Assessment of Use of Air Sampling Collection Methods Following an Outdoor *Bacillus Anthracis* Contamination

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Introduction

- EPA has the responsibility for protecting human health and the environment in the event of a release of biological material in an urban area.
- EPA's toolbox includes approaches for surface, soil, water, and air sample collection.
- This research is assessing air sampling methods for *Bacillus anthracis* following a wide area contamination.
  - Objective 1: Review the literature to identify the best available air sampling methods for outdoor spore sampling.
  - Objective 2: Evaluate different air sampling strategies and identify operational gaps.

Presentation Objectives

- Discus the factors that affect the bioaerosol concentration produced by resuspension and subsequent impact on network design.

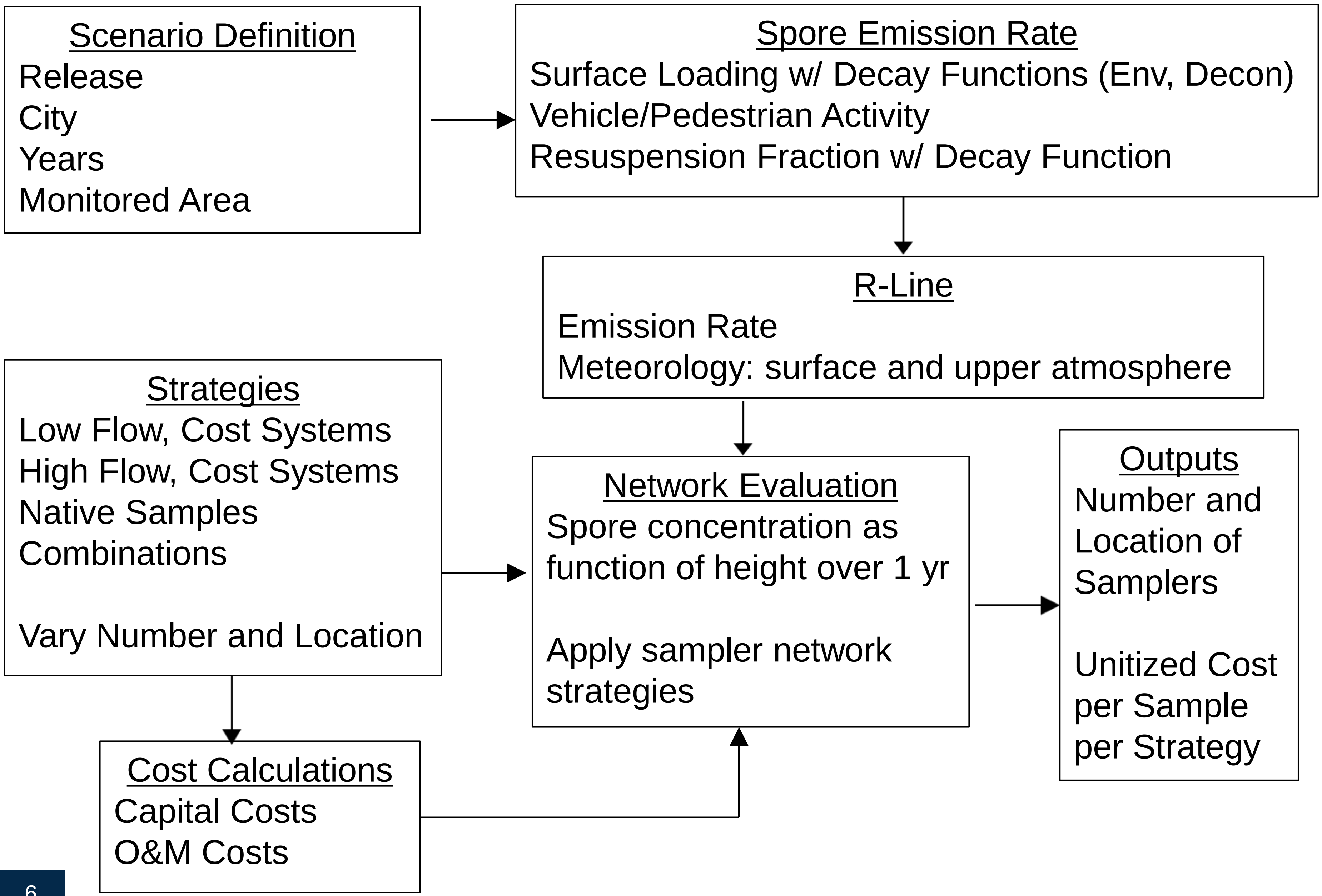
- Preliminary results examining a few simple network designs.

Approach for Evaluating Air Sampling Strategies

- Developed a system performance model in MATLAB to evaluate different air sampling strategies.

