

4.0 SPATIAL AND TEMPORAL DISTRIBUTIONS OF PM_{2.5} and PM₁₀

The most rudimentary form of receptor modeling consists of examination of spatial and temporal distributions of atmospheric constituents and relative abundances of certain chemical species. When coupled with a conceptual understanding of the emissions sources, meteorology, and chemical transformation mechanisms, this receptor-oriented analysis provides qualitative, and even semi-quantitative, evidence of relationships between source emissions and receptor concentrations. This section examines the temporal and spatial distribution of PM_{2.5} and PM₁₀, their chemical components, and several of the gaseous precursors of those components. Lurmann and Main (1992) have completed a similar descriptive analysis for the VOCs, and such an analysis is not repeated here.

4.1 Statistical Summary of Chemical Concentrations

Tables 4-1 through 4-4 present averages, standard deviations, and maximum concentrations for 24-hour average PM_{2.5} and PM₁₀ chemical concentrations for the summer and fall periods. A sample-volume-weighted average of the five diurnal samples taken during SCAQS was calculated to obtain the 24-hour values. The averages in these tables are more useful for comparison with results from earlier studies in the SoCAB (e.g., Gray *et al.*, 1986; Solomon *et al.*, 1989; Chow *et al.*, 1992) and because they can be related to the 24-hour federal PM₁₀ standards. It is expected that these averages will be higher than those which should be compared to the annual average PM₁₀ standard because SCAQS sampling days were intentionally biased toward higher pollution concentrations. The particulate nitrate and ammonium concentrations reported in this table represent those measured on the Teflon-membrane filter (Channels 9 and 12 of the SCAQS sampler shown in Figure 3-2) rather than the particulate nitrate and ammonium measured in Channels 3 and 5, so that the values will be comparable to those found in the compliance monitoring network (Table 2-3).

Wolff *et al.* (1991) compared averages during the SCAQS episodes to those found throughout the summer and fall of 1987 at the Claremont and Long Beach sites and determined that the SCAQS episodes were successful in acquiring higher than average particulate concentrations by about one-third for most of the measured species. Wolff *et al.* (1991) also added the volatilized particulate nitrate and ammonium to their mass, nitrate, and ammonium concentrations, so their averages differ somewhat from those shown here. The effects of these sampling artifacts are discussed later in this section. Tables 4-1 to 4-4 show differences in the average chemical compositions among particle size, sampling site, and season which are consistent with observations from earlier studies.

Tables 4-2 and 4-4 show that the 24-hour federal PM₁₀ standard was exceeded only at the Rubidoux site during the summer campaign. This 164 $\mu\text{g}/\text{m}^3$ PM₁₀ exceedance occurred on August 28, 1987. Daily PM₁₀ exceedances were more frequent during the fall campaign, and they occurred at five sites on December 3, 1987: 162 $\mu\text{g}/\text{m}^3$ at the Burbank site; 157 $\mu\text{g}/\text{m}^3$ at the Downtown Los Angeles site; 194 $\mu\text{g}/\text{m}^3$ at the Long Beach site; 203 $\mu\text{g}/\text{m}^3$ at the

Table 4-1
 Statistical Summary of Twenty-Four Hour PM₁₀ Measurements Between 6/19/87 and 9/3/87 at Nine SCAQS Sites

| Chemical Species | Burbank | | | Downtown Los Angeles | | | Hawthorne | | |
|--|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) |
| Mass | 42.60 | 13.49 | 63.32 | 41.15 | 12.81 | 63.67 | 30.52 | 15.22 | 61.08 |
| Chloride (Cl) | 0.21 | 0.12 | 0.47 | 0.21 | 0.14 | 0.49 | 0.27 | 0.28 | 0.71 |
| Nitrate (NO ₃) | 5.11 | 2.71 | 10.14 | 4.34 | 2.27 | 9.26 | 1.25 | 0.64 | 2.25 |
| Sulfate (SO ₄ ²⁻) | 8.72 | 4.49 | 17.83 | 9.41 | 4.69 | 18.50 | 9.67 | 4.89 | 17.83 |
| Ammonium (NH ₄ ⁺) | 4.30 | 1.93 | 7.53 | 4.28 | 2.13 | 7.86 | 3.59 | 1.57 | 6.21 |
| Organic Carbon (OC) | 9.13 | 1.64 | 10.99 | 8.27 | 1.47 | 10.83 | 3.35 | 1.14 | 5.34 |
| Elemental Carbon (EC) | 2.21 | 0.77 | 3.41 | 2.37 | 1.19 | 5.40 | 0.70 | 0.58 | 1.87 |
| Sodium (Na) | 0.1834 | 0.1328 | 0.4213 | 0.2016 | 0.1439 | 0.4872 | 0.2531 | 0.1967 | 0.6157 |
| Magnesium (Mg) | 0.0321 | 0.0169 | 0.0657 | 0.0244 | 0.0168 | 0.0581 | 0.0347 | 0.0194 | 0.0680 |
| Aluminum (Al) | 0.0252 | 0.0109 | 0.0545 | 0.0351 | 0.0177 | 0.0775 | 0.0299 | 0.0137 | 0.0493 |
| Silicon (Si) | 0.0449 | 0.0456 | 0.1262 | 0.0515 | 0.0551 | 0.1832 | 0.0505 | 0.0437 | 0.1356 |
| Phosphorus (P) | 0.0142 | 0.0060 | 0.0282 | 0.0604 | 0.0789 | 0.2132 | 0.0086 | 0.0032 | 0.0137 |
| Sulfur (S) | 2.6846 | 1.2905 | 5.1636 | 2.8324 | 1.3505 | 5.2718 | 2.8478 | 1.3607 | 5.0794 |
| Chlorine (Cl) | 0.0991 | 0.1205 | 0.3720 | 0.0932 | 0.1176 | 0.3621 | 0.0601 | 0.1721 | 0.6042 |
| Potassium (K) | 0.0375 | 0.0159 | 0.0644 | 0.0411 | 0.0159 | 0.0685 | 0.0299 | 0.0139 | 0.0491 |
| Calcium (Ca) | 0.0166 | 0.0202 | 0.0447 | 0.0223 | 0.0206 | 0.0501 | 0.0347 | 0.0350 | 0.1023 |
| Titanium (Ti) | 0.0032 | 0.0024 | 0.0077 | 0.0051 | 0.0037 | 0.0107 | 0.0068 | 0.0071 | 0.0263 |
| Vanadium (V) | 0.0059 | 0.0010 | 0.0075 | 0.0055 | 0.0009 | 0.0076 | 0.0061 | 0.0011 | 0.0085 |
| Chromium (Cr) | 0.0191 | 0.0066 | 0.0393 | 0.0216 | 0.0083 | 0.0401 | 0.0198 | 0.0053 | 0.0324 |
| Manganese (Mn) | 0.0129 | 0.0020 | 0.0179 | 0.0156 | 0.0033 | 0.0233 | 0.0130 | 0.0008 | 0.0147 |
| Iron (Fe) | 0.0718 | 0.0277 | 0.1119 | 0.0987 | 0.0518 | 0.1904 | 0.0287 | 0.0198 | 0.0607 |
| Nickel (Ni) | 0.0042 | 0.0006 | 0.0052 | 0.0049 | 0.0011 | 0.0084 | 0.0057 | 0.0025 | 0.0128 |
| Copper (Cu) | 0.0183 | 0.0112 | 0.0342 | 0.0629 | 0.0409 | 0.1658 | 0.0727 | 0.0483 | 0.1496 |
| Zinc (Zn) | 0.0178 | 0.0080 | 0.0291 | 0.0896 | 0.0408 | 0.1607 | 0.0585 | 0.0277 | 0.0929 |
| Arsenic (As) | 0.0142 | 0.0081 | 0.0338 | 0.0221 | 0.0071 | 0.0364 | 0.0163 | 0.0034 | 0.0215 |
| Selenium (Se) | 0.0121 | 0.0039 | 0.0205 | 0.0125 | 0.0041 | 0.0183 | 0.0133 | 0.0040 | 0.0213 |
| Bromine (Br) | 0.0155 | 0.0110 | 0.0465 | 0.0133 | 0.0058 | 0.0248 | 0.0103 | 0.0007 | 0.0119 |
| Strontium (Sr) | 0.0210 | 0.0107 | 0.0542 | 0.0189 | 0.0029 | 0.0229 | 0.0207 | 0.0037 | 0.0306 |
| Barium (Ba) | 0.0145 | 0.0097 | 0.0404 | 0.0149 | 0.0085 | 0.0318 | 0.0061 | 0.0019 | 0.0101 |
| Mercury (Hg) | 0.0203 | 0.0036 | 0.0305 | 0.0209 | 0.0029 | 0.0269 | 0.0225 | 0.0041 | 0.0308 |
| Lead (Pb) | 0.0475 | 0.0272 | 0.1224 | 0.0381 | 0.0159 | 0.0729 | 0.0334 | 0.0054 | 0.0495 |

Table 4-1 (continued)
 Statistical Summary of Twenty-Four Hour PM_{2.5} Measurements Between 6/19/87 and 9/3/87 at Nine SCAQS Sites

| Chemical Species | Long Beach | | | Anaheim | | | Rubidoux | | |
|--|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) |
| Mass | 25.44 | 6.72 | 36.45 | 26.76 | 7.24 | 38.63 | 63.86 | 20.14 | 94.64 |
| Chloride (Cl) | 0.15 | 0.13 | 0.37 | 0.11 | 0.10 | 0.31 | 0.35 | 0.12 | 0.59 |
| Nitrate (NO ₃) | 1.44 | 0.80 | 2.51 | 2.36 | 1.06 | 4.01 | 21.19 | 8.64 | 32.25 |
| Sulfate (SO ₄ ²⁻) | 7.42 | 2.44 | 11.41 | 6.49 | 1.93 | 10.02 | 7.13 | 2.09 | 9.96 |
| Ammonium (NH ₄ ⁺) | 3.03 | 1.33 | 5.77 | 2.40 | 0.87 | 3.51 | 8.73 | 3.21 | 13.27 |
| Organic Carbon (OC) | 3.35 | 1.22 | 6.28 | 4.72 | 1.46 | 7.31 | 8.47 | 1.39 | 10.68 |
| Elemental Carbon (EC) | 0.99 | 0.83 | 3.13 | 1.20 | 0.93 | 3.42 | 1.73 | 0.84 | 3.36 |
| Sodium (Na) | 0.2416 | 0.1712 | 0.4737 | 0.2318 | 0.1702 | 0.4724 | 0.0981 | 0.0823 | 0.2254 |
| Magnesium (Mg) | 0.0315 | 0.0220 | 0.0721 | 0.0360 | 0.0239 | 0.0746 | 0.0475 | 0.0184 | 0.0789 |
| Aluminum (Al) | 0.0836 | 0.0734 | 0.2537 | 0.0351 | 0.0249 | 0.0918 | 0.1329 | 0.0919 | 0.3146 |
| Silicon (Si) | 0.1526 | 0.1326 | 0.3987 | 0.0338 | 0.0351 | 0.1017 | 0.2863 | 0.1711 | 0.6514 |
| Phosphorus (P) | 0.0127 | 0.0119 | 0.0442 | 0.0098 | 0.0064 | 0.0204 | 0.0310 | 0.0106 | 0.0535 |
| Sulfur (S) | 2.3058 | 0.8006 | 3.6401 | 1.9246 | 0.5678 | 3.0168 | 2.1495 | 0.6659 | 3.1277 |
| Chlorine (Cl) | 0.0289 | 0.0552 | 0.1826 | 0.0241 | 0.0296 | 0.0910 | 0.1886 | 0.1449 | 0.4176 |
| Potassium (K) | 0.0418 | 0.0336 | 0.1132 | 0.0929 | 0.1077 | 0.3346 | 0.0998 | 0.0346 | 0.1730 |
| Calcium (Ca) | 0.0469 | 0.0295 | 0.0934 | 0.0084 | 0.0117 | 0.0312 | 0.2969 | 0.1775 | 0.6370 |
| Titanium (Ti) | 0.0121 | 0.0106 | 0.0324 | 0.0036 | 0.0052 | 0.0151 | 0.0149 | 0.0083 | 0.0300 |
| Vanadium (V) | 0.0068 | 0.0018 | 0.0116 | 0.0056 | 0.0015 | 0.0098 | 0.0054 | 0.0009 | 0.0069 |
| Chromium (Cr) | 0.0220 | 0.0063 | 0.0331 | 0.0185 | 0.0039 | 0.0275 | 0.0184 | 0.0039 | 0.0295 |
| Manganese (Mn) | 0.0143 | 0.0037 | 0.0258 | 0.0122 | 0.0014 | 0.0152 | 0.0147 | 0.0023 | 0.0184 |
| Iron (Fe) | 0.0714 | 0.0756 | 0.2244 | 0.0296 | 0.0350 | 0.0789 | 0.2062 | 0.0974 | 0.4142 |
| Nickel (Ni) | 0.0110 | 0.0072 | 0.0236 | 0.0045 | 0.0013 | 0.0083 | 0.0047 | 0.0003 | 0.0051 |
| Copper (Cu) | 0.0047 | 0.0004 | 0.0050 | 0.0396 | 0.0519 | 0.1497 | 0.0165 | 0.0090 | 0.0299 |
| Zinc (Zn) | 0.0267 | 0.0220 | 0.0602 | 0.0333 | 0.0334 | 0.0856 | 0.0131 | 0.0062 | 0.0218 |
| Arsenic (As) | 0.0133 | 0.0050 | 0.0263 | 0.0121 | 0.0047 | 0.0209 | 0.0190 | 0.0067 | 0.0311 |
| Selenium (Se) | 0.0102 | 0.0027 | 0.0163 | 0.0115 | 0.0053 | 0.0222 | 0.0123 | 0.0035 | 0.0181 |
| Bromine (Br) | 0.0105 | 0.0018 | 0.0158 | 0.0113 | 0.0030 | 0.0175 | 0.0121 | 0.0036 | 0.0206 |
| Strontium (Sr) | 0.0206 | 0.0044 | 0.0328 | 0.0176 | 0.0020 | 0.0212 | 0.0199 | 0.0040 | 0.0297 |
| Barium (Ba) | 0.0076 | 0.0041 | 0.0163 | 0.0075 | 0.0040 | 0.0158 | 0.0088 | 0.0033 | 0.0144 |
| Mercury (Hg) | 0.0227 | 0.0039 | 0.0303 | 0.0204 | 0.0037 | 0.0266 | 0.0218 | 0.0033 | 0.0265 |
| Lead (Pb) | 0.0356 | 0.0076 | 0.0507 | 0.0346 | 0.0071 | 0.0506 | 0.0350 | 0.0067 | 0.0520 |

Table 4-1 (continued)
 Statistical Summary of 24-hour PM_{1.5} Measurements Between 6/19/87 and 9/3/87 at Nine SCAQS Sites

| Chemical Species | San Nicolas Island | | | Azusa | | | Claremont | | |
|--|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) |
| Mass | 9.72 | 4.72 | 16.97 | 47.11 | 13.20 | 66.82 | 40.99 | 13.15 | 65.88 |
| Chloride (Cl) | 0.39 | 0.28 | 0.85 | 0.16 | 0.10 | 0.32 | 0.11 | 0.08 | 0.30 |
| Nitrate (NO ₃) | 0.46 | 0.29 | 0.98 | 5.09 | 3.03 | 10.46 | 4.89 | 2.81 | 9.43 |
| Sulfate (SO ₄ ²⁻) | 2.77 | 0.95 | 4.48 | 8.28 | 3.87 | 15.40 | 6.79 | 2.88 | 13.08 |
| Ammonium (NH ₄ ⁺) | 0.68 | 0.25 | 1.13 | 4.21 | 2.26 | 8.28 | 3.71 | 1.92 | 7.91 |
| Organic Carbon (OC) | 0.81 | 0.40 | 1.59 | 9.53 | 1.80 | 12.17 | 9.59 | 1.99 | 12.42 |
| Elemental Carbon (EC) | 0.10 | 0.05 | 0.16 | 2.64 | 1.03 | 5.09 | 1.92 | 0.57 | 3.07 |
| Sodium (Na) | 0.2686 | 0.1888 | 0.6127 | 0.1934 | 0.1348 | 0.4480 | 0.1223 | 0.0781 | 0.2681 |
| Magnesium (Mg) | 0.0149 | 0.0117 | 0.0389 | 0.0554 | 0.0292 | 0.1012 | 0.0283 | 0.0155 | 0.0549 |
| Aluminum (Al) | 0.0287 | 0.0353 | 0.1237 | 0.1874 | 0.0948 | 0.3564 | 0.0749 | 0.0654 | 0.2562 |
| Silicon (Si) | 0.0482 | 0.1056 | 0.3272 | 0.4829 | 0.2248 | 0.8721 | 0.1785 | 0.1309 | 0.4990 |
| Phosphorus (P) | 0.0033 | 0.0028 | 0.0122 | 0.0188 | 0.0048 | 0.0313 | 0.0192 | 0.0057 | 0.0285 |
| Sulfur (S) | 0.7463 | 0.3258 | 1.4021 | 2.5289 | 1.1831 | 4.9432 | 2.2789 | 0.9765 | 4.6235 |
| Chlorine (Cl) | 0.1579 | 0.2003 | 0.5346 | 0.0782 | 0.0774 | 0.2057 | 0.0264 | 0.0395 | 0.1235 |
| Potassium (K) | 0.0040 | 0.0025 | 0.0069 | 0.1113 | 0.0454 | 0.1960 | 0.0434 | 0.0199 | 0.0692 |
| Calcium (Ca) | 0.0232 | 0.0509 | 0.1663 | 0.1504 | 0.0796 | 0.2979 | 0.0624 | 0.0334 | 0.1319 |
| Titanium (Ti) | 0.0027 | 0.0047 | 0.0175 | 0.0299 | 0.0189 | 0.0799 | 0.0075 | 0.0028 | 0.0112 |
| Vanadium (V) | 0.0049 | 0.0006 | 0.0064 | 0.0057 | 0.0011 | 0.0075 | 0.0053 | 0.0011 | 0.0073 |
| Chromium (Cr) | 0.0215 | 0.0083 | 0.0396 | 0.0180 | 0.0025 | 0.0249 | 0.0261 | 0.0093 | 0.0406 |
| Manganese (Mn) | 0.0124 | 0.0008 | 0.0137 | 0.0157 | 0.0040 | 0.0247 | 0.0141 | 0.0019 | 0.0178 |
| Iron (Fe) | 0.0249 | 0.0478 | 0.1419 | 0.2819 | 0.1169 | 0.5070 | 0.1123 | 0.0583 | 0.2253 |
| Nickel (Ni) | 0.0047 | 0.0003 | 0.0053 | 0.0045 | 0.0010 | 0.0065 | 0.0078 | 0.0047 | 0.0193 |
| Copper (Cu) | 0.0629 | 0.0706 | 0.2200 | 0.134 | 0.0097 | 0.0307 | 0.0725 | 0.0488 | 0.1707 |
| Zinc (Zn) | 0.0395 | 0.0455 | 0.1425 | 0.0553 | 0.0279 | 0.1031 | 0.0778 | 0.0336 | 0.1468 |
| Arsenic (As) | 0.0092 | 0.0031 | 0.0156 | 0.0181 | 0.0078 | 0.0349 | 0.0231 | 0.0062 | 0.0319 |
| Selenium (Se) | 0.0103 | 0.0028 | 0.0164 | 0.0115 | 0.0040 | 0.0203 | 0.0155 | 0.0073 | 0.0306 |
| Bromine (Br) | 0.0102 | 0.0010 | 0.0123 | 0.0148 | 0.0072 | 0.0301 | 0.0107 | 0.0015 | 0.0147 |
| Strontium (Sr) | 0.0200 | 0.0020 | 0.0240 | 0.0192 | 0.0024 | 0.0233 | 0.0193 | 0.0025 | 0.0239 |
| Barium (Ba) | 0.0040 | 0.0002 | 0.0044 | 0.0265 | 0.0120 | 0.0419 | 0.0128 | 0.0032 | 0.0217 |
| Mercury (Hg) | 0.0220 | 0.0042 | 0.0329 | 0.0198 | 0.0021 | 0.0244 | 0.0233 | 0.0053 | 0.0368 |
| Lead (Pb) | 0.0319 | 0.0028 | 0.0373 | 0.0486 | 0.0219 | 0.1014 | 0.0341 | 0.0055 | 0.0447 |

* Calculation is based on the weighted 24-hour averages for eleven sampling days.

Table 4-2
 Statistical Summary of Twenty-Four Hour PM₁₀ Measurements Between 6/19/87 and 9/3/87 at Nine SCAQS Sites

| Chemical Species | Burbank | | | Downtown Los Angeles | | | Hawthorne | | |
|--|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) |
| Mass | 72.25 | 18.59 | 103.16 | 67.43 | 15.45 | 98.34 | 45.91 | 13.13 | 72.50 |
| Chloride (Cl) | 0.82 | 0.70 | 2.79 | 0.96 | 0.84 | 3.23 | 1.27 | 1.29 | 4.56 |
| Nitrate (NO ₃) | 10.64 | 3.76 | 16.81 | 9.47 | 3.12 | 14.52 | 4.97 | 1.84 | 9.00 |
| Sulfate (SO ₄ ²⁻) | 10.66 | 5.22 | 20.67 | 11.28 | 5.36 | 21.57 | 11.17 | 5.58 | 21.72 |
| Ammonium (NH ₄ ⁺) | 5.01 | 2.71 | 8.52 | 4.61 | 2.22 | 8.21 | 3.76 | 1.90 | 7.32 |
| Organic Carbon (OC) | 12.76 | 2.16 | 15.93 | 11.61 | 2.33 | 15.08 | 4.66 | 1.30 | 6.79 |
| Elemental Carbon (EC) | 3.09 | 0.79 | 4.15 | 3.19 | 1.51 | 6.50 | 0.98 | 0.68 | 2.35 |
| Sodium (Na) | 1.4886 | 0.5587 | 2.6524 | 1.6323 | 0.6033 | 2.7209 | 1.8981 | 0.6502 | 3.0027 |
| Magnesium (Mg) | 0.3504 | 0.0816 | 0.5337 | 0.3350 | 0.0872 | 0.4691 | 0.2848 | 0.0797 | 0.4073 |
| Aluminum (Al) | 0.8264 | 0.2125 | 1.0962 | 0.7578 | 0.2515 | 1.2148 | 0.4854 | 0.2107 | 0.9420 |
| Silicon (Si) | 2.1932 | 0.4239 | 2.6185 | 2.0397 | 0.5397 | 2.9986 | 1.2927 | 0.4271 | 2.0857 |
| Phosphorus (P) | 0.0729 | 0.0155 | 0.0967 | 0.1871 | 0.2259 | 0.7841 | 0.0255 | 0.0112 | 0.0474 |
| Sulfur (S) | 3.1746 | 1.4647 | 5.9106 | 3.3527 | 1.5353 | 6.2233 | 3.3056 | 1.5719 | 6.2069 |
| Chlorine (Cl) | 0.9976 | 0.9864 | 3.6344 | 1.1192 | 1.1640 | 4.2712 | 1.7840 | 1.8265 | 5.6642 |
| Potassium (K) | 0.2685 | 0.0477 | 0.3433 | 0.2371 | 0.0568 | 0.3152 | 0.1641 | 0.0525 | 0.2553 |
| Calcium (Ca) | 0.6515 | 0.1070 | 0.7781 | 0.5851 | 0.1443 | 0.8387 | 0.3160 | 0.0946 | 0.4602 |
| Titanium (Ti) | 0.0907 | 0.0188 | 0.1188 | 0.0767 | 0.0221 | 0.1081 | 0.0391 | 0.0155 | 0.0675 |
| Vanadium (V) | 0.0052 | 0.0013 | 0.0080 | 0.0052 | 0.0016 | 0.0093 | 0.0058 | 0.0028 | 0.0116 |
| Chromium (Cr) | 0.0247 | 0.0099 | 0.0417 | 0.0232 | 0.0080 | 0.0372 | 0.0217 | 0.0115 | 0.0462 |
| Manganese (Mn) | 0.0282 | 0.0052 | 0.0359 | 0.0327 | 0.0107 | 0.0530 | 0.0164 | 0.0036 | 0.0233 |
| Iron (Fe) | 0.8353 | 0.1230 | 0.9962 | 0.8357 | 0.1933 | 1.1947 | 0.3789 | 0.1364 | 0.6111 |
| Nickel (Ni) | 0.0045 | 0.0003 | 0.0052 | 0.0046 | 0.0001 | 0.0047 | 0.0045 | 0.0003 | 0.0051 |
| Copper (Cu) | 0.0071 | 0.0041 | 0.0164 | 0.0224 | 0.0305 | 0.0989 | 0.0305 | 0.0361 | 0.1197 |
| Zinc (Zn) | 0.0445 | 0.0207 | 0.0740 | 0.1138 | 0.0559 | 0.2459 | 0.0365 | 0.0275 | 0.1092 |
| Arsenic (As) | 0.0070 | 0.0004 | 0.0078 | 0.0069 | 0.0002 | 0.0073 | 0.0069 | 0.0003 | 0.0076 |
| Selenium (Se) | 0.0083 | 0.0006 | 0.0092 | 0.0081 | 0.0003 | 0.0086 | 0.0083 | 0.0004 | 0.0093 |
| Bromine (Br) | 0.0092 | 0.0005 | 0.0099 | 0.0163 | 0.0136 | 0.0491 | 0.0090 | 0.0006 | 0.0098 |
| Strontium (Sr) | 0.0180 | 0.0024 | 0.0207 | 0.0179 | 0.0020 | 0.0204 | 0.0177 | 0.0021 | 0.0208 |
| Barium (Ba) | 0.0734 | 0.0150 | 0.0998 | 0.0701 | 0.0189 | 0.1111 | 0.0228 | 0.0085 | 0.0405 |
| Mercury (Hg) | 0.0204 | 0.0023 | 0.0263 | 0.0206 | 0.0030 | 0.0287 | 0.0214 | 0.0035 | 0.0266 |
| Lead (Pb) | 0.0784 | 0.0241 | 0.1224 | 0.0844 | 0.0196 | 0.1172 | 0.0437 | 0.0126 | 0.0796 |

Table 4-2 (continued)
 Statistical Summary of Twenty-Four Hour PM₁₀ Measurements Between 6/19/87 and 9/3/87 at Nine SCAQS Sites

| Chemical Species | Long Beach | | | Anaheim | | | Rubidoux | | |
|--|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) |
| Mass | 46.05 | 12.19 | 64.77 | 51.25 | 11.84 | 68.17 | 120.57 | 28.93 | 163.76 |
| Chloride (Cl) | 0.81 | 0.77 | 2.69 | 0.94 | 0.73 | 2.70 | 0.88 | 0.31 | 1.54 |
| Nitrate (NO ₃) | 5.15 | 1.90 | 7.34 | 7.16 | 2.39 | 11.12 | 28.85 | 10.56 | 41.99 |
| Sulfate (SO ₄ ²⁻) | 8.74 | 2.70 | 13.22 | 8.05 | 2.42 | 11.80 | 8.81 | 2.45 | 12.21 |
| Ammonium (NH ₄ ⁺) | 2.84 | 1.20 | 4.79 | 3.19 | 1.20 | 4.95 | 8.60 | 3.67 | 13.65 |
| Sodium (Na ⁺) | 2.04 | 0.84 | 3.06 | 2.34 | 1.11 | 4.38 | 1.55 | 0.60 | 2.40 |
| Organic Carbon (OC) | 5.10 | 1.53 | 8.99 | 7.16 | 2.08 | 11.08 | 14.66 | 2.98 | 19.61 |
| Elemental Carbon (EC) | 1.47 | 0.96 | 3.53 | 1.70 | 1.24 | 4.42 | 3.15 | 1.37 | 6.03 |
| Sodium (Na) | 1.7278 | 0.7504 | 2.8648 | 1.6593 | 0.6086 | 2.7341 | 1.2451 | 0.4234 | 1.9114 |
| Magnesium (Mg) | 0.3329 | 0.1233 | 0.5245 | 0.3488 | 0.1033 | 0.5280 | 0.7302 | 0.1436 | 0.9326 |
| Aluminum (Al) | 0.7095 | 0.3887 | 1.5874 | 0.7012 | 0.2867 | 1.3526 | 2.1214 | 0.8063 | 3.4039 |
| Silicon (Si) | 1.8080 | 0.8172 | 3.6550 | 1.9228 | 0.5960 | 3.2576 | 5.2886 | 1.5929 | 7.7350 |
| Phosphorus (P) | 0.0460 | 0.0293 | 0.1032 | 0.0514 | 0.0209 | 0.1014 | 0.3606 | 0.0575 | 0.4814 |
| Sulfur (S) | 2.7541 | 0.8393 | 4.1200 | 2.3973 | 0.7158 | 3.5158 | 2.7127 | 0.7722 | 3.7537 |
| Chlorine (Cl) | 1.2849 | 1.3799 | 4.6230 | 1.1797 | 1.1019 | 4.0346 | 1.0250 | 0.4050 | 1.9198 |
| Potassium (K) | 0.2199 | 0.0892 | 0.3784 | 0.2787 | 0.1178 | 0.5357 | 0.8250 | 0.1399 | 1.0436 |
| Calcium (Ca) | 0.4354 | 0.2197 | 0.8685 | 0.4910 | 0.1905 | 1.0142 | 2.9093 | 1.2506 | 5.1687 |
| Titanium (Ti) | 0.0770 | 0.0270 | 0.1281 | 0.0599 | 0.0257 | 0.1099 | 0.1624 | 0.0440 | 0.2343 |
| Vanadium (V) | 0.0068 | 0.0027 | 0.0122 | 0.0051 | 0.0013 | 0.0075 | 0.0084 | 0.0046 | 0.0190 |
| Chromium (Cr) | 0.0209 | 0.0066 | 0.0389 | 0.0196 | 0.0057 | 0.0332 | 0.0241 | 0.0116 | 0.0486 |
| Manganese (Mn) | 0.0213 | 0.0077 | 0.0359 | 0.0236 | 0.0067 | 0.0337 | 0.0607 | 0.0168 | 0.0915 |
| Iron (Fe) | 0.5554 | 0.2650 | 1.1192 | 0.5989 | 0.1983 | 1.0695 | 1.8098 | 0.4518 | 2.5266 |
| Nickel (Ni) | 0.0050 | 0.0007 | 0.0073 | 0.0047 | 0.0004 | 0.0051 | 0.0048 | 0.0005 | 0.0056 |
| Copper (Cu) | 0.0061 | 0.0025 | 0.0135 | 0.0103 | 0.0106 | 0.0327 | 0.0073 | 0.0064 | 0.0264 |
| Zinc (Zn) | 0.0410 | 0.0468 | 0.1326 | 0.0248 | 0.0313 | 0.1132 | 0.0242 | 0.0174 | 0.0603 |
| Arsenic (As) | 0.0076 | 0.0013 | 0.0116 | 0.0070 | 0.0005 | 0.0076 | 0.0075 | 0.0007 | 0.0084 |
| Selenium (Se) | 0.0091 | 0.0015 | 0.0138 | 0.0084 | 0.0006 | 0.0089 | 0.0089 | 0.0009 | 0.0104 |
| Bromine (Br) | 0.0101 | 0.0018 | 0.0155 | 0.0094 | 0.0007 | 0.0099 | 0.0093 | 0.0008 | 0.0105 |
| Strontium (Sr) | 0.0212 | 0.0043 | 0.0327 | 0.0187 | 0.0029 | 0.0244 | 0.0184 | 0.0032 | 0.0240 |
| Barium (Ba) | 0.0343 | 0.0166 | 0.0682 | 0.0420 | 0.0158 | 0.0838 | 0.0726 | 0.0185 | 0.1031 |
| Mercury (Hg) | 0.0222 | 0.0035 | 0.0311 | 0.0202 | 0.0029 | 0.0283 | 0.0233 | 0.0045 | 0.0310 |
| Lead (Pb) | 0.0614 | 0.0163 | 0.0895 | 0.0504 | 0.0177 | 0.0961 | 0.0632 | 0.0289 | 0.1063 |

Table 4-2 (continued)
 Statistical Summary of Twenty-Four Hour PM₁₀ Measurements Between 6/19/87 and 9/3/87 at Nine SCAQS Sites

| Chemical Species | San Nicolas Island | | | Azusa | | | Claremont | | |
|--|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) |
| Maas | 17.38 | 6.17 | 25.78 | 92.14 | 16.58 | 119.90 | 69.97 | 15.66 | 94.59 |
| Chloride (Cl) | 1.64 | 1.10 | 4.37 | 0.64 | 0.48 | 1.99 | 0.39 | 0.28 | 1.21 |
| Nitrate (NO ₃) | 1.58 | 0.82 | 3.03 | 10.63 | 4.45 | 17.61 | 10.14 | 4.17 | 15.85 |
| Sulfate (SO ₄ ²⁻) | 3.57 | 1.14 | 5.36 | 9.91 | 4.63 | 18.79 | 8.15 | 3.36 | 15.58 |
| Ammonium (NH ₄ ⁺) | 0.85 | 0.39 | 1.50 | 4.85 | 2.75 | 9.94 | 3.62 | 2.13 | 7.01 |
| Organic Carbon (OC) | 1.53 | 0.51 | 2.28 | 13.46 | 2.99 | 20.09 | 12.88 | 2.96 | 18.89 |
| Elemental Carbon (EC) | 0.16 | 0.07 | 0.29 | 3.33 | 1.04 | 5.69 | 2.69 | 0.75 | 3.93 |
| Sodium (Na) | 1.4387 | 0.7074 | 2.4756 | 1.5418 | 0.5453 | 2.4892 | 1.1502 | 0.4262 | 1.7986 |
| Magnesium (Mg) | 0.1651 | 0.0914 | 0.2944 | 0.6045 | 0.1133 | 0.8045 | 0.3981 | 0.0828 | 0.4981 |
| Aluminum (Al) | 0.1324 | 0.1220 | 0.3699 | 2.2705 | 0.6333 | 3.6527 | 1.2318 | 0.4105 | 1.8665 |
| Silicon (Si) | 0.3376 | 0.2710 | 0.8380 | 5.7213 | 1.2054 | 8.5396 | 3.1104 | 0.8025 | 4.4999 |
| Phosphorus (P) | 0.0027 | 0.0012 | 0.0065 | 0.1046 | 0.0195 | 0.1515 | 0.0923 | 0.0235 | 0.1223 |
| Sulfur (S) | 1.0242 | 0.3606 | 1.6064 | 2.9169 | 1.3506 | 5.7138 | 2.7073 | 1.1530 | 5.4125 |
| Chlorine (Cl) | 2.2864 | 1.5773 | 5.9408 | 0.7084 | 0.6586 | 2.5228 | 0.4772 | 0.4781 | 1.7457 |
| Potassium (K) | 0.0727 | 0.0299 | 0.1031 | 0.6179 | 0.1072 | 0.8238 | 0.3337 | 0.0705 | 0.4306 |
| Calcium (Ca) | 0.0866 | 0.0664 | 0.1997 | 1.3047 | 0.2725 | 1.9563 | 0.8284 | 0.2051 | 1.0817 |
| Titanium (Ti) | 0.0039 | 0.0041 | 0.0146 | 0.2510 | 0.2664 | 1.0912 | 0.0965 | 0.0217 | 0.1276 |
| Vanadium (V) | 0.0041 | 0.0002 | 0.0045 | 0.0075 | 0.0028 | 0.0122 | 0.0060 | 0.0016 | 0.0085 |
| Chromium (Cr) | 0.0195 | 0.0057 | 0.0332 | 0.0196 | 0.0056 | 0.0360 | 0.0186 | 0.0020 | 0.0238 |
| Manganese (Mn) | 0.0120 | 0.0011 | 0.0138 | 0.0792 | 0.0165 | 0.1169 | 0.0412 | 0.0091 | 0.0548 |
| Iron (Fe) | 0.0755 | 0.0528 | 0.1531 | 1.8409 | 0.3117 | 2.6034 | 1.0444 | 0.2352 | 1.4081 |
| Nickel (Ni) | 0.0062 | 0.0060 | 0.0252 | 0.0046 | 0.0003 | 0.0050 | 0.0050 | 0.0003 | 0.0055 |
| Copper (Cu) | 0.0169 | 0.0267 | 0.0850 | 0.0136 | 0.0105 | 0.0396 | 0.0159 | 0.0136 | 0.0437 |
| Zinc (Zn) | 0.0118 | 0.0138 | 0.0441 | 0.1680 | 0.1437 | 0.6062 | 0.0848 | 0.0310 | 0.1509 |
| Arsenic (As) | 0.0066 | 0.0003 | 0.0073 | 0.0073 | 0.0005 | 0.0081 | 0.0075 | 0.0004 | 0.0084 |
| Selenium (Se) | 0.0078 | 0.0004 | 0.0089 | 0.0087 | 0.0006 | 0.0100 | 0.0089 | 0.0006 | 0.0100 |
| Bromine (Br) | 0.0092 | 0.0003 | 0.0097 | 0.0092 | 0.0005 | 0.0097 | 0.0100 | 0.0005 | 0.0109 |
| Strontium (Sr) | 0.0180 | 0.0019 | 0.0206 | 0.0184 | 0.0027 | 0.0232 | 0.0199 | 0.0028 | 0.0253 |
| Barium (Ba) | 0.0052 | 0.0014 | 0.0076 | 0.1375 | 0.0846 | 0.4024 | 0.0634 | 0.0129 | 0.0835 |
| Mercury (Hg) | 0.0193 | 0.0020 | 0.0235 | 0.0211 | 0.0029 | 0.0267 | 0.0222 | 0.0027 | 0.0289 |
| Lead (Pb) | 0.0330 | 0.0070 | 0.0529 | 0.0811 | 0.0325 | 0.1536 | 0.0858 | 0.0270 | 0.1321 |

* Calculation is based on the weighted Twenty-Four Hour averages for eleven sampling days.

Table 4-3
 Statistical Summary of Twenty-Four Hour PM_{2.5} Measurements Between 11/11/87 and 12/11/87 at Six SCAQS Sites

| Chemical Species | Burbank | | | Downtown Los Angeles | | | Hawthorne | | |
|--|--|--|---|--|--|---|--|--|---|
| | Average* ($\mu\text{g}/\text{m}^3$) | Std. Dev ($\mu\text{g}/\text{m}^3$) | Maximum ($\mu\text{g}/\text{m}^3$) | Average* ($\mu\text{g}/\text{m}^3$) | Std. Dev ($\mu\text{g}/\text{m}^3$) | Maximum ($\mu\text{g}/\text{m}^3$) | Average* ($\mu\text{g}/\text{m}^3$) | Std. Dev ($\mu\text{g}/\text{m}^3$) | Maximum ($\mu\text{g}/\text{m}^3$) |
| Mass | 78.26 | 39.36 | 151.53 | 90.21 | 37.67 | 143.55 | 68.88 | 33.29 | 127.99 |
| Chloride (Cl) | 0.58 | 0.36 | 1.22 | 0.54 | 0.31 | 0.82 | 1.09 | 0.49 | 1.78 |
| Nitrate (NO ₃) | 22.02 | 14.74 | 49.24 | 22.64 | 15.02 | 45.07 | 16.57 | 10.36 | 35.49 |
| Sulfate (SO ₄ ²⁻) | 3.77 | 2.95 | 9.12 | 4.38 | 3.03 | 9.75 | 4.93 | 2.69 | 8.48 |
| Ammonium (NH ₄ ⁺) | 6.52 | 4.72 | 15.39 | 6.80 | 4.22 | 13.04 | 5.53 | 3.68 | 11.51 |
| Organic Carbon (OC) | 19.55 | 7.36 | 31.04 | 18.46 | 6.60 | 27.81 | 14.00 | 5.76 | 22.66 |
| Elemental Carbon (EC) | 6.32 | 1.92 | 8.96 | 7.28 | 2.57 | 12.12 | 5.81 | 1.91 | 7.80 |
| Sodium (Na) | 0.1695 | 0.0956 | 0.3159 | 0.4663 | 0.2348 | 0.7987 | 0.2977 | 0.1490 | 0.5093 |
| Magnesium (Mg) | 0.0526 | 0.0132 | 0.0784 | 0.0750 | 0.0224 | 0.1144 | 0.0745 | 0.0185 | 0.1099 |
| Aluminum (Al) | 0.1493 | 0.0376 | 0.2269 | 0.2502 | 0.0894 | 0.4122 | 0.1633 | 0.0340 | 0.2092 |
| Silicon (Si) | 0.3459 | 0.1175 | 0.5953 | 0.5203 | 0.2035 | 0.9107 | 0.3529 | 0.0706 | 0.4616 |
| Phosphorus (P) | 0.0337 | 0.0106 | 0.0481 | 0.0463 | 0.0150 | 0.0706 | 0.0394 | 0.0083 | 0.0511 |
| Sulfur (S) | 1.7130 | 1.2511 | 3.9102 | 1.9977 | 1.2903 | 4.2823 | 2.2125 | 1.0987 | 3.4136 |
| Chlorine (Cl) | 0.4643 | 0.3215 | 1.0588 | 0.4533 | 0.2948 | 0.8109 | 0.9303 | 0.6060 | 1.9524 |
| Potassium (K) | 0.2031 | 0.0951 | 0.3954 | 0.2167 | 0.0873 | 0.3920 | 0.1750 | 0.0616 | 0.2916 |
| Calcium (Ca) | 0.1937 | 0.0763 | 0.3609 | 0.3353 | 0.1175 | 0.5585 | 0.2022 | 0.0511 | 0.2762 |
| Titanium (Ti) | 0.0293 | 0.0110 | 0.0531 | 0.0596 | 0.0245 | 0.1020 | 0.0298 | 0.0085 | 0.0396 |
| Vanadium (V) | 0.0059 | 0.0015 | 0.0080 | 0.0066 | 0.0021 | 0.0090 | 0.0132 | 0.0036 | 0.0193 |
| Chromium (Cr) | 0.0335 | 0.0098 | 0.0529 | 0.0247 | 0.0079 | 0.0423 | 0.0313 | 0.0089 | 0.0469 |
| Manganese (Mn) | 0.0359 | 0.0089 | 0.0450 | 0.0427 | 0.0147 | 0.0606 | 0.0368 | 0.0119 | 0.0531 |
| Iron (Fe) | 0.3525 | 0.0865 | 0.5207 | 0.5566 | 0.1746 | 0.8452 | 0.3745 | 0.0404 | 0.4189 |
| Nickel (Ni) | 0.0051 | 0.0010 | 0.0073 | 0.0070 | 0.0041 | 0.0159 | 0.0118 | 0.0153 | 0.0460 |
| Copper (Cu) | 0.1797 | 0.0775 | 0.2756 | 0.2728 | 0.1189 | 0.4367 | 0.5184 | 0.5288 | 1.6740 |
| Zinc (Zn) | 0.2055 | 0.0742 | 0.3214 | 0.2982 | 0.0945 | 0.4407 | 0.4525 | 0.4179 | 1.3722 |
| Arsenic (As) | 0.0090 | 0.0032 | 0.0159 | 0.0154 | 0.0064 | 0.0252 | 0.0206 | 0.0050 | 0.0265 |
| Selenium (Se) | 0.0134 | 0.0036 | 0.0176 | 0.0105 | 0.0029 | 0.0167 | 0.0116 | 0.0028 | 0.0175 |
| Bromine (Br) | 0.0791 | 0.0189 | 0.1105 | 0.0652 | 0.0184 | 0.1044 | 0.0553 | 0.0207 | 0.0762 |
| Strontium (Sr) | 0.0357 | 0.0145 | 0.0583 | 0.0280 | 0.0098 | 0.0443 | 0.0207 | 0.0002 | 0.0210 |
| Barium (Ba) | 0.0361 | 0.0138 | 0.0642 | 0.0430 | 0.0100 | 0.0570 | 0.0302 | 0.0079 | 0.0389 |
| Mercury (Hg) | 0.0193 | 0.0012 | 0.0218 | 0.0190 | 0.0006 | 0.0199 | 0.0189 | 0.0010 | 0.0206 |
| Lead (Pb) | 0.2308 | 0.0184 | 0.2658 | 0.1853 | 0.0371 | 0.2308 | 0.1584 | 0.0632 | 0.2366 |

Table 4-3 (continued)
 Statistical Summary of Twenty-Four Hour PM₁₀ Measurements Between 11/11/87 and 12/11/87 at Six SCAQS Sites

| Chemical Species | Long Beach | | | Anaheim | | | Rubidoux | | |
|--|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) |
| Mass | 72.71 | 43.57 | 155.71 | 83.47 | 51.66 | 174.27 | 85.80 | 48.55 | 185.91 |
| Chloride (Cl) | 0.92 | 0.68 | 1.88 | 1.14 | 0.75 | 2.01 | 0.81 | 0.42 | 1.38 |
| Nitrate (NO ₃) | 19.36 | 15.03 | 49.16 | 30.56 | 22.91 | 73.96 | 29.04 | 24.26 | 77.57 |
| Sulfate (SO ₄ ²⁻) | 4.42 | 2.33 | 8.23 | 4.28 | 2.45 | 8.96 | 3.813 | 2.23 | 6.94 |
| Ammonium (NH ₄ ⁺) | 7.18 | 4.83 | 16.27 | 9.93 | 6.99 | 23.50 | 7.51 | 6.39 | 19.94 |
| Organic Carbon (OC) | 17.84 | 9.22 | 33.15 | 13.88 | 6.26 | 20.66 | 13.61 | 5.03 | 23.90 |
| Elemental Carbon (EC) | 6.00 | 2.57 | 9.04 | 5.45 | 2.47 | 8.61 | 5.54 | 1.60 | 8.40 |
| Sodium (Na) | 0.1892 | 0.0837 | 0.3278 | 0.2283 | 0.0947 | 0.4097 | 0.1428 | 0.0748 | 0.2604 |
| Magnesium (Mg) | 0.0595 | 0.0102 | 0.0732 | 0.0636 | 0.0196 | 0.1015 | 0.1633 | 0.0652 | 0.2921 |
| Aluminum (Al) | 0.1433 | 0.0414 | 0.1711 | 0.1711 | 0.0695 | 0.3225 | 0.5893 | 0.2169 | 0.9784 |
| Silicon (Si) | 0.3172 | 0.0937 | 0.3792 | 0.4302 | 0.1720 | 0.7957 | 1.3430 | 0.5069 | 2.2975 |
| Phosphorus (P) | 0.0450 | 0.0133 | 0.0601 | 0.0348 | 0.0160 | 0.0637 | 0.0455 | 0.0153 | 0.0746 |
| Sulfur (S) | 1.9822 | 0.9277 | 3.5990 | 1.9322 | 1.0679 | 3.9488 | 1.4291 | 0.9324 | 3.0070 |
| Chlorine (Cl) | 0.9056 | 0.5251 | 1.6953 | 1.1501 | 0.7031 | 2.0284 | 0.7427 | 0.3479 | 1.2700 |
| Potassium (K) | 0.2263 | 0.1026 | 0.4030 | 0.2129 | 0.0845 | 0.3685 | 0.3427 | 0.1492 | 0.6575 |
| Calcium (Ca) | 0.1804 | 0.0481 | 0.2332 | 0.2457 | 0.0929 | 0.4260 | 2.6012 | 0.8854 | 3.8345 |
| Titanium (Ti) | 0.0367 | 0.0143 | 0.0664 | 0.0349 | 0.0150 | 0.0628 | 0.0761 | 0.0260 | 0.1257 |
| Vanadium (V) | 0.0089 | 0.0020 | 0.0120 | 0.0079 | 0.0016 | 0.0106 | 0.0056 | 0.0014 | 0.0073 |
| Chromium (Cr) | 0.0211 | 0.0044 | 0.0265 | 0.0363 | 0.0159 | 0.0560 | 0.0328 | 0.0092 | 0.0442 |
| Manganese (Mn) | 0.0415 | 0.0129 | 0.0549 | 0.0335 | 0.0172 | 0.0563 | 0.0447 | 0.0131 | 0.0687 |
| Iron (Fe) | 0.3297 | 0.1051 | 0.4165 | 0.3596 | 0.1313 | 0.5731 | 0.8992 | 0.2856 | 1.4353 |
| Nickel (Ni) | 0.0047 | 0.0002 | 0.0051 | 0.0048 | 0.0003 | 0.0055 | 0.0045 | 0.0003 | 0.0050 |
| Copper (Cu) | 0.0741 | 0.0244 | 0.1010 | 0.0817 | 0.0327 | 0.1346 | 0.2080 | 0.1009 | 0.3760 |
| Zinc (Zn) | 0.1921 | 0.0761 | 0.3443 | 0.1368 | 0.0539 | 0.2253 | 0.1932 | 0.0694 | 0.2937 |
| Arsenic (As) | 0.0147 | 0.0059 | 0.0246 | 0.0105 | 0.0053 | 0.0218 | 0.0186 | 0.0082 | 0.0307 |
| Selenium (Se) | 0.0127 | 0.0017 | 0.0156 | 0.0118 | 0.0029 | 0.0158 | 0.0113 | 0.0028 | 0.0152 |
| Bromine (Br) | 0.0843 | 0.0391 | 0.1339 | 0.0673 | 0.0271 | 0.1177 | 0.0662 | 0.0259 | 0.1051 |
| Strontium (Sr) | 0.0252 | 0.0063 | 0.0353 | 0.0334 | 0.0063 | 0.0425 | 0.0224 | 0.0043 | 0.0295 |
| Barium (Ba) | 0.0276 | 0.0172 | 0.0622 | 0.0212 | 0.0086 | 0.0331 | 0.0300 | 0.0104 | 0.0501 |
| Mercury (Hg) | 0.0195 | 0.0010 | 0.0214 | 0.0197 | 0.0017 | 0.0233 | 0.0186 | 0.0010 | 0.0203 |
| Lead (Pb) | 0.2134 | 0.0933 | 0.3234 | 0.1878 | 0.0502 | 0.2684 | 0.1451 | 0.0649 | 0.2512 |

* Calculation is based on the weighted Twenty-Four Hour averages for six sampling days.

