CHESAPEAKE BAY WATERSHED MODEL APPLICATION AND CALCULATION OF NUTRIENT AND SEDIMENT LOADINGS

Appendix D: Phase IV Chesapeake Bay Watershed Model Precipitation and Meteorological Data Development and Atmospheric Nutrient Deposition

A Report of the
Chesapeake Bay Program
Modeling Subcommittee
Annapolis, MD

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Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

CBPAS	Chesapeake Bay Program Air Subcommittee
CBPO	Chesapeake Bay Program Office
CRC	Chesapeake Research Consortium
deg-F	Degrees Fahrenheit
DIP	Dissolved Inorganic Phosphorus
DON	Dissolved Organic Nitrogen
DSN	Data Set Numbers
FORTRAN	Formula Translation
HSPF	Hydrological Simulation Program-FORTRAN
kg/ha	Kilograms per hectare
lb/ac	Pounds per acre
lb/ac-yr	Pounds per acre per year
mg/l	Milligrams per liter
NADP	National Air Deposition Program
NOAA	National Oceanic and Atmospheric Administration
OrN	Organic Nitrogen
OrP	Organic Phosphorus
ppn	Precipitation (mm)
RADM	Regional Acid Deposition Model
STAC	Scientific and Technical Advisory Committee
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WDM	Watershed Data Management
WSM	Watershed Model

Section D.1 Introduction

Precipitation and meteorological data are the primary forcing functions in the Phase IV Chesapeake Bay Watershed Model. Flow, nonpoint source loads, and reaction rates all primarily depend on the continuous hourly input of precipitation, temperature, evaporation, and solar radiation. Consequently, great care is used in the development of the precipitation and meteorological data base.

The Phase IV Chesapeake Bay Watershed Model requires continuous hourly input data for the 1984 to 1995 simulation. Developing twelve years of hourly precipitation time series is a challenge. One of the first decisions encountered in precipitation time series development is the choice between obtaining the greatest number of observed stations and obtaining the greatest consistency in stations. If the greatest number of observed stations is used, many large gaps occur in the data as stations became operative and enter the data set, or, as the stations are discontinued and leave the data set. The possibility of introducing error due to the inconsistency of the precipitation stations throughout the simulation is a concern. On the other hand, if consistency is an absolute priority many stations will be eliminated due to data gaps.

In an effort to compromise, a total of 147 precipitation stations are used, of which 88 are hourly and 59 are daily records of rainfall. Data gaps exist in these observed stations, but overall the observed stations used are relatively continuous over the entire simulation period. A computer program, PRECIP.exe, provides a technique to partially overcome the discontinuity of some station within a segment by re-weighting the data with the exclusion of the station with the missing data.

All seven of the primary meteorological stations within or adjacent to the Chesapeake basin are used, including Binghamton, NY, Williamsport, PA, Harrisburg, PA, Elkton, WV, Dullas Airport, Richmond, VA, and Roanoake, VA. The work in this phase of Watershed Model development is expansion of the precipitation and meteorological data base from 1984-91 to 1984-1995. Slightly different methods were used in the 1991-95 data development due to upgrades in computer hardware and software, and a change from VMS/DOS to UNIX operating systems.

Specifically, in the 1984-91 database development the program NOAA.EXE was used to transform the observed data into WDM file format. In the 1991-95 database development, the newer programs PREDY, PREHR and HSPF programs were used the develop WDM files. In the meteorological data, various programs were used in the development of he 1984-91 WDM files whereas in the 1991-95 WDM development the newer program USGS METCOMP was used. In all cases the programs were designed for the same purpose and generated the same type of output.

To assess comparability between the 1984-91 and the 1991-95 data, a year of overlap 1991 data is used. The 1991 precipitation and meteorological data is developed under the two equivalent methodologies and compared. No significant differences are discerned in the 1991 data generated from either of the two methodologies.

Section D.2 Observed Meteorological Data Base Development

The National Oceanic and Atmospheric Administration (NOAA) standard formatted daily maximum air temperature, minimum air temperature, dew point temperature, cloud coverage, and wind speed for 1991-1994 were collected from seven stations for the seven meteorological regions of the Phase IV Chesapeake Bay Watershed Model. Figure D.2.1 shows the Phase IV Watershed Model segments. The seven meteorological regions and associated model segments are illustrated on Figure D.2.2 and listed in Table D.2.1.

