SANITATION DISTRICTS OF LOS ANGELES COUNTY

Estimating LFG Emission Flux/Collection Efficiency -- the LACSD's Experiences

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California Air Resources Board
Sacramento, CA
August 6, 2014

LACSD LFG Emission Flux/Collection Efficiency Research

- **Studies conducted between 2006 and 2013**
- **Two different approaches were used**
  - Hybrid field monitoring/modeling (ISM/ISC Method)
  - Flux Chambers
- **Despite vastly different methods, results were similar**

County Sanitation Districts of Los Angeles County Landfills in Study

Landfill Characteristics

Property	PHLF	SCLF	CALF	PVLF
Limit of fill area (acre)	622	211	269	291
Permitted daily tonnage (ton)	13,200	3,400	3,500	--
Tonnage in place (2012, Million tons)	128.73	28.57	24.08	23.6
Landfill methane recovery (scfm, 2012)	10,587	2,257	1,273	686
Landfill gas methane content (2012)	35.5%	35%	34.7%	11.5%
Gas to Energy (MW)	55	8.0	6.2	--
Number of landfill wells	1,508	136	673	489
Length of landfill gas trenches (mile)	101	13	19	0.8
Landfill Status	Closed in 2013	Active	Active	Closed in 1980

Landfill Gas Collection Efficiency Overview

- **Efficiency = Collection/Generation**
  - Generation unknown but…

    Generation = Collection + Emission
- **Collection is measured**
- **Need emission**
  - Emission ~ surface flux
  - Surface flux = Direct or indirect flux estimations

LACSD Emission Flux Measurement Methods

- **Indirect Methods**
  - LACSD's ISM/ISC method: air dispersion model coupled with Integrated Surface Methane (ISM) concentration data
    - Broad spatial coverage
    - Abundant field measurement data
    - Weather condition dependent
    - Used by CARB in development of Landfill Methane Reduction Regulation

- **Direct Methods**

  - Dynamic flux chamber and Static flux chamber
    - LACSD used both in the early 1980's and presently
    - More Accurate measurement than Indirect Methods
    - Limited spatial coverage

LACSD's ISM/ISC Method

Recall:

Efficiency = Collection/Generation, or

Efficiency = Q_C / Q_G

But Q_G is unknown so…

Generation = Collection + Emission, or

Q_G = Q_C (measured) + Q_E (?)

But Q_E is diffcult to measure!

LACSD's ISM/ISC Method

- Air dispersion principle says Concentration (e.g., ppm) proportional to Flow (e.g., cfm)
  so, **Efficiency = $Q_C/Q_G = C_C/C_G$**

  $C_G = C_C$ *(modeled* from* Q_c^**)* + C_E *(measured by ISM)*

* Modeled by air dispersion modeling (e.g., USEPA's Industrial Source Complex (ISC) or AERMOD models)

G = Generation; C = Collection; E = Emission

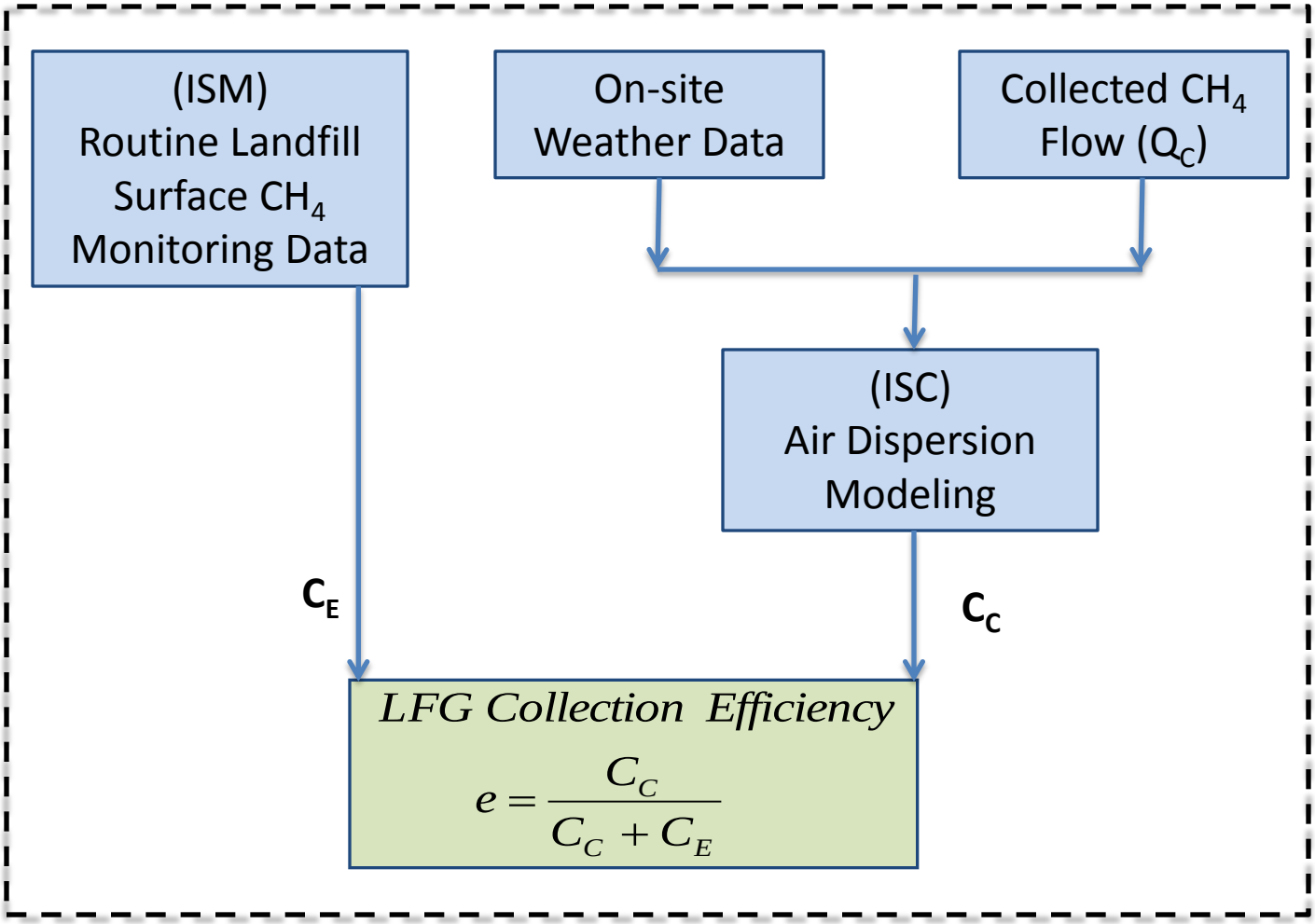
Area-source Atmospheric Dispersion Equation