Table 4-4
 Statistical Summary of Twenty-Four Hour PM₁₀ Measurements Between 11/11/87 and 12/11/87 at Six SCAQS Sites

| Chemical Species | Burbank | | | Downtown Los Angeles | | | Hawthorne | | |
|--|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) |
| Mass | 94.84 | 39.20 | 162.35 | 98.65 | 43.40 | 156.96 | 85.08 | 33.69 | 142.44 |
| Chloride (Cl) | 0.76 | 0.48 | 1.46 | 0.81 | 0.45 | 1.39 | 1.84 | 0.75 | 2.80 |
| Nitrate (NO ₃) | 25.74 | 16.74 | 55.05 | 27.50 | 17.54 | 53.84 | 21.19 | 12.38 | 43.76 |
| Sulfate (SO ₄ ²⁻) | 4.52 | 3.58 | 11.27 | 5.39 | 3.78 | 12.21 | 5.97 | 3.15 | 10.12 |
| Ammonium (NH ₄ ⁺) | 8.90 | 6.78 | 19.58 | 8.67 | 5.67 | 16.29 | 7.07 | 4.23 | 13.48 |
| Organic Carbon (OC) | 22.12 | 6.82 | 32.05 | 23.35 | 8.56 | 36.99 | 17.64 | 6.67 | 28.53 |
| Elemental Carbon (EC) | 7.38 | 1.94 | 10.31 | 8.49 | 2.77 | 13.28 | 6.92 | 2.11 | 9.11 |
| Sodium (Na) | 0.6291 | 0.3952 | 1.2918 | 0.5181 | 0.3254 | 1.1564 | 1.2735 | 0.3794 | 1.6927 |
| Magnesium (Mg) | 0.3033 | 0.0562 | 0.3627 | 0.2868 | 0.0737 | 0.3745 | 0.3383 | 0.0570 | 0.3993 |
| Aluminum (Al) | 0.9514 | 0.1572 | 1.2059 | 0.8470 | 0.2529 | 1.1864 | 0.8168 | 0.1343 | 1.0351 |
| Silicon (Si) | 2.2984 | 0.3787 | 2.9256 | 2.1624 | 0.6524 | 3.0933 | 2.0123 | 0.3321 | 2.5822 |
| Phosphorus (P) | 0.0908 | 0.0159 | 0.1167 | 0.0988 | 0.0294 | 0.1566 | 0.0756 | 0.0165 | 0.0946 |
| Sulfur (S) | 1.9666 | 1.3792 | 4.5798 | 2.2616 | 1.4487 | 4.9327 | 2.5450 | 1.1904 | 4.0235 |
| Chlorine (Cl) | 0.8387 | 0.5092 | 1.5333 | 0.8797 | 0.5058 | 1.6517 | 2.3815 | 0.8072 | 3.5152 |
| Potassium (K) | 0.5291 | 0.1165 | 0.7525 | 0.4596 | 0.1347 | 0.6709 | 0.4712 | 0.0941 | 0.6511 |
| Calcium (Ca) | 1.3913 | 0.2350 | 1.7973 | 1.1896 | 0.2840 | 1.6663 | 1.0162 | 0.1635 | 1.2281 |
| Titanium (Ti) | 0.1890 | 0.0330 | 0.2234 | 0.1652 | 0.0504 | 0.2451 | 0.1393 | 0.0248 | 0.1759 |
| Vanadium (V) | 0.0062 | 0.0017 | 0.0095 | 0.0092 | 0.0033 | 0.0145 | 0.0129 | 0.0035 | 0.0189 |
| Chromium (Cr) | 0.0384 | 0.0128 | 0.0654 | 0.0420 | 0.0139 | 0.0600 | 0.0408 | 0.0158 | 0.0644 |
| Manganese (Mn) | 0.0710 | 0.0143 | 0.0962 | 0.0633 | 0.0199 | 0.1046 | 0.0632 | 0.0179 | 0.0826 |
| Iron (Fe) | 2.0477 | 0.3336 | 2.5784 | 2.1918 | 0.6113 | 3.2729 | 1.7369 | 0.2534 | 1.9745 |
| Nickel (Ni) | 0.0057 | 0.0015 | 0.0088 | 0.0045 | 0.0002 | 0.0048 | 0.0216 | 0.0085 | 0.0305 |
| Copper (Cu) | 0.1489 | 0.0424 | 0.2342 | 0.1783 | 0.0835 | 0.3174 | 0.2296 | 0.1118 | 0.3800 |
| Zinc (Zn) | 0.2266 | 0.0638 | 0.3370 | 0.2934 | 0.1035 | 0.4488 | 0.3178 | 0.1723 | 0.6570 |
| Antenic (As) | 0.0147 | 0.0053 | 0.0235 | 0.0193 | 0.0068 | 0.0323 | 0.0130 | 0.0039 | 0.0203 |
| Selenium (Se) | 0.0139 | 0.0045 | 0.0233 | 0.0096 | 0.0016 | 0.0126 | 0.0121 | 0.0027 | 0.0156 |
| Bromine (Br) | 0.0728 | 0.0180 | 0.0979 | 0.0715 | 0.0281 | 0.1259 | 0.0816 | 0.0323 | 0.1198 |
| Strontium (Sr) | 0.0264 | 0.0074 | 0.0415 | 0.0238 | 0.0048 | 0.0330 | 0.0245 | 0.0078 | 0.0414 |
| Barium (Ba) | 0.1252 | 0.0219 | 0.1537 | 0.1267 | 0.0361 | 0.1967 | 0.1003 | 0.0263 | 0.1315 |
| Mercury (Hg) | 0.0196 | 0.0004 | 0.0203 | 0.0192 | 0.0009 | 0.0204 | 0.0196 | 0.0012 | 0.0219 |
| Lead (Pb) | 0.2644 | 0.0372 | 0.3116 | 0.2512 | 0.0682 | 0.3763 | 0.2592 | 0.0912 | 0.3709 |

Table 4-4 (continued)
 Statistical Summary of Twenty-Four Hour PM₁₀ Measurements Between 11/11/87 and 12/11/87 at Six SCAQS Sites

| Chemical Species | Long Beach | | | Anaheim | | | Riverside | | |
|--|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|---------------------------------|
| | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) | Average* (µg/m ³) | Std. Dev (µg/m ³) | Maximum (µg/m ³) |
| Mass | 96.11 | 49.23 | 193.76 | 103.98 | 56.44 | 203.10 | 111.98 | 57.08 | 229.44 |
| Chloride (Cl) | 1.47 | 0.76 | 2.47 | 1.51 | 0.60 | 2.10 | 0.89 | 0.41 | 1.58 |
| Nitrate (NO ₃) | 24.75 | 16.33 | 56.51 | 35.29 | 25.47 | 84.78 | 29.65 | 24.18 | 76.30 |
| Sulfate (SO ₄ ²⁻) | 5.40 | 2.62 | 9.16 | 5.06 | 2.81 | 10.51 | 3.68 | 2.38 | 7.55 |
| Ammonium (NH ₄ ⁺) | 7.34 | 4.56 | 15.41 | 10.34 | 7.62 | 25.60 | 6.36 | 5.85 | 17.88 |
| Organic Carbon (OC) | 23.84 | 10.82 | 40.93 | 18.46 | 7.77 | 27.77 | 17.32 | 5.93 | 29.11 |
| Elemental Carbon (EC) | 7.27 | 2.81 | 10.25 | 6.76 | 2.76 | 9.99 | 6.86 | 2.03 | 10.36 |
| Sodium (Na) | 0.9855 | 0.2758 | 1.3914 | 1.0613 | 0.4126 | 1.7726 | 0.5581 | 0.2971 | 1.1146 |
| Magnesium (Mg) | 0.3372 | 0.0692 | 0.4399 | 0.3509 | 0.0699 | 0.4619 | 0.5666 | 0.2298 | 1.0661 |
| Aluminum (Al) | 1.0222 | 0.3159 | 1.4529 | 1.0976 | 0.4087 | 1.7136 | 2.0132 | 0.7242 | 3.5872 |
| Silicon (Si) | 2.4227 | 0.7129 | 3.2898 | 2.8801 | 1.0164 | 4.3187 | 5.0600 | 1.8632 | 9.0959 |
| Phosphorus (P) | 0.1123 | 0.0344 | 0.1490 | 0.0862 | 0.0300 | 0.1255 | 0.1121 | 0.0399 | 0.1975 |
| Sulfur (S) | 2.3358 | 1.0066 | 3.9650 | 2.2187 | 1.1155 | 4.3461 | 1.7818 | 0.9578 | 3.3965 |
| Chlorine (Cl) | 1.6305 | 0.6656 | 2.4085 | 1.7616 | 0.5952 | 2.4723 | 1.4587 | 0.6843 | 2.5020 |
| Potassium (K) | 0.6135 | 0.1816 | 0.9124 | 0.6003 | 0.1807 | 0.8706 | 0.9091 | 0.3054 | 1.5688 |
| Calcium (Ca) | 1.3792 | 0.3701 | 1.6992 | 1.4650 | 0.3759 | 2.0502 | 11.9673 | 1.5643 | 14.6158 |
| Titanium (Ti) | 0.2120 | 0.0453 | 0.3024 | 0.1910 | 0.0621 | 0.2565 | 0.2429 | 0.0737 | 0.4033 |
| Vanadium (V) | 0.0125 | 0.0029 | 0.0175 | 0.0116 | 0.0038 | 0.0168 | 0.0099 | 0.0026 | 0.0135 |
| Chromium (Cr) | 0.0356 | 0.0112 | 0.0547 | 0.0334 | 0.0055 | 0.0393 | 0.0323 | 0.0054 | 0.0424 |
| Manganese (Mn) | 0.0752 | 0.0258 | 0.1054 | 0.0627 | 0.0253 | 0.0986 | 0.0985 | 0.0198 | 0.1373 |
| Iron (Fe) | 1.9580 | 0.5743 | 2.4964 | 1.9107 | 0.6166 | 2.7453 | 2.9547 | 0.7719 | 4.6059 |
| Nickel (Ni) | 0.0093 | 0.0027 | 0.0119 | 0.0114 | 0.0099 | 0.0333 | 0.0049 | 0.0004 | 0.0055 |
| Copper (Cu) | 0.1261 | 0.0627 | 0.2454 | 0.0628 | 0.0283 | 0.1143 | 0.0593 | 0.0281 | 0.0952 |
| Zinc (Zn) | 0.2953 | 0.1049 | 0.4907 | 0.1788 | 0.0892 | 0.3591 | 0.1269 | 0.0357 | 0.1619 |
| Arsenic (As) | 0.0213 | 0.0049 | 0.0282 | 0.0137 | 0.0046 | 0.0210 | 0.0144 | 0.0065 | 0.0230 |
| Selenium (Se) | 0.0090 | 0.0007 | 0.0103 | 0.0099 | 0.0014 | 0.0123 | 0.0102 | 0.0014 | 0.0128 |
| Bromine (Br) | 0.0868 | 0.0422 | 0.1383 | 0.0707 | 0.0288 | 0.1034 | 0.0670 | 0.0257 | 0.1023 |
| Strontium (Sr) | 0.0247 | 0.0041 | 0.0302 | 0.0324 | 0.0088 | 0.0494 | 0.0266 | 0.0067 | 0.0385 |
| Barium (Ba) | 0.0984 | 0.0382 | 0.1523 | 0.0850 | 0.0299 | 0.1214 | 0.0820 | 0.0237 | 0.1294 |
| Mercury (Hg) | 0.0208 | 0.0015 | 0.0228 | 0.0204 | 0.0010 | 0.0219 | 0.0207 | 0.0013 | 0.0227 |
| Lead (Pb) | 0.2860 | 0.1243 | 0.4645 | 0.2346 | 0.0782 | 0.3238 | 0.1961 | 0.0616 | 0.2771 |

* Calculation is based on the weighted Twenty-Four Hour averages for six sampling days.

Anaheim site; and $229 \mu\text{g}/\text{m}^3$ at the Rubidoux site. The $\text{PM}_{2.5}$ mass (shown in Tables 4-1 and 4-3) by itself exceeded $150 \mu\text{g}/\text{m}^3$ on December 3, 1987 at all sites except Downtown Los Angeles and Hawthorne. Neither one of these days corresponded to one of the every sixth day sampling schedule followed by the monitors in the compliance network.

The overall SCAQS PM_{10} averages of 17 sampled days exceeded the annual standard of $50 \mu\text{g}/\text{m}^3$ at all but the Hawthorne, Long Beach, and San Nicolas Island sites during the summer and at all sites during the fall. Table 2-3 shows that the annual federal standard was, in actuality, exceeded at these sites in 1987.

Several of the species in Tables 4-1 to 4-4 (e.g., vanadium, chromium, manganese, nickel, copper, zinc, arsenic, selenium, strontium, barium, mercury, lead) are often classified as toxic, and their averages and maxima have been included in Tables 4-1 to 4-4. Many of these species were found at or near their lower quantifiable limits (LQLs) shown in Tables 3-5 to 3-8, so the averages and maximum concentrations are probably upper limits to exposures for several of these species. For these potentially toxic species, the maximum 24-hour PM_{10} concentrations observed at any SCAQS sites were as follows: 1) $0.019 \mu\text{g}/\text{m}^3$ of vanadium at the Hawthorne site; 2) $0.064 \mu\text{g}/\text{m}^3$ of chromium at the Hawthorne site; 3) $0.137 \mu\text{g}/\text{m}^3$ of manganese at the Rubidoux site; 4) $0.033 \mu\text{g}/\text{m}^3$ of nickel at the Anaheim site and $0.031 \mu\text{g}/\text{m}^3$ at the Hawthorne site; 5) $0.38 \mu\text{g}/\text{m}^3$ of copper at the Hawthorne site; 6) $0.667 \mu\text{g}/\text{m}^3$ of zinc at the Hawthorne site; 7) $0.032 \mu\text{g}/\text{m}^3$ of arsenic at the Downtown Los Angeles site; 8) $0.023 \mu\text{g}/\text{m}^3$ of selenium at the Burbank site; 9) $0.042 \mu\text{g}/\text{m}^3$ of strontium at the Burbank and Hawthorne sites; 10) $0.020 \mu\text{g}/\text{m}^3$ of barium at the Downtown Los Angeles site; 11) $0.02 \mu\text{g}/\text{m}^3$ mercury at all sites (these maxima are right at LQLs for mercury); and 12) $0.46 \mu\text{g}/\text{m}^3$ of lead at the Long Beach site. All of these maximum concentrations occurred during the fall campaign.

A few cases have been noted in Appendix A where the $\text{PM}_{2.5}$ concentration for a species exceeds the PM_{10} concentration for some of the metal concentrations in Tables 4-1 through 4-4. This is especially the case for copper, zinc, nickel, and iron, which might be in some of the metal shavings which were observed on some of the Teflon-membrane filters, as noted in Section 3. For a few of the cases in Tables 4-1 to 4-4, the $\text{PM}_{2.5}$ maximum concentration exceeds the corresponding PM_{10} concentration for this reason, or because one or more of the samples with shorter sampling durations used to obtain the 24-hour average were invalid.

Of these metals, only lead has an ambient air quality standard. The $1.5 \mu\text{g}/\text{m}^3$ quarterly average standard is never approached even by the maximum concentrations. While standards have not been set for the other metals, their concentrations are often considered in analyses of cancer risk. The maximum concentrations for these metals are very low, and the risk from exposure to these concentrations is probably minimal.

These low metal concentrations reflect the absence of industrial facilities that emit these metals within the SoCAB. Selenium and arsenic concentrations would be much higher if smelters and coal-fired power plants were present. Vanadium and nickel levels would increase if residual oil was still consumed in SoCAB power plants. The low concentrations of these

species at the Long Beach site indicate that harbor controls on shipping fuels are largely effective. The slightly more abundant maximum concentrations of some of these metals at the Hawthorne and Burbank sites might reflect the proximity of these sites to aerospace manufacturing companies which use several of these metals for construction and plating. The levels are so much lower than $1 \mu\text{g}/\text{m}^3$, however, that these emissions sources are not expected to be significant contributors to the average and maximum $\text{PM}_{2.5}$ and PM_{10} mass concentrations. The exception to this is lead, for which the major emitter is a relatively small number of vehicles which used leaded gasoline during 1987. The abundance of lead in source emissions will be discussed in Section 5.

The most abundant species (generally $> 1 \mu\text{g}/\text{m}^3$) in PM_{10} at all sites are chloride, nitrate, sulfate, ammonium, sodium, organic carbon, elemental carbon, silicon, calcium, and iron. For the maximum concentrations, nitrate, sulfate, ammonium, and organic carbon stand out as being the largest components of both $\text{PM}_{2.5}$ and PM_{10} , reaching concentrations of several tens of $\mu\text{g}/\text{m}^3$. Nitrate is by far the most abundant species, reaching a PM_{10} maximum of $85 \mu\text{g}/\text{m}^3$ at Anaheim on December 3, 1987. Sodium, aluminum, silicon, calcium, and iron are only abundant in the PM_{10} fraction, which is consistent with their presence in marine aerosol (sodium) and suspended dust (aluminum, silicon, calcium, and iron). Averages for all species are generally higher in fall than in summer. The exception is sulfate, where the summer averages are nearly twice the fall averages at the six sites which operated during both seasons. These results are consistent with studies by Zeldin *et al.* (1976), Cass (1977), and Cass and Shair (1984), which show that sulfate concentrations in the SoCAB are highest on the days preceded by morning fogs and stratus clouds; these clouds are uncommon during summer. Aqueous phase oxidation of sulfur dioxide by hydrogen peroxide or metal catalyzed autoxidation in these fogs and clouds is significantly faster than gas-phase oxidation by hydroxyl radicals (e.g., Hoffmann and Lim, 1979; Hoffmann, 1980, 1981; Hoffmann *et al.*, 1981; Boyce *et al.*, 1983; Munger *et al.*, 1983; Jacob *et al.*, 1986a, 1986b).

For the most abundant species, the San Nicolas Island site shows marked differences from the other sampling sites, as it should since it was intended to represent background aerosol transported into the SoCAB. The lowest chemical concentrations in the network are found at the San Nicolas Island site. As expected, there is evidence of a marine aerosol contribution as shown by sodium and chloride concentrations in both the $\text{PM}_{2.5}$ and PM_{10} size fractions, with the PM_{10} concentrations for these species three to four times those of the $\text{PM}_{2.5}$ fraction. The sulfate, nitrate, and ammonium concentrations are higher than those usually found in natural marine aerosol, indicating that there is probably some circulation of pollutants generated in the SoCAB over the Pacific Ocean, as observed by Cass and Shair (1984). $\text{PM}_{2.5}$ sulfate at the San Nicolas Island site far exceeds that which would be expected from a natural marine profile (Pytkowicz and Kester, 1971), and there is sufficient ammonium to attribute this to secondary ammonium sulfate. The high abundance of sodium and nitrate in the PM_{10} fraction compared to the $\text{PM}_{2.5}$ fraction implies a significant concentration of sodium nitrate. It is doubtful that sufficient nitric acid to create this compound is generated anywhere but in the nearby urban area. Organic and elemental carbon are also present at higher abundances than expected at a completely pristine site, though some traffic and power generation at the military facility on San

Nicolas Island may provide local contributions to these species. Crustal species such as aluminum, silicon, calcium, and iron are present at very low levels in both the PM_{2.5} and PM₁₀ fractions at this site, as are the remaining trace species.

Rubidoux is at the other end of the spectrum, with among the highest, or the highest, averages and maxima for all abundant species during summer and fall. Calcium stands out at Rubidoux, as it has in previous studies (Chow *et al.*, 1992), as being nearly six to ten times the calcium measured at the other sites. This is true for both the PM_{2.5} and PM₁₀ fractions. The average calcium concentration at the Rubidoux site in the fall is nearly ten times that found during the summer. Aluminum, silicon, and iron concentrations are also significantly higher than those found at the other sites, consistent with the findings of Chow *et al.* (1992).

Table 4-5 summarizes gaseous sulfur dioxide, ammonia, nitric acid, and total particulate nitrate in the PM_{2.5} fraction. The nitrate in Table 4-5 differs from that in Tables 4-1 and 4-3 because it includes the fraction of ammonium nitrate which volatilizes during sampling. Sulfur dioxide concentrations are generally low, with averages of only 3 to 9 $\mu\text{g}/\text{m}^3$ during the summer and 3 to 13 $\mu\text{g}/\text{m}^3$ during the fall at all of the urban sites. The maximum concentration of 20.6 $\mu\text{g}/\text{m}^3$ was found at the Long Beach site during the summer, and probably reflects the proximity of this site to oil fields, refineries, and ship traffic.

Average ammonia concentrations at all sites except Rubidoux range from 1 to 3 $\mu\text{g}/\text{m}^3$ during the summer and 4 to 7 $\mu\text{g}/\text{m}^3$ during the fall. The effect of the upwind Chino dairies and feedlots is very evident at the Rubidoux site, with average ammonia levels of 19 to 22 $\mu\text{g}/\text{m}^3$ and a maximum of 33 $\mu\text{g}/\text{m}^3$ during the fall. Average nitric acid concentrations are within 4 to 15 $\mu\text{g}/\text{m}^3$ during the summer except at the San Nicolas Island site ($0.35 \pm 0.17 \mu\text{g}/\text{m}^3$). Averages during the fall are about a third to half that of the summer averages except for the anomalously high concentrations at the Burbank site ($21.6 \pm 11.1 \mu\text{g}/\text{m}^3$ average) during the fall. Several of the Burbank nitric acid measurements are suspicious (Hering, 1990). Rubidoux is depleted in nitric acid relative to the other sampling sites, evidence that there is sufficient ammonia to neutralize most of the nitric acid.

Average PM_{2.5} total particulate nitrate follows the same trend among sites as average PM_{2.5} nitrate in Tables 4-1 and 4-3. The inland sites show much larger nitrate levels than do the coastal sites. Rubidoux has over twice the nitrate measured at other sites in the summer, but its average is much closer to those observed at other sites during the fall. Anaheim, rather than Rubidoux, shows the highest PM_{2.5} total particulate nitrate in the fall. Note that the fall PM_{2.5} total particulate nitrate averages and maxima are similar to the PM_{2.5} values in Table 4-3. The summer particulate nitrate values in Table 4-5 are substantially greater than those in Table 4-1.

4.2 Spatial Distributions of Major Particulate Chemical Components

Figures 4-1 to 4-4 show the spatial distributions of average crustal, nitrate, sulfate, ammonium, organic carbon, elemental carbon, and unexplained concentrations of PM_{2.5} and PM₁₀ for the summer and fall episodes during SCAQS. The pie charts in these figures follow

Table 4-5
Statistical Summary of Twenty-Four Hour Average Sulfur Dioxide, Ammonia, Nitric Acid, and
PM_{2.5} Total Particulate Nitrate During SCAQS Summer and Fall Campaigns

| Site | Sulfur Dioxide | | | Ammonia | | | Nitric Acid | | | PM _{2.5} Total Particulate Nitrate | | | | | | |
|------------------------------|----------------|------|-------|---------|-------|------|-------------|------|-------|---|-------|------|-------|-------|-------|----|
| | Avg. | Std. | Max. | Avg. | Std. | Max. | Avg. | Std. | Max. | Avg. | Std. | Max. | No. | | | |
| Summer Sampling Sites | | | | | | | | | | | | | | | | |
| Burbank | 3.85 | 2.09 | 9.32 | 11 | 3.26 | 1.82 | 6.24 | 11 | 14.52 | 6.62 | 24.94 | 11 | 11.54 | 4.67 | 20.41 | 11 |
| Downtown Los Angeles | 5.27 | 2.77 | 11.18 | 11 | 2.30 | 2.00 | 7.87 | 11 | 10.89 | 6.65 | 22.59 | 11 | 9.69 | 4.18 | 17.49 | 11 |
| Hawthorne | 9.21 | 2.56 | 13.27 | 11 | 0.91 | 0.68 | 2.38 | 11 | 6.38 | 5.16 | 16.46 | 11 | 4.29 | 1.93 | 7.38 | 11 |
| Long Beach | 8.11 | 5.79 | 20.60 | 11 | 1.11 | 0.96 | 3.98 | 11 | 6.35 | 2.62 | 11.49 | 11 | 4.33 | 2.07 | 7.35 | 11 |
| Anaheim | 3.99 | 3.17 | 11.49 | 11 | 1.36 | 1.28 | 4.97 | 11 | 6.23 | 3.04 | 12.57 | 11 | 6.26 | 3.10 | 11.21 | 11 |
| Riverside/ Rubidoux | 3.27 | 1.71 | 7.17 | 11 | 18.67 | 8.35 | 30.98 | 11 | 4.02 | 1.53 | 5.98 | 11 | 25.39 | 10.79 | 40.26 | 11 |
| San Nicolas Island | 0.05 | 0.08 | 0.24 | 10 | 0.18 | 0.12 | 0.43 | 8 | 0.35 | 0.17 | 0.72 | 11 | 0.80 | 0.55 | 1.91 | 11 |
| Azusa | 6.79 | 1.14 | 8.88 | 11 | 1.62 | 0.80 | 2.90 | 11 | 12.41 | 3.72 | 18.11 | 11 | 10.03 | 4.89 | 16.94 | 11 |
| Claremont | 3.70 | 1.33 | 6.07 | 11 | 2.06 | 2.36 | 9.29 | 11 | 13.18 | 3.83 | 18.44 | 11 | 11.16 | 4.60 | 17.59 | 11 |

Table 4-5 (Continued)
Statistical Summary of 24-Hour Average Sulfur Dioxide, Ammonia, Nitric Acid, and
PM_{2.5} Total Particulate Nitrate During SCAQS Summer and Fall Campaigns

| Site | Sulfur Dioxide | | | Ammonia | | | Nitric Acid | | | PM _{2.5} Total Particulate Nitrate | | | | | | |
|----------------------------|----------------|------|-------|---------|-------|------|-------------|-----|--------|---|--------|-----|-------|-------|-------|---|
| | Avg. | Std. | Max. | No. | Avg. | Std. | Max. | No. | Avg. | Std. | Max. | No. | | | | |
| Fall Sampling Sites | | | | | | | | | | | | | | | | |
| Burbank | 5.04 | 1.68 | 7.38 | 6 | 5.00 | 1.41 | 6.40 | 6 | 21.56* | 11.14* | 39.93* | 6 | 28.67 | 16.42 | 55.09 | 6 |
| Downtown Los Angeles | 8.10 | 1.14 | 9.24 | 2 | 5.54 | 2.15 | 7.99 | 6 | 4.70 | 1.07 | 5.36 | 6 | 26.37 | 16.05 | 50.55 | 6 |
| Hawthorne | 13.09 | 2.70 | 15.79 | 2 | 5.51 | 3.30 | 10.61 | 6 | 3.19 | 2.73 | 8.78 | 6 | 19.90 | 11.52 | 41.29 | 6 |
| Long Beach | 7.91 | 1.52 | 9.97 | 6 | 4.10 | 2.15 | 7.01 | 6 | 3.54 | 0.71 | 4.46 | 6 | 22.81 | 14.72 | 52.17 | 6 |
| Anaheim | 5.31 | 1.15 | 6.68 | 6 | 6.64 | 2.95 | 10.13 | 6 | 4.99 | 2.66 | 8.45 | 6 | 36.24 | 26.98 | 87.67 | 6 |
| Riverside/ Rubidoux | 3.45 | 1.02 | 4.66 | 6 | 21.89 | 7.21 | 32.69 | 6 | 0.86 | 0.16 | 1.11 | 6 | 27.56 | 21.59 | 69.42 | 6 |

* Suspect data.

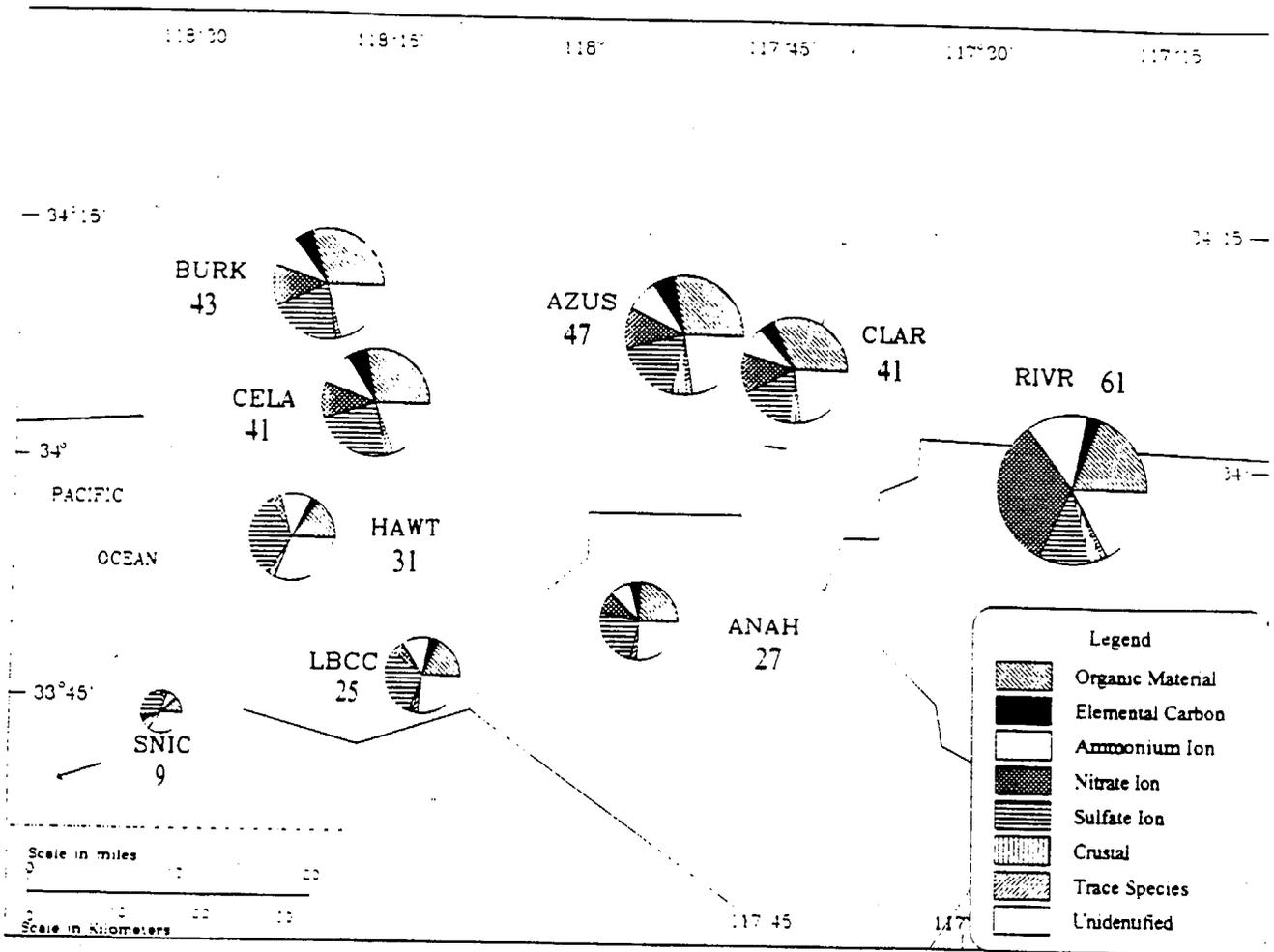


Figure 4-1. Average 24-Hour PM_{2.5} Aerosol Composition (Concentrations in $\mu\text{g}/\text{m}^3$) at Nine SCAQS Sites Between 6/19/87 and 9/3/87

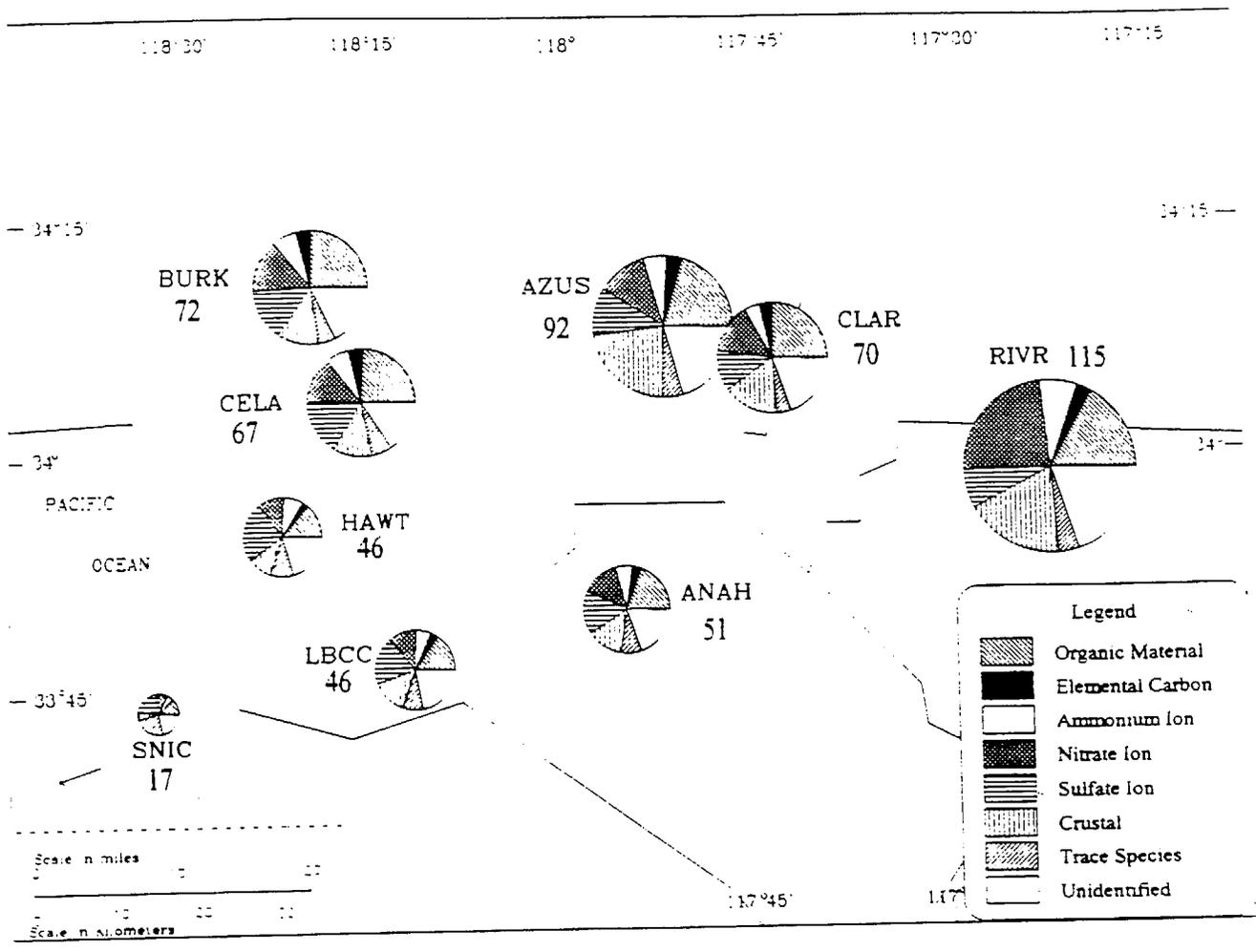


Figure 4-2. Average 24-Hour PM_{10} Aerosol Composition (Concentrations in $\mu g/m^3$) at Nine SCAQS Sites Between 6/19/87 and 9/3/87

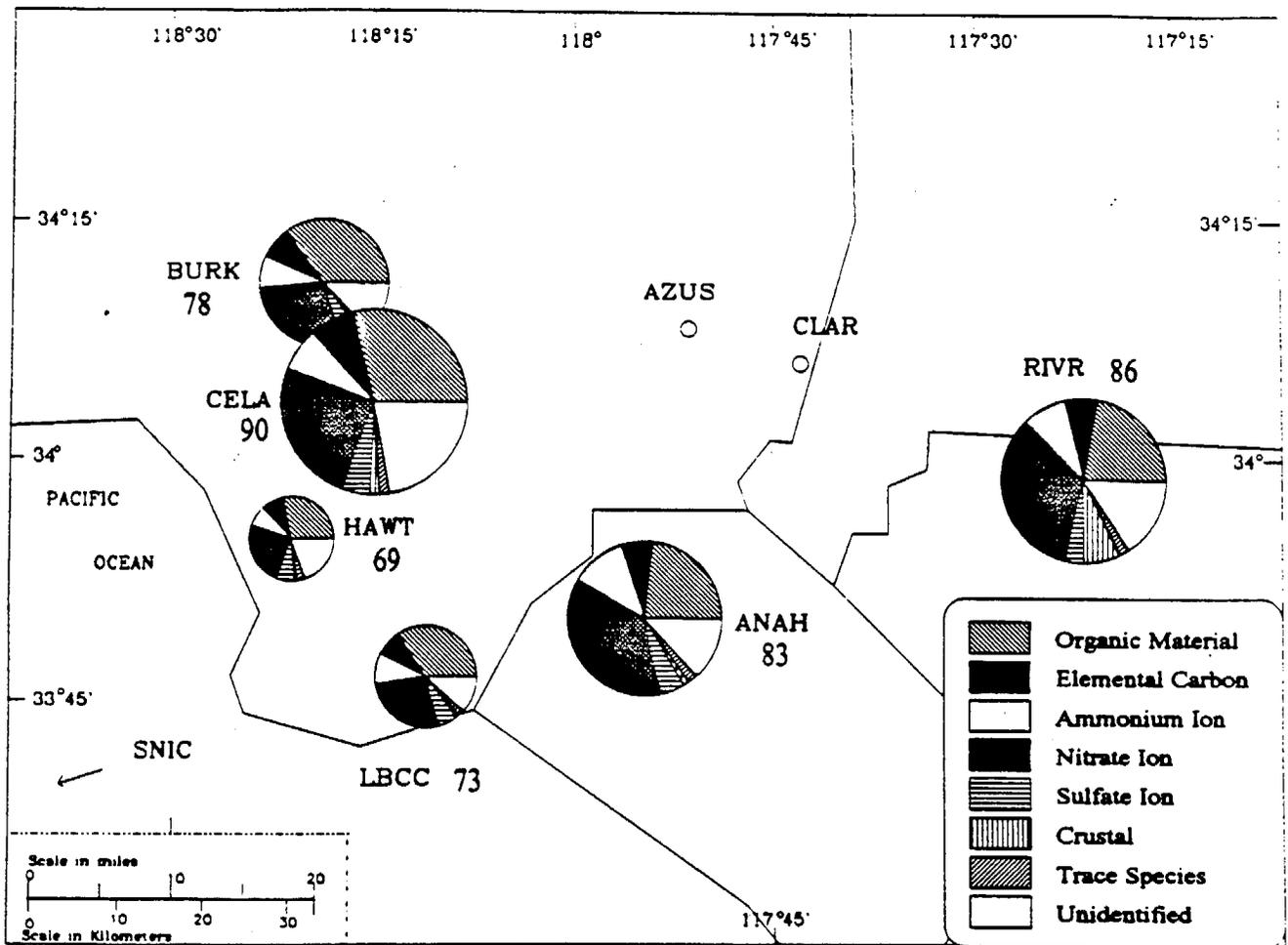


Figure 4-3. Average 24-Hour PM_{2.5} Aerosol Composition (Concentrations in $\mu\text{g}/\text{m}^3$) at Six SCAQS Sites Between 11/11/87 and 12/11/87

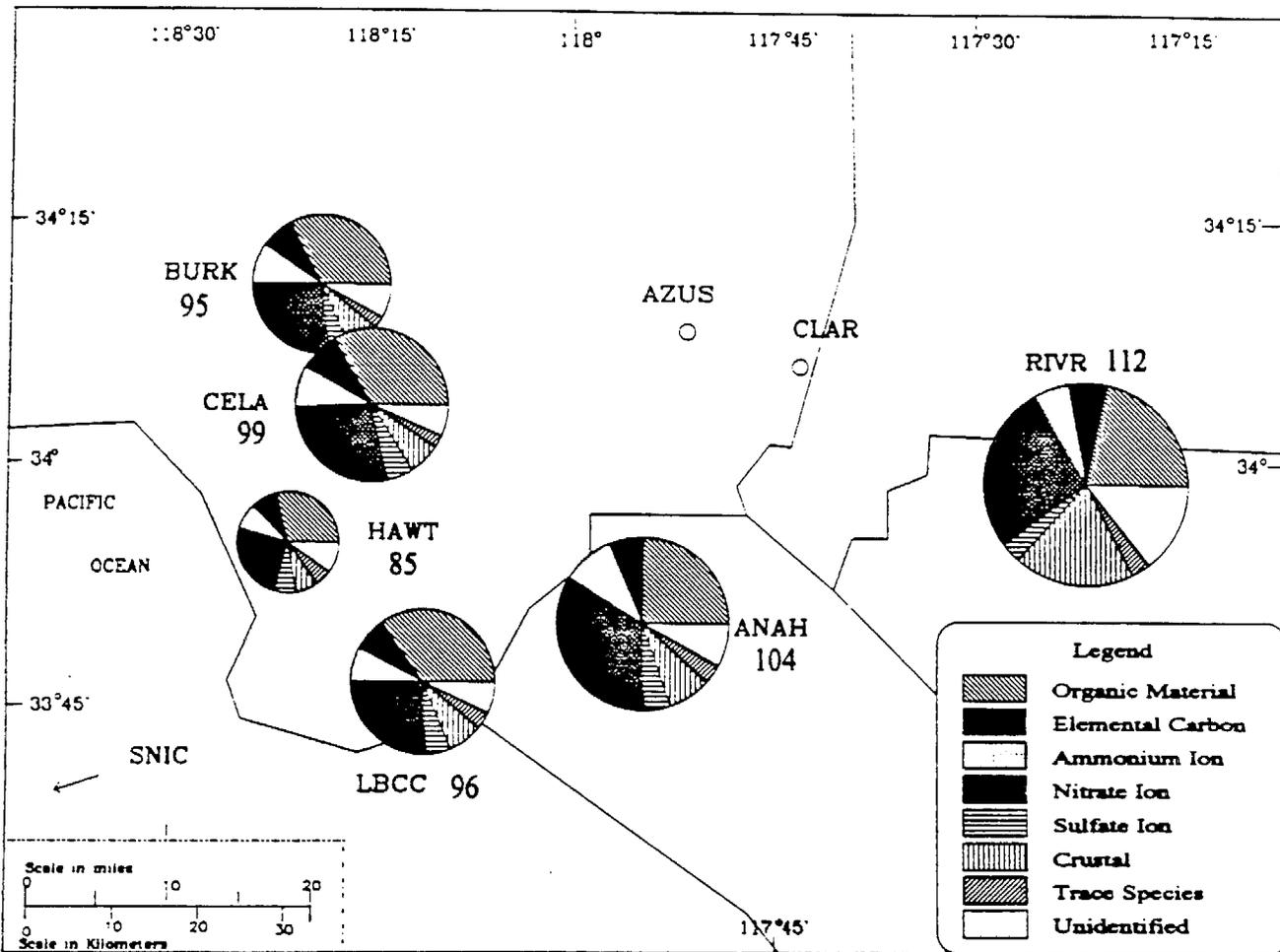


Figure 4-4. Average 24-Hour PM₁₀ Aerosol Composition (Concentrations in $\mu\text{g}/\text{m}^3$) at Six SCAQS Sites Between 11/11/87 and 12/11/87

the conventions of Solomon *et al.* (1989) by multiplying the average organic carbon concentrations by 1.4 to account for unmeasured hydrogen and oxygen in organic material. In addition, crustal material is estimated as the sum of aluminum, silicon, calcium, and iron oxides ($1.89\text{Al} + 2.14\text{Si} + 1.4\text{Ca} + 1.43\text{Fe}$), and trace species includes the sum of other species listed in Tables 4-1 to 4-4 (without double-counting Na and Cl).

The first feature is the large fraction of unexplained $\text{PM}_{2.5}$ and PM_{10} in these average mass balances. This unexplained portion constitutes 20% to 30% of the average $\text{PM}_{2.5}$ and 15% to 20% of the average PM_{10} during summer. The fractions are somewhat lower during fall, but they are still significant. Gray *et al.* (1986), Solomon *et al.* (1989), and Chow *et al.* (1992) show that this unexplained portion is usually less than only ~10% of the average mass concentrations. This unexplained portion offers further evidence that the inhomogeneous filter deposits result in lower than actual measurements for elements (contained in the crustal and trace species fraction) and carbon. Notice that during the fall, when crustal elements and carbon are a smaller fraction of the total mass, the portion of unexplained mass is also proportionally smaller.

Figures 4-1 and 4-3 show minimal contributions from crustal and trace species in the $\text{PM}_{2.5}$ fractions during summer and fall. There is a marked increase in $\text{PM}_{2.5}$ nitrate at the eastern SoCAB sites compared to the coastal sites. Sulfate retains a consistent absolute average concentration across the SoCAB, though its proportion becomes less as the nitrate and ammonium increase toward the eastern SoCAB. Crustal material and trace species are much larger proportions of PM_{10} at the eastern SoCAB sites during the summer.

During the fall, $\text{PM}_{2.5}$ and PM_{10} nitrate constitutes a much larger fraction of total mass at the coastal sites than it does during the summer. Elemental carbon is also a much larger fraction of the total mass during the fall.

Figures 4-5 and 4-6 show the major constituents of PM_{10} on the days which exceeded standards during SCAQS. The chemical distributions are very similar to the PM_{10} averages in Figure 4-2, but there is more of every major constituent. The basin-wide event on December 3, 1987 clearly shows the role of secondary ammonium, nitrate, and sulfate as causes of standard exceedances, as they constitute more than half of the PM_{10} at all sampling sites.

4.3 Temporal Changes in PM_{10} and $\text{PM}_{2.5}$

Figures 4-7a to 4-7c show the sample-to-sample variation in $\text{PM}_{2.5}$ and PM_{10} at all sites. In general, more than half of PM_{10} is in the $\text{PM}_{2.5}$ fraction. The exception is Azusa, where a number of samples show coarse particle concentrations which exceed $\text{PM}_{2.5}$, especially during the episode of August 27 to 29, 1987. Large deviations from the average coarse particle fraction occur only occasionally and at individual sites rather than across the SoCAB. This implies that coarse particle concentrations derive from localized emission events rather than from basin-wide phenomena.

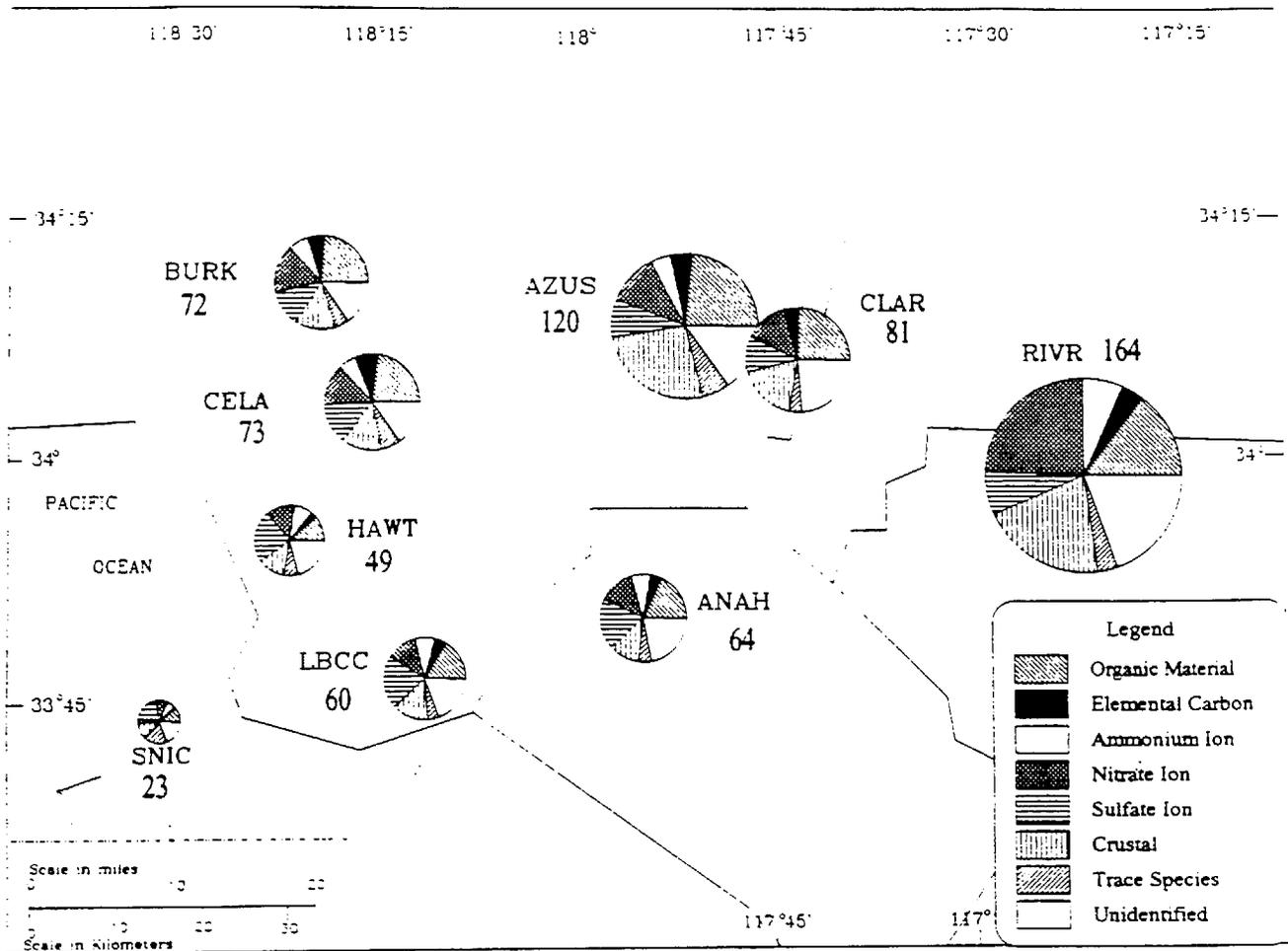


Figure 4-5. 24-Hour PM₁₀ Aerosol Composition (Concentrations in $\mu\text{g}/\text{m}^3$) at Nine SCAQS Sites on 8/28/87

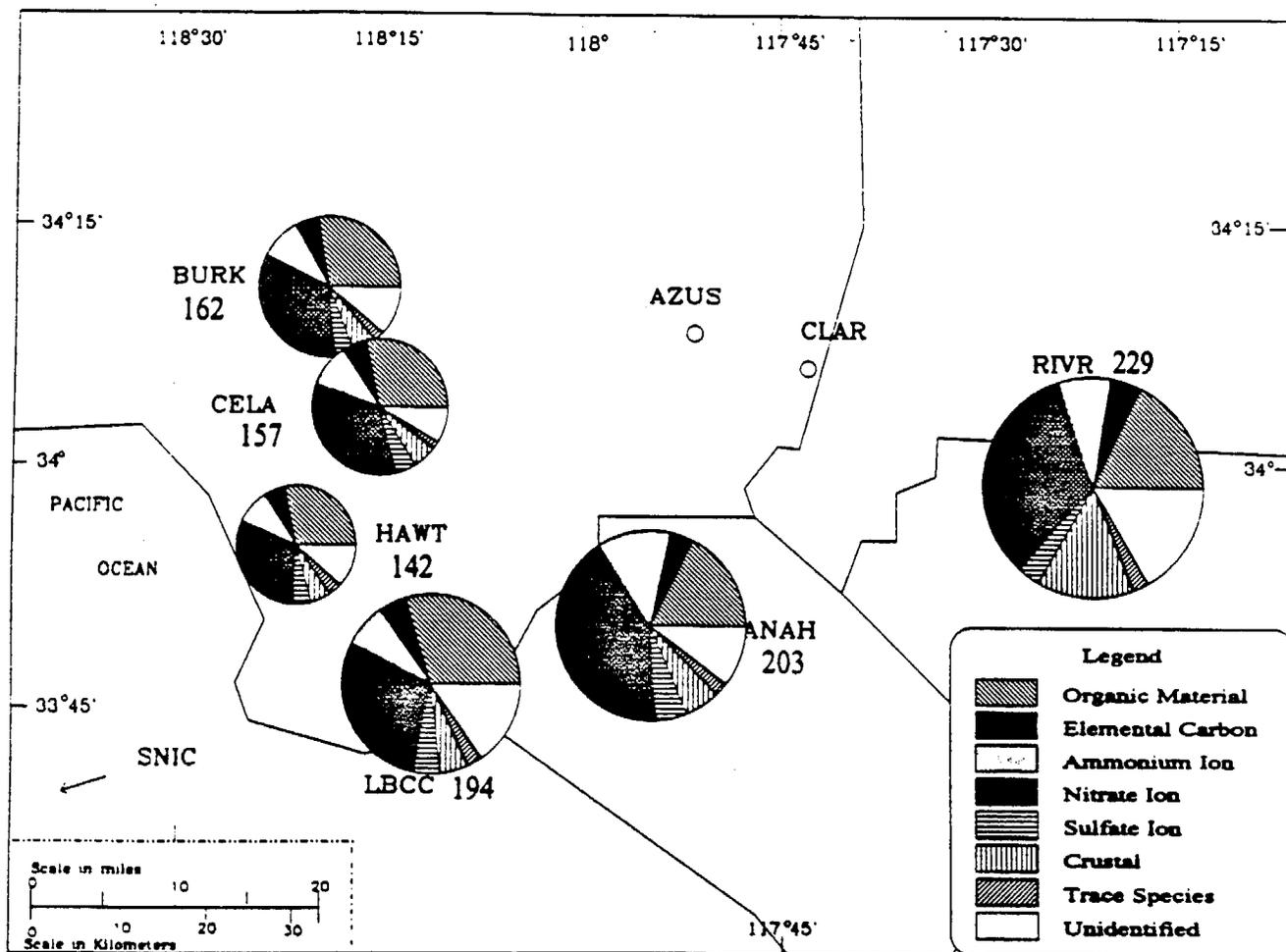
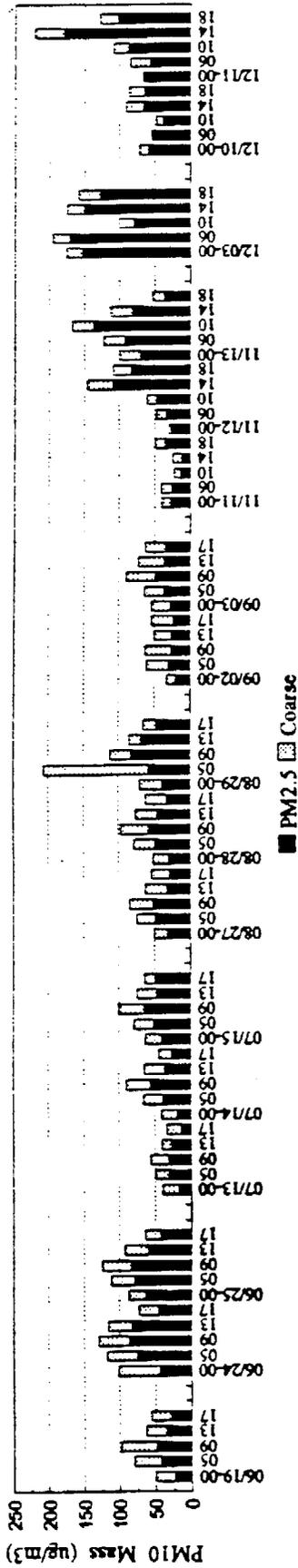
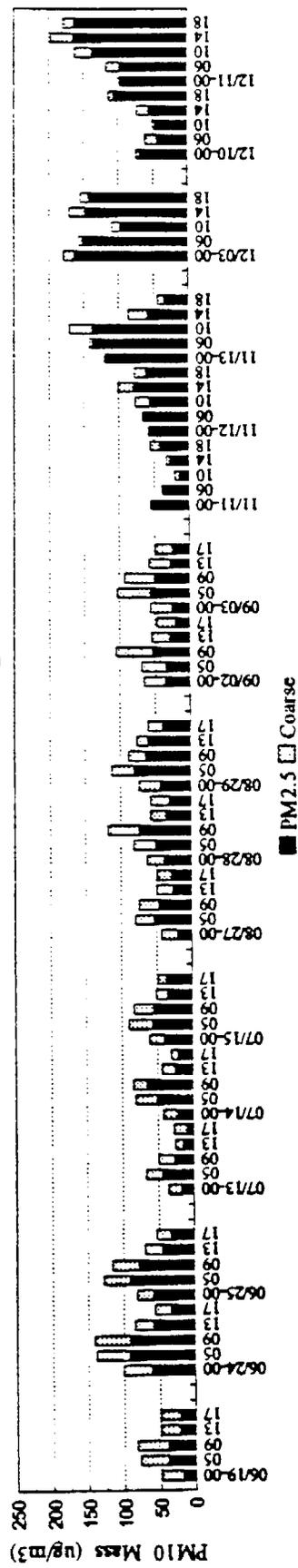


Figure 4-6. 24-Hour PM₁₀ Aerosol Composition (Concentrations in $\mu\text{g}/\text{m}^3$) at Six SCAQS Sites on 12/3/87

