Florida Power
CORPORATION

April 25, 1994

Mr. Hamilton S. Oven, Jr.
Department of Environmental Protection
Douglas Building, Room 953AA
3900 Commonwealth Blvd., MS 48
Tallahassee, FL 32399-3000

Dear Mr. Oven:

Re: Salt Drift Study at Crystal River

Enclosed is the Annual Report of the Crystal River Salt Drift Study 1992-1993 study year, the 12th year of the study. As noted in the conclusions, the vegetation generally continued to be in good condition.

We did observe pronounced salt damage from the March 1993 "Storm of the Century" that deposited 4 to 27 times the amount of salt that had been deposited during the average February-March sampling period. All of the affected vegetation recovered within a few months. If the vegetation can recover from these severe impacts, it is reasonable to conclude that vegetation could also recover from any impacts from a lesser amount of salt that originates from the cooling towers.

Also during this study year, we had the first opportunity to monitor salt deposition originating from the new mechanical draft towers that began operation in June 1993. However, the samples that were collected during the final three months of the study year did not show any elevated levels of salt deposition. Indeed, in many months there was no significant difference between the salt deposition at the on-site stations and the control/off-site stations. Furthermore, most of the difference that was noted could be attributed to deposition at the SW Open Hammock station, which was the closest station to the salt marsh where higher background deposition levels could be expected.

The large areas of stressed vegetation along the coast that were reported in past years were still present and appeared to be growing in size. The affected vegetation does not show symptoms of salt drift damage; and a large-scale cause, such as sea level rise, is suspected. Within the areas with a large number of stressed and dying trees, it is impossible to observe minor salt effects.

ENVIRONMENTAL SERVICES DEPARTMENT
H2G · 3201 Thirty-fourth Street South · P.O. Box 14042 · St. Petersburg, Florida 33733 · (813) 866-5151
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Florida Power believes that the lack of sustained damage to the vegetation during the 12 years of the study, the quick recovery of the vegetation following the acute damage caused by the large amount of salt deposited during the March 1993 storm, the lack of measurable salt deposition from the new mechanical draft cooling towers, and the continued confounding of the study by the large and growing area of vegetation that is being impacted by causes unrelated to the cooling towers are adequate reasons to end the study. Accordingly, as provided by Specific Condition 5.c. of the revised PSD permit for Crystal River Units 4 and 5 (Permit number PSD-FL-007) issued November 30, 1988, Florida Power has requested comments from the Hollins Corporation through Ms. Marilyn Polson, Esq. regarding termination of the salt deposition study in August 1994, the end of this study year, unless the analysis of the data from this year unexpectedly indicates that impacts are occurring.

Pending comments from the Hollins Corporation, FPC will formally request termination of the study. If you have any questions, please contact me at (813) 866-4387.

Sincerely,

W. Jeffrey Pardue, C.E.P., Manager
Environmental Programs

DKV
Enclosures

DKV\Oven.421

bcc: Debbie Segal - w/o enc
Jay Eingold - w/o enc.
Mike Kennedy - w enc.
Bill Grey - w enc.

File: GSCRNC.19.1.1

Department of Environmental Protection

Lawton Chiles
Governor

Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Virginia B. Wetherell
Secretary

March 20, 1996

MAR 25 1996
Department

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

Mr. W. Jeffrey Pardue, Director
Environmental Services Department H2G
Florida Power Corporation
Post Office Box 14042
St. Petersburg, Florida 33733

Re: Crystal River Salt Drift Study
PA 77-09, PSD-FL-007

Dear Mr. Pardue:

The Department has reviewed the recent status reports and your requests to discontinue the salt drift impact study in the vicinity of the Florida Power Corporation (FPC) Crystal River Power Plant. Based on the information provided to the Department and the site visit conducted by department personnel on January 23, the Department has concluded that damage to nearby vegetation has occurred primarily due to natural phenomena rather than by salt drift from the plant.

The Department considers Specific Condition 5 (Ambient Monitoring) of the PSD permit modification dated November 30, 1988 to have been fulfilled. In accordance with Specific Condition 5.c., the Department approves the elimination of the monitoring program contingent on no objections in the next thirty days from EPA. Please note that the plant is still required to monitor particulate matter from the cooling towers.

We have supplied EPA with a copy of all the correspondence related to this intended action. Please note that the authority to eliminate the program applies only to the PSD permit and not to the Site Certification. The parties to the original certification were advised directly and through the notice published in the Florida Administrative Weekly of FPC's request.

If you have any questions regarding this matter, please call Mr. Cleve Holladay at (904)488-1344 or Trudie Bell at (904)921-9886.

Sincerely,

Howard L. Rhodes

Howard L. Rhodes, Director
Division of Air Resources
Management

HLR/aal/l

cc: Winston Smith, EPA
John Bunyak, NPS
Hamilton Oven, DEP
Trudie Bell, DEP
Bill Thomas, SWD

CRYSTAL RIVER
SALT DRIFT STUDY
1992-1993 ANNUAL REPORT

Prepared For:

Florida Power Corporation
3201 34th Street South
St. Petersburg, Florida 33711

Prepared By:

KBN Engineering and Applied Sciences, Inc.
1034 NW 57th Street
Gainesville, Florida 32605

March 1994
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1.0 INTRODUCTION AND BACKGROUND

Florida Power Corporation (FPC), St. Petersburg, Florida, owns and operates an electrical power generating station located in Citrus County, Florida, near the city of Crystal River. This facility, called the Crystal River plant, consists of four coal-fired units (Units 1, 2, 4, and 5) and one nuclear unit (Unit 3). The net summer generating capabilities of these units are: Unit 1--372 megawatts (MW); Unit 2--468 MW; Unit 3--821 MW; and Units 4 and 5--695 MW. Units 4 and 5 began commercial operation in October 1982 and 1984, respectively. In order to meet regulatory standards regarding thermal discharge to the Gulf of Mexico, these units were constructed with hyperbolic natural draft cooling towers for condenser cooling. Make-up for these cooling towers is primarily the discharge from the once-through cooling water from Units 1, 2, and 3. During this study period, the new mechanical draft towers for Units 1, 2, and 3 became operational on June 16, 1993 and ran through the end of the study period (September 15, 1993). The normal operation period for these new towers will extend from May 1 through October 31 of each year.

FPC is required to perform pre-operational and post-operational monitoring of salt deposition and its effects on nearby vegetation as part of the conditions required by environmental permits [Prevention of Significant Deterioration (PSD) Permit No. PSD-FL-007, as modified, and Florida Conditions of Certification, Case No. PA77-09, I.B.7. Special Conditions]. The monitoring programs were required because previous studies have shown that vaporization of salt water by such towers produces a salt mist that may be deposited on surrounding vegetation, and may cause effects to vegetation (McCune et al., 1977; Mulchi et al., 1978).

Preliminary monitoring studies were initiated in 1981. At present, studies consist of a series of assessments of the condition of local plant communities and monitoring of salt deposition. Currently, 12 years of deposition and vegetation monitoring studies have been conducted. Site histories and other information concerning sites under study are presented in Table 1-1. Study sites were selected based on earlier predictions of areas of maximum salt deposition and to provide estimates of natural salt deposition from the Gulf of Mexico.

Vegetation and deposition monitoring for sodium (Na) and chloride (Cl) are performed on an annual cycle, with each study period starting in September and continuing through August of the following year. During the first year of monitoring (1982-1983), the Units 4 and 5 cooling

Table 1-1. Site Histories at Crystal River Deposition Network for Current Sites

Site Name	Distance[a] (km)	Direction[a] (°)	Start Year	Studies Ongoing
Open Test	0.24	230	1982	V
Open Control	1.4	150	1982	D,V
Pine	0.36	260	1982	V
Hardwood	0.40	240	1982	V
NE Open Test	0.5	50	1985	D,V
NW Open Test	0.42	325	1985	V
SW Open Test	0.44	210	1985	V
W Open Pine	0.49	270	1987	D,V
SW Open Hammock	0.85	230	1989	D,V
NW Open Pine	0.60	310	1989	D
Open Hardwood Control	1.90	140	1991	D,V
Coastal Control	2.75	145	1991	D,V
E Open Pine	1.86	100	1991	D,V
NE Open Pine	1.51	75	1991	D,V
N Open Pine	1.01	50	1991	D,V

Note: ° = degrees from north.
km = kilometer.
D = Deposition monitoring.
V = Vegetation monitoring.

[a] Distance and direction from midpoint of Units 4 and 5 cooling towers.

towers were under construction. Data collected during that period served as pre-operational or baseline data to which subsequent deposition levels were compared. Deposition data for that phase of the project were collected from four sites using a bulk collector design [Applied Biology, Inc. (ABI), 1984].

Since 1982, study sites have been added and discontinued as dictated by construction activities and changes in network design. Pre-operational modeling indicated that maximum salt deposition would occur in the vicinity of the Pine, Hardwood, and Open Test sites (Figure 1-1). Results of the first 3 years of deposition monitoring did not show maximum deposition in the vicinity of these three sites, so three additional sites [Southwest (SW) Open Test, Northwest (NW) Open Test, and Northeast (NE) Open Test] were added in 1985 to enlarge the area covered by the monitoring network. Subsequently, operational modeling suggested that maximum salt deposition would occur farther west, so another site [West (W) Open Pine] was added in 1987.

In May of 1989, deposition monitoring was discontinued at the Open Test, SW Open Test, and NW Open Test sites because of their proximity to a new limerock conveyor in the transmission line corridor and potential contamination from dust. However, vegetation monitoring continued at these sites. The SW Open Hammock and NW Open Pine sites were added to the network in January 1989 to replace the discontinued sites and to allow for the study of potential effects of new cooling towers proposed for construction west of the SW Open Hammock site.

During the 1991-1992 study year, five off-site stations were added to the monitoring network (Open Hardwood Control, Coastal Control, East Open Pine, Northeast Open Pine, and North Open Pine sites). This expansion allowed the study of possible effects of new mechanical draft towers for Units 1, 2 and 3 which became operational in 1992-1993, and provided information on conditions farther north and south of Units 4 and 5. As of the current study year, vegetation monitoring has been continuous since 1982 at four sites: Open Test, Open Control, Pine, and Hardwood. The deposition sites with the longest histories are Open Control, NE Open Test, and West Open Pine (Table 1-1). Only the Open Control site has a continuous record of deposition monitoring since 1982.

Results of 11 years of monitoring have been summarized in previous reports (ABI 1984, 1985, and 1986; FPC, 1986; and KBN 1986, 1987, 1988, 1989, 1990, 1991, 1992, and 1993). This

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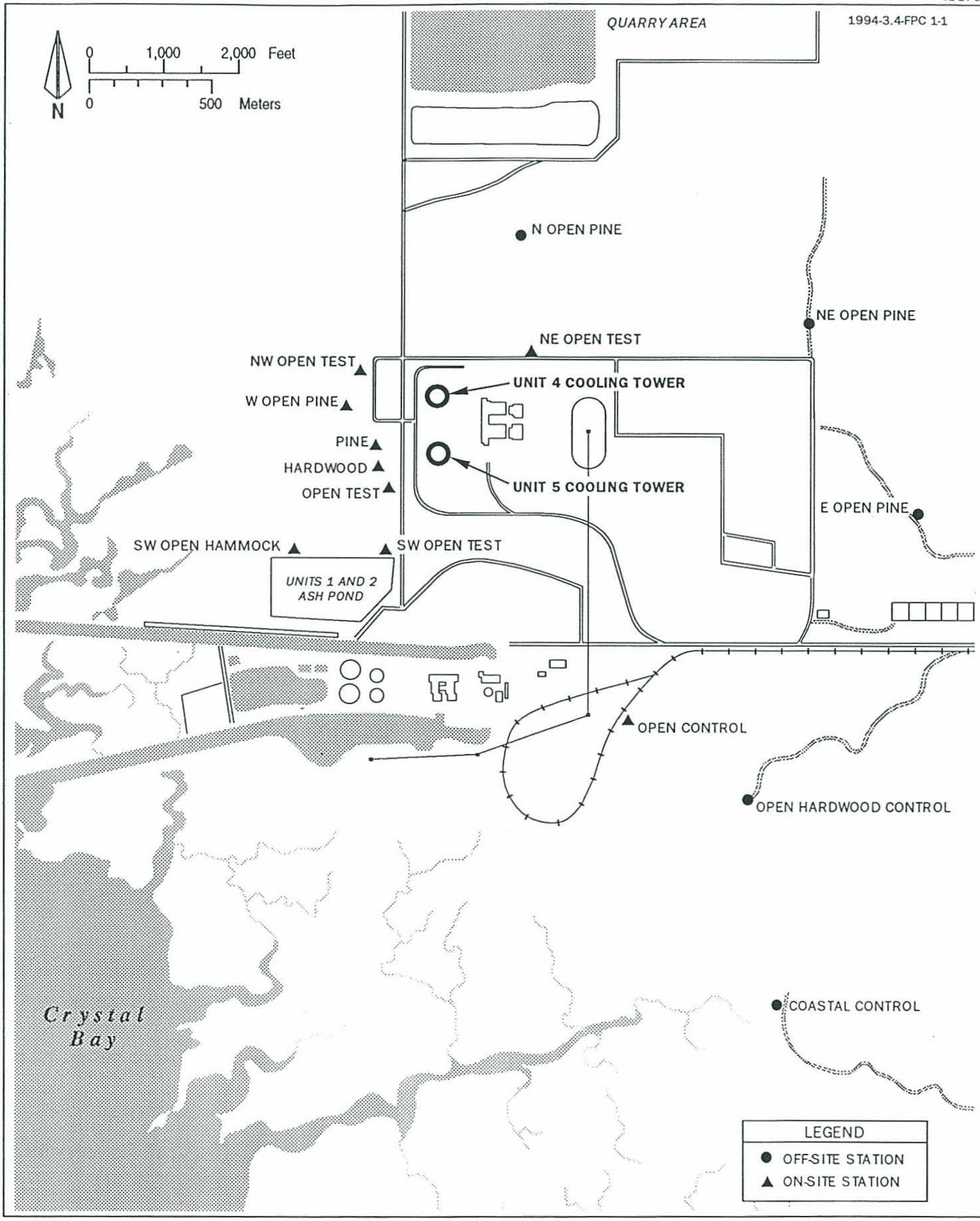

Figure 1-1 LOCATION OF VEGETATION MONITORING STATIONS

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report presents the results of monitoring programs for salt drift deposition, vegetation, and aerial photography for the sampling period September 1992 to August 1993. This period is designated as the twelfth year of monitoring and covers the eleventh year of operational data for Unit 4 and the ninth year of operational data for Unit 5.

