John Watson, Desert Research Institute

"Source Apportionment and Network Design"

SOURCE APPORTIONMENT AND NETWORK DESIGN

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DOE Federal Energy Technology Center
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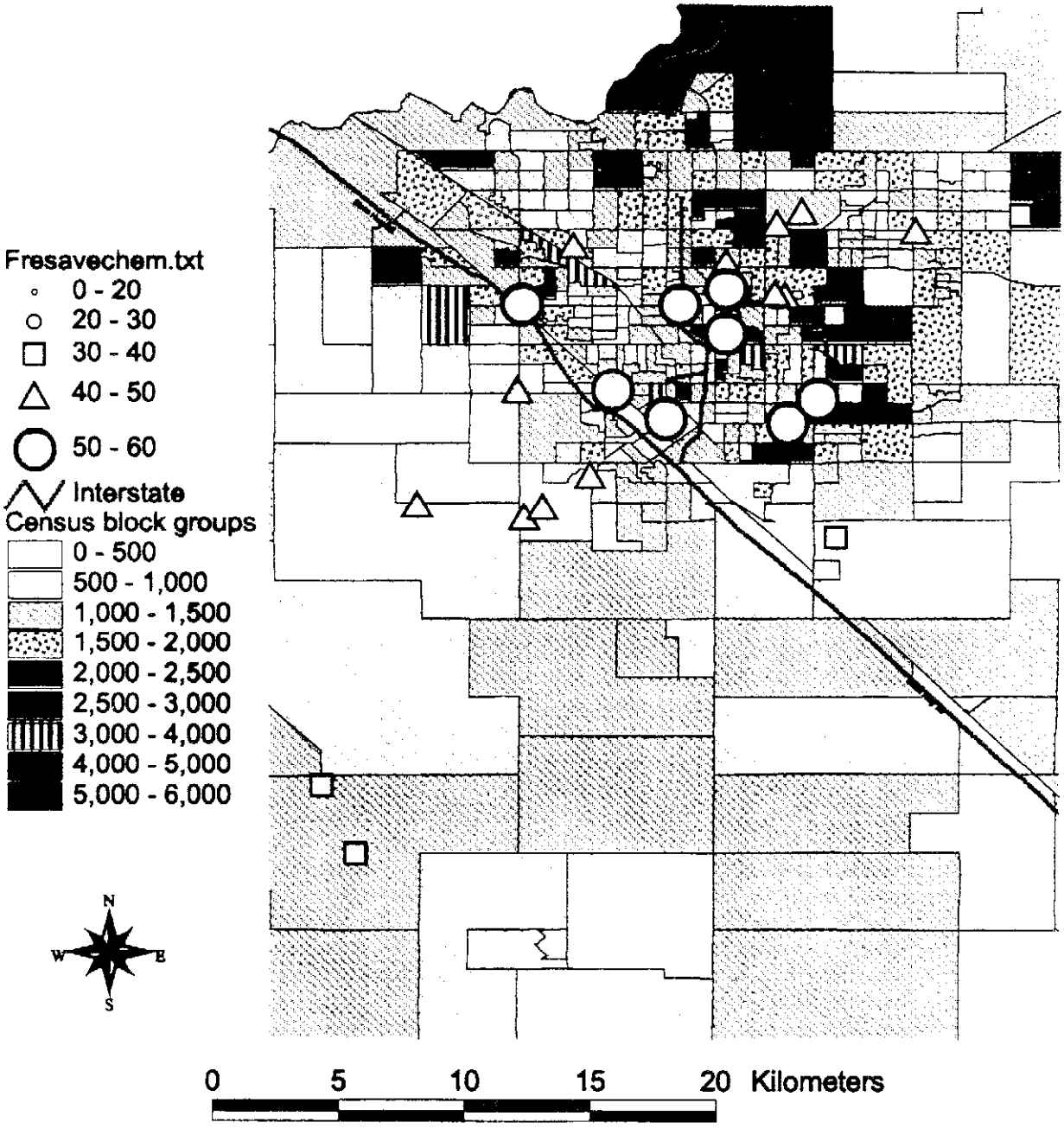
SPATIAL MONITORING SCALES

- Neighborhood-scale (1 to 10 km): Monitors measure concentrations that are well-mixed within a neighborhood, but that may differ substantially between neighborhood, e.g. residential wood combustion, cooking, light vehicle traffic, or very large industrial complexes such as integrated steel mills and coking facilities with elevated and surface emissions.
- Urban-scale (10 to 100 km): Monitors measure mixtures of emissions from several neighborhoods and the end-products of secondary transformation processes.

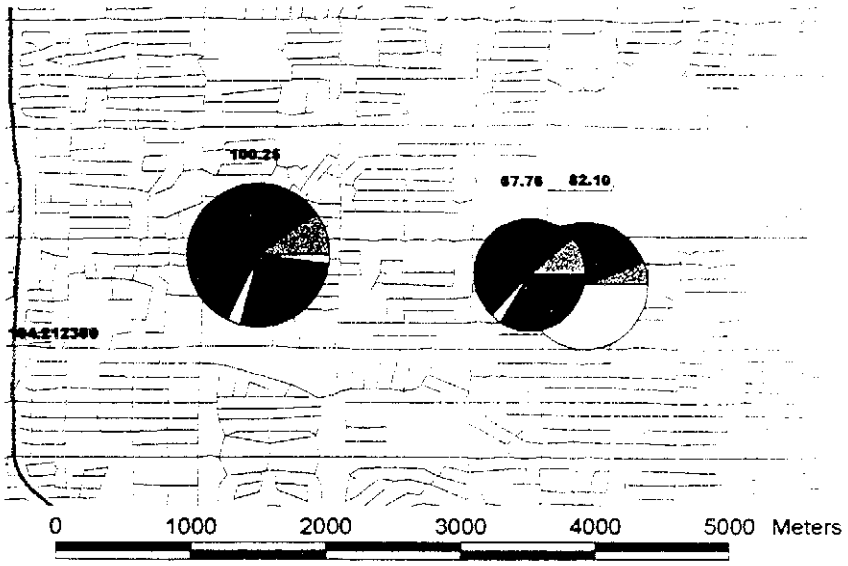
SPATIAL MONITORING SCALES

- Regional-scale (100 to 1000 km): Monitors measure mixtures of emissions and chemical end-products from several urban-scale source areas.
- Continental-scale background (1000 km to 10,000 km): Monitors mixtures of pollutants from several regions on a continent.
- Global-scale background(>10,000 km): Monitors quantify concentrations transported between different continents as well as naturally-emitted particles and precursors from sea spray, volcanoes, and windblown dust.

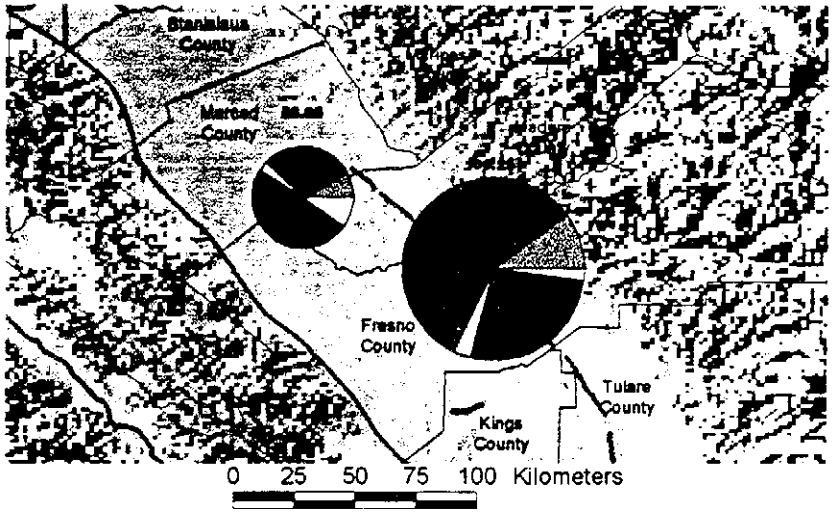
Fresno
Average PM10 Mass During IMS95 Winter Study