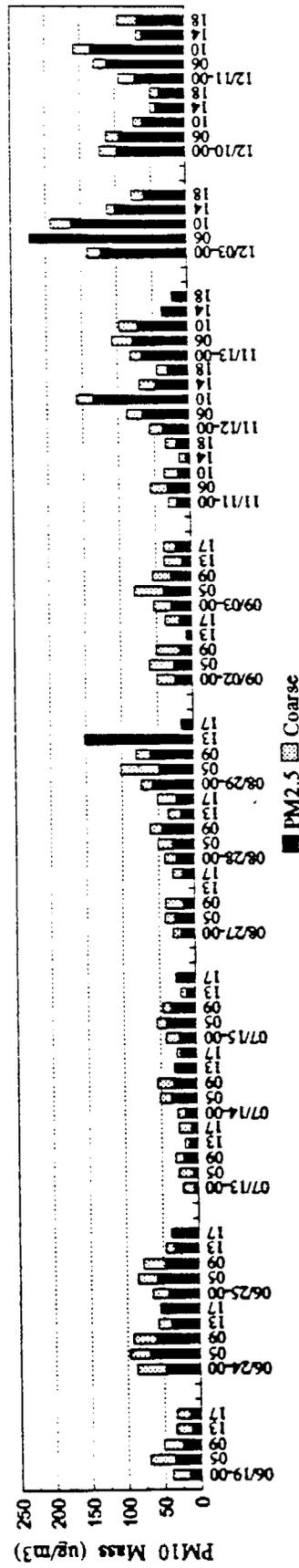
Burbank



Downtown Los Angeles



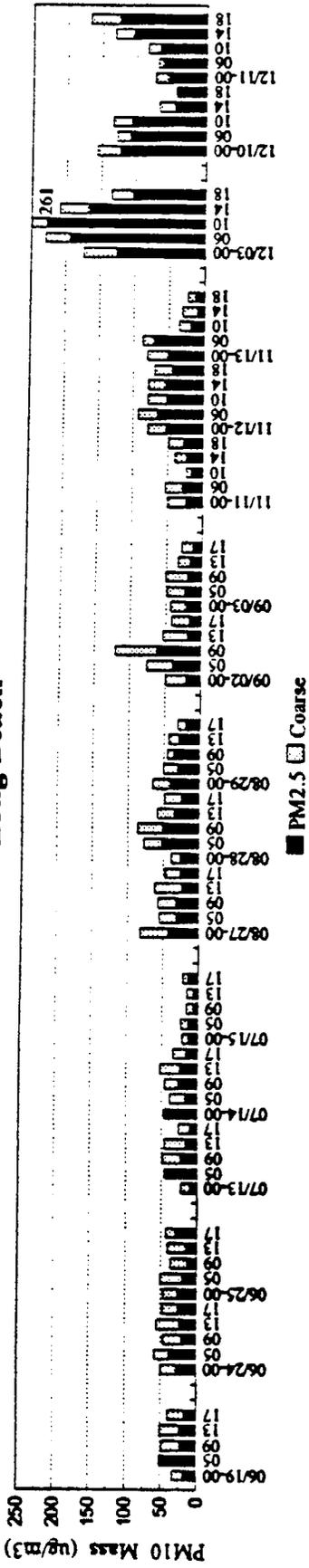
Hawthorne



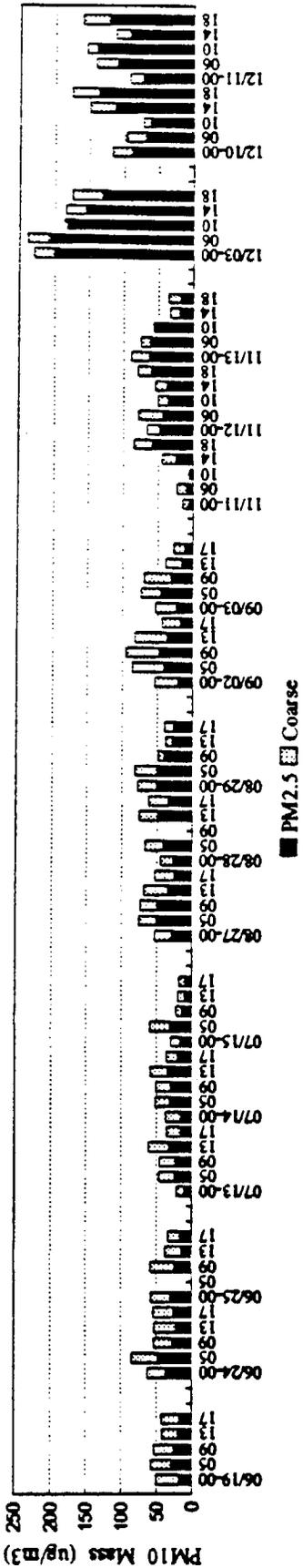
Sampling Dates and Starting Hours (PST)

Figure 4-7a. Variations of PM_{2.5} and PM₁₀ (PM_{2.5} Plus Coarse) with Time for Each SCAQS Episode at the Burbank, Downtown Los Angeles, and Hawthorne Sites Between 6/19/87 and 12/11/87

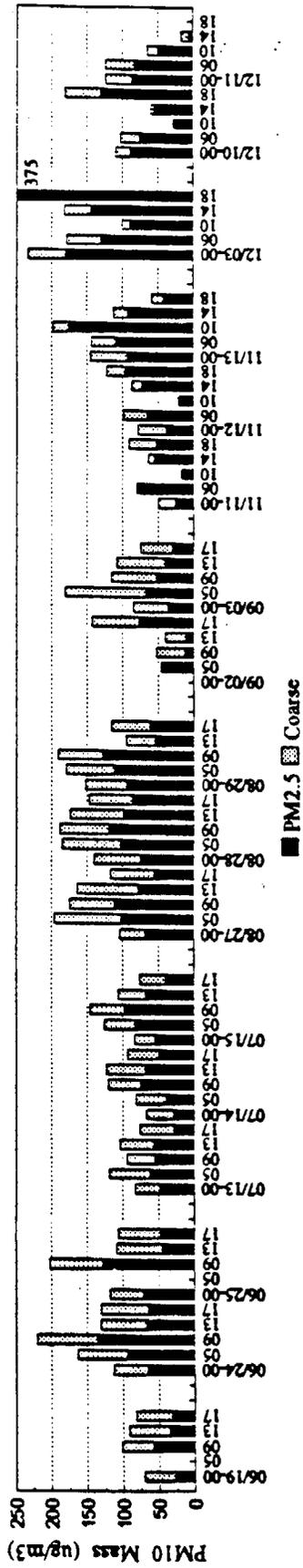
Long Beach



Anaheim



Rubidoux



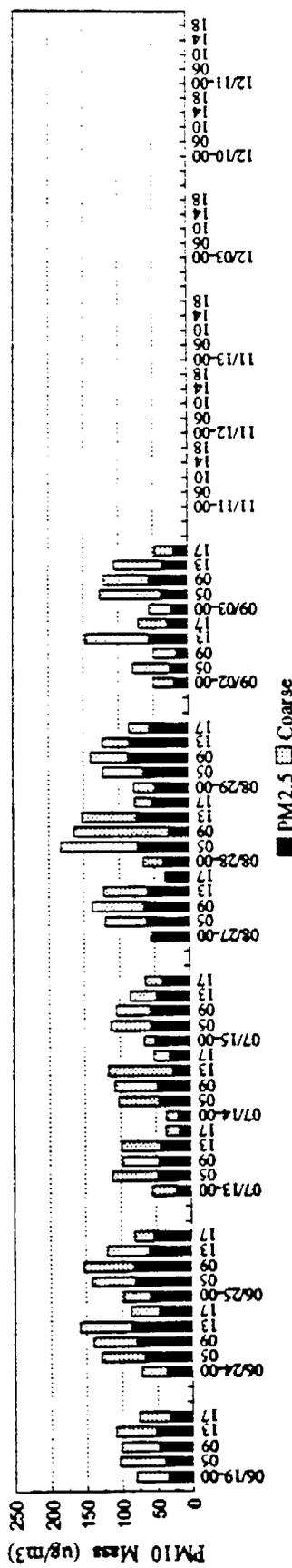
Sampling Dates and Starting Hours (PST)

Figure 4-7b. Variations of PM_{2.5} and PM₁₀ (PM_{2.5} Plus Coarse) with Time for Each SCAQS Episode at the Long Beach, Anaheim, and Rubidoux Sites Between 6/19/87 and 12/11/87

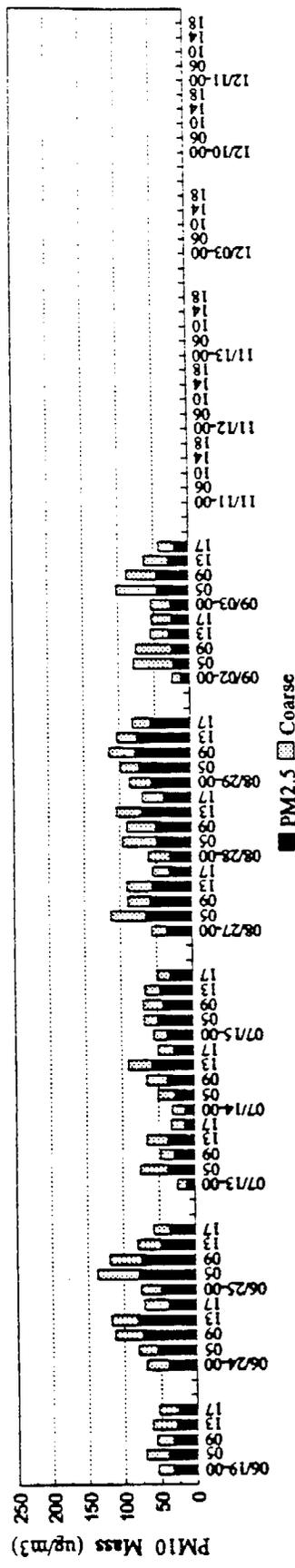
San Nicolas Island



Azusa



Claremont



Sampling Dates and Starting Hours (PST)

Figure 4-7c. Variations of PM_{2.5} and PM₁₀ (PM_{2.5} Plus Coarse) with Time for Each SCAQS Episode at the San Nicolas Island, Azusa, and Claremont Sites Between 6/19/87 and 9/3/87

Though the proportion of coarse particles in PM_{10} at Rubidoux is similar to the proportions at other sites, the absolute Rubidoux coarse particle concentrations are much larger than they are at other sites. The proportion of coarse particles declines at all sites during the fall relative to the summer.

Temporal variations in $PM_{2.5}$ and PM_{10} follow a diurnal cycle during summer in which the mass concentrations reach a low point at 0000 PST, rise through 1300 PST, then drop after 1700 PST. During the fall, maximum mass concentrations occur in the early morning between 0000 and 1000 PST, and reach their minima in the afternoon between 1400 and 1800 PST. Whenever there are exceptions to these patterns, excessive coarse particle mass is present.

The summer situation appears to correspond to late afternoon ventilation of the SoCAB by the west-to-east transport winds. The fall situation corresponds to limited ventilation, nighttime inversions, and coupling of the surface to the mixed layer only during hours of daylight. The diurnal patterns of $PM_{2.5}$ and PM_{10} mass concentrations are consistent with the meteorology on the sampled days.

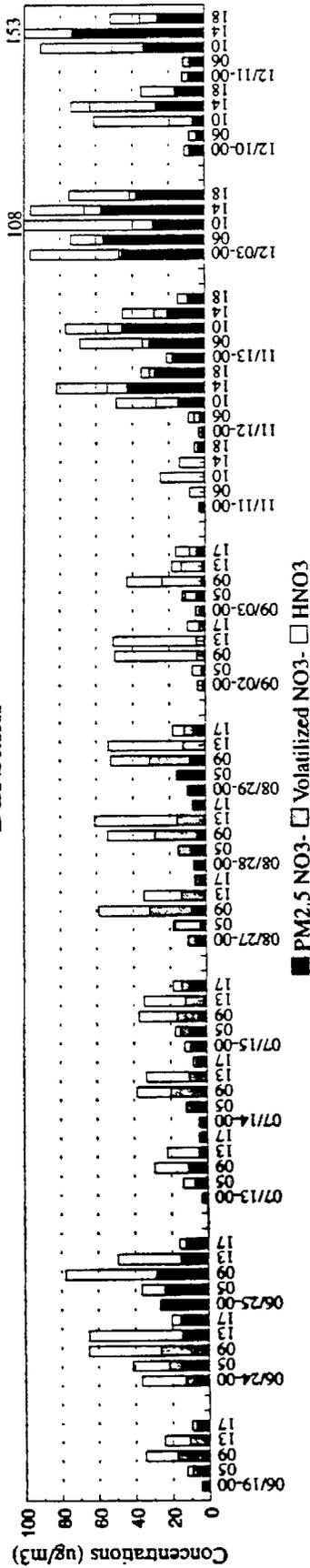
No multi-day buildup was observed during the summer study, except possibly at the Hawthorne site from August 28 to 29, 1987. This was also the episode which exhibited the highest ozone concentrations during SCAQS. The episode of November 11 to 13, 1987 is interesting because PM_{10} concentrations increased during the morning of November 13 at most of the sites. The episode of December 3, 1987 may have also been preceded by just such a buildup of pollutants carried over from the previous day, and it stands out with high $PM_{2.5}$ levels at each site throughout the day.

4.4 Temporal Changes in Particulate Nitrate, Nitric Acid, and Ammonia

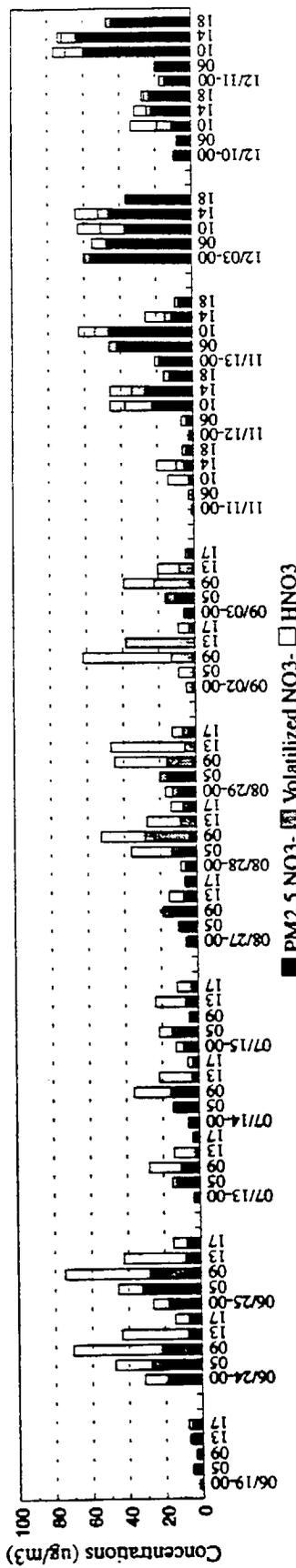
Figures 4-8a to 4-8c show how three types of nitrate vary from sample to sample. The bottom bar represents the $PM_{2.5}$ particulate nitrate on Teflon-membrane filters (Channel 9 in Figure 3-2), the height of the middle bar represents $PM_{2.5}$ total particulate nitrate (non-volatilized and volatilized nitrate from Channel 3), and the height of all the bars represents the sum of gaseous nitric acid and $PM_{2.5}$ total particulate nitrate (Channel 4). Note that all samples typically consist of a combination of all three types of nitrate, but their relative proportions vary among sampling sites, with time of day, and with sampling season.

The outstanding feature of these plots is that total gaseous and particulate nitrate, especially $PM_{2.5}$ particulate nitrate, is much larger during the fall, at all times of the day, than it is during the summer. Though this is reflected in Table 4-5, the plots emphasize the basin-wide character and diurnal development of these nitrate events. During the fall, the Burbank site has much more volatilized particulate nitrate and anomalously high nitric acid concentrations than is found at the other sites; as noted earlier, these high nitric acid values are suspect. For the episode of December 3, 1987, the highest nitrate peaks are found: during the early morning hours at the Anaheim site; during mid-morning at the Long Beach and Hawthorne sites; evenly

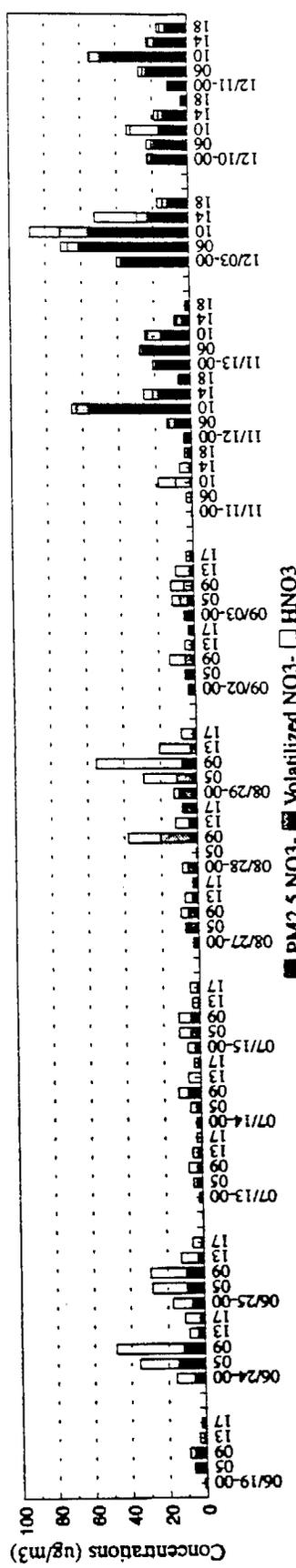
Burbank



Downtown Los Angeles



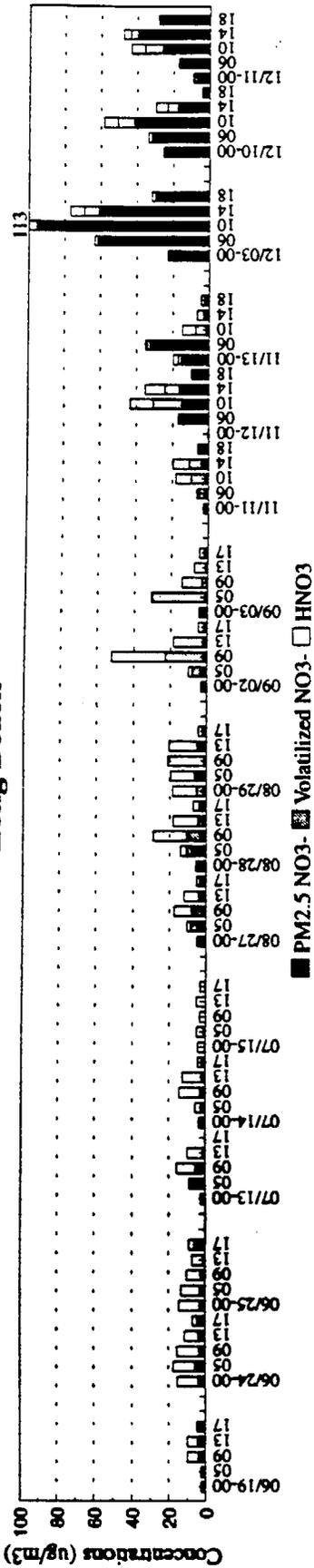
Hawthorne



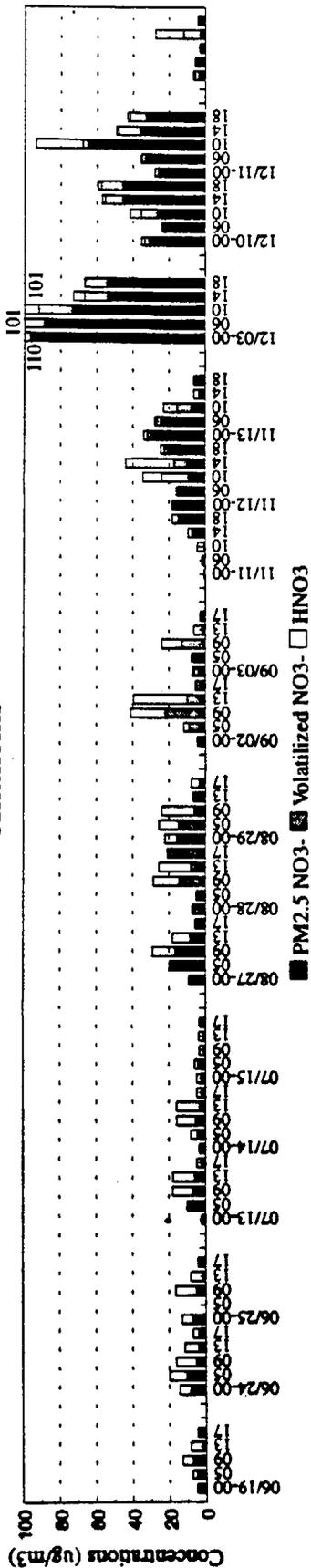
Sampling Dates and Starting Hours (PST)

Figure 4-8a. Variations of PM_{2.5} Nitrate, Volatilized Nitrate, and Nitric Acid with Time for Each SCAQS Episode at the Burbank, Downtown Los Angeles, and Hawthorne Sites Between 6/19/87 and 12/11/87.

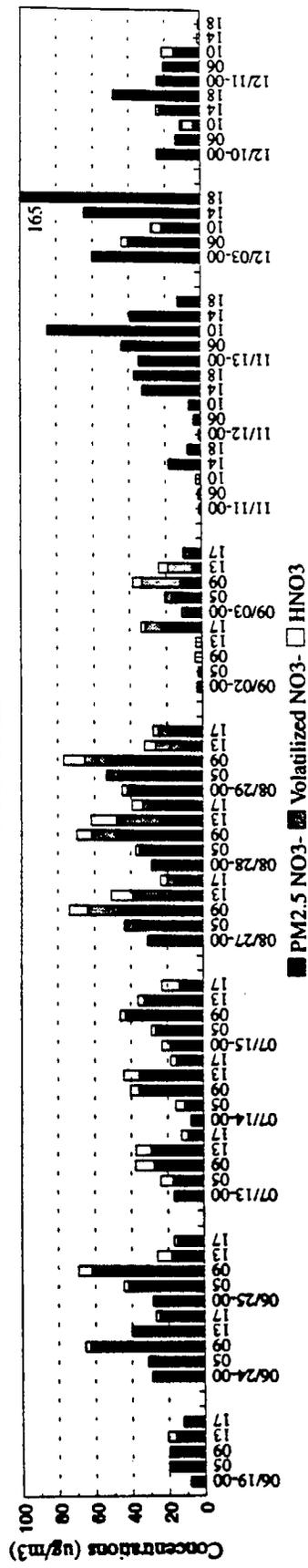
Long Beach



Anaheim



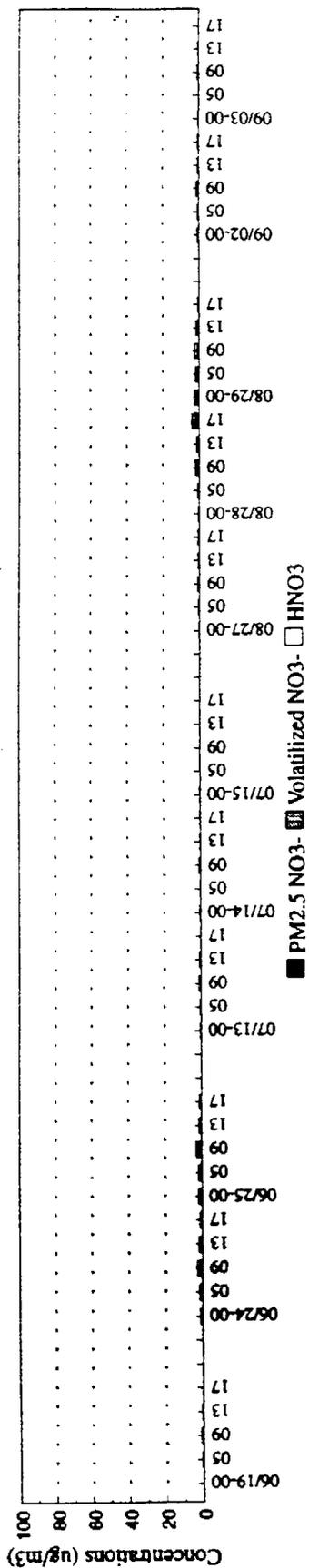
Rubidoux



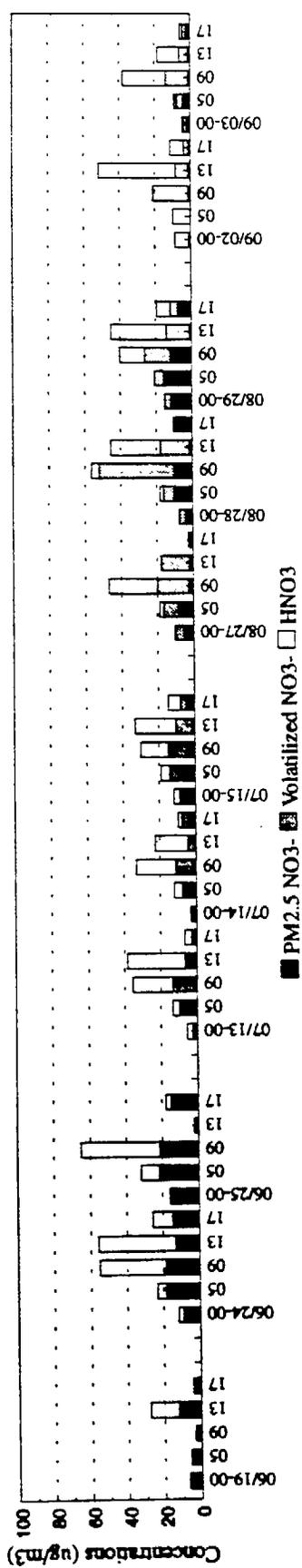
Sampling Dates and Starting Hours (PST)

Figure 4-8b. Variations of PM_{2.5} Nitrate, Volatilized Nitrate, and Nitric Acid with Time for Each SCAQS Episode at the Long Beach, Anaheim, and Rubidoux Sites Between 6/19/87 and 12/11/87.

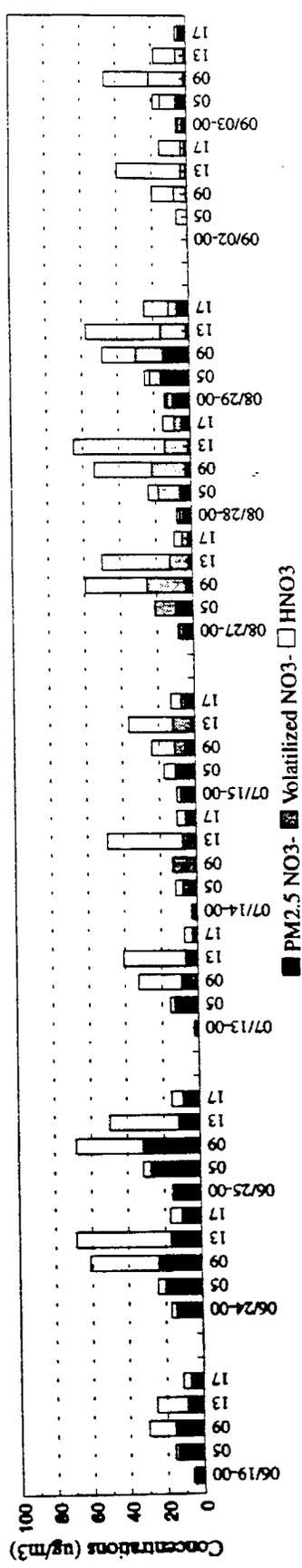
San Nicolas Island



Azusa



Claremont



Sampling Dates and Starting Hours (PST)

Figure 4-8c. Variations of PM_{2.5} Nitrate, Volatilized Nitrate, and Nitric Acid with Time for Each SCAQS Episode at the San Nicolas Island, Azusa, and Claremont Sites Between 6/19/87 and 9/3/87.

interspersed throughout the day at the Downtown Los Angeles site; and late in the afternoon at the Rubidoux site.

Nitrate levels are much lower during the summer, and a much larger fraction is either volatilized or present as nitric acid. Burbank, Azusa, and Claremont show higher proportions of nitric acid than are seen at the other sites, and nitric acid reaches its maximum at these sites between mid-morning and late afternoon. Nitrate tends more toward the volatilized and nitric acid phases during the daytime and toward the $PM_{2.5}$ particulate phase during the nighttime. This is consistent with diurnal changes in equilibrium which correspond to diurnal changes in temperature. Nitrate at Rubidoux is the exception. Though the site shows increased volatilized nitrate during daytime, it shows very little nitric acid at any time.

Figures 4-9a to 4-9c show an analogous time series for $PM_{2.5}$ ammonium (Channel 9), $PM_{2.5}$ total ammonium (Channel 5 filter), and ammonia gas (Channel 5 denuder). The non-volatilized and volatilized ammonium follow the same trends as the non-volatilized and volatilized nitrate. Reflecting the average values, Rubidoux shows much higher gaseous ammonia concentrations than are found at any of the other sites.

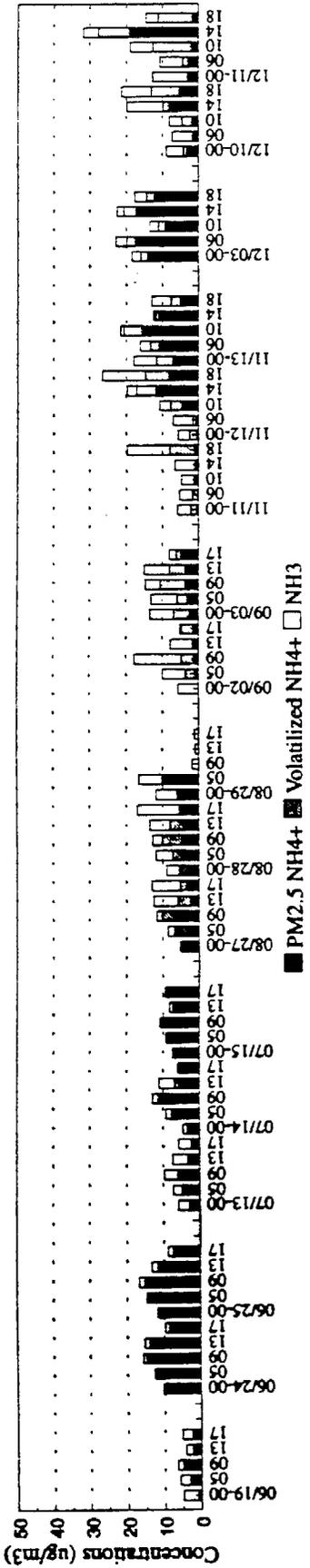
These data show that at the inland sites during the summer, particulate ammonium nitrate concentrations are ammonia-limited at all sites except Rubidoux. Reducing nitric acid and its precursors will not necessarily result in reductions in contributions to PM_{10} , until there is an excess of ammonia to obtain equilibrium. It also implies that reductions in the ammonia emissions from the nearby dairies and feedlots might have a substantial effect on the highest PM_{10} concentrations measured at Rubidoux.

4.5 Temporal Changes in Organic and Elemental Carbon

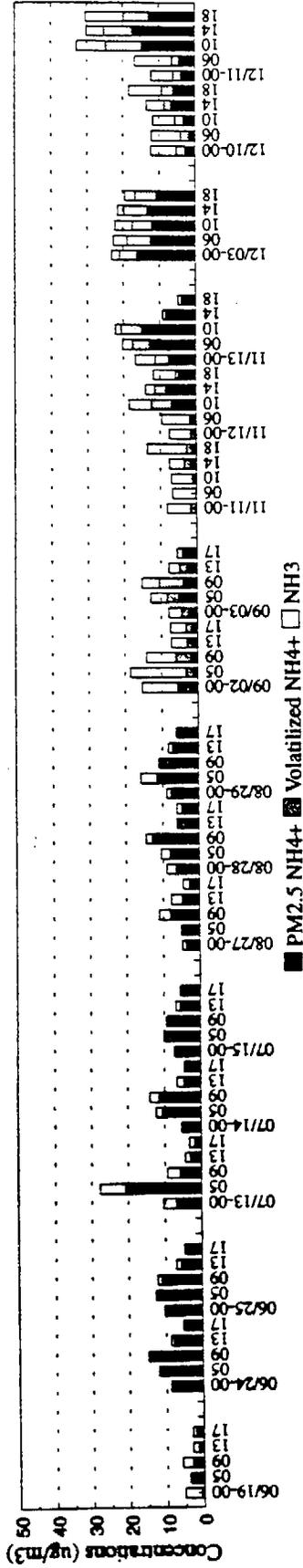
Figures 4-10a to 4-10c show organic and elemental carbon concentrations for summer and fall periods. Hawthorne, Long Beach, and Anaheim have much lower carbon concentrations than are found at the other sampling sites. The elemental carbon concentrations are also much larger proportions of total carbon in the fall than they are during the summer. The summer and fall diurnal cycles for carbon reflect those found for $PM_{2.5}$ and PM_{10} mass in Figures 4-7a through 4-7c.

Figure 4-11 shows the total to elemental carbon ratios measured at the Claremont site during the summer and at the Long Beach site during the summer and fall. The summertime ratios are quite variable, but since the elemental carbon values are so low and close to lower quantifiable limits during summer, these ratios are not very reliable. It is possible to see some slight changes in the ratios during the episode of August 27 to 29, 1987, which might correspond to the observations of Turpin and Huntzicker (1991) with respect to secondary organic aerosol at the Claremont site during this period. The peaks in these ratios at the Claremont site usually occurred between 1300 and 1700 PST on the final two days of the episode and corresponding peaks are not found in the ratios at the Long Beach site. It is possible that there were some

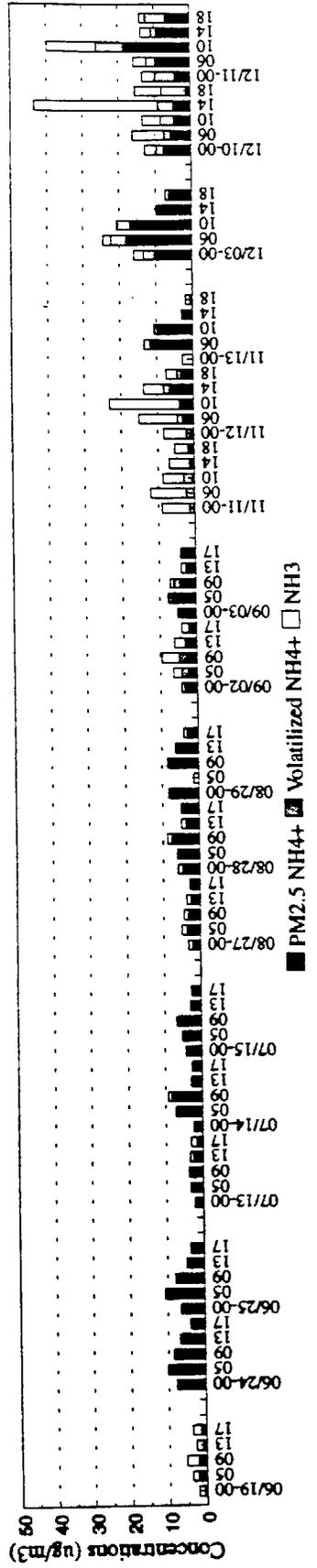
Burbank



Downtown Los Angeles



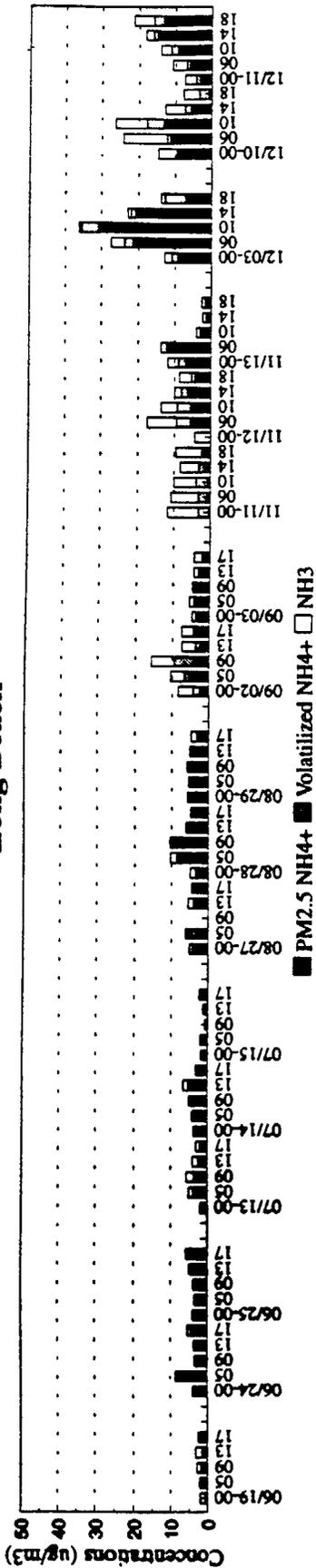
Hawthorne



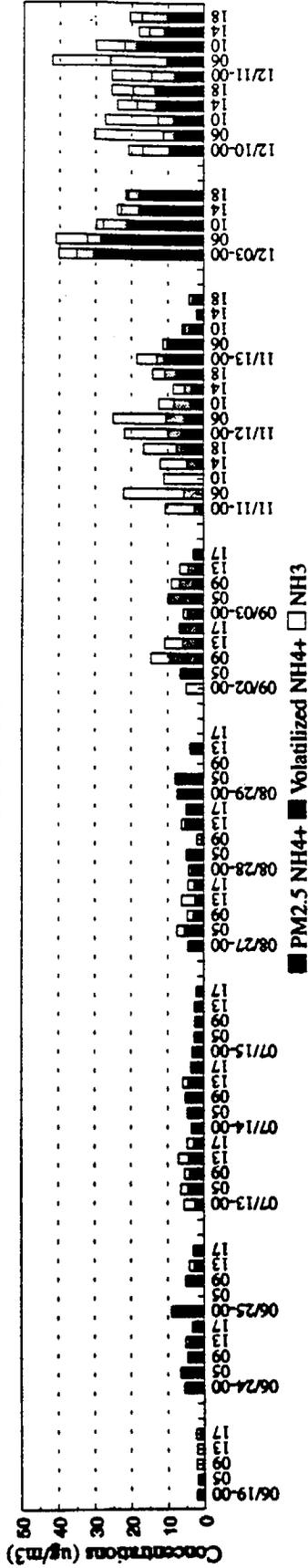
Sampling Dates and Starting Hours (PST)

Figure 4-9a. Variations of PM_{2.5} Ammonium, Volatilized Ammonium, and Ammonia with Time for Each SCAQS Episode at the Burbank, Downtown Los Angeles, and Hawthorne Sites Between 6/19/87 and 12/11/87.

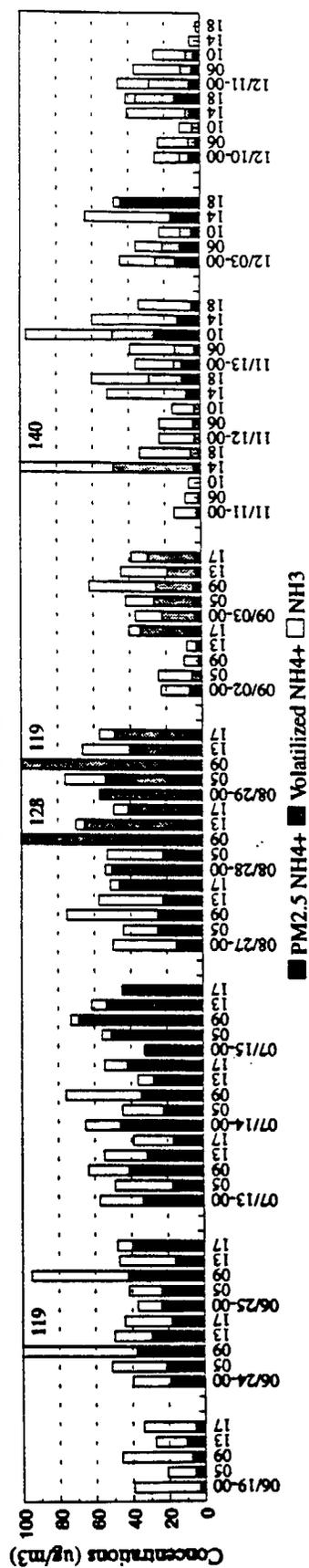
Long Beach



Anaheim



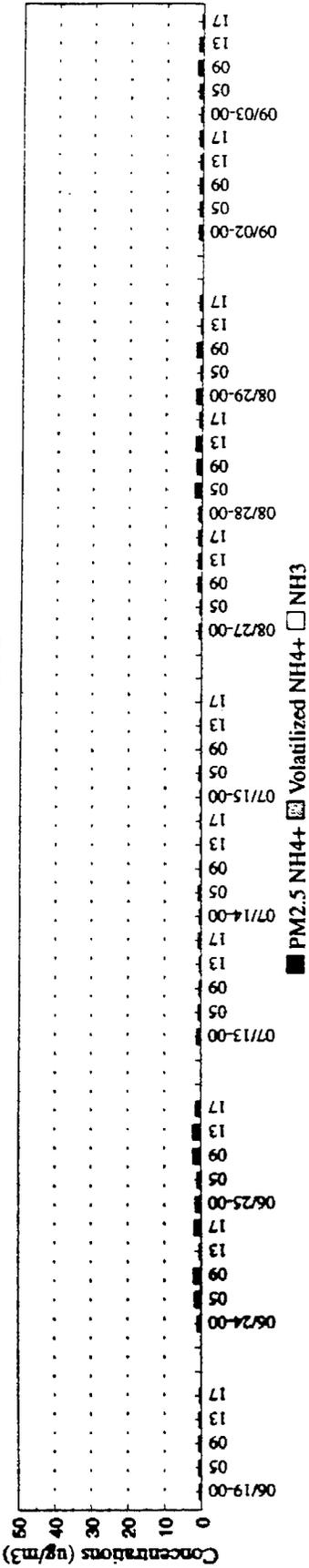
Rubidoux



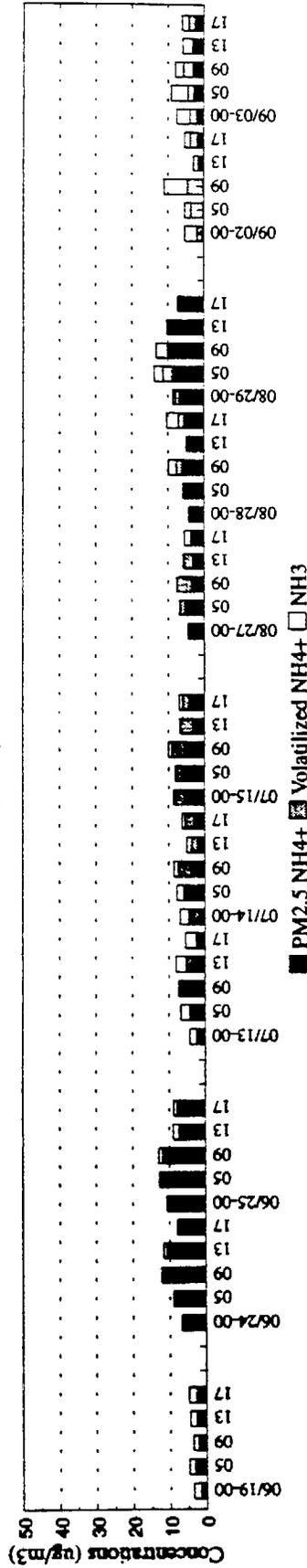
Sampling Dates and Starting Hours (PST)

Figure 4-9b. Variations of PM_{2.5} Ammonium, Volatilized Ammonium, and Ammonia with Time for Each SCAQS Episode at the Long Beach, Anaheim, and Rubidoux Sites Between 6/19/87 and 12/11/87.

San Nicolas Island



Azusa



Claremont

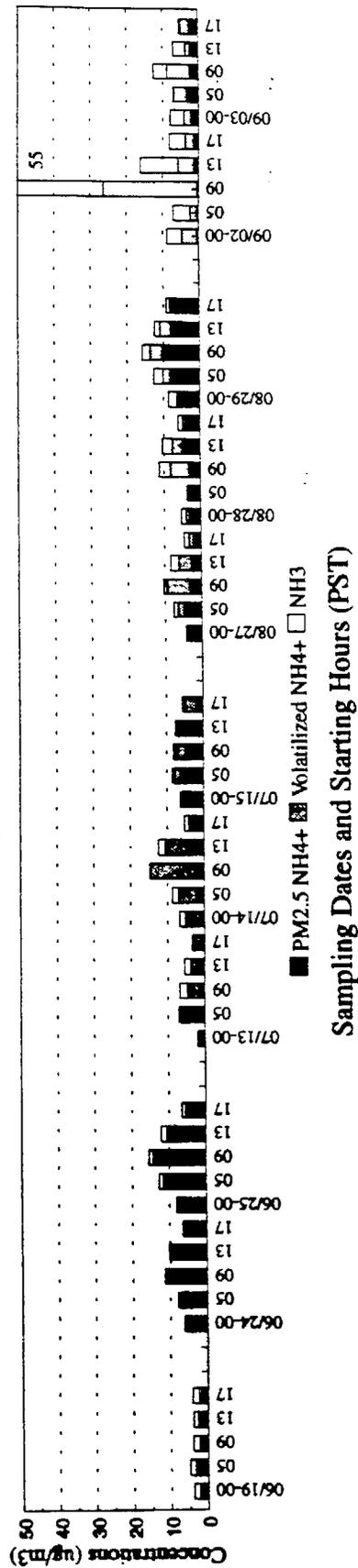
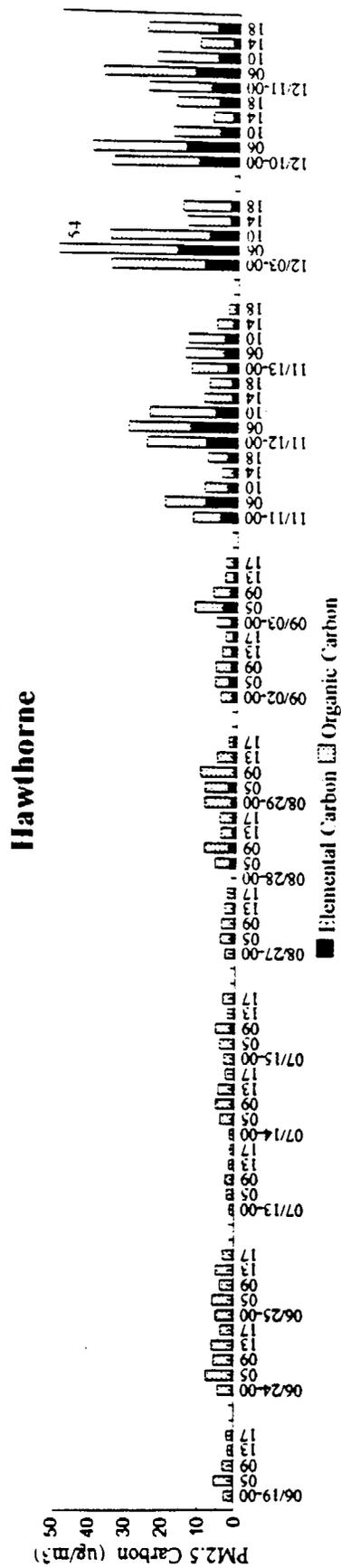
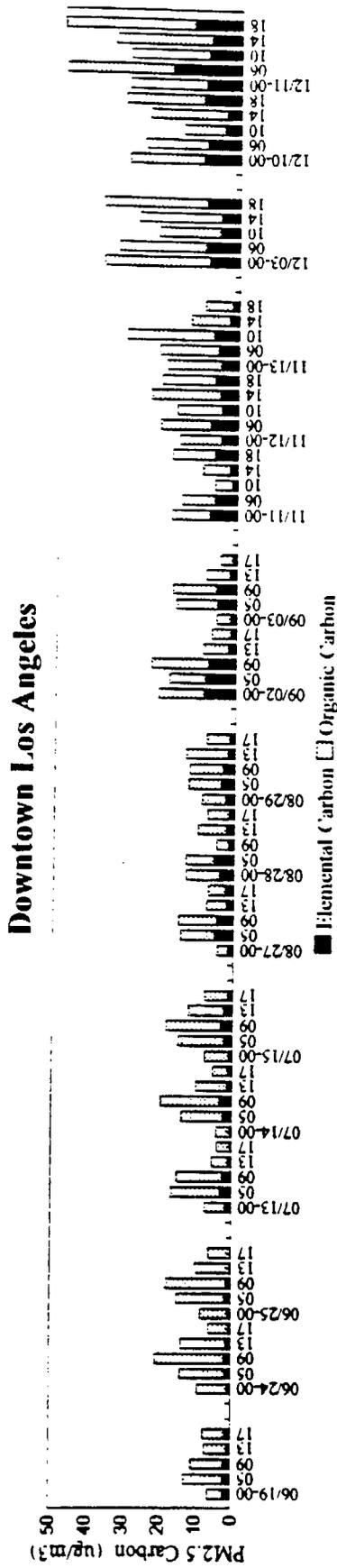
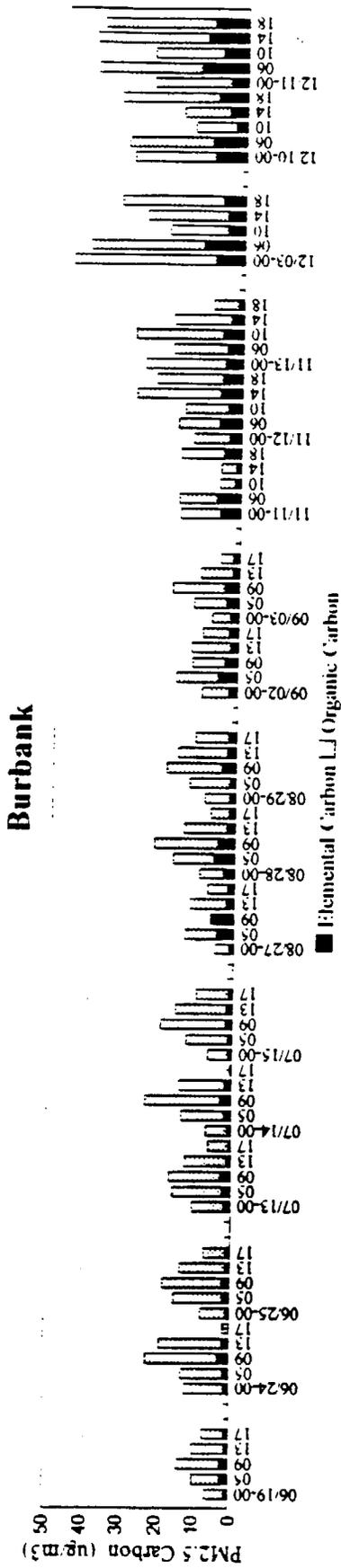


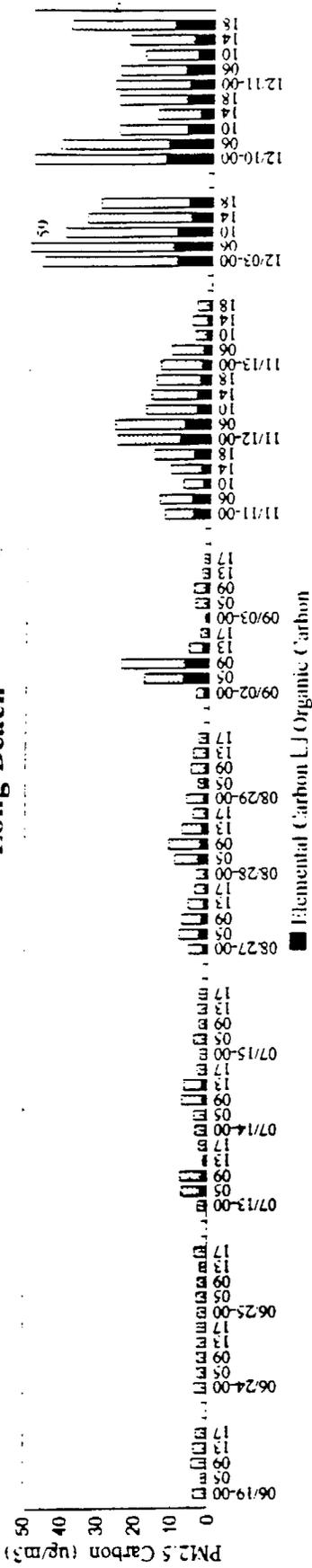
Figure 4-9c. Variations of PM_{2.5} Ammonium, Volatilized Ammonium, and Ammonia with Time for Each SCAQS Episode at the San Nicolas Island, Azusa, and Claremont Sites Between 6/19/87 and 9/3/87.