2.0 MATERIALS AND METHODS

2.1 VEGETATION MONITORING PROGRAM

2.1.1 MONITORING LOCATIONS AND STATION CONDITION

Vegetation was examined monthly at six control/off-site stations and eight on-site stations for gross physical changes in selected individual plants of species representative of the vegetative communities at each station. To assess such changes, observations and color photographs were taken of each plant on a monthly basis. The six control/off-site stations included Open Control, Coastal Control, Open Hardwood Control, E Open Pine, NE Open Pine, and N Open Pine stations (Figure 1-1). Of these six control/off-site stations, the Open Control is actually located on-site but far enough south of the cooling towers to be considered a control site. The eight on-site stations consisted of the SW Open Hammock, SW Open Test Hardwood, Open Test, Pine, W Open Pine, NW Open Test, and NE Open Test sites (Figure 1-1).

2.1.2 MONTHLY FIELD MONITORING PROCEDURES

Selected individual plants of representative species were marked with surveyor's tape at each of the vegetation monitoring sites. These specimens occurred in the ground, shrub, or understory strata of the communities, although some canopy-level trees were included if they possessed readily observable foliage (Table 2-1). Each plant was examined monthly for evidence of changes in vegetative condition. Observations were photographically documented with 35-millimeter (mm) color slides of selected portions of each individual plant.

Plant damage was generally defined in terms of "spotting" (small brown or yellow spots), "chewing" (consumption by insects), and "splotching" (large brown, black, or yellow patches). Any indication of possible salt-induced injury such as browned curling leaves, marginal or tip necrosis, or shoot dieback was also noted.

Observations and photographs were made on the same leaves each month whenever possible. When individual leaves or plants died or were damaged by external causes, new leaves and plants were substituted. The plants substituted resembled the replaced plants as closely as possible.

Table 2-1. Vegetation Monitored During FPC Monthly Vegetation Surveys

		Site										
Common Name	Scientific Name	Open Control	Hardwood	Pine	Open Test	W Open Pine	SW Open Hammock	Coastal Control	Open Hardwood Control	N Open Pine	NE Open Pine	E Open Pine
Saw Palmetto	*Serenoa repens*	X	X	X	X	X	—	—	X	—	—	—
Slash Pine	*Pinus elliottii*	—	—	X	X	X	—	—	X	X	X	—
Saltbush	*Baccharis* sp.	—	—	—	X	—	—	—	—	X	—	—
Winged Sumac	*Rhus copallina*	—	—	X	X	X	—	—	—	—	—	—
Coontie	*Zamia integrifolia*	—	X	X	X	X	—	X	—	X	X	—
Greenbrier	*Smilax* sp.	X	X	X	X	X	X	—	—	X	X	X
American Beautyberry	*Callicarpa americana*	X	X	X	X	X	X	X	X	—	X	—
Sweetgum	*Liquidambar styraciflua*	X	X	X	X	X	—	—	X	—	—	X
Yaupon	*Ilex vomitoria*	X	X	X	X	X	X	—	—	X	X	X
Wax Myrtle	*Myrica cerifera*	X	X	X	X	X	X	—	—	—	X	X
Red Maple	*Acer rubrum*	X	—	X	X	—	—	—	—	—	—	—
Oak	*Quercus* sp.	—	—	X	X	X	—	—	—	—	—	—
Water Oak	*Quercus nigra*	—	—	X	—	—	—	—	—	—	—	—
Laurel Oak	*Quercus laurifolia*	—	X	—	—	—	X	—	—	—	—	X
Live Oak	*Quercus virginiana*	X	X	—	—	—	—	—	—	—	X	—
Sand Live Oak	*Quercus geminata*	—	—	—	—	—	—	—	—	—	—	—
Poison Ivy	*Toxicodendron radicans*	X	—	X	X	—	X	—	—	—	—	—
Sawgrass	*Cladium jamaicense*	X	X	X	—	—	—	—	—	—	—	—
Dahoon	*Ilex cassine*	—	—	—	X	X	—	—	—	X	—	—
Gallberry	*Ilex glabra*	—	X	X	—	—	—	—	—	—	—	—
Blackberry	*Rubus* sp.	—	—	X	—	—	—	—	—	—	—	—
Virginia creeper	*Parthenocissus quinquefolia*	X	—	X	X	—	—	—	—	—	—	—
Southern Magnolia	*Magnolia grandiflora*	X	X	—	—	—	—	—	—	—	—	—
Red Bay	*Persea borbonia*	X	—	—	—	—	—	—	X	—	—	—
Resurrection Fern	*Polypodium polypodioides*	X	X	—	—	—	X	—	—	—	—	—
Grape	*Vitis rotundifolia*	X	X	X	—	X	X	—	X	—	—	X
Fern	*Thelypteris* sp.	X	—	X	X	—	—	—	—	—	—	—
Royal Fern	*Osmunda regalis*	—	—	X	—	—	—	—	—	—	—	—
Red Hibiscus	*Hibiscus coccineus*	—	—	—	—	—	—	—	—	—	—	—
Southern Red Cedar	*Juniperus silicicola*	—	—	—	—	—	X	—	—	X	—	—
Cabbage Palm	*Sabal palmetto*	—	—	—	—	—	X	—	X	X	X	—

2.1.3 QUARTERLY FIELD MONITORING PROCEDURES

Quarterly vegetation monitoring consisted of general and qualitative observations on the overall condition of vegetation at each monitoring site and in the region surrounding the Crystal River power plant based on a prepared checklist. Vegetation was examined at each site for conditions that were symptomatic of salt drift effects. Vegetation at each site was examined for specific indicators of salt injury, such as tip damage, marginal damage, and interveinal damage on the leaves. Where such symptoms were noted, additional information concerning the type of damage (i.e., necrosis, chlorosis) and the patterns of damage (i.e., solid, mottled, blotchy) were also recorded. In addition, data were collected concerning identification of injury type, including such factors as whether the damage extended through or across major veins, down the petiole into the shoot, or patterns of delineation between healthy and injured tissue were present. Additional notes were made regarding species affected, affected location on each plant, whether old or new vegetation was affected, and whether other parts of the plant were affected. This information was used in a systematic diagnostic procedure to determine a probable cause of plant damage or stress and to evaluate whether salt drift was a potential cause. The general health, vigor, seasonal status, and other factors also were noted.

In addition, a total of approximately 120 individual plants were flagged for continuing monitoring. These flagged plants were evaluated on a quarterly basis for signs of injury or stress that might be symptomatic of salt drift damage. On each plant, 10 to 20 individual leaves were examined for leaf damage. The average percent surface area injured per leaf was estimated, and the percent of number of leaves affected was estimated. For each plant, other leaf characteristics (e.g., spotting, splotching, color, chlorosis, abnormal growth or shape, marginal damage, leaf curl, wilt, lesions, infections, insect damage, tip dieback, and deformities) were noted.

2.1.4 AERIAL INFRARED PHOTOGRAPHY

The third portion of the vegetation monitoring program consisted of aerial photographic documentation of overall changes in vegetation cover within a 1-mile radius of the cooling towers, conducted by Breedlove, Dennis, & Associates (BDA). Aerial photographic missions were flown in July, September, and October, 1993. BDA reviewed infrared transparencies using photo-interpretation equipment with enlargements of 6.5 to 17.5X for large scale vegetation patterns that could be attributable to salt drift effects. Results of aerial photographic monitoring were prepared by BDA (Appendix A).

2.2 SALT DEPOSITION MONITORING PROGRAM

2.2.1 MONITORING LOCATIONS

Deposition monitoring was performed from September 15, 1992, to September 16, 1993, at 10 locations (Figure 2-1). All of these locations coincide with vegetation monitoring sites except for the NW Open Pine site, which is located several hundred yards west of the vegetation monitoring site. All deposition collectors are located in open areas. Standing water was collected from small surface water bodies (pools and ditches) every other month at the Open Hardwood Control, NW Open Pine, N Open Pine, and NE Open Pine sites. These areas are subsequently referred to as ponds.

2.2.2 DEPOSITION COLLECTORS

Deposition of Na and Cl was measured using modified bulk precipitation collectors (Model 170, Anderson Samplers, Inc., Atlanta, Georgia). Each collector consisted of a 10-inch-diameter funnel elevated off the ground with a 122-centimeter (cm) stand. To eliminate bird droppings, a "bird-off" ring was installed above the funnel. Bulk (i.e., wet and dry) deposition was collected monthly in a 19-liter (L) collection bucket initially filled with 1.9 L of deionized water. In addition to preventing evaporation of the bucket contents, the added deionized water also provided mass to prevent the buckets from being blown over by wind. Two collectors are located at the Open Control and W Open Pine sites, whereas only one collector is located at all other deposition monitoring sites.

Collectors were sampled monthly by FPC personnel. Care was taken to prevent sample contamination during the collection process. Before the samples were removed from the collector, the funnels were rinsed with 100 milliliters (mL) of deionized water to flush deposited salt into the collector bucket. The collectors were visually inspected for possible sources of contamination and, if present, the contamination was recorded and the data subsequently flagged. The collector buckets were then sealed on-site and a fresh sample bucket containing 1.9 L of deionized water was attached to the collector. Samples were transported to the FPC laboratory located at the Crystal River plant for analysis.

2.2.3 CHEMICAL ANALYSES

Laboratory analyses were performed by FPC personnel. Upon receipt in the laboratory, the volume of each collector sample was determined using a graduated cylinder. Na was determined

