CRYSTAL RIVER
SALT DRIFT STUDY
1993-1994 ANNUAL REPORT

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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. The new mechanical draft towers for Units 1, 2, and 3 became operational during the last study period on June 16, 1993. The normal operation period for these new towers is from May 1 through October 31 of each year during the peak summer demand.

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 vegetation assessments of the local plant communities and monitoring of salt deposition. Currently, 13 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 (1981-1982), the Units 4 and 5 cooling towers were under construction. Data collected during that period served as pre-operational or

Table 1-1. History of Vegetation and Deposition Monitoring Stations

Site Name	Distance[a] (km)	Direction[a] (°)	Start Year	Studies Ongoing
Open Test	0.24	230	1982-1989, 1994[b]	D,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, 1994	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.

[b] Deposition monitoring stopped in 1989 and was reestablished in March 1994. Vegetation monitoring continued uninterrupted.

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 (Figures 1-1 and 1-2). 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 and to provide a broader, more encompassing directional grid around the towers. Subsequently, operational modeling suggested that maximum salt deposition would occur farther west (KBN, 1988a), 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 mechanical draft cooling towers proposed for construction south of the SW Open Hammock site. A deposition monitoring station was then reestablished at the Open Test site in 1994 to better assess vegetative conditions in this area.

At the start of the 1991-1992 study year, three off-site stations (East Open Pine, Northeast Open Pine, and North Open Pine sites) and two control stations (Open Hardwood Control and Coastal Control sites) were added to the monitoring network. This expansion allowed the study of possible effects of new mechanical draft towers for Units 1, 2 and 3 which became operational in June 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.

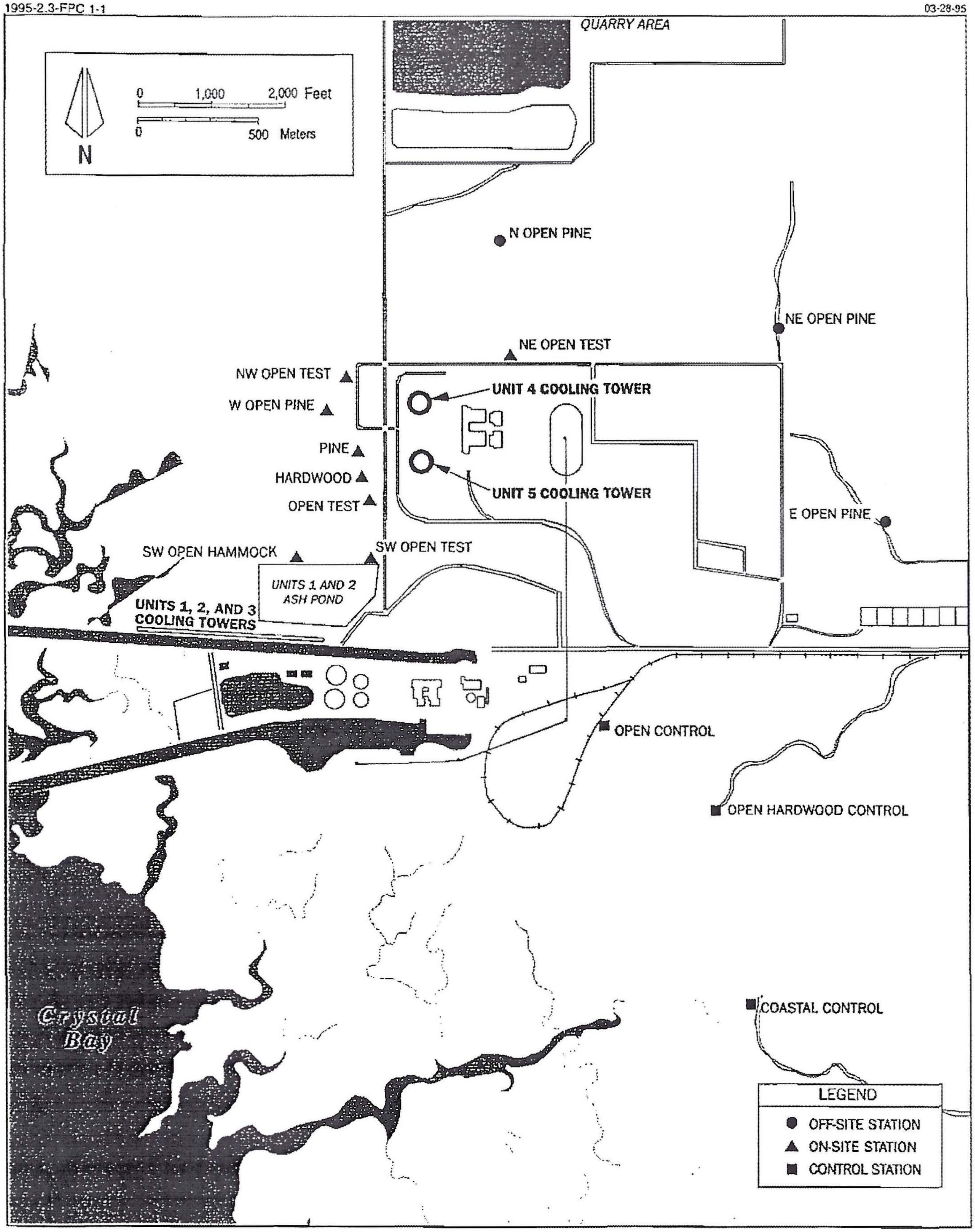

Figure 1-1
Location of Vegetation Monitoring Stations

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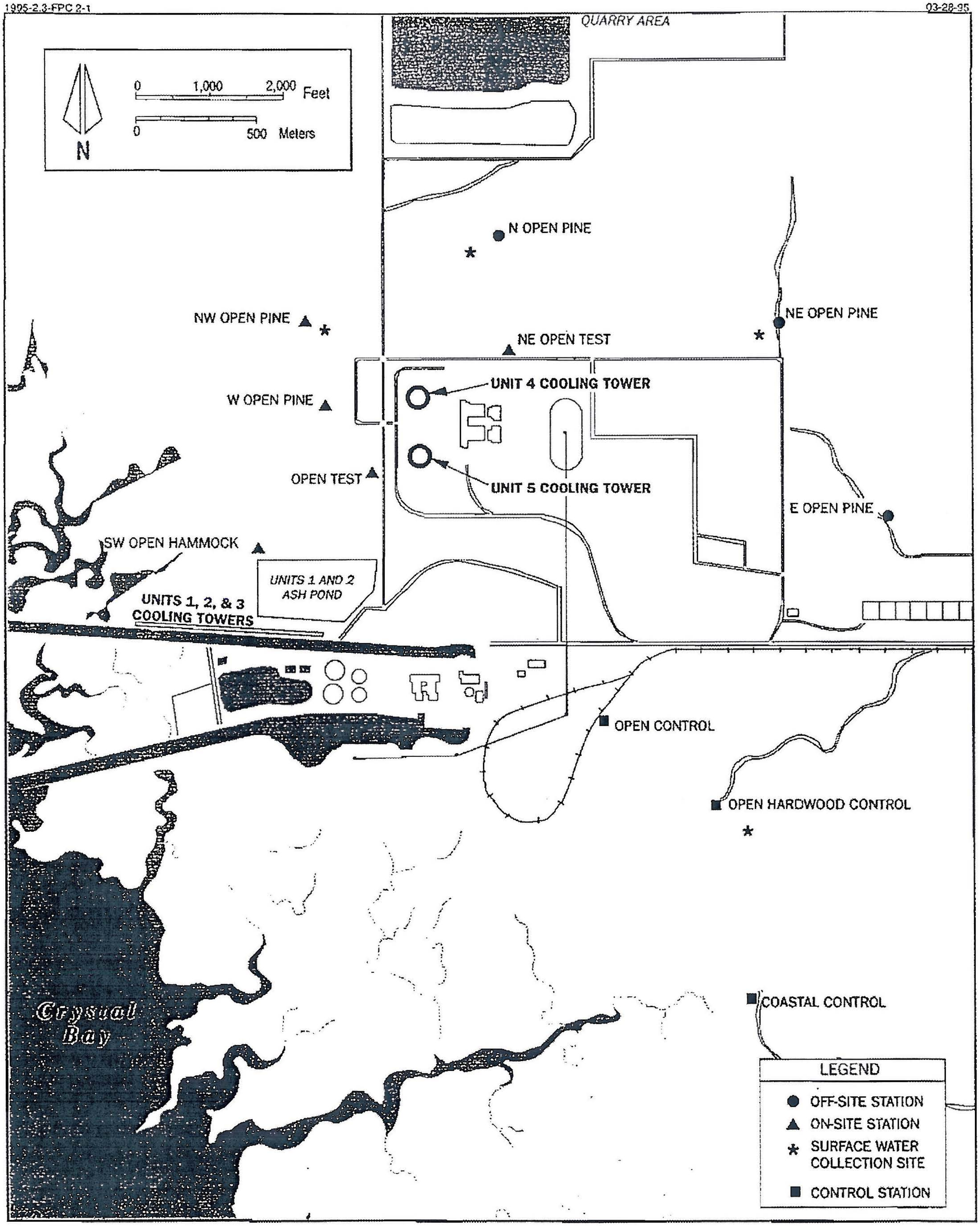

Figure1-2
Location of Deposition and Surface Water Monitoring Stations

KBN

Results of 12 years of monitoring have been summarized in previous reports (ABI 1984, 1985, and 1986; FPC, 1986; and KBN 1986 - 1994). This report presents the results of monitoring programs for salt drift deposition, vegetation, and aerial photography for the sampling period September 1993 to August 1994. This period is designated as the thirteenth year of monitoring and covers the twelfth year of operational data for Unit 4 and the tenth year of operational data for Unit 5. Additionally, this study period covers the first full year of operation for the new Units 1, 2, and 3 cooling towers.

2.0 MATERIALS AND METHODS

2.1 SALT DEPOSITION MONITORING PROGRAM

2.1.1 MONITORING LOCATIONS

Deposition monitoring was performed from September 16, 1993, to September 15, 1994, at 11 locations (Figure 1-2). Five of these sampling stations are located on-site (SW Open Hammock, Open Test, W Open Pine, NW Open Pine, NE Open Test), three sampling stations are located off site (N Open Pine, NE Open Pine, and E Open Pine), and three are control stations (Open Control, Open Hardwood Control, and Coastal Control). All of the deposition stations were operational for the entire study period, except the Open Test station, which was added to the sampling network in March 1994. 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 four 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 (Figure 1-2). These areas are subsequently referred to as ponds.

2.1.2 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, and only one collector is located at all other deposition monitoring sites.

Deposition collection periods began in the middle of each month and ended in the middle of the following month. 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 Central Chemistry Laboratory located at the Crystal River plant for analysis.

2.1.3 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 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 Perstorp autoanalyser using the automated ferricyanide method [Method No. 325.2; U.S. Environmental Protection Agency (EPA), 1983]. Calibration standards of 0.1, 2, 4, 6 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.

2.2 <u>VEGETATION MONITORING PROGRAM</u>

2.2.1 MONITORING LOCATIONS AND STATION CONDITION

Vegetation was examined monthly at eight on-site stations, three offsite stations, and three control 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 three control stations included the Open Control, Coastal Control, and Open Hardwood Control stations, and the three offsite stations included the E Open Pine, NE Open Pine, and N Open Pine stations (Figure 1-1). Of the control 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).

2.2.2 MONTHLY FIELD MONITORING PROCEDURES

Selected individual plants of representative species were marked with surveyor's tape at each of the vegetation monitoring sites (Table 2-1). 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. 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 substituted plants resembled the replaced plants as closely as possible.

2.2.3 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 locations on each plant, and whether old or new vegetation was 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.

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

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

In addition, additional plants were evaluated for average percent of surface area injured per leaf and percent of leaves affected per plant. 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 also noted.

2.2.4 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).

