



Modeling of Hydrogen Sulfide Generation from Processed Construction and Demolition Materials in Landfills

**Federation Conference
Lake George, New York
May 6, 2009**

**Presented By
Gregory P. McCarron, PE
SCS Engineers**

Presentation Overview

- Purpose and introduction
- Site selection and data needs
- C&D fines sulfate data
- Hydrogen sulfide (H₂S) data
- Data and model for one landfill

Introduction

- Construction and demolition (C&D Fines) waste fines & residuals result from C&D processing
- C&D Fines Usage At Landfills
 - Alternative Daily Cover (ADC)
 - Landfill Closure/Shaping & Grading Material
 - Disposed as Solid Waste
- Odor Issues Developed in Many Northeast Landfills From Elevated Hydrogen Sulfide (H_2S) Generation; Linked to Gypsum (Sulfate) in C&D Fines

Introduction (Cont.)

- Resulting LFG Management Challenges
 - Regulatory Pressure
 - Early LFG System Installation
 - Increased LFG O&M
 - Air Emissions Control & LFG Treatment
- Result: Landfills Stopped Accepting C&D Fines
- H₂S Concentrations in LFG has been Observed to Decline After Use of C&D Fines was Halted

H₂S Basics and First Model

- H₂S Generation By Sulfur Reducing Bacteria
- C&D Fines: Greater surface area and percentage of sulfate
- Fines combined with Moisture and Nutrients in MSW Landfills Accelerates H₂S Generation
- Odor Control & LFG Management at These Landfills often Included H₂S and Sulfate Testing
- Basic H₂S model (zero order) Developed for Some Sites

Purpose of EREF Study

- Environmental Research and Education Foundation (EREF)
- University of New Hampshire & SCS
- Development Of First Order H₂S Generation Model
 - Tool for sulfur scrubbing evaluation and design
 - Tool for landfill owners to limit C&D
 - Tool for C&D processors to limit sulfate in C&D fines
- Study Anticipated to be Completed May 2009

Selection of Landfill Study Sites

- Initially 20 Landfill Sites Contacted in Northeast;
- Common Criteria for Study Sites
 - Accepted C&D Fines
 - Elevated H₂S Concentrations
 - Active LFG Collection/Control System
 - Historic Testing of H₂S
 - Quality/Quantity of Data Available
- Short-list of 13; 9 Selected

Data Compilation

- Data Compiled Separately for Each Landfill
- Data Organized Into Monthly Totals
 - LFG Recovery Totals
 - Average H₂S Concentration
 - Waste Totals, including C&D Fines
 - Sulfate Content of C&D Fines by Source
- LFG Recovery and H₂S Concentration Data Normalized to 50% Methane Equivalent
- H₂S Testing Data
 - Lab Analysis Data; H₂S/TRS Method 15/16; 307.91
 - Field Tests with Indicator Tubes (Gastec etc.)
 - Side by Side Field Tests and Lab Samples

Sulfate Content of Fines

- C&D Fines are Required to be Analyzed in Some States (BUD, etc.)
- EPA Method 300 (quantification of sulfate by ion chromatography)
- Some Sulfate Data Questionable
 - Sample Collection Techniques
 - Analytical Techniques (i.e. number dilutions)
 - Sulfate Test Data not Always Reliable!

Sulfate Content of Fines

- Historic Data Sources used for this Study
 - MassDEP database 7 C&D processing Facilities in New England (81 samples in 2007)
 - Two Processing Facilities with Sulfate data Available from 2004 through 2008
 - Additional Data from Previous Studies (UNH)
- Supplemental Testing at Two Landfill Sites in 2008 by UNH as Part of this Study