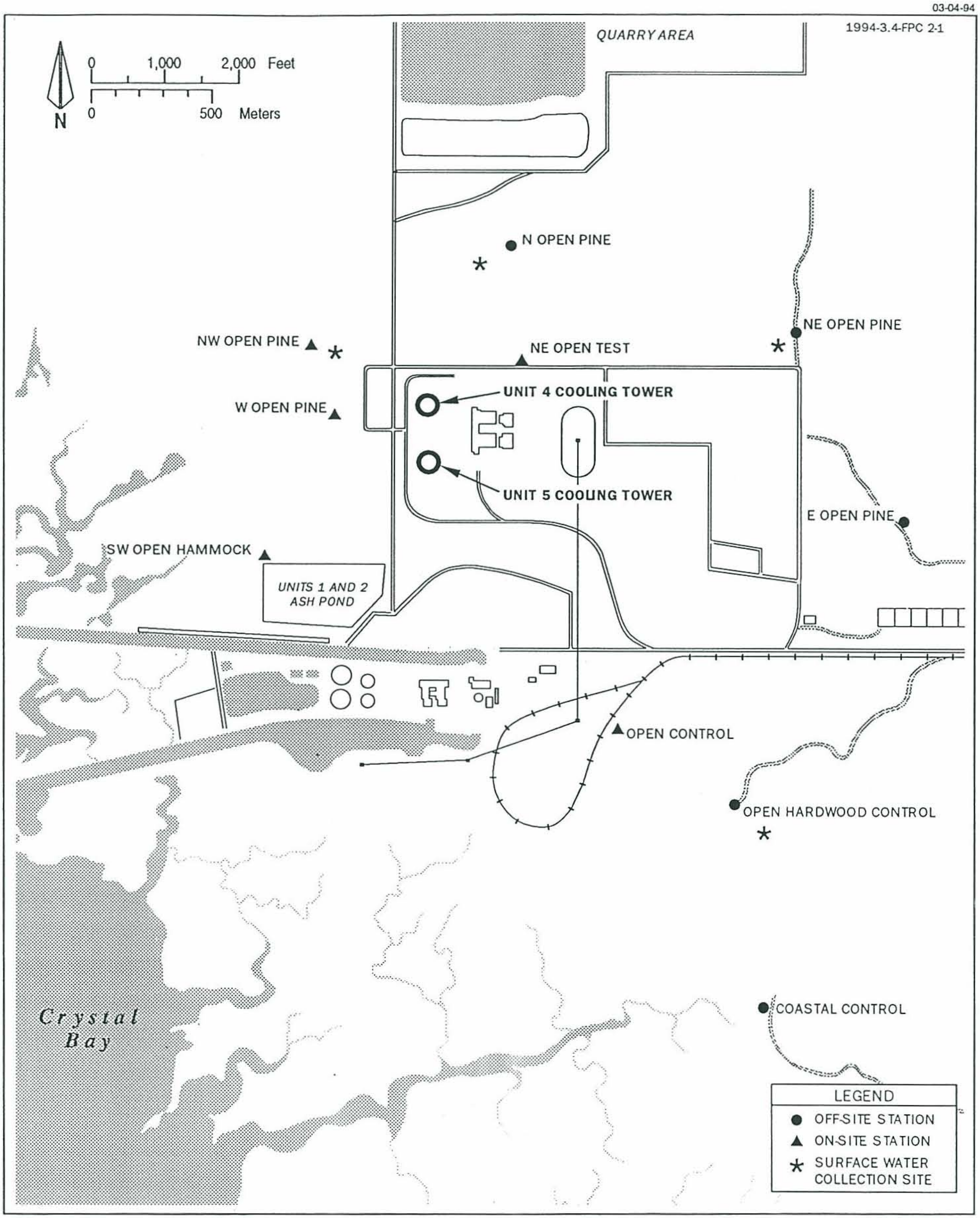

Figure 2-1 LOCATION OF DEPOSITION AND SURFACE WATER MONITORING STATIONS

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by inductively coupled plasma (ICP) according to Method 3120B [American Public Health Association (APHA), 1980]. A calibration standard of 20 milligrams per liter (mg/L) was used and quality control checks with 1- and 5-mg/L standards were run during the analyses. Cl was determined colorimetrically with a Technicon autoanalyser using the automated ferricyanide method [Method No. 325.2; U.S. Environmental Protection Agency (EPA), 1983]. Calibration standards of 5 and 10 mg/L were used as quality control checks during the analyses. Chemical analyses were performed on two laboratory replicates for each sample. All glassware and sample containers were vigorously rinsed in hot tap water followed by deionized water before use as outlined in Standard Methods (APHA, 1980). A series of deionized water blanks was analyzed along with samples as a quality control measure on each sampling date.

2.3 FOLIAR ANALYSES

Samples for foliar analyses were collected on June 18, 1993, from live oak, slash pine, and red cedar to determine internal and bulk deposition (external) Na and Cl concentrations. Collection of foliar samples was attempted from each of the three species at each study site, however, not all species were present at each site. Foliar samples were collected from seven on-site stations and six control/off-site stations (Figure 2-2).

Foliar samples were collected from several trees at each site and composited by species to obtain a single sample. Leaves or needles were removed from the tree using plastic gloves to avoid sample contamination and placed in a labeled polyethylene bag for transport to the laboratory. Each sample was then split into two subsamples. One subsample was rinsed thoroughly in distilled water to remove surface salt deposits and was used to determine internal Na and Cl deposition. The second sample was not rinsed and represented total Na and Cl depositions. Bulk deposition (external) was calculated by subtracting internal deposition (washed sample) from total deposition (unwashed sample). Na and Cl analyses were determined using EPA Method 200.7 (ICP procedure) for Na and EPA Method 325.2 (automated colorimetric procedure) for Cl.

2.4 STATISTICAL ANALYSES

To determine spatial deposition patterns, statistical tests were performed between on-site stations and control and off-site stations using a T-test for each sampling period. Differences in leaf area damage, percent of leaves per plant damaged, aerial deposition, foliar deposition, and deposition

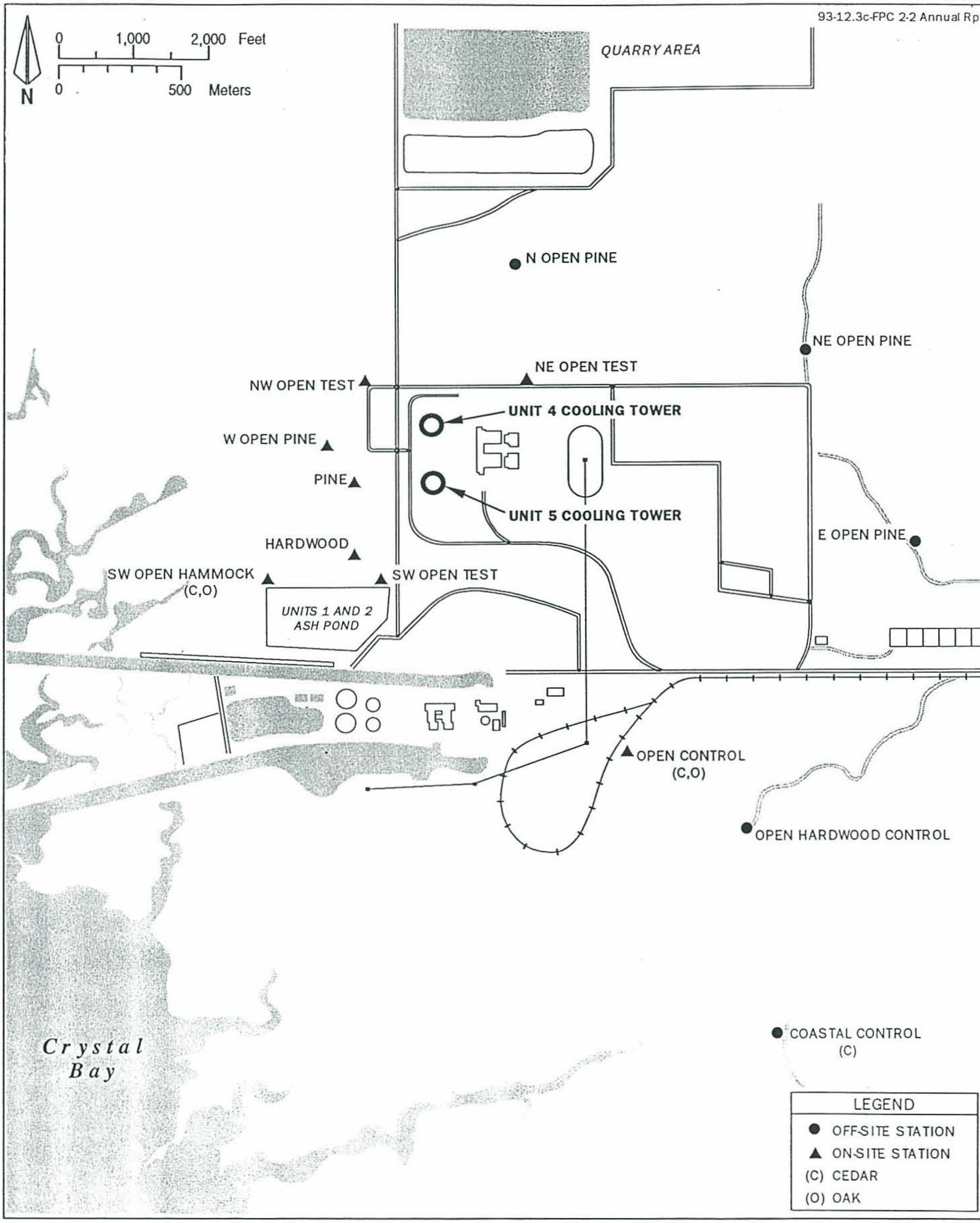

Figure 2-2 LOCATION OF FOLIAR DEPOSITION COLLECTION SITES

NOTE: Samples of red cedar, live oak, and slash pine were collected from each site unless otherwise indicated.

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in pond water were tested at $p \leq 0.05$ level of significance. Temporal deposition patterns and differences in deposition among control/off-site stations and among on-site stations were ascertained using a one-way analysis of variance (ANOVA) at $p \leq 0.05$ level of confidence. Post-hoc comparisons performed to rank the sites in order of sodium and chloride deposition were Tukey-A, Bonferroni, Scheffe, or Newman-Keuls. These tests were selected based on their conservative nature and wide acceptance among scientists and statisticians. The statistical computer package Systat was used for all statistical tests.

3.0 RESULTS

3.1 MONTHLY AND QUARTERLY VEGETATION MONITORING RESULTS

Leaf area injury was higher at on-site stations than at control/off-site stations during all four quarterly monitoring events, however, these differences were not statistically significant (Figure 3-1, Table 3-1). Leaf injury continued to be lowest in May when most plants were new and had little exposure to insects or other damaging factors. These results are consistent with the last 5 years of vegetation monitoring, in which lowest leaf area injury occurred in May (Figure 3-2). Average leaf area injury for the 1992-1993 monitoring year was 9.6 percent for on-site stations and 4.5 percent for control/off-site stations (Table 3-1). Mean leaf area injured was highest for deciduous species such as American beautyberry, sweetgum, and ferns, and lowest for evergreen species such as dahoon holly and yaupon. Leaf area injury for the last 5 study years ranged from 3.1 to 12.8 percent (Table 3-2).

Unlike leaf area injury, the percent of leaves per plant injured was higher at control stations than on-site stations for three of the four quarterly monitoring events, and these differences were statistically significant only during November (Figure 3-3, Table 3-3). Fewer leaves per plant were injured during May for both control/off-site stations and on-site stations, and these differences were significant between November and May for control/off-site stations, and between May and August for on-site stations.

For all plants examined, the percentage of plants considered to be in good condition for each monthly survey ranged from 50 to 67 percent, while the range of plants in poor condition or dead ranged from 2 to 20 percent (Table 3-4). Less than 10 percent of all plants were in poor condition or dead prior to the March 12 and 13 coastal storm, but following the storm, 11 to 20 percent of all plants examined were considered poor or dead.

Qualitative observations revealed that vegetation in most locations showed few symptoms indicative of possible salt drift injury. A trend toward reduced occurrence and severity of possible salt drift injury was noted from November through May. Scattered instances of probable salt drift injury to young leaves of several species including red maple and redbud occurred in

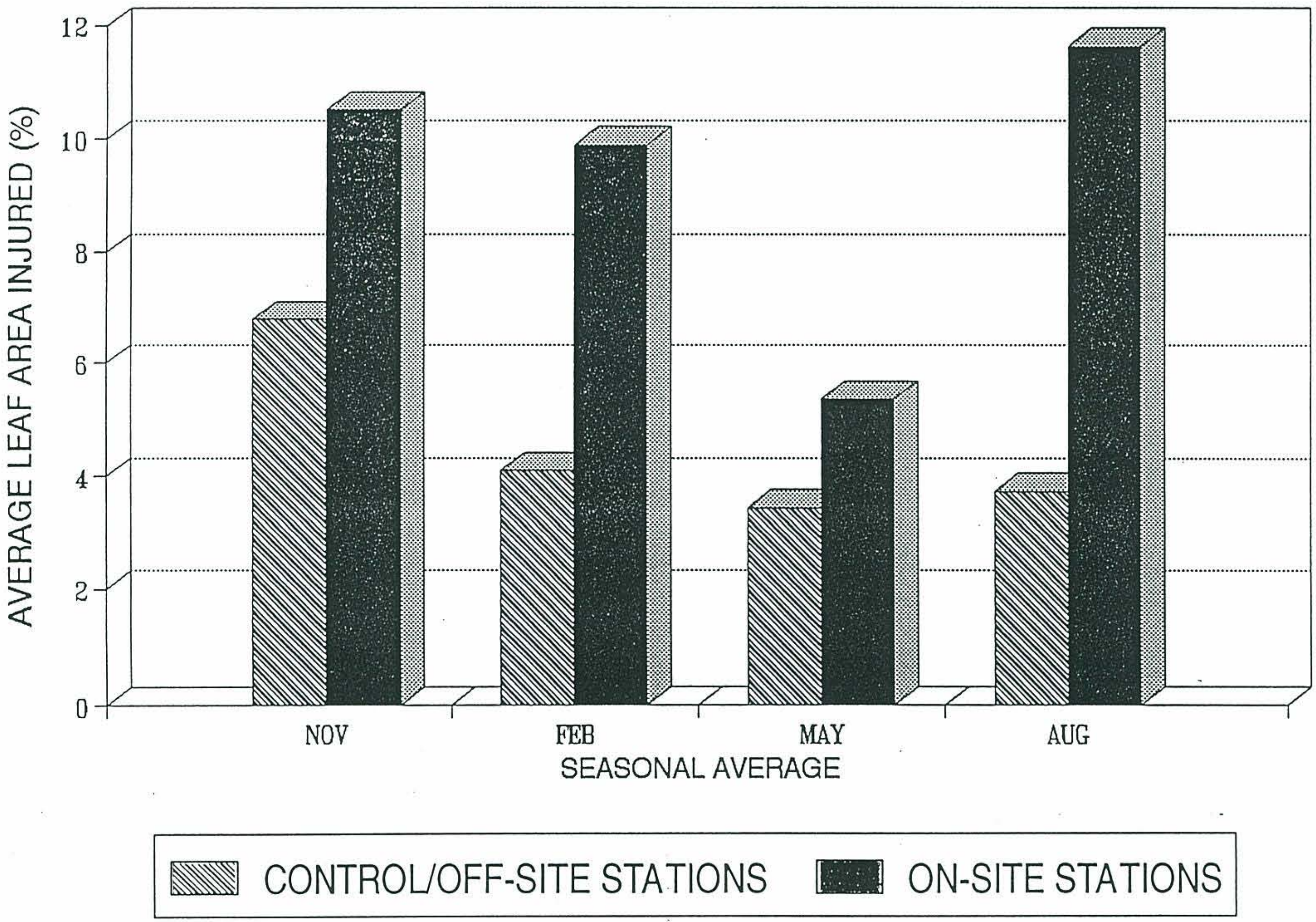

Figure 3-1 AVERAGE LEAF AREA INJURED BETWEEN CONTROL/OFF-SITE AND ON-SITE STATIONS

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Table 3-1. Summary of Average Leaf Area Injured (Percent) during the 1992-1993 Monitoring Period