$$C_C = \frac{Q_A K}{2\pi\mu_S} \int_X \frac{VD}{\sigma_Y \sigma_Z} \left(\int_Y \exp\left[-0.5 \left(\frac{y}{\sigma_Y} \right)^2 \right] dy \right) dx$$

C_C - *concentration at receptor*

Q_A - *area source emission rate*

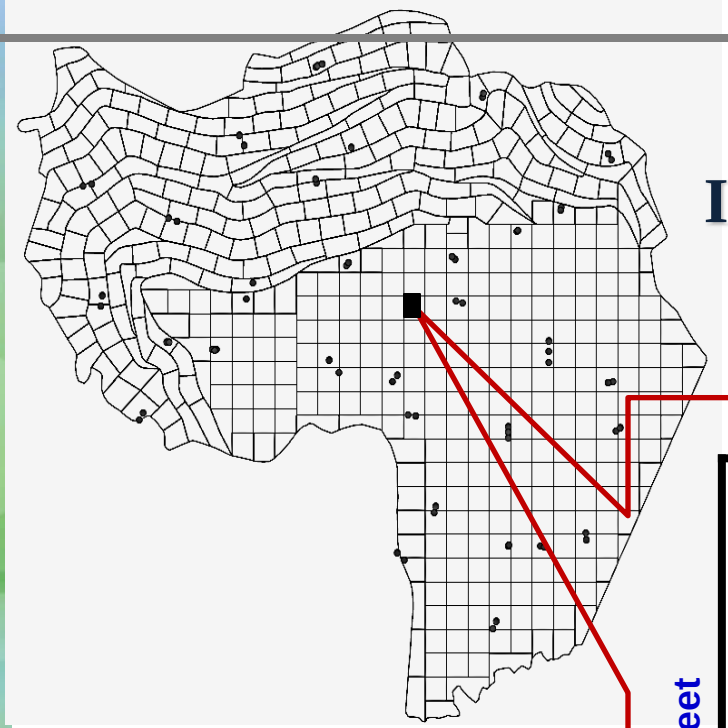
ISM/ISC Flow Chart



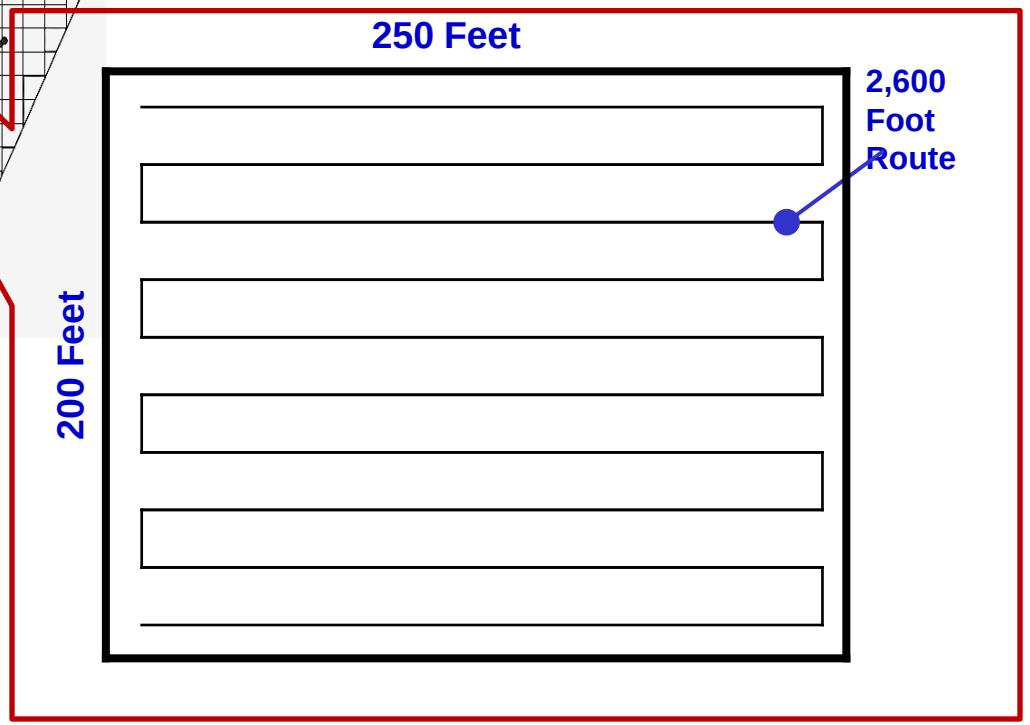
LACSD's ISM/ISC Method

- **Meteorology preprocessing for ISC**
  - Hourly onsite met data
  - Regional mixing height data
  - Calculates "stability" category (A-F)
  - Adjusts minimum wind speeds
  - Calms can't be modeled
    - Discard corresponding ISM results
- **Post-preprocessing filtering**
  - Extract only the hours corresponding to ISM

LACSD's ISM/ISC Method



ISM Grid Schematic



SCAQMD Rule 1150.1 Requirements

- **South Coast Air Quality Management District's Rule 1150.1**
  - *Standardized in 2000*
  - *Divide LF into 50,000 Ft^2 grids*
  - *Monitor each grid along 2,600 foot route*
  - *Quarterly monitoring*
  - *Wind speeds < 5 mph*
  - *Morning hours*
  - *No monitoring for 3 days after storms*
  - *Probe within 3 inches of LF surface*
  - *Continuously monitor CH4*

Flux Chamber Method

Static Flux Chamber Method

$$F = \left(\frac{V}{A}\right)\left(\frac{\Delta C}{\Delta t}\right)$$

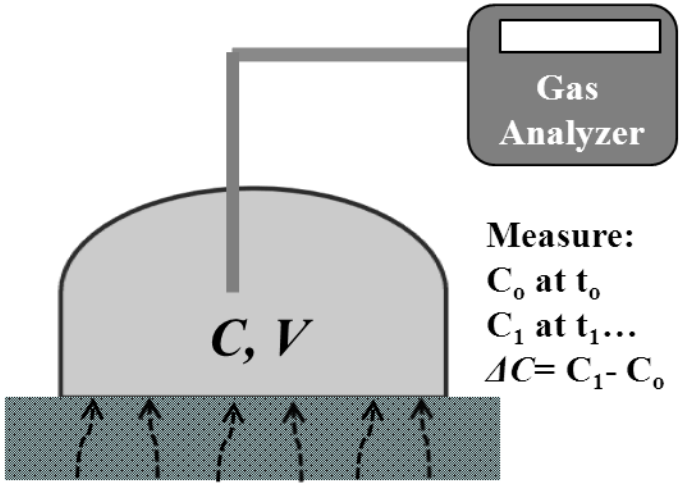
F - flux of a target compound (mg/(d·m^2))

V - volume of the flux chamber (m^3)

