Controlled Bioreactor Landfill Program at the Yolo County Central Landfill

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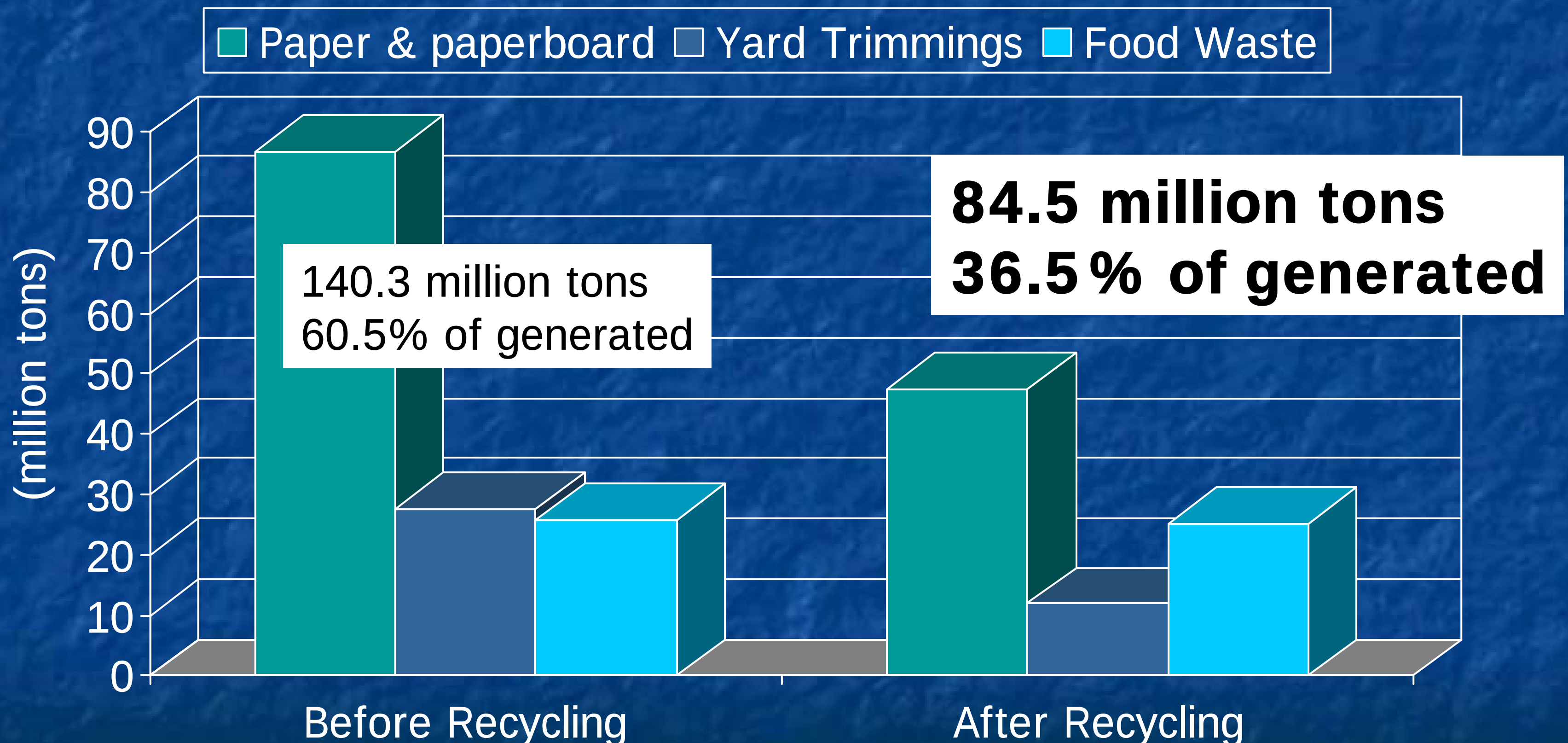
Presentation Outline

- Research objectives
- Introduction
- Experimental facilities
- Project results
- Project findings/conclusions
- Acknowledgments

Research Objectives

- Accelerate waste decomposition, waste settlement and maximize methane capture.
- Analyze the data gathered from full-scale landfill bioreactors.
- Asses the economic benefits of landfill bioreactor versus conventional landfilling.
- Asses the potential carbon impacts of bioreactor landfill.

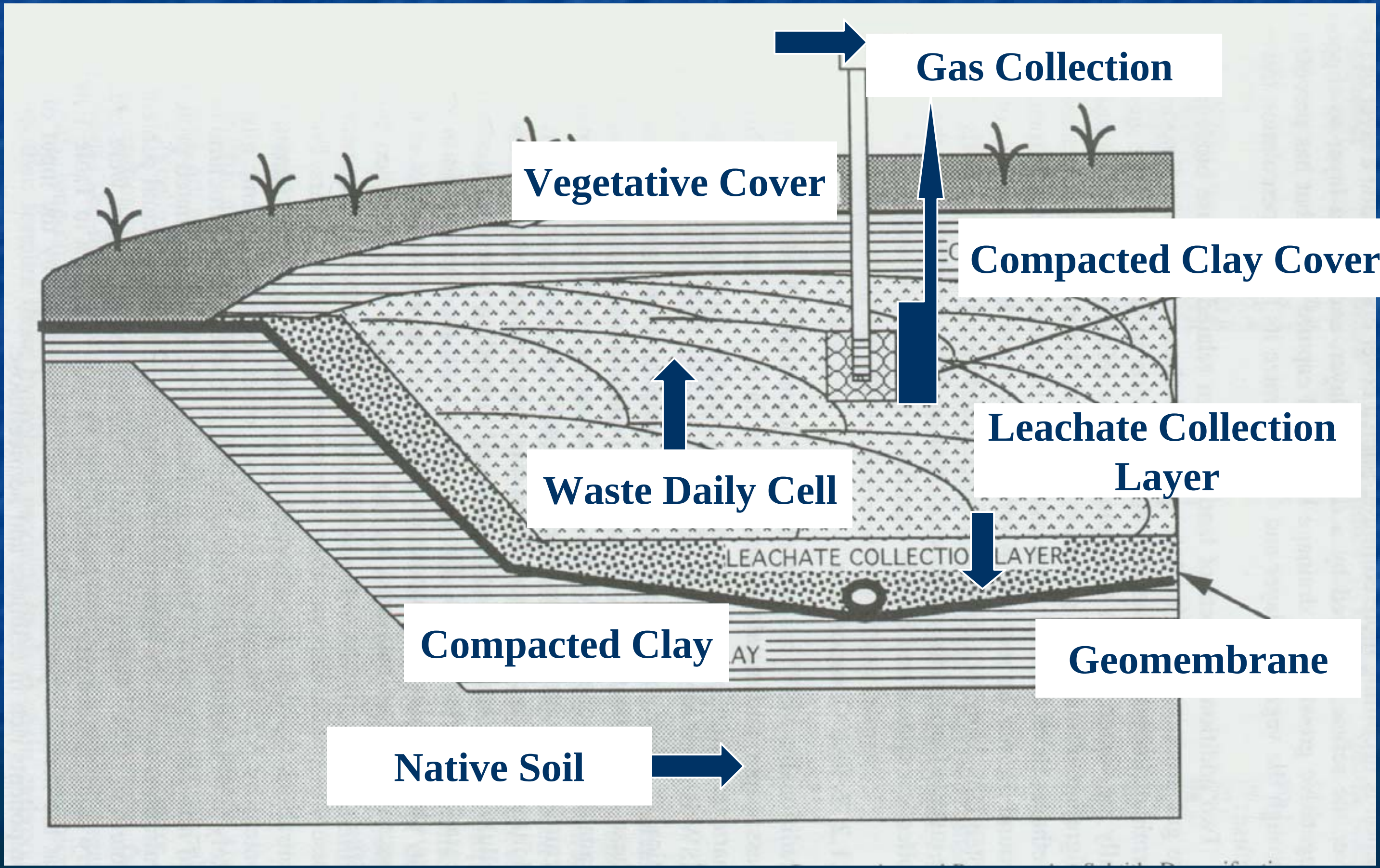
Degradable Organic Waste Landfilled in U.S.



Total waste generated = 231.9 million tons

Source: Franklin Associates (EPA-530-R-02-001), Table ES-4, page 7, 2003

Conventional “Dry” Landfills



Objectives of Current Conventional "Dry" Landfills

- Subtitle D of Resource Conservation and Recovery Act (40 CFR part 258)
  - Minimize the amount of moisture in landfill
  - Minimize the risk of groundwater pollution
  - Limits the amount of leachate and gas generated

Problems with Conventional "Dry" Landfilling

- Waste decomposition at suboptimal rates.
- Waste remains undecomposed for decades to even centuries.
- Leachate and gas generation (50% CH_4, 50% CO_2) persist long into the future.
- Long-term management and monitoring of landfills issues.

