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Oscar Experiment High-Density Network Data Report

Event 4 April 21-23, 1981

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J. M. Thorp**

December 1984

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OSCAR EXPERIMENT HIGH-DENSITY NETWORK
DATA REPORT
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PREFACE

This report is one of a series of four reports that summarize data taken by Pacific Northwest Laboratory at the high-density network component of the OSCAR (Oxidation and Scavenging Characteristics of April Rains) experiment in April 1981. Four storm events were studied during the experiment, and a separate report has been prepared for each event:

PNL-5152, Pt. 1: Event 1 - April 8-9, 1981

PNL-5152, Pt. 2: Event 2 - April 13, 1981

PNL-5152, Pt. 3: Event 3 - April 16-17, 1981

PNL-5152, Pt. 4: Event 4 - April 21-23, 1981

The OSCAR experiment was a cooperative project, and reports from other participants are noted in the introduction.

SUMMARY

The OSCAR (Oxidation and Scavenging Characteristics of April Rains) experiment, conducted during April 1981, was a cooperative field investigation of wet removal in cyclonic storm systems. The high-density component of OSCAR was located in northeast Indiana and included sequential precipitation chemistry measurements on a 100 by 100 km network, as well as airborne air chemistry and cloud chemistry measurements, surface air chemistry measurements, and supporting meteorological measurements.

Four separate storm events were studied during the experiment. This report summarizes data taken by Pacific Northwest Laboratory (PNL) during the fourth storm event, April 21-23. The report contains the high-density network precipitation chemistry data, air and cloud chemistry data from the two PNL aircraft, and meteorological data for the event, including standard National Weather Service products and radar and rawindsonde data from the network.

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SECTION 1

INTRODUCTION

The Oxidation and Scavenging Characteristics of April Rains (OSCAR) experiment, conducted during April 1981, was a cooperative field investigation of wet removal by cyclonic storms. The design and operational aspects of the experiment have been described in detail in an earlier report⁽¹⁾, and a brief summary is given below. This report is the first in a series of four volumes that will present data collected at the high-density network during each of the four OSCAR storm events. This particular report covers the April 21-23, 1981, storm event.

The report is divided into three sections: meteorological data, precipitation chemistry data, and aircraft data. It should be noted that the report is limited in scope to data collected by Pacific Northwest Laboratory (PNL) participants in the experiment. Other relevant data collected at the high density network are being/have been reported elsewhere and include: Brookhaven National Laboratory (BNL) surface air chemistry and aircraft data^(a), Argonne National Laboratory (ANL) aerosol data⁽²⁾, and hydrogen-peroxide measurements made by G. Kok⁽³⁾.

The primary design requirement for OSCAR was to characterize, in as much detail as possible, the physicochemical and dynamical features of selected cyclonic (or "frontal") storm systems as they traversed the eastern portion of the North American continent. The formal objectives of the study were:

(a) Benkovitz, C. M. et al. Oxidation and Scavenging Characteristics of April Rains Data Report. Report in preparation by Atmospheric Sciences Division of Brookhaven National Laboratory, Upton, Long Island, New York for U.S. Environmental Protection Agency.

- To assess spatial and temporal variability of precipitation chemistry in cyclonic storm systems and to test the adequacy of existing networks to characterize this variability
- To provide a comprehensive, high-resolution data base for prognostic, regional deposition model development
- To develop increased understanding of the transport, dynamical, and physicochemical mechanisms that combine to make up the composite wet-removal process, and to identify source areas responsible for deposition at receptor sites.

The OSCAR field experiment was designed to maximize the attainment of these goals, within the practical and financial limitations imposed. Two complementary, sequentially operated precipitation chemistry networks formed the foundation of the experiment. Spatial and temporal resolution were the primary factors considered in network design. A nested high-density and intermediate-density network design was chosen to allow both regional coverage over the MAP3S/RAINE geographical region, and intensive measurements over a limited area to resolve wet-removal mechanisms in cyclonic storms. The networks are depicted schematically in Figures 1.1 and 1.2. The high-density network consisted of 47 stations in a 110 by 110 km area in northeast Indiana/northwest Ohio.

Additional measurements in support of the two networks characterized surface and aloft air chemistry, cloud chemistry, and meteorological variables. The April operational period for OSCAR was chosen so that most precipitation would be rain rather than snow and the storm systems would still be more cyclonic rather than convective in nature.

FIGURE 1.1. OSCAR Intermediate-Density Sampling Station Locations and High-Density Network Position.

FIGURE 1.2. Organization of the OSCAR High-Density Precipitation Chemistry Network. Numbers Indicate Sampling Site Locations. Site 62 Coincides with the Surface Air Chemistry Site. The Weather Radar and Rawinsonde Were Located at FWA (Fort Wayne Airport).

SECTION 2

METEOROLOGICAL DATA

This section describes the synoptic weather events that occurred during the April 22-23 storm, with particular emphasis on weather in the high-density network area. Data utilized in the analyses and interpretations include standard National Weather Service (NWS) products and data collected as part of the high-density network experiment. Surface weather maps have been drawn for time intervals of 24, 12, 6, or 3 hours depending on the proximity of storm activity to the high-density network (Figure 2.1 through 2.16). Constant level charts for 850 mb and 700 mb are shown for 12-hour intervals during the period bracketing the storm (Figure 2.17 through 2.21). Radar precipitation echoes from the Fort Wayne NWS weather radar (Figure 2.22 through 2.26), rawinsonde temperature and moisture profiles from rawindsonde releases made at the Fort Wayne airport (Figure 2.27), and precipitation amounts over the high-density network (Figure 2.30 through 2.37) are shown during the period when the storm crossed the network.

Of the four storm events sampled during the OSCAR experiments, the April 22-23 storm produced the largest precipitation pattern over the high-density network. Most of the intermediate network also received precipitation before the storm moved out over the Atlantic Ocean after 1200 Greenwich Mean Time (GMT), April 24.

At 0000 GMT, April 21, a large high centered near James Bay covered all of the United States east of the Rocky Mountains except the extreme south. A cold front extended from a low off New England to the Georgia coast. From there the front was stationary westward to New Mexico and then angled northward as a warm front to a small low north of Montana.

By 1200 GMT, a cold front had formed east of the Rockies and the warm front and associated low pressure center had moved to North Dakota (Figure 2.1).

A decision was made to sample this approaching storm system. The BNL aircraft was sent to Fort Wayne Airport (FWA), and preliminary alerts were given to the western network stations.

At 0000 GMT, April 22, the two western fronts had merged into a single cold front extending from the low in North Dakota south through Nebraska, Colorado, and New Mexico. The stationary front was still located along the Gulf coast and through northern Texas. The large high over the eastern states had weakened and formed a long ridge from western New York to North Carolina. Scattered showers were occurring in western Illinois and westward in advance of the frontal system.

At 1200 GMT (Figures 2.2, 2.3), the front extended to northern Texas from the low now in northern Minnesota. A secondary cold front from the low center extended back into Saskatchewan. The Gulf coast front was advancing northward as a warm front through coastal Mississippi into southern Arkansas. The eastern high was reduced to a weak north-south ridge across New York. A weak trough was beginning to form north of an east-west line from central Illinois to southwestern Pennsylvania. Showers extended into eastern Ohio in the region of the trough. An area of showers and thundershowers ranged from Minnesota to Arkansas, and a small area of precipitation was occurring in southern Indiana. The high-density network precipitation chemistry collectors were set out by about 1500 GMT. (Radar echos of a precipitation cell that crossed the southern portion of the high-density network at about this time are shown in Figure 2.23.) The PNL DC-3 sampled this cell briefly, but the cell dissipated rapidly after 1415 GMT.

By 1800 GMT, (Figure 2.4), the cold front extended southward from the low in Minnesota to Missouri, then southwestward through Oklahoma and Texas. The warm front reached from Alabama to the cold front in southeastern Iowa. Detailed surface analysis showed warm frontogenesis along the trough line from Pennsylvania to Wisconsin. Rain now extended eastward through southern Ohio ahead of the front. The main mass of precipitation associated with this complex system became noticeable on the FWA weather radar at about 1600 GMT. It reached the western edge of the high-density network at about 1800 GMT (Figures 2.24 and 2.30) and covered the entire network by 2000 GMT (Figures 2.25, 2.31 and 2.32). Precipitation began at FWA at 1904 GMT, and nearly all

stations in the state reported precipitation for the next 6 to 9 hours (Figures 2.5 to 2.7). There were a few thunderstorms embedded in the general precipitation. The radar echo pattern had somewhat of a tattered appearance by 2305 GMT (Figure 2.26) because the main body of precipitation moved on into Ohio.

At 0000 GMT, April 23 (Figure 2.6), the low was located in Wisconsin with the occluded front south to western Illinois. From Illinois, the cold front extended southwest to Mexico, and the warm front southeast to Mississippi. Another cold front in Minnesota was now approaching the low center from the northwest. Warm frontogenesis was still evident in the trough from Wisconsin to Pennsylvania, and the high pressure had moved off the east coast. Rain now extended into New York, Pennsylvania, and West Virginia. By this time, precipitation had ended at roughly half of the high-density network sites and had become light at most of the other sites (Figures 2.33 and 2.34). Total precipitation up to 2300 GMT over the high-density network is shown in Figure 2.29. Precipitation over most of the network was fairly well distributed with most sites receiving 6 to 9 mm. An exception was the southeast corner of the network where amounts were considerably lower.

Rawinsonde observations made during the aircraft sampling period show moisture increasing aloft between 1505 GMT and 1930 GMT (Figure 2.27). A decrease in stability below 750 mb and an increase in the southwesterly wind speeds are also shown. Upper level (850 mb) charts for 1200 GMT, April 22, and 0000 GMT, April 23 (Figures 2.17, 2.18) show that the gradient was also increasing, and that warmer air aloft was being advected over Indiana from the southwest. The 700 mb chart for 1200 GMT, April 22 was not available. However the 0000 GMT, April 23 chart for 700 mb (Figure 2.19) does show that the direction shear detected by the FWA rawinsondes was part of a larger scale shear zone occurring over the states north of the Ohio River.

A comment by an observer aboard the DC-3 at 2200 GMT indicated two cloud layers were visible: one at about 3,000 ft MSL and the other at about 12,000 ft MSL. The 2135 GMT sounding shows slight inversions at about 4000 ft and at 11,000 ft MSL that may well correspond to the observed cloud layers. The 2317 GMT rawinsonde at FWA shows increasing complexity in the profiles of temperature and moisture. Decreases in moisture are noted at 800 mb and above

600 mb. Winds had increased at all levels, being mostly 50 knots from the southwest up to 750 mb and 50 to 80 knots from the west above that level.

The large area of precipitation had decreased somewhat by 0600 GMT, April 23, (Figure 2.8) and the low had moved into eastern Wisconsin. The occluded front extended to southern Illinois, with the cold and warm fronts reaching southwest and southeast respectively from there. The secondary cold front curved from the low center southwest to Iowa then angled northwest. Warm frontogenesis had taken place between Green Bay, Wisconsin, and Erie, Pennsylvania. Rain had reached central New York, eastern Pennsylvania, West Virginia, and Tennessee. On the high density network, some fairly intense cells crossed the northern tier of sites (Figures 2.35 and 2.36), but left most of the network untouched.

By 0900 GMT (Figure 2.9), the occluding frontal system was about 100km west of FWA, and at 1200 GMT the front had passed FWA and precipitation had ended there, (Figure 2.10). The Great Lakes warm front from the common low center over upper Lake Michigan was moving slowly north. This complex frontal system now had two warm fronts and two cold fronts in addition to the occluded portion. The secondary cold front extended southwest from the low center and then curved northwest into the Dakotas. Rain now covered much of New York and extended southward to Kentucky and Tennessee. Figure 2.14 shows the position of the weather fronts and their development during the 12 hour period ending 1200 GMT on the 23rd.

Upper air charts for 850 mb and 700 mb at 1200 GMT (Figures 2.20, 2.21) show the low center to be nearly vertical to at least 2850m. The upper flow over Indiana was still very strong, but had become more westerly during the past 12 hours.

By 1800 GMT, (Figures 2.11, 2.12), the low center was elongating over upper Lakes Michigan and Huron with the occlusion moving to eastern Ohio and southern Kentucky. The cold front angled southward from there. The secondary cold front just east of Lake Michigan into central Illinois appeared to be dissipating. The southern warm front was being rapidly overrun in the occlusion process. The northern warm front was weakening and tending to become stationary. Rain had reached the east coast from New England to southern New Jersey.

At 0000 GMT, April 24 (Figure 2.13), the occluded front extended from the low center over the Great Lakes to western Maryland, and the cold front ran southwestward along the Appalachians. The secondary cold front extended southward from the low center to southern Illinois and then curved westward and northwestward. It was weakening and becoming difficult to identify.

By 0600 GMT, the cold front had reached eastern Massachusetts and trailed southwest from there. The occlusion was bent back to the low center still in Michigan. A remnant warm front lay north of Cape Cod. The secondary cold front had dissipated.

At 1200 GMT, April 24, the cold front had completely cleared the coast north of Cape Hatteras, but the occlusion was still bent back to Lake Ontario. Scattered showers, light rain and drizzle still occurred in eastern New England western New York and Ohio. Figures 2.15 and 2.16 show a time series of the frontal positions from 1500 GMT on April 23rd to 1200 GMT on April 24, at which time it had moved beyond our area of interest.

To obtain a first impression of air-mass trajectories, 24-hour back trajectories at 305 m (1000 ft) above ground level (AGL) and at 850 mb were calculated and are shown in Figures 2.37 and 2.38. These are presented to give an indication of the prefrontal and postfrontal inflow into the high-density network area.

The winds used in calculating the trajectories are from NWS rawinsonde data, without estimates of vertical velocities. Wind flow maps were constructed for each observation time. Wind speed for locations between rawinsonde stations were interpolated. Wind speed and direction were vector averaged over intervals of 1/2 the map time interval to gain a first estimate of the movement of the air parcel back in time.

The 24-hour back trajectories for 305 m above ground level (AGL) indicate the probability of prefrontal air coming from the area extending from eastern Tennessee to northern Alabama. As the frontal system moved closer to FWA the back trajectories show clockwise backing of wind direction and increasing wind speeds near the surface. Thus the low level air over the high-density network just prior to frontal passage (0900 GMT on April 23) probably had its origin

in Mississippi. The prefrontal trajectory at 850 mb for air arriving over northeast Indiana at 0000 GMT on April 23 suggests a source region near the junction of the boundaries of Texas, Oklahoma and Arkansas.

Back trajectories for post frontal air showed a consistent flow from the west and northwest at both 1000 ft AGL and 850 mb, with the air parcels that reached FWA at 1200 GMT on April 23 having a probable origin in the South Dakota-Minnesota area.

FIGURE 2.1. Synoptic Weather Map for 1200 GMT, April 21, 1981.

FIGURE 2.2. Synoptic Weather Map for 1200 GMT, April 22, 1981.

FIGURE 2.3. Synoptic Weather Map for 1200 GMT, April 22, 1981.
Showing Areas of Reported Precipitation.

FIGURE 2.4. Synoptic Weather Map for 1800 GMT, April 22, 1981.

FIGURE 2.5. Synoptic Weather Map for 2100 GMT, April 22, 1981.

FIGURE 2.6. Synoptic Weather Map for 0000 GMT, April 23, 1981.

FIGURE 2.7. Synoptic Weather Map for 0300 GMT, April 23, 1981.

FIGURE 2.8. Synoptic Weather Map for 0600 GMT, April 23, 1981.

FIGURE 2.9. Synoptic Weather Map for 0900 GMT, April 23, 1981.

FIGURE 2.10. Synoptic Weather Map for 1200 GMT, April 23, 1981.

FIGURE 2.11. Synoptic Weather Map for 1500 GMT, April 23, 1981.

FIGURE 2.12. Synoptic Weather Map for 1800 GMT, April 23, 1981.

FIGURE 2.13. Synoptic Weather Map for 0000 GMT, April 24, 1981.

FIGURE 2.14. Time Series of Superimposed Frontal Positions for the Period 0000 GMT - 1800 GMT, April 23, 1981.

FIGURE 2.15. Time Series of Superimposed Frontal Positions for the Period 1500 GMT - 1800 GMT, April 23, 1981.

FIGURE 2.16. Time Series of Superimposed Frontal Positions for the Period 0000 GMT - 1200 GMT, April 24, 1981.

FIGURE 2.17. 850-Millibar Chart for 1200 GMT, April 22, 1981.

FIGURE 2.18. 850-Millibar Chart for 0000 GMT, April 23, 1981.

FIGURE 2.19. 700-Millibar Chart for 0000 GMT, April 23, 1981.

FIGURE 2.20. 850-Millibar Chart for 1200 GMT, April 23, 1981.

FIGURE 2.21. 700-Millibar Chart for 1200 GMT, April 23, 1981.

FIGURE 2.22. High-Density Network Boundary and the 230-km Range (50-km Range Marks) of the Fort Wayne Weather Radar.

FT. WAYNE WEATHER RADAR - OSCAR EVENT 4, APRIL 1981

22/1330 Z

22/1348 Z

22/1433 Z

22/1500 Z

22/1520 Z

22/1559 Z

FIGURE 2.23. Fort Wayne Radar Precipitation Echoes for 1330 GMT to 1559 GMT, April 22, 1981.

FT. WAYNE WEATHER RADAR - OSCAR EVENT 4, APRIL 1981

22/1623 Z

22/1658 Z

22/1730 Z

22/1800 Z

22/1830 Z

22/1903 Z

FIGURE 2.24. Fort Wayne Radar Precipitation Echoes for 1623 GMT to 1903 GMT, April 22, 1981.

FT. WAYNE WEATHER RADAR - OSCAR EVENT 4, APRIL 1981

22/1930 Z

22/1950 Z

22/2001 Z

22/2030 Z

22/2050 Z

22/2113 Z

FIGURE 2.25. Fort Wayne Radar Precipitation Echoes for 1930 GMT to 2113 GMT, April 22, 1981.

FT. WAYNE WEATHER RADAR - OSCAR EVENT 4, APRIL 1981

22/2121 Z

22/2140 Z

22/2200 Z

22/2222 Z

22/2245 Z

22/2305 Z

FIGURE 2.26. Fort Wayne Radar Precipitation Echoes for 2121 GMT to 2305 GMT, April 22, 1981.

FIGURE 2.27. Rawinsonde Profiles of Temperature and Moisture for 1505 GMT to 2317 GMT, April 22, 1981, at Fort Wayne Indiana.

FIGURE 2.28 Total Precipitation Over the High-Density Network for the April 22&23 Storm. Right Side Shows Precipitation Amounts (mm) at Each Network Site. Left Side Shows Contours of the Data (contour levels every 3 mm).

FIGURE 2.29 Precipitation Over the High-Density Network from 1700 GMT to 2300 GMT, April 22. Right Side Shows Precipitation Amounts (mm) at Each Network Site. Left Side Shows Contours of the Data (contour levels every 3 mm).

FIGURE 2.30. Hourly Precipitation Amounts (mm, T = Trace) Over the High-Density Network for 1700-1800 (left) and 1800-1900 (right) GMT, April 22.

FIGURE 2.31. Hourly Precipitation Amounts (mm, T = Trace) Over the High-Density Network for 1900 - 2000 (left) and 2000 - 2100 (right) GMT, April 22.

FIGURE 2.32. Hourly Precipitation Amounts (mm, T = Trace) Over the High-Density Network for 2100 - 2200 (left) and 2000 - 2100 (right) GMT, April 22.

FIGURE 2.33. Hourly Precipitation Amounts (mm, T = trace) Over the High-Density Network for 2300 - 0000 (left) and 0000 - 0100 (right) GMT, April 22.

FIGURE 2.34. Hourly Precipitation Amounts (mm, T = trace) Over the High-Density Network for 0100 - 0200 (left) and 0200 - 0300 (right) GMT, April 22.

FIGURE 2.35. Hourly Precipitation Amounts (mm, T = trace) Over the High-Density Network for 0300 - 0400 (left) and 0400 - 0500 GMT, April 23.

FIGURE 2.36. Hourly Precipitation Amounts (mm, T = trace) Over the High-Density Network for 0500 - 0600 (left) and 0600 - 0700 (right) GMT, April 23.

FIGURE 2.37. Composite of Four 24-hour Back Trajectories From Fort Wayne at 305 m (1000 ft) AGL. April 22-23, 1981.

FIGURE 2.38. Composite of Two 24-hour Back Trajectories From Fort Wayne at 850 mb. April 22-23, 1981.

SECTION 3

PRECIPITATION CHEMISTRY DATA

Precipitation samples for chemical analysis were collected at the 47 sites of the OSCAR intensive network as shown in Figure 1.2. Each site was outfitted with a standard weighing rain gauge and an automatic sequential bulk collector (ASBC). Details on collector design and construction and of sampling and handling procedures may be found in the overview report⁽¹⁾. The ASBC consisted of a 1000 cm² funnel, tubing, and a box containing a manifold of nine collector bottles, or stages. As precipitation occurred, the stages filled in sequence, and, except for the last stage (which was allowed to overflow if necessary), were sealed by hollow floating balls. The first eight stages each contained 67 ml of sample, so that the precipitation amount was constant, about 0.7 mm. The ninth stage was much larger (1130 ml), giving a total rainfall capacity of 16.7 mm. All sample contact surfaces in the collector were polyethylene or polystyrene.

Since the ASBC funnels were not automatically exposed, the collectors were deployed as close as possible to the predicted onset of precipitation so as to minimize dry deposition. In the case of event 4, the prerainfall exposure time averaged 4.4 hours.

Soon after the event, the collectors were returned to the central staging area and the stages separated, identified, sealed, and stored at refrigerator temperature. The samples were shipped by air freight to the PNL precipitation chemistry laboratory for chemical analysis. The event 4 samples arrived at the laboratory within a few days of the storm.