2.3 STATISTICAL ANALYSES

To determine spatial vegetation damage and deposition patterns, statistical tests were performed among onsite, offsite, and control stations using a one-way analysis of variance (ANOVA) for each sampling period. Differences in percentage of leaf area damage, percentage of leaves per plant damaged, aerial deposition, and deposition in pond water were tested at $p \leq 0.10$ level of significance. Temporal deposition patterns and differences in deposition among onsite stations, among offsite stations, and among control stations were also ascertained using an ANOVA at $p \leq 0.10$ level of confidence. Post-hoc comparisons performed to rank the sites for each parameter 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 SALT DEPOSITION

Monthly deposition values for sodium and chloride were adjusted to reflect a standard 30-day month (Tables 3-1, 3-2, and 3-3). The data record was continuous throughout the year at four onsite stations, three control stations, and three offsite stations, except for two missing data values at the SW Open Hammock station caused by suspected contamination. A fifth deposition collector site was added to the onsite stations at the Open Test site in March 1994, at which time deposition collection commenced for that site. A complete listing of the deposition data is included in Appendix B.

The deposition data was highly variable during this study period. The high variability made it difficult to draw definitive conclusions regarding sodium and chloride deposition, however, general results are provided below.

Mean sodium and chloride deposition was higher at onsite stations than control or offsite stations, and these differences were significant in 4 of the 12 collection periods for sodium (Figure 3-1A) and five of the 12 sampling periods for chloride (Figure 3-1B). Although control and offsite stations received the lowest sodium and chloride deposition, control stations received higher sodium deposition than offsite stations during the first 4 months of sampling (September through December). During the last 6 months of sampling (March through August) the reverse pattern occurred; sodium deposition at the offsite stations was higher than at control stations. Differences in sodium deposition between offsite and control stations were not significant ($p \leq 0.10$).

At the onsite stations, the NE Open Test and the SW Open Hammock stations received the highest total annual sodium and chloride deposition while the W Open Pine and the NW Open Pine stations received the lowest total annual sodium and chloride deposition (Figure 3-2). Deposition data from the Open Test site could not be compared with the other onsite stations because the Open Test site became operational midway through the study period. These differences in sodium and chloride deposition among onsite stations reflects a similar pattern to that observed last year, in which the SW Open Hammock site received the highest sodium deposition and the NW Open Pine received the lowest sodium deposition.

Table 3-1. Mean Monthly Sodium (Na) and Chloride (Cl) Deposition (mg/m^2) at Onsite Stations from September 1993 to August 1994

	NE Open Test		W Open Pine		SW Open Hammock		NW Open Pine		Open Test[b]		Mean	
Month[a]	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl	Na	Cl
September[c]	78	175	158	353	—	—	209	460			149	329
October[c]	228	525	235	531	—	—	253	595			239	551
November	141	296	68	158	271	513	92	198			143	291
December	588	1080	222	557	986	1786	271	569			517	998
January	371	837	178	408	579	1085	179	414			326	686
February	489	897	241	459	807	1442	234	475	482	736	450	802
March	205	430	83	159	127	426	42	101	83	159	108	255
April	215	401	252	467	141	286	138	288	184	347	186	358
May[c]	391	742	137	286	266	520	155	352	271	512	244	482
June[c]	354	704	175	349	404	852	289	569	182	404	281	576
July[c]	457	1194	433	1036	518	1257	477	1067	357	942	448	1099
August[c]	734	1598	648	1218	828	1499	557	1097	529	1206	659	1324
Site Mean (mg/m^2)	354	740	236	498	493	967	241	516	298	615		
Total Annual Deposition (mg/m^2)	4250	8879	2829	5981	4926	9665	2896	6186	2088	4306		
Annual Salt Deposition (kg/ha)	131.3		88.1		145.9		90.8		63.9			
Na/Cl Ratio	0.48		0.47		0.51		0.47		0.49			

[a] Monitoring began at the middle of the month indicated and extended to the middle of the following month. Missing values in September and October were excluded from total.
[b] The Open Test Station was installed in March 1994.
[c] Indicates months when the new cooling towers were operational.

Table 3-2. Mean Monthly Sodium (Na) and Chloride (Cl) Deposition (mg/m^2) at Offsite Stations from September 1993 to August 1994

	E Open Pine		NE Open Pine		N Open Pine		Mean	
Month[a]	Na	Cl	Na	Cl	Na	Cl	Na	Cl
September	62	131	48	121	79	162	63	138
October	158	376	164	397	246	514	189	429
November	55	103	69	135	78	176	67	138
December	206	466	154	384	187	409	182	420
January	132	343	121	335	313	636	189	438
February	173	372	148	334	277	572	199	426
March	50	104	86	160	68	158	68	141
April	88	202	68	167	70	171	75	180
May	118	264	115	259	125	303	119	276
June	98	215	97	212	141	307	112	244
July	170	440	163	461	337	906	223	602
August	184	341	185	420	351	701	240	487
Site Mean (mg/m^2)	124	280	118	282	189	418		
Total Annual Deposition (mg/m^2)	1493	3356	1416	3386	2271	5014		
Annual Salt Deposition (kg/ha)	48.5		48.0		72.8			
Na/Cl Ratio	0.44		0.42		0.45			

[a] Monitoring began at the middle of the month indicated and extended to the middle of the following month.

Table 3-3. Mean Monthly Sodium (Na) and Chloride (Cl) Deposition (mg/m^2) at Control Stations from September 1993 to August 1994

	Open Control		Hardwood Control		Coastal Control		Mean	
Month[a]	Na	Cl	Na	Cl	Na	Cl	Na	Cl
September	74	149	57	134	130	238	87	174
October	223	462	188	438	222	506	211	469
November	79	169	74	162	91	167	81	166
December	299	618	197	339	360	646	285	534
January	121	345	93	262	105	247	106	285
February	253	486	218	436	317	563	263	495
March	45	121	35	97	71	140	50	119
April	93	216	64	149	56	112	71	159
May	96	261	76	200	125	221	99	227
June	77	188	82	164	75	163	78	171
July	151	433	130	390	182	411	154	411
August	153	359	151	319	191	373	165	350
Site Mean (mg/m^2)	139	317	114	257	160	316		
Total Annual Deposition (mg/m^2)	1664	3806	1364	3089	1925	3787		
Annual Salt Deposition (kg/ha)	54.7		44.5		57.1			
Na/Cl Ratio	0.44		0.44		0.51			

[a] Monitoring began at the middle of the month indicated and extended to the middle of the following month.

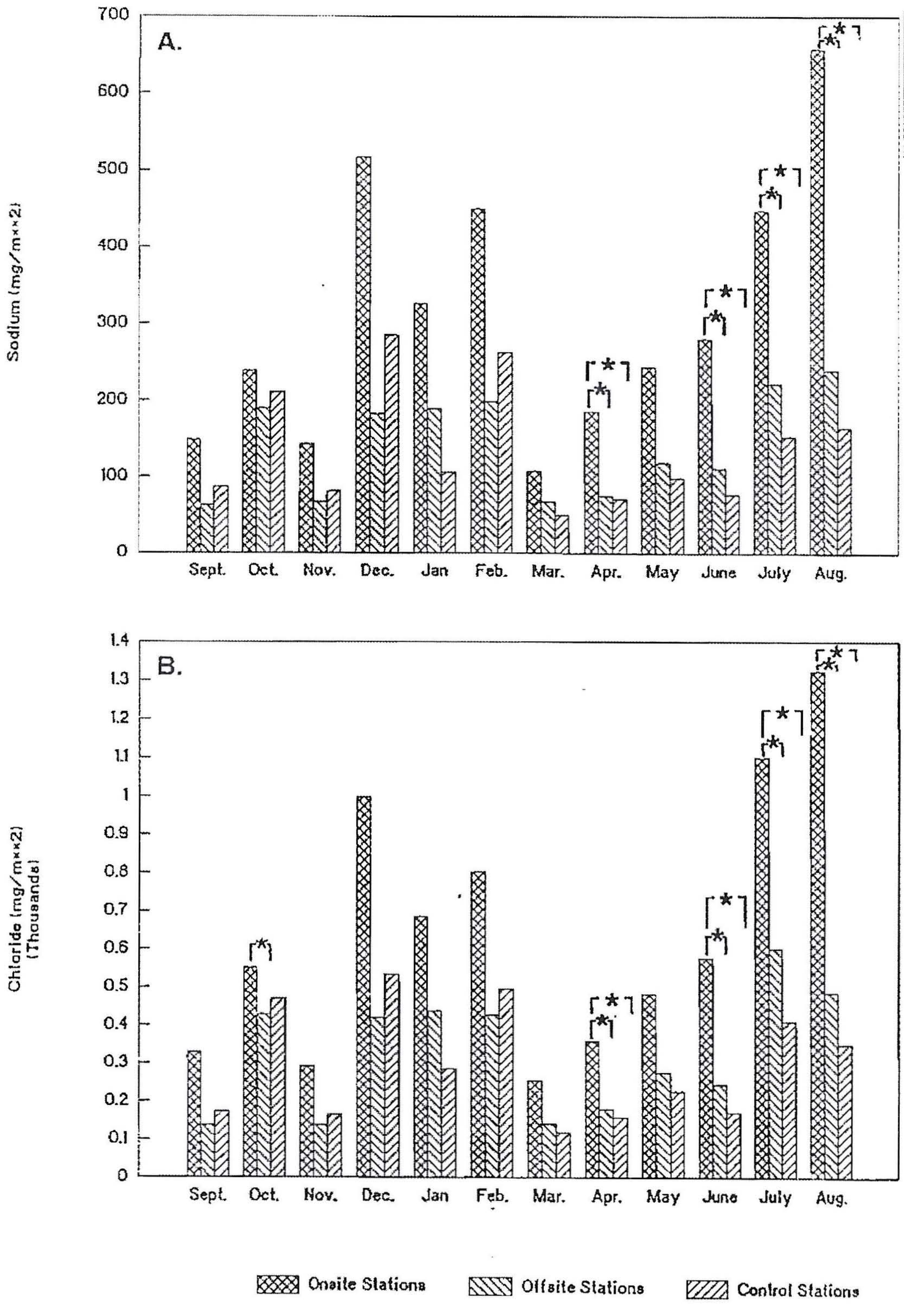

Figure 3-1
(A) Mean Monthly Sodium Deposition and (B) Mean Monthly Chloride Deposition for Onsite, Offsite, and Control Stations for the 1993-1994 Study Period

