

**Environmental Effects of the
STS-1 Flight Readiness
Firing and Launch**

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PREFACE

The following report is in three sections. Section I is the conceptual overview for the overall monitoring effort described in detail in Sections II and III. Section II was prepared from data obtained during and after the Space Transportation System (STS)-1 Flight Readiness Firing (FRF). The monitoring effort and resulting data from launch of the STS-1 is described in Section III. The latter two sections also contain data submitted by several other organizations.

Minor deviations from the plan described in Section I were made for the FRF and the launch of STS-1. Such deviations were necessary in order to incorporate methods, improvements and lessons learned into subsequent work efforts. Consequently, Sections II and III are written in the form of separate reports with their own methods, results, and conclusions.

ABSTRACT

The FRF of the STS-1's main engines was monitored by a network of air sample sets. Equipment was placed from about 400 meters to about 15,000 meters from the STS vehicle. Water from combustion of liquid hydrogen and oxygen was produced during the firing. The subsequent cloud dissipated harmlessly.

The deployment exercise was judged successful even though only about 40 percent of all devices were activated. Analysis of the exercise resulted in improvements which were incorporated into the monitoring effort for the STS-1 launch.

Launch effects of the STS-1 launch were monitored by a network of air sample devices similar to that used during the FRF. Deployment was begun on the afternoon of 11 April, and continued at intervals until about 0300 hours on 12 April 1981. Deployment activities followed specific routes and schedules described in Sections II and III of the following report. Instrumentation remained on site from about four hours to about 20 hours. All equipment was picked up during the daylight hours of 12 April, 1981.

The deployment for launch was a qualified success. About 80 percent of all radio controlled sites were activated. Several sites detected fallout products from the ground cloud. Analysis of the deployment exercise revealed areas wherein improvement was needed. The information gained and lessons learned from the STS-1 launch will be incorporated into the monitoring effort for STS-2.

ACKNOWLEDGEMENTS

The environmental monitoring effort for the launch of STS-1 was the result of cooperation between many different agencies. Many of those organizations contributed data to the following report. Those contributions are recognized as follows:

<u>Organization</u>	<u>Section</u>
Langley Research Center	Filtered Particulates
University of Central Florida	Impactors and Streakers
University of Central Florida	Dry Deposition, Soil and Limited Water Chemistry
University of Texas at Dallas	Environmental Noise
Planning Research Corporation	Benthic
Pan American	Water Analysis
Computer Services Corp.	Far Field Acoustics
Marshall Space Flight Center	Cloud Diffusion Model and Electrets
U.S. Fish and Wildlife Service	Wildlife Monitoring

Most of the organizations associated with the monitoring effort have published or will publish separate reports detailing their involvement.

Invaluable support was provided by several United States Air Force Organizations. The monitoring effort would not have been possible without their cooperation and assistance.

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SECTION I

OVERVIEW OF ENVIRONMENTAL MONITORING PROGRAM*

1.1 SCOPE

The concept for monitoring potentially adverse environmental effects of initial Space Shuttle launches is presented in the following sections. Described therein are the rationale, management, participant organizations, siting procedures, investigative studies and equipment used during the FRF and the STS-1 launch. Particular details of routes, sites, schedules and experiments are found in Sections II and III of this report.

1.2 RATIONALE

Kennedy Space Center (KSC) lies at the interface between the Eastern Deciduous and Tropical Forest Biomes and contains several unique biotic communities and many endangered, threatened or rare species of plants and animals. Some of the largest brackish wetland areas and undisturbed stretches of ocean beach on the East Coast of United States also are found on KSC.

Federal environmental legislation, presidential executive orders, and State of Florida environmental regulations set the criteria for environmental quality and place restrictions on certain activities to ensure that significant deterioration of the environment does not occur as a result of those activities. Potentially detrimental effects resulting from KSC activities are projected in the institutional Environmental Impact Statement (EIS), dated August 1971; the amended EIS, dated August 1973; and the final EIS, dated August 1979. Those documents contain concise information regarding the types of impacts anticipated, sources of the impacts, and references to the scientific and technical literature that formed the bases for the projections. The following review provides a definition of the procedures utilized by KSC and NASA to comply with those published statements.

* Portions of the following Section were reproduced in whole or part from NASA KSC Document KSC-DF-367-SP.

1.3 MANAGEMENT CONTROLS

Coordination of all monitoring activities during the launch of the STS-1 was centralized at the Environmental Evaluation Center (EEC) in the North Bay of the Range Control Center. The EEC also provided a focal point where key personnel could assemble and be provided with real-time mission status, communicate with field teams, and be readily available for consultation. Console operators and control personnel were provided by NASA Medical Directorate (MD): Project Management Office, Environmental Management Staff (DE-EMS) and Technology Incorporated. Those operators were responsible for coordinating with launch personnel and for directing inquiries and responses from field teams to LC-39 firing room personnel. Coordinate coverage of activities from L-30 to L+12 (hours) was provided for the Wet Countdown Demonstration Test (CDDT or FRF) and Launch Countdown (LCD).

1.4 PARTICIPANTS

A combined team of specialists from governmental organizations, educational institutions and contractors was used to implement the environmental monitoring activities. Those Federal organizations represented were: the National Aeronautics and Space Administration (NASA) Headquarters, Johnson Space Center (JSC), Langley Research Center (LaRC), Marshall Space Flight Center (MSFC), Kennedy Space Center (KSC), the Merritt Island National Wildlife Refuge (NWR), and Canaveral National Seashore (CNS). Educational institutions included the University of Central Florida and the University of Texas. Contractors involved in the monitoring effort were Technology Incorporated, Boeing Services Incorporated, Planning Research Corporation, and Pan American. Overall responsibility for the organization, integration, and management of the plan resided with the KSC Environmental Management Staff (DE-EMS). Responsibility for the technical development, implementation, and analysis of results resided with the NASA (MD).

1.5 IMPLEMENTATION

Studies carried out during the FRF and launch of the STS-1 were designed to describe the impact of launch activities on the KSC ecosystem. Those monitoring elements common to the FRF and STS-1 are presented in the following paragraphs. Elements unique to each other are presented in Section II or III.

1.5.1 SITES. Sites were identified with three prefixes. Those sites around and within 1 mile of LC-39A were designated as Launch (L) sites. Sites within the KSC area but outside the L area were designated as Area (A) sites. Perimeter (P) sites were those sites most distant from LC-39A.

1.5.2 AIR AND PARTICULATES. Air quality in the vicinity of KSC was expected to be temporarily degraded by the ground exhaust cloud formed during launch of the Space Shuttle. The principal detrimental components of the cloud were forecast to be hydrogen chloride (HCl) gas and aluminum oxide (Al_2O_3) particulates. Degradation of the local air quality was expected to be of short duration and to occur immediately after launch.

The unique episodic nature of the pollution event made it an unusual environmental perturbation to monitor and evaluate. Consequently, the air monitoring plan was designed to:

- a. Determine ground level concentration of HCl and Al_2O_3 .
- b. Determine the total dosage of HCl experienced at about 60 sites.
- c. Enable verification of the predictive capabilities of the cloud model.
- d. Determine in-cloud concentrations of HCl.
- e. Determine atmospheric particulate content during and after the launch.
- f. Determine if ambient SO_2 , O_3 , and NO_2 levels were affected by the STS-1 operations.

1.5.2.1 Instrumentation. Each air sample site contained all or some combination of the following equipment:

- a. Particulate or rain collection bucket (same device)
- b. pH paper
- c. HCl dosimeter
- d. HCl analyzer
- e. Indicator plants
- f. Mineral oil water droplet collector
- g. Noise monitoring device
- h. Nuclepore filter
- i. Cascade impactors
- j. Streaker
- k. Electret
- l. Permanent Air Monitoring Stations (PAMS)

The particulate or rain buckets were the same as those currently used in the KSC rain collection network equipment (Aerochem-Metrics Model 20/Wet/Dry Collector).

Acid detection papers (pH paper) generally were eight inches square and contained numerous strips of indicator dyes. The material was specially manufactured for KSC use by the Paul Frank Division of Fil-Chem, Inc. No remotely controlled devices were available for opening and then closing the litmus plates. Consequently, the paper was uncovered at deployment and recovered at pickup.

Dosimeter tubes for the measurement of gaseous HCl were borosilicate glass tubes, the inside of which were coated with ultrapure NaCO_3 . Ambient air was delivered through two tubes at each site at a rate of 2 liters per minute. The tubes were analyzed on a Geomet* analyzer within 48 hours of pickup from the field.

Hydrogen chloride analyzers (Geometes) were continuous sample devices which utilized a tube similar to the dosimeter tubes. Output from the

*Brand name device, manufactured by Geomet Incorporated; Pomona, California

analyzers was channeled through the Environmental Computer Facility (ECF). The data generated were stored and converted to analog form for write-out.

Indicator plants used were radish and pennywort. Their use as HCl detectors was pioneered by workers at North Carolina State University.

Shallow containers of mineral oil were placed about the KSC area. Water droplets falling into the oil were surrounded and thus protected from evaporation and the atmosphere. The droplets were extracted with a micro syringe, diluted with deionized water and analyzed for chloride and calcium. Chloride analyses were determined on a Dohrman Microcoulometer and NA and Ca levels were determined via a Jerrel Ash Atomic Absorption Spectrophotometer.

Noise measurement devices were either A weighted and recorded environmental noise or C weighted from which acoustic data (i.e. frequency band analyses) were obtained.

Airborne particulate loads were examined by entrainment on nuclepore membrane filters. That type of filter contains very uniform pores and can be subjected to analysis by Proton Induced X-ray Emission (PIXE) or Neutron Activation. Cascade impactors contained seven collection stages and served to entrap particles according to size. The stages were subjected to PIXE or Neutron Activation Analysis. Streakers contained a circular filter which rotated past and in contact with an orifice through which a negative pressure was applied. Thus a continuous band of entrained material was found on the filter for the length of the filtration period (7 or 30 days).

Electrets are charged plastic membranes which collected various airborne ionic species.

The four PAMS each contained one continuous O₃ analyzer, one continuous SO₂ analyzer, wind speed and azimuth equipment, temperature sensors, and

a relative humidity device. All analyzer outputs were sampled once each minute and the results transmitted to the ECF on CCAFS. There, the data were stored and analog or digital outputs obtained at will.

Numerous aircraft penetrations of the rocket exhaust cloud were made during the launch of the STS-1. Total (including aerosol) and gaseous HCl, particulates, temperature, and relative humidity were measured.

1.5.2.2 Sites. Two methods were available for positioning atmospheric samplers about the KSC area. The preferred method would have relied on a statistically determined grid pattern for sample placement. Such a system was not feasible due to an inadequate number of sampling units and the difficulty of placing sampling units in the dense swampy areas of the KSC reserve.

The second approach to selecting siting relied on identifying areas of importance in the region. Areas of population concentrations were considered most important, followed by areas of agricultural activity. Areas dominated by natural flora and fauna were considered least important.

The population centers of Merritt Island and the mainland area are contained within several well-defined localities. Significant concentrations of people are found in the VAB and the industrial areas of KSC and Cape Canaveral Air Force Station (CCAFS). Greater concentrations of people are found south of KSC in the towns of Merritt Island, Cape Canaveral, and Cocoa Beach. The City of Cocoa is Southwest of KSC and the City of Titusville is west of the center.

Agricultural activities occur within the boundaries of KSC, on the mainland and south toward Merritt Island. Sampling sites were placed in the vicinity of those activities. Wildlife and floral communities are found in the waters and terrestrial areas of KSC. Sample sites were placed at strategic locations within sensitive marsh, beach and floral areas.

Additional sites were selected and instrumented at locations based on the MSFC cloud diffusion predictions for ground cloud transport after the launch. Minor variations in site locations were necessary between launch events. Consequently, site locations and codes for each event are presented in appropriate sections.

1.5.2.3 Equipment Deployment. Equipment was deployed for each event during two sampling periods. The first period functioned to gather baseline data and was instituted 24 to 48 hours prior to launch. The second period was during the event window and gathered launch related data. Model-dependent and permanent sites were instrumented between L-10 and L-1 hours. Location of Model-dependent sites were based on the L-6 hours model predictions.

Equipment was emplaced at 15 to 20 sites for each baseline deployment. Two routes and two vehicles were required. The firing and launch deployment required five routes and resulted in the emplacement of 45 to 60 sample sets.

1.5.2.4 Site Operations. Geomet analyzers were placed at the Permanent Air Monitoring System (PAMS) sites prior to the monitored event. Geomet HCl analyzers were operated for at least one hour, starting at L-0. Long-term streakers were operated at each of the PAMS sites. In addition, four 7-day streakers were deployed for both monitored events. Dry deposition was collected with inert plastic buckets at each air quality sites. Open-faced Nuclepore filters were used to collect particulates at some sample sites. Seven stage, cascade impactors collected samples at several sites during the events. Sample pumps for the dosimeter tubes and Nuclepore filters were activated via a dedicated Remote Control (RC) system.

1.5.3. RAIN AND SOIL. Exhaust from the two Solid Rocket Boosters was expected to contain up to 223, 150 pounds of HCl⁽¹⁾. Consequently, if a local rainfall should coincide with an STS launch, acidic rainfall might be expected in the KSC area. Local rainfall and selected soils have

been analyzed for more than four years to establish average ambient conditions⁽²⁾. Launch-related influences on precipitation and soils were detected by comparing precipitation and soils exposed during a launch with baseline values.

The rain and soil monitoring program was designed to:

- a. Measure the quantity and quality (pH, conductivity, and elemental constituents) of postlaunch rain events for comparison with seasonally recorded ambient conditions.
- b. Determine if nonstandard rain events were launch-related.
- c. Determine the effects of postlaunch rain events on selected soils.

1.5.3.1 Instrumentation. Instrumentation required for precipitation soil sampling and analysis was as follows:

- a. Precipitation collection
 - (1) Aerochem wet/dry collectors
 - (2) Mineral oil dishes - 12 x 12 x 4 - centimeter plastic dishes containing water saturated mineral oil to a depth of 1 centimeter
 - (3) Acid-washed polyethylene buckets
- b. Soil sample collection
 - (1) Core sample collectors
 - (2) Core sample source-identifiable containers
- c. Laboratory facilities
 - (1) pH meters
 - (2) Conductivity meter
 - (3) Ion chromatograph
 - (4) Atomic absorption spectrophotometer

1.5.3.2 Site Operations. Eight existing rain collection sites were utilized in addition to the deposition collectors referred to in paragraph 1.5.2.1.

All rain/deposition buckets were thoroughly cleaned but ten buckets were specially washed with Alkanox, rinsed with nitric acid (HNO_3) and finally rinsed with deionized water. After collection pickup, those specially washed buckets were rinsed with 200 ml of deionized water. An aliquant of each 200 ml rinse was used for conductivity determination. The remaining rinse water was subjected to ion analyses. Conductivity was determined via a YSI model 31 Conductivity Bridge. All ion analyses except Ca^{+2} and Mg^{+2} were performed with a Dionex System 14 Ion Chromatograph. Calcium and magnesium ion concentrations were determined via an Instrumentation Laboratory Flame Spectrophotometer.

Triplicate soil samples were collected at sites beneath the launch cloud's direction of travel.

Mineral oil water droplet collectors were opened at site deployment and closed at pickup.

1.5.4 SURFACE WATER. The quality of waters in the vicinity of Launch Complex 39A was expected to be affected by the introduction of toxic materials, e.g., heavy metals, into the waters; as a result of pH changes due to the introduction of acidic water; or as a result of salinity changes from the introduction of large amounts of fresh water. Two possible routes of contaminant entry were input from the noise suppression and water deluge systems and raindrop scavenging of contaminants from the launch cloud.

1.5.4.1 Instrumentation. Standard collection bottles supplied by the Pan American Environmental Health Office were the primary means of sample collection. In addition, standard laboratory instruments similar to those used in the soil analysis program were required.

1.5.4.2 Site Operations. Samples of water were collected from several sites including the deluge water holding ponds after the STS launch. Most of the samples were analyzed by the Pan American Environmental Health Laboratory. However, some samples were analyzed by independent laboratories.

1.5.5 NOISE. The peak acoustic noise level generated by an STS launch was projected not to exceed 160 decibels (dB). Consequently, measurements of acoustic noise during launch were most important to interpretation of wildlife reactions. Measurement of acoustic noise at selected sites during an STS launch was expected to allow validation of predicted acoustic noise levels.

1.5.5.1 Instrumentation. The following instrumentation and equipment were used to collect noise data during the FRF and the STS launch:

- a. General Radio No. 1560 P5 microphone with AFEC or Chesapeake model FE41A amplifier. The data were recorded on an Ampex FR-1300, Racal Store 4D or Sangamo 350D magnetic tape recorder.
- b. Sony No. PFM-15 magnetic tape recorder and acoustic calibrator.
- c. Metrosonic db-652/301/14 sound level meter
- d. Metrosonic db-652/301/16 sound level meter
- e. General Radio Model GR-1982 precision sound level meter
- f. General Radio sound-level meters, type 1551-C

1.5.5.2 Site Operations. Five far field acoustic devices were deployed independently of other deployment exercises. In addition those devices utilized by the Fish and Wildlife Service, during their surveillance of bird reactions, were deployed and managed by that group.

Environmental noise monitoring devices were deployed along with the environmental monitoring equipment. The devices were turned on when emplaced and recorded environmental noise on the A-weighted scale for six to eight hours. Data thus recorded were retrieved in the laboratory.

1.5.6 VEGETATION. Merritt Island is a mosaic of coastal vegetation communities with over 2,500 acres of citrus groves within the confines of KSC. Therefore, NASA was obligated to determine if the STS program in general, and the launch ground cloud in particular, would impact

native or cultivated vegetation in the area. Injury to the vegetation or degradation of surface appearance of the citrus could cause economic losses to the grove lessees and upset the basic ecology of the area by reducing the producer component. The principal constituents of the STS exhaust ground cloud with significant phytotoxic potential were HCl and aluminum.

Use of indicator plant species is a classical method of assessing impacts from air pollutants. Both greenhouse-reared plants and HCl-sensitive plants growing in the field were used in the indicator species program. The reaction of such plants to aluminum has not been determined.

The vegetation monitoring plan permitted:

- a. Identification of foliar injury that might have resulted from acute exposure of selected plants to the exhaust ground cloud
- b. Determination of vegetation injury around the launch site.
- c. Verification of results from controlled chamber exposures

1.5.6.1 Instrumentation. The following instrumentation, equipment, and plant species were used during the vegetation monitoring program:

- a. Greenhouse, horticultural equipment, and hygrothermographs
- b. Cameras, drying oven, ion chromatograph
- c. Radishes (Raphanus sativus) and pennywort (Hydrocotyle umbellata).

Radishes were planted in 10 cm diameter pots. Four seeds were planted and each pot was thinned to one plant. Pennyworts were planted in 10 cm pots using the same soil mixture. They were started from cuttings of pennyworts taken from a healthy population in a roadside ditch. Planting of both radish and pennywort began 5 weeks before FRF. Pennyworts were thinned to one plant per pot after the third week. The plants were grown under relatively stable greenhouse conditions of temperature, humidity, and sunlight. All plants were watered as required and initially fertilized two weeks after planting; they were fertilized weekly

thereafter. The plants were five to seven weeks old when deployed. Four pots of each species were placed in a single container (flat) for deployment.

1.5.6.2 Site Operations. Natural area vegetation was selected at numerous sites and tagged several weeks before the event to be monitored. Leaves of selected damaged plants were washed post event and the wash water subjected to analyses. No tissue analyses were performed.

Greenhouse-reared indicator plants were deployed along with the environmental monitoring equipment. Damaged plants were described and photographed and some plants were harvested and dried for future chemical analyses.

Each of the natural vegetative sites was revisited at L+72 hours and foliar injury assessed. Injured plants were photographed, harvested, and dried in anticipation of tissue analyses. Such analyses were not conducted for the STS-1 launch.

1.5.7 FAUNA. Kennedy Space Center is designated as a National Wildlife Refuge, therefore, NASA was committed to avoid unnecessary adverse impact on the wildlife and habitat in the KSC vicinity. The varied impacts of an STS launch on wildlife were unknown but the effects of noise were considered the most likely environmental perturbation to cause immediate and measurable reaction in wildlife.

1.5.7.1 Instrumentation. The following instrumentation and equipment was used during the terrestrial fauna monitoring program:

- a. Video cameras and conventional cameras
- b. Hand-held db meters
- c. Chronometers and stop watches
- d. Binoculars and telescopes
- e. Tape recorders

1.5.7.2 Site Operations. Observations of terrestrial fauna were conducted at five areas prior to the monitored event. Observation teams were on station several hours before the event. Sound levels were measured at some sites and reactions of the birds to those sound levels were noted. The area around LC-39A was visited the day after launch of the STS-1.

1.5.8 BENTHIC COMMUNITIES. A large percentage of the noise suppression and deluge water used during a launch eventually finds its way into the lagoons north of LC-39A. Waste water from a launch was expected to be contaminated with a variety of metals and organic substances. Consequently, the effect of such substances on the lagoonal ecosystem was of concern.

1.5.8.1 Instrumentation. The following instruments and equipment were utilized during benthos investigations:

- a. Ekman grab sampler
- b. Soil sieves
- c. Dissecting microscope

1.5.8.2 Site Operations. Benthic invertebrates were sampled at three locations. Samples were obtained via an Ekman grab sampler, screened, washed, and preserved. Random samples were examined at KSC and those organisms in Table 3-17 were identified. The samples were then sent to Dr. D. Reish of Long Beach State University for detailed analysis and report preparation.

1.5.9 CLOUD DIFFUSION MODEL. A mathematical model has been developed to predict exhaust species deposition downwind from a launch ⁽³⁾. That model was used during the FRF and STS-1 launch to predict the ground level concentrations of HCl and Al₂O₃.

1.5.9.1 Instrumentation. The computer system utilized in the ECF for model prediction consisted of the following Hewlett Packard Equipment:

- a. 3050B Automatic Data Acquisition System
- b. 9640A Multiprogramming System
- c. 7970B Digital Tape Unit
- d. 2644A Terminals
- e. 7210A Digital Plotters
- f. 9866A Printer
- g. 2607A Line Printer
- h. 7920 Disc Drive
- i. Teletypes

Weather data utilized were obtained from Rawinsondes, Jimspheres, and Windsondes.

1.5.8.2 Site Operations. Weather data were obtained on the following schedule as shown in Table 1-1.

Table 1-1. Weather Data

<u>T-time</u>	<u>Device</u>
-74 hours	Jimsphere
-52.5 hours	Rawinsonde
-50.0 hours	Jimsphere
-28.5 hours	Rawinsonde
-26.0 hours	Jimsphere
-13.0 hours	Jimsphere
-13.0 hours	Windsonde
-12.0 hours	Rawinsonde
-10.5 hours	Jimsphere
-10.5 hours	Windsonde
- 8.5 hours	Rawinsonde
- 7.0 hours	Jimsphere
- 7.0 hours	Windsonde
- 5.0 hours	Rawinsonde
- 3.5 hours	Jimsphere

Table 1-1. Weather Data (Continued).

<u>T-time</u>	<u>Device</u>
- 3.5 hours	Windsonde
- 130 minutes	Rawinsonde
- 100 minutes	Windsonde
+ 0	Rawinsonde
+ 15 minutes	Jimsphere

Model predictions were not made for each of the times listed above. However, the capability for such activity existed.

The ECF computer filed such weather data as commanded and, via the Rocket Exhaust Effluent Diffusion (REED) model, calculated deposition concentrations and locations based on current wind and weather conditions. Sites located and instrumented as a function of weather or model data were called "model sites".

A more complete and detailed report of the model activities will be presented in an MSFC document.

1.5.10 CLOUD PHOTOGRAPHY. Accurate pictorals of the exhaust ground cloud were essential to determining the actual direction of drift and for estimating density and composition of the cloud.

1.5.10.1 Instrumentation. A variety of still and motion cameras were positioned about the KSC area. Those devices of importance to the environmental monitoring effort were:

- a. Single lens Reflex still frame cameras located at UCS6, UCS2, and UCS9.
- b. Video recorders located at UCS6 and the RCC.
- c. An infrared camera located at UCS6.

The "USC" designation is an abbreviation for Universal Camera Site. Such sites are located throughout the KSC area, but are not shown in this report on a dedicated map.

1.5.10.2 Site Operations. The Video and IR camera began filming several seconds before ignition and followed on the vehicle during FRF and the launch of STS-1. However, both cameras were returned to the ground cloud several minutes after launch.

The still frame photographs were obtained of the ground cloud every 30 seconds for 30 minutes after launch.

1.5.11 AIRCRAFT OPERATIONS. Langley Research Center provided a Cessna 402 aircraft equipped with a variety of instrumentation for in-cloud sampling. Details of that sampling and data will be published in a separate report from LRC. Summary results of the aircraft operations are contained within this report in those sections dealing with in-cloud sampling.

SECTION II

STS-1 FLIGHT READINESS FIRING

2.1 BACKGROUND

A Flight Readiness Firing (FRF) of the Space Shuttle's main engines was conducted on 20 February 1981. The engines were fired for 20 seconds beginning at 0845 EST. They were fueled with liquid hydrogen and liquid oxygen, thus no toxic atmospheric contaminants were expected. Deployment of the atmospheric monitoring network for the FRF was intended to prepare the environmental monitoring crew and equipment for the STS-1 launch and to provide baseline data for that launch.

Every observational element presented in the overview (Section I) was not accomplished for the FRF. Water, soil, and vegetation were not sampled and no environmental noise measurements were made. However, acoustic data were collected at several sites.

2.2 METHODS

2.2.1 NETWORK DESIGN.

2.2.1.1 Sites. The atmospheric monitoring system was designed to detect gaseous HCl, particulates, and acid rain, none of which were expected to be produced during the FRF. Site locations were chosen to monitor the ground cloud in the immediate vicinity of the pad and to detect the presence of exhaust species in areas of population or agricultural concentration. Some sites were remotely controlled and some were manually controlled. The location of some sites was to be determined by the Marshall Cloud Model and a few sites were at the present Permanent Air Monitoring Stations (PAMS) locations. Site locations are shown in various figures throughout paragraph 2.2.

2.2.1.2 Baseline Data. Limited baseline data were obtained about 41 hours (the afternoon of 18 Feb 1981) before the FRF. Sampling equipment for such data collection was deployed among three routes. Route A

covered northern Merritt Island. Route B covered the LC-39A area and Route C covered the south end of KSC. The deployment routes and sites are illustrated in Figures 2-1 through 2-3.

2.2.1.3 Firing Data. The KSC-Merritt Island area was divided into six experimental site deployment routes. All sites sampled during the baseline deployment were sampled during the firing deployment. Deployment routes and sites are shown in Figures 2-4 through 2-9.

2.2.1.4 Pager System. Approximately one-half (29 units) of the total sampling system was designed to be activated via remote control. Tone coded commercial pagers were used as the control signal receiver. An antenna was mounted on the O&C Building (M7-355) from which one pager system (KSC 111 net, 170.400 Mc) was to be activated. A second system (KSC 113 net, 149.175 Mc) was necessary to cover all remote sites. The transmitter for the 113 net was carried north to site P8 at the Wildlife Laboratory, from which the pagers in that area were activated. Location of the pager equipped sites is shown in Figure 2-10.

2.2.1.5 Equipment Deployment and Pickup. Site and travel times were based on an earlier investigation in which some of the routes were actually traveled. Results of that investigation showed about 15 minutes at each site and 15 minutes travel time between sites was reasonable. Such knowledge was necessary to minimize equipment exposure times and for coordination with NASA Safety and Security.