- Model components
  - Spore air concentration
    - Scenario definition
    - Spore emission rate caused by resuspension
    - Spore dispersion
    - Daily average spore concentration in the x,y plane at multiple heights
  - Air sampling strategies
    - Air sampler technical specifications: low flow and high flow systems
    - Air sample costs: equipment costs and per sample costs
  - Network evaluation
    - Number and location of samplers that collect 1 spore
    - Unitized cost per sample per strategy

System Performance Model Framework



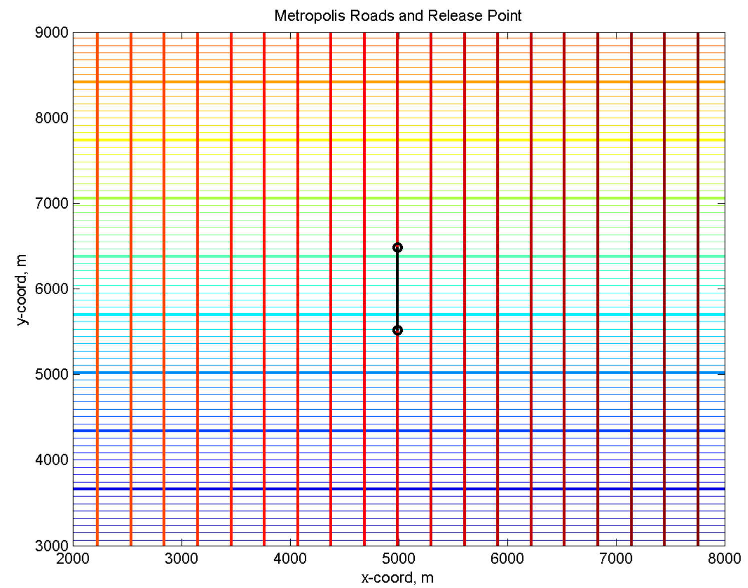
Data Sources and Assumptions

- Data Sources
  - Used publicly available peer-reviewed data when available.
  - Non-peer reviewed but publicly available data used when necessary.

- Key Assumptions
  - Surface loading along the line of release.
  - Decay function to relate resuspension fraction to surface loading
    - Easily resuspended particles are aerosolized first.
    - Decreasing resuspension fraction over time.
  - Did not include rain or mitigation influences on surface loading.

Scenario Modeled for This Presentation

- National Planning Scenario #2 release.
- Urban metropolis with uniform road grid covering 36 km^2.
- 12 time periods from Oct. 2001 to Aug. 2002.
  - 6 fall, 4 spring, 1 winter, and 1 summer.
  - A period is 28 days, with decon @ day 15.
- Input variables constant or allowed to fluctuate.
  - Activity patterns tied to day of the week.
  - Initial resuspension fraction.
  - Surface loading.
- Assume normal activities after release.
- 121 sample points.
- Sampler heights of 2, 4, 10, 20, 30, 40 and 50 m.



General Results & Observations

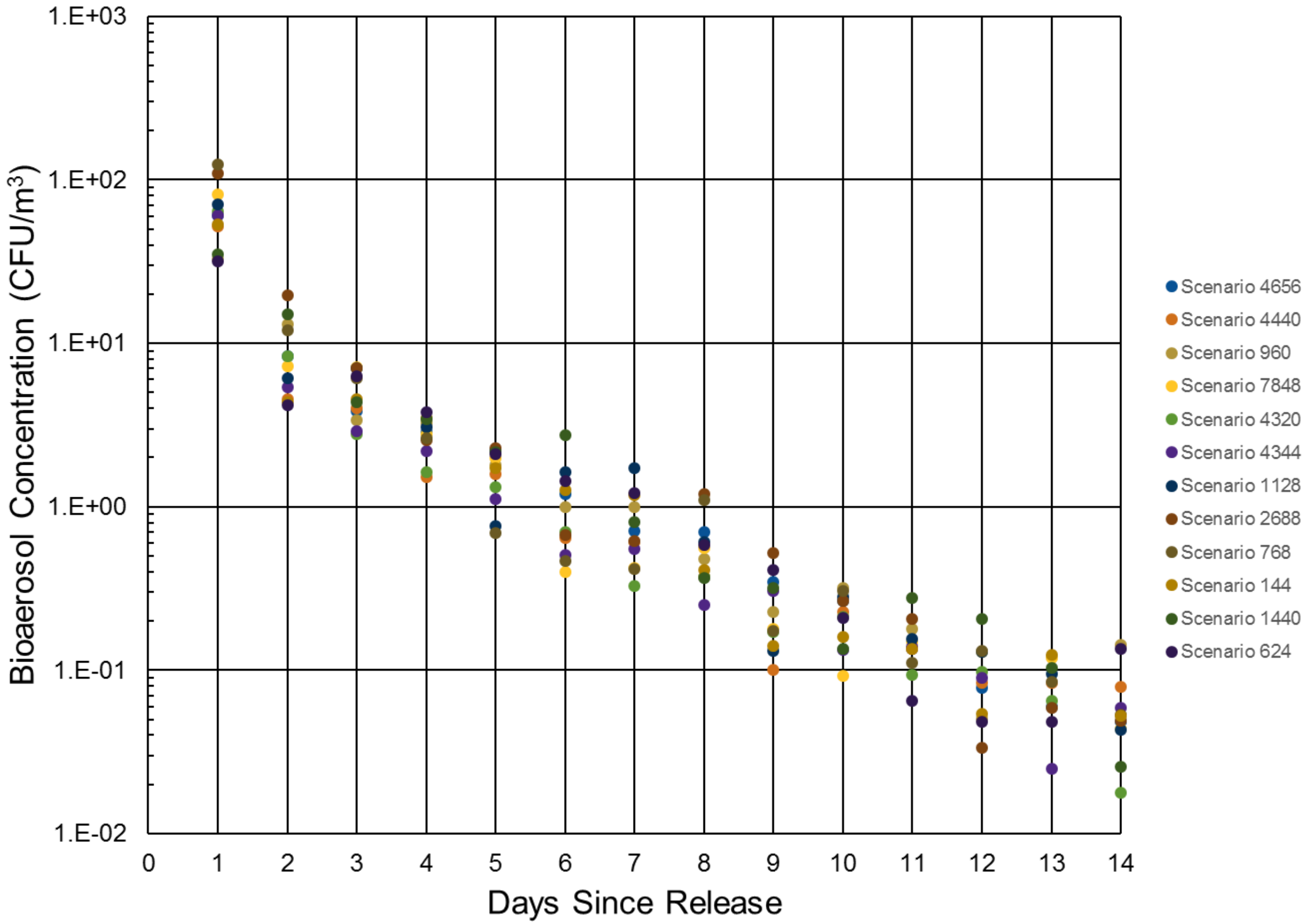
- Decontamination at Day 15 effectively reduced bioaerosol concentration to zero, even adjacent to the point of release
- Selectively choosing results can be misleading and generate wrong conclusions.
- Easy to identify statistically significant or insignificant differences in the bioaerosol concentration.
  - Emission rate caused by resuspension decreases each day because of source depletion.
  - Meteorology influences on wind speed & direction, boundary layer thickness.
  - Distance of the sampler from the initial release location.
  - Height of the sampler above the ground.
- **Need to consider all 3.4 million bioaerosol concentrations produced during this modeled scenario when evaluating the performance of a sampler network.**

