EXECUTIVE SUMMARY
2006 PRECIPITATION CHEMISTRY AND WET DEPOSITION

A wet atmospheric deposition monitoring network was established in Pennsylvania in 1981 to determine the magnitude and distribution of acidic and nutrient elements in precipitation, to assess their potential environmental impacts, and to evaluate the effectiveness of current and future legislation designed to reduce acidic and nutrient deposition in the Commonwealth. Results from the 24th full-year of operation of this network are summarized in this report. Included in this summary are data from seven National Atmospheric Deposition Program/National Trends Network (NADP/NTN) sites and 10 sites supported by The Pennsylvania Department of Environmental Protection (DEP), Bureau of Air Quality Control (BAQC). One of the NADP/NTN sites is also supported by the BAQC. Additional information on atmospheric deposition monitoring in Pennsylvania and the United States can be obtained over the World Wide Web at http://www.dep.state.pa.us and http://nadp.sws.uiuc.edu.

Hydrogen Ion (H^+ as pH). The 2006 statewide mean annual pH (4.46) was the same as in 2005 and the highest pH (lowest acidity) measured in Pennsylvania since monitoring began in 1981 (Table 12). The hydrogen ion concentration (measured as pH) of precipitation in Pennsylvania has declined approximately 51% (40.0 μeq/L) over the last 24 years (Table 13). The decline in "acid rain" has been attributed to reductions in sulfur dioxide and nitrogen oxides emissions and to a much lesser extent increasing base cation and ammonium concentrations in some regions of the state (Lynch et al., 2007). Seasonal pH values in 2006 were very similar; the statewide mean growing season and dormant season pH was 4.43 and 4.51, respectively. Regional differences were also quite small (Table 12), with the highest pH values (lowest acidity) occurring in the eastern third of the state and the lowest pH values occurring in the central portion of Pennsylvania, although the mean difference between central and western Pennsylvania was very small. Despite the decrease in acidity, precipitation in the Commonwealth is still more acidic than nearly all other regions of the United States based on NADP/NTN data shown in Figure 2. Only three sites in the NADP/NTN, one in Ohio and two in West Virginia, recorded mean annual pH values in 2006 that were equal to or lower than the mean annual pH across most of Pennsylvania.

Sulfate (SO_4^{2-}). Sulfate concentrations have decreased approximately 39% (25.1 μeq/L) since 1983 (Table 13). The statewide mean annual sulfate concentration in 2006 was 2.034 mg/L (Table 14). Mean annual sulfate concentrations in 2006 were higher than in 2005 and generally higher than any year since 2002. Higher sulfate concentrations were observed at all sites, except the Millersville and Arendtsville NADP/NTN sites in south central Pennsylvania, with the largest increases reported in central and eastern Pennsylvania. Most of the increase in annual sulfate concentrations resulted from substantially higher concentrations during the dormant season, which averaged 1.717 mg/L across the state. Mean dormant season sulfate concentrations in 2006 were generally higher than values reported since 2001, except at Hills Creek (Tioga County) Little Pine (Lycoming County), and Leading Ridge (Huntingdon County)

Table 12. Annual and seasonal hydrogen ion analyses of precipitation collected at sites throughout Pennsylvania during 2006.

Region/Site	Volume Weighted Mean pH			Total Wet Depositions (kg/ha)			Precipitation Analyzed (Inches)			Precipitation Not Analyzed (Inches)		
	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.
Western Pennsylvania												
GODDARD	4.45	4.45	4.44	0.48	0.34	0.14	52.82	38.08	14.74	0.01	0.00	0.01
CROOKCRK	4.40	4.38	4.44	0.57	0.41	0.15	48.96	33.05	15.91	5.88	5.31	0.57
LAURHILL	4.39	4.33	4.50	0.49	0.33	0.15	43.99	25.33	18.66	2.21	2.21	0.00
ALLEPORT	4.42	4.40	4.46	0.47	0.31	0.16	45.35	28.66	16.69	2.55	1.17	1.38
PRESQISL	4.46	4.44	4.50	0.40	0.27	0.13	44.82	28.80	16.02	0.18	0.00	0.18
KANE	4.42	4.42	4.42	0.59	0.41	0.18	56.10	40.97	15.13	4.54	0.80	3.74
Region Mean	4.42	4.40	4.46	0.50	0.35	0.15	48.67	32.48	16.19	2.56	1.58	0.98
Central Pennsylvania												
LITTPINE	4.39	4.45	4.29	0.42	0.23	0.19	39.25	24.82	14.43	0.93	0.93	0.00
HILLSCRK	4.43	4.39	4.53	0.40	0.30	0.10	41.26	28.43	12.83	0.67	0.59	0.08
LITTBUFF	4.49	4.46	4.53	0.38	0.24	0.13	39.44	24.15	15.29	5.84	3.35	2.49
PSUNADP	4.39	4.36	4.44	0.41	0.28	0.14	38.82	24.38	14.44	0.90	0.45	0.45
LEADRIDG	4.38	4.34	4.45	0.40	0.27	0.14	35.36	21.72	13.64	2.41	0.93	1.48
YOWOCRK	4.39	4.37	4.42	0.46	0.31	0.15	39.74	25.42	14.32	4.24	3.08	1.16
ARENDTSV	4.50	4.50	4.49	0.33	0.19	0.14	38.66	22.83	15.82	1.35	0.12	1.23
Region Mean	4.42	4.41	4.45	0.40	0.26	0.14	38.93	24.54	14.40	2.34	1.35	0.99
Eastern Pennsylvania												
SLOCUM	4.56	4.55	4.58	0.37	0.24	0.13	39.52	24.10	15.42	13.48	9.86	3.62
VALLFORG	4.51	4.46	4.61	0.43	0.31	0.12	53.01	33.28	19.73	2.03	1.96	0.07
MILLERSV	4.66	4.56	4.90	0.27	0.20	0.06	43.16	27.11	16.05	5.50	1.82	3.68
MILFORD	4.51	4.47	4.57	0.42	0.27	0.15	50.71	29.63	21.08	2.38	1.95	0.43
Region Mean	4.56	4.51	4.67	0.37	0.26	0.12	46.60	28.53	18.07	5.85	3.90	1.95
State Mean	4.46	4.43	4.51	0.43	0.29	0.14	44.17	28.28	15.89	3.24	2.03	1.21

Table 13. Estimated changes in concentrations of individual ions in precipitation from 1983 to 2006.

	Hydrogen Ion		Sulfate		Nitrate		Chloride	
Site	Change (ueq/L)	Percent Change	Change (ueq/L)	Percent Change	Change (ueq/L)	Percent Change	Change (ueq/L)	Percent Change
CROOKCRK	-53.751*	-53.543	-29.224*	-37.652	-13.332*	-34.542	-2.008*	-24.907
GODDARD	-43.289*	-51.649	-26.951*	-38.701	-12.530*	-33.181	0.839	17.039
HILLSCRK	-30.924*	-45.121	-18.145*	-33.374	-10.030*	-31.634	0.066	1.479
LAURHILL	-47.776*	-55.178	-31.913*	-45.594	-11.650*	-34.560	-0.321	-6.098
LITTBUFF	-41.332*	-51.773	-20.422*	-32.600	-10.649*	-30.169	-0.072	-1.103
SLOCUM	-33.984*	-47.191	-16.440*	-29.164	-6.384*	-20.254	0.465	8.842
VALLFORG	-34.004*	-50.879	-23.712*	-40.504	-9.080*	-29.966	-4.603*	-38.113
LITTPINE	-49.636*	-56.587	-24.822*	-39.198	-15.928*	-41.323	1.799*	39.044
PSUNADP	-36.246*	-48.267	-26.295*	-40.772	-12.866*	-38.075	-1.985*	-38.618
KANE	-37.701*	-49.567	-27.043*	-41.215	-11.225*	-34.166	-2.216*	-46.543
LEADRIDG	-29.403*	-41.757	-20.338*	-33.549	-9.246*	-28.069	-2.031*	-38.905
MILFORD	-35.698*	-53.291	-27.145*	-49.232	-12.167*	-38.576	-2.158*	-31.364
Mean[1]	-39.978	-50.692	-25.092	-39.308	-11.700	-34.024	-1.154	-15.281

* $p<0.05$

[1] Changes for Slocum State Park were excluded from calculation of the mean because of a malfunction of the Aerochemetric sampler unit from 22 September 2005 through 3 January 2006.

Table 13 (continued).

Site	Ammonium		Calcium		Magnesium		Potassium		Sodium	
	Change (ueq/L)	Percent Change	Change (ueq/L)	Percent Change	Change (ueq/L)	Percent Change	Change (ueq/L)	Percent Change	Change (ueq/L)	Percent Change
CROOKCRK	0.458	2.640	-1.585	-18.819	-0.908*	-32.054	0.551*	79.777	1.033*	55.640
GODDARD	0.692	3.602	-2.446*	-26.830	-1.128*	-37.987	0.826*	144.282	1.253*	64.936
HILLSCRK	2.496	19.119	-0.736	-14.196	-0.579*	-28.284	1.041*	215.474	1.584*	114.384
LAURHILL	-1.502	-9.072	-0.856	-13.830	-0.912*	-40.034	0.659*	88.737	1.419*	84.619
LITTBUFF	1.412	7.225	-1.678*	-24.556	-0.655*	-25.255	0.982*	151.105	1.376*	46.476
SLOCUM	8.428*	63.220	0.514	11.272	-0.493	-23.075	1.005*	156.786	0.933	33.506
VALLFORG	2.175	13.989	-2.218*	-33.866	-3.821*	-65.690	0.814*	125.309	-2.877*	-34.744
LITTPINE	2.295	14.993	-0.386	-7.470	0.240	14.011	0.870*	183.170	2.851*	186.192
PSUNADP	1.816	14.347	-1.462*	-24.532	-0.778*	-42.415	-0.020	-4.771	-1.251*	-46.260
KANE	-0.173	-1.239	-0.868	-15.428	-0.721*	-40.819	-0.028	-6.854	-1.234*	-50.591
LEADRIDG	1.162	8.212	-1.002	-17.521	-0.732*	-38.093	-0.115	-18.849	-1.105*	-39.685
MILFORD	1.659	16.712	-0.807	-19.588	-0.863*	-41.441	-0.086	-18.067	-1.177	-24.486
Mean[1]	1.135	8.230	-1.277	-19.694	-0.987	-34.369	0.499	85.392	0.170	32.407

* $p<0.05$

[1] Changes for Slocum State Park were excluded from calculation of the mean because of a malfunction of the Aerochemetric sampler unit from 22 September 2005 through 3 January 2006.