2.2.2 GASEOUS MEASUREMENTS.

2.2.2.1 HCl Dosimetry. Measurement of the atmospheric HCl dosage was by analysis of dosimetry tube contents.

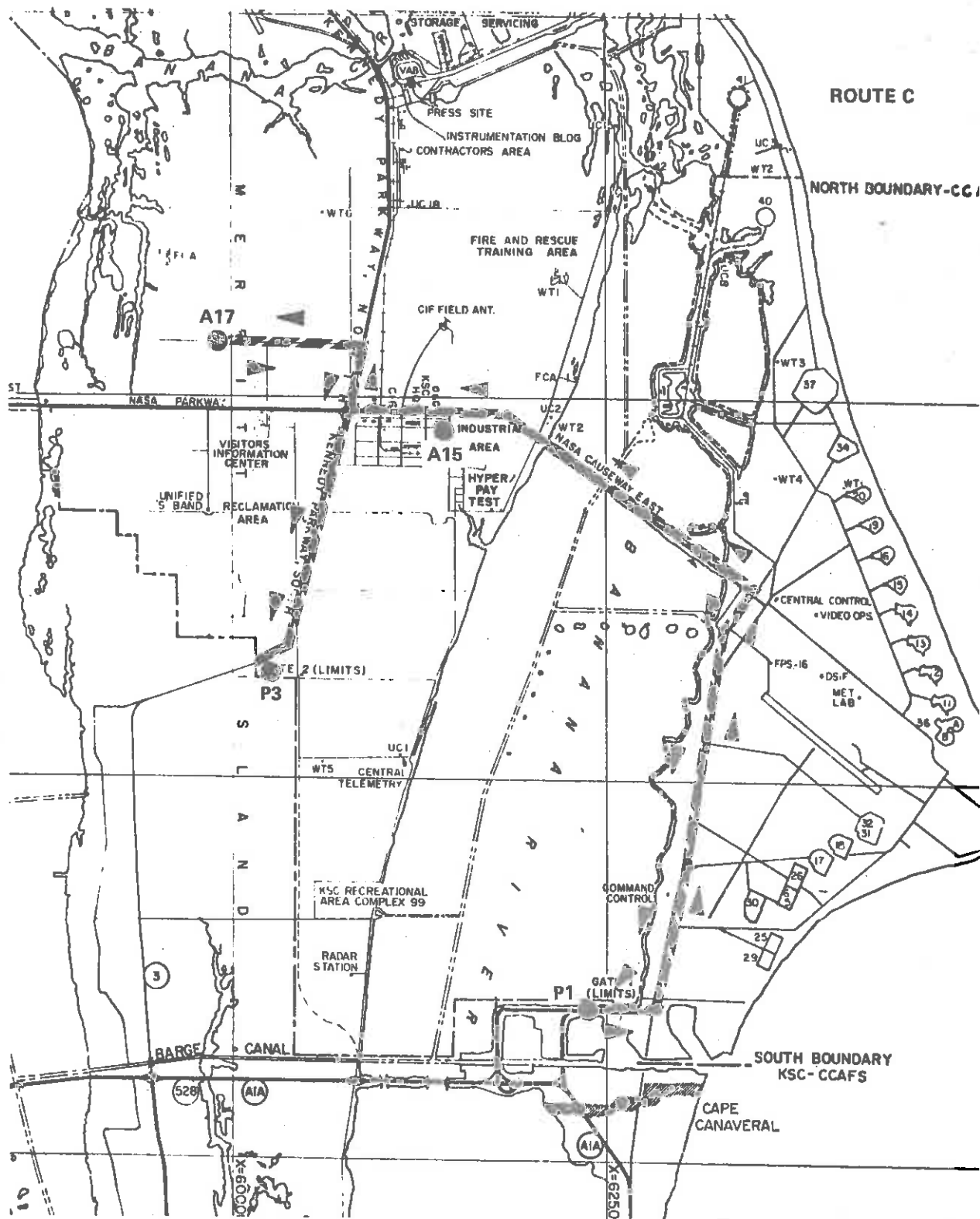


Figure 2-3. Deployment - Route C

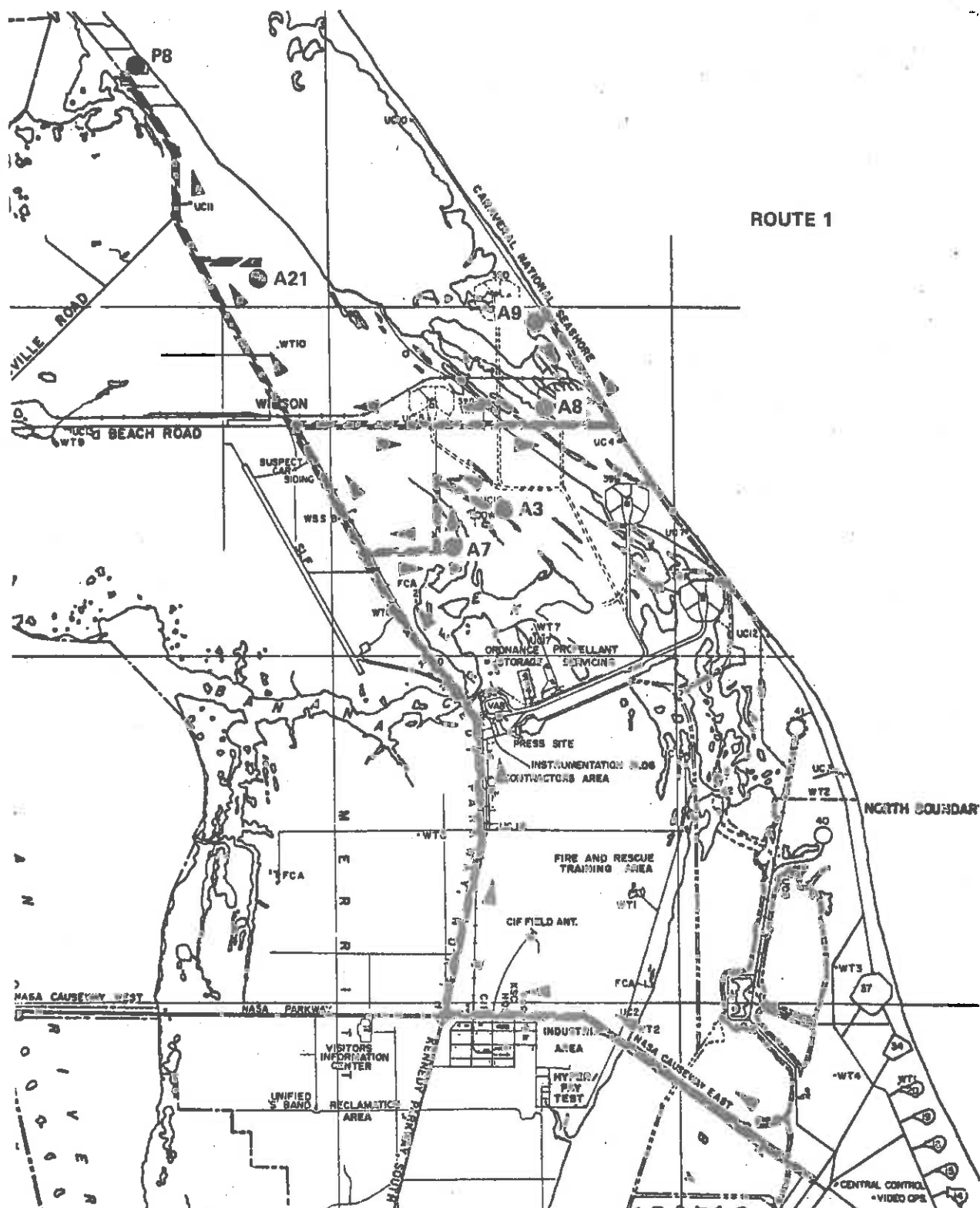


Figure 2-4. Deployment - Route 1

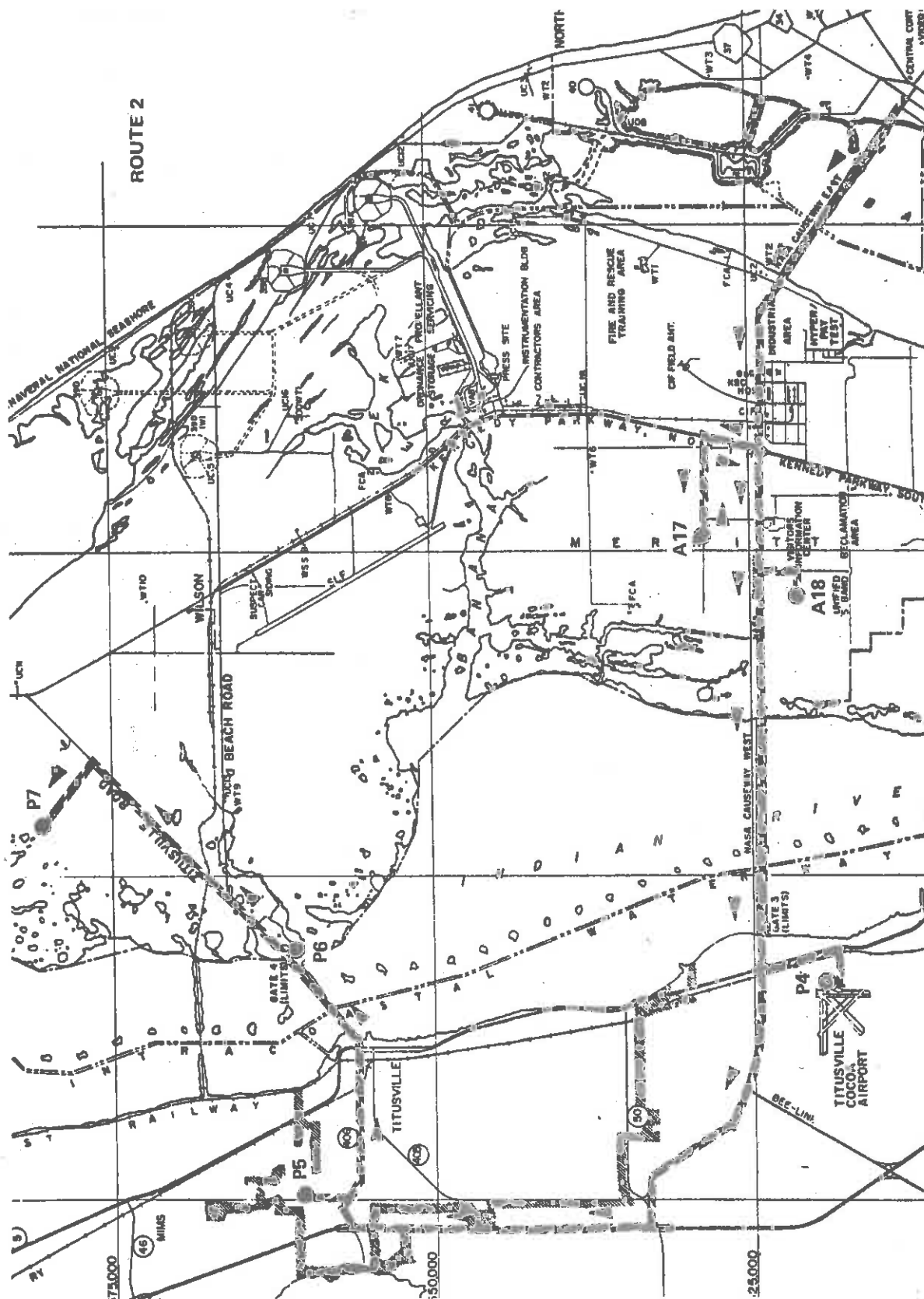


Figure 2-5. Deployment- Route 2

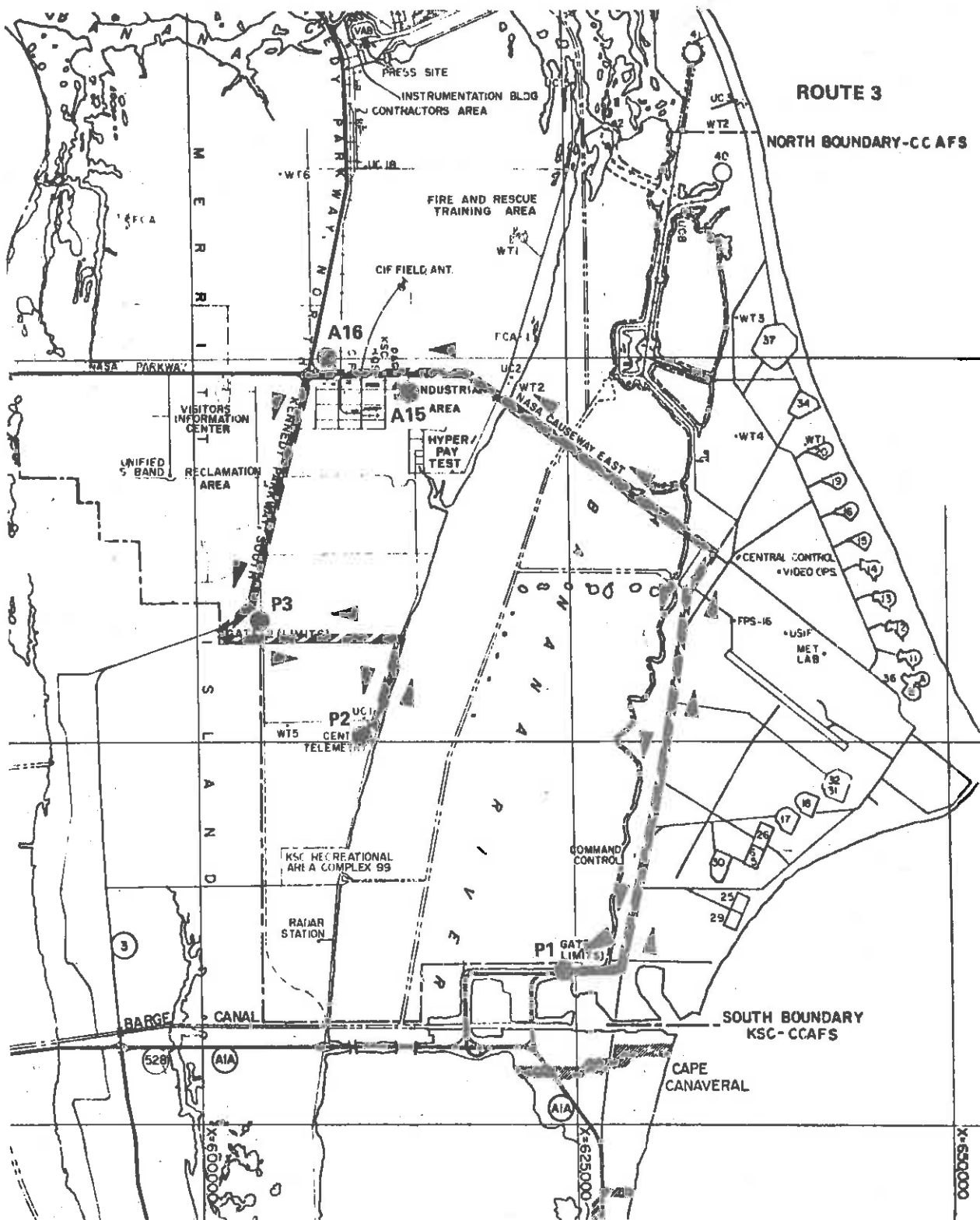


Figure 2-6. Deployment - Route 3

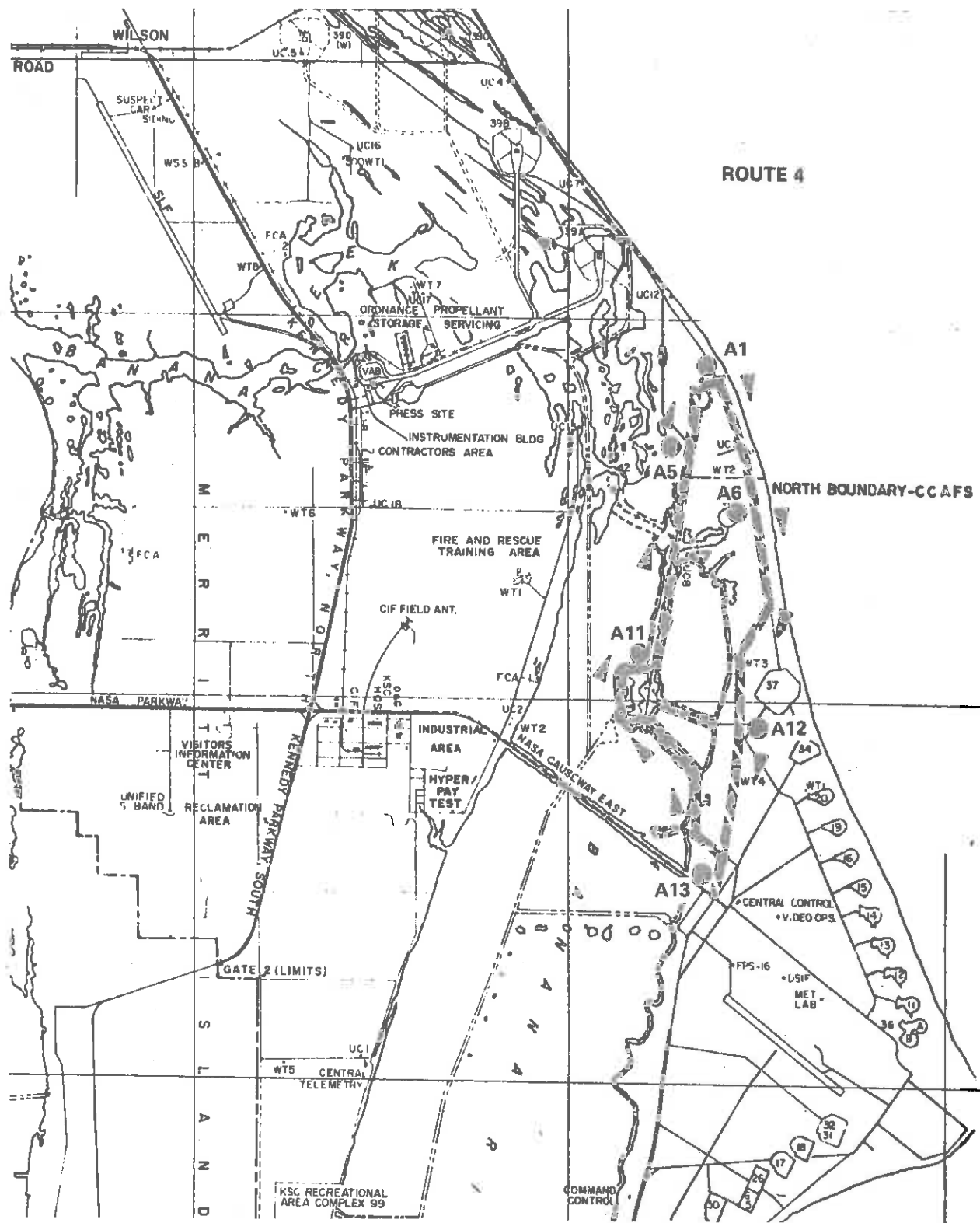


Figure 2-7. Deployment - Route 4

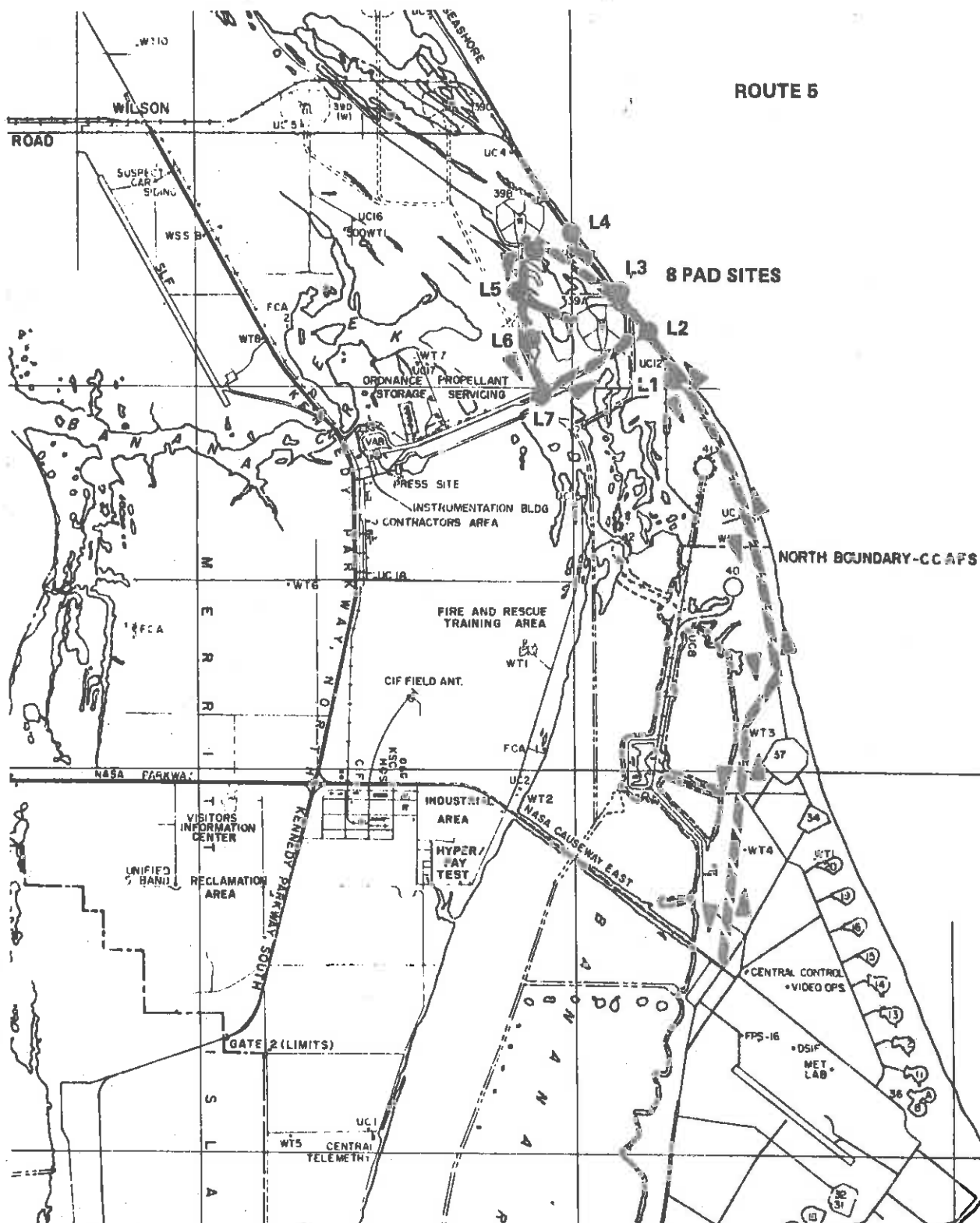


Figure 2-8. Deployment - Route 5

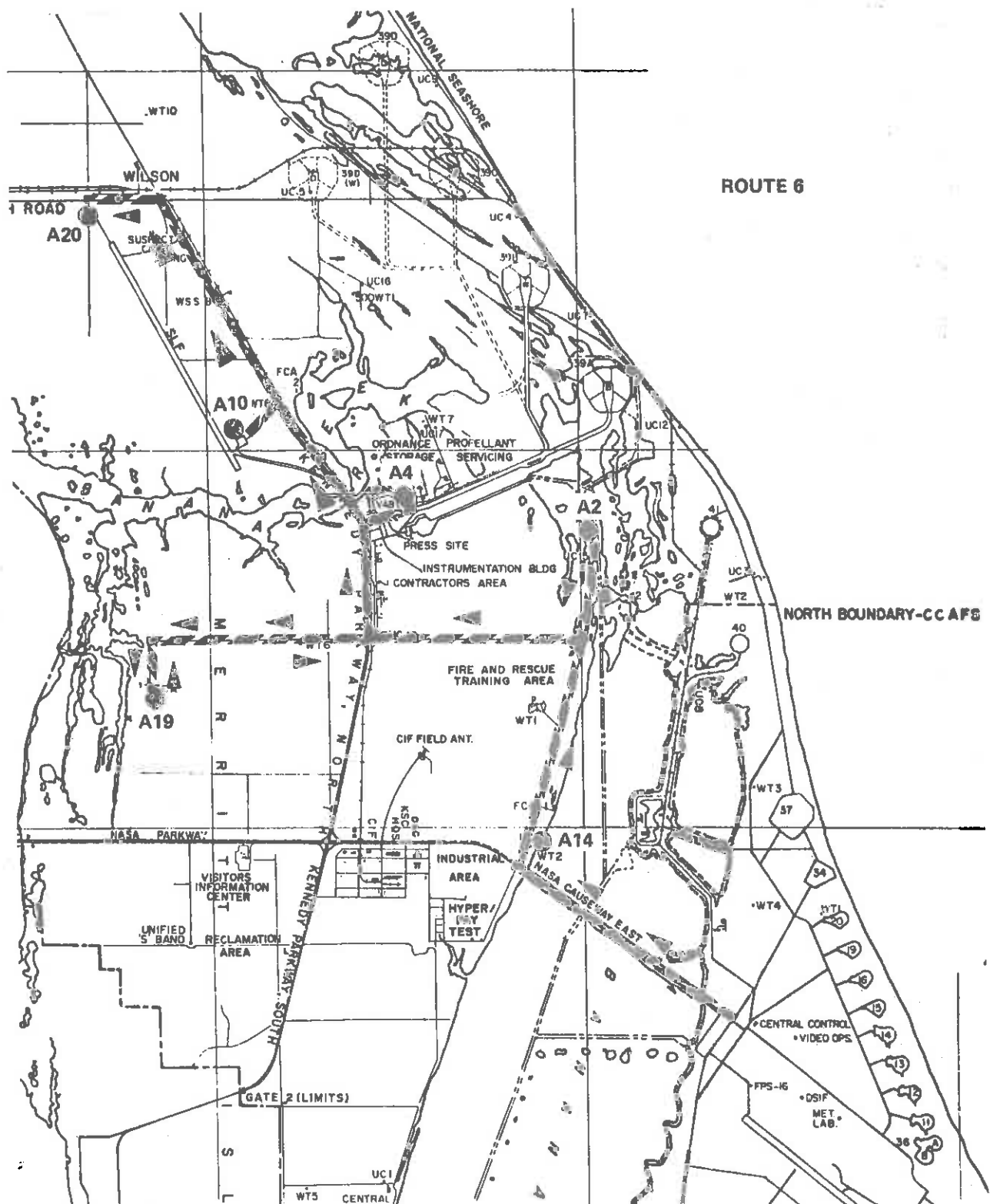


Figure 2-9. Deployment - Route 6

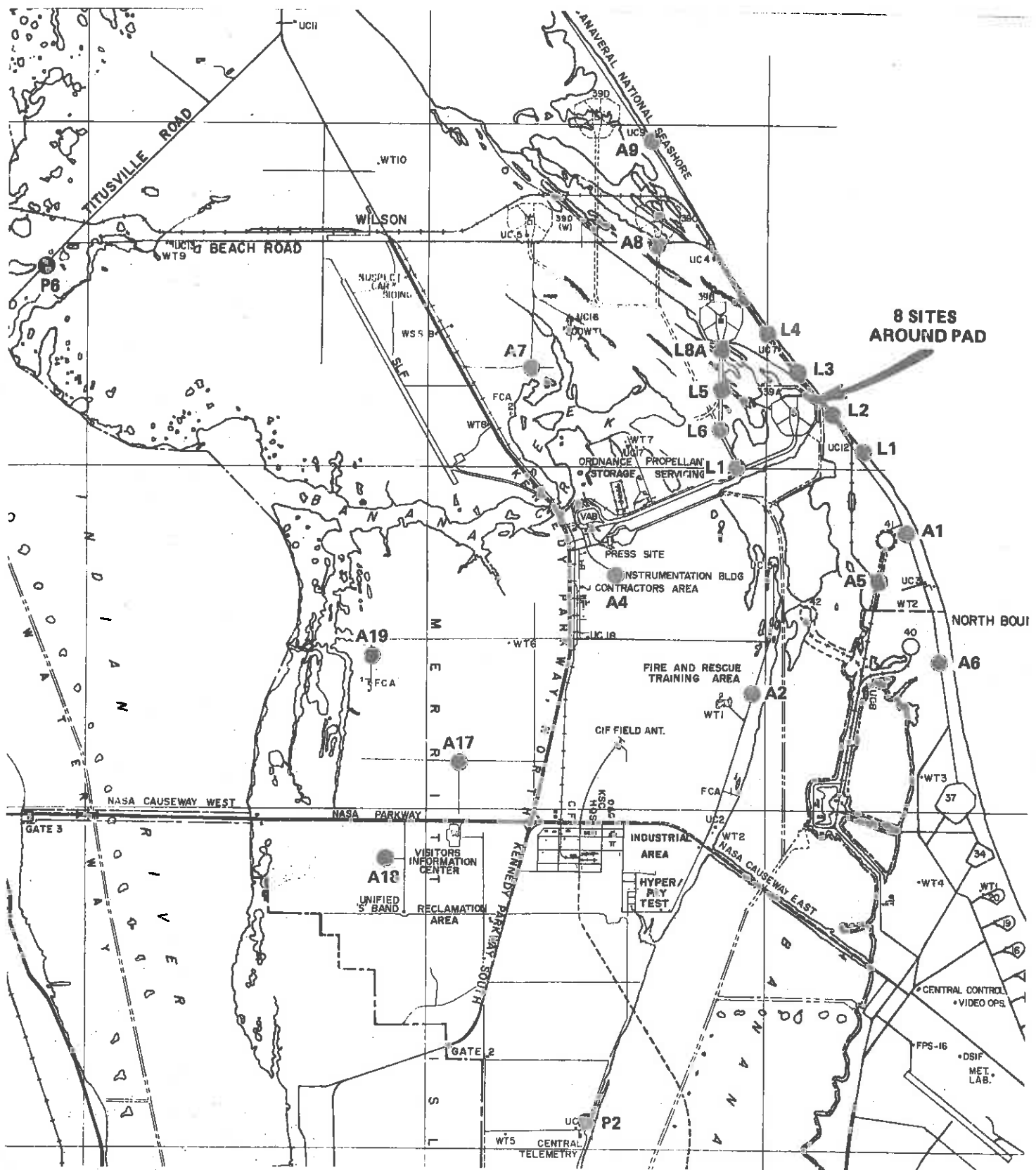


Figure 2-10. Location of Pager Equipped Sample Sites

The mean HCl dose of both tubes was calculated when both values were greater than or equal to 1 ppm/sec. However, when one or both tubes in a pair revealed values of trace or less than 1, no means were obtained. Tubes were located at each site as shown in Figure 2-11.

2.2.2.2 HCl Analyzers. Geomet HCl analyzers were stationed at each of the four PAMS units and one model site (Figure 2-12). The units were restricted to those sites with 120 VAC power. All the devices were cleaned and all tubing and solutions were replaced with fresh supplies while in the laboratory. Each Geomet was then taken to a PAMS during the day of 18 February 1981. The analyzers were calibrated on site before and after the firing.

2.2.2.3 PAMS Data. Four PAMS were operational during the FRF. Of the four, one (PAMS A) was near enough to LC-39A to experience exhaust effects. Each PAMS contained an operational O_3 analyzer. Operational SO_2 analyzers were in PAMS A and F. Locations of the PAMS units are shown in Figure 2-12.

2.2.2.4 In-Cloud Measurements. The NASA LRC aircraft was on-site at KSC several days prior to the FRF. However, the aircraft was forced to return to LRC before the FRF due to slippage of the event.

2.2.3 FALLOUT MEASUREMENTS.

2.2.3.1 Acid Fallout. Acid fallout was assessed by exposure of pH paper to the atmosphere. Large squares (8 x 8 inches) of paper were placed at 30 sites and small squares (4 x 4 inches) of the same paper at 30 sites. The large paper was taped to a larger plastic square which in turn was covered by second square of plastic. The small squares were clipped to an aluminum plate covered by a small plastic bag. Location of the pH paper is shown in Figure 2-13.

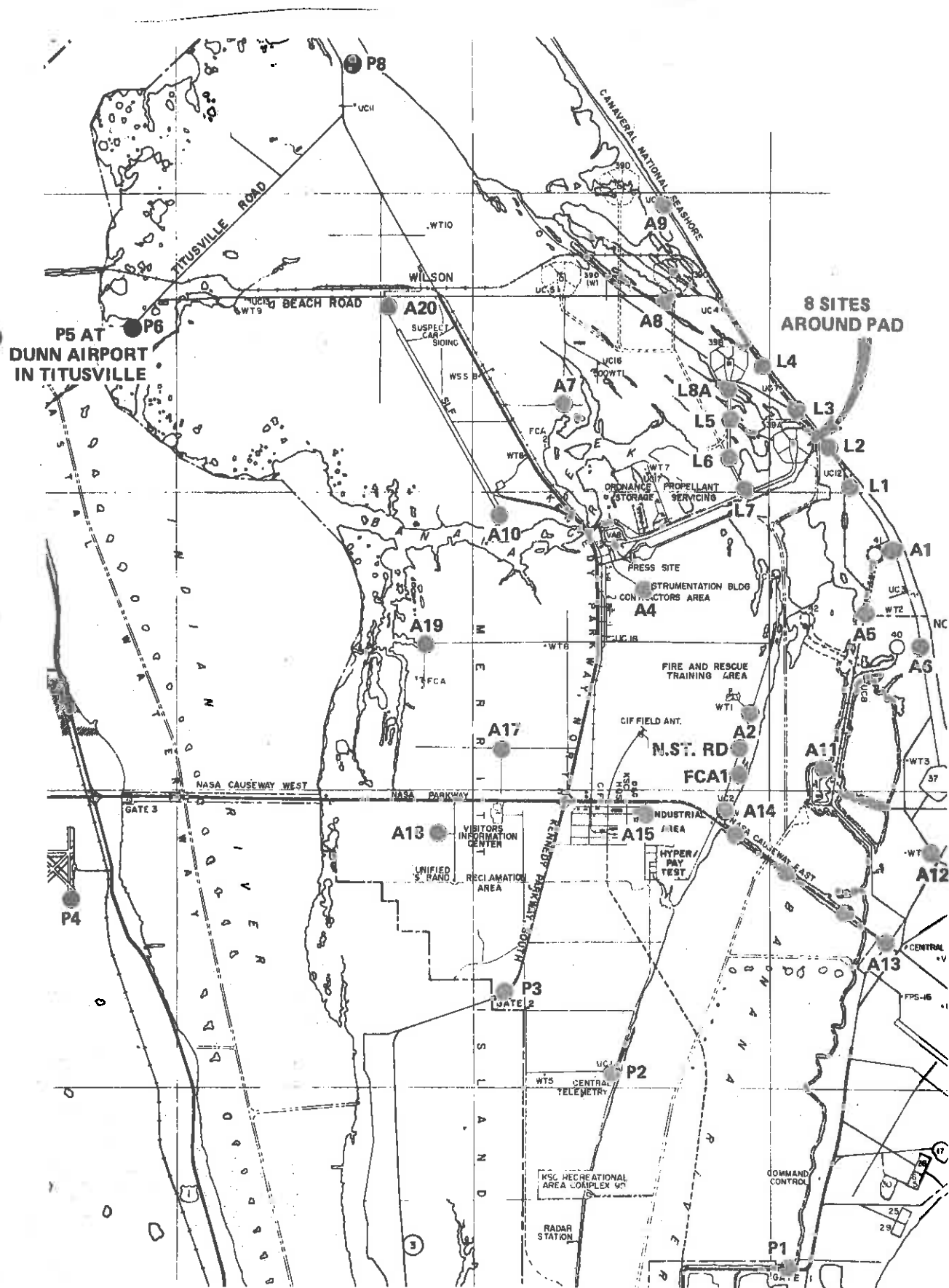


Figure 2-11. Dosimeter Tube and Rain Bucket Sites

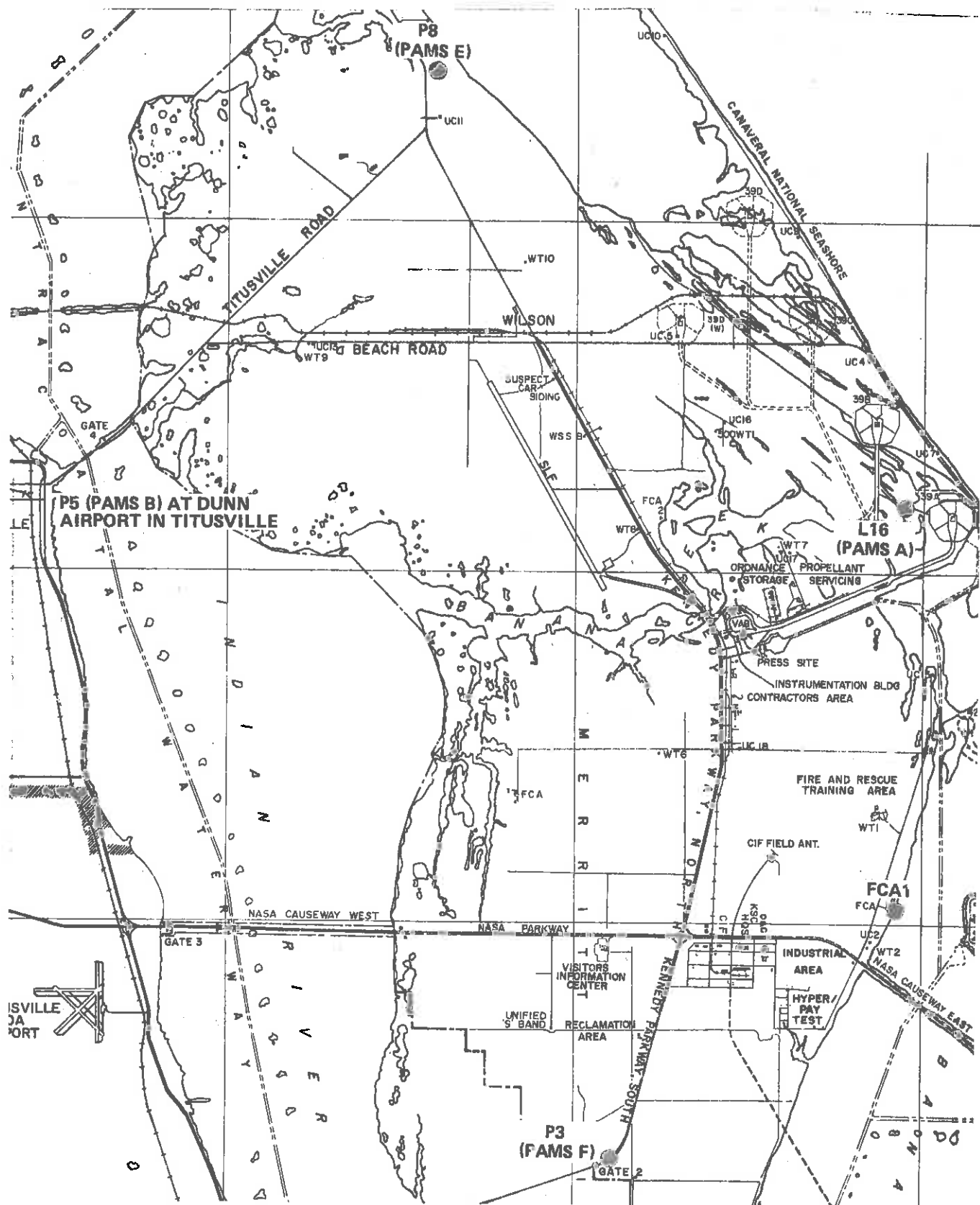


Figure 2-12. Location of Geomet HCl Analyzers

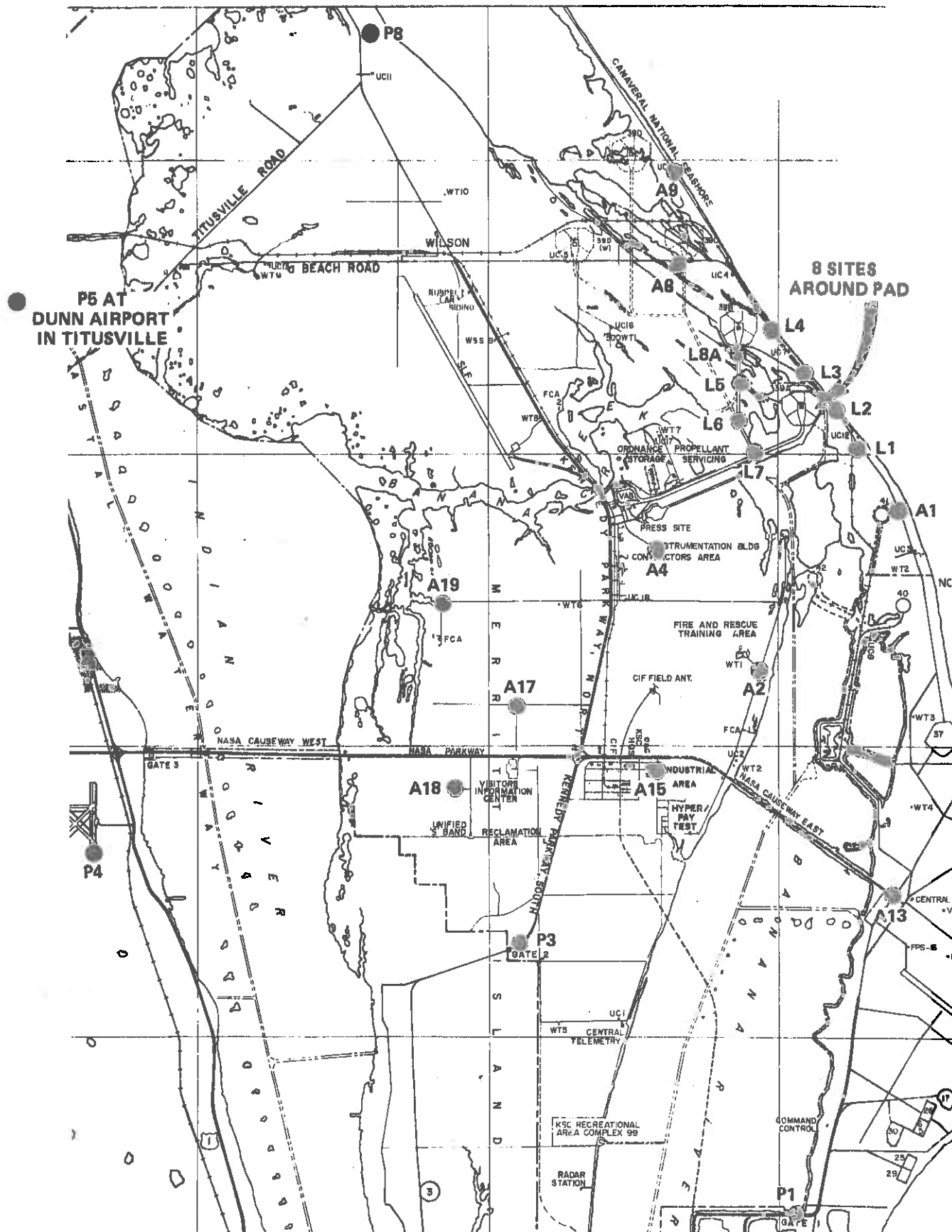


Figure 2-13. Location of pH Paper

2.2.3.2 Rain Collection. Five of the specially washed buckets were deployed about the LC-39A perimeter and five were deployed at predetermined model locations. Rain buckets were at sites with dosimeter tubes, the locations of which are shown in Figure 2-11.