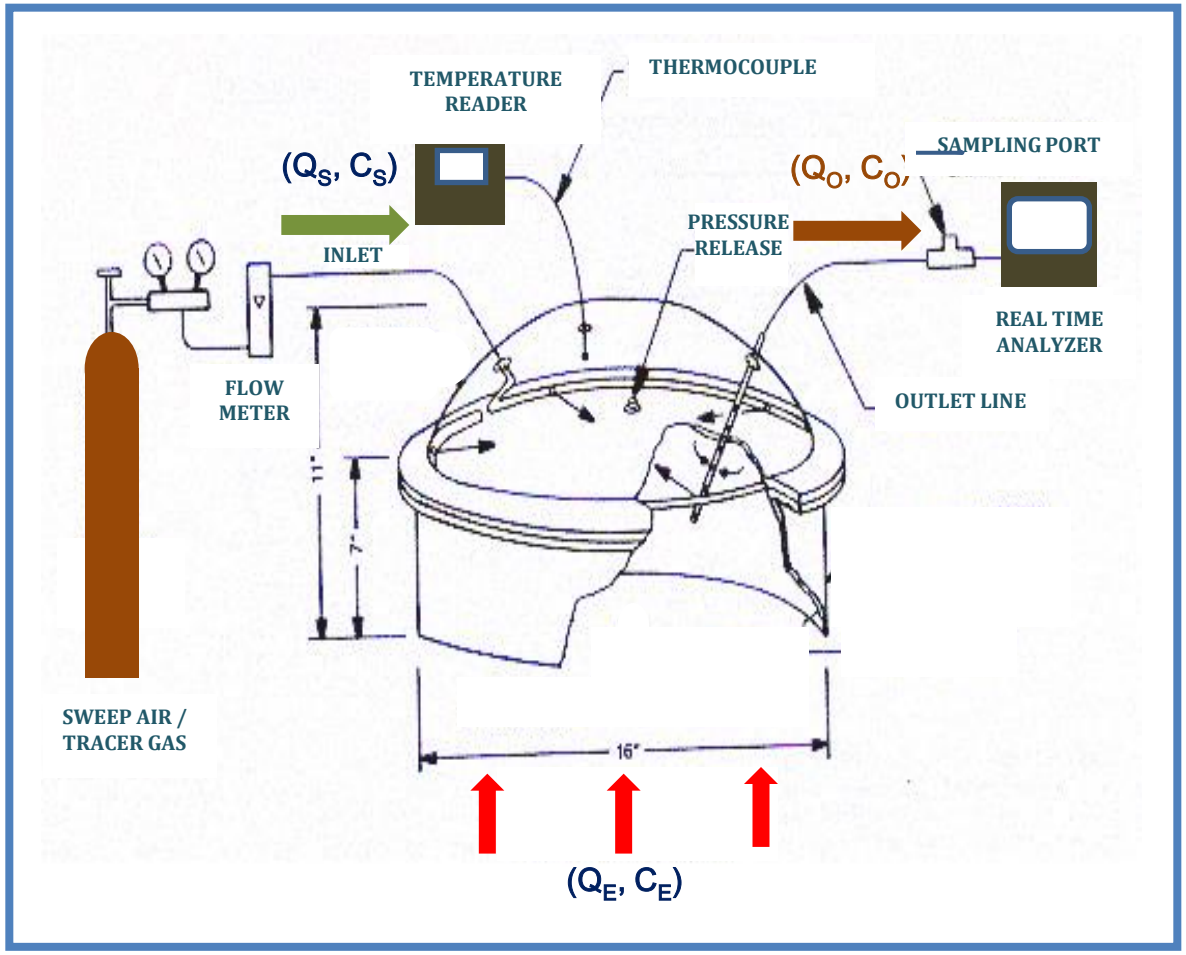
A - surface area (m^2)

ΔC- the change in gas concentration in the enclosure headspace (mg/m^3)

Δt – time change (d)



Dynamic Flux Chamber Method



$$F = C_O(Q_S + Q_E)/A$$

$$F = C_O Q_S / A$$

(as $Q_S > > Q_E$)

F - flux of a target compound ($mg/(d \cdot m^2)$)

A - surface area (m^2)

C_O- gas concentration at steady state (mg/m^3)

Q_S - flow rate of sweep air or tracer gas (m^3/d)

Q_E – Emission rate (m^3/d)