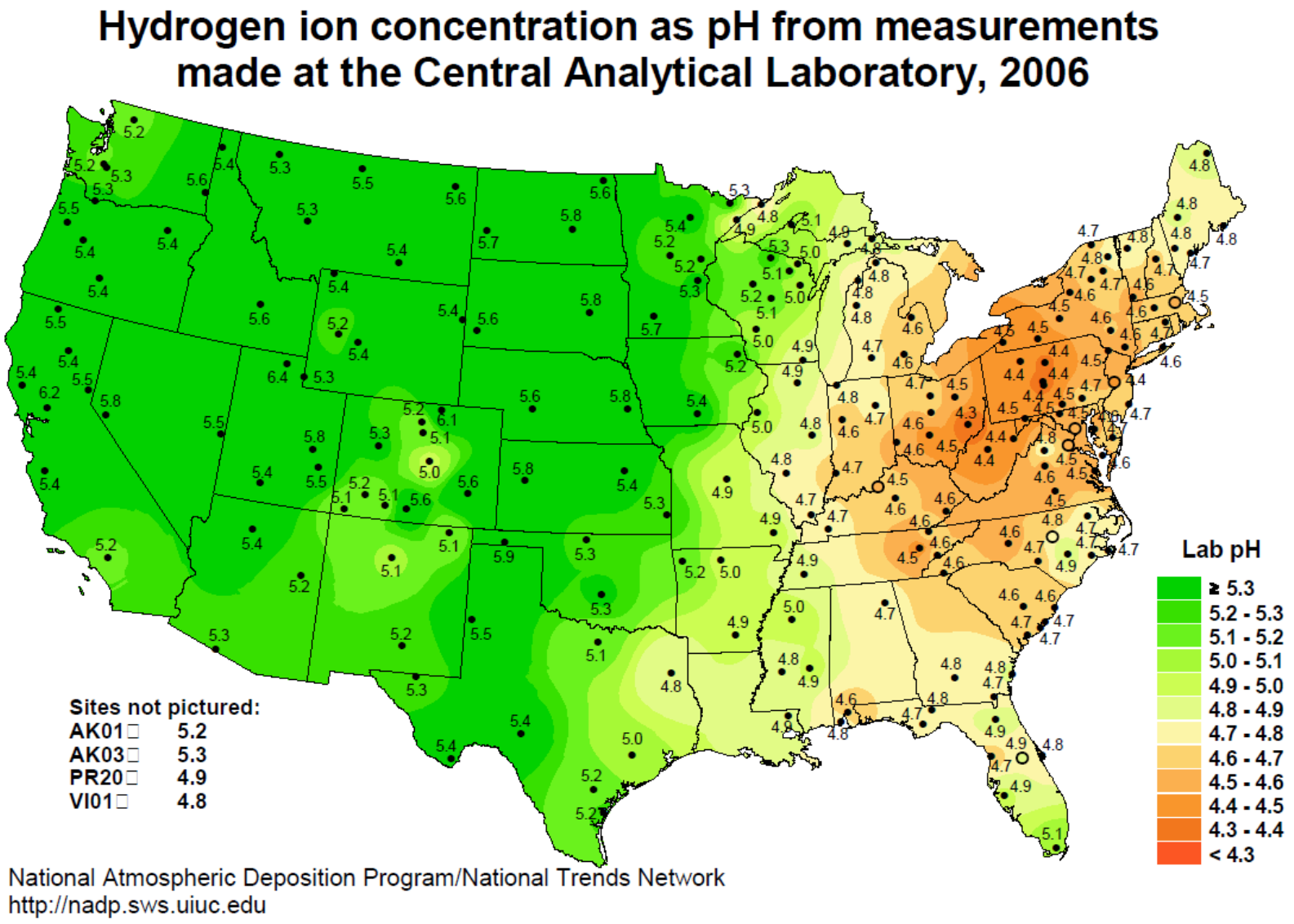

Figure 2. Mean annual hydrogen ion concentrations (as pH) in precipitation collected in the USA in 2006 by the National Atmospheric Deposition Program/National Trends Network.

Table 14. Annual and seasonal sulfate ion analyses of precipitation collected at sites throughout Pennsylvania during 2006.

	Volume Weighted Mean Concentrations (mg/L)			Total Wet Depositions (kg/ha)			Precipitation Analyzed (Inches)			Precipitation Not Analyzed (Inches)		
Region/Site	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.
Western Pennsylvania												
GODDARD	2.135	2.176	2.026	28.64	21.05	7.59	52.61	38.08	14.53	0.22	0.00	0.22
CROOKCRK	2.315	2.477	1.975	32.40	24.14	8.27	48.75	33.05	15.70	6.09	5.31	0.78
LAURHILL	2.300	2.686	1.774	27.19	18.79	8.41	43.91	25.33	18.58	2.29	2.21	0.08
ALLEPORT	2.664	3.035	2.004	32.19	22.99	9.20	44.79	28.66	16.13	3.11	1.17	1.94
PRESQISL	2.219	2.202	2.248	25.36	16.11	9.25	44.74	28.79	15.95	0.26	0.01	0.25
KANE	1.904	1.998	1.648	29.09	21.20	7.90	56.10	40.97	15.13	4.54	0.80	3.74
Region Mean	2.256	2.429	1.946	29.15	20.71	8.43	48.48	32.48	16.00	2.75	1.58	1.17
Central Pennsylvania												
LITTPINE	2.389	2.460	2.265	24.39	16.09	8.30	39.17	24.82	14.35	1.01	0.93	0.08
HILLSCRK	2.023	2.266	1.482	21.56	16.70	4.86	41.13	28.43	12.70	0.80	0.59	0.21
LITTBUFF	1.940	2.199	1.531	22.27	15.36	6.92	39.41	24.15	15.26	5.87	3.35	2.52
PSUNADP	2.089	2.309	1.717	21.06	14.56	6.50	38.82	24.38	14.44	0.90	0.45	0.45
LEADRIDG	2.211	2.416	1.885	21.13	13.89	7.24	35.36	21.72	13.64	2.41	0.93	1.48
YOWOCRK	1.897	2.060	1.609	21.24	14.91	6.33	39.74	25.42	14.32	4.24	3.08	1.16
ARENDTSV	1.826	1.911	1.703	18.52	11.14	7.38	38.66	22.83	15.82	1.35	0.12	1.23
Region Mean	2.054	2.231	1.742	21.45	14.67	6.79	38.90	24.54	14.36	2.37	1.35	1.02
Eastern Pennsylvania												
SLOCUM	1.725	1.904	1.442	23.39	16.42	6.97	39.30	24.10	15.20	13.70	9.86	3.84
VALLFORG	1.842	2.031	1.522	25.83	18.17	7.65	52.84	33.28	19.56	2.20	1.96	0.24
MILLERSV	1.677	1.943	1.228	20.43	14.28	6.15	43.16	27.11	16.05	5.50	1.82	3.68
MILFORD	1.418	1.625	1.127	19.19	13.03	6.16	50.71	29.63	21.08	2.38	1.95	0.43
Region Mean	1.666	1.876	1.330	22.21	15.48	6.73	46.50	28.53	17.97	5.94	3.90	2.05
State Mean	2.034	2.217	1.717	24.35	16.99	7.36	44.07	28.28	15.79	3.35	2.03	1.31

where they were the highest since the early 1990's. At Leading Ridge, sulfate concentrations in 2006 were 42% higher than in 2005 (1.885 mg/L versus 1.327 mg/L) and the highest measured at the site since 1991 (2.108 mg/L). The impact across the region was so pronounced that the dormant season mean (1.742 mg/L) was the highest since 1992.

In contrast, 2006 growing season sulfate concentrations, which averaged 2.217 mg/L across the state, were near their lowest levels in western Pennsylvania and generally higher than in 2005 in central and eastern regions of the state, but still well within the range of values reported since 1995. The higher sulfate concentrations occurred despite a significant drop in SO_2 emissions in 2006 in Pennsylvania and upwind states (EPA, 2007). The higher sulfate concentrations in 2006 were likely due to either long-range emission sources, seasonal differences in emissions, and/or climatic influences. Since the 2006 nitrate concentrations (discussed below) were only slightly higher in 2006 than 2005 and well within the range of values reported since 1995, the higher sulfate concentrations were most likely due to emissions patterns, not climatic variability, since changes in climate would affect but sulfate and nitrate concentrations similarly (Lynch et al., 2007).

Reductions in sulfate concentrations since 1983 resulted in an average decrease of 11.8 kg/ha (34.9%) of wet sulfate deposition across the state (Table 15). Annual and growing season sulfate depositions were generally higher in 2006 than in 2005, but well within the range of values reported over the past five years. This was not the case for dormant season sulfate deposition. Despite the relatively high dormant season sulfate concentrations, wet depositions were below 2005 levels at most monitoring sites. In fact, the western regional mean deposition was the second lowest reported to date, while the statewide mean deposition was the fourth lowest value reported in the last ten years. Obviously the amount and distribution of precipitation during the year influenced wet sulfate deposition patterns in 2006 relative to 2005 and other years, especially in central Pennsylvania.