Landfills Contribute to Greenhouse Gases

- Methane is 20 times more damaging than carbon dioxide on a volume basis (USEPA, 1994).
- Landfills are responsible for 8% of total anthropogenic methane released (based on EPA estimates).
- Landfill gas is also a renewable energy source.

Bioreactor Landfill Definition

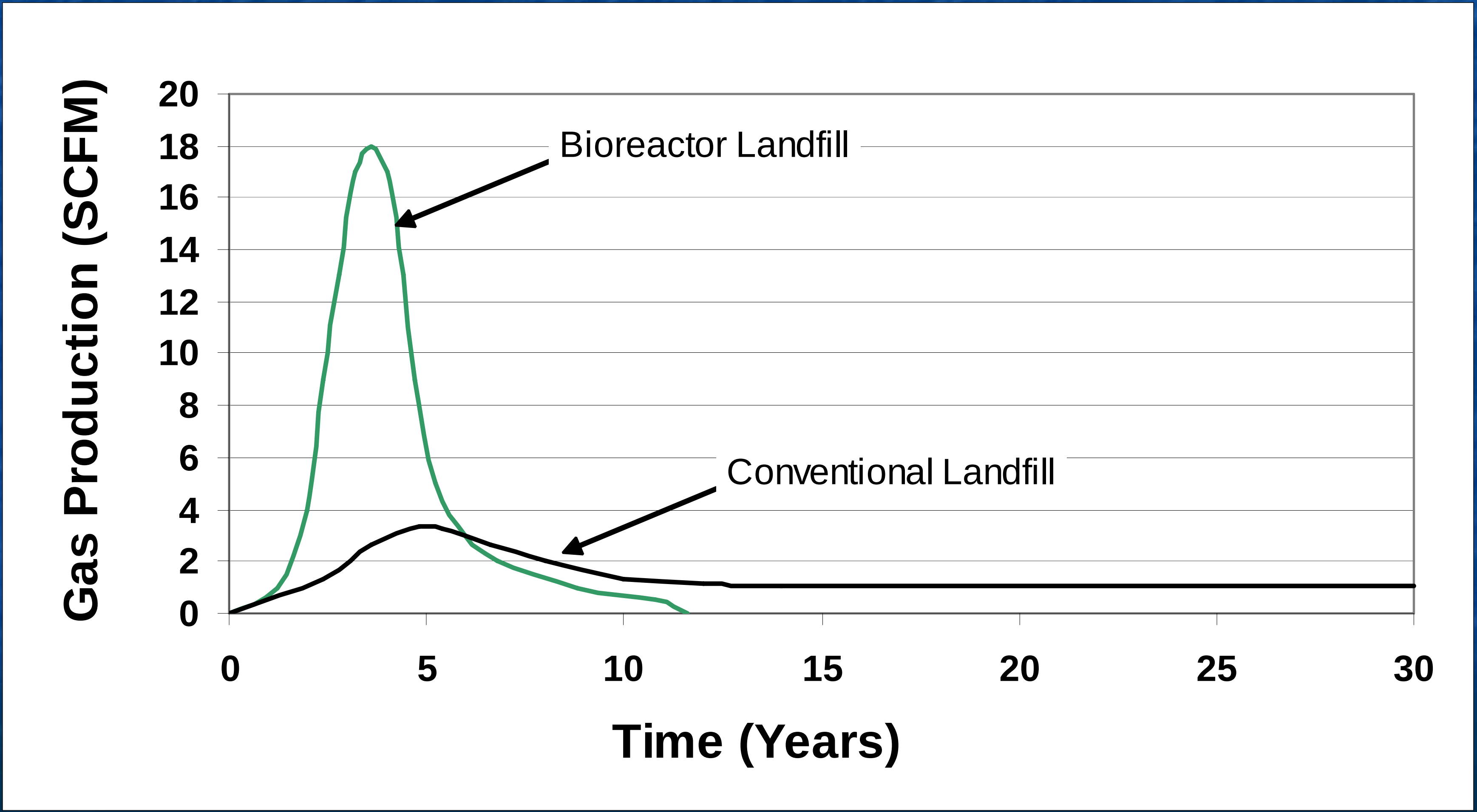
"a bioreactor landfill is a controlled landfill or landfill cell where liquid and gas conditions are actively managed in order to accelerate or enhance biostabilization of the waste."*

*As defined by the Solid Waste Association of North America (SWANA)

What's different about a Controlled Bioreactor Landfill?

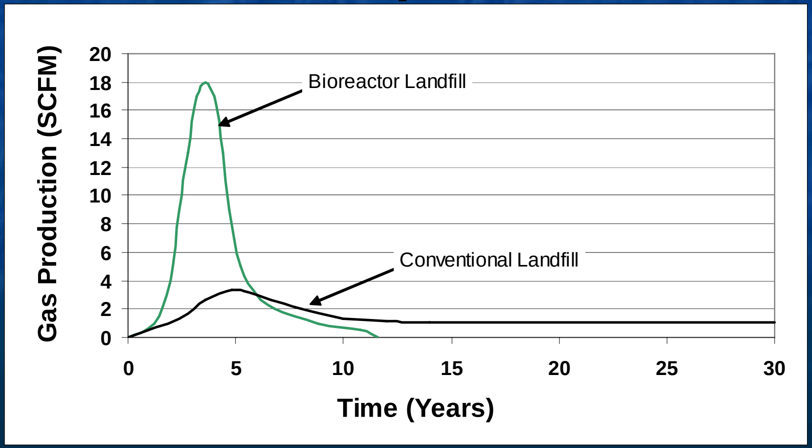
- Controlled quantities of liquid added and recirculated

Landfill Gas Generation Curves



Phases of Decomposition in Bioreactor Landfills

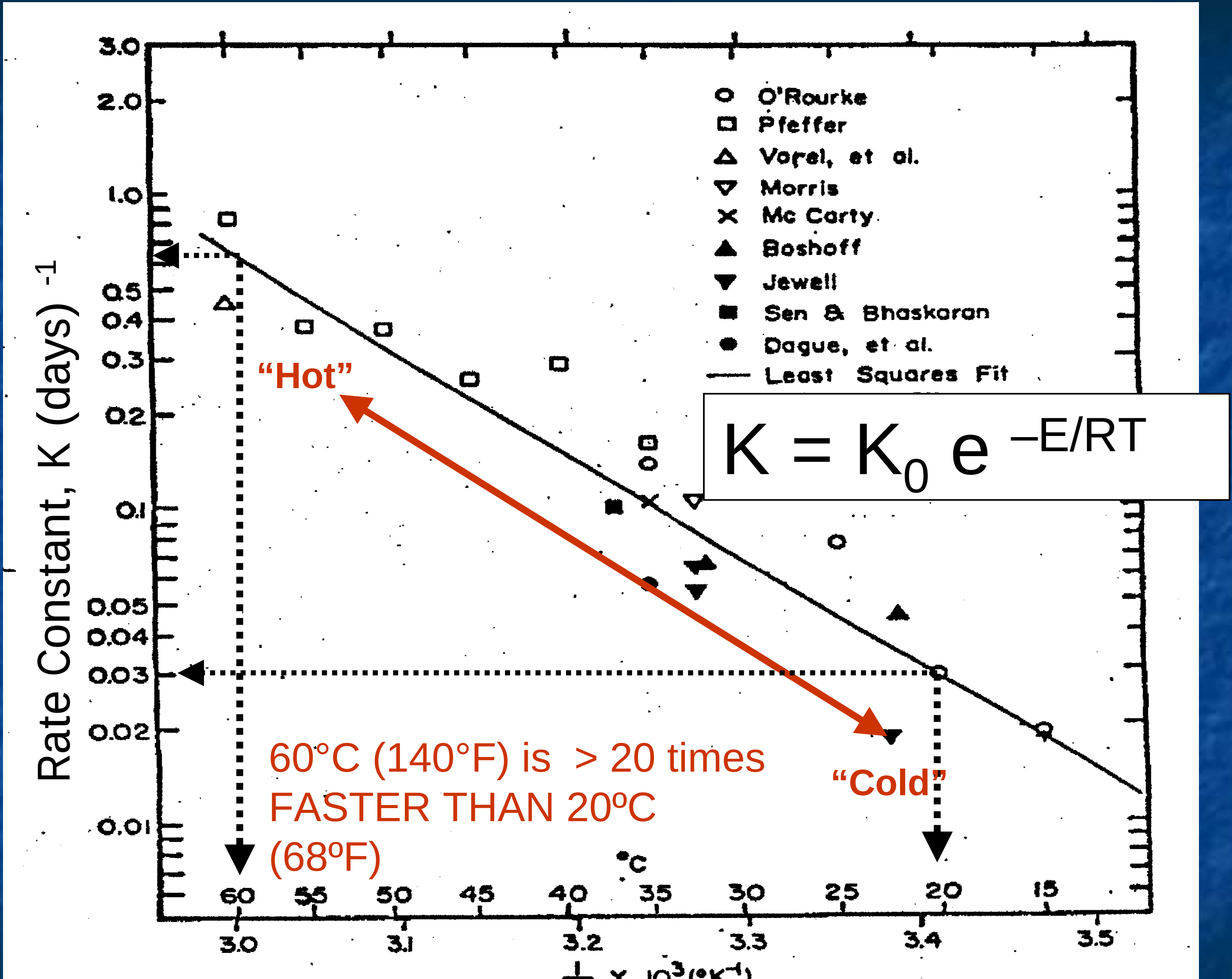
- Aerobic phase
- Anaerobic acid phase
- Accelerated methane production phase
- Decelerated methane production phase



