Development of an Emission Reduction Term for Near-Source Depletion

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May 17 2006

Background

- Air Quality Models for Fugitive Dust Consistently Overpredict Ambient PM-10 Concentrations by up to Factor of 4

- Overprediction Places Unnecessary Restrictions on Military Training Activities

Military Training Activities

- Unpaved Roads
- Tank Trails
- Vehicle Maneuvering
- Construction Activities
- Smoke Releases

Special Characteristics of Fugitive Dust

- Ground Level Release with Electrostatic Tribocharging
- Wide Variety of Particle Sizes, from Sub-Micron to > 100 Micron Diameters
- At Point of Release, Most Dust Mass Confined to Height of Vehicle or Other Source of Energy Input

Elevated Particle Capture Surfaces

- Trees
- Other Vegetation
- Building Structures
- Rough Terrain

Fugitive PM Emissions

- Total PM
  - Measured at 5 m from source
- Depleted PM
  - Captured within 100 m from source through variety of depletion mechanisms
- Transportable PM
  - Lofted for transport beyond 100 m
  - Unaffected by non-gravitational forces

Roadway Plume Profiling

- Concentration
- Wind speed
- Mass flux
- Deposition
- Chemical constituents

Sampling Schemes

- Fixed towers—vertical arrays
- Mobile monitors (continuous/integrating)
- Remote sensing (e.g., FTIR)
- Sampler Deployment
  - Edge of source
  - 20 to 50 m downwind
- Traffic (Roadways)
  - Freely flowing
  - Congested

Open Source Characterization

- Measurement of plume concentration, wind speed and mass flux profiles at the edge of the source and at points downwind
- Measurement of particle deposition (plume depletion) vs. distance from source
- Determination of plume losses on vegetation and other types of groundcover

Collocated Plume Profilers

On-board Mobile Monitor

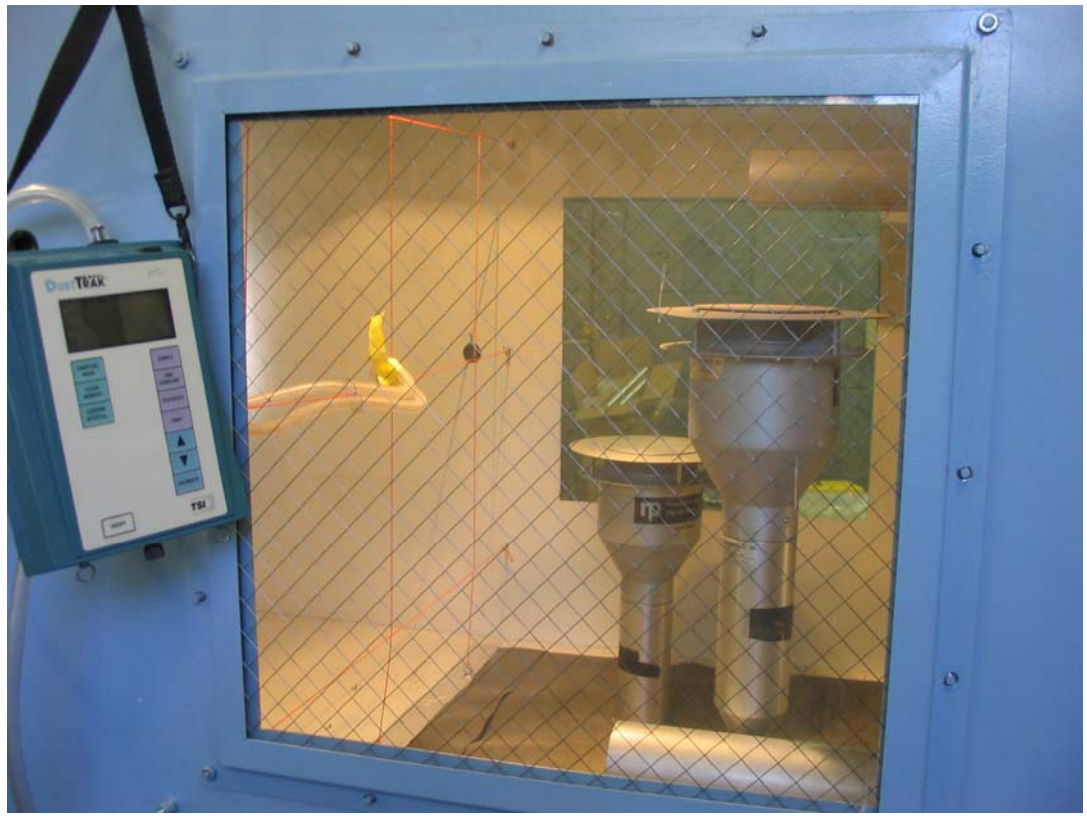
MRI Recirculating Wind Tunnel

- Uniform Wind Velocity (< 10% variation over working cross section)
- Uniform Dust Concentrations (< 10% variation)
- Steady State Conditions (~ 2 hr)
- PM-10 Concentrations (up to 10 mg/m^3 using 20 l/min injection air flow)

