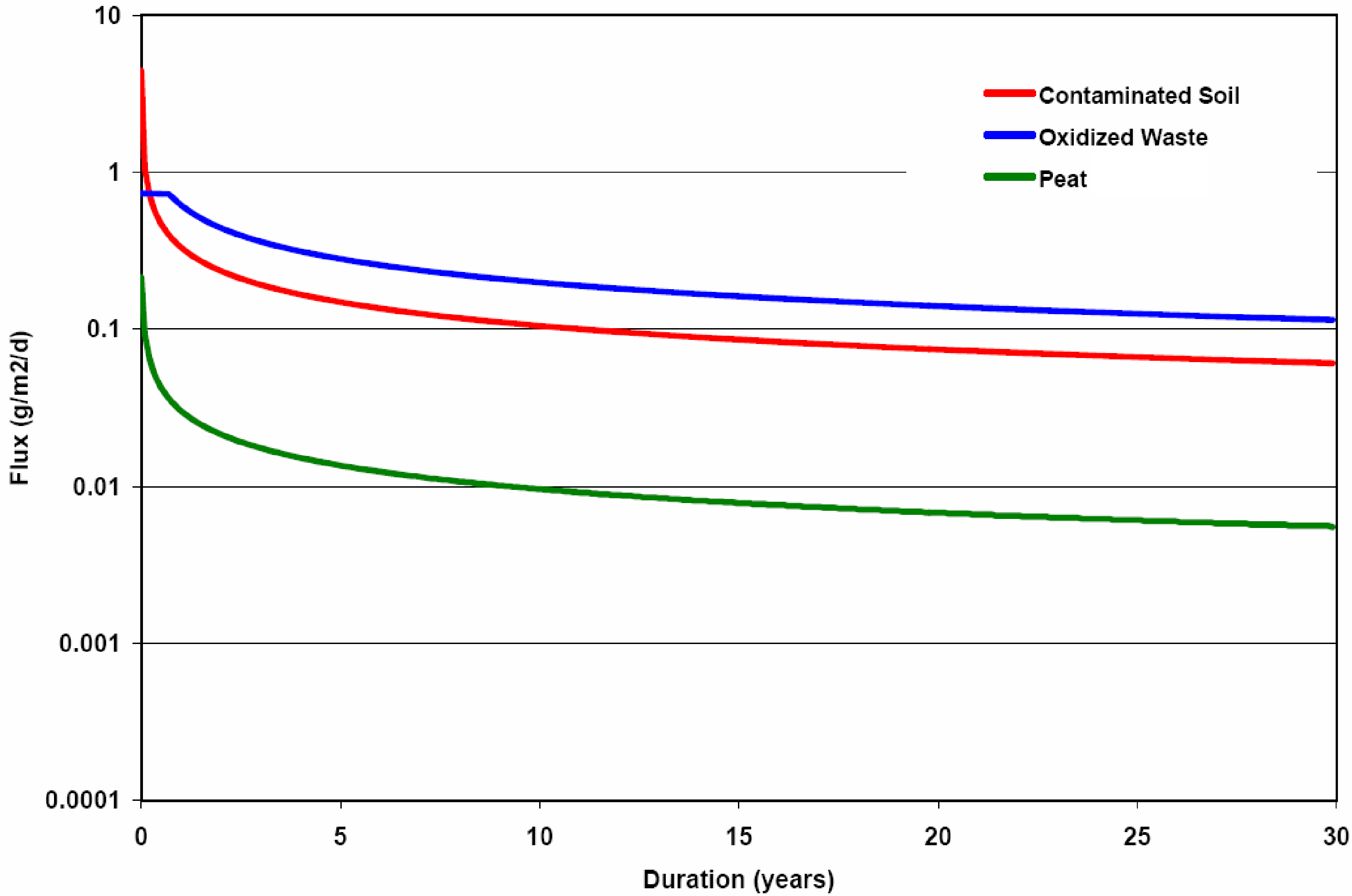
Flux of Zn-Expected



Flux of Zn-Upper Bound



Key Conclusions

- Flux of Zinc to overlying water greatest at lower pH values
- At pH 7, flux of zinc from oxidized waste and peat is reduced relative to acidic pH – not noticed for Contaminated soils
  - For Oxidized waste – result of Fe-oxide co-precipitation
  - For Peat – result of relationship between zinc sorption and pH