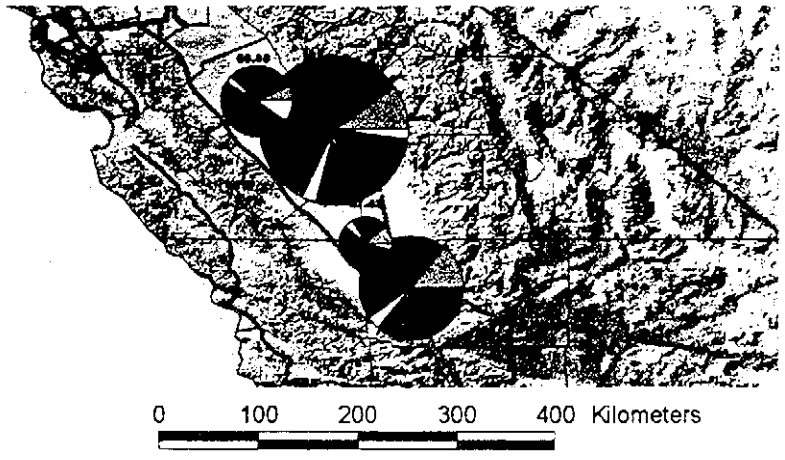
a) Neighborhood Scale
1 to 10 km



b) Urban Scale
10 to 100 km



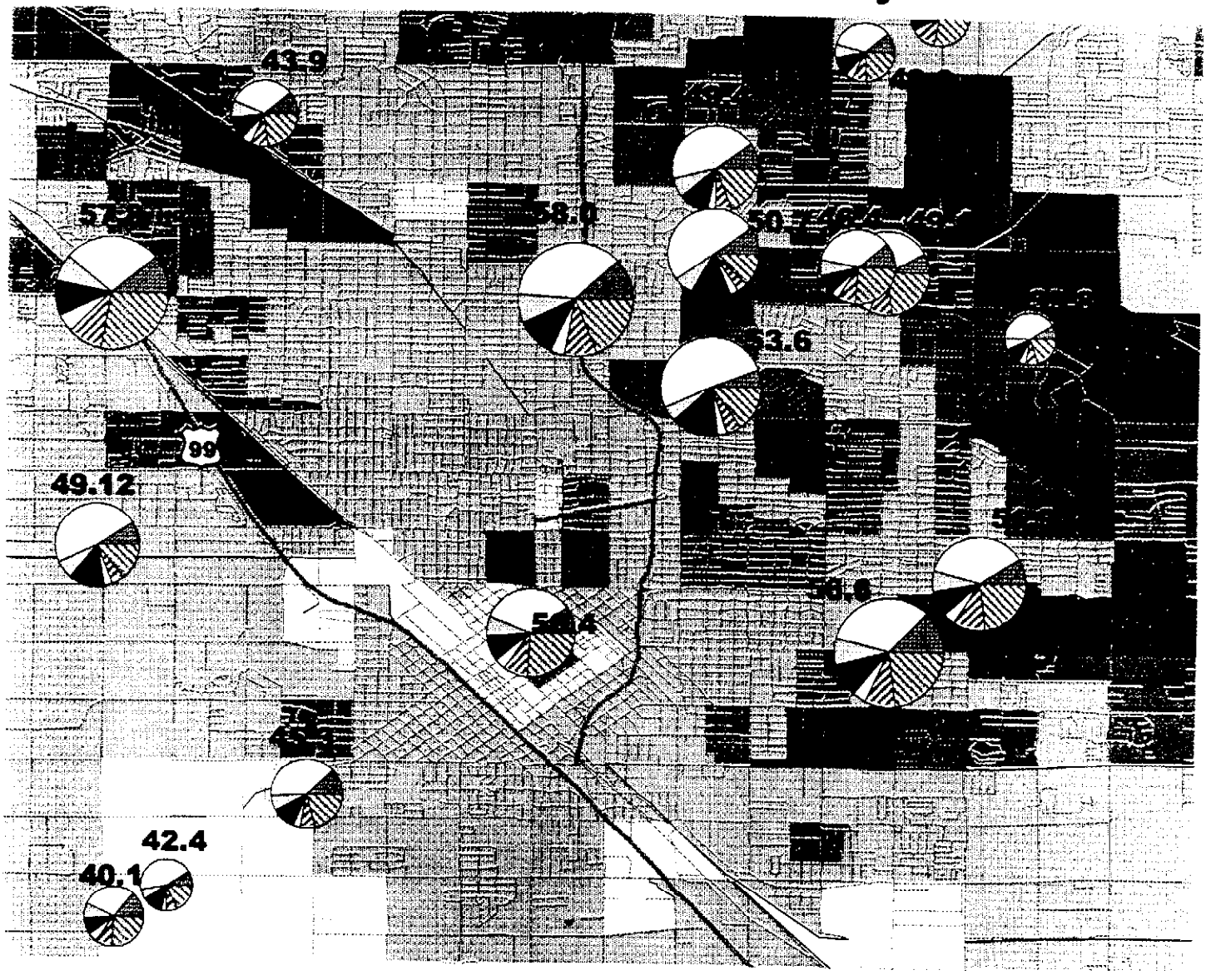
c) Regional Scale
100 to 1000 km

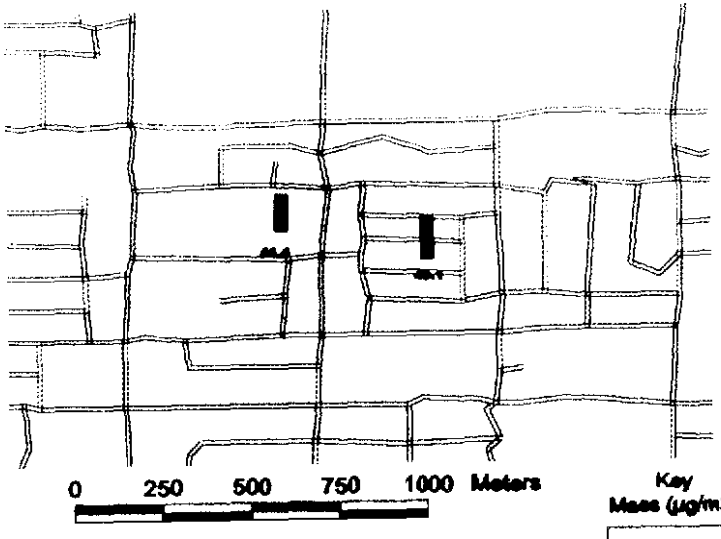


12/27/95 24-h PM10 Mass
- Crustal
- Organic Material
- Trace Species
- Elemental Carbon
- Sulfate Ion
- Ammonium Ion
- Nitrate Ion
- Unidentified

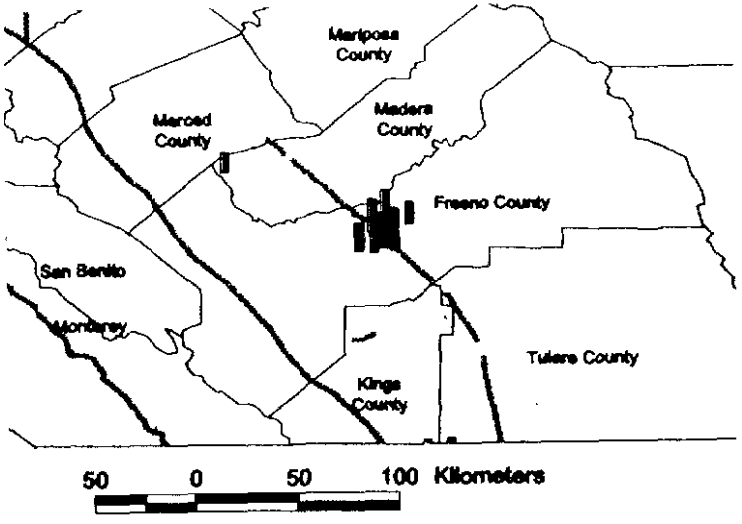
Roads
- Local, Secondary, State Hwy
- Interstate