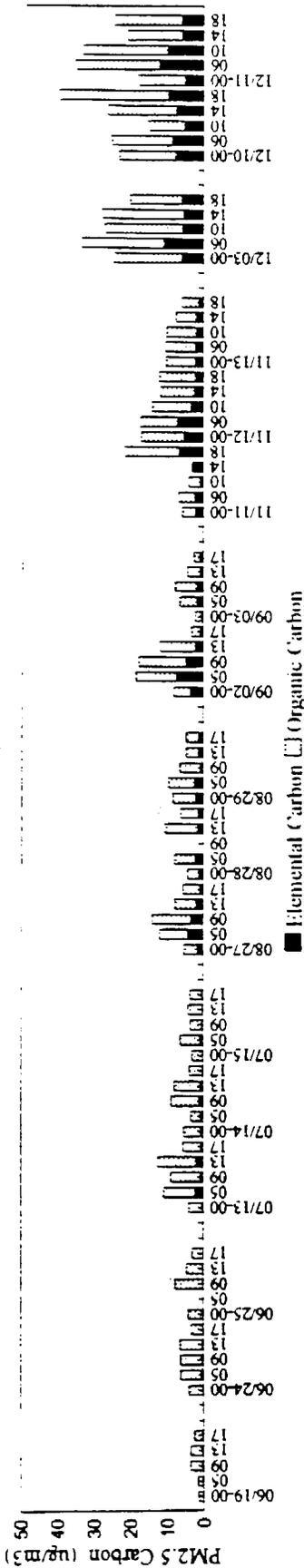
Sampling Dates and Starting Hours (PST)

Figure 4-10a. Variations of PM_{2.5} Carbon with Time for Each SCAQS Episode at the Burbank, Downtown Los Angeles, and Hawthorne Sites Between 6/19/87 and 12/11/87

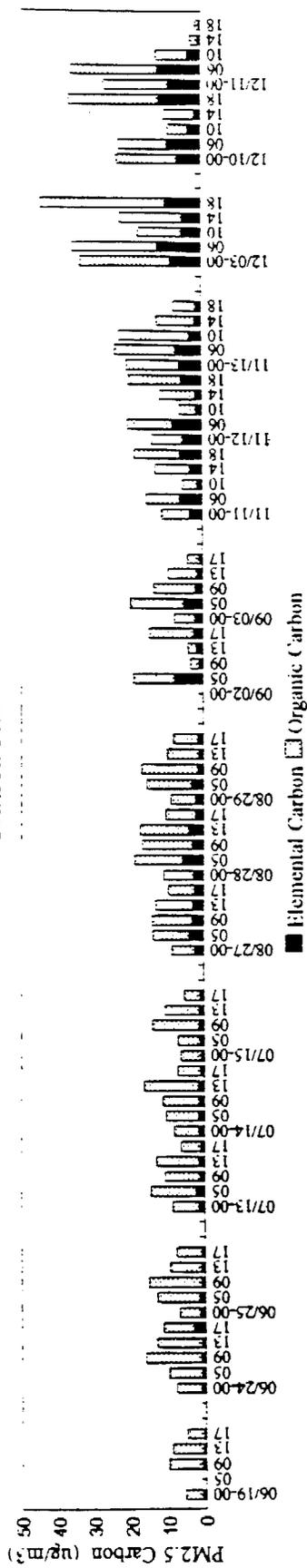
Long Beach



Anaheim



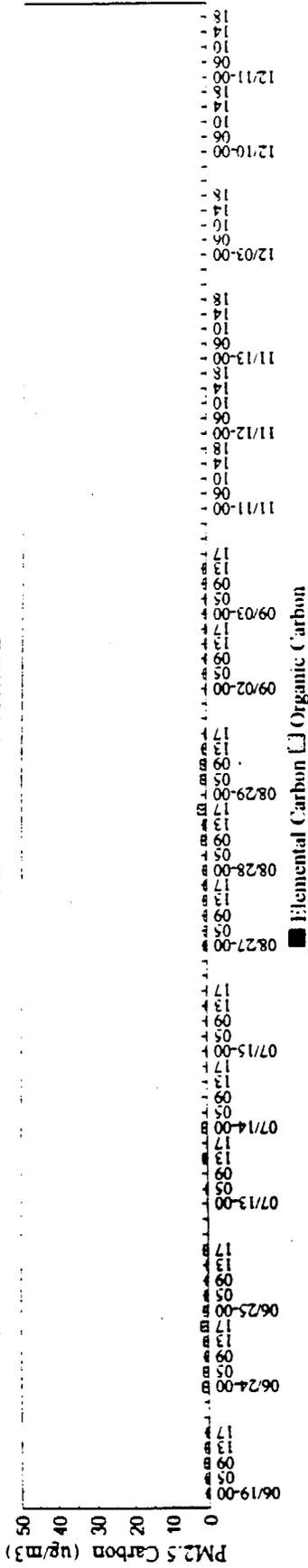
Rubidoux



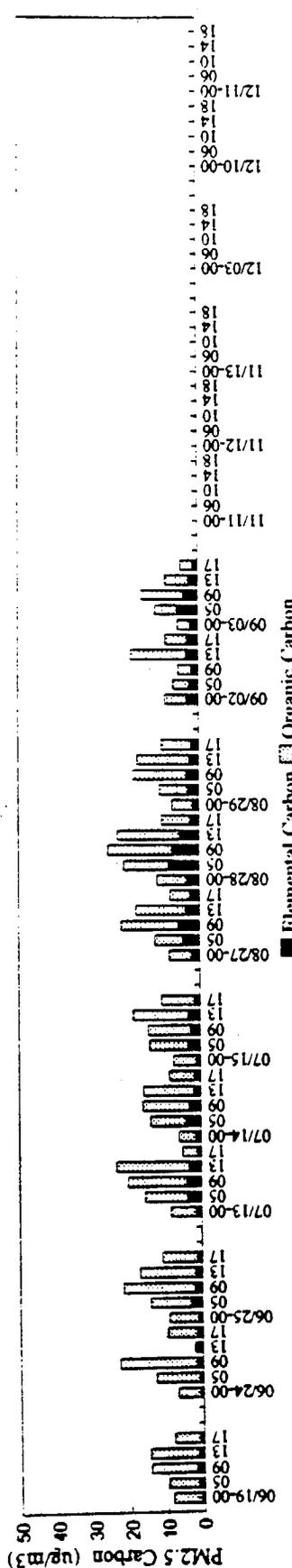
Sampling Dates and Starting Hours (PST)

Figure 4-10b. Variations of PM_{2.5} Carbon with Time for Each SCAQS Episode at the Long Beach, Anaheim, and Rubidoux Sites Between 6/19/87 and 12/11/87

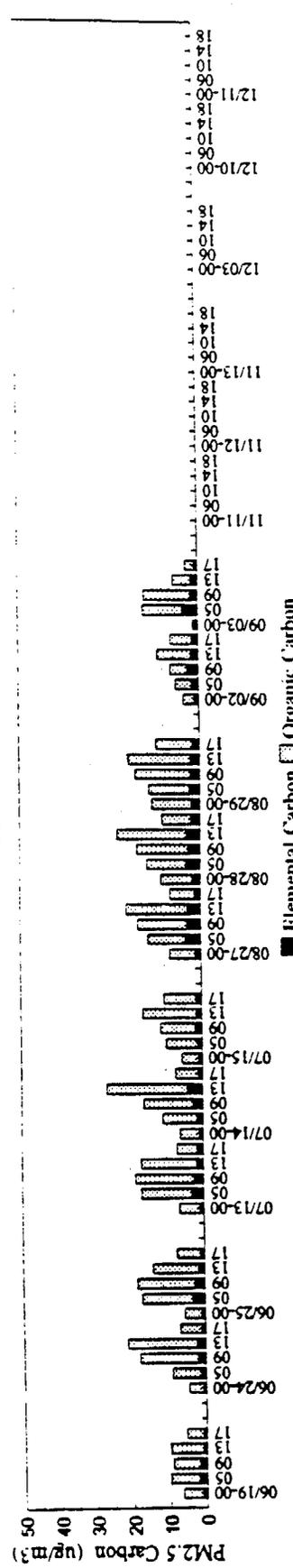
San Nicolas Island



Azusa



Claremont



Sampling Dates and Starting Hours (PST)

Figure 4-10c. Variations of PM_{2.5} Carbon with Time for Each SCAQS Episode at the San Nicolas Island, Azusa, and Claremont Sites Between 6/19/87 and 9/3/87

contributions to the afternoon samples from particulate organic carbon which formed from organic gases (Pandis *et al.*, 1992b), but these contributions are of uncertain magnitude. The fall ratios at the Long Beach site show a slight change in ratio for the afternoon samples, but these changes are well within the uncertainties of the measurements and secondary organic contributions are unlikely. These observations are consistent with the conditions established by Gray *et al.* (1986) for observing secondary organics in ambient aerosol samples.

5.0 SOURCE PROFILES

Receptor modeling applied to source apportionment requires information about the chemical characteristics of the emissions sources which are likely to affect pollutant concentrations at a receptor. For the Chemical Mass Balance (CMB) receptor model, the required information is the fractional composition of each chemical species in the source emissions and an estimate of the variability of those compositions. For this project, source profiles are needed for particulate and reactive organic gas emissions.

In a study to evaluate the feasibility of source apportionment of utility emissions, Javitz and Watson (1988) concluded that the major weakness of all receptor models is inadequate source composition data. They identified the following deficiencies in currently available source profiles: 1) the species measured are more often those which are convenient rather than those which differentiate among sources; 2) the types of species and size fractions measured are not the same for different source types and are not equivalent to the types of measurements made at receptors; 3) measurement methods are non-standard and do not give equivalent results for the same species; 4) source characteristics, fuels, and operating parameters are inadequately documented; 5) data are of poor or unknown quality; 6) source profile uncertainties are not reported; 7) source samples are not representative of source profiles as they appear at the receptor; and 8) data are not available in formats which can be conveniently interfaced to modeling software.

Javitz and Watson (1988) recommended the development of a standardized approach to sampling and analyzing particulate and gaseous emissions which would minimize these concerns with respect to future source profile measurements. Such a protocol was subsequently developed and applied for California Air Resources Board (ARB) source characterization studies of suspended particulate matter (Ahuja *et al.*, 1989; Houck *et al.*, 1989, 1990). This protocol has not been applied to particulate emitters in the SoCAB, though several profiles are available from sampling associated with CMB modeling of the 1986 data set (Cooper *et al.*, 1987). These profiles can be supplemented with profiles measured in other studies which are expected to have a strong similarity to emissions profiles from the SoCAB.

Scheff *et al.* (1989) and Doskey *et al.* (1992) have assembled VOC profiles for several SoCAB source types from a number of studies. These, too, suffer from lack of compatibility with the VOC species measured and sources contributing during SCAQS. Other profiles which have been evaluated for the SCAQS modeling inventory are examined here for potential application to CMB apportionment of the ambient VOC concentrations.

5.1 Particulate Source Types

The potential source types which contribute to primary $PM_{2.5}$ and PM_{10} in the SoCAB are: 1) geological material (fugitive dust from agriculture, paved and unpaved roads, vacant land, and construction; 2) motor vehicle exhaust (from cars, trucks, and buses fueled with

diesel, leaded gasoline, and unleaded gasoline); 3) marine aerosol transported from the Pacific Ocean; and 4) secondary particles (ammonium sulfate, ammonium nitrate, and residual organic carbon). As noted in Section 2, previous studies have also found evidence of construction dust and residual oil combustion. Though residential burning and fires are small emitters according to Table 2-1, they are found in many urban areas, including the SoCAB. Cooking of meat was identified as a potential contributor in Section 2, but SCAQS measurements do not correspond to the organic carbon groupings which have been measured for these profiles, and they cannot be included in this study. If cooking is a major contributor, its profile is likely to be collinear with other sources containing organic carbon, most probably motor vehicle exhaust.

A "source type" does not necessarily correspond to a particular emitter. For the primary contributors, several source sub-types may exist within some of these categories which are not easily distinguishable from each other by receptor models using commonly measured chemical species. The source type perceived at a receptor may be a mixture of these different sub-types, and the profile which best explains the receptor measurement should represent this mixture. Several different profiles are examined in each of the following sub-sections to determine whether or not they possess enough differences to allow them to be distinguished as separate source types by the CMB receptor model.

Table 5-1 lists the particulate source types, a short identifier for each specific profile, and a brief description of the 27 source profiles applied to SCAQS aerosol data. The short identifiers are used to refer to these profiles in subsequent discussions.

As noted in Section 2, a subset of the 1986 motor vehicle source samples acquired by Cooper *et al.* (1987) in the SoCAB was submitted to analyses for carbon and ionic species during 1989 (NEA, 1990a; 1990b; 1990c), but the existence of the additional species in these profiles was not known to the authors when the receptor modeling was performed for this study. Tests performed later in this report show that the inclusion of these additional species makes no difference in the calculated source contributions.

5.1.1 Geological Source Profiles

Table 5-2a compares the geological source profiles from paved roads acquired by Cooper *et al.* (1987) in the SoCAB. Cooper *et al.* (1987) also sampled unpaved roads, soil from vacant lots, and a rock-crusher. Organic and elemental carbon were only measured on the subset of paved road samples listed in Table 5-2a. It is evident from these profiles that carbon is a major component of road dust which cannot be ignored. Fortunately, most of the paved road dust profiles with carbon values were derived from samples taken in the vicinity of several of the SCAQS sampling sites.

The profiles were formed by vacuuming road dust from several streets in the vicinity of each sampling site, sieving the dried material, resuspending it into a chamber, and sampling the resuspended dust through PM_{2.5} and PM₁₀ inlets. Cooper *et al.* (1987) found that typically less

Table 5-1
Source Profiles Applied in SCAQS PM_{2.5} and PM₁₀ Receptor Modeling

| <u>Source Type</u> | <u>Data Base Identifier</u> | <u>Description of Source Profile</u> |
|-----------------------|-----------------------------|---|
| Primary Geological | PRLBSC ^a | Long Beach Paved Road Sample Composite |
| Primary Geological | PRLBPC ^a | Long Beach Paved Road Profile Composite |
| Primary Geological | PRDBSC ^a | Burbank Paved Road Sample Composite |
| Primary Geological | PRDBPC ^a | Burbank Paved Road Profile Composite |
| Primary Geological | PRDNMS ^a | North Main Street Paved Road Dust |
| Primary Geological | PRLAPC ^a | Los Angeles Paved Road Profile Composite |
| Primary Geological | PRDRSC ^a | Riverside Paved Road Sample Composite |
| Primary Geological | PRSTC ^a | Sepulveda Tunnel Paved Road Dust |
| Primary Geological | PRSCAB ^a | SoCAB Paved Road Profile Composite |
| Primary Motor Vehicle | MOVES1 ^a | MOVES-SS(NEA-E,WOB,T42,TVMT) SoCAB Dynamometer Composite |
| Primary Motor Vehicle | MOVES2 ^a | MOVES-SS(NEA-E,WOB,WOT,TVMT) SoCAB Dynamometer Composite |
| Primary Motor Vehicle | PHRD ^b | Phoenix Motor Vehicle Exhaust: Roadside Sample Average After Background |
| Primary Motor Vehicle | PHAUTO ^b | Phoenix Motor Vehicle Exhaust: 100% Gasoline |
| Primary Motor Vehicle | PHDIES ^b | Phoenix Motor Vehicle Exhaust: 100% Diesel |
| Marine Aerosol | MAR100 ^c | Fresh Marine Aerosol |
| Marine Aerosol | MAR75 ^c | Aged Marine Aerosol: 25% chloride replaced with nitrate |
| Marine Aerosol | MAR50 ^c | Aged Marine Aerosol: 50% chloride replaced with nitrate |
| Marine Aerosol | MAR25 ^c | Aged Marine Aerosol: 75% chloride replaced with nitrate |
| Marine Aerosol | MAR0 ^c | Aged Marine Aerosol: 100% chloride replaced with nitrate |

Table 5-1 (continued)
Source Profiles Applied in SCAQS PM_{2.5} and PM₁₀ Receptor Modeling

| <u>Source Type</u> | <u>Data Base Identifier</u> | <u>Description of Source Profile</u> |
|------------------------------|-----------------------------|---|
| Secondary Sodium Nitrate | NANO3 | Secondary Sodium Nitrate: NaNO ₃ |
| Secondary Ammonium Sulfate | AMSUL | Secondary Ammonium Sulfate: (NH ₄) ₂ SO ₄ |
| Secondary Ammonium Bisulfate | AMBSUL | Secondary Ammonium Bisulfate: NH ₄ HSO ₄ |
| Secondary Ammonium Nitrate | AMNIT | Secondary Ammonium Nitrate: NH ₄ NO ₃ |
| Secondary Organic Carbon | OC | Secondary Organic Carbon: 100% Organic Carbon |
| Construction | LIME ^d | EPA Profile Number 21101 Limestone Dust |
| Primary Oil Combustion | SFCRUC ^e | Santa Fe Crude Oil Boiler |
| Vegetative Burning | VIAGBC ^e | Visalia Agricultural Burning |

^d Cooper *et al.* (1987); a composite sample mixes dust aliquots from several different roadways together prior to resuspension and analysis. A profile composite consists of the average and standard deviation from several composite samples.

^b Chow *et al.* (1991).

^c Pytkowicz and Kester (1971).

^d U.S. EPA (1988).

^e Houck *et al.* (1989).

Table 5-2a
Geological Source Profiles (Weight % of Mass)*

| Species ^b | PR1.BSC | | PR1.BPC | | PR1.B3 | | PR1.BSC | | PR1.BPC | | PR1.B3 | | PR1.BSC | | PR1.BPC | | PR1.B3 | |
|----------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|
| | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. |
| Cl | 0.4057 ± 0.0203 | 0.4597 ± 0.0230 | 0.3366 ± 0.0691 | 0.3587 ± 0.1011 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 |
| NO ₃ | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 |
| SO ₂ | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 |
| NH ₄ | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 |
| Na ^c | 0.8075 ± 0.1211 | 0.8584 ± 0.1288 | 0.9190 ± 0.1114 | 0.9118 ± 0.0969 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 |
| TC | 21.8390 ± 3.2102 | 20.1462 ± 1.4681 | 21.8390 ± 3.3966 | 20.1462 ± 1.4699 | 11.6458 ± 1.6817 | 17.7557 ± 2.1733 | 11.6458 ± 1.6817 | 17.7557 ± 2.1733 | 11.6458 ± 1.6817 | 17.7557 ± 2.1733 | 11.6458 ± 1.6817 | 17.7557 ± 2.1733 | 11.6458 ± 1.6817 | 17.7557 ± 2.1733 | 11.6458 ± 1.6817 | 17.7557 ± 2.1733 | 11.6458 ± 1.6817 | 17.7557 ± 2.1733 |
| OC | 19.6257 ± 3.1844 | 18.9586 ± 1.4647 | 19.6257 ± 3.3699 | 18.9586 ± 1.4665 | 10.6469 ± 1.6689 | 15.9778 ± 2.1617 | 10.6469 ± 1.6689 | 15.9778 ± 2.1617 | 10.6469 ± 1.6689 | 15.9778 ± 2.1617 | 10.6469 ± 1.6689 | 15.9778 ± 2.1617 | 10.6469 ± 1.6689 | 15.9778 ± 2.1617 | 10.6469 ± 1.6689 | 15.9778 ± 2.1617 | 10.6469 ± 1.6689 | 15.9778 ± 2.1617 |
| EC | 2.2133 ± 0.4065 | 1.1876 ± 0.1000 | 2.2133 ± 0.4251 | 1.1876 ± 0.1001 | 0.9989 ± 0.2071 | 1.7779 ± 0.2245 | 0.9989 ± 0.2071 | 1.7779 ± 0.2245 | 0.9989 ± 0.2071 | 1.7779 ± 0.2245 | 0.9989 ± 0.2071 | 1.7779 ± 0.2245 | 0.9989 ± 0.2071 | 1.7779 ± 0.2245 | 0.9989 ± 0.2071 | 1.7779 ± 0.2245 | 0.9989 ± 0.2071 | 1.7779 ± 0.2245 |
| Na | 0.8075 ± 0.1211 | 0.8584 ± 0.1288 | 0.9190 ± 0.1114 | 0.9118 ± 0.0969 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 | 0.7599 ± 0.1140 | 0.8452 ± 0.1268 |
| Al | 5.1850 ± 0.7778 | 5.1810 ± 0.7771 | 5.3979 ± 0.6112 | 5.4311 ± 0.5769 | 4.5108 ± 0.6766 | 5.0341 ± 0.7551 | 4.5108 ± 0.6766 | 5.0341 ± 0.7551 | 4.5108 ± 0.6766 | 5.0341 ± 0.7551 | 4.5108 ± 0.6766 | 5.0341 ± 0.7551 | 4.5108 ± 0.6766 | 5.0341 ± 0.7551 | 4.5108 ± 0.6766 | 5.0341 ± 0.7551 | 4.5108 ± 0.6766 | 5.0341 ± 0.7551 |
| Si | 13.4590 ± 2.0188 | 14.3061 ± 2.1459 | 15.3163 ± 1.8574 | 15.1969 ± 1.6152 | 12.6658 ± 1.8999 | 14.0874 ± 2.1131 | 12.6658 ± 1.8999 | 14.0874 ± 2.1131 | 12.6658 ± 1.8999 | 14.0874 ± 2.1131 | 12.6658 ± 1.8999 | 14.0874 ± 2.1131 | 12.6658 ± 1.8999 | 14.0874 ± 2.1131 | 12.6658 ± 1.8999 | 14.0874 ± 2.1131 | 12.6658 ± 1.8999 | 14.0874 ± 2.1131 |
| P | 0.2544 ± 0.0510 | 0.2274 ± 0.0455 | 0.2523 ± 0.0371 | 0.2188 ± 0.0310 | 0.2233 ± 0.0447 | 0.2130 ± 0.0426 | 0.2233 ± 0.0447 | 0.2130 ± 0.0426 | 0.2233 ± 0.0447 | 0.2130 ± 0.0426 | 0.2233 ± 0.0447 | 0.2130 ± 0.0426 | 0.2233 ± 0.0447 | 0.2130 ± 0.0426 | 0.2233 ± 0.0447 | 0.2130 ± 0.0426 | 0.2233 ± 0.0447 | 0.2130 ± 0.0426 |
| S | 1.0019 ± 0.0501 | 0.9028 ± 0.0451 | 0.7889 ± 0.2130 | 0.7171 ± 0.1857 | 0.8720 ± 0.0436 | 0.7029 ± 0.0351 | 0.8720 ± 0.0436 | 0.7029 ± 0.0351 | 0.8720 ± 0.0436 | 0.7029 ± 0.0351 | 0.8720 ± 0.0436 | 0.7029 ± 0.0351 | 0.8720 ± 0.0436 | 0.7029 ± 0.0351 | 0.8720 ± 0.0436 | 0.7029 ± 0.0351 | 0.8720 ± 0.0436 | 0.7029 ± 0.0351 |
| Cl | 0.4057 ± 0.0203 | 0.4597 ± 0.0230 | 0.3366 ± 0.0691 | 0.3587 ± 0.1011 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 | 0.3483 ± 0.0174 | 0.3552 ± 0.0178 |
| K | 1.2221 ± 0.0611 | 1.5514 ± 0.0776 | 1.2408 ± 0.0657 | 1.5922 ± 0.0565 | 0.9181 ± 0.0459 | 1.3521 ± 0.0676 | 0.9181 ± 0.0459 | 1.3521 ± 0.0676 | 0.9181 ± 0.0459 | 1.3521 ± 0.0676 | 0.9181 ± 0.0459 | 1.3521 ± 0.0676 | 0.9181 ± 0.0459 | 1.3521 ± 0.0676 | 0.9181 ± 0.0459 | 1.3521 ± 0.0676 | 0.9181 ± 0.0459 | 1.3521 ± 0.0676 |
| Ca | 4.1929 ± 0.2097 | 3.9286 ± 0.1964 | 4.0143 ± 0.2128 | 3.8377 ± 0.1362 | 5.5422 ± 0.2772 | 5.7322 ± 0.2866 | 5.5422 ± 0.2772 | 5.7322 ± 0.2866 | 5.5422 ± 0.2772 | 5.7322 ± 0.2866 | 5.5422 ± 0.2772 | 5.7322 ± 0.2866 | 5.5422 ± 0.2772 | 5.7322 ± 0.2866 | 5.5422 ± 0.2772 | 5.7322 ± 0.2866 | 5.5422 ± 0.2772 | 5.7322 ± 0.2866 |
| Ti | 0.3276 ± 0.0173 | 0.4044 ± 0.0220 | 0.3373 ± 0.0183 | 0.4096 ± 0.0159 | 0.3339 ± 0.0176 | 0.4321 ± 0.0233 | 0.3339 ± 0.0176 | 0.4321 ± 0.0233 | 0.3339 ± 0.0176 | 0.4321 ± 0.0233 | 0.3339 ± 0.0176 | 0.4321 ± 0.0233 | 0.3339 ± 0.0176 | 0.4321 ± 0.0233 | 0.3339 ± 0.0176 | 0.4321 ± 0.0233 | 0.3339 ± 0.0176 | 0.4321 ± 0.0233 |
| V | 0.0267 ± 0.0042 | 0.0164 ± 0.0052 | 0.0274 ± 0.0032 | 0.0184 ± 0.0038 | 0.0207 ± 0.0041 | 0.0198 ± 0.0055 | 0.0207 ± 0.0041 | 0.0198 ± 0.0055 | 0.0207 ± 0.0041 | 0.0198 ± 0.0055 | 0.0207 ± 0.0041 | 0.0198 ± 0.0055 | 0.0207 ± 0.0041 | 0.0198 ± 0.0055 | 0.0207 ± 0.0041 | 0.0198 ± 0.0055 | 0.0207 ± 0.0041 | 0.0198 ± 0.0055 |
| Cr | 0.0222 ± 0.0020 | 0.0273 ± 0.0016 | 0.0229 ± 0.0017 | 0.0286 ± 0.0012 | 0.0195 ± 0.0019 | 0.0267 ± 0.0016 | 0.0195 ± 0.0019 | 0.0267 ± 0.0016 | 0.0195 ± 0.0019 | 0.0267 ± 0.0016 | 0.0195 ± 0.0019 | 0.0267 ± 0.0016 | 0.0195 ± 0.0019 | 0.0267 ± 0.0016 | 0.0195 ± 0.0019 | 0.0267 ± 0.0016 | 0.0195 ± 0.0019 | 0.0267 ± 0.0016 |
| Mn | 0.0830 ± 0.0048 | 0.0922 ± 0.0047 | 0.0871 ± 0.0049 | 0.0980 ± 0.0057 | 0.0759 ± 0.0045 | 0.0953 ± 0.0049 | 0.0759 ± 0.0045 | 0.0953 ± 0.0049 | 0.0759 ± 0.0045 | 0.0953 ± 0.0049 | 0.0759 ± 0.0045 | 0.0953 ± 0.0049 | 0.0759 ± 0.0045 | 0.0953 ± 0.0049 | 0.0759 ± 0.0045 | 0.0953 ± 0.0049 | 0.0759 ± 0.0045 | 0.0953 ± 0.0049 |
| Fe | 3.6922 ± 0.1865 | 4.3138 ± 0.2170 | 3.8296 ± 0.2037 | 4.5462 ± 0.2324 | 3.3190 ± 0.1678 | 4.2802 ± 0.2153 | 3.3190 ± 0.1678 | 4.2802 ± 0.2153 | 3.3190 ± 0.1678 | 4.2802 ± 0.2153 | 3.3190 ± 0.1678 | 4.2802 ± 0.2153 | 3.3190 ± 0.1678 | 4.2802 ± 0.2153 | 3.3190 ± 0.1678 | 4.2802 ± 0.2153 | 3.3190 ± 0.1678 | 4.2802 ± 0.2153 |
| Ni | 0.0119 ± 0.0016 | 0.0132 ± 0.0008 | 0.0130 ± 0.0013 | 0.0136 ± 0.0006 | 0.0087 ± 0.0015 | 0.0128 ± 0.0008 | 0.0087 ± 0.0015 | 0.0128 ± 0.0008 | 0.0087 ± 0.0015 | 0.0128 ± 0.0008 | 0.0087 ± 0.0015 | 0.0128 ± 0.0008 | 0.0087 ± 0.0015 | 0.0128 ± 0.0008 | 0.0087 ± 0.0015 | 0.0128 ± 0.0008 | 0.0087 ± 0.0015 | 0.0128 ± 0.0008 |
| Cu | 0.0248 ± 0.0021 | 0.0259 ± 0.0014 | 0.0248 ± 0.0018 | 0.0253 ± 0.0010 | 0.0251 ± 0.0021 | 0.0262 ± 0.0015 | 0.0251 ± 0.0021 | 0.0262 ± 0.0015 | 0.0251 ± 0.0021 | 0.0262 ± 0.0015 | 0.0251 ± 0.0021 | 0.0262 ± 0.0015 | 0.0251 ± 0.0021 | 0.0262 ± 0.0015 | 0.0251 ± 0.0021 | 0.0262 ± 0.0015 | 0.0251 ± 0.0021 | 0.0262 ± 0.0015 |
| Zn | 0.2233 ± 0.0117 | 0.2255 ± 0.0114 | 0.2644 ± 0.0412 | 0.2492 ± 0.0237 | 0.2170 ± 0.0115 | 0.2154 ± 0.0109 | 0.2170 ± 0.0115 | 0.2154 ± 0.0109 | 0.2170 ± 0.0115 | 0.2154 ± 0.0109 | 0.2170 ± 0.0115 | 0.2154 ± 0.0109 | 0.2170 ± 0.0115 | 0.2154 ± 0.0109 | 0.2170 ± 0.0115 | 0.2154 ± 0.0109 | 0.2170 ± 0.0115 | 0.2154 ± 0.0109 |
| As | 0.0081 ± 0.0094 | 0.0000 ± 0.0085 | 0.0063 ± 0.0098 | 0.0000 ± 0.0089 | 0.0047 ± 0.0107 | 0.0000 ± 0.0125 | 0.0047 ± 0.0107 | 0.0000 ± 0.0125 | 0.0047 ± 0.0107 | 0.0000 ± 0.0125 | 0.0047 ± 0.0107 | 0.0000 ± 0.0125 | 0.0047 ± 0.0107 | 0.0000 ± 0.0125 | 0.0047 ± 0.0107 | 0.0000 ± 0.0125 | 0.0047 ± 0.0107 | 0.0000 ± 0.0125 |
| Se | 0.0000 ± 0.0011 | 0.0000 ± 0.0011 | 0.0000 ± 0.0008 | 0.0000 ± 0.0005 | 0.0000 ± 0.0011 | 0.0000 ± 0.0003 | 0.0000 ± 0.0011 | 0.0000 ± 0.0003 | 0.0000 ± 0.0011 | 0.0000 ± 0.0003 | 0.0000 ± 0.0011 | 0.0000 ± 0.0003 | 0.0000 ± 0.0011 | 0.0000 ± 0.0003 | 0.0000 ± 0.0011 | 0.0000 ± 0.0003 | 0.0000 ± 0.0011 | 0.0000 ± 0.0003 |
| Br | 0.0066 ± 0.0016 | 0.0085 ± 0.0006 | 0.0058 ± 0.0011 | 0.0089 ± 0.0004 | 0.0044 ± 0.0015 | 0.0087 ± 0.0006 | 0.0044 ± 0.0015 | 0.0087 ± 0.0006 | 0.0044 ± 0.0015 | 0.0087 ± 0.0006 | 0.0044 ± 0.0015 | 0.0087 ± 0.0006 | 0.0044 ± 0.0015 | 0.0087 ± 0.0006 | 0.0044 ± 0.0015 | 0.0087 ± 0.0006 | 0.0044 ± 0.0015 | 0.0087 ± 0.0006 |
| Sr | 0.0379 ± 0.0031 | 0.0834 ± 0.0042 | 0.0328 ± 0.0051 | 0.0681 ± 0.0153 | 0.0278 ± 0.0027 | 0.0506 ± 0.0026 | 0.0278 ± 0.0027 | 0.0506 ± 0.0026 | 0.0278 ± 0.0027 | 0.0506 ± 0.0026 | 0.0278 ± 0.0027 | 0.0506 ± 0.0026 | 0.0278 ± 0.0027 | 0.0506 ± 0.0026 | 0.0278 ± 0.0027 | 0.0506 ± 0.0026 | 0.0278 ± 0.0027 | 0.0506 ± 0.0026 |
| Mo | 0.0000 ± 0.0080 | 0.0000 ± 0.0017 | 0.0000 ± 0.0055 | 0.0000 ± 0.0013 | 0.0000 ± 0.0073 | 0.0000 ± 0.0018 | 0.0000 ± 0.0055 | 0.0000 ± 0.0013 | 0.0000 ± 0.0073 | 0.0000 ± 0.0018 | 0.0000 ± 0.0055 | 0.0000 ± 0.0013 | 0.0000 ± 0.0073 | 0.0000 ± 0.0018 | 0.0000 ± 0.0055 | 0.0000 ± 0.0013 | 0.0000 ± 0.0073 | 0.0000 ± 0.0018 |
| Cd | 0.0000 ± 0.0139 | 0.0080 ± 0.0027 | 0.0000 ± 0.0095 | 0.0040 ± 0.0040 | 0.0000 ± 0.0129 | 0.0108 ± 0.0031 | 0.0000 ± 0.0095 | 0.0040 ± 0.0040 | 0.0000 ± 0.0129 | 0.0108 ± 0.0031 | 0.0000 ± 0.0095 | 0.0040 ± 0.0040 | 0.0000 ± 0.0129 | 0.0108 ± 0.0031 | 0.0000 ± 0.0095 | 0.0040 ± 0.0040 | 0.0000 ± 0.0129 | 0.0108 ± 0.0031 |
| Sn | 0.0000 ± 0.0208 | 0.0080 ± 0.0040 | 0.0000 ± 0.0143 | 0.0074 ± 0.0031 | 0.0000 ± 0.0193 | 0.0125 ± 0.0045 | 0.0000 ± 0.0143 | 0.0074 ± 0.0031 | 0.0000 ± 0.0193 | 0.0125 ± 0.0045 | 0.0000 ± 0.0143 | 0.0074 ± 0.0031 | 0.0000 ± 0.0193 | 0.0125 ± 0.0045 | 0.0000 ± 0.0143 | 0.0074 ± 0.0031 | 0.0000 ± 0.0193 | 0.0125 ± 0.0045 |
| Sb | 0.0000 ± 0.0458 | 0.0000 ± 0.0087 | 0.0000 ± 0.0314 | 0.0000 ± 0.0068 | 0.0000 ± 0.0425 | 0.0000 ± 0.0096 | 0.0000 ± 0.0314 | 0.0000 ± 0.0068 | 0.0000 ± 0.0425 | 0.0000 ± 0.0096 | 0.0000 ± 0.0314 | 0.0000 ± 0.0068 | 0.0000 ± 0.0425 | 0.0000 ± 0.0096 | 0.0000 ± 0.0314 | 0.0000 ± 0.0068 | 0.0000 ± 0.0425 | 0.0000 ± 0.0096 |
| Ba | 0.0000 ± 0.0860 | 0.1039 ± 0.0177 | 0.0000 ± 0.0591 | 0.0881 ± 0.0158 | 0.0000 ± 0.0796 | 0.0665 ± 0.0186 | 0.0000 ± 0.0591 | 0.0881 ± 0.0158 | 0.0000 ± 0.0796 | 0.0665 ± 0.0186 | 0.0000 ± 0.0591 | 0.0881 ± 0.0158 | 0.0000 ± 0.0796 | 0.0665 ± 0.0186 | 0.0000 ± 0.0591 | 0.0881 ± 0.0158 | 0.0000 ± 0.0796 | 0.0665 ± 0.0186 |
| Hg | 0.0000 ± 0.0015 | 0.0000 ± 0.0003 | 0.0000 ± 0.0010 | 0.0000 | | | | | | | | | | | | | | |

Table 5-2a (continued)
Geological Source Profiles (Weight % of Mass)^a

| Species ^b | PRI/BSX | | PRI/BPC | | PRD/BSX | | PRD/BPC | |
|------------------------------|-----------------------------------|-------------------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|-----------------------------------|------------------------|
| | PM _{2.5} Conc. ± Unc. | Coarse ^c Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. | PM _{2.5} Conc. ± Unc. | Coarse Conc. ± Unc. |
| Cl | 0.3524 ± 0.0176 | 0.4278 ± 0.0214 | 0.3111 ± 0.0412 | 0.3639 ± 0.0638 | 0.2406 ± 0.0120 | 0.2320 ± 0.0116 | 0.2981 ± 0.0576 | 0.3051 ± 0.0586 |
| NO ₃ | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 | 0.1000 ± 0.4000 |
| SO ₄ ⁻ | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 | 0.2000 ± 0.4000 |
| NH ₄ ⁺ | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 | 0.0010 ± 0.0200 |
| Na ⁺ | 0.5663 ± 0.0850 | 0.6592 ± 0.0989 | 0.5951 ± 0.0702 | 0.6863 ± 0.0729 | 1.1158 ± 0.1674 | 0.9882 ± 0.1482 | 0.9266 ± 0.0777 | 0.9660 ± 0.0714 |
| TC | 20.1245 ± 5.4708 | 23.2395 ± 1.6355 | 20.1245 ± 5.5958 | 23.2395 ± 1.6372 | 7.8975 ± 1.5372 | 11.9744 ± 0.9497 | 15.8441 ± 2.0447 | 16.9004 ± 1.5457 |
| OC | 19.2666 ± 5.4540 | 21.5220 ± 1.6297 | 19.2666 ± 5.5791 | 21.5220 ± 1.6314 | 7.4781 ± 1.5273 | 11.8008 ± 0.9483 | 14.7285 ± 2.0232 | 15.9277 ± 1.5199 |
| EC | 1.7175 ± 0.1373 | 1.7175 ± 0.1373 | 0.8579 ± 0.4321 | 1.7175 ± 0.1374 | 0.4194 ± 0.1741 | 0.1736 ± 0.0508 | 1.1156 ± 0.2954 | 0.9727 ± 0.2811 |
| Na | 0.5663 ± 0.0850 | 0.6592 ± 0.0989 | 0.5951 ± 0.0702 | 0.6863 ± 0.0729 | 1.1158 ± 0.1674 | 0.9882 ± 0.1482 | 0.9266 ± 0.0777 | 0.9660 ± 0.0714 |
| Al | 2.8929 ± 0.4340 | 3.7340 ± 0.5601 | 3.6746 ± 0.7816 | 4.2967 ± 0.5627 | 8.3200 ± 1.2480 | 7.1225 ± 1.0684 | 5.7044 ± 0.5563 | 5.9137 ± 0.4427 |
| Si | 9.4390 ± 1.4159 | 10.9871 ± 1.6481 | 9.9187 ± 1.1696 | 11.4382 ± 1.2145 | 18.5969 ± 2.7896 | 16.4702 ± 2.4705 | 15.4440 ± 1.2956 | 16.0992 ± 1.1905 |
| P | 0.5237 ± 0.1048 | 0.4962 ± 0.0992 | 0.3733 ± 0.1504 | 0.3600 ± 0.1361 | 0.2278 ± 0.0456 | 0.1869 ± 0.0374 | 0.2123 ± 0.0408 | 0.1843 ± 0.0378 |
| S | 0.8524 ± 0.0426 | 0.7815 ± 0.0391 | 0.8977 ± 0.0560 | 0.8100 ± 0.0287 | 0.7389 ± 0.0370 | 0.5548 ± 0.0277 | 0.9354 ± 0.1752 | 0.7058 ± 0.1078 |
| Cl | 0.3524 ± 0.0176 | 0.4278 ± 0.0214 | 0.3111 ± 0.0412 | 0.3639 ± 0.0638 | 0.2406 ± 0.0120 | 0.2320 ± 0.0116 | 0.2981 ± 0.0576 | 0.3051 ± 0.0586 |
| K | 0.6626 ± 0.0331 | 1.1072 ± 0.0554 | 0.6516 ± 0.0401 | 1.0829 ± 0.0384 | 1.6670 ± 0.0833 | 1.9126 ± 0.0956 | 1.0317 ± 0.1072 | 1.4702 ± 0.0854 |
| Ca | 3.6093 ± 0.1804 | 4.4050 ± 0.2202 | 3.2431 ± 0.3661 | 4.0600 ± 0.3450 | 3.7928 ± 0.1896 | 3.5898 ± 0.1795 | 3.6232 ± 0.2572 | 3.9655 ± 0.3316 |
| Ti | 0.2579 ± 0.0138 | 0.3541 ± 0.0195 | 0.3050 ± 0.0471 | 0.4572 ± 0.1031 | 0.4578 ± 0.0235 | 0.4962 ± 0.0261 | 0.3747 ± 0.0327 | 0.4726 ± 0.0288 |
| V | 0.0249 ± 0.0035 | 0.0190 ± 0.0048 | 0.0279 ± 0.0033 | 0.0262 ± 0.0072 | 0.0283 ± 0.0052 | 0.0223 ± 0.0059 | 0.0249 ± 0.0014 | 0.0174 ± 0.0025 |
| Cr | 0.0308 ± 0.0023 | 0.0393 ± 0.0021 | 0.0484 ± 0.0176 | 0.0711 ± 0.0318 | 0.0245 ± 0.0019 | 0.0273 ± 0.0016 | 0.0250 ± 0.0036 | 0.0330 ± 0.0059 |
| Mn | 0.0779 ± 0.0045 | 0.0888 ± 0.0045 | 0.0776 ± 0.0051 | 0.0844 ± 0.0044 | 0.1174 ± 0.0063 | 0.1193 ± 0.0061 | 0.0807 ± 0.0056 | 0.1013 ± 0.0043 |
| Fe | 7.1199 ± 0.3587 | 6.1312 ± 0.3083 | 5.2102 ± 1.9097 | 5.3759 ± 0.7553 | 4.7892 ± 0.2413 | 5.1172 ± 0.2573 | 3.9195 ± 0.2694 | 4.9273 ± 0.2251 |
| Ni | 0.0107 ± 0.0015 | 0.0125 ± 0.0008 | 0.0292 ± 0.0185 | 0.0413 ± 0.0288 | 0.0083 ± 0.0012 | 0.0084 ± 0.0006 | 0.0143 ± 0.0024 | 0.0161 ± 0.0038 |
| Cu | 0.0496 ± 0.0032 | 0.0593 ± 0.0031 | 0.0526 ± 0.0036 | 0.0600 ± 0.0022 | 0.0096 ± 0.0012 | 0.0097 ± 0.0006 | 0.0359 ± 0.0074 | 0.0367 ± 0.0099 |
| Zn | 0.3983 ± 0.0205 | 0.4369 ± 0.0220 | 0.4281 ± 0.0298 | 0.4313 ± 0.0154 | 0.0870 ± 0.0048 | 0.0859 ± 0.0044 | 0.2514 ± 0.0438 | 0.2458 ± 0.0427 |
| As | 0.0060 ± 0.0084 | 0.0000 ± 0.0097 | 0.0098 ± 0.0092 | 0.0000 ± 0.0098 | 0.0116 ± 0.0065 | 0.0000 ± 0.0064 | 0.0060 ± 0.0059 | 0.0000 ± 0.0066 |
| Se | 0.0000 ± 0.0010 | 0.0000 ± 0.0002 | 0.0000 ± 0.0007 | 0.0000 ± 0.0002 | 0.0000 ± 0.0008 | 0.0000 ± 0.0002 | 0.0000 ± 0.0002 | 0.0002 ± 0.0002 |
| Br | 0.0018 ± 0.0013 | 0.0060 ± 0.0005 | 0.0016 ± 0.0011 | 0.0062 ± 0.0003 | 0.0025 ± 0.0010 | 0.0067 ± 0.0005 | 0.0066 ± 0.0020 | 0.0098 ± 0.0023 |
| Sr | 0.0302 ± 0.0027 | 0.0836 ± 0.0043 | 0.0211 ± 0.0091 | 0.0748 ± 0.0088 | 0.0283 ± 0.0022 | 0.0441 ± 0.0023 | 0.0633 ± 0.0251 | 0.1205 ± 0.0470 |
| Mo | 0.0000 ± 0.0065 | 0.0036 ± 0.0018 | 0.0000 ± 0.0050 | 0.0098 ± 0.0062 | 0.0000 ± 0.0053 | 0.0000 ± 0.0018 | 0.0000 ± 0.0017 | 0.0016 ± 0.0012 |
| Cd | 0.0000 ± 0.0116 | 0.0000 ± 0.0028 | 0.0000 ± 0.0091 | 0.0000 ± 0.0020 | 0.0000 ± 0.0093 | 0.0000 ± 0.0027 | 0.0014 ± 0.0029 | 0.0035 ± 0.0012 |
| Sn | 0.0000 ± 0.0174 | 0.0123 ± 0.0043 | 0.0000 ± 0.0135 | 0.0095 ± 0.0031 | 0.0000 ± 0.0139 | 0.0000 ± 0.0040 | 0.0004 ± 0.0044 | 0.0041 ± 0.0014 |
| Sb | 0.0000 ± 0.0385 | 0.0000 ± 0.0091 | 0.0000 ± 0.0299 | 0.0000 ± 0.0066 | 0.0000 ± 0.0307 | 0.0000 ± 0.0087 | 0.0000 ± 0.0096 | 0.0025 ± 0.0026 |
| Ba | 0.0000 ± 0.0728 | 0.0906 ± 0.0178 | 0.0000 ± 0.0559 | 0.0701 ± 0.0205 | 0.0000 ± 0.0575 | 0.0546 ± 0.0171 | 0.0146 ± 0.0182 | 0.0918 ± 0.0131 |
| Hg | 0.0000 ± 0.0012 | 0.0000 ± 0.0004 | 0.0000 ± 0.0010 | 0.0000 ± 0.0003 | 0.0000 ± 0.0010 | 0.0000 ± 0.0003 | 0.0003 ± 0.0003 | 0.0004 ± 0.0002 |
| Pb | 0.1365 ± 0.0087 | 0.1752 ± 0.0090 | 0.2094 ± 0.0728 | 0.2410 ± 0.0658 | 0.1012 ± 0.0068 | 0.1143 ± 0.0059 | 0.2754 ± 0.0830 | 0.3057 ± 0.0930 |
| Sum | 46.6162 ± 5.7125 | 52.8694 ± 2.4886 | 45.6139 ± 6.1186 | 52.7873 ± 2.3514 | 47.8251 ± 3.4870 | 48.8836 ± 2.9325 | 48.4798 ± 2.5810 | 52.4957 ± 2.1248 |

^a See Table 5-1 for source profile descriptions.

^b TC (Total Carbon)=OC+EC; Sum does not include Na⁺, Cl⁻, S, or TC. ^c PM₁₀ minus PM_{2.5}.

than 10% of the PM_{10} was in the $PM_{2.5}$ fraction, and the PM_{10} and coarse particle (PM_{10} minus $PM_{2.5}$) source profiles were nearly identical. Both $PM_{2.5}$ and coarse particle source profiles are listed in Table 5-2a, and though there are some minor differences between the two size fractions, these differences do not result in large differences in CMB source contribution estimates. Each profile results from the average of several samples (typically three) taken around each measurement location. The "PRSCAB" profile consists of the average and standard deviation from several samples taken throughout the SoCAB.

Organic carbon (OC) is the most abundant species in each of SoCAB paved road dust profiles, ranging from 11% to 22% of total mass in these samples. Organic carbon usually exceeds elemental carbon (EC) in these samples by factors of 15 to 20. When the typical contributors to paved road dust are considered, this finding is not surprising. Dust on a paved road surface builds up by being tracked out from unpaved areas such as construction sites, unpaved roads, parking lots, and shoulders; by spills from trucks carrying dirt and other particulate materials; by transport of dirt collected on vehicle undercarriages; by wear of vehicle components such as tires, brakes, clutches, and exhaust system components; by wear of the pavement surface; by deposition of suspended particles from many emissions sources; and by water and wind erosion from adjacent areas.

Axetell and Zell (1977) estimated typical deposition rates of 240 lb/mile of curb/day for particles of all sizes from the following sources: 1) 42% from mud and dirt carryout; 2) 17% from litter; 3) 8% from biological debris; 4) 8% from ice control compounds (in areas with cold winters); 5) 8% from erosion of shoulders and adjacent areas; 6) 7% from motor vehicles; 7) 4% from atmospheric dustfall; 8) 4% from pavement wear; and 9) less than 1% from spills. These proportions are highly uncertain because they apply to the Total Suspended Particulate (TSP) size fraction (rather than to the PM_{10} size fraction) and their sample size was small. Nevertheless, they identify many sources from which organic carbon might originate.

Elemental carbon (EC), aluminum (Al), silicon (Si), potassium (K), calcium (Ca), titanium (Ti), and iron (Fe) are also present in paved road dust in abundances which exceed 1%. The abundance of total potassium (K) in geological materials has been found to be approximately 10 times that of soluble potassium (K^+) (Houck *et al.*, 1989). This is an important difference, since soluble potassium is one of the key markers for vegetative burning. It is partly because soluble potassium is not very abundant in geological material that vegetative burning can be distinguished from other sources when K^+ is measured in receptor samples. Since soluble potassium was not measured in SCAQS aerosol samples, this identifier cannot be used for vegetative burning.

The abundances of lead (Pb) and bromine (Br) in paved road dust are also higher than might be expected in pristine soil, which demonstrates the presence of tailpipe exhaust from vehicles burning leaded fuels. Enrichments in species from clutch and brake wear are absent in these paved road dust profiles. These are often composed of asbestos and/or semi-metal carbon composites. Ondov (1974) measured abundances of ~ 14% magnesium (Mg), ~ 2% calcium (Ca), ~ 4% iron (Fe), and ~ 1% barium (Ba) in asbestos brake shoes, while Anderson *et al.* (1973)

reported silicon (Si) abundances of ~10%. Cooper *et al.* (1987) examined the elemental composition of semi-metal brake shoes and found abundances of ~45% iron (Fe), ~2% copper (Cu), ~0.5% tin (Sn), ~3% barium (Ba), and ~0.5% molybdenum (Mo). None of these species is found in the SoCAB paved road dust profiles at levels which are significantly in excess of their abundances in the other geological sub-types. Approximately 50% of the mass is unaccounted for in these profiles. This is due to the presence of oxygen in oxides which is not measured directly by the measurement methods which were applied.

When the percent composition for a species is several times larger than its uncertainty, that species is a good marker for that source type. When few other source profiles contain this species, then it is very probable that the source types which these profiles represent can be distinguished from each other by CMB modeling. The high concentrations, low uncertainties, and uniqueness with respect to other source types of Al, Si, Ca, Ti, and Fe make it likely that these geological profiles can be easily distinguished from other source types. Paved road dust profiles are too similar to agricultural soil and windblown dust profiles to be distinguished from these source types. However, the site descriptions in Table 3-1 show that paved roads are the only major emitters of geological material in close proximity to all of the sampling sites except San Nicolas Island and Rubidoux.

5.1.2 Particulate Motor Vehicle Exhaust Profiles

Mobile source particulate emissions are among the most difficult to measure with respect to emission rate and chemical composition. This difficulty arises from: 1) the large number of mobile source types (passenger cars, light duty trucks, diesel trucks, diesel buses, etc.); 2) inadequate characterization of the high emitters within each type; 3) a large number of individual emitters within each type; 4) fuel-use characteristics which have radically changed over the past decade (e.g., the phase-out of lead in gasoline); 5) a large variety of undefined (and probably undefinable) operating conditions; 6) a variety of emissions points on each vehicle (i.e., tailpipe, resuspended dust, fuel evaporation, tire wear, brake wear); and 7) a large fraction of emissions which are probably semi-volatile or are secondary particle precursors.

Watson (1979), Pierson and Brachaczek (1976) and Pierson *et al.* (1983) summarize studies of motor vehicle exhaust particulate source profiles measured from the 1970's through 1981, but these profiles are not relevant to exhaust emissions found during SCAQS. Only a few post-1985 measurements of these profiles have been conducted. Watson *et al.* (1988a) obtained six roadside samples under a freeway overpass, in a city bus yard, and near busy intersections in Reno, NV during 1986. These profiles provided good fits to the ambient $PM_{2.5}$ and PM_{10} in combination with profiles from geological material and residential wood combustion (Chow *et al.*, 1988).

Watson *et al.* (1990a) report the results from dynamometer tests of eight unleaded, three leaded, and three light- to medium-duty diesel vehicles tested in the SCENIC Denver Study during 1987. The Federal Test Procedure (FTP) driving cycle was applied to vehicles which

had been prepared at cold temperatures ($<40^{\circ}\text{F}$) similar to those found in wintertime Denver. These profiles have been used in PM_{10} source apportionment studies in support of State Implementation Plans in Colorado, Utah, and Idaho (Watson and Chow, 1992), as well as to apportion light extinction in Denver (Watson *et al.*, 1988b).

Houck *et al.* (1989) took three samples of heavy-duty diesel truck exhaust at a roof monitor over the Wheeler weigh station near Bakersfield, CA during 1987 in support of PM_{10} State Implementation Plans in California's San Joaquin Valley.

Cooper *et al.* (1987) measured profiles from vehicle exhaust in the SoCAB during 1986. Exhausts from 11 unleaded gasoline vehicles, 3 leaded-gasoline vehicles, and 2 heavy-duty diesel trucks operating on laboratory dynamometers were sampled. The Federal Test Procedure (FTP) and a steady-state test at 35 miles per hour (mph) were followed for the gasoline-fueled tests. The diesel trucks were tested under modified FTP and steady-state conditions. Cooper *et al.* (1987) also took three roadside samples in a tunnel under the Los Angeles Airport.

Watson *et al.* (1993a) report profiles taken during 1988 in Phoenix, AZ, at: 1) a centralized dynamometer inspection and maintenance station for passenger cars; 2) a centralized dynamometer inspection and maintenance station for heavy duty diesel trucks and buses; 3) a dynamometer station for city buses; and 4) alongside urban roadways.

There are significant similarities and differences between the chemical compositions of these different motor vehicle profiles measured in different areas. For example, the SCENIC Denver diesel profiles have a much higher abundance of elemental carbon ($74 \pm 21\%$) than the SoCAB ($52 \pm 5\%$), Wheeler Station ($43 \pm 8\%$), or the Phoenix diesel ($33 \pm 8\%$) profiles. This difference may be due to differences in the test procedures, sampling methods, vehicles tested, or carbon analysis methods. Watson *et al.* (1989) used several of the profiles from other studies, including those from the SoCAB in CMB modeling of Phoenix PM_{10} . None of the SoCAB profiles reproduced the measured concentrations as well as the roadside motor vehicle profiles measured in Phoenix.