2.2.4 INDICATOR PLANTS. Two indicator species, radish (Raphanus sativus) and pennywort (Hydrocotyle umbellata) were exposed during the FRF. Flats containing four radish and four pennywort were placed at 37 sites prior to the FRF. Location of those sites is shown in Figure 2-14.

2.2.5 WILDLIFE MONITORING. Fish and wildlife biologists monitored five sites to determine the effect of FRF generated sound on selected wildlife species. Normal activities at the five sites (Figure 2-15) were determined at no more than T-72 hours. Those activities were compared with observations made immediately before, during, and after the FRF.

2.2.6 BENTHIC COMMUNITIES. Methods for sampling the benthos were described in Section I, paragraph 1.5.8.

2.3 RESULTS

2.3.1 NETWORK DESIGN ELEMENTS.

2.3.1.1 Sites. The choice of monitoring sites for the FRF generally was adequate. The cloud drifted southeasterly thus limiting the availability of potential cloud sample sites. Such wide-spread site distribution was not necessary for the FRF. However, one of the major functions of the FRF deployment exercise was to provide an opportunity for a full scale deployment prior to the launch of STS-1.

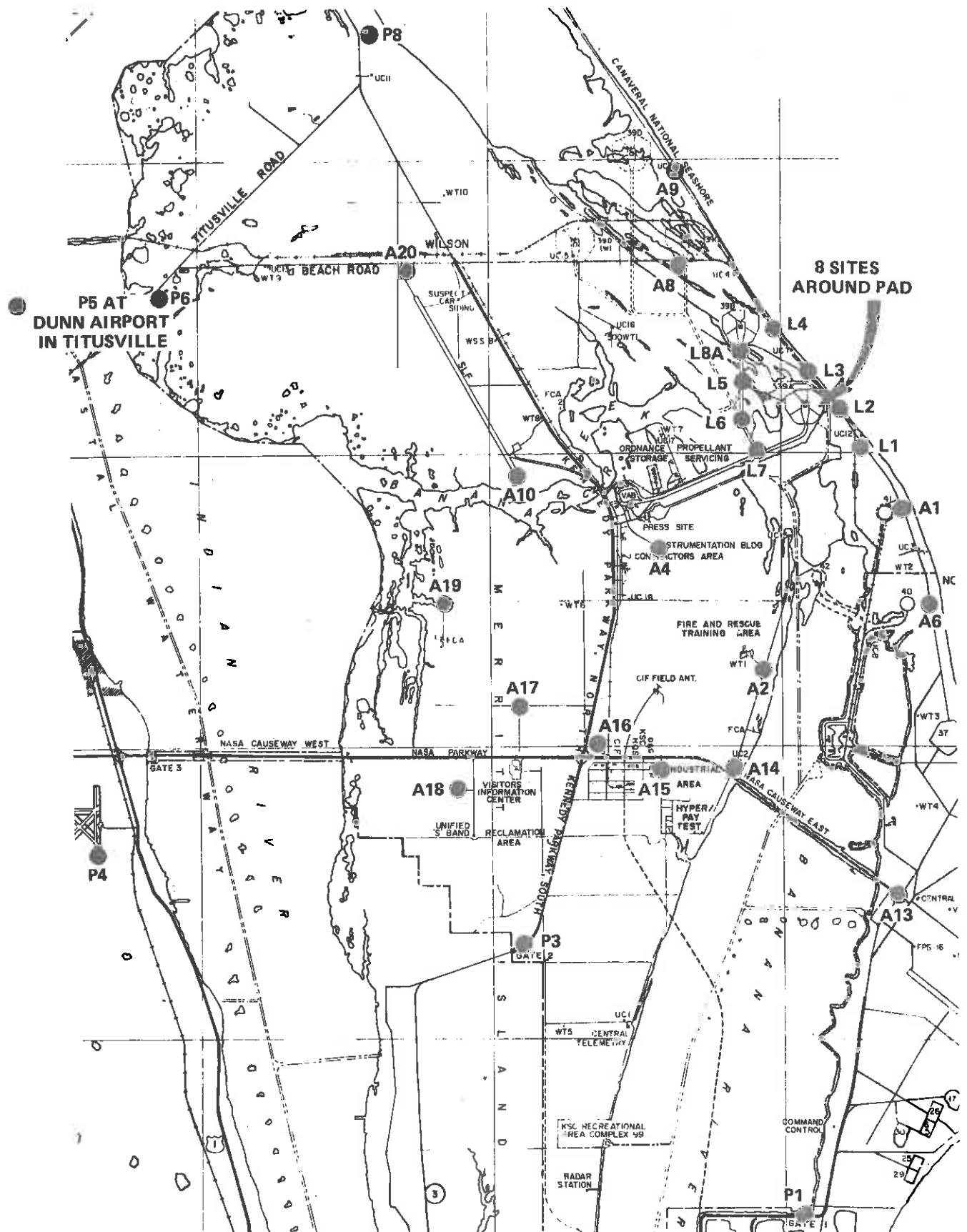


Figure 2-14. Locations of Indicator Plants



2.3.1.2 Baseline Data. Data obtained during the baseline deployment were largely not utilized. Several factors contributed to the decision not to attempt any extensive use of the baseline data. Those factors were:

- a. Failure of many remote control systems
- b. The small number of sites actually instrumented
- c. Confusion over analytical procedures
- d. The expected production of a steam (water) cloud during the firing.

However, the baseline exercise provided a first opportunity for deployment of some data systems. It also allowed a "field practice" before the deployment for the FRF.

2.3.1.3 Firing Data. Valid data were obtained from several sample systems during the FRF. Results from those systems are presented in paragraphs 2.3.2 through 2.3.4.

2.3.1.4 Pager System. Pager operation was checked before deployment and all devices functioned properly. However, the sample network experienced an estimated 60 percent remote control unit failure in the field. The failure estimate was derived from an inspection of the data shown in Table 2-1. Those data reflect the following observations:

- a. 29 pager units were deployed
- b. 8 units recorded positive (≥ 1 ppm/sec) values
- c. 10 units are known to have been activated as indicated by the Lapsed Time Meter (LTM)
- d. Two units recorded positive values even though the LTM did not operate.

Those units indicating no dosimeter response and unknown LTM readings were assumed not to have operated. Those units with any combination of dosimeter response or LTM readings were assumed to have operated

Table 2-1. Pager Performance

Remoted System	LTM* Activated	Dosimeter Response
L1	Yes	Yes
L2	No	Yes
L3	Yes	No
L4	No	No
L5	Yes	No
L6	No	No
L7	No	No
L8	Yes	No
L8A	Yes	Yes
L9	No	No
L10	Yes	Yes
L11	Yes	Yes
L12	No	No
L13	Yes	Yes
L14	Yes	Yes
L15	No	Yes
A1	?	No
A2	?	No
A4	?	No
A5	?	No
A6	?	No
A8	?	No
A9	?	No
A17	?	No
A18	?	No
A19	?	No
P2	Yes	No
P6	?	No
*---Lapsed Time Meter		
?---No LTM		

correctly. Thus, a total of 12 units appear to have functioned properly. The data do not allow estimation of how many pager units with unknown LTM readings and no dosimeter response actually operated properly.

2.3.1.5 Equipment Deployment and Pickup. All deployment schedules were based on 15 minutes on-site and 15 minutes travel time between sites. Mean on-site and travel times for each route were calculated from data supplied by route personnel. Those mean times are given in Table 2-2.

Data presented in Table 2-2 indicate that on-site and travel times generally were adequate for deployment of sampling equipment utilized during the FRF.

Table 2-2. On-Site and Travel Times (min)

Deployment			Pickup	
Route	On-Site	Travel	On-Site	Travel
1	15	14	8	15
2	15	21	5	29
3	16	15	6	13
4	14	7	6	6
5	3	3	Unavailable	Unavailable
6	14	9	Unavailable	Unavailable

2.3.2 GASEOUS MEASUREMENTS.

2.3.2.1 Cloud Predictions. The NASA/MSFC Multilayer Diffusion Model (REEDM) was used to generate numerous cloud deposition predictions during the FRF. However, two of the most pertinent predictions were from soundings made at 2254 EST, 19 February 1981 and 0545 EST, 20 February

1981. The REED model, based on data from 19 February indicated the exhaust cloud would drift almost directly eastward, while those soundings from 20 February indicated a southeasterly drift. Isopleths of calculated HCl values at ground level were plotted from both the 19 February and 20 February data. Those plots are shown in Figures 2-16 and 2-17. The cloud produced at firing was observed to drift in a southeasterly direction as indicated in Figure 2-17.

2.3.2.2 HCl Dosimetry. Two sets of dosimeter tubes recorded values of 1 ppm/sec or greater during the baseline deployment. One set was located at L3 and recorded 1.4 ppm/sec. The other set was in the vicinity of LC-39A where a value of 1.4 ppm/sec was recorded.

Results of HCl dosimeter tube analyses for the FRF are given in Table 2-3. Those sites not listed in the table recorded values of <1 ppm/sec.

Table 2-3. HCl Dosimetry

Condition	Site	Run Interval	Dosimeter Value ppm/sec
Blank tubes	----	----	1 or trace
24 hr baseline	L3	Unknown	1
	Pad	Unknown	1
FRF	A7	Unknown	1
	A15	Unknown	1
	A12	3:10	3
	A13	Approx. 3:00	2
	A14	Approx. 2:00	2
	A10	Unknown	8
	A20	Unknown	1
	L8A	00:35	9
	L10	00:15	2
	L11	00:14	5
	L13	00:46	1

Table 2-3. HCl Dosimetry
(Continued)

Condition	Site	Run Interval	Dosimeter Value ppm/sec
Model	L1	00:36	5
	L2	00:01?	1
	L14	00:31	8
	L15	Unknown	1
	Banana River West	Unknown	2

All values in Table 2-3 have been rounded to the nearest whole number. Locations of values <1 ppm/sec or greater are shown in Figure 2-18.

Low level concentrations of a dosimeter tube reactant appeared to be confined to two areas. One area extended from LC-39A westward to the Shuttle Landing Facility (SLF). The second area was along NASA Causeway East from the O&C Building to the Cape Canaveral Air Force Station (CCAFS) Dispensary (Building 49635) and north on Cape Road to the Complex 37 area.

2.3.2.3 HCl Analyzers. Geomet analyzers were deployed at six sites. Analog data from the Geomet unit at each PAMS can be inspected in Figures 2-19 through 2-22. Analyzers also were deployed at two model sites. Portions of the data from UCS-2, (Site A14) can be studied in Figure 2-23. Data are not available from the second model site.

The unit at PAMS A was on continuously and exhausted its H₂O₂ supply after the FRF. The unit at PAMS F was not activated. The unit at PAMS B was activated about 0840 hours and allowed to run until about 0900 hours. The unit at PAMS E was on and sampling several hours before the event but a scale change was made about 0840. Those analyzer units at the two model sites operated correctly but recorded abnormally high baseline values due to light leaks into the instrument. The slight

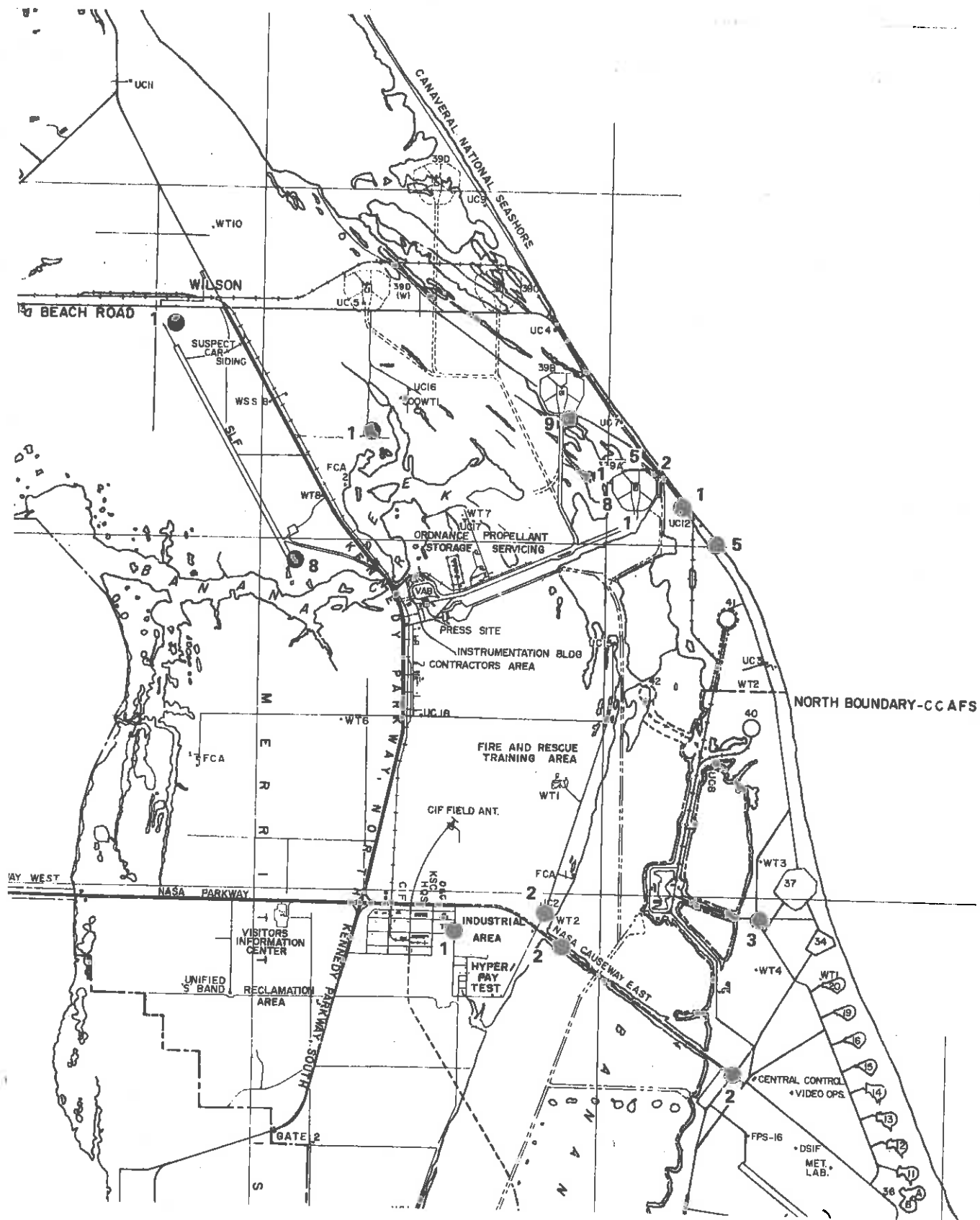


Figure 2-18. Location of Dosimeter
Values ≥ 1 ppm/sec

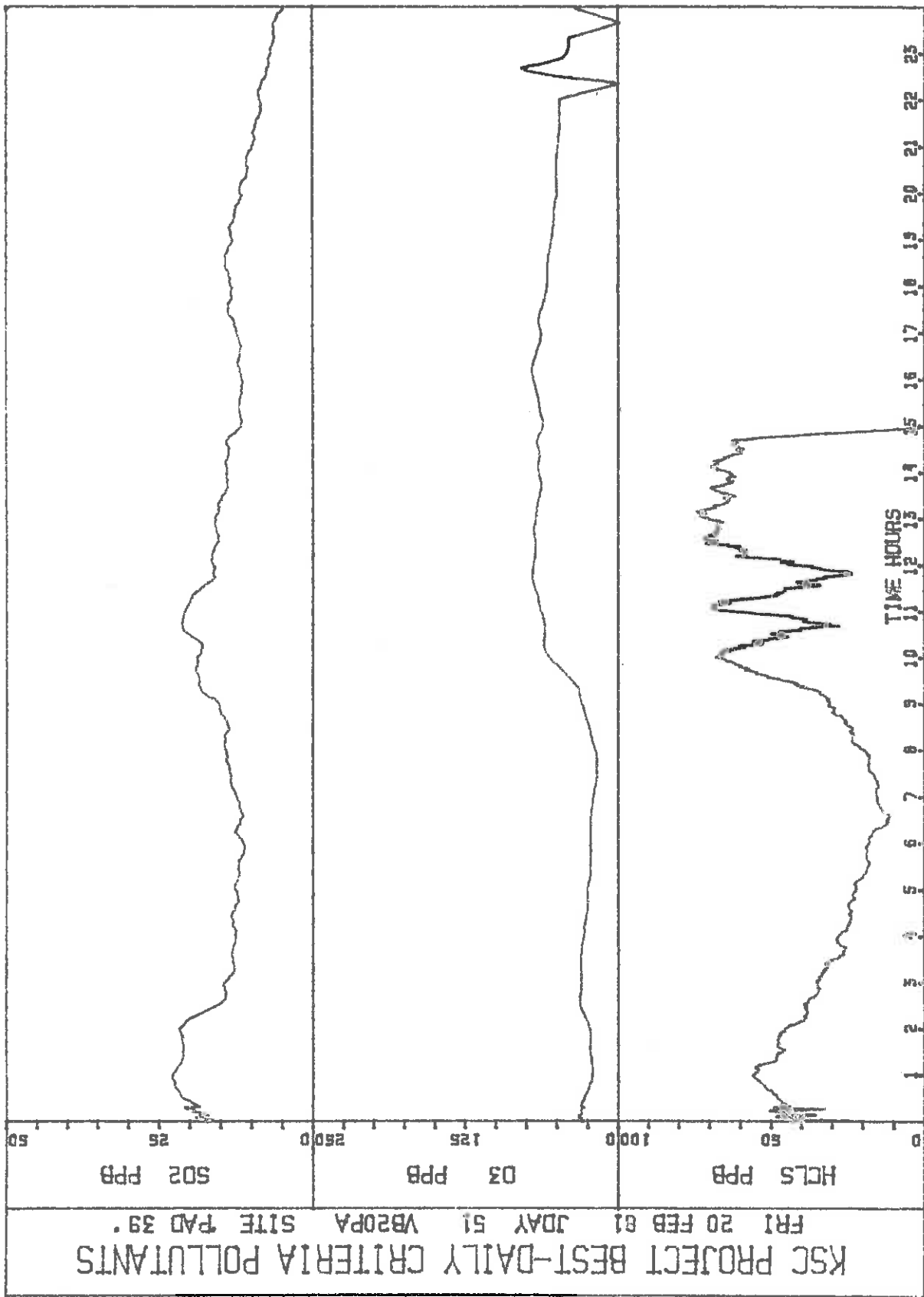


Figure 2-19. Analog Data Output from PAMS A

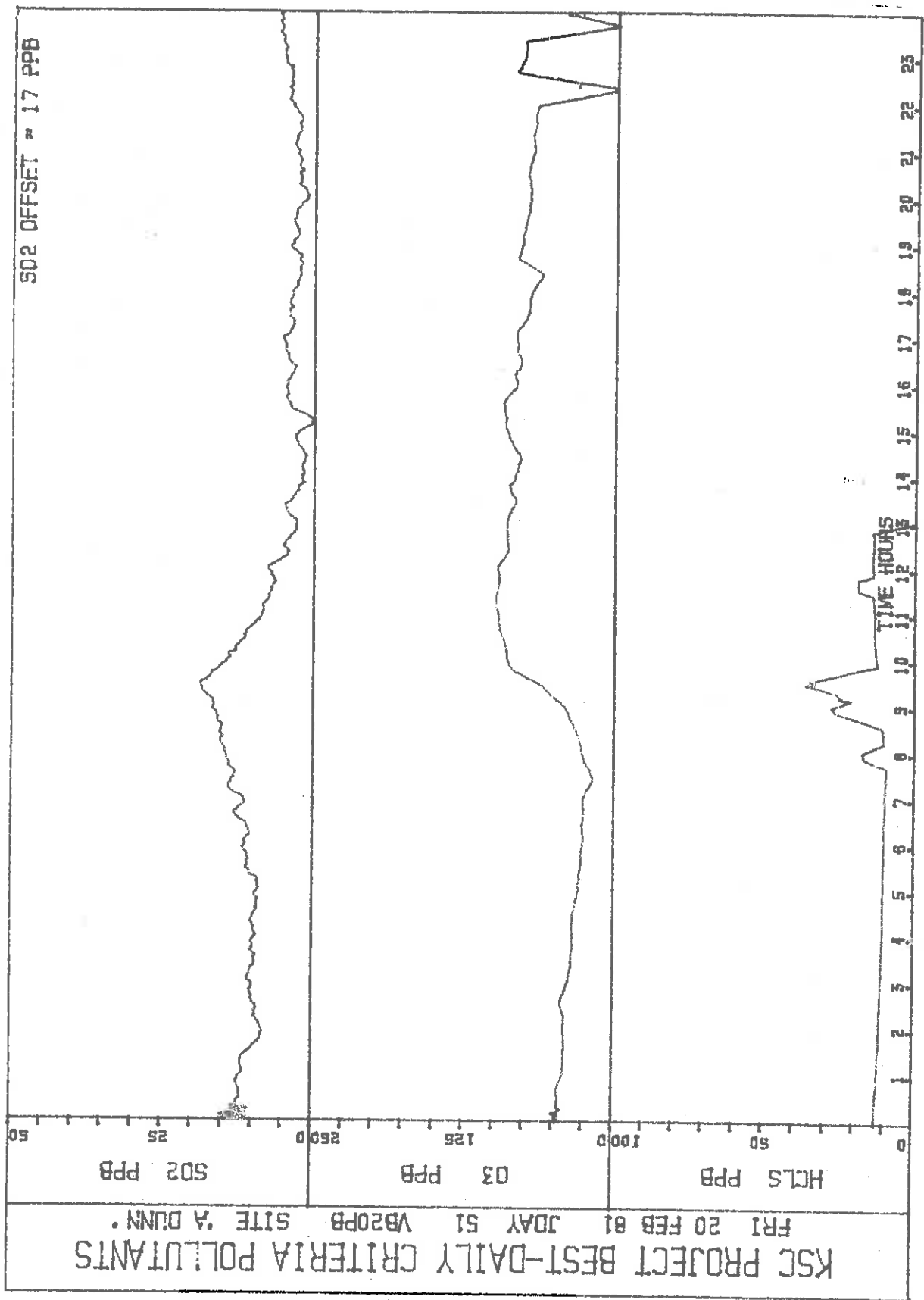


Figure 2-20. Analog Data Output from PAMS B

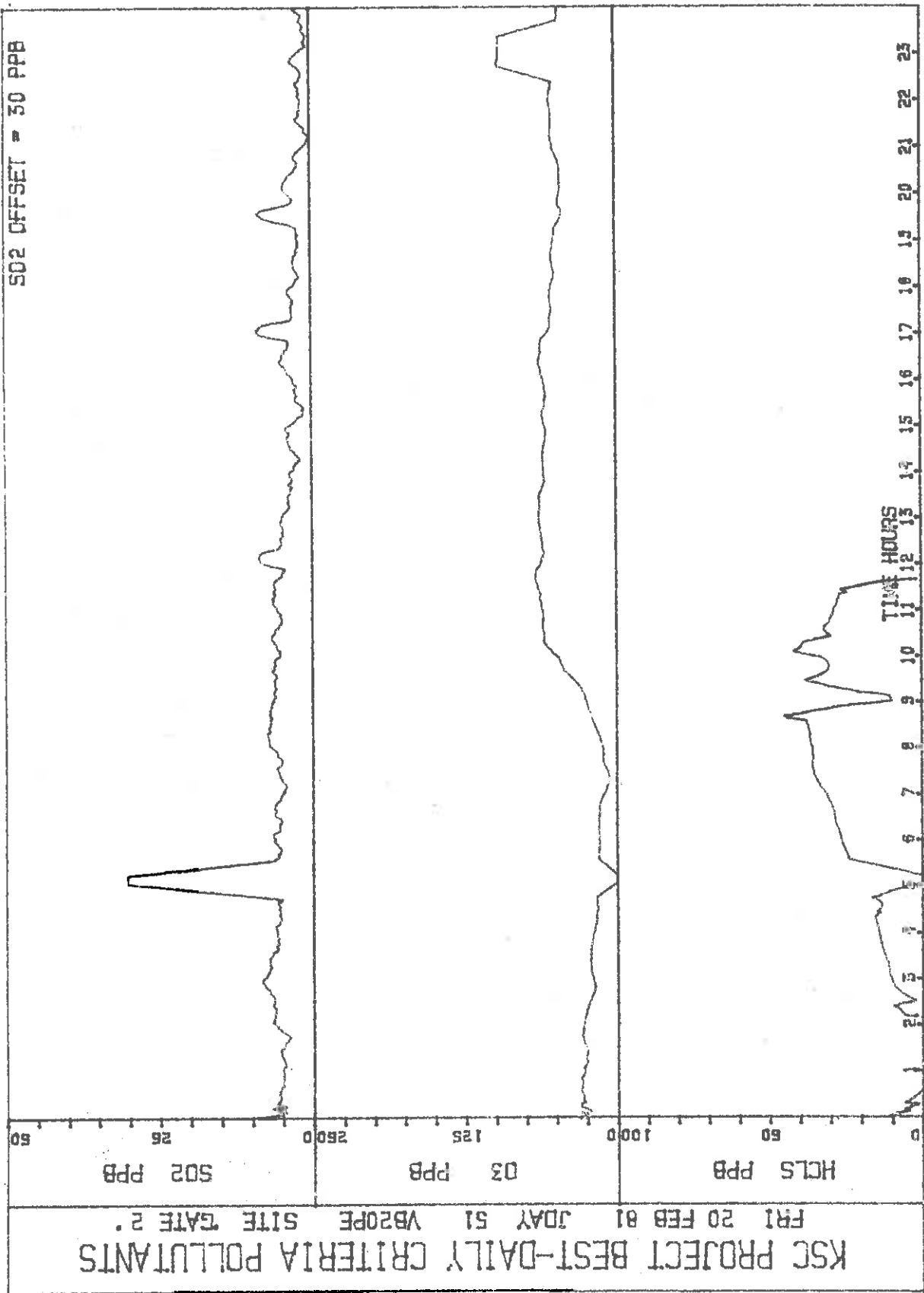


Figure 2-21. Analog Data Output from PAMS E

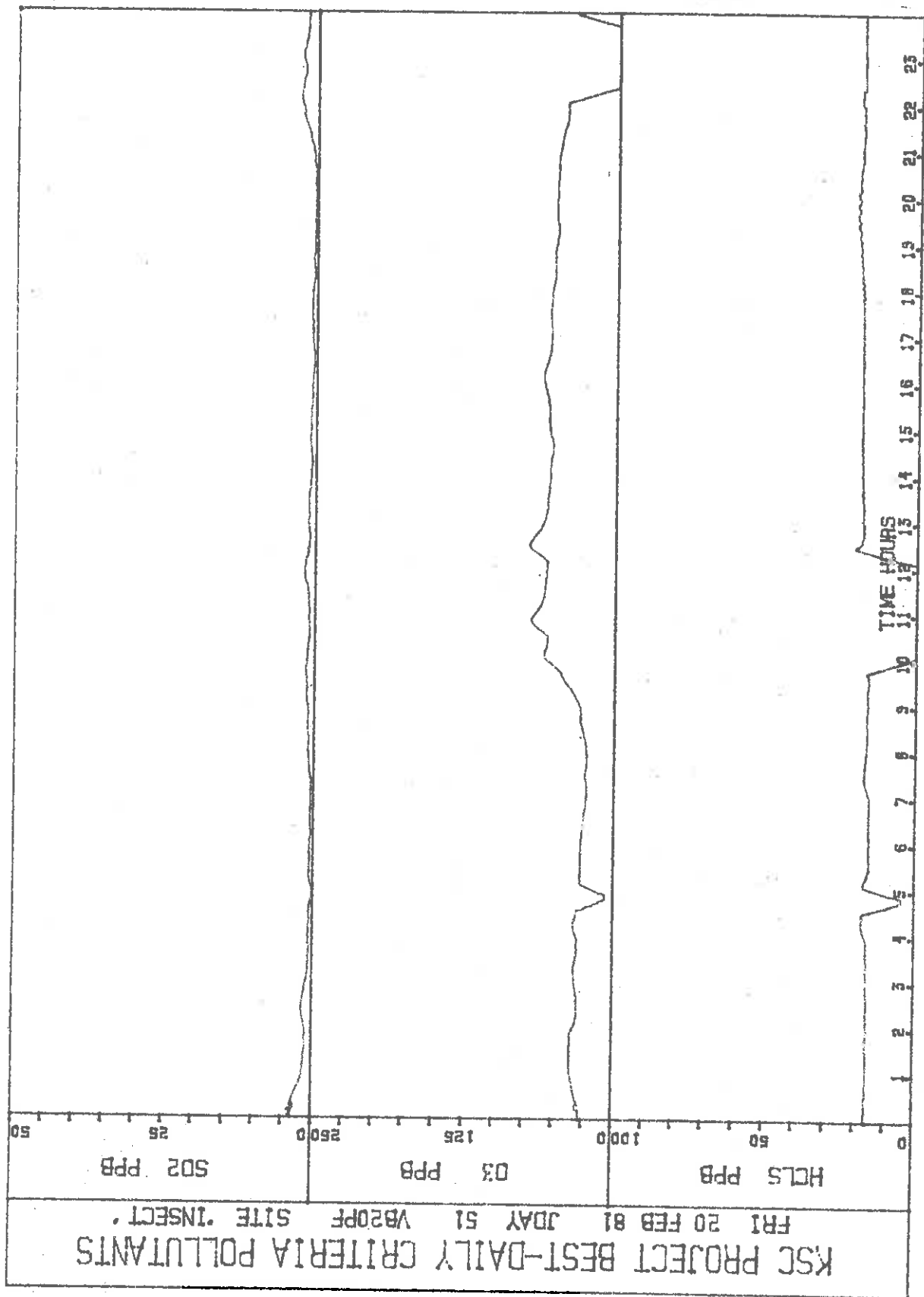


Figure 2-22. Analog Data Output from PAMS F

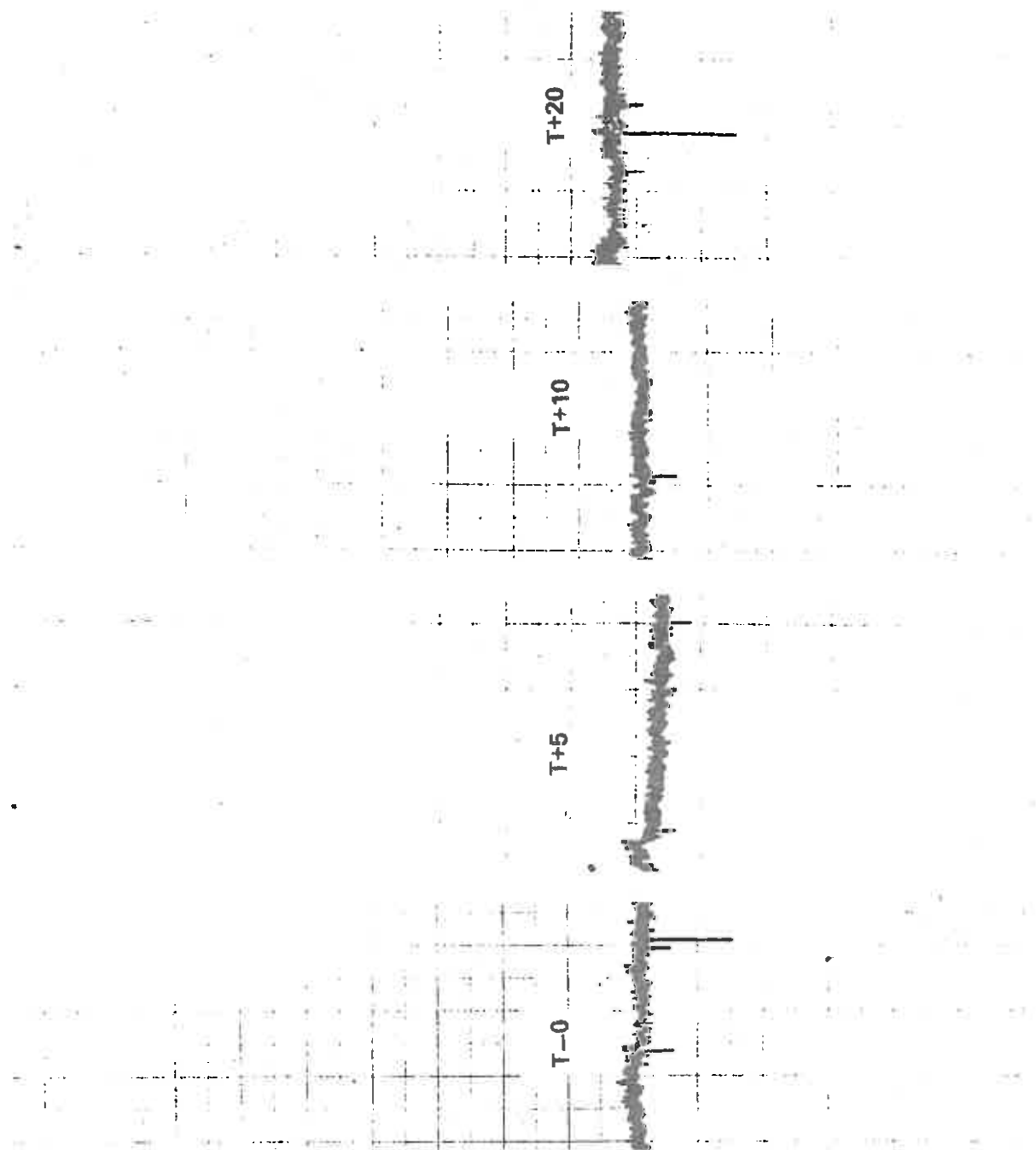


Figure 2-23. Portions of Geomet HCI Analyzer Output from Universal Camera Site 2

baseline elevation seen at T+20 minutes in Figure 2-23 is thought to be due to instrument drift.

2.3.2.4 PAMS Data. All stationed PAMS were in operation during the FRF. Table 2-4 lists the active gas measurement instrumentation at each PAMS unit.

Table 2-4. Functional PAMS Instrumentation

PAMS	Ozone	Sulphur Dioxide	HCl
A	Yes	Yes	Yes
B	Yes	No	Yes
E	Yes	No	Yes
F	Yes	Yes	No

Analog data output from each PAMS was generated by the ECF and is shown in Figures 2-19 through 2-22. Those data show no perturbations attributable to the FRF.

2.3.2.5 In-Cloud Measurements. No aircraft operations for in-cloud sampling were carried out during the FRF. However, prior to the firing, the aircraft was used to check out procedures and communications for sampling the launch cloud produced in the STS-1.

2.3.3 FALLOUT MEASUREMENTS.

2.3.3.1 Acid Fallout. Exposure of pH paper to the atmosphere was accomplished for several hours at 31 sites. Reaction of the papers at each site is given in Table 2-5.

