Sixth Annual Conference on Carbon Capture & Sequestration

Terrestrial-Related Sequestration R&D

Development of an Intelligent Bioreactor Management Information System for Mitigation of Greenhouse Gas Emissions from Landfills

P.T. Imhoff, P. Chiu, R. Yazdani, D. Augenstein, H. Bentley, B. Travis, S. Smith, M.E. Mostafid

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Project Partners & Funding

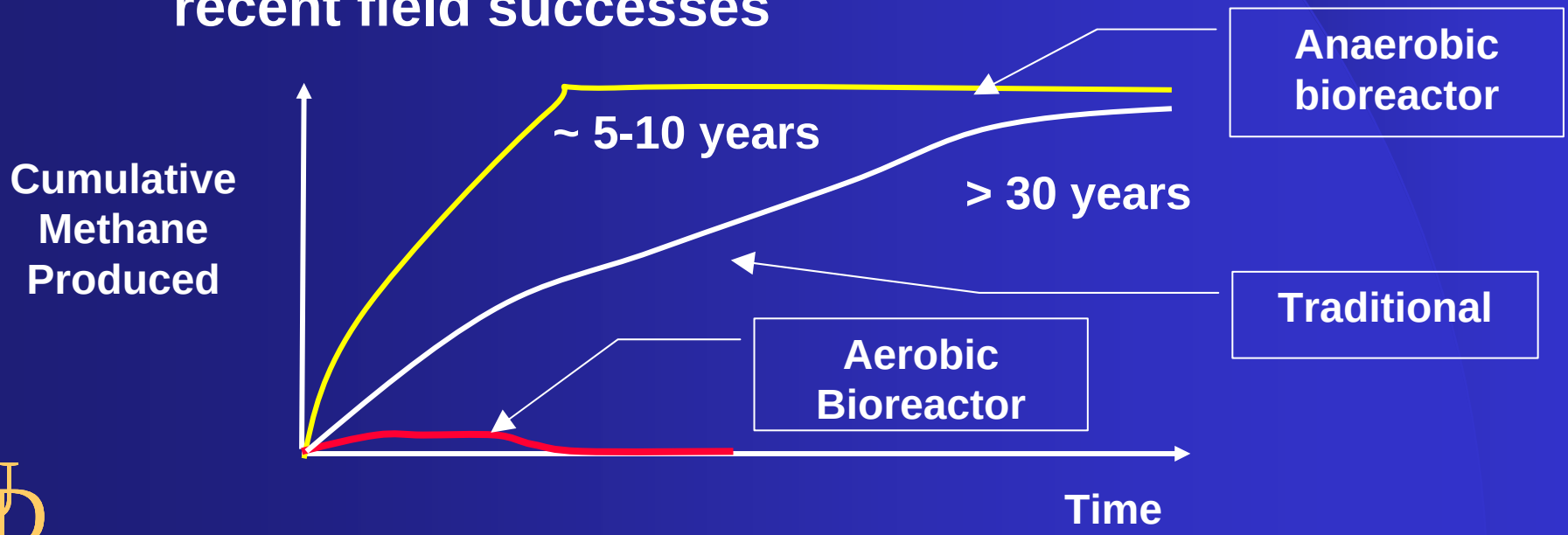
- **Project Partners**
  - National Energy Technology Laboratory (Heino Beckert, Karen Cohen)
  - California Energy Commission-PIER
  - Sacramento Municipal Utility District
  - California Integrated Waste Management Board
  - **Yolo County, CA (Ramin Yazdani)**
  - **Institute for Environmental Management, Inc. (Don Augenstein)**
  - **Hydro Geo Chem, Inc. (Harold Bentley)**
  - **University of Delaware (Paul Imhoff & Pei Chiu)**

Background

- **Landfill Methane Emissions**
  - **Methane's contribution to total climate forcing ~ 20% that of CO_2 in last 20 yrs.**
  - **Landfills are largest anthropogenic source of methane - 30% of emissions.**
  - **Bioreactor landfilling may reduce annual US greenhouse emissions by about 50-120 million tons of CO_2 carbon (equivalent) at costs between $1-13/ton carbon**
    - **Enhanced CH4 generation and efficient capture (anaerobic)**
    - **Reduced CH4 generation (aerobic)**

Background

- **Bioreactor Landfills**
  - **Controlled Landfilling – liquid added to increase rates of degradation, producing more methane over shorter time periods**
  - **2000's – tremendous growth in interest, based on recent field successes**