Calculating LFG Collection Efficiency using measured methane flux

- **Efficiency = Collection/Generation**

$$e = \frac{CH_4\ Collection}{CH_4\ Generation}$$

Alternatively,

$$e = \frac{Collection\ (CH_4)}{Emissions\ (CH_4) + Collection\ (CH_4)}$$

- **Collection is measured**
- **Emissions = Methane flux × Surface area**

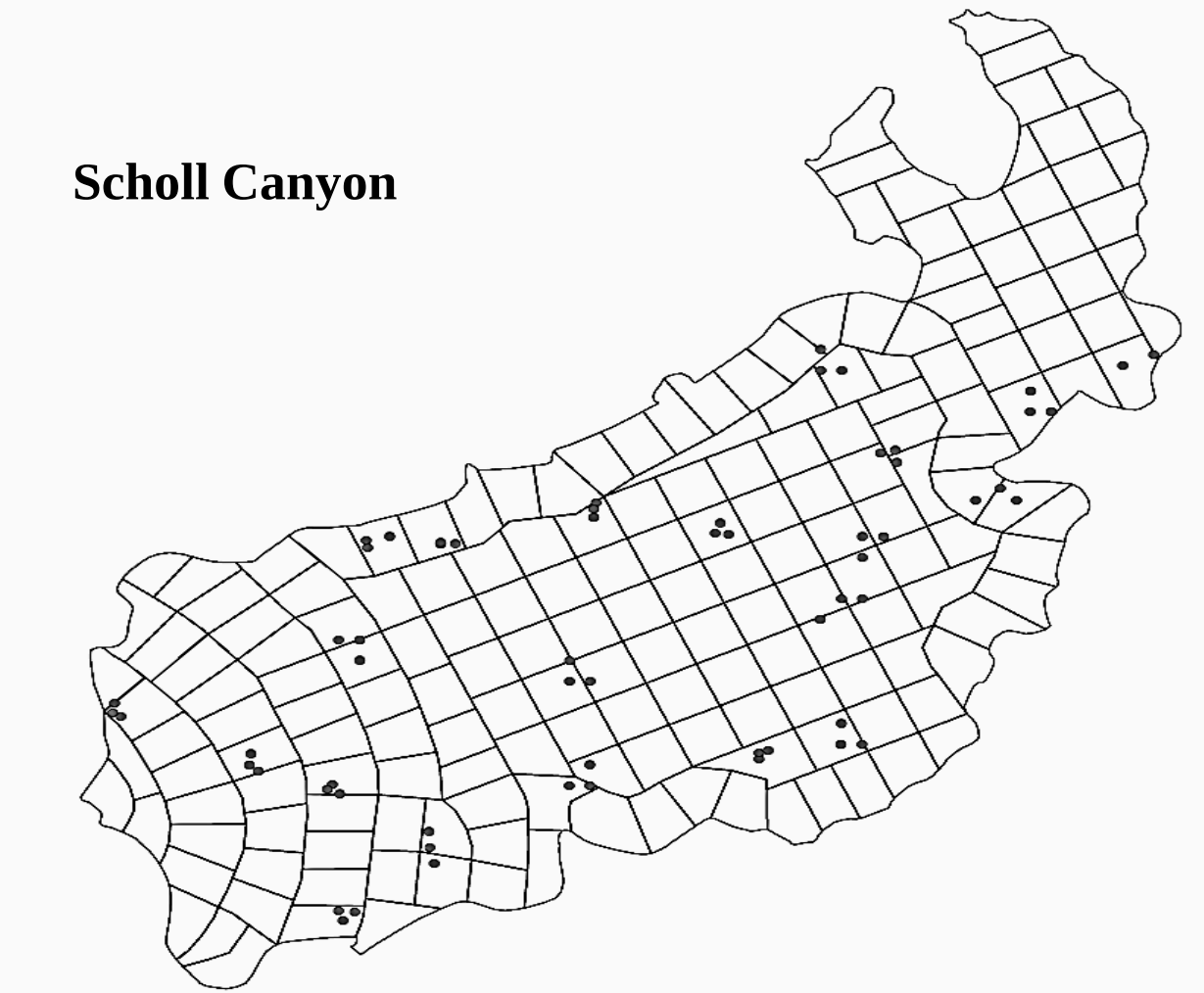
Flux Chamber Method

Field Measurement – Statistical random selection for testing locations

Landfill	Total Monitoring Grids	NO. of Tests	Testing Time Period
Puente Hills	540	65	Aug. 2010 - Mar. 2011
Scholl Canyon	188	62	Aug. 2011 - Oct. 2011
Calabasas	259	40	Nov. 2012 - Jan. 2013
*Palos Verdes	137	21	Aug. 2006