Exposure Chamber with Sampler Inlets

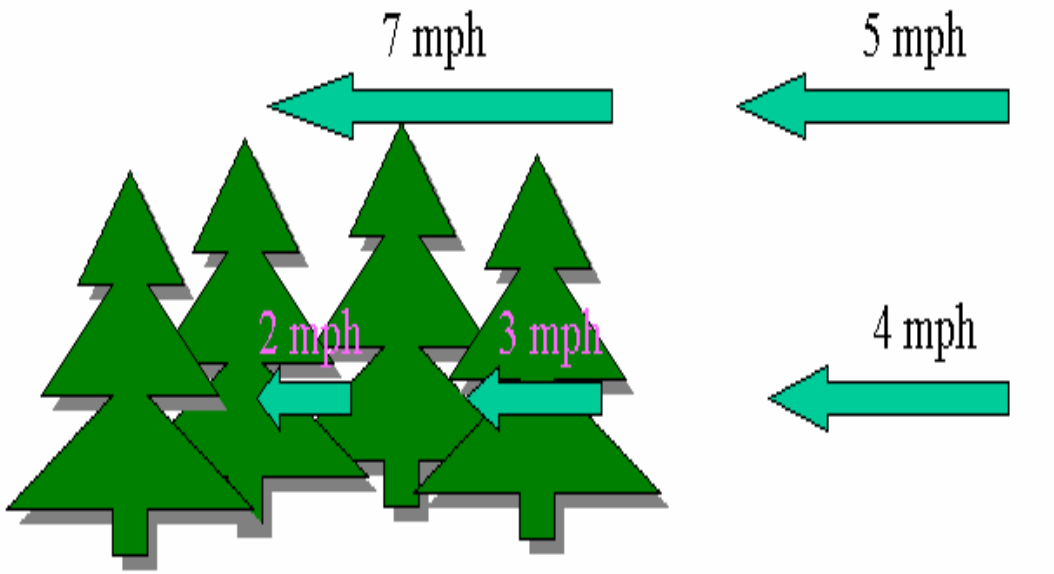
MRI Laboratory Wind Tunnel

Viewing Window with Continuous PM Mass Monitor



Ref. Method Sampling Equipment

Vegetative Porosity: Wind Speed Reduction in Forests



Vegetative Capture of Particles

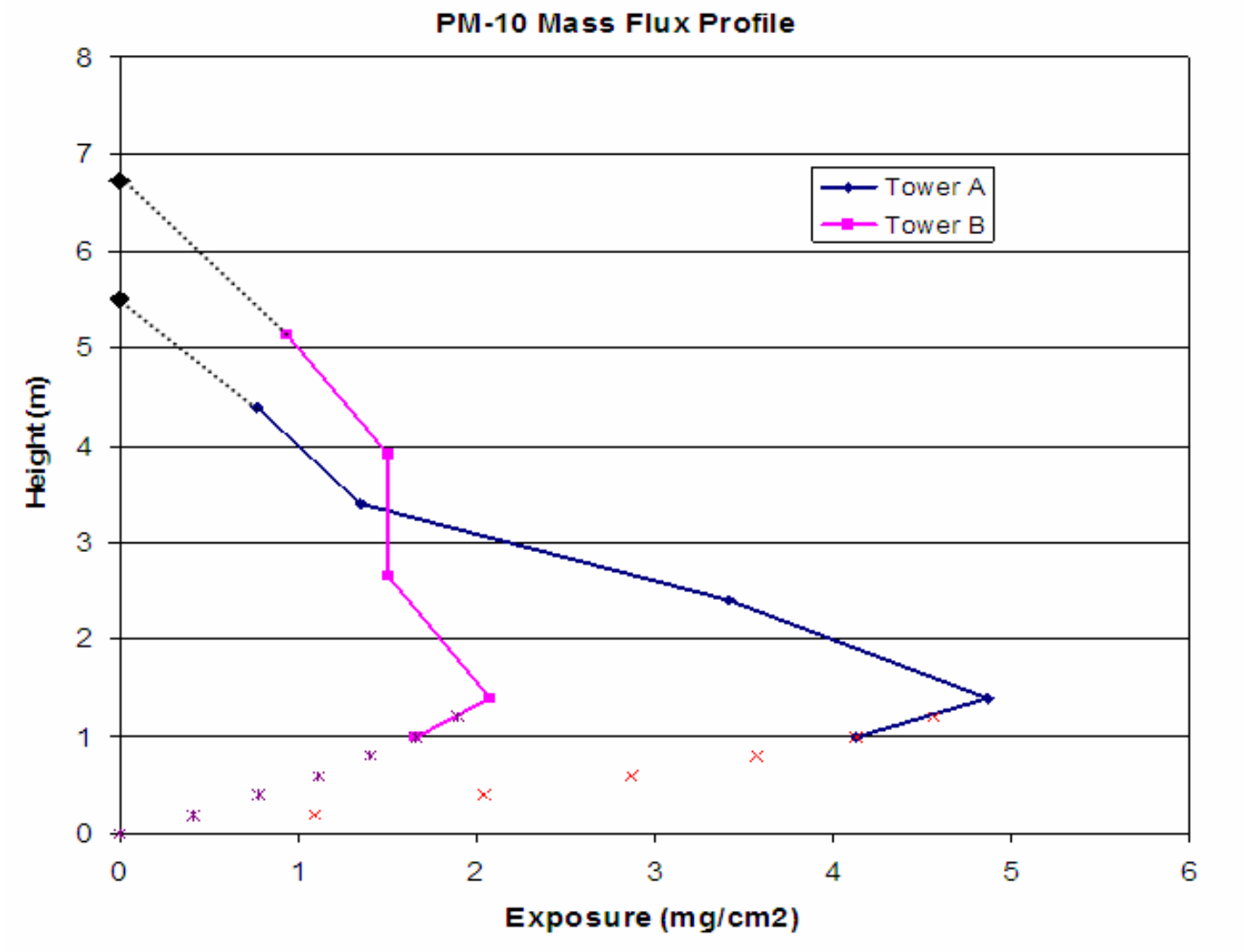
- Two Series of Tests at Ft. Leonard Wood, MO, 2003-2004
- Two Series of Tests at Ft. Riley, KS, 2005

