MOVEMENT OF NACL THROUGH THREE SOIL PROFILES

AND ITS EFFECT ON SOIL CHEMICAL PROPERTIES

R. W. McCormick, D. C. Wolf, G. McClung, and J. E. Foss 1/

ABSTRACT

The movement of NaCl through the upper 45 cm of three representative soils in the area which could be affected by the Chalk Point Electrical Generating Station was studied. Three replicate treatments of 0, 10, and 20 g NaCl/m^2 were applied to a Sassafras loam, Sassafras sandy loam, and Lakeland loamy sand at three different times. Soil samples were taken at 0-15, 15-30, and 30-45 cm depths at approximately monthly intervals for 13 months and analyzed for exchangeable Na and electrical conductivity.

When NaCl was added to the soils at rates of 10 and 20 g/m^2, the soluble salt levels as measured by electrical conductivity returned to the level of the control treatments within one month. The Na cation was not leached through the soil profiles as rapidly as the Cl anion. Nine months after the last salt application, the Na content of all soils had returned to that of the control treatment except for the Sassafras sandy loam which contained significantly more Na at all three sampling depths than the control. Under the experimental conditions studied, it would appear that Na could accumulate in the soil as a result of a salt deposition at a rate of 10 g/m^2-month.

INTRODUCTION

The addition of salts to soil may lead to an increase in the soluble salt content, salinization, and an increase in the exchangeable sodium content, sodication (8, 13). Along with decreased productivity associated with both salinization and sodication, undesirable physical properties may develop in the finer textured soils as a result of sodication. Increased levels of sodium on the exchange complex may cause dispersion of the particles and destruction of soil aggregation which would result in decreased water conductivity (1).

Since Na is not tightly held on the exchange complex, it along with the soluble salts can be leached through the soil with water (10). Edelman et al. (4) showed that following the application of 200 kg/ha of Cl^- as KCl, the Cl^- moved 15-20 cm/day with 2.5 cm of daily irrigation in a sandy loam soil. Yimprasert et al. (15), also working with a sandy loam soil, found that Cl^- and NO_3^- anions move through the soil at similar rates. With

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the application of 6.3 cm of water, 67% of the added 150 kg/ha NO_3-N was lost from the upper 105 cm of the soil profile and after 11.2 cm of water was applied, 82% of the NO_3-N was lost.

Wiedenfeld et al. (14), reported that salt water cooling towers near Galveston, Texas deposited 1,200 kg/ha-yr of total salts within 100 m of the towers. The increased salt deposition due to the cooling towers is expected to eventually lead to salinization and sodication of the surrounding soil.

The electrical generating plant at Chalk Point, Maryland currently has one cooling tower in operation and a second scheduled to begin operation in the early 1980's. Since these towers utilize the brackish water of the lower Patuxent River, salts are present in the drift and are deposited on the surrounding crops and soils.

In a drift and deposition model (5), Israel and Overcamp predicted a maximum salt deposition rate of approximately 50 kg/ha-month from one cooling tower. An updated model by the Applied Physics Laboratory of Johns Hopkins University (9) predicted that maximum salt deposition would occur during the summer with a maximum rate estimated to be 8.1 kg/ha-month. Meyer et al. (7) measured salt deposition in June 1977, and determined that a total of 13 mg Na/m^2-4 hr (24 kg Na/ha-month) was being deposited at a distance of 0.5 km from the tower.

The objective of this study was to determine if salt added to the soil at rates similar to those predicted to be dispersed by the power plants and cooling towers would accumulate in the soil.

MATERIALS AND METHODS

Plots were established at research sites 1.6 km east and 4.8 and 9.6 km north of the Chalk Point Electrical Generating Station. The soil types at these three sites are Lakeland loamy sand, Sassafras sandy loam, and a Sassafras loam, respectively. These soils were selected because they represented the greatest range in soil physical properties of the sites currently under investigation (Table 1). Each plot was 1.5 x 1.5 m and was surrounded with plastic edging to prevent runoff between plots. Three replicate treatments of 0, 10, and 20 g NaCl/m^2 (0, 100, 200 kg/ha) were applied to a 1 x 1 m area in the center of each plot. Treatments were applied by dissolving the appropriate amount of NaCl in 550 ml of distilled water and spraying the 1 m^2 area with a portable sprayer. The existing vegetation was killed by herbicide application prior to treatment application and the plots were maintained free of vegetation throughout the study. The NaCl was applied on 17 July, 20 August, and 1 November, 1974. Soil samples were taken at 0-15, 15-30, and 30-45 cm depths at periodic intervals for a period of 13 months. Five cores, 2.5 cm in diameter were taken at each sampling, air dried, crushed to pass a 2 mm sieve, and thoroughly mixed. The levels of exchangeable Na were determined using autoanalyzer techniques (Bandel, V.A., C.K. Stottlemyer, amd C.E. Rivard. 1969. Soil Testing Methods. University of Maryland Soil Testing

Laboratory. Agronomy Mimeo 37) following extraction with 1 N ammonium acetate at pH 7.0 (6). Electrical conductivity (EC) was determined on a 1:5 soil water extract using a conductivity bridge (2, 11).

The data were subjected to analysis of variance and LSD was used to compare treatments to the control when differences in means existed.

RESULTS AND DISCUSSION

The amounts of Na extracted from the three soils with the 0, 10 and 20 g $NaCl/m^2$ treatments are presented in Figs. 1-6. The control treatments presented are an average Na value for all three soil depths as there were insignificant differences in Na levels with depth. All three soils are naturally low in Na averaging approximately 20 µg/g soil.

The addition of 10 g $NaCl/m^2$ to the Lakeland loamy sand increased the Na content of the soil (Fig. 1). With time it was observed that the Na content of the 0-15 cm depth decreased with an increase in the Na content of the 15-30 and 30-45 cm depths. This would be expected since Na is a highly mobile cation (10) and apparently moved readily through the soil. Five months after the third of three salt applications, there was still significantly greater amounts of Na at all soil depths with the application of 10 g $NaCl/m^2$ when compared to the control treatment. The 0-15 cm depth contained less Na than the 15-30 and 30-45 cm depths indicating that the salt moved through the first 15 cm of the profile. Nine months after the last salt application, the Na content of all depths had returned to that of the control. With the application of 20 g $NaCl/m^2$, the Na content of the 0-15 cm depth was approximately twice that of the 10 g $NaCl/m^2$ treatment (Fig. 2). The Na content of the 15-30 and 30-45 cm depths were similar in both the 10 and 20 g $NaCl/m^2$ treatments, which indicated that the salt moved through the soil at a uniform rate and did not accumulate in the lower depths. Since the clay content of the soil was approximately 3%, Na would not be expected to accumulate to a large degree in this soil.

The Na content of the Sassafras sandy loam in both the 10 and 20 g $NaCl/m^2$ treatments was similar to that of the Lakeland loamy sand during the period of salt application (Figs. 3 and 4). After the last salt application, the Na did not move through the profile as rapidly as occurred in the Lakeland loamy sand. This would be expected, due to the greater clay content in the Sassafras sandy loam (Table 1). Since Na is a cation, it will be adsorbed onto the clay and its mobility decreased with increasing amounts of clay (1). The high clay content of the 36-69 cm depth, 26%, is reflected in the increased Na content of the 30-45 cm depth. Nine months after the last NaCl application, the Na level of the 15-30 and 30-45 cm depths remained statistically greater than the Na content of the 0-15 cm depth in both the 10 and 20 g $NaCl/m^2$ treatment. The addition of 20 g $NaCl/m^2$ increased the Na content of the soil greater than did the 10 g $NaCl/m^2$ as would be expected.

In the Sassafras loam, the addition of increasing salt levels was reflected in increased extractable Na levels (Figs. 5 and 6). During the

period of salt application, the amount of Na extracted was approximately twice that of the other two soils studied. Nine months after the last salt application there were no significant differences in Na content between the control and any of the three soil depths in either the 10 or 20 g $NaCl/m^2$ treatment. The Sassafras loam did not show the Na accumulation in the 15-30 and 30-45 cm depths that the other two soils showed. Only in the 20 g $NaCl/m^2$ treatment was there an increase in the Na content in the 15-30 cm depth, and that was one month after each of the last two salt applications. Apparently when the Na leached past the 15 cm depth, it moved through the 15-45 cm depth rapidly, rather than accumulating as was observed in the two other soils studied.