Status of Bioreactor Landfills

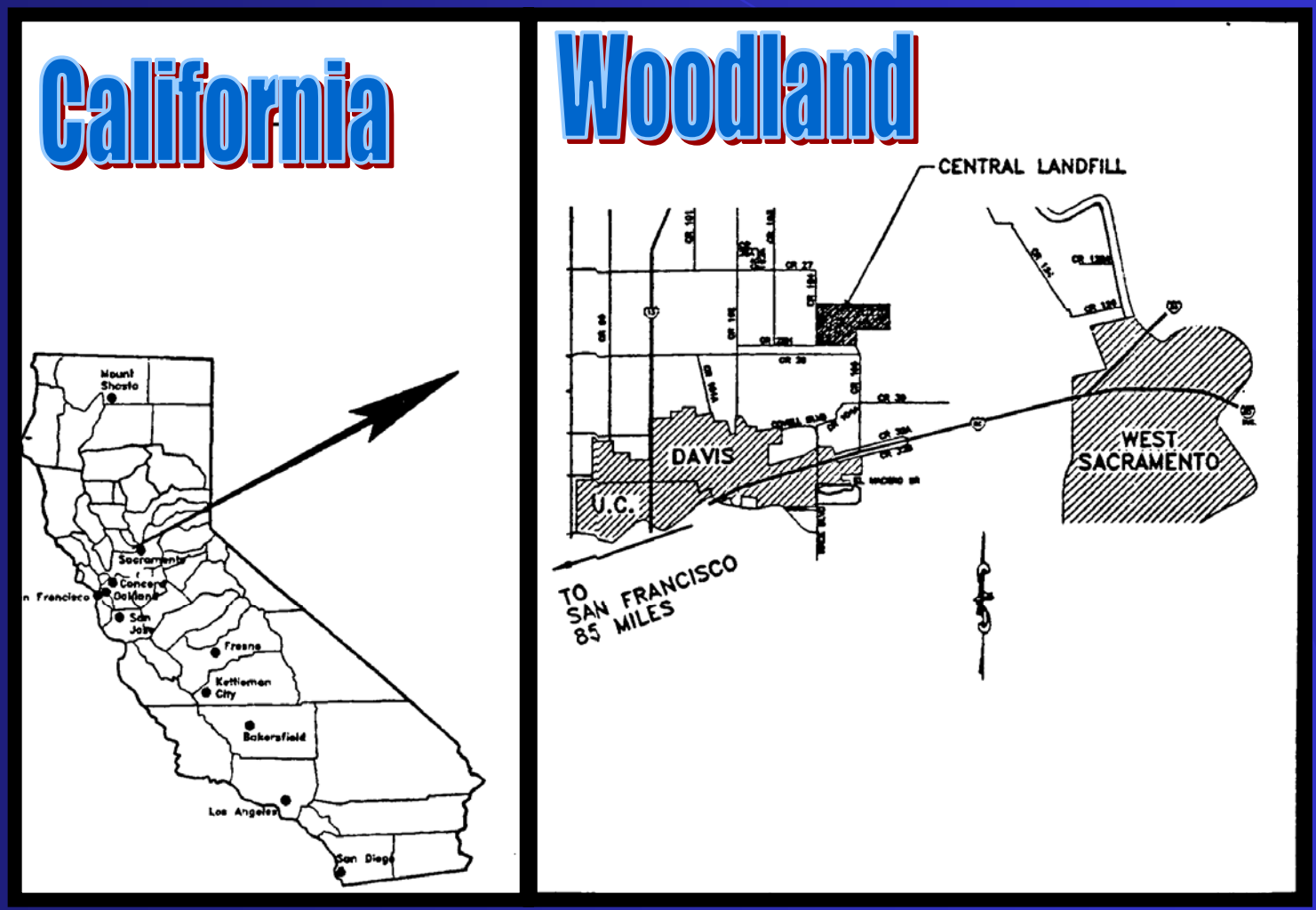
- Technology advancing by addressing concerns over
  - Liquid addition effects (side seeps, landfill failures)
  - Fires (aerobic bioreactors)
  - Capture of enhanced methane generation

- Intelligent bioreactor management information system addresses these issues through
  - Improved understanding of fluid movement in refuse
  - Rationalizing landfill design
  - Modeling operations and feedback systems