MRI Streamlined Profiling Tower in Trees

Collocated HVS-3 Cyclones

Deposition on Tall Grass at Ft. Riley KS

Example Plume Profiles

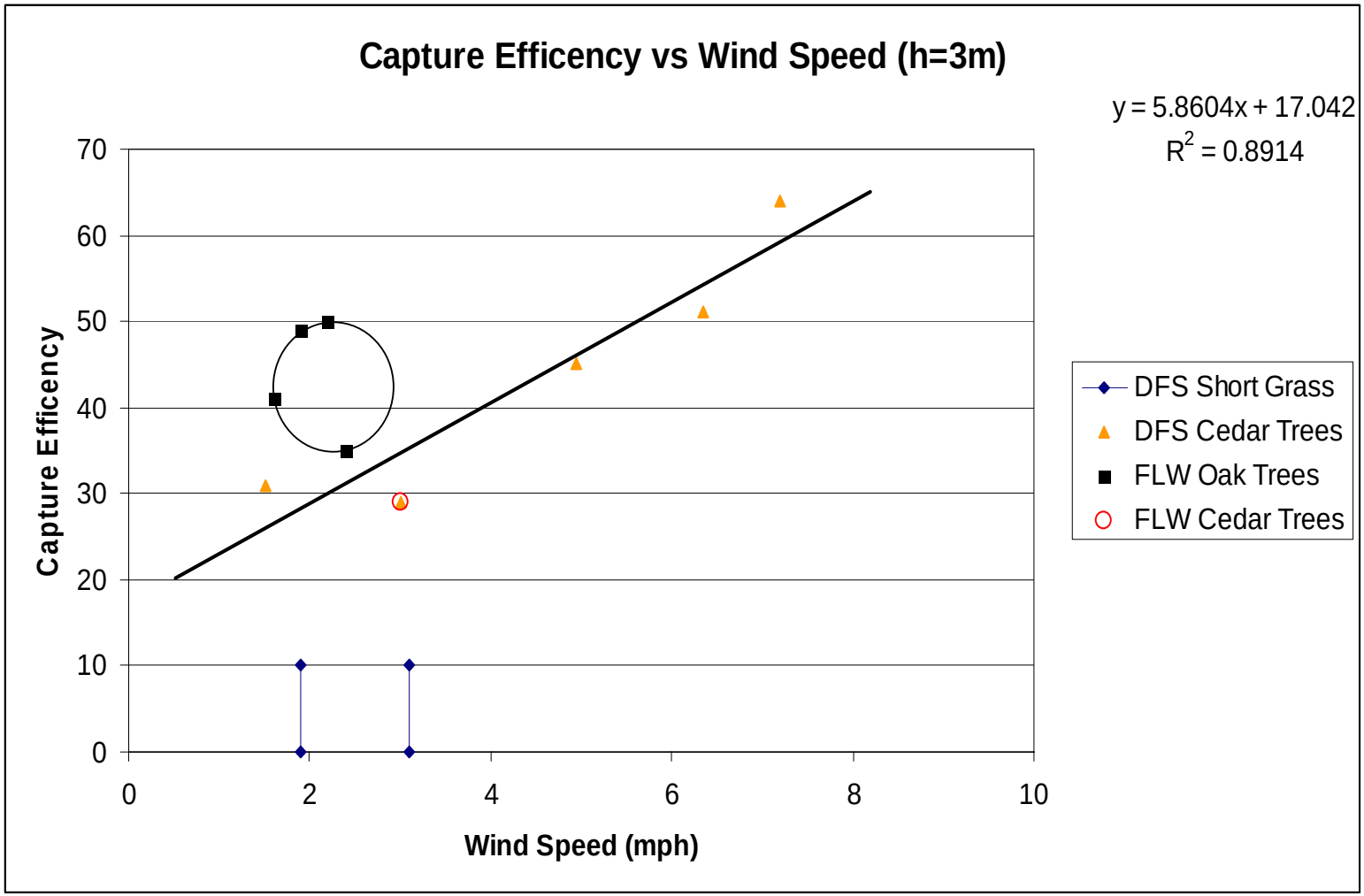


PM-10 Deposition