Important Factors in Biodegradation of Waste

- Moisture content
- Temperature
- pH
- Nutrients
- Particle size
- Toxins

Temperature Dependence of Methanogenesis



Ashare E., et al., 1978 "Methane production from animal residue", By Dynatech. R&D Report for U.S. DOE (ERDA)

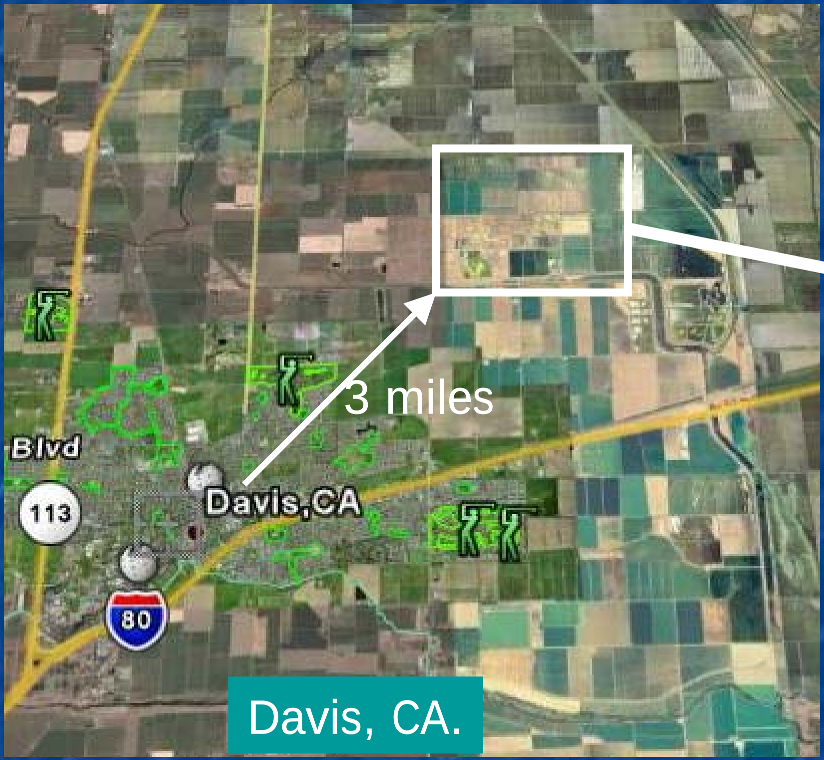
Bioreactor Landfill Potential Benefits

- Maximizing landfill gas capture for renewable energy (anaerobic).
- Rapid organic waste conversion & stabilization.
- Increased landfill space capacity reuse.
- Reduction of post-closure care maintenance and future risk.
- Improved leachate treatment.
- Reduction of landfill gas fugitive emissions.
- Carbon sequestration potential (anaerobic).

Experimental Facilities: Bioreactor Research Cells

- 8,000 tons control cell “dry cell” (0.25 acre)
- 8,000 tons anaerobic bioreactor cell (0.25 acre)
- 76,000 tons anaerobic bioreactor cell (3.5 acres)
- 194,000 tons anaerobic bioreactor cell (6.0 acres)
- 15,000 tons aerobic bioreactor cell (2.5 acres)

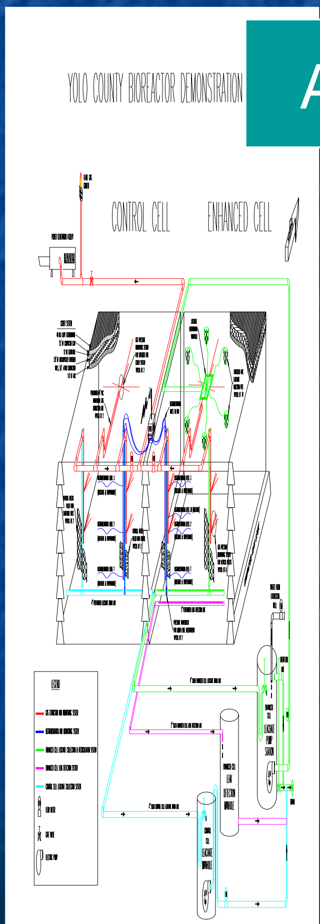
Location of Research Facilities



Experimental Landfill Bioreactors Cell Components

- Operational flow diagram
- Waste containment facilities
- In-situ instrumentations
- Landfill gas collection and removal system
- Leachate injection and recirculation system
- Landfill cover system
- Data monitoring and collection system