Note: * indicates a significant difference between stations

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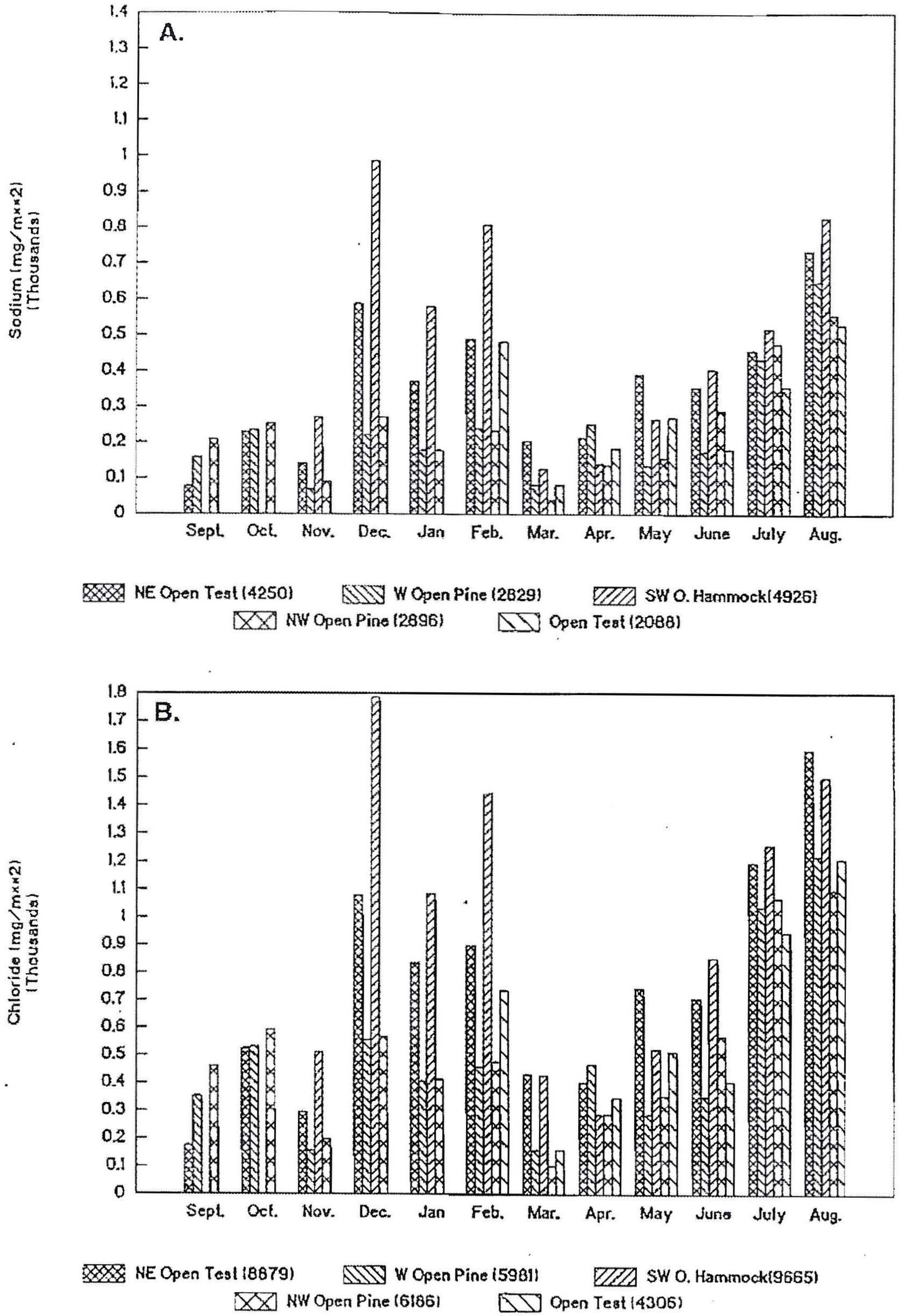

Figure 3-2
(A) Monthly Sodium Deposition and (B) Monthly Chloride Deposition for Each Onsite Station During the 1993-1994 Study Period

Note: * The Open Test Station became operational in February.
(Numbers in parentheses indicate total annual deposition)

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At the offsite stations, the N Open Pine received substantially more total annual sodium and chloride deposition while the E Open Pine and NE Open Pine stations received comparative levels of sodium and chloride (Figure 3-3). This pattern partially reflects lasts years deposition pattern in which the N Open Pine station received the highest sodium and chloride deposition.

A comparison of sodium deposition among control stations revealed that the highest total annual sodium deposition occurred at the Coastal Control station (1925 mg/m^2), an intermediate amount was deposited at the Open Control station (1664 mg/m^2), and the lowest level occurred at the Hardwood Control station (1364 mg/m^2; Figure 3-4A). A different pattern occurred for chloride deposition where the Open Control site received slightly more chloride than the Coastal Control site (Figure 3-4B). This pattern is opposite of that observed last year in which the Coastal Control station received the lowest sodium deposition and the Hardwood Control station received the highest sodium deposition.

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 ranged from 0.47 to 0.51 (Table 3-1), which was lower than that expected for marine deposition. Data from previous years also have shown a lower sodium to chloride ratio than expected.

3.2 SURFACE WATER SAMPLING

Surface water samples collected from one onsite station (NW Open Pine), two offsite stations (N Open Pine and NE Open Pine), and one control station (Hardwood Control) showed high concentrations of both sodium and chloride in November, followed by a decline in concentration from January through September (Table 3-4 and Figures 3-5A and 3-5B). This pattern was consistent for all four sites except the NW Open Pine site, which had relatively low concentrations throughout the study period. The pond water at the Hardwood Control site exhibited the highest sodium and chloride concentrations in November and January, but declined in concentration for the remaining three sampling periods in July and September. Dilution from high rainfall presumably led to low sodium and chloride concentrations in pond water in the summer months.

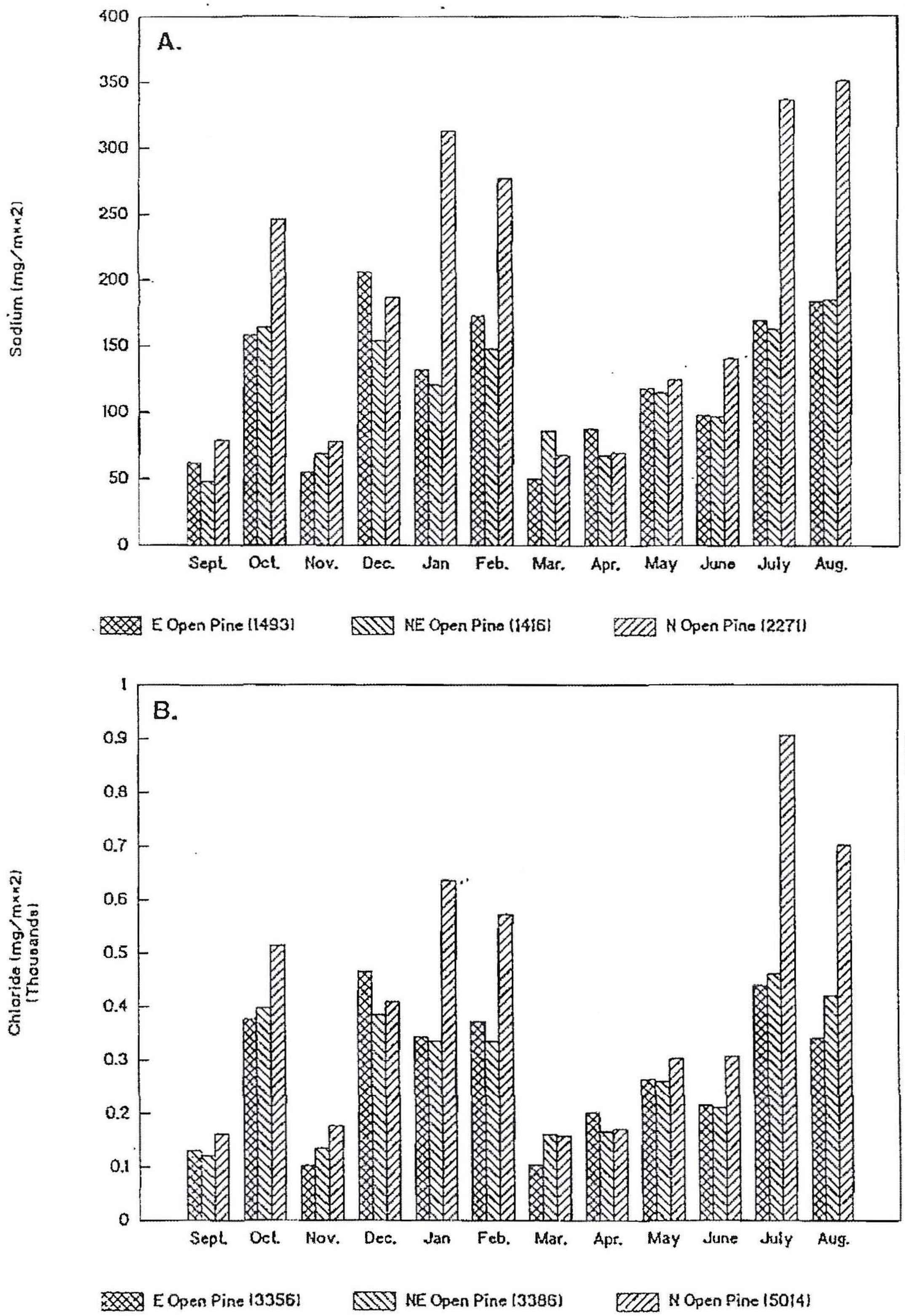

Figure 3-3
(A) Monthly Sodium Deposition and (B) Monthly Chloride Deposition for Each Offsite Station for the 1993-1994 Study Period

Note:
(Numbers in parentheses indicate total annual deposition)

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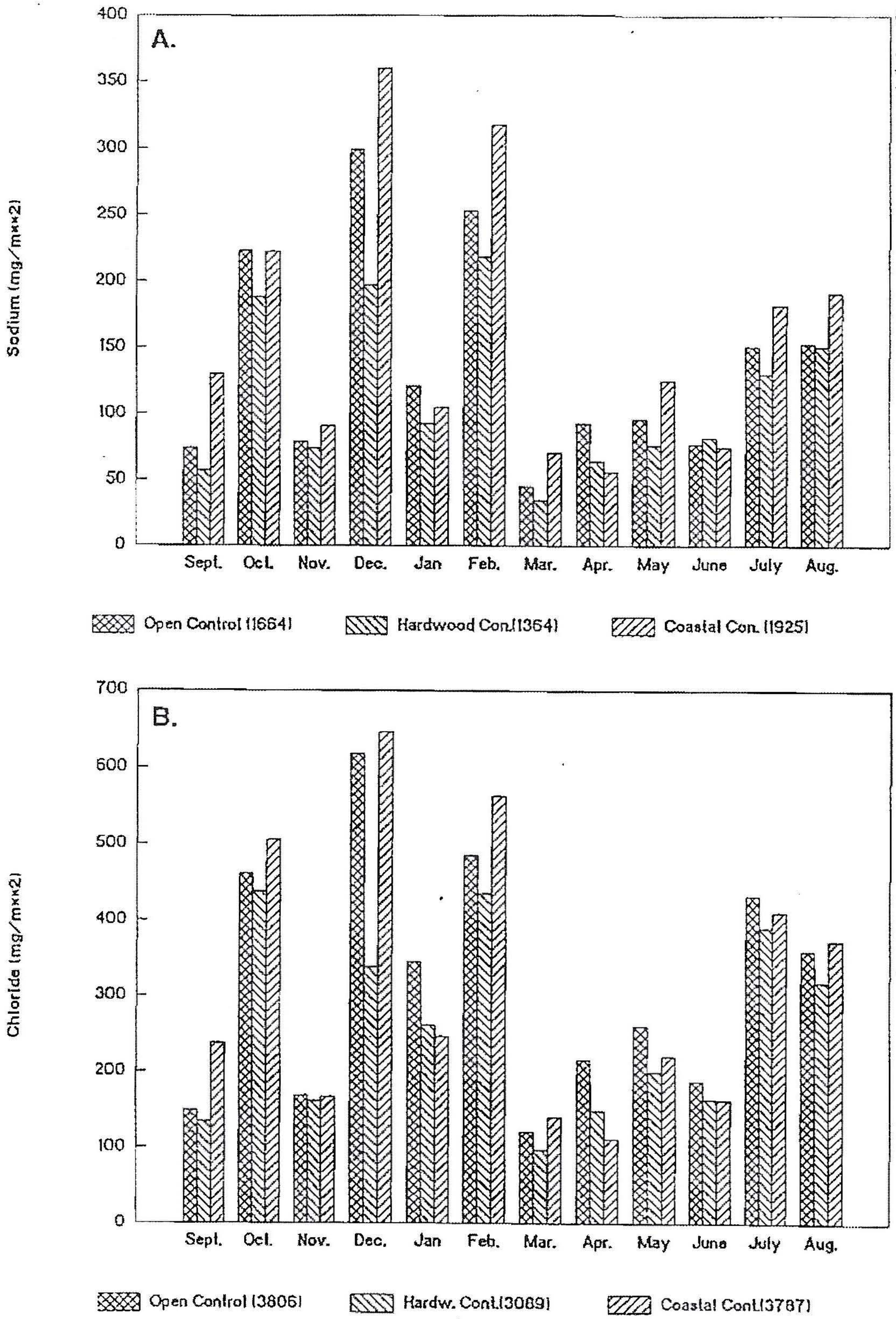

Figure 3-4
(A) Monthly Sodium Deposition and (B) Monthly Chloride Deposition for Each Control Station for the 1993-1994 Study Period

Note:
(Numbers in parentheses indicate total annual deposition)

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Table 3-4. Pond Deposition Data for 1993-1994

	Pond at NWOP		Pond at HC		Pond at NEOP		Pond at NOP	
Sample Period	Na	Cl	Na	Cl	Na	Cl	Na	Cl
November 15, 1993	307.5	478.5	903.5	1420.5	547.5	929.5	572.5	929.5
January 17, 1994	216.6	336.0	476.9	788.0	336.2	515.5	391.9	580.5
May 16, 1994	282.0	461.5	96.1	197.5	163.1	245.5	238.8	314.0
July 15, 1994	274.5	566.5	253.0	440.5	135.0	262.0	82.0	156.5
September 16, 1994	157.0	254.0	97.5	128.0	102.5	167.5	290.5	396.0

Note: Sodium (Na) and Chloride (Cl) values are presented as parts per million (ppm). April-May deposition was not determined.