When Countess (1991) used the Phoenix and SoCAB profiles to apportion PM_{10} in Santa Barbara County during 1989, he also found that the Phoenix dynamometer test profiles explained the ambient data better than the SoCAB profiles. Countess (1990) observed that the majority of fuel in Phoenix arrives by pipeline from Santa Barbara County's Gaviota Terminal, and that vehicle types, driving patterns, and inspection and maintenance are similar in Arizona and in southern California. Countess (1991) therefore concluded that the Phoenix profiles were reasonable representatives for southern California emissions. Lowenthal *et al.* (1992) confirmed this in CMB sensitivity and collinearity tests on the Santa Barbara samples.

Table 5-2b includes the profiles from the SoCAB (MOVES1 and MOVES2) and from Phoenix (PHRD, PHAUTO, and PHDIES). Cooper *et al.* (1987) and Houck *et al.* (1989) found that more than 90% of vehicle exhaust was in the $\text{PM}_{2.5}$ size fraction, so the $\text{PM}_{2.5}$ profiles are used to represent contributions in both $\text{PM}_{2.5}$ and coarse material. It is believed that most of the

motor vehicle contributions to the coarse particle fraction are really PM_{2.5} particles which are removed in the PM_{2.5} inlet of the ambient sampler.

The "MOVES1" and "MOVES2" profiles are weighted averages of separate profiles from light and heavy duty vehicles fueled with unleaded, leaded, and diesel fuels. Tire wear is included in "MOVES1" but not in "MOVES2". Weighting for each profile is the normalized product of the total particle emission rate measured in the dynamometer tests and the relative number of vehicle types counted for samples taken in the Sepulveda tunnel. "MOVES1" and "MOVES2" are similar to each other, with approximately equal amounts of organic and elemental carbon. The presence of tire dust in "MOVES1" raises the organic content slightly, but does not significantly change the profile. Significant amounts of sulfate, bromine, chloride, and lead are detectable in the profile, though lead levels are much lower than those reported in earlier tests (Watson, 1979; Pierson and Brachaczek, 1976; Pierson *et al.*, 1983).

The "PHRD" profile in Table 5-2b was created from roadside samples taken in Phoenix, AZ during 1988 (Watson *et al.*, 1993a). Though these samples were taken through a PM_{2.5} inlet, they were also affected by vehicle-related resuspended road dust. Contributions to the mass and chemical species concentrations were estimated for each sample using the CMB model, with road dust as the only contributing source with Al, Si, Ca, and Fe as fitting species. As noted above, these species are very abundant in geological material and are depleted in directly emitted motor vehicle exhaust. This method assumes that ~100% of these species measured in the roadside samples originates in suspended road dust. The contributions of road dust to all remaining (non-fitting) species concentrations were calculated by the CMB model and subtracted from the measured concentrations, including the mass. The remaining species concentrations were then divided by the remaining mass to obtain profiles for the non-road dust motor vehicle exhaust samples. These individual roadside sample profiles were then averaged and their standard deviations calculated to obtain the "PHRD" profile. It is assumed that contributions from sources other than motor vehicle exhaust are negligible (<10%) in this profile, and this assumption is valid for the source-dominated sampling sites and short (~2 hr) sample durations.

The "PHAUTO" and "PHDIES" profiles were derived from samples obtained from an exhaust duct at an Arizona Department of Environmental Quality Inspection and Maintenance facility. One exhaust duct ventilates the area where only passenger cars are tested on dynamometers. The "PHAUTO" profile is the average and standard deviation of individual samples from these ducts. Another duct ventilates the area where only heavy duty diesel vehicle exhaust is tested under load, and the "PHDIES" profile is the average and standard deviation of these samples.

The "PHRD" profile contains abundances similar to a combination of the "PHDIES" and "PHAUTO" profiles, which is expected since there was a mixture of passenger cars and diesel vehicles contributing to the roadside samples. The most abundant species are OC (39±10%), EC (36±11%), nitrate (11±10%), sulfate (6±2%), and ammonium (4±3%). The nitrate, sulfate, and ammonium abundances are more than twice those of the dynamometer profiles. This is probably due to the longer residence time of the motor vehicle exhaust in the air being

Table 5-2b
Motor Vehicle Source Profiles (Weight % of Mass)^a

| Species ^b | MOVES1 | MOVES2 | PHRD | PHAUTO | PHDIES |
|------------------------------|---|--|--|--|--|
| | PM _{2.5} & Coarse ^c Conc. ± Unc. | PM _{2.5} & Coarse Conc. ± Unc. |
| Cl ⁻ | 0.5350 ± 0.4730 | 0.0290 ± 0.0200 | 1.1573 ± 0.7545 | 0.6400 ± 0.6554 | 1.6204 ± 4.3981 |
| NO ₃ ⁻ | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 | 11.0254 ± 10.4066 | 3.8949 ± 2.8743 | 0.3095 ± 0.3995 |
| SO ₄ ⁻ | 4.0920 ± 2.7780 | 3.1110 ± 3.5460 | 6.0125 ± 2.0920 | 2.2885 ± 1.3188 | 2.4448 ± 1.0048 |
| NH ₄ ⁺ | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 | 4.1064 ± 2.7397 | 1.6722 ± 1.0236 | 0.8661 ± 0.1261 |
| Na ⁺ | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 |
| TC | 98.1320 ± 27.1520 | 103.9620 ± 31.2192 | 75.4677 ± 21.6194 | 43.5773 ± 14.6806 | 73.0145 ± 10.3475 |
| OC | 52.7280 ± 21.5780 | 49.8090 ± 24.1510 | 39.0031 ± 18.6177 | 30.0752 ± 12.2989 | 40.0956 ± 6.6018 |
| EC | 45.4040 ± 16.4810 | 54.1530 ± 19.7830 | 36.4646 ± 10.9899 | 13.5021 ± 8.0161 | 32.9189 ± 7.9679 |
| Na | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 | 0.0000 ± 0.1000 |
| Al | 0.0760 ± 0.0390 | 0.0770 ± 0.0510 | 0.0723 ± 0.5250 | 0.4118 ± 0.2046 | 0.1735 ± 0.1211 |
| Si | 0.6450 ± 0.9240 | 0.9570 ± 1.3910 | 0.0828 ± 1.1319 | 1.6443 ± 0.8785 | 0.4627 ± 0.1838 |
| P | 0.1240 ± 0.1030 | 0.0570 ± 0.0200 | 0.0837 ± 0.1327 | 0.1147 ± 0.0653 | 0.0609 ± 0.0583 |
| S | 1.3640 ± 0.9260 | 1.0370 ± 1.1820 | 2.0156 ± 0.6026 | 1.0111 ± 0.4806 | 1.2395 ± 0.2824 |
| Cl | 0.5350 ± 0.4730 | 0.0290 ± 0.0200 | 0.5624 ± 0.4085 | 0.3376 ± 0.3217 | 0.0282 ± 0.0613 |
| K | 0.0050 ± 0.0060 | 0.0080 ± 0.0080 | 0.2150 ± 0.2294 | 0.2493 ± 0.1414 | 0.0421 ± 0.0332 |
| Ca | 0.0560 ± 0.0530 | 0.0720 ± 0.0790 | 0.1253 ± 0.9805 | 0.7071 ± 0.4068 | 0.1586 ± 0.0631 |
| Ti | 0.0060 ± 0.0040 | 0.0010 ± 0.0030 | 0.0872 ± 0.4008 | 0.0654 ± 0.1256 | 0.0015 ± 0.1530 |
| V | 0.0010 ± 0.0010 | 0.0010 ± 0.0020 | 0.0233 ± 0.2011 | 0.0047 ± 0.0538 | 0.0008 ± 0.0621 |
| Cr | 0.0000 ± 0.0010 | 0.0000 ± 0.0020 | 0.0187 ± 0.0402 | 0.0151 ± 0.0104 | 0.0039 ± 0.0147 |
| Mn | 0.0180 ± 0.0160 | 0.0280 ± 0.0240 | 0.1782 ± 0.1142 | 0.1048 ± 0.0359 | 0.0082 ± 0.0113 |
| Fe | 0.0010 ± 0.0030 | 0.0010 ± 0.0050 | 0.9341 ± 0.5294 | 0.6849 ± 0.4231 | 0.1588 ± 0.0652 |
| Ni | 0.0000 ± 0.0010 | 0.0000 ± 0.0020 | 0.0189 ± 0.0149 | 0.0094 ± 0.0093 | 0.0026 ± 0.0054 |
| Cu | 0.0030 ± 0.0020 | 0.0050 ± 0.0030 | 0.3558 ± 0.1351 | 0.0739 ± 0.0642 | 0.0132 ± 0.0082 |
| Zn | 0.3850 ± 0.2210 | 0.0530 ± 0.0280 | 0.5054 ± 0.3873 | 0.2727 ± 0.2250 | 0.0699 ± 0.0190 |
| As | 0.0030 ± 0.0080 | 0.0040 ± 0.0120 | 0.0057 ± 0.0942 | 0.0021 ± 0.0351 | 0.0009 ± 0.0208 |
| Se | 0.0000 ± 0.0010 | 0.0000 ± 0.0020 | 0.0042 ± 0.0335 | 0.0010 ± 0.0090 | 0.0009 ± 0.0103 |
| Br | 0.1740 ± 0.1060 | 0.2640 ± 0.1520 | 0.0580 ± 0.0339 | 0.0294 ± 0.0163 | 0.0023 ± 0.0089 |
| Sr | 0.0030 ± 0.0040 | 0.0000 ± 0.0030 | 0.0042 ± 0.0476 | 0.0070 ± 0.0106 | 0.0018 ± 0.0132 |
| Mo | 0.0000 ± 0.0080 | 0.0000 ± 0.0120 | 0.0101 ± 0.1058 | 0.0058 ± 0.0285 | 0.0019 ± 0.0328 |
| Cd | 0.0000 ± 0.0130 | 0.0000 ± 0.0200 | 0.0270 ± 0.2522 | 0.0106 ± 0.0680 | 0.0098 ± 0.0785 |
| Sn | 0.0000 ± 0.0200 | 0.0000 ± 0.0310 | 0.0589 ± 0.4008 | 0.0149 ± 0.1072 | 0.0118 ± 0.1238 |
| Sb | 0.0000 ± 0.0450 | 0.0000 ± 0.0690 | 0.1009 ± 0.4694 | 0.0189 ± 0.1255 | 0.0108 ± 0.1444 |
| Ba | 0.0010 ± 0.0850 | 0.0000 ± 0.1290 | 0.2002 ± 1.5018 | 0.0580 ± 0.4029 | 0.1397 ± 0.4669 |
| Hg | 0.0000 ± 0.0010 | 0.0000 ± 0.0020 | 0.0035 ± 0.0798 | 0.0018 ± 0.0216 | 0.0014 ± 0.0248 |
| Pb | 0.2450 ± 0.1490 | 0.3730 ± 0.2070 | 0.2700 ± 0.1261 | 0.1553 ± 0.0723 | 0.0147 ± 0.0294 |
| Sum | 104.505 ± 27.3160 | 109.0030 ± 31.4528 | 100.618 ± 24.3670 | 56.4334 ± 15.1044 | 78.0158 ± 10.4222 |

^a See Table 5-1 for source profile descriptions.

^b TC (Total Carbon) = OC + EC; Sum does not include Na⁺, Cl⁻, S, or TC.

^c PM₁₀ minus PM_{2.5}.

sampled at the roadside when compared to that sampled from a dynamometer. The abundances of lead ($0.27 \pm 0.13\%$) and bromine ($0.6 \pm 0.3\%$) in the "PHRD" profile are nearly twice the corresponding abundances in the "PHAUTO" profile, but similar to those of the "MOVES1" and "MOVES2" profiles. This implies that the proportion of emissions from leaded-gasoline-fueled vehicles was larger during the roadside tests than during dynamometer facility tests.

5.1.3 Marine Aerosol Source Profiles

It is known that marine aerosols will react rapidly with nitric acid in the environment, and that pure sea salt will probably never be found as a contributor to suspended particles in the SoCAB (though it probably will be found at San Nicolas Island). Several different marine profiles have been constructed in Table 5-2c to represent different levels of reaction between marine aerosol and nitric acid.

The bulk seawater composition of Pytkowicz and Kester (1971) is selected as a pure marine aerosol (MAR100). Additional profiles are created from "MAR100" by reacting different proportions of the profile mass with nitric acid. This liberates the chloride and replaces it with nitrate. "MAR75" represents the profile when 25% of the sea salt has reacted, "MAR50" is the profile with 50% reacted, "MAR25" is the profile with 75% reacted, and "MAR0" is the profile with 100% of the original marine aerosol reacted with nitric acid. The abundances of non-reactive species are smaller in "MAR100" than they are in "MAR0" owing to the increase in the total mass of the aerosol due to replacement of chlorine (Cl) with nitrate (NO_3). A pure ammonium nitrate profile is also included for sensitivity testing.

5.1.4 Secondary Sulfate, Nitrate, and Organic Source Profiles

Because species such as nitrate (NO_3), sulfate (SO_4^-), and organic carbon (OC) can be formed through gas-to-particle transformation in the atmosphere, they cannot be entirely accounted for by primary emissions. Secondary source profiles are included in Table 5-2d which consist of "pure" ammonium bisulfate, ammonium sulfate, ammonium nitrate, sodium nitrate, and organic carbon to apportion remaining ammonium (NH_4^+), sulfate (SO_4^-), nitrate (NO_3), and organic carbon (OC) which is not apportioned to the primary particle profiles.

5.1.5 Other Particulate Source Profiles

Besides the source profiles described above, several other profiles are included for sensitivity testing, even though they are not expected to be contributors to suspended particles in the SoCAB. Table 5-2e contains a profile from an agricultural burn in Visalia to represent vegetative burning and from a crude oil boiler in Kern County (Houck *et al.*, 1989) to represent residual oil combustion. Also included in Table 5-2e is a limestone dust profile (U.S. EPA, 1988) which is sometimes used as a surrogate for cement work when ambient calcium (Ca) concentrations cannot be explained by other geological or construction profiles.

Table 5-2c
Marine Aerosol Source Profiles (Weight % of Mass)^a

| Species ^b | MAR0 | | MAR25 | | MAR50 | | MAR75 | | MAR100 | | NAN03 | |
|------------------------------|--|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|--------------|---------------------------|--------------|
| | PM ₁₀ & Coarse ^c | Conc. ± Unc. | PM ₁₀ & Coarse | Conc. ± Unc. | PM ₁₀ & Coarse | Conc. ± Unc. | PM ₁₀ & Coarse | Conc. ± Unc. | PM ₁₀ & Coarse | Conc. ± Unc. | PM ₁₀ & Coarse | Conc. ± Unc. |
| Cl | 0.0000 ± 0.0300 | | 10.7686 ± 1.2744 | | 23.4884 ± 2.6795 | | 38.7426 ± 4.4017 | | 57.3724 ± 6.8802 | | 0.0000 ± 0.0000 | |
| NO ₃ | 70.4532 ± 8.7677 | | 57.2301 ± 6.7729 | | 41.6110 ± 4.7469 | | 22.8799 ± 2.5994 | | 0.0037 ± 0.0004 | | 72.9500 ± 7.2950 | |
| SO ₄ ⁻ | 5.5425 ± 0.6898 | | 6.0029 ± 0.7104 | | 6.5468 ± 0.7468 | | 7.1990 ± 0.8179 | | 7.9955 ± 0.9588 | | 0.0000 ± 0.0000 | |
| NH ₄ ⁺ | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.0000 | |
| Na ⁺ | 22.1700 ± 2.7590 | | 24.0117 ± 2.8417 | | 26.1871 ± 2.9874 | | 28.7960 ± 3.2716 | | 31.9822 ± 3.8354 | | 27.0500 ± 2.7050 | |
| TC | 0.0000 ± 0.1414 | | 0.0000 ± 0.1414 | | 0.0000 ± 0.1414 | | 0.0000 ± 0.1414 | | 0.0000 ± 0.1414 | | 0.0000 ± 0.0000 | |
| OC | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.0000 | |
| EC | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.1000 | | 0.0000 ± 0.0000 | |
| Na | 22.1700 ± 2.7590 | | 24.0117 ± 2.8417 | | 26.1871 ± 2.9874 | | 28.7960 ± 3.2716 | | 31.9822 ± 3.8354 | | 27.0500 ± 2.7050 | |
| Al | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Si | 0.0062 ± 0.0008 | | 0.0067 ± 0.0008 | | 0.0073 ± 0.0008 | | 0.0080 ± 0.0009 | | 0.0089 ± 0.0011 | | 0.0000 ± 0.0000 | |
| P | 0.0001 ± 0.0000 | | 0.0001 ± 0.0000 | | 0.0001 ± 0.0000 | | 0.0001 ± 0.0000 | | 0.0001 ± 0.0000 | | 0.0000 ± 0.0000 | |
| S | 1.8475 ± 0.2299 | | 2.0010 ± 0.2368 | | 2.1823 ± 0.2489 | | 2.3997 ± 0.2726 | | 2.6652 ± 0.3196 | | 0.0000 ± 0.0000 | |
| Cl | 0.0000 ± 0.0000 | | 10.7686 ± 1.2744 | | 23.4884 ± 2.6795 | | 38.7426 ± 4.4017 | | 57.3724 ± 6.8802 | | 0.0000 ± 0.0000 | |
| K | 0.8211 ± 0.1022 | | 0.8993 ± 0.1052 | | 0.9699 ± 0.1106 | | 1.0665 ± 0.1212 | | 1.1845 ± 0.1421 | | 0.0000 ± 0.0000 | |
| Ca | 0.8457 ± 0.1053 | | 0.9160 ± 0.1084 | | 0.9990 ± 0.1140 | | 1.0985 ± 0.1248 | | 1.2201 ± 0.1463 | | 0.0000 ± 0.0000 | |
| Ti | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| V | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Cr | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Mn | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Fe | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Ni | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Cu | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Zn | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| As | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Se | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Br | 0.1375 ± 0.0171 | | 0.1490 ± 0.0176 | | 0.1625 ± 0.0185 | | 0.1786 ± 0.0203 | | 0.1984 ± 0.0238 | | 0.0000 ± 0.0000 | |
| Sr | 0.0162 ± 0.0020 | | 0.0176 ± 0.0021 | | 0.0192 ± 0.0022 | | 0.0211 ± 0.0024 | | 0.0234 ± 0.0028 | | 0.0000 ± 0.0000 | |
| Mo | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Cd | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Sn | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Sb | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Ba | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Hg | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Pb | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | | 0.0000 ± 0.0000 | |
| Sum | 99.9926 ± 9.2203 | | 99.9919 ± 7.4919 | | 99.9912 ± 6.2650 | | 99.9903 ± 6.1290 | | 99.9893 ± 7.9397 | | 100.0000 ± 7.7804 | |

^a See Table 5-1 for source profile descriptions.

^b TC (Total Carbon)=OC+EC; Sum does not include Na⁺, Cl⁻, S, or TC.

^c PM₁₀ minus PM_{2.5}.

Table 5-2d
Secondary Aerosol Source Profiles (Weight % of Mass)^a

| Species ^b | AMSUL | AMBSUL | AMNTT | OC |
|-------------------------------|--|--|--|--|
| | PM _{2.5} & Coarse Conc. ± Unc. |
| Cl ⁻ | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| NO ₃ ⁻ | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 77.5000 ± 7.7500 | 0.0000 ± 0.0000 |
| SO ₄ ²⁻ | 72.7000 ± 7.2700 | 83.4500 ± 8.3450 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| NH ₄ ⁺ | 27.3000 ± 2.7300 | 15.6700 ± 1.5670 | 22.5500 ± 2.2550 | 0.0000 ± 0.0000 |
| Na ⁺ | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| TC | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 100.0000 ± 10.0000 |
| OC | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 100.0000 ± 10.0000 |
| EC | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Na | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Al | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Si | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| P | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| S | 24.2700 ± 2.4270 | 27.8600 ± 2.7860 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Cl | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| K | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Ca | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Ti | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| V | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Cr | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Mn | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Fe | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Ni | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Cu | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Zn | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| As | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Se | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Br | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Sr | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Mo | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Cd | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Sn | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Sb | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Ba | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Hg | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Pb | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 | 0.0000 ± 0.0000 |
| Sum | 100.0000 ± 7.7657 | 99.1200 ± 8.4908 | 100.0500 ± 8.0714 | 100.0000 ± 10.0000 |

^a See Table 5-1 for source profile descriptions.

^b TC (Total Carbon) = OC + EC; Sum does not include Na⁺, Cl⁻, S, or TC.

^c PM₁₀ minus PM_{2.5}.

Table 5-2e
Other Source Profiles (Weight % of Mass)^a

| Species ^b | LIME | | SFCRUC | VIAGBC |
|------------------------------|-----------------------------------|-------------------------------------|--|--|
| | PM _{2.5} Conc. ± Unc. | Coarse ^c Conc. ± Unc. | PM _{2.5} & Coarse Conc. ± Unc. | PM _{2.5} & Coarse Conc. ± Unc. |
| Cl | 0.4550 ± 0.0480 | 0.4100 ± 0.0410 | 0.0240 ± 0.0021 | 15.3995 ± 5.4539 |
| NO ₃ | 0.0000 ± 0.0834 | 0.0000 ± 0.0834 | 0.0000 ± 0.0017 | 0.3491 ± 0.0710 |
| SO ₄ ^c | 1.0230 ± 0.1040 | 0.6630 ± 0.0660 | 20.3215 ± 4.2445 | 1.7352 ± 0.8722 |
| NH ₄ ⁺ | 0.0000 ± 0.1525 | 0.0000 ± 0.1525 | 0.0076 ± 0.0054 | 2.3572 ± 1.0431 |
| Na ⁺ | 0.0000 ± 0.0438 | 0.0000 ± 0.0438 | 0.7619 ± 0.3993 | 1.1076 ± 1.5019 |
| TC | 0.0000 ± 1.5295 | 0.0000 ± 1.5295 | 0.0894 ± 0.1385 | 45.3962 ± 8.6648 |
| OC | 0.0000 ± 1.4429 | 0.0000 ± 1.4429 | 0.0894 ± 0.1184 | 34.4923 ± 8.0287 |
| EC | 0.0000 ± 0.5075 | 0.0000 ± 0.5075 | 0.0000 ± 0.0719 | 10.9039 ± 3.2586 |
| Na | 0.0000 ± 0.0438 | 0.0000 ± 0.0438 | 0.7619 ± 0.3993 | 1.1076 ± 1.5019 |
| Al | 2.1100 ± 0.2110 | 1.1990 ± 0.1200 | 0.0000 ± 0.0093 | 0.0283 ± 0.0821 |
| Si | 6.4960 ± 0.6500 | 3.3940 ± 0.3390 | 0.0112 ± 0.0164 | 0.0000 ± 0.0516 |
| P | 0.1260 ± 0.0400 | 0.1000 ± 0.0290 | 0.0000 ± 0.1724 | 0.0000 ± 0.0415 |
| S | 1.0230 ± 0.1040 | 0.6630 ± 0.0660 | 5.4521 ± 0.3860 | 0.6437 ± 0.2852 |
| Cl | 0.4550 ± 0.0480 | 0.4100 ± 0.0410 | 0.0240 ± 0.0021 | 15.3995 ± 5.4539 |
| K | 0.1630 ± 0.0420 | 0.1350 ± 0.0230 | 0.0444 ± 0.0054 | 10.0339 ± 3.5395 |
| Ca | 29.5150 ± 2.9510 | 29.7230 ± 2.9720 | 0.0616 ± 0.0045 | 0.0137 ± 0.1634 |
| Ti | 0.0810 ± 0.1000 | 0.0530 ± 0.1000 | 0.0120 ± 0.0019 | 0.0037 ± 0.0509 |
| V | 0.0000 ± 0.0370 | 0.0000 ± 0.0370 | 0.8230 ± 0.0583 | 0.0015 ± 0.0209 |
| Cr | 0.0000 ± 0.0101 | 0.0000 ± 0.0101 | 0.0069 ± 0.0245 | 0.0025 ± 0.0050 |
| Mn | 0.0500 ± 0.0070 | 0.0280 ± 0.0070 | 0.0056 ± 0.0010 | 0.0025 ± 0.0037 |
| Fe | 1.0430 ± 0.1040 | 0.5360 ± 0.0540 | 0.2134 ± 0.0221 | 0.0184 ± 0.0104 |
| Ni | 0.0000 ± 0.0035 | 0.0000 ± 0.0035 | 0.7893 ± 0.0931 | 0.0010 ± 0.0017 |
| Cu | 0.0160 ± 0.0100 | 0.0000 ± 0.0100 | 0.0009 ± 0.0034 | 0.0006 ± 0.0028 |
| Zn | 0.1040 ± 0.0060 | 0.0200 ± 0.0060 | 0.2597 ± 0.0335 | 0.0065 ± 0.0044 |
| As | 0.0200 ± 0.0130 | 0.0000 ± 0.0990 | 0.0006 ± 0.0007 | 0.0000 ± 0.0076 |
| Se | 0.0000 ± 0.0050 | 0.0000 ± 0.0050 | 0.0114 ± 0.0016 | 0.0009 ± 0.0033 |
| Br | 0.0270 ± 0.1000 | 0.0000 ± 0.0044 | 0.0003 ± 0.0002 | 0.0383 ± 0.0236 |
| Sr | 0.0240 ± 0.0050 | 0.0180 ± 0.0050 | 0.0015 ± 0.0003 | 0.0014 ± 0.0031 |
| Mo | 0.0000 ± 0.0109 | 0.0000 ± 0.0109 | 0.0168 ± 0.0023 | 0.0001 ± 0.0099 |
| Cd | 0.0420 ± 0.0450 | 0.0000 ± 0.0487 | 0.0006 ± 0.0020 | 0.0021 ± 0.0244 |
| Sn | 0.0000 ± 0.0520 | 0.0000 ± 0.0692 | 0.0007 ± 0.0030 | 0.0010 ± 0.0399 |
| Sb | 0.0000 ± 0.0950 | 0.0000 ± 0.0170 | 0.0006 ± 0.0034 | 0.0101 ± 0.0462 |
| Ba | 0.0000 ± 0.2560 | 0.0000 ± 0.0440 | 0.0013 ± 0.0111 | 0.0172 ± 0.1561 |
| Hg | 0.0000 ± 0.0105 | 0.0000 ± 0.0105 | 0.0000 ± 0.0009 | 0.0013 ± 0.0114 |
| Pb | 0.2700 ± 0.0270 | 0.0480 ± 0.1000 | 0.0000 ± 0.0013 | 0.0105 ± 0.0209 |
| Sum | 41.5650 ± 3.4171 | 36.3270 ± 3.3728 | 23.4662 ± 4.2707 | 76.5403 ± 11.024 |

^a See Table 5-1 for source profile descriptions.

^b TC (Total Carbon)=OC+EC; Sum does not include Na⁺, Cl⁻, S, or TC.

^c PM₁₀ minus PM_{2.5}.

5.2 Volatile Organic Compound Source Profiles

The most applicable, though not ideal, VOC profiles for SCAQS data are those compiled by the ARB's Modeling Emissions Data System (MEDS, California Air Resources Board, 1992) and from recent experiments related to VOC emissions from motor vehicles. Several of these profiles have been used to speciate the SCAQS reactive organic gas (ROG) emissions inventory for photochemical modeling (Harley *et al.*, 1992b). An added benefit of using these profiles for receptor modeling of SCAQS data is to see how well they reproduce the ambient measurements. If these profiles cannot perform adequately in CMB source apportionment of ambient measurements, they are unlikely to supply accurate emission input to photochemical models. Several of the MEDS source profiles have been adjusted with updated weighting factors, and weight percentages for unresolved species or groups have been allocated to individual species. VOC compounds other than the 60 VOCs in the ambient data base or which are reported as "unidentified" were grouped into a species named "others". While this is often deemed adequate for source-oriented modeling since "others" do not usually constitute more than a few percent of reactive organic gases, it is undesirable for receptor models because the detection of individual species, even at low levels, can minimize collinearity and more precisely resolve one source contribution from another.

Table 5-3 lists the source types, a short identifier for each specific profile, and a brief description of the 23 source profiles used for source apportionment of the SCAQS NMHC measurements. The actual source profiles are presented in Tables 5-4a through 5-4c. The profile elements are expressed as weight percentages of total NMHC. As in the ambient data base, source profile data reported in units of ppbC were converted to $\mu\text{g}/\text{m}^3$ prior to calculating the weight percentages using species-specific conversion factors.

5.2.1 Light Duty Vehicle Exhaust Emissions Profiles

Table 5-4a presents several NMHC profiles for motor vehicle exhaust. Profile "Exh801" was derived from the FTP tests of Sigsby *et al.* (1987) which involved 46 in-use passenger vehicles for 1975 to 1982 model years. Profile "Exh801" was re-calculated by the ARB from original measurements in Sigsby *et al.* (1987) to provide a more complete chemical break down. Propane/propene, benzene/cyclohexane, and toluene/2,3-dimethylhexane were not separately reported by Sigsby *et al.* (1987), so ratios of 3:1, 1:1, and 9:1 were assumed by the ARB for these pairs of species, respectively.

Motor vehicle exhaust profiles measured in the San Francisco Bay area at the Caldecott Tunnel by Zielinska and Fung (1992) and in FTP dynamometer tests by Stump *et al.* (1989; 1990; 1992a; 1992b), Hoekman (1992), Burns *et al.* (1991), and Chock and Winkler (1992) are inconsistent with the abundances in "Exh801". Propane/propene, benzene/cyclohexane, and toluene/2,3-dimethylhexane ratios of 3:22, 19:1, and 1:0, consistent with those found by Zielinska and Fung (1992) were applied to obtain profile "Exh801a" from the data of Sigsby *et al.* (1987).

Table 5-3
Source Profiles Applied in SCAQS VOC Receptor Modeling

| <u>Source Type</u> | <u>Data Base Identifier</u> | <u>Description of Source Profile</u> |
|------------------------------|-----------------------------|--|
| Vehicle Exhaust | Exh801 ^a | FTP Composite from ARB MEDS 801 (EPA 46-car study) |
| Vehicle Exhaust | Exh801a | Exh801 with more appropriate splits for unresolved species |
| Vehicle Exhaust ^e | ExhCT ^b | Mean composition of 13 samples from the Caldecott Tunnel |
| Vehicle Exhaust | ExhCS564 ^a | Mean incremental cold start, Auto/Oil "current" (1989) MEDS 564 |
| Vehicle Exhaust | ExhSt565 ^a | Mean incremental stabilized, Auto/Oil "current" (1989) MEDS 565 |
| Vehicle Exhaust | ExhHS566 ^a | Mean incremental hot start, Auto/Oil "current" (1989) MEDS 566 |
| Vehicle Exhaust | AOComp ^d | FTP Composite from Auto Oil "older fleet" (1983-85) |
| Gasoline Evaporation | AODium ^d | Diurnal evaporative emissions, Auto/Oil "older fleet" (1983-85) |
| Gasoline Evaporation | AOHSoak ^d | Hot Soak evaporative emissions, Auto/Oil "older fleet" (1983-85) |
| Gasoline Evaporation | AORunLs ^d | Running Loss evaporative emissions, Auto/Oil "older fleet" (1983-85) |
| Liquid Gasoline | LGS709 ^a | Summer liquid gasoline, MEDS 709 with updated sales weighting |
| Liquid Gasoline | LGW729 ^a | Winter liquid gasoline, MEDS 729 with updated sales weighting |
| Gasoline Vapor | VGS710 ^a | Summer gasoline headspace, MEDS 710 with updated sales weighting |
| Gasoline Vapor | VGW730 ^a | Winter gasoline headspace, MEDS 730 with updated sales weighting |
| Solvent | ACoat196 ^a | Architectural coatings - composite solvent, MEDS 196 |
| Solvent | ICoat783 ^a | Industrial coatings - solvent based, MEDS 783 |
| Solvent | Degrease ^a | Industrial degreasers, MEDS 515 |
| Solvent | DryClean ^a | Dry-cleaning solvents, MEDS 516 |
| Biogenic | Biogenic | Isoprene emission from biogenic sources |
| Gas | CNG ^c | Commercial natural gas |
| Gas | GNG ^c | Geogenic natural gas |
| Gas | LPG ^c | Liquefied petroleum gas |
| Unidentified | Unid | Sum of unidentified species |

a California Air Resources Board (1992). The number corresponds to the profile number in ARB's Modeling Emissions data system (MEDS).

b Zielinska and Fung (1992)

c Mayrsohn et al. (1975)

d Gorse (1992)

e Contains running and resting losses as well as exhaust.

The "ExhCT" profile in Table 5-4a is an average of the 13 samples collected from the Caldecott Tunnel in June 1991 (Zielinska and Fung, 1992). The NMHC profile in this highway tunnel represents hot stabilized exhaust emissions since most of the traffic consisted of commuters between Oakland and the residential areas of Contra Costa and Alameda Counties. Local traffic was negligible in comparison. This profile also includes running and resting loss emissions.

Profiles "ExhCS564", "ExhSt565", and "ExhHS566" (California Air Resources Board, 1992) are averages for incremental cold start, stabilized, and hot start emissions derived from the Auto/Oil exhaust experiment for the "current" (1989) vehicle fleet using industry average gasoline (Fuel A, based on 1988 Motor Vehicle Manufacturers Association [MVMA] summer nationwide fuel survey). "AOCComp" is the FTP composite profile for the Auto/Oil (Burns *et al.*, 1991; Chock and Winkler, 1992) "older" fleet (1983 to 1985) using Fuel A (Gorse, 1992).

5.2.2 Gasoline Emissions Profiles

Table 5-4b shows seven profiles for gasoline vapor. Profiles "AODiurn", "AOHSoak", and "AORunLs" are average diurnal, hot soak, and running loss emissions, respectively, for the Auto/Oil "older" fleet (Gorse, 1992). The four MEDS profiles for liquid gasoline and headspace vapor are: "LGS709", "LGW729", "VGS710", and "VGW730", based upon data reported by Oliver and Peoples (1985) for gasoline sold in the Los Angeles area in 1984. Oliver and Peoples (1985) sampled leaded and unleaded fuels, regular and premium grade, summertime and wintertime, and analyzed the whole gasoline and headspace hydrocarbon concentrations. They used the gasoline sales distributions for 1979 to calculate composite liquid gasoline and gasoline vapor profiles for summer and winter. Harley *et al.* (1992b) recalculated these composite profiles to reflect the sales distribution for 1987. The liquid gasoline and headspace vapor profiles in Table 5-4b reflect the 1987 sales distribution.

Additionally, the weight percentages in composite liquid gasolines that were reported by Oliver and Peoples (1985) as isomers of hexane and isomers of heptane were assigned to individual isomers according to the average ratios in liquid gasoline reported by Mayrsohn *et al.* (1975) and Sigsby *et al.* (1987). The ratios are 1:3 for 2,3-dimethylbutane and 2-methylpentane, and 13:14 for 3,3-dimethylpentane, 2-methylhexane, 2,3-dimethylpentane, and 3-ethylpentane.

Table 5-4a
Light Duty Vehicle Exhaust Emissions Profiles (Weight % of NMHC)

| Species | Exh801 | Exh801a | ExhCT | ExhCS564 | ExhSt565 | ExhHS566 | AOComp |
|------------------------|---------------|----------------|--------------|-----------------|-----------------|-----------------|---------------|
| Ethane | 2.87 | 2.87 | 0.87 | 2.50 | 12.53 | 6.55 | 5.14 |
| Ethylene | 9.90 | 9.90 | 6.43 | 9.06 | 2.06 | 10.25 | 8.23 |
| Acetylene | 2.78 | 2.78 | 2.12 | 4.08 | 0.00 | 0.00 | 4.36 |
| Propene | 0.89 | 3.13 | 2.75 | 4.55 | 0.00 | 2.18 | 3.01 |
| Propane | 2.67 | 0.43 | 0.36 | 0.00 | 0.00 | 0.00 | 0.28 |
| i-Butane | 0.92 | 0.92 | 0.70 | 0.05 | 0.00 | 0.03 | 0.21 |
| 1-Butene | 0.86 | 0.86 | 1.71 | 0.42 | 0.00 | 0.00 | 0.36 |
| 1,3-Butadiene | 0.00 | 0.00 | 0.57 | 0.73 | 0.00 | 0.00 | 0.45 |
| n-Butane | 6.44 | 6.44 | 2.84 | 3.75 | 19.57 | 7.59 | 7.80 |
| trans-2-Butene | 0.22 | 0.22 | 0.32 | 0.43 | 0.00 | 0.00 | 0.32 |
| cis-2-Butene | 0.59 | 0.59 | 0.26 | 0.20 | 0.00 | 0.50 | 0.18 |
| 3-Methyl-1-Butene | 0.27 | 0.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 |
| Isopentane | 4.93 | 4.93 | 7.79 | 3.23 | 13.17 | 6.34 | 5.68 |
| 1-Pentene | 0.31 | 0.31 | 0.29 | 0.10 | 0.00 | 0.00 | 0.13 |
| 2-Methyl-Butene | 0.63 | 0.63 | 0.44 | 0.73 | 0.00 | 0.01 | 0.22 |
| n-Pentane | 2.21 | 2.21 | 2.73 | 2.54 | 3.62 | 5.49 | 4.09 |
| Isoprene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 |
| trans-2-Pentene | 0.43 | 0.43 | 0.48 | 0.43 | 0.00 | 0.00 | 0.31 |
| cis-2-Pentene | 0.27 | 0.27 | 0.27 | 0.09 | 0.00 | 0.00 | 0.14 |
| 2,2-Dimethylbutane | 0.44 | 0.44 | 0.35 | 1.01 | 0.00 | 0.85 | 1.73 |
| Cyclopentane | 0.21 | 0.21 | 0.44 | 0.00 | 0.00 | 0.00 | 0.34 |
| 2,3-Dimethylbutane | 0.81 | 0.81 | 0.89 | 1.24 | 0.00 | 1.68 | 1.91 |
| 2-Methylpentane | 1.91 | 1.91 | 3.17 | 3.47 | 3.69 | 6.40 | 4.94 |
| 3-Methylpentane | 1.37 | 1.37 | 1.85 | 1.82 | 1.27 | 3.05 | 2.56 |
| n-Hexane | 0.92 | 0.92 | 1.72 | 0.77 | 1.72 | 2.94 | 2.37 |
| 2-Methyl-2-Pentene | 0.27 | 0.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 |
| Methylcyclopentane | 0.92 | 0.92 | 1.77 | 0.77 | 0.00 | 0.83 | 0.86 |
| 2,4-Dimethylpentane | 0.82 | 0.82 | 0.00 | 0.83 | 0.00 | 0.90 | 0.88 |
| Benzene | 2.06 | 3.91 | 5.42 | 4.98 | 12.11 | 7.53 | 4.08 |
| 3,3-Dimethylpentane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 |
| Cyclohexane | 2.06 | 0.22 | 0.29 | 0.02 | 0.00 | 0.00 | 0.17 |
| 2-Methylhexane | 0.76 | 0.76 | 1.20 | 1.06 | 0.00 | 0.81 | 1.08 |
| 2,3-Dimethylpentane | 0.76 | 0.76 | 0.46 | 1.20 | 0.00 | 1.55 | 1.53 |
| 3-Methylhexane | 1.38 | 1.38 | 1.25 | 1.19 | 0.00 | 1.45 | 1.32 |
| 2,2,4-Trimethylpentane | 2.91 | 2.91 | 1.59 | 2.79 | 7.11 | 4.84 | 3.54 |
| n-Heptane | 0.78 | 0.78 | 0.93 | 0.00 | 0.00 | 0.94 | 0.77 |
| Methylcyclohexane | 0.64 | 0.64 | 0.51 | 0.23 | 0.00 | 0.00 | 0.35 |
| 2,3,4-Trimethylpentane | 0.17 | 0.17 | 0.00 | 1.55 | 0.00 | 1.37 | 1.49 |
| Toluene | 6.39 | 7.10 | 8.27 | 7.77 | 9.24 | 9.03 | 5.14 |
| 2-Methylheptane | 0.33 | 0.33 | 0.47 | 0.58 | 0.00 | 0.30 | 0.61 |
| 3-Methylheptane | 0.55 | 0.55 | 0.00 | 0.95 | 0.00 | 0.63 | 0.83 |
| 2,2,5-Trimethylhexane | 0.76 | 0.76 | 0.33 | 0.32 | 0.00 | 0.18 | 0.32 |
| Cycloheptane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| n-Octane | 0.44 | 0.44 | 0.32 | 0.58 | 0.00 | 0.25 | 0.42 |
| 2,5-Dimethylheptane | 0.14 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Ethylbenzene | 0.79 | 0.79 | 1.50 | 3.20 | 0.00 | 2.86 | 1.92 |
| m,p-Xylene | 3.32 | 3.32 | 5.95 | 7.78 | 1.92 | 5.69 | 4.49 |
| 4-Methyloctane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.28 |
| 3-Methyloctane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 |
| o-Xylene | 2.22 | 2.22 | 2.46 | 2.71 | 0.00 | 1.97 | 1.52 |
| 1-Nonene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| n-Nonane | 0.31 | 0.31 | 0.00 | 0.06 | 0.00 | 0.00 | 0.11 |
| n-Propylbenzene | 0.69 | 0.69 | 0.36 | 0.51 | 0.00 | 0.00 | 0.46 |
| m-Ethyltoluene | 1.63 | 1.63 | 1.64 | 0.00 | 0.00 | 0.00 | 1.38 |
| p-Ethyltoluene | 0.00 | 0.00 | 0.85 | 0.00 | 0.00 | 0.00 | 0.55 |
| o-Ethyltoluene | 0.28 | 0.28 | 0.00 | 0.76 | 0.00 | 0.20 | 0.37 |
| 1,2,4-Trimethylbenzene | 3.33 | 3.33 | 2.27 | 2.59 | 0.00 | 1.13 | 1.19 |
| n-Decane | 0.17 | 0.17 | 0.00 | 0.06 | 0.00 | 0.00 | 0.09 |
| 1,1,1-Trichloroethane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Freon 113 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Others | 22.27 | 21.56 | 22.81 | 16.37 | 11.99 | 3.67 | 8.61 |

Table 5-4b
Gasoline Emissions Profiles (Weight % of NMHC)

| <u>Species</u> | <u>AODturn</u> | <u>AOHSoak</u> | <u>AORunLs</u> | <u>LGS709</u> | <u>LGW729</u> | <u>VGS710</u> | <u>VGW730</u> |
|------------------------|----------------|----------------|----------------|---------------|---------------|---------------|---------------|
| Ethane | 0.01 | 0.13 | 0.00 | 0.00 | 0.05 | 0.19 | 0.10 |
| Ethylene | 0.00 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Acetylene | 0.00 | 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Propene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Propane | 0.95 | 0.56 | 0.16 | 0.00 | 0.07 | 2.19 | 2.11 |
| i-Butane | 1.76 | 0.60 | 1.69 | 0.75 | 2.10 | 11.51 | 17.40 |
| 1-Butene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1,3-Butadiene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| n-Butane | 37.69 | 11.27 | 54.97 | 3.18 | 5.60 | 30.22 | 30.48 |
| trans-2-Butene | 0.00 | 0.00 | 0.00 | 0.10 | 0.24 | 1.69 | 1.64 |
| cis-2-Butene | 0.00 | 0.00 | 0.00 | 0.13 | 0.22 | 1.35 | 1.19 |
| 3-Methyl-1-Butene | 0.00 | 0.00 | 0.05 | 0.10 | 0.08 | 0.42 | 0.26 |
| Isopentane | 13.29 | 6.35 | 16.63 | 6.60 | 6.19 | 22.40 | 14.28 |
| 1-Pentene | 0.57 | 0.31 | 0.43 | 0.34 | 0.31 | 1.01 | 0.70 |
| 2-Methyl-Butene | 0.89 | 0.62 | 0.84 | 0.39 | 0.38 | 1.24 | 0.90 |
| n-Pentane | 8.11 | 5.25 | 7.94 | 3.63 | 2.56 | 6.32 | 4.40 |
| Isoprene | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| trans-2-Pentene | 1.39 | 1.05 | 1.20 | 0.69 | 0.59 | 1.68 | 1.09 |
| cis-2-Pentene | 0.85 | 0.60 | 0.67 | 0.34 | 0.32 | 0.85 | 0.56 |
| 2,2-Dimethylbutane | 1.40 | 1.14 | 1.33 | 1.05 | 0.91 | 1.06 | 0.84 |
| Cyclopentane | 0.47 | 0.44 | 0.14 | 0.46 | 0.49 | 0.51 | 0.53 |
| 2,3-Dimethylbutane | 1.54 | 1.61 | 1.13 | 0.80 | 0.71 | 0.72 | 0.63 |
| 2-Methylpentane | 4.99 | 5.36 | 3.34 | 2.59 | 2.32 | 2.33 | 2.03 |
| 3-Methylpentane | 2.00 | 2.59 | 1.30 | 2.03 | 1.77 | 1.56 | 1.49 |
| n-Hexane | 1.85 | 2.79 | 1.03 | 1.94 | 1.69 | 1.14 | 1.19 |
| 2-Methyl-2-Pentene | 0.30 | 0.39 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| Methylcyclopentane | 0.69 | 1.14 | 0.20 | 2.44 | 2.19 | 1.08 | 1.49 |
| 2,4-Dimethylpentane | 0.53 | 0.84 | 0.12 | 1.09 | 0.98 | 0.40 | 0.56 |
| Benzene | 1.45 | 3.72 | 0.10 | 1.98 | 1.88 | 0.59 | 1.20 |
| 3,3-Dimethylpentane | 0.00 | 0.00 | 0.00 | 0.69 | 0.52 | 0.13 | 0.27 |
| Cyclohexane | 0.47 | 0.42 | 0.04 | 0.57 | 0.50 | 0.33 | 0.27 |
| 2-Methylhexane | 0.70 | 1.20 | 0.19 | 2.26 | 1.68 | 0.41 | 0.87 |
| 2,3-Dimethylpentane | 0.61 | 1.31 | 0.12 | 1.79 | 1.34 | 0.33 | 0.69 |
| 3-Methylhexane | 0.64 | 1.30 | 0.17 | 1.90 | 1.51 | 0.33 | 0.62 |
| 2,2,4-Trimethylpentane | 1.11 | 2.32 | 0.28 | 0.00 | 0.00 | 0.00 | 0.00 |
| n-Heptane | 0.45 | 1.06 | 0.12 | 1.96 | 1.58 | 0.22 | 0.53 |
| Methylcyclohexane | 0.32 | 0.68 | 0.00 | 0.97 | 0.86 | 0.09 | 0.26 |
| 2,3,4-Trimethylpentane | 0.61 | 1.38 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| Toluene | 4.31 | 12.29 | 0.16 | 10.67 | 9.64 | 0.57 | 1.54 |
| 2-Methylheptane | 0.33 | 0.63 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3-Methylheptane | 0.36 | 0.80 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2,2,5-Trimethylhexane | 0.00 | 0.41 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cycloheptane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| n-Octane | 0.30 | 0.54 | 0.02 | 0.95 | 0.90 | 0.02 | 0.13 |
| 2,5-Dimethylheptane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Ethylbenzene | 1.20 | 3.82 | 0.03 | 1.95 | 2.02 | 0.03 | 0.15 |
| m,p-Xylene | 2.68 | 8.96 | 0.06 | 8.66 | 8.63 | 0.11 | 0.51 |
| 4-Methyloctane | 0.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3-Methyloctane | 0.47 | 0.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| o-Xylene | 0.93 | 2.96 | 0.00 | 3.25 | 3.42 | 0.04 | 0.23 |
| 1-Nonene | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| n-Nonane | 0.00 | 0.23 | 0.00 | 0.56 | 0.58 | 0.00 | 0.01 |
| n-Propylbenzene | 0.27 | 0.67 | 0.00 | 0.55 | 0.65 | 0.00 | 0.00 |
| m-Ethyltoluene | 0.88 | 1.98 | 0.00 | 2.73 | 3.12 | 0.00 | 0.05 |
| p-Ethyltoluene | 0.41 | 0.85 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| o-Ethyltoluene | 0.24 | 0.59 | 0.00 | 1.14 | 1.21 | 0.03 | 0.01 |
| 1,2,4-Trimethylbenzene | 0.73 | 2.40 | 0.00 | 3.32 | 3.87 | 0.31 | 0.03 |
| n-Decane | 0.00 | 0.00 | 0.00 | 0.19 | 0.25 | 0.00 | 0.00 |
| 1,1,1-Trichloroethane | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Freon 113 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Others | 1.23 | 4.73 | 5.19 | 25.24 | 26.08 | 6.58 | 8.71 |

5.2.3 Solvent and Other Emissions Profiles

VOC profiles for solvent, biogenic, natural and liquefied petroleum gases, and unidentified NMHC are shown in Table 5-4c. A large variety of formulations is used in surface coatings, and it is unlikely that one or two profiles adequately represent the emissions from all surface coatings. Furthermore, coatings contain a variety of oxygenated compounds, which in many cases account for a majority of the solvent content. The hydrocarbon fraction of the coating solvents consists of complex mixtures of higher molecular weight hydrocarbons that have not been adequately characterized.

Isoprene is taken to constitute 100 percent of NMHC in the biogenic emissions profile, mainly because other biogenic species such as pinenes were not detected in SCAQS ambient samples and because detailed profiles are not available. Biogenic NMHC emissions are extremely reactive in the atmosphere, and biogenic source contributions derived from CMB modeling will supply only a lower limit to the actual contributions from biogenic emissions.

The commercial natural gas (CNG) profile is based on samples taken in the summer of 1972 at Los Angeles, CA and in the summer of 1973 at El Monte, CA. The geogenic natural gas (GNG) profile is based upon samples taken in the spring of 1972 in Newhall, CA and at a well head in Redondo Beach, CA in the fall of 1973. The composition of the samples of both types of natural gas did not vary despite the differences in time and location of sample collection.

Weight fractions for compounds in the emissions profiles that were not identified in the ambient samples or reported as unidentified were combined into "others". A single component source profile named "unidentified" was used to account for "others" that could not be assigned to other sources. The species included in "others" do not correspond exactly to total unidentified NMHC in the ambient data base. The ambient data consist of three categories of species: 60 uniquely identified compounds; 17 compounds identified as generic isomers (e.g., C₉ aromatic); and the sum of unidentified compounds. The sum of isomeric species should properly be combined with total unidentified and re-named "others" in order to relate directly to the source profiles. Since the sum of the isomeric species in the ambient samples was typically less than one or two percent of the total mass, this was not applied here. The consequence is a slight, but negligible, underprediction in the contribution of the "Unid" source type listed in Table 5-4c.

The quality of the measurements used in the NMHC source profiles is as important as the ambient data quality. Because less variable species abundances provide a larger influence on the source contribution estimates, source profile values must not only be accurately and precisely measured, their uncertainties must also represent the range of variability expected from a number of individual emitters in the same source type. The published profiles do not adequately estimate uncertainties, even though the profile values result from averaging a number of tests and standard deviations could be calculated. Where uncertainty estimates are provided, they apply to a limited sample of emitters and to conditions which may not reflect the actual

Table 5-4c
Solvent and Other Emissions Profiles (Weight % of NMHC)

| Species | Acoat196 | ICoat783 | Degrease | DryClean | Biogenic | CNG | GNG | LPG | Unid |
|------------------------|----------|----------|----------|----------|----------|-------|-------|-------|--------|
| Ethane | 0.00 | 0.00 | | | | 69.40 | 15.80 | 4.10 | |
| Ethylene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| Acetylene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| Propene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 5.10 | |
| Propane | 0.00 | 0.00 | | | | 21.30 | 25.20 | 90.40 | |
| i-Butane | 0.00 | 0.00 | | | | 2.10 | 5.90 | 0.20 | |
| 1-Butene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 1,3-Butadiene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| n-Butane | 0.00 | 0.00 | | | | 3.10 | 14.60 | 0.00 | |
| trans-2-Butene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| cis-2-Butene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 3-Methyl-1-Butene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| Isopentane | 0.00 | 0.00 | | | | 0.70 | 6.20 | 0.00 | |
| 1-Pentene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 2-Methyl-Butene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| n-Pentane | 0.00 | 0.00 | | | | 0.70 | 6.20 | 0.00 | |
| Isoprene | 0.00 | 0.00 | | | 100.00 | 0.00 | 0.00 | 0.00 | |
| trans-2-Pentene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| cis-2-Pentene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 2,2-Dimethylbutane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| Cyclopentane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 2,3-Dimethylbutane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 2-Methylpentane | 0.00 | 0.00 | | | | 0.30 | 2.90 | 0.00 | |
| 3-Methylpentane | 0.00 | 0.00 | | | | 0.10 | 1.50 | 0.00 | |
| n-Hexane | 38.71 | 0.00 | | | | 0.40 | 1.80 | 0.00 | |
| 2-Methyl-2-Pentene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| Methylcyclopentane | 0.00 | 0.00 | | | | 1.00 | 2.60 | 0.00 | |
| 2,4-Dimethylpentane | 0.00 | 2.32 | | | | 0.00 | 0.00 | 0.00 | |
| Benzene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 3,3-Dimethylpentane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| Cyclohexane | 38.71 | 0.68 | | | | 0.00 | 0.00 | 0.00 | |
| 2-Methylhexane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 2,3-Dimethylpentane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 3-Methylhexane | 0.00 | 0.00 | | | | 0.20 | 4.50 | 0.00 | |
| 2,2,4-Trimethylpentane | 0.00 | 0.00 | | | | 0.30 | 0.90 | 0.00 | |
| n-Heptane | 0.00 | 3.96 | | | | 0.20 | 1.20 | 0.00 | |
| Methylcyclohexane | 0.00 | 4.91 | | | | 0.10 | 2.20 | 0.00 | |
| 2,3,4-Trimethylpentane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| Toluene | 9.67 | 51.57 | | | | 0.00 | 0.00 | 0.00 | |
| 2-Methylheptane | 0.00 | 0.00 | | | | 0.40 | 3.30 | 0.00 | |
| 3-Methylheptane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 2,2,5-Trimethylhexane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| Cycloheptane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| n-Octane | 0.00 | 0.00 | | | | 0.00 | 1.00 | 0.00 | |
| 2,5-Dimethylheptane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| Ethylbenzene | 8.04 | 0.68 | | | | 0.00 | 0.00 | 0.00 | |
| m,p-Xylene | 4.86 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 4-Methyloctane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 3-Methyloctane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| o-Xylene | 0.00 | 6.00 | | | | 0.00 | 0.00 | 0.00 | |
| 1-Nonene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| n-Nonane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| n-Propylbenzene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| m-Ethyltoluene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| p-Ethyltoluene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| o-Ethyltoluene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 1,2,4-Trimethylbenzene | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| n-Decane | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 | |
| 1,1,1-Trichloroethane | 0.00 | 0.00 | 20.00 | 40.00 | | 0.00 | 0.00 | 0.00 | |
| Freon 113 | 0.00 | 0.00 | 20.00 | | | 0.00 | 0.00 | 0.00 | |
| Others | 0.00 | 29.88 | 60.00 | 60.00 | 0.00 | 0.50 | 4.40 | 0.00 | 100.00 |

range of variability for the source type. Therefore, estimates of NMHC profile uncertainties are made here based on past experience and engineering judgment rather than actual data.