Operational Flow Diagram for Bioreactor Cells



Anaerobic Bioreactor Research Cell - 8,000 tons

Control Cell

Enhanced Cell

← Gas out

Leachate in ↑

Instrumentation

Instrumentation

Leachate out →

Leakage out →

Leachate out →

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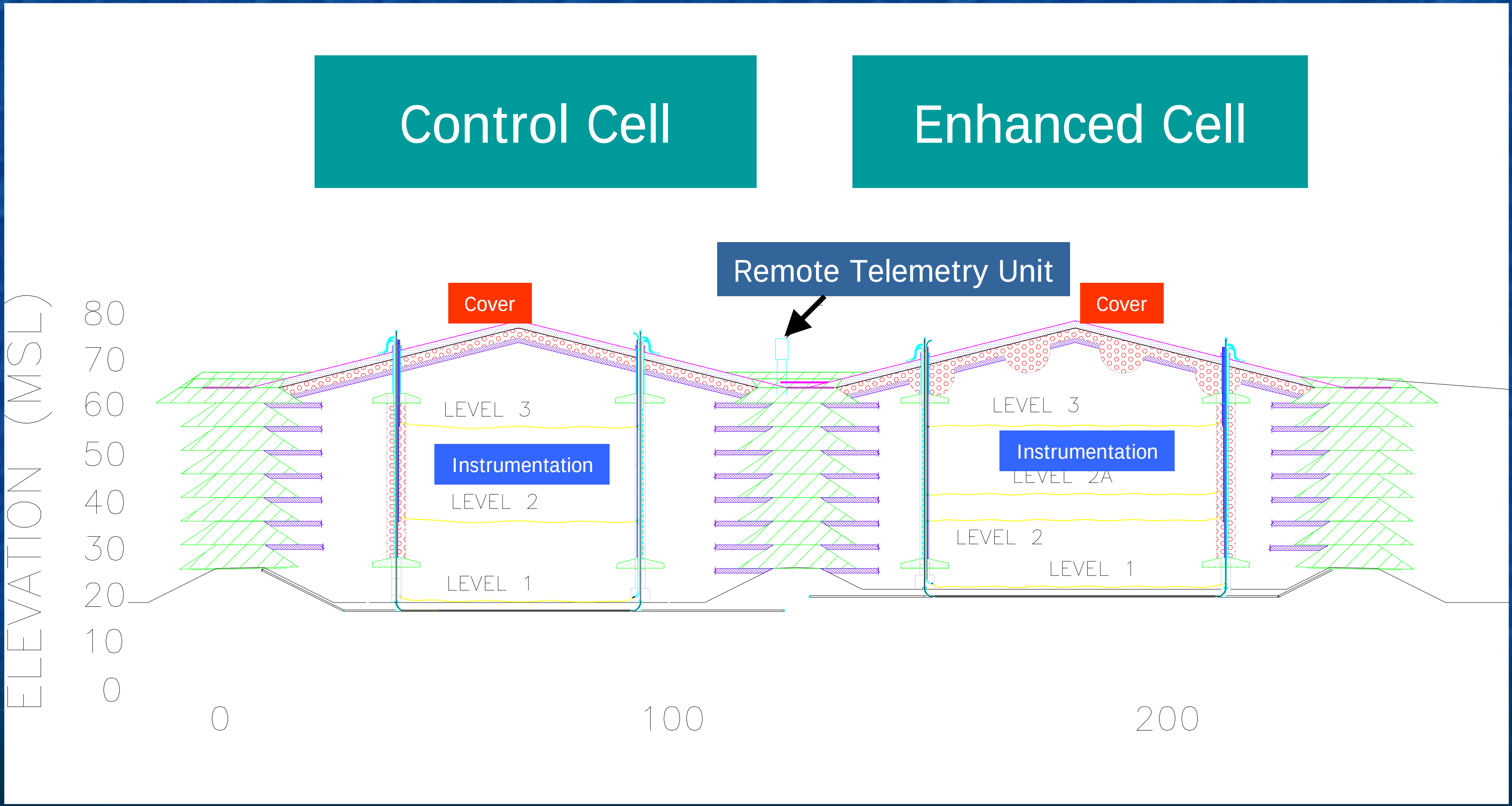
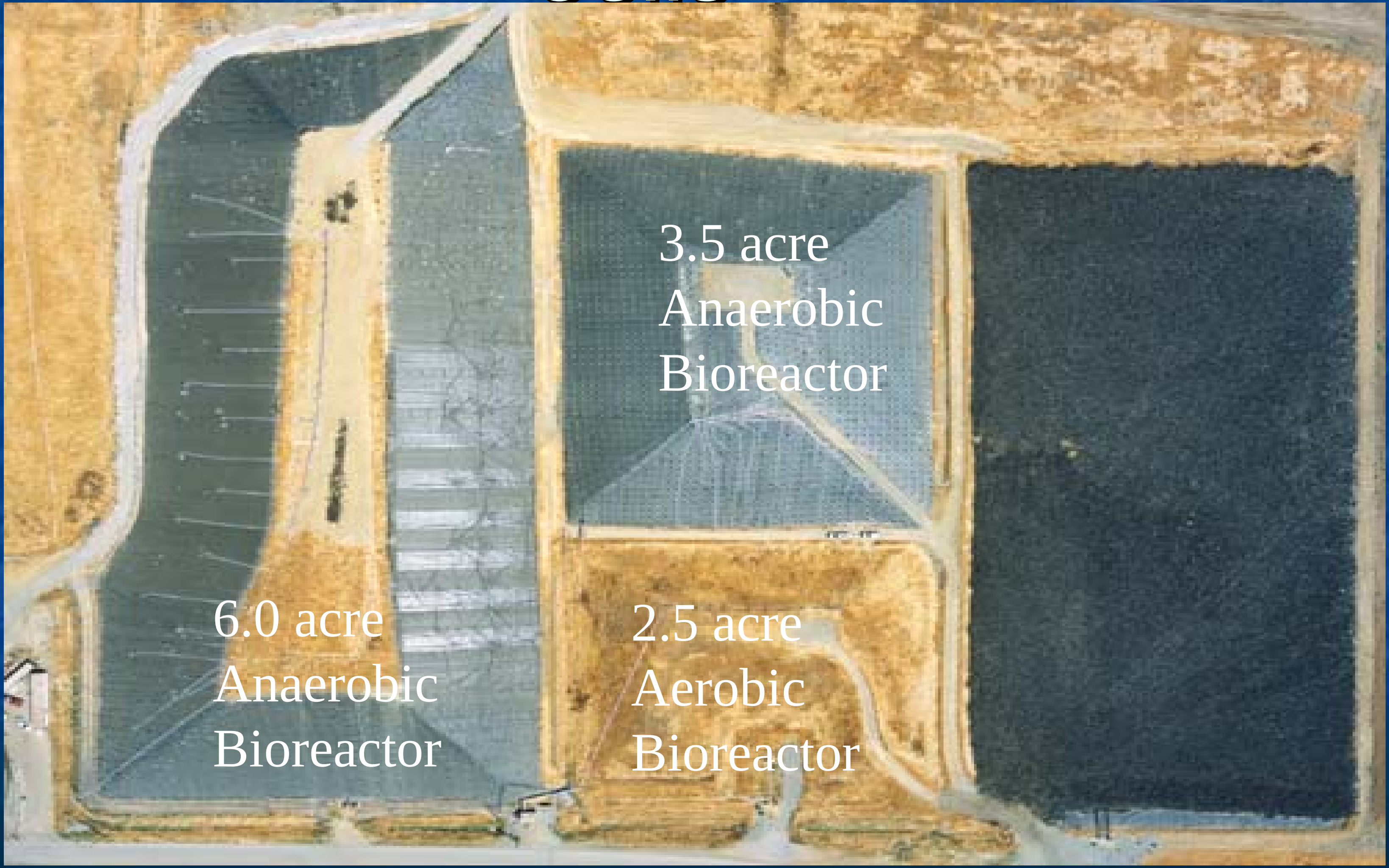
a

Experimental Landfill Bioreactors

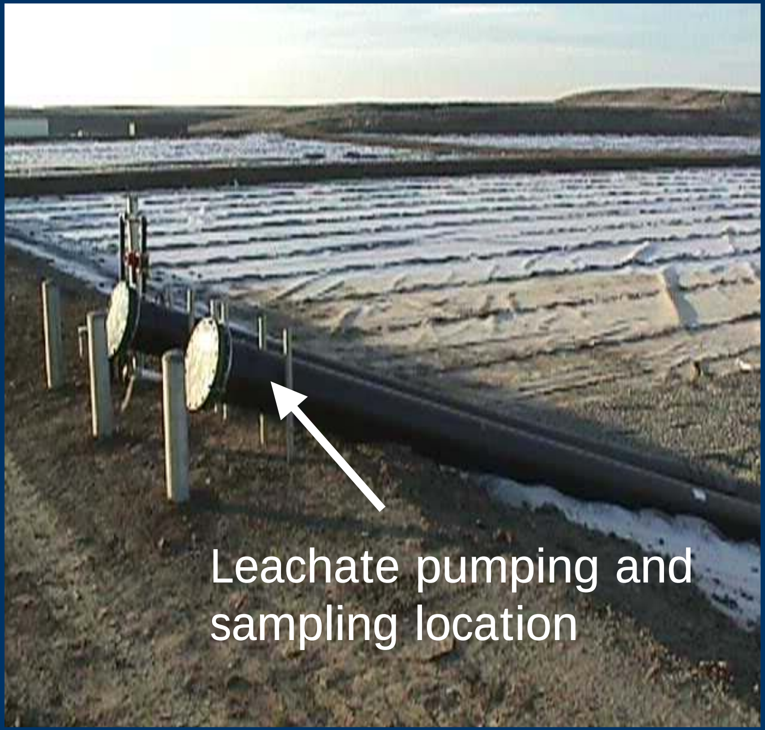


Experimental Landfill Bioreactor Cells



Waste Containment Facilities

- Construction of base liner system



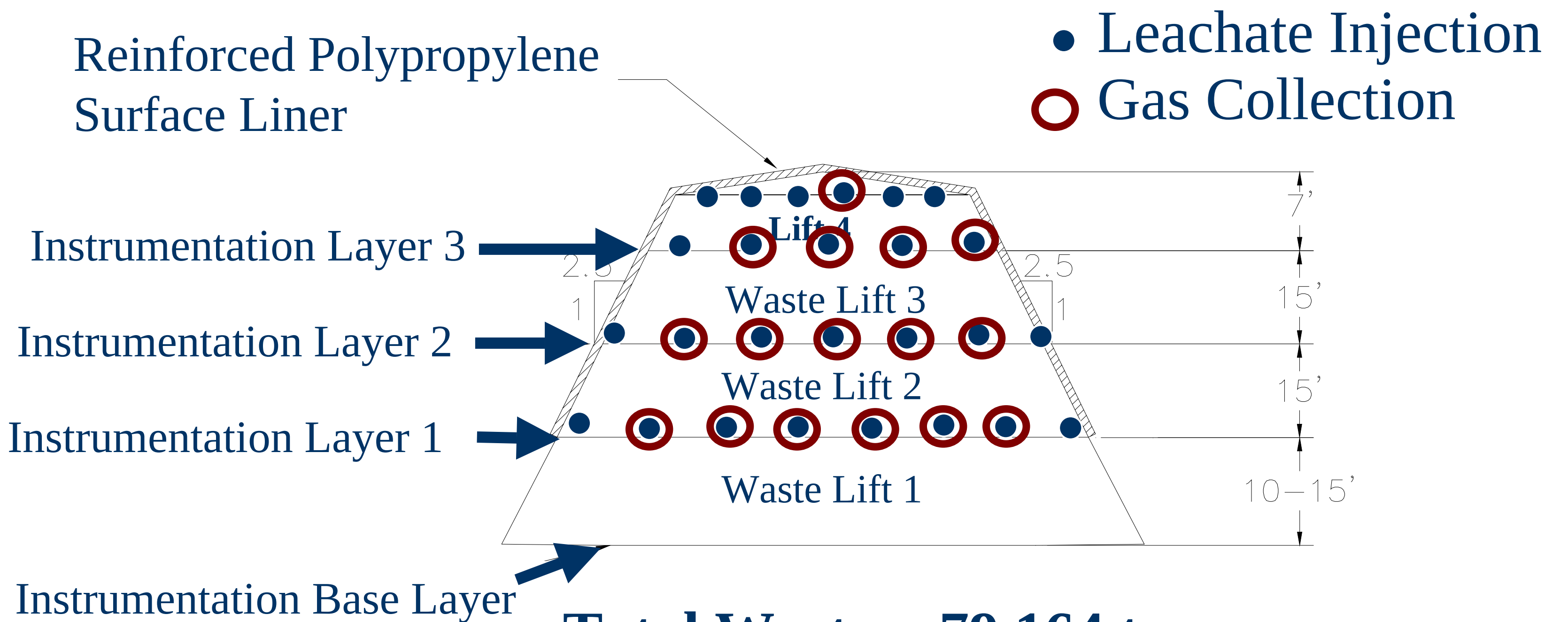
In-situ Instrumentation

Over 400 instruments and 20 miles of wires were installed in the landfill for collecting data.