NWOP = Northwest Open Pine.
HC = Hardwood Control.
NEOP = Northeast Open Pine.
NOP = North Open Pine.

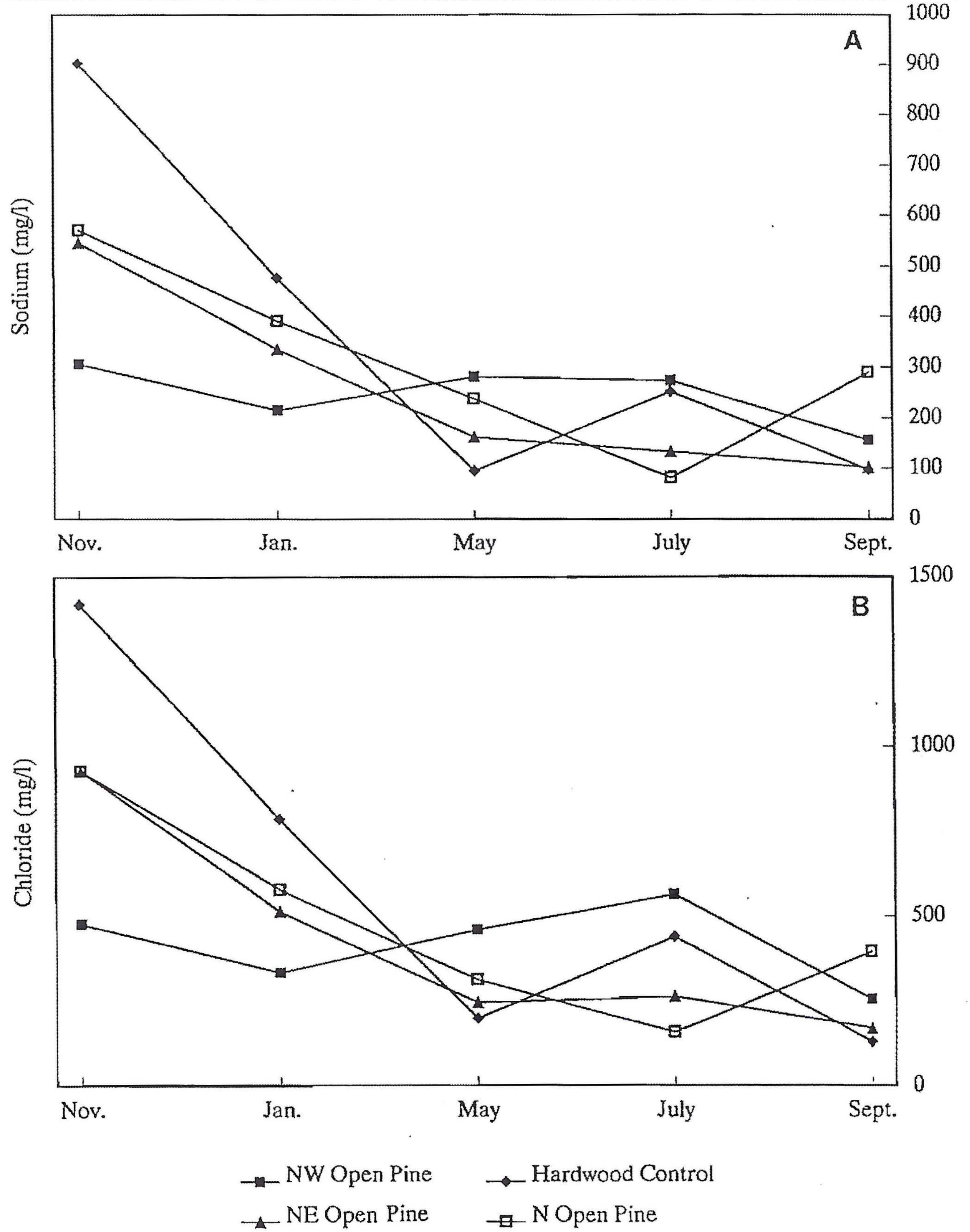

Figure 3-5
(A) Sodium Concentration and (B) Chloride Concentration in Pond Water for the 1993–1994 Study Period

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3.3 MONTHLY AND QUARTERLY VEGETATION MONITORING

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, and leaf spotting and decay prior to seasonal leaf senescence.

3.3.1 BACKGROUND VEGETATION OBSERVATIONS

Annual mean leaf area injury from insects and other natural causes for the 1993-1994 monitoring period was 19.9 percent for onsite stations, 20.5 percent for offsite stations, and 20.7 percent for control stations (Table 3-5). Leaf area injury was most similar among onsite, offsite, and control stations during the November and February quarterly monitoring events (Figure 3-6A). However, significant site differences were detected in May and August, when leaf area injury was significantly higher at control stations than onsite stations in May, and significantly higher at control stations than offsite stations in August. Leaf injury continued to be lowest in May and in August when most plants were new and had little exposure to insects or other damaging factors. These results are consistent with the last 6 years of vegetation monitoring, in which lowest leaf area injury occurred in May and in August (Table 3-6 and Figure 3-7). Mean leaf area injured was highest for deciduous species such as redbud, red maple, and sweetgum, and for the two evergreen species red bay and wax myrtle (Table 3-5). Evergreen species such as dahoon holly, red cedar, saw palmetto, slash pine, and yaupon holly sustained among the lowest percentage leaf area injured of those plant species studied.

Annual mean number of leaves injured per plant was very similar among station types, and was 33.6 percent for onsite stations, 34.8 percent for offsite stations, and 34.8 percent for control stations (Table 3-7). Number of leaves injured per plant was also similar among stations for each of the four quarterly monitoring events (Figure 3-6B). An exception to this observation occurred in November when percentage of leaves injured per plant was significantly higher at offsite stations than control stations. Fewer leaves per plant were injured during May and August for onsite, offsite, and control stations. The species which sustained the highest percentage of leaves injured were red bay, redbud, red maple, sweetgum, and wax myrtle, and the species with the

Table 3-5. Summary of Average Leaf Area Injured (Percent) from All Causes During the 1993-1994 Monitoring Period

	Onsite Stations				Offsite Stations				Control Stations				Annual Mean		
Species	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Onsite Stations	Offsite Stations	Control Stations
Cabbage Palm	36.5	14.8	11.0	9.5	36.7	14.0	15.0	9.6	37.9	19.2	15.6	12.1	18.8	20.1	22.2
Dahoon	21.4	22.9	10.7	11.9	22.5	15.0	8.3	13.3	18.0	13.8	8.0	10.0	17.9	15.5	13.3
Ferns	38.0	25.0	6.7	24.7	40.0	10.0	10.0	—	19.0	33.8	8.3	16.0	24.1	16.0	19.7
Live Oak	35.4	30.3	10.9	14.1	29.0	27.0	7.5	12.8	17.5	22.5	10.0	10.0	24.3	20.6	19.0
Red Bay	48.0	35.0	26.7	25.0	43.0	36.7	38.0	32.5	47.0	30.6	35.0	37.8	35.0	37.2	38.1
Redbud	60.0	—	23.3	36.7	—	—	—	—	—	—	—	25.0	40.0	—	25.0
Red Cedar	15.3	10.7	8.9	7.9	6.7	9.3	6.7	5.0	11.0	10.8	7.5	6.1	10.9	7.0	9.1
Red Maple	70.0	—	10.0	10.0	79.2	—	17.5	25.0	44.0	—	5.0	30.0	32.5	56.0	36.4
Salt Bush	19.0	8.1	5.0	10.0	31.4	24.5	14.2	10.5	23.8	18.8	8.3	7.8	10.9	19.8	15.0
Saw Palmetto	23.8	11.5	7.1	8.3	30.4	11.5	14.4	7.8	24.0	15.0	9.2	8.3	13.5	17.0	15.5
Slash Pine	22.0	21.3	—	5.8	23.7	34.5	10.0	5.0	66.7	—	—	—	13.8	20.1	66.7
Sweetgum	52.5	—	12.1	22.7	76.0	—	5.0	10.0	55.0	—	13.8	20.8	31.8	34.5	30.3
Wax Myrtle	37.2	27.6	19.4	22.4	34.6	31.7	13.3	18.2	35.0	23.9	41.7	39.4	27.5	25.7	34.4
Yaupon	28.8	15.8	5.7	9.5	16.7	9.6	5.0	5.0	19.2	10.4	7.1	6.8	16.6	11.4	11.4
Mean of all Groups	31.9	18.6	10.9	13.8	31.5	21.0	13.2	11.6	29.2	18.2	16.0	16.0	19.9	20.5	20.7

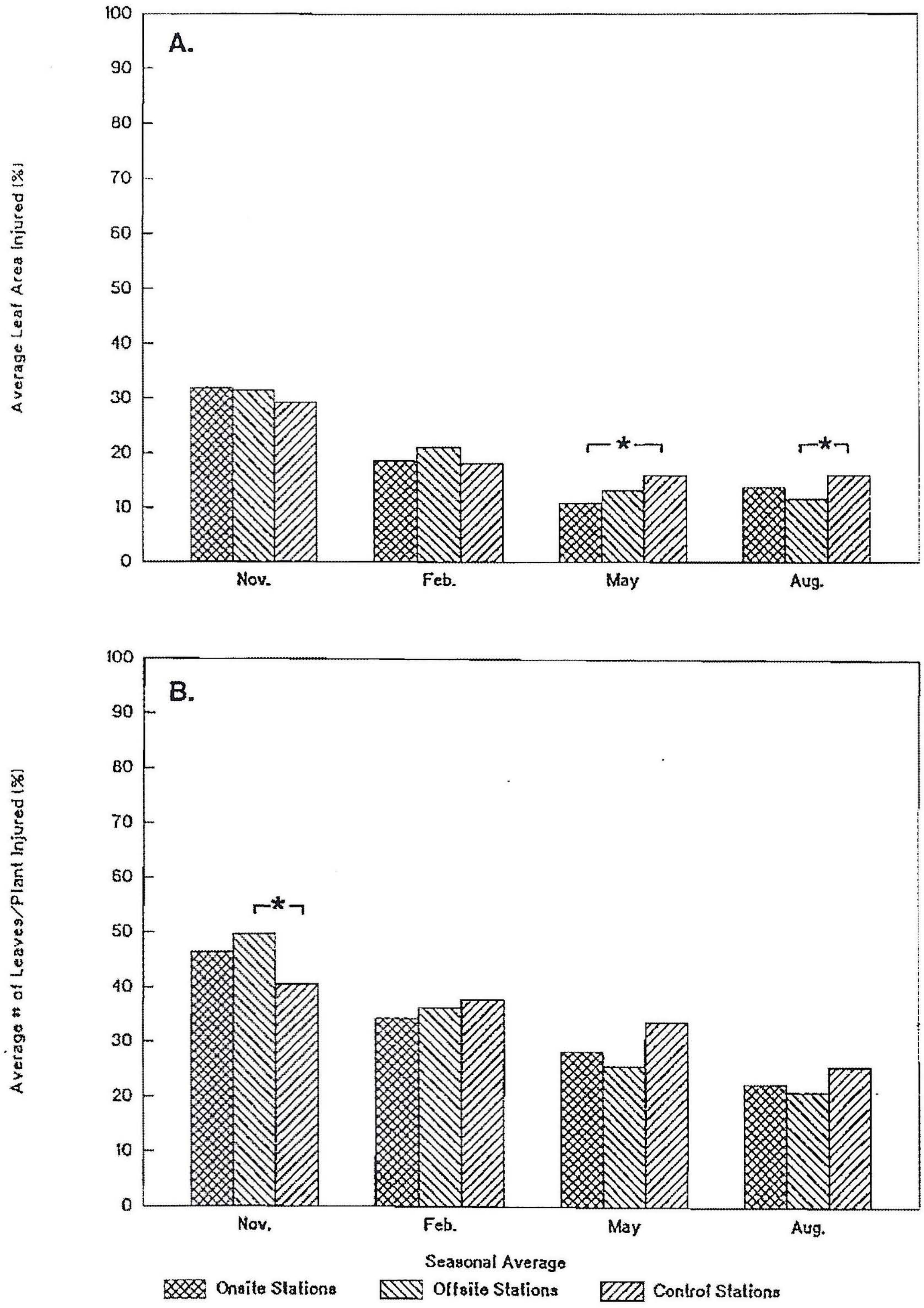

Figure 3-6
(A) Average Percent Leaf Area Injured from all Causes, and (B) Average Percent of Leaves Injured Per Plant Among Onsite, Offsite, and Control Stations During the 1993-1994 Study Period

Note: * Indicates a significant difference between stations.