Table D.2.1.

Stations Used to Develop 1992-1994 Regional Meteorological Data

Region #	Station #	Location
1	04725	Binghamton, NY
2	14778	Williamsport, PA
3	14711	Middletown Harrisburg, PA*
4	13729	Elkins, WV
5	93738	Dulles Airport, VA
6	13741	Roanoke, VA
7	13740	Richmond, VA
1b**	14768	Rochester, NY
2b**	14777	Wilkes-Barre/Scranton, PA
7b**	13733	Lynchburg AP, VA

* Note: The Harrisburg Station, PA was used in Phase II. However, data after 10/01/91 were no longer available from the Harrisburg Station, PA so the Middletown Harrisburg Station, PA was used in Phase IV (1992-1994). Therefore, for the intercomparison stage 1 and stage 2 data transformations, Phase IV data for 1/91-9/91 were from Harrisburg and the 10/91-12/91 data were from Middletown Harrisburg, PA.

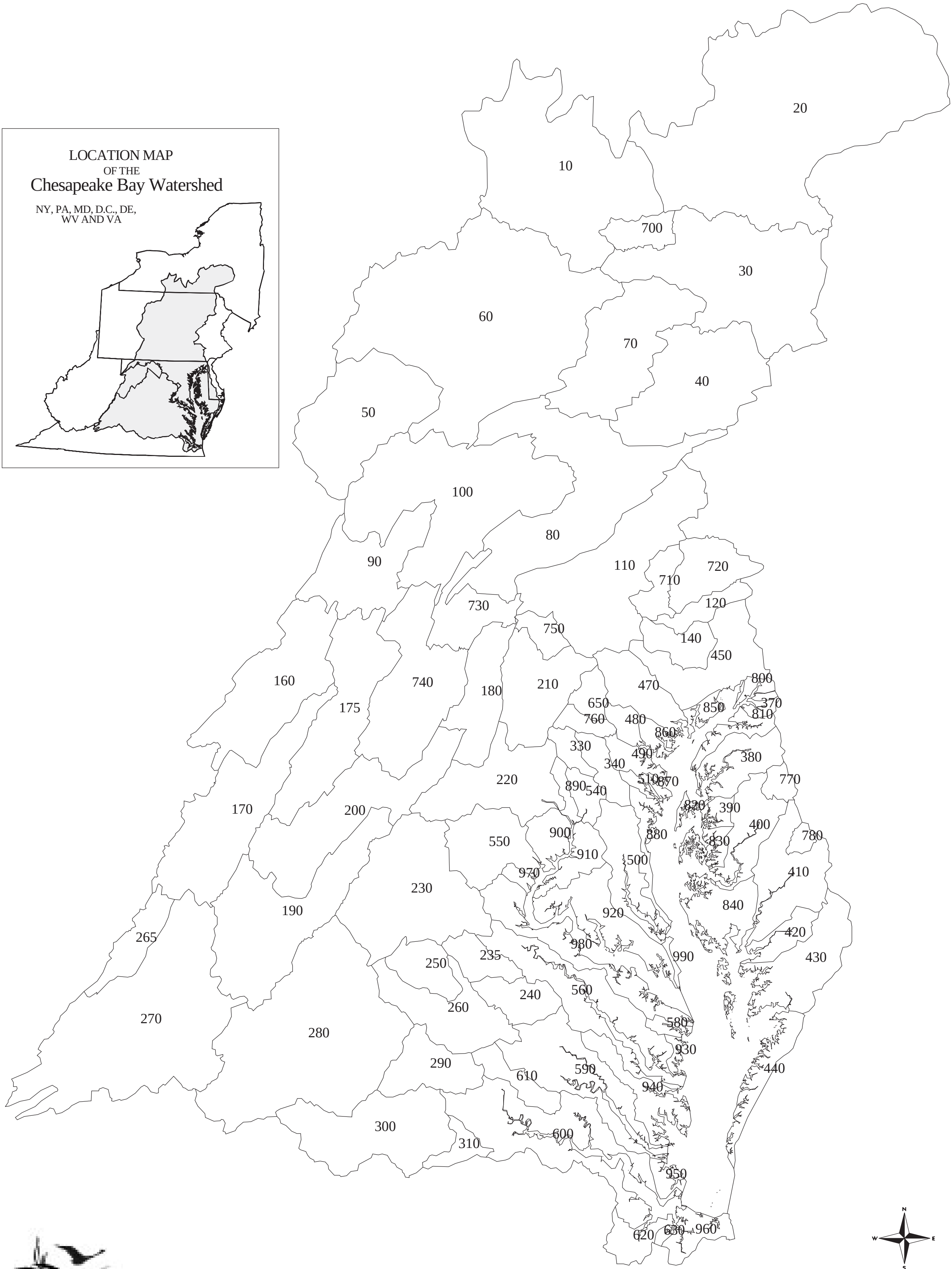
** Note: The stations with the region number possessing the suffix ‘b’ were utilized as alternative stations to fill in any missing data for the corresponding primary stations.