Annual and seasonal precipitation patterns and volumes in 2006 were very different than those in 2005. Although annual precipitation was generally higher in 2006 than in 2005 by two to four inches, seasonal distributions were very different. Regional growing season precipitation in 2006 averaged from seven inches (central Pennsylvania) to 12 inches (western Pennsylvania) above 2005 volumes and was nearly ten inches higher across the entire state. In contrast, 2006 statewide dormant season precipitation was 7 inches below 2005 levels with the largest deficits occurring in western (8 inches) and central (6.5 inches) Pennsylvania. Such differences can exert substantial influence on annual and seasonal concentrations and wet deposition patterns across the state as well as comparisons of 2006 ionic concentrations and wet deposition patterns with patterns measured in 2005 and earlier years. However, as previously noted, annual and seasonal nitrate concentrations in 2006 were not substantially different from 2005, even during the dormant season, which suggests that precipitation differences were not the driving force behind the differences in sulfate concentrations. To illustrate this point, nitrate concentrations were approximately 11% higher in central Pennsylvania during the 2006 dormant season than they were in 2005. The higher concentrations were likely the result of lower precipitation during the 2006 dormant season because concentrations are generally inversely related to precipitation

Table 15. Estimated changes in wet deposition of individual ions in precipitation from 1983 to 2006.

	Hydrogen Ion		Sulfate		Nitrate		Chloride	
Site	Change (kg/ha)	Percent Change	Change (kg/ha)	Percent Change	Change (kg/ha)	Percent Change	Change (kg/ha)	Percent Change
CROOKCRK	-0.453*	-45.03	-11.098*	-29.28	-5.778*	-24.59	-0.194	-7.16
GODDARD	-0.436*	-48.69	-11.872*	-33.33	-6.667*	-27.33	0.490*	27.28
HILLSCRK	-0.221*	-36.96	-5.269*	-23.14	-3.314*	-20.29	0.255	19.76
LAURHILL	-0.704*	-61.02	-23.697*	-52.76	-11.849*	-43.09	-0.443	-18.17
LITTBUFF	-0.369*	-45.38	-7.227*	-23.54	-4.525*	-20.58	0.242	10.51
SLOCUM	-0.309*	-41.70	-6.121*	-21.80	-2.347	-11.96	0.372	20.15
VALLFORG	-0.388*	-51.05	-12.979*	-40.71	-5.572*	-27.32	-1.642*	-35.34
LITTPINE	-0.416*	-48.97	-8.438*	-28.53	-7.021*	-31.04	0.841*	54.18
PSUNADP	-0.281*	-39.07	-8.710*	-29.34	-5.104*	-26.10	-0.428*	-25.70
KANE	-0.475*	-51.24	-17.429*	-44.82	-8.847*	-36.35	-0.966*	-48.31
LEADRIDG	-0.329*	-43.95	-11.127*	-35.87	-6.460*	-30.40	-0.765*	-40.66
MILFORD	-0.333*	-47.76	-11.634*	-42.38	-6.638*	-32.51	-0.385	-16.13
Mean[1]	-0.400	-47.19	-11.771	-34.88	-6.525	-29.06	-0.272	-7.25

* $p<0.05$

[1] Changes for Slocum State Park were excluded from calculation of the mean because of a malfunction of the Aerochemetric sampler unit from 22 September 2005 through 3 January 2006.

Table 15 (continued).

Site	Ammonium		Calcium		Magnesium		Potassium		Sodium	
	Change (kg/ha)	Percent Change	Change (kg/ha)	Percent Change	Change (kg/ha)	Percent Change	Change (kg/ha)	Percent Change	Change (kg/ha)	Percent Change
CROOKCRK	0.492	15.53	-0.089	-5.28	-0.071	-20.70	0.252*	88.72	0.360*	87.82
GODDARD	0.318	8.41	-0.273	-14.73	-0.125*	-32.52	0.393*	166.98	0.348*	75.72
HILLSCRK	0.806*	39.42	0.010	1.12	-0.037	-17.32	0.420*	264.93	0.370*	140.26
LAURHILL	-0.822*	-20.73	-0.413*	-25.07	-0.163*	-45.09	0.245*	65.27	0.313*	61.84
LITTBUFF	0.629	17.03	-0.219	-15.68	-0.052	-16.41	0.468*	180.87	0.404*	61.22
SLOCUM	1.997*	80.24	0.213	22.88	-0.040	-15.11	0.494*	188.68	0.300*	48.82
VALLFORG	0.428	13.47	-0.444*	-31.28	-0.501*	-65.60	0.371*	133.89	-0.653	-32.26
LITTPINE	0.940*	35.19	0.087	8.76	0.067	33.91	0.415*	235.27	0.767*	237.31
PSUNADP	0.664*	29.34	-0.126	-11.15	-0.068*	-32.15	0.020	12.70	-0.207*	-36.75
KANE	-0.261	-8.37	-0.250	-18.23	-0.112*	-42.74	-0.014	-6.98	-0.347*	-52.24
LEADRIDG	0.140	5.16	-0.241*	-19.90	-0.093*	-38.53	-0.058	-22.80	-0.279*	-42.72
MILFORD	0.344	17.15	-0.022	-2.70	-0.083*	-31.64	0.023	12.62	-0.144	-12.80
Mean[1]	0.334	13.78	-0.180	-12.12	-0.113	-28.07	0.230	102.86	0.085	44.31

* $p<0.05$

[1] Changes for Slocum State Park were excluded from calculation of the mean because of a malfunction of the Aerochemetric sampler unit from 22 September 2005 through 3 January 2006.

volumes. In contrast, the 2006 mean dormant season sulfate concentration in central Pennsylvania was 43% higher than in 2005. Obviously, below average precipitation was a contributing factor to the substantially higher sulfate concentrations in 2006; however, if precipitation was the main driving force behind the lower sulfate concentrations, nitrate concentrations should have been similarly affected, but were not. The only other contributing factor would be differences in dormant season sulfur dioxide emissions between 2005 and 2006 (Lynch et al., 2007).

Despite the dramatic reductions, sulfate concentrations and wet depositions in western Pennsylvania continue to be higher than in most regions in the United States (Figure 3). The highest mean annual sulfate concentration (2.6 mg/L) at NADP/NTN sites in 2006 was recorded at an Ohio site; the second highest concentration (2.2 mg/L) was recorded at the Leading Ridge NADP/NTN site in Huntingdon County (Figure 3). When DEP supported deposition monitoring sites are included in the comparison (Table 14), the mean annual concentration at the Allegheny Portage site on Cresson Mountain in Cambria County was actually higher than the highest reported NADP/NTN concentration in Ohio. In fact, mean annual sulfate concentrations at four western Pennsylvania sites (Crooked Creek Lake, Laurel Hill, Allegheny Portage, and Presque Isle) and the Little Pine site in central Pennsylvania were higher in 2006 than recorded at the Leading Ridge NADP/NTN site in Huntingdon County (Table 14).

The highest annual wet sulfate deposition (29.1 kg/ha) in the United States in 2006 was recorded at the Kane NADP/NTN site in Elk County (Figure 4). The second highest sulfate deposition (28 kg/ha) was measured at a site in southeastern Ohio. However, annual wet sulfate deposition at the Crooked Creek Lake and Allegheny Portage sites exceeded 32 kg/ha in 2006, the highest amount recorded in the United States. Although precipitation differences across the region was a contributing factor to the relatively high deposition at these sites, higher sulfate concentrations especially during the growing season (Table 14) was the primary reason for the high annual sulfate deposition at these sites and across the region in general. The volume-weight mean growing season concentration at the Allegheny Portage site (3.035 mg/L) was the highest concentration reported at the site since 2001.

Nitrate (NO_3^-). Nitrate concentrations have decreased approximately 34% (11.7 μeq/L) since 1983 (Table 13). The statewide mean annual nitrate concentration in 2006 was 1.274 mg/L (Table 16) which was the second lowest (by 0.001 mg/L) mean concentration recorded the past 24 years. Growing and dormant season mean nitrate concentrations in 2006 were 1.155g/L and 1.491g/L, respectively (Table 16). Regional differences were also evident in 2006. Regardless of season, the highest nitrate concentrations occurred in the western portion of the state and decreased to the lowest levels in eastern Pennsylvania (Table 16). Reductions in nitrate concentrations since 1983 have resulted in a 6.5 kg/ha (29.1%) reduction in wet nitrate deposition across the state (Table 15). Annual nitrate deposition to the state in 2006 was 15.3 kg/ha, the second lowest amount reported to date. Approximately 58% of the nitrate deposition fell during the growing season (Table 16). Although wet nitrate deposition was highest in western Pennsylvania (18.0 kg/ha), differences in deposition in central and eastern Pennsylvania were much smaller (Table 16). The measured reductions in nitrate concentrations and wet