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Table 3-6. Summary of Average Leaf Area Injured (Percent) from All Causes from 1987 to 1993, Crystal River

	1987 - 1988				1988 - 1989				1989 - 1990			
Plant Group	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
Oaks	12	32	40	8	11	11	0	8	7	28	9	9
Sweetgum	11	4	3	5	23	0	1	3	9	1	5	12
Red Maple	33	0	1	8	7	1	1	5	5	0	3	12
Dahoon	7	7	8	5	4	10	5	2	3	4	2	3
Yaupon	1	3	7	5	4	10	1	1	1	4	3	1
Pine	7	2	0	2	0	0	0	0	1	0	1	1
Ferns	3	42	0	1	6	4	0	1	2	9	0	0
Greenbriers	8	14	5	2	20	2	4	3	10	28	5	15
American Beautyberry	10	0	7	17	40	0	0	15	38	1	0	11
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

	1990 - 1991				1991 - 1992				1992 - 1993			
Plant Group	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug
Southern Magnolia	14	30	10	3	2	9	2	9	4.5	10.0	1.0	10.0
Oaks	9	22	4	11	13	16	7	8	11.1	9.2	5.7	6.6
Sweetgum	21	0	1	8	12	0	1	6	21.1	5.9	6.5	11.4
Red Maple	15	0	0	6	7	0	0	5	6.5	0	13.0	7.2
Dahoon	3	4	2	3	3	3	3	5	2.0	2.3	1.8	1.9
Yaupon	1	3	2	5	3	9	2	6	1.9	1.7	0.4	0.5
Pine	1	0	0	1	2	2	0	8	0.6	0.5	7.3	0.9
Ferns	3	4	6	7	3	30	3	5	8.4	23.5	5.0	13.5
Greenbriers	8	8	5	11	15	9	8	4	7.4	10.1	3.3	5.3
American Beautyberry	28	-[a]	1	13	8	-[a]	5	9	23.2	[a]	0.1	19.7
Mean of All Groups	10.1	7.9	7.7	6.8	6.8	8.7	3.1	6.5	8.7	7.0	4.4	7.7

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

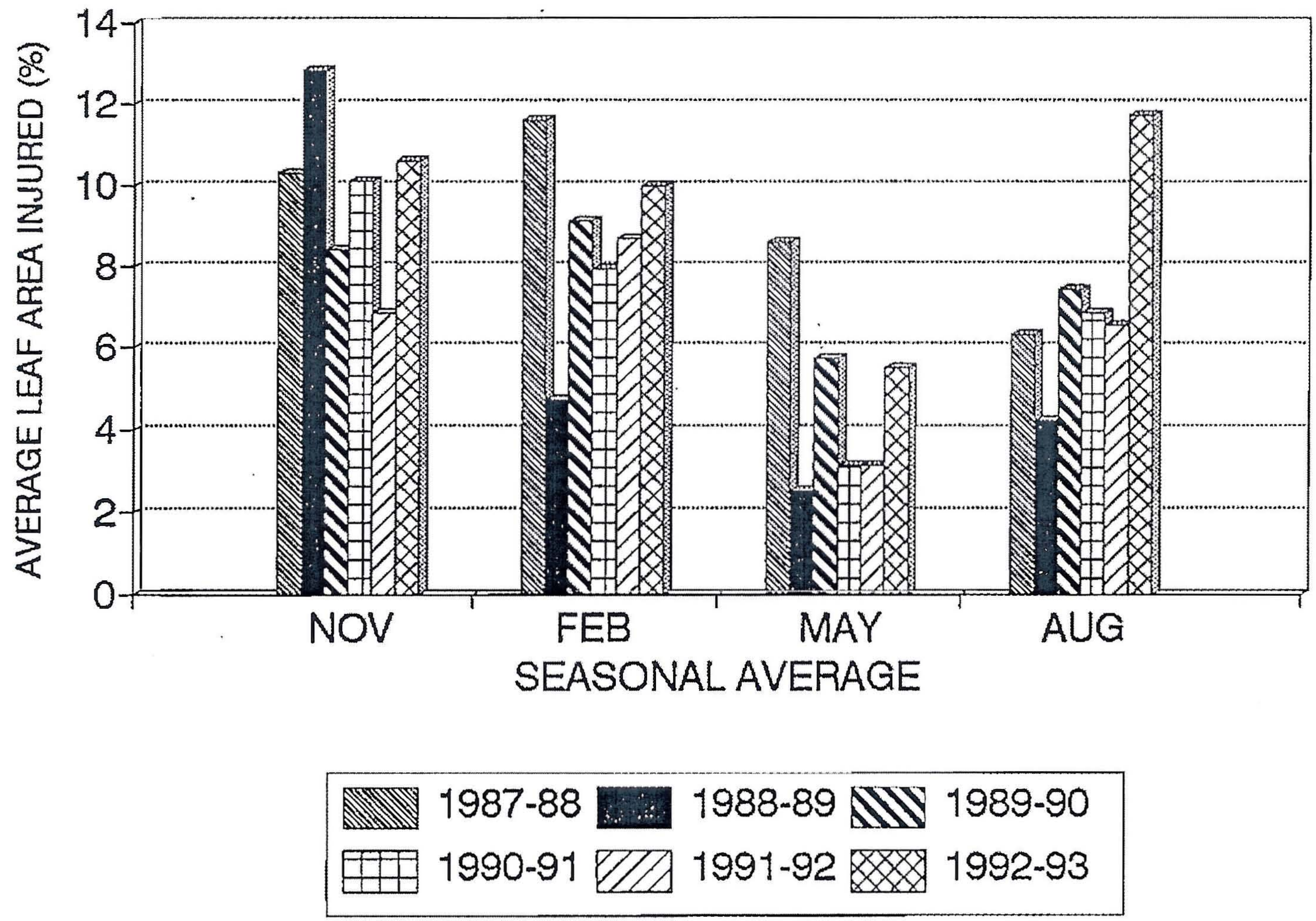

Figure 3-7
Average Leaf Area Injured from all Causes for Onsite Stations from 1987 through 1993

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lowest number of leaves injured per plant were red cedar, slash pine, and yaupon holly (Table 3-7). These plant species were among the same species reported above that also sustained among the highest and lowest leaf areas injured.

For all plants examined, the percentage of plants considered to be in good condition for each monthly survey ranged from 39.4 to 66.4 percent, while the number of plants dead or in poor condition ranged from 13.9 to 24.0 percent (Table 3-8). Plants categorized in moderate condition ranged from 18.9 to 41.4 percent. The highest number of plants in good condition occurred during the early and mid growing season from March through August, while the greatest number of plants in poor/dead condition were observed during the dormant season from December through March (Table 3-8). These data are consistent with those data presented in Figure 3-6, which show that the lowest plant injury occurred during the growing season in May and August, while the highest plant injury occurred during the nongrowing season in November and February.

Canopy dieback of primarily live oaks was observed in several locations throughout the Crystal River Power Complex as well as at or near the control stations (Figure 3-8). The area of greatest concern extends from the SW Open Test site north to the Hardwood site and west along the edge of the hammock. Many of the oaks in this region sustained over 50 percent canopy dieback, and living foliage was generally restricted to stem sprouts from branches greater than 4 inches in diameter. This canopy dieback appears to end at the south, southwest, and southeast side of the Hardwood site; a fuller and more healthy live oak canopy was documented north of the Hardwood site. A dieback of oaks was also reported near the W Open Pine station, but only during the November monitoring event.

Some dieback of sweetgums, red bays, and live oaks has continued adjacent to the Open Control station within and near the railroad loop. Similar dieback was observed at the Hardwood Control station and at the northwest corner of the power complex just east of the conveyor belt. Red maples and blackgums located in the sawgrass marsh just west of the NE Open Test site have shown extensive stem dieback and leaf loss. The remaining foliage on many red maples was confined to the main stem and several of the trees have died.

The effects of the unnamed tropical storm which struck the area in March 1993 are still evident at the Coastal Control site. Several dead cabbage palms were noted in the open tidal marsh,

Table 3-7. Summary of Average Number of Leaves Injured (Percent) from All Causes During the 1993-1994 Monitoring Period

	Onsite Stations				Offsite Stations				Control Stations				Annual Mean		
Species	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Nov	Feb	May	Aug	Onsite Stations	Offsite Stations	Control Stations
Cabbage Palm	37.8	20.7	29.5	11.8	33.3	18.3	27.5	10.0	35.4	23.5	39.4	12.9	24.2	22.1	27.3
Dahoon	32.7	42.5	22.1	15.0	17.5	25.0	10.0	23.3	20.5	35.6	10.0	17.1	30.1	17.7	22.0
Ferns	54.0	41.3	13.9	29.4	100.0	15.0	11.7	—	28.0	50.0	8.3	15.0	34.1	30.0	25.9
Live Oak	65.4	71.0	30.9	26.8	72.0	64.5	23.3	18.3	25.0	80.0	25.0	25.0	50.7	47.7	58.0
Red Bay	75.0	75.0	86.7	53.8	83.0	73.3	69.0	54.2	72.5	66.1	63.3	55.0	71.9	69.8	64.6
Redbud	96.7	—	41.7	61.7	—	—	—	—	—	—	—	75.0	66.7	—	75.0
Red Cedar	21.3	17.0	15.7	9.2	6.3	11.3	11.1	6.1	12.3	14.6	10.8	7.1	15.9	8.5	11.2
Red Maple	96.7	—	45.0	57.5	92.5	—	30.0	80.0	90.0	—	60.0	90.0	67.5	77.5	85.7
Saltbush	24.0	12.3	7.5	12.0	78.6	55.0	32.5	26.5	32.5	37.5	11.7	12.2	14.5	47.3	23.1
Saw Palmetto	27.4	12.7	41.1	8.9	38.3	12.0	20.0	10.6	26.5	14.4	56.7	8.3	20.6	21.4	25.3
Slash Pine	19.3	50.0	—	6.3	31.7	41.5	10.0	6.4	25.0	—	—	—	16.1	25.4	25.0
Sweetgum	90.0	—	25.0	55.3	100.0	—	43.3	32.0	95.0	—	47.5	57.5	61.1	60.8	67.3
Wax Myrtle	59.6	58.0	50.6	41.7	87.1	60.0	28.9	37.9	80.5	79.4	58.3	67.2	52.9	56.0	72.8
Yaupon	40.6	26.7	6.1	13.4	23.3	13.3	5.0	6.7	24.6	21.9	7.1	8.2	24.3	15.8	16.7
Mean of all groups	46.4	34.4	28.4	22.6	49.7	36.4	25.8	21.1	40.6	37.9	33.8	25.7	33.6	34.8	34.8