Complete location, rainfall, and chemical analysis results for each site are listed in Appendix A. An examination of the chemical stability of the samples during the period of analysis is presented in

Appendix B. The following subsections describe the chemical and rainfall results graphically and statistically.

INDIVIDUAL SITE DATA

Figures 3.1 through 3.3 show, for all sites, concentrations of the major ionic species (SO_4^{--} , H^+ (from pH), NO_3^- , NH_4^+ , Ca^{++}) and rainfall rate versus stage number. Each figure shows results from sites in each north-south "column" of sites (see Figure 1.2). The rainfall rates are stage averages, using stage start and end times derived from the stage volumes and rain gauge chart records.

Figures 3.4 through 3.6 show the same concentration and rainfall data, but plotted versus time (on the dates April 22-23, 1981). The concentrations are still stage averages, but now the horizontal lengths of the segments reflect the actual time taken for the stages to fill. The rainfall rates here are not stage averages, but are real-time rates determined from rain gauge chart records. Thus the time segments of the rainfall rate curves (plotted within Figures 3.5a-g) do not necessarily coincide with those of the concentrations.

These two groups of figures show the trends of chemistry and rainfall through the course of the event, but in slightly different ways. The stage plots show changes with increasing rainfall amount in constant increments (up to stage 9), while the time plots demonstrate time and rainfall rate trends and the time span of precipitation for each site.

One can note considerable variation in concentrations of the major species at the start of the event. This is a strong indication that some of the sites were affected by local sources of scavenged or dry-deposited material, particularly Ca^{++} and NH_4^+ . It is not surprising to find this effect in the study area, an agricultural region, during a season when many fields were bare. Blowing dust and organic decay products could easily account for the increased Ca^{++} and NH_4^+ at certain sites. Since these species contribute to neutralization of acid

solutions, the free H^+ is reduced at the same locations. These conditions, which with few exceptions affect the stage 1 chemistry only, are apparent in many of the following data displays.

Although the stage 1 acidity, Ca^{++} and NH_4^+ show much variation, this is not apparent for sulfate and nitrate, implying that these strong acid anions did not originate from local sources.

Another factor contributing to early event spatial variation was the large range of rainfall rates which accompanied the onset of precipitation. High rainfall rates would be expected to result in more dilute solutions of any scavenged local source material; this effect would be expected to stretch over several of the fixed-volume stages. However, scavenging efficiency may well increase along with increasing rainfall rate, both for below-cloud scavenging of local material and in-cloud scavenging of species from more distant sources. A factor that should also be considered is the near certainty that material dry-deposited on the funnels prior to rainfall was delivered to the first stage only.

Although not a serious problem for evaluating the scavenging of long-range-transported acidic materials, the large range of rainfall rates and apparent local source effects may confound attempts to study the spatial pattern of chemistry over the network for this event. Analysis of the other storms of the series may shed some light on whether these complications are general or particular to event 4.

SPATIALLY AVERAGED DATA

Figures 3.7 through 3.9 show volume-weighted concentrations for the stages, averaged over all the active sites. These concentrations, C_j , were calculated using

$$C_j = \frac{\sum_i C_{ji} V_{ji}}{\sum_i V_{ji}} \quad (3.1)$$

where i = site number

j = stage number

c_{ji} = corresponding species concentrations
 v_{ji} = stage rain volumes.

The weighted averages, incidentally, are the same as the arithmetic averages for all stages except the "last" stage (usually the ninth) since all the volumes are the same.

Figures 3.10 through 3.12 are corresponding plots showing spatially averaged major ion concentrations and precipitation rate versus time. The averages are calculated using

$$c(t') = \frac{\sum_i \bar{c}_i(t') \bar{r}_i(t')}{\sum_i \bar{r}_i(t')} \quad (3.2)$$

where $\bar{c}_i(t')$ = concentration of the species at site i and time t'
 $\bar{r}_i(t')$ = precipitation rate at site i and time t'

The overbar indicates that 0.05 hr. time averages of the $\bar{c}_i$ and $\bar{r}_i$ were used in the calculations. The time t' used in the averaging is time from the onset of precipitation at each site.

Several general features, apparent when considering individual sites, become clearer when spatial averages are computed. The relationships among species concentrations are relatively steady with time, except at the beginning of the event. In particular, neutralization by increased ammonium and calcium at the beginning affected the sulfate- and nitrate-hydrogen ion relationships. On the average, the rainfall rate decreased through the event, and concentrations decreased as well to about the middle stage. It appears that the negative correlation between rainfall rate and concentration, normally observed for a number of whole event data points, does not apply to stages of this event. As a particular event progresses, the chemistry results from a combination of various factors: changes in scavenging efficiency, depletion of pollutant, and incursions of differently-polluted air, as well as dilution and evaporation.

There is a clear indication of increasing concentrations at the end of the event in the much larger capacity ninth stage (which also took a longer time to fill). The results for this stage, and for the latter hour or so of the time history of the spatial coverage, are difficult to interpret because of the large spatial variability of rainfall rate, and the likelihood that new, unscavenged air began to affect a portion of the network. It is interesting to note that Ca^{++} does not increase at the end, while NH_4^+ does. The calcium probably does not recover because the dust is well settled. The source of the increased ammonium is not clear, but it apparently does not contribute to any neutralization, as it may have at the start of the events.

Figures 3.13 through 3.15 show ratios of selected species for site-composite stages. Of particular note is the general increase of the sulfate/nitrate ratio with time, up to near the end of the event, which may indicate a change in the relative importance of removal mechanisms during the event.

Simple statistics for single stages and all stages combined are listed in Table 3.1. The number of sites, N, is less than 47 for the single stage statistics and less than 423 for the combined statistics because of missing values for certain species (see Appendix A for reasons for missing values), and because some sites had less than 9 stages of rainfall (see Figure 3.1). Listed are minima, maxima, arithmetic means and standard deviations and geometric means and standard deviations for concentrations. Stages 3 through 8 are not listed because the results for these stages follow the general trends shown by the preceding figures, and the statistical variability exhibited by stage 2. Stage 1 and 9 statistics reflect the event beginning and ending situations discussed above. In particular, H^+ , NH_4^+ , Ca^{++} and Mg^{++} show considerable scatter in stage 1, while the strong acidic anions are as well behaved as in later stages. The stage 9 values have lower variances probably because of the much larger averaging time resulting from the large stage volume and the lower likelihood of dryfall contamination. The "ALL" row does not show this feature because the treatment of all the sites includes all the stages,

TABLE 3.1. OSCAR High-Density Network Event 4 Statistics for Single Stages and All Stages Combined. Units Are: $\mu\text{mho/cm}$ for Conductivity; $\mu\text{eq/L}$ for H^+ , Anion Sum, and Cation Sum; $\mu\text{mol/L}$ for All Other Species.

Species	Stage	N	Min	Max	Arithmetic		Geometric	
					Mean	S.D.	Mean	S.D.
SO_4^{--}	1	42	22.0	150.0	94.3	27.4	89.6	1.4
	2	45	21.0	120.0	49.8	23.7	45.3	1.5
	9	25	12.0	69.0	41.2	15.0	38.3	1.5
	ALL	331	7.3	150.0	45.1	27.4	34.4	1.8
NO_2^-	1	24	0.1	1.2	0.3	0.3	0.2	2.1
	2	23	0.1	0.4	0.2	0.1	0.1	1.5
	9	12	0.1	0.3	0.2	0.1	0.2	1.5
	ALL	174	0.1	1.2	0.2	0.1	0.1	1.6
NO_3^-	1	42	15.0	110.0	72.1	20.7	68.6	1.4
	2	45	12.0	110.0	37.3	22.0	32.7	1.6
	9	25	6.4	62.0	27.5	16.3	23.1	1.8
	ALL	331	3.5	110.0	28.2	23.2	21.5	2.0
Cl^-	1	42	4.1	23.0	10.1	3.5	9.6	1.4
	2	45	1.9	37.0	5.9	5.5	4.9	1.8
	9	25	1.0	9.4	3.6	1.8	3.3	1.6
	ALL	330	0.7	37.0	4.3	3.6	3.4	1.9
Anion Sum	1	42	63.2	424.0	271.0	75.7	258.5	1.4
	2	45	56.7	363.0	142.9	70.9	129.3	1.5
	9	25	33.0	196.6	113.6	46.8	103.9	1.5
	ALL	331	19.5	424.0	114.7	80.2	94.6	1.8
Conductivity	1	42	10.0	100.0	58.5	19.2	54.7	1.5
	2	43	13.0	110.0	40.1	21.0	35.6	1.6
	9	23	11.0	60.0	32.3	12.0	30.2	1.5
	ALL	322	5.0	110.0	31.9	18.1	27.8	1.7
H^+	1	42	0.6	177.8	88.2	45.3	68.4	2.7
	2	44	12.9	229.1	73.3	44.3	62.0	1.8
	9	25	22.9	104.7	58.8	22.1	54.9	1.5
	ALL	327	0.5	229.1	57.3	33.5	48.6	1.9
NH_4^+	1	42	12.0	100.0	61.2	18.8	57.6	1.5
	2	45	2.5	66.0	26.7	15.8	22.1	1.9
	9	25	1.7	76.0	30.7	21.2	23.1	2.4
	ALL	325	0.5	120.0	23.0	22.6	13.8	3.0
Na^+	1	42	0.6	17.0	5.9	2.7	5.3	1.6
	2	45	0.6	36.0	3.0	5.2	2.0	2.2
	9	25	0.3	4.3	1.9	1.0	1.6	1.3
	ALL	297	0.3	36.0	2.1	3.0	1.4	2.4
Ca^{++}	1	42	10.0	63.0	29.0	11.9	26.7	1.5
	2	45	2.2	24.0	10.1	5.4	8.8	1.7
	9	25	1.0	12.0	3.9	3.0	3.2	1.3
	ALL	330	0.8	63.0	8.1	9.8	5.0	2.5
Mg^{++}	1	42	2.8	31.0	12.3	7.6	10.1	1.9
	2	45	0.7	13.0	4.2	3.2	3.1	2.2
	9	25	0.4	8.8	2.1	2.1	1.5	2.1
	ALL	322	0.4	31.0	3.5	4.8	2.0	2.7
Cation Sum	1	42	53.8	357.6	240.7	60.3	231.3	1.4
	2	44	50.9	317.4	131.8	61.9	120.1	1.5
	9	25	29.8	191.0	104.4	41.3	96.3	1.5
	ALL	330	11.3	357.6	104.8	70.4	86.6	1.8

TABLE 3.2. OSCAR High-Density Network Event 4 Statistics for Site Event Data. Chem Coverage is the Fraction of the Precipitation for Which Chemistry Data for the Corresponding Species was Available. Sites With Chem Coverage Less Than 0.80 Were not Included in the Statistics. N is the Number of Sites Used for Each Statistic. Units for Other Statistics Are: mm for Precipitation, $\mu\text{mho/cm}$ for Conductivity; $\mu\text{eq/L}$ for H^+ , Anion Sum, and Cation Sum; $\mu\text{mol/L}$ for Other Species.

Species	N	Min	Max	Arithmetic		Geometric		Chem Coverage	
				Mean	S.D.	Mean	S.D.	Mean	S.D.
Precip	46	1.3	17.1	7.9	3.6	7.1	1.7		
Conduc.	43	15.6	74.0	33.9	11.3	32.3	1.4	0.96	0.13
SO_4^{--}	44	18.7	96.5	44.6	15.0	42.5	1.4	0.98	0.09
NO_3^-	44	11.0	65.0	30.7	11.2	28.8	1.4	0.98	0.09
Cl^-	44	2.0	25.5	4.8	3.5	4.3	1.6	0.98	0.09
An. Sum	44	51.3	283.5	124.8	43.6	118.5	1.4	0.98	0.09
H^+	43	28.2	138.1	61.2	23.2	57.5	1.4	0.96	0.12
NH_4^+	43	5.3	51.5	26.2	11.3	23.8	1.6	0.96	0.14
Na^+	43	1.0	22.1	2.5	3.2	1.9	1.7	0.96	0.14
Ca^{++}	43	3.1	23.5	8.3	4.7	7.3	1.6	0.97	0.10
Mg^{++}	44	0.9	9.0	3.4	2.3	2.8	1.9	0.98	0.09
Cat. Sum	43	44.5	233.8	111.3	34.3	106.4	1.4	0.97	0.12

rather than the composites of all the stages for each site. The ratio of the arithmetic standard deviation to the arithmetic mean--the coefficient of variation--for the five major species averages 0.85 for the larger data set, whereas the average for the collection of event-weighted averages for sites is 0.43. No doubt the increased variance when all stages are included follows because a stage at one site does not correspond to the same numbered stage at another site, due to the complicated motions and rainfall variations within the storm. A much more sophisticated statistical analysis would be required to coordinate the stages, if indeed this is possible for this event.

Similar statistical calculations were performed on the event average (volume-weighted mean of all stages) concentration data; the results of these are listed in Table 3.2. Since some stage (or all stage) concentrations from certain sites are missing for various reasons (see Appendix A), those sites whose event average for a species represents less than 80% of the total precipitation collected at the sites were not included in the summary statistics. The average fraction of the total precipitation represented by the averages for each species is listed as "chem coverage."

SCATTER PLOTS AND SPECIES CORRELATIONS

To demonstrate the relationships among species concentrations for individual observations, scatter plots are shown for the major species in Figures 3.16 through 3.19. Presented are plots for stage 1, stage 2, and all stages combined from all sites. The regression relationships shown differ greatly between stages 1 and 2, but for stages following stage 1, they are quite uniform. Figures 3.20 through 3.23 are plots of weighted average concentrations (cf. eq. 3.1) for each stage including all sites. The stage numbers are shown as the data points exhibiting the trend of the relationships with accumulated rainfall during the event.

The scatter is quite large for stage 1 for the species pairs including H^+ and NH_4^+ . Stage 1 in these cases contributes essentially all the outliers to the all-stage plots. Sulfate and nitrate, however, have strong positive correlations for all stages, possibly reflecting their common long-range sources. The relationship between the two does change as the event progresses, however, as was seen in the ratio Figure 3.15. The site-composite plots for the stages include considerable smoothing of the variations over the sites, and demonstrate the strong positive correlations among the major species that are normally observed for multiple events at one site. These plots also show that gross spatial variations in species relationships were not a feature of this event.

SPATIAL DISTRIBUTIONS

In this subsection, the precipitation chemistry data for the April 22-23 storm are examined for spatial patterns in the concentration or deposition. The location of the high-density network in northeastern Indiana was largely chosen because of the absence of strong pollutant sources on or near the network, with the hope that wet deposition would be relatively uniform across the network. The figures of this subsection demonstrate that this was largely the case for this storm event. Although the aircraft air chemistry measurements (presented in Section 4) show spatial patterns for some of the important pollutants over the network area, these appear to have had little effect on the wet deposition, at least on scales discernable with the high-density network's site spacing.

Figures 3.24 through 3.28 show the spatial distributions of total sulfur, NO_3^{--} , H^+ , NH_4 and Ca^{++} concentrations over the network for the entire storm event. The only really noticeable structure in the data are the somewhat higher concentrations in the southeastern corner of the network. This particular portion of the network received significantly lower rainfall for the event than the rest of the network (see Figure 2.27), and these higher concentrations are typical of the usual inverse relation between scavenging ratio and precipitation. The spatial distributions of event total deposition for the same five species are shown in Figures 3.29 through 3.33. The patterns in the deposition are in fact somewhat reversed from the concentration patterns and is apparently are dominated by the precipitation amounts. The high depositions along the northern boundary of the network largely reflect the additional precipitation these sites received after 0400 GMT, April 23.

Figures 3.34 through 3.38 show the spatial distributions of the same five ions in the first collector stage. Although the data exhibit significant variability, any patterns in the distributions are much less pronounced than in the total event data. This variability is not too

surprising in view of the convective activity associated with the event. The network spacing of 15 to 20 km between sites is greater than the typical horizontal dimension of convective cells; therefore, variability in the wet deposition caused by meteorological and microphysical processes could be expected to appear as "noise" in the data.

[Note: the contour lines shown in Figures 3.24 - 3.38 were drawn by a relatively unsophisticated contouring algorithm that utilized a simple $1/r^3$ weighting to interpolate between the sites. The contours have been presented primarily to display any dominant spatial patterns in the data (or lack of them) and are not intended to be a rigorous analysis of the spatial distributions of the data.]

FIGURE 3.1. Sulfate and H^+ (From pH) vs. Stage Number.
a) - g) Show Site Columns, North-South, as
Defined by Figure 1.2.

FIGURE 3.1a

FIGURE 3.1b

FIGURE 3.1c

FIGURE 3.1d

FIGURE 3.1e

FIGURE 3.1f.

FIGURE 3.1g.

FIGURE 3.2. Precipitation Rate and Nitrate vs. Stage Number.
a) - g) Show Site Columns, North-South, as
Defined by Figure 1.2.

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The following information is for your information only.
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FIGURE 3.2a.

FIGURE 3.2b.

FIGURE 3.2c.

FIGURE 3.2d.

FIGURE 3.2e.

FIGURE 3.2f.

FIGURE 3.2g.

FIGURE 3.3. Ammonium and Calcium vs. Stage Number. a) - g)
Show Site Columns, North-South, as Defined by
Figure 1.2.

FIGURE 2.13. A comparison of the
growth of the two species in the
field.

FIGURE 3.3a.

FIGURE 3.3b.

FIGURE 3.3c.

FIGURE 3.3d.

FIGURE 3.3e.

FIGURE 3.3f.

FIGURE 3.3g.

Figure 3A

FIGURE 3.4. Sulfate and H^+ (From pH) vs. Time (April 22, 1981).
a) - g) Show Site Columns, North-South, as Defined
by Figure 1.2.

FIGURE 3.4a.

FIGURE 3.4b.

FIGURE 3.4c.

FIGURE 3.4d.

FIGURE 3.4e.

FIGURE 3.4f.

FIGURE 3.4q.

FIGURE 3.5. Precipitation Rate and Nitrate vs. Time (April 22, 1981). a) - g) Show Site Columns, North-South, as Defined by Figure 1.2.

FIGURE 8.2. Precipitation Rate and Site vs. Time (April 22, 1981 - May 1, 1981). Data from the North-South, as defined by Figure 1.2.

FIGURE 3.5a.

FIGURE 3.5b.

FIGURE 3.5c.

FIGURE 3.5d.

FIGURE 3.5e.

FIGURE 3.5f.

FIGURE 3.5g.

FIGURE 3.6. Ammonium and Calcium vs. Time (April 22, 1981).
a) - g) Show Site Columns, North-South, as
Defined by Figure 1.2.

FIGURE 3.6a.

FIGURE 3.6b.

FIGURE 3.6c.

FIGURE 3.6d.

FIGURE 3.6e.

FIGURE 3.6f.

FIGURE 3.6g.

FIGURE 3.7. All-Site (Spatial) Volume-Weighted Average H⁺ (From pH) and Sulfate vs. Stage Number.

FIGURE 3.8 All-Site (Spatial) Volume-Weighted Average for Precipitation Rate and Nitrate vs. Stage Number.

FIGURE 3.9. All-Site (Spatial) Volume-Weighted Average for Ammonium and Calcium vs. Stage Number

FIGURE 3.10. All-Site (Spatial) Volume-Weighted Average for H^+ (From pH) and Sulfate vs. Time. (See Equation 3.2)

FIGURE 3.11. All-Site (Spatial) Volume-Weighted Average for Precipitation Rate and Nitrate vs. Time. (See Equation 3.2)

FIGURE 3.12. All-Site (Spatial) Volume-Weighted Average for Ammonium and Calcium vs. Time. (See Equation 3.2)

FIGURE 3.13. Sulfate/Ammonium Ratio vs. Stage Number. Data From Figures 3.7 and 3.9.

Figure 3.14. Nitrate/Ammonium Ratio vs. Stage Number.
Data from Figures 3.8 and 3.9.

FIGURE 3.15. Sulfate/Nitrate Ratio v. Stage Number.
Data From Figures 3.7 and 3.8.

FIGURE 3.16. Species-Pair Plots for Sulfate and H^+ (From pH).

FIGURE 3.16a.

FIGURE 3.16b.

FIGURE 3.16c.

FIGURE 3.17. Species-Pair Plots for Nitrate and Sulfate.

FIGURE 1. Spectroscopic data for nitrate and sulfate.

FIGURE 3.17a.

FIGURE 3.17b.

FIGURE 3.17c.

FIGURE 3.18. Species-Pair Plots for Nitrate and H^+ (From pH).

FIGURE 2.10 - Spectral density of the process $X(t)$ (see text)

FIGURE 3.18a.

FIGURE 3.18b.

FIGURE 3.18c.

FIGURE 3.19. Species-Pair Plots for Sulfate and Ammonium.

FIGURE 3.19a.

FIGURE 3.19b.

FIGURE 3.19c.

FIGURE 3.20. Weighted Stage Averages for All Sites for Sulfate and H^+ (From pH). Data Points are Stage Numbers.

FIGURE 3.21. Weighted Stage Averages for All Sites for Nitrate and Sulfate. Data Points are Stage Numbers.

FIGURE 3.22. Weighted Stage Averages for All Sites for Nitrate and H^+ (From pH). Data Points are Stage Numbers.

FIGURE 3.23. Weighted Stage Averages for All Sites for Sulfate and Ammonium. Data Points are Stage Numbers.

FIGURE 3.24. Spatial Distribution of Event SO_4^{--} Concentration Across the Network. Right-Hand Side Shows Concentration in $\mu\text{mol/l}$ (x's Indicate Sites With Missing or Incomplete Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $15 \mu\text{mol/l}$).

FIGURE 3.25. Spatial Distribution of Event NO_3^- Concentration Across the Network. Right-Hand Side Shows NO_3^- Concentration in $\mu\text{mol}/\ell$ (x's Indicate Sites With Missing or Incomplete Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $10 \mu\text{mol}/\ell$).