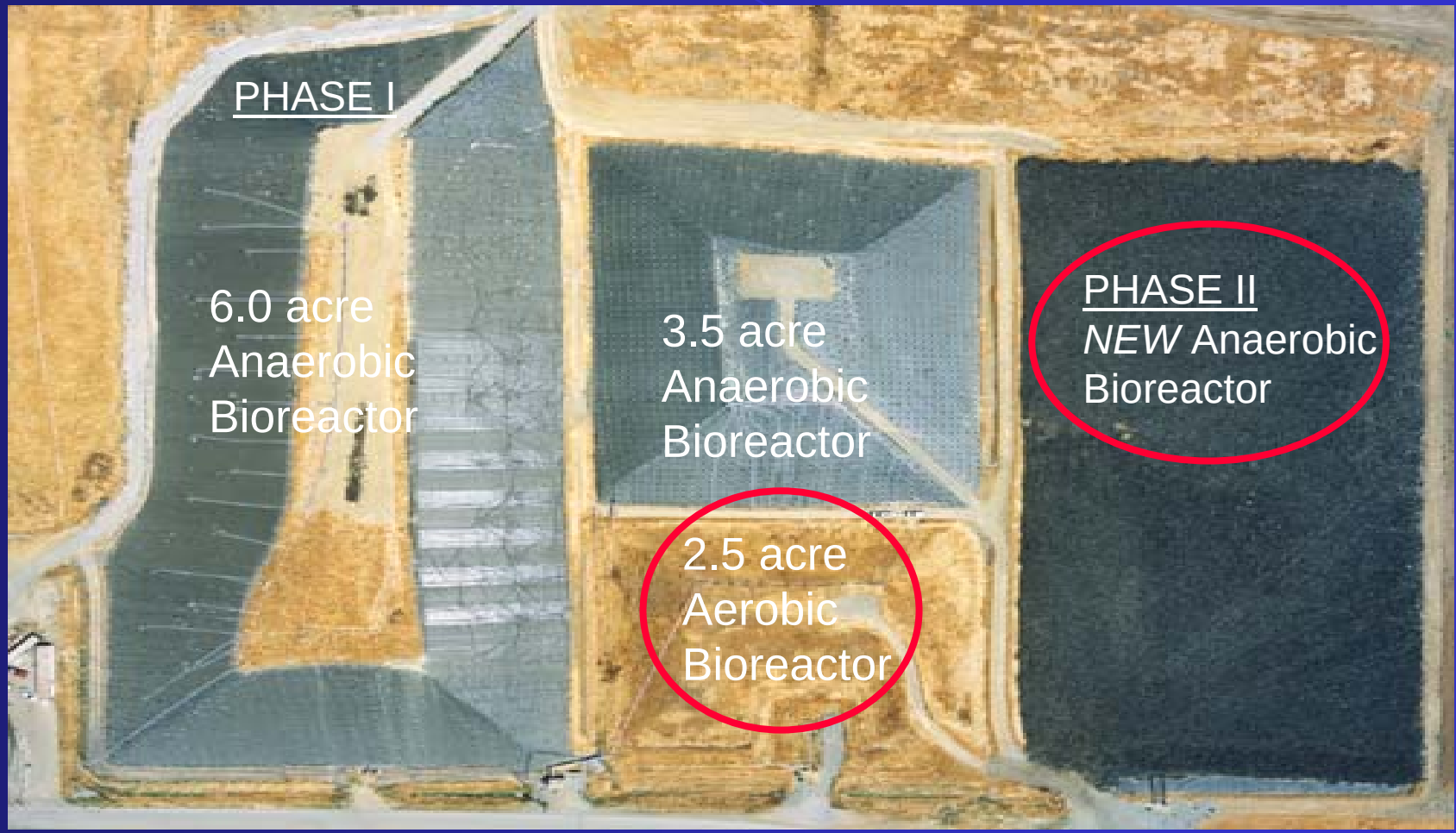
Project Objectives

- Develop Intelligent Bioreactor Management Information System (IBM-IS) for controlling CH_4 capture (anaerobic) or air injection (aerobic)
  - Models to guide CH_4 capture and air injection linked to distributed sensors
  - Automated feedback system
- Develop IBM-IS for liquid addition
- Demonstrate utility of IBM-IS to reduce GHG emissions
- Develop cost/benefit ratio for IBM-IS