Under the conditions of this study, it appears that if salt was added at a continuous rate of 10 g/m^2-month, an increase in the Na content of the soils studied would occur. When NaCl applications were terminated, the Na levels had returned to that of the control in nine months in all cases except in the Sassafras sandy loam. With continued salt deposition, Na levels in the soil could increase to a level ultimately determined by the Na leaching rate in each soil (3). The ramifications of salt deposition at rates of 10 g/m^2-month on the physical properties of the individual soils have not been determined.

Figures 7-12 present the electrical conductivity (EC) of the three soils with the 0, 10, and 20 g $NaCl/m^2$ treatments. In the Lakeland loamy sand, the added salt was reflected in an increased EC of the 0-15 cm depth. One month after treatments were applied, the EC of the soil had returned to that of the control with the 10 g $NaCl/m^2$ treatment (Fig. 7). The 20 g $NaCl/m^2$ treatment (Fig. 8), increased the EC of the 0-15 cm depth greater than did the 10 g $NaCl/m^2$ treatment, however after one month the EC values had generally returned to those of the control soil. It appeared that the rainfall (Table 2) was capable of rapidly leaching the soluble salts through the soil.

In a Sassafras loamy sand, the 20 g $NaCl/m^2$ treatment could be easily detected by EC measurements in the 0-15 cm depth, but EC changes in the 10 g $NaCl/m^2$ treatment were less defined (Figs. 10 and 11). At most sampling times, the control treatment exhibited an EC approximately equal to that of the 10 g $NaCl/m^2$ treatment.

The Sassafras loam had greater EC values than the other soils, which is consistent with the higher Na values obtained at this site following salt application (Figs. 11 and 12). With the addition of 10 and 20 g $NaCl/m^2$, the EC values were increased in the 0-15 cm depth with the 20 g treatment the more dramatic. After salt application, more than one month was required to lower the EC values to that of the control in both the 10 and 20 g $NaCl/m^2$ treatments. This may be related to the low amount of precipitation at this site compared to the other sites during the study period (Table 2). The Sassafras loam is the only soil studied in which a tendency was shown for the EC to increase in the 15-30 cm depth as the EC decreased in the 0-15 cm depth. In the two other soils, the salts moved beyond the 45 cm sampling depth between samplings.

Under the experimental conditions studied, the addition of 10 g NaCl/m^2-month would result in a slight increase in the EC of the soil. However, even in the Sassafras loam, which exhibited the largest increase in EC, the value was not great enough to result in a decrease in soil productivity (12). With normal rainfall, the soluble salts are leached through the soil at a rate great enough to prevent accumulation to a level which would be harmful to plants.

SUMMARY AND CONCLUSIONS

Under the experimental conditions of this investigation, salt deposition at a rate of 10 g/m^2-month would most likely result in an increase in the exchangeable Na content and soluble salt levels of the three soils studied. Nine months after the third application of 20 g NaCl/m^2, the Na level in the 0-45 cm depth of the Lakeland loamy sand and Sassafras loam was not different from the control treatment. The soluble salt levels, as measured by electrical conductivity, in the 20 g NaCl/m^2 treated Lakeland loamy sand and Sassafras sandy loam decreased to levels approximately equal to the control treatments in less than two months following salt application. The long range effect of salt deposition on the chemical and physical properties of soils in the vicinity of the Chalk Point Electrical Generating Station will depend upon the soil type, deposition rate, and leaching rate.

ACKNOWLEDGEMENTS

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Table 1. Partial physical characterization of the three soils utilized for the salt movement study.

Soil Series	Surface Texture	Horizon	Depth	Textural Analysis Sand	Silt	Clay
			--cm--	-------- %		---------
Lakeland	loamy sand	Ap	0- 26	90	7	3
		B2	26- 47	89	8	3
		C1	47- 66	90	9	1
		C2	66- 88	93	5	2
		C3	88-100	94	4	2
		C4	100-120	95	2	3
		C5	120-148	96	1	3
		C6	148-165	96	1	3
Sassafras	sandy loam	Ap	0- 21	75	19	6
		A2	21- 36	75	16	9
		B2t	36- 69	64	10	26
		B3	69- 92	85	2	13
		C1	92-133	93	nd†	nd
		C2	133-153	94	nd	nd
Sassafras	loam	Ap	0- 28	54	34	12
		A2	28- 53	69	20	11
		B1	53- 71	70	18	12
		B2t	71- 86	72	11	17
		IIB3	86-138	95	nd	nd
		IIC1	138-153	98	nd	nd

† Values were not determined.

Table 2. Amount of rainfall recorded at the three sites studied during the sampling period.

Month	Year	Site Location (km) 1.6 East	4.8 North	9.6 North
		cm		
July	1974	10.4	8.6	18.8
August	1974	10.7	17.3	3.6
September	1974	11.2	12.2	1.27
October	1974	3.6	6.4	5.6
November	1974	3.3	0.5	2.3
December	1974	10.2	9.9	8.9
January	1975	nd†	nd	nd
February	1975	nd	nd	nd
March	1975	4.3	15.7	7.1
April	1975	14.2	3.0	11.9

† Rainfall information was not recorded.

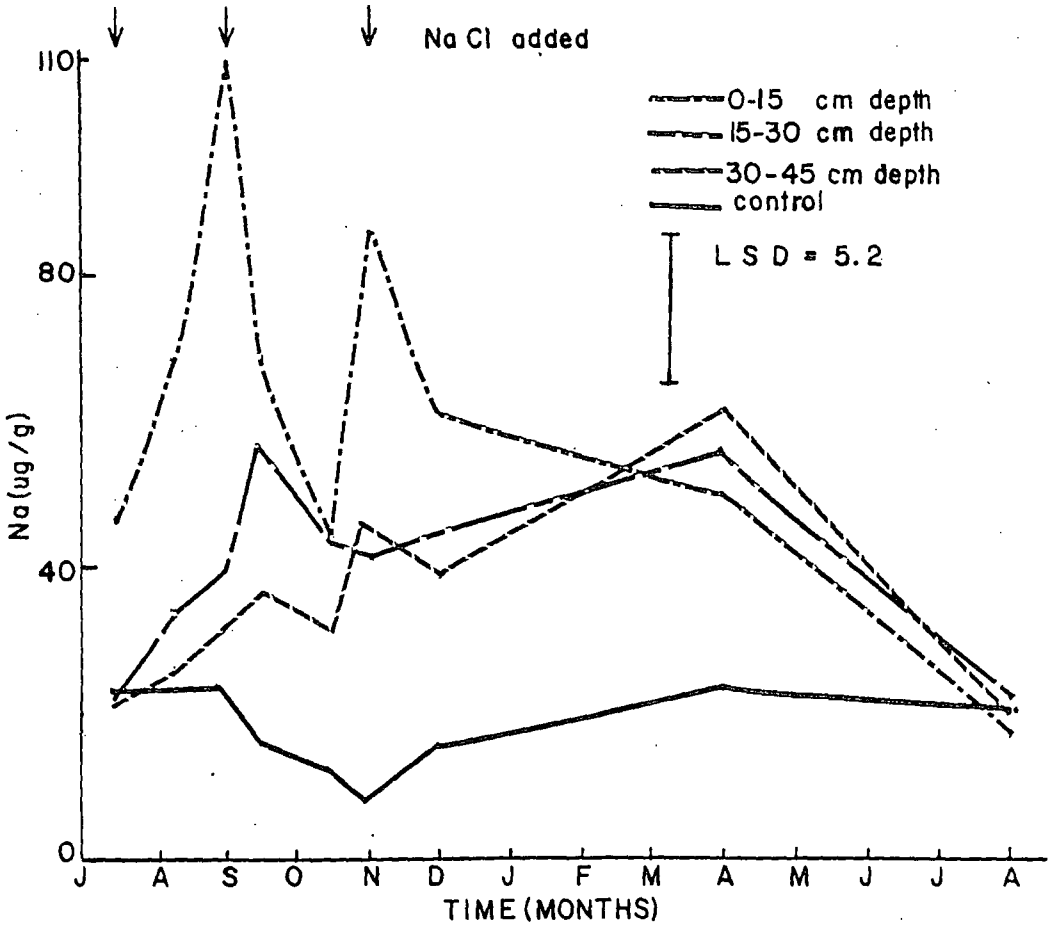

Fig. 1 — The effect of three additions of 10g $NaCl/m^2$ on the extractable Na levels at three depths in a Lakeland loamy sand.