C&D Fines Sulfate Content

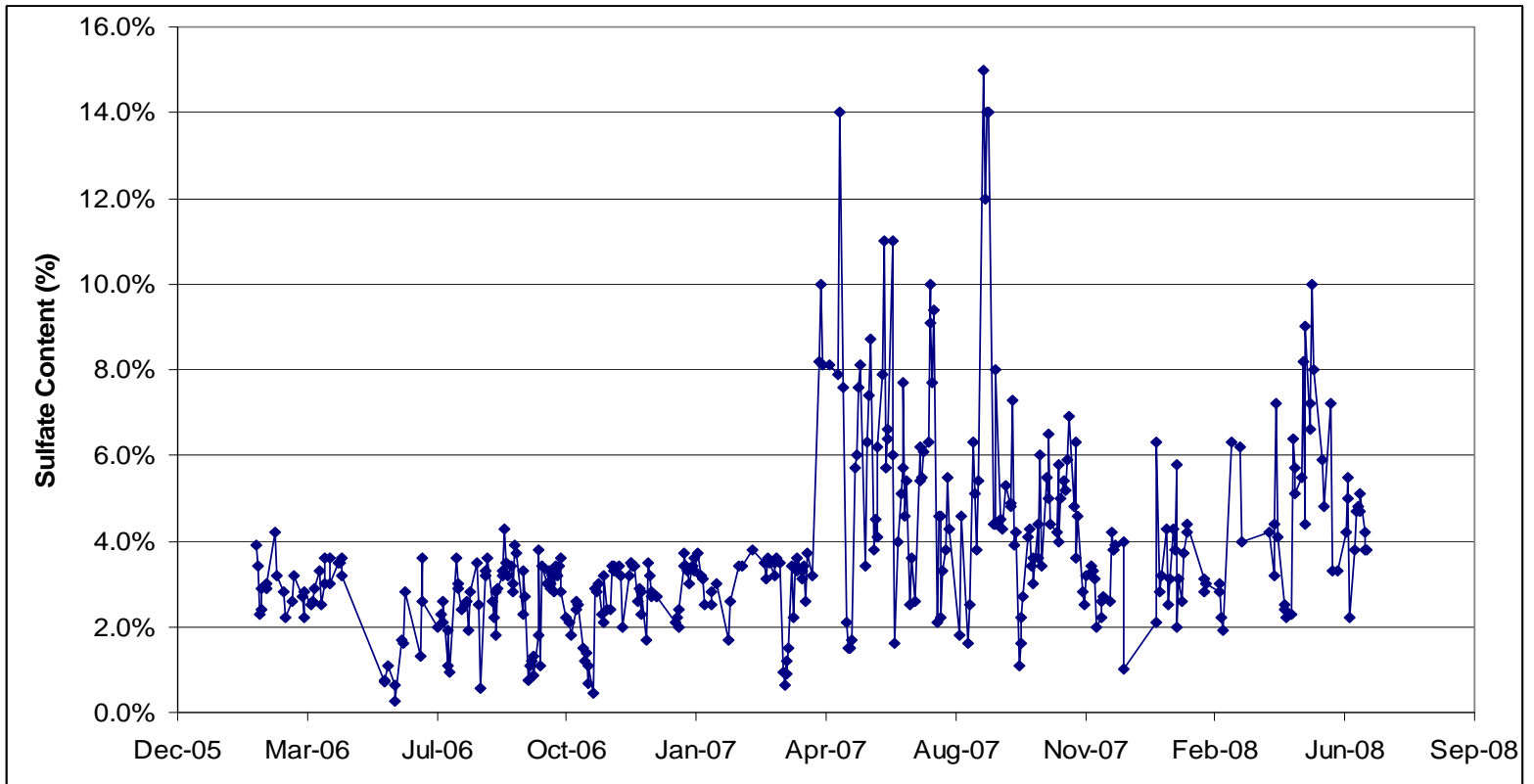