Project Location Map

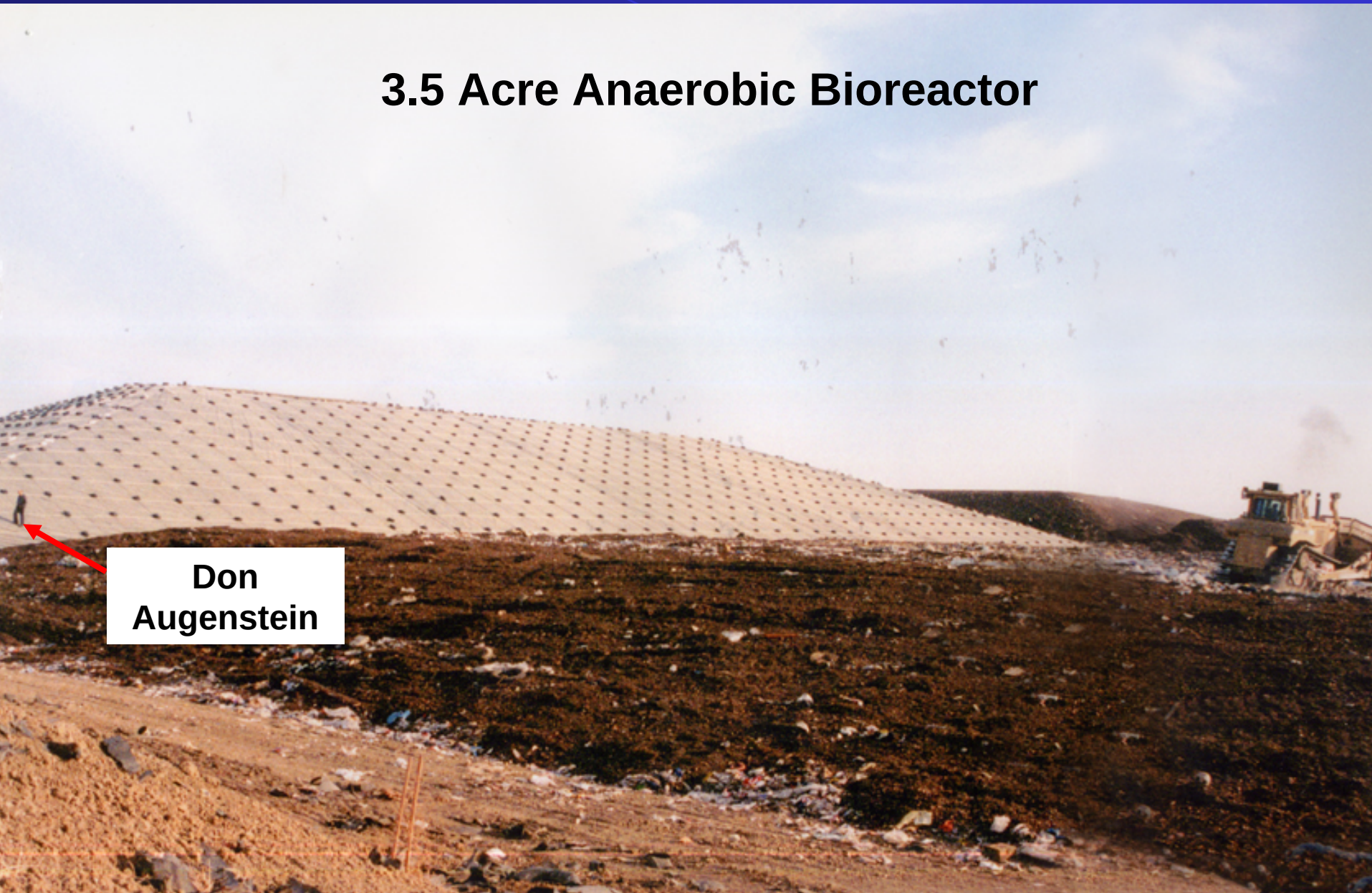


Bioreactor Landfill Cells at Site



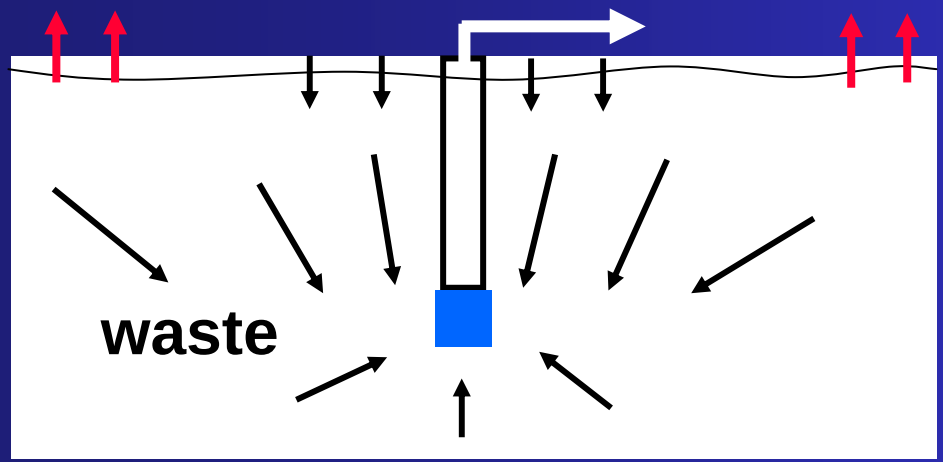
Unique Design – highly instrumented

Bioreactor Landfill Cells at Site

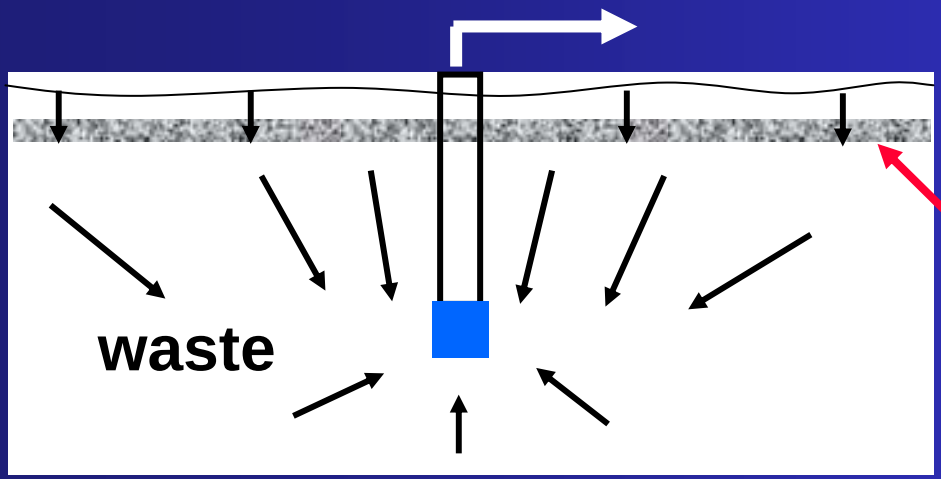


Anaerobic Bioreactor – CH4 Capture

- Design of innovative permeable layer for enhanced methane collection



Conventional



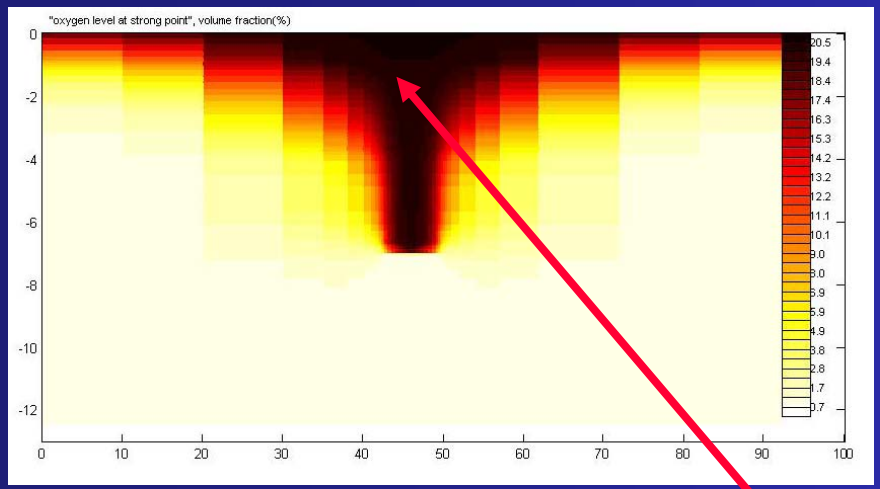
New Design

Shredded tires act as high-permeability layer for gas collection

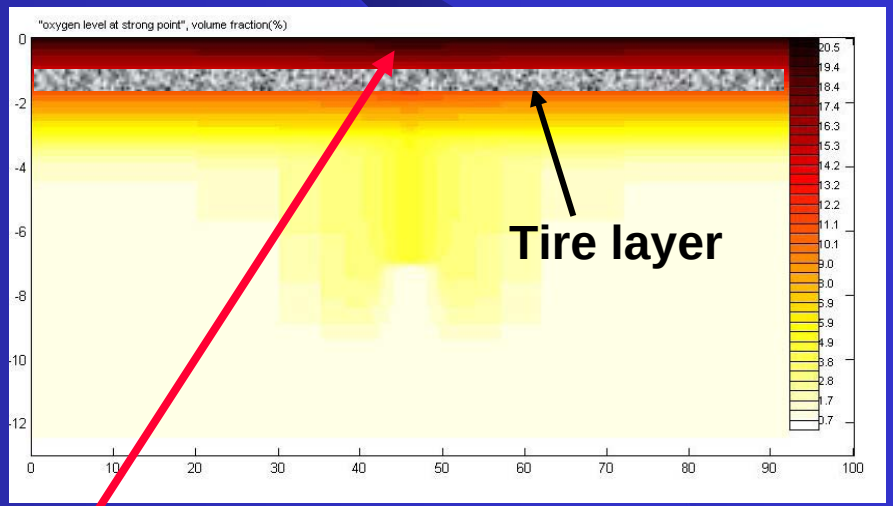
Anaerobic Bioreactor – CH4 Capture

- **Modeling intrusion of air**