All pH papers retrieved after the FRF were wet and the dye lines generally were somewhat diffused. However, such diffusion was shown in the laboratory not to interfere with the acid reaction. That reaction would

Table 2-5. pH Paper Reaction

Site	Exp. Time (hr) ^a	Paper Condition at Pickup	Dye Condition at Pickup	Useful for PH Assess.
L1	16.50	WET	S.D. ^(b)	YES
L2	16.25	NO PAPER ^(c)	NA	NO
L3	16.25	NO PAPER	NA	NO
L4	16.25	NO PAPER	NA	NO
L8A	15.75	WET	S.D.	YES
L5	16.00	NO PAPER	NA	NO
L6	15.75	WET	S.D.	YES
L7	15.75	NO PAPER	NA	NO
L8	18.0	WET	S.D.	YES
L9	18.0	WET	S.D.	YES
L10	18.0	WET	S.D.	YES
L11	18.0	NO PAPER	NA	NO
L12	18.0	WET	S.D.	YES
L13	18.0	WET	S.D.	YES
L14	18.0	WET	S.D.	YES
L15	18.0	WET	S.D.	YES
A1	7.00	MOIST	GOOD LINES	YES
A2	NA	WET	S.D.	YES
A4	NA	WET	NO LINES	NO
A8	7.5	WET	S.D.	YES
A9	8.00	WET	S.D.	YES
A13	6.50	WET	S.D.	YES
A15	7.25	MOIST	GOOD LINES	YES
A17	8.75	WET	NO LINES	NO
A18	8.75	WET	S.D.	YES
A19	NA	WET	S.D.	YES
P1	8.25	WET	S.D.	YES
P3	4.52	WET	NO LINES	NO
P4	6.25	WET	NO LINES	NO
P5	5.75	WET	NO LINES	NO
P8	6.25	WET	S.D.	YES

(a)--Time is given in hours to the nearest quarter hour.

(b)--S.D. indicates the dye lines on the paper were slightly diffused due to absorbed moisture.

(c)--Pager was missing from site.

have resulted in a reddish or magenta coloration of the paper. No such coloration was noted on any deployed papers, thus no acid fallout with a pH of about 2.0 or less was encountered.

2.3.3.2 Rain. No measurable moisture was collected in the rain buckets. However, 28 of 40 buckets did contain some particulate material (i.e. sand, detritus and insects). Ten specially washed buckets were rinsed with deionized water which was subjected to conductivity and ion analyses. Results of conductivity determinations are shown in Table 2-6.

The conductivities of three different waters were measured to provide a baseline to which the data in Table 2-6 might be compared. Those reference measurements revealed the following:

- a. Tap water = approximately 500
- b. Rain water = 20-40
- c. Deionized water = 0.35.

Some of the material contained in the buckets was slightly soluble in water and resulted in conductivity values between those of deionized and rain water.

No rain was encountered during the FRF so those ion concentrations in Table 2-7 reflect soluble particulate material and rinse water residual. The units (ppm) of Table 2-7 reflect the fact that 200 ml of deionized water was used to wash the buckets. That water was then subjected to analysis and the data reported as ppm of wash water.

Table 2-6. Conductivity of Rinse Water

Deployment	Site	Bucket No.	Hours Open ^a	Conductivity
LC-39A	L3	60	16.25	5.9
	L8A	45	15.75	5.7
	L2	54	16.25	4.2
	L4	50	16.25	3.9
	L6	57	15.75	3.3
Model	NA	06-A	NA	5.6
	NA ^b	01-A	NA	3.6
	NA	03-A	NA	3.5
	B. Riv. W. ^c	10-A	2.75	2.5
	NA	08-A	NA	2.3
<p>a--Hours to the nearest quarter hour</p> <p>b--Not available</p> <p>c--NASA Causeway near the west shore of the Banana River</p>				

Table 2-7. Ion Concentrations (ppm) Recovered from Deposition Buckets

Site	Bucket No.	pH	Na	K	Ca	Mg	NH ₄	Cl	F	NO ₃	SO ₄	PO ₄	Br	NO ₂	Cl: Na
A ^a	01A	5.74	---	---	---	---	---	0.09	0.80	0.37	0.12	0.16	0	0	---
B	03A	---	---	---	---	---	---	---	---	---	---	---	---	---	---
C	06A	5.77	0.08	0.04	0.42	0.14	0.08	0.12	0.50	1.82	0.07	0.16	0	0	1.5
D	08A	---	---	---	---	---	---	---	---	---	---	---	---	---	---
E	10A	---	---	---	---	---	---	0.13	0.40	0.28	0.17	0	0	0	---
L8A	45	6.20	0.19	0.13	0.97	0.09	0.07	0.29	0.40	0.34	0.53	0.1	0	0	1.5
L4	50	---	---	---	---	---	---	---	---	---	---	---	---	---	---
L2	54	---	---	---	---	---	---	0.16	0.60	0.21	0.45	0	0	0	---
L6	57	---	---	---	---	---	---	---	---	---	---	---	---	---	---
L3	60	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Lab	Control ^c	5.71	0.03	0.02	0.05	0.002	0.015	0.06	0	0.05	0.08	0	0	0	2.0
Causeway ^d	---	6.43	0.65	0.23	---	0.26	0.002	1.04	0.90	0.35	0.55	0	0	0	1.6

a-----sites spaced along NASA Causeway East from CCAFS to camera site UC-2 (our site A14)

b-----Analyses not run

c-----mean analyses of three buckets kept in laboratory

d-----bucket from NASA Causeway East on 17 March 1981

2.3.4 FLORAL EFFECTS. No visible injury to Pennyworts was observed. Also, no visible injury to radishes at area (A) and perimeter (P) sites was observed. However, two radishes at L-13 (inside the LC-39A perimeter fence) showed minor injury. The injury consisted of leaf margin necrosis and resembled cold or frost damage.

2.3.5 WILDLIFE RESPONSE.

2.3.5.1 Eagle's Nest. Two adult birds and one feathered young were observed in the nest at 0655 hours. The sound of the firing was audible to the observers for 17 to 20 seconds. The eagles showed no sign of behavioral alteration during that period of time.

2.3.5.2 Moore Creek Wading Bird Colony. The site was selected because it would contain an active wood stork colony during the launch of STS-1. Pre-FRF observations were made on 18 February 1981. The following species and numbers were observed:

- a. Island number 4
 - (1) Active double-crested cormorant nests - 60
 - (2) Great blue heron - 8
 - (3) Anhinga - 2
- b. Island number 3
 - (1) Double-crested cormorant - 2
 - (2) Great blue heron - 3

A variety of other waterfowl, wading birds, gulls, terns and vultures also were observed in the vicinity. No observable difference in the behavior or activity of any birds was noticed during or after the FRF.

2.3.5.3 Bird Island. The site was selected because it was expected to contain an active brown pelican nesting colony during the launch of STS-1.

No pre-FRF observations were made. The following species and numbers were observed about 0810 hours on 20 February 1981.

- a. Brown pelican - 400
- b. White pelican - 80
- c. Double-crested cormorant - 55
- d. Great blue heron - 40
- e. Laughing and ring-billed gull - 50

The observers could not hear the FRF nor see the ground cloud. However, no observable behavioral changes were noted after the firing.

2.3.5.4 Picnic Island Wading Bird Colony. The site was chosen because it is one of two breeding colonies close to LC-39A.

Pre-FRF observations were made on 18 February 1981. The following species and numbers were observed:

- a. Great blue heron - 5
- b. Louisiana heron - 10
- c. Black-crowned night heron - 1
- d. Snowy egret - 6
- e. American coot - 300
- f. Anhinga - 5

No observable differences in behavior or species numbers were noted between the pre and post FRF surveys.

2.3.5.5 Launch Complex Wading Bird Colony. This site was the closest to LC-39A. The following species and numbers were observed on 18 February 1981.

- a. Double-crested cormorant - 100
- b. Great blue heron - 3
- c. White ibis - 5
- d. Louisiana heron - 2
- e. Brown pelican - 4

A post FRF survey conducted on 20 February noted about 60 cormorants. No change in other species numbers was observed.

2.4 DISCUSSION

The FRF provided an opportunity for a full scale monitoring deployment exercise prior to the launch of the STS-1. A synopsis of the data thus obtained during the FRF is presented in Table 2-8.

Table 2-8. FRF Data Synopsis

System	Data Status	Results	Constraints
pH paper	Useful	No acid	None
Mineral oil water droplet collectors	Not used	None	None deployed
Nuclepore filters	Not used	None	Not analyzed
HCl dosimeter tubes	Useful	Very low Background values	Impingers used
PAMS	Useful	No effects on criteria pollutants	Units not located in cloud path
Indicator plants	Useful	Very slight plant damage	None
Deposition buckets	Useful	Background	Too few analyzed
Geomet HCl analyzers	Not used	None	Not placed in cloud path
Cloud prediction	Useful	Accurate directional forecast	No HCl or Al ₂ O ₃ produced
Wildlife monitoring	Useful	No effect	Unable to observe animals inside 3 mile limit

The exhaust cloud produced was composed essentially of water vapor and drifted seaward. Thus, no pH reaction was experienced. The papers were wet when retrieved but that was due to surface condensation only.

Production of a water cloud with no exhaust particulates was anticipated so study personnel elected not to analyze mineral oil water droplet collectors or nuclepore filters.

The dosimetry tube values seemed to show a pattern roughly related to vehicular traffic. Those values were quite low and, in the light of a study undertaken during the summer of 1981, reflected background levels. Even so, the coincident traffic patterns indicated that some material might have been drawn into the tube. The identity of that material was unknown but it most probably was not HCl.

No perturbation of any EPA criteria pollutants was observed at any PAMS unit. The PAMS west of LC-39A was the only unit close enough to actually be affected by the firing. However, the easterly cloud drift prevented any impaction of the site.

Indicator plants reared in the greenhouse were placed at many sample sites, but damage was observed at only one pad site. That damage resembled cold or frost damage and may have been the result of cold O₂ venting. The site was near the LO₂ facility and frost was noted in the area.

Deposition buckets were useful in collecting background data. The SRB's were not fired so no aluminum or HCl was produced by the test engines. Consequently, no aluminum was detected. The chlorine to sodium ratio was 1.5 to 1.6 along the NASA Causeway and at LC-39B. Such ratio values are a bit lower than that for sea water (1.8), but are within the error spread for such coastal areas. Thus no chlorides were introduced into the environment by the FRF. No precipitation was recorded during the FRF so the material in the buckets must have been wind-borne debris. The source of that debris was unknown.

Geomet HCl analyzers were operated at two sites. Neither site was in the direction of the cloud travel nor did either site detect any HCl.

Cloud deposition predictions were conducted at several times throughout the firing test period. The model required a fallout species to be specified. Therefore, since Al_2O_3 was not produced at the firing, gaseous HCl was chosen as the dependent species. The forecast direction of cloud drift is dependent upon the judgment of meteorological personnel. Those personnel did forecast an easterly cloud drift.

Wildlife monitoring was limited to the observation of bird behavior before, during, and after the firing. The sites chosen for observation were expected to be occupied during the STS-1 launch. Consequently, data acquired during the firing were actually baseline data with which STS-1 data might be compared. No instance of behavioral alteration was noted between the pre-burn and post-burn observations.

2.5 CONCLUSIONS

Firing the main engines of the STS-1 produced no adverse environmental effects. The greatest single perturbation produced was the noise of the firing. However, that was short-lived and caused no observable wildlife disturbances. The FRF monitoring exercise indicated background levels of all measured parameters to be as expected.

SECTION III

STS-1 LAUNCH

3.1 BACKGROUND

The first launch of the Space Transportation System (STS) vehicle occurred from Kennedy Space Center at 0750 on 12 April 1981. Concern had been expressed as to the effect STS exhaust effluents might have on the KSC-Merritt Island environments. Reasons for that concern were the relatively high quantities of HCl AND Al_2O_3 exhausted by the SRB's.

3.2 METHODS

3.2.1 DEPLOYMENT. A pre-launch, 24 hour, deployment of sample units was made to determine background levels of effluent species in the KSC and Titusville area. Fifteen sites were deployed in three routes. Those routes were described in Section II of this report.

A total of 44 complete atmospheric sample sites were instrumented prior to the STS-1 launch. In addition, nine other sites were instrumented with various combinations of equipment. Equipment deployed per site during the STS-1 launch is listed in Table 3-1. Figure 3-1 shows the location of all sample sites except three located north from Titusville on US Highway 1. The range and bearing of all fixed sites from LC-39A is given in Table 3-2.

3.2.2 PAGER PERFORMANCE. The STS-1 rocket effluent monitoring system was composed of 57 sampling units of which 19 units were manually controlled. The remaining units (38) were Remotely Controlled (RC). The RC systems were composed of two different pumps and pagers. Those units deployed about LC-39A contained a "large" pump and a pager system operated on the KSC 111 net. Other units deployed at area sites contained a "small" pump and were operated on the KSC 113 net. A total of 8 different pager codes were used.

Table 3-1. STS-1 Instrument/Site Matrix for Environmental Monitoring

Site	NUC	pH	PART	ELEC	GEO	DOSE	PLT	MO	NOIS	STRK	IMP	VEG
L1		X	X			X					X	X
L2	X	X	X			X	X	X				X
L3	X	X	X			X	X	X				X
L4	X	X	X			X	X	X			X	X
L5	X		X	X		X	X	X				X
L6	X		X			X	X	X				X
L7	X	X	X	X		X	X	X				X
L8	X	X	X			X	X	X		X	X	
L9	X	X	X			X	X	X				
L10	X	X	X	X		X	X	X				
L11	X	X	X			X	X					
L12	X	X	X	X		X	X			X	X	
L13	X	X	X			X	X					
L14	X	X	X	X		X	X					
L15	X	X	X			X	X					
L8A	X	X	X			X	X	X				
A1	X	X	X			X	X	X				X
A2	X	X	X	X		X	X	X	X			
A3			X			X						X
A4	X	X	X	X		X	X	X	X			X
A5	X		X			X						X
A6												
A7	X	X	X	X		X	X	X				X
A8	X	X	X	X		X	X	X	X			X
A9		X	X	X		X			X			X
A10	X	X	X			X			X			X
A11			X			X						X
A12			X			X						X
A13			X			X			X		X	X
A14		X	X			X			X			X
A15	X	X	X			X	X	X	X			X
A16			X			X						X
A17	X	X	X			X	X	X				X
A18			X			X			X			X
A19	X	X	X			X	X	X	X			X
A20	X		X	X	X	X	X	X	X			X
A21				X		X						X
P1	X	X	X	X		X	X	X				X
P2			X			X			X			X
P3	X	X	X	X	X	X	X	X	X	X	X	X
P4			X			X			X			X
P5	X	X	X		X	X	X	X	X	X	X	X
P6					X	X		X	X			X
P7						X		X				X
P8	X	X	X	X	X	X	X	X	X	X	X	X
GSE					X							
6M1						X		X				

Table 3-1. STS-1 Instrument/Site Matrix for Environmental Monitoring (Cont'd)

Site	NUC	pH	PART	ELEC	GEO	DOSE	PLT	MO	NOIS	STRK	IMP	VEG
6M2						X		X				
6M3						X						
UC5						X						
UC11						X						
L.H.*									X			
UC18B					X	X						
UC18A						X						
JPH*			X	X	X							
L16			X		X					X	X	
L16E**			X									
L16W**			X									
UC6					X							

LEGEND: NUC Nuclepore Filters
 pH Litmus Paper
 PART Dry Buckets
 ELEC Electrets
 GEO Geomet Analyzers
 DOSE Dosimeters
 PLT Indicator Plants
 MO Mineral Oil Dishes
 NOIS Noise (Metrosonic)
 STRK Streakers (7-Day)
 IMP 7-Stage Cascade Impacters
 VEG Natural Vegetation Tagged

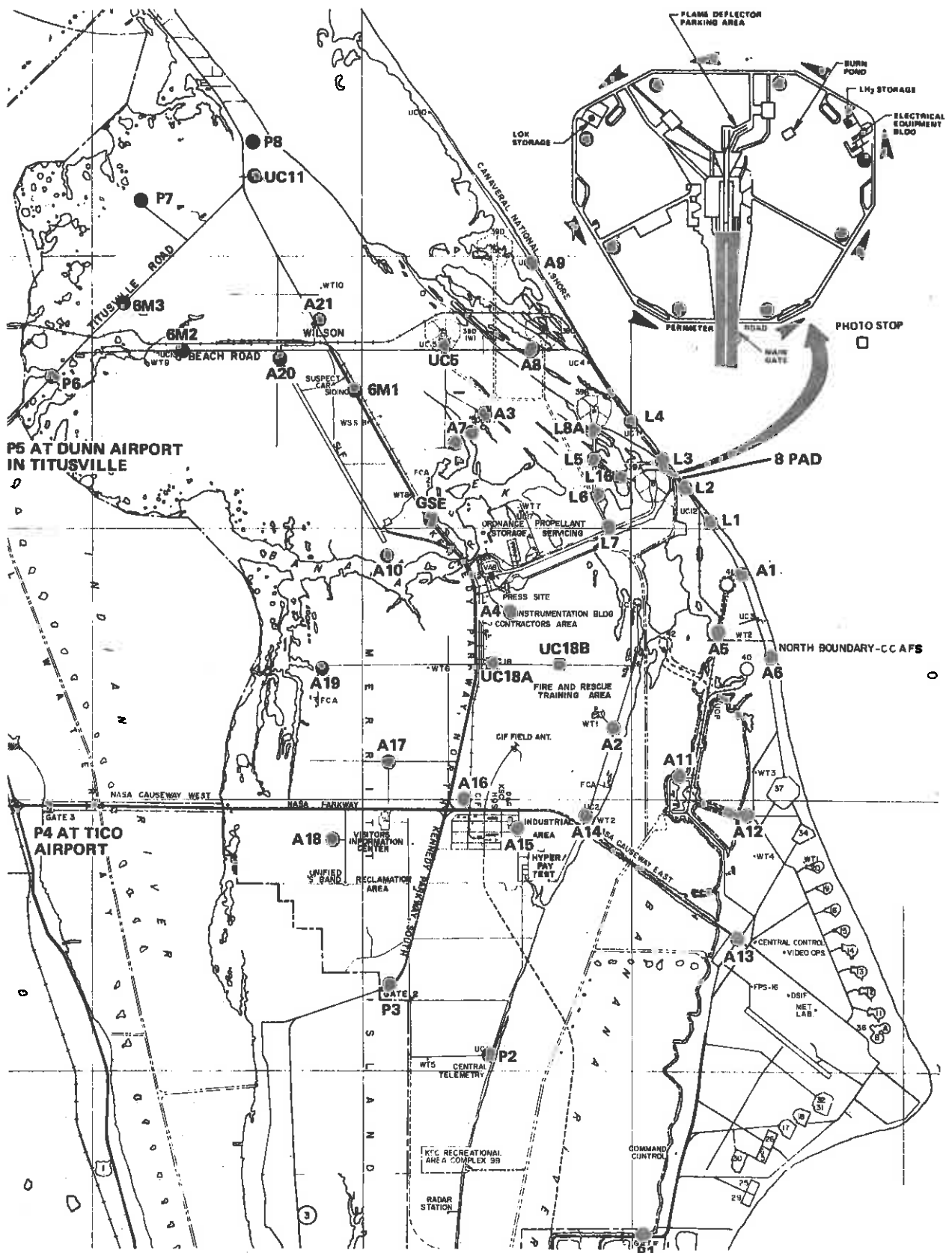


Figure 3-1. Air Quality Monitoring Sites for STS-1

Table 3-2. Approximate Range and Azimuth of Permanent Deployment Sites
Relative to LC-39A

Site	Range In Meters	Azimuth	Site	Range In Meters	Azimuth
L1	2,007	122	A12	9,813	164
L2	892	095	A13	12,980	170
L3	892	008	A14	9,600	191
L4	2,007	340	A15	10,080	201
L5	1,680	111	A16	10,200	211
L6	1,680	255	A17	10,800	224
L7	1,800	225	A18	13,580	222
L8	421	160	A19	10,800	237
L9	404	115	A20	10,800	288
L10	458	78	A21	10,420	303
L11	421	14	P1	21,000	181
L12	422	334	P2	16,580	195
L13	480	293	P3	16,080	207
L14	404	247	P4	21,950	240
L15	421	200	P5	23,400	275
L16	282	732	P6	17,040	280
A1	3,480	137	P7	16,440	298
A2	6,850	186	P8	14,900	310
A3	5,480	292	L8A	2,160	311
A4	5,280	245			
A5	4,200	155			
A6	5,520	147			
A7	5,880	281			
A8	4,800	317			
A9	6,840	331			
A10	7,550	262			
A11	8,160	175			

3.2.3 GASEOUS MEASUREMENTS.

3.2.3.1 HCl Dosimetry. Dosimeter tubes were deployed at 50 sites. Location of the dosimetry tubes sites is shown in Figure 3-2.

3.2.3.2 HCl Analyzers. Geomet HCl analyzers were deployed at 11 sites. Four sites were emplaced several hours prior to launch within the Impact Limit Area (ILA) and subsequently could not be moved. Four additional area sites (A sites) were positioned after those deployed to the ILA. Four analyzers were positioned on the mainland in and north from Titusville. The most northern analyzer was mobile and eventually was placed about 10 miles north of Titusville on U.S. Highway 1 in the path of the ground cloud. One analyzer was about 3 miles north of Titusville, one was in the US Post Office Parking lot, and one was in place at an airport in north Titusville (Site P-5). Geomet equipped sites are shown in Figure 3-3.

3.2.3.3 PAMS Data. Four Permanent Air Monitoring Stations (PAMS) (Figure 3-4) were operational during the launch of STS-1. One station (PAMS A) was about 1 kilometer west of LC-39A. Table 3-3 lists the instrumentation contained in each station.

Table 3-3. PAMS Instrumentation

Unit	O ₃	SO ₂	HCl	NO ₂	Wind Azimuth	Air Temp	RH
A	X	X	X	X	X	X	X
B	X	X	X		X	X	X
E	X	X	X		X	X	X
F	X	X	X		X	X	X



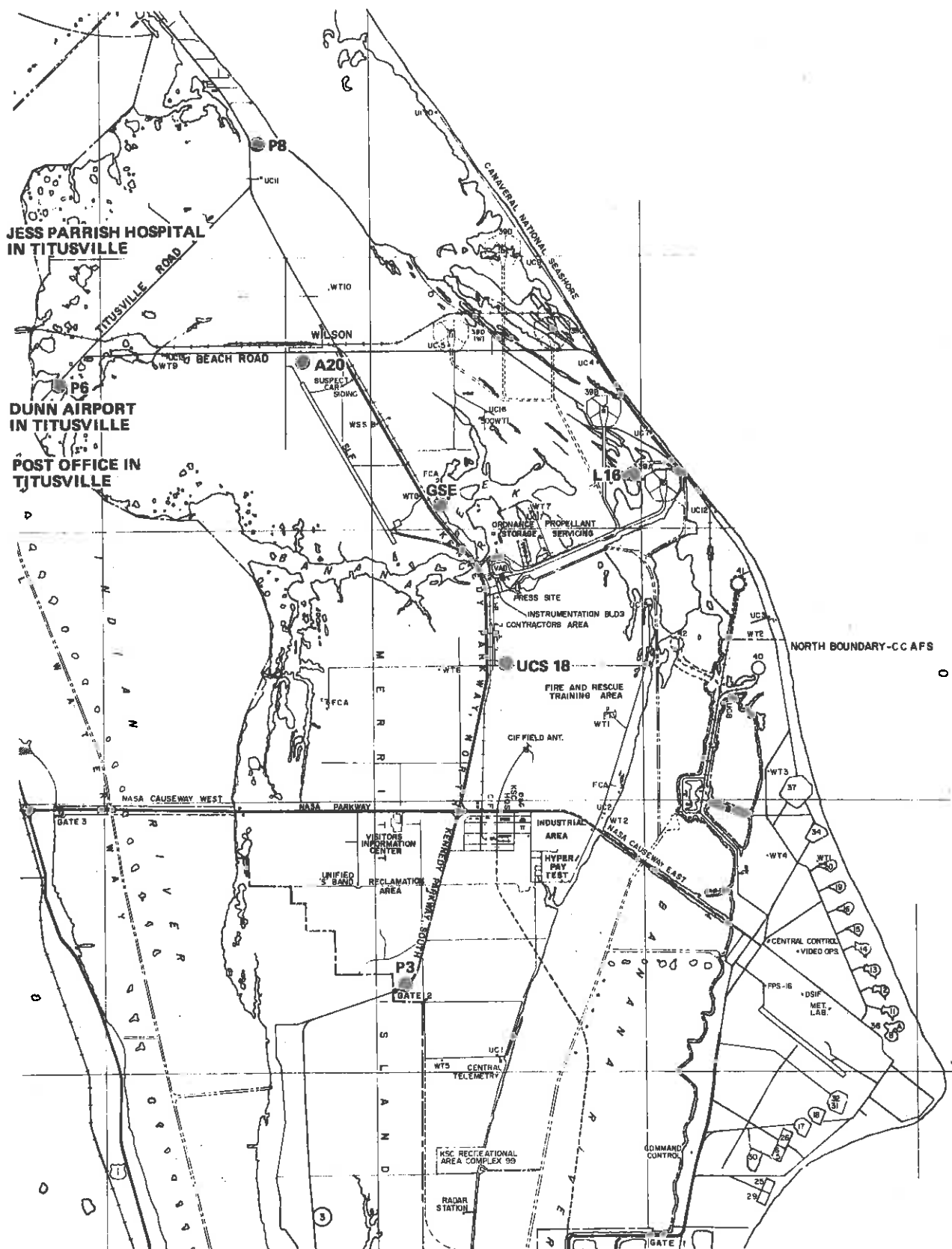


Figure 3-3. Geomet Equipped Sites

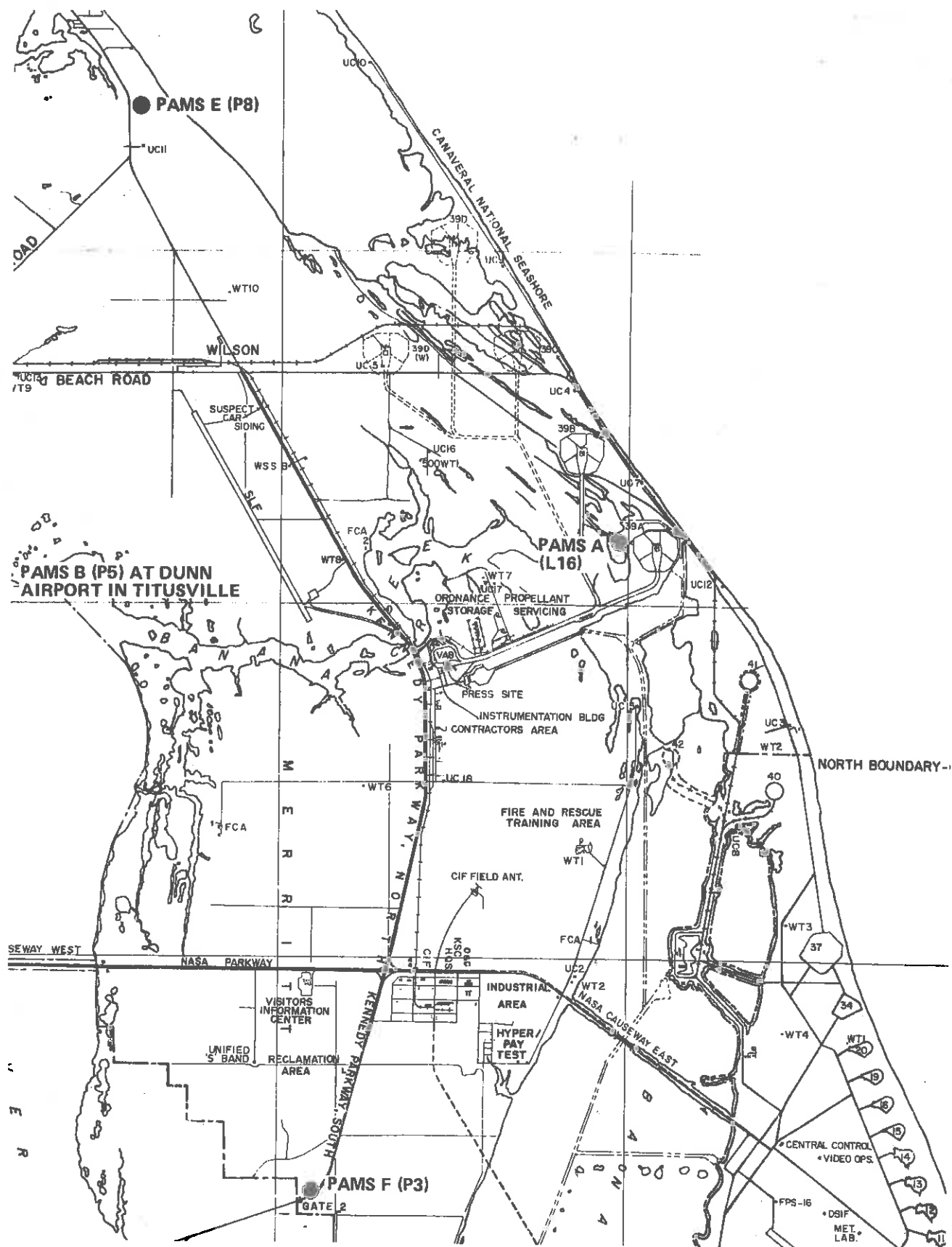


Figure 3-4. PAMS Locations

The O₃, SO₂, HCl, and NO₂ analyzers were continuous analytical devices. Hydrogen chloride analyzers were installed in the PAMS during launch activities from LC-39A.

3.2.3.4 In-Cloud HCl. An HCl Gas Filter Correlation (GFC) detector and a Geomet total HCl detector were carried aboard an aircraft through two of the exhaust clouds. The GFC device measured gaseous HCl while total HCl was measured by the Geomet. The difference between those two measurements was equated to aerosol HCl.

The lower north cloud was penetrated nine times from T+9 minutes to T+43 minutes. The higher west cloud was penetrated 24 times from T+51 minutes to T+136 minutes.

3.2.4 FALLOUT MEASUREMENTS.

3.2.4.1 In-Cloud Particulates. A multistage impactor and an integrating nephelometer were carried aboard an aircraft which made numerous penetrations of the lower ground cloud and the higher westerly moving cloud.

The impactor contained a piezoelectric crystal microbalance in each stage for sensing the mass of impacting particles. The nephelometer was used to measure scattering coefficients and to indicate when the aircraft entered and exited the cloud.

The impactor stages were analyzed by SEM and energy dispersive X-ray analysis.

3.2.4.2 Fallout Morphology. Evidence of particulate fallout from the STS-1 booster exhaust cloud was observed up to about seven kilometers from LC-39A.

Adverse reactions of personnel to exhaust residue present on LC-39A prompted an examination by Scanning Electron Microscopy (SEM). Fallout adhering to pH paper was also examined and compared to the LC-39A residue.

3.2.4.3 Acid Fallout. Acid atmospheric contaminants were detected on pH paper exposed to the atmosphere during and after the launch. The papers were uncovered when the sample unit was deployed, thus very long exposure times were accrued at some sites. Papers were exposed at 30 sites, the locations of which are shown in Figure 3-5.

3.2.4.4 Dry Deposition. Conductivity and pH were determined from 36 plastic collection buckets deployed during the launch. No measurable moisture was recorded during the launch event so the buckets were used as dry deposition collectors. Laboratory instrumentation utilized was described in Section II of this report. Locations of collection bucket sites are shown in Figure 3-2.

3.2.4.5 Wet Disposition. Water droplet collection was described previously in paragraph 1.5.2.1.

3.2.4.6 Impactors and Streakers. Seven-stage cascade impactors were installed at nine locations about the KSC area. Four of the devices were at each of the four PAMS, two were on the perimeter of LC-39A, two were at camera sites on the coast north and south of LC-39A and one was at the dispensary on CCAFS.

Streaker filters were installed at two locations inside the perimeter fence of LC-39A and at each PAMS. Figure 3-6 shows the locations of each of the devices.

3.2.4.7 Filtered Particulates. Nuclepore filters were weighed and placed at 14 sites for prelaunch coverage and at 30 sites for launch coverage. A rotary solenoid was employed to position a cover over the inlet side of the filter holder, thus opening and closing the holder. Air flow through each filter, holder and pump was calibrated as a unit in a clean laminar flow bench before deployment. Location of each filter unit is shown in Figure 3-7.