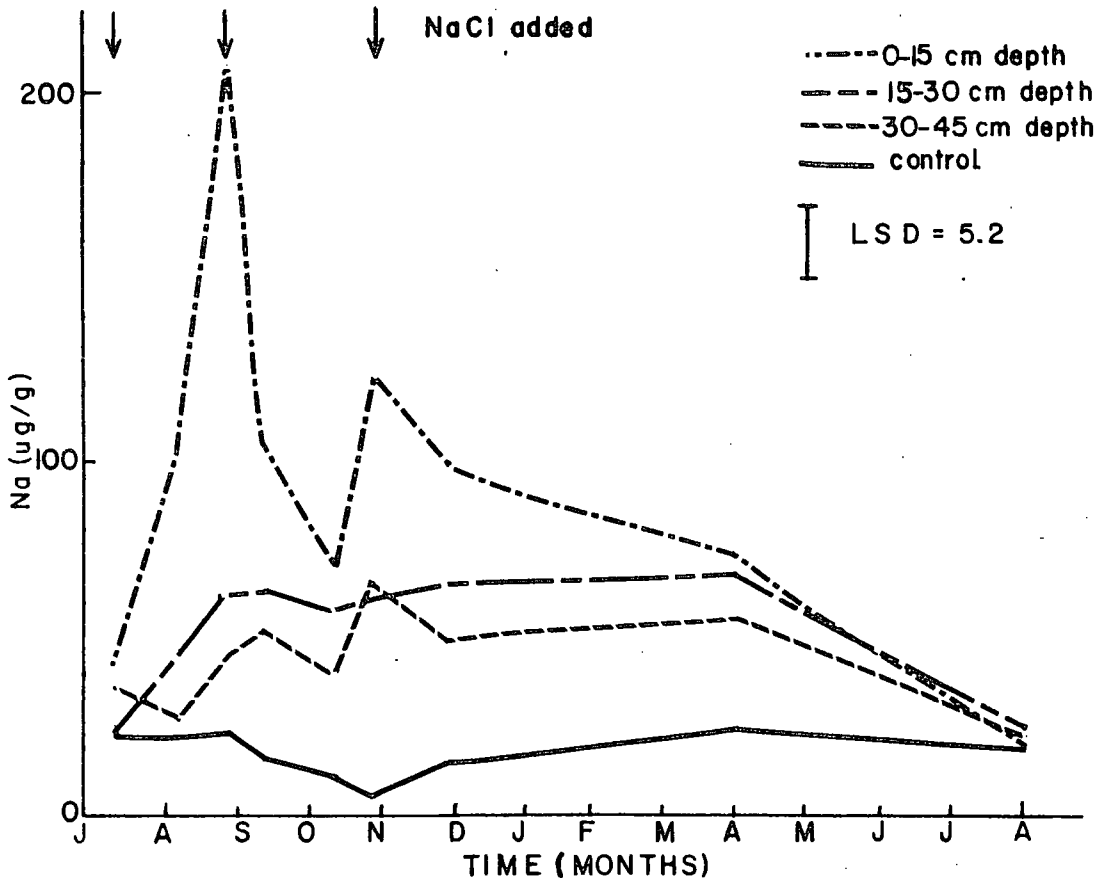

Fig. 2 — The effect of three additions of 20g NaCl/m^2 on the extractable Na levels at three depths in a Lakeland loamy sand.

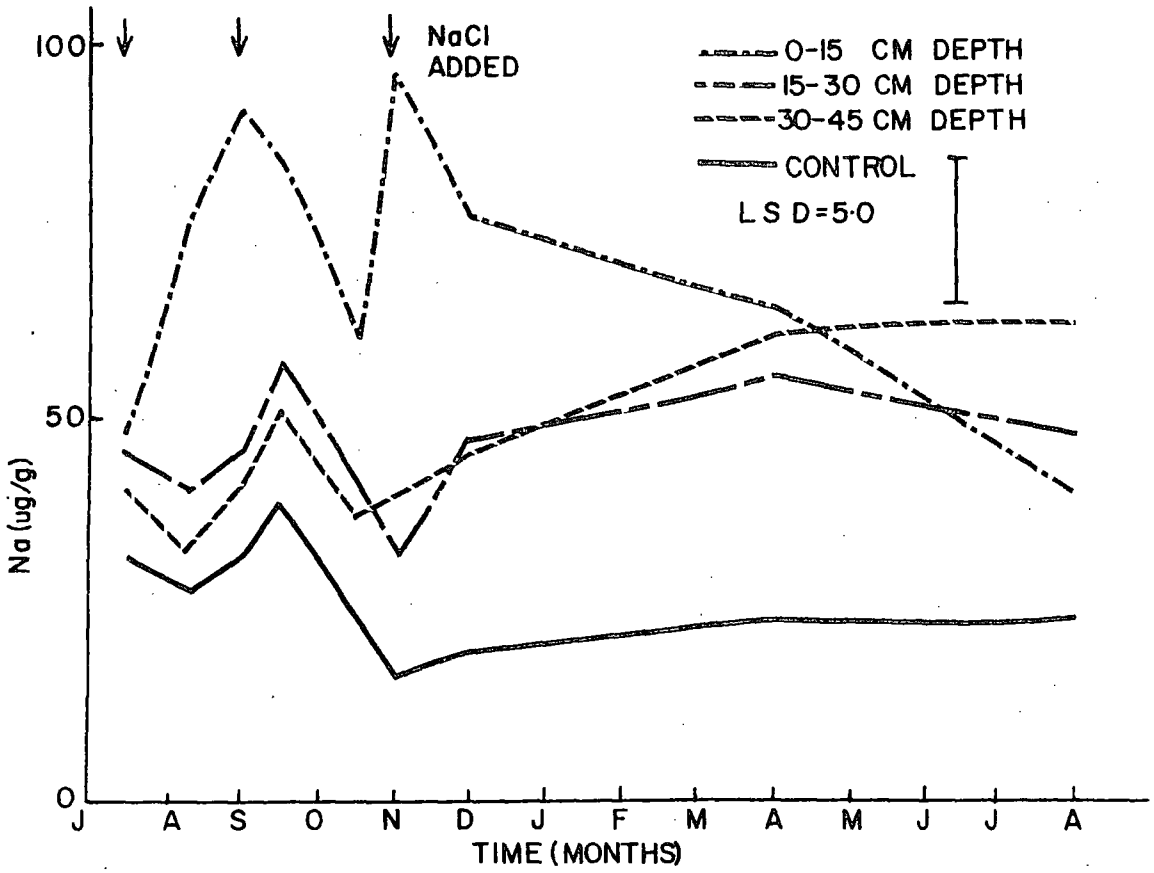

Fig. 3 — The effect of three additions of 10g $NaCl/m^2$ on the extractable Na levels at three depths in a Sassafras sandy loam.