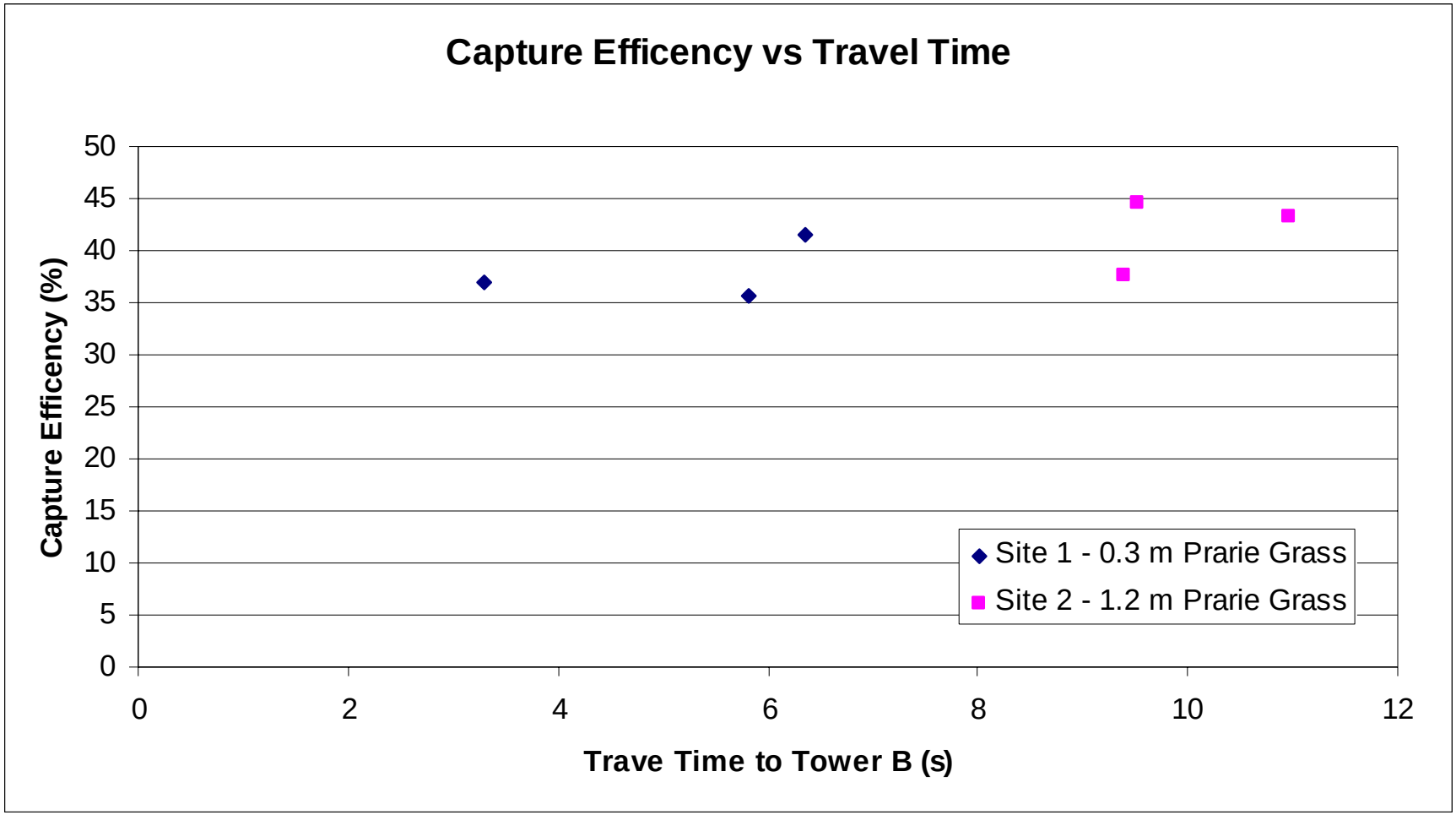
Type of Vegetation	PM-10 Plume Loss*
Short Grass	< 10%
Tall Grass	35-45%
Tall Cedar Trees	45-67%
Short Cedar Trees	29%
Tall Oak Trees (light winds)	41-50%