Influences on Daily Average Bioaerosol Concentration

- Statistical model was a general linear model with sampler location as a categorical variable and all other variables as continuous.

- Results
  - Days since release: p-value < 0.0001
  - Meteorology: p-value = 0.328
  - Sampler height: p-value < 0.0001
  - Sampler location (x,y plane): p-value < 0.0001

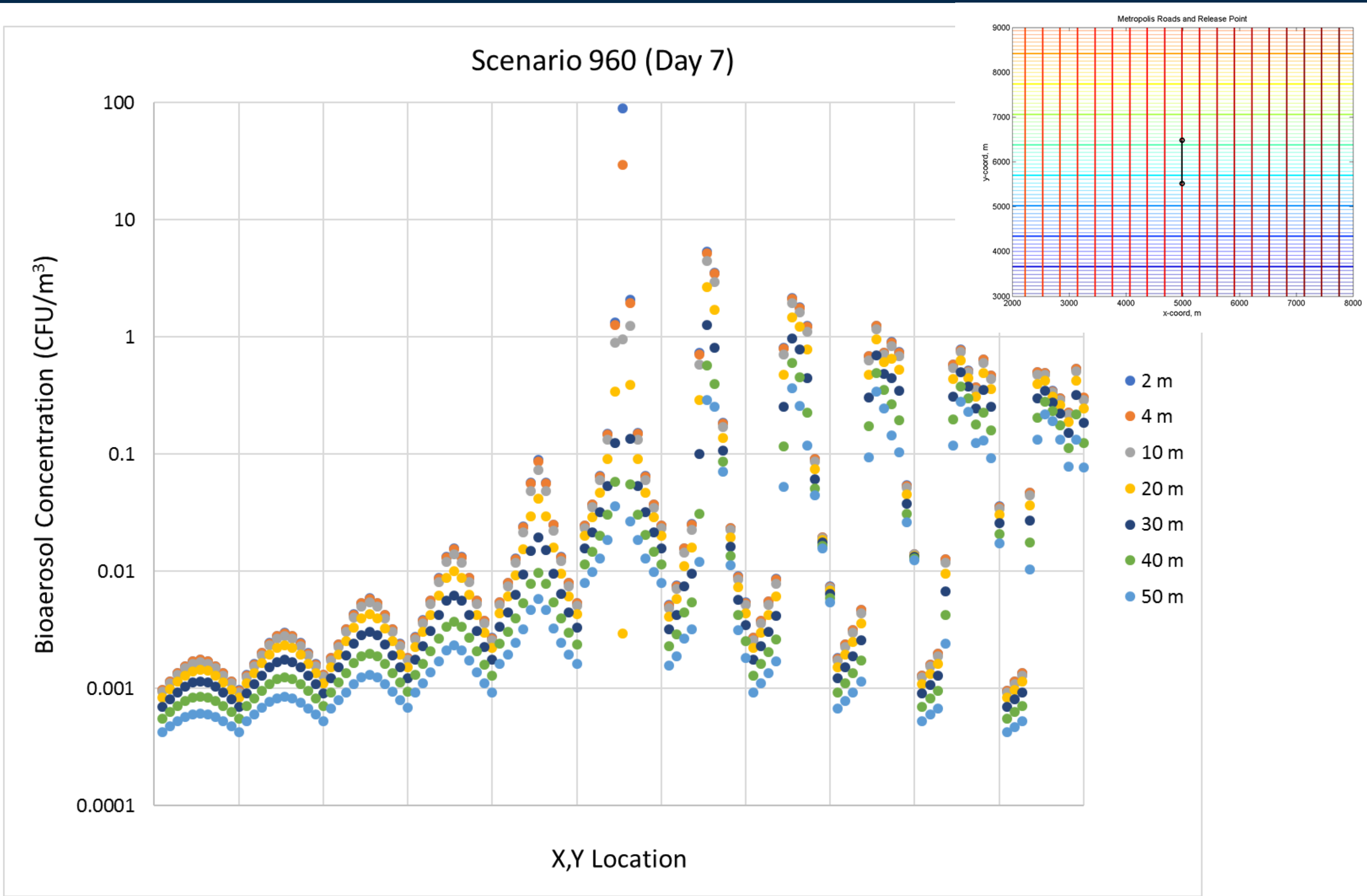
Daily Average Bioaerosol Concentration



- All inputs constant except for meteorology.
- 12 scenarios modeled.
- Average concentration across the 36 km^2 area.