	1992 - 1993									
	On-Site Stations[a]				Control/Off-Site Stations				Annual Mean	
Plant Group	Nov	Feb	May	Aug	Nov	Feb	May	Aug	On-Site Stations	Control/Off-Site Stations
Southern Magnolia	3.0	9.0	0.0	15.0	6.0	11.0	2.0	5.0	6.8	6.0
Oaks	11.9	13.0	9.7	9.5	10.3	5.3	1.7	3.7	11.0	5.3
Sweetgum	27.5	11.8	3.6	13.0	14.7	0.0	9.3	9.7	14.0	8.4
Red Maple	9.0	0.0	19.0	10.3	4.0	0.0	7.0	4.0	9.6	3.4
Dahoon	2.0	3.6	2.6	2.8	2.0	1.0	1.0	1.0	2.8	1.3
Yaupon	2.4	2.8	0.2	0.6	1.3	0.5	0.5	0.3	1.5	0.7
Pine	0.8	0.6	4.6	0.0	0.3	0.3	10.0	1.7	1.5	3.1
Ferns	11.7	35.0	10.0	26.0	5.0	12.0	0.0	1.0	20.7	4.5
Greenbriers	8.7	13.3	3.8	4.0	6.0	6.8	2.8	6.5	7.5	5.5
American Beautyberry	28.0	[b]	0.2	35.0	18.3	[b]	0.0	4.3	21.1	7.5
Mean of All Groups	10.5	9.9	5.4	11.6	6.8	4.1	3.4	3.7	9.6	4.5

[a] Excludes Open Control Station, which is included in Control/Off-Site Stations.
[b] All plants without leaves at time of survey.

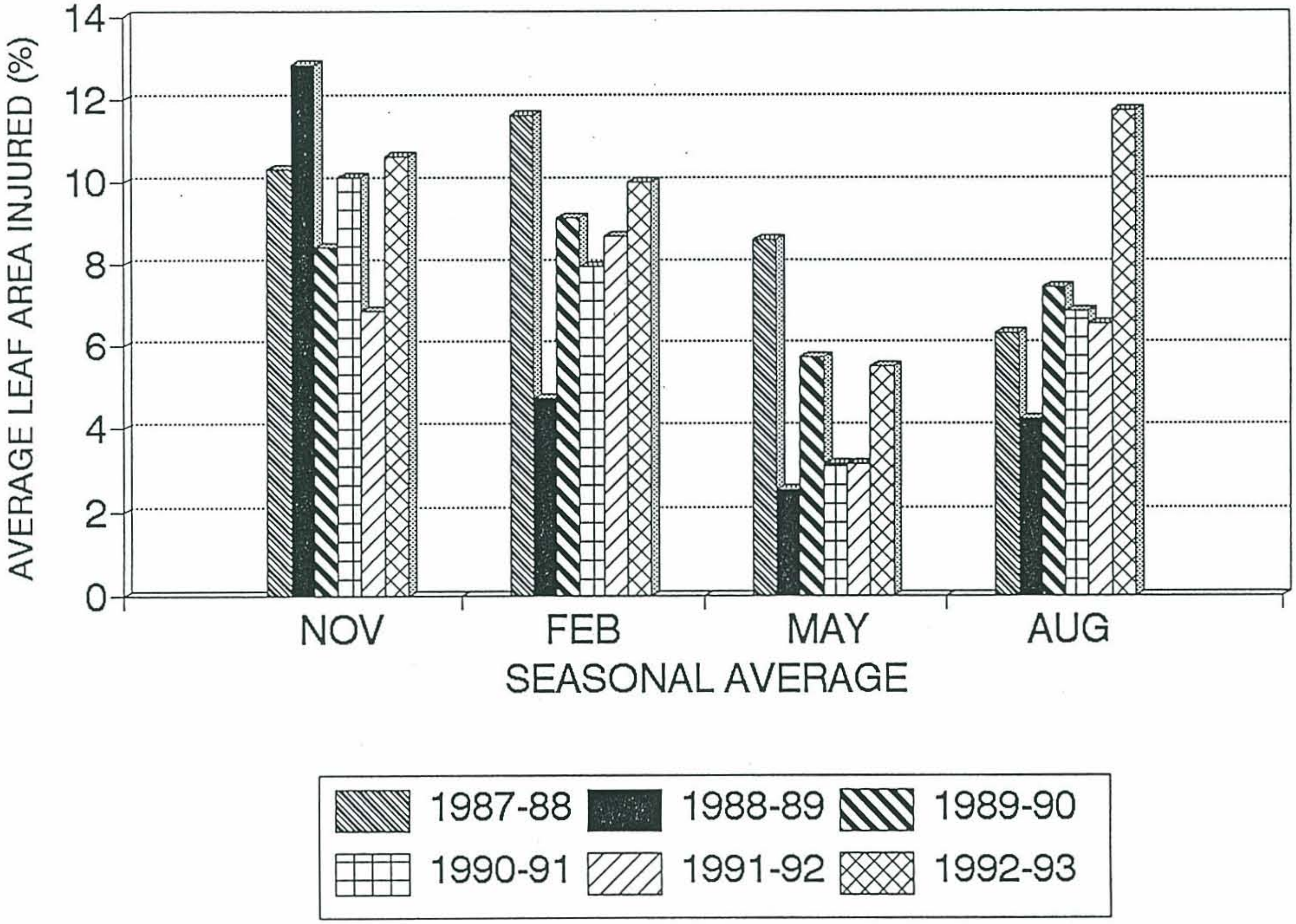

Figure 3-2 AVERAGE LEAF AREA INJURED FOR ON-SITE STATIONS FROM 1987 THROUGH 1993

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Table 3-2. Summary of Average Leaf Area Injured (Percent) from 1987 to 1993, Crystal River

	1987 - 1988				1988 - 1989				1989 - 1990				1990 - 1991				1991 - 1992			
Plant Group	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug
Southern Magnolia	11	12	15	10	13	9	13	4	8	16	29	10	14	30	10	3	2	9	2	9
Oaks	12	32	40	8	11	11	0	8	7	28	9	9	9	22	4	11	13	16	7	8
Sweetgum	11	4	3	5	23	0	1	3	9	1	5	12	21	0	1	8	12	0	1	6
Red Maple	33	0	1	8	7	1	1	5	5	0	3	12	15	0	0	6	7	0	0	5
Dahoon	7	7	8	5	4	10	5	2	3	4	2	3	3	4	2	3	3	3	3	5
Yaupon	1	3	7	5	4	10	1	1	1	4	3	1	1	3	2	5	3	9	2	6
Pine	7	2	0	2	0	0	0	0	1	0	1	1	1	0	0	1	2	2	0	8
Ferns	3	42	0	1	6	4	0	1	2	9	0	0	3	4	6	7	3	30	3	5
Greenbriers	8	14	5	2	20	2	4	3	10	28	5	15	8	8	5	11	15	9	8	4
American Beautyberry	10	0	7	17	40	0	0	15	38	1	0	11	28	-[a]	1	13	8	-[a]	5	9
Mean of All Groups	10.3	11.6	8.6	6.3	12.8	4.7	2.5	4.2	8.4	9.1	5.7	7.3	10.1	7.9	7.7	6.8	6.8	8.7	3.1	6.5

[a] All plants without leaves at time of survey.

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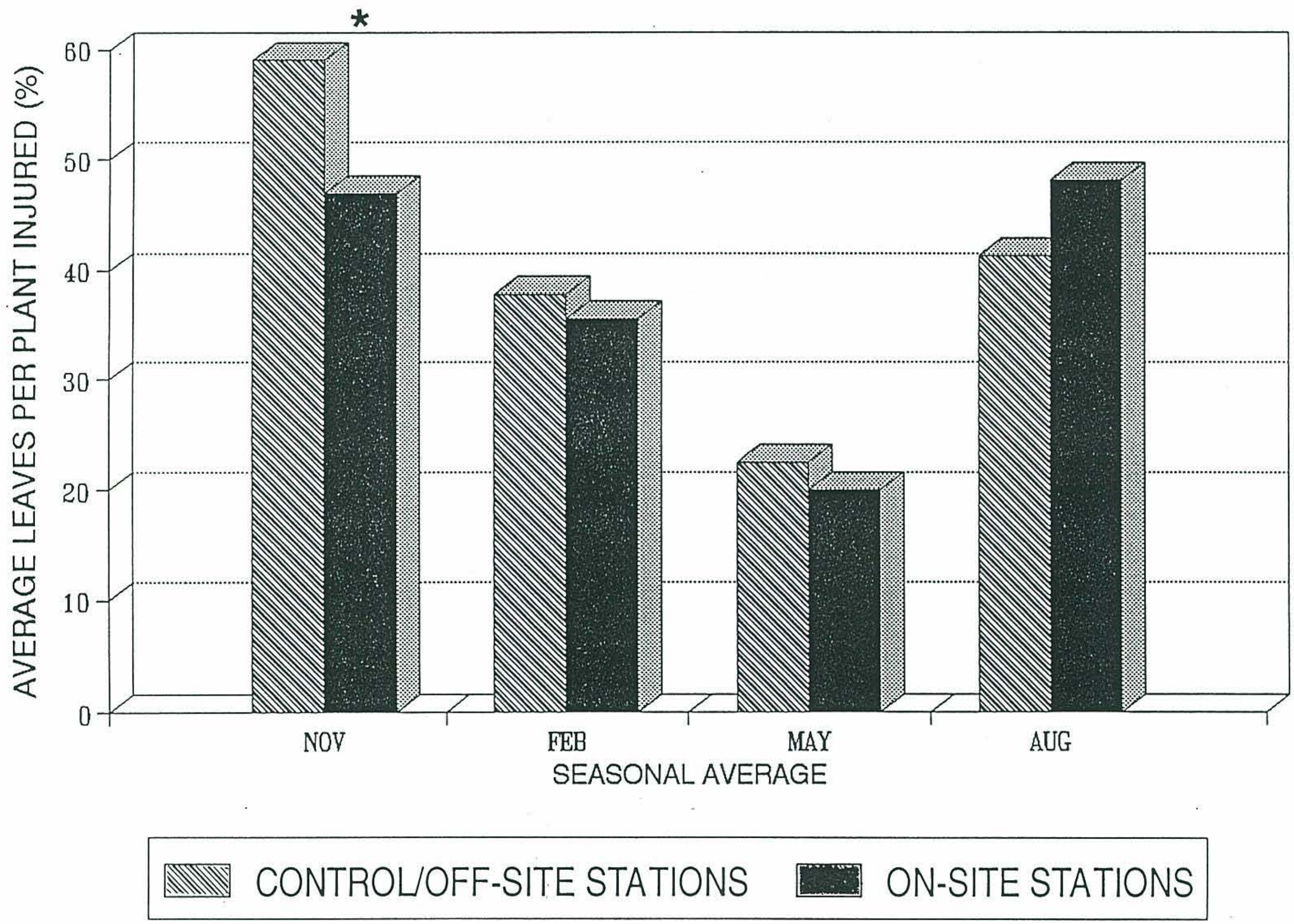

Figure 3-3 AVERAGE PERCENT OF LEAVES PER PLANT INJURED BETWEEN CONTROL/OFF-SITE AND ON-SITE STATIONS

(NOTE: Asterisk indicates significant differences.)

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Table 3-3. Summary of Average Leaf Number Injured (Percent) Per Plant During the 1992-1993 Monitoring Period

	1992 - 1993									
	On-Site Stations[a]				Control/Off-Site Stations				Annual Mean	
Plant Group	Nov	Feb	May	Aug	Nov	Feb	May	Aug	On-Site Stations	Control/ Off-Site Stations
Southern Magnolia	54.0	46.0	4.0	68.0	86.0	80.0	44.0	90.0	43.0	75.0
Oaks	53.3	68.0	27.2	33.8	66.7	78.3	11.7	40.0	45.6	49.2
Sweetgum	93.8	13.3	25.6	64.6	80.0	0.0	42.0	51.3	49.3	43.3
Red Maple	48.8	0.0	48.7	54.3	80.0	0.0	44.5	47.0	38.0	42.9
Dahoon	15.4	37.6	21.0	15.4	40.0	70.0	10.0	55.0	22.4	43.8
Yaupon	8.0	23.0	4.0	15.0	15.8	6.3	8.8	3.0	12.5	8.5
Pine	0.8	4.6	22.0	1.0	33.3	26.7	28.3	21.7	7.1	27.5
Ferns	43.3	80.0	25.0	84.0	36.0	34.0	0.0	20.0	58.1	22.5
Greenbriers	51.7	48.0	19.5	51.7	52.0	45.0	35.0	46.3	42.7	44.6
American Beautyberry	100.0	-[b]	2.0	93.6	100.0	-[b]	0.0	38.8	65.2	46.3
Mean of All Groups	46.9	35.6	19.9	48.1	59.0	37.8	22.4	41.3	37.6	40.1

[a] Excludes On-Site Open Control Station, which is included in Control/Off-Site Stations.
[b] All plants without leaves at time of survey.