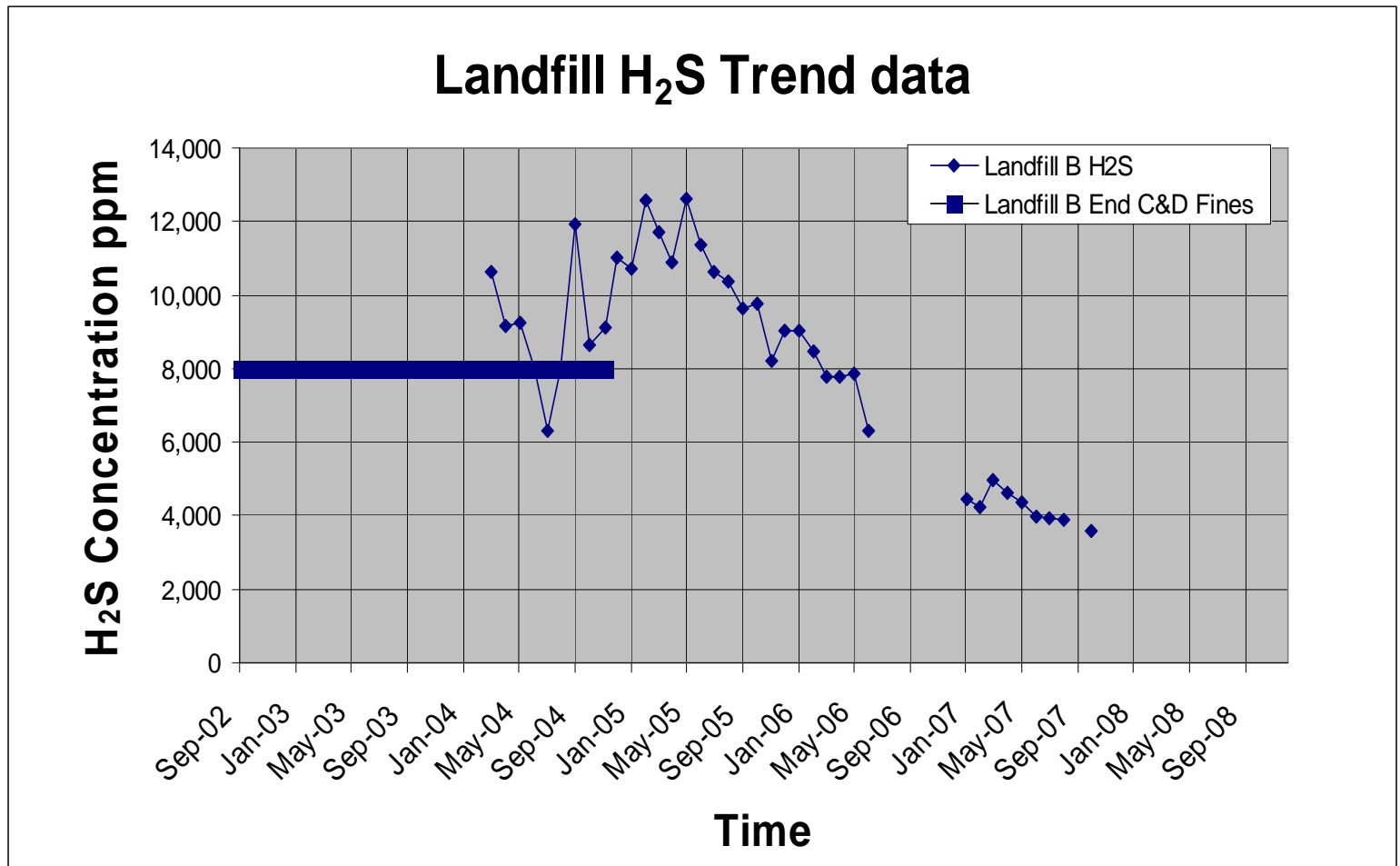
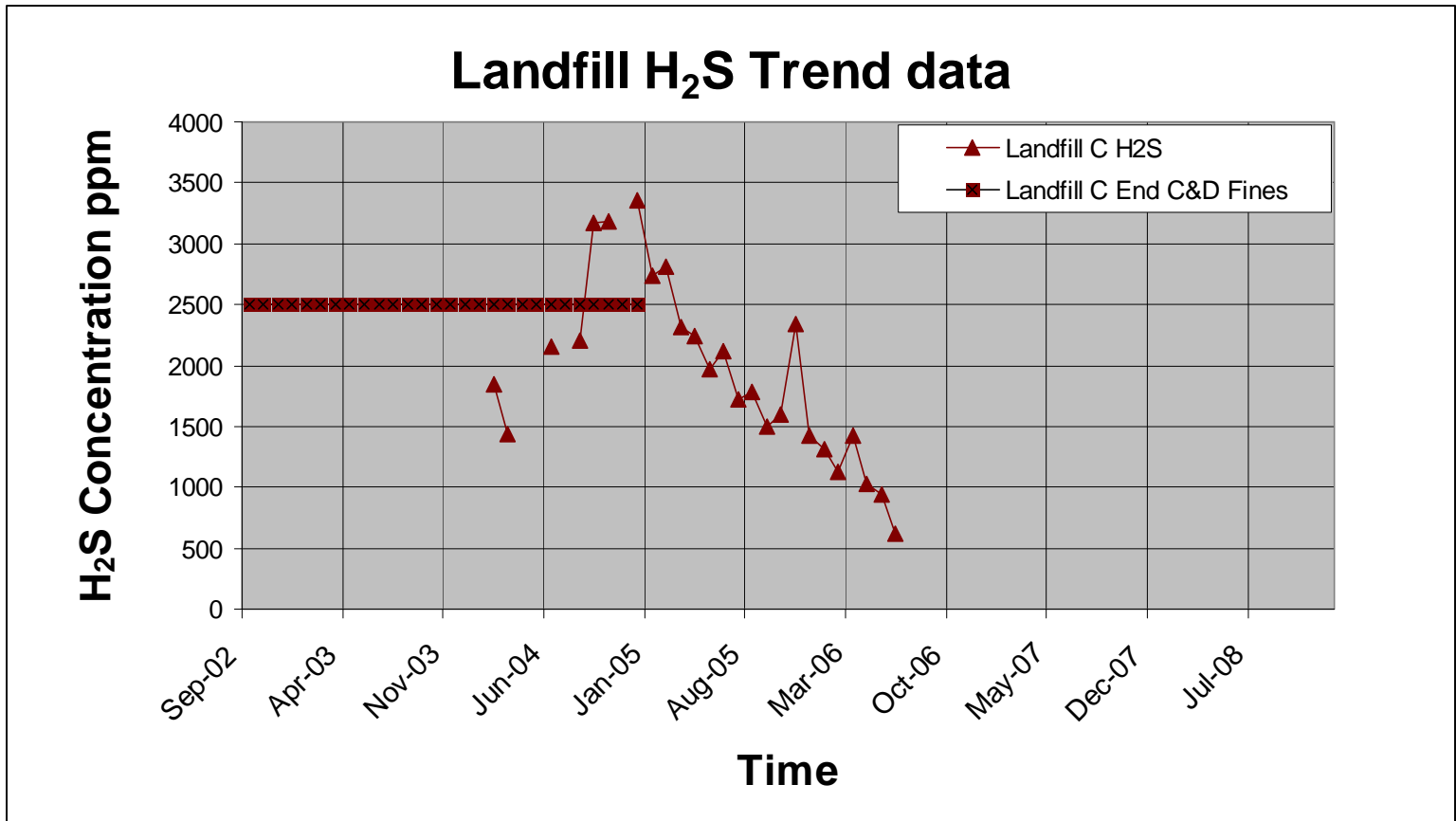