* PV project used prescreening method to select testing locations

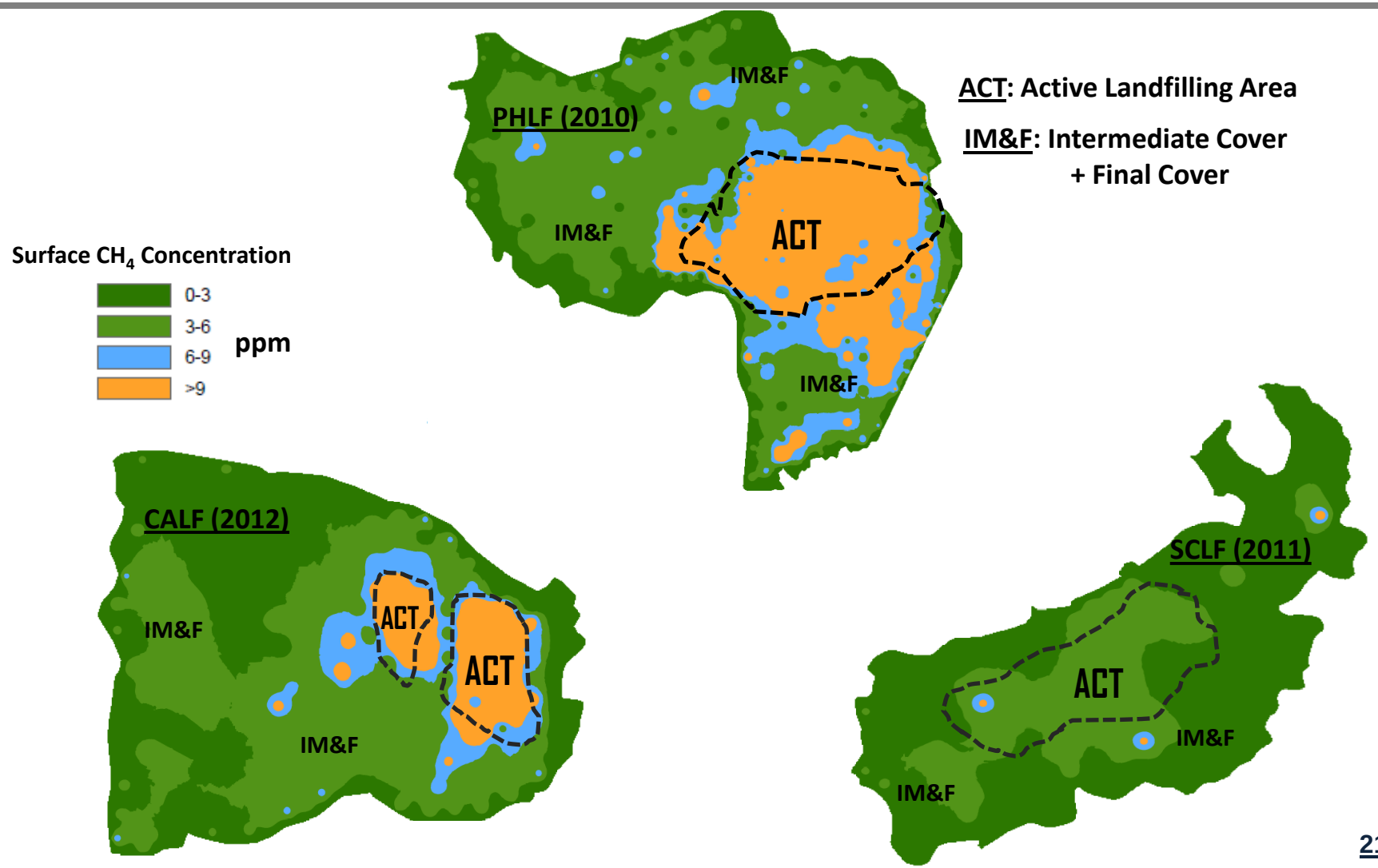
Flux Chamber Measurement Locations



Flux Data Analysis

- **Overall emissions estimated by:**
  - **Active Landfilling Area (ACT)**
    - Daily cover
    - Intermediate Cover (non-active for less than 6 months)
  - **IM&F Cover Area (IM&F)**
    - Final Cover
    - Intermediate Cover (non-active for more than 6 months)
- **95% Upper Confidence Level (UCL)**