FIGURE 3.27. Spatial Distribution of Event NH_4^+ Concentration Across the Network. Right-Hand Side Shows Concentration in $\mu\text{mol}/\ell$ (x's Indicate Sites With Missing or Incomplete Data). Left-Hand Side Shows the Data Contoured (Contour Interval = 10 $\mu\text{mol}/\ell$).

FIGURE 3.28. Spatial Distribution of Event Ca^{++} Concentration Across the Network. Right-Hand Side Shows Concentration in $\mu\text{mol}/\ell$ (x's Indicate Sites With Missing or Incomplete Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $5 \mu\text{mol}/\ell$).

FIGURE 3.29. Spatial Distribution of Event SO_4^{--} Deposition Across the Network. Right-Hand Side Shows Deposition in $\mu\text{mol/m}^2$ (x's Indicate Sites With Missing or Incomplete Data). Left-Hand Side Shows the Data Contoured (Contour Interval = 100 $\mu\text{mol/m}^2$).

FIGURE 3.30. Spatial Distribution of Event NO_3^- Deposition Across the Network. Right-Hand Side Shows Deposition in $\mu\text{mol}/\text{m}^2$ (x's Indicate Sites With Missing or Incomplete Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $100 \mu\text{mol}/\text{m}^2$).

FIGURE 3.31. Spatial Distribution of Event H^+ Deposition Across the Network. Right-Hand Side Shows Deposition in $\mu\text{mol}/\text{m}^2$ (x's Indicate Sites With Missing or Incomplete Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $200 \mu\text{mol}/\text{m}^2$).

FIGURE 3.32. Spatial Distribution of Event NH_4^+ Deposition Across the Network. Right-Hand Side Shows Deposition in $\mu\text{mol}/\text{m}^2$ (x's Indicate Sites With Missing or Incomplete Data). Left-Hand Side Shows the Data Contoured (Contour Interval = 25 $\mu\text{mol}/\text{m}^2$).

FIGURE 3.33. Spatial Distribution of Event Ca^{++} Deposition Across the Network. Right-Hand Side Shows Deposition in $\mu\text{mol}/\text{m}^2$ (x's Indicate Sites With Missing or Incomplete Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $25 \mu\text{mol}/\text{m}^2$).

FIGURE 3.34. Spatial Distribution of First Collector Stage SO_4^{--} Concentration Across the Network. Right-Hand Shows Concentration in $\mu\text{mol}/\ell$ (x's Indicate Sites With Missing Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $25 \mu\text{mol}/\ell$).

FIGURE 3.35. Spatial Distribution of First Collector Stage NO_3^- Concentration Across the Network. Right-Hand Side Shows Concentration in $\mu\text{mol}/\ell$ (x's Indicate Sites With Missing Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $25 \mu\text{mol}/\ell$).

FIGURE 3.36. Spatial Distribution of First Collector Stage H^+ Concentration Across the Network. Right-Hand Side Shows Concentration in $\mu\text{mol}/\ell$ (x's Indicate Sites With Missing Data). Left-Hand Side Shows the Data Contoured (Contour Interval = 40 $\mu\text{mol}/\ell$).

FIGURE 3.37. Spatial Distribution of First Collector Stage NH_4^+ Concentration Across the Network. Right-Hand Side Shows Concentration in $\mu\text{mol}/\ell$ (x's Indicate Sites With Missing Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $20 \mu\text{mol}/\ell$).

FIGURE 3.38. Spatial Distribution of First Collector Stage CA^{++} Concentration Across the Network. Right-Hand Side Shows Concentration in $\mu\text{mol}/\ell$ (x's Indicate Sites With Missing Data). Left-Hand Side Shows the Data Contoured (Contour Interval = $10 \mu\text{mol}/\ell$).

SECTION 4

AIRCRAFT DATA

During the April 22-23 storm event, three aircraft made sampling flights over or near the high-density network: the PNL Douglas DC3, the PNL Cessna 411, and the BNL Islander. The aircraft and their sampling instrumentation are described in the OSCAR overview report⁽¹⁾. The aircraft were utilized for two types of sampling: first, to measure trace gas and aerosol concentrations in low level inflow areas of the storm, and second, to collect cloud water samples in the storm for chemical analysis (only the DC3 performed in-cloud sampling).

The DC3 made two sampling flights on April 22. On the first flight (1440 to 1710 GMT), in-cloud sampling was performed during the initial portion of the flight, followed by clear-air sampling during the latter portion. On the second flight (1955 to 2250 GMT), only in-cloud sampling was done. (For reference, precipitation began on the western portion of the network at about 1900 GMT.) The Cessna 411 performed two clear-air sampling flights, from 0900 to 1100 GMT and 1725 to 1810 GMT. The BNL Islander made a clear-air sampling flight between 1530 and 1800 GMT before moving east to sample over other portions of the intermediate density network. On this flight, the Islander sampled first about 30 km south of the high-density network, then 60 km southeast and east of the network. The Islander's data are being reported elsewhere⁽²⁾.

CLEAR AIR DATA

Most of the important clear-air measurements aboard the aircraft involved filters (for aerosols, SO_2 , and HNO_3) or real-time, trace-gas analyzers (for SO_2 , O_3 , and NO_x). On the April 22 flights, the DC3 collected one set of filter samples on its first flight, and the Cessna collected one set on each of its flights. The data from these filter samples, along with data from the operational real-time instruments (averaged over the filter collection periods), are presented in Table 4.1. The aircraft flight tracks during this sampling are shown in Figure 4.1.

TABLE 4.1. Summary of Clear Air Measurements by Cessna and DC3 on April 22.

Aircraft:	Cessna	Cessna	DC3
Sampling Period (GMT):	1416-1526	1744-1805	1709-1800
Altitude (m MSL):	660	740	850
Temperature (C):	10	10	11
Relative Humidity (%):	80	87	92
<u>Filter Pack Measurements:</u>			
H ⁺ ($\mu\text{g}/\text{m}^3$ as H ₂ SO ₄):	0.9	0.7	2.1
($\mu\text{mol}/\text{m}^3$):	0.009	0.007	0.021
NH ₄ ⁺ ($\mu\text{g}/\text{m}^3$):	1.3	1.9	1.4
($\mu\text{mol}/\text{m}^3$):	0.074	0.10	0.078
NO ₃ ⁻ ($\mu\text{g}/\text{m}^3$):	6.2	0.3	0.0
($\mu\text{mol}/\text{m}^3$):	0.099	0.005	0.0
HNO ₃ ($\mu\text{g}/\text{m}^3$):	8.7	6.1	2.7
($\mu\text{mol}/\text{m}^3$):	0.14	0.098	0.044
SO ₄ ⁻⁻ ($\mu\text{g}/\text{m}^3$):	4.4	4.1	6.0
($\mu\text{mol}/\text{m}^3$):	0.046	0.043	0.063
SO ₂ ($\mu\text{g}/\text{m}^3$):	37.0	25.0	11.0
($\mu\text{mol}/\text{m}^3$):	0.58	0.38	0.18
<u>Real-Time Measurements*:</u>			
SO ₂ (ppb):	23.0	18.00	--
($\mu\text{mol}/\text{m}^3$):	0.92	0.69	--
NO _x (ppb):	--	--	1.9
($\mu\text{mol}/\text{m}^3$):	--	--	0.074
O ₃ (ppb):	73.0	77.0	70.0
b _{scat} (10 ⁻⁴ m ⁻¹):	0.5	0.7	0.5
CNC ⁺ (cm ⁻³):	--	--	3900

* Measurements were averaged over the filter collections period. Averages may not correspond exactly to the filter data because of sections of missing data or calibration checks.

+ Condensation or Aitken nuclei.

Real-time measurements made aboard the Cessna during the filter collection on its first flight are shown in Figures 4.2a, b, and c. The flight was made north and west of Fort Wayne, and winds at the sampling elevation were predominantly from the south. The data show considerable variation in SO_2 on distance scales of 10-20 km. (At the aircraft speed of 70-75 m/s, a one minute interval corresponds to a distance of roughly 4 km).

Real-time measurements during the Cessna's second flight are shown in Figures 4.3a and b. At this time, winds at the sampling elevation were more from the southwest. The area of high SO_2 concentration at the start of the sampling period (Figure 4.3a) may correspond to that seen on the earlier flight (Figure 4.2b, 1457-1500 GMT).

Real-time measurements made aboard the DC3 during the filter collection on its first flight are shown in Figures 4.4a, b, and c. As seen in Figure 4.1, the DC3 made repeated traverses over the south-central portion of the network during this sampling. Each time segment in Figure 4.4a, b, and c corresponds to a west-to-east then east-to-west leg along the flight track. The region of higher NO_x concentrations shown in the center of each of these plots corresponds to the eastern portions of the aircraft's flight track.

IN CLOUD DATA

Cloud water samples were collected aboard the DC3 on both its first and second flights. Data for these sample are summarized in Table 4.2. During the first flight, three sets of samples were obtained at altitudes of 1850 m, 2350 m, and 1880 m. (The aircraft had three warm cloud water collectors so could collect three samples simultaneously.) The aircraft flight tracks during the sample collection are shown in Figure 4.5. The sampling was to the southeast of Fort Wayne, and all three sets of samples were collected in approximately the same area. During the second flight, two sets of samples were collected at 3200 and 3600 m. An attempt was made to collect a third set of samples, also at 3600 m, but insufficient water was collected at this position. The aircraft flight tracks during cloud water sampling on the second flight are shown on Figure 4.6.

The data in Table 4.2 indicate a significantly different chemistry between the samples collected on the first flight (below 2500 m) and on the second flight (above 2500 m). In the lower altitude samples, ion concentrations are higher, and SO_4^{--} and NO_3^- dominate the cations. In the higher altitude samples, ion concentration is generally lower, and SO_4^{--} and NO_3^- are of the same magnitude (or smaller) as Cl^- and Na^+ . This suggests that the lower and higher altitude samples came from considerably different air masses, which is not surprising since the meteorological analyses (Section 2) indicate a frontal surface at about 2000 m over the network.

TABLE 4.2. Cloud Water Samples Collected on April 22 by the PNL DC3.

Collection Time (GMT)	Alt. (m)	Temp. (C)	Liq. Water (g/m ³)	Sample Vol. (ml)	pH	Cond	Ion Bal.	SO ₄ ⁻⁻	NO ₃ ⁻	Cl ⁻	Anion Sum	H ⁺	NH ₄ ⁺	Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Cation Sum
1517-1546	1850	5	.25	11.	ISA	ISA	ISA	43.0	15.0	2.5	103.5	ISA	31.0	2.2	1.6	4.7	1.5	ISA
1517-1546	1850	5	.25	8.4	ISA	ISA	ISA	46.0	16.0	2.5	110.5	ISA	33.0	3.6	1.2	4.5	1.9	ISA
1522-1546	1840	5	.28	15.	ISA	ISA	ISA	45.0	17.0	2.2	109.2	ISA	32.0	2.4	0.7	4.4	1.5	ISA
1557-1608	2350	2	.62	21.	4.63	ISA	0.19	12.0	6.3	2.0	32.3	23.4	13.0	0.5	<0.4	1.0	<0.4	38.9
1557-1609	2350	2	.61	14.	4.72	ISA	-0.20	16.0	8.3	2.5	42.8	19.1	14.0	0.8	1.1	ISA	ISA	35.0
1558-1610	2350	2	.59	32.	4.75	8.5	0.03	12.0	6.0	2.2	32.3	17.8	12.0	0.8	0.8	0.9	<0.4	33.3
1609-1625	1880	5	.36	26.	ISA	ISA	ISA	29.0	15.0	3.0	76.0	ISA	27.0	1.0	<0.4	1.5	<0.4	ISA
1609-1625	1880	5	.36	10.	ISA	ISA	ISA	37.0	19.0	3.3	96.3	ISA	31.0	2.2	0.9	1.9	0.4	ISA
1610-1625	1850	5	.37	22.	4.30	ISA	-0.01	32.0	17.0	2.9	83.9	50.1	28.0	1.1	<0.4	1.7	0.4	83.4
2058-2116	3200	-1	.14	7.6	ISA	ISA	ISA	2.3	2.7	7.3	14.6	ISA	10.0	6.9	3.7	8.5	1.7	ISA
2100-2120	3220	-1	.13	7.6	ISA	ISA	ISA	3.4	4.3	9.5	20.6	ISA	3.4	7.2	3.5	10.0	2.2	ISA
2141-2200	3650	-3	.03	33.	5.96	ISA	0.71	1.8	1.9	1.8	7.5	1.1	4.8	1.5	1.3	2.8	0.7	15.7
2142-2203	3620	-3	.04	32.	5.92	ISA	0.40	2.0	2.0	2.1	8.1	1.2	1.6	1.4	1.3	2.6	0.7	12.2

Notes:

1. Units, unless noted, are $\mu\text{eq}/\text{L}$ for H^+ , Anion Sum, Cation Sum, and $\mu\text{mol}/\text{L}$ for other species
2. ISA means insufficient sample for the analysis
3. Ion balance is $2 \times (\text{Cations} - \text{Anions}) / (\text{Cations} + \text{Anions})$
4. On all samples, PO_4^{---} was below the detection limit ($0.2 \mu\text{mol}/\text{L}$)
5. The first 9 samples were collected with the warm cloud water collectors; the other 4 samples were collected with the supercooled cloud water collectors.

FIGURE 4.1. Aircraft Flight Tracks for the DC3 and Cessna During Filter Sample Collections On April 22. Dashed Line Shows Cessna Position From 1438 to 1526 GMT (Data for 1416 and 1438 are Missing); Dotted Line Shows Cessna Position for 1744 to 1805 GMT; Solid Line Shows DC3 Position From 1709 to 1800 GMT. Small Squares Show Positions at Start of Each Time Segment. "FWA" is Fort Wayne Airport and the Large (Dashed) Square Outlines the High-Density Network (See Figure 1.2).

FIGURE 4.2a. Real-Time Measurements Aboard the Cessna From 1438 to 1445 GMT on April 22. This Time Segment Corresponds to the Initial NE to SW Leg of the (Dashed) Flight Path Shown in Figure 4.1.

Figure 4.2b. Real-Time Measurements Aboard the Cessna From 1445 to 1511 GMT on April 22. This Time Segment Corresponds to the Long SW to NE Leg of the (Dashed) Flight Path Shown in Figure 4.1.

FIGURE 4.2c. Real-Time Measurements Aboard the Cessna From 1511 to 1526 GMT on April 22. This Time Segment Corresponds to the Final NE to SW Leg of the (Dashed) Flight Path Shown in Figure 4.1.

FIGURE 4.3a. Real-Time Measurements Aboard the Cessna From 1744 to 1758 GMT on April 22. This Time Segment Corresponds to the Initial West to East Leg of the (Dotted) Flight Path Shown in Figure 4.1.

FIGURE 4.3b. Real-Time Measurements Aboard the Cessna From 1758 to 1805 GMT on April 22. This Time Segment Corresponds to the Final East to West Leg of the (Dotted) Flight Path Shown in Figure 4.1.

FIGURE 4.4a. Real-Time Measurements Aboard the DC3 From 1712 to 1726 GMT on April 22.

FIGURE 4.4b. Real-Time Measurements Aboard the DC3 From 1726 to 1741 on April 22.

FIGURE 4.4c. Real-Time Measurements Aboard the DC3 From 1741 to 1800 GMT on April 22.

FIGURE 4.5. Aircraft Flight Tracks for the DC3 During Cloud Water Sample Collections on the First Flight April 22. Dashed Line Shows Position From 1517 to 1546 GMT; Dotted Line Shows Position From 1557 to 1610 GMT; Solid Line Shows Position From 1609 to 1625 GMT. Small Squares Show Positions at Start of Each Time Segment. "FWA" is Fort Wayne Airport and the Large (Dashed) Square Outlines the High-Density Network (See Figure 1.2).

FIGURE 4.6. Aircraft Flight Tracks for the DC3 During Cloud Water Sample Collections On the Second Flight April 22. Solid Line Shows Position From 2058 to 2120 GMT; Dotted Line Shows Position From 2141 to 2203 GMT; Dashed Line Shows Position From 2219 to 2237 GMT. Small Squares Show Positions at Start of Each Time Segment. "FWA" is Fort Wayne Airport and the Large (Dotted) Square Outlines the High-Density Network (See Figure 1.2).

5.0 REFERENCES

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2. Sheih, C. M., S. A. Johnson and F. T. DePaul. "Case Studies of Aerosol Size Distribution and Chemistry During Passages of a Cold and Warm Front". Atmos. Environ., Vol. 17, 1983, pp. 1299-1306.
3. Kok, G. L. Measurements of Hydrogen Peroxide in the OSCAR Program. Report to Coordinating Research Council, Atlanta, Georgia, CAPA-21-80, 1982.

APPENDIX A

DATA TABULATIONS

APPENDIX A

DATA TABULATIONS

Oscar intensive network site locations are shown in Figure 1.2 and detailed in Table A.1.

Complete precipitation chemistry and rainfall data for Event 4 are listed in Table A.2. Each page contains data from one of the 47 sites. The collection efficiency is the total rainfall collected by the sequential collector, divided by the total rainfall measured by the accompanying weighing rain gauge. For sites where the collector overflowed, and thus collection efficiency was impossible to compute, "OVF" is printed. "START" is the day and time of the start of filling of each stage, "DT" is the duration of each stage, and "R-RATE" is the rainfall rate (stage volume/DT). "ION BAL" is the ion balance check, given by

$$(\text{Cation Sum} - \text{Anion Sum})/[0.5(\text{Cation Sum} + \text{Anion Sum})]$$

(difference of ion totals divided by the mean). The AVG figures are volume-weighted averages for all stages (equivalent to the event-average values), calculated using Equation 3.1. Additional codes, generally following those used by the MAP3S Precipitation Chemistry Network, are listed below.

<	Less than detection limit (given)
NAP	No analysis performed
ISA	Insufficient sample for analysis
RPC	Rejected--probable contamination

TABLE A.1: High-Density Precipitation Chemistry Site Positions

<u>Site No.</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Site No.</u>	<u>Latitude</u>	<u>Longitude</u>
11	41.591	85.603	45	41.129	84.862
12	41.639	85.378	46	41.175	84.646
13	41.638	85.199	51	40.995	85.659
14	41.575	85.038	52	41.001	85.423
15	41.561	84.849	53	41.032	85.293
16	41.588	84.720	54	40.966	84.966
21	41.377	85.624	55	40.986	84.817
22	41.430	85.403	56	41.058	84.710
23	41.439	85.194	57	40.929	84.561
24	41.443	85.059	58	41.015	84.391
25	41.394	84.892	61	40.806	85.679
26	41.409	84.701	62	40.844	85.464
27	41.435	84.482	63	40.914	85.231
31	41.276	85.582	64	40.798	85.153
32	41.331	85.464	65	40.791	84.966
33	41.305	85.178	66	40.860	84.756
34	41.306	85.069	67	40.810	84.521
35	41.251	84.859	71	40.663	85.693
36	41.309	84.564	72	40.665	85.466
37	41.338	84.431	73	40.665	85.303
41	41.175	85.645	74	40.668	85.092
42	41.136	85.489	75	40.665	84.858
43	41.143	85.152	76	40.644	84.628
44	41.198	85.019			

TABLE A.2 OSCAR HIGH-DENSITY NETWORK PRECIPITATION CHEMISTRY
AND RAINFALL DATA.

SITE 11

COLLECTION EFFICIENCY = 0VF

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	TOTAL RAINFALL
1	4-22	19.24	0.50	1.31	3.95	70.0	-0.16
2	4-22	19.74	0.26	2.54	4.39	23.0	-0.16
3	4-22	20.00	0.26	2.54	4.55	14.0	-0.10
4	4-22	20.26	0.28	2.36	4.62	12.0	-0.17
5	4-22	20.54	0.28	2.36	4.57	13.0	-0.12
6	4-22	20.82	0.28	2.36	4.56	13.0	-0.15
7	4-22	21.10	0.28	2.36	4.48	15.0	-0.08
8	4-22	21.38	0.28	2.36	4.50	15.0	-0.13
9	4-22	21.66	7.72	1.47	4.28	27.0	-0.10
AVG				1.64	4.31	25.4	-0.11
	S02	S04	N02	N03	CL	P04	AN SUM $\mu\text{EQ/L}$
1	NAP	130.0	0.1	100.0	10.0	<0.2	370.
2	NAP	27.0	0.2	25.0	2.2	<0.2	81.
3	NAP	19.0	0.2	15.0	1.3	<0.2	54.
4	NAP	14.0	0.2	10.0	3.3	<0.2	41.
5	NAP	17.0	0.2	9.0	1.0	<0.2	44.
6	NAP	18.0	0.1	7.9	1.1	<0.2	45.
7	NAP	21.0	0.1	10.0	1.8	<0.2	54.
8	NAP	21.0	0.1	9.8	1.7	<0.2	54.
9	NAP	36.0	0.1	26.0	2.5	<0.2	101.
AVG	--	35.2	0.1	25.2	2.6	--	92.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	112.2	96.0	5.2	2.1	37.0	13.0	316.
2	40.7	2.5	0.7	0.9	8.8	3.6	70.
3	28.2	8.6	0.4	0.7	4.0	1.7	49.
4	24.0	4.9	<0.5	<0.4	2.2	0.9	35.
5	26.9	5.2	0.6	0.5	2.1	0.9	34.
6	27.5	6.1	<0.5	0.5	1.6	0.8	29.
7	33.1	8.8	0.8	0.5	2.2	1.1	50.
8	31.6	8.9	0.6	0.6	1.7	0.9	47.
9	52.5	31.0	1.2	<0.4	2.1	1.0	91.
AVG	40.7	24.7	1.1	0.2	3.8	1.6	88.

TABLE A.2, CONTINUED.