Waste Placement in Experimental Cells

Construction of landfill waste filling

Experimental Landfill Cell Cross-sectional View



Total Waste = 79,164 tons

Landfill Gas Collection System

Over 12,000 feet of piping for gas collection and removal system was installed.

Landfill Gas Collection and Removal System

Leachate Injection and Recirculation System

Over 17,000 feet of piping for leachate injection and recirculation was installed.

Construction of Cover System

Over 500,000 square feet synthetic landfill liner (HDPE) was installed.

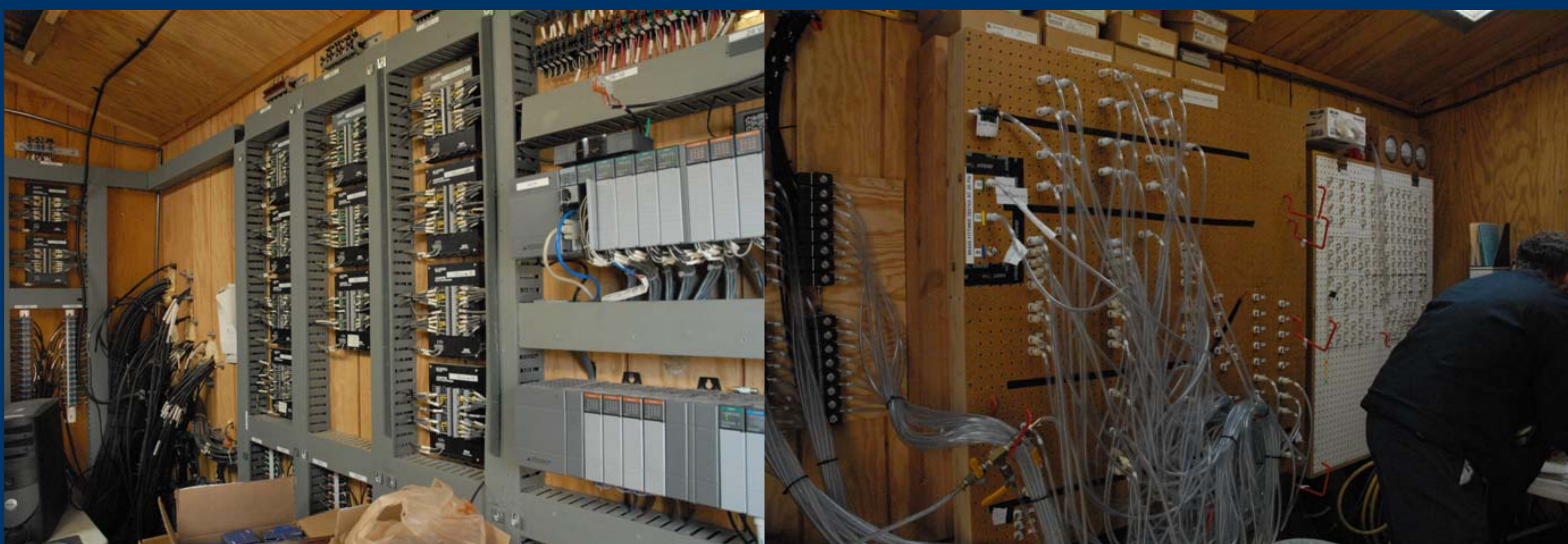




Installed Cover System

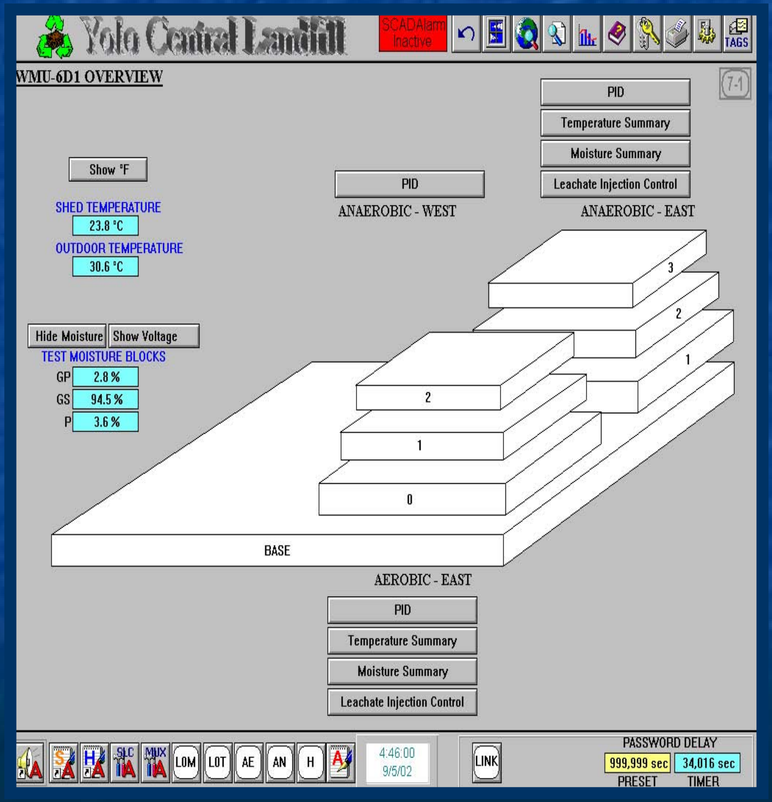
Data Monitoring and Collection System

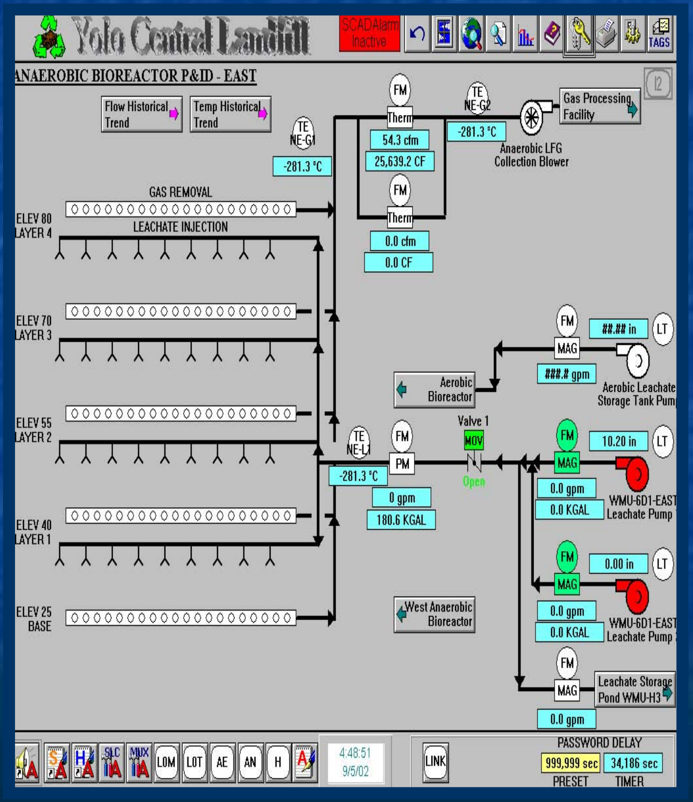
Supervisory Control and Data Acquisition (SCADA) System



Data Monitoring and Collection System

SCADA computer screen





Waste Sampling & Testing

Automated Data Collection System (monitored continuously)

- In-situ Measurements
  - Waste temperature (degree C)
  - Moisture sensor (% saturation)
  - Static head on the base liner (ft)
- Volume of leachate added and recirculated (gallons)
- Volume of landfill gas collected (scfm)
- Mass and type of waste and cover soil (tons)

Bioreactor Landfill Leachate Quality Monitoring Parameters

Parameters	Monitoring Frequency (1st/2nd yr)
Temperature (°C)	Monthly
pH	Monthly
Conductivity (µSm/cm)	Monthly
Biochemical Oxygen Demand (mg/L)	Monthly/Quarterly
Chemical Oxygen Demand (mg/L)	Monthly/Quarterly
Dissolved Oxygen (mg/L)	Monthly/Quarterly
Dissolved Solids (mg/L)	Monthly/ Quarterly
Total Organic Carbon (mg/L)	Monthly/Quarterly
Nutrients (NH_3, TKN, TP) (mg/L)	Monthly/ Quarterly
Common ions (mg/L)	Monthly/Quarterly
Heavy metal (mg/L)	Monthly/ Quarterly
Organic priority pollutants (µg/L)	Monthly/Quarterly