  - This essentially means that one can be 95% confident that the true distribution of the sampling data has a population mean less than or equal to the calculated UCL.
  - Generated by taking the sample mean, and adding some number of sample standard deviations to it.
- **EPA ProUCL**

Surface Methane Concentration and Landfill Cover Type

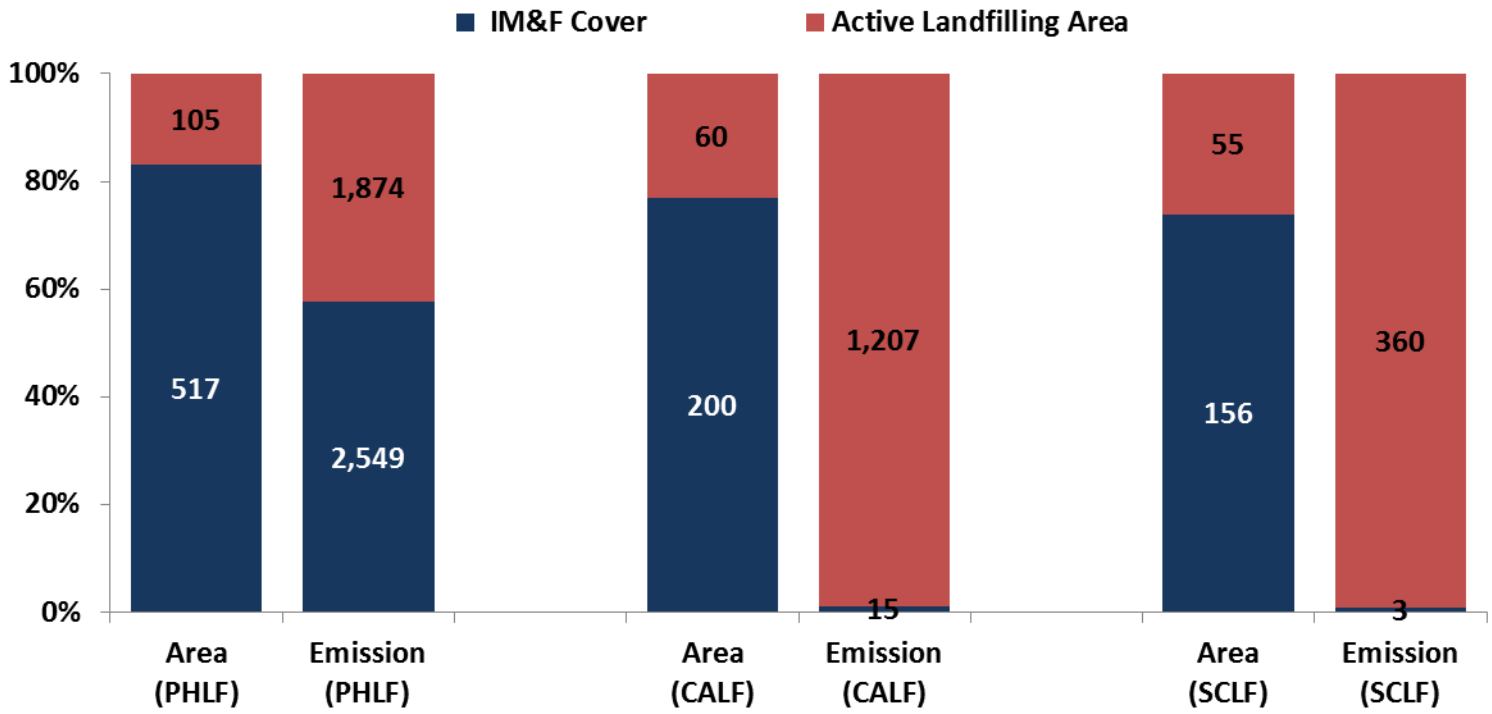


Methane Flux Measurement Results

Methane flux in ($g/m^2/d$)