SITE 12

COLLECTION EFFICIENCY = ONE

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAH PH	COND $\mu\text{MHO}/\text{CM}$	TOTAL
1	4-22	17.91	1.08	0.61	3.92	67.0	-0.18
2	4-22	18.99	0.40	1.63	4.46	17.0	-0.16
3	4-22	19.39	0.28	2.35	4.60	14.0	-0.07
4	4-22	19.67	0.28	2.35	4.60	13.0	0.01
5	4-22	19.95	0.28	2.35	4.59	14.0	-0.19
6	4-22	20.23	0.28	2.35	4.57	15.0	-0.09
7	4-22	20.52	0.28	2.35	4.54	16.0	-0.14
8	4-22	20.80	0.28	2.35	4.44	20.0	0.02
9	4-22	21.08	0.09	1.40	4.30	27.0	-0.11
AVG				1.47	4.33	25.4	-0.10
	S02	S04	N02	N03	CL	P04	ANALYSIS GEO/L
1	NAP	120.0	0.2	86.0	9.5	<0.2	334.
2	NAP	28.0	0.1	21.0	3.6	<0.2	81.
3	NAP	16.0	0.2	12.0	1.7	<0.2	46.
4	NAP	13.0	0.1	7.8	2.8	<0.2	37.
5	NAP	16.0	0.1	6.7	1.9	<0.2	41.
6	NAP	18.0	0.1	7.1	1.8	<0.2	45.
7	NAP	20.0	0.1	8.7	1.8	<0.2	51.
8	NAP	24.0	0.1	10.0	2.7	<0.2	61.
9	NAP	31.0	0.1	22.0	2.9	<0.2	87.
AVG	--	31.3	0.1	21.3	3.0	--	87.
	FREE H	NH4	NA	K	CA	MG	CAT ANALYSIS GEO/L
1	120.2	73.0	5.4	<0.4	29.0	12.0	281.
2	34.7	7.9	0.6	0.5	8.2	4.2	69.
3	25.1	2.2	0.6	0.9	4.9	2.0	43.
4	25.1	3.3	<0.5	0.6	2.5	1.5	37.
5	25.7	1.2	<0.5	<0.4	2.3	1.1	30.
6	26.9	3.7	0.6	1.3	2.9	1.4	41.
7	28.8	6.8	0.9	<1.2	2.4	1.3	44.
8	36.3	12.0	2.8	2.8	2.6	1.4	62.
9	50.1	21.0	1.2	<2.3	2.0	0.9	78.
AVG	47.0	18.7	1.3	0.2	3.5	1.6	78.

TABLE A.2, CONTINUED.

SITE 13

COLLECTION EFFICIENCY = 0VF

UNITS ARE UMOL/L UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAB PH	COND (UMHO/CM)	ION BAL.
1	4-22	19.47	0.15	4.50	4.07	67.0	-0.11
2	4-22	19.62	0.20	3.38	4.12	51.0	-0.11
3	4-22	19.81	0.04	14.99	4.27	37.0	-0.07
4	4-22	19.86	0.08	8.53	4.57	20.0	-0.26
5	4-22	19.93	0.26	2.50	4.47	21.0	-0.11
6	4-22	20.20	0.26	2.50	4.48	19.0	-0.16
7	4-22	20.46	0.26	2.50	4.53	16.0	-0.19
8	4-22	20.73	0.26	2.50	4.50	17.0	-0.17
9	4-22	20.99	8.59	1.32	4.12	41.0	-0.14
AVG				1.64	4.18	37.8	-0.14
	SO2	SO4	NO2	NO3	CL	PO4	AM SUM UEG/L
1	NAP	120.0	NAP	74.0	7.4	<0.2	321.
2	NAP	70.0	NAP	51.0	6.6	<0.2	198.
3	NAP	48.0	NAP	42.0	4.8	<0.2	143.
4	NAP	29.0	NAP	19.0	9.0	<0.2	86.
5	NAP	24.0	NAP	16.0	1.5	<0.2	66.
6	NAP	22.0	NAP	15.0	1.6	<0.2	61.
7	NAP	19.0	NAP	13.0	1.9	<0.2	53.
8	NAP	19.0	NAP	13.0	4.3	<0.2	55.
9	NAP	51.0	NAP	44.0	5.0	<0.2	151.
AVG	--	48.7	--	39.7	4.9	--	142.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UEG/L
1	85.1	75.0	4.7	<4.5	44.0	18.0	289.
2	75.9	43.0	3.0	<2.5	20.0	7.7	177.
3	53.7	27.0	1.5	<1.5	19.0	6.6	133.
4	26.9	6.9	0.5	<0.4	11.0	5.1	66.
5	33.9	7.2	0.8	<0.4	6.0	2.4	59.
6	33.1	4.2	<0.5	<0.4	5.0	2.1	52.
7	29.5	4.4	<0.5	<0.4	3.4	1.6	44.
8	31.6	3.3	0.4	<0.4	3.8	1.5	46.
9	75.9	46.0	1.4	<2.0	2.9	1.4	132.
AVG	66.4	38.2	1.4	--	6.4	2.7	124.

TABLE A.2, CONTINUED.

SITE 14

COLLECTION EFFICIENCY = 0.23

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	OT HR	R-RATE MM/HR	LAB PH	COND UMHO/CM	ION BAL	
1	4-22	19.76	1.11	2.58	4.15	47.0	-0.08
2	4-22	20.87	1.25	2.28	4.24	32.0	-0.08
3	4-22	22.12	1.27	2.25	4.11	42.0	-0.07
4	4-22	23.39	6.05	0.47	4.22	34.0	-0.06
5	4-23	5.45	0.26	10.95	4.36	25.0	-0.03
6	4-23	5.71	0.53	5.36	4.15	41.0	-0.05
AVG			1.64	4.20	36.8	-0.06	
	SO2	SO4	NO2	NO3	CL	P04	AM SUM UEQ/L
1	NAP	70.0	<0.1	56.0	4.1	<0.2	204.
2	NAP	40.0	0.2	21.0	2.0	<0.2	103.
3	NAP	48.0	0.2	38.0	2.9	<0.2	137.
4	NAP	38.0	0.2	38.0	3.5	<0.2	118.
5	NAP	27.0	0.2	25.0	4.5	<0.2	88.
6	NAP	45.0	0.2	43.0	3.4	<0.2	137.
AVG	--	44.7	0.1	36.8	4.7	--	131.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UEQ/L
1	70.8	29.0	3.7	3.4	42.0	8.6	188.
2	57.5	31.0	0.9	<0.4	2.2	0.8	95.
3	77.6	40.0	1.6	1.1	2.8	0.9	128.
4	60.3	41.0	2.1	0.6	2.6	0.7	111.
5	43.7	30.0	2.7	3.1	2.5	0.5	86.
6	70.8	48.0	2.0	0.9	3.6	0.7	160.
AVG	63.4	36.5	2.2	1.5	7.6	2.1	123.

TABLE A.2, CONTINUED.

SITE 15

COLLECTION EFFICIENCY = 0.96

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	ION BAL
1	4-22	20.00	0.32	2.18	3.87	85.0	-0.15
2	4-22	20.32	0.32	2.18	3.85	68.0	-0.10
3	4-22	20.64	0.32	2.18	4.28	25.0	-0.11
4	4-22	20.95	0.36	1.92	4.36	23.0	-0.04
5	4-22	21.31	0.45	1.52	4.56	18.0	-0.05
6	4-22	21.76	0.35	1.99	4.56	15.0	-0.10
7	4-22	22.11	0.23	3.05	4.40	21.0	0.02
8	4-22	22.33	0.23	3.05	4.29	28.0	0.00
9	4-22	22.56	8.03	0.74	4.00	56.0	-0.05
AVG				1.08	4.08	46.1	-0.06
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	VAP	140.0	NAP	93.0	10.0	<0.2	383.
2	NAP	82.0	NAP	75.0	7.4	<0.2	246.
3	NAP	31.0	NAP	20.0	2.4	<0.2	84.
4	NAP	26.0	NAP	20.0	2.1	<0.2	74.
5	ISA	18.0	ISA	13.0	1.5	<0.2	51.
6	ISA	16.0	ISA	12.0	2.3	<0.2	46.
7	ISA	23.0	ISA	14.0	1.3	<0.2	61.
8	ISA	31.0	ISA	20.0	2.0	<0.2	84.
9	ISA	67.0	ISA	55.0	3.5	<0.2	193.
AVG	--	56.8	--	44.6	3.6	--	162.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	134.9	90.0	8.4	9.8	35.0	7.9	329.
2	141.3	32.0	3.8	4.5	17.0	3.5	223.
3	52.5	6.8	0.9	1.2	5.7	1.0	76.
4	43.7	12.0	1.5	1.8	5.0	1.1	71.
5	27.5	11.0	1.1	<0.4	3.4	0.8	48.
6	27.5	6.6	0.5	<0.4	2.7	0.8	42.
7	39.8	12.0	1.2	<1.3	3.5	1.2	62.
8	51.3	25.0	1.4	<2.5	2.7	1.0	84.
9	100.0	73.0	2.1	<0.4	2.9	1.3	184.
AVG	83.0	49.6	2.2	1.0	6.0	1.7	151.

TABLE A.2, CONTINUED.

SITE 15

COLLECTION EFFICIENCY = 1.02

UNITS ARE UMOL/L UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAB PH	COND UMHO/CM	ION BAL
1	4-22	20.51	0.26	2.58	???	???	--
2	4-22	20.77	0.26	2.58	4.24	30.0	0.02
3	4-22	21.02	0.26	2.58	4.40	19.0	0.05
4	4-22	21.28	0.28	2.37	4.54	14.0	-0.03
5	4-22	21.56	0.57	1.16	4.43	18.0	-0.01
6	4-22	22.12	0.23	2.87	4.35	24.0	-0.01
7	4-22	22.35	0.19	3.44	4.27	30.0	-0.03
8	4-22	22.54	0.19	3.44	4.36	24.0	-0.02
9	4-22	22.74	7.97	0.67	3.98	60.0	-0.01
AVG				1.04	4.12	42.7	-0.01
	SD2	SD4	NO2	NO3	CL	PO4	AM SUM UEQ/L
1	???	???	???	???	???	???	???
2	ISA	31.0	ISA	28.0	3.0	<0.2	93.
3	ISA	19.0	ISA	15.0	2.2	<0.2	55.
4	0.4	15.0	ISA	11.0	2.4	<0.2	43.
5	ISA	18.0	ISA	14.0	2.0	<0.2	52.
6	ISA	26.0	ISA	17.0	2.3	<0.2	71.
7	ISA	35.0	ISA	30.0	3.3	<0.2	103.
8	ISA	27.0	ISA	23.0	2.5	<0.2	80.
9	0.1	63.0	ISA	62.0	5.1	<0.2	193.
AVG	0.1	45.1	--	42.4	3.9	--	137.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UEQ/L
1	???	???	???	???	???	???	???
2	57.5	16.0	1.3	1.8	7.2	1.9	95.
3	39.8	6.7	0.6	0.8	3.8	1.2	58.
4	28.8	5.4	0.6	0.8	2.6	0.7	42.
5	37.2	7.6	0.5	<0.6	2.3	0.9	52.
6	44.7	16.0	0.6	2.0	2.6	1.2	71.
7	53.7	39.0	1.1	<3.5	2.6	0.8	101.
8	43.7	29.0	0.9	<3.5	1.5	0.6	74.
9	104.7	76.0	1.9	<1.8	3.0	1.2	191.
AVG	76.4	48.7	1.4	0.4	3.1	1.1	135.

TABLE A.2, CONTINUED.

SITE 21

COLLECTION EFFICIENCY = 0.75

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	TAH PH	COND $\mu\text{MHO/CM}$	ION BAL
1	4-22	18.75	0.06	15.24	3.87	76.0	-0.01
2	4-22	18.81	0.06	15.24	4.04	48.0	-0.06
3	4-22	18.87	0.09	9.78	4.30	25.0	0.01
4	4-22	18.96	0.33	2.64	4.25	28.1	-0.10
5	4-22	19.29	0.33	2.64	4.33	25.0	-0.07
6	4-22	19.62	0.33	2.64	4.35	22.0	-0.09
7	4-22	19.96	0.48	1.85	4.48	17.0	-0.03
8	4-22	20.43	0.72	1.22	4.38	21.0	0.02
9	4-22	21.16	4.18	0.62	4.17	35.0	-0.06
AVG				1.47	4.20	33.4	-0.05
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	0.1	100.0	0.2	69.0	7.4	<0.2	277.
2	ISA	54.0	0.1	35.0	3.7	<0.2	147.
3	ISA	28.0	0.1	15.0	2.2	<0.2	73.
4	2.8	29.0	<0.1	19.0	2.2	<0.2	79.
5	ISA	24.0	<0.1	15.0	2.1	<0.2	65.
6	ISA	22.0	0.1	15.0	3.0	<0.2	62.
7	ISA	16.0	0.1	11.0	1.3	<0.2	44.
8	ISA	21.0	0.1	11.0	2.1	<0.2	55.
9	<0.2	41.0	0.1	24.0	3.7	<0.2	110.
AVG	0.6	37.9	0.1	23.8	3.2	--	103.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	134.0	76.0	6.5	1.6	21.0	6.6	274.
2	91.2	30.0	1.7	0.8	5.5	1.5	132.
3	50.1	10.0	0.7	0.8	5.7	0.7	74.
4	56.2	8.5	0.5	0.7	2.3	0.6	72.
5	46.8	7.3	0.5	0.7	2.1	0.7	61.
6	44.7	6.0	<0.5	0.6	2.4	0.4	57.
7	33.1	3.3	<0.5	2.4	1.6	0.4	43.
8	41.7	8.4	0.5	0.5	2.0	0.5	56.
9	67.4	27.0	1.7	1.4	2.2	0.9	104.
AVG	63.8	20.9	1.4	1.1	4.5	1.3	99.

TABLE A.2, CONTINUED.

SITE 22

COLLECTION EFFICIENCY = 0.51

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	19.08	0.25	5.24	4.47	48.0	-0.15
2	4-22	19.33	0.40	3.27	4.32	31.0	-0.09
3	4-22	19.73	0.40	3.27	4.35	26.0	-0.18
4	4-22	20.13	0.69	1.89	4.49	17.0	-0.07
5	4-22	20.82	0.85	1.53	4.56	14.0	-0.15
6	4-22	21.67	2.02	0.65	4.59	13.0	-0.17
AVG				1.70	4.45	24.8	-0.13
	SO2	SO4	NO2	NO3	CL	PO4	AN SUP $\mu\text{EQ/L}$
1	ISA	110.0	1.2	76.0	9.5	<0.2	307.
2	ISA	50.0	0.1	36.0	5.3	<0.2	141.
3	ISA	36.0	0.2	29.0	7.6	NAP	109.
4	ISA	20.0	0.2	13.0	3.1	<0.2	56.
5	ISA	17.0	0.1	8.1	3.6	<0.2	46.
6	ISA	16.0	0.1	8.9	5.8	<0.2	47.
AVG	--	41.5	0.3	28.5	5.8	--	118.
	FREE H	NH4	RA	K	CA	MG	CAT SUP $\mu\text{EQ/L}$
1	33.9	64.0	11.0	9.8	47.0	26.0	245.
2	47.9	27.0	3.8	4.1	16.0	7.5	130.
3	44.7	14.0	1.2	<1.8	11.0	4.6	91.
4	32.4	3.0	1.0	1.1	5.3	2.2	52.
5	27.5	0.6	0.5	0.5	3.6	1.5	39.
6	25.7	1.1	0.8	0.7	3.4	2.1	39.
AVG	35.3	18.3	3.1	2.7	14.4	7.3	103.

TABLE A.2, CONTINUED.

SITE 23

COLLECTION EFFICIENCY = 0.50

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	ION BAL
1	4-22	19.42	0.10	12.88	4.67	40.0	-0.18
2	4-22	19.52	0.35	3.80	4.03	59.0	-0.13
3	4-22	19.87	0.25	5.23	4.09	46.0	-0.15
4	4-22	20.13	0.37	3.62	4.38	28.0	-0.15
5	4-22	20.49	1.19	1.12	4.62	16.0	-0.22
6	4-22	21.68	0.44	3.05	4.92	8.0	-0.22
7	4-22	22.12	2.22	0.60	4.69	12.0	-0.27
8	4-23	0.34	5.83	0.23	4.61	16.0	-0.14
9	4-23	6.16	0.00	6.10	4.32	ISA	-0.10
AVG				0.99	4.40	28.1	-0.18
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	0.1	99.0	0.1	69.0	16.0	<0.2	283.
2	NAP	88.0	<0.1	76.0	7.5	<0.2	260.
3	NAP	61.0	<0.1	58.0	5.6	<0.2	186.
4	0.3	37.0	<0.1	36.0	5.4	<0.2	115.
5	NAP	22.0	<0.1	14.0	4.6	<0.2	63.
6	NAP	9.9	<0.1	6.6	1.7	<0.2	28.
7	NAP	15.0	<0.1	8.3	3.3	<0.2	42.
8	0.1	23.0	0.1	13.0	2.9	<0.2	62.
9	NAP	57.0	ISA	58.0	2.4	<0.2	176.
AVG	0.2	44.4	0.0	35.2	5.9	--	130.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	21.4	60.0	17.0	5.5	42.0	24.0	236.
2	93.3	56.0	4.8	0.7	24.0	12.0	227.
3	81.3	33.0	2.5	<0.4	15.0	6.4	160.
4	41.7	13.0	1.6	0.7	14.0	7.2	99.
5	24.0	3.9	0.5	0.5	6.8	3.8	50.
6	12.0	3.1	<0.5	<0.4	2.2	1.5	23.
7	20.4	0.5	0.5	<0.4	3.1	2.0	32.
8	24.5	12.0	0.6	0.7	4.9	3.2	54.
9	47.9	66.0	3.7	0.7	12.0	8.8	160.
AVG	39.8	22.8	3.4	1.0	14.0	7.5	110.

TABLE A.2, CONTINUED.

SITE 24

COLLECTION EFFICIENCY = 0.91

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAR PH	COND $\mu\text{MHO/CM}$	TOTAL
1	4-22	19.92	0.14	5.08	4.27	62.0	-0.19
2	4-22	20.06	0.14	5.08	4.79	15.0	0.03
3	4-22	20.20	0.14	5.08	4.54	17.0	-0.01
4	4-22	20.35	0.14	5.08	4.50	18.0	-0.05
5	4-22	20.49	0.14	5.08	4.54	16.0	-0.08
6	4-22	20.63	0.55	1.33	4.59	14.0	0.09
7	4-22	21.18	0.66	1.11	4.51	18.0	0.00
8	4-22	21.84	0.14	5.08	4.40	23.0	-0.08
9	4-22	21.98	8.27	0.43	4.14	46.0	-0.10
AVG				0.91	4.32	31.7	-0.04
	SO2	SO4	NO2	NO3	CL	PO4	AM SUM $\mu\text{EC/L}$
1	ISA	120.0	0.4	110.0	15.0	<0.2	365.
2	ISA	27.0	0.2	20.0	3.7	<0.2	78.
3	ISA	21.0	0.1	13.0	2.5	<0.2	58.
4	ISA	21.0	0.2	15.0	2.7	<0.2	60.
5	ISA	19.0	0.2	12.0	3.3	<0.2	53.
6	ISA	15.0	0.2	8.6	2.6	<0.2	41.
7	ISA	20.0	0.1	8.9	2.3	<0.2	51.
8	ISA	31.0	0.1	15.0	3.4	<0.2	41.
9	ISA	63.0	0.2	52.0	5.1	<0.2	183.
AVG	--	45.2	0.2	35.5	4.7	--	131.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EC/L}$
1	53.7	66.0	8.9	4.5	43.0	21.0	303.
2	16.2	8.0	4.6	2.2	16.0	8.7	30.
3	28.8	5.8	0.9	1.0	7.1	3.1	57.
4	31.6	7.4	1.0	0.8	5.7	2.3	57.
5	28.8	6.7	1.1	1.2	4.1	1.7	40.
6	29.7	6.1	0.6	0.7	4.5	1.6	45.
7	30.9	4.4	0.6	0.5	5.0	2.3	51.
8	39.8	19.0	1.3	0.7	4.7	2.2	75.
9	72.4	65.0	2.1	0.7	8.3	4.9	167.
AVG	47.3	34.3	2.3	1.3	11.7	5.2	119.

TABLE A.2, CONTINUED.

SITE 25

COLLECTION EFFICIENCY = 0.95

UNITS ARE UMOL/L UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAH PH	COND UMHO/CM	ION BAL
1	4-22	19.70	0.25	2.84	4.00	68.0	-0.10
2	4-22	19.95	0.25	2.84	4.32	27.0	-0.07
3	4-22	20.19	0.25	2.84	4.47	20.0	-0.12
4	4-22	20.44	0.30	2.36	4.46	19.0	0.05
5	4-22	20.73	0.35	1.97	4.63	13.0	-0.12
6	4-22	21.09	0.72	0.97	4.52	15.0	-0.17
7	4-22	21.80	0.21	3.28	4.40	20.0	-0.13
8	4-22	22.02	0.20	3.55	4.25	30.0	-0.12
9	4-22	22.21	4.03	0.39	4.26	30.0	-0.11
AVG				1.09	4.32	27.3	-0.11
	S02	S04	M02	M03	CL	P04	4-1 SUM UMOL/L
1	NAP	120.0	<0.1	88.0	8.6	ISA	337.
2	NAP	30.0	<0.1	24.0	2.4	ISA	86.
3	NAP	22.0	0.1	20.0	1.3	ISA	65.
4	NAP	21.0	0.1	9.5	2.0	ISA	54.
5	NAP	13.0	0.1	9.2	1.8	ISA	37.
6	NAP	17.0	0.1	9.3	2.6	ISA	44.
7	NAP	27.0	0.2	3.5	4.2	ISA	62.
8	NAP	37.0	0.1	18.0	2.4	ISA	95.
9	NAP	37.0	0.1	25.0	3.6	ISA	103.
AVG	--	36.1	0.1	23.2	3.3	--	99.
	FREH H	NH4	NA	K	CA	MG	CAT SUM UMOL/L
1	100.0	63.0	4.2	0.8	41.0	14.0	278.
2	47.0	9.2	0.6	<0.4	8.3	3.3	81.
3	33.0	13.0	<0.5	<0.4	3.8	1.7	50.
4	34.7	13.0	0.5	<0.4	2.7	1.3	56.
5	23.4	4.8	<0.5	<0.4	1.5	0.8	33.
6	30.2	3.3	0.6	<0.4	1.6	0.9	39.
7	39.8	8.3	0.8	<0.4	1.7	1.1	54.
8	56.2	21.0	0.9	<0.4	2.0	1.0	84.
9	55.0	27.0	1.5	0.5	2.5	1.5	92.
AVG	47.8	19.2	1.0	0.2	6.7	2.7	97.