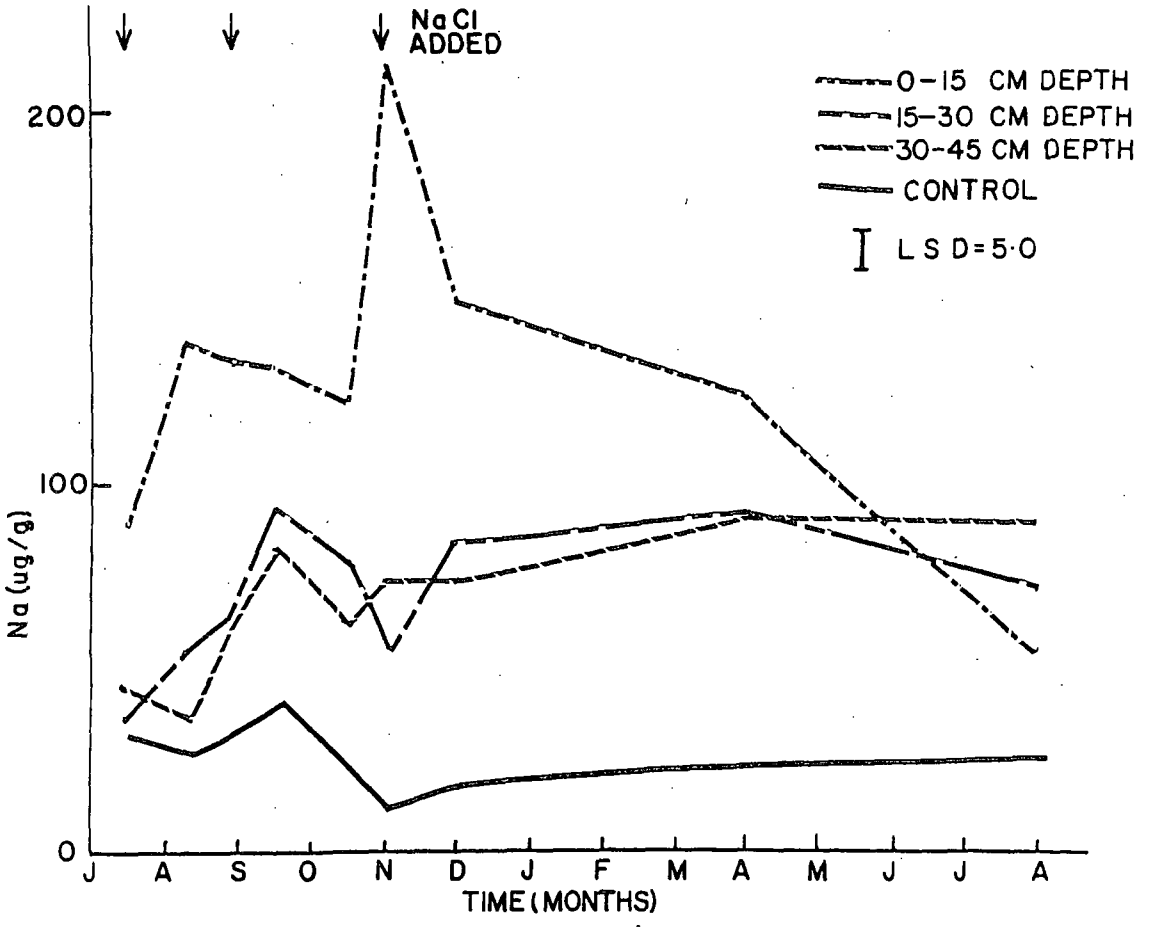

Fig. 4 — The effect of three additions of 20g $NaCl/m^2$ on the extractable Na levels at three depths in a Sassafras sandy loam.

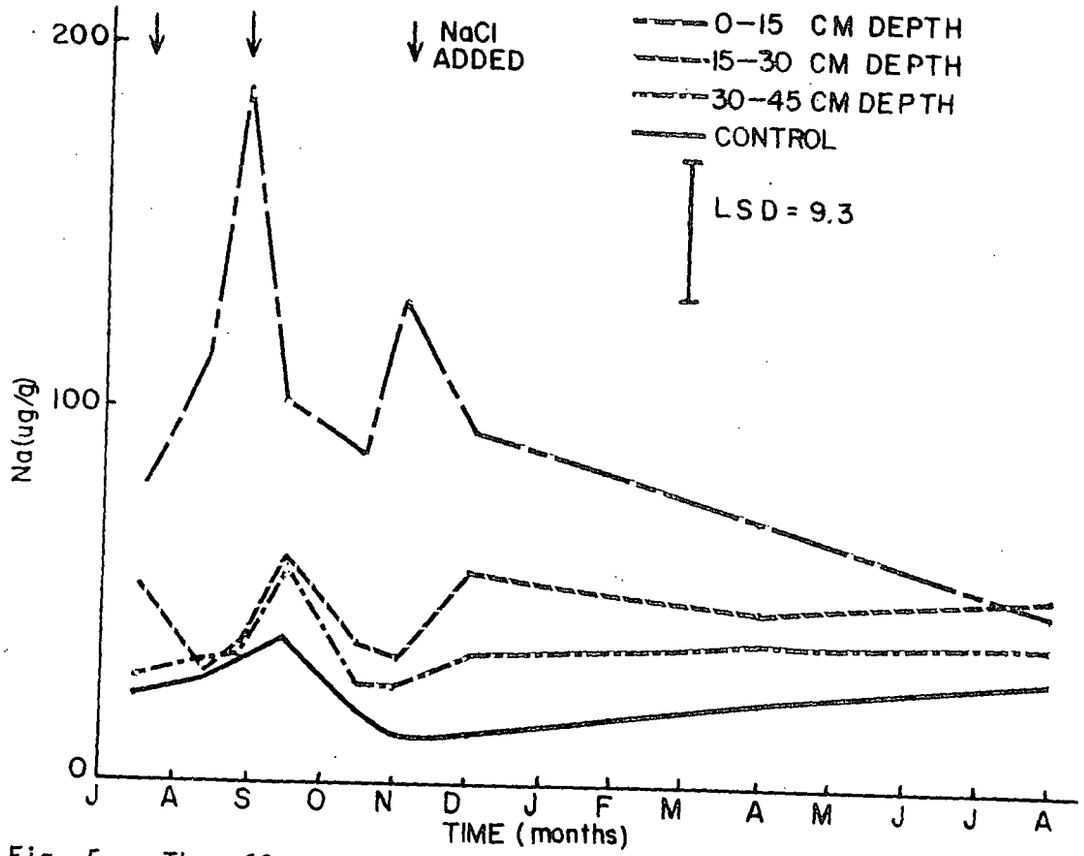

Fig. 5 — The effect of three additions of 10g $NaCl/m^2$ on the extractable Na levels at three depths in Sassafras loam.

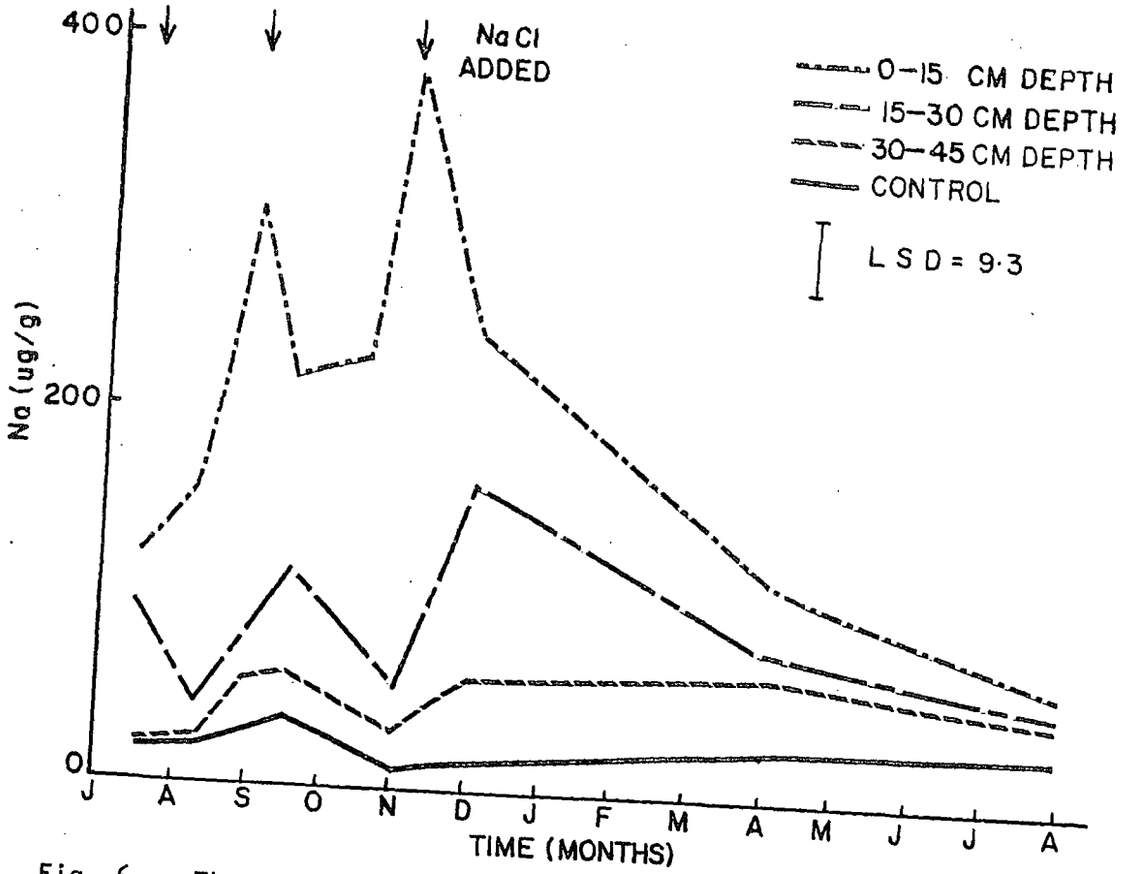

Fig. 6 — The effect of three additions of 20g $NaCl/m^2$ on the extractable Na levels at three depths in Sassafras loam.

