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In cooperation with the Texas Agricultural Experiment Station, Corpus Christi, Texas

Nitrogen Concentrations and Deposition in Rainfall at Two Sites in the Coastal Bend Area, South Texas, 1996–98

The Coastal Bend Bays and Estuary Program (CBBEP) (formerly Corpus Christi Bay National Estuary Program), instituted by the U.S. Environmental Protection Agency (EPA) and the Texas Natural Resource Conservation Commission (TNRCC), is a community-based effort to identify the status of problems associated with the bays and estuaries of the Coastal Bend area in south Texas (fig. 1), and to develop a long-range, comprehensive conservation and management plan. The primary objectives of the CBBEP include protection, restoration, and enhancement of water quality, sediments, and living resources within the Coastal Bend

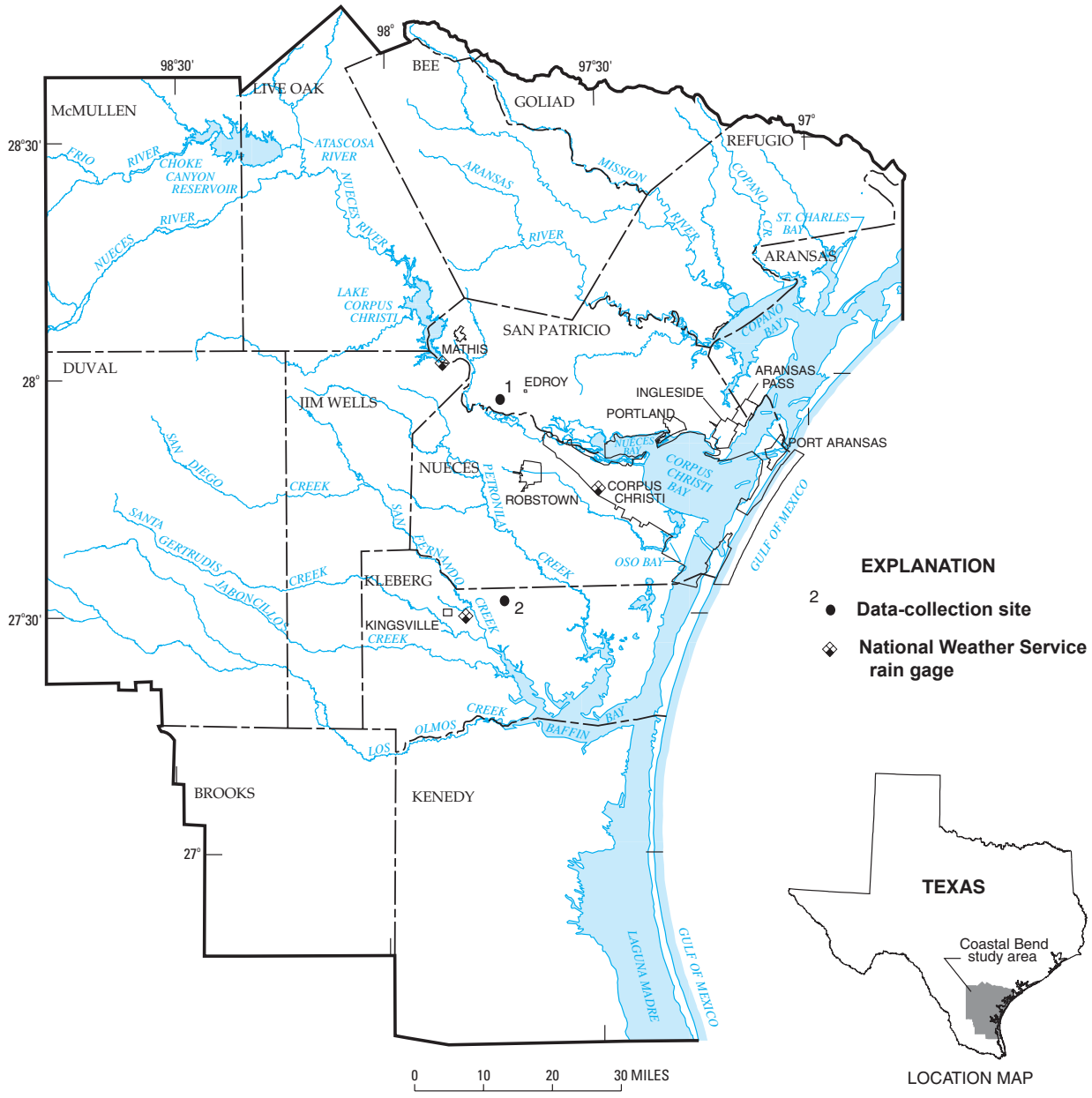

Figure 1. Location of selected data-collection sites and National Weather Service rain gages, Coastal Bend area, south Texas.