Table 3-4. Summary of Plant Condition (Percent) Noted in Monthly Qualitative Surveys, 1992-1993 (includes plants from on-site and control/off-site stations)

	Vegetation Condition Class		
Month	Good	Moderate	Poor/Dead
September	64.8	29.7	5.3
October	67.2	29.5	3.2
November	65.5	31.0	3.5
December	62.1	34.7	3.2
January	53.0	44.6	2.4
February	54.2	37.5	8.3
March	50.5	35.6	13.9
April	50.9	29.1	20.0
May	59.6	26.6	13.8
June	50.0	37.0	13.0
July	51.8	31.8	16.4
August	53.4	35.3	11.3
Range	50.0 to 67.2	26.6 to 44.6	2.4 to 20.0

May, primarily along the transmission corridor from the SW Open Test Site to the NW Open Test Site. In August, symptoms of salt drift injury occurred in red maple, red bud, grape, sweetgum, laurel oak, and live oak at the SW Open Test and Open Test Sites. Twig die-back symptomatic of salt drift damage was also noted in red maple, red bud, and sweetgum for the first time.

Canopy defoliation and decline of oaks continued in the hammock area between the SW Open Hammock and SW Open Test Site. The defoliation pattern appeared to be spreading eastward toward the SW Open Test Site and northward to the Hardwood Site. Defoliation and dieback of oaks was also recorded at the Control/Off-Site Sites as well as the coastline and islands south of the Crystal River power plant. Similar effects were noted at the Open Hardwood Control Site and along the coastal forest edge north of the Coastal Control Site. Dieback of sweetgums occurred at the Hardwood Site. This was the first time that sustained dieback of canopy hardwoods other than oaks has been documented.

Variation in condition of cabbage palms was noted in the hammocks and islands adjacent to the brackish marshes along the coast. An increase in green foliage in palms noted in 1990-1991 continued through the first three quarters of the 1991-1992 season. However, a return to the apparent stressed condition and an increase in brown foliage was noted from August 1992 through February 1993. Cabbage palm condition had improved at most sites, with a predominance of healthy green foliage in May and August 1993.

3.2 SALT DEPOSITION

Monthly deposition values for sodium and chloride were adjusted to reflect a standard 30-day month (Table 3-5). Deposition collection periods began in the middle of each month and ended in the middle of the following month. The data record was continuous throughout the year at four on-site stations and six control/off-site stations, except for eight missing data values caused by malfunction of the collector or dismantling of the collector by heavy wind. Six of the eight missing data values were caused by the March coastal storm which dismantled collectors at three sites. A complete listing of the deposition data is included in Appendix B.

Table 3-5. Mean Monthly Sodium (Na) and Chloride (Cl) Deposition at Crystal River Power Plant, 1992-1993

	On-Site Stations								Control/Off-Site Stations															
	NE Open Test		W Open Pine		SW Open Hammock		NW Open Pine		Open Control		Hardwood Control		Coastal Control		E Open Pine		NE Open Pine		N Open Pine		All Sites	
Month[a]	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl
September	111	329	341	774	352	680	120	268	93	185	83	183	110	222	83	175	77	154	78	205	145	317
October	159	303	93	171	306	531	78	162	86	153	80	150	95	185	82	153	88	189	137	257	120	225
November	220	430	123	211	355	609	140	240	134	244	108	189	111	178	82	177	85	160	152	271	151	271
December	286	560	159	293	824	1473	162	310	71	166	64	146	98	180	63	168	96	231	235	440	206	397
January	256	461	338	662	745	1254	245	449	122	215	119	208	123	198	139	250	105	193	206	355	240	424
February	10805	17923	1036	1862	—	—	942	1710	2825	4629	1614	2904	—	—	—	—	911	1638	1118	1813	2750	4640
March	963	1591	463	794	419	709	550	938	391	669	536	897	112	179	415	625	514	847	619	1041	498	829
April	256	874	310	550	194	455	190	506	114	354	97	406	127	160	110	327	122	407	128	456	175	449
May	362	689	216	445	171	352	189	388	41	88	30	61	—	—	60	120	78	155	54	127	133	269
June	153	275	167	315	226	416	222	425	96	197	98	206	115	178	105	189	107	203	97	173	139	258
July	252	512	145	293	259	488	175	365	143	400	111	324	153	296	170	333	135	383	136	272	168	367
August	124	588	284	738	168	420	356	892	61	188	61	149	55	113	88	218	98	310	122	360	142	397
Site Mean	1171	2044	306	592	365	672	281	554	348	624	250	485	110	189	127	249	201	406	257	481	405	737
Total Annual Deposition	14046	24534	3675	7107	4019	7387	3367	6653	4177	7488	3001	5821	1097	1888	1397	2735	2415	4871	3082	5769	4866	8844
Total Annual Deposition Excluding February	3241	6611	2639	5245	4019	7387	2425	4943	1352	2859	1387	2917	1230	2157	1397	2735	1504	3233	1964	3956	2116	4204
Annual Salt Deposition, kg/ha	385.80		107.82		114.06		100.20		116.65		88.22		29.85		41.32		72.86		88.57		137.10	
Na/Cl Ratio	0.4763		0.5145		0.5279		0.4934		0.4682		0.4663		0.5855		0.4882		0.4593		0.4810		0.4946	

Note: All values are mg/m²-month.
Missing values are due to collector malfunction or lost samples.

[a] Monitoring began at the middle of the month indicated and extended to the middle of the following month. Missing values in May and February were excluded from total.

Sodium

Mean sodium deposition for all 12 collection periods was higher at on-site stations than control/off-site stations, and these differences were significant in 7 of the 12 collection periods (Figure 3-4A). Sodium deposition was relatively constant throughout the year except for a substantial increase during the February-March sampling period caused by the coastal storm on March 12 and 13. Deposition collectors were removed and sampled 3 days after the coastal storm struck the west coast of Florida. A comparison of the February-March deposition results between this year and the previous four years shows that sodium deposition from this year was 4 to 27 times higher at individual sites compared to the last 4 years (Table 3-6).

At the on-site stations, the SW Open Hammock site received the highest annual sodium deposition, while the NW Open Pine site showed the lowest annual sodium deposition (Figure 3-4B). At the control/off-site stations, the N Open Pine site received the highest sodium deposition while the Coastal Control site received the lowest deposition (Figure 3-4C). Although deposition levels varied among sites, there were no statistically significant differences among on-site stations or among control/off-site stations. However, when all sites were compared, sodium deposition at the SW Open Hammock was significantly higher than all control/off-site sites except the N Open Pine. These data exclude deposition from the coastal storm in March which dismantled several collection buckets and made annual comparisons difficult.

Chloride

Similar to sodium, mean chloride deposition was higher at on-site stations than control/off-site stations during all 12 sampling periods, and these differences were significant during half of the sampling periods (Figure 3-5A). Chloride deposition was substantially higher during the February-March sampling period when the coastal storm struck west Florida. A comparison of the February-March deposition results between 1992-1993 and the previous 4 years shows that chloride deposition from this year was 3 to 24 times higher at individual sites compared to the last 4 years (Table 3-6).

At the on-site stations, the SW Open Hammock site received the highest annual chloride deposition while the NW Open Pine site received the lowest annual chloride deposition (Figure 3-5B). At the control/off-site stations, the N Open Pine site showed the highest chloride deposition while the Coastal Control received the lowest chloride deposition (Figure 3-5C).

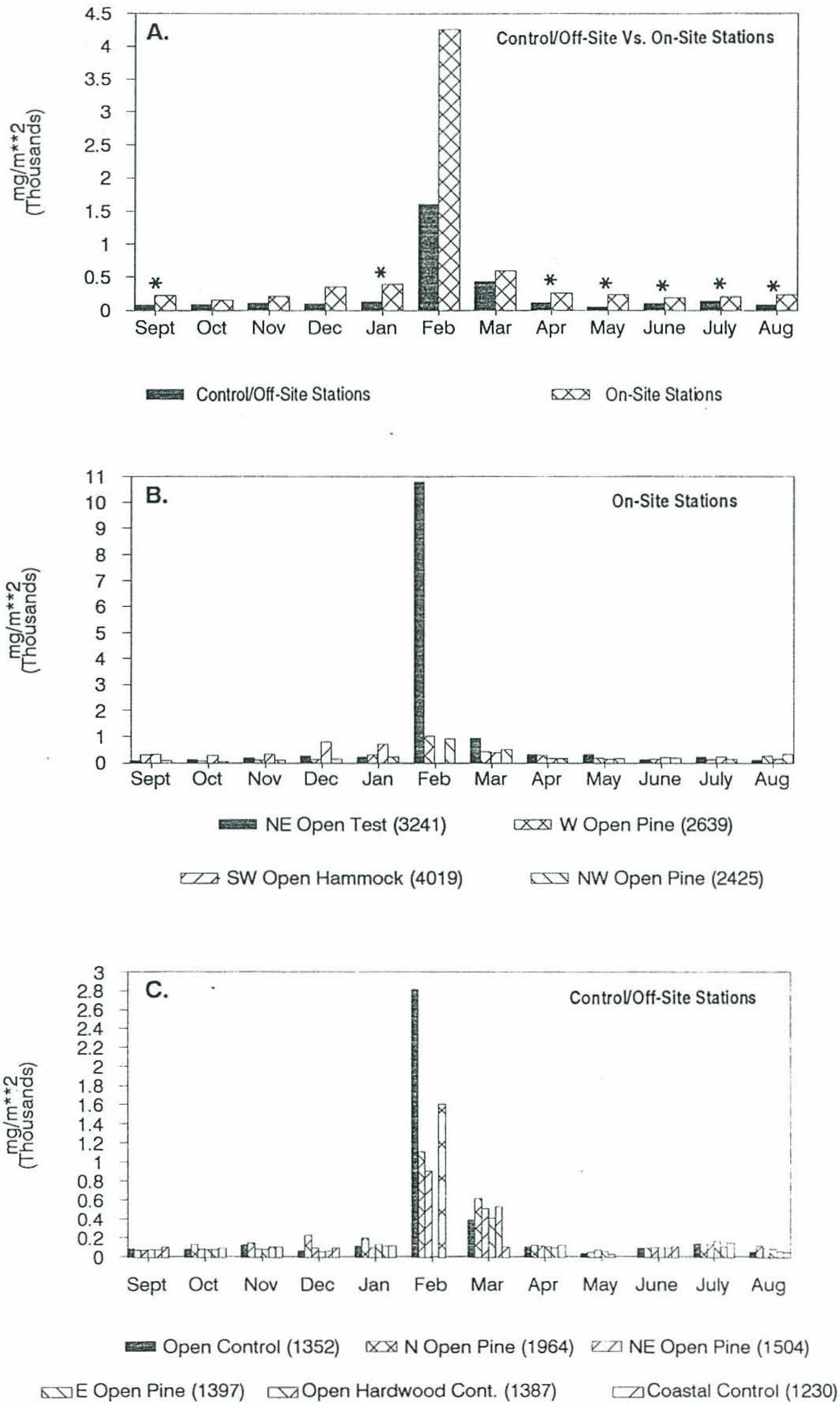

Figure 3-4 (A) MEAN SODIUM DEPOSITION BETWEEN CONTROL/OFF-SITE AND ON-SITE STATIONS; (B) SODIUM DEPOSITION AMONG ON-SITE STATIONS; AND (C) SODIUM DEPOSITION AMONG CONTROL STATIONS

NOTE: Numbers in parentheses indicate annual sodium deposition for each site excluding February. Asterisk indicates significant difference.