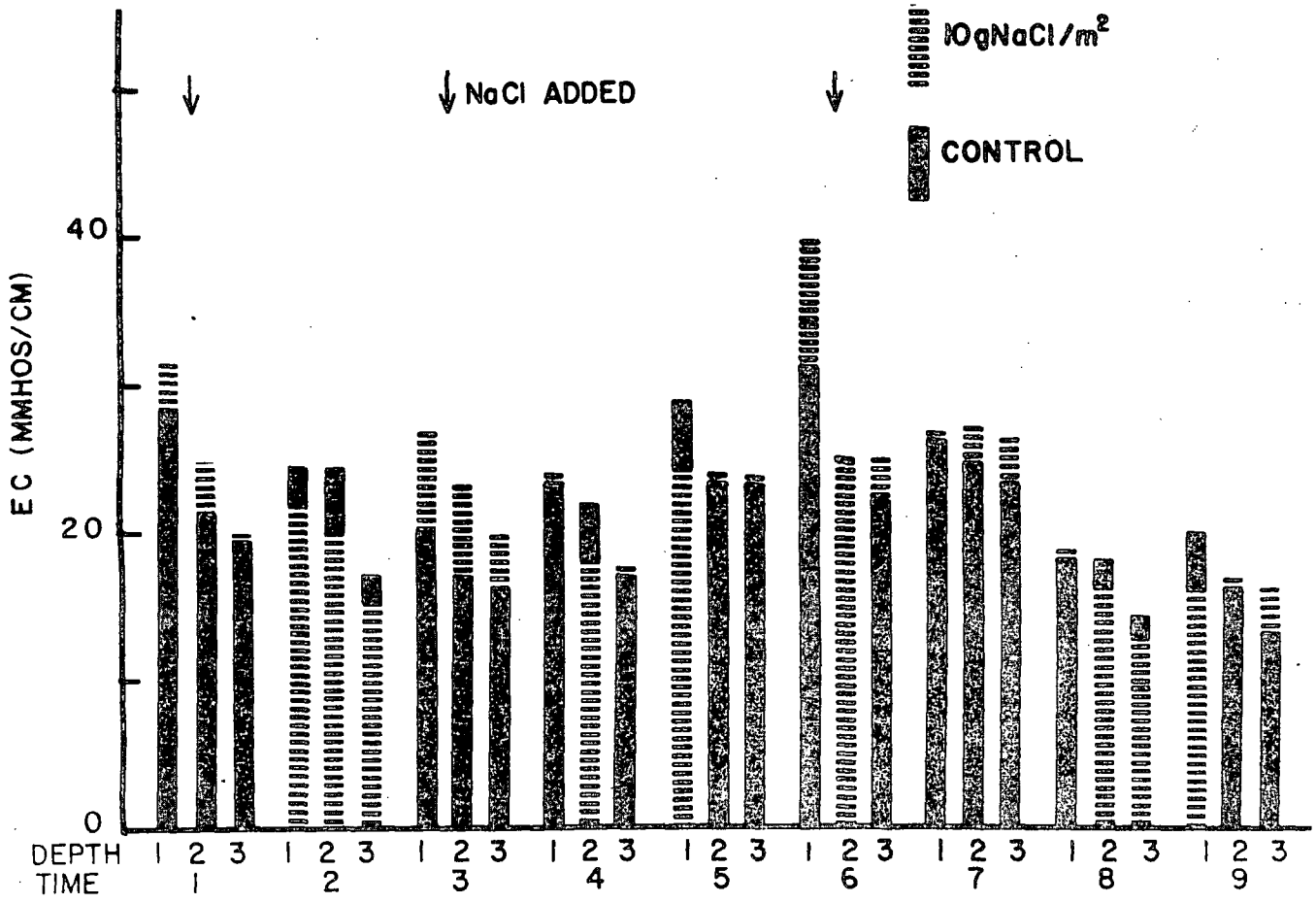

Fig. 7 — The effect of three additions of 10g $NaCl/m^2$ on the EC values at three depths in a Lakeland loamy sand.

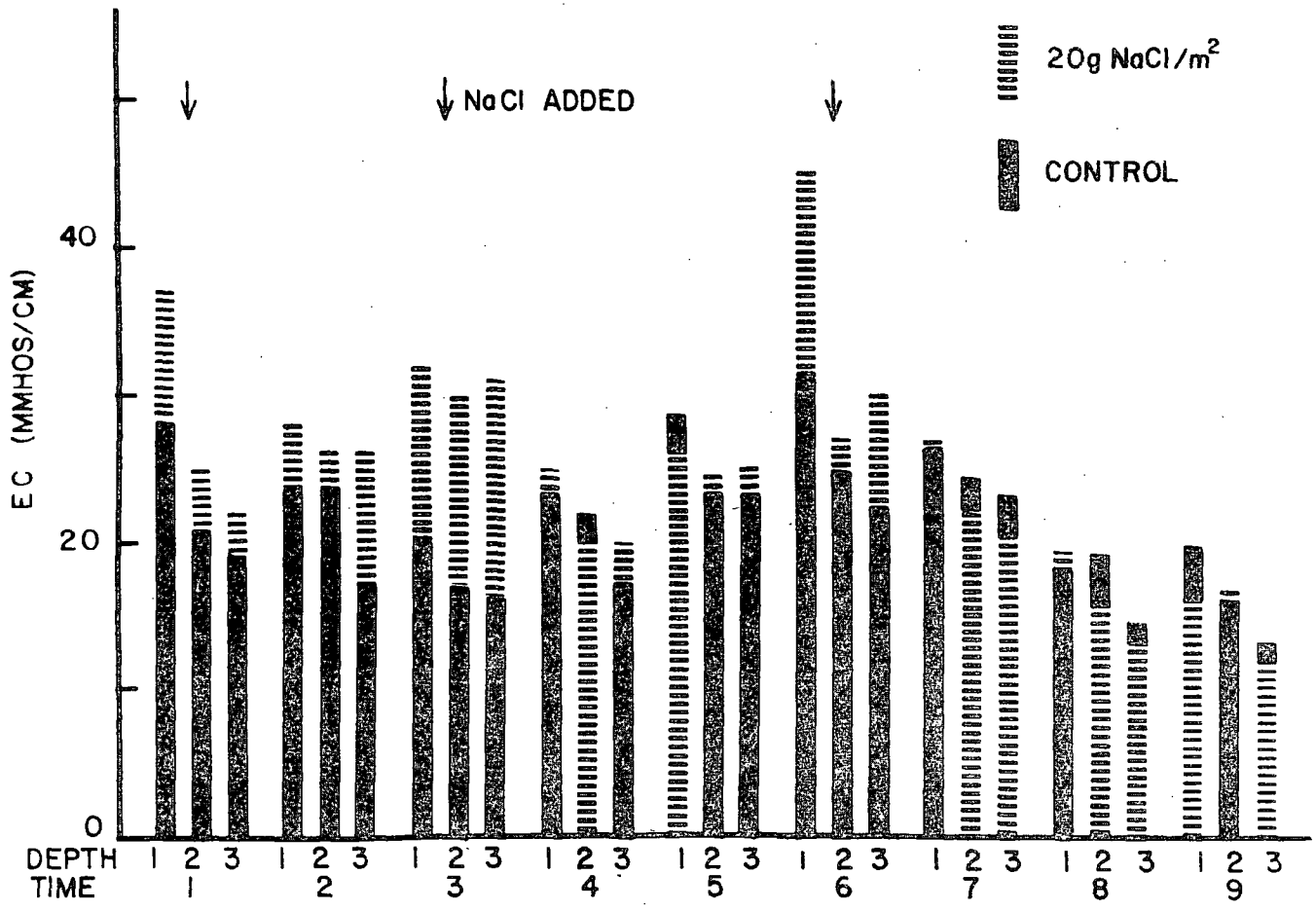

Fig. 8 — The effect of three additions of 20g $NaCl/m^2$ on the EC values at three depths in a Lakeland loamy sand.