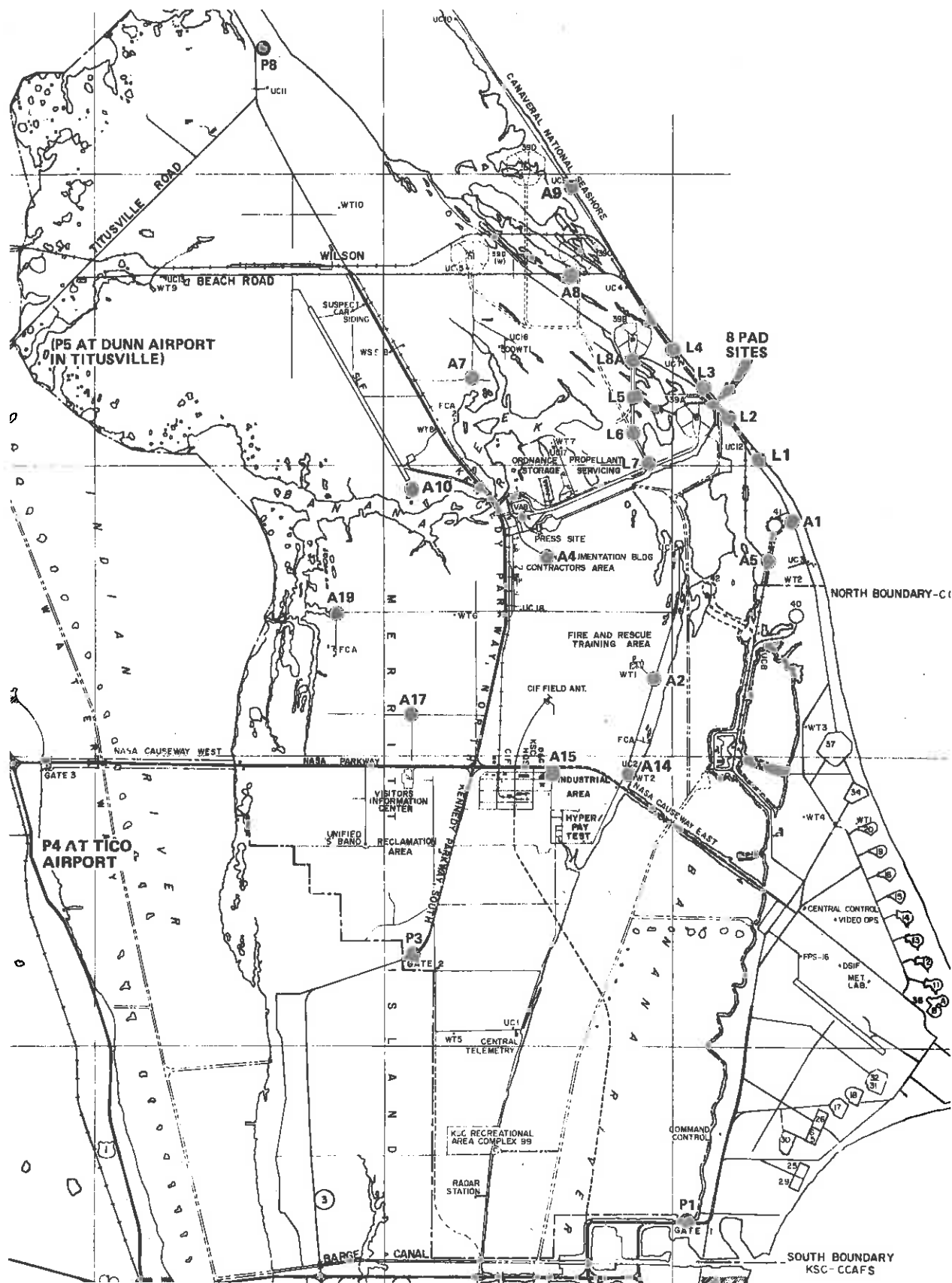
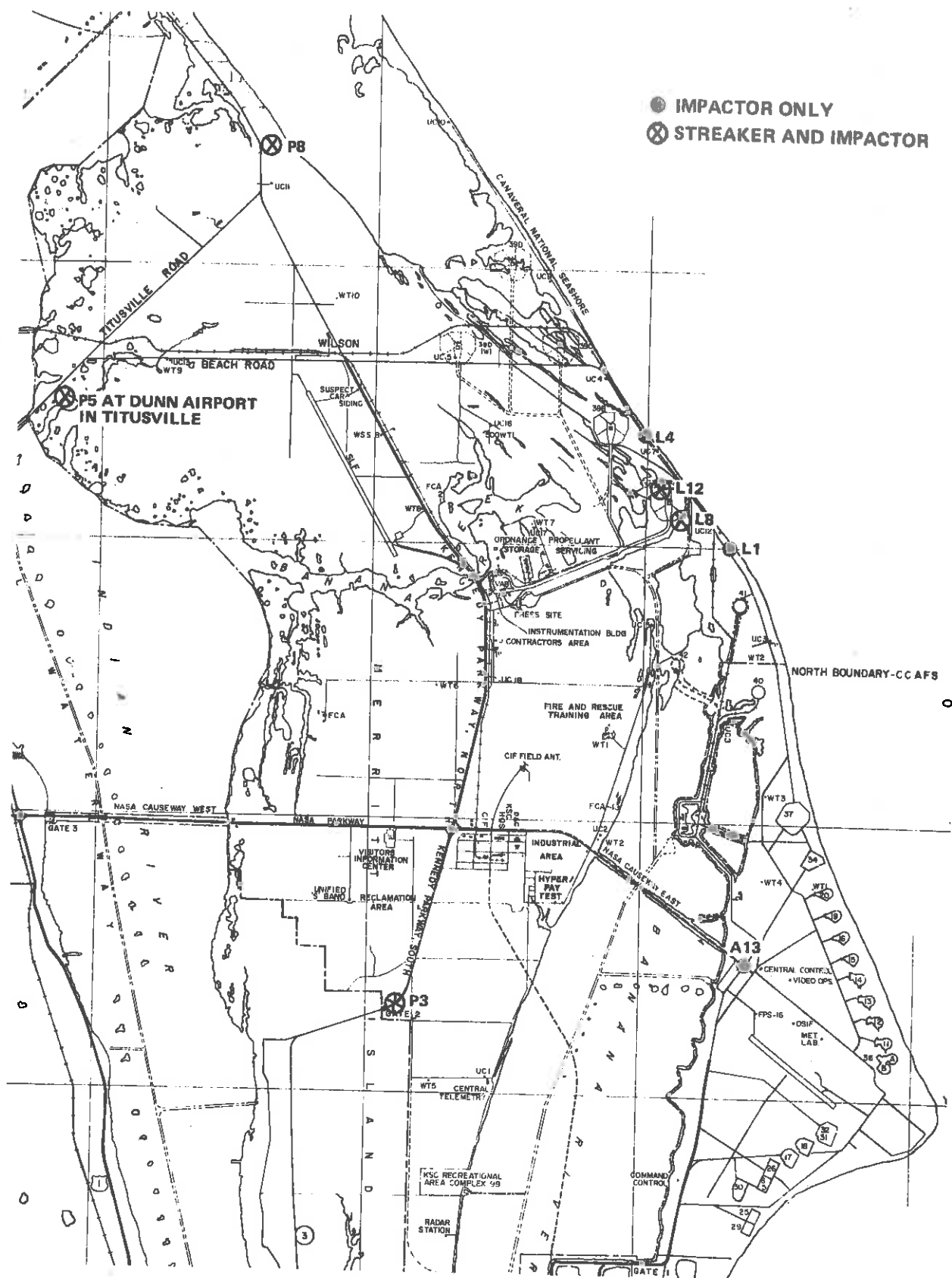


Figure 3-5. pH Paper Sites



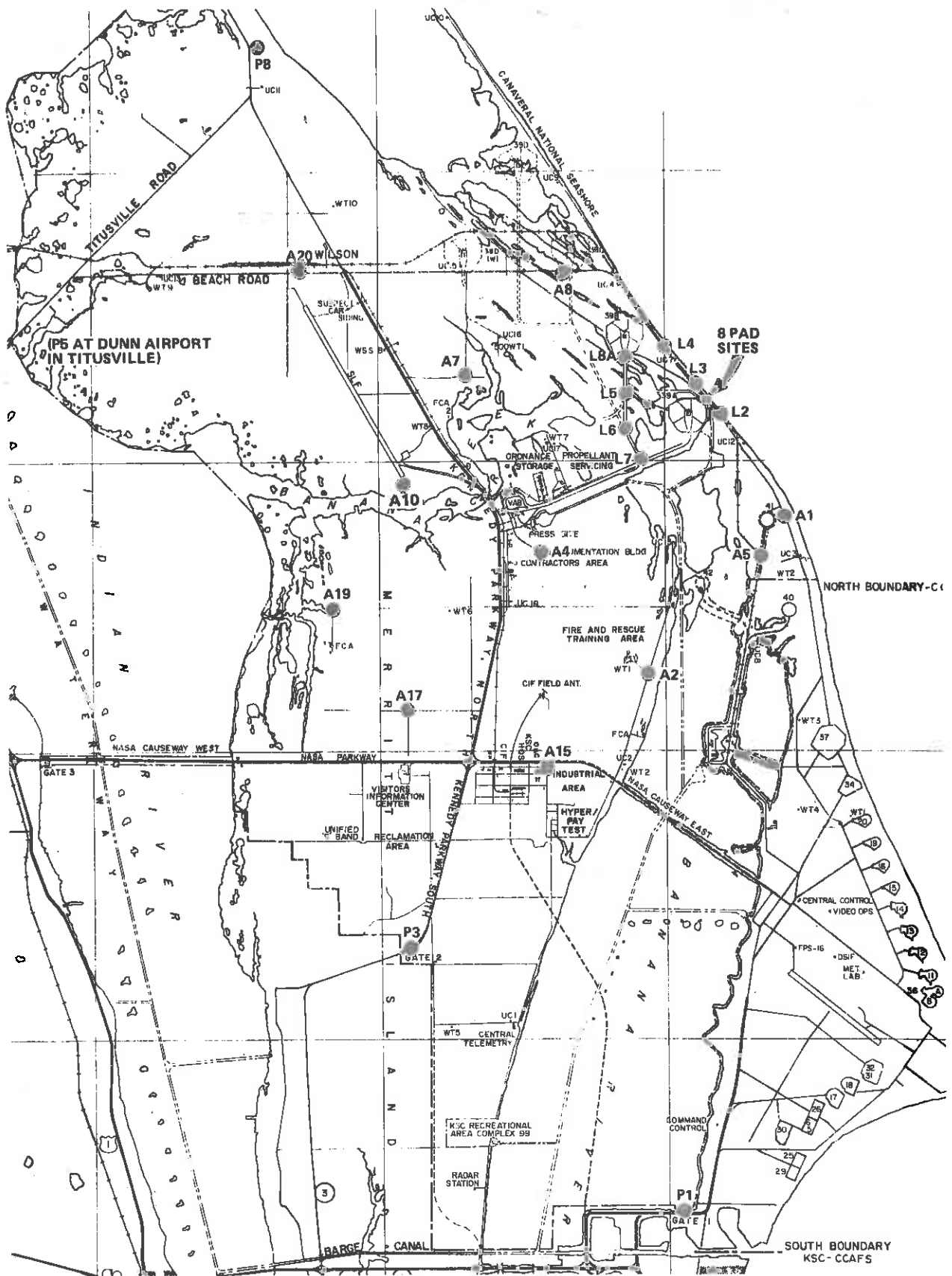


Figure 3-7. Nuclepore Filter Sites

Elemental analyses of material entrained on nuclepore filters was conducted via Neutron Activation Analysis (NAA) and Proton Induced X-ray Emission (PIXE).

The filters were bisected and pieces of the same filter analyzed via NAA and PIXE techniques. A single filter located at Site A-15 in the KSC Industrial Area was used to assess background levels and handling effects.

3.2.4.8 Soil Chemistry. Ten soil samples were collected five days after the launch of STS-1 from locations at and north of LC-39A. A surface sample and a four-inch core sample were taken from each of five sites. The samples were not dried or sieved but were analyzed as aqueous extracts as received. Location of the soil sample sites are shown in figure 3-8.

3.2.4.9 Surface Waters. Water samples were obtained from six sites (Figure 3-9) three days prior to launch of the STS-1. The two deluge holding ponds inside LC-39A were sampled initially at T+8 hours. All sites were sampled again at T+8 days. Post launch samples from the holding ponds were analyzed by three different laboratories.

3.2.5 FLORAL EFFECTS.

3.2.5.1 Gross Effects. The effects of STS-1 exhaust effluents on vegetation were investigated with greenhouse-reared and native plants. The two greenhouse-reared species were Hydrocotyle umbellata (pennywort), and a cultivar, Raphanus sativus ('comet' radish).

Native vegetation at specific sample sites was tagged with yellow tape approximately 2 weeks before STS-1. Those plants tagged included Baccharis halimifolia, Borrchia frutescens, Iva frutescens, Myrica cerifera, and Salix caroliana. One or more native species were tagged at each site when possible except at the eight sites inside LC-39A and at P5.

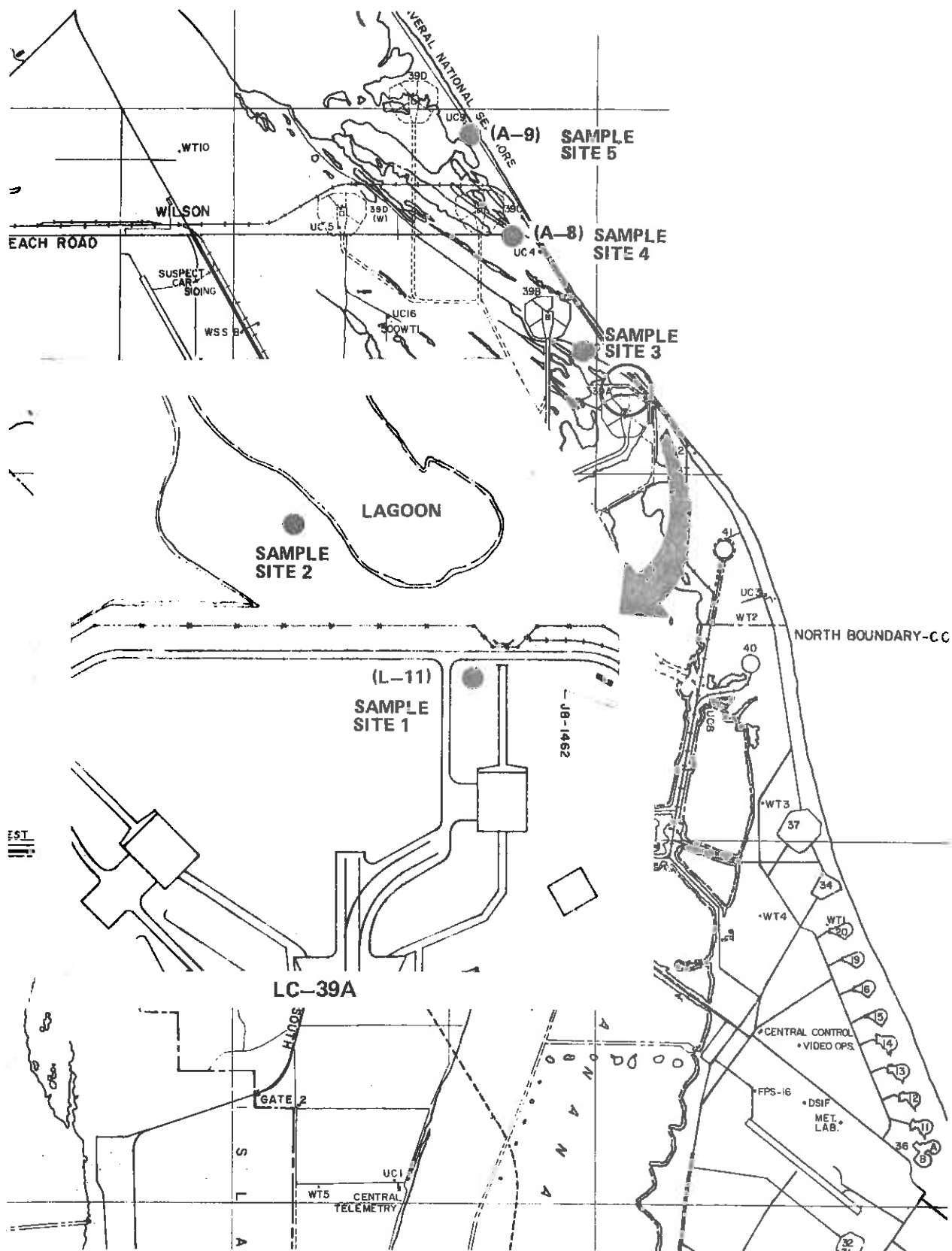


Figure 3-8. Soil Sample Sites

Figure 3-9. Surface Water Quality, Holding Pond, and Marine Invertebrate Sampling Sites

One flat was placed at each of the following air sample sites: eight pad perimeter sites, eight sites within a one-mile radius of the pad and 14 area and perimeter sites. Location of the indicator plants is shown in Figure 3-10.

3.2.5.2 Remote Sensing. An aerial photography overflight was made from complex 41 to UC9 north along Cape Road on 15 April 1981. The aircraft and equipment was from the Florida Department of Transportation. The first leg north along Cape Road was flown at 6000 feet and covered UC12, LC-39A, UC7, LC-39B, UC4, and UC9. A second leg was flown at 1200 feet from Wilson Corners east along Titusville Beach Road to the ocean. Flight routes and approximate widths of the survey areas are shown in Figure 3-11. False color infrared film was used during both flights.

3.2.5.3 Foliage Chemistry. Foliage samples were obtained from an intensively damaged area immediately north of LC-39A. Undamaged samples were obtained from an area southwest of LC-39A. Both samples were from the shrub, Mryica cerifera. Twenty grams of each sample were washed with 200 ml of deionized water. The water was then filtered and analyzed.

3.2.5.4 Surface Waters. Methods for sampling and analyzing surface waters have been described in Section I.

3.2.6 SOUND. Noise levels were measured by three different sets of instrumentation. Those devices are listed in Section I, paragraph 1.5.4.1.

Acoustic data were obtained at five sites. Sound pressure levels and spectral distributions were obtained from those data.

Noise measurements also were made at three wildlife monitoring sites.

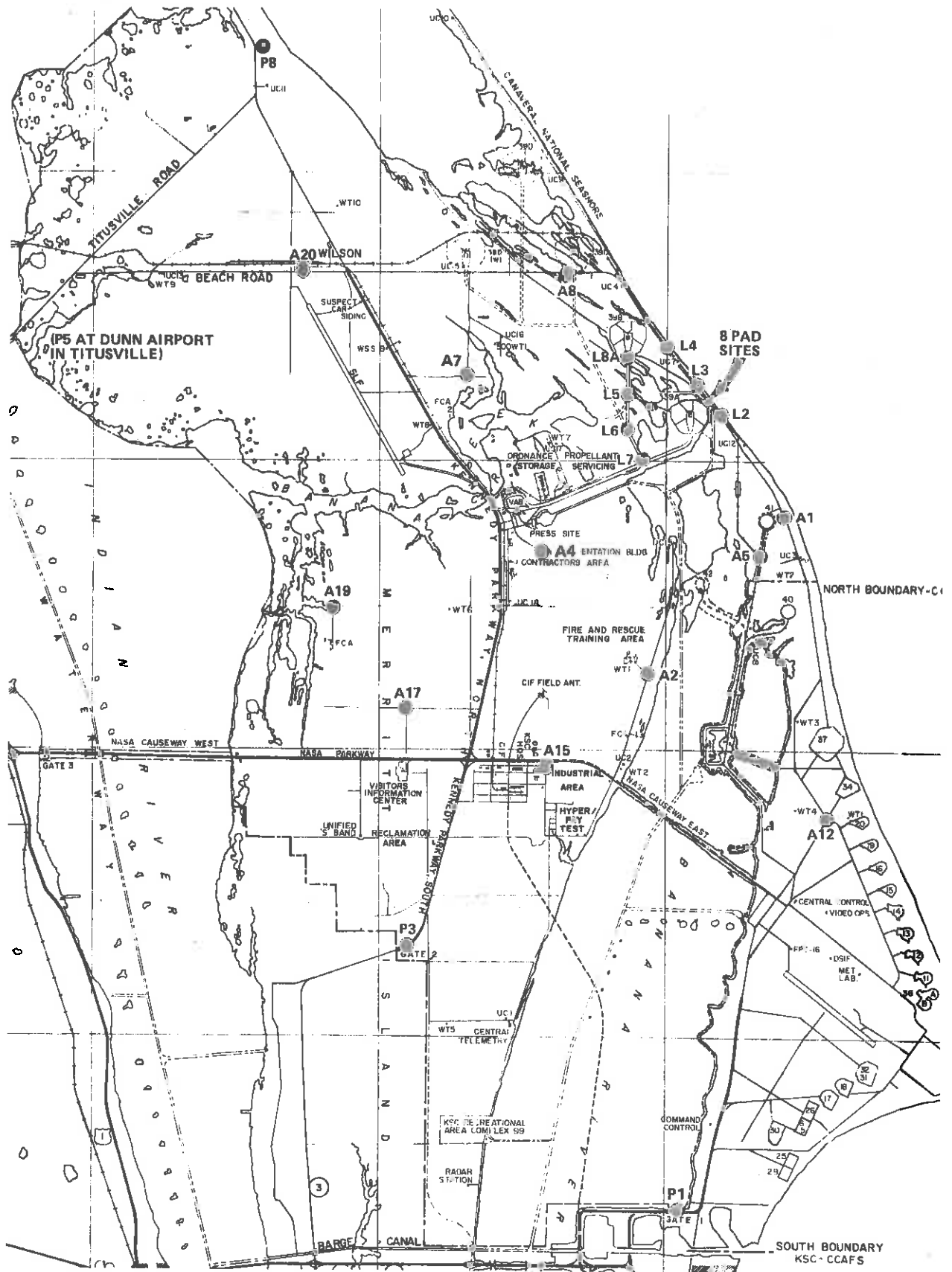


Figure 3-10. Location of Indicator Plant

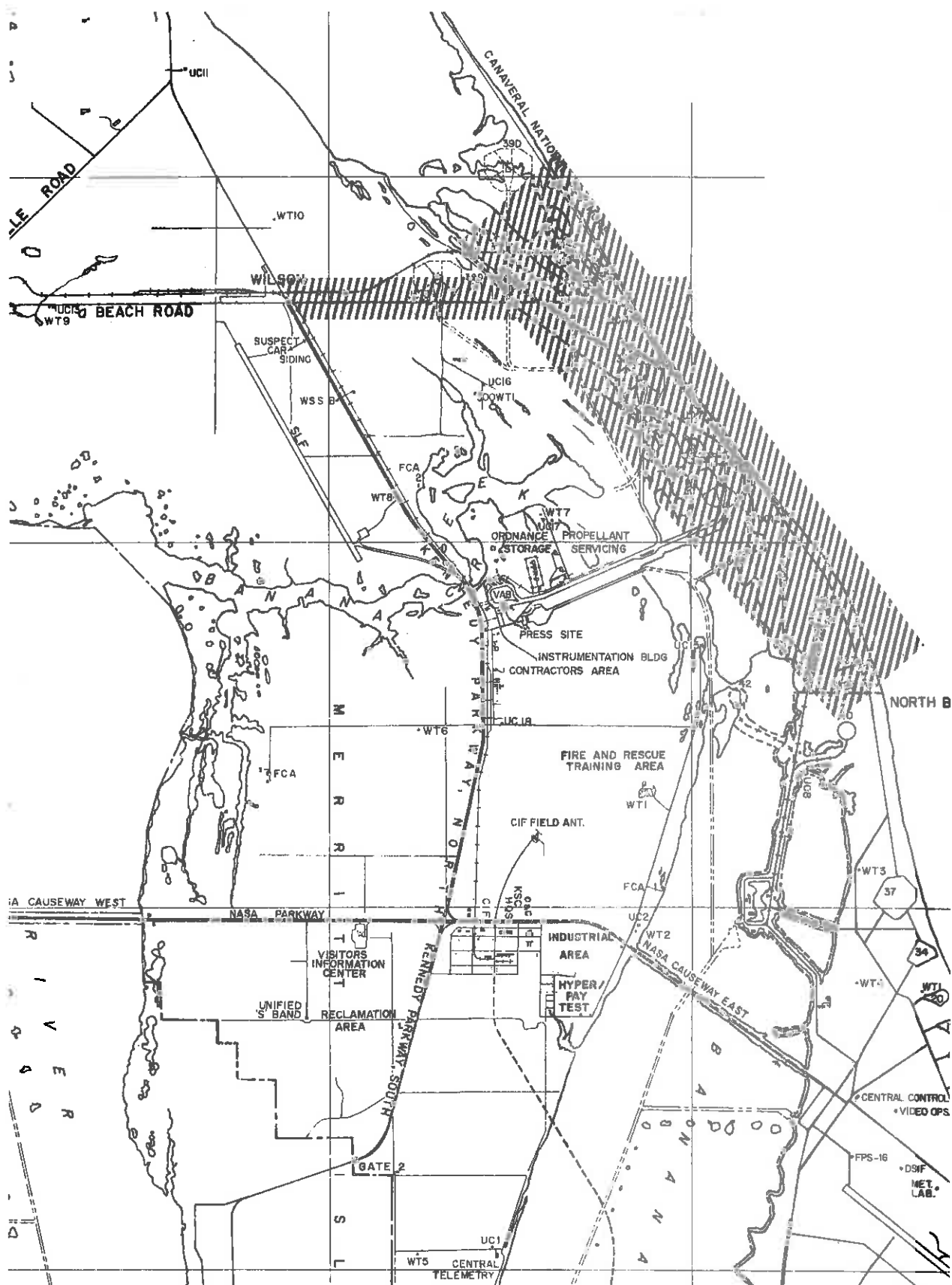


Figure 3-11. Area Photographic Coverage

Environmental noise was monitored by 15 Metrosonic db-652 devices. In addition, one GR-1982 Precision Sound Level meter with peak hold was used at the VAB (near Site A4). The Metrosonic devices were placed 4.8 to 22.5 kilometers from LC-39A. Four samples per second were taken and integrated over one minute. Thus, the data output consisted of 60 discrete values per hour.

Most of the Metrosonic instruments were activated about six hours prior to launch. However, the devices have the capability of storing up to eight hours of data. The instruments were deactivated at pickup (up to eight hours after deployment) and the data retrieved in the laboratory. Location of all noise monitoring sites including those utilized during the wildlife and acoustics monitoring effort is shown in Figure 3-12.

3.2.7 WILDLIFE MONITORING. Observations of wildlife reaction to the STS-1 launch were limited to birds at the five sites indicated in Figure 2-15.

3.2.8 BENTHIC COMMUNITIES. Methods for sampling and analyzing benthic communities have been described in Section I.

3.3 RESULTS

3.3.1 CLOUD PREDICTION. Prelaunch meteorology indicated a northwesterly cloud movement. Consequently, an additional five sample sets were deployed in the northwest Merritt Island area. Each subsequent prediction showed the cloud track to be swinging more northerly but due to movement restrictions within the impact area, relocation of the sample units was impossible.

Isopleths of ground level HCl and Al_2O_3 concentrations are shown in Figures 3-13 and 3-14, respectively. The data required for such plots were obtained from T-0 Rawinsonde soundings. The highest ground level

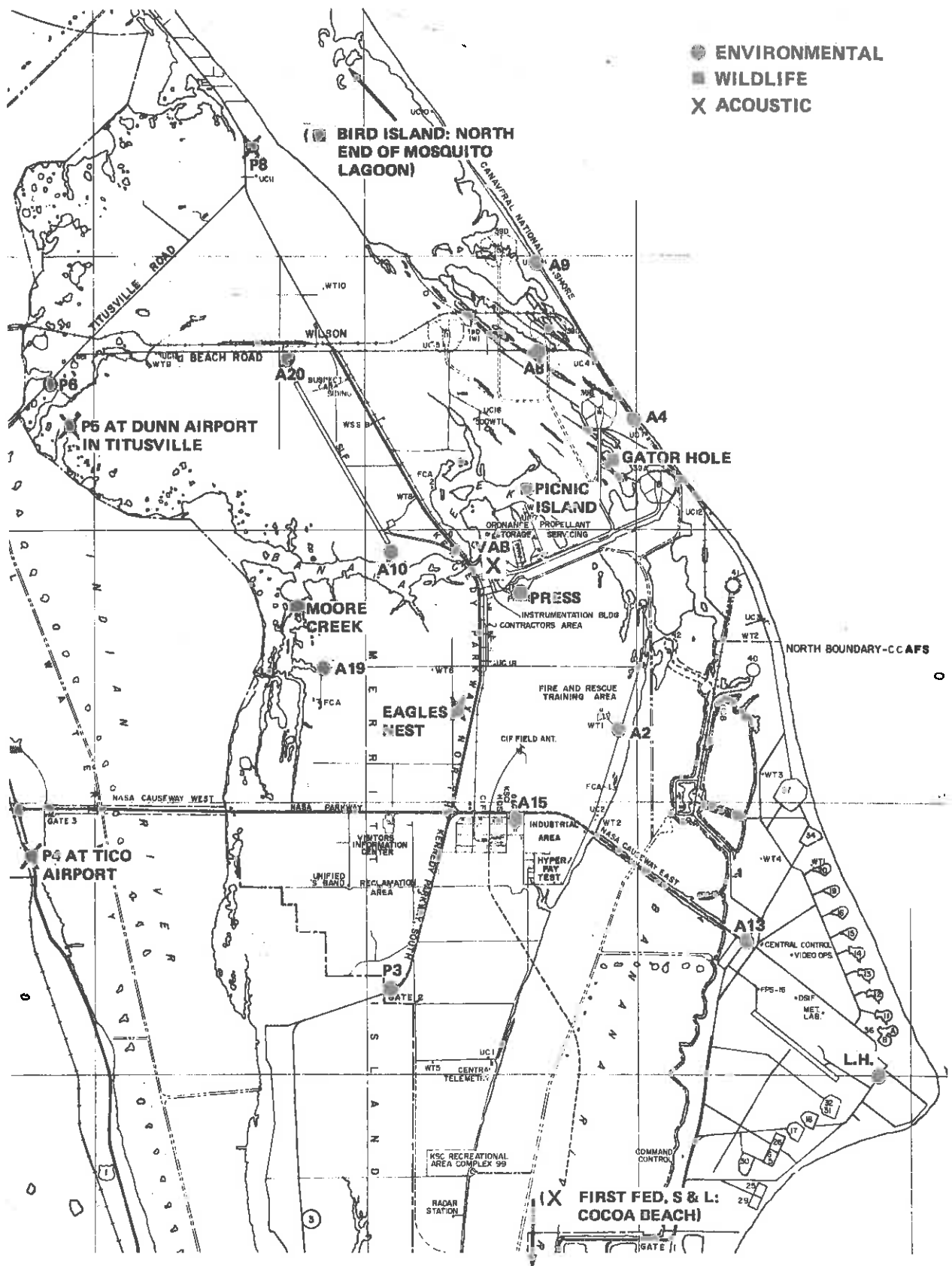


Figure 3-12. Noise Monitoring Sites

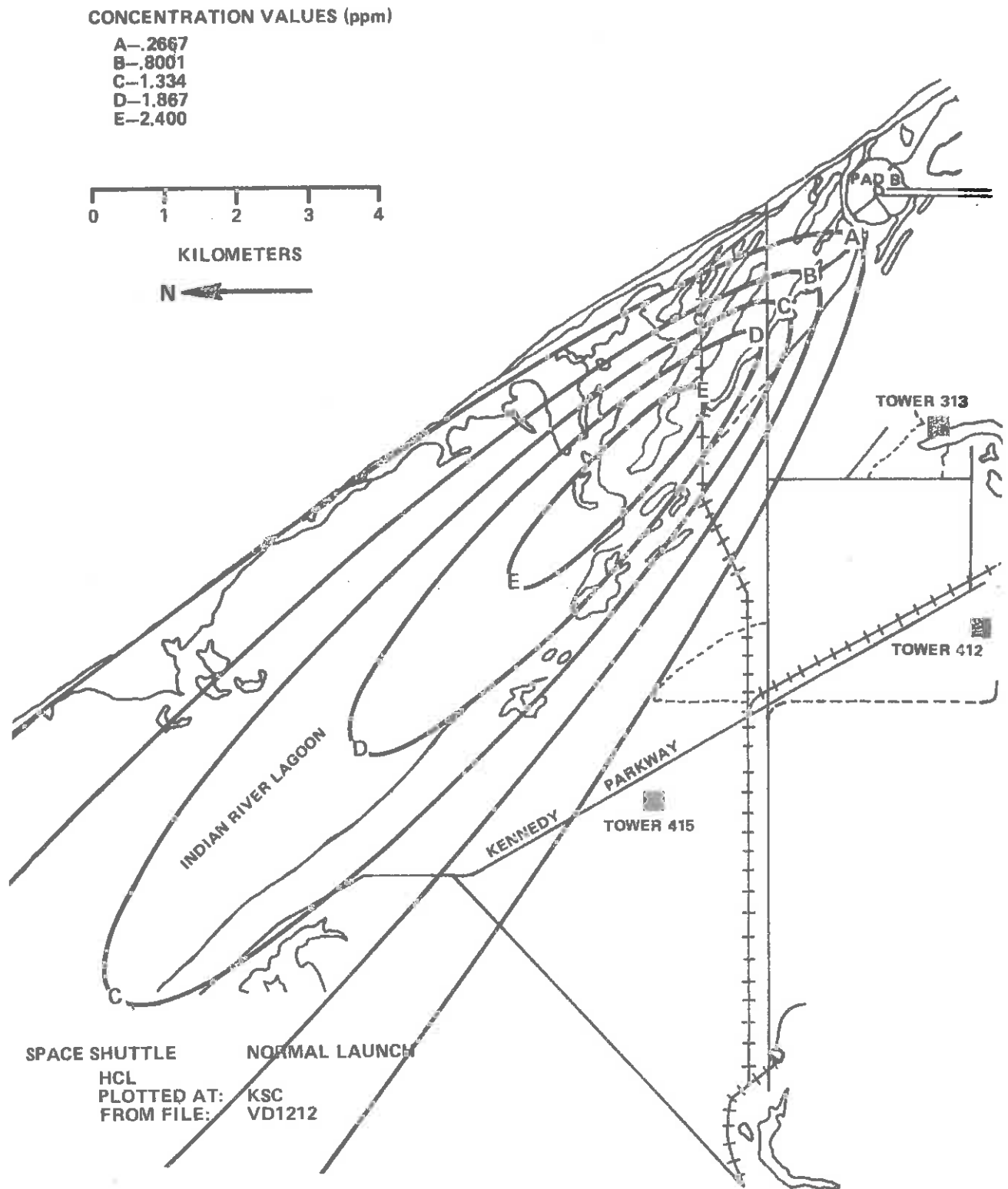


Figure 3-13. Predicted Ground-Level HCl Concentrations

CONCENTRATION VALUES (ppm)
GRAVITATIONAL DEPOSITION MG/M²

A - 11.99
B - 35.96
C - 59.94
D - 83.91
E - 107.9

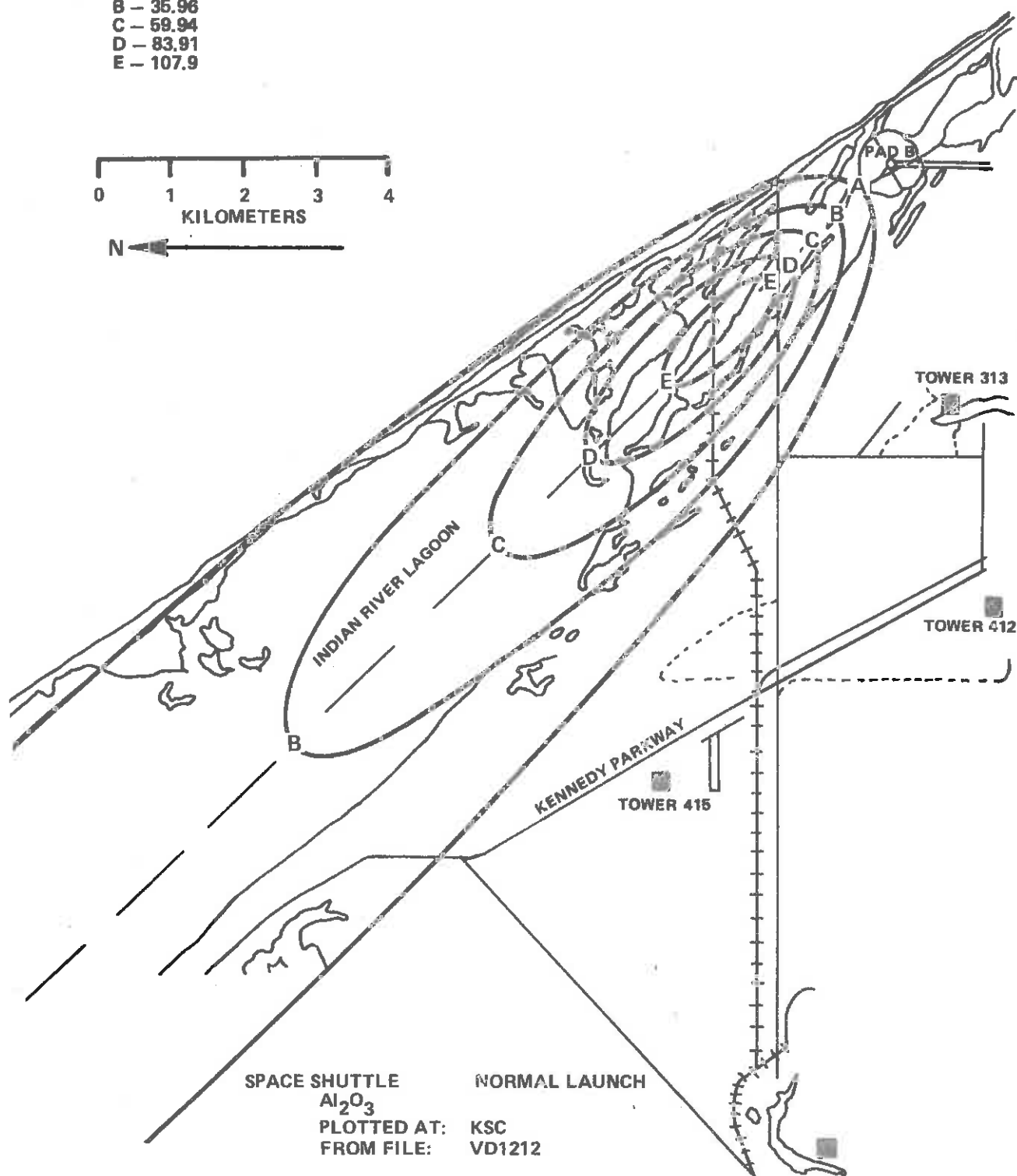


Figure 3-14. Predicted Ground-Level Al_2O_3 Concentrations

concentration of Al_2O_3 was predicted to occur at the railroad northwest of LC-39A on a true bearing of about 318° from the pad. A survey revealed no obvious deposition of Al_2O_3 in that area.