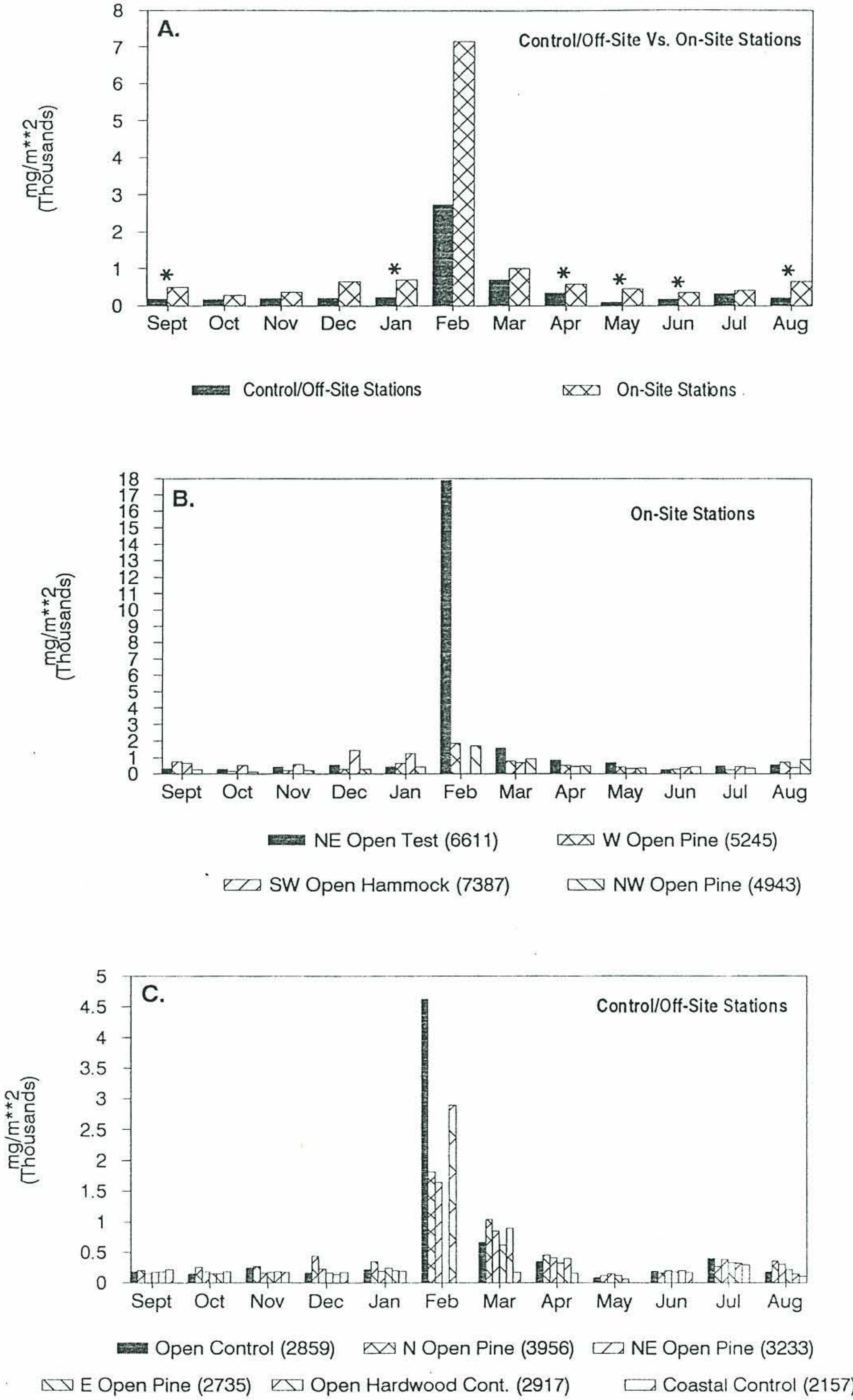

Figure 3-5 (A) MEAN CHLORIDE DEPOSITION BETWEEN CONTROL/ OFF-SITE AND ON-SITE STATIONS; (B) CHLORIDE DEPOSITION AMONG ON-SITE STATIONS; AND (C) CHLORIDE DEPOSITION AMONG CONTROL STATIONS.

NOTE: Numbers in parentheses indicate annual chloride deposition for each site excluding February. Asterisk indicates significant difference.

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Table 3-6. Sodium (Na) and Chloride (Cl) Deposition at On-Site and Control Stations[a] During February-March Since 1985, Crystal River Power Plant

	On-Site Stations								Control/Off-Site Stations													
	NW Open Pine		NE Open Test		W Open Pine		SW Open Hammock		Open Control		Hardwood Control		Coastal Control		E Open Pine		NE Open Pine		N Open Pine		All Sites	
Year[b]	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl
1989	82	204	138	269	99	182	171	349	112	216	—	—	—	—	—	—	—	—	—	—	120	244
1990	194	459	149	382	204	440	273	562	86	184	—	—	—	—	—	—	—	—	—	—	171	379
1991	227	423	395	746	207	387	531	906	219	407	—	—	—	—	—	—	—	—	—	—	316	574
1992	236	387	—	—	203	324	515	808	149	263	127	306	148	195	—		109	219	232	416	206	340
1993	942	1,710	10,805	17,923	1,036	1,862	—	—	2,825	4,629	1,614	2,904	—	—	—		911	1,638	1,118	1,813	2,750	4,640

Note: All values are mg/m²-month.
Missing values are due to collector malfunction or lost samples.

[a] All control/off-site sites except the Open Control were installed in 1992.
[b] Sampling began at the middle of February and extended through the middle of March.

Similar to sodium, differences in chloride deposition were not statistically significant among control/off-site sites or among on-site stations. However chloride deposition at the SW Open Hammock was significantly higher than chloride deposition at all control/off-site stations except the N Open Pine site. Unlike sodium, the NE Open Test received significantly higher chloride deposition than the E Open Pine. As with sodium deposition, these data exclude deposition from the coastal storm in February which dismantled several collection buckets and made annual comparisons difficult.

Surface Water Sampling

Surface water samples collected from one on-site station (NW Open Pine) and three off-site stations (N Open Pine, NE Open Pine, Hardwood Control) showed low concentrations of both sodium and chloride in October and December (Figure 3-6A and 3-6B). Surface water concentration increased substantially at all four sites from April through August. This increase in both sodium and chloride mid-way through the sampling period corresponds with the coastal storm in March. A 6- to 12-ft tidal surge occurred during the storm and deposited saltwater into ponds throughout the Crystal River Power Plant. In addition to tidal surges, high concentrations of salt in ponds can reflect the saltwater chemistry of the shallow groundwater.

In sea water, the mass ratio of sodium to chloride is relatively constant at 0.553 to 0.556 (Horne, 1969; Stumm and Morgan, 1981). Deposition of marine-derived aerosols and particulates should reflect this ratio. The mean sodium to chloride ratio measured in this study was 0.4946 (Table 3-5), which was lower than that expected for marine deposition. Data from previous years also have shown a lower sodium to chloride ratio than expected.

3.3 FOLIAR ANALYSES

Internal, external, and total sodium and chloride were compared among species (red cedar, live oak, and slash pine) and between on-site and control/off-site stations. Statistically, few differences were detected due primarily to a high standard deviation associated with foliar deposition. However, several trends were observed.

Sodium

Internal foliar sodium was highest in slash pine, intermediate in red cedar, and lowest in live oak (Figure 3-7A). However, for external and total sodium deposition, red cedar at the on-site

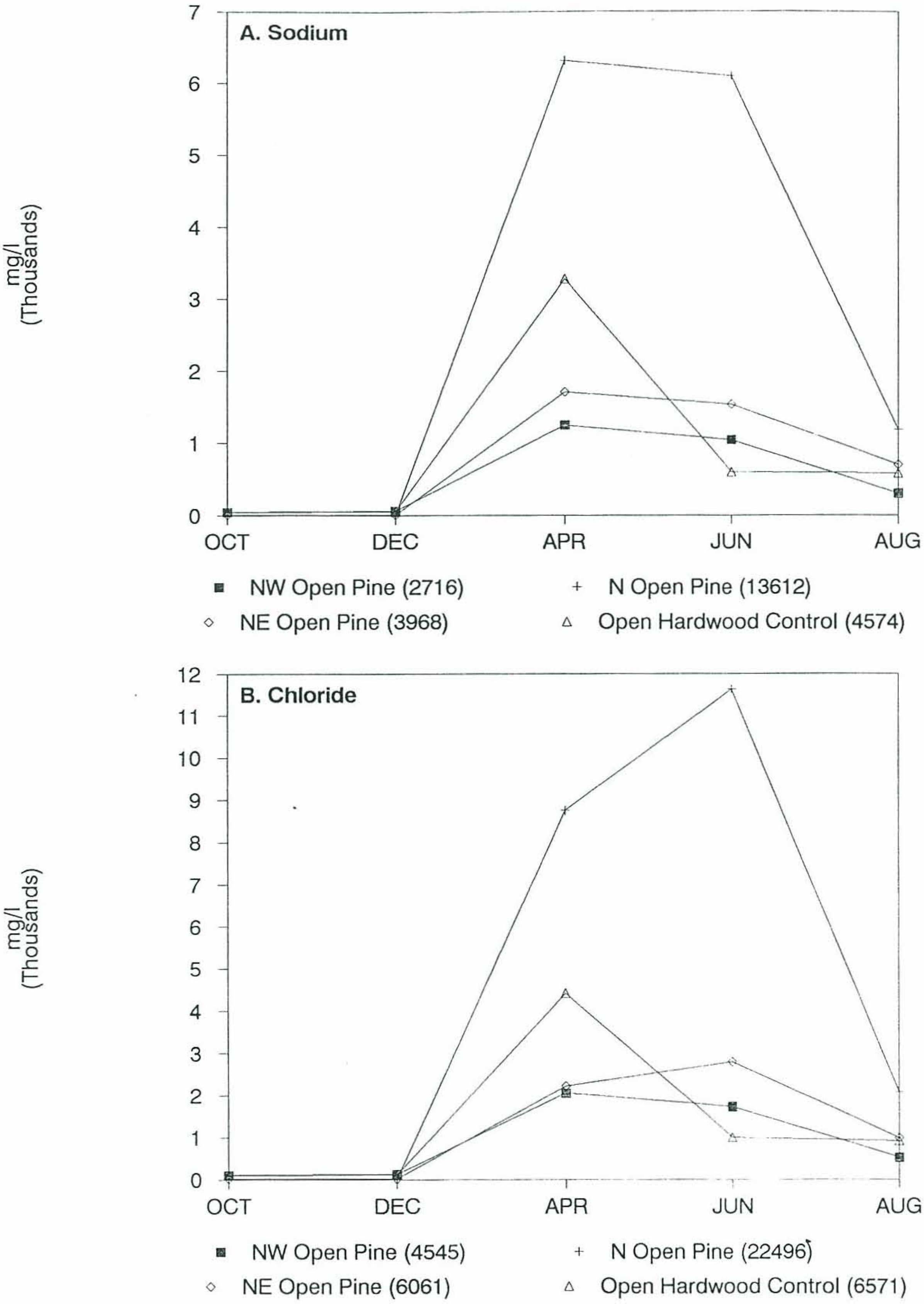

Figure 3-6 (A) SODIUM AND (B) CHLORIDE DEPOSITION IN FOUR PONDS DURING BIMONTHLY SAMPLING

Note: The on-site station is the NW OPEN PINE; the other three sites are off-site stations. The number in parentheses is total deposition.

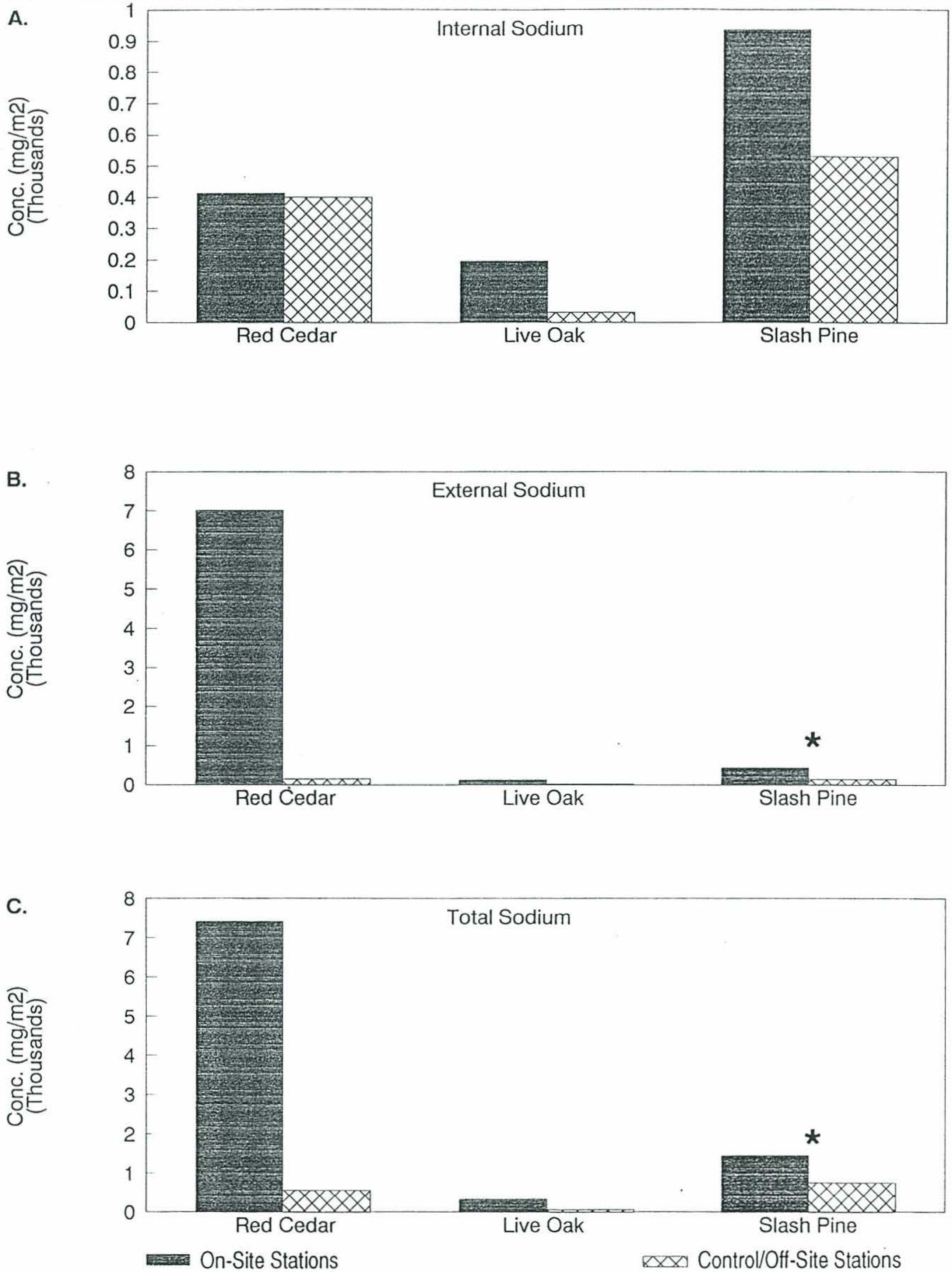

Figure 3-7 (A) MEAN INTERNAL FOLIAR SODIUM; (B) MEAN EXTERNAL FOLIAR SODIUM; AND (C) MEAN TOTAL FOLIAR SODIUM DEPOSITION AT ON-SITE AND CONTROL STATIONS

NOTE: Asterisk indicates significant differerence between on-site and control/off-site stations.