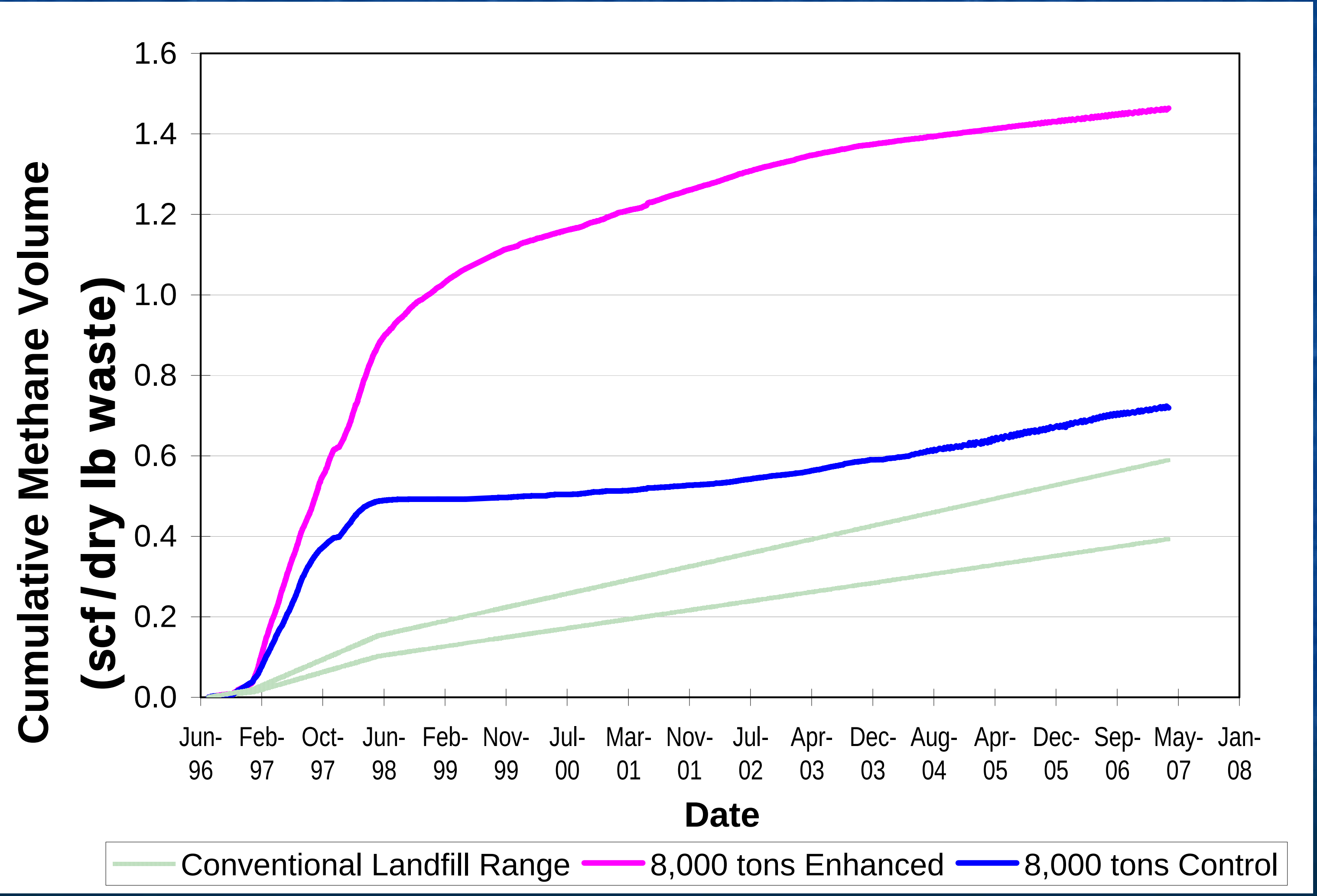
Analytical Parameters Monitored

Parameters	Monitoring Frequency
Landfill Gas	
CH_4, CO_2, O_2, N_2, CO (%V/V)	Weekly
NMOC (%V/V)	Monthly/Quarterly
H_2S (%V/V)	Monthly/Quarterly
N_2O (%V/V)	Monthly/Quarterly
Solids Testing	
Moisture content (% M/M)	Annually
Volatile solids (% M/M)	Annually
Methane yield (mL CH_4/g)	Annually
Cellulose (% M/M)	Annually
Lignin (% M/M)	Annually
Landfill Settlement	
Topographic survey	Annually

Bioreactor Research Questions (partial list)

- Does operation of a landfill as a bioreactor:
  - Enhance the rate of methane production compared to a conventional “dry” landfill?
  - Increase waste settlement and volume loss?
  - Improve leachate quality?
  - Increase moisture content to optimum level?
  - Reduce refuse stabilization time?
  - Increase the benefit-cost ratio when compared with a conventional “dry” landfill?

Methane Generation Curves



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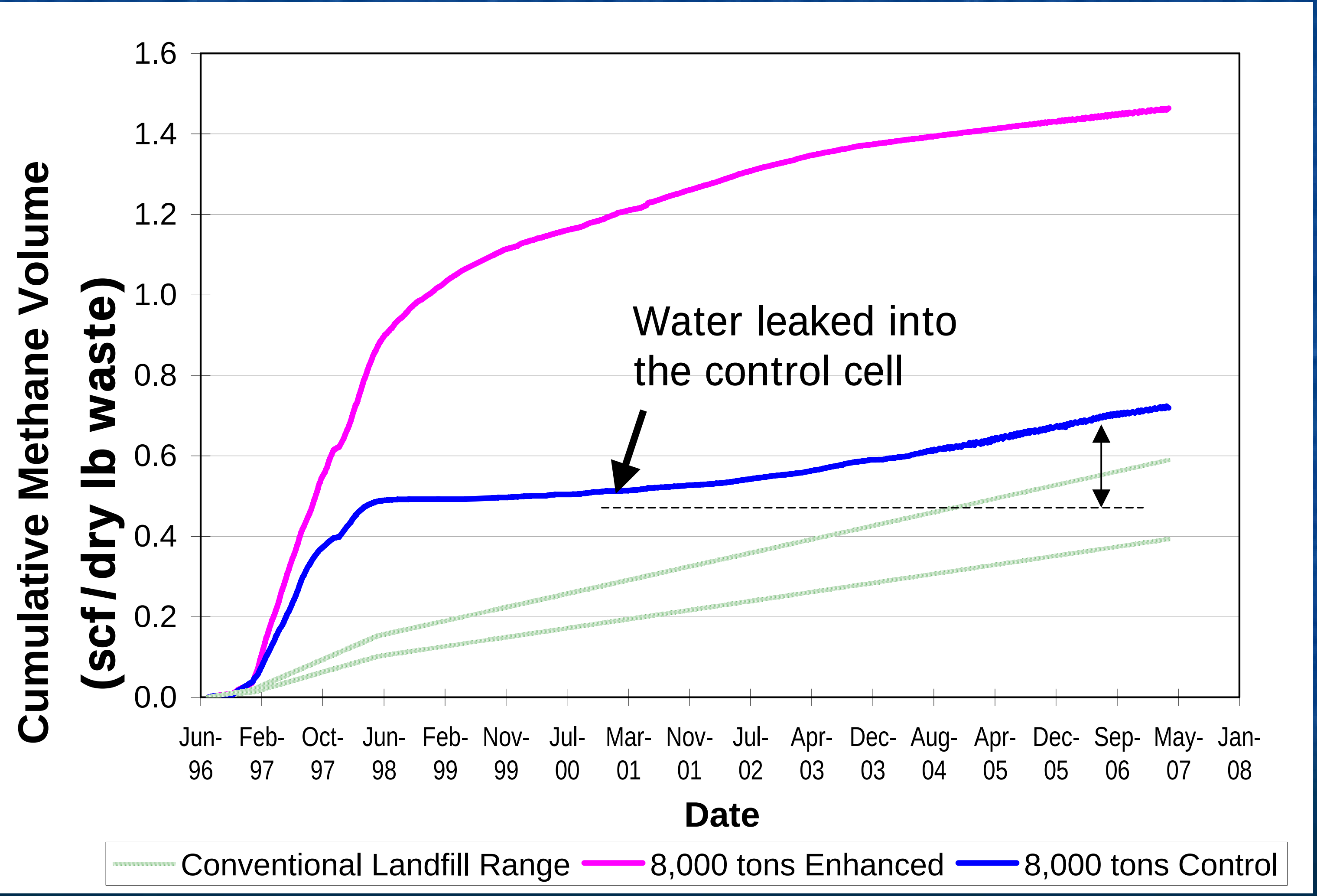