TABLE A.2, CONTINUED.

SITE 26

COLLECTION EFFICIENCY = 0.50

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAB PH	COND UMHO/CM	TOT. CAL.
1	4-22	17.48	2.81	0.47	4.02	57.0	-0.10
2	4-22	20.29	0.53	2.47	4.36	NAP	-0.10
3	4-22	20.82	0.53	2.47	4.50	17.0	-0.15
4	4-22	21.35	0.82	1.60	4.56	16.0	-0.05
5	4-22	22.17	0.55	2.37	4.48	18.0	-0.12
6	4-22	22.73	2.07	0.63	4.78	10.0	-0.17
AVG				1.08	4.38	23.6	-0.12
	SO2	SO4	NO2	NO3	CL	PO4	AM SUM UMOL/L
1	NAP	85.0	0.1	63.0	5.6	<0.2	239.
2	NAP	27.0	0.1	24.0	1.9	<0.2	80.
3	NAP	18.0	0.2	14.0	0.9	<0.2	51.
4	NAP	16.0	0.1	12.0	1.0	<0.2	45.
5	NAP	19.0	<0.1	12.0	1.1	<0.2	51.
6	NAP	9.9	<0.1	5.8	1.1	<0.2	27.
AVG	--	29.1	0.1	21.8	2.0	--	82.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UMOL/L
1	95.5	42.0	4.2	5.4	29.0	5.6	216.
2	43.7	12.0	0.7	1.0	6.0	1.5	72.
3	31.6	7.5	<0.5	<0.4	1.7	0.7	44.
4	27.5	11.0	0.5	<0.4	1.5	0.5	43.
5	33.1	8.3	<0.5	<0.4	1.5	0.4	45.
6	16.6	2.8	<0.5	0.6	1.3	<0.4	23.
AVG	41.3	13.9	0.9	1.2	6.9	1.5	74.

TABLE A.2, CONTINUED.

SITE 27

COLLECTION EFFICIENCY = 0.69

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAR PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	17.62	2.56	0.37	4.15	46.0	-0.09
2	4-22	20.18	0.49	1.94	4.34	24.0	-0.07
3	4-22	20.67	0.37	2.54	4.42	21.0	-0.10
4	4-22	21.04	0.37	2.59	4.48	17.0	-0.11
5	4-22	21.41	0.37	2.59	4.34	23.0	-0.09
6	4-22	21.78	0.41	2.32	4.37	20.0	-0.06
7	4-22	22.19	0.43	2.20	4.45	17.0	-0.06
8	4-22	22.62	0.59	1.62	4.33	24.0	-0.10
9	4-22	23.21	3.49	0.52	4.54	32.0	-0.47
AVG				1.03	4.38	25.5	-0.16
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	ISA	64.0	0.9	57.0	8.2	<0.2	194.
2	ISA	28.0	0.2	18.0	3.0	<0.2	77.
3	ISA	24.0	0.2	16.0	2.3	<0.2	66.
4	ISA	17.0	0.2	11.0	1.1	<0.2	46.
5	ISA	24.0	0.1	13.0	1.6	<0.2	63.
6	ISA	22.0	0.2	10.0	1.8	<0.2	56.
7	NAP	17.0	0.1	9.1	2.4	<0.2	46.
8	ISA	26.0	0.2	13.0	2.1	<0.2	67.
9	ISA	46.0	0.3	32.0	6.2	<0.2	130.
AVG	--	31.2	0.2	21.0	3.5	--	87.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	70.8	57.0	3.7	2.4	18.0	3.5	177.
2	45.7	14.0	0.7	0.5	4.8	0.8	72.
3	38.0	15.0	0.4	<0.4	2.8	0.5	60.
4	33.1	5.3	<0.5	<0.4	1.6	<0.4	42.
5	45.7	6.1	1.4	0.5	1.3	0.4	57.
6	42.7	5.7	0.5	0.7	1.6	<0.4	53.
7	35.5	4.4	0.5	0.7	1.0	<0.4	43.
8	46.8	10.0	0.5	<0.4	1.4	0.4	61.
9	28.8	36.0	3.7	2.5	3.6	1.4	81.
AVG	41.7	18.8	1.5	1.0	4.0	0.8	73.

TABLE A.2, CONTINUED.

SITE 31

COLLECTION EFFICIENCY = 0.20

UNITS ARE UMOL/L UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R+RATE MM/HR	LAB PH	COND UMHO/CM	ION BAL
1	4-22	18.83	0.45	7.39	4.11	57.0	-0.07
2	4-22	19.29	1.58	2.13	4.20	32.0	-0.10
3	4-22	20.86	2.71	0.56	ISA	ISA	-1.17
AVG				1.73	4.15	44.5	-0.29
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM UEQ/L
1	ISA	100.0	0.1	69.0	9.5	<0.2	279.
2	ISA	40.0	0.1	25.0	3.9	<0.2	109.
3	ISA	27.0	ISA	17.0	3.3	<0.2	74.
AVG	--	62.0	0.1	41.4	6.1	--	172.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UEQ/L
1	77.6	53.0	6.1	4.7	42.0	17.0	259.
2	63.1	15.0	1.0	<0.4	7.0	2.7	98.
3	ISA	6.9	0.6	<0.4	4.7	1.3	19.
AVG	70.4	29.0	3.0	1.9	20.8	8.3	149.

TABLE A.2, CONTINUED.

SITE 32

COLLECTION EFFICIENCY = 0.89

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND UMHO/CM	ION BAL
1	4-22	19.00	0.03	27.43	4.22	54.0	-0.22
2	4-22	19.03	0.03	27.43	4.30	31.0	0.12
3	4-22	19.05	0.03	27.43	4.15	38.0	-0.12
4	4-22	19.08	0.11	7.02	4.40	22.0	-0.03
5	4-22	19.19	0.11	6.53	4.26	29.0	0.13
6	4-22	19.30	0.11	6.53	4.36	23.0	-0.12
7	4-22	19.41	0.11	6.53	4.51	17.0	-0.10
8	4-22	19.53	0.11	6.53	4.57	14.0	-0.11
9	4-22	19.64	2.53	1.58	4.47	17.0	-0.11
AVG				3.13	4.38	23.9	-0.08
	SDP	SD4	NO2	NO3	CL	PO4	ANL SUM ($\mu\text{MOL/L}$)
1	NAP	110.0	<0.1	72.0	8.4	0.3	301.
2	NAP	39.0	<0.1	29.0	3.2	<0.2	110.
3	NAP	46.0	<0.1	33.0	3.8	<0.2	129.
4	NAP	25.0	<0.1	17.0	2.1	<0.2	69.
5	NAP	27.0	<0.1	20.0	2.1	<0.2	76.
6	NAP	24.0	<0.1	16.0	1.9	<0.2	66.
7	NAP	17.0	<0.1	9.0	1.3	<0.2	44.
8	NAP	15.0	<0.1	7.0	0.8	<0.2	38.
9	NAP	19.0	<0.1	10.0	1.0	<0.2	49.
AVG	--	30.3	--	19.2	2.2	0.0	92.
	FREE H	NH4	NA	K	CA	MG	CAT SUM ($\mu\text{MOL/L}$)
1	60.3	76.0	8.2	2.1	29.0	18.0	241.
2	50.1	45.0	3.2	<0.4	8.8	3.9	124.
3	70.8	24.0	1.5	<0.4	6.6	2.6	115.
4	39.8	17.0	0.9	<0.4	3.3	1.4	67.
5	55.0	20.0	1.6	<0.4	3.8	1.2	87.
6	43.7	4.6	0.8	1.8	2.9	1.0	59.
7	30.9	2.3	0.8	0.5	2.1	0.7	40.
8	26.9	1.2	0.8	<0.4	2.1	0.4	34.
9	33.9	5.9	0.9	<0.4	1.0	0.7	40.
AVG	41.8	16.6	1.7	0.3	4.8	2.5	75.

TABLE A.2, CONTINUED.

SITE 33

COLLECTION EFFICIENCY = 0.35

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	ION BAL
1	4-22	19.60	0.43	4.42	???	???	--
2	4-22	20.03	0.53	3.59	4.20	40.0	-0.09
3	4-22	20.56	1.32	1.43	4.37	24.0	-0.02
4	4-22	21.88	0.93	2.04	4.53	15.0	-0.06
5	4-22	22.81	1.67	0.19	ISA	ISA	-0.65
AVG				1.62	4.35	26.3	-0.09
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	???	???	???	???	???	???	???
2	ISA	58.0	ISA	48.0	7.0	<0.2	171.
3	ISA	29.0	ISA	20.0	3.6	<0.2	82.
4	ISA	17.0	ISA	8.7	2.8	<0.2	46.
5	ISA	15.0	ISA	8.6	3.1	<0.2	42.
AVG	--	33.6	--	24.7	4.4	--	96.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	???	???	???	???	???	???	???
2	63.1	29.0	1.9	<3.2	22.0	8.8	156.
3	42.7	9.0	0.6	<2.0	9.5	4.3	80.
4	29.5	NAP	NAP	NAP	4.7	1.9	43.
5	ISA	1.0	0.9	0.9	6.6	2.6	21.
AVG	45.1	17.6	1.2	0.1	11.8	4.9	89.

TABLE A.2, CONTINUED.

SITE 34

COLLECTION EFFICIENCY = 0.86

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	19.49	0.27	2.82	4.02	61.0	-0.09
2	4-22	19.76	0.27	2.82	4.16	26.0	0.14
3	4-22	20.03	0.27	2.82	4.35	16.0	0.12
4	4-22	20.30	0.28	2.76	4.45	13.0	0.16
5	4-22	20.58	0.75	1.02	4.40	13.0	0.23
6	4-22	21.33	0.45	1.70	4.35	16.0	0.13
7	4-22	21.78	0.38	2.02	4.16	26.0	0.14
8	4-22	22.16	0.43	1.78	4.18	32.0	0.15
9	4-22	22.59	3.38	0.22	4.48	22.0	0.02
AVG				1.06	4.26	25.0	0.11
	SO2	SO4	NO2	NO3	CL	PO4	AM SUM $\mu\text{EQ/L}$
1	ISA	130.0	0.4	110.0	11.0	<0.2	381.
2	ISA	37.0	0.1	29.0	4.0	<0.2	107.
3	ISA	19.0	0.1	12.0	2.5	<0.2	53.
4	ISA	14.0	0.1	9.2	1.2	<0.2	38.
5	ISA	16.0	0.1	8.3	1.4	<0.2	42.
6	ISA	22.0	0.1	10.0	2.0	<0.2	56.
7	ISA	34.0	0.2	16.0	3.1	<0.2	87.
8	NAP	38.0	<0.1	19.0	2.4	<0.2	97.
9	NAP	35.0	NAP	22.0	2.7	<0.2	95.
AVG	--	38.3	0.1	26.2	3.4	--	106.
	FRPE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	95.5	73.0	6.2	6.4	53.0	31.0	340.
2	69.2	10.0	1.0	0.9	13.0	8.1	123.
3	44.7	1.2	<0.5	<0.4	4.4	2.3	59.
4	35.5	NAP	NAP	NAP	3.4	1.5	45.
5	39.8	2.2	0.6	0.5	3.2	1.6	53.
6	44.7	3.3	<0.4	<0.4	4.9	3.0	64.
7	69.2	19.0	1.1	<0.4	3.6	2.2	101.
8	66.1	33.0	2.1	0.8	5.7	2.1	114.
9	33.1	28.0	1.5	0.8	9.4	7.1	96.
AVG	55.4	21.2	1.6	1.2	11.0	6.5	112.

TABLE A.2, CONTINUED.

SITE 35

COLLECTION EFFICIENCY = 0.75

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND UMHO/CM	ION BAL
1	4-22	19.54	0.13	6.81	4.00	63.0	0.03
2	4-22	19.67	0.13	6.81	4.30	29.0	-0.07
3	4-22	19.80	0.16	5.67	4.59	15.0	0.07
4	4-22	19.95	0.27	3.29	4.61	13.0	0.14
5	4-22	20.22	0.33	2.65	4.58	14.0	0.04
6	4-22	20.55	0.52	1.69	4.62	13.0	-0.09
7	4-22	21.07	0.67	1.32	4.41	20.0	-0.11
8	4-22	21.74	0.29	3.03	4.30	26.0	-0.08
9	4-22	22.03	7.99	0.26	4.40	25.0	-0.08
AVG				0.87	4.38	24.3	-0.03
	S02	S04	N02	NO3	CL	P04	AN SUM MER/L
1	NAP	84.0	0.2	74.0	8.0	<0.2	250.
2	NAP	34.0	<0.1	28.0	3.0	<0.2	99.
3	NAP	15.0	<0.1	8.4	0.8	<0.2	39.
4	NAP	12.0	<0.1	6.7	0.7	<0.2	31.
5	NAP	13.0	0.1	6.4	2.2	<0.2	35.
6	NAP	14.0	0.1	6.2	1.0	<0.2	35.
7	NAP	23.0	0.1	9.2	1.5	<0.2	57.
8	NAP	32.0	<0.1	12.0	1.1	<0.2	77.
9	NAP	28.0	<0.1	12.0	1.3	<0.2	60.
AVG	--	28.3	0.0	17.3	2.1	--	76.
	FREE H	NH4	NA	K	CA	MG	CAT SUM MER/L
1	100.0	64.0	4.7	1.2	32.0	12.0	258.
2	50.1	14.0	0.8	<0.4	9.6	3.9	92.
3	25.7	2.3	0.5	0.5	4.5	2.1	42.
4	24.5	2.3	<0.5	<0.4	3.1	1.5	36.
5	26.3	1.3	<0.5	<0.4	3.1	1.2	36.
6	24.0	1.7	0.5	<0.4	1.9	1.1	32.
7	38.9	1.0	0.6	<0.4	3.6	1.6	51.
8	50.1	10.0	0.8	<0.4	3.3	1.7	71.
9	39.8	13.0	0.8	0.7	2.9	1.8	64.
AVG	41.8	12.3	0.9	0.3	6.5	2.8	74.

TABLE A.2, CONTINUED.

SITE 36

COLLECTION EFFICIENCY = 0.62

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	ION BAL
1	4-22	19.94	0.44	2.45	3.96	63.0	-0.08
2	4-22	20.37	0.40	2.64	4.40	22.0	0.01
3	4-22	20.78	0.53	2.00	4.53	15.0	-0.15
4	4-22	21.31	0.60	1.77	4.43	18.0	-0.14
5	4-22	21.91	0.49	2.19	4.28	26.0	-0.03
6	4-22	22.40	0.43	2.51	4.30	24.0	-0.07
7	4-22	22.83	7.95	0.12	4.23	27.0	0.02
AVG				0.68	4.27	27.9	-0.06
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EG/L}$
1	0.1	79.0	<0.1	72.0	8.1	<0.2	238.
2	NAP	27.0	<0.1	22.0	2.7	<0.2	79.
3	NAP	19.0	<0.1	11.0	1.5	<0.2	51.
4	2.4	20.0	0.1	11.0	1.5	<0.2	53.
5	NAP	27.0	0.1	11.0	1.1	<0.2	66.
6	NAP	25.0	0.1	9.4	1.8	<0.2	61.
7	<0.2	28.0	0.1	12.0	1.5	<0.2	70.
AVG	0.9	32.2	0.1	21.4	2.6	--	89.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EG/L}$
1	109.7	46.0	5.0	4.3	23.0	4.3	220.
2	39.8	19.0	3.4	2.7	6.0	1.1	79.
3	29.5	3.7	0.9	0.6	3.9	0.6	44.
4	37.2	1.6	0.7	0.4	2.3	0.6	46.
5	52.5	3.5	1.1	0.9	2.7	0.6	65.
6	50.1	1.6	0.9	<0.4	1.7	0.7	57.
7	58.9	5.5	1.2	0.9	1.8	0.6	71.
AVG	53.8	11.7	1.9	1.4	6.0	1.2	93.

TABLE A.2, CONTINUED.

SITE 37

COLLECTION EFFICIENCY = 0.85

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	W-RATE MM/HR	LAB PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	20.24	0.22	3.49	3.97	59.0	-0.08
2	4-22	20.47	0.22	3.49	4.08	40.0	-0.03
3	4-22	20.69	0.25	3.05	4.24	27.0	-0.04
4	4-22	20.94	0.30	2.60	4.40	20.0	0.10
5	4-22	21.24	0.38	2.03	4.35	20.0	0.02
6	4-22	21.62	0.43	1.79	4.35	21.0	-0.01
7	4-22	22.06	0.41	1.89	4.17	30.0	0.04
8	4-22	22.47	0.41	1.89	4.28	22.0	0.01
9	4-22	22.88	8.42	0.23	4.22	26.0	-0.01
AVG				0.73	4.21	29.0	0.00
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM ($\mu\text{EQ/L}$)
1	ISA	77.0	0.1	65.0	17.0	<0.2	236.
2	ISA	41.0	0.1	36.0	3.9	<0.2	122.
3	ISA	29.0	<0.1	20.0	2.4	<0.2	40.
4	ISA	19.0	0.1	12.0	1.5	<0.2	52.
5	ISA	21.0	0.1	15.0	1.1	<0.2	58.
6	ISA	22.0	0.1	13.0	1.5	<0.2	59.
7	ISA	33.0	0.1	16.0	1.3	<0.2	83.
8	ISA	23.0	0.1	11.0	1.5	<0.2	59.
9	ISA	29.0	0.2	13.0	1.7	<0.2	73.
AVG	--	32.2	0.1	21.0	3.3	--	89.
	FREE H	NH4	MA	K	CA	MG	CAT SUM ($\mu\text{EQ/L}$)
1	107.2	46.0	3.9	3.9	22.0	6.3	218.
2	83.2	20.0	1.3	<0.4	5.9	1.2	119.
3	57.5	10.0	0.5	<0.4	3.8	0.7	77.
4	39.8	8.6	0.7	0.6	3.0	0.6	57.
5	44.7	7.6	0.6	<0.4	2.5	0.6	59.
6	44.7	6.5	1.4	0.6	2.1	0.5	58.
7	47.6	11.0	0.8	<0.4	3.1	0.5	87.
8	52.5	1.8	0.5	<0.4	1.7	0.4	59.
9	60.3	7.5	0.3	<0.4	1.6	0.4	72.
AVG	61.7	12.4	1.0	0.5	4.6	1.1	87.

TABLE A.2, CONTINUED.

SITE 41

COLLECTION EFFICIENCY = 0.65

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE ML/HR	LAB PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	18.65	0.07	15.29	4.35	37.0	-0.10
2	4-22	18.72	0.17	5.91	4.26	30.0	-0.14
3	4-22	18.89	0.21	4.89	4.23	32.0	-0.17
4	4-22	19.10	0.51	2.01	4.21	31.0	-0.08
5	4-22	19.60	0.61	1.67	4.36	22.0	-0.23
6	4-22	20.21	0.61	1.67	4.40	20.0	-0.14
7	4-22	20.82	1.03	0.98	4.46	17.0	-0.14
8	4-22	21.85	3.44	0.29	4.35	23.0	-0.10
9	4-23	1.29	0.00	6.12	4.17	ISA	-0.04
AVG				1.22	4.32	26.5	-0.14
	S02	S04	NO2	NO3	CL	P04	AN SUM MEQ/L
1	ISA	68.0	ISA	47.0	7.6	<0.2	191.
2	ISA	42.0	ISA	24.0	4.0	<0.2	112.
3	ISA	40.0	ISA	24.0	3.5	<0.2	108.
4	ISA	35.0	ISA	21.0	3.0	<0.2	94.
5	ISA	29.0	ISA	12.0	2.8	<0.2	73.
6	ISA	22.0	ISA	15.0	3.1	<0.2	62.
7	ISA	17.0	ISA	13.0	3.2	<0.2	50.
8	ISA	29.0	ISA	13.0	2.8	<0.2	74.
9	ISA	50.0	ISA	28.0	4.9	<0.2	133.
AVG	--	35.3	--	21.1	3.8	--	95.
	FREE H	NH4	NA	K	CA	MG	CAT SUM MEQ/L
1	44.7	47.0	4.4	2.9	26.0	11.0	173.
2	55.0	21.0	1.4	1.2	6.6	2.6	97.
3	58.9	17.0	1.3	0.8	4.9	1.5	91.
4	61.7	13.0	0.8	0.7	3.9	1.3	87.
5	43.7	6.3	<0.5	0.4	2.8	0.8	58.
6	39.8	4.7	0.9	1.0	3.1	0.8	54.
7	34.7	1.4	0.5	1.2	1.9	0.9	44.
8	44.7	11.0	1.1	2.7	2.6	1.1	67.
9	67.6	33.0	3.8	8.4	4.6	2.6	127.
AVG	47.0	15.3	1.3	1.4	6.5	2.5	84.

TABLE A.2, CONTINUED.