Without permeable layer



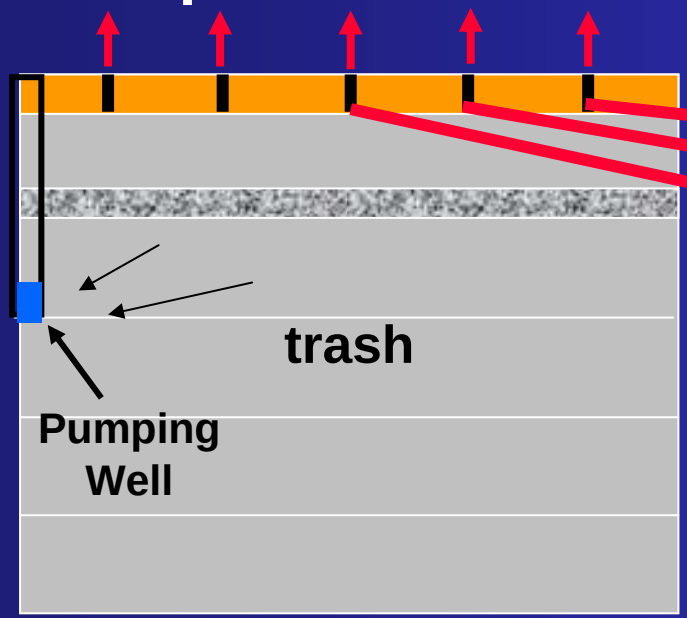
With permeable layer

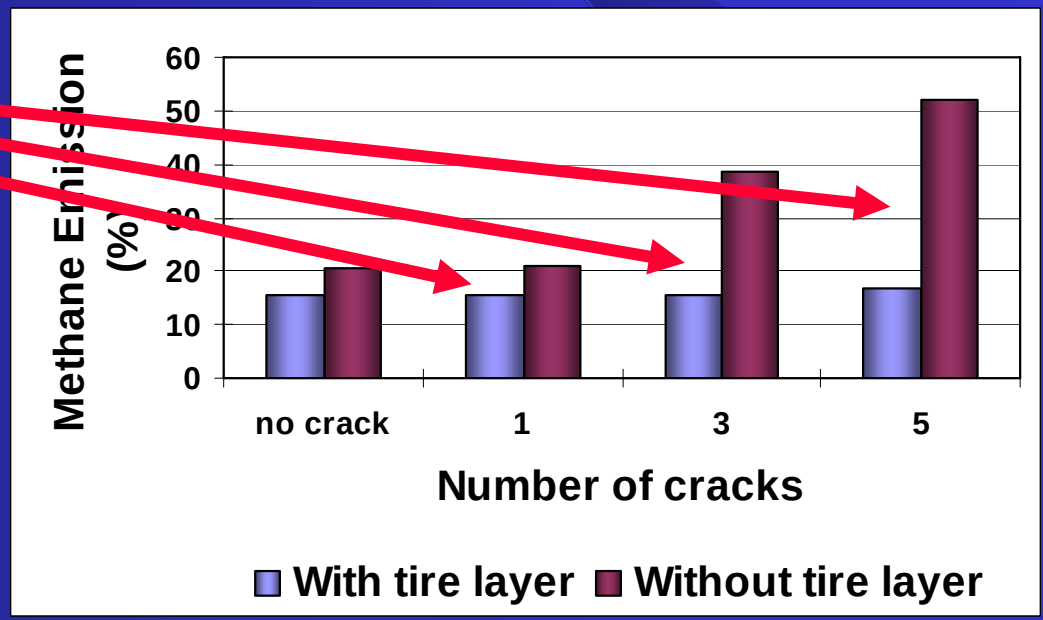


Intruding oxygen

Anaerobic Bioreactor – CH4 Capture

- **Simulated effect of cracks in biocover**
  - **Permeable layer *increases* the efficiency of CH_4 capture**





Anaerobic Bioreactor – Field Testing

- Fugitive methane emissions measured in bioreactor with permeable layer
  - Model predictions match field data
  - Negligible methane fluxes to date

Biocover + CH_4 Emission Sampling

Enhancement of CH4 Capture – Cost Analysis

- **Cost analysis for installation of permeable layer + automated system for adjusting extraction due to atm. pressure changes**

I. CAPITAL COSTS (for 1000 TPD and 100FT deep)

INCREMENTAL EQUIPMENT ITEM	INSTALLED CAPITAL COST (FULL LANDFILL)
Vacuum regulator	$ 5,000 – 10,000
Variable flow valve and software	$ 5,000-10,000
Pressure sensors (assumed 10) + leads and wiring	$ 30,000-40,000
Permeable layer costs (depends on material; shred tires zero)	$ 0 to 100,000
Engineering, programming and miscellaneous@ 25%	~~$ 10,000 to 40,000~~
Total	**$ 50,000 to 200,000**

COSTS VARY WITH SITE, MATERIALS (FOR EXAMPLE SHRED TIRES OR RUBBLE CAN BE "FREE")