- Bioaerosol concentration decreases over time because of source depletion.
- Concentration fluctuation between scenarios illustrates the variability caused by meteorology, although a statistically insignificant variable.

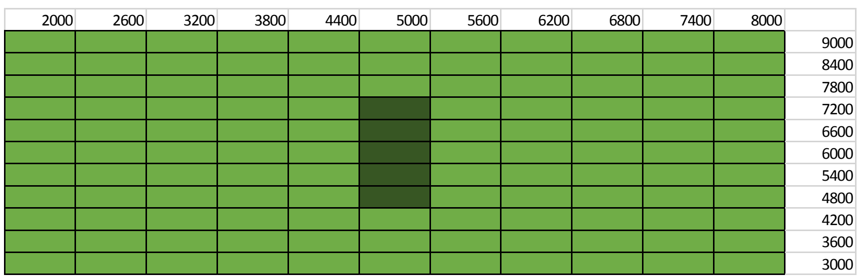
Sampler Height Influence: All other inputs constant

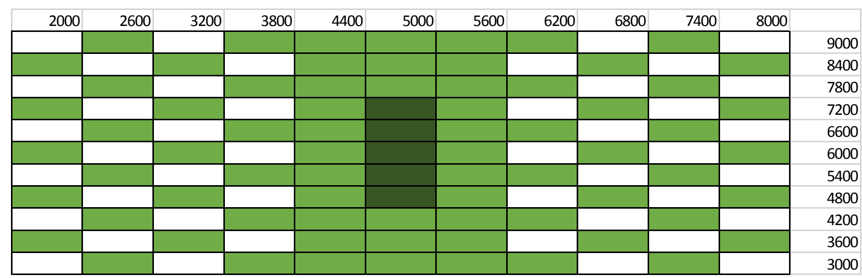


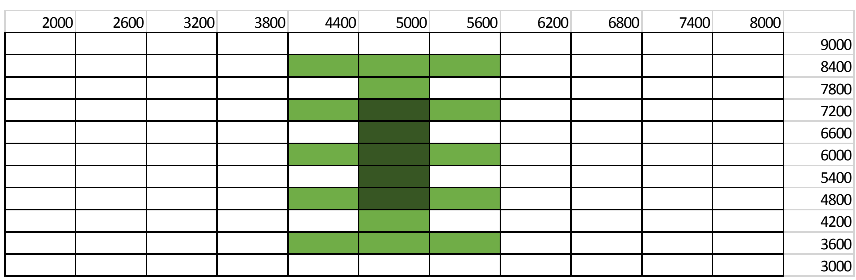
- 2, 4, 10 m concentrations always statistically similar.
- On certain days, the concentration at 20 m is the same as the lower heights.
- Concentrations at 30, 40, and 50 m decrease with height as expected.

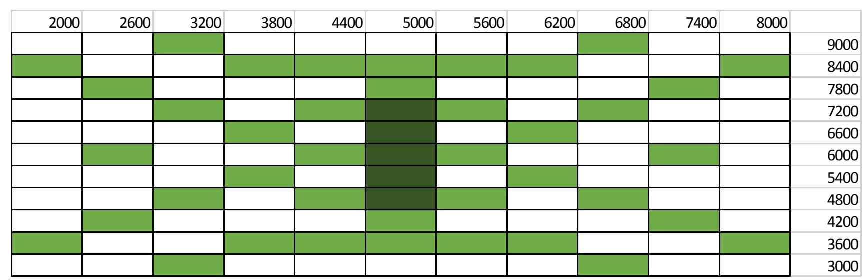
Number of Samplers that Collect 1 Spore in 24 Hours

- Gives an initial understanding of required sampler density
- High (300 Lpm) and low flow (10 Lpm) samplers
- All samples at 4 m (assumed easy to deploy samplers and collect samples)
- Average of all 12 time periods, all other variables constant
- 4 sampler deployment patterns (121, 77, 45, 19 samplers)