The highest ground level concentration of gaseous HCl was predicted to be about 1.6 kilometers north of the government railroad on a true bearing of about 312° from LC-39A. A ground survey revealed affected plants from Playalinda Beach west along Titusville Beach Road for about 0.9 kilometer. Affected plants were observed north, to the vicinity of UC9, but no evidence of acid damaged plants west along the railroad was found.

3.3.2. EQUIPMENT DEPLOYMENT. The choice of monitoring sites for the launch of STS-1 generally was adequate. The site locations were planned to cover as large an area as possible yet still be assured of detecting exhaust fallout products from the cloud.

The exhaust cloud was narrower than had been anticipated. Also, it drifted in a more northerly direction than anticipated. Consequently, fewer sample sites were impacted than were hoped for. The ground cloud and its fallout products were detected by seven sites. However, the density of those sites was insufficient to establish a positive ground print of the fallout pattern.

3.3.3 PAGER PERFORMANCE. Seventy-seven percent of all pump activations attempted by radio control were successful. All failures occurred in the "large" pump system which utilized an older pager and acoustic coupling from the pager to the control circuit. The activation criteria were identical to those in Section II, paragraph 2.2.1.4 of this report. Those criteria are summarized for the launch of STS-1 in Table 3-4. An unauthorized intrusion into the 111 net occurred during the paging sequence. We believe that intrusion was responsible for some of the "no runs" recorded.

3.3.4 GASEOUS MEASUREMENTS.

3.3.4.1 HCl Dosimetry. Results of HCl dosimetry are presented in Table 3-5. The values in that table are means from two tubes at each site. Those values followed by a question mark are the means of two widely variant values (i.e. 13 and 1 or 14 and 51) from the same location. Values of <1 ppm sec were taken as "0" for mean calculations. Only those tube sets with mean values ≥ 1 ppm sec are listed. Additional studies are underway to determine if one value of such widely variant pairs is more valid than the other value.

3.3.4.2 HCl Analyzers. Hydrogen chloride appeared to be detected by the HCl analyzer at Site P5 in north Titusville. All other analyzers failed to detect any trace of the material. The recorder at P5 indicated, about 0750 hours, an increase in HCl above background to 5 ppb which lasted for about 15 minutes. Another increase to 10 ppb followed and lasted for about one minute. The concentration of HCl continued to increase to 100 ppb and stabilized there for an additional minute. The HCl concentration declined after reaching its highest value about 0840 hours and eventually stabilized at 2 to 3 ppb. Analog data output from Site P5 is shown in Figure 3-15.

3.3.4.3 PAMS Data. Ozone, sulfur dioxide and an HCl analyzer were operational in all PAMS at STS-1 liftoff. Analog data outputs during that time showed no perturbations from the launch event. No unusual perturbations which might be ascribable to the launch event were noted from three of the PAMS. However, the HCl analyzer in PAMS E, at Dunn Airport in Titusville did record what appeared to be atmospheric HCl. That event is presented in paragraph 3.3.4.2.

Analog data from the O₃ and SO₂ channels are shown in Figures 3-16 through 3-19. Geomet HCl output was recorded directly in analog from each PAMS.

Table 3-4. Pager Performance

Remoted System	LTM Activated	HCI Detected
L1	Yes	No
L2	Yes	No
L3	Yes	No
L4	No	No
L5	Yes	No
L6	Yes	No
L7	Yes	No
L8	No	No
L8A	No	No
L9	Yes	No
L10	Yes	No
L11	Yes	No
L12	Yes	Yes
L13	No	No
L14	No	Yes
L15	No	No
A1	Yes	Yes
A2	No	Yes
A3	Yes	Yes
A4	Yes	Yes
A5	Yes	Yes
A8	No	No
A10	Yes	Yes
A11	Yes	Yes
A12	Yes	Yes
A14	Yes	Yes

Table 3-4. Pager Performance (Cont'd)

Remoted System	LTM Activated	HCI Detected
A15	Yes	No
A16	Yes	No
A17	No	No
A18	Yes	Yes
A21	Yes	Yes
P2	No	No
P6	Yes	Yes
P7	Yes	Yes
6M2	Yes	Yes

Table 3-5. HCl Dosimetry

Site	ppm/sec
L12	1700
A9	32?
A3	16?
6M2	16?
A14	16?
A21	12?
L14	8
P6	8?
A12	8?
A4	7?
A10	6
A1	6?
A18	4
6M3	4
A11	4?
A2	4?
P7	3
A19	3
A7	2
6M1	2?
A5	2?
P5	1
A20	1?
UC5	1?

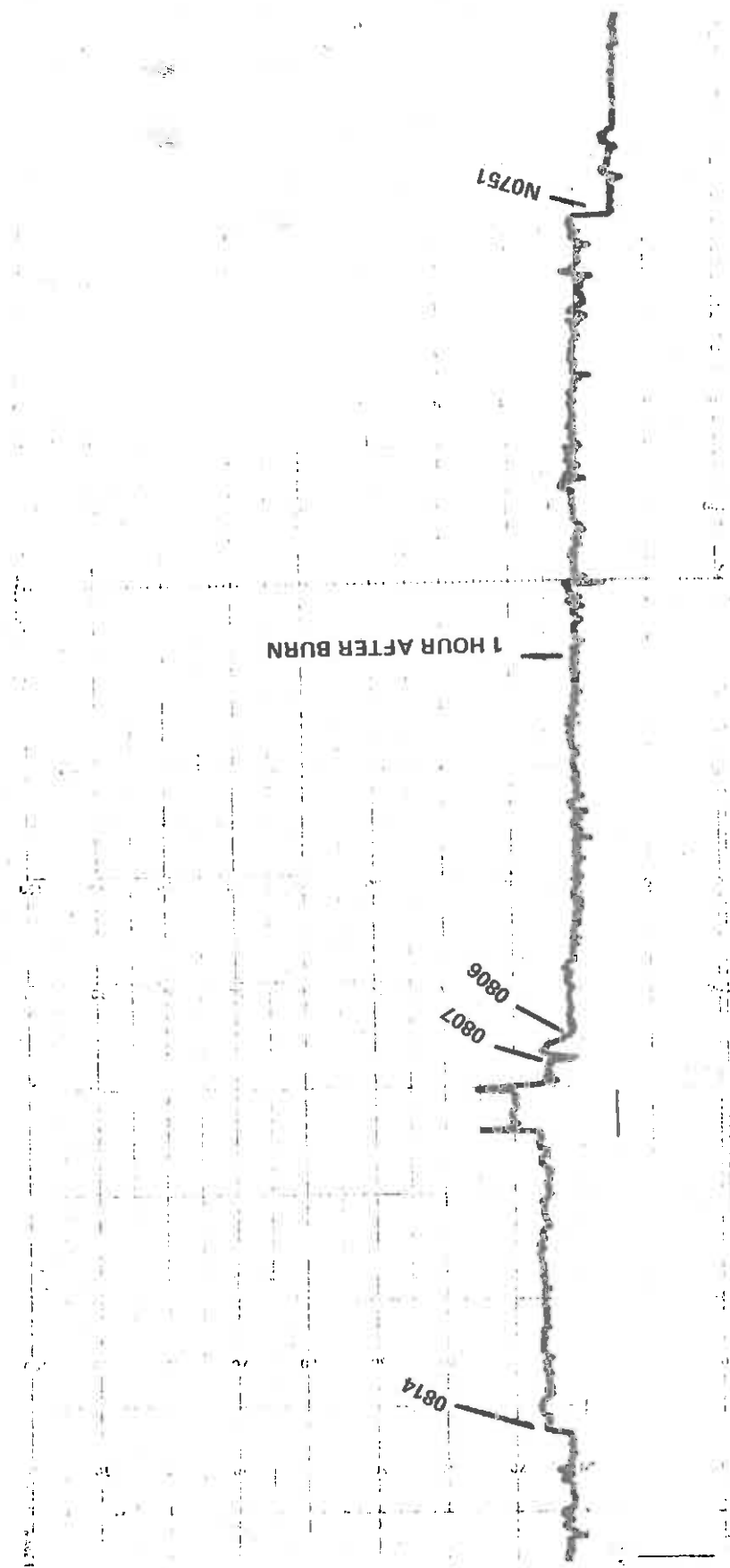


Figure 3-15. Site P5 Geomet Output

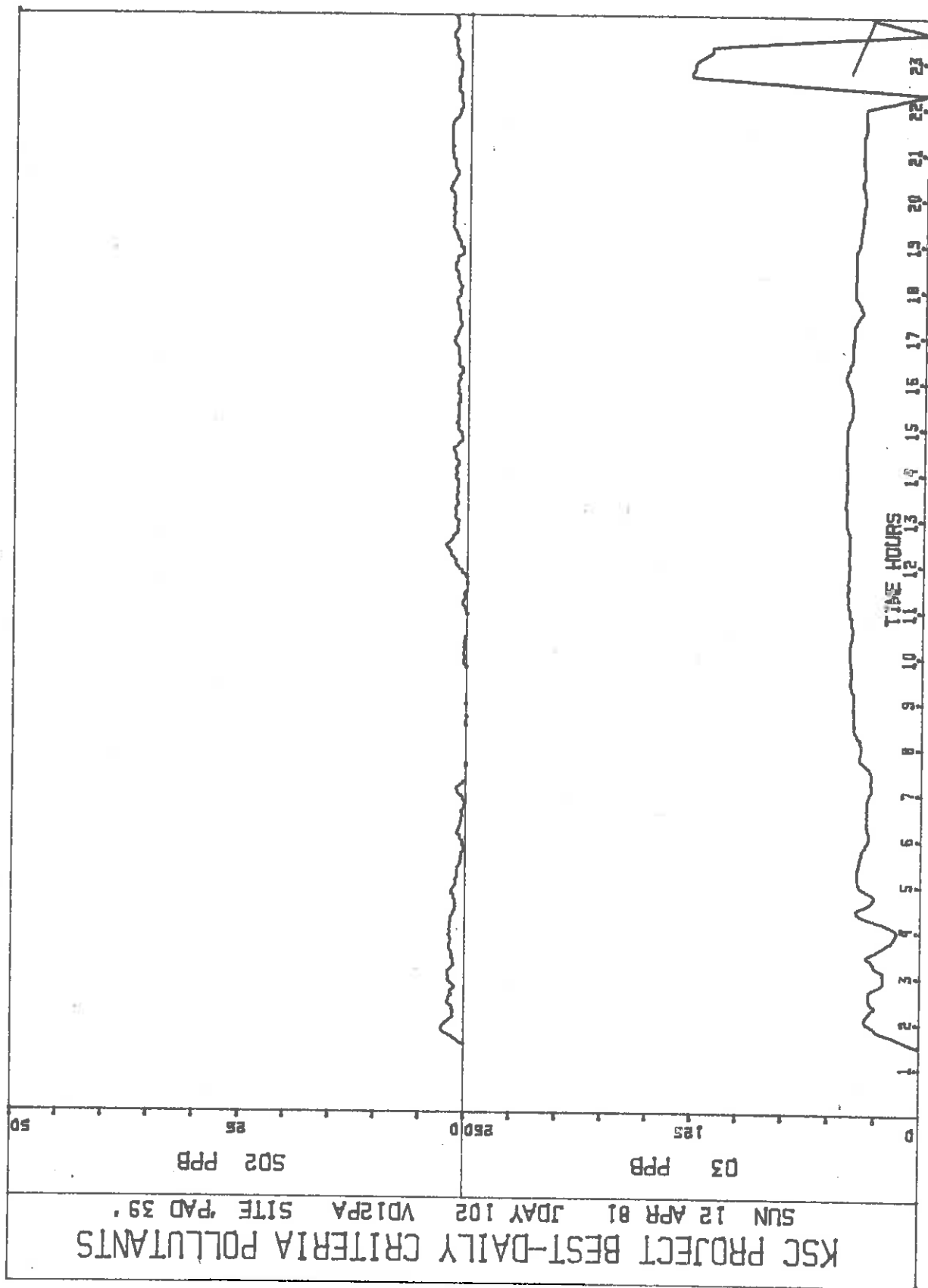


Figure 3-16. Analog Data Output from PAMS A

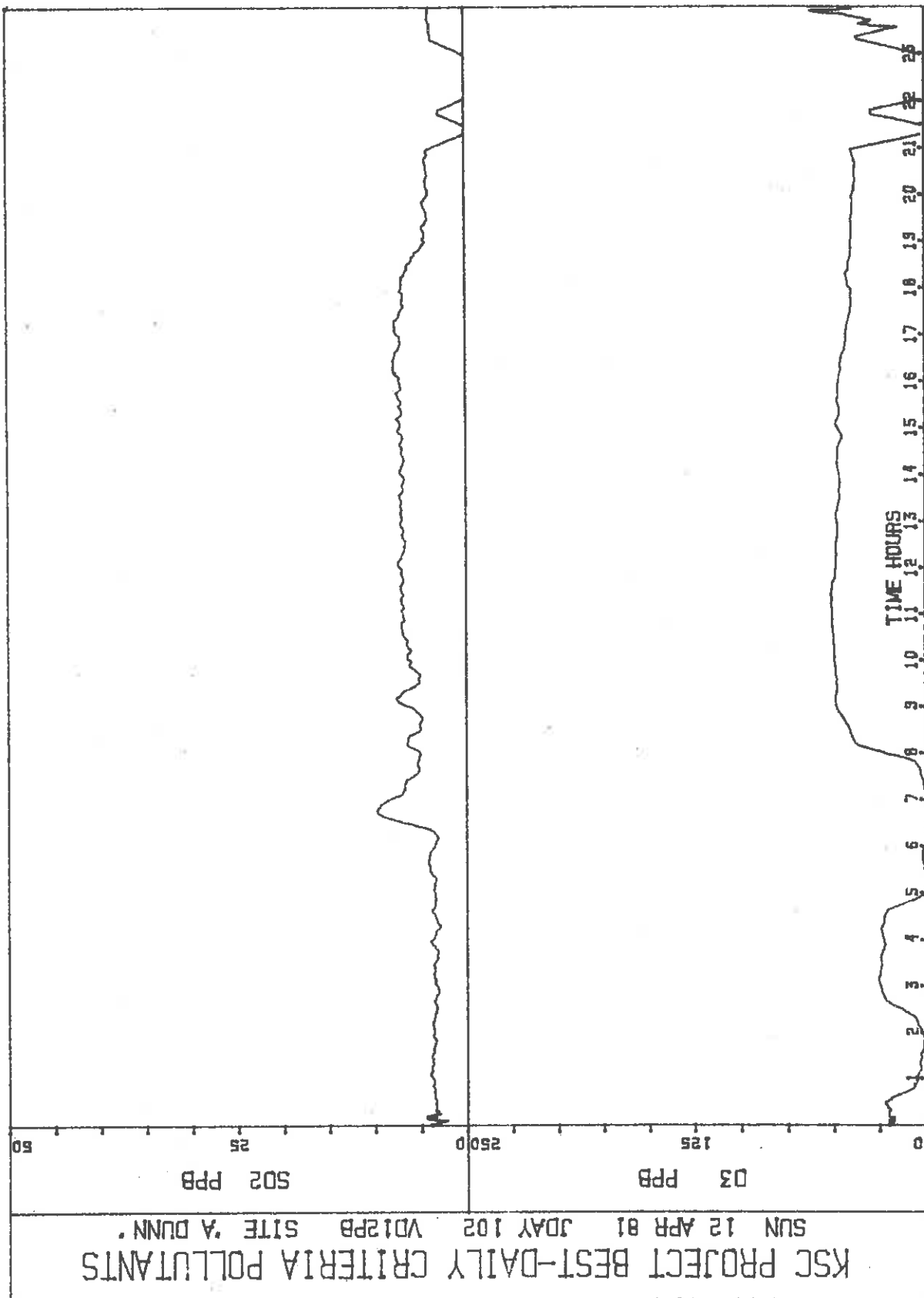


Figure 3-17. Analog Data Output from PAMS B

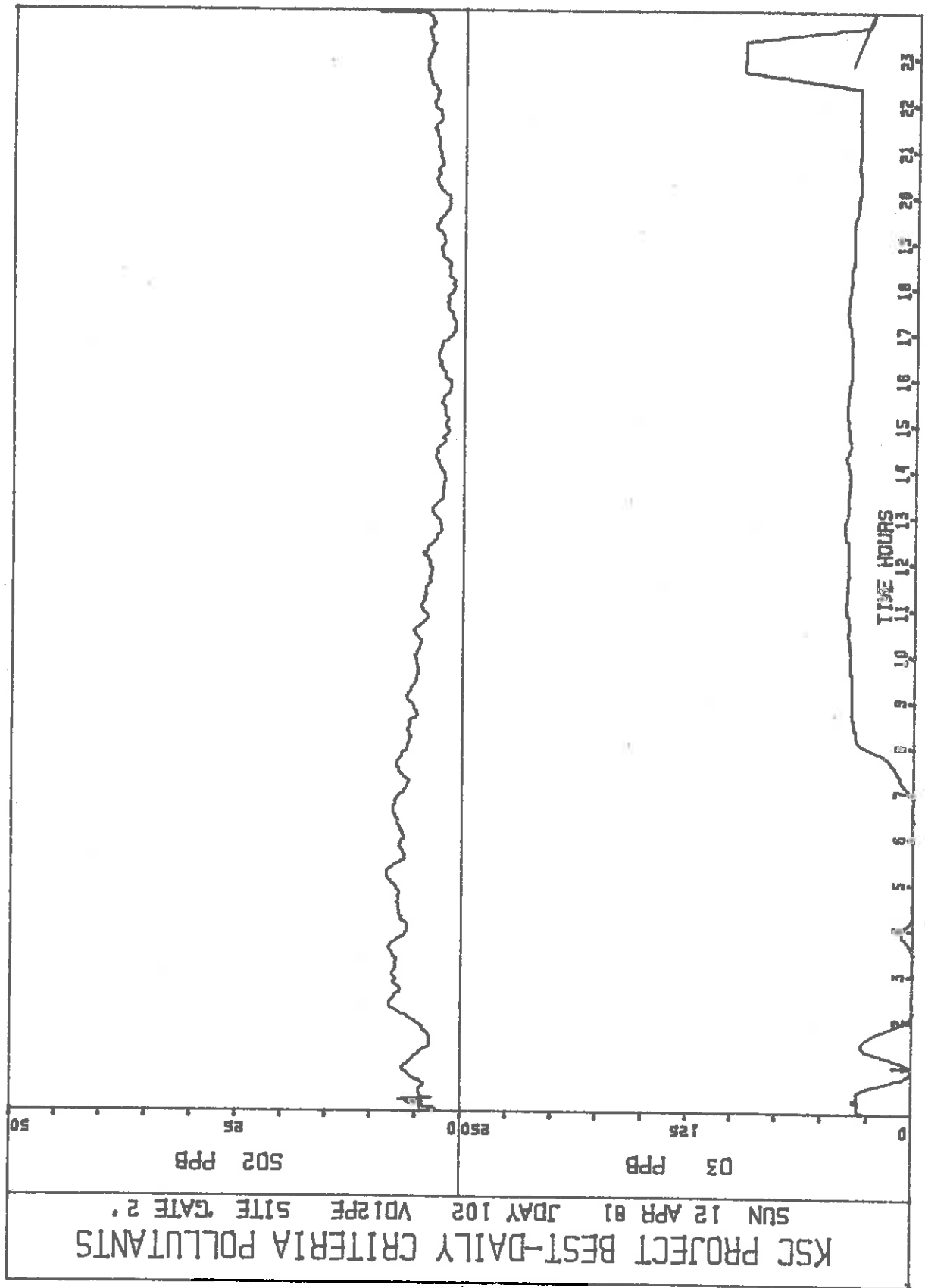


Figure 3-18. Analog Data Output from PAMS E

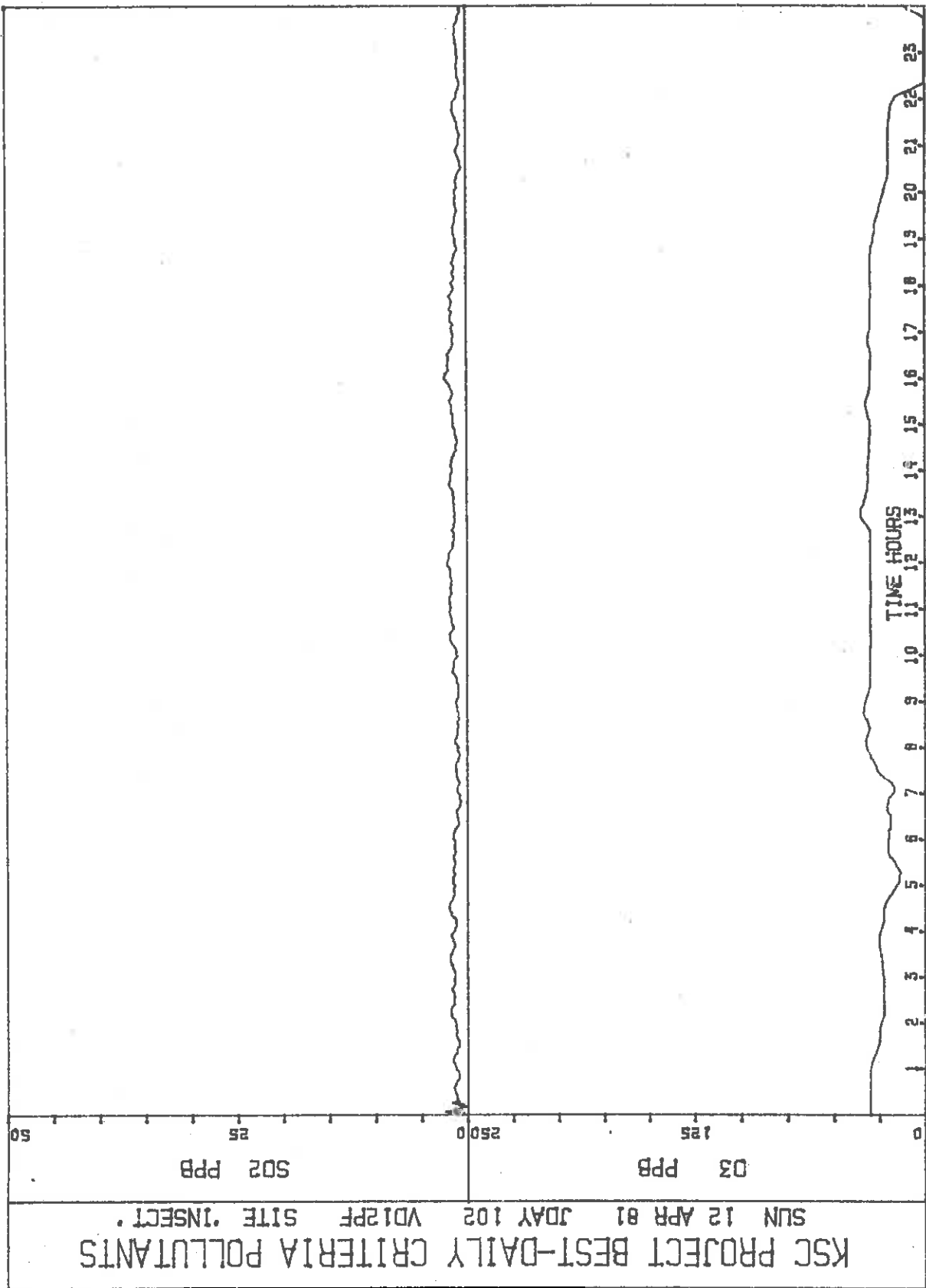


Figure 3-19. Analog Data Output from PAHS F

3.3.4.4 In-Cloud HCl. The lower cloud rose to an altitude of 650 to 950 meters under relatively high humidity conditions. The higher, westerly cloud drifted between 1,350 to 1,880 meters in low relative humidity conditions.

Total HCl concentrations in the lower cloud decreased rapidly during the first few aircraft penetrations. Concentrations of total HCl and gaseous HCl were approximately equal in the higher altitude cloud.

Airborne instrumentation revealed overall HCl concentrations from 0.90 to 17.50 ppm and relative humidity from 86 percent to less than 10 percent.

A separate report will be published by NASA LRC.

3.3.5 FALLOUT MEASUREMENTS.

3.3.5.1 In-Cloud Particulates. In-cloud particulate data are presented in the original LRC report in mass concentrations as a function of impactor stage and geometric mean diameter. Wide variations in concentrations were noted from stage one.

Early passes through the cloud showed high particle concentrations near 0.1 micrometer in diameter. The concentrations shifted to about 5.4 micrometers for later passes. Agglomerated particles also were observed on some impactor stages after later penetrations.

Particles spherical in shape and abundant in aluminum were found in all impactor stages. Those few particles on stage one which were analyzed ranged from 10 micrometers to about 20 micrometers and showed strong aluminum signals with traces of iron and calcium. The agglomerated particles were about 50 micrometers to about 80 micrometers in diameter and showed strong aluminum signals with traces of chlorine and iron. Those particles on stage six were about 1 micrometer to 3 micrometers in diameter and showed aluminum with traces of silicon and calcium.

A more detailed separate report will be published by NASA LRC.

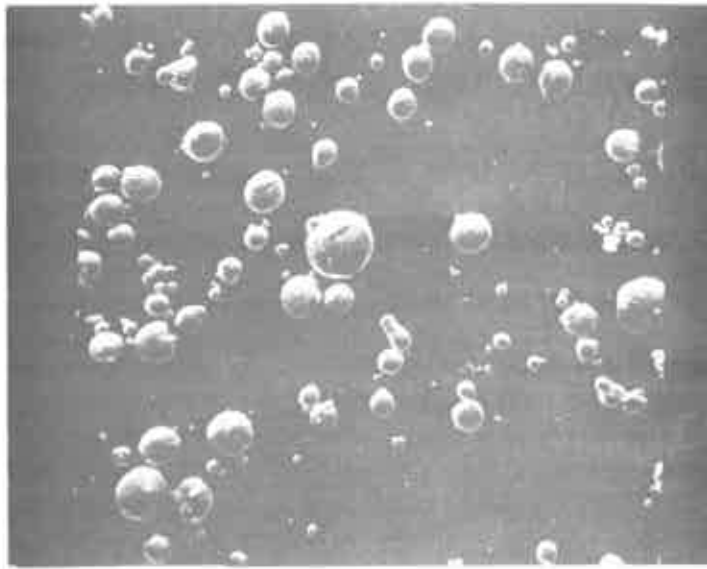
3.3.5.2 Acid Precipitation. Acid atmosphere contaminants were detected from LC-39A to about 7.4 kilometers north of the pad. The fallout pattern approximated an angle of about 16° with its apex at LC-39A and bisected by a true bearing from the pad of approximately 325° .

The ground cloud apparently lifted after leaving the immediate vicinity of LC-39A. The result of lifting was a particulate (rain or solids) fallout which produced discrete spots and blemishes on vegetative leaves, exposed pH paper, and other objects. The presence of moisture (dew, surface condensation and fallout) caused the pH dyes to run but the papers were still able to indicate the existence of low pH material. If an acid gas cloud had been present at the outlying sites, moist papers at those sites would have been uniformly colored with no circular or annular patterns. Such a uniformity was observed at some of the LC-39A perimeter sites.

Deployment of the paper was not sufficient to determine the precise ground pattern of the fallout. Figure 3-20 shows the location of those papers with a positive acid reaction.

3.3.5.3 Fallout Morphology. Samples of residue from LC-39A were collected and examined via SEM. Those photographs showed individual spherules ranging from submicrometer to about 20 to 30 micrometers in diameter (Figure 3-21). The fallout material adhered to pH paper also was examined via SEM. Those spots appeared to be composed of the same type and size of spherules as the LC-39A residue. They also appeared to be somewhat coalesced into large diameter (perhaps up to 50 micrometers) particulates. Entrainment of such large particles by impactors and low flow filters is doubtful.

The material deposited on surfaces beneath the cloud appeared light gray and streaked vertical surfaces much like a light mud. Acidity of the fallout was evidenced by pH paper and foliage reactions.



A. LC-39A RESIDUE - 840X



B. FALLOUT MATERIAL ON pH PAPER - 840X

Figure 3-21. Exhaust Particulate Material from the Launch of STS-1

3.3.5.4 Dry Deposition. Conductivity and pH of rinse water from dry deposition buckets was determined. The results of those determinations are listed in Table 3-6. The lowest pH was recorded at Site A8 and is reasonably consistent with the predicted position of the ground cloud (paragraph 3.3.1). Some of the buckets contained a quantity of insoluble material which appeared to be Al_2O_3 , quartz sand or other similar debris. However, others contained many small spots which remained after the evaporation of a liquid phase. Some of those spots appeared to be soluble in water. Other buckets contained no visible indication of exhaust deposition yet still produced high conductivity values. Those buckets with noticable spot-type residues generally produced the higher conductivity values.

Fifteen deposition buckets were selected for chemical analysis. The selection was made by considering location of the site and previously determined conductivity and pH values. The remaining samples were considered as potential baseline data. Results of analyses for major ionic components are shown in Table 3-7.

The droplet residues appeared to go into solution or at least suspend well in an aqueous medium. Such samples contained a soluble form of aluminum. However, those suspended samples showed an increase in aluminum content by more than 50 percent after standing overnight in 0.1N HCl.

Excess chloride in the samples was calculated by assuming the sodium concentration in those samples was principally a function of sea salt deposition. The ratio of sodium to chloride in sea spray deposition has been determined previously⁽³⁾. More excess chloride and greater aluminum deposition was demonstrated from those buckets with noticable residues than from relatively clean buckets or buckets away from the cloud.

Table 3-6. Conductivity and pH Determinations
from Dry Deposition Samples

Sample Site Code	Conductivity ($\mu\text{mhos cm}^{-1}$)	pH	Material Observed in Buckets
L-14	83.0	5.40	X
L-12	53.8	5.34	X
L-4	46.8	6.71	
L-3	42.0	6.68	
L-11	40.5	6.10	X
A-8	38.5	4.67	X
L-15	33.5	7.92	
L-8	25.7	7.51	
L-7	25.5	6.80	
A-9	25.5	5.26	X
L-5	23.3	7.27	
L-16E ¹	20.0	5.43	X
A-1	19.2	5.75	
L-9	16.0	6.29	
L-10	15.0	6.36	
L-13	13.7	6.84	
L-6	10.0	6.36	
A-14	9.6	6.03	
A-18	8.7	6.78	
A-16	8.3	5.46	

Table 3-6. Conductivity and pH Determinations
from Dry Deposition Samples (Cont'd)

Sample Site Code	Conductivity ($\mu\text{mhos cm}^{-1}$)	pH	Material Observed in Buckets
A-3	8.3	6.16	X
P-8	8.3	6.16	
A-7	8.2	5.69	
L-16W ²	8.2	5.82	
A-10	7.5	6.00	
A-4	6.8	5.63	
L-16	6.4	5.48	
A-2	6.0	5.67	
A-5	5.8	5.92	
L-16PL ³	8.0	5.60	
A-20	4.8	6.12	
A-6	4.5	6.07	
P-3	3.9	6.01	
A-17	3.9	6.41	
A-19	3.8	5.60	
P-4	3.6	5.55	
JPH ⁴	5.1	5.56	

¹East of PAMS A

²West of PAMS A

³Jess Parrish Memorial Hospital

⁴PAMS A prelaunch Background

Table 3-7. Dry Deposition Fallout ($\text{mg}/\text{m}^2/\text{hr}$)

Site No.	Bucket No.	pH	Hrs Exp.	Note Dep.	Cond	Na	K	Ca	Mg	Cl	NO ₃	SO ₄	Al
L14	47	5.40	20	yes	83.0	0.67	0.06	-	0.12	3.75	0.05	0.76	0.32
L12	59	5.34	20	yes	53.9	0.26	0.04	0.90	0.05	2.38	0.03	0.17	0.09
L4	55	6.71	20	no	46.8	0.85	0.04	1.83	0.14	1.43	0.04	0.40	<0.0002
A8	53	4.70	9	yes	38.5	0.70	0.10	0.94	0.10	3.73	0.09	0.22	0.26
A9	52	5.30	9	yes	23.5	0.67	0.06	0.57	0.10	1.88	0.04	0.24	0.01
L11	50	6.10	20	yes	40.5	0.30	0.04	1.02	0.05	1.45	0.02	0.12	0.006
L15	12	7.21	20	no	33.5	0.16	0.02	-	0.04	0.32	0.07	0.16	<0.0002
L10	9	6.40	20	no	15.0	0.20	0.02	-	0.04	0.40	0.02	0.07	<0.0002
L16E	-	5.43	44	yes	20.0	0.10	0.03	0.11	0.02	0.32	0.01	0.09	0.007
P8	54	5.55	9	no	9.5	0.20	0.03	0.72	0.03	0.31	0.04	0.12	<0.0006
A7	51	5.69	9	no	8.2	0.19	0.01	0.62	0.03	0.28	0.04	0.13	<0.0006
L16	-	5.82	44	no	8.2	0.06	0.009	0.03	0.009	0.11	0.009	0.02	0.0007
A20	45	6.12	7	no	4.8	0.08	0.03	0.33	0.03	0.10	0.04	0.04	0.003
bControl	a01A	5.74	3	-	3.6	-	-	-	-	0.03	0.12	0.04	0
	06A	5.77	3	-	5.6	0.03	0.01	0.14	0.05	0.04	0.61	0.02	0
	10A	-	3	-	2.5	-	-	-	-	0.04	0.09	0.06	0
	-	5.71	-	-	-	0.03	0.02	0.05	0.002	0.06	0.05	0.08	-

a - FRF data
b - clean buckets kept in laboratory

a - FRF data

b - clean buckets kept in laboratory

3.3.5.5 Wet Disposition. Results of water droplet analyses are given in Table 3-8.

Table 3-8. Water Droplet Analyses

Site	Cl (ppm)	Na ⁺ (ppm)	Ca ⁺⁺ ppm	Cl:Na
L4	7705	4613	180	1.7
A8	5415	680	140	8.0
A7	150	83	33	1.8
L8A	122	122	23	1.0
P6	61	39	11	1.6
A4	43	51	6	0.8
A20	35	43	11	0.8

The chloride to sodium ratio's for Sites L4, A7, and P6 were similar to that of sea water. Site A8 showed an excess of chloride, while Sites L8A, A4, and A20 revealed an excess of sodium.

3.3.5.6 Streakers and Impactors. Impactor slides and streaker filters were examined initially via an incident light microscope. Those impactors around the pad appeared to have sampled a fluid. The upper impactor stages bore the greatest washout effect and thus were of little value in assessing particle size distribution. The full effect of washout on the remaining stages has not been determined. A preliminary observation revealed no cubic crystals and no particulates with a large aspect ratio, however, a few marine organism shells were found.

Nothing unusual was reported on the streaker filters for the time interval of the launch event. However, two very dark bands, approximately 4 and 8 hours long respectively, were observed about the day before the scrub. Exact times are being calculated in order to identify their source.

Identification of material entrained on the slides and filters is being accomplished at the University of Central Florida by (PIXE). Those data will be published in a separate report.