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stations exhibited the highest deposition (Figure 3-7B and 3-7C). An unusually high total sodium deposition at the NE Open Test site accounted for the high external and total foliar sodium at the on-site stations.

In slash pine, external and total foliar sodium deposition was statistically higher at the on-site stations than at the control/off-site stations (Figure 3-7B and 3-7C). For red cedar and live oak, internal, external, and total foliar sodium deposition was also higher at on-site stations than control/off-site stations, however, these differences were not statistically significant. These results are consistent with results from 1991-1992, which demonstrated that foliar samples collected from on-site stations contained higher, although not significantly higher, sodium deposition than control/off-site stations (KBN, 1993).

Chloride

Unlike sodium, foliar chloride deposition was similar among species and lacked distinct species-related patterns. However, for all three species, mean internal, external, and total foliar chloride deposition was higher at on-site stations than at control/off-site stations (Figure 3-8A, 3-8B, 3-8C). These differences were statistically significant in slash pine for internal, external, and total chloride deposition.

Foliar samples were collected in January and July during the 1991-1992 study period. Results from these two sets of samples showed that chloride foliar deposition was higher at on-site stations than control/off-site stations for all samples except red cedar, which was higher in chloride at control/off-site stations during the July sampling event. All differences in foliar deposition from last year were not statistically significant.

Foliar sodium and chloride deposition would be expected to be higher at the SW Open Hammock and Coastal Control) since these sites are located adjacent to coastal salt marshes. However, at the SW Open Hammock site, red cedar and live oak foliar samples were collected. Sodium and chloride deposition from these two species were intermediate compared to the other on-site stations (Table 3-7). At the Coastal Control site, red cedar was the only species collected. This species contained among the highest foliar sodium and chloride deposition when compared to the other control/off-site stations (Table 3-7).

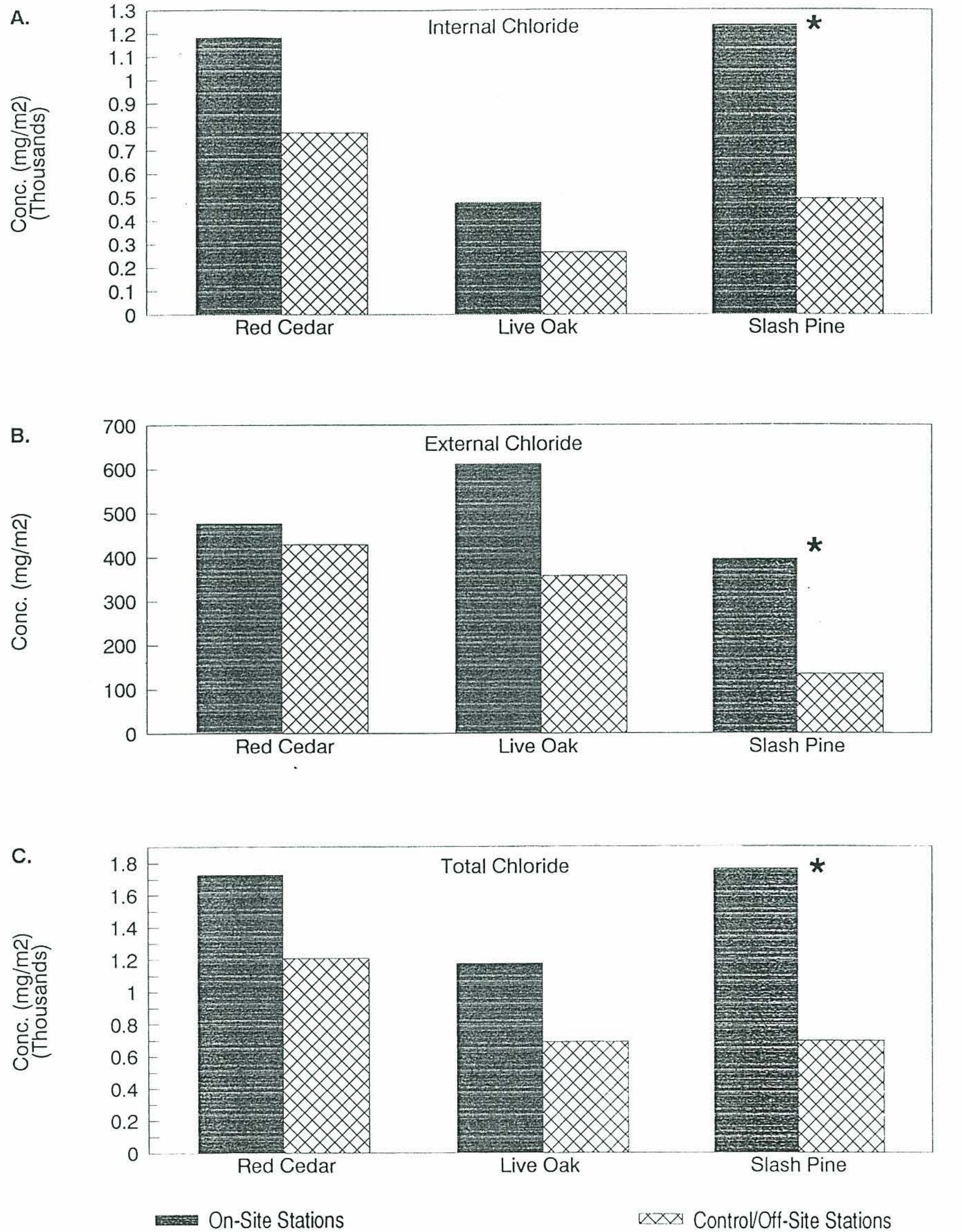

Figure 3-8 (A) MEAN INTERNAL FOLIAR CHLORIDE; (B) MEAN EXTERNAL FOLIAR CHLORIDE; AND (C) MEAN TOTAL FOLIAR CHLORIDE DEPOSITION AT ON-SITE AND CONTROL/OFF-SITE STATIONS

NOTE: Asterisk indicates significant difference between on-site and control/off-site stations.

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Table 3-7. Foliar Sodium and Chloride Deposition - June 1993 (Page 1 of 2)

	Internal Concentration			External Concentration			Total Concentration		
Site	Cedar	Oak	Pine	Cedar	Oak	Pine	Cedar	Oak	Pine
<u>Sodium Concentration</u>									
Pine	384	66.9	1480	185	91.1	570	569	158	2050
Hardwood	455	998	939	214	602	711	669	1,600	1650
W Open Pine	270	23.9	330	85	28.5	153	355	52.4	483
NW Open Test	225	34.8	758	34	46.8	442	259	81.6	1,200
NE Open Test	362	146	1020	47,938	126	690	48,300	272	1,710
SW Open Test	845	56.7	1090	495	26.4	520	1,340	83.1	1,610
SW Open Hammock	353	36.6	—	130	64.4	0	483	101	—
Mean	413.4	194.7	936.2	7,011.6	140.7	440.9	7,425.0	335.4	1,450.5
Open Control	130	9.9	—	121	33.9	0	251	43.8	—
Coastal Control	627	—	—	235	0	0	862	—	—
Hardwood Control	172	34.1	424	149	45.2	139	321	79.3	563
N Open Pine	458	56.2	677	184	34.1	413	642	90.3	1,090
NE Open Pine	244	37.2	617	145	49	184	389	86.2	801
E Open Pine	769	24.8	408	106	24.1	182	875	48.9	590
Mean	400.0	32.4	531.5	156.7	31.0	153.0	556.7	69.7	761.0

Table 3-7. Foliar Sodium and Chloride Deposition - June 1993 (Page 2 of 2)

	Internal Concentration			External Concentration			Total Concentration		
Site	Cedar	Oak	Pine	Cedar	Oak	Pine	Cedar	Oak	Pine
Chloride Concentration									
Pine	1,250	420	1,690	1210	540	470	2,460	960	2,160
Hardwood	2,440	460	840	420	640	700	2,860	1,100	1,540
W Open Pine	670	550	710	340	480	200	1,010	1,030	910
NW Open Test	440	310	1,110	260	600	340	700	910	1,450
NE Open Test	750	730	1,210	490	1710	550	1,240	2,440	1,760
Open Test	—	—	—	0	0	0	—	—	—
SW Open Test	1,430	560	1,850	700	580	910	2,130	1,140	2,760
SW Open Hammock	1,300	310	—	400	350	0	1,700	660	—
Mean	1,182.9	477.1	1,235.0	477.5	612.5	396.3	1,728.6	1,177.1	1,763.3
Open Control	800	120	—	470	580	0	1,270	700	—
Coastal Control	990	—	—	520	0	0	1,510	—	—
Hardwood Control	740	520	440	280	930	280	1,020	1,450	720
N Open Pine	940	280	400	380	450	410	1,320	730	810
NE Open Pine	350	22	610	160	178	90	510	200	700
E Open Pine	840	380	530	770	10	30	1,610	390	560
Mean	776.7	264.4	495.0	430.	358.0	135.0	1,206.7	694.0	697.5

4.0 DISCUSSION

4.1 VEGETATIVE CONDITION

Normal environmental factors such as herbivory, moisture stress, and nutrient deficiencies can produce symptoms in vegetation similar to those indicative of salt drift. During this study, we tried to differentiate between characteristics that were attributable to natural environmental or seasonal factors and characteristics that were symptomatic of salt drift. Examples of natural vegetation stress observed at Crystal River included increased herbivory during the dormant season, thin chlorotic pine canopies in areas adjacent to marshes, leaf spotting and decay prior to seasonal senescence, and dieback of ferns and vines from the March storm.

Salt drift injury as evidenced by chlorotic leaves or needles, leaf hypertrophy, tip or margin damage, and small or deformed leaves was observed in May in young leaves of several species including red maple and red bud, primarily along the transmission corridor from the SW Open Test site to the NW Open Test site (Figure 1-1). In August, possible salt drift effects were noted in additional species along the SW Open Test and Open Test Sites. The current monitoring period marks the first time that potential salt damage was noted in species and locations that corresponded to areas where canopy dieback has occurred. Foliar characteristics symptomatic of salt drift were noted in oaks for the first time between the SW Open Test and Open Test sites where canopy loss has been occurring. Twig and foliar damage to sweetgums was also observed near the Open Test and Hardwood sites.

It is not possible to draw conclusions linking deposition data to vegetation observations since there are no deposition collectors in the immediate vicinity of the affected vegetation. However, sodium and chloride deposition collected from both deposition collectors and foliar samples was higher at on-site stations than control/off-site stations (Figures 3-4, 3-5, 3-7, and 3-8). Average leaf area injury was also higher at on-site stations, but average percent of leaves injured per plant was generally higher at control/off-site stations (Figures 3-1 and 3-3). Highest leaf area injured occurred in deciduous species such as American beautyberry and sweetgum, whereas evergreen species such as yaupon and dahoon holly had the lowest leaf area injured. During the next study period, a deposition collector will be placed at the Open Test site so deposition can be measured in the vicinity where salt drift damage was observed.

Site Comparisons

Sodium and chloride deposition was significantly higher at the SW Open Hammock than all control/off-site sites except the N Open Pine. However, deposition levels at the SW Open Hammock were not statistically different from other on-site stations. The maritime forest at the SW Open Hammock site is adjacent to a salt marsh and has shown signs of significant stress and vegetation decline for several years. Decline of oaks has been especially noticeable, resulting in smaller leaves, sparser canopies, and die-back of twigs and branches, particularly in the upper canopy. In some areas, whole trees have died or the only living tissue is on stem sprouts. A decline in cabbage palms has also been observed, usually in places where oaks are stressed. The areas most affected by these conditions are located along the edges of marshes where a transition from uplands to wetlands occurs. More salt-tolerant species such as red cedar, saltbush, and marsh elder have proliferated in the understory. These observations of vegetation decline at the SW Open Hammock site have persisted for several years and do not appear to be related to operation of the new cooling towers. Although this site has experienced both high salt deposition and substantial vegetation stress, we surmise that a considerable amount of salt spray originates from the adjacent salt marsh and from traffic-related dust from the plant area and ash pond. In earlier study years, it was found that dust could significantly contribute to salt deposition. A monitoring site at the plant's switchyard was discontinued in 1986 because high deposition at this site was considered unrelated to salt drift from the cooling towers. Dust was often observed in the collector buckets at the switchyard site.