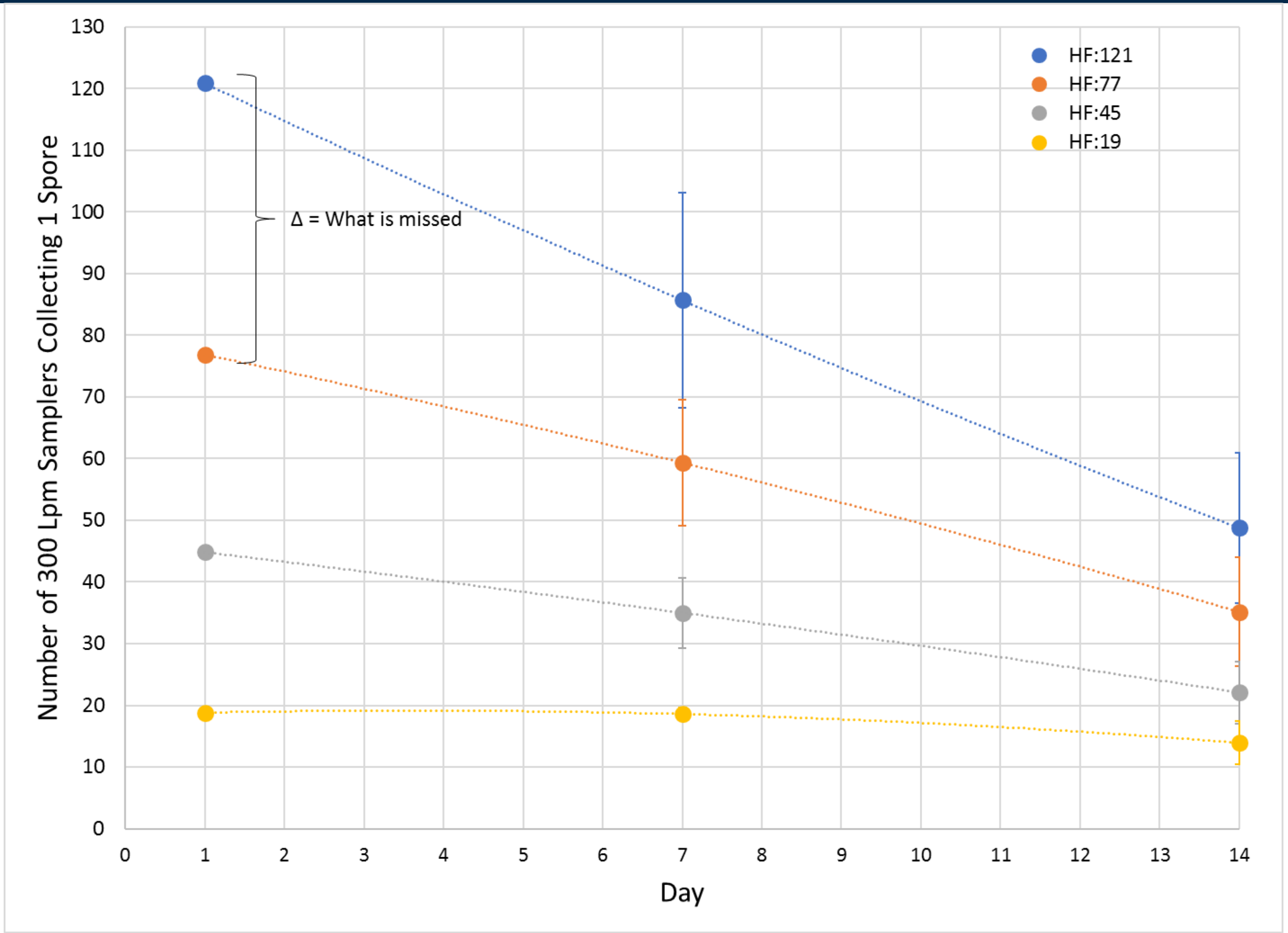








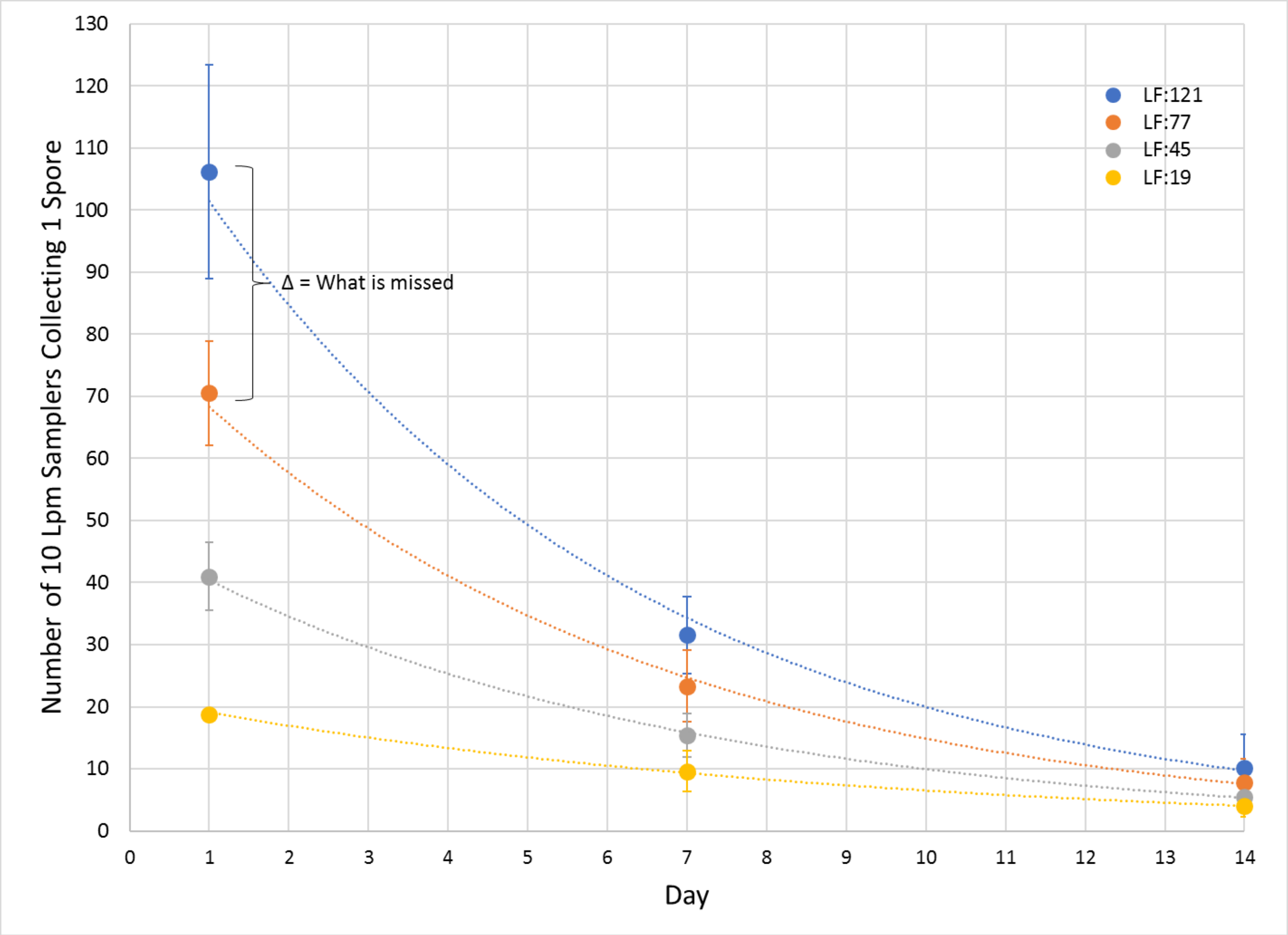
High Flow Sampler Network



- Day 1: 100% of samplers collect at least 1 spore.
- Day 14: "positive" samples concentrated around point of release.
- Error bars indicate the influence of meteorology.

- Dense network = more "positive" samples and a faster rate of decrease in the number of "positive" samples over time.
- The difference between HF:121 and other HF networks equals the number of "positive" samples missed by using a lower density network.

Low Flow Sampler Network



- Day 1: Less than 100% of samplers collect at least 1 spore.
- Day 14: “positive” samples concentrated around point of release.

- Network density trends hold: dense network = more “positive” samples and a faster rate of decrease.
- The relative number of “missed” samples decreases for a low-flow sampler network.

Summary

- We developed a MATLAB tool to evaluate bioaerosol sampler network strategies for deployment in an urban metropolis.

- Bioaerosol concentration resulting from resuspension is a function of:
  - Number of days since release
  - Sampler location and height

- Meteorology causes fluctuations in the bioaerosol concentration but was a statistically insignificant variable at the network level.

Summary (cont.)

- The detection of resuspended spores by the network increased when high flow samplers used and at higher sampler density.
- Limiting bioaerosol sample collection to the area near the release point missed detectable spores that transport several kilometers downwind.
- Next Steps
  - Include native samplers: building outdoor air intake filters.
  - Mixed strategy: combination of high flow, low flow, and native samples.
  - Work costs into simulations to optimize detection probability versus cost.