Figure 1. Sulfate Content By Weight at C&D Processing Facility III

Study Landfills H₂S Trend Data



Study Landfills H₂S Trend Data



Example - Landfill A

- **MSW Landfill, Located in Massachusetts; Closed and Capped in 2006**
- **Approximately 2.5 Million Tons WIP**
- **Accepted C&D Fines for 4 years Between 2001 and 2004**
- **Two Landfill Areas: Old Area and Expansion Area; No C&D Fines Were Placed in Old Area**
- **Odor Issues Drove LFG System Installation Between 2003-2005**

Example - Landfill A

- LFG System Generally Comprehensive Post 2004
- LFG Management Since 2004- Two Flares, Flow & Methane Monitoring, Rigorous O&M
- H₂S Testing Program- Field Testing and Lab Analysis
- 'Baseline' H₂S Concentrations at Gas Wells in Old Landfill Area Show Avg. < 100 ppmv

H₂S Test Data - Landfill A

- H₂S Testing Conducted Between October 2004 and December 2008
- Field Testing on a Weekly Basis: ~550 Samples on 184 Sample Event Days
- Lab Analysis Samples Collected Monthly/Quarterly: 38 Test Samples on 24 Sample Event Days
- Average Difference Lab Analysis and Field Results From Side by Side Sample Events +/- 5%, Std Dev 12% (outliers included)