Fresno
IMS95 Winter Saturation Study Sites

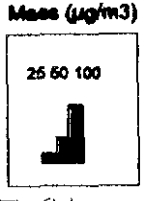




Middle-scale

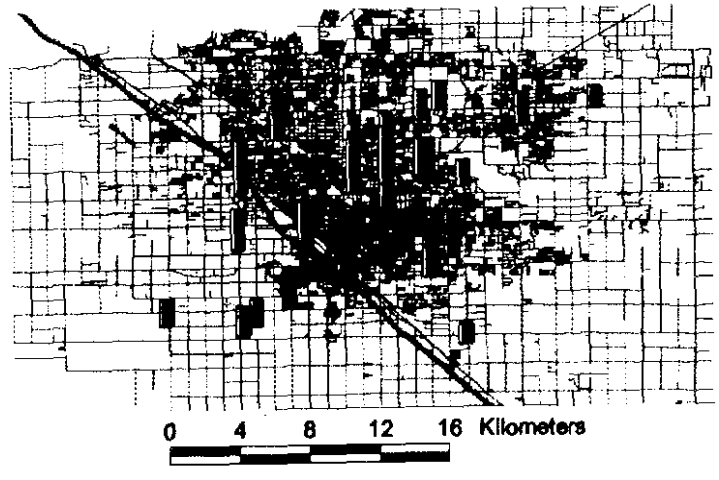


Urban-scale

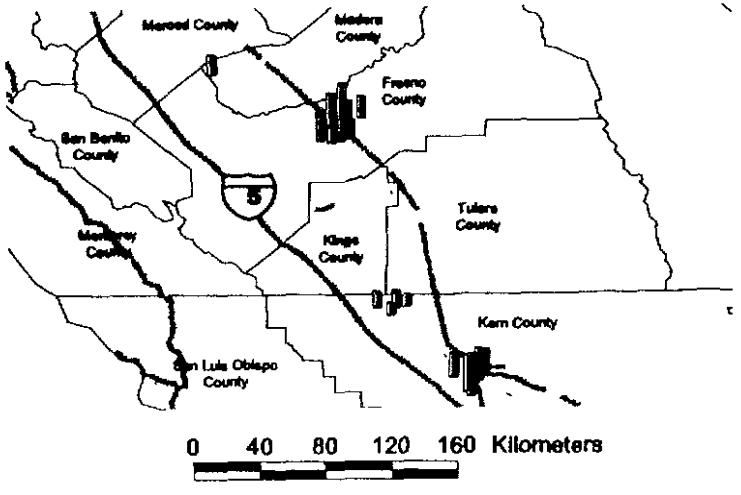


Average 24-h PM10 mass over IMS 95 Winter Study

Local, Secondary, State Hwy
Major highways



Neighborhood-scale

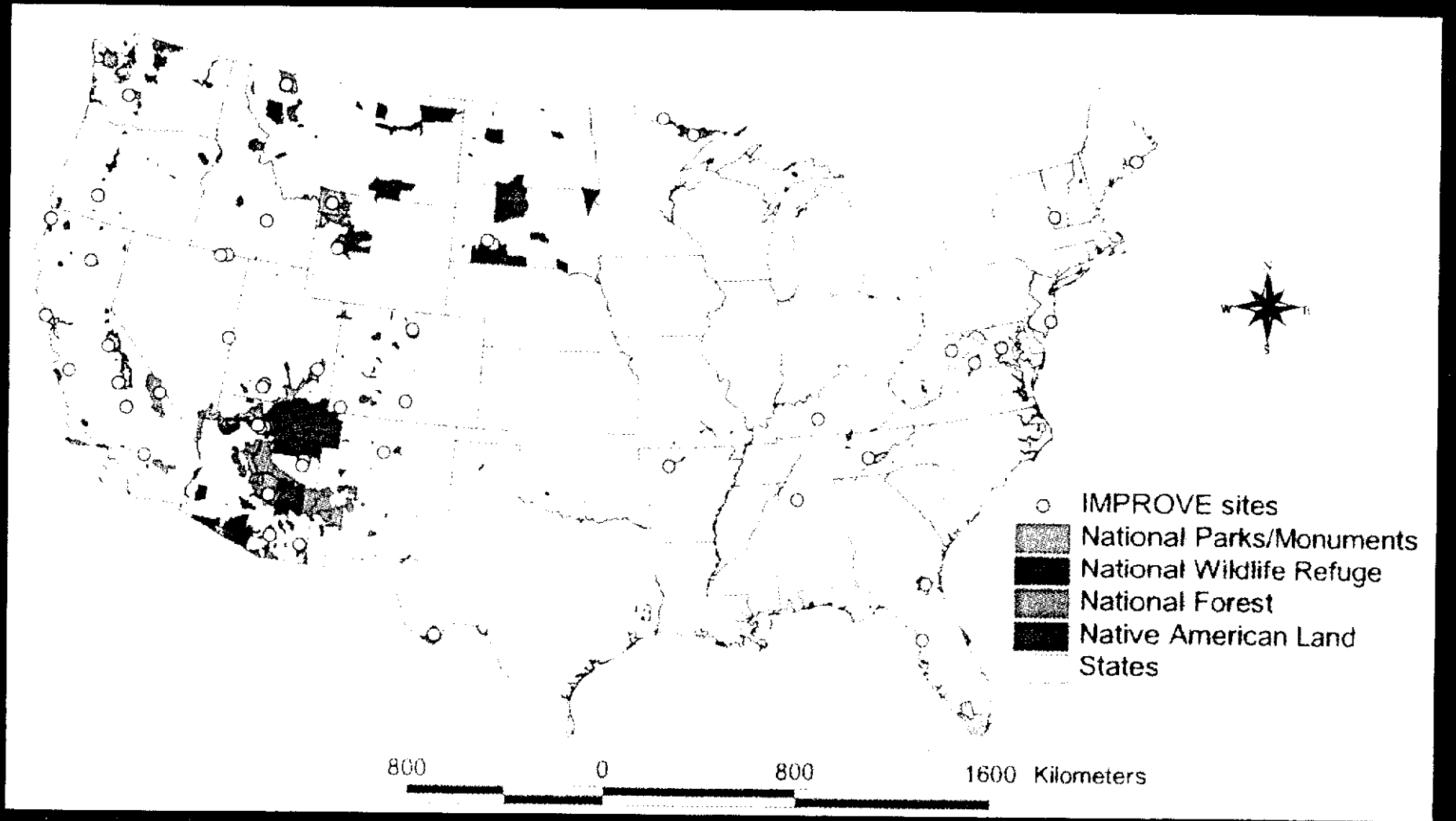


Regional-scale

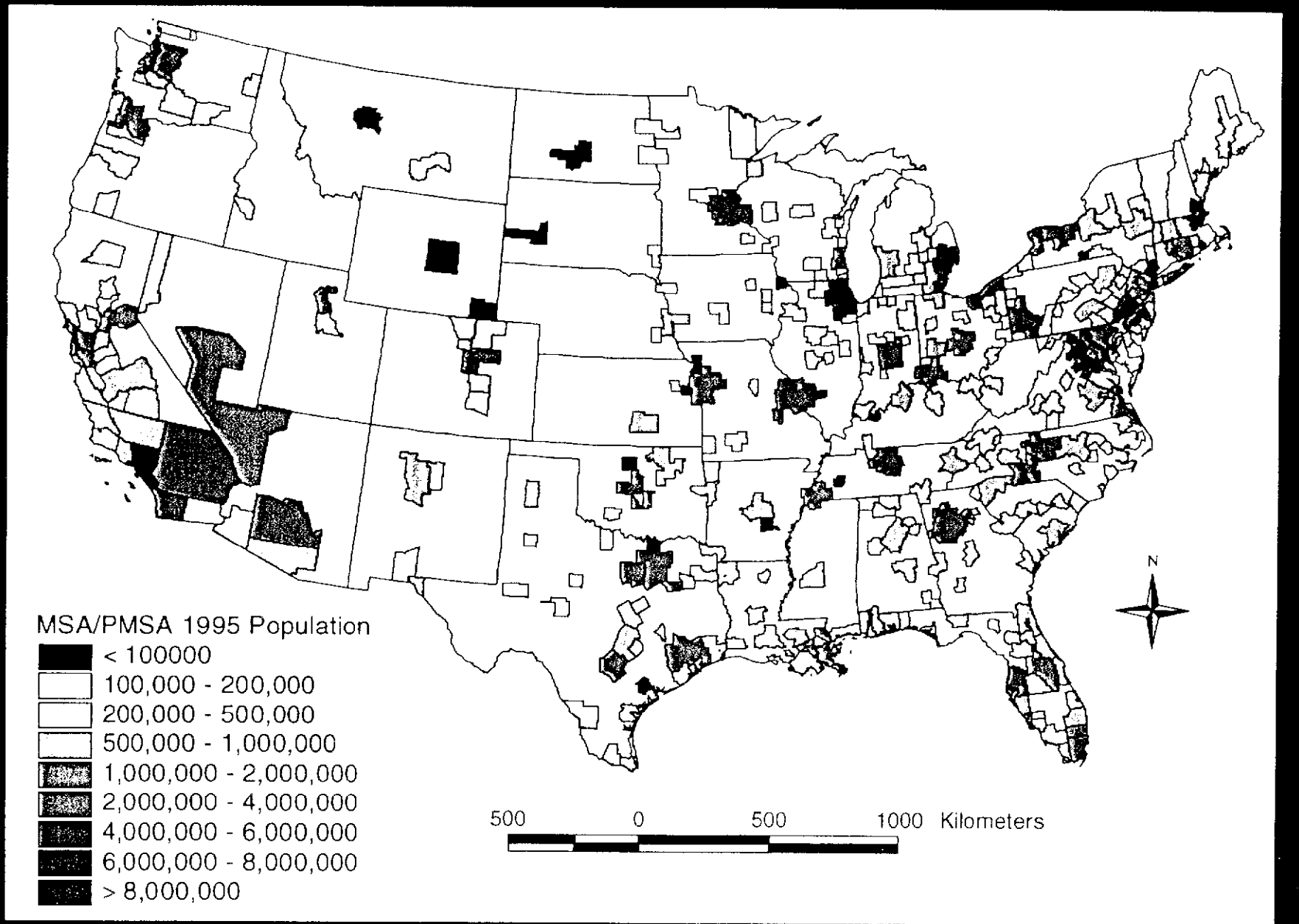
PROPOSED $PM_{2.5}$ NETWORKS

- Population-oriented or <u>co</u>mmunity-<u>re</u>presentative (CORE) sites for compliance. (Initially 850 sites nationwide. Total of 1,500 sites phased in over 3 years.)
- Collocation with PAMS sites.
- Special purpose monitoring sites to evaluate source contributions and to evaluate zones of representation for long-term sites.
- Transport and background sites for regional source assessment.

National Parks and Monuments, National Wildlife Refuges, National Forests, Indian Reservations, and IMPROVE Background Monitoring Sites



Metropolitan Statistical Areas



SOURCE APPORTIONMENT MODELS

- Conceptual model-Describes the relevant physical and chemical processes in an area. No mathematics.
- Emissions model. Estimates temporal and spatial emission rates based on activity level, emission rate per unit of activity, and meteorology.
- Meteorological model. Describes transport, dispersion, vertical mixing, and moisture in time and space.