To a first approximation, the NMHC profiles can be no more precise than the uncertainties of the analytical methods applied to obtain them. The analytical uncertainties for hydrocarbons should be similar for ambient and source measurements since the same analytical method is used. This uncertainty is typically in the range of $\pm 10\%$ to $\pm 15\%$ for values exceeding five times the lower quantifiable limit. A default coefficient of variation of $\pm 20\%$ is applied for all species in the profiles with a minimum detectable weight percentage of 0.1% or larger. For values less than 0.1%, the uncertainty is estimated as the square root of the sum of the squares of the lower quantifiable limit and the square of the product of the relative standard error and weight percentage. This is analogous to the error propagation applied to ambient NMHC measurements to estimate their precision.

These default uncertainty estimates do not necessarily account for the variability among individual emitters in a source type or range of operating conditions. Past experiments show that, in many cases, this type of variability can far exceed the variability due to measurement errors. For example, Sigsby *et al.* (1987) report the average NMHC weight fraction of acetylene between 5.2% for 1975 model-year vehicles and 0.5% for 1982 model-year vehicles with a relative standard error of 108% for the 46-car data set. For comparison, the NMHC weight fraction of acetylene was 2.1% in the Caldecott Tunnel (Zielinska and Fung, 1992) (ExhCT) and 4.4% (AOCComp) for the composite vehicle exhaust profile for the Auto/Oil "older" fleet (Gorse, 1992).

While the variability in the acetylene/NMHC ratio among the different vehicle exhaust profiles is quite large, the variability in the corresponding ambient ratio is much smaller. The acetylene/NMHC ratios from the SCAQS ambient data base averaged $2.8 \pm 1.1\%$ for all sampling sites, periods and seasons, and $3.0 \pm 1.0\%$ for the 0700-0800 PST commute period. These comparisons demonstrate that variability among available source profiles taken from small numbers of sources (relative to the total number contributing in a given airshed) can be substantially greater than the actual variability for a source type at the time and location of the ambient measurements. This is not unexpected considering that source profiles were collected in different areas over a period spanning many years and with many different sampling and analysis methods. Moreover, the vehicle exhaust profiles were developed from a limited sample, while the ambient data reflect the average contributions from a large population of on-road vehicles.

Lacking profiles which were specifically acquired for receptor modeling, this study applies constant default uncertainties which are slightly higher than the analytical precision. The effect of this decision is that all species have nearly the same influence on the CMB fit to ambient data. This sacrifices one of the main advantages of the effective variance solution to the CMB (Watson *et al.*, 1984) which gives less influence to those species with higher uncertainty and greater influence to those species which are more precisely determined. The

assigned source profile uncertainties are still propagated along with the ambient measurement uncertainties so that a realistic standard error is associated with source contribution estimates.

A subset of the profiles in Tables 5-4a to 5-4c was selected for inclusion in the individual CMB analyses of each SCAQS VOC sample based upon sensitivity tests which examined the ability of these profiles to explain the SCAQS data. The U.S. EPA/DRI Version 7.0 CMB software (Watson *et al.*, 1990b; 1990c) provides several performance measures which can be used to evaluate the validity of a profile, its uncertainties, and the species which should be used in a CMB fit.

6.0 SCAQS AEROSOL SOURCE APPORTIONMENT

Both source-oriented dispersion models and receptor models have been used to apportion atmospheric constituents to sources. Current scientific understanding is that both approaches are necessary, either operating independently (U.S. EPA, 1987) to engender the reconciliation of model results, or operating together (Chow, 1985; Freeman *et al.*, 1987; Watson *et al.*, 1987) so that the strengths of one type of model can compensate for the weaknesses of the other. This section addresses the receptor modeling of PM_{2.5} and PM₁₀ in the SoCAB. As noted in Section 2, Pandis *et al.* (1992a; 1992b) are performing source-oriented modeling of SCAQS aerosol data.

Types of receptor models include: 1) chemical mass balance (CMB); 2) principal components analysis (PCA, otherwise known as factor analysis); and 3) multiple linear regression (MLR). Extensive discussions of each of these models, operating separately and together, are given by Watson *et al.* (1984), Chow (1985), Hopke (1985), Watson *et al.* (1987), and Javitz and Watson (1988). The CMB model, as specified by U.S. EPA guidelines for State Implementation Plan (SIP) development (Pace and Watson, 1987), is applied here. Different variations of PCA models are being applied in other SCAQS data analysis studies (Henry, 1992; Hopke, 1992).

6.1 Chemical Mass Balance Receptor Model

The CMB model consists of a least-squares solution to a set of linear equations which expresses each receptor concentration of a chemical species as a linear sum of products of source profile species and source contributions. The source profile species (the fractional amount of the species in the emissions from each source type) and the receptor concentrations, each with realistic uncertainty estimates, serve as input data to the CMB model. The output consists of the contributions for each source type to the total ambient aerosol mass as well as to individual chemical species concentrations. The model calculates values for contributions from each source and the uncertainties of those values. Input data uncertainties are used both to weight the relative importance of the input data to the model solution and to estimate uncertainties of the source contributions.

CMB software currently in use (Watson *et al.*, 1990b; 1990c) applies the effective variance solution developed and tested by Watson *et al.* (1984) because: 1) it calculates realistic uncertainties of source contributions from both the source and receptor uncertainties; and 2) chemical species measured more precisely in both source and receptor samples are given greater influence in the solution than are less precisely measured species.

Watson (1979) observed that individual sources with similar source profiles, such as different soils and road dusts, would yield unreliable source contribution estimates if used in the same CMB. Henry (1982; 1992) proposed a quantitative method of identifying this interference among similar source compositions, which is known as "collinearity." Henry's "singular value

decomposition" defines an "estimable space in which resolvable sources should lie" (Henry, 1982; 1992). The source types which do not fall into this estimable space are collinear, or too similar to be resolved from a combination of one or more of the source types which do lie within the estimable space. Henry (1982; 1992) further proposed that linear combinations of source contributions resulting from collinear source compositions would be more representative of the summed contributions of these sources. Analytical measures of collinearity are available in the U.S. EPA/DRI Version 7.0 of the CMB model (Watson *et al.*, 1990b).

6.2 CMB Application and Validation

The CMB modeling procedure requires: 1) identification of the contributing source types; 2) selection of chemical species to be included; 3) estimation of the fractions of each chemical species contained in each source type (i.e., the source profiles); 4) estimation of the uncertainties of both ambient concentrations and source compositions; and 5) solution of the chemical mass balance equations.

These procedures are described in an applications and validation protocol (Watson *et al.*, 1991b) which has been assembled for PM₁₀ source assessment. Since this study is not being done specifically for PM₁₀ SIP development, there is no requirement that this protocol be followed. The protocol does provide a regimen which makes the results from this source apportionment study comparable with those from other PM₁₀ non-attainment areas, so it will be applied to the SCAQS aerosol source apportionment.

The CMB applications and validation protocol consists of seven steps: 1) determination of model applicability; 2) initial source contribution estimates; 3) examination of model outputs and performance measures; 4) identification of deviations from model assumptions; 5) identification and correction of model input errors; 6) verification of the consistency and stability of source contribution estimates; and 7) evaluation of the results of the CMB analysis with respect to other source assessment methods. The activities carried out for each of these steps are described in this section.

6.2.1 CMB Model Applicability

The requirements for CMB model applicability are as follows: 1) a sufficient number of receptor samples is taken with an accepted method to evaluate compliance with standards; 2) samples are analyzed for chemical species which are also present in source emissions; 3) potential source contributors have been identified and chemically characterized; and 4) the number of non-collinear source types is less than the number of measured species.

Samples were taken through well-characterized PM_{2.5} and PM₁₀ inlets during the SCAQS summer and fall campaigns. All of these samples were submitted to analysis for mass, elements, carbon, and ion concentrations, as discussed in Section 3. All major source types in the SoCAB

have been identified, sampled, and analyzed, as reported in Section 5. The examination of chemical profiles in Section 5 showed significant differences among profiles for major source types such as primary geological material, primary motor vehicle exhaust, primary marine aerosol, and secondary sulfates and nitrates. The number of species measured in source and receptor samples is greater than the number of non-collinear sources.

The SCAQS data set was not randomly obtained over a one-year period, and it should not be used to evaluate compliance with the annual average PM_{10} standard. However, since meteorological conditions on sampled days reflect the conditions most conducive to high PM_{10} concentrations, and since several cases were observed for which the PM_{10} standard was exceeded, the SCAQS data set can be used to determine source contributions to exceedances of the 24-hour standard. It is especially useful when placed into the context of the 1986 (Gray *et al.*, 1988) and 1988 (Chow *et al.*, 1992) PM_{10} receptor model studies in the SoCAB.

There do appear to be negative biases in the x-ray fluorescence and carbon data. Since mass closure was not found for the chemical species measured in SCAQS, it is not anticipated for the CMB source contribution estimates. These biases will probably affect the source contributions from motor vehicle exhaust and geological material, which account for most of the organic carbon and trace elements in SCAQS sources, as explained in Section 5.

6.2.2 Initial Source Contribution Estimates

A number of samples in both the $PM_{2.5}$ and coarse (PM_{10} minus $PM_{2.5}$) size fractions were used to calculate initial source contribution estimates. These initial tests were intended to determine which profiles best explain the data at each site. Profiles which represent the following source types were used in different combinations to reproduce the ambient concentrations: 1) geological material (different samples of paved road dust); 2) motor vehicle exhaust (roadway tests from Phoenix and linear combinations of dynamometer source tests in the SoCAB); 3) particles formed from the transformation of gases in the atmosphere (ammonium sulfate, $(NH_4)_2SO_4$, and ammonium nitrate, NH_4NO_3); and 4) aged marine aerosol (assuming different displacements of chloride by nitrate from the reaction of sodium chloride with nitric acid). These source types were expected to be found in every sample. In addition, profiles for residual oil combustion and construction (lime/gypsum) dust were initially used in most of the CMB analyses because these sources had been found to be contributors in previous studies, as noted in Section 2. Finally a vegetative burning source profile was applied since there may have been some forest fire influence during the summer and residential fireplace burning influence in the fall.

Several initial CMB runs were performed using data from each site, and the CMB performance measures were examined to determine how well the ambient concentrations were explained by the source contribution estimates. These performance measures are described in the next sub-section, and examples of their use to test model outputs are shown.

Primary geological and marine sources were required to explain chemical measurements in nearly every coarse particle sample. Secondary ammonium nitrate and primary motor vehicle exhaust were often needed to account for a portion of the coarse particles, even though the majority of these are in the PM_{2.5} particle fraction. As noted in Section 4, sampling inlets do not provide perfect separations at 2.5 μm, and it is expected that some PM_{2.5} material will be found in the coarse fraction and vice versa. The lime/gypsum profile was required only at the Rubidoux site, similar to findings in previous studies.

Secondary ammonium sulfate, secondary ammonium nitrate, and primary motor vehicle exhaust were always required to account for the chemical concentrations in the PM_{2.5} samples. Small amounts of geological material and marine aerosol were needed for a large number of these samples. Residual oil combustion and vegetative burning profiles were applied, but there was never a case in the initial source apportionments, or in any of the source apportionments, where the inclusion of these profiles resulted in source contribution estimates which exceeded standard errors. The secondary organic carbon profile, which contains only organic carbon to represent particulate carbon formed from reactions of volatile organic gases in the atmosphere, was not needed since the primary sources of carbon were sufficient to account for the measured concentrations of these species. This may be an artifact, however, of the need to use total carbon rather than organic and elemental carbon as fitting species owing to the differences in carbon analysis methods for source profiles and receptor samples. This issue is discussed in the next sub-section.

The initial source apportionments at each site showed that the following profiles best explained the data across the SoCAB: 1) "PRSCAB" for primary geological material; 2) "PHRD" for primary motor vehicle exhaust; 3) "MAR0" or "MAR25" for primary marine aerosol; 4) "AMSUL" for secondary ammonium sulfate; 5) "AMNIT" for secondary ammonium nitrate; and 6) "LIME" for primary lime/gypsum, cement, or construction. As shown below, the source contribution estimates are not overly sensitive to substitution of the other profiles in Table 5-1 for these default profiles. It was desired to use the same profiles at all sites, if possible, so that any systematic errors would be consistent across the SoCAB.

The initial source apportionments also examined the fitting species which would provide the best indication of the presence or absence of sources. Many of the trace elements were omitted as fitting species (phosphorus [P], chromium [Cr], manganese [Mn], cobalt [Co], copper [Cu], zinc [Zn], arsenic [As], selenium [Se], strontium [Sr], molybdenum [Mo], cadmium [Cd], tin [Sn], antimony [Sb], cesium [Cs], barium [Ba], platinum [Pt], and mercury [Hg]) because their concentrations were less than or close to their lower quantifiable limits and because these species are not present in SoCAB source emissions. Sulfate was used in place of sulfur and chloride was used in place of chlorine as fitting species owing to the suspected bias in the elemental data and because the soluble fractions of these species are more typical of secondary sulfate and marine sources than the total elemental fractions. Ammonium and nitrate were also included as initial fitting species to account for ammonium nitrate, as were aluminum, silicon, potassium, calcium and iron as indicators of soils. Vanadium and nickel were also retained, even though their concentrations were very low, so that residual oil combustion could be sought.

Initial CMB calculations used both organic carbon (OC) and elemental carbon (EC) as fitting species. It was found that OC was always overpredicted and EC was always underpredicted. This often moved performance measures significantly away from their targets and biased the motor vehicle exhaust source contributions. This discrepancy is due to the incompatibility of the carbon measurements in the ambient data and in the source profiles. After several trials, it became apparent that only total carbon (TC) was consistent between source and receptor samples. Using TC instead of OC and EC has major consequences for the apportionment of motor vehicle exhaust. Lowenthal *et al.* (1992) show that the OC and EC abundances are crucial to separating gasoline-fueled vehicle exhaust from diesel exhaust. When OC and EC are included in the apportionment of other data sets, it is often possible to assign excess OC to secondary organic carbon. This is not possible using the SCAQS aerosol data with current profiles, and any secondary carbon will be attributed to primary motor vehicle exhaust by this modeling. Fortunately, Turpin and Huntzicker (1991) have examined the secondary organic contribution during SCAQS, and it only appears on a few afternoons during the summer campaign.

6.2.3 Model Outputs and Performance Measures

Pace and Watson (1987) define several performance measures which are examined with each CMB to eliminate many combinations of profiles from further consideration. There may be more than one combination of profiles which attains the performance criteria to the same extent. When this is the case, it is necessary to group these individual sources into more comprehensive source types which are not specific to individual sources.

Evaluations of several different combinations of profiles were made for every $PM_{2.5}$ and coarse particle sample in the SCAQS aerosol data. An example of the process is given here to illustrate the evaluation process and the grouping of similar profiles into source types. The selected model outputs, ambient concentrations, source profiles, and modeling software are available from the authors for other researchers to reproduce these tests on this example and for all data reported in this study.

Tables 6-1a and 6-1b show examples of the CMB7 output format which are examined with every initial source apportionment and every change in source/fitting species configuration. A separate output is obtained for $PM_{2.5}$ and coarse particle apportionments. These outputs contain every specification for the configuration under which the model was applied. The upper part of the display shows the source profiles included in each model application. The profiles associated with these mnemonics are described in Section 5 and the meanings of the chemical species mnemonics are described in Appendix D. Gas as well as particle concentrations were carried through the model, even though they did not affect the source apportionment calculations. This was useful for examining phenomena such as ammonium nitrate contributions in the presence of different concentrations of ammonia and nitric acid. The lower part of the

Table 6-1a
Example CMB Output for PM_{2.5} Samples Collected at the Long Beach Site
on December 10, 1987 Between 1400 and 1800 PST

SOURCE CONTRIBUTION ESTIMATES - SITE: LBCC DATE: 12/10/87 CMB7 33889
SAMPLE DURATION 4 START HOUR 14 SIZE: F
R SQUARE .99 PERCENT MASS 93.7
CHI SQUARE .15 DF 13

| SOURCE | * TYPE | SCE(UG/M3) | STD ERR | TSTAT |
|--------|--------|------------|---------|--------|
| 13 | PHRD | 20.6543 | 5.0851 | 4.0617 |
| 25 | AMSUL | 1.3698 | .7982 | 1.7161 |
| 27 | AMMIT | 19.9277 | 2.4917 | 7.9977 |

MEASURED CONCENTRATION FOR SIZE: F
44.8+- 4.5

UNCERTAINTY/SIMILARITY CLUSTERS CMB7 33889 SUM OF CLUSTER SOURCES

SPECIES CONCENTRATIONS - SITE: LBCC DATE: 12/10/87 CMB7 33889
SAMPLE DURATION 4 START HOUR 14 SIZE: F
R SQUARE .99 PERCENT MASS 93.7
CHI SQUARE .15 DF 13

| SPECIES | I | MEAS | CALC | RAT | IO C/M | RATIO R/U | |
|---------|------|--------------|-----------|------------|---------|--------------|------|
| MTGC | MTGU | T 44.77000+- | 4.51000 | 41.95184+- | 4.75593 | .94+- .14 | -.4 |
| CLIC | CLIU | * .15000+- | .12000 | .23903+- | .15584 | 1.59+- 1.64 | .5 |
| HN3C | HN3U | 2.42000+- | .66000 | ***** | ***** | ***** | -1.5 |
| N33C | N33U | 23.57000+- | 1.16000 | 17.72119+- | 2.64672 | .75+- .12 | -2.0 |
| N34C | N34U | 29.71000+- | 1.22000 | 17.72119+- | 2.64672 | .60+- .09 | -4.1 |
| N31C | N31U | * 17.55000+- | .53000 | 17.72119+- | 2.64672 | 1.01+- .15 | .1 |
| S41C | S41U | * 2.23000+- | .24000 | 2.23771+- | .44342 | 1.00+- .23 | .0 |
| HN3C | HN3U | 7.62000+- | .63000 | ***** | ***** | ***** | -1.5 |
| N45C | N45U | 7.55000+- | .57000 | 5.71581+- | .72356 | .76+- .11 | -2.0 |
| N44C | N44U | * 5.76000+- | .15000 | 5.71581+- | .72356 | .99+- .13 | -.1 |
| NAAC | NAAU | -99.00000+- | -99.00000 | .00000+- | .02065 | .00+- .00 | 1.0 |
| TCTC | TCTU | * 15.57000+- | 1.55910 | 15.58732+- | 4.46533 | 1.00+- .30 | .0 |
| OCTC | OCTU | 11.79000+- | 1.53000 | 8.05581+- | 3.84535 | .68+- .34 | -.9 |
| ECTC | ECTU | 3.78000+- | .30000 | 7.53150+- | 2.26989 | 1.99+- .62 | 1.6 |
| MAXC | MAXU | * .01920< | .03920 | .00000< | .02065 | .00< 1.08 | -.4 |
| MGXC | MGXU | .02450+- | .01520 | .00000+- | .00000 | .00+- .00 | -1.6 |
| ALXC | ALXU | * .09340+- | .06430 | .01493+- | .10844 | .16+- 1.17 | -.6 |
| S1XC | S1XU | * .10340+- | .15550 | .01710< | .23379 | .17< 2.27 | -.3 |
| PHXC | PHXU | .01510+- | .00600 | .01729+- | .02741 | 1.14+- 1.87 | .1 |
| SUXC | SUXU | .74690+- | .12820 | .74877+- | .12883 | 1.00+- .24 | .0 |
| CLXC | CLXU | .10210+- | .07200 | .11616+- | .08437 | 1.14+- 1.15 | .1 |
| KPXC | KPXU | * .02530< | .05240 | .04441< | .04738 | 1.76< 4.09 | .3 |
| CAXC | CAXU | * .18920< | .35930 | .02588< | .20252 | .14< 1.10 | -.4 |
| TIXC | TIXU | * .01100< | .01260 | .01801< | .08278 | 1.64< 7.76 | .1 |
| VAXC | VAXU | * .00530+- | .00530 | .00481+- | .04154 | .91+- 7.89 | -.0 |
| CRXC | CRXU | .02110+- | .02110 | .00386+- | .00830 | .18+- .43 | -.8 |
| HNXC | HNXU | .01810+- | .01810 | .03681+- | .02359 | 2.03+- 2.42 | .6 |
| FEXC | FEXU | * .12710+- | .11220 | .19293+- | .10934 | 1.52+- 1.59 | .4 |
| COXC | COXU | .00580+- | .00580 | .00000+- | .00000 | .00+- .00 | -1.0 |
| N1XC | N1XU | * .00650+- | .00650 | .00390+- | .00308 | .60+- .76 | -.4 |
| CUXC | CUXU | .09830< | .12530 | .07349< | .02790 | .75< .99 | -.2 |
| ZNXC | ZNXU | .17870+- | .08130 | .10439+- | .07999 | .58+- .52 | -.7 |
| ASXC | ASXU | .00950+- | .00950 | .00118+- | .01946 | .12+- 2.05 | -.4 |
| SEXC | SEXU | .01120+- | .01120 | .00087+- | .00692 | .08+- .62 | -.8 |
| BRXC | BRXU | * .02070+- | .01350 | .01198+- | .00700 | .58+- .51 | -.6 |
| SRXC | SRXU | .01580< | .02630 | .00087< | .00983 | .05< .63 | -.5 |
| MOXC | MOXU | .11620+- | .05760 | .00209+- | .02185 | .02+- .19 | -1.9 |
| COXC | COXU | .00250< | .00290 | .00558< | .05209 | 2.23< 21.00 | .1 |
| SNXC | SNXU | .00780+- | .00780 | .01217+- | .08278 | 1.56+- 10.73 | .1 |
| S8XC | S8XU | .00370+- | .00370 | .02084+- | .09695 | 5.63+- 26.80 | .2 |
| CSXC | CSXU | .00510+- | .00510 | .00000+- | .00000 | .00+- .00 | -1.0 |
| BAXC | BAXU | .01030+- | .00990 | .04135+- | .31019 | 4.01+- 30.36 | .1 |
| PTXC | PTXU | .02430+- | .02430 | .00000+- | .00000 | .00+- .00 | -1.0 |
| HGXC | HGXU | .02550+- | .02550 | .00072+- | .01648 | .03+- .65 | -.8 |
| PBXC | PBXU | * .08110+- | .04410 | .05577+- | .02605 | .69+- .49 | -.5 |

Table 6-1b
Example CMB Output for Coarse Particle Samples Collected at the Long Beach Site
on December 10, 1987 Between 1400 and 1800 PST

SOURCE CONTRIBUTION ESTIMATES - SITE: LBCC DATE: 12/10/87 CMB7 33889
SAMPLE DURATION 4 START HOUR 14 SIZE: C
R SQUARE .98 PERCENT MASS 95.9
CHI SQUARE .29 DF 12

| SOURCE | * TYPE | SCE(UG/M3) | STD ERR | TSTAT |
|--------|--------|------------|---------|--------|
| 09 | PRSCAB | 10.8990 | 1.0926 | 9.9752 |
| 13 | PHRD | 5.2056 | 2.8034 | 1.8569 |
| 23 | MAR25 | 3.0827 | .4168 | 7.3962 |
| 27 | AMNIT | 2.7840 | 1.0102 | 2.7558 |

MEASURED CONCENTRATION FOR SIZE: C
22.9+- 6.3

UNCERTAINTY/SIMILARITY CLUSTERS CMB7 33889 SUM OF CLUSTER SOURCES

SPECIES CONCENTRATIONS - SITE: LBCC DATE: 12/10/87 CMB7 33889
SAMPLE DURATION 4 START HOUR 14 SIZE: C
R SQUARE .98 PERCENT MASS 95.9
CHI SQUARE .29 DF 12

| SPECIES | I | MEAS | CALC | RATIO C/M | RATIO R/U | | |
|---------|------|--------------|-----------|------------|-----------|-------------|-------|
| MTGC | MTGU | T 22.92000+- | 6.33580 | 21.97139+- | 2.57329 | .96+- .29 | -.1 |
| CLIC | CLIU | * .32000+- | .16280 | .42546+- | .05592 | 1.33+- .70 | .6 |
| HM3C | HM3U | 2.42000+- | .66000 | ***** | ***** | ***** | -1.7 |
| N33C | N33U | -99.00000+- | -99.00000 | 4.50669+- | .62090 | .00+- .00 | 1.0 |
| N34C | N34U | -99.00000+- | -99.00000 | 4.50669+- | .62090 | .00+- .00 | 1.0 |
| N31C | N31U | * 4.94000+- | .72180 | 4.50669+- | .62090 | .91+- .18 | -.5 |
| S41C | S41U | * .49000+- | .27780 | .51984+- | .11933 | 1.06+- .65 | .1 |
| NH3C | NH3U | 7.62000+- | .63000 | ***** | ***** | ***** | -1.7 |
| N45C | N45U | -99.00000+- | -99.00000 | .84167+- | .15587 | .00+- .00 | 1.0 |
| N4CC | N4CU | * .70000+- | .25000 | .84167+- | .15587 | 1.20+- .48 | .5 |
| NAAC | NAAU | -99.00000+- | -99.00000 | .84549+- | .08810 | .00+- .00 | 1.0 |
| TCTC | TCTU | * 6.98000+- | 2.44310 | 5.77054+- | 1.13797 | .83+- .33 | -.4 |
| OCTC | OCTU | 5.90000+- | 2.39300 | 3.76632+- | .98323 | .64+- .31 | -.8 |
| ECTC | ECTU | 1.08000+- | .49200 | 2.00422+- | .57292 | 1.86+- 1.00 | 1.2 |
| NAXC | NAXU | * .85680+- | .05700 | .84549+- | .08810 | .99+- .12 | -.1 |
| MGXC | MGXU | .21650+ | .02160 | .00000+- | .00000 | .00+- .00 | -10.0 |
| ALXC | ALXU | * .71310+- | .09070 | .64830+- | .05545 | .91+- .14 | -.6 |
| SIXC | SIXU | * 1.62460+- | .21930 | 1.75917+- | .14251 | 1.08+- .17 | .5 |
| PHXC | PHXU | .04880+- | .00840 | .02445+- | .00804 | .50+- .19 | -2.1 |
| SUXC | SUXU | .17650< | .18000 | .24353< | .03428 | 1.38< 1.42 | .4 |
| CLXC | CLXU | .44310+- | .10120 | .39449+- | .04513 | .89+- .23 | -.4 |
| KPXC | KPXU | * .15090+- | .07350 | .19884+- | .01548 | 1.32+- .65 | .6 |
| CAXC | CAXU | * .50410< | .50440 | .46696< | .06263 | .93< .94 | -.1 |
| TIXC | TIXU | * .07530+- | .01770 | .05605+- | .02110 | .74+- .33 | -.7 |
| VAXC | VAXU | * .00060< | .00790 | .00311< | .01047 | 5.18< 70.43 | .2 |
| CRXC | CRXU | .00000< | .02830 | .00457< | .00219 | .00< .00 | .2 |
| MNXC | MNXU | .01200< | .02380 | .02032< | .00596 | 1.69< 3.39 | .3 |
| FEXC | FEXU | * .58600+- | .15750 | .58565+- | .03690 | 1.00+- .28 | .0 |
| CDXC | CDXU | .00000< | .00810 | .00000< | .00000 | .00< .00 | .0 |
| NIXC | NIXU | * .00000< | .00890 | .00274< | .00088 | .00< .00 | .3 |
| CLXC | CLXU | .00000< | .17590 | .02252< | .00712 | .00< .00 | .1 |
| ZNXC | ZNXU | .09730< | .11430 | .05310< | .02069 | .55< .68 | -.4 |
| ASXC | ASXU | .00030< | .01340 | .00030< | .00496 | .99< 47.80 | .0 |
| SEXC | SEXU | .00090< | .01650 | .00024< | .00174 | .27< 5.27 | -.0 |
| BRXC | BRXU | * .00000< | .01900 | .00868< | .00186 | .00< .00 | .5 |
| SRXC | SRXU | .00940< | .03640 | .01389< | .00569 | 1.48< 5.76 | .1 |
| MORC | MORU | .00000< | .07730 | .00070< | .00551 | .00< .00 | .0 |
| CDXC | CDXU | .00000< | .00410 | .00179< | .01313 | .00< .00 | .1 |
| SNXC | SNXU | .00000< | .01090 | .00351< | .02086 | .00< .00 | .1 |
| SBXC | SBXU | .00000< | .00520 | .00552< | .02444 | .00< .00 | .2 |
| CSXC | CSXU | .00000< | .00690 | .00000< | .00000 | .00< .00 | .0 |
| BAXC | BAXU | .05650+- | .01390 | .02043+- | .07819 | .36+- 1.39 | -.5 |
| PTXC | PTXU | .00000< | .03290 | .00000< | .00000 | .00< .00 | .0 |
| NGXC | NGXU | .00000< | .03570 | .00023< | .00415 | .00< .00 | .0 |
| PBXC | PBXU | * .00000< | .06220 | .04737< | .01208 | .00< .00 | .7 |

display shows the species that were measured at the receptor and the species which were included in the CMB calculation (indicated by a '*' under the column labeled 'I').

Each of the CMB results in Tables 6-1a and Table 6-1b present values for the performance measures which are used to evaluate the goodness of the solution, following the regulatory guidance of Pace and Watson (1987). The most useful performance measures are:

- Source Contribution Estimate (SCE). This is the contribution of each source type to the pollutant being apportioned, which is mass concentration in the case of particulate matter. Each of the SCE should be greater than zero and none should exceed the total mass concentration.
- Standard Error (STDERR). This is an indicator of the precision or certainty of each SCE. The STDERR is estimated by propagating the precisions of the receptor data and source profiles through the effective variance least-squares calculations. Its magnitude is a function of the uncertainties in the input data and the amount of collinearity (i.e., degree of similarity) among source profiles. It is desirable to have this value be much less than the source contribution estimate. When the SCE is less than the STDERR, the STDERR is interpreted as an upper limit of the source contribution.
- t-Statistic (TSTAT). This is the ratio of the source contribution estimate to the standard error. A high value for TSTAT (>2.0), shows that the relative precision of the source contribution estimate is high and that the contribution is significant. A low TSTAT value (<2.0) means that a source contribution is not present at a level which exceeds two times the STDERR. Twice the STDERR is a reasonable estimate of the upper limit for a source contribution when TSTAT <2.0 .
- R-Square (R SQUARE) and Chi-Square (CHI SQUARE). The R SQUARE measures the variance in the receptor concentrations which is explained by the calculated species concentrations. The CHI SQUARE statistic is the weighted sum of the squares of differences between calculated and measured species concentrations divided by the effective variance and the degrees of freedom (DF). A low R SQUARE (<0.8) indicates that the selected source profiles have not accounted for the variance in the selected receptor concentrations. A large CHI SQUARE (>4.0) means that one or more of the calculated species concentrations differs from the measured concentrations by several uncertainty intervals. The values for these statistics exceed their targets when: 1) contributing sources have been omitted from the CMB calculation; 2) one or more source profiles have been selected which do not represent the contributing source types; 3) precisions of receptor or source profile data are underestimated; and/or 4) source or receptor data are inaccurate.

- Percent of Mass Accounted For (PERCENT MASS). This is the ratio of the sum of the source contributions to the measured mass for particulate samples. The target value is 100%, with a reasonable range of 80% to 120%. Percent mass values which are outside of this range result when: 1) source profiles have been incorrectly specified; 2) contributing source types have been omitted from the calculation; 3) mass or chemical species measurements are inaccurate; and/or 4) mass measurements are less than $10 \mu\text{g}/\text{m}^3$ and within a few precision intervals of the measurements.
- Uncertainty/Similarity Clusters (U/S CLUSTERS). This display shows the results of a singular value decomposition analysis for collinearity. When source profiles are similar in composition, the CMB model does not accurately apportion species to the source types which they represent. This is often the case for geological sources, vegetative burning, and motor vehicle exhaust. These clusters summarize the results of a singular value decomposition analysis of the receptor concentrations, source profiles, and their uncertainties. Source identifiers on the same line show the potential for different sources to be collinear.
- Sum of Combined Sources (SUM OF CLUSTER SOURCES). This value is the sum of the source contributions in the cluster coupled with the standard error of that sum. The standard error is not a simple square root of the sum of the squares of the standard errors of the source contributions in the cluster. It contains cross-product terms to account for correlated errors resulting from collinearity. When the relative standard error for this sum is much less than the relative standard errors of any or all of the contributions from sources in the cluster, the standard errors of source contribution estimates can probably be reduced by creating a composite profile for the sources in the cluster. This uncertainty reduction comes at the expense of resolving the collinear source contribution estimates from one another.
- Ratio of Residual to Its Standard Error (RATIO R/U). This column contains the ratio of the signed difference between the calculated and measured concentration (the residual) divided by the uncertainty of that residual (square root of the sum of the squares of the uncertainty in the calculated and measured concentrations). The RATIO R/U specifies the number of uncertainty intervals by which the calculated and measured concentrations differ. When the absolute value of the RATIO R/U exceeds 2, the residual is significant. If it is positive, then one or more of the profiles is contributing too much to that species. If it is negative, then there is an insufficient contribution to that species and a source may be missing. The sum of the squared RATIO R/U for fitting species divided by the degrees of freedom yields the CHI-SQUARE. The highest RATIO R/U values for fitting species are the cause of high CHI SQUARE values.

- Ratio of Calculated to Measured Species (RATIO C/M). The column entitled RATIO C/M shows the ratio of calculated to measured concentration and the standard error of that ratio for every chemical species with measured data. The ratios should be near 1.00 if the model has accurately explained the measured concentrations. Ratios which deviate from unity by more than two uncertainty intervals indicate that an incorrect set of profiles is being used to explain the measured concentrations. The RATIO C/M for most species is within the target range for each example.

Tables 6-2a and 6-2b show examples of a typical CMB run and the performance measures associated with it. Numerous tests of this type were made to select initial fitting species and profiles, and the results were comparable to those in Table 6-2a. The first column in Table 6-2a shows the best fit of source contributions to the data while Trial 1 shows the results with the default set of profiles. Notice that "PRSCAB" and "MAR0" contributions are less than their standard errors, and that their retention or elimination from the CMB fit does not significantly affect the other contributions. Profiles were generally retained in the calculations even when contributions were less than standard errors when no uncertainty/similarity clusters were found. They were removed from the calculation when they appeared in clusters with other profiles.

Trials 2 to 6 examine the effects of different primary motor vehicle exhaust profiles on the source apportionments. The inclusion of "PHAUTO" and "PHDIES" in Trial 2 show obvious collinearity, and demonstrate that these source sub-types cannot be resolved with the current fitting species. Trial 3 vastly overestimates the PERCENT MASS, and demonstrates that gasoline-fueled vehicles are not the major contributors. Trial 4, using "PHDIES", provides a result very similar to Trial 1, while Trials 5 and 6 provide lower estimates, but values which are within overlapping standard errors with the contributions in Trial 1. The "PHRD" profile was found to explain more of the measured mass and it provided a better comparison of calculated and measured chemical species for most samples. The "MOVES1" would be an equally valid selection for this profile, however.

Trials 7 through 9 examine the sensitivity of source contributions to the selection of carbon fractions as fitting species. In Trial 7 TC is replaced by OC and EC. The source contribution estimate of "PHRD" is 75% of the Trial 1 value, though the standard error intervals still overlap. CHI SQUARE increases from 0.15 to 0.97, reflected the poorer agreement between calculated and measured OC and EC. Trial 8 substitutes OC for TC, and obtains slightly higher "PHRD" source contribution than Trial 1. Substituting EC for TC in Trial 9 significantly reduces the "PHRD" source contribution.

Vegetative burning (VIAGBC) and residual oil combustion (SFCRUC) are sought in Trials 10 and 11, and they are shown to be insignificant contributors to this sample. These profiles were inserted from time to time, especially when vanadium was detected, but a significant contribution was never found from either of them in any of the SCAQS samples. Trials 12 and 13 examine the sensitivity of the motor vehicle exhaust contribution to the removal of lead and total carbon. The source contributions are seen to be fairly robust.

Table 6-2a
Sensitivity of PM_{2.5} Source Contribution Estimates to Changes in Source Profiles and Fitting Species

| Profile* | Source Contributions (µg/m ³) at Long Beach on December 10, 1987 at 1400 PST | | | | | | | | |
|----------------------|--|----------|------------------|-----------|-----------|----------|-----------|-------------------------|----------------|
| | Best Fit | Trial 1 | Trial 2* | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Trial 7 | Trial 8 |
| PRSCAB | 20.8±5.1 | 0.6±1.3 | -2.3±2.4 | -2.0±1.7 | 0.7±0.8 | 1.3±0.8 | 1.4±0.8 | 0.9±1.1 | 0.47±1.5 |
| PHRD | | 20.1±5.1 | | | | 15.8±4.2 | | 15.6±3.7 | 23.8±7.7 |
| MOVES1 | | | | | | | 13.6±3.8 | | |
| MOVES2 | | | | | | | | | |
| PHAUTO | | | 40.6±22.8 | 36.3±10.9 | | | | | |
| PHDIES | | | -3.0±14.9 | | 21.3±3.7 | | | | |
| MAR0 | | 0.06±0.2 | 0.18±0.27 | 0.17±0.25 | 0.07±0.20 | 0.03±0.2 | 0.03±0.19 | 0.05±0.19 | 0.07±.21 |
| AMSUL | | 1.4±0.8 | 1.9±0.9 | 1.9±0.8 | 2.3±0.5 | 2.2±0.7 | 2.5±0.8 | 1.8±0.7 | 1.1±1.0 |
| AMNIT | | 20.0±2.4 | 20.4±1.1 | 20.6±2.0 | 22.2±1.7 | 22.7±1.7 | 22.6±1.7 | 20.5±2.1 | 19.6±2.8 |
| CHI SQUARE | 0.15 | 0.15 | 0.19 | 0.2 | 0.64 | 0.4 | 0.98 | 0.97 | 0.98 |
| R SQUARE | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 | 0.98 | 0.51 | 0.51 | 0.17 |
| PERC MASS | 93.7 | 94.1 | 129.3 | 127.3 | 104 | 93.9 | 89.5 | 86.8 | 100.5 |
| FIT SPEC. & CLUSTERS | | | PHAUTO PHDIES | | | | | -TCTC +OCTC +ECTC | -TCTC +OCTC |

| Profile | Trial 9 | | | Trial 10 | | | Trial 11 | | | Trial 12 | | | Trial 13 | | |
|----------------------|----------------|------------|-----------------|------------|-----------------|-----------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | Trial 9 | Trial 10 | Trial 11 | Trial 9 | Trial 10 | Trial 11 | Trial 9 | Trial 10 | Trial 11 | Trial 9 | Trial 10 | Trial 11 | Trial 9 | Trial 10 | Trial 11 |
| PRSCAB | 1.0±0.95 | 0.71±1.3 | 0.6±1.3 | 0.71±1.3 | 0.6±1.3 | 0.6±1.3 | 19.8±5.1 | 19.9±5.1 | 19.9±5.1 | 20.7±8.7 | | | | | |
| PHRD | 11.6±3.3 | 21.0±5.5 | 19.8±5.1 | 21.0±5.5 | 19.8±5.1 | 19.8±5.1 | | | | | | | | | |
| VIAGBC | | -0.35±0.67 | | -0.35±0.67 | | | | | | | | | | | |
| SFCRUC | | | 0.31±0.9 | | 0.31±0.9 | | | | | | | | | | |
| MAR0 | 0.05±0.19 | 0.08±0.21 | 0.04±0.2 | 0.08±0.21 | 0.04±0.2 | 0.04±0.2 | | | | | | | | | |
| AMSUL | 2.1±0.6 | 1.3±0.8 | 1.4±0.8 | 1.3±0.8 | 1.4±0.8 | 1.4±0.8 | | | | | | | | | |
| AMNIT | 20.9±1.9 | 19.9±2.5 | 10.2±2.5 | 19.9±2.5 | 10.2±2.5 | 10.2±2.5 | | | | | | | | | |
| CHI SQUARE | 0.26 | 0.13 | 0.15 | 0.13 | 0.15 | 0.15 | | | | | | | | | |
| R SQUARE | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | | | | | | | | | |
| PERC MASS | 79.8 | 95.2 | 94.3 | 95.2 | 94.3 | 94.3 | | | | | | | | | |
| FIT SPEC. & CLUSTERS | -TCTC +ECTC | | SFCRUC AMSUL | | SFCRUC AMSUL | SFCRUC AMSUL | | | | | | | | | |

* See Table 5-1 for profile names.
 † Similar test results were obtained using OCTC and ECTC instead of TCTC.

Table 6-2h
Sensitivity of Coarse Particle Source Contribution Estimates to Changes in Source Profiles and Fitting Species

| | <u>Source Contributions ($\mu\text{g}/\text{m}^3$) at Long Beach on December 10, 1987 at 1400 PST</u> | | | | | | |
|-------------------------|--|----------------|-----------------|-----------------|----------------|----------------|----------------|
| <u>Profile</u> | <u>Best Fit</u> | <u>Trial 1</u> | <u>Trial 2</u> | <u>Trial 3</u> | <u>Trial 4</u> | <u>Trial 5</u> | <u>Trial 6</u> |
| PRSCAB | 10.9 \pm 1.1 | 10.8 \pm 1.1 | 11.0 \pm 1.1 | 10.9 \pm 1.1 | | | |
| PRLBSC | | | | 12.2 \pm 1.5 | | | |
| PRLBPC | | | | | | 11.6 \pm 1.3 | |
| PRDRSC | | | | | | | 9.8 \pm 1.2 |
| PHRD | 5.2 \pm 2.8 | 7.1 \pm 3.5 | 5.0 \pm 3.3 | 5.7 \pm 3.4 | 4.7 \pm 2.8 | 4.8 \pm 2.8 | 5.9 \pm 2.9 |
| MAR0 | | 3.4 \pm 0.5 | | | | | |
| MAR25 | 3.1 \pm 0.4 | | | 3.1 \pm 0.4 | 3.1 \pm 0.4 | 3.1 \pm 0.4 | 3.1 \pm 0.4 |
| MAR50 | | | 2.6 \pm 0.3 | | | | |
| AMSUL | | -0.2 \pm 0.5 | -0.12 \pm 0.5 | -0.15 \pm 0.5 | | | 2.7 \pm 1.0 |
| AMNIT | 2.8 \pm 1.0 | 2.2 \pm 1.1 | 3.4 \pm 1.0 | 2.8 \pm 1.0 | 2.9 \pm 1.0 | 2.9 \pm 1.0 | |
| CHI SQUARE | 0.29 | 0.35 | 0.81 | 0.3 | 0.32 | 0.34 | 0.27 |
| R SQUARE | 0.98 | 0.98 | 0.96 | 0.98 | 0.98 | 0.98 | 0.98 |
| PERC MASS | 95.9 | 101.2 | 95.1 | 97.4 | 99.8 | 97.7 | 93.5 |
| FIT SPEC. & CLUSTERS | | | | MAR25 AMNIT | | | |

• See Table 5-1 for profile names.

Table 6-2b examines source contributions to the coarse particle fraction. Trial 1 shows the contributions with the default profiles, and they are comparable to the best-fit source contributions. Trials 1 to 3 examine the effect of changing the fraction of marine aerosol which has reacted with nitric acid. "MAR0" and "MAR25" explain the data better than "MAR50". This was true for all samples at all sites except San Nicolas Island, where "MAR100" and "MAR75" were common. Even at sites near the coast such as Long Beach, the majority of the marine aerosol has reacted with nitric acid during SCAQS. Trials 4 to 6 examine the effects of different paved road dust profiles on the apportionments. These profiles are so similar throughout the SoCAB that it doesn't really matter where each one is used. The SoCAB composite profile (PRSCAB) was selected for consistency. The exception to this might be at Rubidoux, where excessive calcium is found in ambient samples. Unfortunately, samples from geological sources in the vicinity of this site have never been analyzed -- certain soils may contain a high abundance of calcium and they would be resolvable from other soils by the CMB. The LIME profile is used as a surrogate for these missing Rubidoux profiles.

6.2.4 Deviations from Model Assumptions

The basic assumptions of the CMB model (Watson, 1979) are: 1) compositions of source emissions are constant over the period of ambient and source sampling; 2) chemical species do not react with one another (i.e., they add linearly); 3) all sources which may significantly contribute to the receptor have been identified and their emissions characterized; 4) the number of source categories is less than or equal to the number of chemical species; 5) the source profiles are linearly independent (i.e., they are statistically different); and 6) measurement uncertainties are random, uncorrelated, and normally distributed.

The degree to which these assumptions are met in practice depends to a large extent on the types and quality of chemical measurements made at the sources and receptor. The CMB model has been subjected to a number of tests to determine its ability to tolerate deviations from the model assumptions (e.g., Watson, 1979; Gordon *et al.*, 1981; Henry, 1982, 1992; Currie *et al.*, 1984; Dzubay *et al.*, 1984; Watson and Robinson, 1984; DeCesar *et al.*, 1985; Watson *et al.*, 1985; Watson *et al.*, 1987; Javitz and Watson, 1988; Lowenthal *et al.*, 1992).

Section 5 shows that there is substantial variability among individual profiles, and even among similar profiles from different source types; Assumption 1 is never completely met. Table 6-2a shows that the primary motor vehicle exhaust source contribution estimate is not very sensitive to the selection of "MOVES1", "MOVES2", or "PHRD" profiles, nor is it sensitive to the removal of lead or organic carbon. This is in spite of substantial uncertainties assigned to the abundances in these profiles.

With respect to Assumption 2, all of the source types are treated as non-reactive. This is definitely the case for primary emissions from motor vehicle exhaust, in which little change is expected between source and receptor. By apportioning PM₁₀ to secondary ammonium nitrate

and secondary ammonium sulfate, rather than to their ammonia, sulfur dioxide, and oxides of nitrogen precursors, the CMB problem has been linearized for the reactive precursors. Watson *et al.* (1993b) demonstrate how chemical equilibrium modeling might be applied to these secondary species to determine how emissions reductions in their precursors might affect their ambient concentrations.

With respect to Assumption 3, it appears from the lower than target PERCENT MASS performance measures for the majority of the CMBs that there is mass which is unaccounted for by the included sources. However, it has been amply demonstrated that the carbon and elemental data are negatively biased, and this is a valid explanation for the mass which has not been accounted for.

With respect to Assumption 4, 16 chemical species and up to 6 source profiles were used in each calculation. The number of chemical species always exceeded the number of source types.

The examples in Tables 6-2a and 6-2b show how well Assumption 5 could be met and why it is necessary to group specific profiles into source types defined as geological material and motor vehicle exhaust. For many cases, the individual profiles within these categories were too collinear to be separated from each other. This was especially the case when vegetative burning, diesel vehicle exhaust, and gasoline vehicle exhaust were present in the same source, as illustrated in Table 6-2a.

The effects of deviations from Assumption 6 have not been studied to a great extent. Non-randomness and correlation among measurement errors would result in biases in the calculated concentration with respect to measured concentrations.

For this study, all of the CMB assumptions are met to the extent that the source contribution estimates can be considered valid.

6.2.5 Identification and Correction of Model Input Errors

In several cases it was evident that certain chemical species concentrations were physically unreasonable. This was indicated by large CHI-SQUARE values with a large R/U value for the related species. In these cases the Level II data validation summary in Appendix A was consulted, and it was usually found that the discrepancy had already been identified by the validation tests. The suspect species was removed from the fit in these cases.

6.2.6 Consistency and Stability of Source Contributions

Separate CMBs were performed on PM_{2.5} and coarse particle samples for the nine SCAQS sites. The stability of these solutions was tested periodically by adding or dropping fitting species and examining changes in the source contribution estimates. In all but a few cases, the source contribution estimates changed by no more than one standard error. In those cases where the presence or absence of a single species made a large difference in the source contribution estimates, the species was left in the fit when all performance measures were within target ranges. The species was deleted from the fit when this would bring performance measures into acceptable target ranges.

Source contribution estimates were calculated separately by two different individuals at all sites. A comparison of the results of the source contribution estimates is shown in Figure 6-1. The vertical bars provide the relative magnitude of the standard errors for each of the estimates. The "Old Estimates" were calculated first using OC instead of TC as a fitting species and with the "PRLBSC" profile for geological material. The "New Estimates" were calculated using the default profiles and fitting species described above, with minor modifications. There are slight systematic biases for the geological and motor vehicle exhaust profiles which are consistent with the sensitivity tests in Tables 6-2a and 6-2b. The results reported below correspond to the "New Estimates." Figure 6-2 compares the calculated and measured TC, OC, and EC for all of the PM_{2.5} samples. The effect of differences between profile and ambient carbon measurements is apparent.

6.2.7 Reconciliation with Other Source Apportionment Methods

The source apportionments have been examined with respect to their spatial and temporal distributions and with respect to the emissions summary. The results and implications of this reconciliation are discussed below.

6.2.8 Comparisons Between the "Original" and "Revised" SoCAB Source Profiles

The "original" source profiles in the SoCAB source composition library for the geological material and motor vehicle exhaust did not include ion speciation. For the geological source profiles presented in Table 5-2a, the averages and standard deviations for water soluble ions were estimated to be the same as the average values for 28 different geological source profiles collected in the San Joaquin Valley as part of the California Air Resources Board Source Composition Library (Houck *et al.*, 1989).