Table 3-8. Summary of Plant Condition (Percent) Noted in Monthly Qualitative Surveys, from All Causes, 1993-1994 (includes plants from onsite, offsite, and control stations)

	Vegetation Condition Class		
Month	Good	Moderate	Poor/Dead
September	44.6	31.4	24.0
October	51.6	30.1	18.3
November	47.2	36.1	16.7
December	39.4	41.4	19.2
January	46.6	33.0	20.4
February	40.0	37.8	22.2
March	55.5	21.8	22.8
April	55.7	27.1	17.2
May	56.6	29.5	13.9
June	55.6	28.5	15.9
July	59.5	25.4	15.1
August	66.4	18.9	14.7
Range	39.4 to 66.4	18.9 to 41.4	13.9 to 24.0

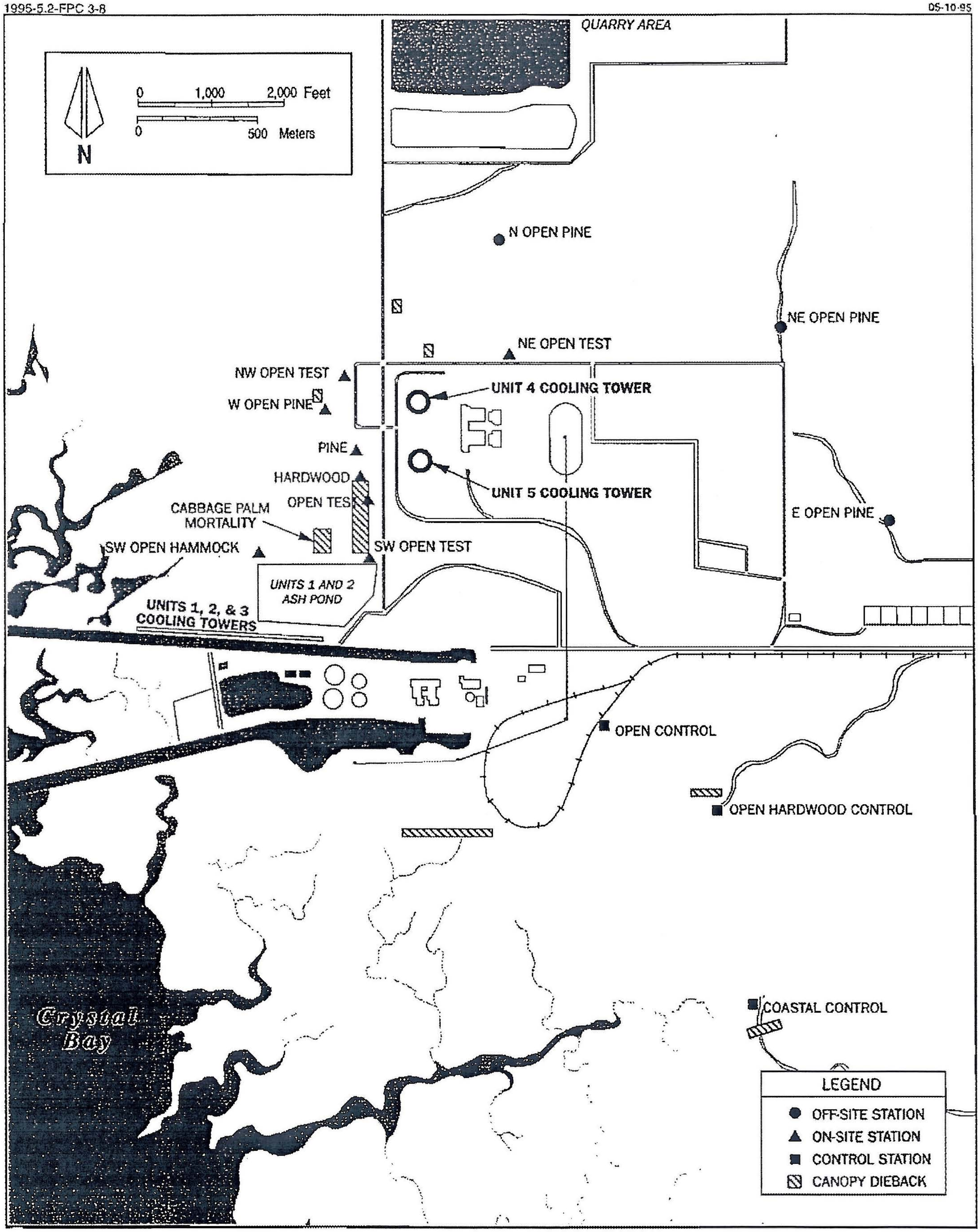

Figure 3-8
Approximate Location of Canopy Dieback

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whereas palms nearest and within the upland islands were thriving. Many of the non-holophytic species, including red bay, coontie, and American beautyberry have died since the storm. Red cedars at this station showed severe foliar dieback and several cedars have perished. Live oak dieback has continued at the Coastal Control station, with roughly 20 percent loss in oaks along the edge of the marsh. After the March 1993 tropical storm struck, many clumps of ferns appeared to have perished. However, in December 1993 several ferns at the SW Open Test, W Open Test, Pine, and Hardwood stations began to produce new fronds from the root stock. These ferns have flourished during the 1993/1994 study period.

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 improved at most sites, with a predominance of healthy green foliage in May through July 1994. In August 1994 the overall health and vigor of several cabbage palms at the SW Open Hammock site began to decline. The most stressed individuals appear to be located in the lowest areas along the edge of the water. The cabbage palms at this site have continued to exhibit an accelerated rate of mortality, with the demise of up to 24 palms by the end of 1994. Regeneration, or the production of seedlings, of cabbage palms was high throughout the SW Open Hammock even in areas where palm mortality had occurred.

Chlorosis has been observed in slash pines scattered throughout the onsite and offsite stations intermittently during this study period as well as during previous study periods. Chlorosis was most pronounced in those trees located near marshes and appeared to be related to saturated soil conditions. An additional contributor to the chlorosis may be lack of available substrate for the root structure of the pine trees, as rock outcropping and rock substrate is common in the area.

3.3.2 SALT DRIFT VEGETATION OBSERVATIONS

Qualitative observations revealed that vegetation in most locations showed few symptoms indicative of salt drift injury. In several instances when an individual plant was observed to be symptomatic, other nearby plants of the same species were asymptomatic. This suggests that even when salt drift damage was suspected those occurrences were isolated events which only affected a minimal number of individual plants. Apparent salt drift damage was observed on a few plants

at 5 of the 14 vegetation study sites, the SW Open Test, W Open Test, W Open Pine, NW Open Test, and Pine stations. All of these study sites were onsite stations; there were no instances of salt drift damage observed at control or offsite stations. The most frequent observations of apparent salt drift damage were reported along the west edge of the transmission line corridor between the SW and W Open Test stations. Vegetative stress indicative of salt drift damage was reported in this area during 7 of the 12 monthly monitoring events. Species affected were redbud (T8), red maple, live oak, sweetgum, grapevine, wax myrtle, and popash. A synopsis of vegetative conditions as related to conditions symptomatic of salt drift damage is provided in Table 3-9.

Table 3-9. Vegetative Conditions Indicative of Salt Drift Damage (Page 1 of 2)

Month	Observations
September	A dahoon holly (T13), red maple, and wax myrtle at the NW Open Test site exhibited leaf deformities indicative of salt drift damage. Only the side of the plant which faced the cooling towers was affected. Other nearby plants of the same species showed no effects.
October	Several red maples at the NW Open Test site had substantial dieback and necrotic leaf margins consistent with salt injury. Carolina willow, grapevine, and saltbush had necrotic leaf margins and leaf deformities. These symptoms were most prevalent on the east and southeast side of the plant which faced the cooling towers.
	At the W Open Pine site, several sweetgums and winged sumacs exhibited necrosis of the leaf margin, tip, and interveinal area.
	Salt drift symptoms in individual red maple, live oak, sweetgum, redbud, and grape at the Open Test Station were evident.
November	A winged sumac (W8) at the W Open Pine site exhibited characteristics symptomatic of salt drift damage. Other winged sumacs at the W Open Pine station exhibited extensive branch dieback and sweetgums contained necrotic leaf tissue.
	At the SW and W Open Test stations a popash exhibited severe tip necrosis and branch dieback. A red maple also exhibited these symptoms, although the necrosis was less pronounced. Several sweetgums and redbuds were also symptomatic.
	Sweetgums at the Pine station exhibited necrotic leaf margins, leaf curling, and dieback in the upper canopy.
December	Several wax myrtles at the NW Open Test site showed noticeable leaf margin deformities.
January	No salt drift damage to vegetation noted. Species that have exhibited salt drift damage in the past, such as red maple, sweetgum, and winged sumac were without leaves during this winter monitoring event.
February	Approximately four oaks at the Open Test station had necrotic tips and margins. Other oaks in the vicinity showed no effects.
March	Approximately four oaks at the Open Test station exhibited burned leaf margins.
April	A redbud tree (T8) located at the SW Open Test site exhibited burned leaf margins on roughly 40 percent of the leaves. Several species that exhibited salt drift damage in the past, such as red maple, sweetgum, live oak, and winged sumac all had new leaves and were very healthy in appearance.

Table 3-9. Vegetative Conditions Indicative of Salt Drift Damage (Page 2 of 2)

Month	Observations
May	The red bud (T8) at the SW Open Test site continued to have burned leaf margins on roughly 40 percent of the leaves. One live oak at the Open Test site exhibited contorted new growth. Other nearby oaks and redbuds appeared unaffected.
June	At the SW and W Open Test site a few live oaks, sweetgums, and wax myrtles exhibited burned leaf margins characteristic of salt drift damage. This was not widespread with respect to number of individuals or number of leaves affected per plant. The redbud (T8) continued to show apparent salt drift damage.
July	At the SW and W Open Test stations the following salt drift observations were noted: a stand of grape vines exhibited burned leaf margins that encompassed roughly one-third of the leaves; a wax myrtle had mottled and necrotic leaves; and the redbud (T8) was almost completely defoliated with the remaining few leaves discolored.
August	Several sweetgums along the SW and W Open Test Station exhibited numerous necrotic spots and burned leaf margins, while other sweetgums lacked these symptoms and showed high growth and vigor.

4.0 DISCUSSION

In coastal and maritime communities, natural background levels of salt deposition determine to a large degree the biotic composition. This is evident on the high energy Atlantic coast where salt spray caused by wind has produced a zonation of vegetation in sand dune communities and maritime forests (Boyce 1954, Martin 1959). Although not as visual, a zonation of salt-tolerant species also occurs in the region of the Crystal River Power Complex where the most salt-tolerant species occur closest to the coast. Studies of coastal vegetation in various parts of the country have shown that natural deposition levels of 1680 to 4500 kg/ha-yr may be experienced in highly exposed beach-dune areas (Van der Valk 1974, Profitt 1977), while levels of 150 to 400 kg/ha-yr have been recorded in areas supporting maritime forests and coastal hammock vegetation which are less exposed to salt spray (Art 1971, Van der Valk 1974, Fletcher 1975, Profitt 1977). These deposition levels can rise when coastal storms deposit large amounts of background salt onto the vegetation.