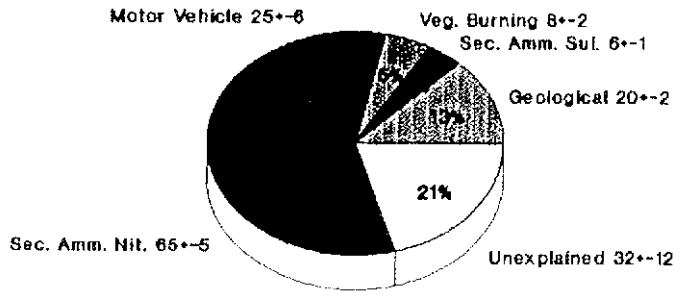
SOURCE APPORTIONMENT MODELS

- Air quality model. Estimates concentrations at receptors based on emissions, transport, and transformation.
- Chemical model. Describes transformation of gases to particles and equilibrium between gas and particlle phases.
- Chemical mass balance receptor model. Infers source contributions from chemical fingerprints of source emissions and receptor concentrations.
- Multivariate receptor models. Infer source profiles from ambient data.

Comparisons of Measurement: Source and Receptor Model Components to Reality on an Urban Scale

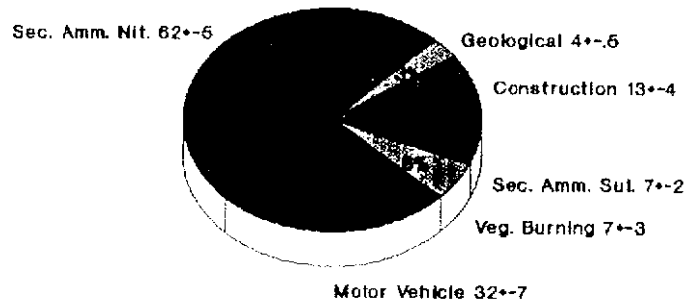
	Reality	Measurement	Source Model	Receptor Model
Air Volume (m^3)	10^{11}	10^3	10^7	10^3
No. of Variables	10^3	50	50	50
Range of Pollutant Concentrations (g)	10^{-15} to 10^{-3}	10^{-9} to 10^{-3}	10^{-6} to 10^{-3}	10^{-9} to 10^{-3}
No. of Variable Interactions	10^4	0	10	0
No. of Pollutant Sources	10^3	10	10^2	10
Range of Pollutant Emissions (g/sec)	10^{-2} to 10^3	1 to 10^3	1 to 10^3	1 to 10^3
Emissions Time Scale (sec)	10^2	10^7	10^7	10^7
Emissions Spatial Scale (m)	vert. 10 horiz. 100	10 100	10 100	10 100
Dispersion Time Scale (sec)	10^2	10^2	10^3	10^4
Dispersion Spatial Scale (m)	vert. 0 to 1,000 horiz. 100, micro 10^4, meso 10^6, macro	10, 100 1,000 few few	10 1,000 none none	10 1,000 none none