Table 1. Mean monthly and annual rainfall for three National Weather Service rain gages, Coastal Bend area, south Texas, 1967–96 (National Oceanic and Atmospheric Administration, 1999)

[In inches]

Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Annual standard deviation
Corpus Christi	1.73	1.98	1.44	1.98	3.76	3.88	2.19	3.56	5.21	3.60	1.79	1.79	32.91	8.61
Kingsville	1.62	2.01	1.21	1.76	3.80	4.43	2.14	3.02	3.97	3.14	1.57	1.34	30.01	8.95
Mathis	2.04	2.06	1.71	2.14	4.16	4.26	2.73	3.06	4.51	3.41	1.80	1.56	33.44	10.89

area. To achieve these objectives, the CBBEP has initiated a series of studies designed to characterize the water quantity and quality in the Coastal Bend area.

Atmospheric deposition, resulting from rainfall and dry deposition of atmospheric particles, has been identified nationwide as a significant nonpoint source of nutrients to surface waters either from direct deposition on surface water or from stormwater runoff. Baird and others (1996, p. 72) reported that 4.8 percent of the total nitrogen deposited on Oso Bay during 1988–92 originated from rainfall directly onto the bay. Quenzer and others (1998, p. 84) reported that atmospheric sources account for about one-third of the total nitrogen deposited on the area bays and estuaries.

The Coastal Bend study area in south Texas (fig. 1) has a population of about 540,000 (Texas State Data Center, 1999), with about one-half residing in Corpus Christi, the major urban center in the area. Other cities in the Coastal Bend area include Aransas Pass, Ingleside, Kingsville, Portland, and Robstown. Land use in the Coastal Bend study area is about two-thirds agriculture and ranching. Corpus Christi is a major port and home to the Nation's third largest refinery and petrochemical complex. The bays and estuaries in the area are known for their recreational and commercial fisheries. The climate of the Coastal Bend area is subtropical (short, mild winters and long, hot and humid summers). Prevailing winds are southeasterly most of the year but are briefly interrupted during winter and spring by southward-moving fronts. Average annual rainfall varies from about 25 to 35 inches (in.). The mean monthly and annual rainfall during 1967–96 for three National Weather Service (NWS) rain gages in the Coastal Bend area (Corpus Christi, Kingsville, and Mathis) are listed in table 1.

During 1996–98, the U.S. Geological Survey (USGS), in cooperation with the Texas Agricultural Experiment Station in Corpus Christi, Tex., collected and analyzed rainfall for nitrogen at two sites in the Coastal Bend area. This fact sheet presents concentrations of several forms of nitrogen from 39 rainfall events at the two sites. It describes the computation of nitrate nitrogen, ammonia nitrogen, and total nitrogen deposition from the rainfall and concentration data; and presents the regression equations from which daily deposition was estimated. Monthly and annual deposition obtained by summing daily deposition also are presented.

Rainfall Data and Analysis

Rainfall data were collected at two sites in the Coastal Bend study area. The northern site (site 1) is near Edroy in western San Patricio County (fig. 1). The southern site (site 2) is east of Kingsville in northern Kleberg County. Rainfall data were collected using automatic samplers equipped with polyethylene buckets. Rainfall at each site was recorded by a tipping-bucket rain gage measuring 0.01-in. increments. At the end of a rainfall event, the samples were retrieved and shipped to the USGS National Water Quality Laboratory in Arvada, Colo., for nitrogen analysis. The samples were analyzed for dissolved nitrate nitrogen, dissolved nitrite nitrogen, dissolved ammonia nitrogen, total ammonia plus organic nitrogen, and dissolved ammonia plus organic nitrogen.