The NOAA formatted data were reformatted to the HYDDY format using dBase and a FORTRAN program PREDY.F.[1] A copy of this program is located at the end of this section. The HYDDY format is a code including information such as the station number, year, month and data. The format is generally encoded as follows:

[1] Wang, P. (1995). Chesapeake Bay Program Office, Annapolis, MD.

Figure D.2.1

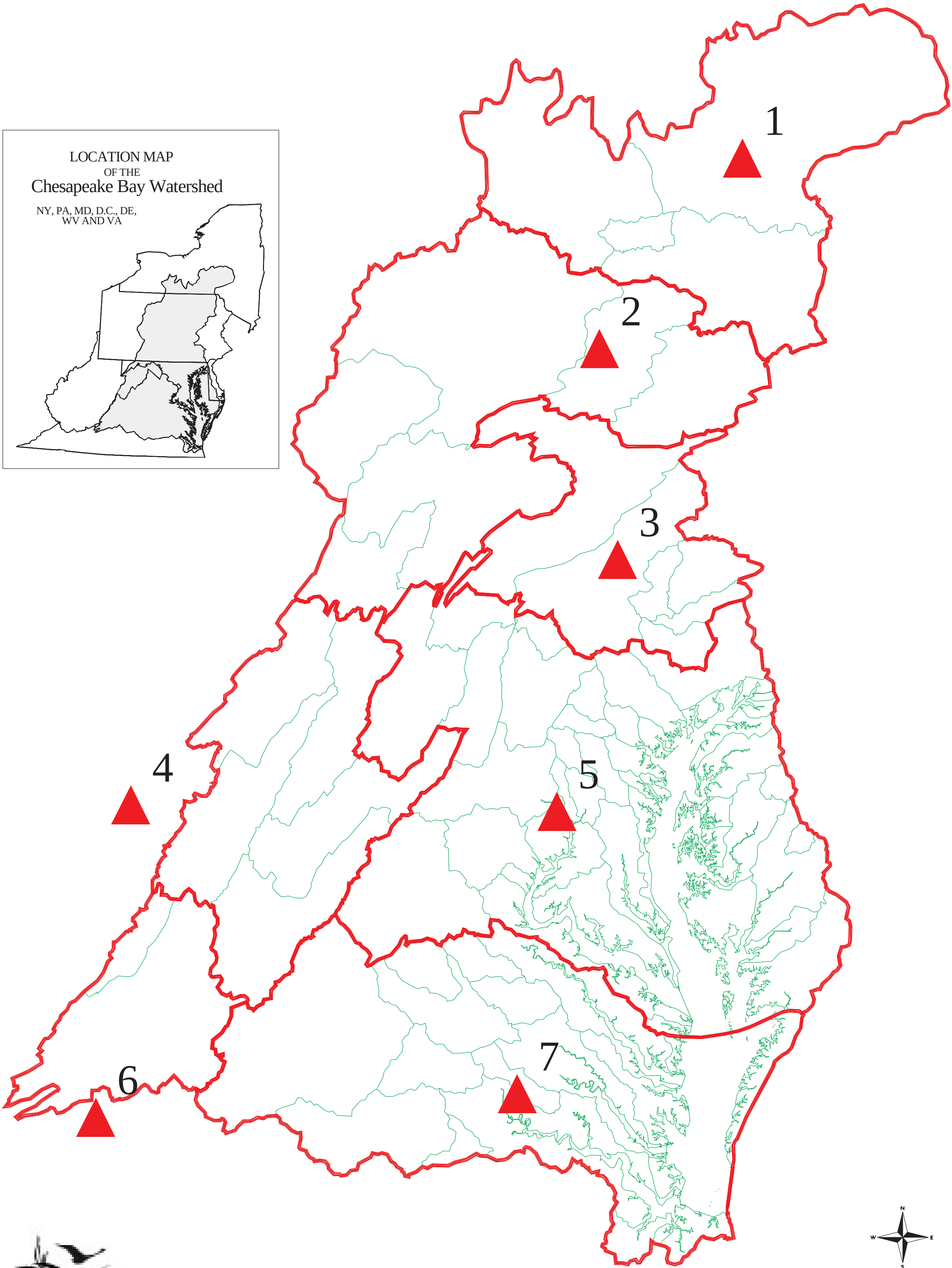
Phase IV Chesapeake Bay Watershed Model Segments