3.3.5.7 Filtered Particulates. The background atmospheric particulate burden was assessed with 14 Nuclepore filters strategically placed about the KSC area. Filter weight gain and run times are listed by site in Table 3-9. Only those sites at which the pump Lapsed Time Meter (LTM) indicated positive activation are listed.

The atmospheric particulate burden during the launch period was assessed by a network of 29 nuclepore filters placed at various air sample sites in the KSC and mainland area. Table 3-10 lists weight gains at those sites with a positive LTM indication. The column labeled weight gain ($\times 10^{-3}$ g/min) in Tables 3-9 and 3-10 is the result of dividing the gained filter weight by the pump run time. Such a dividend does not strictly describe deposition of launch produced particulates due to the difference in time between exposure to the event and exposure to the atmosphere. Gained filter weights compared between site groups are summarized in Table 3-11. The listing of "exceptions" in Table 3-11 refers to values which, if used in \bar{x} and SD calculations, would result in biased statistics. The exceptions might be viewed as outliers, but they represent real values and thus cannot be statistically discarded. Their inclusion in the mean and standard deviations would not have reflected the true similarity between the background and launch event. The unit at All did not sample the ground cloud. However, its weight gain is believed to be valid and due to spectator stirred fugitive particulates.

A total of 14 filters were subjected to analysis. The key criteria for determining whether analytical values were valid was location of the filter. If the filters were in a location to receive cloud particulates, and those filters showed a gain in elemental analysis weight, they then were designated as receiving a "hit". Analytical results and filter location assessments are shown in Table 3-12.

Data shown in Table 3-12 are results of single analyses, thus no range estimates are available. Also, an effort is being made to resolve the large discrepancies between the two analytical techniques. Significant discrepancies exist between the NAA and PIXE data for aluminum values at

Table 3-9. Filter Weight Gain - Background

Site	($\times 10^{-3}g$)	Run Time (Minutes)	Wt Gain ($\times 10^{-3}g/min$)
L2	.080	29	.0028
L3	.052	44	.0012
L6	.031	44	.0007
L8A	.127	40	.0032
L5	.080	43	.0019
L7	.133	38	.0035
P3	.022	43	.0005
P5	.042	44	.0010
P8	.119	139	.0008

Table 3-10. Launch Related Nuclepore Filter Weight Gain

Site	Wt Gain ($\times 10^{-3}g$)	Run Time (Minutes)	Wt Gain ($\times 10^{-3}g/min$)
L2	0.070	13.0	.0054
L3	0.116	62.0	.0019
L5	0.100	44.0	.0023
L7	0.212	68.0	.0031
L8	0.065	1.5	.0433
L9	0.040	60.0	.0007
L10	0.088	74.0	.0012
L11	0.138	61.0	.0023
L12	2.001	73.0	.0274
L13	0.533	5.1	.1045

Table 3-10. Launch Related Nuclepore Filter Weight Gain (Continued)

Site	Wt Gain ($\times 10^{-3}g$)	Run Time (Minutes)	Wt Gain ($\times 10^{-3}g/min$)
A4	0.108	202.0	.0005
A7	0.065	108.0	.0006
A11	0.530	103.0	.0051
A13	0.054	55.0	.0010
A14	0.190	289.0	.0007
A15	0.101	131.0	.0008
A19	0.186	522.0	.0004
A20	0.475	496.0	.0010
P1	0.129	265.0	.0005
P3	0.041	87.0	.0005
P5	0.160	139.0	.0012
P8	0.082	131.0	.0006

Table 3-11. Summary Filter Weights ($\times 10^{-3}gm/min$)

Background			Launch		
Sites	\bar{x}	SD	\bar{x}	SD	Wt.
Launch	0.0020	0.0011	0.0024	0.0014	
Area	Did not run		0.0007	0.0002	
Perimeter	0.0008	0.0002	0.0007	0.0003	
L8	<div>Exceptions</div> <div> </div> <div>(none)</div>			Exceptions	0.043
L12					0.027
L13					0.104
A11					0.0051

Sites L9, L3, and A20. The chlorine values at Site L10 show similar variations. The reasons for such discrepancies are unknown, but an effort is underway to discover and correct the problem.

A separate more detailed report will be published by NASA LRC.

Table 3-12. Elemental Analyses of Filter Entrained Particulates ($\mu\text{g}/\text{m}^3$ air)

Filter Status	Site	Chlorine		Aluminum	
		NAA	PIXE	NAA	PIXE
NR	L4	-	-	-	10.7
NR	L13	-	-	0.2	-
NR	L14	-	0.7	-	-
NH	L5	-	-	-	-
NH	L7	-	1.2	-	15.8
NH	L2	-	0.2	0.6	-
?H	P5	-	-	-	-
NH	A15	-	-	-	-
?H	L9	-	1.6	0.5	37.4
?H	L10	13.4	0.5	0.1	-
?H	L3	18.3	-	0.3	20.2
?H	A20	2.0	1.8	0.02	5.7
H	L11	1.7	3.9	-	34.7
H	L12	23.6	18.5	363.0	230.3
NR---No run ?H---Questionable hit NH---No hit H---Hit					

3.3.5.8 Soil Chemistry. Major components of each soil sample are presented in milligrams per kilogram of soil in Table 3-13. The extreme variability of soil chemistry makes direct comparisons of separated sites tenuous at best. Nevertheless, data from five widely separated sites, sampled in 1980, also are shown in Table 3-13. Location of all sample sites is shown in Figure 3-22.

The chloride to sodium ratio for sea water is 1.80. Such calculations made for each soil sample indicate the chloride to sodium ratio generally is similar to that of sea water at those sites north of LC-39A. The two sites within and very near LC-39A show higher chloride to sodium ratios than could be attributed to sea salt alone. The source of such excess chloride in LC-39A samples must be attributed to deposition products from the STS-1 SRB's.

A comparison of area wide samples from 1980 with post launch samples reveals overall higher chloride levels in the launch affected samples. However those launch sample sites were much closer to the ocean than the area sites.

3.3.5.9 Surface Waters. Results of baseline water sample analysis are given in Table 3-14. Post launch analyses are listed in Table 3-15. (Site locations are as shown in Figure 3-9.) Data from Tables 3-14 and 3-15 are summarized in Table 3-16. The parameter change assessment (Table 3-16) was made by considering the data range. If the baseline and post launch data range overlapped, no change was assessed. An increase in concentration was assessed if the post launch data range was greater than and outside the baseline range. Similar reasoning was applied to arrive at assessments of decreased concentration.

3.3.6 FLORAL EFFECTS.

3.3.6.1 Gross Effects. Indicator plant damage was observed at the five sites listed in Table 3-17.

Table 3-13. Major Soil Ions (mg/kg soil)

Site No.	pH	COND	+1 Na	+1 K	+1 NH ₄	+2 Mg	+2 Ca	+3 AI	-1 Cl	-1 F	-1 NO ₂	-2 NO ₃	-2 SO ₄	-3 PO ₄	Cl:Na
a 1	6.91	1,350.0	52.4	99	8.0	67.0	-	0.25	1,455	1.9	6.8	9.0	122.0	0	2.8
2	6.83	2,940.0	1,037.0	157	31.3	313.0	3,315	0.40	2,650	3.3	10.5	375.0	1,475.0	9.3	2.6
3	7.23	220.0	28.7	21	5.7	17.0	-	0.10	55	0.8	0	16.0	46.0	18.6	1.9
4	7.13	2,480.0	2,267.0	63	142.0	210.0	388	0.15	3,060	2.8	2.8	9.0	9.5	17.8	1.3
5	7.08	2,930.0	2,930.0	132	10.8	452.0	483	0.10	2,425	3.7	3.0	7.5	2,215.0	14.6	1.3
b 1	6.78	990.0	49.6	36	5.2	21.0	-	0.20	500	2.2	0	11.5	30.0	0	10.1
2	7.12	695.0	130.0	34	29.0	28.0	2,645	0.30	269	5.0	0	15.0	128.0	0	2.1
3	7.36	128.0	15.9	8	0.4	8.0	80	1.05	14	0.8	0	7.5	21.5	0	0.9
4	7.33	705.0	454.0	45	2.4	54.0	154	5.00	685	5.5	0	13.0	125.0	0	1.5
5	7.36	960.0	592.0	60	5.7	85.0	105	0.70	930	3.5	0	27.0	440.0	0	1.6
b 01	-	-	17.0	12.5	1.5	9.5	-	-	11.0	-	-	1.0	10.0	8.0	0.6
07			14.5	19.0	1.8	2.8	8.8	-	8.8	-	-	0.5	11.8	21.8	0.6
13			13.5	5.2	2.5	0.5	3.0	-	5.2	-	-	2.8	9.5	6.0	0.4
14			20.2	12.5	0.1	1.5	3.5	-	8.5	-	-	0.5	12.8	24.0	0.4
16			15.8	6.2	9.0	4.5	-	-	9.5	-	-	6.0	9.0	5.5	0.4

a---Post STS-1 samples

b---1980 rain collection site samples

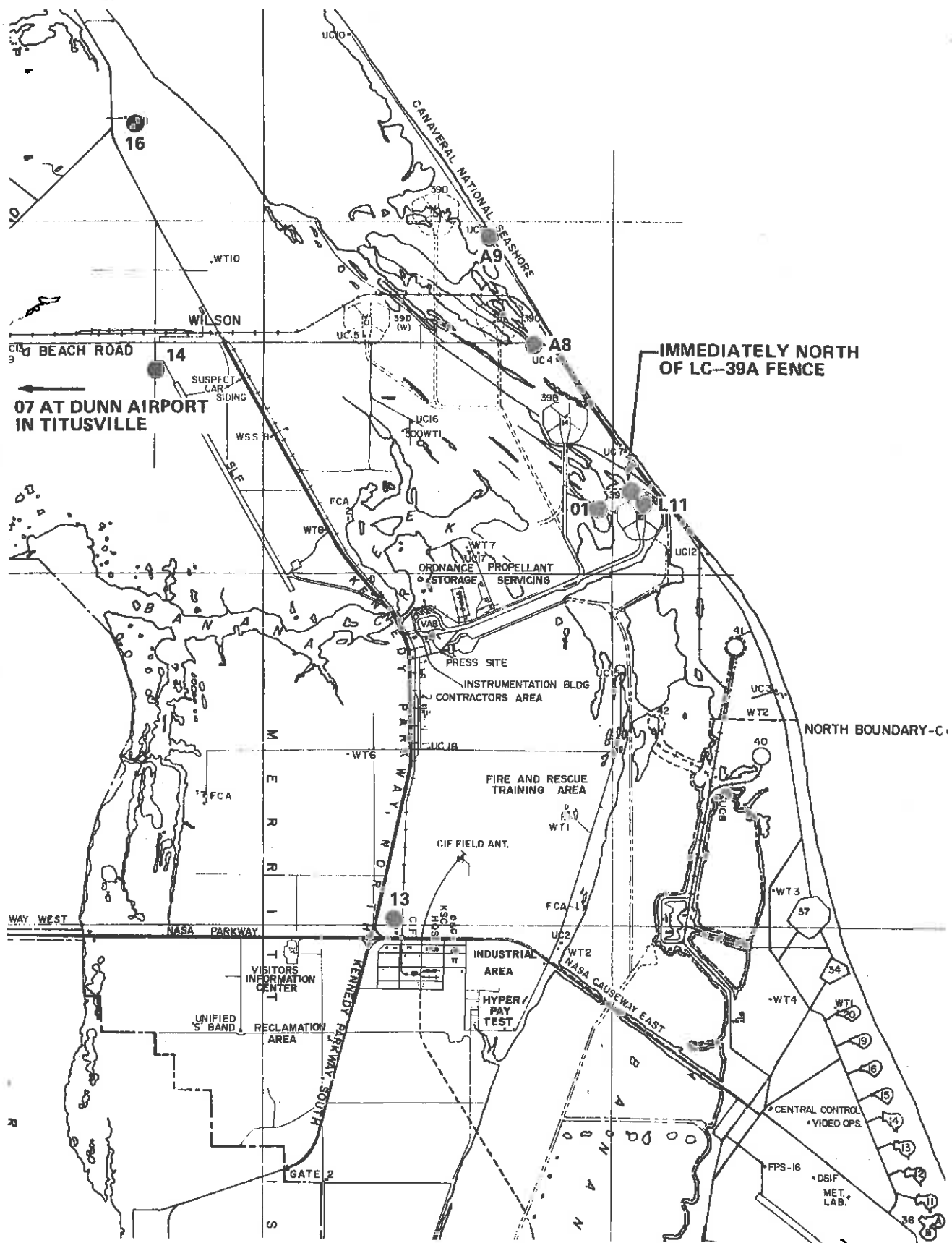


Figure 3-22. Location of Soil Sample Sites

Table 3-14. Base line Water Quality Data (Milligrams per Liter)

Sites									
Parameter	Max Hoek Back Creek	Banana Creek	L-3 Days			L+8 HRS			
			10	2	5	6	L1	L1	GH
Turbidity (NTU)	18±4	26±3	4.4±2.5	4.5±0.1	5.7±0.2	4.8±0.4	16±1	17±2	
pH (no units)	8.06	8.05	8.10	8.05	8.22	8.33	1.6	1.5	
Conductivity (umho/cm)		27,000±1,000	22,000±1,000	15,000±1,000	16,200±1,000		647±31	663±25	
NH ₃	0.05±0.04	<0.01	0.02±0.01	0.02±0.01	0.01±0.01	0.02±0.01	0.26±0.01	0.31±0.01	
TKN	13.4±0.8	5.2±5.9	1.8±1.7	1.1±0.1	3.0±1.7	5.6±0.7	3.0±0.07	1.7±0.1	
NO ₃	73±21	87±6	78±10	55±5	68±10	57±3	8.8±1.0	7.5±0.4	
NO ₂	0.02±0.01	0.03±0.01	<0.02	0.02±0.01	<0.02	<0.02	0.04±0.01	0.04±0	
C1	16,000±2,000	24,000±2,000	17,000±2,000	40,000±38,000	12,000±1,000	16,000±5,000	2,200±173	2,000±0	
ON	<0.002		<0.002	<0.002	<0.002	<0.002	0.007±0.001	0.008±0.001	
PO ₄	<0.2	0.2±0.1	<0.2	0.3±0.1	0.2±0.1	<0.2	11.0±1.0	11.0±1.3	
Al	1.0±0.9	<1.0	<1.0	<1.0	<1.0	<1.0	23.9±0.2	20.8±0.5	
Sb	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	
As	0.003±0.002	<0.001	<0.001	0.001±0	0.001±0.001	<0.001	0.021±0.002	0.016±0.002	
Bi	1.1±3.2	1.1±0.8	0.2±0.2	0.19±0.11	0.8±1.1	0.2±0.1	<0.03	0.27±0.37	
B	1.8±1.4	4±1	1.7±1.4	1.6±0.6	1.7±0.6	5±3	1.3±0.6	1.0±0.9	
Cd	0.045±0.004	0.074±0.003	0.042±0.007	0.035±0.004	0.035±0.005	0.037±0.006	0.12±0	0.17±0.01	
Cr	0.04±0.01	0.07±0	0.05±0.01	<0.05	<0.05	<0.05	0.19±0.01	0.4±0	
Cu	0.06±0.01	0.08±0	0.06±0.01	0.04±0	0.05±0	0.04±0.01	0.2±0	0.9±0	
Fe	0.62±0.19	0.78±0.36	0.25±0.06	0.19±0.01	0.23±0.06	0.12±0.01	25.0±0.2	10±0	
Pb	0.01±0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.95±0.06	1.3±0.1	
Mn	0.2±0	0.06±0.01	0.03±0.02	<0.05	<0.05	<0.05	0.8±0.1	0.7±0.4	
Mb	1.1±1.6	<0.4	<0.4	<0.3	0.1±0.1	<0.3	0.1±0	0.2±0.1	
Ni	0.28±0.03	0.37±0.03	0.28±0.03	0.17±0.03	0.2±0	0.2±0	0.6±0.1	0.65±0.4	
Ag	0.03±0.02	<0.05	0.03±0.02	<0.05	<0.05	<0.05	<0.05	<0.05	
Sn	<0.3	0.8±0.9	<0.4	<0.3	<0.2	<0.3	<0.03	<0.02	
Tl	<0.3	<0.4	<0.4	0.2±0.2	0.1±0.1	0.2±0.2	0.2±0.1	0.2±0.1	
V	<0.3	<0.4	<0.3	<0.3	<0.2	<0.3	0.1±0.1	0.2±0.1	
Zn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	183±15	214±6	

Table 3-16. Change in Water Quality Parameters (T+8 Days)

Parameter(a)	Site							
	L1*	GH*	2	5	6	MHBC	BC	10
Turbidity	D	D	D	D	D	D	D	D
pH	I	I				NC	NC	NC
Conductivity								
NH ₃	I	I	I	I		NC		I
TKN						D		
NO ₃								
NO ₂	D	D						
TP								
PO ₄		D					I	
Cl								
CN	D	D						
Al								
Sb								
As		D						
Bi								
B							I	I
Cd						I		
Cr	D	D					D	
Cu								
Fe				I				
Pb		D	I	I	I	I	I	I
Mn		I				I		
Mo								
Ni								
Ag								
Sn								
Ti								
V								
Zn	D	D						

(a) L1 and GH were referenced to L+8 hours samples.
 All other sites were referenced to L-3 days samples.
 I = Increase in concentration
 D = Decrease in concentration
 NC = No change

Table 3-17. Indicator Plant Damage

		Total % Plant Injury	
Site	Location	Hydrocotyle	Raphanus
A8	Titusville Beach Rd.	5	5-10
L8A	NW of Pad A	1	1
L11	Inside Pad A	1	5
L12	Inside Pad A	25-65	20-99
L14	Inside Pad A	1-5	10-40

Examples of the more severely injured plants are shown in Figure 3-23.

An area of native vegetation located north of the LC-39A flame trench suffered extensive damage during the launch of STS-1. The area included a pond immediately north of LC-39A. The extensively damaged area was approximately 10 hectares in size (including the pond) and consisted primarily of Baccharis halimifolia, Borrichia frutescens, and Myrica cerifera. Borrichia was located around the pond's edge in an area 5 to 20 meters wide.

The leaves of most Borrichia plants around the pond's perimeter were extensively damaged. The injured leaves of Myrica turned a dark brown and generally were covered with a whitish-gray particulate. The injured Baccharis leaves were light tan and had what appeared to be particulate spots on them.

An area southeast of Pad B and east of the crawlerway to Pad B is composed predominantly of Quercus (oaks). No noticeable leaf injury to any oaks was observed though most plants had liberal amounts of particulate matter on them.



A. PENNYWORT



B. RADISH

Figure 3-23. Indicator Plant Injury at Site L12

The vegetation along Pad B Road, is composed primarily of *Baccharis* and *Myrica*. *Borrichia* interspersed with *Iva Frutescens* is found along the pond margins to the north and south of the road. A species of *Eupatorium* and *Physalis* is also found in the area and showed somewhat greater leaf injury than *Baccharis* and *Myrica*.

Another area of slight injury was located approximately 0.8 kilometer north of Pad B. *Borrichia* is the most common plant in and around the marshes and sandflats of the area. Some slight spotting and particulates were observed on the leaves of many *Borrichia* plants in the area.

Injury to the greenhouse-reared and native plants was observed along a short section of Titusville Beach Road (Site A8). The injury seemed to affect *Borrichia*, *Baccharis*, *Eupatorium*, *Hydrocotyle* (both greenhouse and native plants) and *Physalis*. A species of *Ipomoea* sustained as much as 40 percent total leaf injury as spotting. The area of injury extended from about Gate 6, west along Titusville Beach Road for approximately 1.2 kilometers. An example of acid spotting in the area is shown in Figure 3-24. Particulate matter was noticed on plants along Playalinda Beach Road from Gate 6 to UC-9 (our Site A9). Total plant injury to *Hydrocotyle umbellata* and a species of *Polygonum* at Site A9 was assessed as 1 to 5 percent. *Baccharis* and *Myrica* leaves supported some slight particulate matter. The plant injury and particulate matter was noticeable only on the west side of Playalinda Beach Road.

Plant injury proved to be the single most descriptive indicator of the ground cloud's path. Areas of such injury are shown in Figure 3-25.

3.3.6.2 Remote Sensing. An area from LC-39A north to Titusville Beach Road was photographed with false color infrared film. The damaged vegetation immediately north of LC-39A exhibited a noticeably reduced reflectance. The characteristic red coloring of green foliage was missing and the area appeared rather gray. Also, the red color saturation closer to and southeast of LC-39B appeared to be less than that in areas west of the crawlerway. Changes in vegetation reflectance characteristics were not noticeable north of LC-39B.



Figure 3-24. Acid Spotting at Site A8

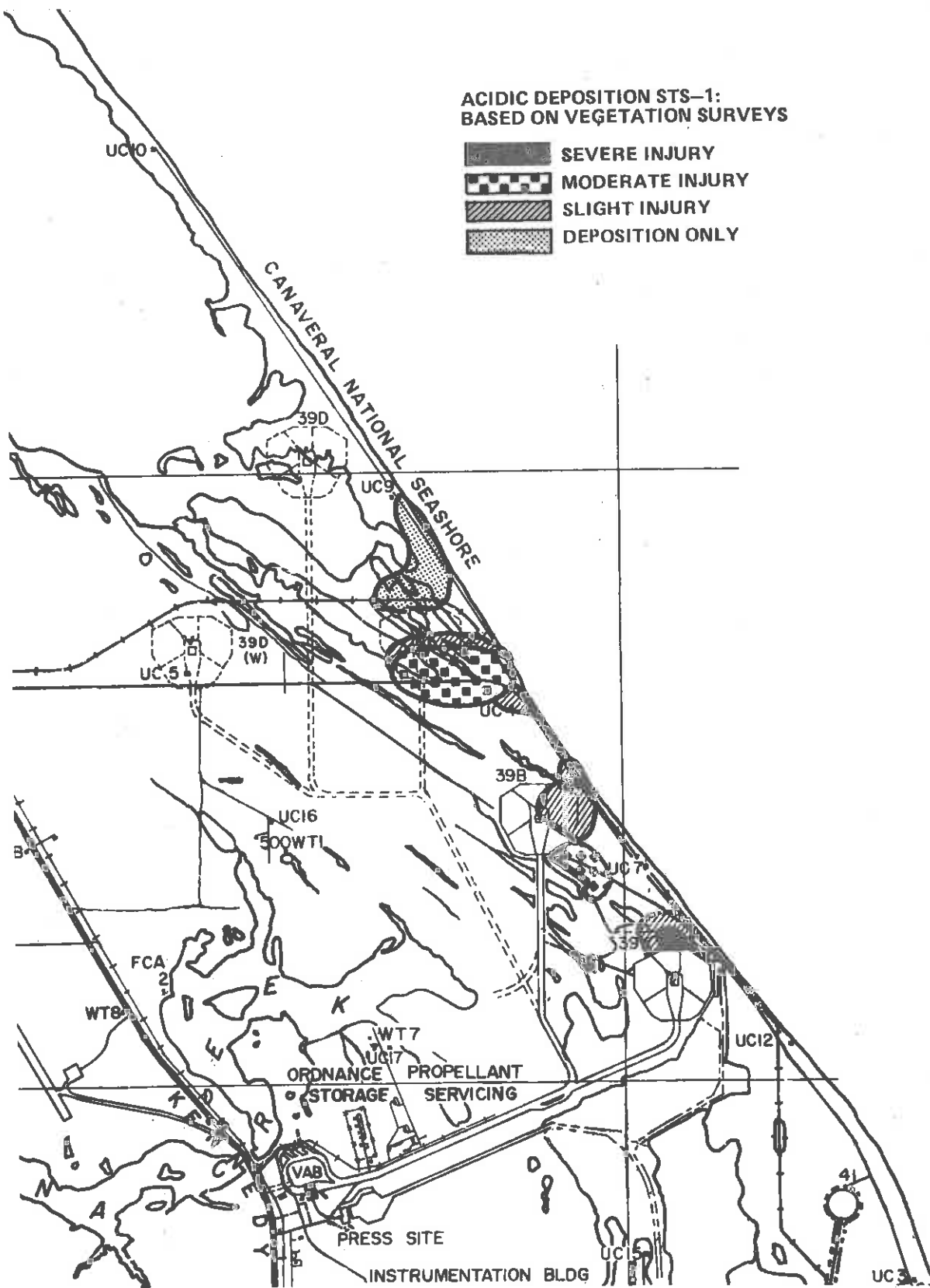


Figure 3-25. Areas of Vegetative Injury

3.3.6.3 Foliage Chemistry. Damaged vegetation between LC-39A and LC-39B supported quantities of powdery exhaust residue. Leaves of that vegetation were washed and compared with washings from nondamaged areas. Washings from the damaged foliage exhibited lower pH values and high chloride ion concentrations. Water soluble and insoluble aluminum forms also were recovered from the damaged foliage. Results of Foliage wash water analyses are shown in Table 3-18.

3.3.7 SOUND

Environmental noise levels were obtained before launch, during launch, and post launch. Isopleths of the 60 second energy equivalent average sound levels [$L_{eq}(60)$] and the Sound Exposure Levels (SEL) are plotted in Figures 3-26 and 3-27 respectively.

Sixty second A-weighted L_{eq} 's of 94 db were recorded about 5.3 kilometers from LC-39A while 69 db was recorded about 23.2 kilometers from LC-39A at Dunn Airport in Titusville. A single peak hold device recorded about 112 db at the VAB press site.

A comparison of data from far field acoustic measurements and environmental noise measurements was made at three sites occupied by both types of instrumentation. Environmental noise values at the Eagle's Nest were interpolated from isopleth data shown in Figure 3-26. Those comparisons are shown in Table 3-19. The similarity between $L_{eq}(60)$'s and A-corrected acoustic data strengthens the validity of both measurements.

3.3.8 WILDLIFE RESPONSE. Noise was measured at three observation sites. The highest level recorded was 114.5 db on the "C" weighted scale. The remaining effort was observation of the bird's behavior before, during and after launch. Refer to Figure 3-12 for locations of the various islands and areas discussed.

Table 3-18. Foliage Deposition (mg/kg foliage)

Sampling Date	Foliage type	pH	Foliage Location	Conda ^a	Na	K	Ca	Mg	NH ₄	Cl	F	NO ₃	SO ₄	PO ₄	Al	%TSb
April 28	Myrica	4.26	Sharkey Rd.	150	137	150	125	66	0	303	8	6	14	6	0.005	0.09
April 28	Myrica	4.23	Sharkey Rd.	650	-	-	-	-	-	-	-	-	-	-	0.10	0.21
April 28	Baccharis	6.53	Sharkey Rd.	3,650	-	-	-	-	-	-	-	-	-	-	0.005	-
June 5	Baccharis	6.55	Kennedy Parkway	4,450	-	-	-	-	-	-	-	-	-	-	0.015	-
June 5	Saliconia	6.10	N. of OPF Kennedy Parkway	3,100	-	-	-	-	-	-	-	-	-	-	0.005	-
April 28	Myrica	3.18	App. 60 m. N. of 39A	2,200	1,109	1,940	677	365	0	6,042	170	68	413	100	224	1.4
April 28	Myrica	2.80	App. 60 m. N. of 39A	4,500	-	-	-	-	-	-	-	-	-	-	168	3.9
April 28	Baccharis	3.37	App. 60 m. N. of 39A	8,400	-	-	-	-	-	-	-	-	-	-	428	3.3
April 28	Baccharis	3.47	App. 60 m. N. of 39A	10,400	-	-	-	-	-	-	-	-	-	-	420	5.6
April 28	Saliconia	3.39	App. 60 m. N. of 39A	10,800	-	-	-	-	-	-	-	-	-	-	499	-
April 28	Mixed	2.99	Inside 39A N. fence	9,000	-	-	-	-	-	-	-	-	-	-	617	-
a---Conductivity																
b---% Total Solids																

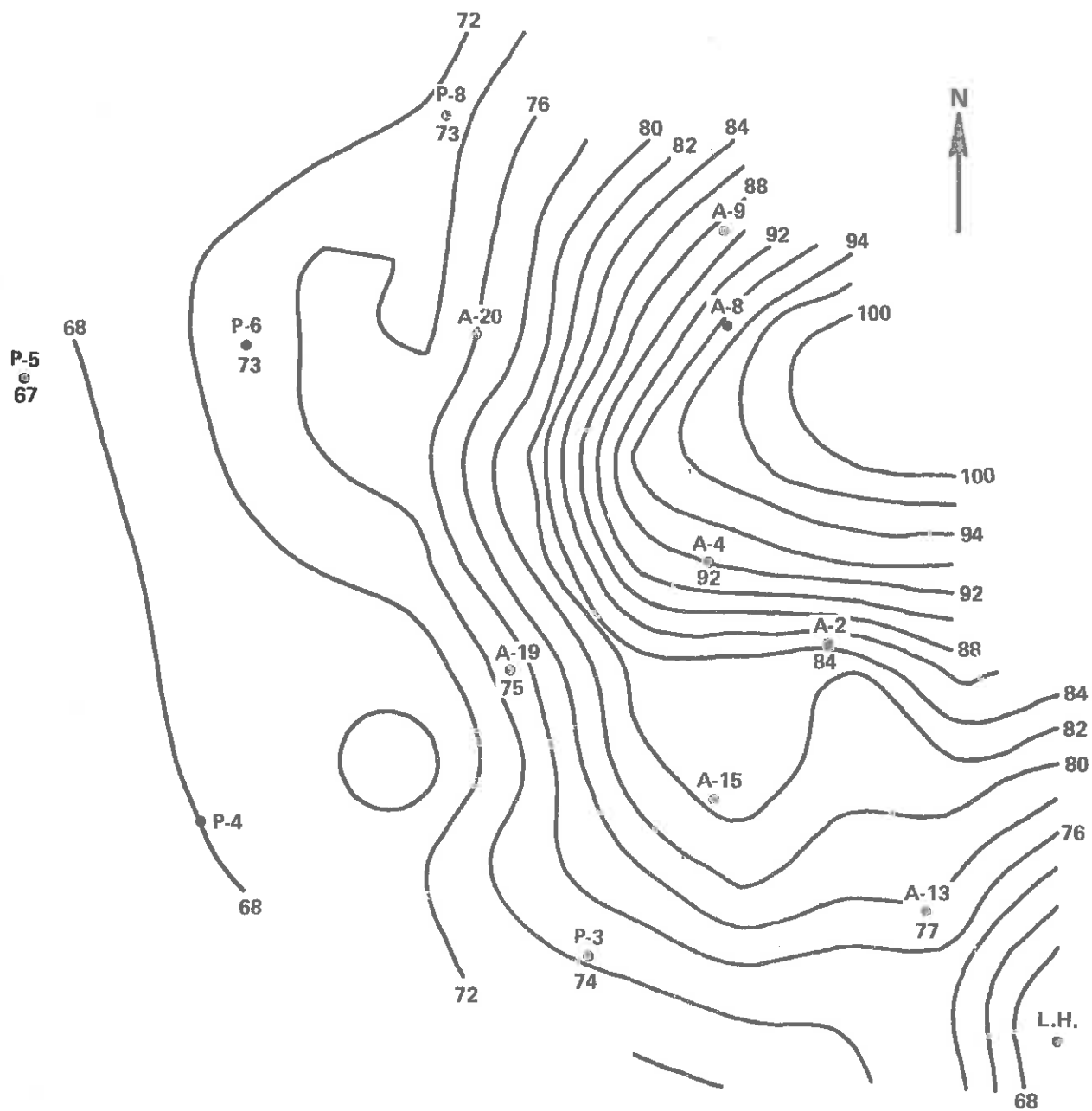


Figure 3-26. 60 Second Energy Equivalent Average Sound Level (Leq 60s)

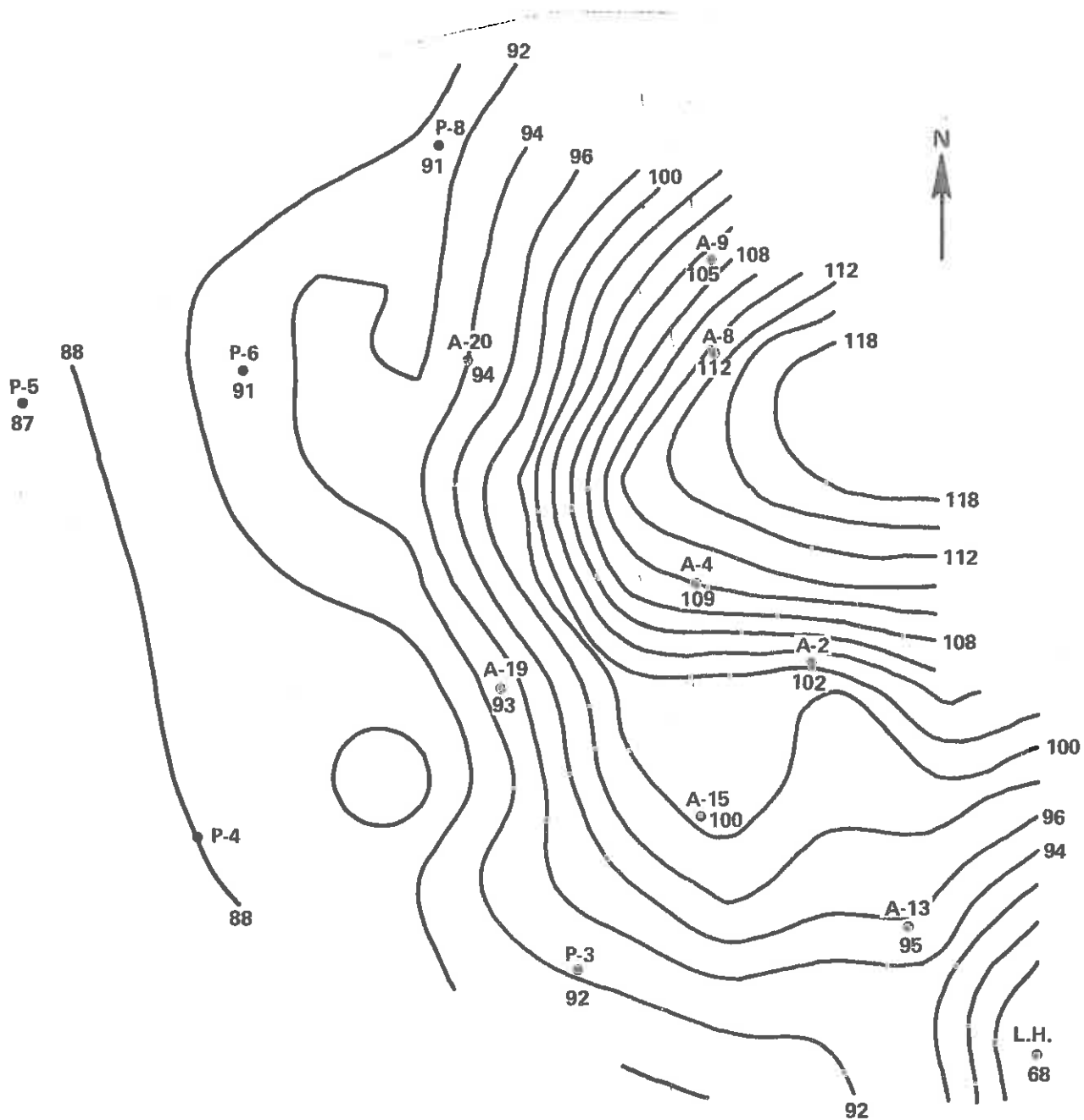


Figure 3-27. Sound Exposure Levels

Table 3-19. Comparison of Far Field and Environmental Noise Measurements (dB)

Site	Sound Exposure Level	Far Field ^a	Environmental
Eagle's nest	102	88	84
Wildlife lab	91	75	73
TICO airport	91	72	73
VAB roof	111 ^b	94	93 ^b
<p>a---Calculated A weighted values</p> <p>b---The environmental noise measurement site was located at ground level about one kilometer southeast of the VAB</p>			

3.3.8.1 Eagle's Nest. Pre-launch observations were part of a survey series conducted at 2-week intervals from November 1980 through April 1981. One young had been raised and had been observed flying in the nest's vicinity. The fledgling was still spending time in the nest and both adults were still present.