Samples were collected and analyzed for 39 rainfall events at the two sites during May 1996–October 1998. During the data-collection period, site 1 had a total of 79.02 in. of rain and site 2 had a total of 71.58 in. The samples collected at sites 1 and 2 represent 28.71 and 29.20 in. of rain, respectively (table 2). These amounts correspond to 36 and 41 percent of rainfall totals at each site during the sampling period. Sampled rainfall events ranged from 0.19 to 5.52 in.; the mean and median rainfall amounts were 1.48 and 1.03 in., respectively.

Nitrogen concentrations from the water samples collected represent rainfall event-mean concentrations (EMC). Statistical tests were done to determine if EMCs significantly differed between samples collected at the two data-collection sites. The Wilcoxon rank-sum test (Helsel and Hirsch, 1992) was used to test whether differences between median concentrations for nitrate nitrogen, ammonia nitrogen, and total nitrogen at the two sites were significant. The tests did not indicate significant differences (p-values for nitrate, ammonia, and total nitrogen = 0.14, 0.65, and 0.67, respectively). As a result of the tests, EMCs from both sites were combined into one dataset for further analysis.

Summary statistics for dissolved nitrate nitrogen, dissolved nitrite nitrogen, dissolved ammonia nitrogen, total and dissolved ammonia plus organic nitrogen, and total nitrogen (table 3) were computed for the combined dataset. Total nitrogen was not analyzed directly but was computed from other analyses. In most cases, total nitrogen was computed as the sum of dissolved nitrate, dissolved nitrite, and total ammonia plus organic nitrogen. However, for several samples, concentrations of dissolved ammonia nitrogen were greater than concentrations of total ammonia plus

Table 2. Rainfall, pH, alkalinity, and event-mean concentrations of several forms of nitrogen from sites 1 and 2, Coastal Bend area, south Texas, 1996–98

[in., inches; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; --, no data; <, less than laboratory reporting limit]

Date	Rainfall (in.)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia plus organic, total[1] (mg/L as N)	Nitrogen, ammonia plus organic, dissolved[1] (mg/L as N)	Nitrogen, total (mg/L) as N
Site 1									
06/01/96	0.70	--	--	0.17	<0.01	0.30	0.37	0.31	0.54
06/23/96	1.13	--	--	.14	<.01	.21	.20	.33	.35
06/24/96	.44	--	--	.19	<.01	.39	.42	.39	.61
06/25/96	4.05	--	--	.07	<.01	.07	.07	.09	.14
08/08/96	1.08	5.7	2.8	.15	<.001	.13	<.1	.01	.28
08/09/96	.31	--	--	.22	<.001	.21	.30	.30	.52
08/21/96	1.12	5.4	--	.11	.002	.17	.17	.20	.28
08/24/96	1.21	5.5	--	.07	<.001	.08	.14	.05	.21
09/10/96	.50	--	--	.32	.003	.38	.50	.40	.82
09/20/96	.56	--	--	.21	<.001	.23	.30	.30	.51
11/24/96	.79	--	--	.04	<.001	.16	.20	.20	.24
12/15/96	.68	--	--	.22	<.001	.30	.80	.80	1.0
02/12/97	.21	--	--	.67	<.001	.75	.80	.80	1.5
03/11/97	.41	6.0	2.8	.10	<.01	.18	.30	.20	.40
05/09/97	1.31	--	--	.22	<.001	.23	.16	.19	.44
06/22/97	4.48	--	--	.10	.001	.10	.04	.02	.20
09/21/97	.78	--	--	.17	.005	.17	.29	.20	.46
10/06/97	.25	--	--	.14	<.001	.09	.14	.16	.28
10/11/97	3.43	--	--	.02	<.001	.02	.08	.04	.10
10/18/98	5.27	--	--	.24	.005	.10	.10	.17	.34
Site 2									
05/11/96	.47	--	--	.17	<.01	.41	.50	.40	.67
08/09/96	.19	--	--	.22	<.001	.24	.30	.30	.52
08/21/96	.61	6.2	--	.20	.002	.14	.15	.17	.35
08/23/96	.90	--	--	.06	.002	.20	.40	.16	.46
09/20/96	1.63	--	--	.07	<.001	.20	.20	.30	.27
11/24/96	.28	--	--	.11	<.001	.32	.50	.50	.61
12/15/96	.31	--	--	.14	<.001	.30	.40	.30	.54
03/11/97	.65	7.8	9.2	.10	.01	.14	.30	.30	.40
04/02/97	1.73	--	--	.03	<.001	.06	<.1	.01	.09
04/03/97	3.51	--	--	.03	<.001	.09	.01	.01	.12
05/09/97	1.03	4.9	--	.17	<.001	.18	.14	.13	.35
05/16/97	2.02	--	--	.12	.002	.15	.08	.08	.27
08/23/97	.40	--	--	.45	.01	.09	.45	.21	.90
09/22/97	2.74	--	--	.06	.002	.11	.13	.10	.19
09/24/97	1.96	--	--	.10	.001	.28	.28	.26	.38
10/11/97	5.52	--	--	.04	<.001	.01	.14	.12	.18
02/14/98	1.54	--	--	.14	.002	.30	.38	.34	.52
09/23/98	1.50	5.2	--	.07	.001	.05	.09	.01	.16
10/18/98	2.21	6.0	--	.06	.001	.05	.09	.04	.15