SITE 42

COLLECTION EFFICIENCY = 0.91

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LA9 PH	COND $\mu\text{MHO/CM}$	TOTAL
1	4-22	18.95	0.03	22.94	4.41	34.0	-0.03
2	4-22	18.98	0.06	12.52	4.39	24.0	-0.10
3	4-22	19.04	0.14	5.36	4.46	19.0	-0.07
4	4-22	19.17	0.20	3.67	4.47	18.0	-0.61
5	4-22	19.37	0.19	3.84	5.05	5.0	-0.53
6	4-22	19.56	0.20	3.62	4.47	17.0	-0.07
7	4-22	19.76	0.62	1.17	4.46	17.0	-0.19
8	4-22	20.38	0.62	1.17	4.33	23.0	-0.32
9	4-22	21.01	1.30	1.40	4.23	30.0	-0.14
AVG				2.27	4.40	22.1	-0.22
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	NAP	56.0	0.1	40.0	9.6	<0.2	162.
2	NAP	29.0	<0.1	19.0	4.7	<0.2	82.
3	NAP	20.0	<0.1	12.0	1.5	<0.2	54.
4	NAP	34.0	<0.1	21.0	2.4	<0.2	91.
5	NAP	7.3	<0.1	3.9	1.0	<0.2	20.
6	NAP	17.0	0.1	9.3	1.2	<0.2	45.
7	NAP	18.0	<0.1	11.0	1.8	<0.2	49.
8	NAP	33.0	0.1	14.0	2.1	<0.2	82.
9	NAP	37.0	<0.1	17.0	2.6	<0.2	94.
AVG	--	29.2	0.0	16.4	2.9	--	78.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	38.9	46.0	4.7	<3.5	22.0	12.0	158.
2	40.7	16.0	1.4	0.5	5.4	2.1	74.
3	34.7	7.3	0.8	<0.4	2.5	0.9	50.
4	33.9	9.1	0.5	<0.4	2.1	0.6	49.
5	8.9	0.9	<0.5	<0.4	0.8	<0.4	11.
6	33.9	2.2	<0.5	<0.4	2.3	0.5	42.
7	34.7	1.4	<0.5	<0.4	1.4	0.8	20.
8	46.8	6.5	0.9	<0.4	1.9	0.8	60.
9	58.9	15.0	1.5	<0.4	1.9	0.9	81.
AVG	40.0	12.1	1.1	0.0	4.1	1.9	65.

TABLE A.2, CONTINUED.

SITE 43

COLLECTION EFFICIENCY = 0.41 UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND ($\mu\text{MHQ/CM}$)	ION BAL
1	4-22	19.24	0.09	18.26	4.66	34.0	-0.14
2	4-22	19.33	0.17	9.79	4.41	26.0	-0.03
3	4-22	19.49	0.73	2.21	4.45	20.0	-0.04
4	4-22	20.23	1.50	1.08	4.45	18.0	-0.06
5	4-22	21.72	0.37	2.61	4.32	23.0	-0.04
AVG				2.61	4.46	24.3	-0.06
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM DEQ/L
1	<0.2	82.0	0.2	61.0	7.8	<0.2	233.
2	NAP	43.0	0.2	28.0	4.0	<0.2	118.
3	NAP	29.0	0.2	14.0	2.6	<0.2	75.
4	2.2	23.0	0.2	12.0	2.3	<0.2	60.
5	1.7	28.0	ISA	16.0	3.1	<0.2	75.
AVG	1.2	42.2	0.2	27.1	4.0	--	116.
	FREE H	NH4	NA	K	CA	MG	CAT SUM DEQ/L
1	21.9	47.0	3.8	<0.4	39.0	26.0	203.
2	38.9	26.0	1.2	<0.4	15.0	9.2	115.
3	35.5	13.0	0.7	<0.4	7.5	3.9	72.
4	35.5	9.2	0.6	<0.4	4.3	1.6	57.
5	47.9	13.0	0.8	<0.4	4.3	1.1	72.
AVG	34.9	22.4	1.5	--	14.9	9.0	107.

TABLE A.2, CONTINUED.

SITE 44

COLLECTION EFFICIENCY = 0.89

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT)		DT	R-RATE	LAB PH	COND	ION BAL
	DAY	HR	HR	MM/HR		$\mu\text{MHO/CM}$	
1	4-22	19.53	0.02	36.34	4.28	51.0	-0.14
2	4-22	19.55	0.02	36.34	4.89	16.0	-0.11
3	4-22	19.57	0.02	36.34	4.41	22.0	-0.12
4	4-22	19.59	0.02	36.34	4.30	28.0	-0.12
5	4-22	19.61	0.60	1.24	4.46	19.0	-0.17
6	4-22	20.21	0.64	1.16	4.55	16.0	-0.11
7	4-22	20.85	0.61	1.21	4.54	17.0	-0.13
8	4-22	21.46	0.43	1.72	4.49	19.0	-0.15
9	4-22	21.89	0.99	2.47	4.34	26.0	-0.03
AVG				2.50	4.42	24.2	-0.10
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	<0.2	92.0	NAP	77.0	11.0	<0.2	272.
2	1.9	35.0	NAP	21.0	4.2	<0.2	95.
3	1.8	28.0	NAP	15.0	2.9	<0.2	74.
4	1.5	33.0	NAP	22.0	3.1	<0.2	91.
5	1.8	22.0	NAP	14.0	1.9	<0.2	60.
6	0.6	18.0	NAP	9.7	1.7	<0.2	47.
7	<0.2	21.0	NAP	9.4	1.5	<0.2	53.
8	<0.2	23.0	NAP	9.5	2.3	<0.2	58.
9	<0.2	31.0	NAP	11.0	2.1	<0.2	75.
AVG	0.7	33.1	--	18.9	3.1	--	88.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	52.5	67.0	4.2	7.2	33.0	20.0	237.
2	12.9	15.0	1.5	1.9	16.0	11.0	85.
3	38.9	9.5	0.7	<1.8	5.6	2.5	65.
4	50.1	12.0	0.8	0.9	5.8	2.6	81.
5	34.7	3.8	0.3	0.6	3.7	1.9	51.
6	28.2	3.0	1.0	<0.4	3.3	1.9	43.
7	28.8	4.0	<0.5	0.4	4.3	2.3	46.
8	32.4	5.3	<0.5	<0.4	3.7	2.3	50.
9	45.7	15.0	1.4	1.3	3.0	1.6	73.
AVG	38.0	15.0	1.2	1.4	7.5	4.4	79.

TABLE A.2, CONTINUED.

SITE 45

COLLECTION EFFICIENCY = 0.75

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	TOTAL
1	4-22	19.59	0.03	30.46	5.09	10.0	-0.16
2	4-22	19.62	0.03	30.46	4.72	13.0	-0.11
3	4-22	19.65	0.03	30.46	4.56	16.0	-0.22
4	4-22	19.67	0.03	30.46	4.46	19.0	-0.25
5	4-22	19.70	0.27	3.26	4.50	17.0	-0.10
6	4-22	19.97	0.28	3.17	4.63	12.0	-0.21
7	4-22	20.25	0.31	2.82	4.25	29.0	0.00
8	4-22	20.56	0.66	1.34	4.44	18.0	-0.12
9	4-22	21.23	4.90	0.37	4.64	11.0	-0.10
AVG				1.36	4.55	15.6	-0.15
	S02	S04	NO2	NO3	CL	P04	AN SUM MG/L
1	NAP	22.0	0.1	15.0	4.1	ISA	63.
2	NAP	21.0	<0.1	12.0	2.7	ISA	57.
3	NAP	20.0	<0.1	10.0	4.3	ISA	54.
4	NAP	24.0	<0.1	13.0	2.3	ISA	64.
5	NAP	19.0	0.1	9.5	1.9	ISA	49.
6	ISA	13.0	0.1	8.9	1.4	ISA	36.
7	NAP	26.0	0.1	17.0	2.1	ISA	71.
8	NAP	19.0	0.1	12.0	3.1	ISA	53.
9	NAP	12.0	0.1	6.4	2.5	ISA	33.
AVG	--	18.7	0.1	11.0	2.7	--	51.
	FREE H	NH4	NA	K	CA	MG	CAT SUM MG/L
1	8.1	12.0	0.6	0.4	12.0	4.3	54.
2	19.0	6.5	5.7	0.8	6.0	3.4	51.
3	27.5	4.3	1.1	0.5	3.2	1.8	43.
4	34.7	6.0	0.8	<1.0	2.8	1.3	50.
5	31.6	3.5	0.7	0.4	1.7	0.8	41.
6	23.4	3.0	0.6	<0.4	0.8	0.4	29.
7	56.2	8.7	0.6	<0.4	2.1	0.8	71.
8	36.3	6.3	0.6	<0.4	1.2	0.7	47.
9	22.9	1.7	0.7	<0.4	1.5	0.7	30.
AVG	28.2	5.3	1.2	0.2	3.3	1.5	45.

TABLE A.2, CONTINUED.

SITE 46

COLLECTION EFFICIENCY = 0.35

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAR PH	COND ($\mu\text{MHO/CM}$)	TOTAL
1	4-22	19.84	0.12	15.21	3.96	58.0	-0.02
2	4-22	19.96	0.47	4.02	4.15	33.0	-0.02
3	4-22	20.44	0.95	2.01	4.24	27.0	-0.08
4	4-22	21.34	1.67	1.14	4.15	33.0	-0.06
AVG				2.37	4.11	37.7	-0.04
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM ($\mu\text{EQ/L}$)
1	NAP	72.0	0.2	56.0	8.6	ISA	269.
2	NAP	34.0	0.1	26.0	5.2	ISA	94.
3	NAP	29.0	0.1	20.0	2.7	ISA	81.
4	NAP	36.0	<0.1	21.0	4.8	ISA	94.
AVG	--	42.8	0.1	30.8	5.3	--	122.
	FREE H	NH4	NA	K	CA	MG	CAT SUM ($\mu\text{EQ/L}$)
1	100.7	45.0	4.3	3.5	18.0	3.5	205.
2	69.2	14.0	0.8	1.3	5.1	0.7	97.
3	57.5	11.0	0.5	<0.4	2.8	<0.4	75.
4	70.8	14.0	0.6	<0.4	ISA	3.5	92.
AVG	76.8	21.0	1.5	1.2	8.6	1.9	117.

TABLE A.2, CONTINUED.

SITE 51

COLLECTION EFFICIENCY = 0.40

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	W-RATE MM/HR	LAB PH	COND $\mu\text{MHQ/CM}$	TOT BAL
1	4-22	18.40	0.09	18.34	4.44	34.0	-0.13
2	4-22	18.49	0.11	14.77	4.67	16.0	-0.05
3	4-22	18.61	0.23	7.13	4.55	16.0	-0.01
4	4-22	18.84	0.23	7.13	4.44	19.0	-0.01
5	4-22	19.07	1.22	1.36	4.31	24.0	-0.03
6	4-22	20.28	1.61	1.03	4.35	23.0	-0.01
AVG				2.84	4.44	22.0	-0.04
	S02	S04	NO2	NO3	CL	P04	AN SUM UEQ/L
1	NAP	71.0	0.2	53.0	4.1	ISA	203.
2	NAP	29.0	0.2	18.0	5.6	ISA	82.
3	NAP	23.0	0.1	10.0	2.6	ISA	59.
4	NAP	23.0	0.1	9.0	2.3	ISA	57.
5	NAP	29.0	0.1	14.0	3.0	ISA	75.
6	NAP	27.0	0.1	14.0	3.0	ISA	71.
AVG	--	33.7	0.1	19.7	4.1	--	91.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UEQ/L
1	36.3	47.0	4.0	<0.4	29.0	17.0	179.
2	21.4	20.0	1.3	<0.4	11.0	6.4	77.
3	28.2	20.0	0.7	<0.4	3.5	1.0	56.
4	36.3	14.0	0.4	<0.4	2.5	0.6	57.
5	49.0	16.0	0.8	<0.4	3.1	0.5	73.
6	44.7	16.0	0.5	<0.4	3.8	0.7	70.
AVG	36.0	22.2	1.3	--	8.8	4.4	86.

TABLE A.2, CONTINUED.

SITE 52

COLLECTION EFFICIENCY = 1.08

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	18.88	0.04	16.50	3.96	67.0	-0.45
2	4-22	18.92	0.04	16.50	4.06	47.0	-0.24
3	4-22	18.96	0.12	5.54	4.11	43.0	-0.22
4	4-22	19.08	0.13	5.28	4.41	23.0	-0.20
5	4-22	19.20	0.13	5.28	4.56	17.0	-0.39
6	4-22	19.33	0.53	1.26	4.64	13.0	-0.51
7	4-22	19.85	0.77	0.86	4.67	12.0	-0.57
8	4-22	20.63	0.77	0.86	4.28	28.0	-0.29
9	4-22	21.40	0.71	2.18	4.23	35.0	-0.50
AVG				2.11	4.25	32.1	-0.39
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	NAP	130.0	0.1	100.0	12.0	<0.2	372.
2	NAP	61.0	0.1	43.0	9.2	<0.2	174.
3	NAP	51.0	0.1	34.0	10.0	<0.2	146.
4	NAP	27.0	0.1	22.0	5.1	<0.2	81.
5	NAP	25.0	0.2	17.0	8.1	<0.2	75.
6	NAP	19.0	0.3	12.0	5.3	<0.2	56.
7	NAP	17.0	0.2	9.6	5.7	<0.2	50.
8	NAP	35.0	0.2	19.0	4.8	<0.2	94.
9	NAP	69.0	0.2	49.0	9.4	<0.2	197.
AVG	--	50.9	0.2	35.9	8.0	--	146.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	109.7	67.0	4.4	1.1	19.0	8.1	236.
2	87.1	36.0	1.9	<0.4	4.6	1.7	138.
3	77.6	30.0	1.5	<0.4	3.1	0.9	117.
4	38.9	23.0	0.8	<0.4	1.6	0.4	67.
5	27.5	20.0	0.6	<0.4	1.3	<0.4	51.
6	22.9	7.4	0.5	<0.4	1.1	<0.4	33.
7	21.4	4.2	<0.5	<0.4	1.0	<0.4	28.
8	52.5	8.6	1.0	<0.4	3.0	1.0	70.
9	58.9	50.0	1.6	<0.4	2.6	1.2	118.
AVG	55.6	30.3	1.4	0.1	3.9	1.4	96.

TABLE A.2, CONTINUED.

SITE 53

COLLECTION EFFICIENCY = 0.77

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT)		DT	R-RATE	LAB PH	COND	JON BAL
	DAY	HR	HR	MM/HR		$\mu\text{MHQ/CM}$	
1	4-22	19.26	0.09	9.43	4.48	37.0	-0.17
2	4-22	19.35	0.43	1.98	4.17	47.0	-0.28
3	4-22	19.78	0.64	1.33	4.18	40.0	-0.19
4	4-22	20.42	0.64	1.33	4.43	22.0	-0.18
5	4-22	21.07	0.53	1.63	4.49	19.0	-0.24
6	4-22	21.59	0.46	1.87	4.37	24.0	-0.22
7	4-22	22.05	0.50	1.71	4.27	30.0	-0.19
8	4-22	22.55	1.35	0.31	4.14	42.0	-0.15
AVG				1.38	4.31	32.0	-0.21
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	<0.1	89.0	ISA	64.0	8.7	<0.2	251.
2	<0.1	64.0	0.4	45.0	14.0	<0.2	187.
3	0.7	50.0	0.3	35.0	3.8	<0.2	139.
4	2.0	27.0	0.2	19.0	2.4	<0.2	76.
5	1.2	24.0	0.1	15.0	4.7	<0.2	62.
6	<0.2	31.0	0.1	15.0	2.5	<0.2	40.
7	<0.1	40.0	0.1	19.0	3.0	<0.2	102.
8	NAP	59.0	0.1	30.0	3.9	<0.2	152.
AVG	0.6	47.2	0.2	30.3	5.5	--	130.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	53.1	74.0	6.1	2.2	31.0	17.0	211.
2	67.6	40.0	1.5	<0.4	11.0	5.0	141.
3	66.1	26.0	1.4	<0.4	7.4	3.1	114.
4	37.2	15.0	1.2	<0.4	3.3	1.7	64.
5	32.4	10.0	0.5	<0.4	3.4	1.9	53.
6	42.7	4.7	0.7	<0.4	5.1	2.8	60.
7	53.7	13.0	1.0	<0.4	5.3	3.0	94.
8	72.4	40.0	2.0	<0.4	6.2	2.3	131.
AVG	49.1	27.0	1.8	0.3	9.3	4.8	106.

TABLE A.2, CONTINUED.

SITE 54

COLLECTION EFFICIENCY = 1.10

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAR PH	COND $\mu\text{MHQ/CM}$	TON BAL
1	4-22	19.44	0.13	5.03	???	???	--
2	4-22	19.57	0.11	6.14	4.34	33.0	0.11
3	4-22	19.68	0.25	2.60	4.45	21.0	0.14
4	4-22	19.94	0.28	2.39	4.14	37.0	-0.03
5	4-22	20.21	0.42	1.55	4.44	20.0	-0.08
6	4-22	20.64	0.47	1.40	4.40	22.0	-0.01
7	4-22	21.11	0.86	0.77	4.40	22.0	-0.03
8	4-22	21.97	0.13	4.19	4.45	18.0	-0.03
AVG				1.95	4.36	24.9	0.01
	S02	S04	N02	N03	CL	P04	AN SUM DEG/L
1	???	???	???	???	???	???	???
2	<0.1	44.0	0.1	30.0	4.1	<0.2	122.
3	<0.2	25.0	0.1	11.0	2.0	<0.2	63.
4	<0.2	45.0	0.1	26.0	4.3	<0.2	120.
5	<0.2	25.0	0.1	14.0	2.2	<0.2	66.
6	<0.2	30.0	0.1	15.0	2.1	<0.2	77.
7	<0.2	32.0	0.1	13.0	2.5	<0.2	80.
8	1.0	23.0	0.1	8.4	1.6	<0.2	56.
AVG	0.1	32.2	0.1	17.0	2.7	--	84.
	FREE H	NH4	NA	K	CA	MG	CAT SUM DEG/L
1	???	???	???	???	???	???	???
2	45.7	24.0	1.6	0.5	19.0	13.0	136.
3	35.5	8.3	0.6	0.8	8.6	5.3	73.
4	72.4	17.0	0.9	0.5	8.2	5.0	117.
5	36.3	NAP	NAP	NAP	7.5	4.9	61.
6	39.8	3.9	<0.5	0.5	9.8	6.3	76.
7	39.8	11.0	0.5	<0.4	8.0	4.8	77.
8	35.5	9.6	<0.5	<0.4	3.2	1.5	54.
AVG	43.8	12.4	0.6	0.4	9.3	5.9	86.

TABLE A.2, CONTINUED.

SITE 55

COLLECTION EFFICIENCY = 1.14

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	TION BAL
1	4-22	19.68	0.11	6.26	3.89	79.0	-0.07
2	4-22	19.79	0.13	4.95	4.02	50.0	-0.06
3	4-22	19.92	0.29	2.31	4.14	36.0	-0.07
4	4-22	20.21	0.37	1.77	4.36	28.0	-0.11
5	4-22	20.58	0.60	1.10	4.81	19.0	-0.14
6	4-22	21.18	0.79	0.84	4.56	20.0	-0.03
7	4-22	21.47	0.20	3.30	4.47	20.0	-0.05
8	4-22	22.17	0.06	3.30	4.55	ISA	-0.04
AVG				1.90	4.23	36.0	-0.07
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EOL/L}$
1	NAP	110.0	NAP	82.0	9.6	<0.2	312.
2	NAP	57.0	NAP	36.0	4.1	<0.2	154.
3	NAP	41.0	NAP	20.0	3.4	<0.2	105.
4	NAP	41.0	NAP	24.0	3.0	<0.2	109.
5	NAP	38.0	NAP	21.0	2.8	<0.2	100.
6	NAP	31.0	NAP	14.0	2.5	<0.2	79.
7	NAP	26.0	NAP	11.0	4.1	<0.2	67.
8	NAP	21.0	NAP	7.2	3.0	<0.2	52.
AVG	--	48.0	--	28.8	4.2	--	129.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EOL/L}$
1	128.8	66.0	6.3	<5.0	30.0	14.0	289.
2	95.5	24.0	2.0	<1.7	8.7	3.3	146.
3	72.4	12.0	1.1	1.1	4.3	1.6	98.
4	43.7	8.3	0.8	2.3	14.0	7.2	97.
5	15.5	3.3	1.0	5.0	19.0	12.0	87.
6	27.5	3.3	0.4	2.4	15.0	6.3	74.
7	33.9	2.7	0.5	1.4	9.3	3.4	64.
8	28.2	<0.6	0.4	1.0	8.0	2.2	50.
AVG	58.3	16.4	1.7	1.7	14.1	6.6	119.

TABLE A.2, CONTINUED.

SITE 56

COLLECTION EFFICIENCY = 1.14

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	TON BAL
1	4-22	19.67	0.09	7.53	3.86	77.0	-0.05
2	4-22	19.76	0.09	7.53	3.72	92.0	-0.02
3	4-22	19.85	0.09	7.53	3.92	59.0	0.01
4	4-22	19.93	0.09	7.53	4.18	33.0	-0.02
5	4-22	20.02	0.15	4.34	4.14	36.0	0.01
6	4-22	20.17	0.26	2.55	4.10	38.0	0.02
7	4-22	20.43	0.41	1.62	4.12	36.0	-0.01
8	4-22	20.84	0.41	1.62	4.19	33.0	-0.03
9	4-22	21.25	1.31	1.04	4.31	28.0	0.10
AVG				2.30	4.04	45.9	0.01
	SO2	SO4	NO2	NO3	CL	P04	AN SUM $\mu\text{EQ/L}$
1	NAP	89.0	0.2	65.0	8.4	<0.2	252.
2	NAP	96.0	0.2	84.0	7.8	<0.2	284.
3	NAP	55.0	0.2	50.0	5.7	<0.2	166.
4	NAP	32.0	0.2	23.0	2.5	<0.2	90.
5	NAP	33.0	0.2	21.0	2.8	<0.2	90.
6	NAP	36.0	0.2	21.0	3.1	<0.2	96.
7	NAP	34.0	0.2	17.0	2.7	<0.2	98.
8	NAP	31.0	0.2	15.0	1.1	<0.2	78.
9	NAP	32.0	0.3	18.0	3.3	<0.2	86.
AVG	--	46.9	0.2	33.1	4.1	--	131.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	138.0	51.0	5.0	<3.0	16.0	6.2	238.
2	190.6	58.0	3.7	<4.0	11.0	2.4	279.
3	120.2	34.0	1.8	<2.0	4.3	1.2	168.
4	46.1	14.0	1.0	<0.4	2.8	0.8	88.
5	72.4	11.0	0.6	<0.4	2.5	0.8	91.
6	79.4	11.0	0.8	<1.0	2.8	0.9	99.
7	75.9	4.9	<0.5	<0.4	2.2	0.9	87.
8	68.6	3.4	0.5	0.8	2.5	0.9	76.
9	49.0	13.0	2.6	3.8	10.0	3.2	95.
AVG	90.3	21.3	1.9	0.9	6.5	2.1	131.