Subsequent to completion of the SCAQS CMB modeling described here, "revised" source profiles became available for which NO₃⁻, SO₄⁼, and NH₄⁺ abundances were determined (NEA, 1990a; 1990b; 1990c) for the "PRSCAB" profile. The new abundances for the coarse particle

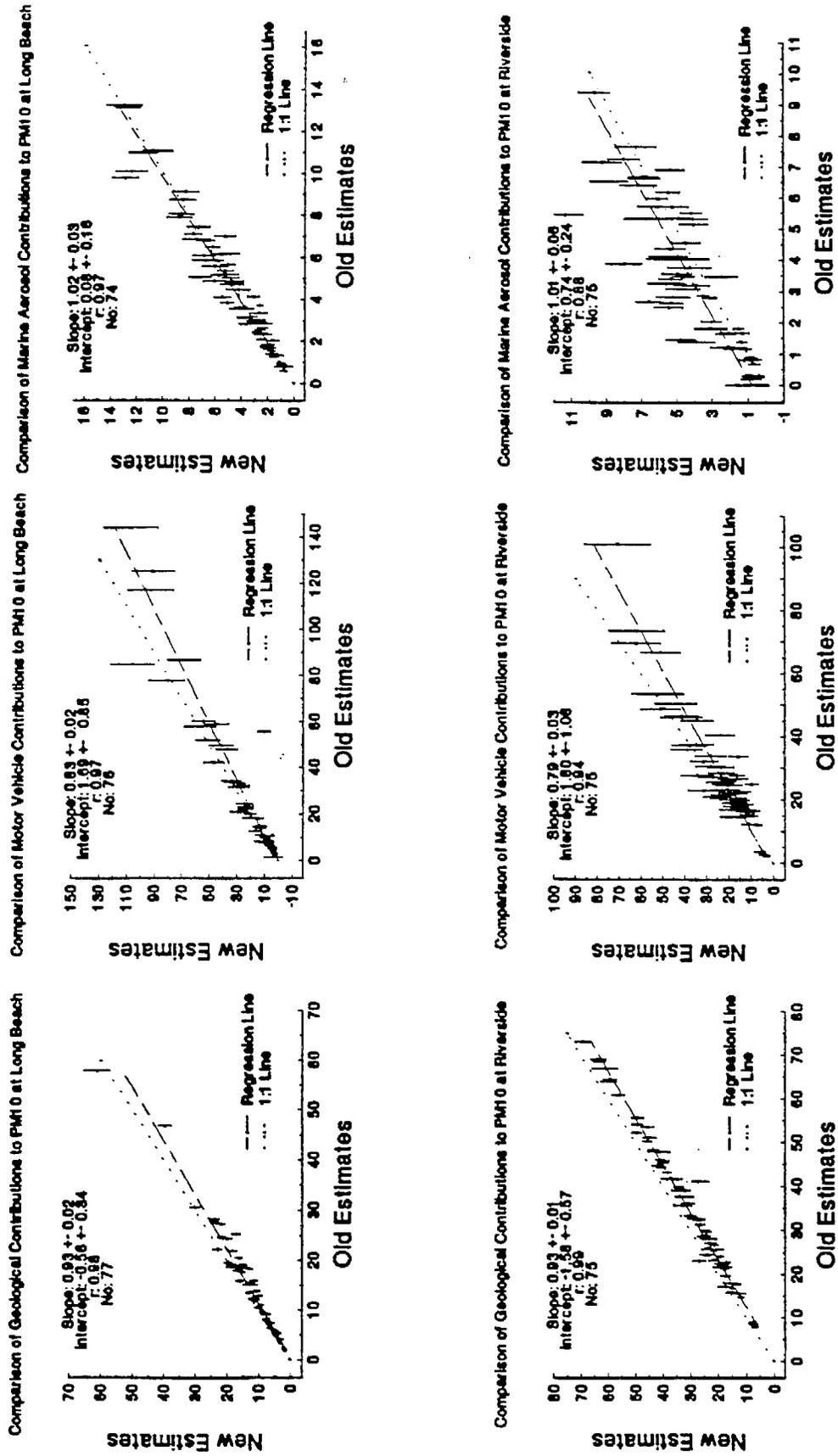


Figure 6-1. Comparison of Source Contribution Estimates Calculated by Two Independent Researchers

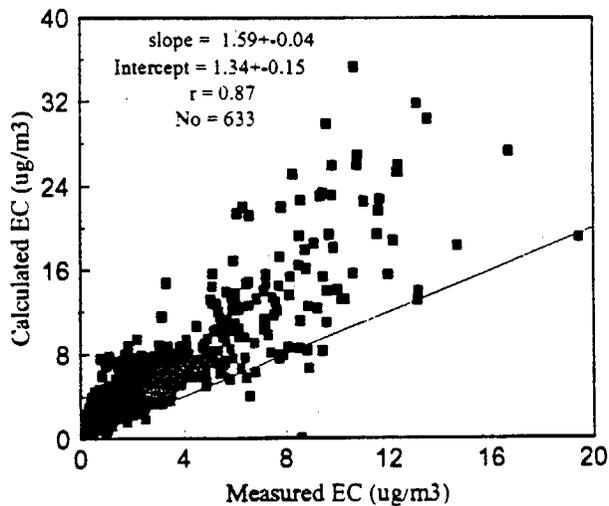
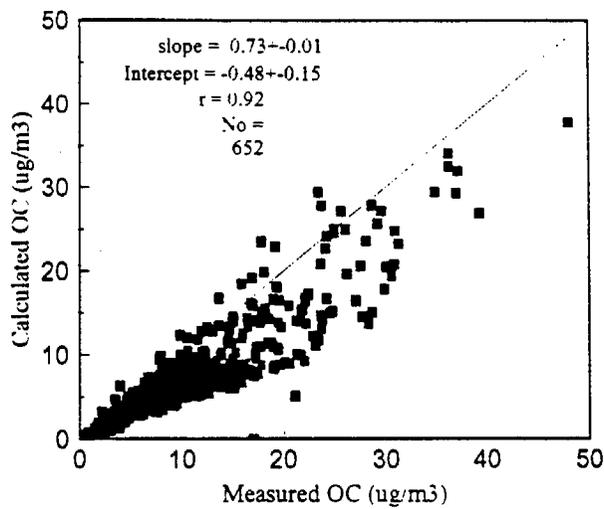
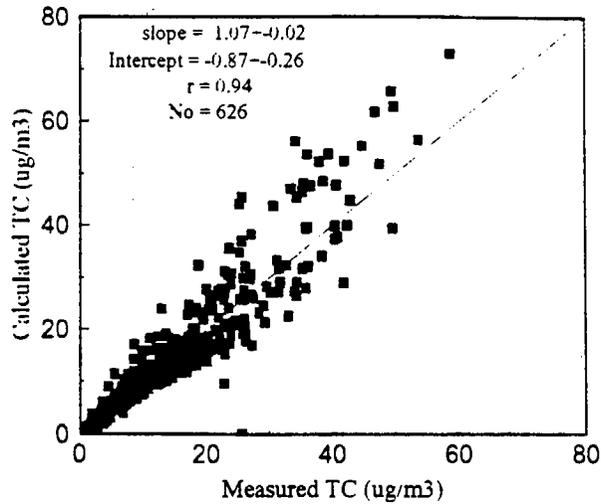


Figure 6-2. Scatterplots of PM_{2.5} Calculated Versus Measured Carbon for the SCAQS Samples Between 6/19/87 and 12/11/87 (TC=Total Noncarbonate Carbon, OC=Organic Carbon, EC=Elemental Carbon)

fraction are $0.45 \pm 0.17\%$ for NO_3^- , $0.96 \pm 0.12\%$ for SO_4^{2-} , and $0.03 \pm 0.05\%$ for NH_4^+ . These differ only slightly from the assumed ion abundances for the "PRSCAB" profile in Table 5-2a.

Figure 6-3 compares source contribution estimates using the "revised" "PRSCAB" profile for 24-hour average chemical concentrations measured on two days at all nine SCAQS sites with the source contributions calculated using the "original" profiles. In all cases, the slopes are close to unity with negligible intercepts. Correlation coefficients are 1.0 for the 18 sample pairs. Substituting the "revised" for the "original" profile resulted in negligible changes in the source contribution estimates.

6.3 Average Source Contribution Estimates

Summaries of CMB source contributions for each sample, including results for the $\text{PM}_{2.5}$ and PM_{10} (sum of $\text{PM}_{2.5}$ and coarse particle apportionments) at each of the nine SCAQS sites are given in Appendix B. Appendix B includes the source contribution estimates for every four- to seven- hour sample as well as the 24-hour average source contributions. Most of the discussion here will focus on the 24-hour average PM_{10} owing to its importance in standards attainment.

Average contributions to PM_{10} mass for the summer and fall campaigns are summarized in Tables 6-3a and 6-3b. The standard deviation is also given as an indication of the variability of the source contributions. These average contributions are plotted in Figures 6-4a and 6-4b so that spatial patterns can be more easily observed. The unexplained portion of these averages is comparable to the unexplained portions found in Section 4. The reported contributions from primary geological material and primary motor vehicle exhaust are lower than they ought to be.

Primary geological material was the major contributor to PM_{10} during summer at the eastern sites, and average source contributions at the Rubidoux and Azusa sites were approximately five times the primary geological contribution at the Hawthorne site. Long Beach, Anaheim, and Burbank received primary geological contributions which were half to a third of those found at the sites with the highest contributions. Rubidoux was the only site with the lime/gypsum contribution, which is termed primary construction in Tables 6-3a and 6-3b. Primary motor vehicle exhaust was generally the second largest contributor, except at the Rubidoux, Hawthorne, and Long Beach sites. The average contributions at the Burbank, Downtown Los Angeles, Rubidoux, Azusa, and Claremont sites were two to three times the averages contributed at the Hawthorne, Long Beach, and Anaheim sites. Secondary ammonium sulfate was fairly uniform across the SoCAB, with the highest average contribution found at the Hawthorne site. Primary marine aerosol also shows a fairly homogeneous distribution across the SoCAB, including its contribution at San Nicolas Island. This indicates good transport from west to east during the SCAQS summer campaign. Secondary ammonium nitrate stands out at Rubidoux, being five to ten times larger than averages measured at the other sites. This is true even for nearby sites such as Azusa and Claremont. This is good evidence that the majority of the secondary ammonium nitrate in the SoCAB is ammonia-limited, and that Rubidoux's proximity to major upwind ammonia sources is the cause of these high nitrate levels. A

Table 6-3a
CMB PM₁₀ Source Contribution Estimates During the Summer Campaign

| Source | Average Source Contributions to PM ₁₀ (µg/m ³) | | | | | | | | | |
|------------------------------------|---|-------------------------|---------------|---------------|---------------|----------------|-----------------------|---------------|---------------|--|
| | Burbank | Downtown Los Angeles | Hawthorne | Long Beach | Anaheim | Rubidoux | San Nicolas Island | Azusa | Claremont | |
| Primary Geological | 14.04 ± 2.82 | 12.65 ± 3.33 | 6.81 ± 3.39 | 11.10 ± 5.27 | 11.38 ± 3.89 | 34.86 ± 8.74 | 1.62 ± 1.67 | 34.92 ± 6.75 | 19.40 ± 5.01 | |
| Primary Motor Vehicle | 17.02 ± 2.08 | 16.24 ± 2.71 | 5.66 ± 1.93 | 6.30 ± 2.89 | 8.48 ± 3.15 | 17.23 ± 4.66 | 0.85 ± 0.54 | 15.90 ± 4.26 | 14.43 ± 3.00 | |
| Marine | 5.67 ± 2.38 | 6.53 ± 2.58 | 6.56 ± 2.72 | 6.24 ± 2.53 | 6.54 ± 2.22 | 5.10 ± 2.16 | 4.30 ± 2.32 | 5.74 ± 2.20 | 4.66 ± 1.83 | |
| Primary Construction (Lime/Gypsum) | 0.02 ± 0.07 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 4.51 ± 3.14 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | |
| Primary Residual Oil | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.08 ± 0.23 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | |
| Secondary Ammonium Nitrate | 6.45 ± 3.22 | 4.40 ± 2.35 | 0.58 ± 0.88 | 0.82 ± 1.06 | 2.88 ± 1.84 | 27.36 ± 13.04 | 0.50 ± 0.47 | 6.13 ± 4.77 | 6.27 ± 4.97 | |
| Secondary Ammonium Sulfate | 12.41 ± 6.79 | 13.02 ± 6.94 | 14.21 ± 7.29 | 10.91 ± 3.99 | 8.96 ± 2.47 | 9.46 ± 3.29 | 3.66 ± 1.35 | 11.42 ± 6.17 | 9.53 ± 4.56 | |
| Unexplained Mass | 16.65 ± 7.01 | 14.59 ± 4.61 | 11.70 ± 7.43 | 10.94 ± 2.53 | 12.54 ± 2.72 | 22.67 ± 4.40 | 6.97 ± 2.13 | 18.03 ± 5.17 | 15.68 ± 3.59 | |
| Measured Mass | 72.25 ± 18.59 | 67.43 ± 15.45 | 45.91 ± 18.11 | 46.40 ± 12.05 | 50.79 ± 10.40 | 114.78 ± 33.09 | 17.38 ± 6.17 | 92.13 ± 16.58 | 69.97 ± 15.66 | |

• Average of 24-hour source contributions plus or minus standard deviation of these source contributions.

Table 6-3b
CMB PM₁₀ Source Contribution Estimates During the Fall Campaign

| Source | Average Source Contributions to PM ₁₀ (µg/m ³) | | | | | | | | | |
|------------------------------------|---|----------------------|---------------|---------------|----------------|----------------|--------------------|-------|-----------|----|
| | Barbank | Downtown Los Angeles | Hawthorne | Long Beach | Anaheim | Rubidoux | San Nicolas Island | Azusa | Claremont | |
| Primary Geological | 10.99 ± 1.86 | 9.43 ± 2.96 | 8.93 ± 1.56 | 11.31 ± 3.62 | 13.20 ± 5.07 | 19.15 ± 7.93 | NA | NA | NA | NA |
| Primary Motor Vehicle | 39.05 ± 14.56 | 41.09 ± 16.37 | 35.1 ± 13.63 | 42.78 ± 21.75 | 37.24 ± 17.28 | 30.31 ± 11.31 | NA | NA | NA | NA |
| Marine | 1.88 ± 1.40 | 1.79 ± 1.03 | 3.65 ± 1.31 | 2.72 ± 0.97 | 3.07 ± 1.39 | 1.05 ± 0.72 | NA | NA | NA | NA |
| Primary Construction (Lime/Gypsum) | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 16.05 ± 3.33 | NA | NA | NA | NA |
| Primary Residential Oil | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.023 | 0.00 ± 0.00 | 0.00 ± 0.00 | NA | NA | NA | NA |
| Secondary Ammonium Nitrate | 25.08 ± 19.41 | 27.52 ± 19.52 | 20.44 ± 13.62 | 23.21 ± 17.95 | 38.47 ± 30.07 | 31.57 ± 26.89 | NA | NA | NA | NA |
| Secondary Ammonium Sulfate | 3.12 ± 4.38 | 3.85 ± 4.90 | 5.05 ± 4.03 | 3.77 ± 2.57 | 3.73 ± 3.27 | 2.09 ± 2.36 | NA | NA | NA | NA |
| Unexplained Mass | 18.13 ± 8.14 | 17.97 ± 4.24 | 12.28 ± 6.70 | 13.27 ± 12.21 | 10.52 ± 7.44 | 9.59 ± 11.12 | NA | NA | NA | NA |
| Measured Mass | 94.84 ± 39.20 | 98.65 ± 43.40 | 85.08 ± 33.69 | 96.11 ± 49.33 | 103.98 ± 56.43 | 111.98 ± 57.09 | NA | NA | NA | NA |

* Average of 24-hour source contributions plus or minus standard deviation of these contributions.

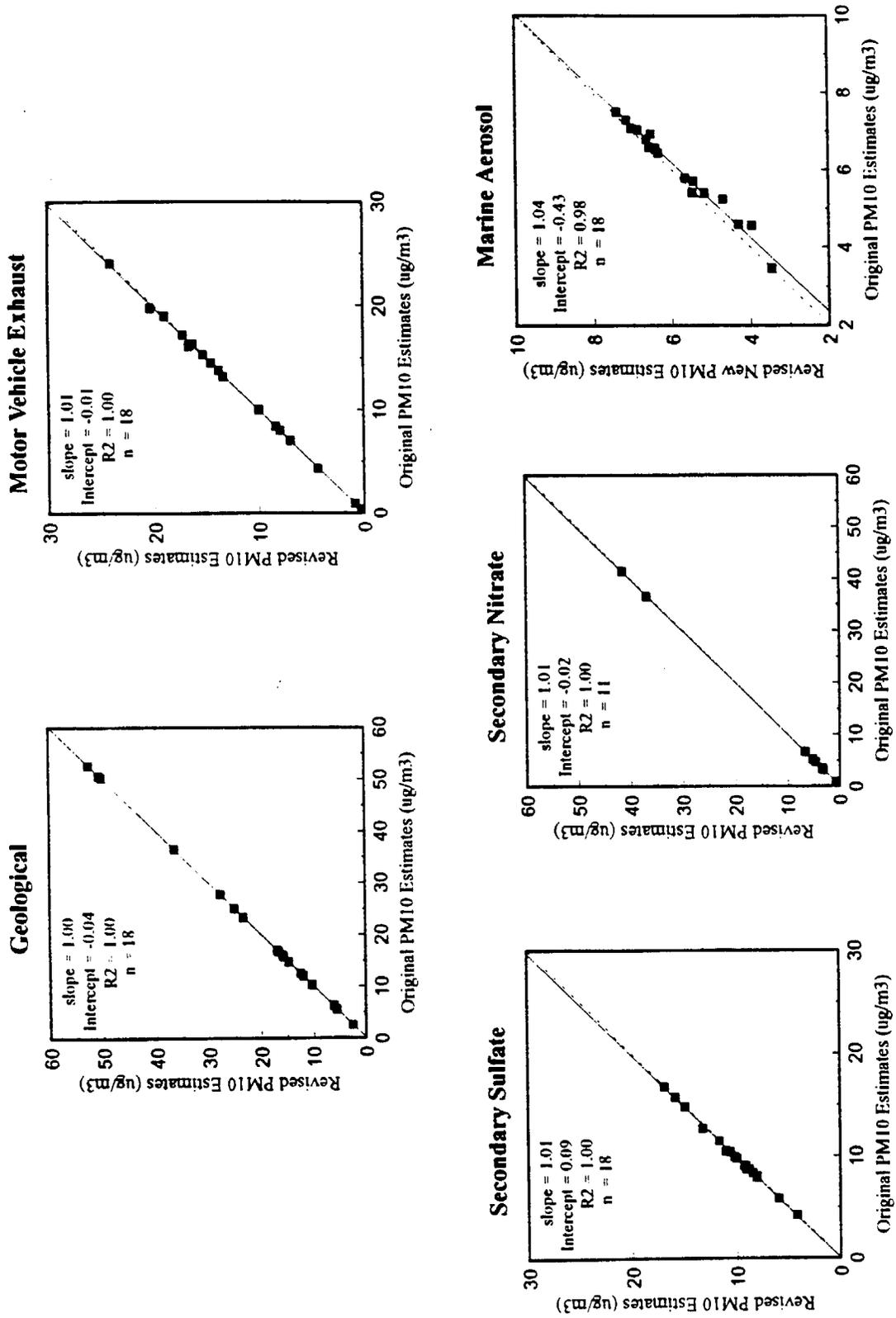


Figure 6-3. Comparisons of the PM₁₀ Source Contribution Estimates Using the "Original" and "Revised" Geological Source Profiles on 8/27/87 and 8/28/87 at Nine SCAQS Sites

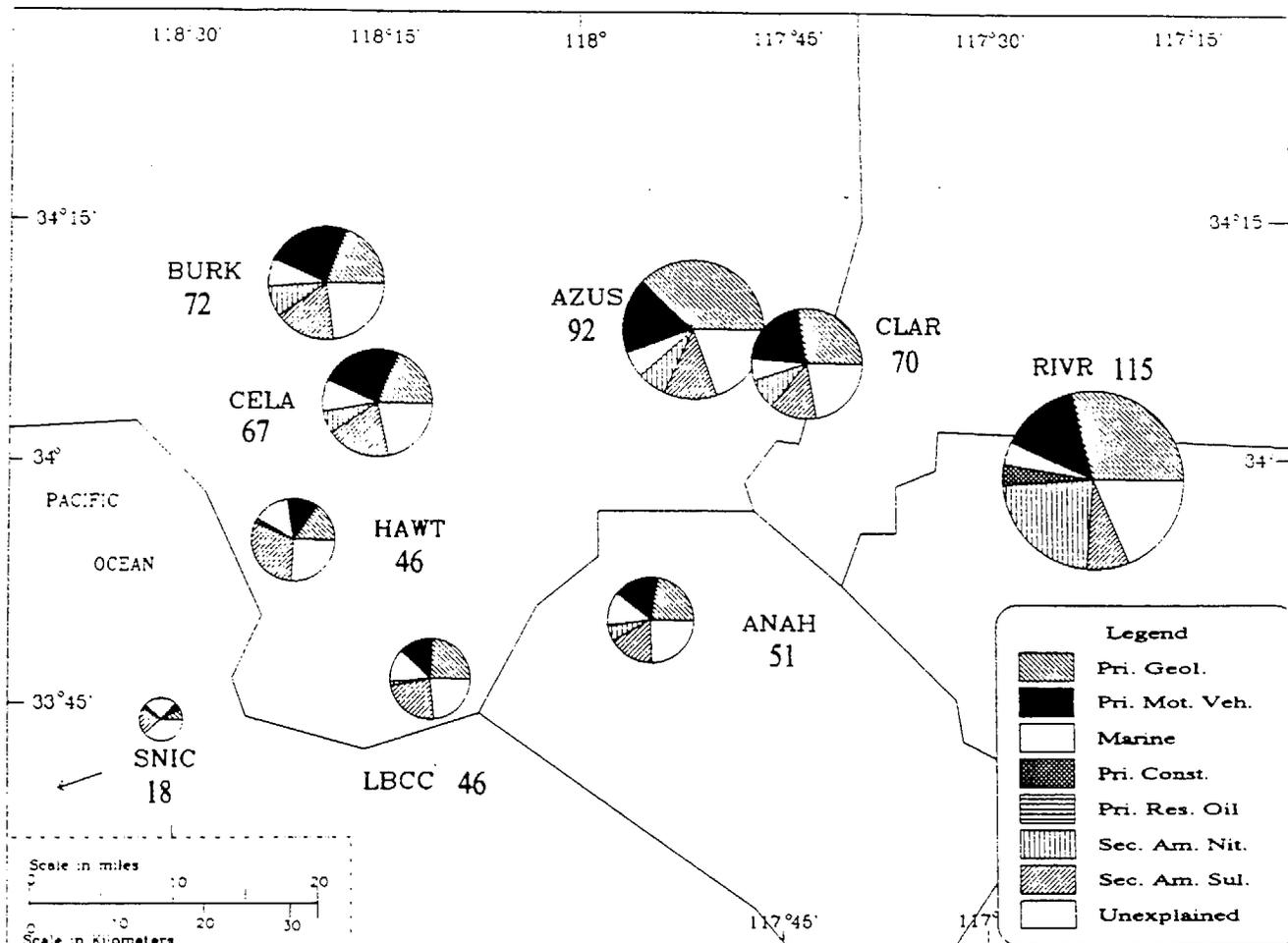


Figure 6-4a. Average Source Contributions ($\mu\text{g}/\text{m}^3$) to PM_{10} Mass at Nine SCAQS Sites Between 6/19/87 and 9/3/87

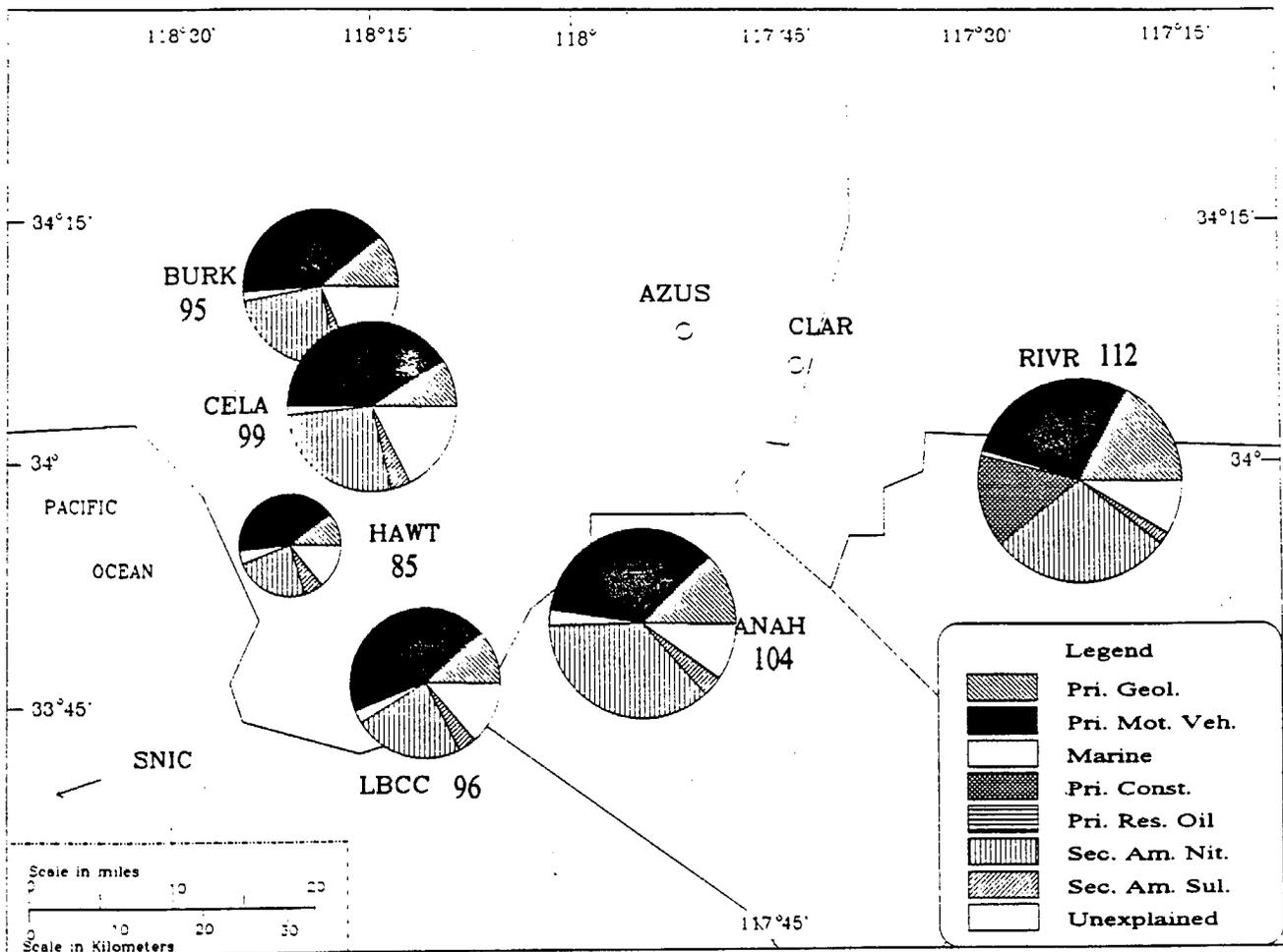


Figure 6-4b. Average Source Contributions ($\mu\text{g}/\text{m}^3$) to PM₁₀ Mass at Six SCAQS Sites Between 11/11/87 and 12/11/87

secondary ammonium nitrate contribution at the Hawthorne site was not detectable. There are few upwind ammonia sources near the Hawthorne site.

The fall average source contributions are substantially different from the summer contributions. Primary motor vehicle exhaust was the major contributor at all sites, even at the Hawthorne, Long Beach, and Anaheim sites which had much lower contributions from this source during the summer. Secondary ammonium nitrate was the second largest contributor at all sites, even at the Hawthorne site. Secondary ammonium sulfate contributed uniformly across the SoCAB, but its average contribution was less than half that found during the summer. The primary marine aerosol contribution was lower during fall than during summer and was substantially lower at the inland sites relative to the sites near the coast; this reflects the lack of west-to-east transport during the fall campaign. Primary geological contributions were significantly lower during the fall, with the exception of contributions at the Rubidoux site. The primary construction contribution nearly equaled the primary geological contribution at the Rubidoux site during the fall campaign.

6.4 Individual Source Contribution Estimates

Figures 6-5a to 6-5i show the diurnal distributions of source contributions for each SCAQS episode. For the most part, these diurnal distributions show the same distribution of source contributions, differences and similarities among sampling sites, and differences between summer and fall which were observed for the average source contributions. The diurnal patterns for PM_{10} mass and nitrate follow those observed in Section 4. There are a few subtle patterns revealed by the diurnal distribution of source contributions, however.

The geological contributions follow a diurnal pattern with the highest contributions generally found in the morning samples. These correspond to morning traffic and are consistent with a paved road dust source with emissions somewhat proportional to traffic volume. The highest "primary construction" (lime/gypsum) contributions at the Rubidoux site are often found in the early morning samples (i.e., 0000-0500 PST and 0000-0600 PST), however. This is hardly a period during which major construction activities are occurring.

Zeldin (1993) examined wind roses for significant increases in wind frequency from the north-northeast, and east-northeast during the fall months, which places two major cement production facilities upwind of the Rubidoux site. This wind component is caused by nighttime and early morning "land breezes" (or "drainage winds") which move from the inland areas toward the coast due to radiational cooling during the longer fall nights. During the summer, the higher wind velocities from the north-northeast reflect Santa Ana wind conditions, which over many years, may have transported calcium-rich material from the cement facilities to other areas, causing calcium enrichment of soils all around the Rubidoux site. This would account for noticeable calcium in the summer samples. Paved and unpaved road dust emissions from even a few trucks or cars in and around the cement facilities might be transported to the

Burbank

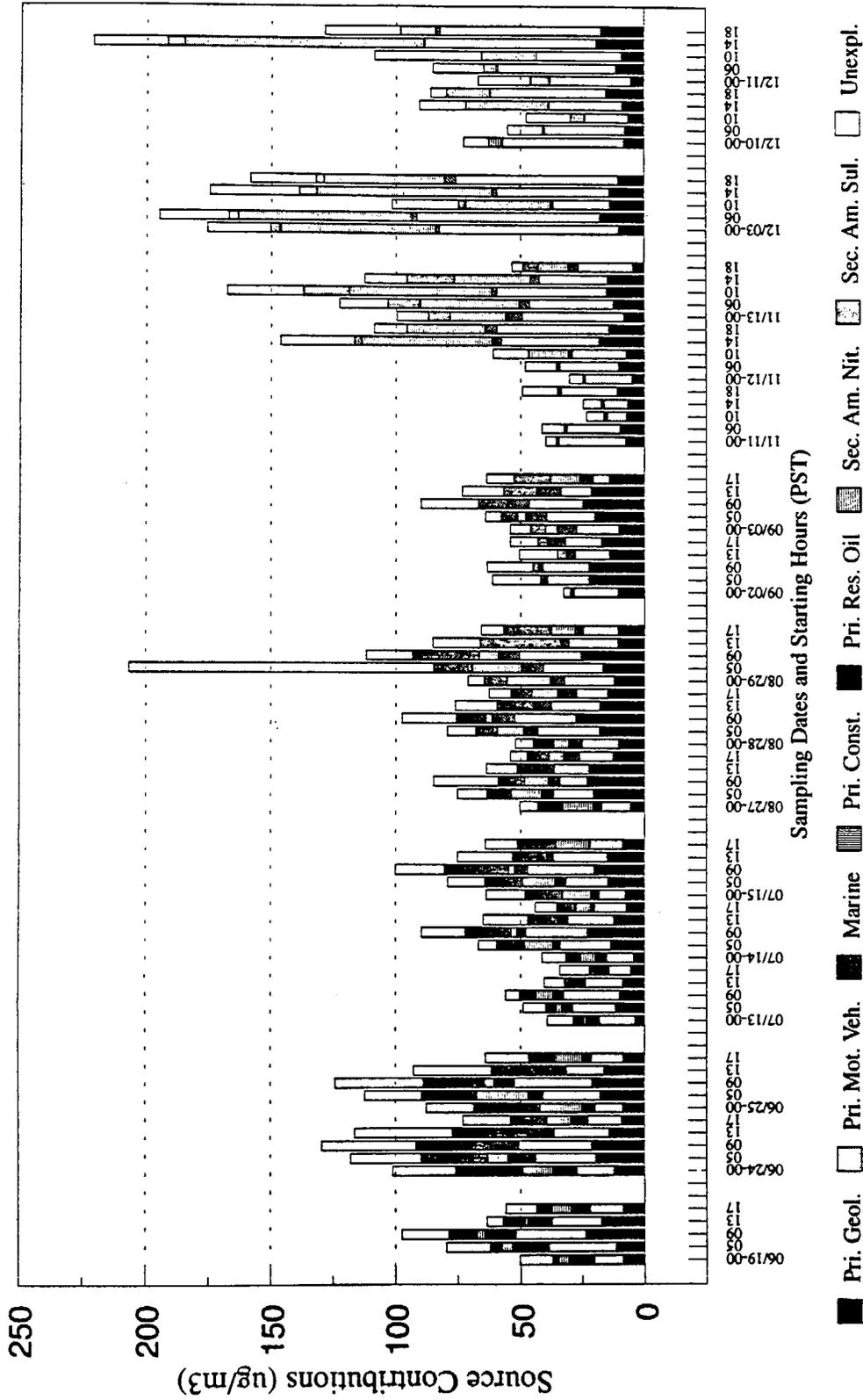


Figure 6-5a. Diurnal Source Contributions to PM₁₀ at the Burbank Site Between 6/19/87 and 12/11/87

Downtown Los Angeles

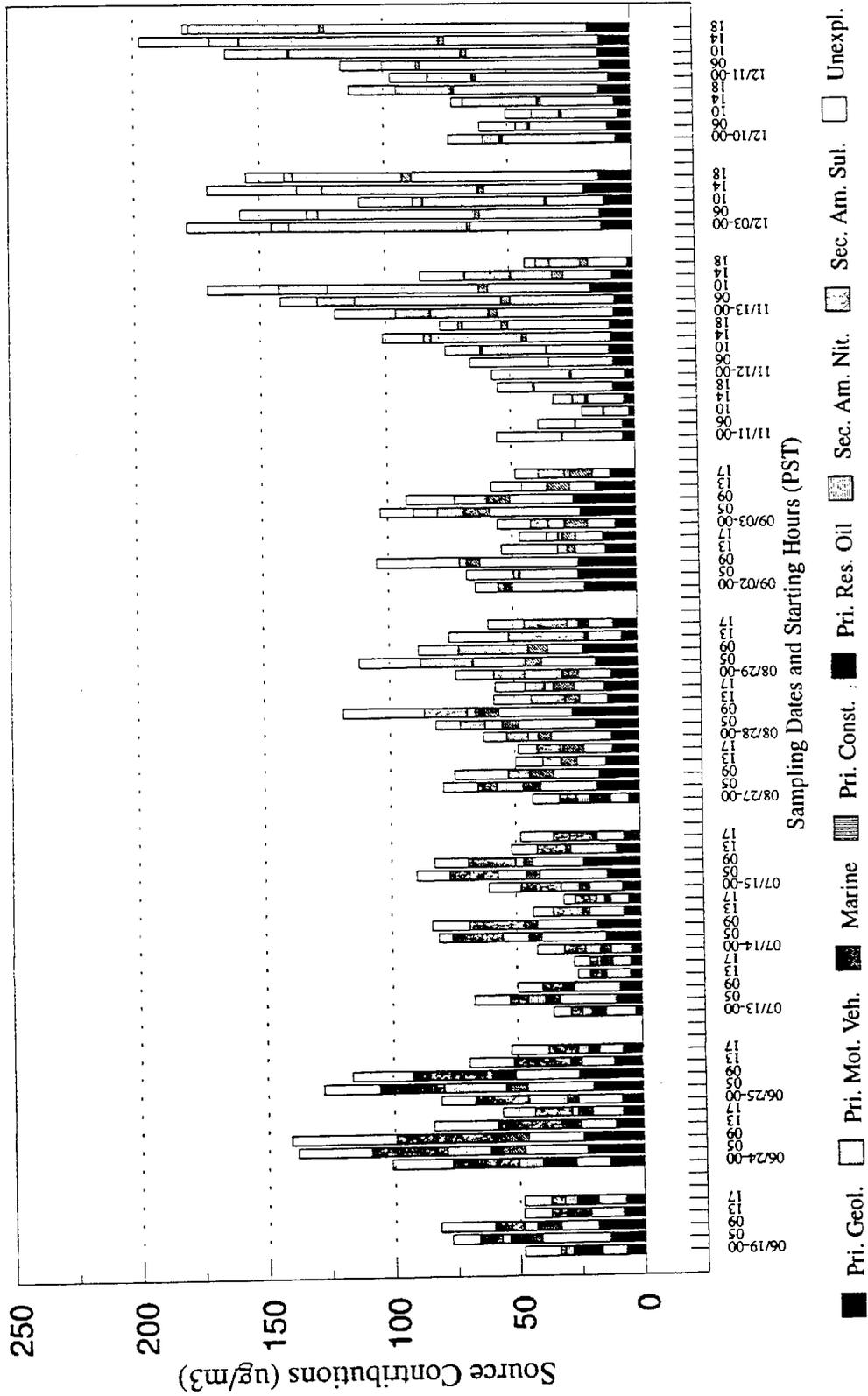


Figure 6-5b. Diurnal Source Contributions to PM₁₀ at the Downtown Los Angeles Site Between 6/19/87 and 12/11/87

Hawthorne

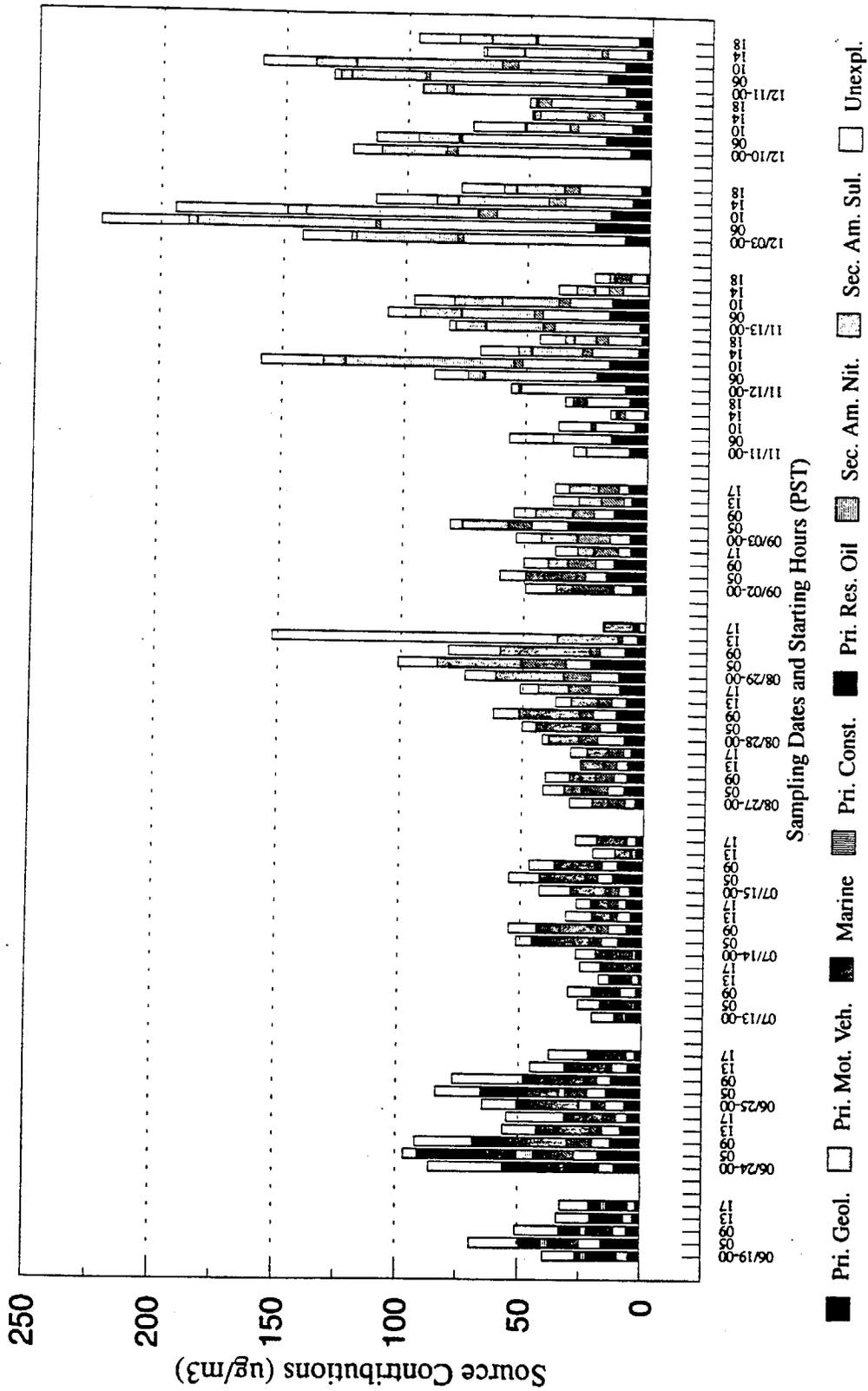


Figure 6-5c. Diurnal Source Contributions to PM₁₀ at the Hawthorne Site Between 6/19/87 and 12/11/87

Long Beach

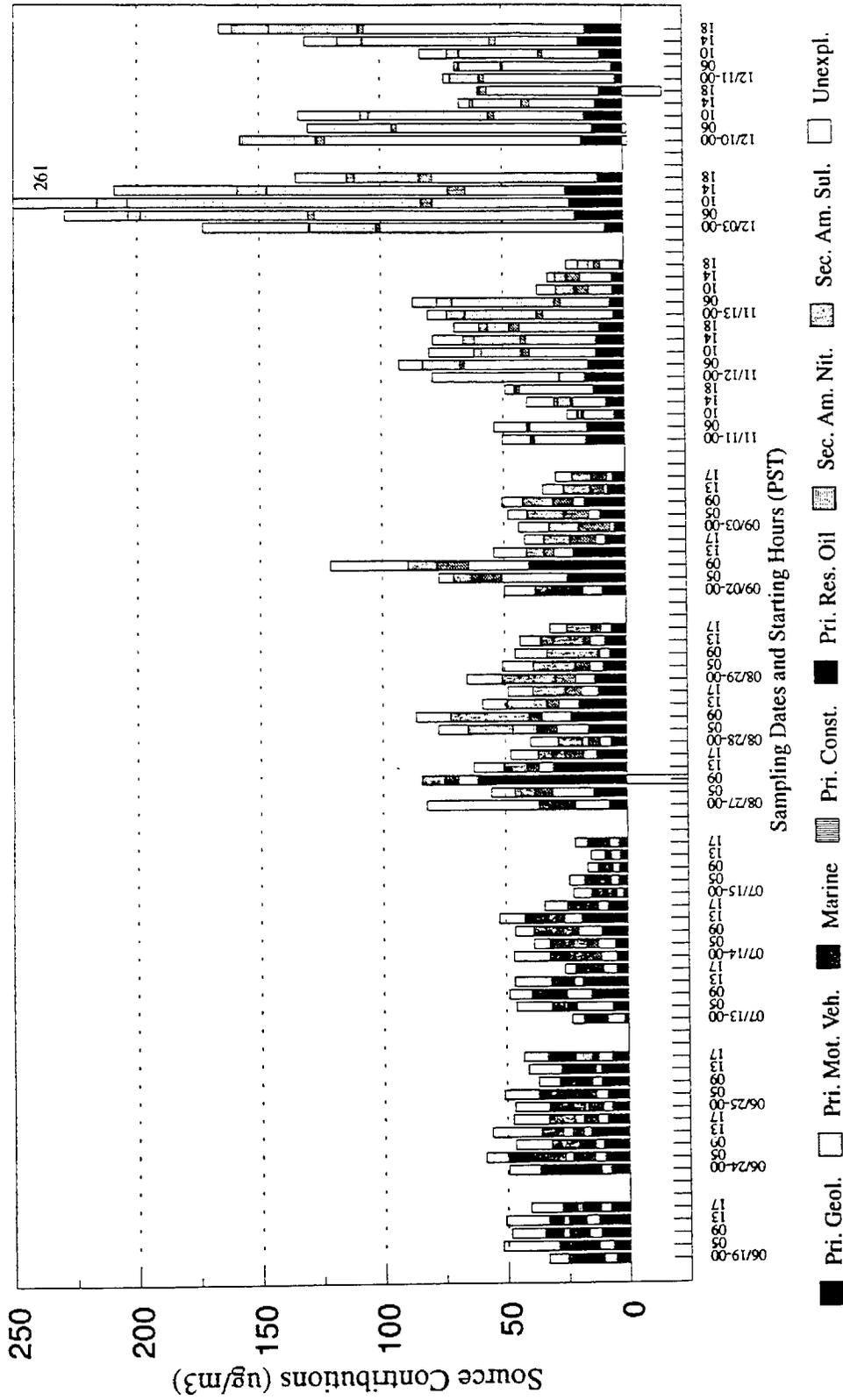


Figure 6-5d. Diurnal Source Contributions to PM₁₀ at the Long Beach Site Between 6/19/87 and 12/11/87

Anaheim

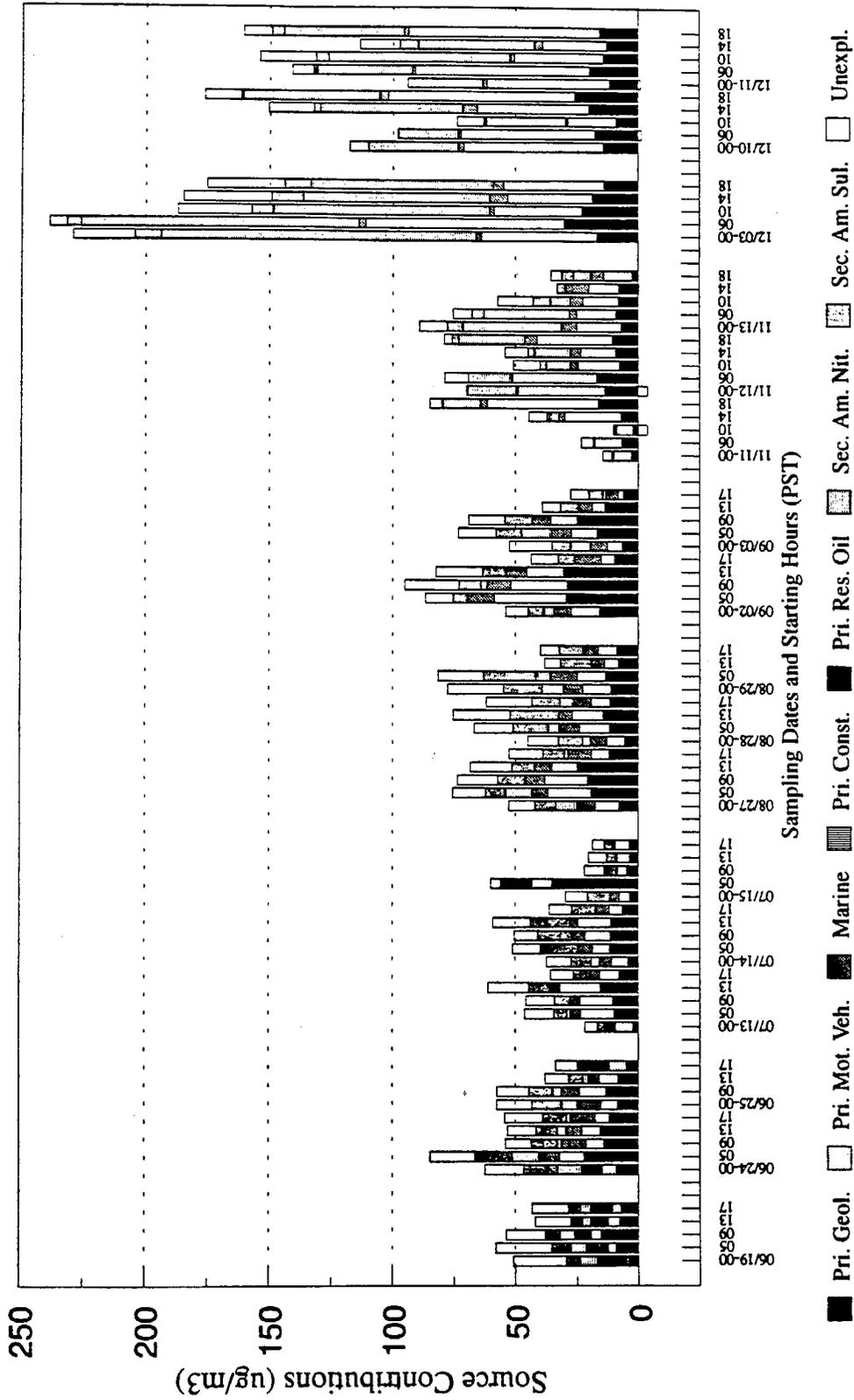


Figure 6-5e. Diurnal Source Contributions to PM₁₀ at the Anaheim Site Between 6/19/87 and 12/11/87

Rubidoux

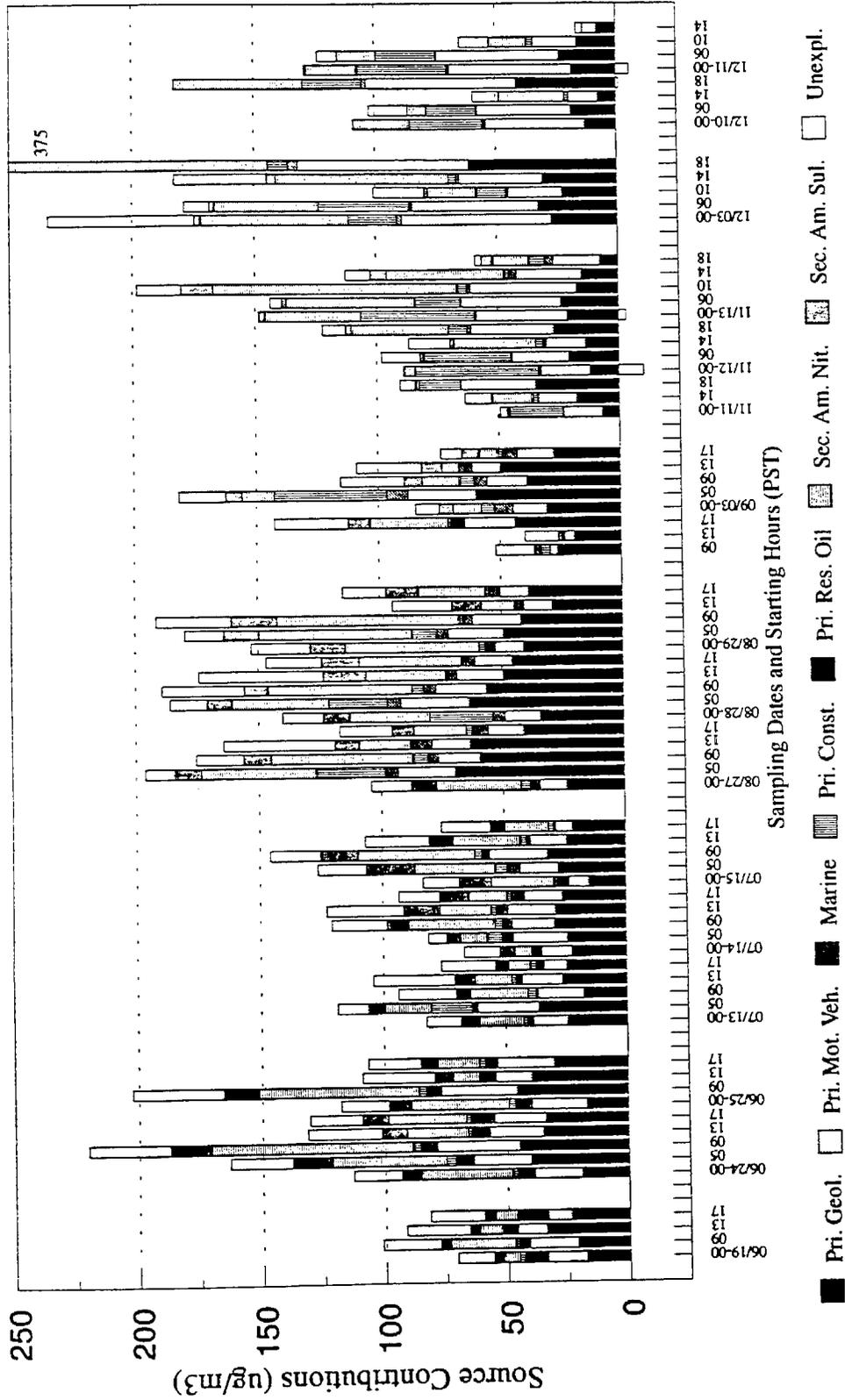


Figure 6-5f. Diurnal Source Contributions to PM₁₀ at the Rubidoux Site Between 6/19/87 and 12/11/87

San Nicolas Island

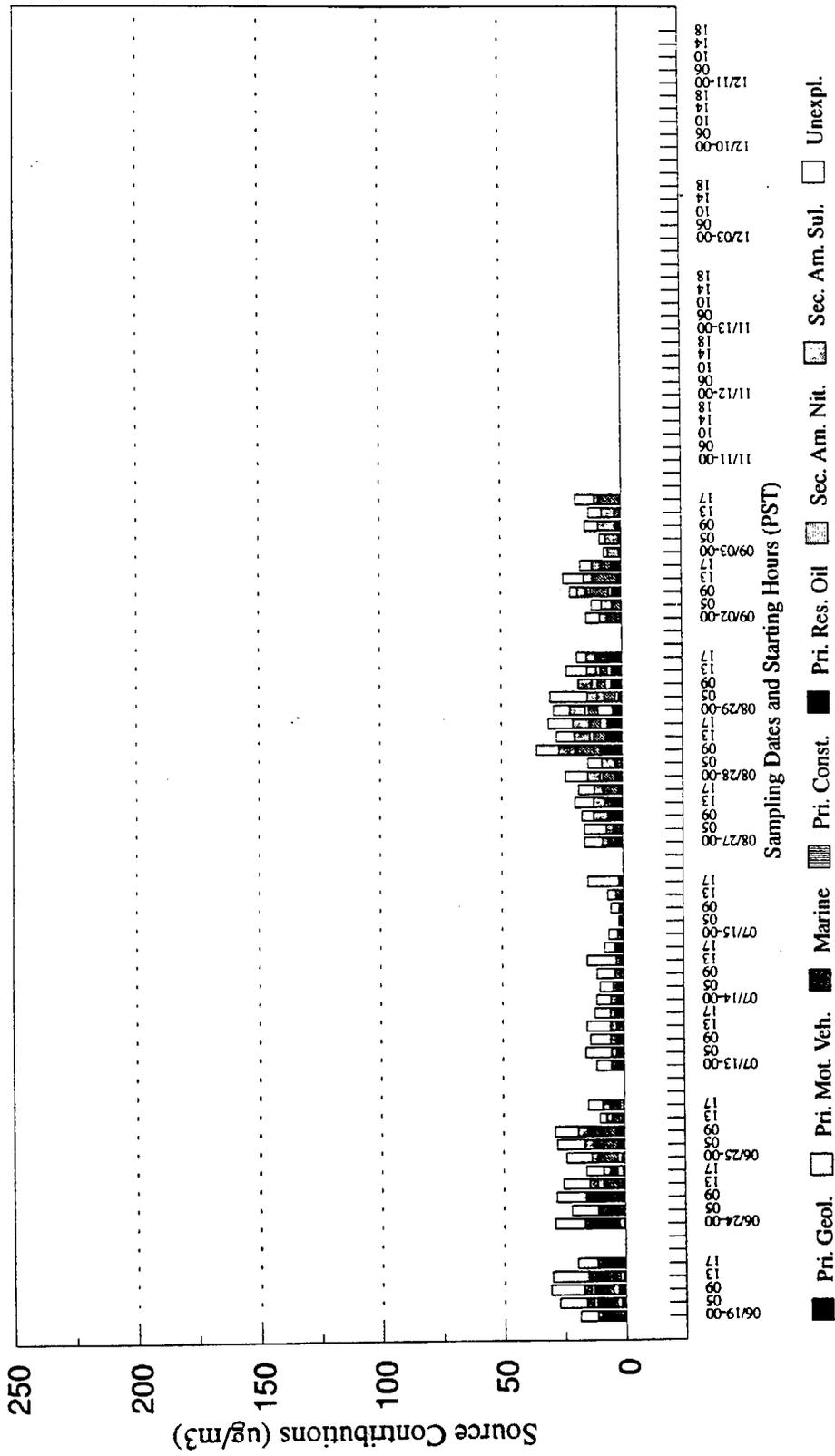


Figure 6-5g. Diurnal Source Contributions to PM₁₀ at the San Nicolas Island Site Between 6/19/87 and 9/3/87