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Key Conclusions

- Zinc flux estimates after 10 years:
  - Contaminated soils: 0.06 to 0.10 $g/m^2/d$
  - Oxidized waste: 0.04 to 0.20 $g/m^2/d$
  - Peat: 0.002 to 0.01 $g/m^2/d$

- If pH levels maintained around pH 9, zinc flux rates can be reduced – possibly 2 orders of magnitude relative to neutral pH

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EXTRA SLIDES

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Field Investigations

- Waste Inventory and Configurations
  - What is currently in the Pit now
  - What will be in the Pit at the end

- Collected several composite samples, representing various materials including:
  - contaminated soils (industrial site and base of low-grade ore stockpile)
  - west sector/microwave peat+soil
  - oxidized waste rock

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Column Test Results

- Mass balance indicates that Zn is lost from the porewaters/overlying waters in the test chambers.
- Physical diffusion dominates Zn transport to waste surface (Contaminated Soils and Oxidized Waste).
- Chemical precipitation is indicated as dissolved metals diffuse into overlying water (Oxidized Waste).

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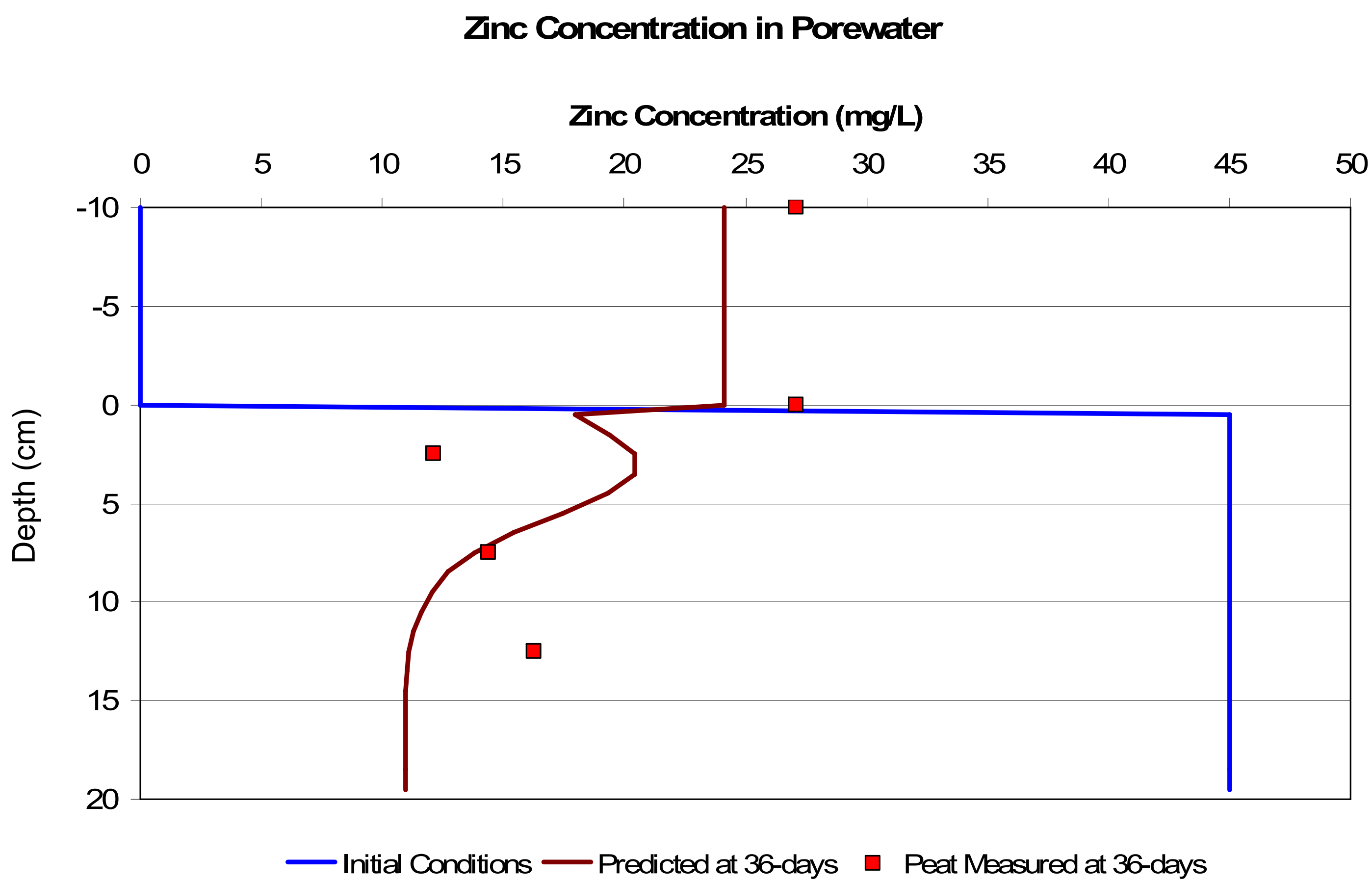
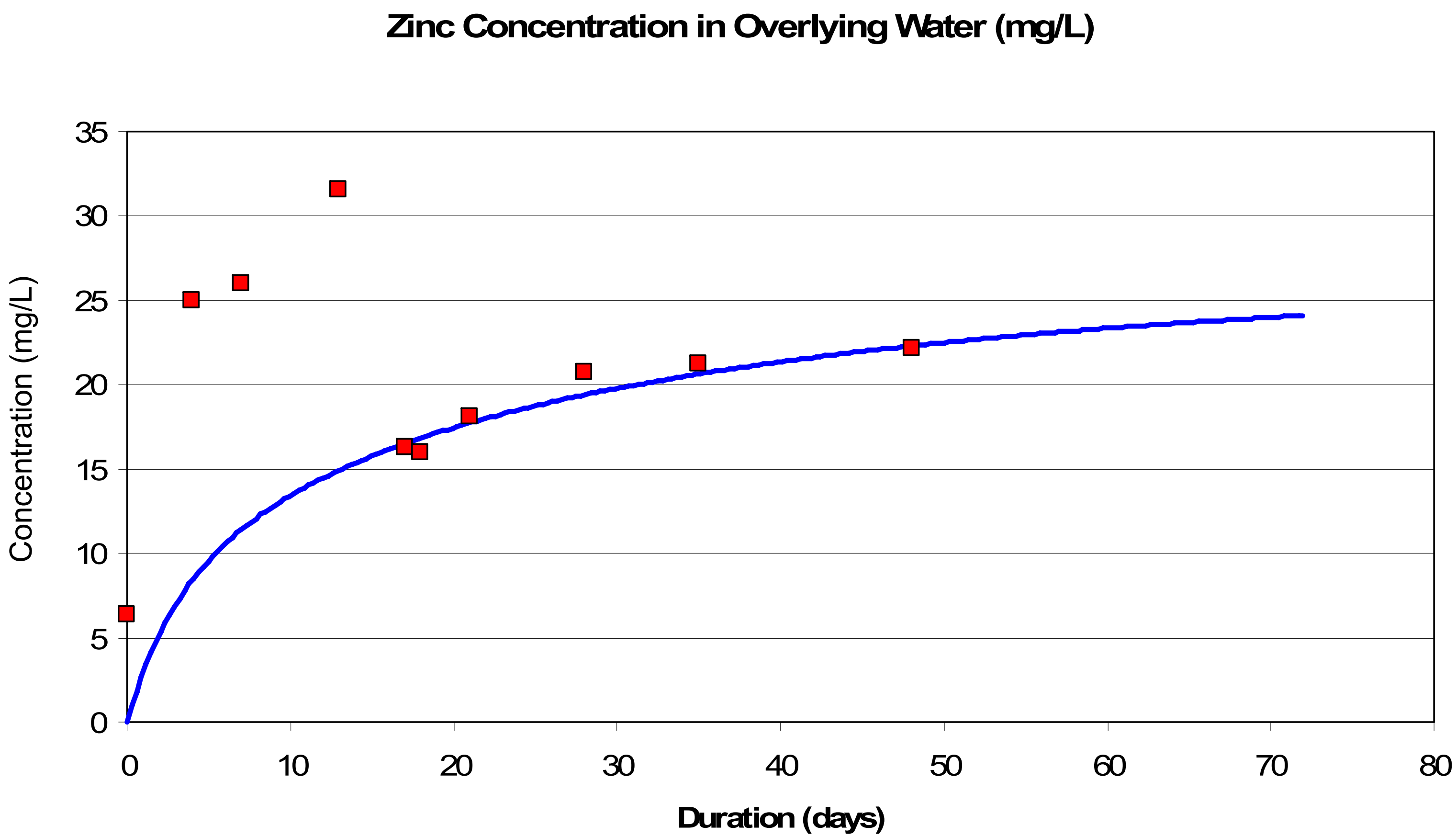
Calibration Results - Peat