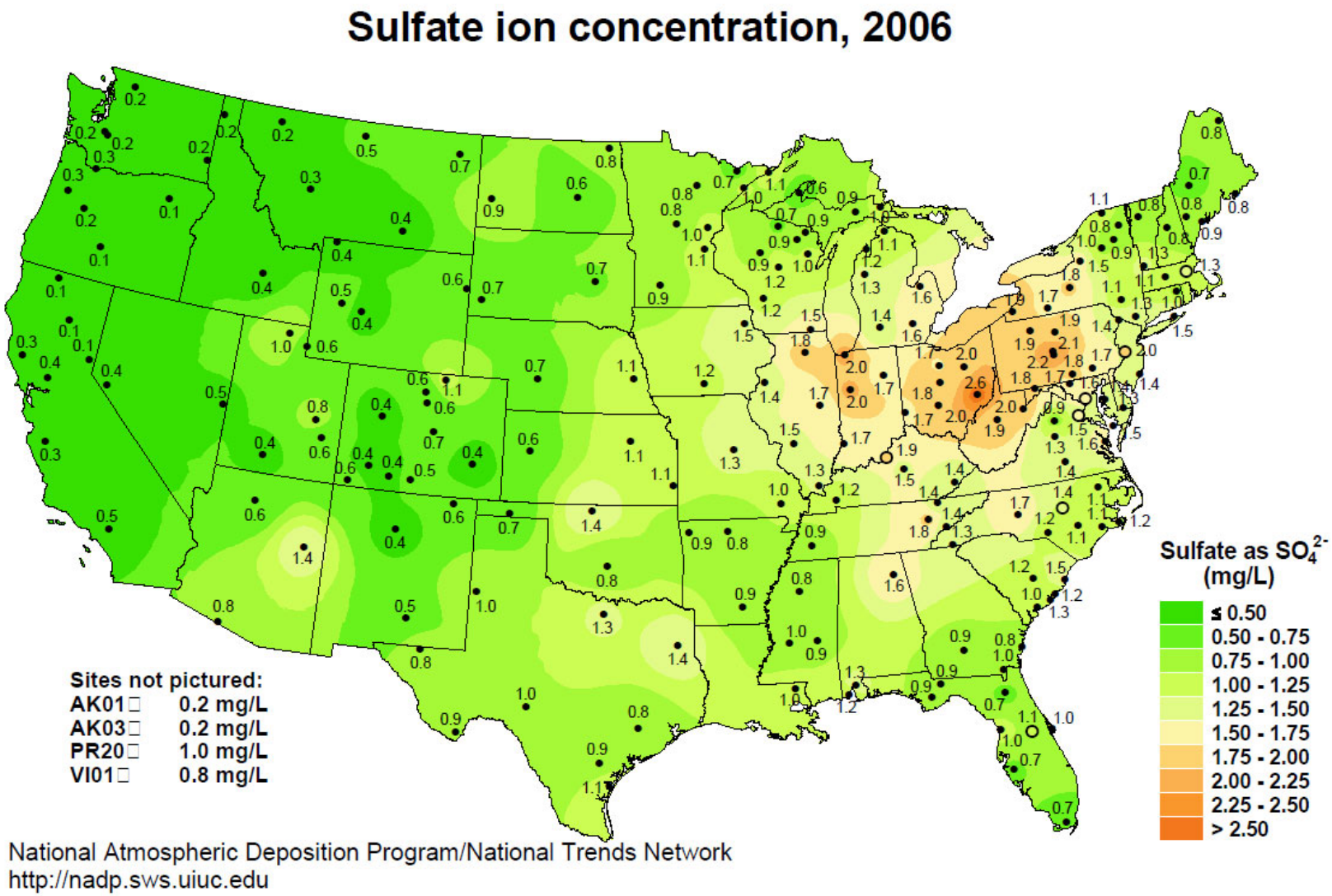

Figure 3. Mean annual sulfate ion concentrations in precipitation collected in the USA in 2006 by the National Atmospheric Deposition Program/National Trends Network.

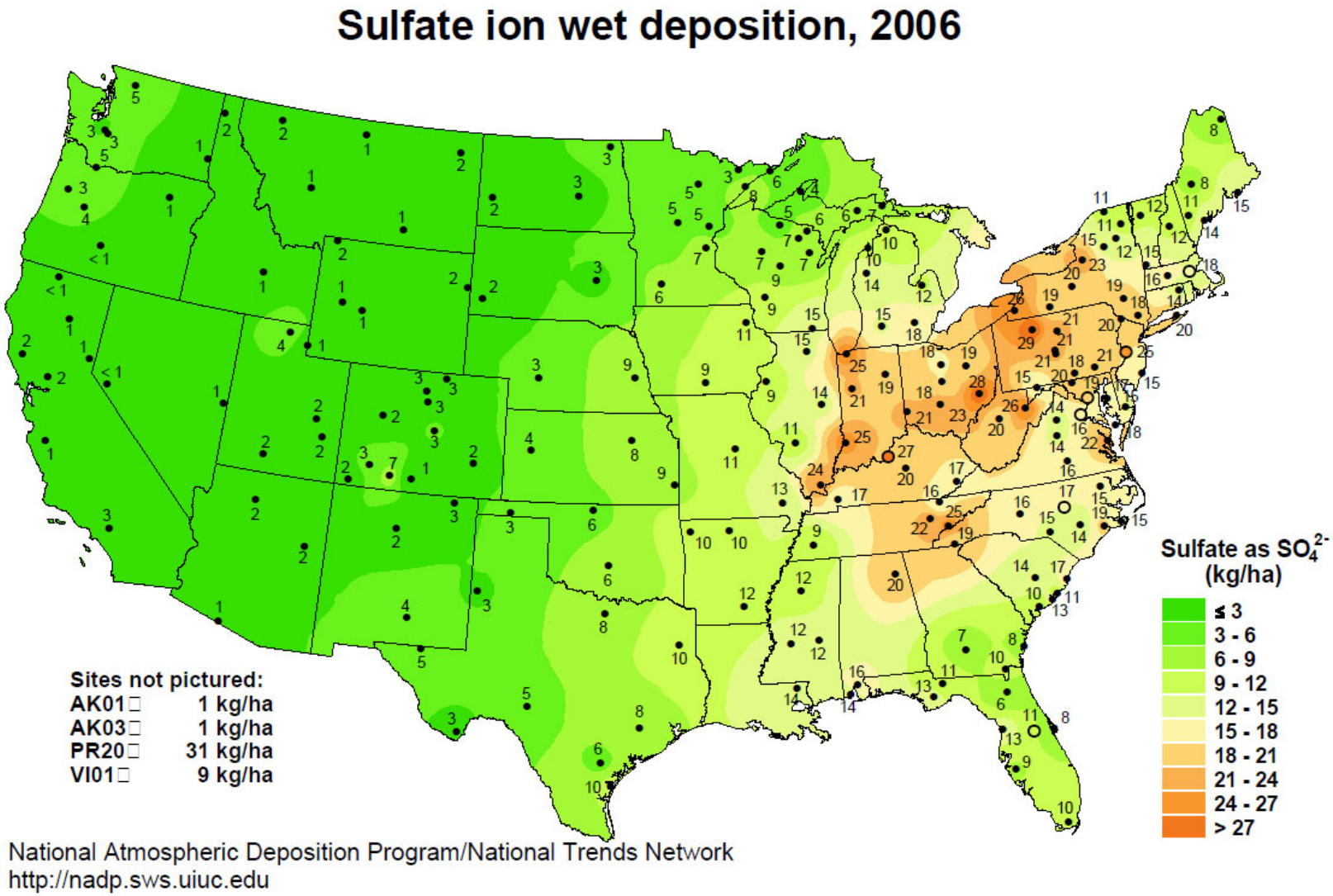

Figure 4. Annual sulfate ion wet deposition in the USA in 2006 based on precipitation collected by the National Atmospheric Deposition Program/National Trends Network.

Table 16. Annual and seasonal nitrate ion analyses of precipitation collected at sites throughout Pennsylvania during 2006.

	Volume Weighted Mean Concentrations (mg/L)			Total Wet Depositions (kg/ha)			Precipitation Analyzed (Inches)			Precipitation Not Analyzed (Inches)		
Region/Site	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.
Western Pennsylvania												
GODDARD	1.387	1.258	1.726	18.63	12.16	6.46	52.61	38.08	14.53	0.22	0.00	0.22
CROOKCRK	1.272	1.154	1.519	17.60	11.25	6.36	48.75	33.05	15.70	6.09	5.31	0.78
LAURHILL	1.441	1.293	1.643	16.83	9.05	7.79	43.91	25.33	18.58	2.29	2.21	0.08
ALLEPORT	1.408	1.233	1.720	17.23	9.34	7.89	44.79	28.66	16.13	3.11	1.17	1.94
PRESQISL	1.852	1.798	1.950	21.18	13.15	8.02	44.74	28.79	15.95	0.26	0.01	0.25
KANE	1.039	0.906	1.399	16.32	9.62	6.70	56.10	40.97	15.13	4.54	0.80	3.74
Region Mean	1.400	1.274	1.659	17.97	10.76	7.20	48.48	32.48	16.00	2.75	1.58	1.17
Central Pennsylvania												
LITTPINE	1.615	1.248	2.250	16.41	8.16	8.25	39.17	24.82	14.35	1.01	0.93	0.08
HILLSCRK	1.094	1.024	1.253	11.65	7.54	4.11	41.13	28.43	12.70	0.80	0.59	0.21
LITTBUFF	1.354	1.289	1.457	15.58	9.00	6.58	39.41	24.15	15.26	5.87	3.35	2.52
PSUNADP	1.240	1.065	1.537	12.53	6.71	5.81	38.82	24.38	14.44	0.90	0.45	0.45
LEADRIDG	1.332	1.124	1.664	12.85	6.46	6.39	35.36	21.72	13.64	2.41	0.93	1.48
YOWOCRK	1.183	1.037	1.442	13.18	7.51	5.67	39.74	25.42	14.32	4.24	3.08	1.16
ARENDTSV	0.985	0.898	1.111	10.05	5.24	4.81	38.66	22.83	15.82	1.35	0.12	1.23
Region Mean	1.258	1.098	1.530	13.18	7.23	5.95	38.90	24.54	14.36	2.37	1.35	1.02
Eastern Pennsylvania												
SLOCUM	1.304	1.219	1.439	17.47	10.51	6.96	39.30	24.10	15.20	13.70	9.86	3.84
VALLFORG	1.242	1.240	1.247	17.37	11.10	6.27	52.84	33.28	19.56	2.20	1.96	0.24
MILLERSV	0.901	0.924	0.861	11.11	6.79	4.31	43.16	27.11	16.05	5.50	1.82	3.68
MILFORD	1.009	0.926	1.126	13.58	7.43	6.15	50.71	29.63	21.08	2.38	1.95	0.43
Region Mean	1.114	1.077	1.168	14.88	8.96	5.92	46.50	28.53	17.97	5.94	3.90	2.05
State Mean	1.274	1.155	1.491	15.27	8.88	6.38	44.07	28.28	15.79	3.35	2.03	1.31