SOURCE CONTRIBUTIONS TO 24-HOUR PM10
12/11/88 at Stockton



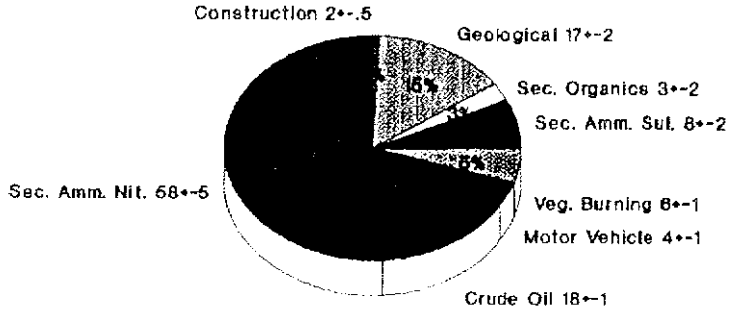
Calc./Meas. PM10: 132+-9/166+-8 ug/m3

SOURCE CONTRIBUTIONS TO 24-HOUR PM10
12/11/88 at Fresno



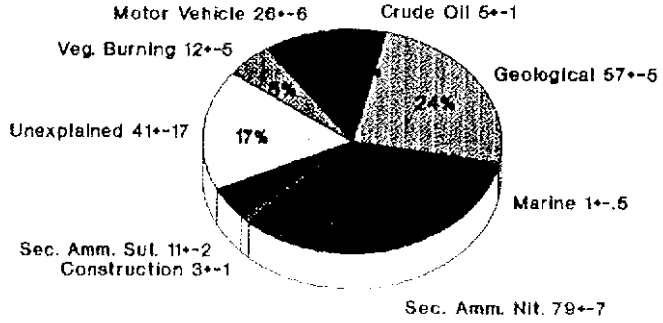
Calc./Meas. PM10: 113+-10/90+-6

SOURCE CONTRIBUTIONS TO 24-HOUR PM10
12/11/88 at Fellows

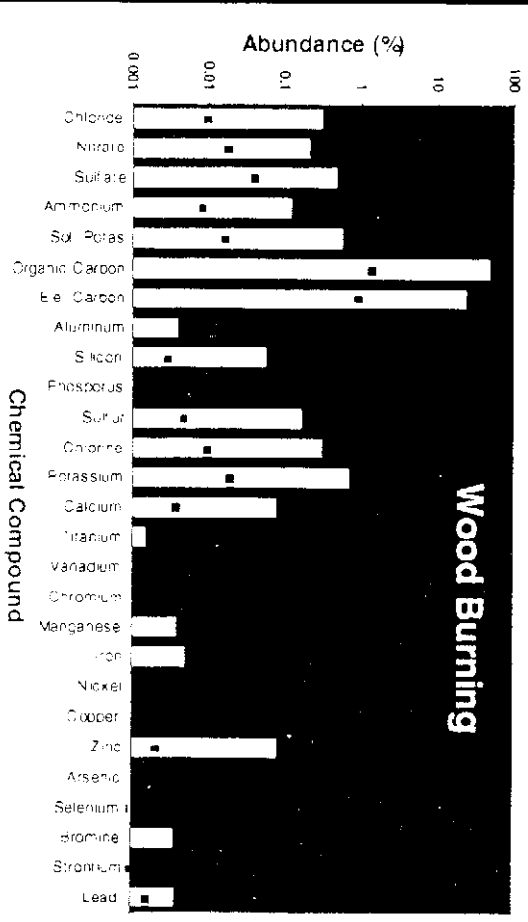


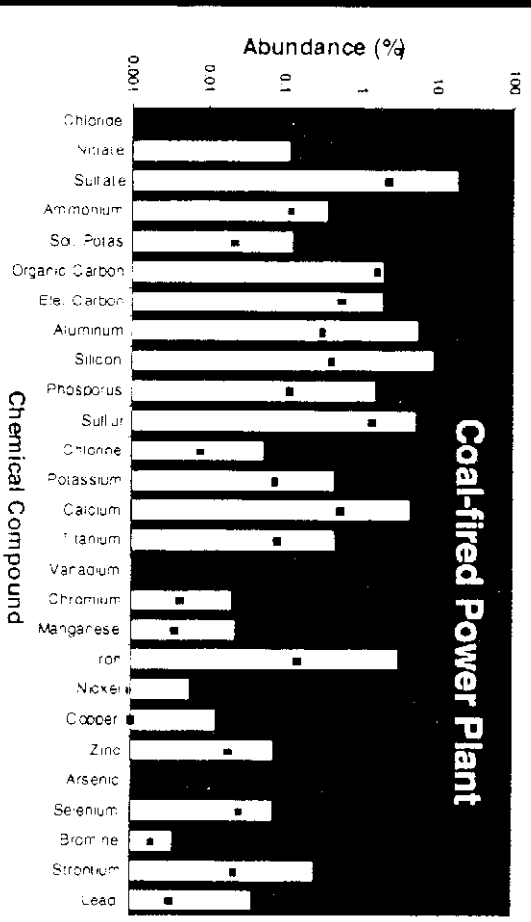
Calc./Meas. PM10: 126+-6/120+-6

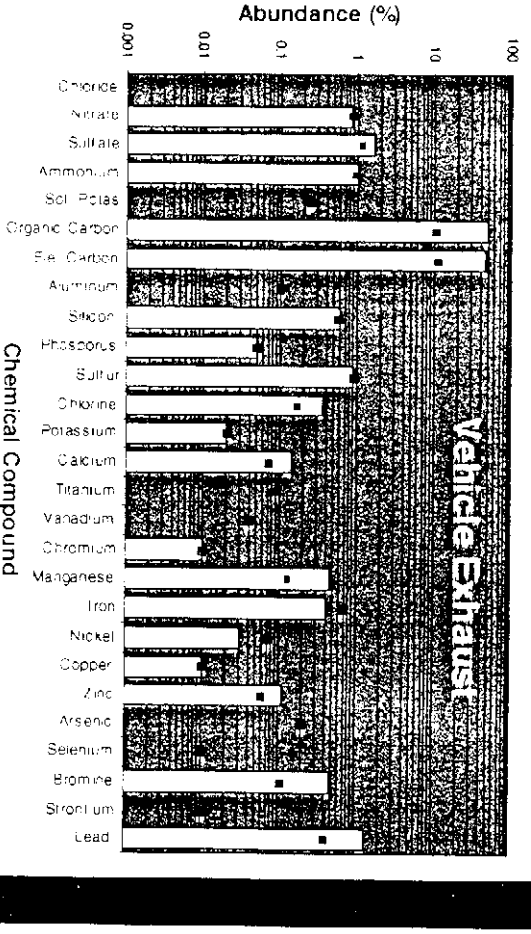
SOURCE CONTRIBUTIONS TO 24-HOUR PM10
12/11/88 at Bakersfield