Review and Analysis of H₂S Data

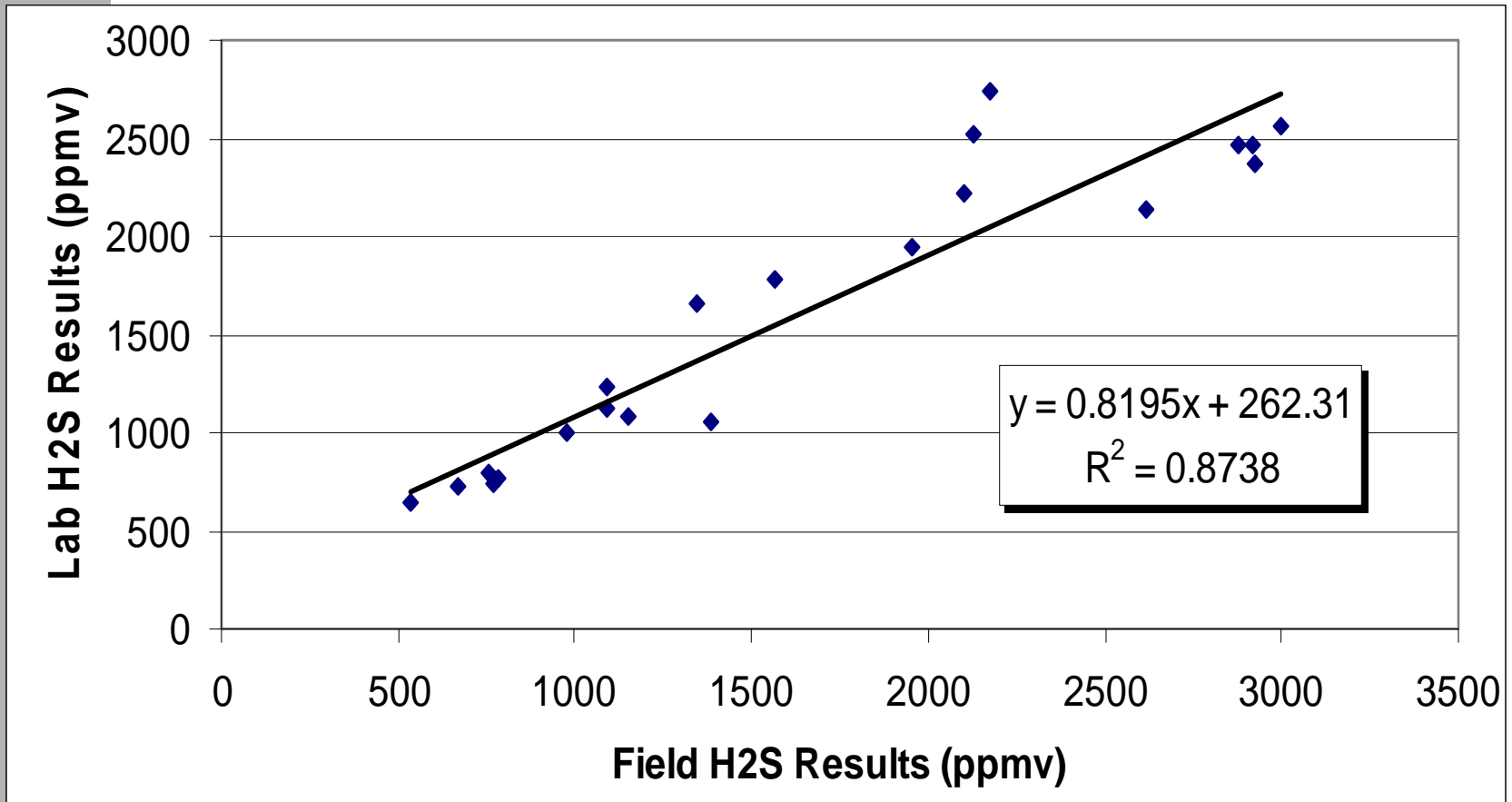


Figure 2. Correlation Between Lab and Field Test H₂S Results

Review and Analysis of H₂S Data

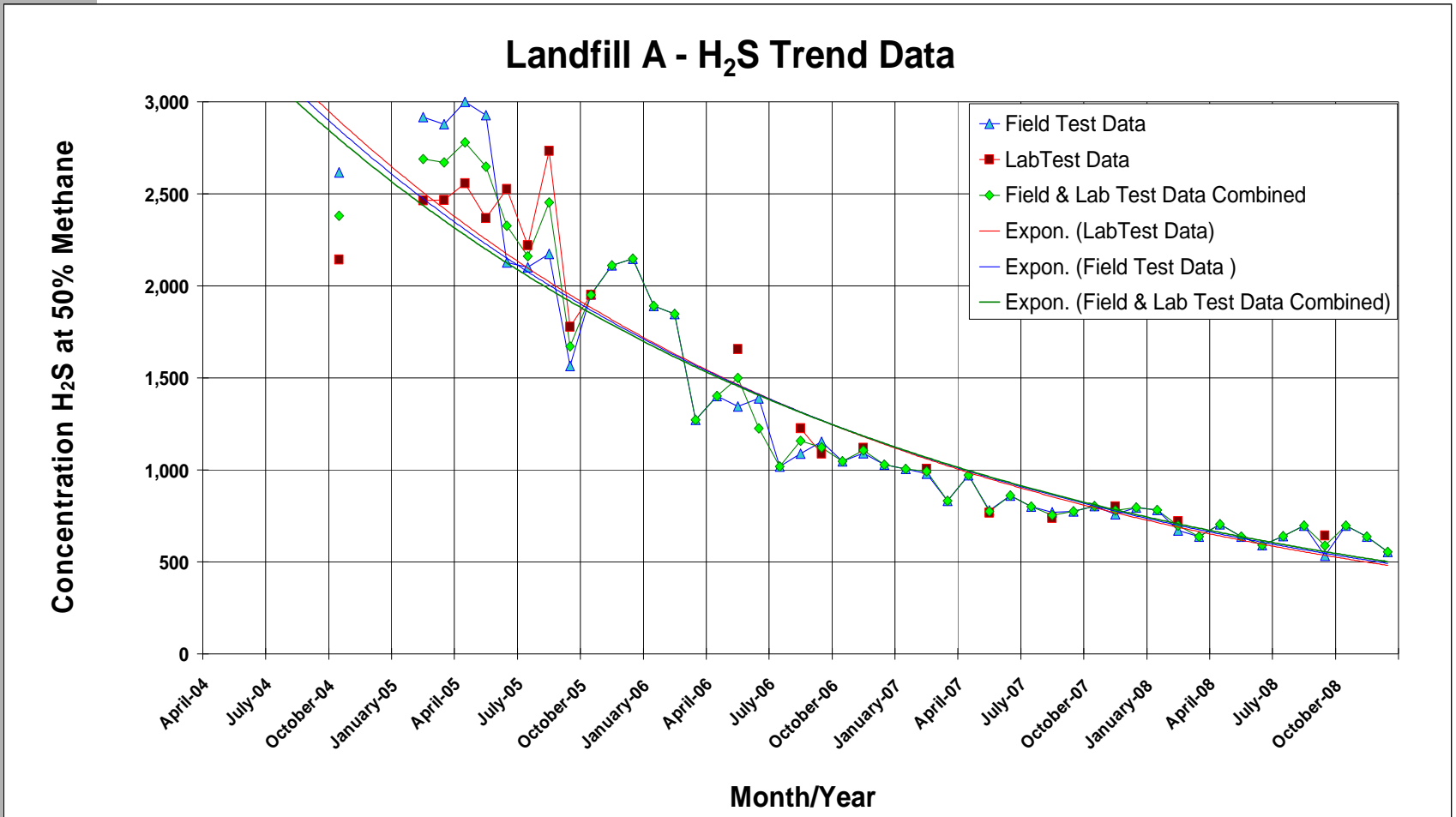


Figure 3. H₂S Concentrations at Landfill A Over Time

Mass Balance - Landfill A

- Laboratory & Field Data were Combined and Weighted Equally
- Cubic Feet & Pounds of H₂S Recovered (For Years available) was Calculated Using H₂S Concentration Data and LFG Recovery
- A Mass Balance was Developed comparing Sulfur in from C&D Fines and Sulfur out as H₂S