II. OPERATING

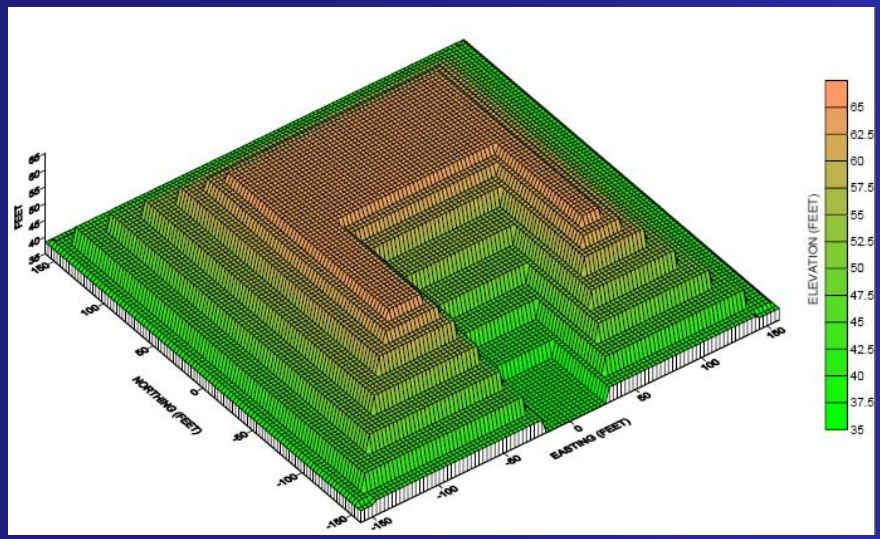
OPERATING COST SIMILAR TO "CONVENTIONAL" PRACTICE

Enhancement of CH4 Capture – Cost Analysis

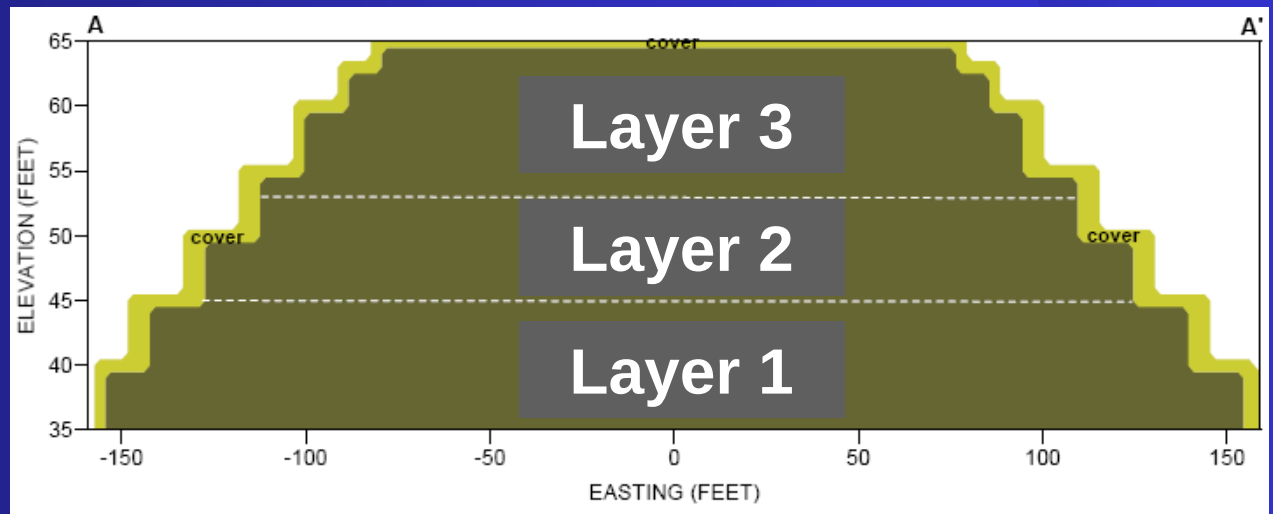
- **Cost/Benefit Summary:**
  - Incremental expenses add less than 10% to capital costs for "normal" gas collection system
  - ~ 30% improvement in CH_4 capture and $1-3/ton carbon credit gives 1 to 5 year payback
  - CO_2 equivalent capture cost is under $2/ton CO_2 equivalent
- **Energy Benefit**
  - Increase in recovered CH_4 (~30%) is available for energy use.