TABLE A.2, CONTINUED.

SITE 57

COLLECTION EFFICIENCY = 0.47

UNITS ARE UMOL/L, UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND UMHO/CM	ION BAL
1	4-22	19.70	0.03	40.67	4.06	53.0	-0.09
2	4-22	19.73	1.40	1.01	4.34	24.0	-0.02
3	4-22	21.13	1.23	1.15	4.36	24.0	-0.05
4	4-22	22.36	2.40	0.40	3.90	61.0	-0.07
AVG				1.03	4.15	38.7	-0.05
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM UEQ/L
1	NAP	73.0	<0.1	52.0	5.7	<0.2	204.
2	NAP	27.0	<0.1	18.0	2.5	<0.2	75.
3	NAP	28.0	<0.1	18.0	3.7	<0.2	76.
4	NAP	68.0	<0.1	42.0	6.4	<0.2	134.
AVG	--	47.4	--	31.7	4.4	--	131.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UEQ/L
1	87.1	50.0	4.9	2.3	16.0	5.3	187.
2	45.7	14.0	2.3	0.6	4.1	1.1	73.
3	43.7	20.0	2.0	0.7	3.0	0.7	74.
4	125.9	29.0	2.6	NAP	6.0	1.5	172.
AVG	71.2	28.2	3.0	1.2	7.4	2.2	123.

TABLE A.2, CONTINUED.

SITE 58

COLLECTION EFFICIENCY = 0.80

UNITS ARE UNOL/L UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAB PH	COND UMHO/CM	ION BAL
1	4-22	19.92	0.46	1.79	RPC	RPC	--
2	4-22	20.38	0.07	12.30	RPC	RPC	--
3	4-22	20.45	0.42	1.95	RPC	RPC	--
4	4-22	20.87	1.01	0.81	RPC	RPC	--
5	4-22	21.88	0.66	1.24	RPC	RPC	--
6	4-22	22.55	0.34	2.39	RPC	RPC	--
7	4-22	22.89	3.24	0.25	RPC	RPC	--
8	4-23	2.13	7.35	0.11	RPC	RPC	--
9	4-23	9.47	0.22	4.92	RPC	RPC	--
AVG				0.55	--	--	--
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM UF/L
1	RPC	RPC	RPC	RPC	RPC	RPC	RPC
2	RPC	RPC	RPC	RPC	RPC	RPC	RPC
3	RPC	RPC	RPC	RPC	RPC	RPC	RPC
4	RPC	RPC	RPC	RPC	RPC	RPC	RPC
5	RPC	RPC	RPC	RPC	RPC	RPC	RPC
6	RPC	RPC	RPC	RPC	RPC	RPC	RPC
7	RPC	RPC	RPC	RPC	RPC	RPC	RPC
8	RPC	RPC	RPC	RPC	RPC	RPC	RPC
9	RPC	RPC	RPC	RPC	RPC	RPC	RPC
AVG	--	--	--	--	--	--	--
	FREE H	NH4	NA	K	CA	MG	CAT SUM UG/L
1	RPC	RPC	RPC	RPC	RPC	RPC	RPC
2	RPC	RPC	RPC	RPC	RPC	RPC	RPC
3	RPC	RPC	RPC	RPC	RPC	RPC	RPC
4	RPC	RPC	RPC	RPC	RPC	RPC	RPC
5	RPC	RPC	RPC	RPC	RPC	RPC	RPC
6	RPC	RPC	RPC	RPC	RPC	RPC	RPC
7	RPC	RPC	RPC	RPC	RPC	RPC	RPC
8	RPC	RPC	RPC	RPC	ISA	ISA	RPC
9	RPC	RPC	RPC	RPC	RPC	ISA	RPC
AVG	--	--	--	--	--	--	--

TABLE A.2, CONTINUED.

SITE 61

COLLECTION EFFICIENCY = 0.31

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HP	R-RATE MM/HR	LAR PH	COND $\mu\text{MHO/CM}$	ION PAL
1	4-22	18.42	0.05	39.62	4.05	52.0	0.06
2	4-22	18.47	0.20	10.66	4.12	40.0	-0.10
3	4-22	18.67	0.61	3.47	4.32	29.0	-0.14
4	4-22	19.28	2.15	0.99	4.34	27.0	-0.09
AVG				2.82	4.19	37.0	-0.07
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	NAP	59.0	<0.1	53.0	7.9	<0.2	179.
2	NAP	44.0	<0.1	30.0	6.8	<0.2	125.
3	NAP	31.0	<0.1	19.0	2.9	<0.2	84.
4	NAP	24.0	<0.1	17.0	4.6	<0.2	73.
AVG	--	40.5	--	29.8	5.6	--	116.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	89.1	68.0	6.6	1.5	10.0	2.8	191.
2	75.9	25.0	1.9	1.1	3.6	0.9	113.
3	47.9	16.0	1.2	0.7	3.0	0.7	73.
4	45.7	18.0	1.3	0.9	2.0	0.6	71.
AVG	64.6	31.8	2.8	1.0	4.7	1.2	112.

TABLE A.2, CONTINUED.

SITE 62

COLLECTION EFFICIENCY = 0.55

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	ION BAL
1	4-22	18.58	0.17	6.86	4.12	39.0	-0.18
2	4-22	18.76	0.20	6.04	4.15	31.0	-0.02
3	4-22	18.95	0.49	2.44	4.34	19.0	-0.03
4	4-22	19.44	1.65	0.72	4.31	19.0	0.01
5	4-22	21.09	0.59	2.03	4.24	22.0	0.03
6	4-22	21.68	0.82	0.48	ISA	ISA	-0.50
AVG				1.62	4.22	26.0	-0.07
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	<0.2	72.0	0.2	61.0	7.5	<0.2	213.
2	<0.2	45.0	0.2	29.0	3.9	<0.2	123.
3	2.3	26.0	0.2	16.0	1.9	<0.2	70.
4	1.9	25.0	0.2	14.0	2.1	<0.2	66.
5	0.5	31.0	0.2	17.0	2.6	<0.2	82.
6	<0.2	75.0	0.2	85.0	6.4	<0.2	242.
AVG	0.9	42.0	0.2	31.0	3.8	--	119.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	75.9	43.0	3.6	<0.4	18.0	9.3	177.
2	70.8	29.0	1.5	0.8	6.7	2.5	120.
3	45.7	14.0	0.5	0.4	2.9	0.9	68.
4	49.0	11.0	1.1	0.6	1.9	0.7	67.
5	57.5	17.0	1.3	0.8	2.7	0.9	84.
6	ISA	98.0	3.8	<0.4	15.0	6.7	145.
AVG	59.8	27.5	1.7	0.5	7.0	3.1	106.

TABLE A.2, CONTINUED.

SITE 63

COLLECTION EFFICIENCY = 1.04

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	19.00	0.10	6.36	6.26	36.0	-0.05
2	4-22	19.11	0.10	6.36	4.19	39.0	-0.09
3	4-22	19.21	0.10	6.36	4.12	43.0	-0.11
4	4-22	19.32	0.19	3.56	4.20	34.0	-0.13
5	4-22	19.50	0.21	3.18	4.22	32.0	-0.06
6	4-22	19.71	0.21	3.18	4.19	33.0	-0.11
7	4-22	19.92	0.56	1.17	4.27	27.0	-0.10
8	4-22	20.48	0.98	0.67	4.28	27.0	-0.09
9	4-22	21.46	0.55	2.47	4.17	36.0	0.01
AVG				2.21	4.24	34.3	-0.08
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	<0.2	84.0	0.6	67.0	9.2	<0.2	245.
2	<0.2	50.0	<0.1	33.0	4.5	<0.2	138.
3	<0.2	49.0	<0.1	38.0	5.8	<0.2	142.
4	<0.2	40.0	<0.1	24.0	4.5	<0.2	109.
5	<0.2	37.0	<0.1	20.0	2.5	<0.2	97.
6	<0.2	37.0	<0.1	24.0	2.6	<0.2	101.
7	<0.2	30.0	<0.1	22.0	2.3	<0.2	84.
8	<0.2	29.0	<0.1	18.0	2.0	<0.2	78.
9	<0.2	47.0	<0.1	24.0	2.9	<0.2	121.
AVG	--	45.0	0.1	29.4	3.9	--	123.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	0.6	75.0	5.5	2.3	44.0	31.0	233.
2	64.6	28.0	2.2	0.7	10.0	5.2	126.
3	75.9	33.0	1.9	0.8	5.7	2.3	128.
4	63.1	17.0	1.0	0.5	4.5	2.1	95.
5	60.3	19.0	1.0	0.4	3.5	1.6	91.
6	64.6	15.0	0.8	0.4	3.0	1.8	90.
7	53.7	8.0	0.6	0.4	3.4	1.9	73.
8	52.5	5.1	0.5	<0.4	4.0	2.5	71.
9	67.6	29.0	1.5	1.0	6.8	4.7	122.
AVG	57.1	25.8	1.6	0.8	9.2	5.8	115.

TABLE A.2, CONTINUED.

SITE 64

COLLECTION EFFICIENCY = 1.04

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND ($\mu\text{MHQ}/\text{CM}$)	ION BAL
1	4-22	19.17	0.03	19.07	4.26	40.0	0.06
2	4-22	19.21	0.03	19.07	3.96	55.0	-0.14
3	4-22	19.24	0.12	5.54	4.35	24.0	0.05
4	4-22	19.36	0.18	3.71	3.95	52.0	-0.03
5	4-22	19.54	0.18	3.71	3.95	54.0	0.04
6	4-22	19.72	0.56	1.17	4.30	27.0	0.03
7	4-22	20.28	0.81	0.82	4.36	23.0	0.01
8	4-22	21.09	0.43	1.54	4.17	36.0	-0.07
9	4-22	21.52	0.24	5.56	4.44	19.0	0.28
AVG				2.56	4.18	34.8	0.05
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM UEQ/L
1	NAP	61.0	0.1	51.0	23.0	<0.2	196.
2	NAP	66.0	<0.1	54.0	7.7	<0.2	194.
3	NAP	25.0	<0.1	23.0	6.3	<0.2	79.
4	NAP	54.0	<0.1	45.0	6.2	<0.2	159.
5	NAP	53.0	<0.1	43.0	5.2	<0.2	154.
6	NAP	27.0	<0.1	18.0	2.6	<0.2	75.
7	NAP	21.0	<0.1	15.0	1.5	<0.2	59.
8	NAP	40.0	<0.1	19.0	3.6	<0.2	103.
9	NAP	22.0	<0.1	10.0	2.6	<0.2	57.
AVG	--	39.0	0.0	28.7	6.1	--	113.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UEQ/L
1	55.0	79.0	9.2	11.0	18.0	8.8	208.
2	109.7	33.0	3.6	3.1	7.4	2.2	169.
3	40.7	27.0	2.1	1.3	3.4	0.9	84.
4	112.2	27.0	2.8	1.1	4.3	1.3	154.
5	112.2	29.0	2.0	1.3	6.0	1.7	160.
6	50.1	13.0	1.3	0.7	4.5	1.3	77.
7	43.7	3.6	1.2	0.5	3.4	1.6	59.
8	67.6	13.0	0.8	0.5	4.9	1.8	95.
9	36.3	24.0	4.3	2.2	2.9	1.2	75.
AVG	66.6	27.2	3.2	2.4	5.8	2.2	115.

TABLE A.2, CONTINUED.

SITE 65

COLLECTION EFFICIENCY = 1.19

UNITS ARE UMOL/L UNLESS NOTED

STAGE	START DAY	(GMT) HR	OT HR	R-RATE MM/HR	LAB PH	COND UMHO/CM	ION BAL
1	4-22	19.63	0.59	1.12	3.88	92.0	-0.09
2	4-22	20.22	0.59	1.12	4.02	56.0	0.00
3	4-22	20.80	0.81	0.81	4.30	28.0	-0.04
4	4-22	21.62	0.23	2.84	4.30	29.0	-0.04
5	4-22	21.85	0.49	1.35	4.25	31.0	-0.08
6	4-22	22.34	0.35	0.89	4.41	24.0	-0.13
AVG				1.18	4.13	45.2	-0.06
	SOP	S04	NO2	NO3	CL	P04	AN SUM UEQ/L
1	NAP	120.0	0.4	110.0	16.0	<0.2	466.
2	NAP	66.0	0.2	55.0	7.3	<0.2	194.
3	NAP	31.0	0.1	23.0	4.8	<0.2	90.
4	NAP	37.0	0.1	16.0	3.8	<0.2	94.
5	NAP	37.0	0.1	16.0	3.7	<0.2	94.
6	NAP	36.0	ISA	15.0	NAP	<0.2	87.
AVG	--	56.3	0.2	41.5	7.1	--	161.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UEQ/L
1	131.8	100.0	8.2	NAP	32.0	15.0	344.
2	95.5	63.0	1.8	NAP	12.0	5.1	195.
3	50.1	12.0	0.5	<0.4	7.5	4.2	86.
4	50.1	18.0	0.6	<0.4	6.5	4.1	90.
5	56.2	19.0	0.6	<0.4	3.6	2.0	87.
6	38.9	20.0	0.8	<0.4	4.7	3.6	76.
AVG	73.5	40.5	2.2	--	11.7	5.9	151.

TABLE A.2, CONTINUED.

SITE 66

COLLECTION EFFICIENCY = 1.64

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	20.00	0.47	1.40	3.77	90.0	-0.13
2	4-22	20.47	0.47	1.40	3.97	53.0	-0.11
3	4-22	20.94	0.47	1.40	4.11	37.0	-0.09
4	4-22	21.42	0.47	1.40	4.09	38.0	-0.10
5	4-22	21.89	0.22	1.40	4.08	41.0	-0.09
AVG				1.40	3.97	53.1	-0.10
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	NAP	120.0	NAP	83.0	13.0	<0.2	336.
2	NAP	63.0	NAP	41.0	5.5	<0.2	173.
3	NAP	40.0	NAP	21.0	3.5	<0.2	105.
4	NAP	42.0	NAP	19.0	3.4	<0.2	106.
5	NAP	46.0	NAP	20.0	4.7	<0.2	117.
AVG	--	64.1	--	38.8	6.2	--	173.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	169.8	79.0	6.9	NAP	15.0	4.9	296.
2	107.2	30.0	2.2	<3.0	5.9	1.9	155.
3	77.6	5.8	0.7	0.9	4.0	1.4	96.
4	81.3	8.5	0.8	<0.4	2.2	0.9	97.
5	83.2	11.0	0.9	<0.4	4.2	1.8	107.
AVG	106.3	28.7	2.4	0.3	6.5	2.2	155.

TABLE A.2, CONTINUED.

SITE 67

COLLECTION EFFICIENCY = 0.88

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	19.40	1.12	0.67	3.80	89.0	-0.05
2	4-22	20.52	0.99	0.67	3.94	57.0	-0.03
AVG				0.67	3.86	74.0	-0.04
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM $\mu\text{EQ/L}$
1	NAP	110.0	<0.1	84.0	12.0	<0.2	316.
2	NAP	61.0	<0.1	36.0	5.2	<0.2	163.
AVG	--	87.1	--	61.5	8.8	--	245.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	158.5	74.0	8.9	4.6	22.0	5.2	300.
2	114.8	26.0	2.4	1.1	5.2	1.6	158.
AVG	138.1	51.5	5.9	3.0	14.1	3.5	234.

TABLE A.2, CONTINUED.

SITE 71

COLLECTION EFFICIENCY = 1.02

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAR PH	COND $\mu\text{MHO/CM}$	ION BAL
1	4-22	18.33	0.03	24.93	4.10	46.0	-0.02
2	4-22	18.36	0.03	24.93	4.10	42.0	0.02
3	4-22	18.39	0.03	24.93	3.85	71.0	0.02
4	4-22	18.41	0.09	7.00	3.87	67.0	0.04
5	4-22	18.51	0.11	6.23	3.96	52.0	-0.12
6	4-22	18.61	0.11	6.23	4.08	40.0	0.15
7	4-22	18.72	0.72	0.92	4.12	36.0	-0.06
8	4-22	19.44	0.97	0.68	4.14	34.0	0.12
9	4-22	20.41	1.92	1.04	3.98	51.0	0.15
AVG				1.82	4.00	49.2	0.05
	S02	S04	NO2	NO3	CL	P04	AN SUM $\mu\text{EQ/L}$
1	NAP	54.0	<0.1	45.0	12.0	<0.2	165.
2	NAP	44.0	0.1	33.0	5.4	<0.2	126.
3	NAP	66.0	0.1	55.0	7.4	<0.2	195.
4	NAP	60.0	0.1	50.0	6.8	<0.2	177.
5	NAP	47.0	0.1	35.0	4.0	<0.2	133.
6	NAP	37.0	0.1	23.0	3.3	<0.2	100.
7	NAP	44.0	0.1	24.0	3.4	<0.2	115.
8	NAP	32.0	0.1	19.0	2.3	<0.2	85.
9	NAP	51.0	0.1	23.0	4.7	<0.2	130.
AVG	--	48.8	0.1	32.1	5.3	--	135.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	79.4	39.0	4.2	<2.0	16.0	3.6	162.
2	79.4	31.0	2.8	<2.0	6.4	1.4	129.
3	141.3	41.0	3.0	<2.0	5.8	1.0	199.
4	134.9	36.0	2.3	<2.0	4.9	0.8	185.
5	109.7	NAP	NAP	NAP	3.4	0.6	118.
6	83.2	25.0	1.0	<1.0	3.5	0.5	117.
7	75.9	22.0	1.5	<1.0	3.8	0.9	109.
8	72.4	18.0	0.6	<1.0	2.3	0.5	97.
9	104.7	37.0	2.3	<1.0	2.3	0.7	150.
AVG	99.1	32.3	2.2	--	4.8	1.1	142.

TABLE A.2, CONTINUED.

SITE 72

COLLECTION EFFICIENCY = 1.29

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE $\mu\text{M}/\text{HR}$	LAR PH	COND $\mu\text{MHO}/\text{CM}$	ION BAL.
1	4-22	18.83	0.17	3.95	3.77	81.0	-0.10
2	4-22	19.00	0.14	4.89	3.64	110.0	-0.13
3	4-22	19.14	0.21	3.14	3.90	62.0	0.11
4	4-22	19.35	0.80	0.83	4.04	46.0	0.06
5	4-22	20.14	0.78	0.84	4.05	42.0	0.05
6	4-22	20.92	0.31	2.15	4.15	33.0	0.11
7	4-22	21.23	0.31	2.15	3.99	50.0	0.04
8	4-22	21.54	0.38	1.72	4.05	44.0	-0.04
9	4-22	21.92	2.08	0.30	4.13	35.0	-0.07
AVG				1.14	3.94	56.0	0.00
	S02	S04	NO2	NO3	CL	PO4	AN SUM ($\mu\text{E}/\text{L}$)
1	NAP	90.0	NAP	76.0	9.3	<0.2	265.
2	NAP	120.0	NAP	110.0	13.0	<0.2	363.
3	NAP	58.0	NAP	46.0	5.0	<0.2	167.
4	NAP	46.0	NAP	30.0	3.9	<0.2	126.
5	NAP	38.0	NAP	27.0	3.2	<0.2	106.
6	NAP	29.0	NAP	17.0	2.4	<0.2	77.
7	NAP	56.0	NAP	27.0	3.7	<0.2	143.
8	NAP	53.0	<0.1	23.0	3.7	<0.2	133.
9	NAP	39.0	<0.1	21.0	4.1	<0.2	103.
AVG	--	58.9	--	42.0	5.4	--	165.
	FREE H	NH4	NA	K	CA	MG	CAT SUM ($\mu\text{E}/\text{L}$)
1	169.8	28.0	3.3	<3.0	15.0	4.4	240.
2	229.1	58.0	5.1	<3.0	10.0	2.6	317.
3	125.0	46.0	2.1	<0.4	4.7	1.2	186.
4	91.2	32.0	1.3	<0.4	3.7	0.7	133.
5	89.1	14.0	0.9	<2.0	3.0	0.8	112.
6	70.8	7.5	0.6	<0.4	2.8	1.1	87.
7	102.3	38.0	1.3	<0.4	2.7	0.7	148.
8	89.1	31.0	1.6	<0.4	2.4	0.7	128.
9	74.1	15.0	1.4	<0.4	2.2	0.8	96.
AVG	115.9	30.0	2.0	--	5.2	1.4	161.

TABLE A.2, CONTINUED.