Sulfur Balance- Landfill A

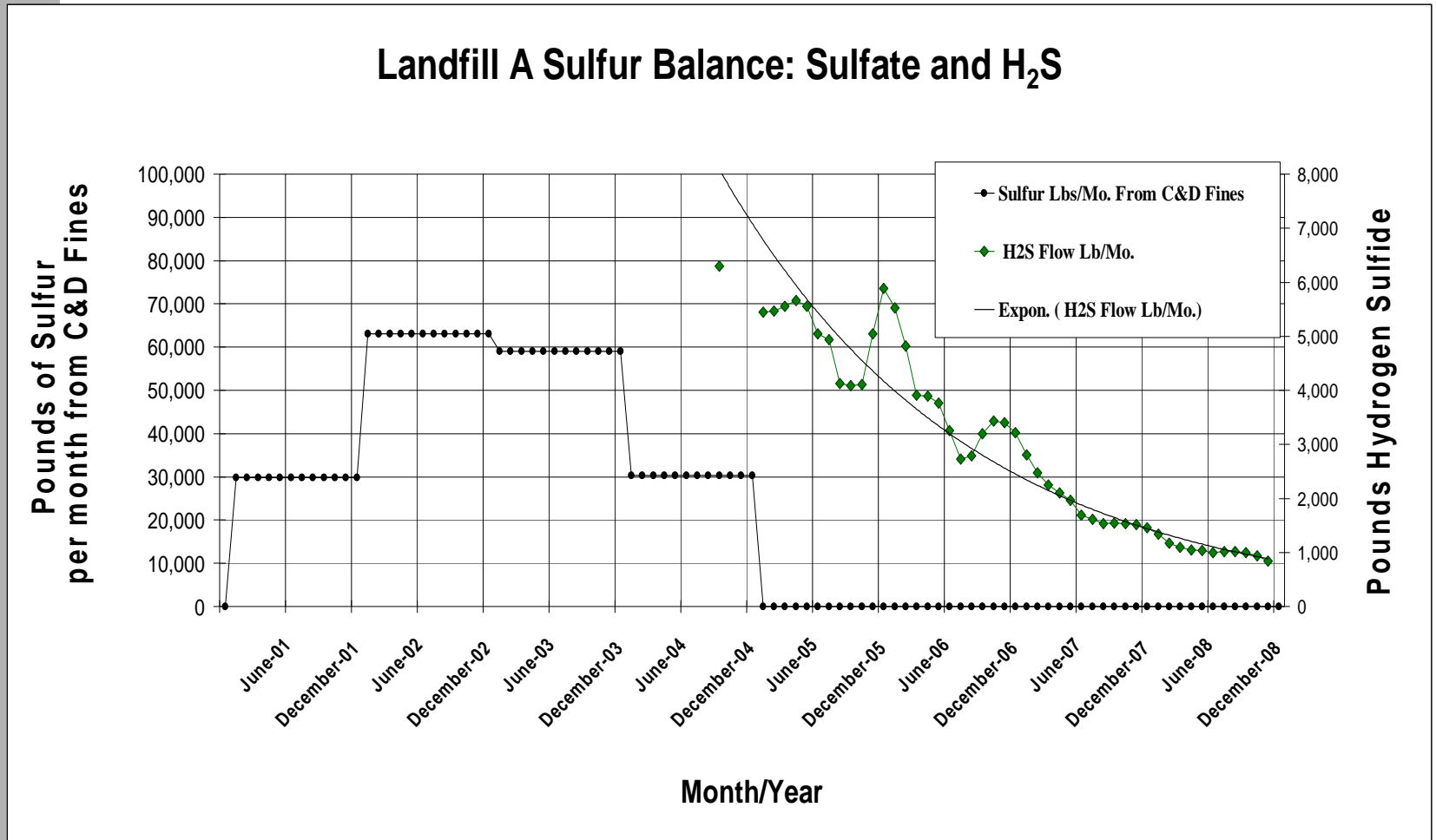


Figure 4. Mass of Sulfur Input into Landfill A and Mass of H₂S out in Landfill Gas

Preliminary H₂S Model

- Model Equation Format for Selected for H₂S is as Follows:

$$QH_2S = \sum_{i=1}^n k L_0 M_i (e^{-kti})$$

QH_2S = H₂S generation rate from the landfill, cf

k = H₂S generation rate constant, 1/yr

L_0 = H₂S generation potential, CuFt/ton sulfur

M_i = mass of sulfur from C&D Fines deposited in the i th section, Tons

t_i = age of the i th section, months

i = section number

- Looks Familiar?- Methane Generation Model; A Typical Biological Process/Decay Equation

Preliminary H₂S Model

- Decay Rate 'K' (1/time) Value From Actual H₂S Recovery Rate (CuFt) Trend
- Mass, M_i value equal to Tons of Sulfur from Fines
- Obtaining H₂S Generating Potential 'Lo Value': Model Fitted to Actual LFG/H₂S Recovery
- Results Were Compared to Experience with Zero Order Model & Mathematical Check