PW Map Date: June 20, 1997 spot:home/pwang/setup/gis/arc7/cov/

Source: USEPA Chesapeake Bay Program Office

Phase IV Chesapeake Bay Watershed Model
Meteorologic Regions and Principal Stations



PW Map Date: June 20, 1997 spot:/home/pwang/setup/gis/arc7/cov/

Source: USEPA Chesapeake Bay Program Office

HYDDY
1. Station identifier (7 digits)
2. Year (last two digits)
3. Month (two digits)
4. Card Number: 1 is for days 1-10
2 is for days 11-20
3 is for days 21up to 31
5. Ten fields, for the daily data (11 fields for the card number 3).

The HYDDY formatted data were then reformatted to Watershed Data Management (WDM) format using the HSPF software. WDM files are the type used as input to the watershed model.

Data were inspected manually in order to locate any possible missing data periods. The missing data periods in some meteorological regions were filled in manually by utilizing data from nearby stations, as listed in Table D.2.2.

Table D.2.2

Missing Data and Filling Method

Region with missing data	**Missing data type**	**Missing period**	**Region used for filling data**
1	Cloud cover	11/01/95-12/31/95	8
2	Cloud cover	06/01/94-09/30/94	1
		09/01/95-12/31/95	9
3	Cloud cover	09/01/91-09/30/91	2
4	Cloud cover	09/28/92-10/28/92	5
		10/13/94-12/31/94	
		01/01/95-09/30/95	6
7	Cloud cover	10/01/95-12/31/95	10

The Metcmp software[2] was used to retrieve the WDM formatted meteorological data in order to generate the required input data in HSPF format in order to compute the following operations:

[2] Flynn, K., Lumb, A. (1991). *Computation and Modification of Meteorolgic Time Series*. Version 1.1. United States Geological Survey, Water Resources Division, Reston, VA.

a. Hourly air temperature was calculated from daily maximum and minimum air temperature.

b. Hourly wind speed was disaggregated from daily data.

c. Hourly solar radiation was generated using cloud coverage data and the regional latitudes.

d. Hourly potential evaporation was generated by applying the Penman method[3] using daily maximum air temperature, daily minimum air temperature, daily dew point temperature, daily wind speed, and hourly solar radiation. Monthly correction factors to the potential evaporation for the seven regions were estimated by examination of observed evaporation records and used on the potential evaporation data calculated with the Penman method. Monthly correction factors are tabulated in Table D.2.3.