Calibration Results – Peat



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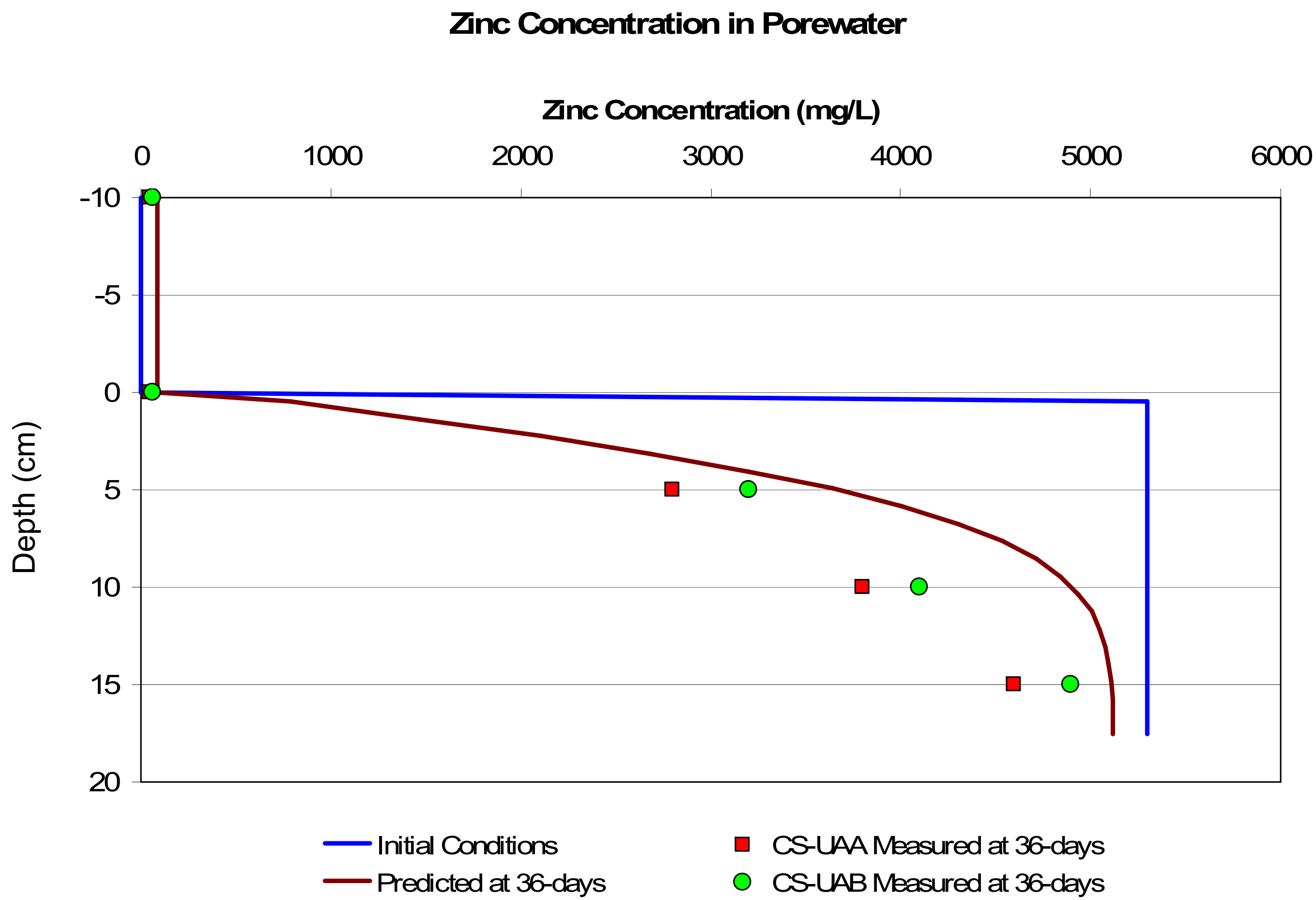
Calibration Results – Contaminated Soils