Aerobic Bioreactor – Inhibit CH4 Generation

- **Multiphase flow model developed to guide air injection**



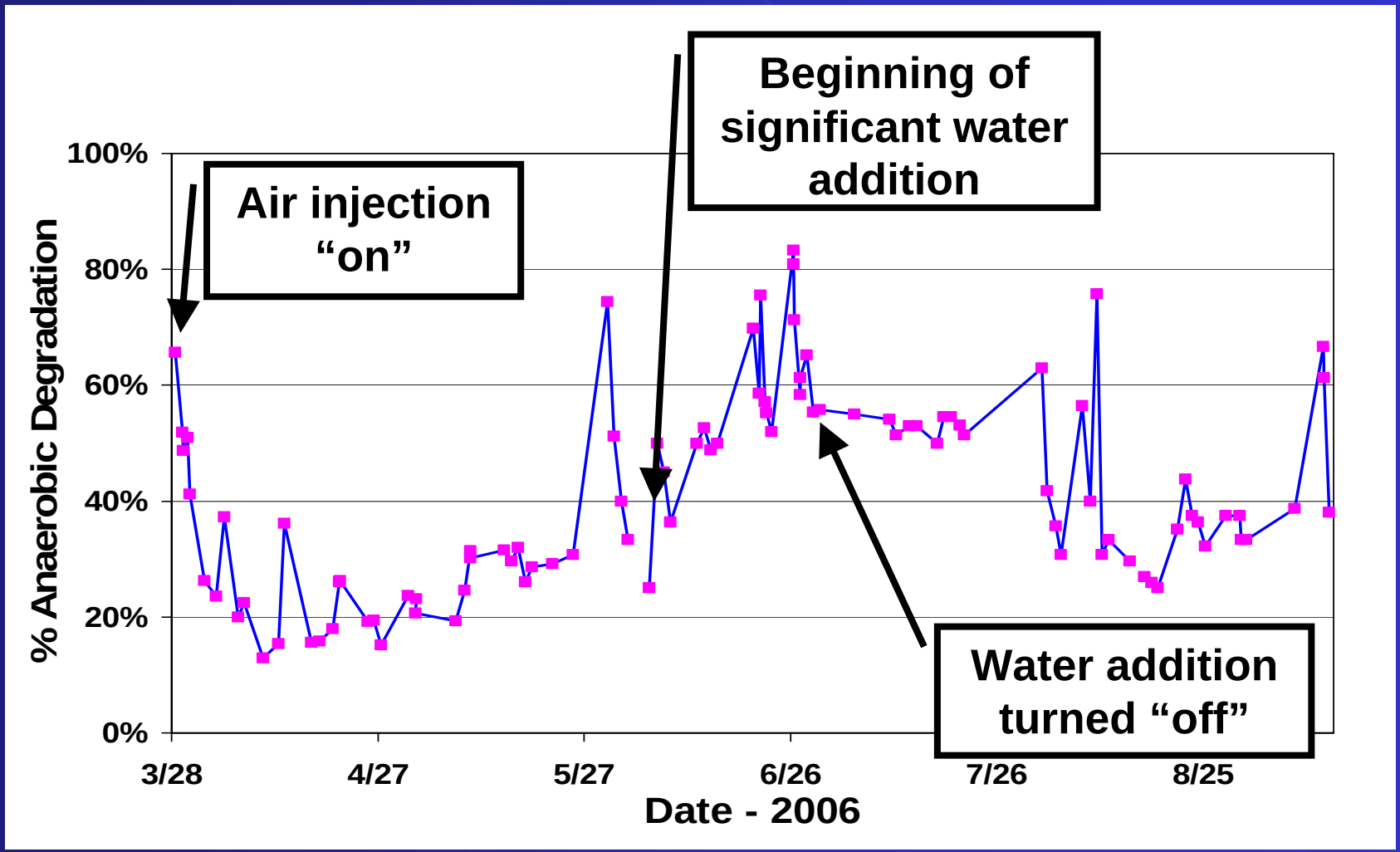
3 layers with homogeneous properties for each layer (K_H,K_V)



Aerobic Bioreactor – Inhibit CH4 Generation

- **Field tests used to evaluate aerobic operations**
  - **“standard” – operator guided**
  - **“intelligent” – guided by modeling (IBM-IS)**
    - **Case 1: Extract air from both north and south sides of landfill**
    - **Case 2: Case 1 + inject air in bottom of cell**
  - **Results from “Case 1” shown on next slide**

Anaerobic Activity During Aerobic Operations



Aerobic Operations: Observations

- Significant water addition inhibited aerobic activity
- Anaerobic activity always accounted for at least 20% of waste degradation
- “Intelligent” operations showed marginal improvements (Case 1 only)
- Other field tests indicate local mass transfer to anaerobic “pockets” limits aerobic activity

Summary

- **Bioreactor landfill promising**
  - **Enhanced CH4 generation and capture – energy production (anaerobic)**
  - **Reduced CH4 generation (aerobic)**
- **Anaerobic tests**
  - **IBM-IS using permeable layers and adjusting gas collection to changes in atm. pressure promising**
  - **Cost/benefit analysis very good**

- **Aerobic tests**
  - IBM-IS showed marginally improved conditions
  - Significant anaerobic activity
  - **Modifications to IBM-IS planned**

- **Ongoing work**
  - Developing and testing IBM-IS for liquid addition
  - Enhancing models (heat transport, biodegradation)
  - Laboratory tests of waste properties for improved constitutive modeling

Flow cell

Questions ?

University of Delaware