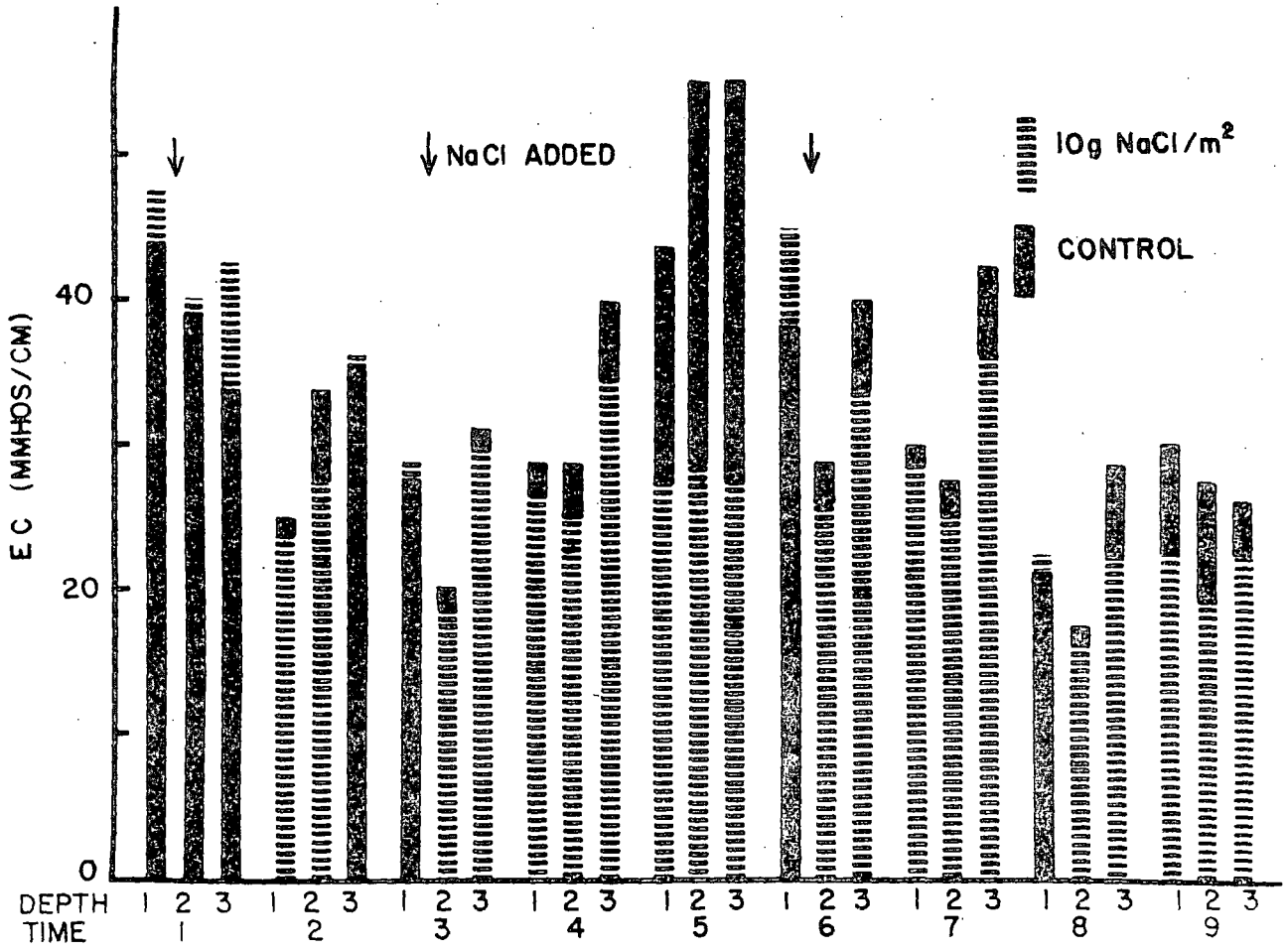

Fig. 9 — The effect of three additions of 10g $NaCl/m^2$ on the EC values at three depths in a Sassafras sandy loam.

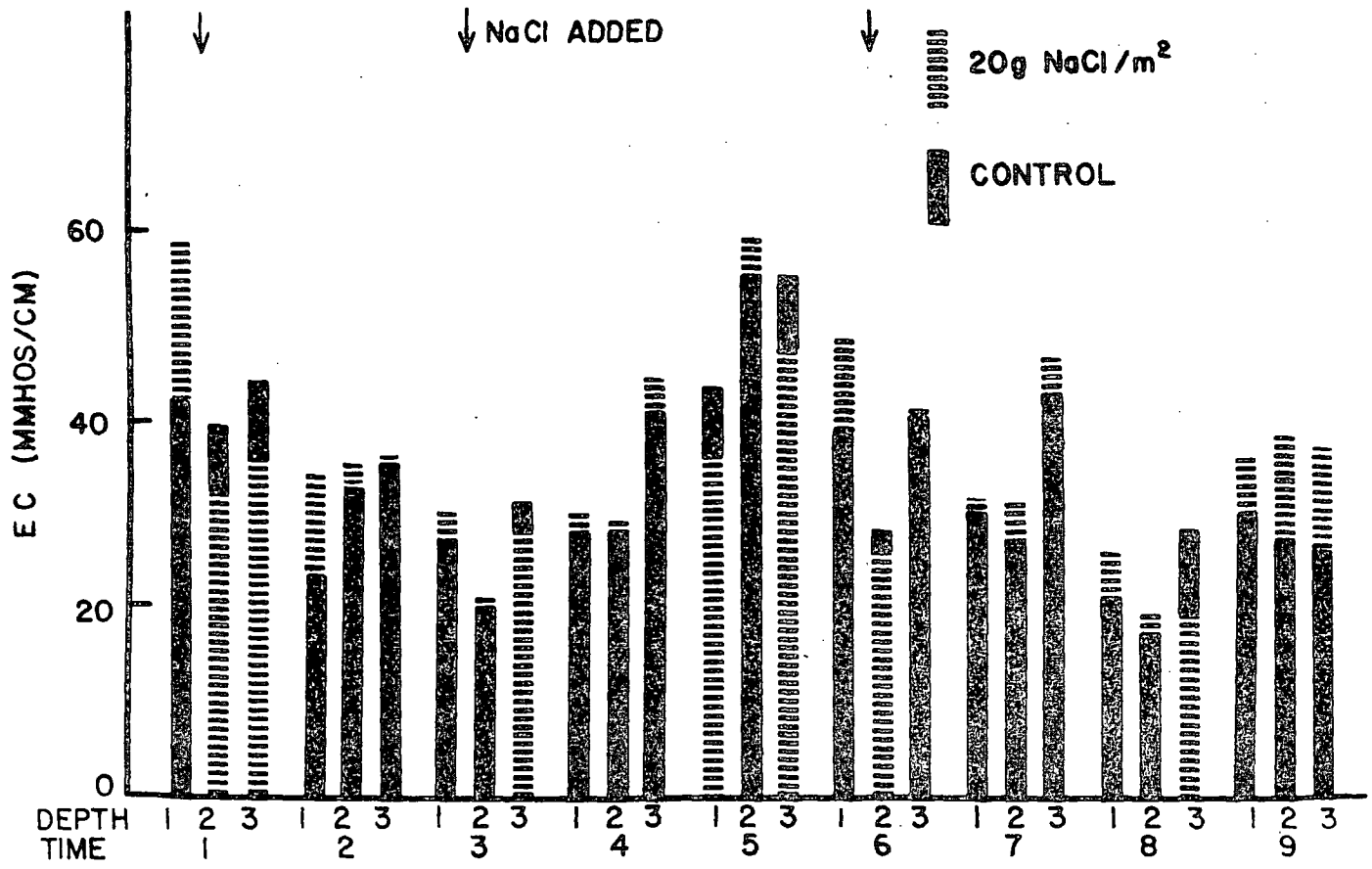

Fig. 10 — The effect of three additions of 20g $NaCl/m^2$ on the EC values at three depths in a Sassafras sandy loam.