[1] Laboratory reporting limit is 0.1 mg/L. Values less than 0.1 mg/L are laboratory estimates.

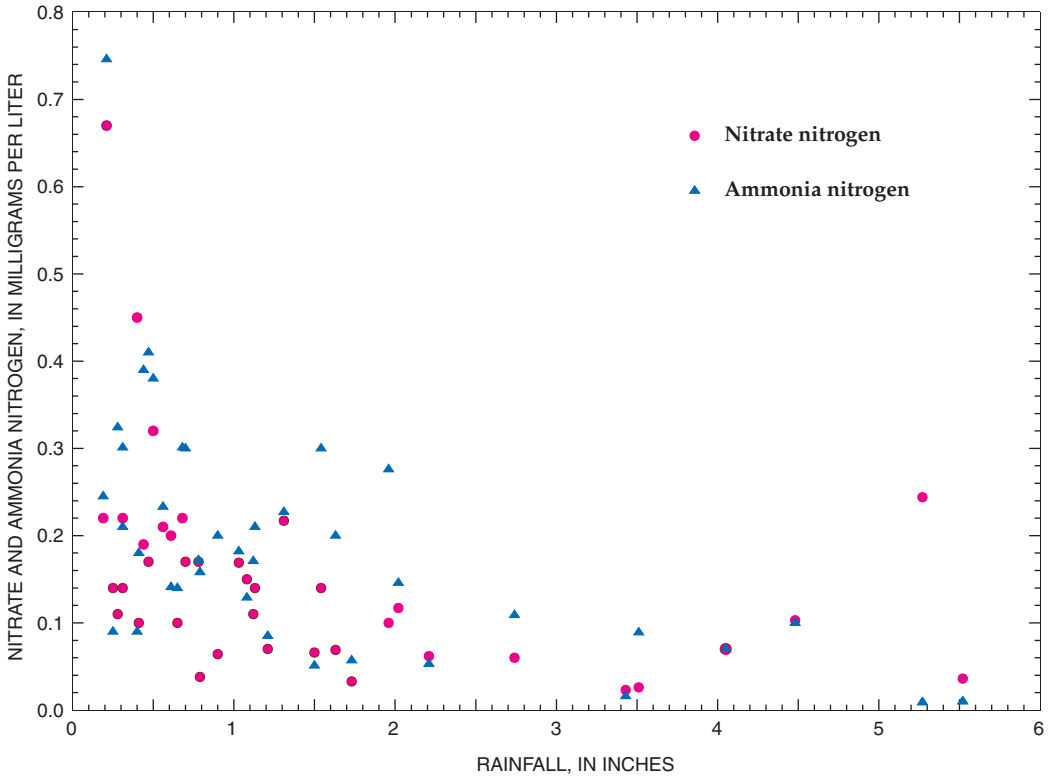

Figure 2. Event-mean concentrations of nitrate and ammonia nitrogen, Coastal Bend area, south Texas, 1996–98.

organic nitrogen[1]. In those cases, total nitrogen was computed as the sum of dissolved nitrate, dissolved nitrite, and dissolved ammonia nitrogen. Rain-weighted mean concentrations for dissolved nitrate nitrogen, dissolved ammonia nitrogen, and total nitrogen were computed by summing the product of rainfall and EMC for the 39 rainfall events and dividing by the sum of the rainfall.