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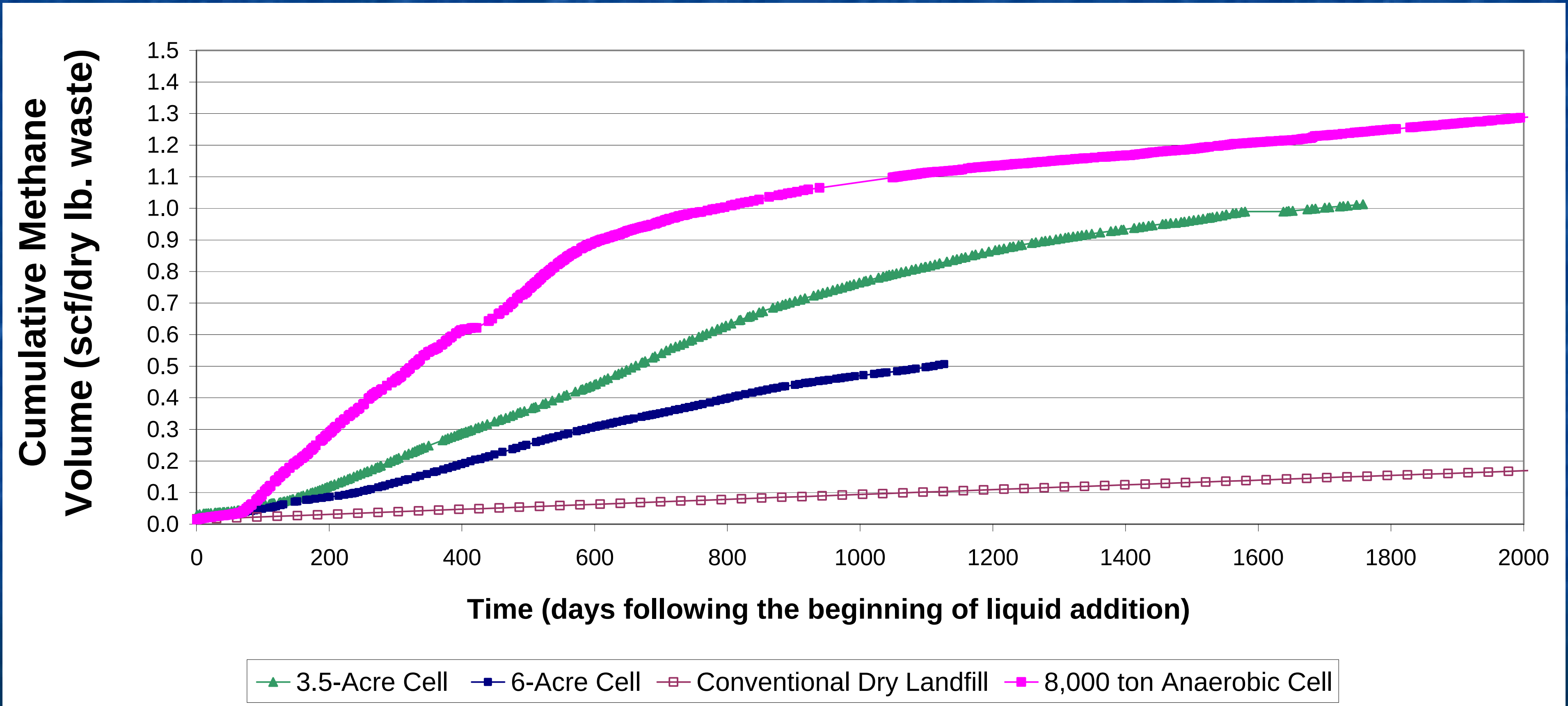
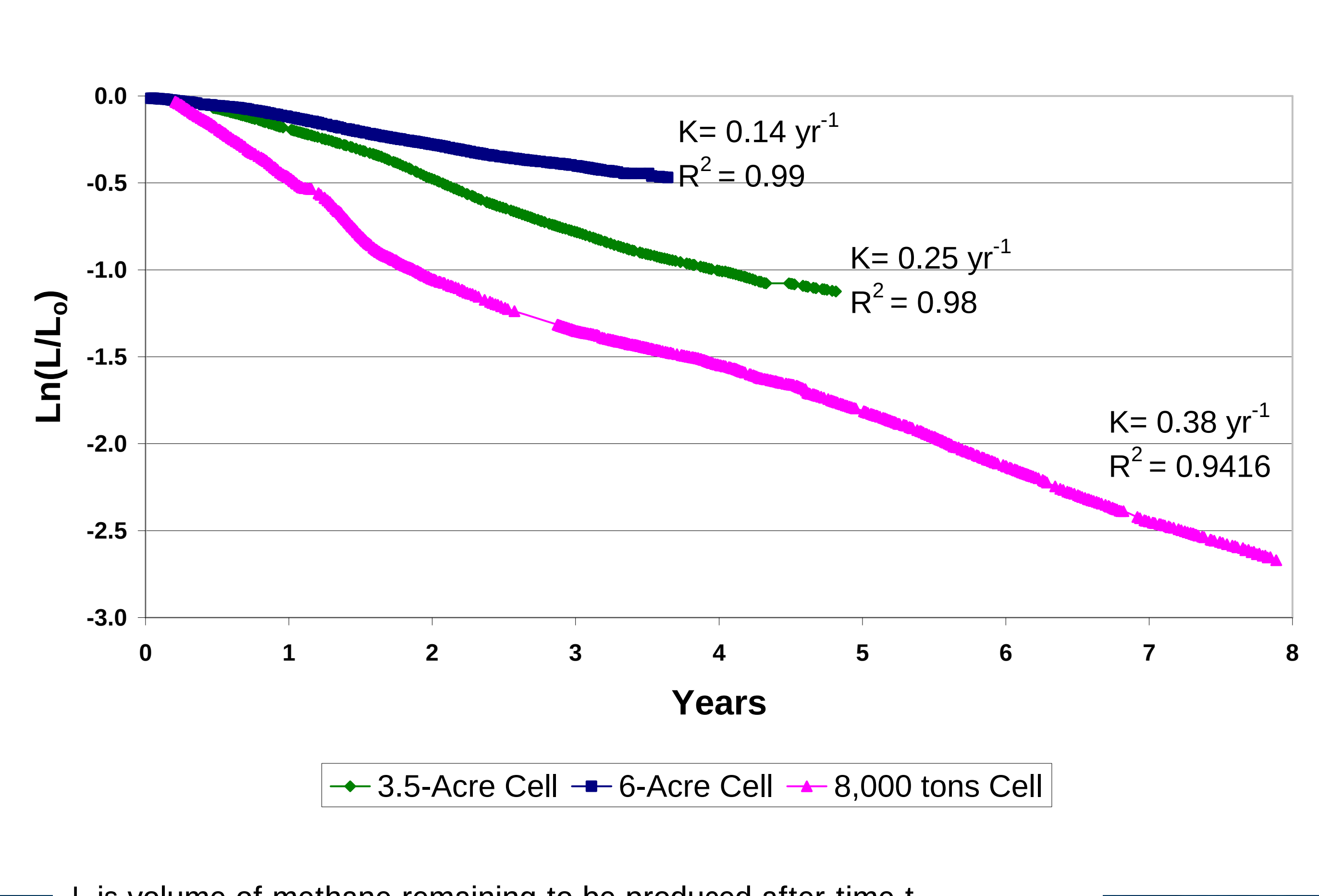