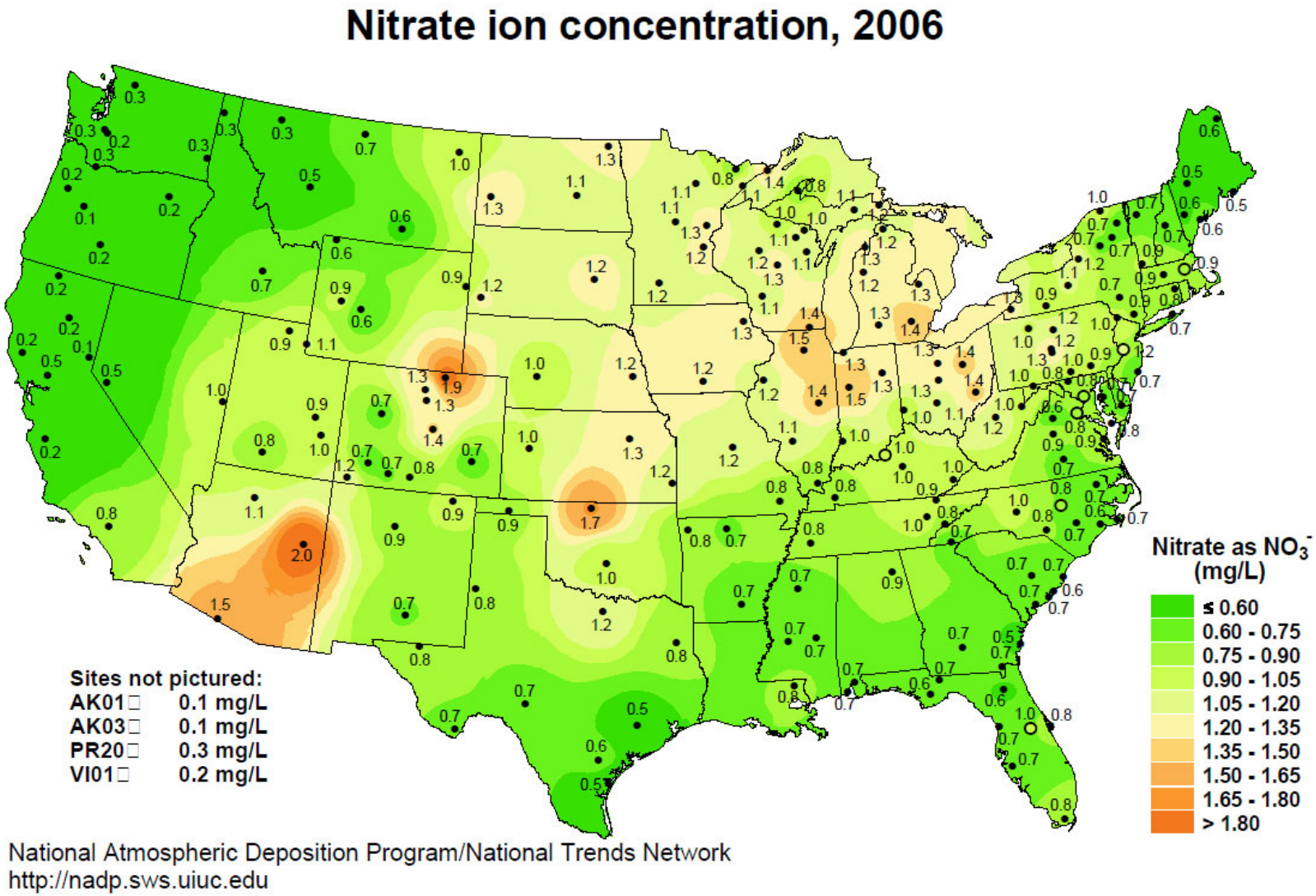

Figure 5. Mean annual nitrate ion concentrations in precipitation collected in the USA in 2006 by the National Atmospheric Deposition Program/National Trends Network.

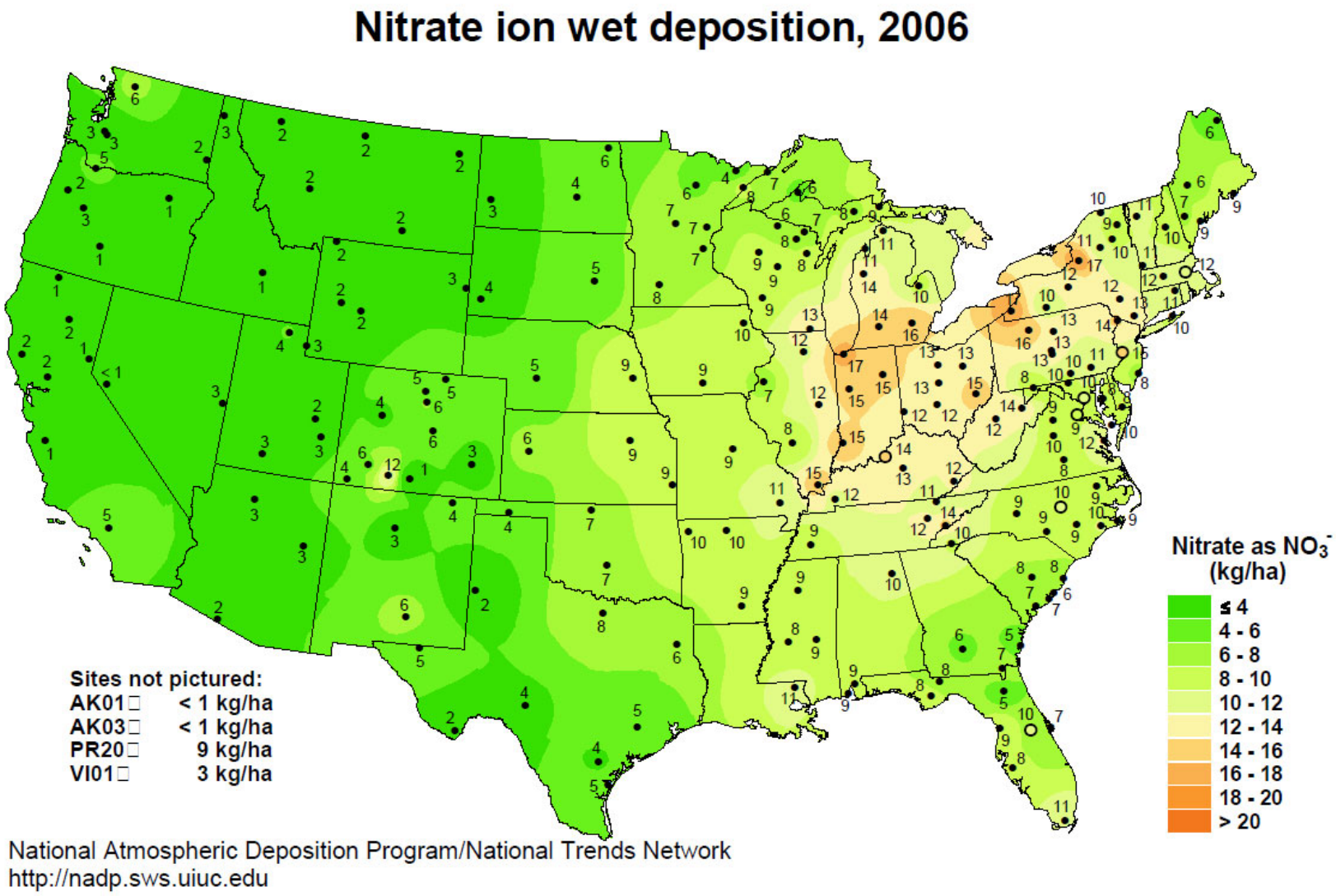

Figure 6. Annual nitrate ion wet deposition in the USA in 2006 based on precipitation collected by the National Atmospheric Deposition Program/National Trends Network.

depositions can be attributed to reductions in nitrogen oxides emissions in Pennsylvania and in upwind states (EPA, 2007; Lynch et al., 2007). Although nitrate concentrations in Pennsylvania are fairly comparable to those in neighboring states (Figure 5), wet nitrate deposition in the western third of the Commonwealth (see Table 16) continues to be higher than in most regions in the United States (Figure 6). Nitrate deposition at the Presque Isle site near Erie was 21.2 kg/ha in 2006, which is higher than any of the deposition estimates at the NADP/NTN sites shown in Figure 6. In fact, nitrate deposition across all of western Pennsylvania in 2006 was higher than any of the NADP/NTN sites in the United States. (Table 16, Figure 6).

Ammonium (NH_4^+). Ammonium concentrations and wet depositions have generally increased across the state since 1983, although the increases are not generally statistically significant (Tables 13 and 15). The highest ammonium concentrations and wet depositions in 2006 were measured at the Millersville (0.427 mg/L) site in Lancaster County, the Presque Isle State Park (0.424 mg/L) site near Erie, the Allegheny Portage (0.438 mg/L) site in Cambria County and the Little Pine (0.443 mg/L) site in Lycoming County (Table 17). The Millersville site is located on an active farm in Lancaster County and the likely source of ammonium is from ammonia emissions from agricultural activities. The relatively high ammonium concentrations near Erie are likely from the decomposition of plant material in the shallow waters of Lake Erie which releases ammonia to the atmosphere. Ammonia emissions from urban sources in the city of Erie may also be a contributing source. Ammonia emissions from utility sources are likely influencing the Allegheny Portage site. Why high ammonium concentrations were observed at Little Pine in 2006 is not readily apparent, although the site is located in a field, part of which is managed as a cover crop for wildlife.

Ammonium concentrations at the Millersville site are similar to concentrations reported at many NADP/NTN sites located in agricultural regions of the mid-west, in southeastern United States, and around the Great Lakes (Figure 7). In fact, the 2006 mean annual ammonium concentration at Millersville was the highest concentration of any site east of the Ohio River and comparable to many sites located in the Mid-west and around the Great Lakes (Figure 7). Ammonium deposition in Pennsylvania in 2006 averaged 4.06 kg/ha across the state (Table 17). The highest annual wet depositions were measured at Millersville (5.3 kg/ha) and at Allegheny Portage (5.3 kg/ha). The annual ammonium deposition at Millersville was the highest amount recorded along the East Coast in 2006 and the fourth highest amount reported among all NADP/NTN sites; the other sites are located in the Mid-west, primarily in Indiana (Figure 8).