Landfill	Cover Type	No. of Tests	Mean	95% UCL
PHLF	IM&F	51	1.1	3.3
	Active Landfilling	14	3.2	12.1
CALF	IM&F	32	0.04	0.05
	Active Landfilling	8	2.9	13.6
SCLF	IM&F	35	0.007	0.01
	Active Landfilling	27	0.6	4.4

Total Methane Emissions

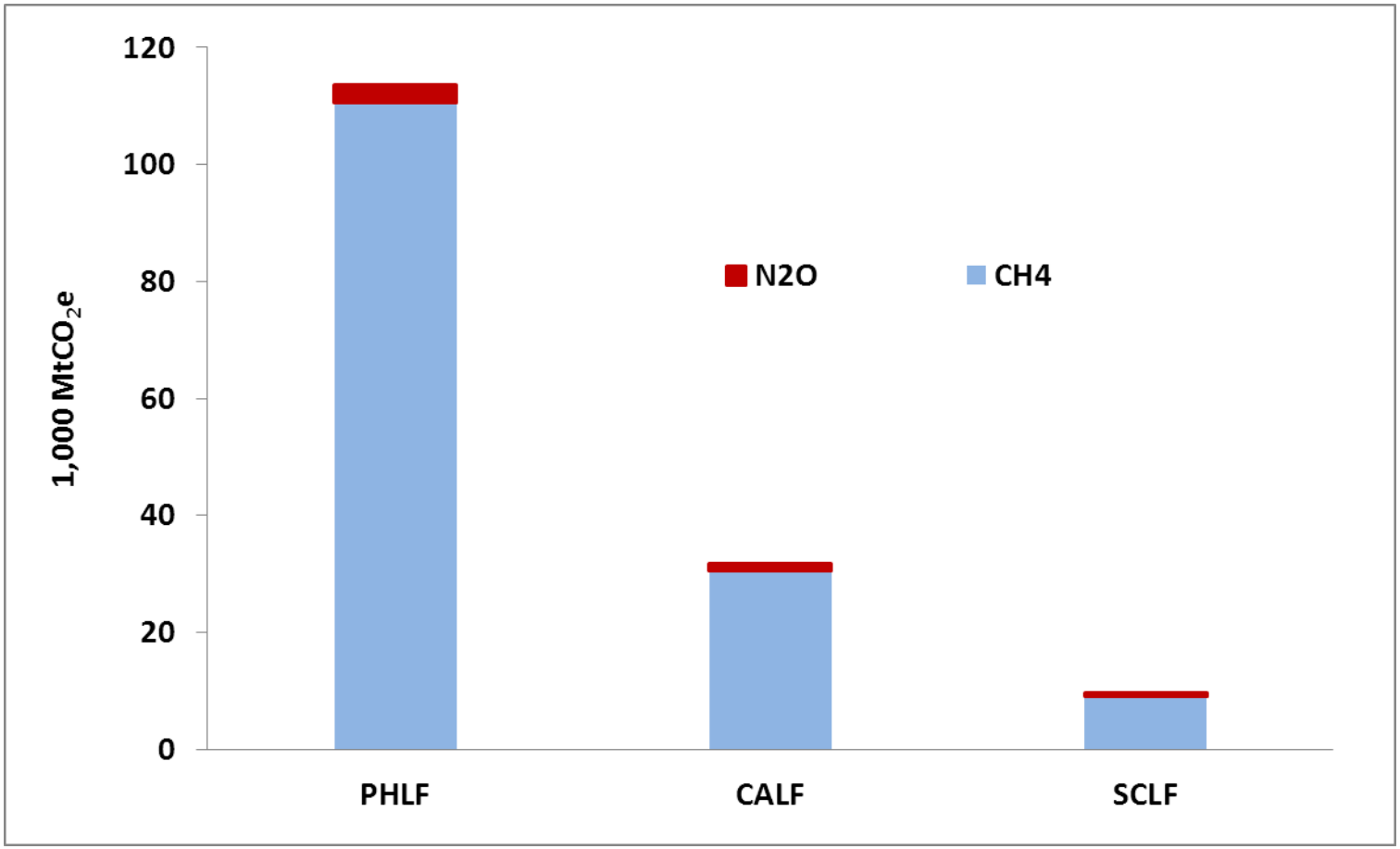


Landfill Surface Area: Acre

Total CH_4 emissions: Metric Ton Per Year

- **Total Emission = Emission Rate × Area**

Total GHG Emissions



$MtCO_2e$: Metric Tonne (ton) Carbon Dioxide Equivalent

Collection Efficiency – Flux Chamber Approach

Landfill Site	Emission Rate ($g/(m^2 \cdot d)$)	Total CH_4 Emitted (Mt/Year)	Total CH_4 Collected (Mt/Year)	Collection Efficiency
Puente Hills	4.8	4,423	103,366	95.9%
Calabasas	3.2	1,222	12,429	91.1%
Scholl Canyon	1.2	363	22,036	98.4%
*Palos Verdes	~ 0	~ 0	6697	> 99%