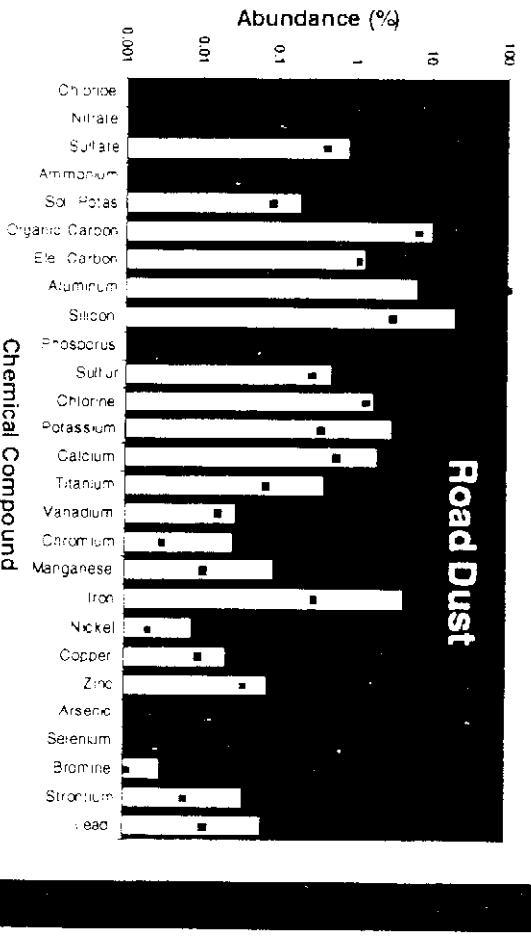


Calc./Meas. PM10: 194+-12/235+-12

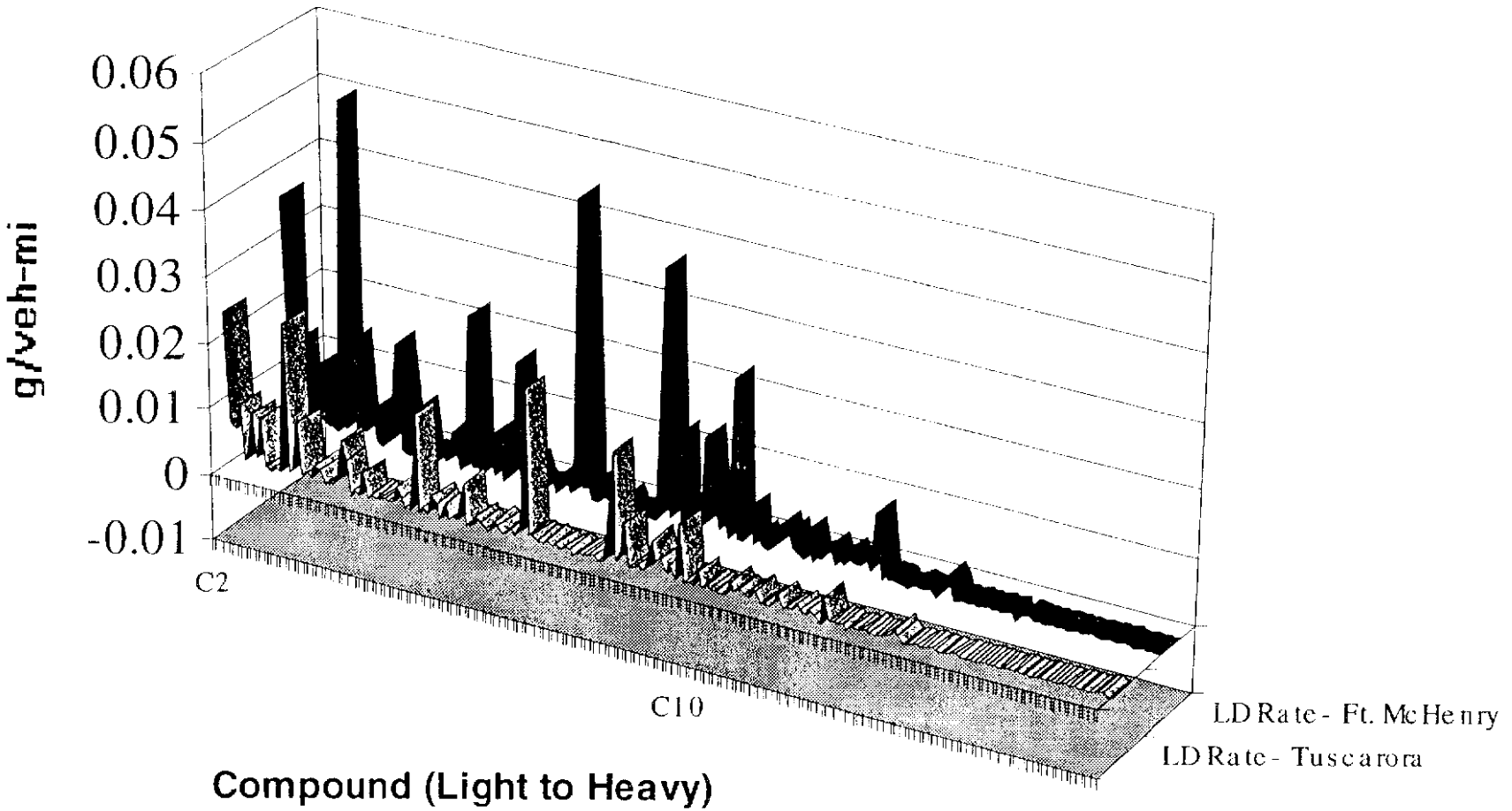

Abundance (%)
0.001
0.01
0.1
1
10
100
Chloride
Nitrate
Sulfate
Ammonium
Sol. Potas
Organic Carbon
Ele. Carbon
Aluminum
Silicon
Phosphorus
Sulfur
Chlorine
Potassium
Calcium
Titanium
Vanadium
Chromium
Manganese
Iron
Nickel
Copper
Zinc
Arsenic
Selenium
Bromine
Strontium
Lead
Chemical Compound
Wood Burning


Abundance (%)
0.001
0.01
0.1
1
10
100
Chloride
Nitrate
Sulfate
Ammonium
Sol. Potas
Organic Carbon
Ele. Carbon
Aluminum
Silicon
Phosphorus
Sulfur
Chlorine
Potassium
Calcium
Titanium
Vanadium
Chromium
Manganese
Iron
Nickel
Copper
Zinc
Arsenic
Selenium
Bromine
Strontium
Lead
Chemical Compound
Coal-fired Power Plant