[1] The analysis for dissolved ammonia nitrogen is more precise than the analysis for total (or dissolved) ammonia plus organic nitrogen at concentrations less than 0.1 mg/L. The laboratory reporting limit for dissolved ammonia nitrogen is 0.002 mg/L and for total (or dissolved) ammonia plus organic nitrogen is 0.1 mg/L.

Concentrations

Total nitrogen EMCs ranged from 0.09 to 1.5 milligrams per liter (mg/L), with an arithmetic mean of 0.42 mg/L (tables 2, 3). Concentrations of nitrate and ammonia nitrogen were detected in all samples and account for most (about 81 percent) of the total nitrogen detected in the samples. Nitrite concentrations

Table 3. Summary statistics of event-mean concentrations of nitrogen from rainfall, Coastal Bend area, south Texas, 1996–98

[mg/L, milligrams per liter; --, not determined; <, less than]

Constituent	No. of samples	Arithmetic mean	Rain-weighted mean	Median	Standard error of mean	Standard deviation	Minimum	Maximum
Nitrogen, nitrate, dissolved (mg/L as N)	39	0.15	0.11	0.14	0.019	0.12	0.02	0.67
Nitrogen, nitrite, dissolved (mg/L as N)	39	--	--	<.001	--	--	<.001	.01
Nitrogen, ammonia, dissolved (mg/L as N)	39	.19	.12	.17	.022	.14	.01	.75
Nitrogen, ammonia plus organic, total (mg/L as N)	39	.25	.15	.20	.031	.19	<.1	.8
Nitrogen, ammonia plus organic, dissolved (mg/L as N)	39	.23	.15	.20	.029	.18	.01	.8
Nitrogen, total (mg/L as N)	39	.42	.28	.35	.048	.28	.09	1.5

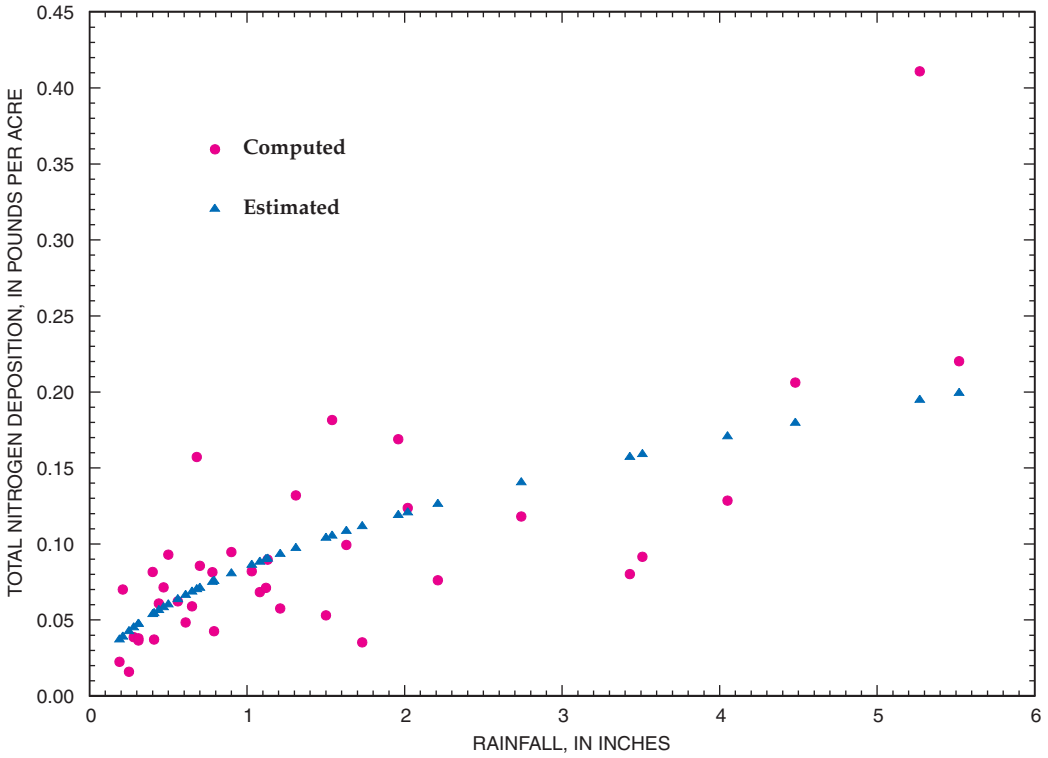

Figure 3. Comparison of computed and estimated (from regression) total nitrogen deposition for selected rainfall events, Coastal Bend area, south Texas, 1996–98.