Disclaimer

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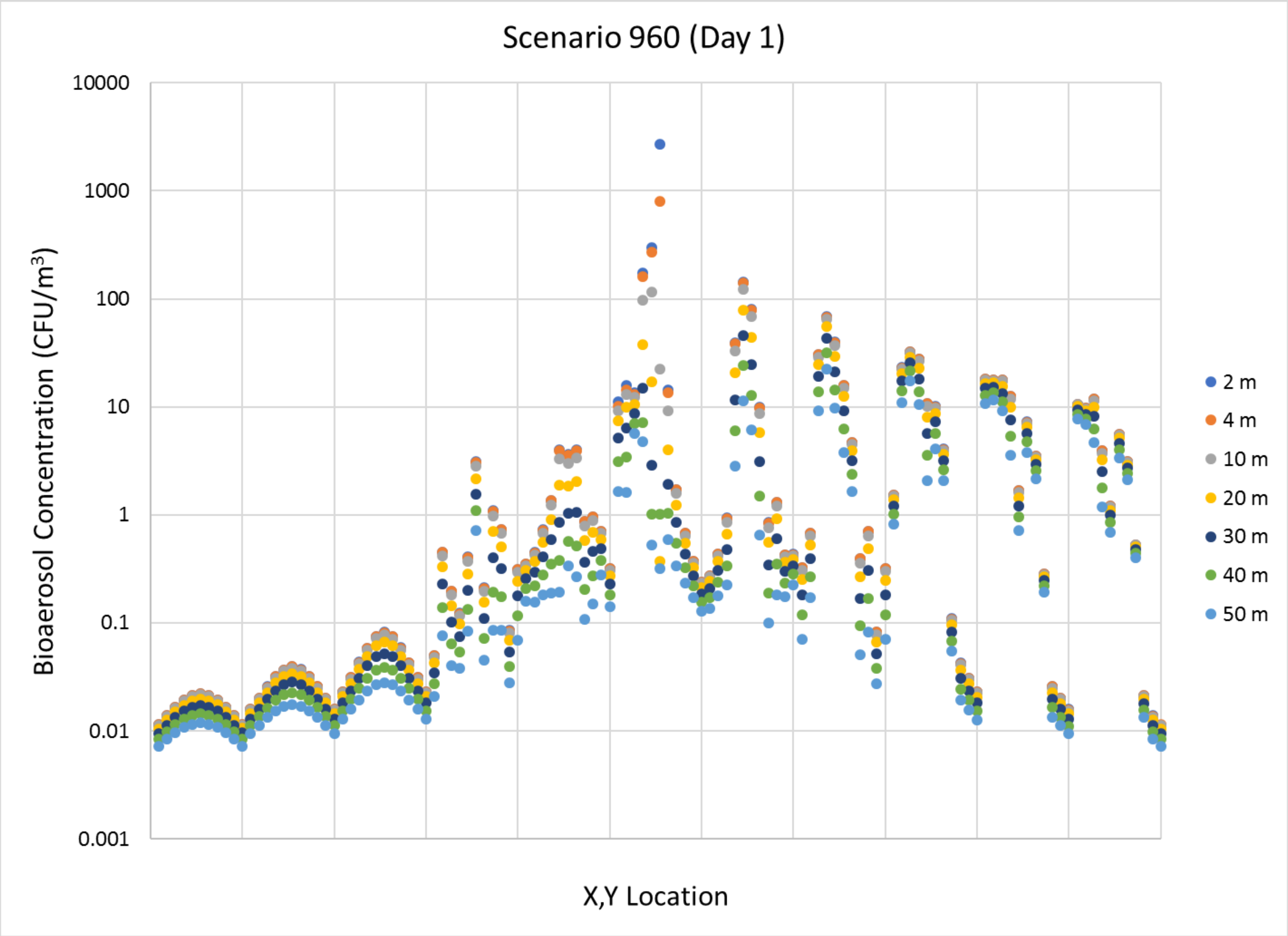
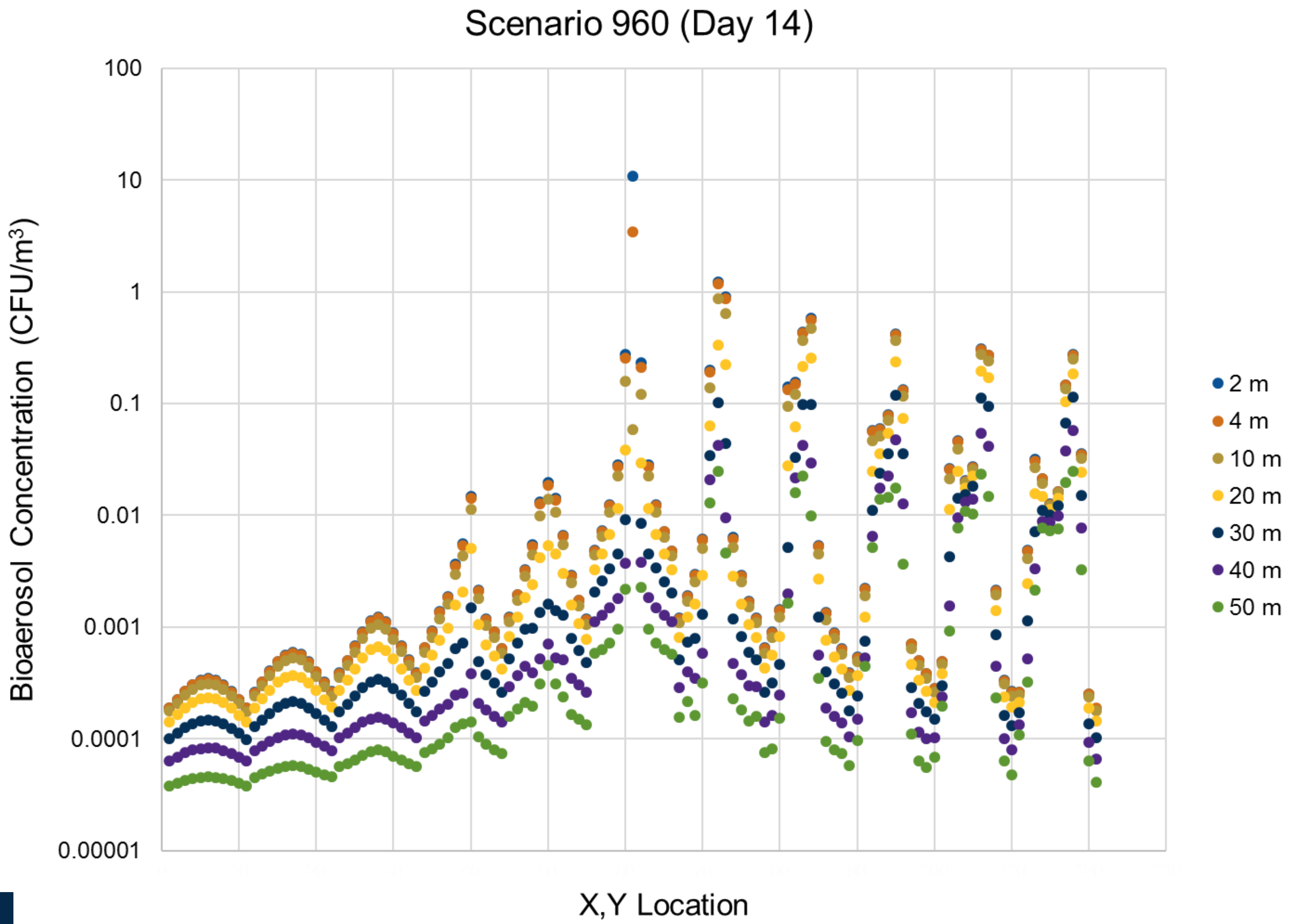
Extra/Back-up Slides