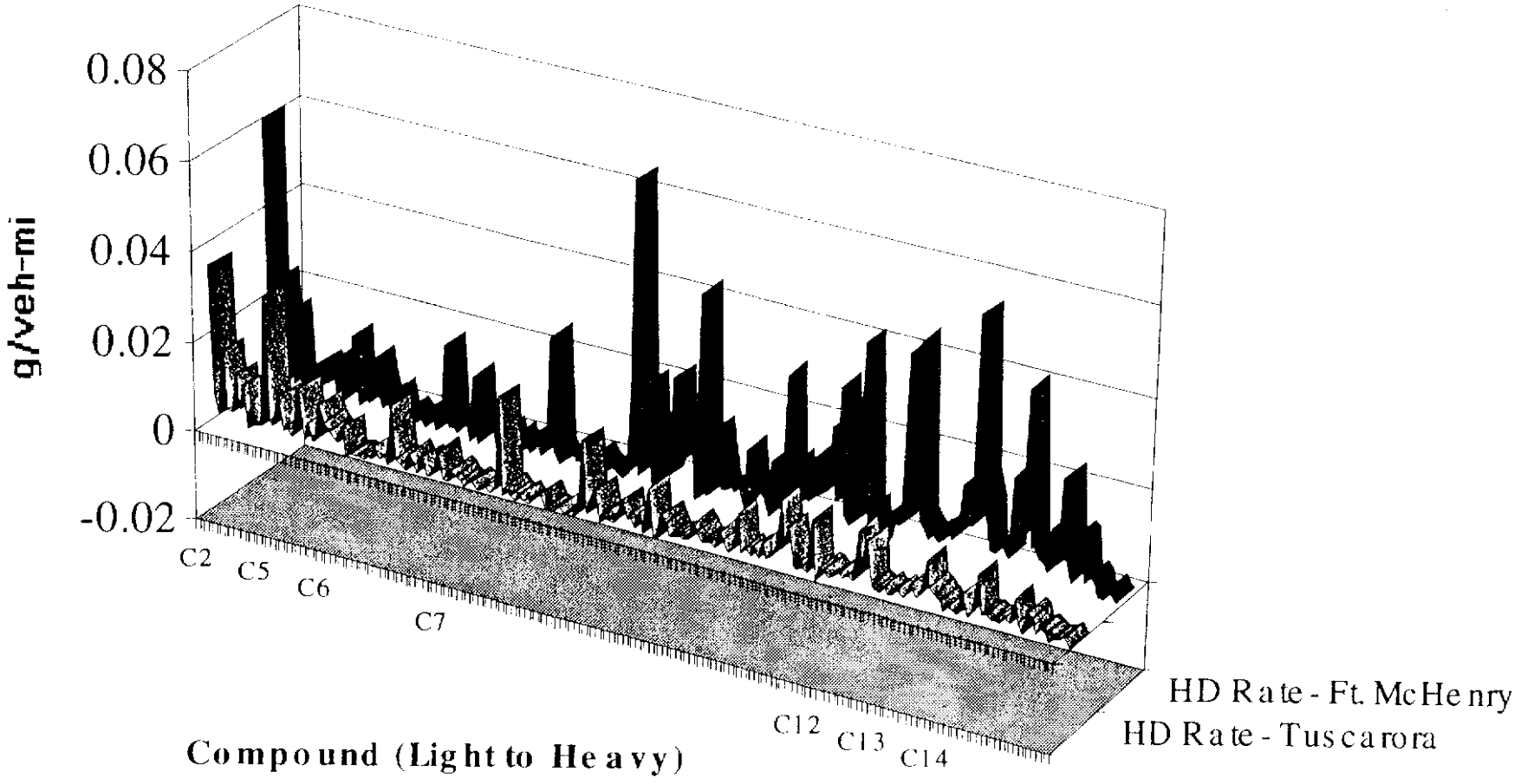

Abundance (%)
0.001
0.01
0.1
1
10
100
Chloride
Nitrate
Sulfate
Ammonium
Sol. Potas
Organic Carbon
Ele. Carbon
Aluminum
Silicon
Phosphorus
Sulfur
Chlorine
Potassium
Calcium
Titanium
Vanadium
Chromium
Manganese
Iron
Nickel
Copper
Zinc
Arsenic
Selenium
Bromine
Strontium
Lead
Chemical Compound
Vehicle Exhaust


Abundance (%)
0.001
0.01
0.1
1
10
100
Chloride
Nitrate
Sulfate
Ammonium
Sol. Potas
Organic Carbon
Ele. Carbon
Aluminum
Silicon
Phosphorus
Sulfur
Chlorine
Potassium
Calcium
Titanium
Vanadium
Chromium
Manganese
Iron
Nickel
Copper
Zinc
Arsenic
Selenium
Bromine
Strontium
Lead
Chemical Compound
Road Dust

Ft. McHenry vs. Tuscarora Light Duty Emission Rates



Ft. McHenry vs. Tuscarora Heavy Duty Emission Rates



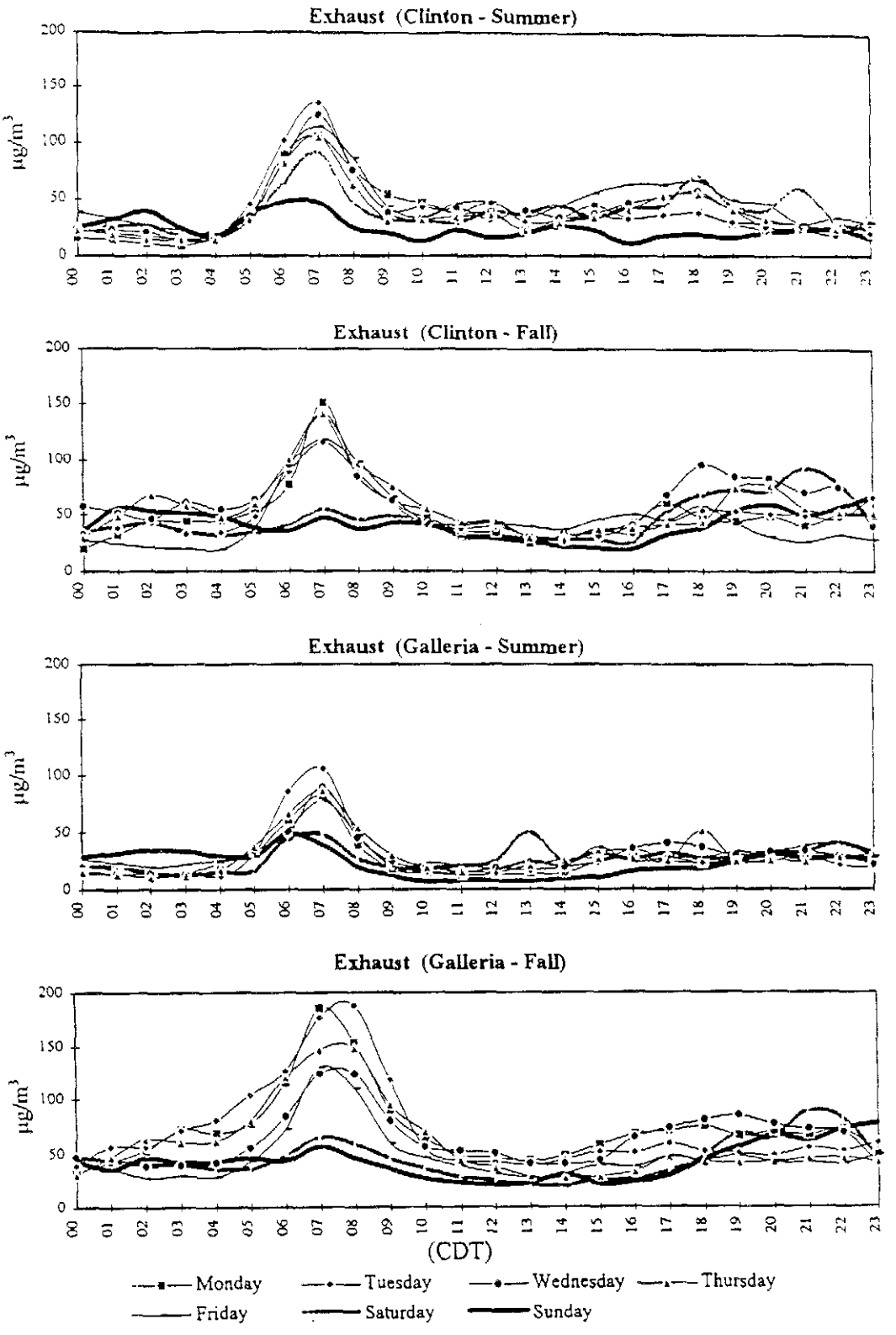


Figure 5-5 Diurnal Variations of Exhaust Contributions by Day of the Week ($\mu g/m^3$)