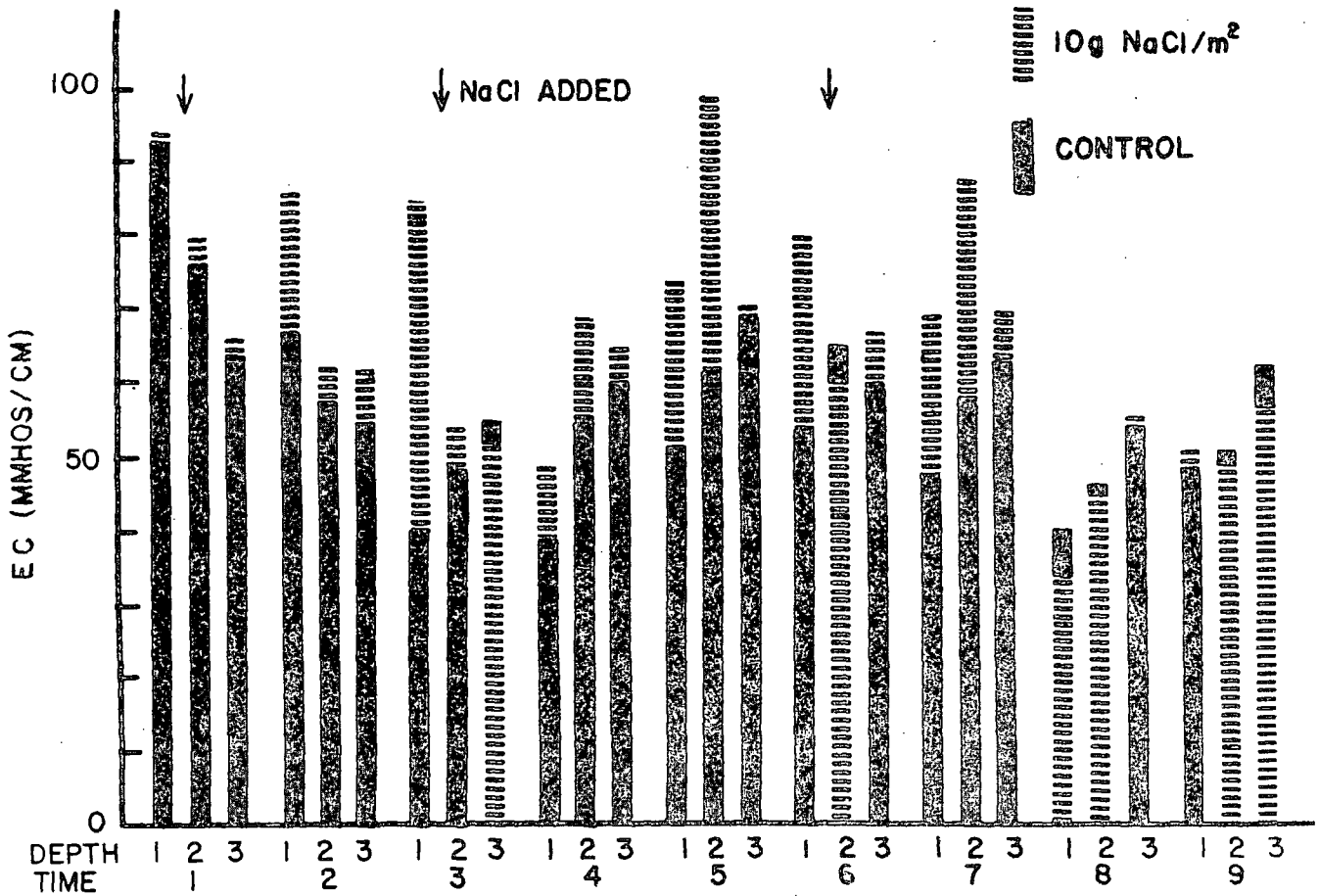

Fig. 11 — The effect of three additions of 10g $NaCl/m^2$ on the EC values at three depths in a Sassafras loam.

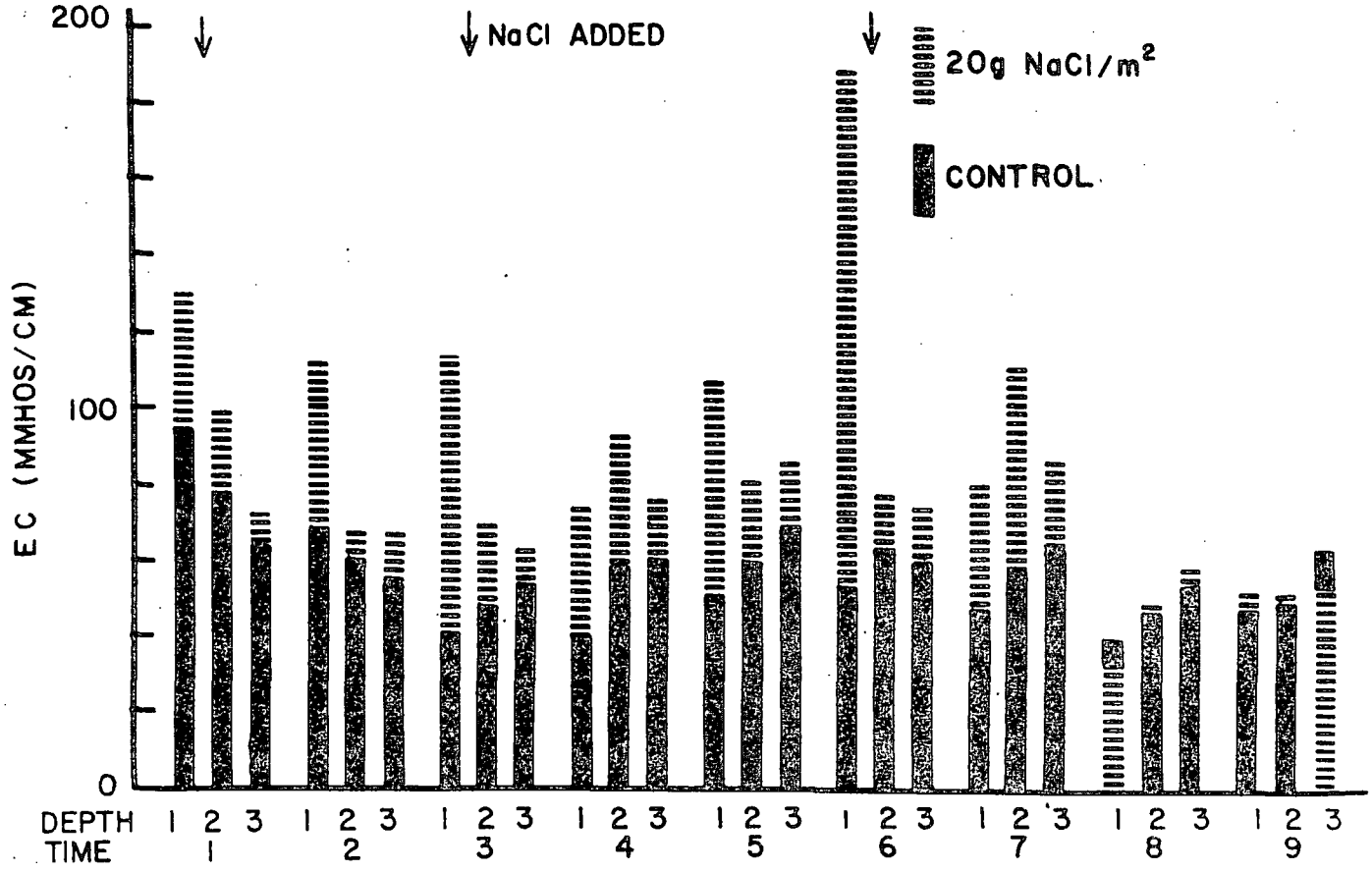

Fig. 12 — The effect of three additions of 20g $NaCl/m^2$ on the EC values at three depths in a Sassafras loam.

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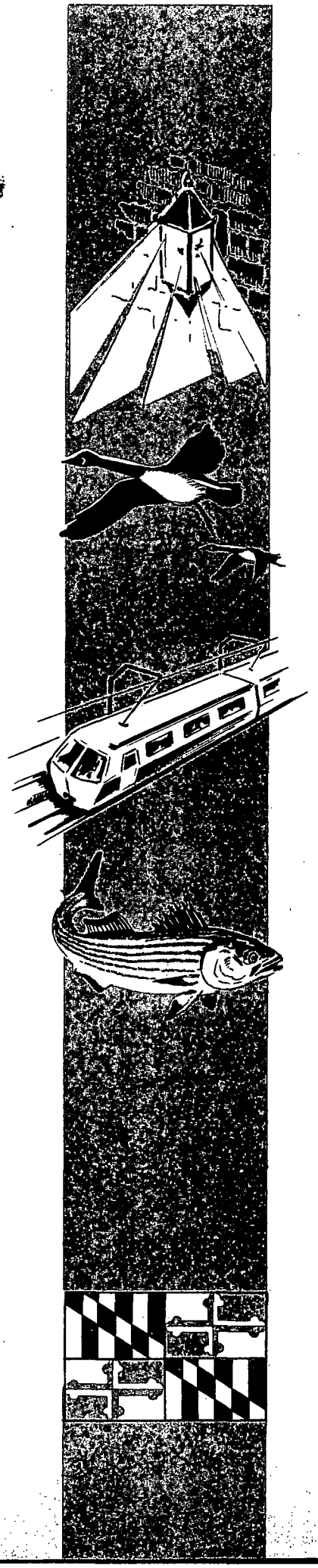

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ERRATA

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Page Number	Nature of Correction
I-12	Figure 5: new copy enclosed: current reproduction cannot be read.
I-15	Figure 8: ordinate should be g, not mg.
I-16	Figure 9: ordinate should be g, not mg.
I-106	Table 1: a new page is enclosed with corrections in the surface texture column.
I-119	Figure 1: LSD = 20.8 instead of 5.2
I-120	Figure 2: LSD = 20.8 instead of 5.2
I-121	Figure 3: LSD - 20.0 instead of 5.0
I-122	Figure 4: LSD = 20.0 instead of 5.0
I-123	Figure 5: LSD = 37.2 instead of 9.3
I-124	Figure 6: LSD = 37.2 instead of 9.3
I-125	Figure 7: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-126	Figure 8: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-127	Figure 9: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-128	Figure 10: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-129	Figure 11: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
I-130	Figure 12: Units on EC reported should be μMHOS/cm instead of MMHOS/cm
II-28	Figure 9: Dash line is for K = 3.69 instead of 2.97 and dash-dot line is for K = 2.97 instead of 3.69
II-34	Table 1: Number of afternoon visible plumes observed should be changed from 125 to 175 in "Characterization of Cooling Tower Plumes from Paradise Steam Plant"

6/1/78

Errata cont.