Azusa

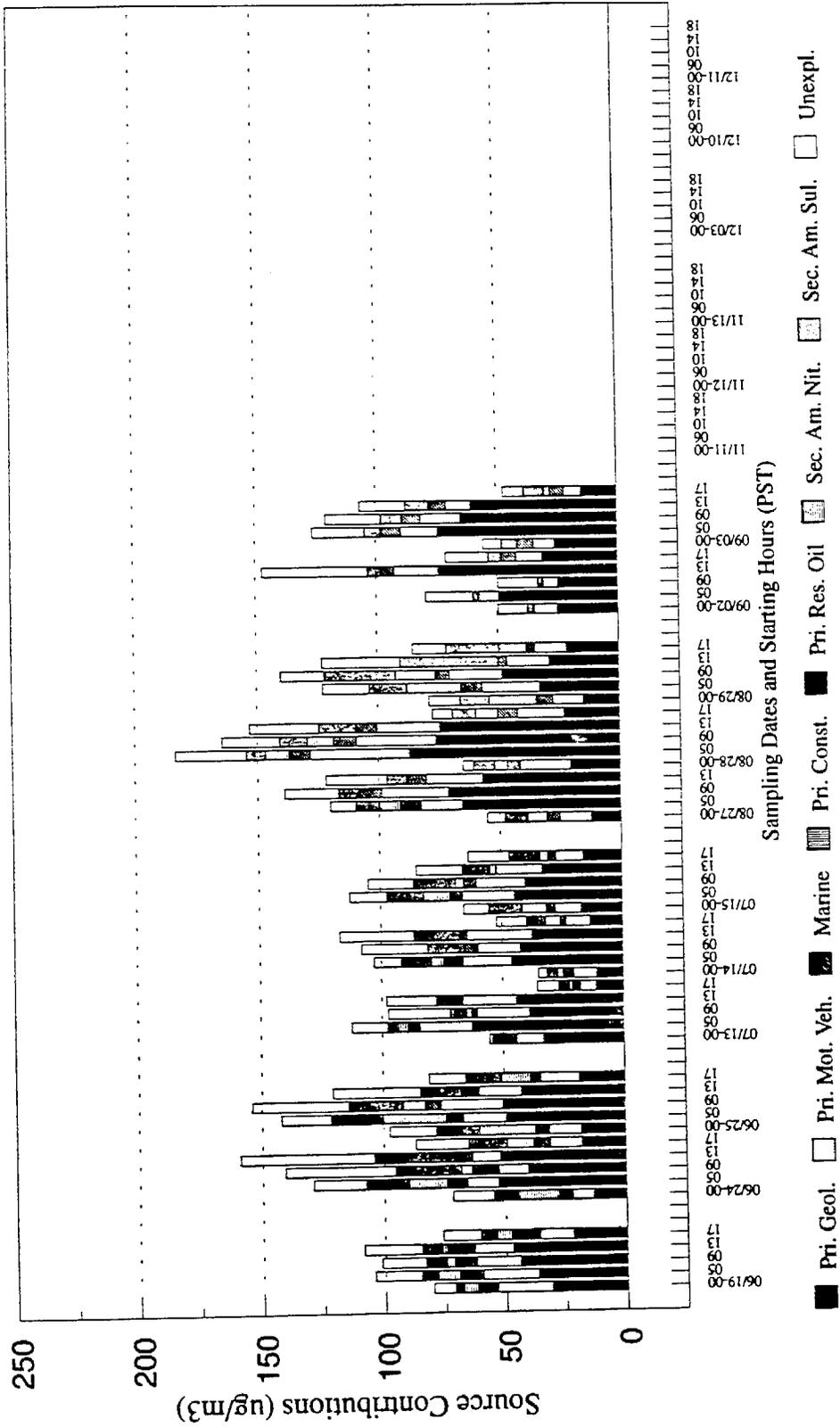


Figure 6-5h. Diurnal Source Contributions to PM₁₀ at the Azusa Site Between 6/19/87 and 9/3/87

Claremont

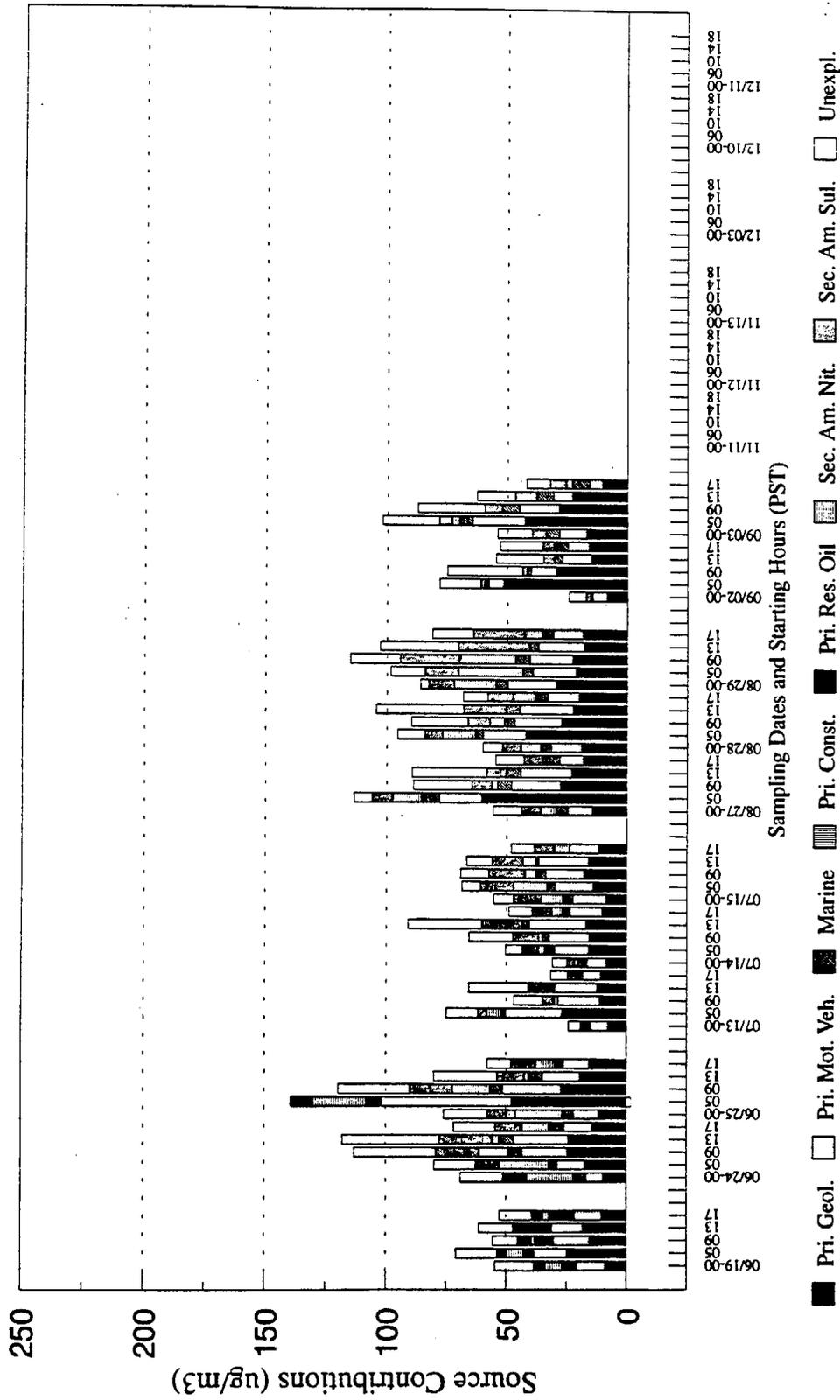


Figure 6-5i. Diurnal Source Contributions to PM₁₀ at the Claremont Site Between 6/19/87 and 9/3/87

Rubidoux monitoring site, resulting in much higher calcium loadings during fall drainage wind periods than are observed during summertime wind regimes.

Primary motor vehicle exhaust contributions peak in the morning samples, and sometimes in the evening samples. This contribution is expected to be more pronounced in the morning owing to the existence of a surface layer which usually dissipates before the evening rush hour.

6.5 Contributions to Maximum 24-Hour PM_{10}

Figures 6-6a to 6-6i show the individual source contributions averaged over 24-hour periods. The spatial distribution of these averages for the two PM_{10} exceedance days is shown in Figures 6-7a and 6-7b. These show many of the same characteristics found in the averages and show how source contributions generally increase from the western to eastern part of the SoCAB. Primary geological material, primary motor vehicle exhaust, and secondary ammonium nitrate are the main contributors to these excessive PM_{10} concentrations.

The highest source contributions do not necessarily correspond to the highest PM_{10} concentrations. The largest primary geological contribution of $51 \pm 5 \mu\text{g}/\text{m}^3$ was found at the Azusa site on August 28, 1987 when PM_{10} was $120 \mu\text{g}/\text{m}^3$. The largest primary construction contribution was $21 \pm 6 \mu\text{g}/\text{m}^3$ on November 12, 1987 at the Rubidoux site when PM_{10} was $60 \mu\text{g}/\text{m}^3$. The largest primary motor vehicle exhaust contribution of $74 \pm 31 \mu\text{g}/\text{m}^3$ was found at the Long Beach site on December 3, 1987 when PM_{10} was $194 \mu\text{g}/\text{m}^3$. The largest secondary ammonium nitrate contribution of $96 \pm 18 \mu\text{g}/\text{m}^3$ was found at the Anaheim site on December 3, 1987 when PM_{10} was $203 \mu\text{g}/\text{m}^3$. The largest secondary ammonium sulfate contribution of $27 \pm 9 \mu\text{g}/\text{m}^3$ was measured at the Hawthorne site on June 24, 1987 when PM_{10} was $75 \mu\text{g}/\text{m}^3$. The largest primary marine aerosol contribution of $11 \pm 2 \mu\text{g}/\text{m}^3$ was found at the Long Beach site on September 2, 1987 when PM_{10} was $65 \mu\text{g}/\text{m}^3$. Only two of these highest contributions correspond to PM_{10} standard exceedances. Several sources contribute at elevated, but not necessarily maximum, levels when 24-hour standards are exceeded.

6.6 Source Sub-Types

To develop PM_{10} emissions control strategies, the major source types of primary geological material, primary motor vehicle exhaust, primary marine aerosol, secondary ammonium nitrate, and secondary ammonium sulfate must be related to specific types of emitters. The differences in profiles for the species measured have not been sufficient to quantify the contributions of these sub-types. Estimates of their influence can be made, however, by examining the CMB source apportionments in light of knowledge of the meteorology, emissions, spatial distribution, and temporal distribution of source contributions.

Burbank

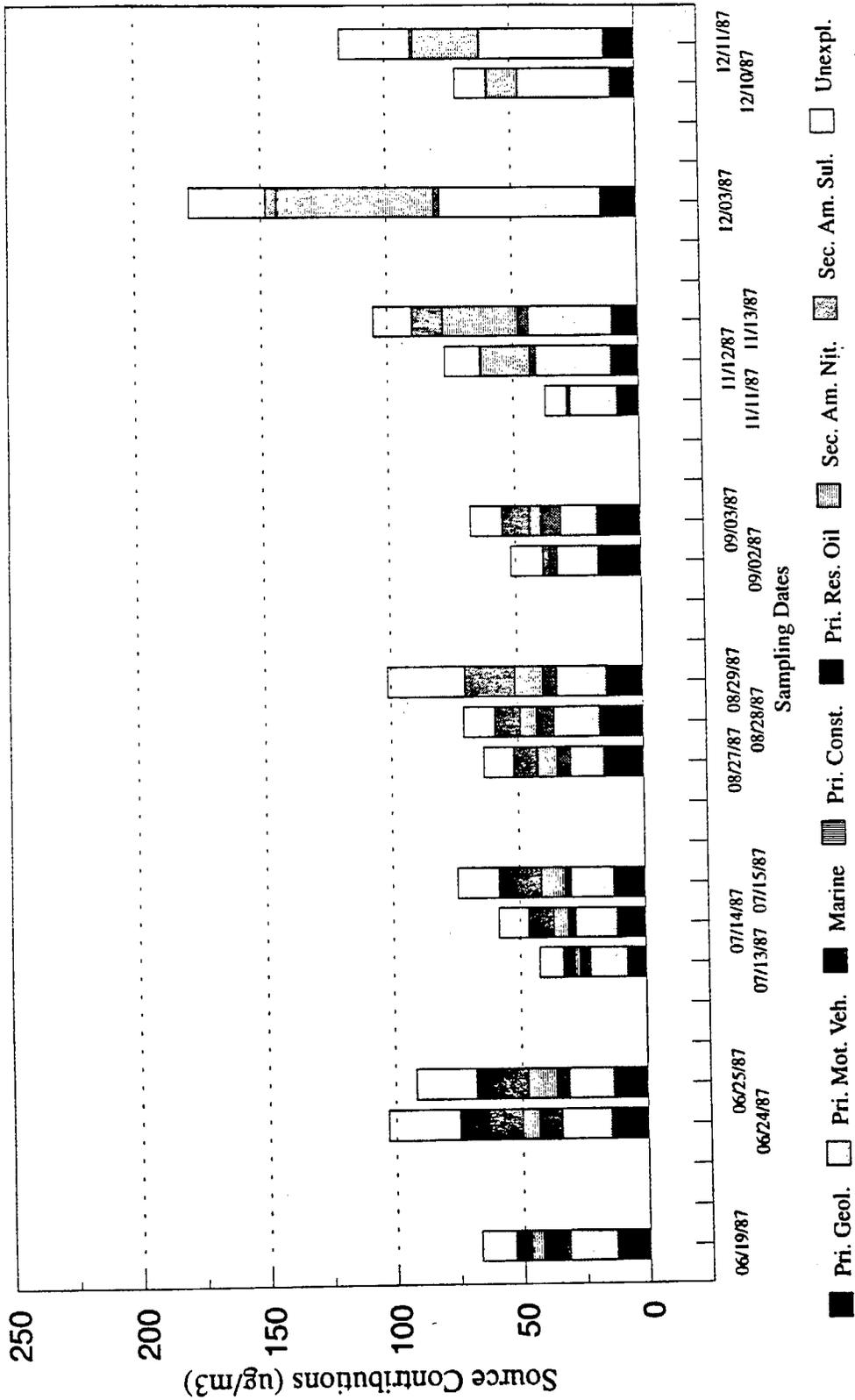


Figure 6-6a. Twenty-Four Hour Source Contributions to PM₁₀ at the Burbank Site Between 6/19/87 and 12/11/87

Downtown Los Angeles

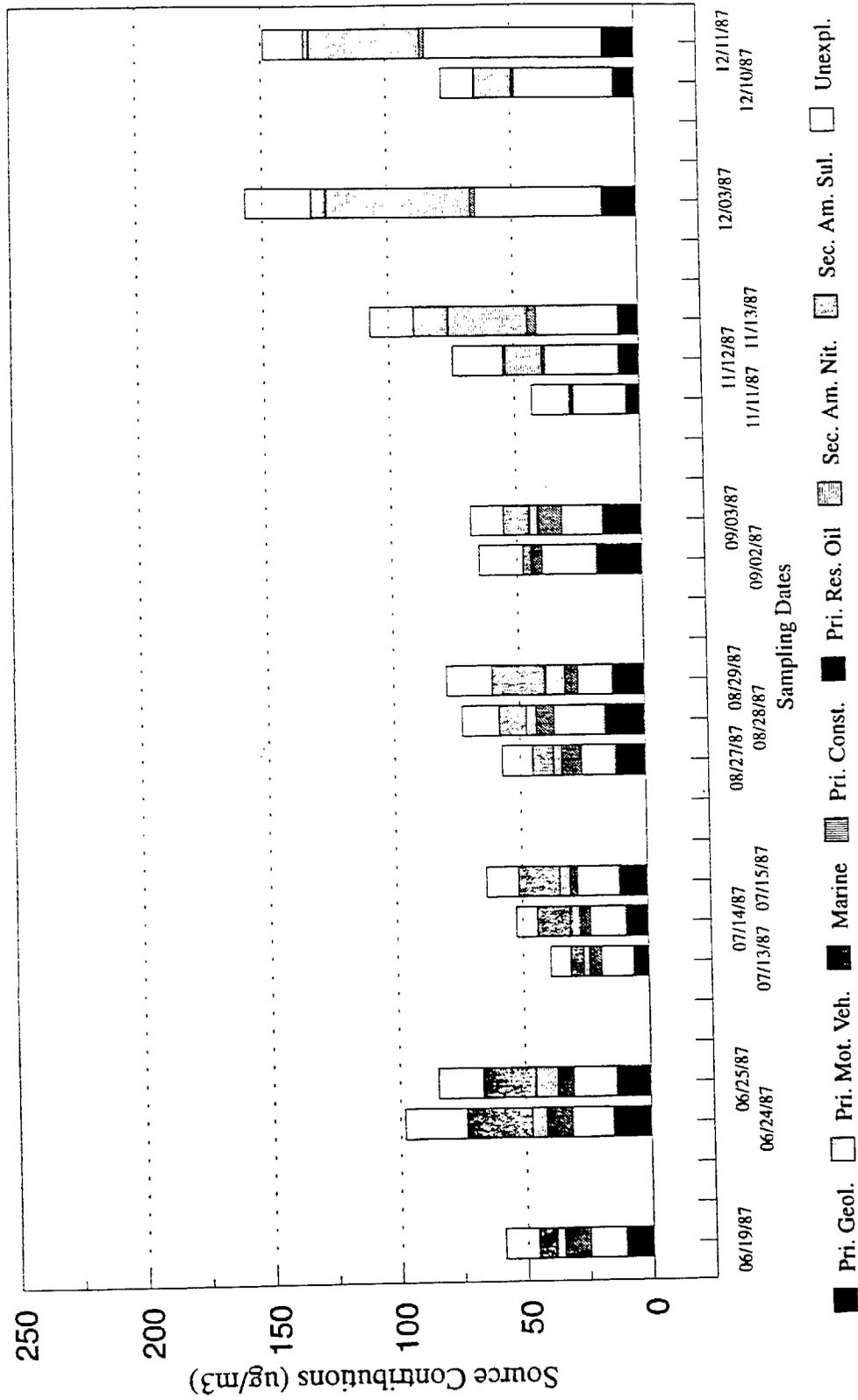


Figure 6-6b. Twenty-Four Hour Source Contributions to PM₁₀ at the Downtown Los Angeles Site Between 6/19/87 and 12/11/87

Hawthorne

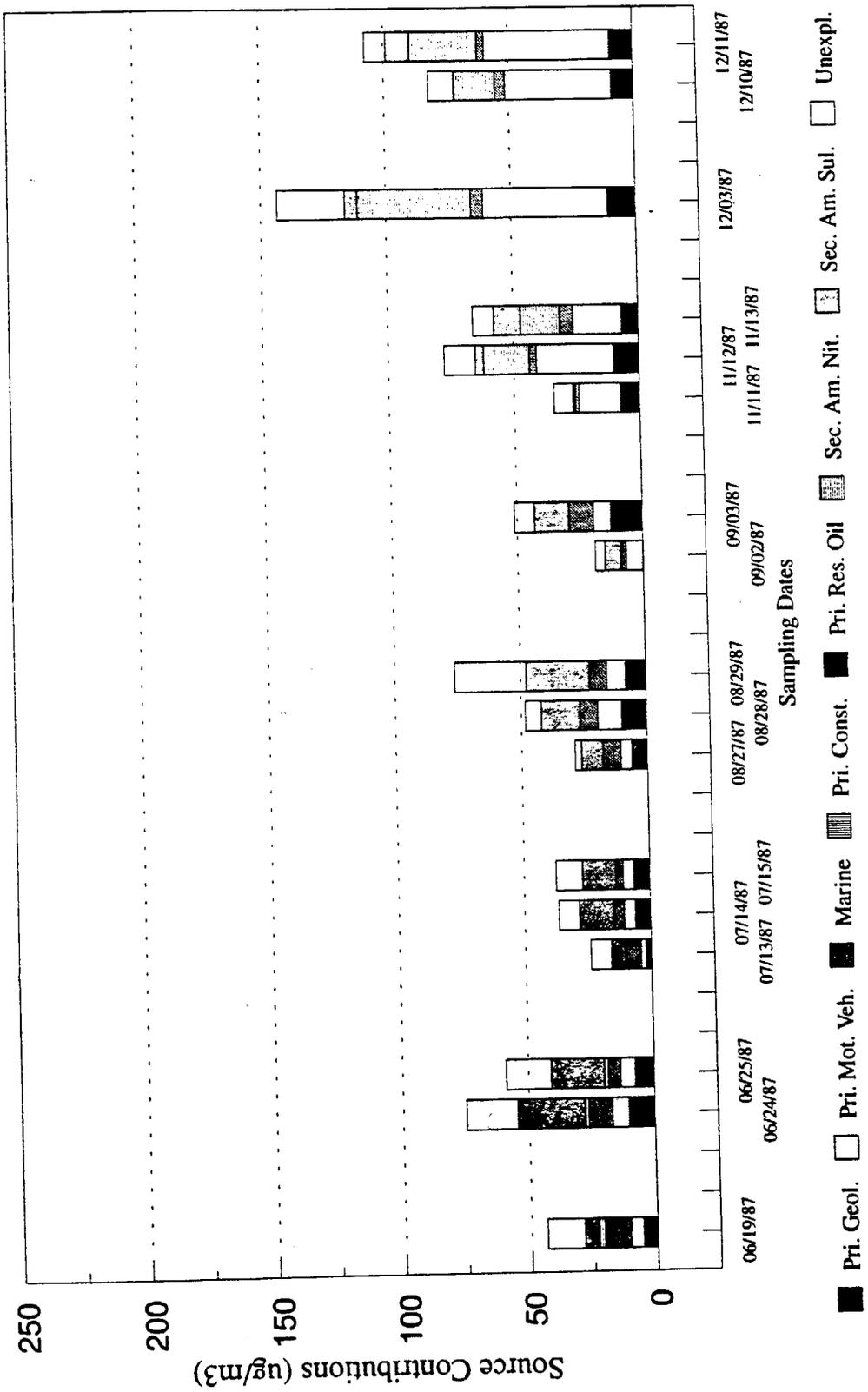


Figure 6-6c. Twenty-Four Hour Source Contributions to PM₁₀ at the Hawthorne Site Between 6/19/87 and 12/11/87

Long Beach



Figure 6-6d. Twenty-Four Hour Source Contributions to PM₁₀ at the Long Beach Site Between 6/19/87 and 12/11/87

Anaheim

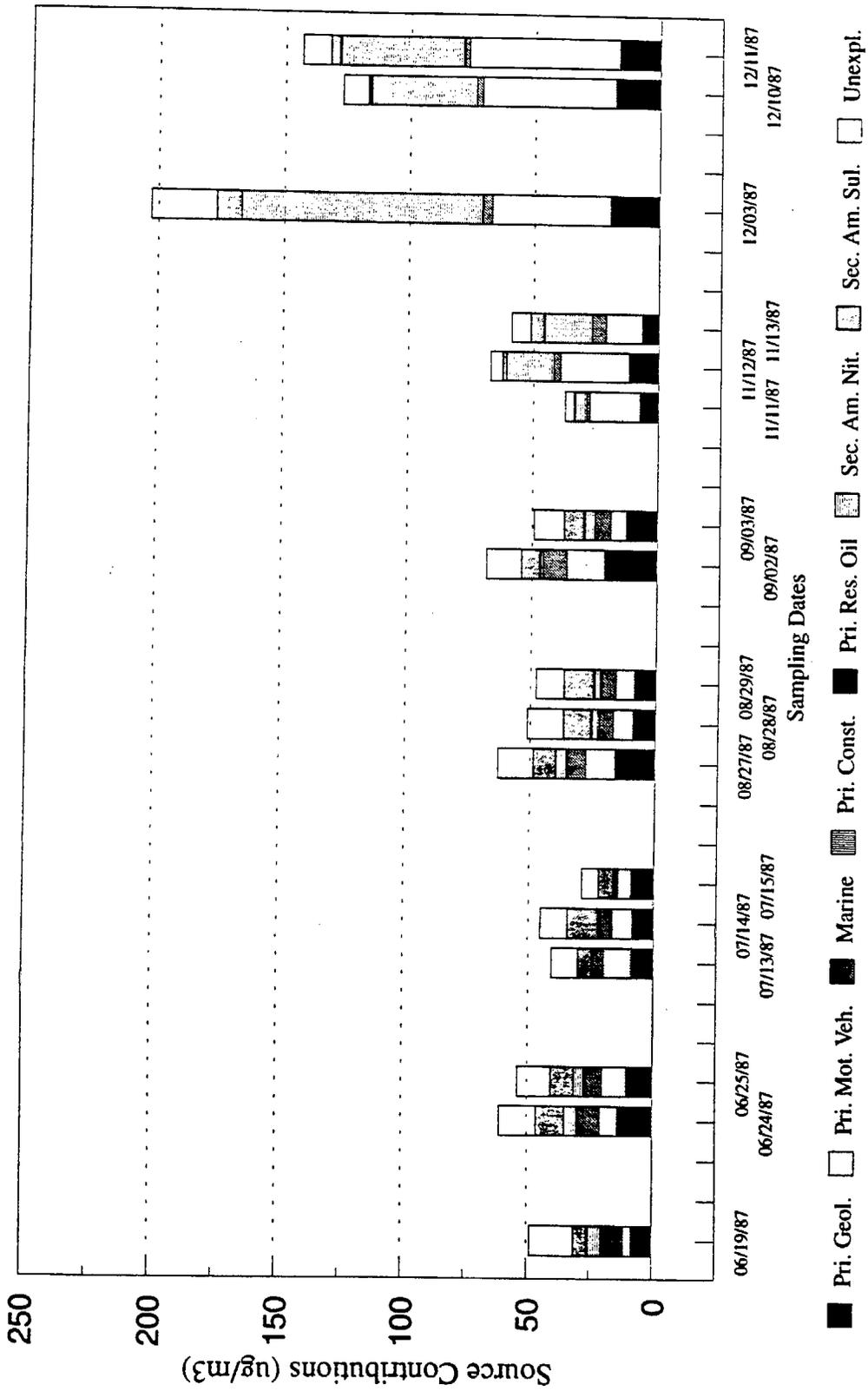


Figure 6-6e. Twenty-Four Hour Source Contributions to PM₁₀ at the Anaheim Site Between 6/19/87 and 12/11/87

Rubidoux

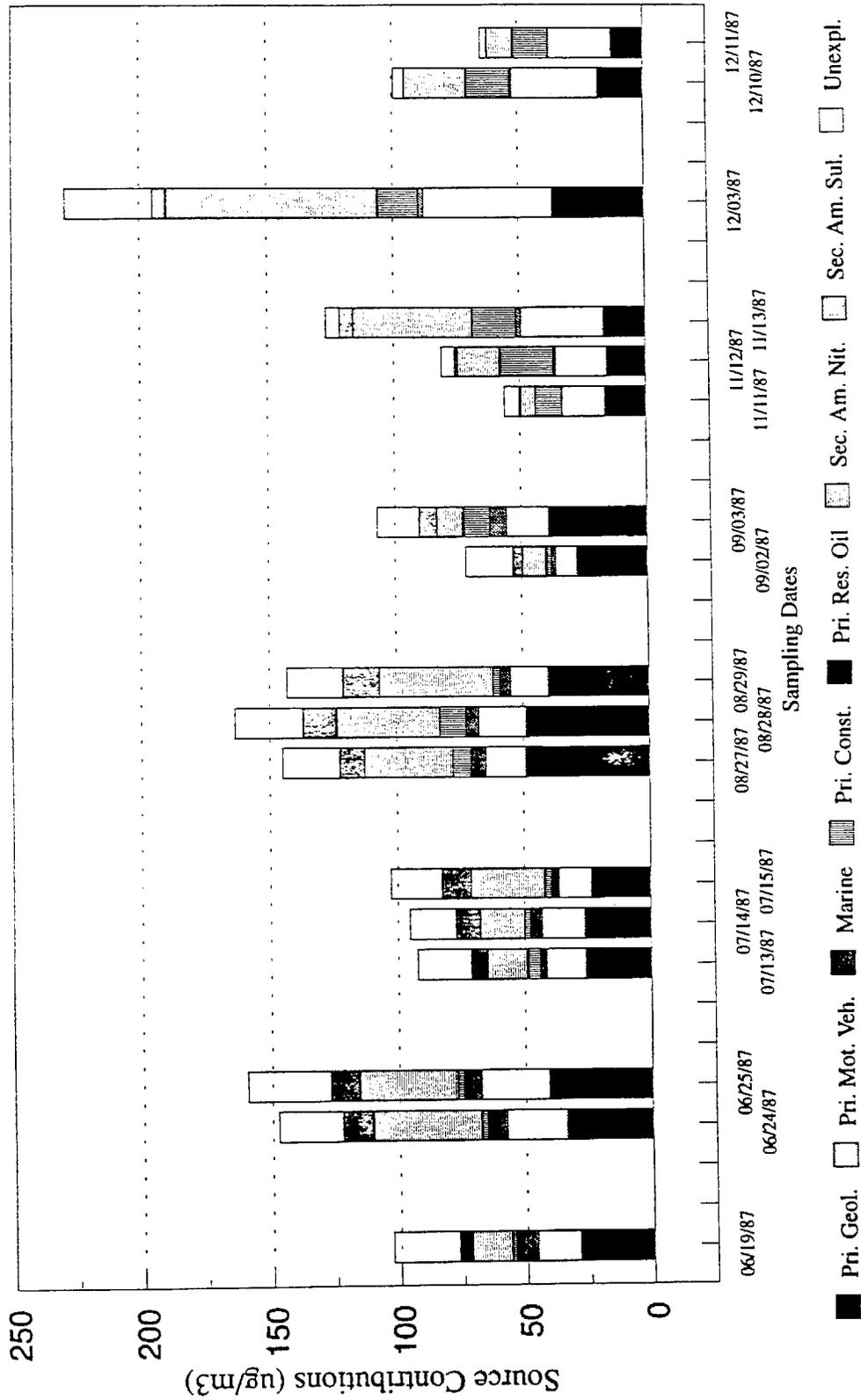


Figure 6-6f. Twenty-Four Hour Source Contributions to PM₁₀ at the Rubidoux Site Between 6/19/87 and 12/11/87

San Nicolas Island

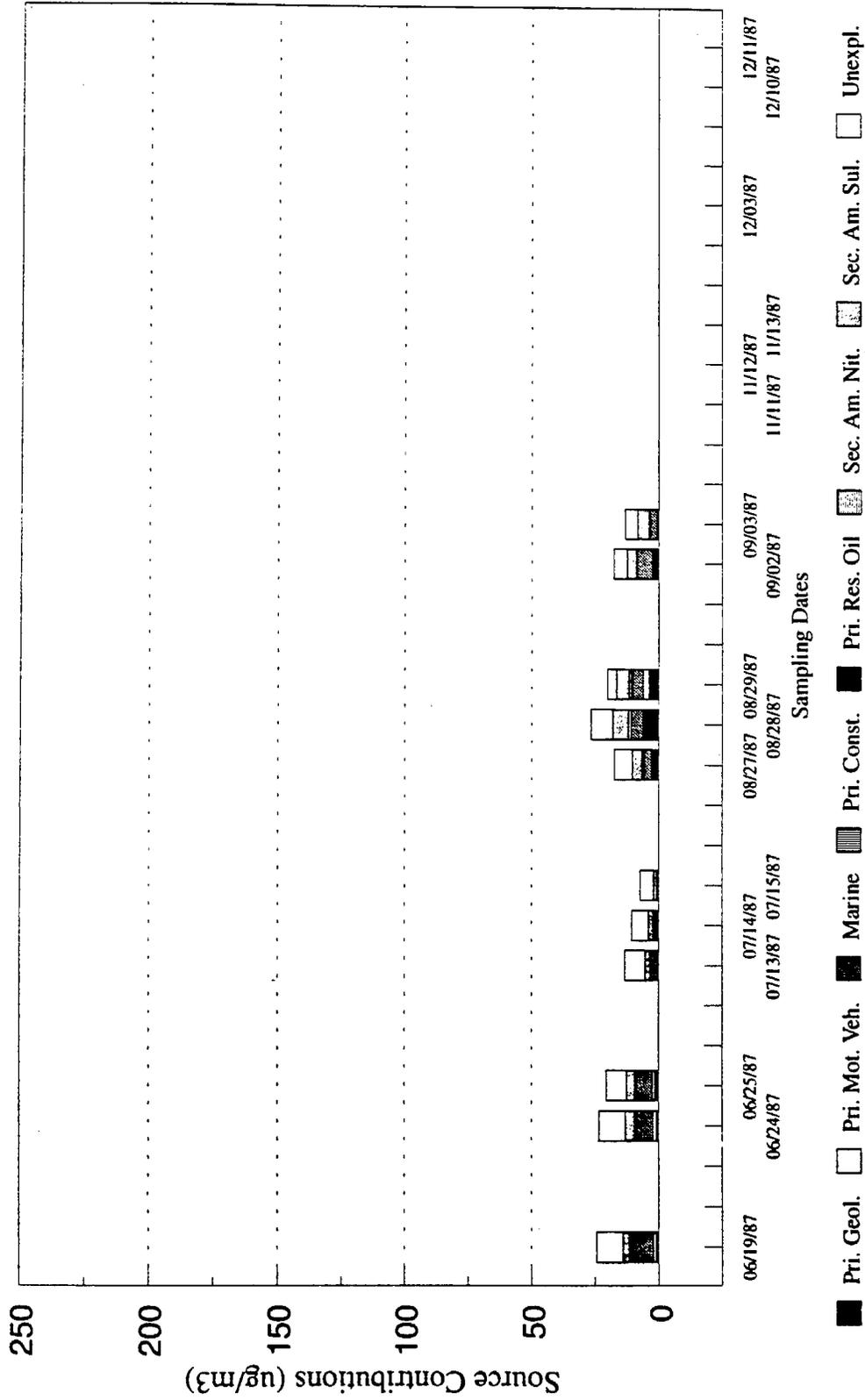


Figure 6-6g. Twenty-Four Hour Source Contributions to PM₁₀ at the San Nicolas Island Site Between 6/19/87 and 9/3/87

Azusa

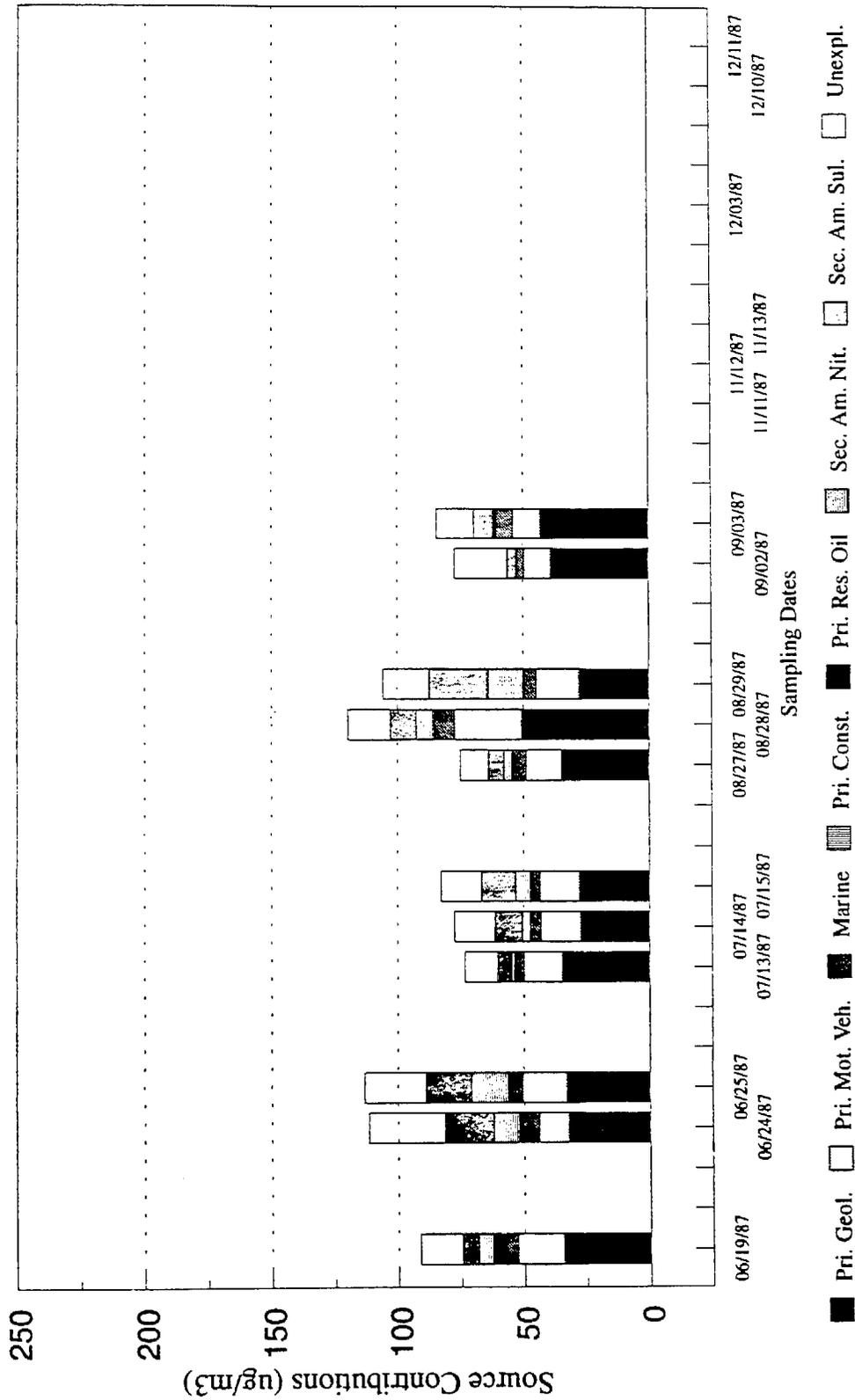


Figure 6-6h. Twenty-Four Hour Source Contributions to PM₁₀ at the Azusa Site Between 6/19/87 and 9/3/87

Claremont

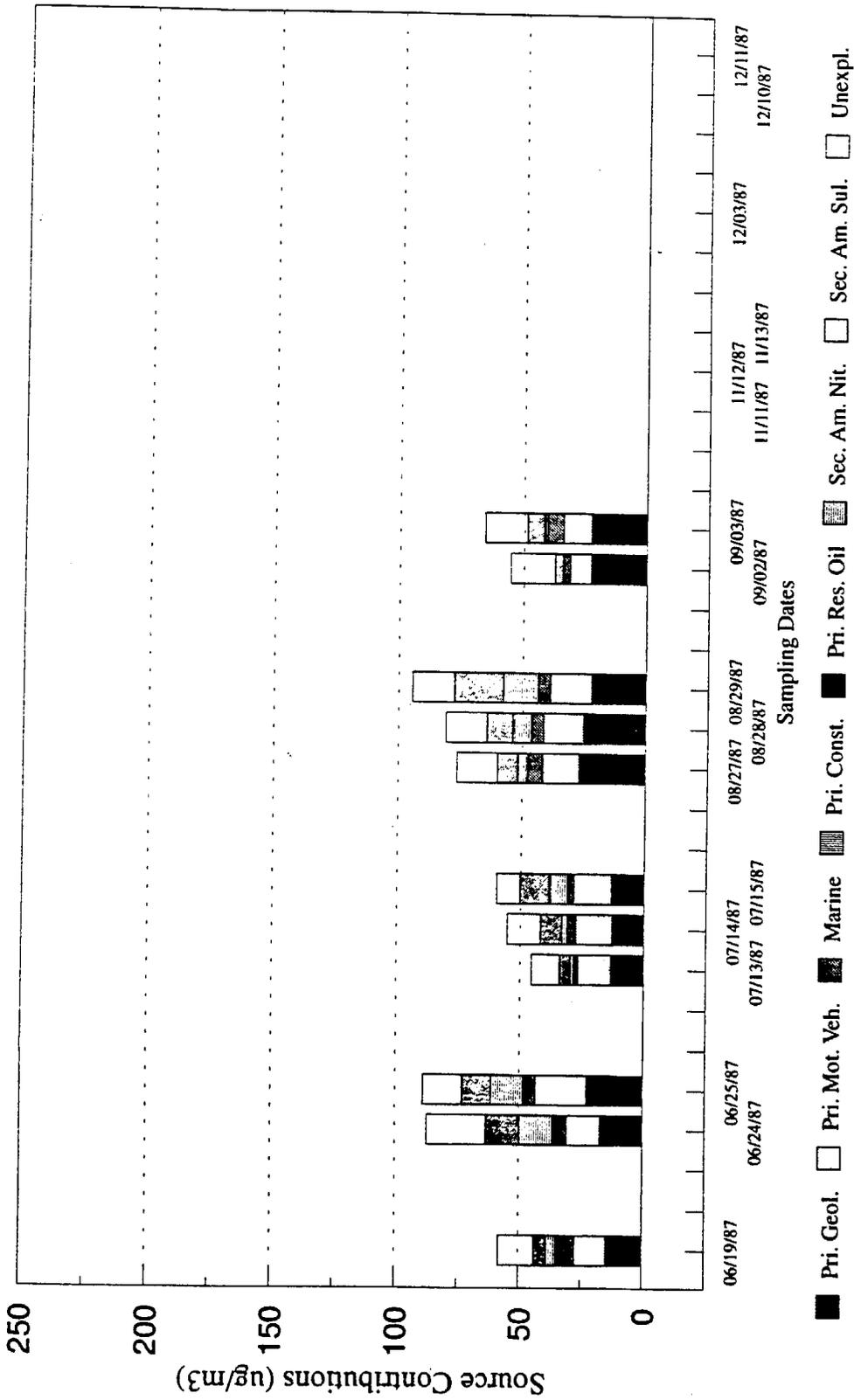


Figure 6-6i. Twenty-Four Hour Source Contributions to PM₁₀ at the Claremont Site Between 6/19/87 and 9/3/87

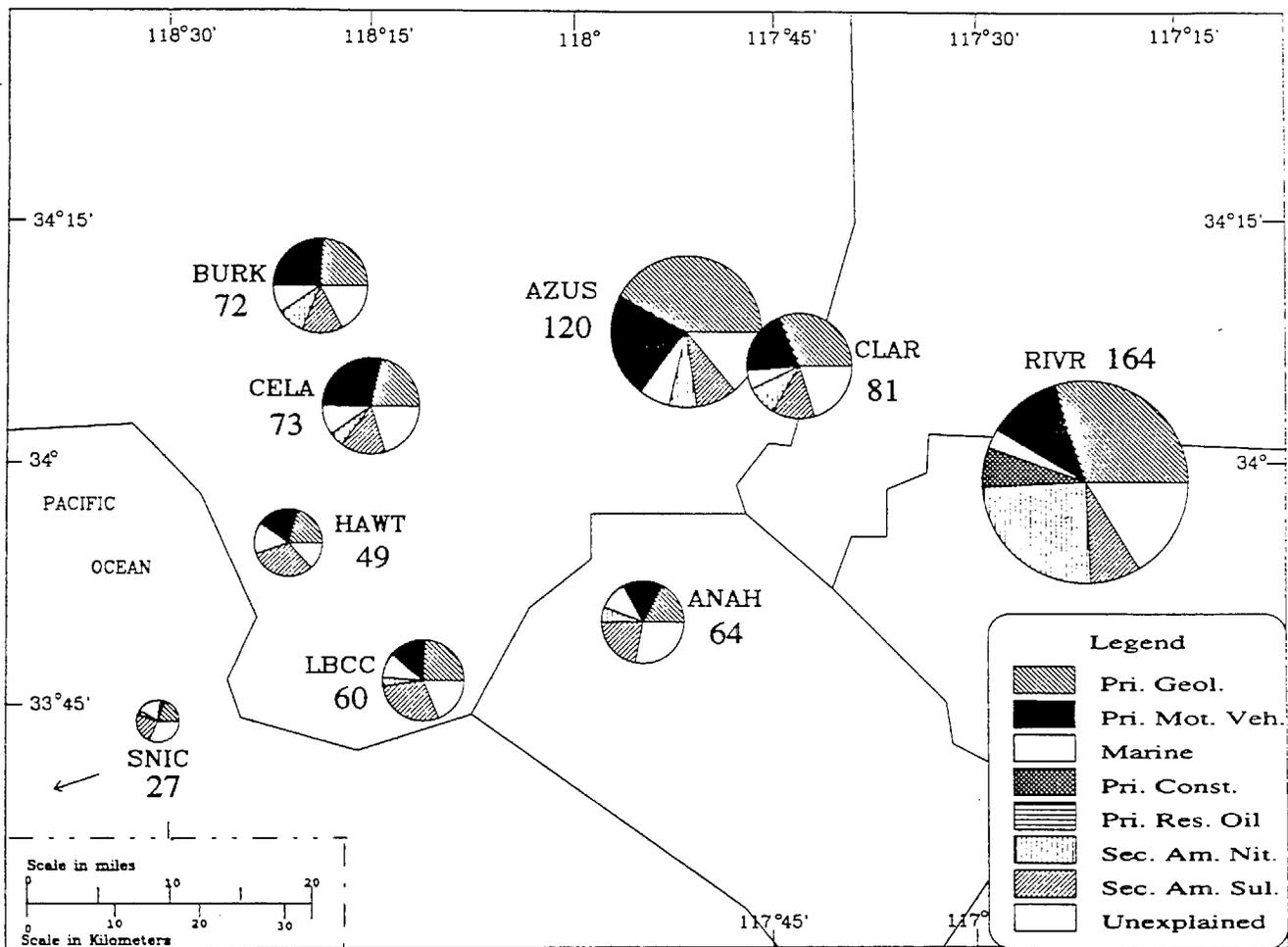


Figure 6-7a. Source Contributions ($\mu\text{g}/\text{m}^3$) to 24-Hour Average PM_{10} Mass at Nine SCAQS Sites on 8/28/87

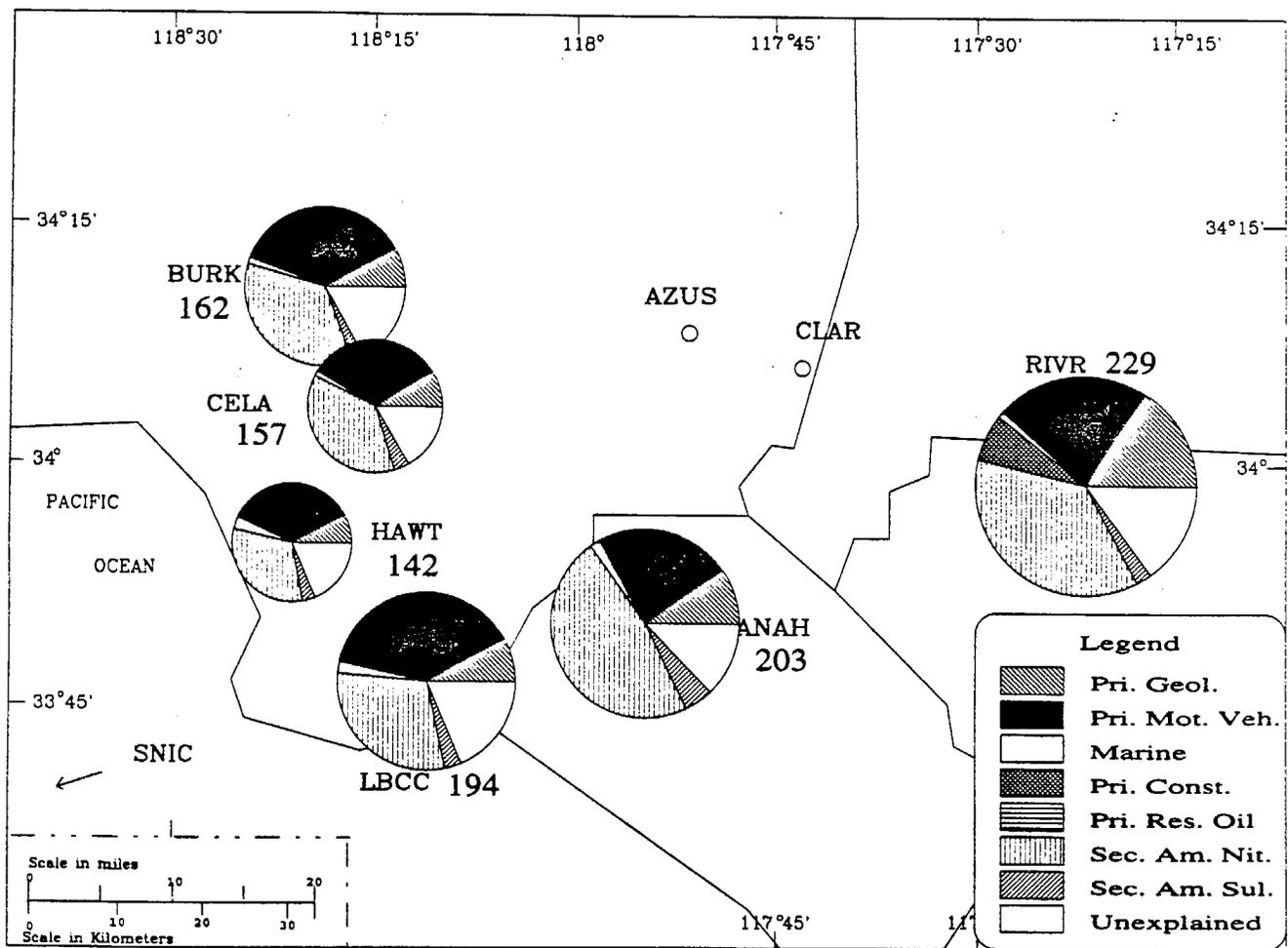


Figure 6-7b. Source Contributions ($\mu\text{g}/\text{m}^3$) to 24-Hour Average PM₁₀ Mass at Six SCAQS Sites on 12/28/87

6.6.1 Primary Geological Material

Source sub-types are paved roads, unpaved roads, agricultural tilling, construction, and windblown dust. The proximity of the SCAQS sampling sites to paved roads, and their distance from unpaved roads and agricultural activities implies that nearly all of the geological material measured originated from paved roads. Since Figures 6-5a to 6-5c show no correspondence between geological contributions at different sampling sites, and since nominal sample spacing is 20 to 40 kilometers, the influence area for the majority of suspended road dust must be less than the distance between samplers, so paved roads within a few kilometers of the sampling site have the greatest influence on PM_{10} . Major construction activities were not recorded during SCAQS monitoring, except for earth moving on the I-405 freeway near the Hawthorne site. In fact, the sites were specifically chosen to distance themselves from such sporadic local influences. Evidence of construction contributions was not observed in abnormally high calcium concentrations.

The exception is the Rubidoux site, which is in the vicinity of agricultural fields, cement plants, and grading and quarrying activities. It is doubtful that the "construction" designation for the lime/gypsum profile at the Rubidoux site really corresponds to construction. This contribution has been observed in every other source apportionment study at Rubidoux, and a careful survey and sampling of nearby geological sources would probably provide the information needed to determine the precise character of this important source contribution.

6.6.2 Primary Motor Vehicle Exhaust

Primary motor vehicle exhaust is defined as those particles which are emitted directly from the tailpipe. Other motor-vehicle-related particulate emissions include brake and tire wear. It was noted in Section 5 that no evidence of brake or tire wear was found in resuspended dust from paved roads or in the SCAQS elemental concentrations. These are negligible contributors to PM_{10} .

Since TC rather than EC or OC was used as a fitting species, it is possible that other sources of OC are represented by the motor vehicle exhaust source profiles. Section 2 identified emissions from cooking of meat as a potential interferant. This contribution would probably peak during the evening when most meat is cooked, however, and this is not observed in the diurnal plots. Contributions from secondary organic carbon are also interpreted as primary motor vehicle exhaust in this analysis. As shown by Turpin and Huntzicker (1991), secondary organic carbon is only a contributor to a few afternoon samples during summer in the eastern SoCAB.

It would be desirable to allocate the direct tailpipe emissions from motor vehicles to diesel-, leaded-gasoline-, and unleaded-gasoline- fueled vehicles. It may be possible for the CMB to do this with the proper profiles, but the currently-available profiles are not compatible enough with the SCAQS data set to attempt this.

6.6.3 Secondary Ammonium Nitrate and Ammonium Sulfate

Secondary ammonium nitrate was a major contributor on many occasions. The sources of its precursors are nitrogen oxides from motor vehicle exhaust (with some from gas-fired power plants and home heating) and ammonia from agricultural operations. During the summer, secondary ammonium nitrate contribution appears to be ammonia-limited at all sites except Rubidoux. This is not the case during the fall, when it is not known whether the secondary ammonium nitrate is limited by ammonia or nitric acid precursors.

The major source of sulfur dioxide in the SoCAB is also primary motor vehicle exhaust, and secondary ammonium sulfate contributions are so homogeneous across the SoCAB that the formation of secondary ammonium sulfate does not appear to be ammonia limited. Reductions in sulfur dioxide precursor emissions will probably result in reductions in ambient sulfate concentrations. In an ammonia-limited environment like the SoCAB during the summer, this might allow more free ammonia to be available for reaction with nitric acid.