Cations (Ca^{2+}, Mg^{2+}, K^+, Na^+). Base cation (calcium, magnesium, sodium, and potassium) concentrations occur in precipitation at very low concentrations (Tables 18-21) with annual means ranging from around 0.10 mg/L for calcium to around 0.02 mg/L for magnesium. Calcium and magnesium concentrations have generally decreased the past 24 years where as sodium and potassium concentrations have increased (Table 13). These cations are important in that they are a source of acid neutralizing capacity in precipitation and are also essential plant nutrients. Wind blown soil particles are an important source for these cations, although in coastal areas sea sprays can also be an important source.

Table 17. Annual and seasonal ammonium ion analyses of precipitation collected at sites throughout Pennsylvania during 2006.

Region/Site	Volume Weighted Mean Concentrations (mg/L)			Total Wet Depositions (kg/ha)			Precipitation Analyzed (Inches)			Precipitation Not Analyzed (Inches)		
	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.
Western Pennsylvania												
GODDARD	0.375	0.374	0.379	5.04	3.62	1.42	52.61	38.08	14.53	0.22	0.00	0.22
CROOKCRK	0.296	0.298	0.291	4.13	2.91	1.22	48.75	33.05	15.70	6.09	5.31	0.78
LAURHILL	0.330	0.328	0.333	3.87	2.29	1.58	43.91	25.33	18.58	2.29	2.21	0.08
ALLEPORT	0.438	0.481	0.361	5.30	3.65	1.66	44.79	28.66	16.13	3.11	1.17	1.94
PRESQISL	0.424	0.404	0.459	4.84	2.96	1.89	44.74	28.79	15.95	0.26	0.01	0.25
KANE	0.250	0.259	0.228	3.83	2.74	1.09	53.50	38.38	15.13	7.13	3.39	3.74
Region Mean	0.352	0.357	0.342	4.50	3.03	1.48	48.05	32.05	16.00	3.18	2.02	1.17
Central Pennsylvania												
LITTPINE	0.443	0.469	0.399	4.53	3.07	1.46	39.17	24.82	14.35	1.01	0.93	0.08
HILLSCRK	0.262	0.260	0.268	2.79	1.91	0.88	41.13	28.43	12.70	0.80	0.59	0.21
LITTBUFF	0.401	0.427	0.362	4.61	2.98	1.63	39.41	24.15	15.26	5.87	3.35	2.52
PSUNADP	0.303	0.304	0.302	3.06	1.92	1.14	38.82	24.38	14.44	0.90	0.45	0.45
LEADRIDG	0.334	0.316	0.360	3.20	1.82	1.38	32.79	19.15	13.64	4.98	3.50	1.48
YOWOCRK	0.269	0.275	0.258	3.01	1.99	1.02	39.74	25.42	14.32	4.24	3.08	1.16
ARENDTSV	0.322	0.343	0.291	3.26	2.00	1.26	38.66	22.83	15.82	1.35	0.12	1.23
Region Mean	0.334	0.342	0.320	3.50	2.24	1.25	38.53	24.17	14.36	2.74	1.72	1.02
Eastern Pennsylvania												
SLOCUM	0.379	0.427	0.301	5.14	3.69	1.46	39.30	24.10	15.20	13.70	9.86	3.84
VALLFORG	0.318	0.337	0.285	4.45	3.02	1.43	52.84	33.28	19.56	2.20	1.96	0.24
MILLERSV	0.427	0.428	0.426	5.28	3.14	2.13	43.16	27.11	16.05	5.50	1.82	3.68
MILFORD	0.198	0.217	0.173	2.68	1.74	0.95	50.12	29.04	21.08	2.97	2.54	0.43
Region Mean	0.330	0.352	0.296	4.39	2.90	1.49	46.35	28.38	17.97	6.09	4.05	2.05
State Mean	0.339	0.350	0.322	4.06	2.67	1.39	43.73	27.94	15.79	3.68	2.37	1.31

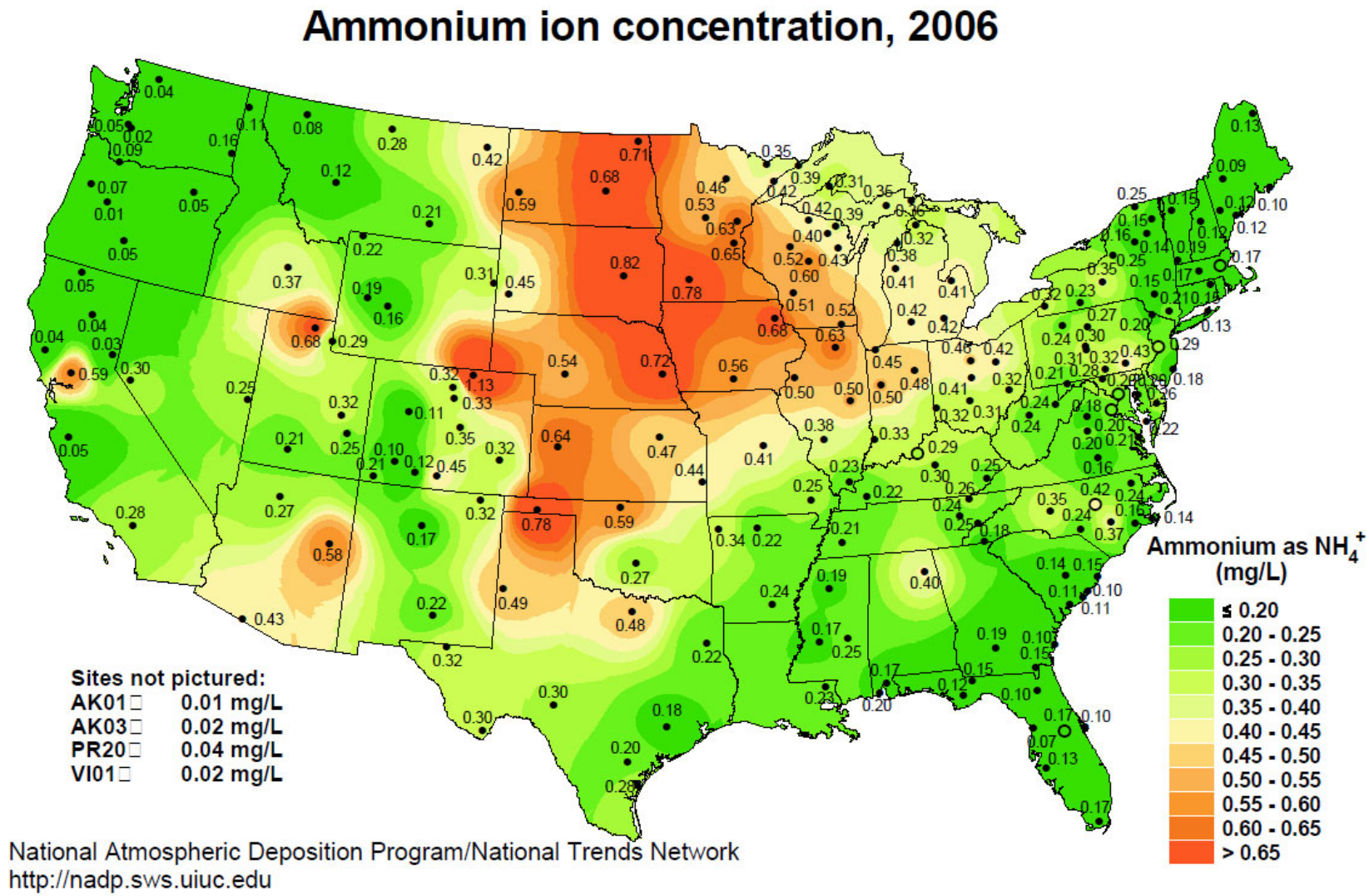

Figure 7. Mean annual ammonium ion concentrations in precipitation collected in the USA in 2006 by the National Atmospheric Deposition Program/National Trends Network.