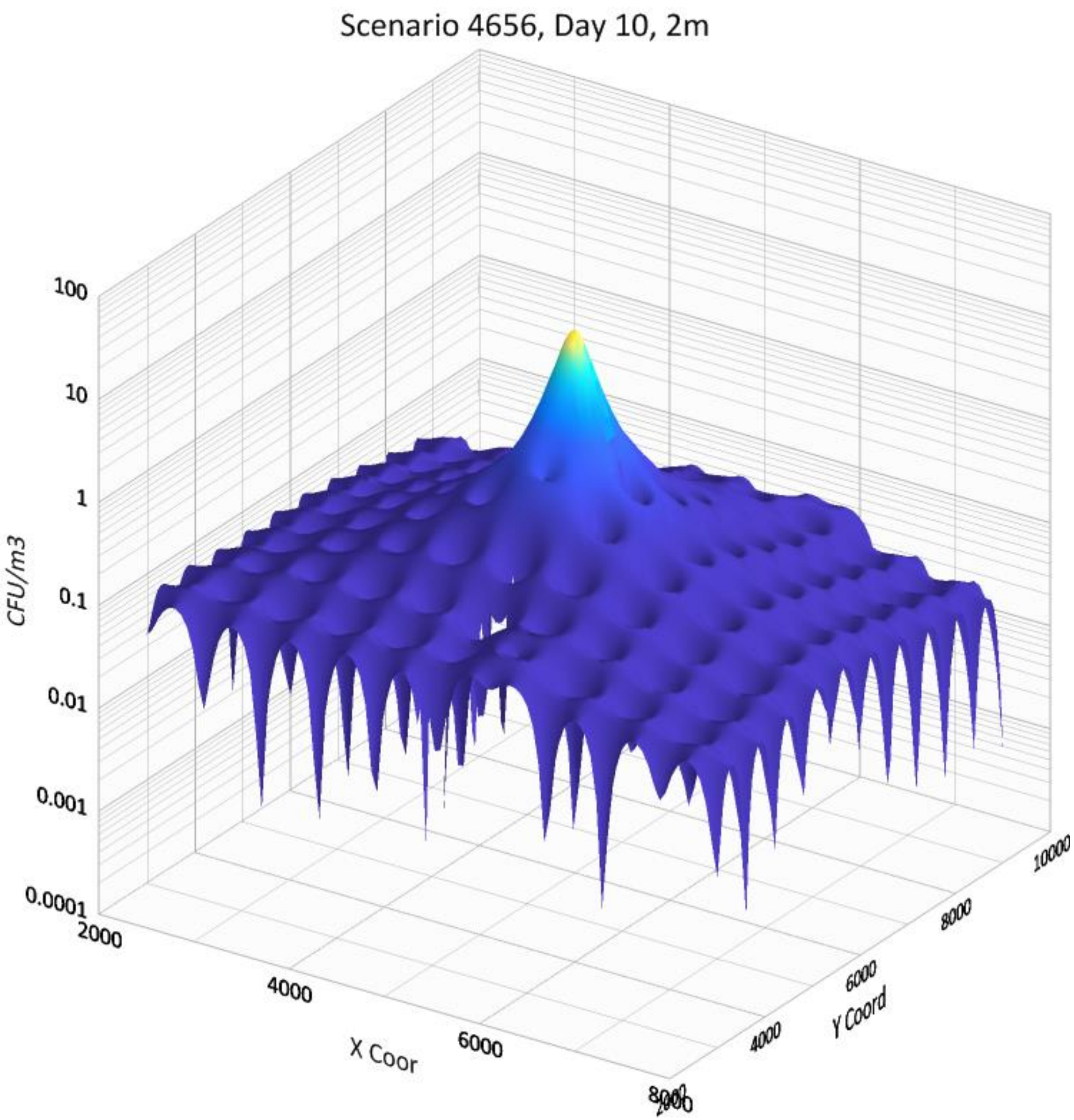
Sampler Height Influence: All other inputs constant



Sampler Height Influence: All other inputs constant



Spatial Concentration & Sampler Location



- Highest concentrations at the release point because of meteorology
- Light, southwest wind
- "Icicles" are modeled concentrations
- Dimples and ridges caused by the spline fitting algorithm in the graphics program

Definitions and Conversions

- 1 CFU/m^3 = 1E-3 ACPLA
  - Or 100 ACPLA = 1E+5 CFU/m^3, lowest possible detection limit for real-time instrumentation
- Low Flow Sampler = 10 Lpm (SKC Leland Pump)
  - ~0.07 CFU/m^3 to collect 1 spore in 24 hours
- High Flow Sampler = 300 Lpm (XMX, etc.)
  - ~0.003 CFU/m^3 to collect 1 spore in 24 hours

High and Low Flow Networks: What is Missed?

Day	Sampler Density	High Flow: 300 Lpm	Low Flow: 10 Lpm
1	77	44 ± 0	37 ± 9
	45	76 ± 0	66 ± 12
	19	102 ± 0	89 ± 17
7	77	26 ± 8	9 ± 2
	45	51 ± 12	17 ± 4
	19	67 ± 17	23 ± 5
14	77	14 ± 5	2 ± 2
	45	27 ± 8	5 ± 3
	19	35 ± 10	6 ± 4