Observations were conducted approximately 45 minutes prior to launch (0615 hours). One adult bird and the fledgling were perched in a snag (frequently used by them) located just south of the nest tree. Both birds remained perched at liftoff. As the sound reached its peak (114.5 dB C) the fledgling flew off the snag and headed south southwest; the adult followed almost immediately. They flew in the same direction and out of eyesight. After the launch, the adult and the fledgling were observed perched together in a pine approximately 400 meters south of the snag. The second adult had left the area between 0600 and 0615 hours flying in northwest direction.

3.3.8.2 Moore Creek Wading Bird Colony. A pre-launch survey of all islands plus an area of the dike was conducted on 8 April 1981, between 0930 and 1130 hours. No evidence of wading bird nesting was observed on the northernmost island. Double-crested cormorants and anhingas were seen loafing, and a barn owl nest occupied by five or six young was observed.

No evidence of nesting was noted at the wood stork colony. However, one stork was observed flying low over the island. Several great egrets were seen on the southern end of the island but probably were not nesting.

Estimates of the number of nesting pairs on island 03 were as follows:

- a. Double-crested cormorant - 130
- b. Great blue heron - 15 to 20
- c. Egret - 20
- d. Anhinga - 20

Cormorants observed on island 03 were incubating and brooding nest-bound young. Approximately 10 snowy egrets and 20 Louisiana herons were seen on the south end of the island.

Observation of island 04 revealed about 85 active double-crested cormorant nests and about 100 of the adult birds. Some nests contained small young but many adults were incubating eggs. About two or three pairs of nesting anhingas were seen. Also about three great blue herons were observed at their nests.

The area east of Moore Creek dike contained over 100 snowy egrets. Approximately 50 Louisiana herons and numerous anhingas were observed nesting or in stages of colony formation.

Most birds took flight when the sound of the launch reached them, however, some cormorants remained on their nests. The birds calmed and settled in one to two minutes after the peak noise level (103 dB C) subsided.

3.3.8.3 Bird Island, Mosquito Lagoon. Pre-launch surveys were conducted on 9 April 1981, between 0930 and 1000 hours, and on 10 April 1981, between 0615 and 0630 hours. Weather conditions were excellent both days and the number of each species present was virtually the same. Observations were made from a position 50 meters south southwest of the island and only those birds visible from the location were counted.

The species and numbers observed were:

- a. White pelican - 6
- b. Brown pelican - 140
- c. Double-crested cormorant - 25
- d. Great blue heron - 36
- e. Great egret - 7
- f. Laughing gull - 12
- g. Ring-billed gull - 10

Brown pelicans were in a nesting posture but no chicks were visible.

The number of birds observed during the launch essentially was identical to the number seen during the pre-launch survey. Sound from the launch reached the island in 1 minute 12 seconds and peaked at 105 dB C.

3.3.8.4 Picnic Island Wading Bird Rookery. A pre-launch survey was conducted on 8 April 1981, between 1430 and 1530 hours. A canoe was launched inside the dike at the island's southeast corner. The rookery was active and many nests were visible in the area. The number of adult birds present were estimated as follows:

- a. Snowy egret - 250 to 300
- b. Louisiana heron - 100
- c. Anhinga - 75
- d. Little blue heron - 25 to 50
- e. Great blue heron - 5
- f. Black crowned night heron - 5

Most of the colony appeared to be near completion of their nest building.

A post-launch survey was conducted on 12 April 1981, between 1030 and 1130 hours. Colony activity appeared to be unchanged from that observed during the pre-launch survey. Some low nests contained eggs and estimates of the number of adults were the same as during pre-launch.

3.3.8.5 Launch Complex Colony in Gator Hole. A pre-launch survey was conducted on 7 April 1981, at 0930 hours. Approximately 100 double-crested cormorants were observed on or around the colony island. An estimated 75 to 100 active nests were also noted. Three to five great egrets were seen at nests in addition to several other egrets observed in the vicinity. About five active great blue heron nests were noted.

Qualified personnel were unable to obtain clearance to visit the colony on 12 April 1981. Consequently, a post-launch survey was made on 13 April 1981, at 0930 hours. The following species and numbers were observed:

- a. Double-crested cormorant - 100
- b. Great egret (young adults) - 20
- c. Great blue heron - 6
- d. Snowy egret - 3 to 5
- e. White ibis loafing - 4
- f. Cattle egret - 1
- g. Anginga - 2

3.3.9 BENTHIC COMMUNITIES.

Preliminary results of the KSC examination were presented as relative dominance for each species. A summary of those results is shown in Table 3-20. Site locations are as shown in Figure 3-9. One coelenterate and mollusc were identified, thus only the Highest Relative Dominance (HRD) is shown in Table 3-20 for those two species. Several annelids and arthropods were identified but only the HRD for each group

Table 3-20. Benthic Invertebrate Dominance Trends

Date	Coelenterates	Molluscs	Annelids		Arthropods		
	HRD	HRD	No. of Species	HRD	No. of Species	HRD	ΣRD
Dec. 79	0	48	0	-	3	36	84
Mar. 80	0	72	0	-	4	20	92
Jul. 80	0	73	0	-	3	13	86
Oct. 80	0	82	0	-	2	12	94
Dec. 80	0	54	0	-	4	37	91
Apr. 81	0	54	0	-	4	20	74
Apr. 81	0	46	0	-	5	23	69
Jun. 81	0	56	0	-	4	21	77
Dec. 79	0	<10	2	10	4	57	72
Mar. 80	0	0	2	10	2	79	89
Jul. 80	0	68	0	-	2	26	94
Sept. 80	0	19	1	10	2	38	67
Dec. 80	0	<10	2	12	2	67	84
Apr. 81	0	0	1	<10	3	83	88
Apr. 81	0	<10	1	<10	4	78	88
Jun. 81	0	19	1	<10	4	52	76
Mar. 80	0	57	1	<10	5	18	80
Jul. 80	0	93	0	-	1	<10	98
Sept. 80	<10	66	0	-	1	26	97
Dec. 80	<10	<10	2	<10	3	76	91
Apr. 81	0	12	0	-	3	49	61
Apr. 81	0	18	0	-	3	46	64

HRD -- Highest relative Dominance.

ΣRD -- Sum of listed relative dominance values for each sample date.

<10 -- Assumed to be 5 for ERD calculations.

is presented. Even so, approximately 61 to 97 percent of those organisms identified at KSC are accounted for. Those species not accounted for in Table 3-20 are represented by relative dominance values of about 10 or less.

The value, <10, listed in Table 3-20 was treated as 5 for computation of RD.

3.3.10 DATA SUMMARY.

A data summary including noise and wildlife observations is presented in Table 3-21. The shuttle exhaust clouds traveled west and north from LC-39A. Therefore only data from those sample sites north of Banana Creek and the crawlerway are tabulated. The location of those sites which appear to have sustained some cloud effect or suspected effect are shown in Figure 3-28.

3.4 DISCUSSION

3.4.1 SCOPE. The environmental effects monitoring effort undertaken for the launch of STS-1 included characterizing the ground level concentrations and doses of Al_2O_3 , and other particulates, HCl, O_3 , SO_2 , NO_x , acid fallout, and noise. The effort primarily was planned to determine the effect of exhaust effluent species on vegetation. The mobility of most animals resulted in limited faunal studies.

3.4.2 INSTRUMENT CONTROL. Instrument siting generally was adequate for STS-1. The RC system used for the FRF and STS-1 launch was not as reliable as it should have been. That unreliability was due to utilization of two pager frequencies; two different pagers, each of which signaled with a different tone; and a desire to make all pump activation circuits respond to both tones. The sample network deployed could not tolerate much less than 100 percent RC reliability due to site separation distances. However, if the density of sites were increased, some small (perhaps 10 percent) loss of control might be acceptable.

Table 3-21. Data Summary

Filter	Wt. (10 ⁻³ g/min)	Cl by NAA (µg/m ³)	Cl by PIXE (µg/m ³)	Al by NAA (µg/m ³)	Al by PIXE (µg/m ³)	Notable Deposition	Conductivity	Deposition Cl (mg/m ² /hr)	Deposition Al (mg/m ² /hr)	Bucket Rinse Water pH	pH Paper Reaction	Dosimeter	Valve ppm-sec	Indicator Plant % Leaf Damage	Model Prediction HCl (ppm)	Model Prediction Al ₂ O ₃ (mg/m ³)	Surface Soil Cl (mg/kg)	Surface Soil Al (mg/kg)	Core Soil Cl (mg/kg)	Core Soil Al (mg/kg)	Location
L12	0.0274	23.6	18.5	363.0	230.3	Yes	53.8	2.4	0.09	5.3	Yes	1700	65-99	NA	NA	NA	NS	NS	NS	NS	North Side Pad
L11	0.002	1.7	3.9	-	34.7	Yes	40.5	1.4	0.01	6.1	Yes	B	1-5	NA	NA	NA	1455.0	0.20	500.0	0.20	North Side Pad
L14	NR	ND	ND	ND	ND	Yes	83.0	3.8	0.32	5.4	Yes	16	1-40	NA	NA	NA	NS	NS	NS	NS	South West Side Pad
L13	NR	ND	ND	ND	ND	No	13.7	NA	NA	6.8	Yes	B	0	NA	NA	NA	NS	NS	NS	NS	West Side Pad
L15	NA	NA	NA	NA	NA	No	33.5	0.3	<0.01	7.9	No	B	0	NA	NA	NA	NS	NS	NS	NS	South Side Pad
L10	0.001	13.4	0.5	0.1	-	No	15.0	0.4	<0.01	6.4	No	B	0	NA	NA	NA	NS	NS	NS	NS	East Side Pad
L9	0.001	-	1.6	0.5	37.4	No	16.0	NA	NA	6.3	No	B	0	NA	NA	NA	NS	NS	NS	NS	South East Side Pad
L8	0.043	NA	NA	NA	NA	No	25.7	NA	NA	6.8	No	B	0	NA	NA	NA	NS	NS	NS	NS	South Side Pad
L8A	NA	NA	NA	NA	NA	No	NA	NA	NA	NA	Yes	B	1	<0.27	<11.99	<11.99	NS	NS	NS	NS	Entrance to LC-39B 2.3 km NW of LC-39A
L5	0.002	-	-	-	-	No	23.3	NA	NA	7.3	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	Crawlerway 1.8 km NW of LC-39A
L6E	NA	NA	NA	NA	NA	Yes	20.0	0.3	<0.01	5.4	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	Pans A 0.7 km W of LC-39A
L6	NA	NA	NA	NA	NA	No	10.0	NA	NA	6.4	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	Crawlerway 1.7 km WSW of LC-39A
L7	0.003	-	1.2	-	15.8	No	25.5	NA	NA	6.8	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	Crawlerway 1.7 km SW of LC-39A
L1	NA	NA	NA	NA	NA	No	NA	NA	NA	NA	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	Beach Road 2.1 km SE of LC-39A
L2	0.005	-	0.2	0.6	-	No	NA	NA	NA	NA	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	Beach Road 0.8 km E of LC-39A
L3	0.002	18.3	-	0.3	20.2	No	42.0	NA	NA	6.7	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	Beach Road 0.8 km N of Pad
L4	NR	ND	ND	ND	ND	No	46.8	1.4	<0.01	6.7	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	Beach Road 2.1 km NW of Pad
A10	NA	NA	NA	NA	NA	No	7.5	NA	NA	6.0	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	S End of SLF 7.9 km WSW of LC-39A
A8	NA	NA	NA	NA	NA	Yes	38.5	3.7	0.26	4.7	Yes	B	5-10	1.3	83.9	3060	0.15	685.0	5.0	5.0	Titusville Beach Rd 5.0 km NW of LC-39A
A9	NA	NA	NA	NA	NA	Yes	25.5	1.9	0.01	5.3	Yes	32	0	<0.27	12.0	2425	0.10	930	0.7	0.7	Playalinda Bch USC 9 7.1 km NW of LC-39A
A3	NA	NA	NA	NA	NA	No	8.3	NA	NA	6.2	No	16	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	N of VAB 5.5 km NW of LC-39A
A7	0.001	NA	NA	NA	NA	No	8.2	0.3	<0.01	5.7	No	R	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	NNW of VAB 6.1 km NW of LC-39A
A4	<0.001	NA	NA	NA	NA	No	6.8	NA	NA	5.6	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	South of VAB 5.5 km SW of LC-39A
A20	0.001	2.0	1.8	0.02	5.7	No	4.8	0.1	<0.01	6.2	No	B	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	N End of SLF 11.2 km NW of LC-39A
A21	NA	NA	NA	NA	NA	No	NA	NA	NA	NA	No	12	0	<0.27	<11.99	<11.99	NS	NS	NS	NS	SR 3 N of Wilson 11.0 km NW of LC-39A
PR	0.001	NA	NA	NA	NA	No	8.3	0.3	<0.01	6.2	No	B	0	0.8	12.0	NS	NS	NS	NS	NS	Wildlife Lab 15.1 km NW of LC-39A

B Baseline

ND No Determination
NS No SampleNR Not Run
NA No Analysis

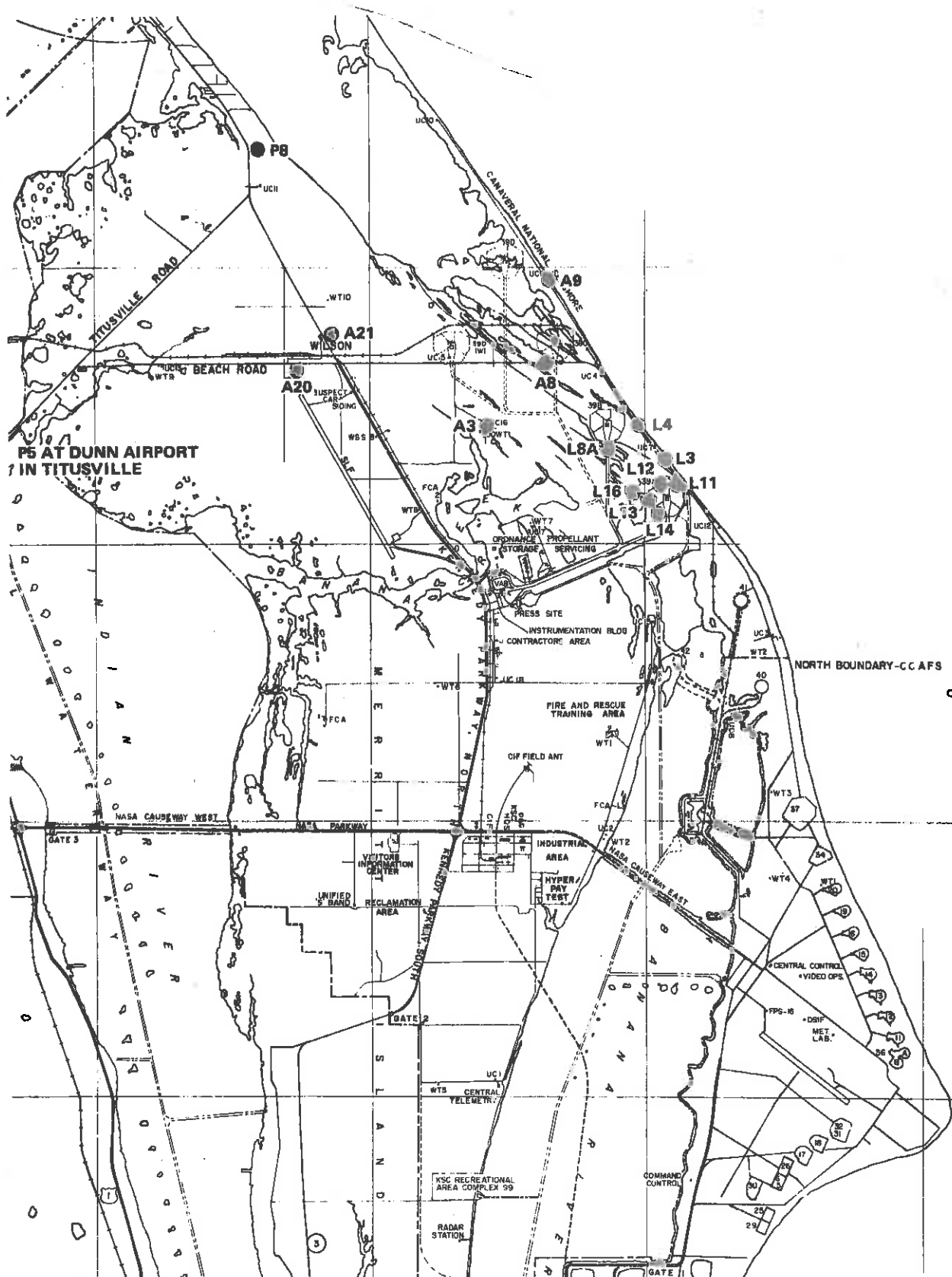


Figure 3-28. Cloud Affected Sample Sites

3.4.3 ACOUSTICS. Liftoff noise was the first environmental affector produced by the STS launch. Various federal agencies have defined certain noise standards which, if strictly adhered to, would prevent most people from experiencing damaging noise. Such standards have been established by the U.S. EPA, HUD and OSHA.

The U.S. EPA has established sound levels to protect against outdoor activity interference and to protect against hearing loss. The levels at fourteen STS Environmental Monitoring sites exceeded that level required to protect against outdoor activity interference. However, the level to protect against hearing loss was not exceeded.

Cumulative Leq's (A weighted) were obtained at 14 STS environmental monitoring sites for four to eight hour periods. The noise levels at all sites were less than the 90db(A) permissible for eight hours of occupational exposure.

Site A4 was 4.8 kilometers from LC-39A. A peak sound level of 111 db(A) was recorded at that site. If the regression curve ⁽⁴⁾ in Figure 3-29 were extrapolated to LC-39A, a peak sound level of about 124db(A) would be predicted at the pad. The closest human approach to LC-39A during a launch is about 3.2 kilometers. The peak sound level extrapolation at that distance would be about 117db(A). Personnel at sites closer than or equal to three kilometers from LC-39A should be provided hearing protection.

Octave band analyses were used to determine sound frequency distributions. Such analyses revealed peak centers of 16 to 32 Hertz depending on the transducer location. A comparison of corrected A-weighted values from the frequency analyses and environmental data showed good agreement at three sites occupied by both types of instruments.

Wildlife's reaction to the launch of the STS-1 was noted through observations of several wading bird colonies. The animals were not seriously affected by launch operations. A transient disturbance was noted at

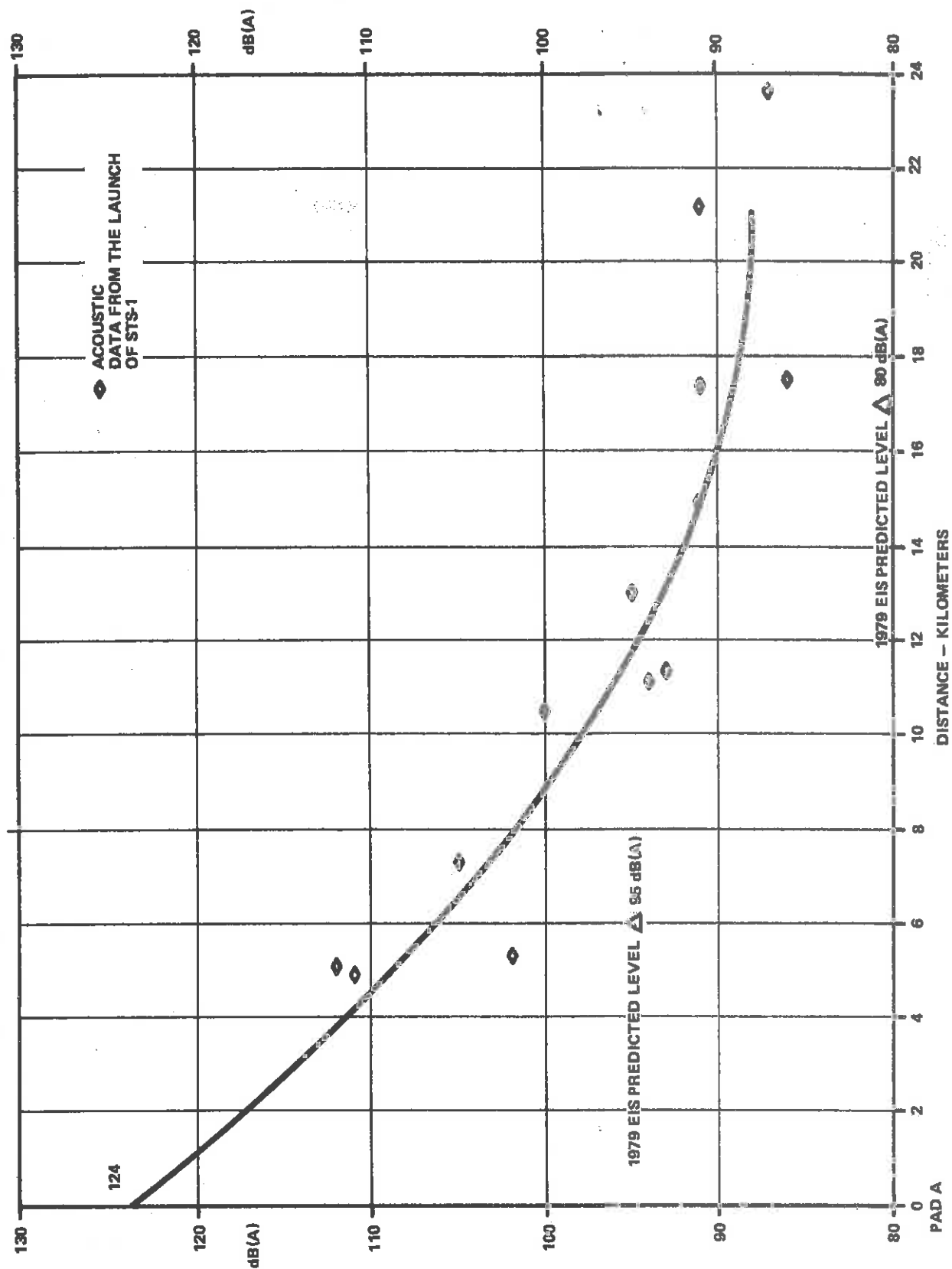


Figure 3-29. Parabolic Regression Curve

liftoff but in all cases the birds quieted quickly and settled back into their undisturbed routine.

3.4.4 LAUNCH CLOUDS. Liftoff was accompanied by two very large clouds consisting primarily of steam which resulted from vaporization of the cooling and sound suppression water. The north cloud contained most of the exhausted Al_2O_3 and HCl and issued from the flame trench at a high horizontal speed. However, the cloud from the south trench was deflected up and thus lost its momentum rather quickly. That rapid loss of momentum resulted in fallout very close to the pad and in the vicinity of Site L14. Photographs from UCS6 indicated the presence of some type of fallout south of the pad but within or close to the perimeter fence and Sites L14 and L16E.

The LC-39A structures were heavily coated with a layer of particulate material. That material appeared to have been suspended in a liquid medium and had collected in quantity about the base of upright members and on the underside of tubular members. Personnel exposed to exhaust residue on the pad experienced respiratory distress, apparently from inhaling dried particles. Particulates detected on pH paper and the LC-39A service structures were examined via SEM. The material consisted of what appeared to be Al_2O_3 spherules from submicrometer to 10 to 20 micrometers in diameter.

In most cases, that fallout detected by pH paper was quite acid as was evidenced by the reaction of metal and plant surfaces impacted by the material. However, areas were observed in which no corrosive reaction was noted.

The form HCl acquired when injected into the cooling and sound suppression water is uncertain. In any case, a cloud containing gaseous HCl was produced and impacted at least two sites about the pad. The cloud at Site L14 southwest of the pad contained no particulates large enough to be noticeable on the pH paper even though that paper was uniformly discolored. Thus, site L14 must have been affected primarily by the acid

Aluminum was present in some of the deposition buckets in its chloride and oxide forms. Relatively high levels of aluminum or chloride were found in deposition buckets at Sites L4, L11, L12, L14, L16E, A8 and A9. Site L4 was on the beach road and the high chloride concentration in the absence of aluminum at that site indicates that deposition probably was from the ocean. Site L16E was about 0.5 kilometer west of LC-39A between PAMS A and the pad perimeter fence. The deposition bucket at PAMS A and the one west of PAMS A received no noticeable fallout. Those buckets with noticeable deposition demonstrated chloride in excess of that which could be accounted for by the marine environment. Such excess chloride indicates the presence of HCl or $AlCl_3$. It is possible that some Al_2O_3 particles might serve as nuclei for HCl droplets, or that the particle agglomerates might form effective traps for free moisture. The formation of aluminum chlorides is also a possible source of deposited chlorides and aluminum.

3.4.8 SOIL. Surface soil samples from two area sites and inside LC-39A showed an excess of chloride. That excess was also seen in core samples from those sites. Increased excesses following STS launches would suggest a buildup of HCl or $AlCl_3$. The chloride-to-sodium ratio of soils from three sites north of the LC-39A area was near that of sea water. Those sites were within about 300 meters of the beach. It is not clear if chloride deposition from the ground cloud impacted the three northern sites. However, if such impaction occurred, the deposition quantities were low and may have been masked by background chloride levels. Sites farther inland were sampled in late 1980 and were found to have a chloride-to-sodium ratio lower than sea water⁽²⁾.

3.4.9 FILTERS. Background atmospheric particulate data were obtained during the morning of 9 April. Later, nuclepore filters were deployed for several hours before and during the launch period. The overall particulate burden was nearly identical for two periods. Aluminum and chloride content of filter entrained particulates was assessed by NAA and PIXE techniques. At least partial agreement between the two techniques was achieved at three sites. The filter at Site L12 contained about an

order of magnitude more aluminum than chlorine. The filters at Sites L11 and A20 contained about an order of magnitude less chlorine than the filter at L12.

The high aluminum value at L12 (approximately $296 \mu\text{g}/\text{m}^3$) was a result of the SRB exhaust products. The relatively lower chlorine values probably resulted from gaseous chlorine or HCl, neither of which would be retained appreciably by a nuclepore filter. Chlorine values were low and in approximate agreement at Sites L11 and A20. However, little or no aluminum was detected. The chlorine values alone obtained at Sites L11 and A20 do not permit a reasonable assessment of what, if anything, impacted those sites.

3.4.10 STREAKERS AND IMPACTORS. Streaker filters and cascade impactors deployed about the pad appear to have functioned properly but did not collect the material for which they had been designed. The impactors appeared to have sampled a very moist atmosphere or even liquid water and the streakers showed no evidence of having collected large particulate material. The absence of cubic crystals on the cascade impactor slide indicates the source of fluid sampled by those devices was not the ocean. Such crystals are characteristic of NaCl and are not a component of the cooling and noise suppression water. Some concern was expressed as to the possible expulsion of asbestos from the SRB's. The absence of particles with a large aspect ratio indicates a probability of no asbestos in the exhaust effluent. A few marine shells were observed on the impactor slides. Such shell fragments are common in the sand and probably were disturbed by the turbulence of the launch event and drawn into the impactors.

Location of an impactor at L12 was inappropriate due to the presence of moisture from the cooling and sound suppression system. Also, the impactor at L8 apparently was inundated by moisture from the main engines and the deluge water. Streaker filters were at both locations and suffered the same fate. If particulates from the SRB's are to be studied, the

sample devices must be placed well out of the deluge area. Perhaps the most appropriate location for such devices would be above the deluge water on the fixed service structure. Alternate locations might be on small platforms in the initial cloud impact area just north of LC-39A. Whether the impactors or streakers would function properly in light of the observed aggregate fallout particles is unknown. Even if such particles were sampled, their large aggregate size would place them on an upper stage of the impactor which would not reflect the true size distribution of the SRB particulates. However, if a particular period of time or set of cloud conditions is necessary for the formation of such aggregates then samplers placed high on the service structures might be able to collect the dry particulates before they form aggregates.

3.4.11 SURFACE WATERS. The decrease in turbidity observed in the holding ponds was directly due to settling of solids entrapped from the launch. However, outlying sites were not thought to receive sufficient solids to cause the turbidity decrease observed to occur there.

The pH increase in the holding ponds was expected. Conversely, no change in the pH of surface waters was expected due to the buffering capacity of those waters. Post launch increases in the ammonia, boron, and lead content of surface waters is not understood but it is doubtful that such increases were a result of the STS-1 launch. Most changes occurring in the holding ponds were seen as decreases in the post launch concentration of a few elements. The most significant post launch change to occur in the surface waters of the area was an increase in the lead content. The source of the element was unknown.

Water contained in the holding ponds is now used to water the grass inside LC-39A. However, consideration must be given to disposal of impounded water during periods of frequent launches. Consequently, a study should be initiated to determine the feasibility of releasing such water directly into the lagoons north of LC-39A.

3.4.12 VEGETATION. The cloud moved quickly through the fence and into the area north of LC-39A. Large quantities of particulates mixed with water from the cooling and noise suppression system were contained within that cloud. A thin, mud-like mixture was produced which adhered to structures and plants upon contact. Thus, the potential exposure time to an acid environment could have been quite long. A series of experiments conducted at NCSU showed a gaseous exposure time of 80 minutes to 20 ppm HCl caused 88 percent foliar damage to pennyworts⁽⁶⁾. Consequently, even if the in-cloud acid concentration were not as high as estimated, (28 ppm) its presence on plants for long periods of time might still have caused vegetative damage.

Vegetation behind the flame trench showed no immediately obvious reaction to the cloud. In fact, a noticeable deterioration in the vegetative vigor was not observed until 24 to 48 hours after the launch. An initial wilting was observed which gradually developed into what appeared to be grossly dehydrated vegetative structures. Dehydration would have occurred if anhydrous HCl had been present in the cloud. However, due to the use of water for cooling and sound suppression, a dry HCl gas would probably exist only a very short time if at all. Nevertheless, a relatively dry acidic gas was noted via the pH paper reactions at a few pad sites but not in the direction of the flame trench discharge. The foliage directly impacted by the exhaust cloud eventually shriveled and turned black. Such a reaction was consistent with early reports by Hasselhoff and Lindau⁽⁷⁾ in which black or brown deposits of tannin were observed to nearly fill cells of certain plants damaged by HCl fumigation.

Foliage chemistry was limited to analysis of leaf washings. Those analyses showed a chloride excess of 434 ppm and an aluminum excess of 224 ppm from damaged plants. Such analyses suggest the presence of $AlCl_3$, however, whether that material could cause foliage damage is unknown. Aluminum is not an essential plant element and naturally occurring aluminum concentrations are not toxic to vegetation.

Remote sensing via color infrared film appears to have a limited use in detecting exhaust damaged vegetation. The method was able to detect changes in reflectance in the severely damaged area just north of LC-39A, but detection of spotting was unsuccessful. Also, a complicating factor was a prolonged drought which caused physiological changes in the plants. Future remote sensing efforts must be planned to acquire imagery before the launch event and periodically after the event. In addition, capabilities of multispectral scanners should be investigated.

3.4.13 CLOUD MODEL. Personnel from Marshall Space Flight Center conducted several cloud prediction sessions with the REED computer programs. The model accurately portrayed the direction of travel for the lower cloud. However, it appeared to predict areas of greatest ground level concentrations of Al_2O_3 and HCl farther from LC-39A than occurred. An area of ground-level HCl concentration was predicted from the U.S. Government railroad (Figure 3.13) northwest for about 4.75 kilometers. The point of greatest HCl concentration was predicted to occur a little over 2 kilometers northwest of the railroad. Ground surveys of the area failed to identify any evidence of HCl. The adopted TLV for continuous human exposure to HCl is 5 ppm. The highest model predicted concentration of HCl was 2.6 ppm. Studies at NCSU have shown that 3 ppm of HCl for 80 minutes will produce only 3 to 5 percent foliar injury to radish⁽⁶⁾. Consequently, no far field plant damage or human injury would have been expected and indeed was not observed in the predicted deposition area.

The area of greatest Al_2O_3 deposition was predicted to be about 2.2 kilometers long with the point of greatest deposition centered on the U.S. Government railroad. A ground survey along the railroad failed to show deposition of Al_2O_3 . However, a survey along Titusville Beach Road was successful in detecting some plant damage from particulate fallout. Such damage was observed to occur about 1 kilometer west of the beach and consisted of discrete necrotic spots on the upper surfaces of leaves.

The incidence of spots was observed to decrease sharply north of Titusville Beach Road. The maximum spot size was about 2 millimeters in diameter and appeared to have a nucleus. That nucleus was assumed to be identical to the deposition material observed on pH paper placed about the area.

Consideration of the material responsible for field vegetation spotting offers an explanation of the discrepancy between the observed fallout pattern and the fallout pattern predicted by the MSFC model. Particulates detected on pH paper consisted of many spherules apparently "stuck" together and were contained within the coalescence. Consequently, the actual fallout particle was not always a single small spherule but a coalescence of many spherules with moisture. The result was a much greater particle weight and size than was predicted. Such an aggregate particle would have been subject to more rapid gravitational deposition than had been predicted.

3.4.14 BENTHIC COMMUNITIES. A comparison of baseline and post launch data collected in April 1981 seems to show little or no launch related effect. No statistical treatment of the data was attempted. The summer of 1981 and, to a lesser degree, the summer of 1980 were very dry. Consequently, any attempt to average data from December 1979 through 9 April 1981 incorporates that drought period and biases the result.

3.5 CONCLUSION

All summary statements can be made only for the meteorological conditions which prevailed during the launch of STS-1. More data are required to determine where those conditions fall in the range from "worst case" to "ideal".

Launch of the STS-1 produced some unexpected environmental effects. The greatest threat proved to be acid fallout from the ground cloud. Such fallout seems to be the only STS pollution element which might cause harm over a wide spread area. Damage from acid fallout could take the form of metal corrosion, paint spotting, or even chemical burns to humans and

animals. Acid particulate fallout is expected to occur on subsequent launches. That occurrence during the STS-1 launch caused no serious problems. Even fewer problems would have resulted if the cloud had drifted seaward. Kennedy Space Center were fortunate that the exhaust cloud did not drift in a compass direction of about 290° to 160°. A large number of spectators were present in that defined area and the impact of acid fallout on the area must be seriously considered. It is doubtful that the frequency of far field acid fallout will be high enough in any one area to cause a cumulative vegetation effect. Obviously, instrumentation and structures repeatedly exposed even at widely separated times ultimately will show some corrosion effect but that effect may lie within the projected usable life of the instrument or structure.

Little human danger from ground level HCl clouds is perceived even though vegetation in line with the north flame trench was seriously damaged. However, human occupation of that area during a launch is forbidden. On the other hand, the mixture of Al_2O_3 particulates, moisture, and HCl remaining on the pad structures is a hazard to human health and must be dealt with.

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