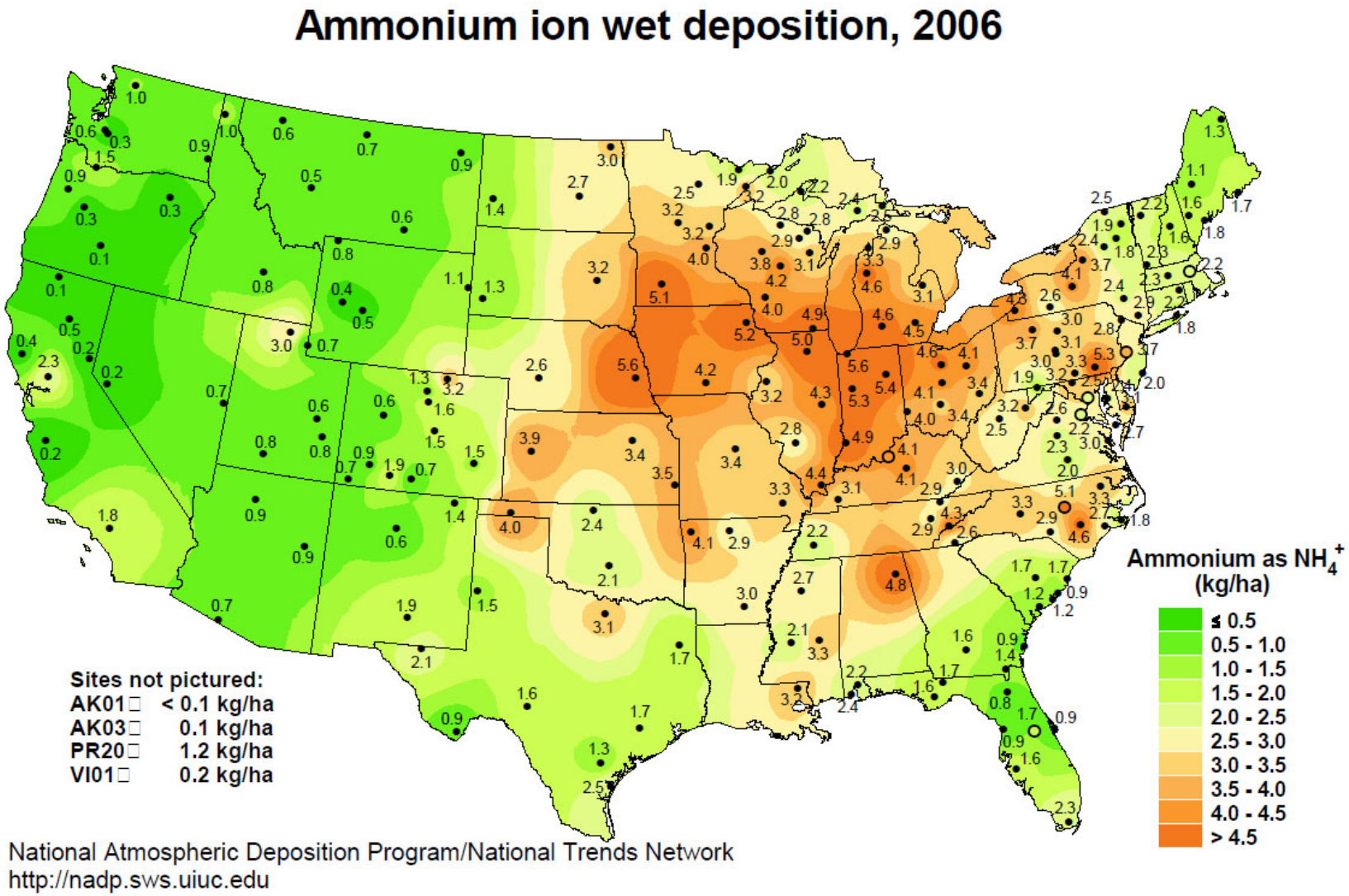

Figure 8. Annual ammonium ion wet deposition in the USA in 2006 based on precipitation collected by the National Atmospheric Deposition Program/National Trends Network.

Table 18. Annual and seasonal calcium ion analyses of precipitation collected at sites throughout Pennsylvania during 2006.

Region/Site	Volume Weighted Mean Concentrations (mg/L)			Total Wet Depositions (kg/ha)			Precipitation Analyzed (Inches)			Precipitation Not Analyzed (Inches)		
	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.
Western Pennsylvania												
GODDARD	0.151	0.126	0.216	2.02	1.21	0.81	52.61	38.08	14.53	0.22	0.00	0.22
CROOKCRK	0.132	0.119	0.160	1.83	1.16	0.67	48.75	33.05	15.70	6.09	5.31	0.78
LAURHILL	0.173	0.140	0.217	2.01	0.98	1.03	43.91	25.33	18.58	2.29	2.21	0.08
ALLEPORT	0.217	0.182	0.279	2.66	1.38	1.28	44.79	28.66	16.13	3.11	1.17	1.94
PRESQISL	0.242	0.179	0.355	2.77	1.31	1.46	44.74	28.79	15.95	0.26	0.01	0.25
KANE	0.092	0.084	0.115	1.44	0.89	0.55	56.10	40.97	15.13	4.54	0.80	3.74
Region Mean	0.168	0.138	0.224	2.12	1.16	0.97	48.48	32.48	16.00	2.75	1.58	1.17
Central Pennsylvania												
LITTPINE	0.146	0.125	0.180	1.48	0.82	0.66	39.17	24.82	14.35	1.01	0.93	0.08
HILLSCRK	0.122	0.127	0.110	1.30	0.94	0.36	41.13	28.43	12.70	0.80	0.59	0.21
LITTBUFF	0.118	0.124	0.109	1.36	0.87	0.49	39.41	24.15	15.26	5.87	3.35	2.52
PSUNADP	0.116	0.103	0.137	1.17	0.65	0.52	38.82	24.38	14.44	0.90	0.45	0.45
LEADRIDG	0.134	0.098	0.192	1.30	0.57	0.74	35.36	21.72	13.64	2.41	0.93	1.48
YOWOCRK	0.085	0.076	0.101	0.94	0.55	0.40	39.74	25.42	14.32	4.24	3.08	1.16
ARENDTSV	0.080	0.071	0.094	0.82	0.41	0.41	38.66	22.83	15.82	1.35	0.12	1.23
Region Mean	0.114	0.104	0.132	1.20	0.69	0.51	38.90	24.54	14.36	2.37	1.35	1.02
Eastern Pennsylvania												
SLOCUM	0.126	0.117	0.140	1.69	1.01	0.68	39.30	24.10	15.20	13.70	9.86	3.84
VALLFORG	0.124	0.110	0.148	1.73	0.99	0.75	52.84	33.28	19.56	2.20	1.96	0.24
MILLERSV	0.087	0.092	0.078	1.06	0.67	0.39	43.16	27.11	16.05	5.50	1.82	3.68
MILFORD	0.077	0.064	0.094	1.03	0.51	0.52	50.71	29.63	21.08	2.38	1.95	0.43
Region Mean	0.103	0.096	0.115	1.38	0.80	0.58	46.50	28.53	17.97	5.94	3.90	2.05
State Mean	0.131	0.114	0.160	1.57	0.88	0.69	44.07	28.28	15.79	3.35	2.03	1.31

Table 19. Annual and seasonal magnesium ion analyses of precipitation collected at sites throughout Pennsylvania during 2006.

Region/Site	Volume Weighted Mean Concentrations (mg/L)			Total Wet Depositions (kg/ha)			Precipitation Analyzed (Inches)			Precipitation Not Analyzed (Inches)		
	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.
Western Pennsylvania												
GODDARD	0.027	0.024	0.034	0.36	0.23	0.13	52.61	38.08	14.53	0.22	0.00	0.22
CROOKCRK	0.026	0.026	0.027	0.37	0.25	0.11	48.75	33.05	15.70	6.09	5.31	0.78
LAURHILL	0.027	0.024	0.031	0.31	0.17	0.15	43.91	25.33	18.58	2.29	2.21	0.08
ALLEPORT	0.051	0.049	0.056	0.63	0.37	0.26	44.79	28.66	16.13	3.11	1.17	1.94
PRESQISL	0.048	0.036	0.069	0.55	0.27	0.28	44.74	28.79	15.95	0.26	0.01	0.25
KANE	0.012	0.010	0.018	0.19	0.11	0.09	56.10	40.97	15.13	4.54	0.80	3.74
Region Mean	0.032	0.028	0.039	0.40	0.23	0.17	48.48	32.48	16.00	2.75	1.58	1.17
Central Pennsylvania												
LITTPINE	0.028	0.025	0.034	0.29	0.16	0.12	39.17	24.82	14.35	1.01	0.93	0.08
HILLSCRK	0.022	0.022	0.022	0.23	0.16	0.07	41.13	28.43	12.70	0.80	0.59	0.21
LITTBUFF	0.027	0.027	0.027	0.31	0.19	0.12	39.41	24.15	15.26	5.87	3.35	2.52
PSUNADP	0.018	0.016	0.021	0.18	0.10	0.08	38.82	24.38	14.44	0.90	0.45	0.45
LEADRIDG	0.024	0.019	0.031	0.23	0.11	0.12	35.36	21.72	13.64	2.41	0.93	1.48
YOWOCRK	0.012	0.011	0.014	0.14	0.08	0.06	39.74	25.42	14.32	4.24	3.08	1.16
ARENDTSV	0.016	0.011	0.022	0.16	0.07	0.09	38.66	22.83	15.82	1.35	0.12	1.23
Region Mean	0.021	0.019	0.024	0.22	0.13	0.09	38.90	24.54	14.36	2.37	1.35	1.02
Eastern Pennsylvania												
SLOCUM	0.028	0.027	0.030	0.38	0.23	0.15	39.30	24.10	15.20	13.70	9.86	3.84
VALLFORG	0.047	0.036	0.067	0.66	0.32	0.34	52.84	33.28	19.56	2.20	1.96	0.24
MILLERSV	0.021	0.018	0.026	0.26	0.13	0.13	43.16	27.11	16.05	5.50	1.82	3.68
MILFORD	0.022	0.016	0.030	0.29	0.13	0.16	50.71	29.63	21.08	2.38	1.95	0.43
Region Mean	0.030	0.024	0.038	0.40	0.20	0.19	46.50	28.53	17.97	5.94	3.90	2.05
State Mean	0.027	0.023	0.033	0.33	0.18	0.14	44.07	28.28	15.79	3.35	2.03	1.31

Table 20. Annual and seasonal potassium ion analyses of precipitation collected at sites throughout Pennsylvania during 2006.