Preoperational or ambient baseline deposition levels were measured at the Crystal River Power Complex prior to construction of the cooling towers, and ranged from 34.9 to 66.7 kg/ha-yr (KBN 1988a). This range in deposition is considerably less than that reported above by Art (1971), Van der Valk (1974), Fletcher (1975), and Profitt (1977) for less exposed maritime forests and coastal hammocks. However, these values are thought to be lower than what actually occurred because the deposition collectors were placed in forested areas, and the tree canopy may have intercepted some of the sodium and chloride. Supporting documentation as well as deposition measurements made during the unnamed coastal storm which struck in March 1993 show that background levels of deposition can rise substantially during the storm events, far exceeding deposition from cooling towers (KBN, 1994)

During preparation of the Environmental Impact Statement produced for the Crystal River Units 4 and 5 (EPA 1981), maximum salt deposition was estimated through mathematical modeling to be 127.2 kg/ha-yr, which would occur at a point 0.2 miles west of the cooling towers. Annual deposition measured at the deposition monitoring stations for the 1993 - 1994 study period shows that four of the five onsite stations (NE Open Test, NW Open Pine, W Open Pine, and SW Open Hammock) and one offsite station (N Open Pine) exceeded the ambient or preoperation deposition levels of 34.9 to 66.7 kg/ha-yr predicted for the site, while only two of these sites, the NE Open

Test and the SW Open Hammock, exceeded the predicted maximum salt deposition of 127.2 kg/ha-yr (Figure 4-1). The highest level of deposition occurred at the SW Open Hammock site which is adjacent to a salt marsh. It is theorized that a substantial amount of salt spray recorded at this site originates from the adjacent salt marsh, while substantially less salt spray is emitted from the original Units 4 and 5 cooling towers, as well as the new cooling towers. Hence, background levels of salt spray are thought to contribute most significantly at the SW Open Hammock site. The NE Open Test site, the site which received the second highest level of salt drift, is located next to two small open water bodies. It is conceivable that a small amount of salt spray recorded at this site can be attributed to salt spray from these aquatic systems during times of heavy winds, although the majority of the salt spray probably comes from the adjacent Units 4 and 4 cooling towers.

The Open Test site was the only onsite station that did not exceed ambient deposition levels, however, this station was installed midway through the study period and was only operational for 7 of the 12 months of monitoring. A comparison of the 7 months of deposition data measured at the Open Test with deposition data during the same 7 months from the other onsite stations shows that deposition was higher at the Open Test site than the W Open Pine or NW Open Pine sites, two of the stations which exceeded ambient deposition levels, but lower than the NE Open Test and SW Open Hammock, the two stations which exceeded predicted maximum salt deposition based on mathematical modeling (Table 4-1). It seems safe to assume that annual deposition at the Open Test site in all likelihood exceeded ambient deposition, but it is unclear whether this site would have exceeded predicted maximum salt deposition. The current 1994-1995 study period should provide sufficient data for the Open Test station, which is important because it is the only station that is located 0.2 miles west of the cooling tower, the distance specified in the mathematical model for predicting maximum salt deposition.

Salt drift injury as evidenced by chlorotic leaves or needles, leaf hypertrophy, tip or margin damage, and small or deformed leaves was observed at five onsite stations, (SW Open Test, Open Test, W Open Pine, NW Open Test, and Pine), however, occurrences of salt drift injury appeared to be isolated events which were limited to a relatively few individuals and in a small band of forest located west of the cooling towers. All of these sites exceeded ambient deposition levels or were located adjacent to a deposition monitoring station which exceeded ambient levels (Figure 4-1). Of these five sites, the area along the edge of the transmission line ROW between

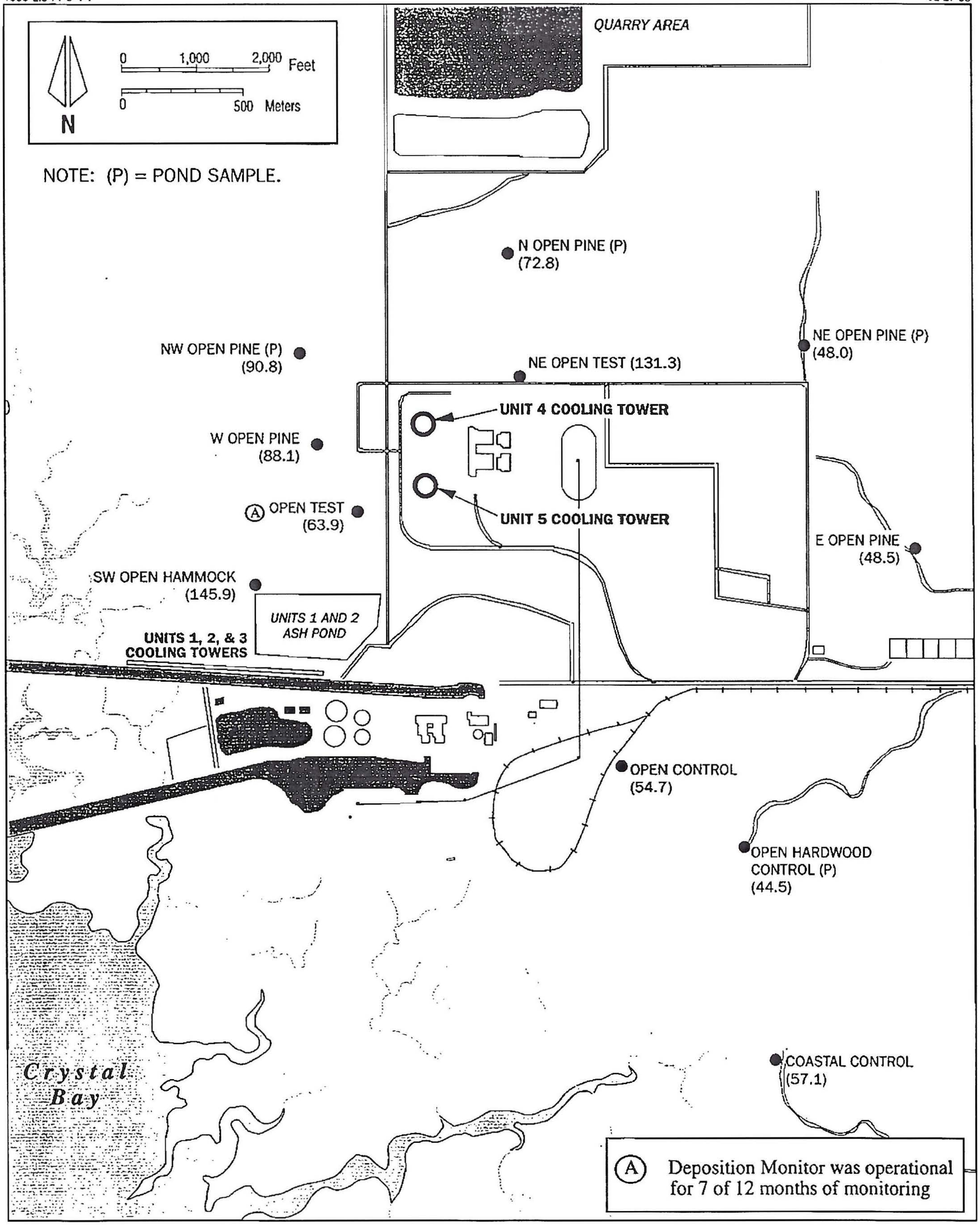

Figure 4-1
Annual Deposition of Total Salt (kg/ha) at Deposition Monitoring Sites, (September 1993 to August 1994)

KBN

Table 4-1. Total and Mean Sodium and Chloride Deposition at Onsite Stations from February 1994 through August 1994[a]

		NE Open Test	W Open Pine	SW Open Hammock	NW Open Pine	Open Test
Sodium	Total	2,845	1,969	3,091	1,892	2,088
	Mean	406.4	281.3	441.6	270.3	298.3
Chloride	Total	5,966	3,974	6,282	3,949	4,306
	Mean	852.3	567.7	897.4	564	615.1

[a] The new Open Test deposition collector became operational during this period.

the SW Open Test and the Open Test contained the most frequently observed salt drift damage (7 out of 12 monthly monitoring events). Species affected in this area were redbud, red maple, live oak, sweetgum, grapevine, wax myrtle, and popash. In several instances when an individual plant was observed to have symptoms indicative of salt drift damage, other nearby plants of the same species were asymptomatic. However, defoliation and canopy dieback of primarily live oaks and to a lesser degree sweetgums and red maples has also occurred in this forested area. Therefore, for the second consecutive study period, the study has been confounded because possible salt drift damage has been noted in species and locations that correspond to the same areas where canopy dieback has occurred. In most instances when salt drift injury was suspected on a plant, only one or a few individuals were symptomatic, whereas the canopy dieback affected a larger number of trees in the area.

Several studies have indicated that salt injury is caused by accumulation of chloride in leaves (Bernstein, et al 1956, Boyce 1954, Martin 1959, Freudenthal and Beals 1978) and is directly related to total salts deposited on the leaf surface. In general, the potential for botanical injury is dependent upon the concentration of salt deposition, the length of time salt accumulates without washing off by rainfall or other factors, and is independent of the rate at which salt is deposited and whether deposition occurs as a single dose or as several cumulative doses.
The greatest amount of botanical injury observed during this study period was not to plants with symptoms indicative of salt drift injury, but rather dieback of live oaks and other canopy trees southwest of the cooling towers, and high mortality of cabbage palms further southwest of the towers between the SW Open Hammock and the SW Open Test vegetation stations (Figure 3-3). A study designed to investigate the vegetation stress in this area summarized that the dieback appeared to be related to topographic or hydrologic factors, in particular, salinity changes in soils and groundwater and flooding of root zones due to fluctuations in water table level and soil water content (KBN 1991a). A complex combination of changes in sea level, hurricane or storm conditions, patterns of rainfall and Floridan aquifer flow, and resultant vertical and horizontal changes in ground water availability and salt content are the most likely causes of damage to vegetation in this area. However, because this area of vegetation stress is located adjacent to the Units 1 and 2 ash pond and water has been observed seeping through the bottom of the berm which separates the ash pond from the adjacent forest, hydrologic and/or chemical changes associated with ash pond seepage could be contributing to plant mortality as well.

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 Waccasassa Bay, approximately 15 miles north of the Crystal River Power Complex. These researchers have found that cabbage palms and red cedars 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 has been 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 cedars and cabbage palms is high, whereas live oak regeneration is low.

Wolfe (1990) also described the large-scale die-off of primarily cabbage palms and to a lesser extent live oaks and red cedars that occurred from 1985 to 1991 as being attributed to the gradual acceleration of sea-level rise predicted by the greenhouse effect theory. If current projections of a rise in sea-level of 84 to 104 cm for the next century (Titus et al 1984) come to pass, almost all of the hammock and swamp forest within Waccasassa Bay State Preserve, the lower Suwannee National Wildlife Refuge, and the Chassahowitzka National Wildlife Refuge will die and become salt marsh (Wolfe 1990).