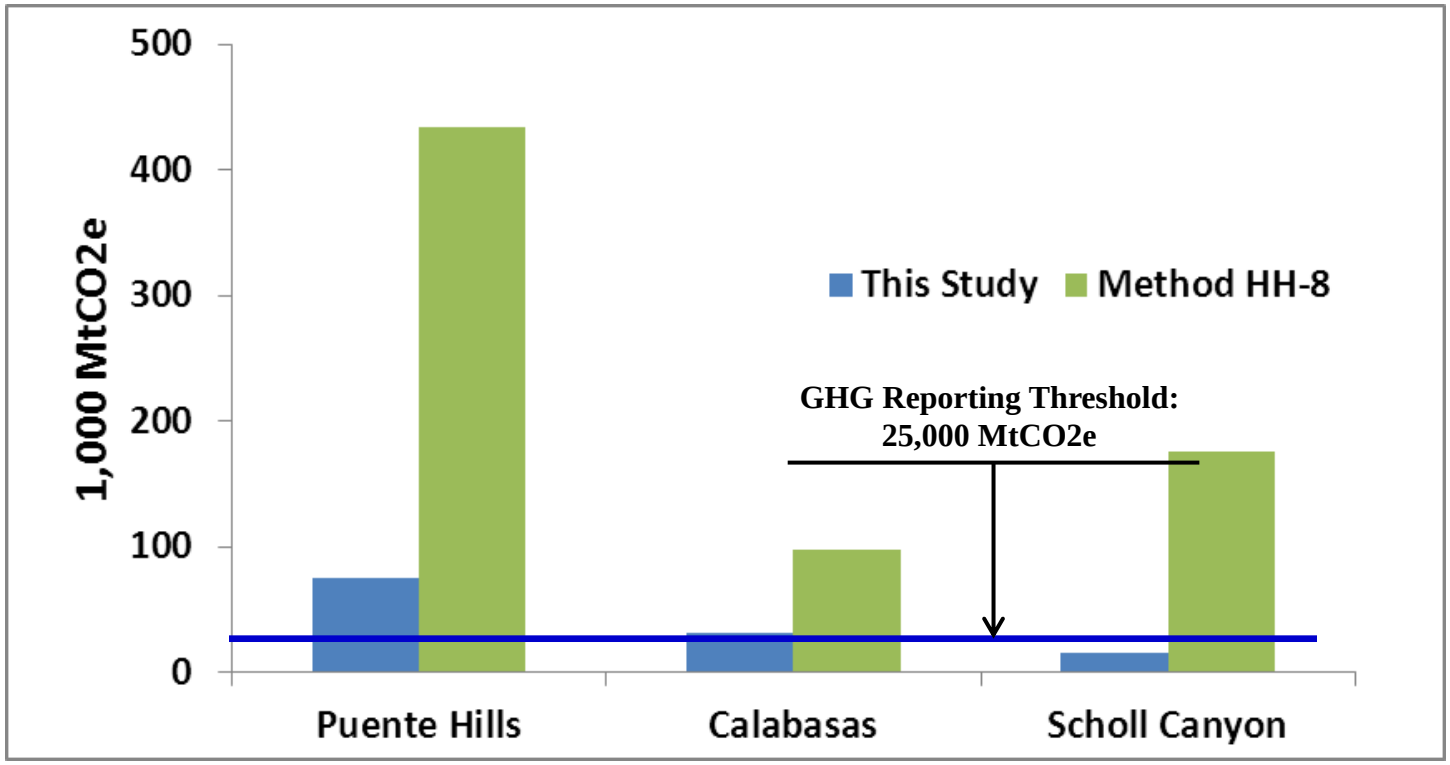
**Most CH_4 emission results below RL*

Collection Efficiency – LACSD's ISM/ISC Approach

Landfill Site	ISM (ppm)	ISC (ppm)	Collection Efficiency (ISM/ISC Method)	Collection Efficiency (Flux Chamber Method)
Puente Hills	6.02	56.73	93.1%	95.9%
Calabasas	3.90	22.34	91.6%	91.1%
Scholl Canyon	2.18	28.44	98.8%	98.4%
Palos Verdes	1.94	13.40	99.3%	> 99%

Total GHG Emissions (CH_4)

Comparison with EPA's Greenhouse Gas Reporting Program



- *This Study: Directly measured emissions using Flux Chamber technique*
- *EPA HH-6: LandGEM Modeled CH_4 Generation – Recovered CH_4*
- *EPA HH-8: Estimated CH_4 Generation – Recovered CH_4*
  - *Based on assigned collection efficiencies*

Concluding Remarks

- **LACSD's ISM/ISC method**:
  - ✓ an alternative methodology
  - ✓ combines existing surface methane monitoring with air dispersion modeling
  - ✓ time-efficient and cost-effective tool

- **Flux chamber approach**:
  - ✓ a reliable direct method for quantifying LFG emissions
  - ✓ time consuming and labor intensive
  - ✓ probably the only way to verify other indirect approaches

Concluding Remarks

- **90% or more collection efficiencies were observed at all Districts' landfills**
  - ✓Well-operated gas collection systems
  - ✓Stringent surface gas control regulations
- **Both methods generated similar results**
- **Results indicate that the EPA GHG inventory methods significantly overestimate emissions**

References

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