greater than the laboratory reporting limit were detected in 15 of the 39 samples (38 percent) but never greater than 0.01 mg/L. Organic nitrogen (not analyzed directly, but calculated as the difference between ammonia plus total organic nitrogen and dissolved ammonia) was detected in most samples and accounts for about 19 percent of the total nitrogen. EMCs of nitrate and ammonia nitrogen decreased with increasing rainfall amounts (fig. 2).

Deposition

An EMC multiplied by the rainfall, in inches, and a conversion factor yields the deposition (pounds per acre) for the rainfall event. Deposition for nitrate nitrogen, ammonia nitrogen, and total nitrogen for the 39 rainfall events were computed accordingly.

Least-squares regression was used with the computed event-deposition amounts to develop relations between deposition and rainfall for nitrate nitrogen, ammonia nitrogen, and total nitrogen. The resulting equations were used with daily rainfall totals (measured at the sampling site) to estimate daily deposition for unsampled rainfall events; estimated daily depositions were summed to determine monthly and annual deposition.

Because of the nonlinearity observed in the relations between deposition and rainfall amounts, the data were log-transformed for regression. The estimated depositions from log-transformed regression equations, when detransformed to original units, are biased low and thus underestimate the actual depositions. To compensate, bias-correction factors equal to the mean of the regression residuals (in original units) were applied to the equations (Helsel and Hirsch, 1992, p. 256–257). The resulting regression equations for deposition (table 4) were of the form

$$L = a \bullet R^b \bullet \Phi,$$

where

L = estimated deposition, in pounds per acre;

a, b = regression coefficients;

R = rainfall, in inches; and

Φ = bias-correction factor.

A comparison between total nitrogen deposition computed for the rainfall events and estimated from the regression equation, as functions of rainfall, is shown in figure 3.

Estimated monthly and annual total nitrogen deposition for 1996–98 at the two data-collection sites, computed by summing daily deposition estimated from the regression equations, are listed in table 5.

Table 4. Regression equations for estimating nitrogen deposition from rainfall, Coastal Bend area, south Texas, 1996–98

Nitrogen form	Deposition equation
Nitrate, dissolved	$0.025 \bullet R^{0.433} \bullet 1.16$
Ammonia, dissolved	$0.034 \bullet R^{0.372} \bullet 1.16$
Total	$0.076 \bullet R^{0.456} \bullet 1.08$

Table 5. Monthly and annual total nitrogen deposition at sites 1 and 2, Coastal Bend area, south Texas, 1996–98

Site	Annual rainfall (inches)	Total nitrogen (pounds per acre)												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
							1996							
1	18.21	0.01	0	0.10	0.09	0.02	0.47	0	0.69	0.23	0.11	0.18	0.16	2.06
2	11.16	0	0	.02	.15	.06	.07	.02	.49	.36	.10	.18	.12	1.57
							1997							
1	33.83	.17	.30	.41	.42	.56	.49	.01	.06	.33	.67	.29	.08	3.79
2	35.71	.11	.22	.38	.49	.59	0	0	.08	.36	.69	.27	.01	3.20
							1998							
1	31.87	.12	.37	.27	.08	0	.05	.09	.55	.36	.61	.34	.26	3.10
2	28.87	.11	.26	.19	.04	0	.05	.04	.38	.72	.55	.37	.15	2.86

Monthly rainfall nitrogen deposition was highly variable, ranging from 0 to 0.72 pound per acre (September 1998, site 2). Greater annual rainfall generally resulted in greater deposition. However, site 1 deposition in 1997 was greater than site 2, even though site 2 had greater annual rainfall because, compared with site 1, more of the rainfall at site 2 occurred in larger events[2] when nitrogen concentrations were lower (fig. 2).

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[3] U.S. Geological Survey.
[4] Texas Agricultural Experiment Station.

[2] During 1997, daily rainfall of 0.01 in. or more occurred 101 days at site 1 compared to 77 days at site 2. Site 1 had an average daily rainfall (considering only days when rainfall occurred) of 0.33 in. The site 2 daily rainfall was 0.46 in.

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