During this study, KBN personnel visited three nearby coastal areas to qualitatively assess the overall health and vigor of cabbage palms, live oaks, red cedars, and slash pines (Figure 4-2). At the Ozello site, which was the southernmost site visited, substantial cabbage palm and to a lesser degree red cedar mortality had occurred. In the worst area observed, roughly 80 percent of the cabbage palms had died. Mortality was highest around the edges of the islands. According to Matt Clemins with Florida Department of Environmental Protection (FDEP) in Crystal River, the high mortality at Ozello may be attributed to an altered hydrology caused by inadequate culverts installed under the Ozello road (Clemins, pers. comm.). Cabbage palm mortality was also observed along the island edges at the second observation site where the Crystal River reaches the Gulf of Mexico. This observation site, called the Crystal River site, also contained several live oaks which exhibited noticeable stem dieback. However, the majority of the cabbage palms, slash

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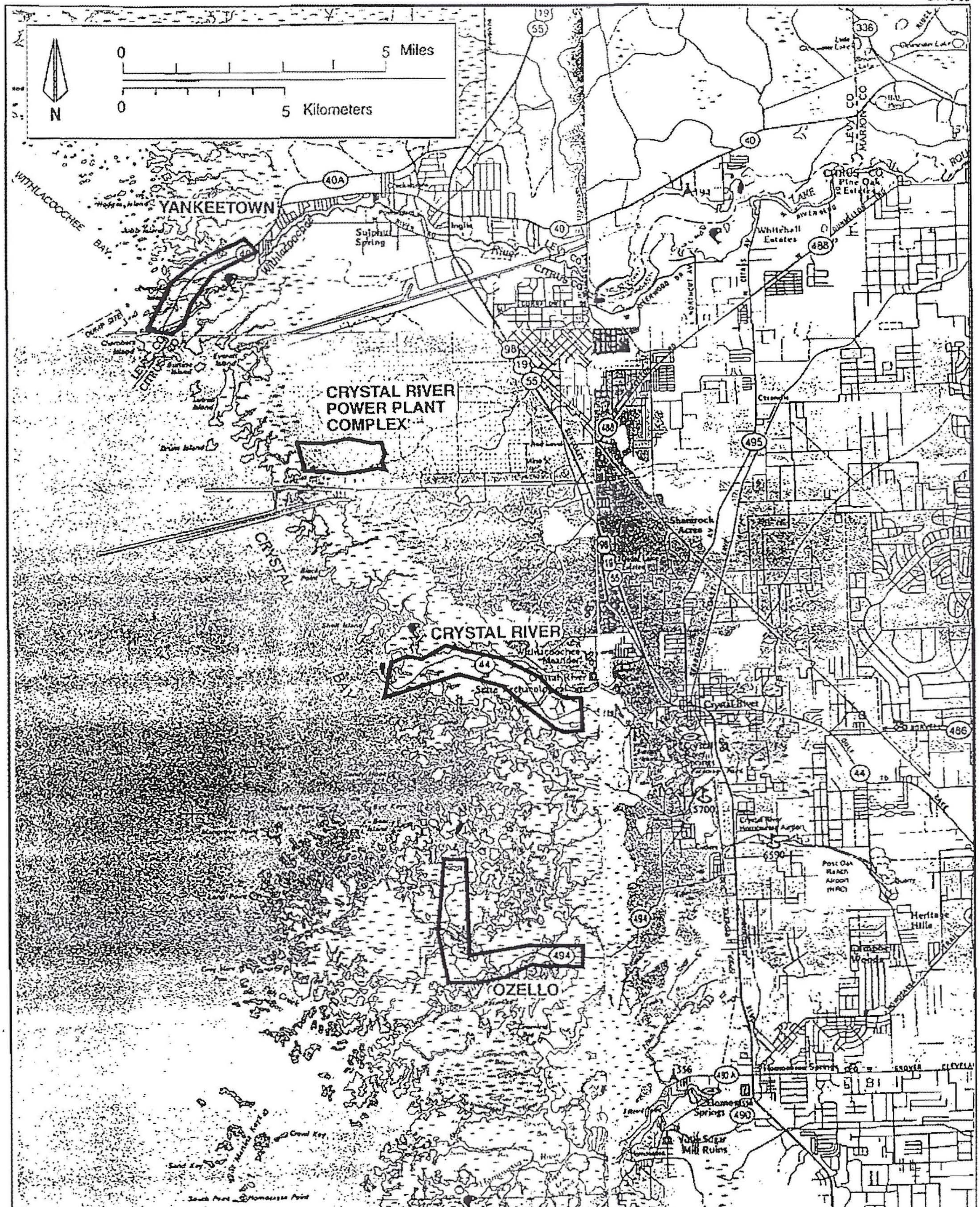

Figure 4-2
Approximate Location of Observation Sites for Tree Mortality in Relation to the Crystal River Power Plant Complex

pines, and red cedars appeared healthy and vigorous. This site probably contained among the lowest salinity levels as a result of the fresh water inflow from the Crystal River. At the third site, which is Yankeetown, tree mortality was much less visible than at the above two sites.

Severe coastal storms can more rapidly and dramatically influence the coast compared to sea-level rise or changes caused by human activity (Wolfe 1990). Because of the low gradient along the Gulf coast, a storm surge of 3 to 3.7 m during a hurricane would flood most of the coastal areas from Dixie County south to Pasco County. We observed the effects of the unnamed coastal storm which struck the area in March 1993. The storm caused extensive damage including broken tree limbs, uprooted trees, flooding from the tidal surge, and deposition of debris. Deposition levels measured at the deposition monitoring stations during March 1993 right after the coastal storm accounted for 50 percent of the total deposition measured for the entire study year, and was the highest ever measured at the three sites with the longest record of measurement (Figure 4-3). Floodwater rose roughly 1 m at many of the study sites. A large debris pile that was deposited at the Coastal Control site is still visible 2 years after the storm. Many plants such as ferns, coonties, and low-lying vines disappeared after the storm, and leaves of winged elm and red cedar turned brown and dropped from the twigs. Most of the trees produced new leaves within a few months of the storm, and many of the ferns surprisingly began to resprout 7 months later. It was also observed that seeds of Brazilian pepper, red mangrove, and black mangrove were dispersed after the storm in areas where these species had not previously been observed (Clemins, pers. comm.). During this study period several coastal storms struck the study area, including Tropical Storm Beryl in August 1994. Precipitation data collected from the Inverness National Oceanic and Atmospheric Administration (NOAA) Climatological station indicate that although some months received higher than normal rainfall, the study period ended at 2.40 inches below normal (Table 4-2, Owenby and Ezell 1992). It appears from the resiliency of the vegetation that these biotic communities have evolved to survive and even flourish in maritime environments where episodic large pulses of salt spray are periodically produced by large coastal storms, and as a result, the vegetation overall appears unaffected by minor salt drift spray produced by the cooling towers.

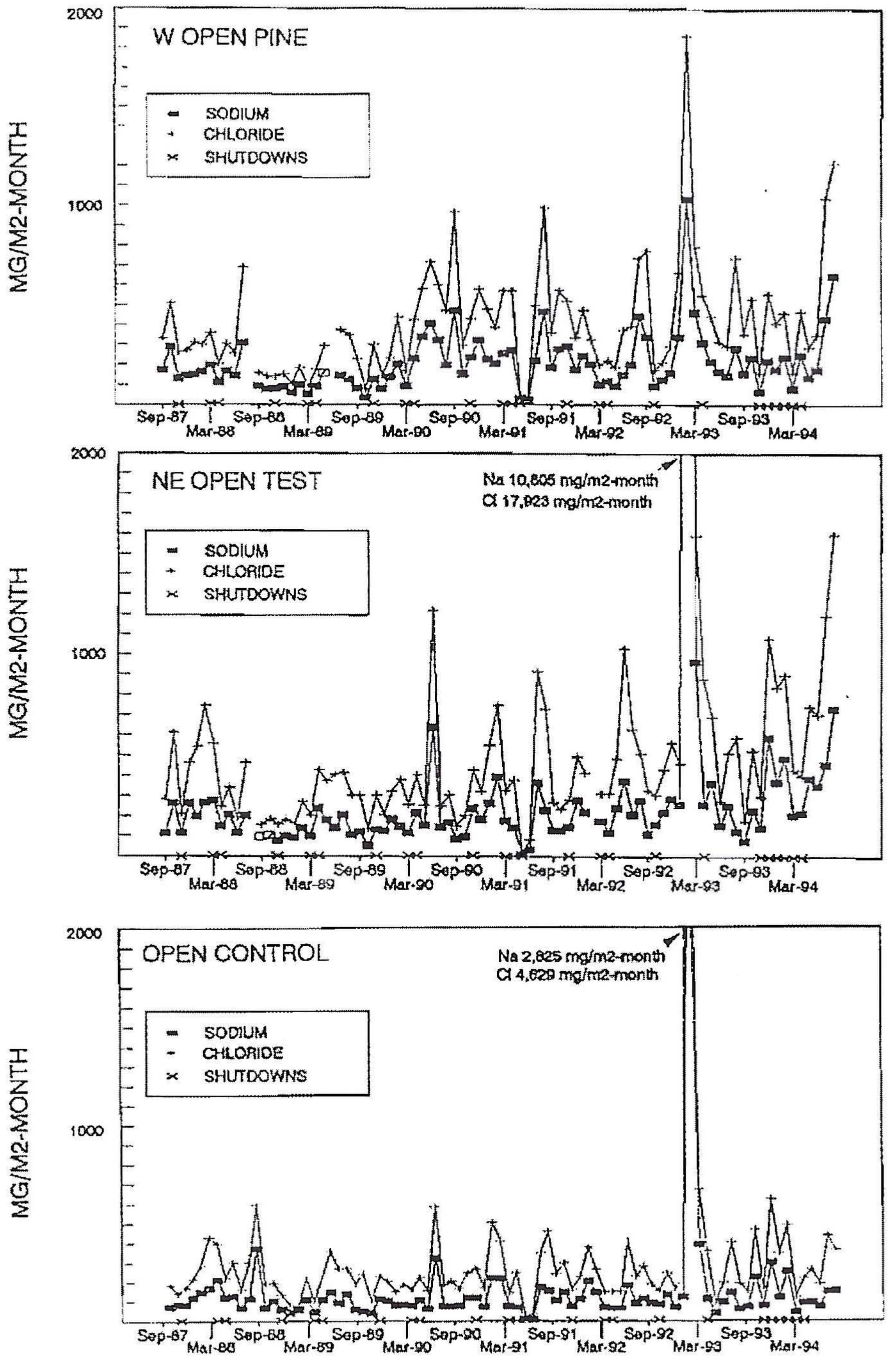

Figure 4-3
Mean Monthly Deposition at the Three Sites with the Longest Monitoring Record from 1987 through 1994

Note: Cooling tower shutdowns are indicated with an X. Highest level of deposition occurred in March 1993 from the unnamed tropical storm.

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Table 4-2. Comparison of Actual and Normal Rainfall at the Crystal River Power Plant

Date		Actual Rainfall Measured at Inverness NOAA Weather Station (in.)	Normal Rainfall Measured at Inverness NOAA Weather Station[a] (in.)	Percent of Normal Rainfall
September	1993	8.19	6.07	2.12
October	1993	5.38	1.92	3.46
November	1993	0.23	2.21	-1.98
December	1993	1.87	2.62	-0.75
January	1994	9.56	3.28	6.28
February	1994	1.27	3.45	-2.18
March	1994	1.20	3.89	-2.69
April	1994	1.98	2.07	-0.09
May	1994	0.42	3.84	-3.42
June	1994	8.85	7.30	1.55
July	1994	4.49	8.12	-3.63
August	1994	7.57	8.64	-1.07
Annual		51.01	53.41	-2.40

[a] Normal rainfall based on a 30-year average (Owenby and Ezell, 1992).

5.0 CONCLUSIONS

1. Annual deposition levels measured for the 1993-1994 study period exceeded ambient annual deposition at four onsite stations and one offsite station. Salt drift injury was noted on some individuals in the same areas that received high salt deposition. However, occurrences of salt drift injury appeared to be isolated events which were limited to a relatively few individuals and in a narrow band of forest located west and southwest of the cooling towers along the edge of the transmission line ROW.

2. The greatest amount of botanical injury observed during this study period has not been to plants with symptoms indicative of salt drift injury, but rather dieback of live oaks and other canopy trees southwest of the cooling towers, and high mortality of cabbage palms further southwest of the towers between the SW Open Hammock and the SW Open Test vegetation stations. However, large scale dieback is not isolated to the Crystal River complex but has been documented throughout the Florida Springs coast. Large scale dieback is surmised by many researchers as associated with sea-level rise.

3. Longterm deposition monitoring at the site indicates that highest deposition levels have been associated with coastal storms. Vegetation monitoring following coastal storms suggests that the vegetative communities are adapted to large salt deposition episodes associated with coastal storms such as the unnamed tropical storm which struck in March 1993 and produced more deposition than was produced for an entire study year.

4. Deposition data collected to date do not indicate a high level of salt deposition from the new cooling towers. Longterm deposition monitoring indicates that lowest deposition levels have coincided with shutdown of the mechanical draft cooling towers, however it is difficult to elucidate the contribution of salt spray from coastal storms compared to salt spray from the cooling towers.

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