Fitted 1st Order Kinetic Rate Coefficients



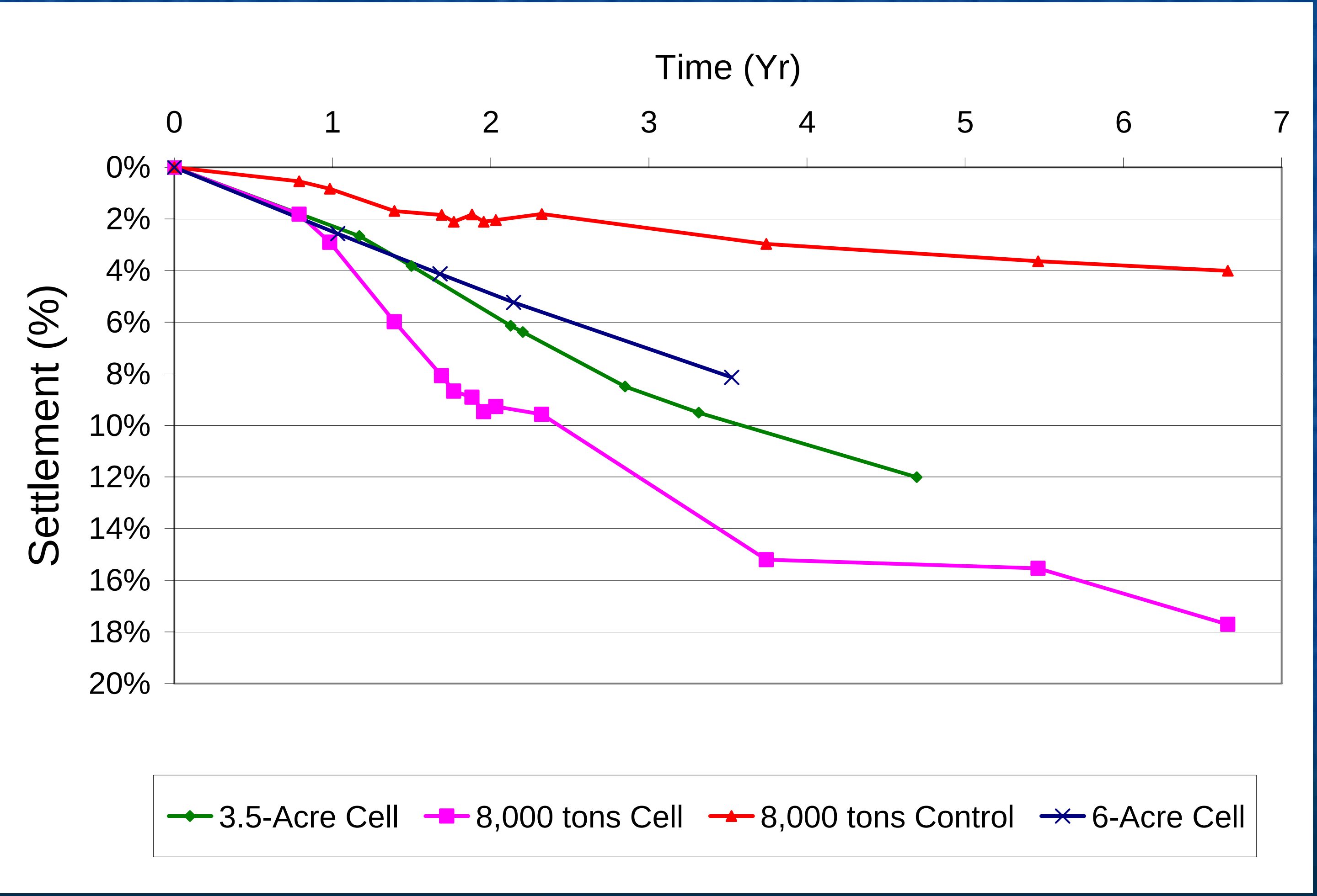
L is volume of methane remaining to be produced after time t

L_0 is maximum volume of methane (SCF/dry pounds). L_0 = 1.5 scf/dry lbs

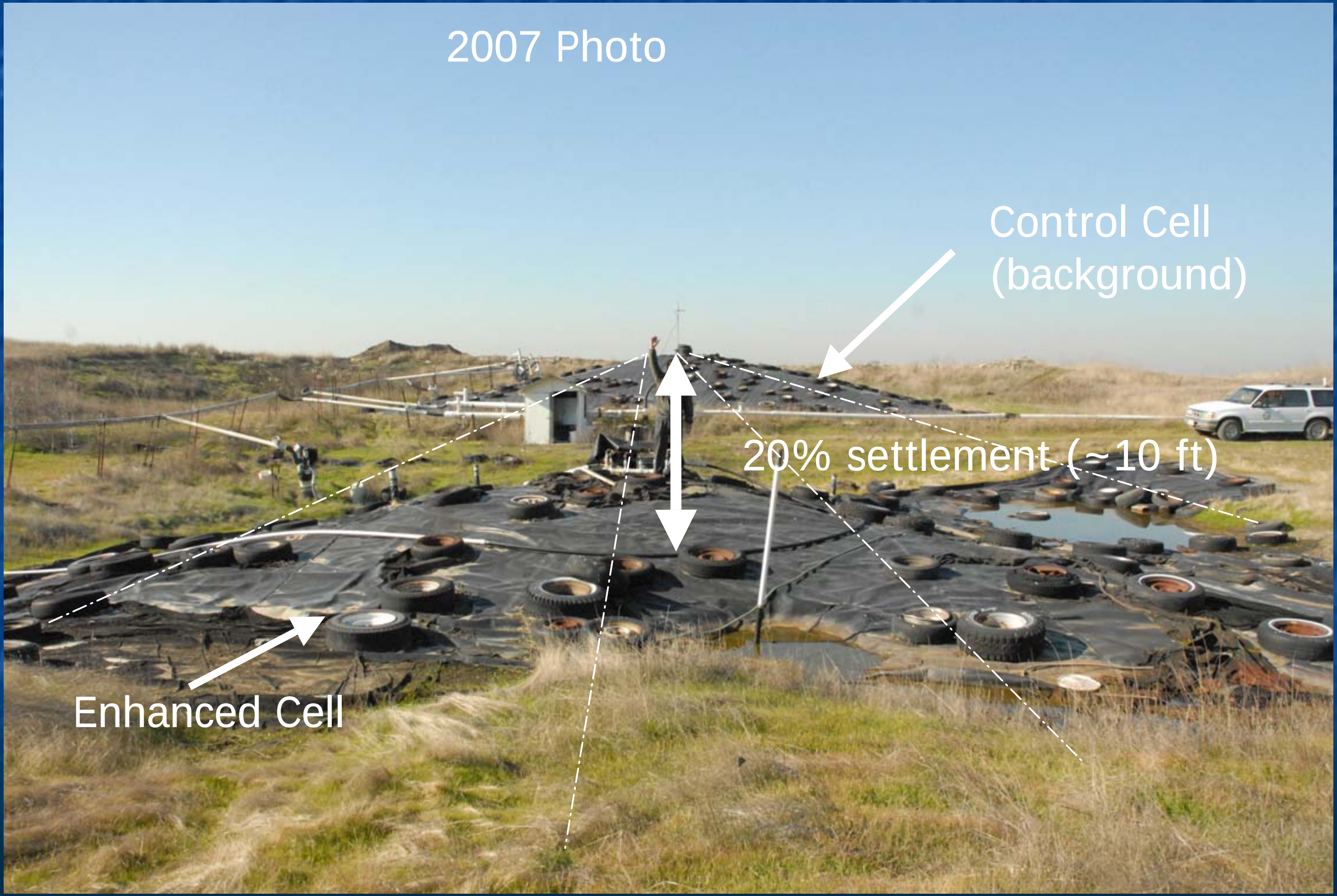
Project Findings

- Liquid addition and recirculation in all anaerobic bioreactor cells increased first order rate constant by factor of three to as much as eightfold over "typical" landfill experience. This method of operation will result in early completion of organic waste decomposition.
- Methane capture efficiency can be increased significantly when waste is covered quickly with a synthetic cover.
- Enhanced methane capture results in reduction of global warming impacts.

Waste Settlement Data



8,000 ton Control and Enhanced Experimental Cells



Findings

- Liquid addition and recirculation in all anaerobic bioreactor cells increased settlement by factor of two to as much as fivefold over a conventional “dry” landfill.
- The additional air space gained is estimated to yield a revenue of $80,000 to $100,000 per acre per ft.

Findings

- Parasitic energy use is less than 2% of gross methane energy produced. Typical in vessel digester parasitic energy use is in 30-40%.
- Net cost is $1 to $4 per ton of waste (large vs. small landfill). If assigned to fuel, equivalent to $6 to $30 per equivalent barrel of oil.
- Volume reduction and landfill life extension alone can yield revenue to justify controlled bioreactor landfill.

Findings

- If bioreactor technology is applied to 50-75% of US waste:
  - Fugitive methane emission < 5%-10% of generated.
  - Increased recovered methane by 30-100%; potential for 100,000-200,000 daily barrel oil equivalent.
  - Greenhouse benefits for US ~50-100+ million tons CO_2 equivalent at cost of \$1-\$5 per ton CO_2 equivalent.

Reference: IEM, 1999. Landfill Operation for Carbon Sequestration and Greenhouse Gas Mitigation, for National Energy Technology Laboratory, US DOE, Program DE-AC26-98FT40422.

Conclusions

- Substantial acceleration of methanogenesis and decomposition, over fivefold (k>0.4-0.5 year^{-1}) by moisture addition and recirculation.
- Efficient gas capture (>95%) using permeable layer under synthetic membrane.
- Can maximize landfill gas energy recovery predictability compared to conventional practice, minimal fugitive emissions.
- Avoid low permeability daily cover soil to ensure uniform moisture distribution.
- Control cell (“dry”) results strongly validate “dry tomb” and it’s problems.

Research Funding

- Yolo County Public Works-Division of Integrate Waste Management
- California Energy Commission-Public Interest Energy Research
- California Integrated Waste Management Board
- U.S. Department of Energy-National Energy Technology Laboratory
- Western Regional Biomass Energy Program

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Thank you

Questions?