	Volume Weighted Mean Concentrations (mg/L)			Total Wet Depositions (kg/ha)			Precipitation Analyzed (Inches)			Precipitation Not Analyzed (Inches)		
Region/Site	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.
Western Pennsylvania												
GODDARD	0.053	0.056	0.045	0.71	0.54	0.17	52.61	38.08	14.53	0.22	0.00	0.22
CROOKCRK	0.069	0.075	0.055	0.97	0.74	0.23	48.75	33.05	15.70	6.09	5.31	0.78
LAURHILL	0.095	0.126	0.052	1.13	0.88	0.25	43.91	25.33	18.58	2.29	2.21	0.08
ALLEPORT	0.127	0.161	0.065	1.52	1.22	0.30	44.79	28.66	16.13	3.11	1.17	1.94
PRESQISL	0.105	0.121	0.076	1.20	0.88	0.31	44.74	28.79	15.95	0.26	0.01	0.25
KANE	0.018	0.017	0.021	0.28	0.18	0.10	56.10	40.97	15.13	4.54	0.80	3.74
Region Mean	0.078	0.093	0.052	0.97	0.74	0.23	48.48	32.48	16.00	2.75	1.58	1.17
Central Pennsylvania												
LITTPINE	0.107	0.141	0.048	1.10	0.92	0.18	39.17	24.82	14.35	1.01	0.93	0.08
HILLSCRK	0.109	0.132	0.058	1.17	0.98	0.19	41.13	28.43	12.70	0.80	0.59	0.21
LITTBUFF	0.078	0.094	0.052	0.90	0.66	0.24	39.41	24.15	15.26	5.87	3.35	2.52
PSUNADP	0.027	0.031	0.021	0.28	0.20	0.08	38.82	24.38	14.44	0.90	0.45	0.45
LEADRIDG	0.053	0.072	0.024	0.51	0.42	0.09	35.36	21.72	13.64	2.41	0.93	1.48
YOWOCRK	0.026	0.032	0.015	0.29	0.23	0.06	39.74	25.42	14.32	4.24	3.08	1.16
ARENDTSV	0.013	0.011	0.015	0.13	0.06	0.06	38.66	22.83	15.82	1.35	0.12	1.23
Region Mean	0.059	0.074	0.033	0.62	0.50	0.13	38.90	24.54	14.36	2.37	1.35	1.02
Eastern Pennsylvania												
SLOCUM	0.133	0.151	0.106	1.81	1.30	0.51	39.30	24.10	15.20	13.70	9.86	3.84
VALLFORG	0.094	0.108	0.070	1.32	0.97	0.35	52.84	33.28	19.56	2.20	1.96	0.24
MILLERSV	0.017	0.016	0.017	0.21	0.12	0.09	43.16	27.11	16.05	5.50	1.82	3.68
MILFORD	0.030	0.037	0.019	0.40	0.29	0.11	50.71	29.63	21.08	2.38	1.95	0.43
Region Mean	0.068	0.078	0.053	0.93	0.67	0.26	46.50	28.53	17.97	5.94	3.90	2.05
State Mean	0.068	0.081	0.045	0.82	0.62	0.19	44.07	28.28	15.79	3.35	2.03	1.31

Table 21. Annual and seasonal sodium ion analyses of precipitation collected at sites throughout Pennsylvania during 2006.

Region/Site	Volume Weighted Mean Concentrations (mg/L)			Total Wet Depositions (kg/ha)			Precipitation Analyzed (Inches)			Precipitation Not Analyzed (Inches)		
	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.
Western Pennsylvania												
GODDARD	0.091	0.075	0.132	1.23	0.73	0.50	52.61	38.08	14.53	0.22	0.00	0.22
CROOKCRK	0.083	0.073	0.105	1.15	0.71	0.44	48.75	33.05	15.70	6.09	5.31	0.78
LAURHILL	0.107	0.100	0.117	1.25	0.70	0.55	43.91	25.33	18.58	2.29	2.21	0.08
ALLEPORT	0.128	0.088	0.199	1.58	0.67	0.91	44.79	28.66	16.13	3.11	1.17	1.94
PRESQISL	0.100	0.088	0.120	1.14	0.65	0.49	44.74	28.79	15.95	0.26	0.01	0.25
KANE	0.033	0.018	0.074	0.54	0.19	0.35	56.10	40.97	15.13	4.54	0.80	3.74
Region Mean	0.090	0.074	0.124	1.15	0.61	0.54	48.48	32.48	16.00	2.75	1.58	1.17
Central Pennsylvania												
LITTPINE	0.109	0.092	0.138	1.11	0.60	0.51	39.17	24.82	14.35	1.01	0.93	0.08
HILLSCRK	0.127	0.125	0.130	1.35	0.92	0.43	41.13	28.43	12.70	0.80	0.59	0.21
LITTBUFF	0.121	0.088	0.172	1.39	0.61	0.78	39.41	24.15	15.26	5.87	3.35	2.52
PSUNADP	0.044	0.018	0.088	0.44	0.11	0.33	38.82	24.38	14.44	0.90	0.45	0.45
LEADRIDG	0.052	0.021	0.101	0.51	0.12	0.39	35.36	21.72	13.64	2.41	0.93	1.48
YOWOCRK	0.030	0.014	0.058	0.33	0.10	0.23	39.74	25.42	14.32	4.24	3.08	1.16
ARENDTSV	0.073	0.034	0.129	0.75	0.20	0.56	38.66	22.83	15.82	1.35	0.12	1.23
Region Mean	0.079	0.056	0.117	0.84	0.38	0.46	38.90	24.54	14.36	2.37	1.35	1.02
Eastern Pennsylvania												
SLOCUM	0.133	0.104	0.179	1.76	0.90	0.87	39.30	24.10	15.20	13.70	9.86	3.84
VALLFORG	0.260	0.171	0.413	3.61	1.53	2.08	52.84	33.28	19.56	2.20	1.96	0.24
MILLERSV	0.108	0.066	0.178	1.38	0.49	0.89	43.16	27.11	16.05	5.50	1.82	3.68
MILFORD	0.133	0.075	0.215	1.78	0.60	1.17	50.71	29.63	21.08	2.38	1.95	0.43
Region Mean	0.159	0.104	0.246	2.13	0.88	1.25	46.50	28.53	17.97	5.94	3.90	2.05
State Mean	0.102	0.074	0.150	1.25	0.58	0.68	44.07	28.28	15.79	3.35	2.03	1.31

Table 22. Annual and seasonal chloride ion analyses of precipitation collected at sites throughout Pennsylvania during 2006.

Region/Site	Volume Weighted Mean Concentrations (mg/L)			Total Wet Depositions (kg/ha)			Precipitation Analyzed (Inches)			Precipitation Not Analyzed (Inches)		
	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.	Annual	Grow.	Dorm.
Western Pennsylvania												
GODDARD	0.157	0.117	0.263	2.12	1.13	0.99	52.61	38.08	14.53	0.22	0.00	0.22
CROOKCRK	0.170	0.131	0.253	2.33	1.27	1.06	48.75	33.05	15.70	6.09	5.31	0.78
LAURHILL	0.199	0.182	0.223	2.33	1.27	1.06	43.91	25.33	18.58	2.29	2.21	0.08
ALLEPORT	0.260	0.178	0.404	3.21	1.35	1.86	44.79	28.66	16.13	3.11	1.17	1.94
PRESQISL	0.170	0.138	0.226	1.94	1.01	0.93	44.74	28.79	15.95	0.26	0.01	0.25
KANE	0.087	0.061	0.155	1.39	0.65	0.74	56.10	40.97	15.13	4.54	0.80	3.74
Region Mean	0.174	0.134	0.254	2.22	1.11	1.11	48.48	32.48	16.00	2.75	1.58	1.17
Central Pennsylvania												
LITTPINE	0.169	0.128	0.241	1.72	0.84	0.88	39.17	24.82	14.35	1.01	0.93	0.08
HILLSCRK	0.217	0.207	0.239	2.31	1.53	0.78	41.13	28.43	12.70	0.80	0.59	0.21
LITTBUFF	0.212	0.149	0.312	2.45	1.04	1.41	39.41	24.15	15.26	5.87	3.35	2.52
PSUNADP	0.123	0.082	0.193	1.25	0.52	0.73	38.82	24.38	14.44	0.90	0.45	0.45
LEADRIDG	0.134	0.084	0.214	1.30	0.48	0.82	35.36	21.72	13.64	2.41	0.93	1.48
YOWOCRK	0.102	0.083	0.134	1.13	0.60	0.53	39.74	25.42	14.32	4.24	3.08	1.16
ARENDTSV	0.161	0.092	0.261	1.67	0.54	1.13	38.66	22.83	15.82	1.35	0.12	1.23
Region Mean	0.160	0.118	0.228	1.69	0.79	0.90	38.90	24.54	14.36	2.37	1.35	1.02
Eastern Pennsylvania												
SLOCUM	0.195	0.156	0.256	2.58	1.34	1.24	39.30	24.10	15.20	13.70	9.86	3.84
VALLFORG	0.447	0.272	0.743	6.17	2.44	3.74	52.84	33.28	19.56	2.20	1.96	0.24
MILLERSV	0.223	0.157	0.335	2.83	1.15	1.68	43.16	27.11	16.05	5.50	1.82	3.68
MILFORD	0.255	0.163	0.386	3.41	1.30	2.11	50.71	29.63	21.08	2.38	1.95	0.43
Region Mean	0.280	0.187	0.430	3.75	1.56	2.19	46.50	28.53	17.97	5.94	3.90	2.05
State Mean	0.193	0.140	0.285	2.36	1.09	1.28	44.07	28.28	15.79	3.35	2.03	1.31

Chloride (Cl^-). Sea-salts are also an important source of chloride concentrations in south eastern Pennsylvania (Table 22), while coal combustion and the release of hydrochloric acids is an important source in western Pennsylvania. Mean annual chloride concentrations range from 0.16 mg/L to 0.45 mg/L across the state (Table 22) with the highest concentrations occurring at the Valley Forge site in Montgomery County. Chloride concentrations have exhibited mixed temporal patterns with some sites increasing slightly while others have decreased (Table 13).

Summary. Although significant progress has been made in reducing "acid rain" in Pennsylvania and across the Northeast and Mid-Atlantic regions, additional reductions in sulfur dioxide and nitrogen oxides emissions may be necessary to protect acid sensitive aquatic and terrestrial ecosystems and cultural and material resources in the Commonwealth, particularly in western Pennsylvania where 2006 sulfate concentrations and wet depositions were higher than any region of the United States. Some of the relatively high wet sulfate deposition in western and central Pennsylvania in 2006 over previous years can be attributed to above average precipitation; however, sulfur dioxide emissions from upwind sources, particularly during the 2006 dormant season was a major contributing factor. Since precipitation is an unmanageable parameter of climate, the only way to provide additional protection to the citizens of the Commonwealth and the environment is to reduce further sulfur dioxide and nitrogen oxides emissions in Pennsylvania and in upwind states. The expeditious implementation of a stringent national multi-pollutant strategy would not only reduce emissions but improve visibility. An assessment of source-receptor relationships should be undertaken to identify those sources that would provide the greatest opportunity for further reductions in acidic deposition in Pennsylvania. A detailed evaluation of spatial and temporal variations in precipitation and its influence on deposition patterns in the Commonwealth should also be undertaken. Such analyses would provide valuable information to determine the location and the level of emissions reductions that would be necessary to achieve adequate protection of all sensitive aquatic and terrestrial ecosystems and cultural and material resources in the Commonwealth.

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