SITE 73

COLLECTION EFFICIENCY = 0.93

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAB PH	COND $\mu\text{MHO/CM}$	ION BAL
1	4-22	19.25	0.02	30.48	3.87	72.0	-0.17
2	4-22	19.27	0.02	30.48	3.77	87.0	-0.16
3	4-22	19.30	0.02	30.48	4.28	28.0	-0.12
4	4-22	19.32	0.12	5.75	4.55	15.0	0.80
5	4-22	19.44	0.27	2.67	4.22	29.0	-0.14
6	4-22	19.71	0.27	2.67	4.21	30.0	-0.06
7	4-22	19.97	1.32	0.54	4.11	38.0	-0.07
8	4-22	21.29	0.23	3.05	4.18	30.0	-0.13
9	4-22	21.52	1.23	0.56	4.20	29.0	-0.12
AVG				1.81	4.10	39.8	-0.02
	SO2	SO4	NO2	NO3	CL	PO4	AM SUM $\mu\text{MOL/L}$
1	NAP	110.0	<0.1	84.0	11.0	<0.2	315.
2	NAP	120.0	0.1	100.0	11.0	<0.2	351.
3	NAP	38.0	<0.1	29.0	4.1	<0.2	109.
4	NAP	22.0	<0.1	16.0	2.3	<0.2	62.
5	NAP	40.0	0.1	22.0	3.4	<0.2	104.
6	NAP	42.0	<0.1	28.0	3.5	<0.2	116.
7	NAP	53.0	<0.1	34.0	4.0	<0.2	144.
8	NAP	38.0	<0.1	27.0	3.1	<0.2	106.
9	NAP	37.0	0.2	22.0	3.4	<0.2	100.
AVG	--	55.6	0.0	40.3	5.1	--	157.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{MOL/L}$
1	134.9	50.0	4.7	2.9	25.0	11.0	265.
2	169.8	66.0	6.3	2.6	20.0	7.3	299.
3	52.5	32.0	1.4	0.7	3.9	1.3	97.
4	28.2	90.0	16.0	6.5	2.1	0.6	146.
5	60.3	25.0	1.1	0.6	1.9	0.5	92.
6	61.7	40.0	1.2	0.6	2.1	0.5	109.
7	77.6	45.0	2.1	1.0	3.5	1.0	135.
8	66.1	15.0	1.3	0.4	3.9	1.2	93.
9	63.1	13.0	2.2	0.5	3.2	1.6	88.
AVG	79.4	41.9	4.0	1.8	7.3	2.8	147.

TABLE A.2, CONTINUED.

SITE 74

COLLECTION EFFICIENCY = 1.04

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE ML/HR	LAR PH	COND $\mu\text{MHQ/CM}$	ION BAL
1	4-22	18.95	1.57	0.42	3.75	100.0	-0.17
2	4-22	20.52	1.33	0.50	ISA	ISA	--
AVG				0.46	3.75	100.0	-0.17
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM UEQ/L
1	0.1	150.0	<0.1	110.0	14.0	<0.2	424.
2	NAP	43.0	ISA	20.0	37.0	<0.2	143.
AVG	0.1	96.5	--	65.0	25.5	--	284.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UEQ/L
1	177.8	79.0	8.2	0.6	34.0	12.0	358.
2	ISA	14.0	36.0	7.5	13.0	4.0	ISA
AVG	177.8	46.5	22.1	4.0	23.5	8.0	358.

TABLE A.2, CONTINUED.

SITE 75

COLLECTION EFFICIENCY = 1.13

UNITS ARE $\mu\text{MOL/L}$ UNLESS NOTED

STAGE	START (GMT) DAY	HR	DT HR	R-RATE MM/HR	LAH PH	COND $\mu\text{MHO/CM}$	ION BAL
1	4-22	18.95	0.29	2.26	4.16	58.0	-0.19
2	4-22	19.24	1.08	0.61	3.97	60.0	-0.18
3	4-22	20.32	0.73	0.91	4.22	32.0	-0.16
4	4-22	21.05	0.64	1.04	4.25	27.0	-0.20
5	4-22	21.69	1.72	0.35	4.11	39.0	-0.20
AVG				0.73	4.13	43.3	-0.19
	S02	S04	NO2	NO3	CL	P04	AN SUM $\mu\text{EQ/L}$
1	NAP	120.0	0.1	89.0	11.0	<0.2	340.
2	NAP	80.0	0.3	63.0	6.7	<0.2	230.
3	NAP	50.0	<0.1	26.0	2.8	<0.2	129.
4	NAP	42.0	<0.1	16.0	1.9	<0.2	102.
5	NAP	58.0	<0.1	29.0	3.0	<0.2	148.
AVG	--	70.2	0.1	44.9	5.1	--	191.
	FREE H	NH4	NA	K	CA	MG	CAT SUM $\mu\text{EQ/L}$
1	69.2	87.0	8.9	4.0	40.0	16.0	281.
2	107.2	43.0	2.9	1.5	14.0	4.7	192.
3	60.3	25.0	2.5	1.1	7.2	3.4	110.
4	56.2	14.0	1.0	0.5	4.0	1.9	84.
5	77.6	21.0	1.7	0.6	6.6	3.3	121.
AVG	74.0	38.3	3.4	1.6	14.5	5.9	158.

TABLE A.2, CONTINUED.

SITE 76

COLLECTION EFFICIENCY = 0.99

UNITS ARE UMOL/L UNLESS NOTED

STAGE	START DAY	(GMT) HR	DT HR	R-RATE MM/HR	LAB PH	COND UMHO/CM	ION BAL
1	4-22	18.75	1.30	0.51	???	???	--
2	4-22	20.05	0.40	1.66	???	???	--
3	4-22	20.45	0.40	1.66	???	???	--
4	4-22	20.85	0.40	1.66	4.15	39.0	-0.46
5	4-22	21.25	0.42	1.58	4.24	30.0	-0.09
6	4-22	21.67	0.23	0.82	6.32	ISA	0.23
AVG				1.12	4.26	34.5	-0.21
	SO2	SO4	NO2	NO3	CL	PO4	AN SUM UMOL/L
1	???	???	???	???	???	???	???
2	???	???	???	???	???	???	???
3	???	???	???	???	???	???	???
4	NAP	56.0	0.2	27.0	4.4	<0.2	144.
5	NAP	41.0	0.2	26.0	4.1	<0.2	112.
6	NAP	46.0	ISA	35.0	4.1	<0.2	131.
AVG	--	48.2	0.2	27.6	4.2	--	128.
	FREE H	NH4	NA	K	CA	MG	CAT SUM UMOL/L
1	???	???	???	???	???	???	???
2	???	???	???	???	???	???	???
3	???	???	???	???	???	???	???
4	70.8	NAP	NAP	NAP	6.5	3.0	90.
5	55.0	28.0	0.9	2.7	5.5	2.8	103.
6	0.5	120.0	1.4	6.1	11.0	7.5	165.
AVG	55.0	48.6	1.0	3.5	6.6	3.5	105.

APPENDIX B

CHEMICAL STABILITY OF OSCAR RAIN SAMPLES

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CHEMICAL STABILITY OF OSCAR RAIN SAMPLES

The rain samples collected during OSCAR were chemically analyzed at the PNL precipitation chemistry laboratory for all of the inorganic ionic species normally measured in MAP3S Precipitation Chemistry Network (PCN) samples. Although the analysis process began immediately on receipt of the samples at the laboratory, the large number of samples (about 2,800) generated during a one-month period resulted in a backlog and a necessary delay in analysis of many samples beyond the normal lag time for MAP3S/PCN. Naturally, there was concern about the possibility of chemical change in the samples during the storage period prior to analysis. A study consisting of reanalysis of selected samples at various times was conducted to determine if any significant alteration of chemical content occurred. In addition to this "long-term" stability study, an examination of normal laboratory short-term reanalyses was done in an effort to assess the effect of accuracy and precision variations.

SHORT-TERM STABILITY

In the course of analysis of precipitation samples at the PNL precipitation chemistry laboratory, a significant fraction of the samples are routinely reanalyzed for one or more chemical species. This occurs primarily with the ion chromatography species--sulfate, nitrate, chloride, phosphate, sodium, ammonium, and potassium--since the need to reanalyze one species results in the reanalysis of two or three others that also appear on the chromatogram. These reruns, however, do not normally take place on the same day or analysis "session" and may be delayed up to one month because of workload and scheduling. Thus, these reanalyses do not represent a measure of analytical precision, but are--if one assumes that the samples are chemically stable over this time period--a measure of a combination of accuracy and precision variations between analytical sessions.

The statistics of short-term stability measurements may be compared with the long-term results to derive an estimate of the "background" of laboratory variability influencing the latter. Most of the chemical species can be considered to be stable over a time period of a month or so, particularly in fairly acidic samples, so these data can be used to assess how the laboratory meets its goals for combined accuracy and precision and to standardize in some way the variations observed in the long-term stability study.

Approximately 5% of the OSCAR rain samples were reanalyzed for at least one species on a short-term basis. Table B.1 lists elementary statistics for the major ions rerun in this process. Shown are the number of samples, the means and standard deviations of the first measured concentrations and means and standard deviations of ΔC , given by

$$\Delta C = \frac{C_1 - C_2}{C_1 + C_2} \times 100\%, \quad (B-1)$$

where C_1 = first measured concentrations
 C_2 = second measured concentrations.

This parameter is a measure of variability and can be compared to the MAP3S/PCN goal for overall variability (including sampling, handling and analysis) of $|\Delta C| < 10\%$.

The samples involved in this analysis were selected on the basis of the need to rerun (except for H^+); most often, this need followed from one of the peaks of the chromatogram being off-scale. Thus, there may be a slight bias toward the higher concentration samples, since most of the species concentrations are positively correlated. The standard deviations of C_1 show that a fairly broad range of magnitudes is represented, however. The H^+ data, from pH measurements, represent routine reanalyses during analytical sessions; so for H^+ , unlike all the other species shown in the table, the statistics are true precision statistics.

TABLE B.1. Elementary Statistics for Short-Term Stability

Species	N(a)	C _i , $\mu\text{mol}/\ell$		ΔC , %		ΔC , %	
		Mean	S.D. (b)	Mean	S.D.	Mean	S.D.
Sulfur ^(c)	136	41	34	4.0	4.4	+2.0	5.9
Nitrate	152	39	43	4.5	5.2	+9.3	5.9
Chloride	83	14	17	9.0	12.	+2.1	14.
Hydrogen ^(d)	125	48	40	2.3	2.6	+1.5	8.7
Ammonium	97	24	26	4.5	5.9	-.66	7.4

(a) number of samples

(b) standard deviation

(c) S^{IV} and S^{VI} measured as sulfate

(d) statistics for hydrogen from pH represent true precision

The mean of $|\Delta C|$ for most species is less than five, which is an acceptable value of accuracy and precision variations. The standard deviation of $|\Delta C|$ is only an indicator of the number of outliers--values of ΔC which are far from zero. The mean of ΔC indicates if there is any significant bias toward the second measurement being consistently higher or lower than the first (the mean of ΔC should be zero). The slight bias for Cl^- is unexplained, while that for H^+ is probably due to pH meter drift over the approximate one hour period between measurements.

The chemistry of the OSCAR events was such that the concentrations of NO_3^- , NH_4^+ and Cl^- were often below $10 \mu\text{mol}/\ell$. In this area, an acceptable value of $|\Delta C|$ may be somewhat larger than five because rather small changes in concentration result in relatively large values of ΔC . Accordingly, shown in Table B.2 are similar statistics for these species for the concentration range 10-100 $\mu\text{mol}/\ell$ (concentrations above 100 are subject to an up-to 5% roundoff error). The means of $|\Delta C|$ for NH_4^+ and Cl^- are somewhat improved by this exercise.

For largely practical reasons the long-term stability samples were analyzed contemporaneously in batches. Thus, there are a limited number of time periods separating analyses and accuracy and precision variations from the previous analysis sessions presumably affect all the measurements for the groups.

The samples were analyzed one storm at a time. Therefore, samples from the last storm treated were not analyzed until about one year after collections, and long-term stability data for this storm are sparse. One might expect that stability might vary from storm to storm or between the two networks for a given storm, so initially three general groupings of rerun samples were formed. The three groups represent different networks and storms and also are divided according to the date of initial analysis and time between analyses. A fourth group was added at the end of the study. This group includes samples from some previously untested storms and has the latest initial analysis dates. Table B.3 lists details of these groups.

The concentration measurements for these groups are plotted in Figures B.1 - B.6 for the major species. The magnitudes of concentrations observed for NO_2^- , PO_4^{3-} , K^+ , and Mg^{2+} were generally not large enough to allow meaningful stability comparisons. In these figures, the first measured value is simply plotted against the second; the solid line represents 1:1 correspondence, and the dashed lines show $\Delta C = < 10\%$. Table B.4 lists the fractions of samples in groups 1-3 with $|\Delta C| < 10\%$.

When chemical analysis was complete enough to obtain an ion balance, the percent difference for positive and negative ion sums,

TABLE B.2. Elementary Statistics for Short-Term Stability:
 $10 < C_1 < 100 \text{ } \mu\text{mol}/\ell$

<u>Species</u>	<u>N</u>	<u>ΔC, %</u>	
		<u>Mean</u>	<u>S.D</u>
Nitrate	102	4.6	6.8
Chloride	31	4.0	3.3
Ammonium	62	2.9	3.4

In summary, the short-term stability statistics indicate that the variations are approximately the same as one might expect from acceptable laboratory variations and may, in fact, be a measure of these variations.

LONG-TERM STABILITY

If it is assumed that the prescribed sample collection and handling procedures were followed in the field and in the laboratory, the dominant factor affecting chemical stability should be the initial physical and chemical makeup of the samples. That is, the relative concentrations of measured and unmeasured chemical and biological constituents and insoluble matter should be the factor influencing chemical change. It was impossible to conduct a study that would test all of the variables implied by this hypothesis, but an effort was made to select samples for reanalysis which would be representative of several important variables. Among these were: sampling location, sample sequence number, pH, magnitude of concentrations of major ions, presence of visible insoluble matter, and date of first analysis. It was not practical, however, to select statistically representative samples of most of these variables. For example, the number of samples studied with sulfate between 10 and 20 $\mu\text{moles}/\ell$ may not be large enough to provide a statistically significant comparison with samples whose sulfate concentrations were over 50 $\mu\text{moles}/\ell$, similarity for any number of possible combinations of variables.

TABLE B.3. Characteristics of Four Long-Term Stability Sample Groups

Group	Storm	Network	t ^(b) days	Δt ^(c) days	N ^(d)	Sites represented
1	April 17	HD ^(a)	7-75	>250	11	11, 12, 13, 24, 27, 34, 62
2	April 23	HD	>90	100-180	10	22, 35, 45, 46, 61, 72, 75
3	April 22-24	IO	90-240	>100	13	00, 02, 11, 30, 32, 62, 63, 71, 72, 81, 91
4	April 9, 13, 23	HD & IO	>250	>100	6	HO: 16, 21, 45, 55 IO: 01, 11, 50, 61, 91

a HD = high density network, IO = intermediate density network

b Number of days between collection and first analysis of major ions.

c Number of days between first and second analysis of major ions.

d Number of samples in group reanalyzed for sulfate.

$$I = \frac{I_- - I_+}{I_- + I_+} \times 100\% \quad (\text{B-2})$$

was calculated. I_+ and I_- are the ion sums in $\mu\text{eq/L}$. I is plotted for the two measurements (I_1 and I_2) in Figure B.7. A ΔI parameter may be formed similarly to ΔC ; this parameter is included in Table B.4.

The figures show no significant differences in stability behavior between groups 2 and 3, which differed in geographic locations of sampling but had similar analysis histories. Group 1, which consisted of samples of early first analysis and--unfortunately--higher concentrations than the other groups, shows tendencies toward decreasing concentrations with time for NO_3^- and H^+ and increasing for NH_4^+ . The NH_4^+ increase is also suggested for groups 2 and 3 but not so clearly. The group 4 samples--albeit few in number--showed less change between analyses. This and the trends for group 1

TABLE B.4. Fractions of Samples With ΔC Within 10% of Means: Groups 1-3 (see Table B.3)

Species	Group 1	Group 2	Group 3
S^+	0.91	0.90	0.85
NO_3^-	0.82	0.80	1.00
Cl^-	0.64	0.50	0.62
H^+	0.46	1.00	0.93
NH_4^+	0.55	0.60	0.85
Ca^{++}	0.91	1.00	1.00
ΔI	0.80	0.78	1.00

suggest that any real chemical changes observed probably took place early after collection, so that the early-analyzed samples are the only ones that show the change. It should be made clear however, that the group 1 samples initially are considerably different chemically from the others and no comparable time history analyses were done for the others.

The ion balances are good ($|I| < 10$ is considered very good), but there is a slight tendency for the second ion balance to be better. This may reflect a stabilization of the sample chemistry (e.g., the disappearance of non-analyzed species), but may also follow from better care unconsciously taken by the analysts the second time, since the analysts were aware that the samples had been run before.

Plots of time history of stability may be drawn for samples which are rerun more than twice. These are shown in Figures B.8 to B.11 for the major ions. The first point of each line, at $\Delta C = 0$, represents the time of the first analysis. Equation (B-1) was applied in each case with C_1 being the first concentration and C_2 the second; the second point was thus generated. Subsequent points were generated by applying equation B-1 for each reanalysis, with C_1 being the concentration from the initial analysis and C_2 the concentration from each reanalysis. Apparent increases in concentration result in negatively-sloped lines.

The time histories for samples analyzed three or more times show clearly the effect of laboratory variations, as the samples for each group were reanalyzed contemporaneously. With few exceptions, there are neither upward nor downward trends in concentration.

Finally, statistics analogous to those of the short-term reanalysis (Table B.1) were generated for the first two analyses of the long-term samples, all the groups being lumped together. These are shown in Table B.5. The results are similar, although it should be noted that the N's differ significantly. The mean values of $|\Delta C|$ are generally higher for the long-term statistics for all species but the relationships among the various species are the same. The mean ΔC values, despite what Figures B.1 to B.6 show in terms of trends, are all positive implying that on the average, the concentrations decreased for all species.

These statistics suggest that normal laboratory variations make up a large part of the apparent differences in concentration for both the short-term and long-term reanalyses and that the trends shown by the mean ΔC for the latter may be fortuitous.

CONCLUSIONS

There is no strong evidence for significant chemical change in the OSCAR rain samples over the time period during which they were analyzed. The only suggested changes occurred for the group 1 samples which were mostly analyzed within 10 days of samples collection. These samples, however, are not typical of the remaining samples chosen for reanalysis. If real, any changes probably take place early

TABLE B.5. Elementary Statistics for Long-Term Stability -- All Groups

Species	N	C, $\mu\text{moles}/\ell$		ΔC		ΔC	
		mean	S.D.	mean	% S.D.	mean	% S.D.
Sulfur	40	45	35	4.7	3.7	+2.5	5.5
Nitrate	44	40	33	5.5	3.4	+2.0	6.2
Chloride	41	10	11	10.0	9.7	+5.1	13.0
Hydrogen	36	69	49	5.3	5.6	+3.4	12.0
Ammonium	38	37	26	7.1	6.5	+1.4	9.4

after collection--earlier, in fact, than the typical time of the first analysis of the ordinary MAP3S/PCN samples. Average statistics for both short-term and long-term reanalyses suggest that the major apparent variability in concentration with time is caused by normal and acceptable laboratory accuracy and precision variations.

FIGURE B.1. Scatter Plot of First and Second Concentration Values for Sulfur (S) = SIV + SVI, Measured as Sulfate ($\mu\text{mol}/\%$). Solid Line is 1:1; Dashed Lines Show $\Delta C = \pm 10$. Δ = Group 1; $\circ$ = Group 2; $\blacktriangle$ = Group 3; $\bullet$ = Group 4 (See Table B.3).

FIGURE B.2. Scatter Plot of First and Second Concentration Values for Nitrate (NO_3 , $\mu\text{mol/l}$). Solid Line is 1:1; Dashed Lines Show $\Delta c = \pm 10$. Δ = Group 1; $\circ$ = Group 2; $\blacktriangle$ = Group 3; $\bullet$ = Group 4 (See Table B.3).

FIGURE B.3. Scatter Plot for First and Second Concentration Values for Chloride (Cl^- , $\mu\text{mol/l}$). Solid Line is 1:1; Dashed Lines Show $\Delta c = \pm 10$. Δ = Group 1; $\circ$ = Group 2; $\blacktriangle$ = Group 3; $\bullet$ = Group 4 (See Table B.3).

FIGURE B.4. Scatter Plot of First and Second Concentration Values for Hydrogen (from pH) (H^+ , $\mu\text{eq/l}$). Solid Lines Show $\Delta c = \pm 10$. Δ = Group 1; $\circ$ = Group 2; $\blacktriangle$ = Group 3; $\bullet$ = Group 4 (See Table B.3).

FIGURE B.5. Scatter Plot of First and Second Concentration Values for Ammonium (NH_4^+ , $\mu\text{mol/l}$). Solid Line is 1:1, Dashed Lines Show $\Delta c = \pm 10$. Δ = Group 1; $\circ$ = Group 2; $\blacktriangle$ = Group 3; $\bullet$ = Group 4 (see Table B.3).

FIGURE B.6. Scatter Plot of First and Second Concentration Values for Calcium (Ca^{++} , $\mu\text{mol/l}$). Solid Line is 1:1, Dashed Lines Show $\Delta C = \pm 10$. Δ = Group 1; $\circ$ = Group 2; $\blacktriangle$ = Group 3; $\bullet$ = Group 4 (See Table B.3).

FIGURE B.7. Scatter Plot of Two Measures of Ion Balance (Equation B.2)
 Δ = Group 1; $\circ$ = Group 2; $\blacktriangle$ = Group 3; $\bullet$ = Group 4 (See Table B.3).

FIGURE B.9. Time History of ΔC for Multiply-Analyzed Samples: Nitrate. Dashed Lines Are for Intermediate-Density Network Samples; Solid Lines for High-Density Network Samples.

FIGURE B.10. Time History for ΔC for Multiply-Analyzed Samples: Hydrogen (From pH). Dashed Lines Are for Intermediate-Density Network Samples; Solid Lines for High-Density Network Samples.

FIGURE B.11. Time History of ΔC for Multiply-Analyzed Samples: Ammonium. Dashed Lines are For Intermediate-Density Network Samples; Solid Lines for High-Density Network Samples.

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