***20-30 m travel distance**

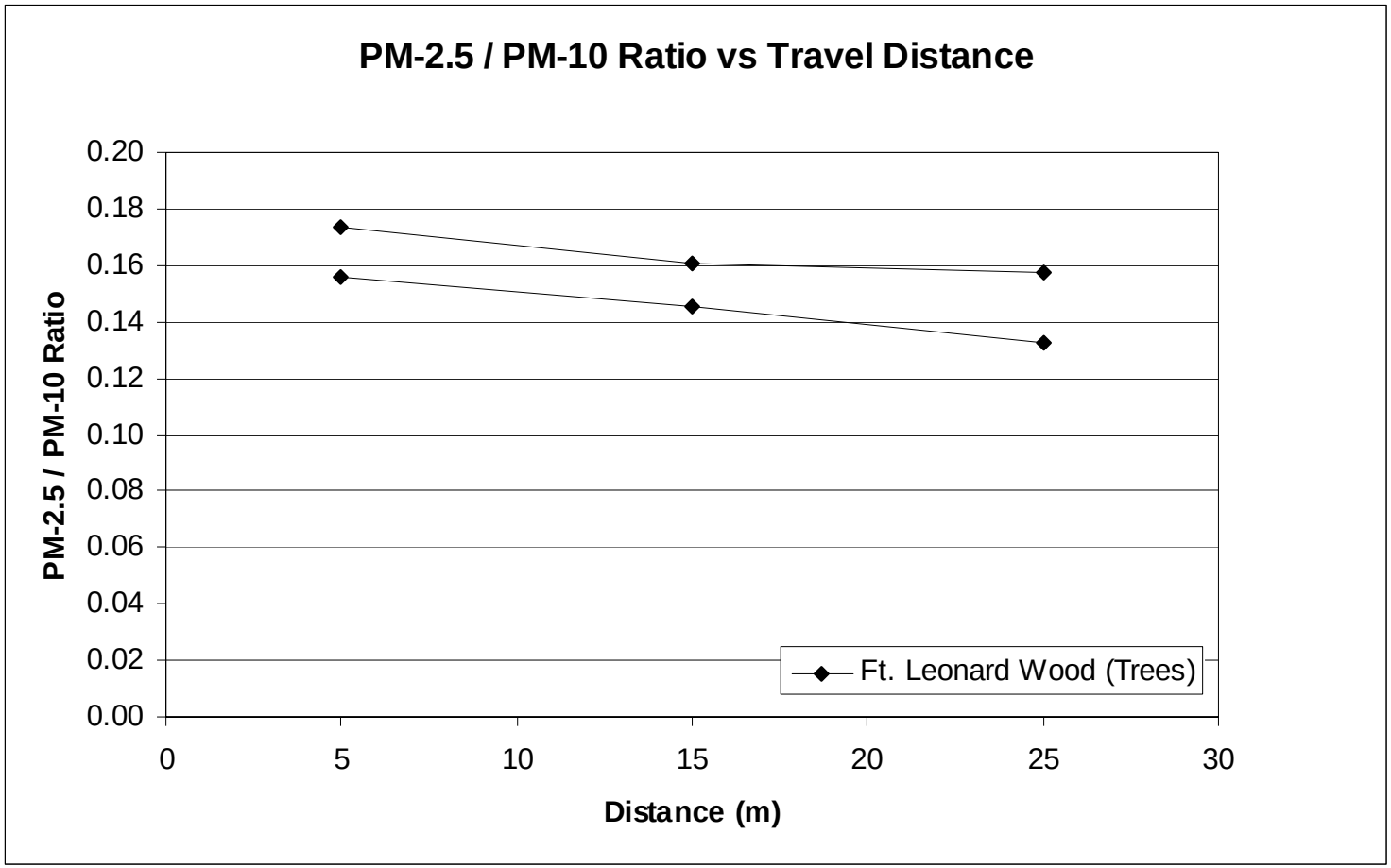
PM-10 Capture Efficiency on Oak and Cedar Trees