Preliminary H₂S Model

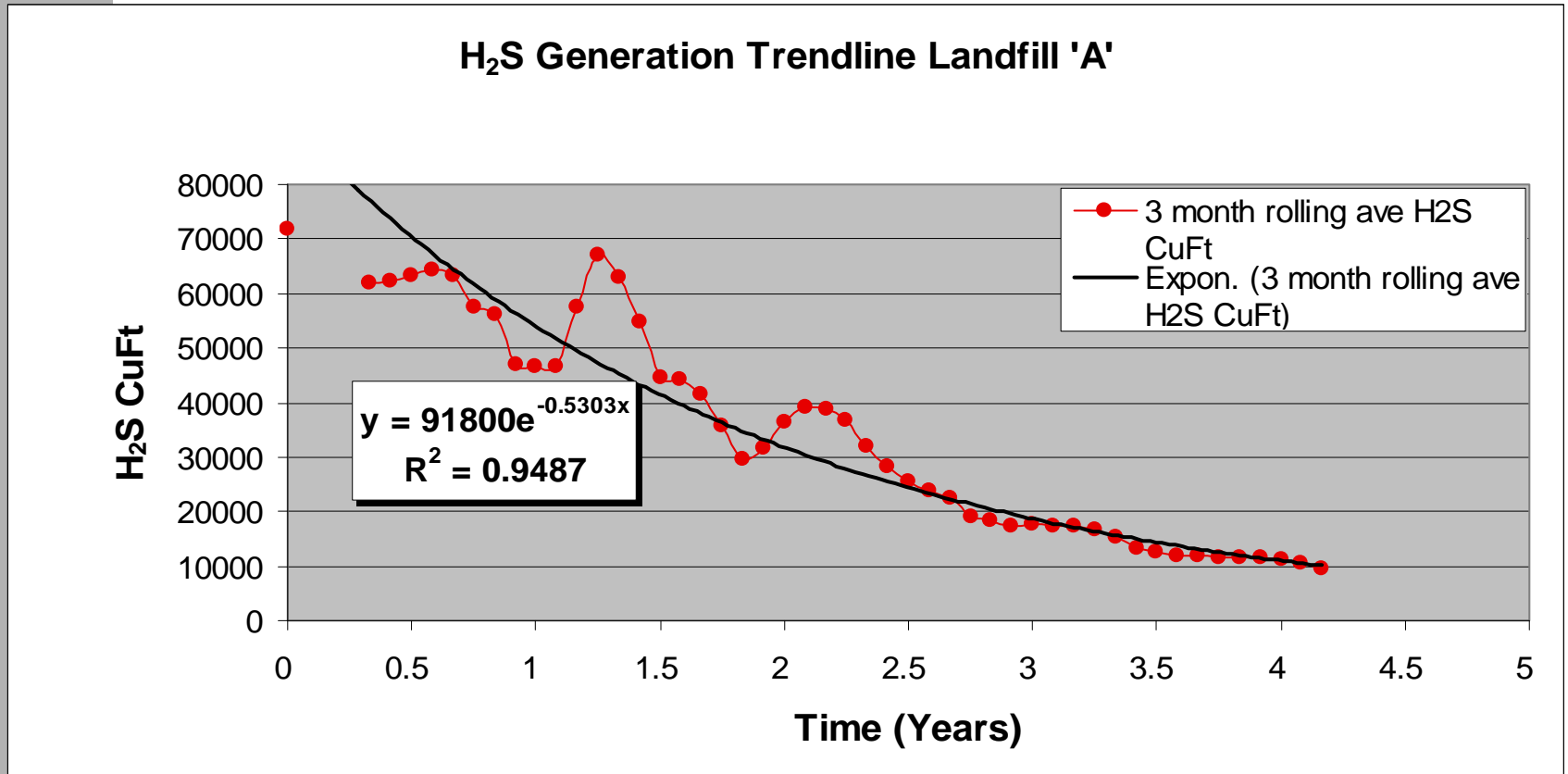


Figure 5. Trendline Developed from Volume of H₂S Produced per Month from Landfill A over time

Preliminary H₂S Model- Results Landfill A

- Decay Rate Value k of 0.53
- Lo Value of 3,280 CuFt/ton (102 M³/Megagram) as Sulfur or ~ 1,100 CuFt/ton as Sulfate
- Lo Value Equivalent to ~ 100 Pounds H₂S produced for Each Ton of Sulfate Deposited as C&D Fines/ADC
- Equates 1 Ton C&D Fines with 5% Sulfate Content to produce about ~ 5 Pounds H₂S over Decay Life
- Landfill A Model Results Compared to Actual H₂S Generation Data R Squared = 0.92

Conclusions (Preliminary)

- H₂S Generation Resulting from C&D Fines is Rapid- Sharp Peak and Decline
- Decay Rate (k) is Shown to be Much More Rapid than Methane ~ 0.5
- H₂S Generating Potential (Lo) for Sulfate Deposited as C&D Fines Believed to be ~ 1100 CuFt/Ton
- Model is Valuable to Estimate the Cost of C&D Fines for LFG Management, Treatment

Next Steps in EREF Study

- Complete H₂S Model for the Other 8 Landfills
- Compare Results, Analyze k, Lo Values Derived for Other Sites
- Develop 'Standard' k, Lo Default Values and Confidence Factors
- Provide Recommendations for Future Research

Acknowledgements

- Environmental Research and Education Foundation (EREF).
- Dr. Jenna Jambeck, University of New Hampshire and Russ Anderson, SCS (Co-Authors)
- Participating Landfills