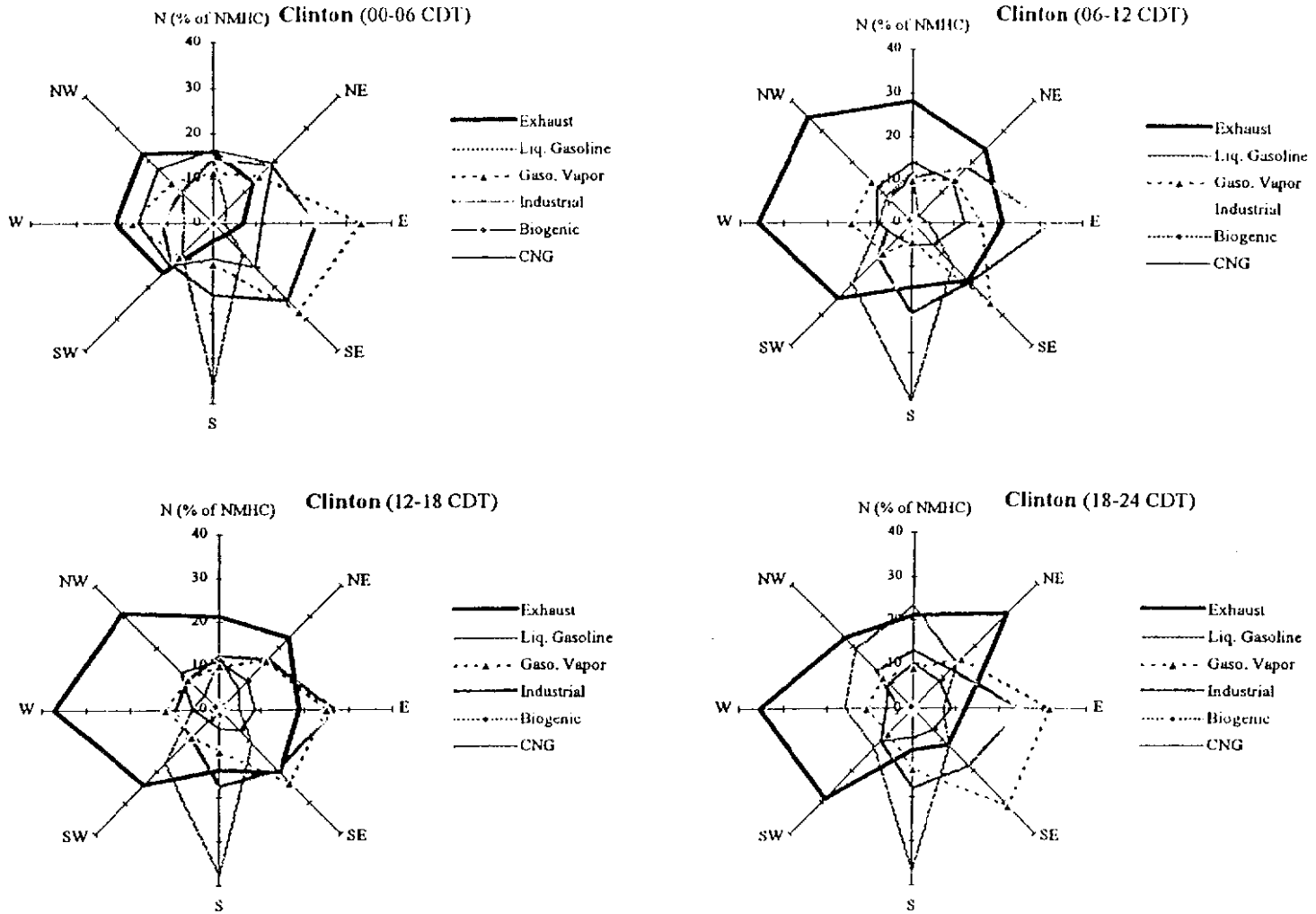


Figure 5-17. Wind directional dependence of source contributions by time of the day at Clinton site (wt%).

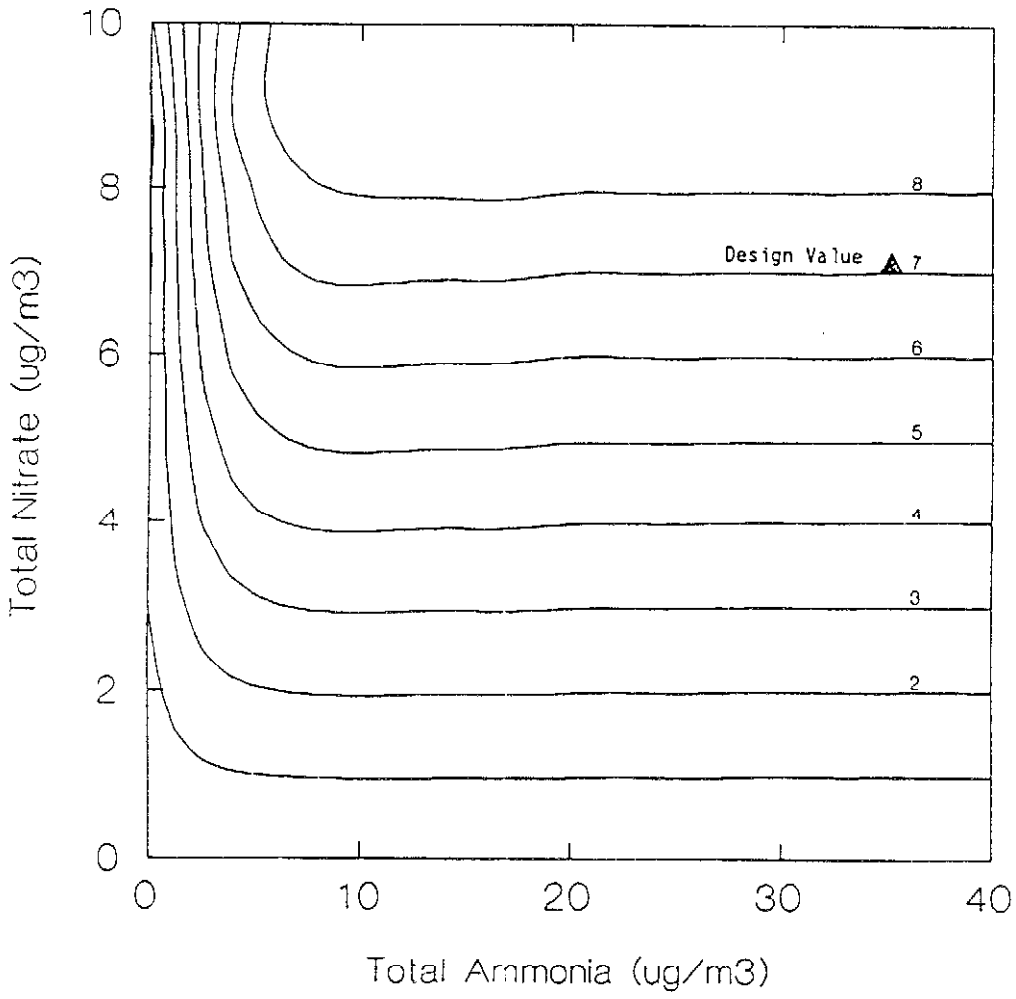


Figure 8-9. Particulate Nitrate Isopleths for High Relative Humidity Conditions on the Morning of 12/30/89. The number on each isopleth is the ammonium nitrate concentration in $\mu g/m^3$. The design value corresponds to the total nitrate and total ammonia measured on this sample.

CMB DATA TYPES: PM_{10} and $PM_{2.5}$

- Conventional: Filter samples analyzed for mass, elements, ions, carbon. Distinguishes vehicle exhaust, burning, dust, industrial dust, sea salt & road sand, coal burning, residual oil burning, various industries, secondary inorganic compounds.

- Unconventional: Filter and continuous samplers for isotopes, single particles, organic compounds, organic functional groupings, microbes, DNA. Possibly distinguish different dusts, different vehicle types, cooking, secondary organics.

CMB DATA TYPES: VOCS

- Conventional: Hydrocarbons in canisters, set list of species. Distinguishes vehicle exhaust, evaporative, liquid gasoline, LNG, CNG, biogenic (lower limit), industrial.

- Unconventional: Canister, TENAX, DNPH, XAD/PUF, continuous monitors. Additional peak identification from canister, C_8 to C_{20} hydrocarbons, aldehydes, semi-volatiles. May distinguish vehicle sub-types, specific industries, garbage.

CONTROL DECISIONS MADE AFTER CMB STUDIES

- Burning bans, new technology stoves, stove phase-outs, gas appliances.
- Some, but not all, unpaved roads need suppressants, and most are ineffective.
- Ordinary street sweepers on relatively clean roads create PM_{10}.
- Mexicali causes PM_{10} in Calexico, but not in other parts of Imperial County.

CONTROL DECISIONS MADE AFTER CMB STUDIES

- Sulfur dioxide reductions, or none, at coal-fired power stations stations.
- Various process changes and abatement activities at steel mills.
- Vehicle emissions models need improvement.
- Move dairies out of SoCAB.

RESEARCH RECOMMENDATIONS

- Coordinated monitoring networks on several spatial scales, especially to assess superposition of neighborhood, urban, and regional zones of influence.
- Development and application of high time resolution particle chemistry measurement methods.
- More emphasis on formulation of conceptual models, less emphasis on applying complex mathematical source apportionment models to a few case-studies.

RESEARCH RECOMMENDATIONS

- More emissions characterization, especially for characteristics that allow their quantitative apportionment from ambient samples.
- Integration of source and receptor models. Use complementary source apportionment methods to detect and correct inadequacies.
- GIS-based, bottom-up, emissions inventories. Current inventories have inadequate scientific basis, yet they are used for major decisions.