A study was conducted several years ago to study the decline in oaks and cabbage palm at the SW Open Hammock in more detail (KBN, 1991a). Field observation and aerial evaluation indicated no signs of foliar effects consistent with salt drift or air pollution injury. The pattern of tree mortality appeared to have been in effect at least since 1983. The pattern of damage appeared to have followed topographic contours beginning at the lower limits of tree growth and extending upward. In the process, the damage had also extended eastward into the hammock along low areas. This pattern supports the hypothesis that the effect is due to a hydrologic factor. Possible hydrologic factors include salinity, water stress caused by high salinity, anaerobic conditions in the root zones, fluctuations in soil water levels, and the presence of contaminants in groundwater.

Vegetation decline in low-lying coastal forests is not confined to the Crystal River Power Plant, but has been observed throughout the west coast of Florida. Researchers from the University of

Florida are studying vegetation decline on low-lying coastal islands at Wacasassa Bay, approximately 15 miles north of the Crystal River Power Complex. These researchers have found that cabbage palm and red cedar on low elevation coastal islands are in a more advanced stage of decline than those same species at higher elevations (K. Williams, pers. comm.). The cause of vegetation decline is attributed to sea level rise that is affecting plants located in the topographically lowest reaches. Live oak was not targeted in the Wacasassa Bay study because this species is less salt tolerant and, consequently, less abundant on these low-lying coastal areas.

The researchers at Wacasassa Bay have noticed that regeneration of cabbage palm and red cedar ceases before plant mortality occurs. At the SW Open Hammock site where live oak and cabbage palm mortality is most noticeable, regeneration of red cedar and cabbage palm is high, whereas live oak regeneration is quite low. Although the vegetation decline at this site is probably attributable to sea level rise, the stage of decline at the SW Open Hammock site does not appear to be as advanced as that observed at the nearby low-lying coastal islands.

Beginning in early 1992, decline of oak trees was noticed in two off-site stations, the Coastal Control and Open Hardwood Control site. The extent of defoliation of oaks at these sites is not as pronounced as the SW Open Hammock but oak defoliation appears to have increased in 1992 and 1993. At the Open Hardwood Control site, additional species such as American elm and sugarberry appear to be affected. At the Hardwood Control station, sodium and chloride deposition was intermediate to low in foliar samples and intermediate to high in air-deposited samples. Salt deposition was lower at the Coastal Control station than any other monitoring station (Figures 3-4 and 3-5). These results were surprising since the Coastal Control station, like the SW Open Hammock station, is located adjacent to a coastal marsh and assumed to receive salt spray from the marsh.

Historical comparison of the three sites with the longest deposition record (Open Control, W Open Pine, and NE Open Test) indicates that deposition received during this study year was similar to the previous 4 years (Figure 4-1). The exception to this trend was the high sodium and chloride deposition recorded during the February sampling, which included deposition deposited from February 17 to March 17, and included the March 12-13 coastal storm. February 1993 deposition was the highest recorded at these three sites since 1987. Low deposition at the W Open Pine, NE Open Test, and to a lesser degree, the Open Control appears to correspond to

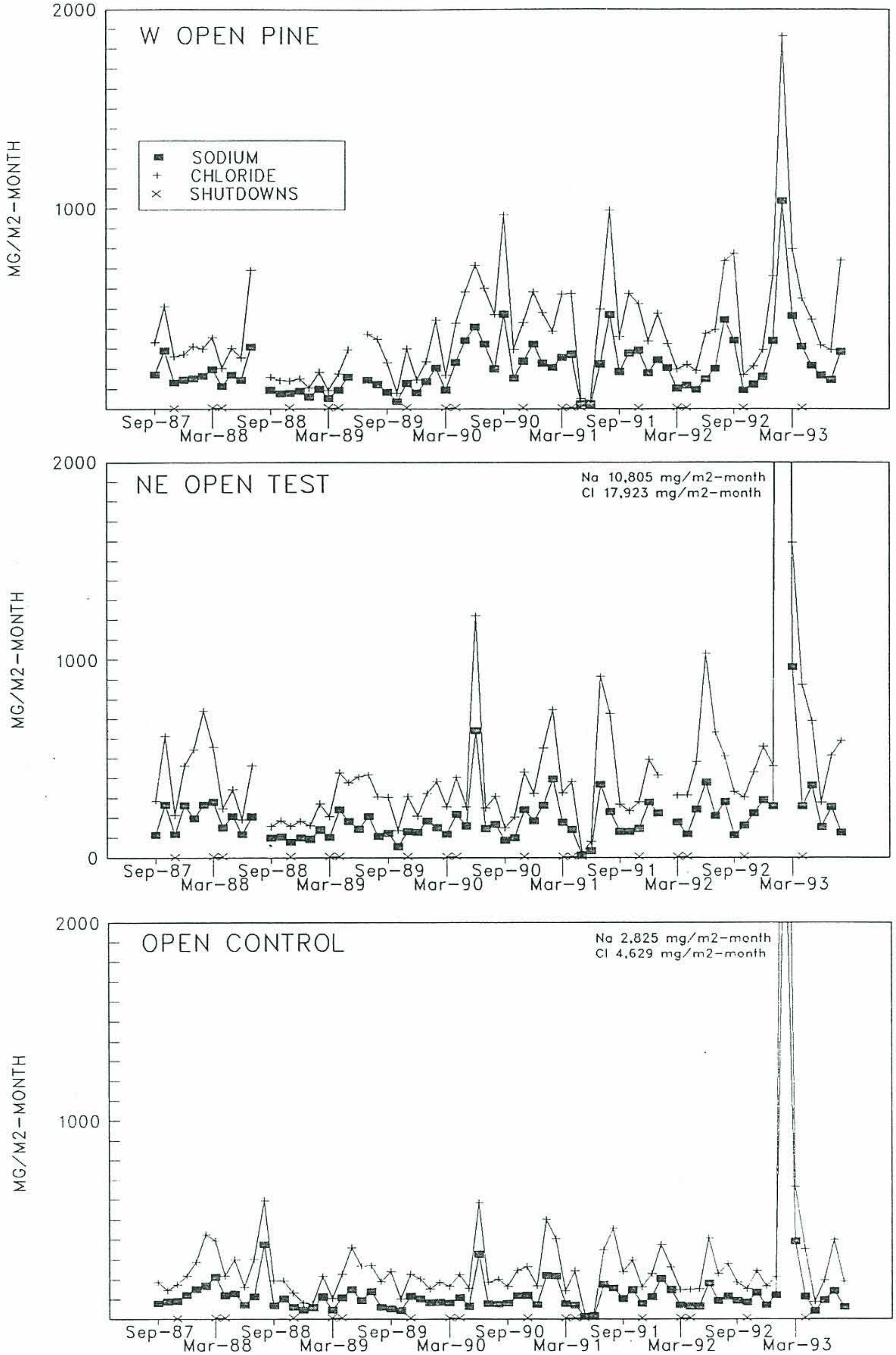

Figure 4-1 MEAN MONTHLY DEPOSITION AT THREE SITES FROM 1987 THROUGH 1993, WITH SHUTDOWN OF COOLING TOWERS INDICATED AS AN X

KBN

cooling tower shutdowns, however, high variability in the data tends to obscure any clear deposition pattern (Figure 4-1). Shutdowns of Units 3 and 4 typically occur in spring and fall to allow periodic maintenance. The fall shutdowns are of shorter duration than spring shutdowns and do not appear to affect deposition values to the same extent. With operation of the new cooling towers extending from May 1 through October 31 of each year, the possible relationship between operation of the cooling towers and deposition amounts will be examined further.

Coastal Storm

On March 12 and 13, a severe coastal storm struck the west coast of Florida. This storm caused extensive damage including breaking tree limbs, falling trees, flooding from the tidal surge, and accumulation of debris. Many of the monitoring sites at the Crystal River power plant were flooded with several feet of water. Debris and driftline deposition indicated that flooding occurred at all on-site and off-site stations except the NE and E Open Pine sites. Floodwater rose 2 to 3 ft at some sites, including the SW Open Hammock, Open Control, Hardwood, NE Open Test, and Coastal Control sites. Effects of this storm were evident in the monthly surveys for several months. Many plants such as ferns, coontie, and low-lying vines disappeared after the storm, and overall condition of the remaining plants was affected for several months. The percentage of plants considered to be in poor condition was greater than 12 percent in the 5 months following the storm, whereas the percentage of plants considered poor remained below 10 percent for each of the 16 months preceding the storm.

Salt damage from the storm was evident on leaves of many species near the SW Open Hammock and Coastal Control Sites and south of Units 1 to 2 following the storm. Leaves of winged elm and southern red cedar turned brown and dropped from twigs on the west side of many plants. However, new growth replaced the lost leaves by June and no apparent long-term damage was evident. Most of the ferns remained without foliage and were thought to be dead until October, when they started resprouting at the base.

Salt deposition samples collected in March and surface water samples in April and June following the storm accounted for approximately 50 and 85 percent, respectively, of the deposition measured for the entire year. These data suggest that 50 to 85 percent of the salt deposited during the entire study year was attributed to salt spray during the March storm. Short-term vegetation stress was documented after the storm, although the species most affected by the storm began resprouting 6 to 8 months later. Although this storm was labeled "the storm of the century," less severe coastal storms commonly strike the Gulf coast and deposit salt spray on adjacent vegetation communities. This storm marks the first storm where high deposition could actually be measured. Previous storms have destroyed the deposition collectors and prevented actual measurement. It appears from the resiliency of the vegetation that these communities have evolved to survive and even flourish in maritime environments where large pulses of salt spray occur.

Overall, vegetation at and around the Crystal River Power Plant appears to have remained in good condition. As suggested by the Wacasassa Bay study, the vegetation decline at the SW Open Hammock site may be due more to sea level rise than salt spray from the cooling towers. Because salt drift damage has been noted at nearby sites, it is possible that salt spray could magnify or accelerate characteristics of stress observed at these sites. No large-scale effects such as plant mortality appear to be present as a result of cooling tower operation, based upon the monitoring procedures used in this study, although it is possible that salt drift may be, in some degree, a contributing factor to stress levels noted in some areas. For the first time, there have been signs of salt damage in those species that are experiencing canopy die-back, but there appears to be no direct correlation between canopy dieback and salt deposition.

5.0 CONCLUSIONS

1. The March 12 and 13 storm resulted in substantial physical damage to vegetation, and caused substantial flooding, breaking of limbs, and debris deposition. Deposition during February when the storm struck was 4 to 27 times higher than deposition received during February for the past 4 years of monitoring. Deposition from the storm accounted for 50 percent of the aerial deposition and 85 percent of the surface water deposition measured for the entire study year. Many plants sustained damage from the storm, but most plants recovered within 3 to 6 months following the storm.
2. Overall, vegetation at the monitoring stations and near the Units 4 and 5 cooling towers appeared to be in good condition. Some instances of salt injury seen along the transmission corridor area indicated that effects of salt deposition may be greater than in the 1991-1992 study year. The extent of vegetation affected was small and confined to only a few individuals of laurel oak, live oak, sweetgum, red maple, red bud, and grape.
3. Operation of the new cooling towers occurred for only 3 months during this study period and does not appear to have increased salt deposition. Clearly, the highest amount of salt deposition during this study period occurred during the severe March storm.
4. Foliar levels of salt damage were within the range seen between 1987 and 1992 except for the August, 1993 period. Foliar damage levels were less than in 1991-1992 at the control/off-site sites, but greater at the on-site stations.
5. Signs of vegetation stress (e.g., canopy dieback) continued in the area adjacent to the SW Open Hammock site. The affected area continued to increase in size, with effects apparent at the Hardwood and SW Open Test sites. Similar trends occurred along the coast in the vicinity of the Coastal Control, Open Control, and Open Hardwood Control sites located southwest of the Crystal River property. The stress consisted of a decline in canopy coverage and has been noted throughout the central Florida Gulf coast region. The primary species affected were live oaks and cabbage palms, although sweetgums were affected in the 1992-1993 study period. The stress is regional and appears to be related to sea level rise.
6. Sodium deposition was significantly higher at on-site stations than control/off-site stations for 7 months, and chloride deposition was significantly higher at on-site stations than control/off-site stations for 6 months.

7. There were no statistically significant differences in deposition among on-site stations or among control/off-site stations. However, when all sites were compared, the SW Open Hammock received significantly higher deposition than all control/off-site sites except the N Open Pine.
8. Significant differences in foliar deposition were detected between on-site and control/off-site stations in slash pine. There were no differences in foliar deposition for red cedar or live oak between on-site and control/off-site stations.

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