III-3 2.1 Mathematical Modelling, 4th line:
park, $1 \leq M \leq 10$ uncoupled systems consisting...

11th line: .....the two components v_z and v_x of...

2nd equation:

$$\mu_1 = (K_1 v_z^2/v^2 + K_2 v_z v_x^2/v^3 + K_4 F)/R + K_3 \Delta\rho g/\rho v^2$$

4th line after the equations:

initially had no vertical momentum (μ)

III-4 $$\frac{da}{ds} = (0.5\ \mu_1\ a - \theta_1 + K_y/av)/(1 + \alpha/(1 - W))$$

$$\frac{da}{ds} = (0.5\ \mu_1\ b - \theta_2 + K_z/bv)/(1 + \beta/(1 - W))$$

III-5 page center:

This method delivers N_K Gaussian plumes for the N_K cooling towers which are then superposed point by point in the space downwind of the plant.

3rd line from bottom:

.....the plume of tower j and $\alpha - \beta = (1 - W \frac{dW}{ds})$. Fig. 2

III-13 2nd line:

.....due to the drift droplets but - mainly in the case of

III-119 2nd paragraph, lines 9 and 10:

"1.2×10^3 Kg/Km-Month" and "0.60×10^3 Kg/Km-Month" rather than "1.2×10^6 Kg/Km^2-Month" and "0.60×10^6 Kg/Km^2-Month".

III-122 2nd paragraph, line 11: same corrections as above.

III-123 Table 2: "total at range" values should be "10^3" not "10^6" and have units "Kg/Km-Month".

III-125 Table 3: footnote should be "*Kg/Km-Month multiplied by 10^{-3}".

III-162 Add reference:

Thompkins, D. M. (1976) Atmospheric dispersion and deposition of saline water drops, Master of Science Thesis, Graduate Program in Meteorology, University of Maryland, College Park, Md., 69 pp.

6/1/78

Figure 5. Recovery of NaCl from Ropes with Known Amounts of NaCl Added

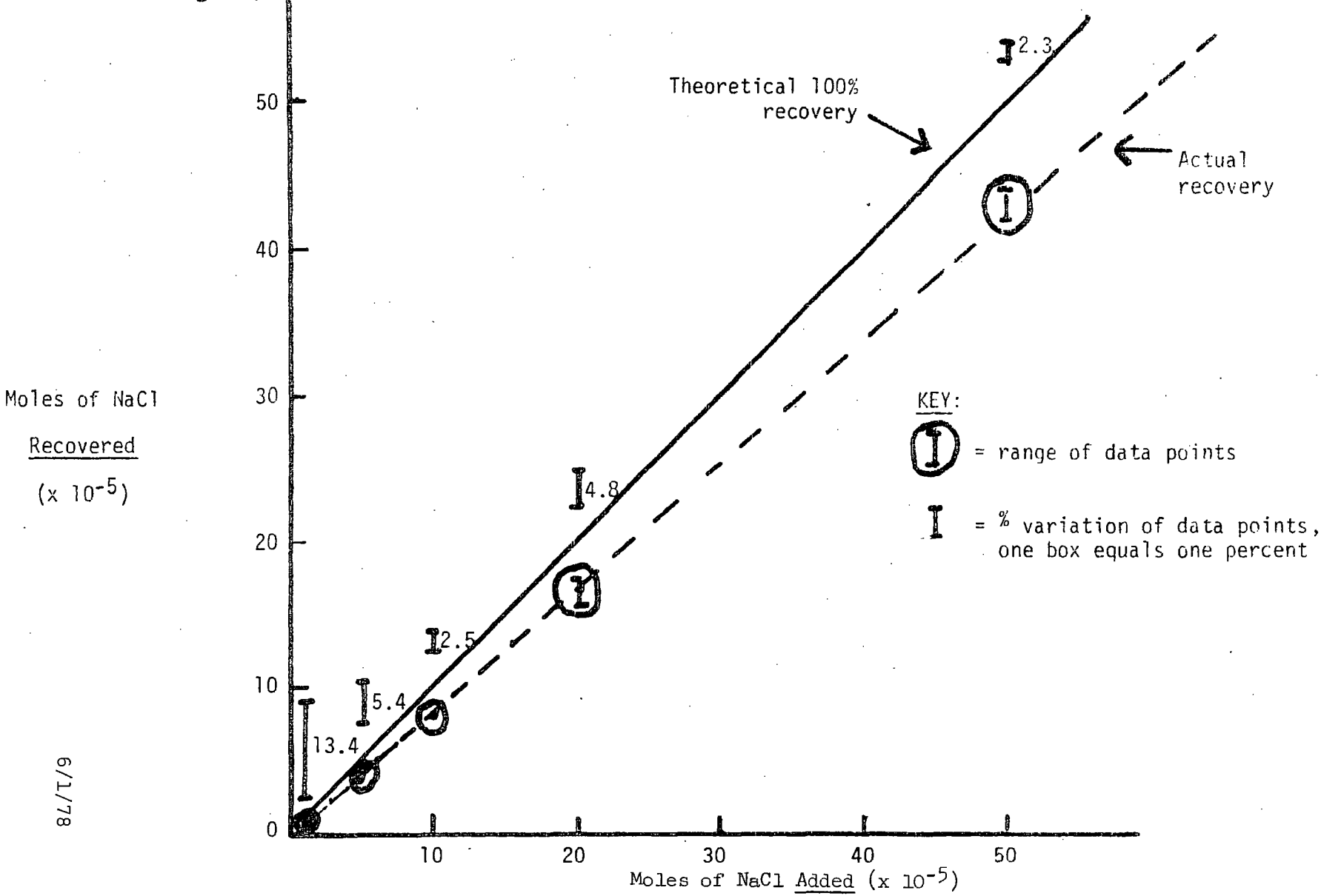

Table 1. Classification and partial chemical and physical characterization of the soils at the Chalk Point research sites.

Location with Respect to Cooling Tower		Soil	Surface	Physical Analysis*			Chemical Analysis*						
							Extractable					Organic	
Distance	Direction	Series	Texture*	Sand	Silt	Clay	Mg	P	K	Ca	Na	Matter	pH
-- km --				------ % -------			------ μg/g -------					-- % --	
1.6	north	Lakeland	fine sand	90	3	7	67	61	22	57	17	0.9	5.1
	east	Lakeland	fine sand	90	7	3	23	51	45	236	20	0.9	6.5
	south	Mattapex	loam	45	45	10	28	19	71	50	19	1.5	5.5
	west	Sassafras	fine sandy loam	73	21	6	62	12	51	96	18	0.8	5.8
4.8	north	Sassafras	fine sandy loam	75	19	6	29	24	59	152	20	0.9	5.8
	east	Woodstown	fine sandy loam	76	15	9	64	50	83	210	22	1.9	5.4
	south	Sassafras	fine sandy loam	68	25	7	50	5	31	245	20	0.6	5.9
	west	Westphalia	loamy fine sand	83	12	5	24	65	48	24	18	1.3	6.0
9.6	north	Sassafras	sandy loam	54	34	12	67	53	70	102	22	2.3	5.6
	east	Matapeake	loam	45	45	10	73	6	31	404	22	1.1	5.9
	south	Galestown	fine sandy loam	71	24	5	37	46	93	344	17	1.1	6.1
	west	Woodstown	loamy sand	78	17	5	53	4	28	164	21	1.0	6.0

* All values are reported for samples collected at a depth of 0-15 cm.