PM-10 Capture Efficiency on Tall Grass



PM2.5/PM10 Ratios as Function of Downwind Distance (Oak Trees)



Options for Modeling Representation of Near-Source Depletion

- Mitigation Term on Emission Factor
  - Similar to any other natural mitigation effect
  - Uncontrolled emission factor remains in tact
- Improved Deposition Algorithm within Dispersion Model
  - Builds on past approach to treatment of deposition

Mitigation Term--Advantages

- Does not require changes to EPA models
- Near-source deposition zone (< 50-100 m) not normally associated with reliable predictions
- Vegetation (groundcover) is placed in same category as other dust control measures

Mitigation Term--Disadvantages

- Near-source concentrations will be grossly underpredicted
- For local effects, term must be direction specific, unless groundcover is uniform
- May cause confusion over permitted emissions

Improved Algorithm--Advantages

- Correctly represents actual emissions at the source
- Has the potential to correctly represent near-source plume impacts
- Is consistent with current algorithms that represent plume loss phenomena

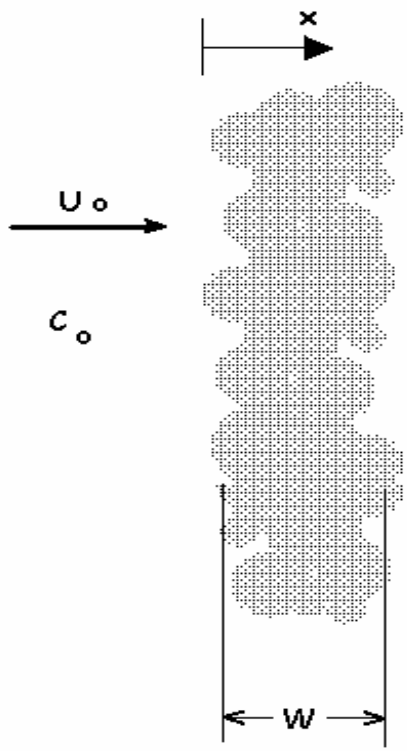
Improved Algorithm--Disadvantages

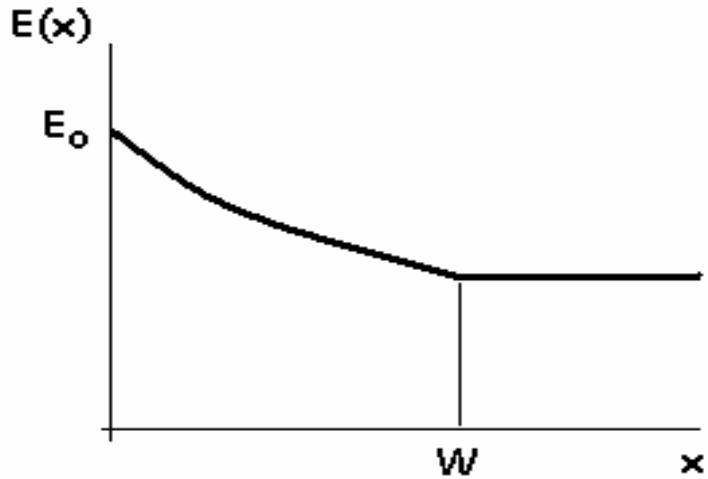
- Near source depletion phenomena will require complex mathematical representation
- Will also require detailed near-source groundcover inputs
- EPA model changes will require lengthy review period