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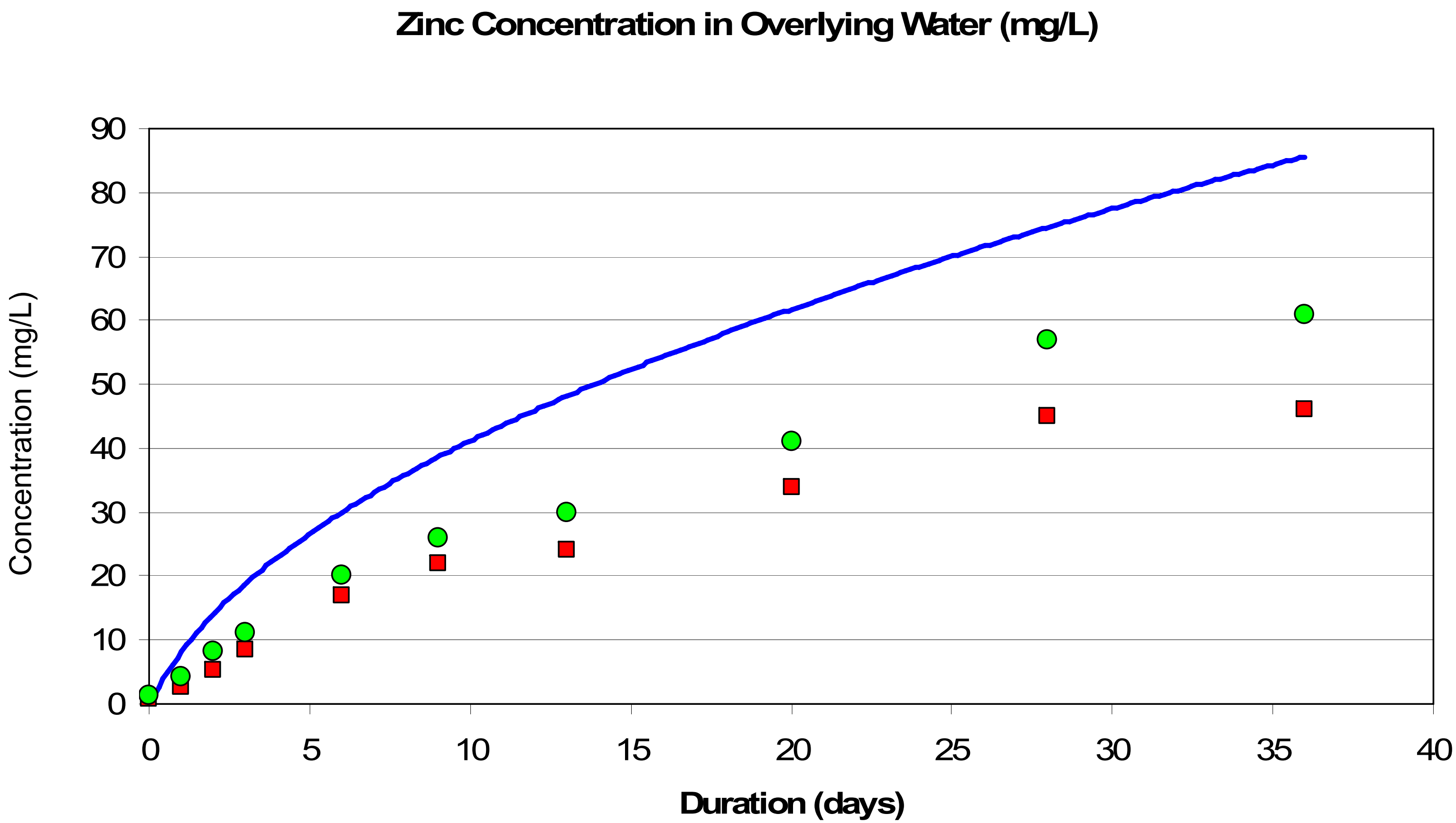
Calibration Results – Contaminated Soils



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