Basis for Deposition Algorithm

- Change in mass flux with distance is proportional to the remaining mass flux
- Proportionality constant, k, does not vary with height
- k varies with vegetative density and wind speed
- No further reduction in mass flux downwind of barrier

Dust Transport Across Vegetative Barrier

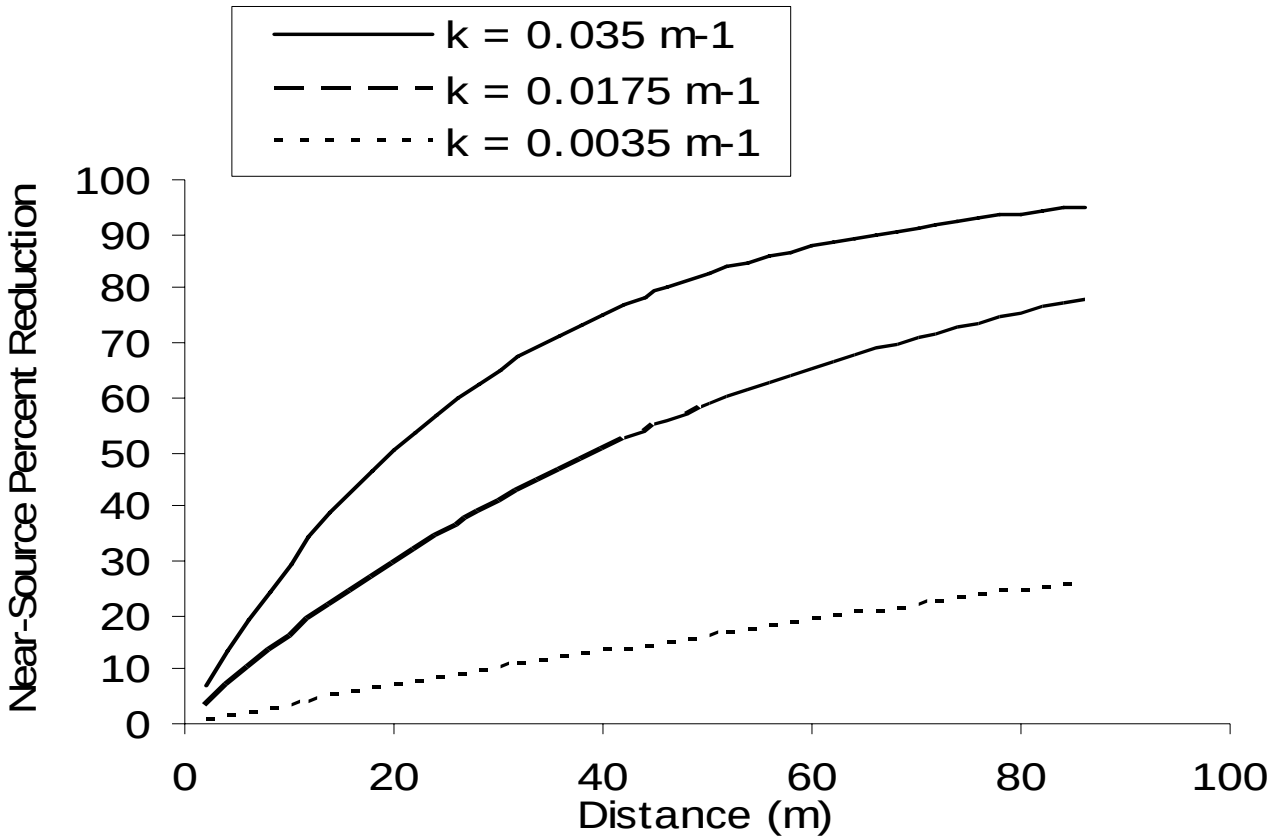




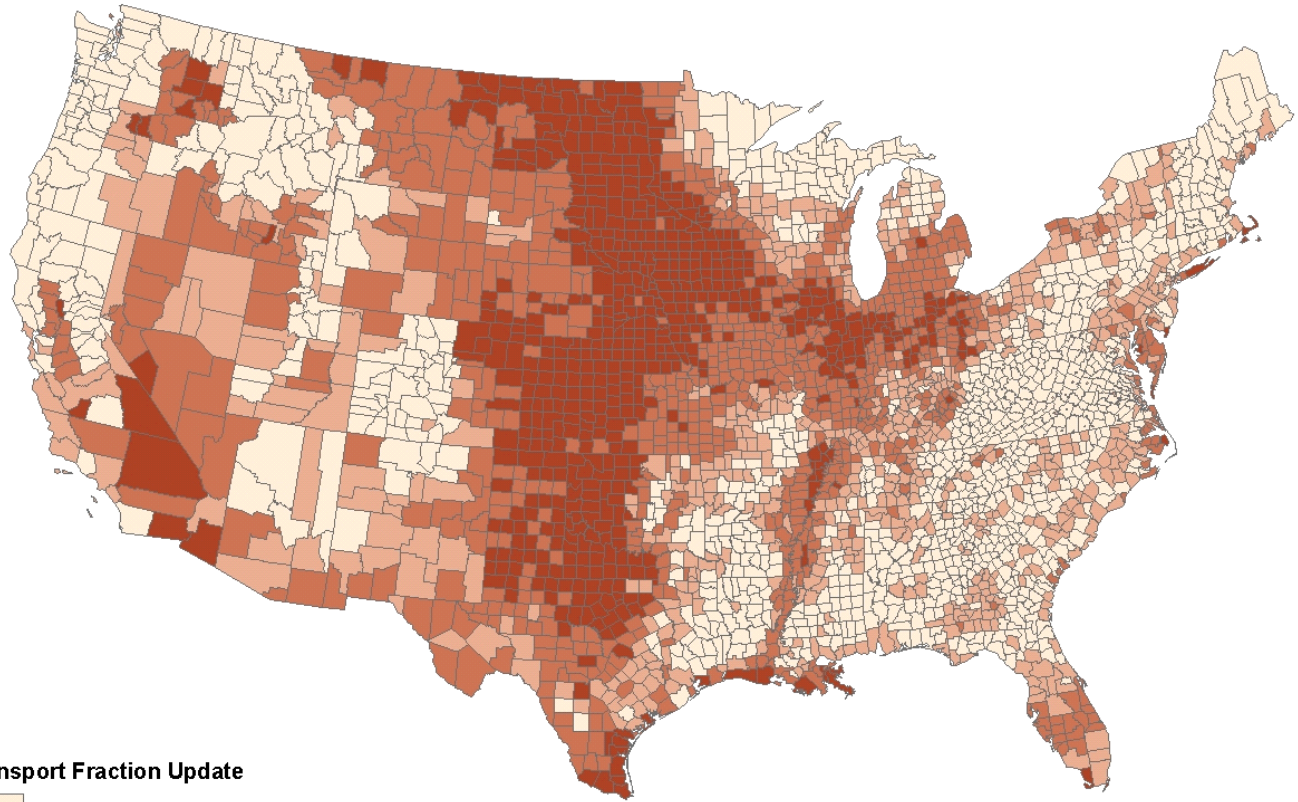
$$E(x) = \int_0^{\infty} M\ (h, x)\ dh$$

$$\mathbf{E(x) = E_0 \exp(-kx)}$$

Reduction of Plume Mass



Fugitive Dust Transport Fraction, by County (DRAFT)



Note - Transport Fraction (TF) is the fraction of fugitive dust estimated to leave the vicinity of its source and thus be available for long range transport.
It is based on the premise that much of the dust plume is below the height of surrounding vegetation and is thus subject to capture within the vegetative canopy.

Summary

- Near-source dust depletion results from
  - Electrostatic agglomeration
  - Deposition on groundcover
- Higher winds promote groundcover contact
- Capture efficiency is similar for PM-10 and PM-2.5
- Up to 50% plume loss occurs within 20-30 m from the source for tall vegetation

Summary

- Mitigation Term Offers Decided Advantages for Treatment of Plume Loss
  - Simpler approach
  - Requires only basic knowledge of groundcover adjacent to source
  - Conservatism can be added to representation
- Effective Method for Dealing with Current Over-Prediction of Dust Impacts
  - Will provide a source mitigation of at least a factor of 2 over a 50-100 m travel distance