Table D.2.3[4]

Monthly Correction Factors to Potential Evaporation

		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	1	0.555	0.593	0.722	0.851	0.889	0.912	0.912	0.897	0.836	0.745	0.646	0.562
R	**2**	0.548	0.585	0.713	0.840	0.878	0.900	0.900	0.885	0.825	0.735	0.638	0.555
E	**3**	0.562	0.601	0.732	0.862	0.901	0.924	0.924	0.909	0.847	0.755	0.655	0.570
G	**4**	0.569	0.608	0.741	0.874	0.913	0.936	0.936	0.920	0.858	0.764	0.663	0.577
I	**5**	0.562	0.601	0.732	0.862	0.901	0.924	0.924	0.909	0.847	0.755	0.655	0.570
O	**6**	0.562	0.601	0.732	0.862	0.901	0.924	0.924	0.909	0.847	0.755	0.655	0.570
N	**7**	0.540	0.608	0.703	0.829	0.866	0.888	0.888	0.873	0.814	0.725	0.629	0.548

Test for Consistency Between the 1984-91 and 1991-1995 Data Sets

The program ANNIE.exe[5] was used to export the hourly air temperature, wind speed, solar radiation, cloud coverage, and potential evaporation data from both (a) the WDM file which was generated in the above process (for 1991-1995), and (b) the WDM file which was developed in stage 1 (for 1984-1991) to insure the consistency between them. The HSPF software was used to process the 1991 meteorological data from these two Phases by summing up the daily values to yield a monthly summation. The results are summarized in Table D.2.4.

Table D.2.4 shows that the 1984-1991 and 1991-1995 methodologies are entirely consistent -- most with <0.01% difference, although up to 1-2% difference in the monthly values summed from the daily data are observed. These differences may be due to the

[3] Viessman, W., Lewis, G.L., and Knapp, J.W. (1989). *Introduction to Hydrology*. Harper & Row Publishers. New York.

[4] Provided by Aqua Terra Inc.

[5] Lumb, A.M., Kittle, J., and Flynn, K.M. (1990). *Users Manual for ANNIE, A Computer Program for Interactive Hydrologic Analyses and Data Management.* U.S. Geological Survey. Reston, Virginia.

different methods in calculation, particularly for solar radiation, which in turn affects the calculation of evaporation.

Based on the above analysis documenting the consistency of data from the two methodologies, the 1992-94 data were combined with the 1984-91 data using the ANNIE.exe software.

Comparison of Meteorological Data Development for Stage 1 and Stage 2
Region I (monthly averages from daily data in 1991)

	Date	Evapor. (inch)	Dew Point (deg F)	Cloud Cov (/10)	Wind Speed (meters/hr)	SolarRad (Langleys)	MaxTemp (deg F)	MinTemp (deg F)	AirTemp (deg F)
Stage 1	Jan-91	0.0258	16.4355	7.7419	265.4704	123.9651	30.4194	16.5161	23.1707
	Feb-91	0.0348	20.5714	7.6429	248.5714	182.2173	36.0357	20.7857	28.1875
	Mar-91	0.0740	25.7164	7.2258	271.1962	248.5887	43.6774	28.2258	35.5981
	Apr-91	0.1488	35.8694	7.0000	248.6389	336.9861	58.4000	39.8667	48.7986
	May-91	0.2189	50.5161	5.6774	218.7903	484.4220	72.4839	50.9677	61.3091
	Jun-91	0.2576	52.7861	5.8000	211.5972	512.2778	77.4000	55.8667	66.1611
	Jul-91	0.2357	56.5323	6.2903	205.7796	442.8226	80.5161	59.7097	69.6895
	Aug-91	0.1986	58.6935	5.9677	215.2285	404.0457	79.0000	59.3871	68.6882
	Sep-91	0.1473	48.1903	5.4667	218.2361	352.4444	69.5667	48.4333	58.5917
	Oct-91	0.0939	40.5390	6.5806	238.2258	233.4946	61.3226	41.4516	50.9261
	Nov-91	0.0456	30.0264	7.8667	231.7639	131.1333	46.2667	32.0333	38.8125
	Dec-91	0.0291	23.1129	7.7419	263.1452	110.4005	37.0968	23.2258	29.7460
Stage 2	Jan-91	0.0256	16.1707	7.7419	265.4704	113.1989	30.4194	16.3226	23.0645
	Feb-91	0.0341	20.5432	7.6429	248.5714	171.0714	36.0357	20.7857	28.1860
	Mar-91	0.0723	25.7164	7.2258	271.1962	236.0215	43.6774	28.2258	35.5981
	Apr-91	0.1461	35.8694	7.0000	248.6389	326.3056	58.4000	39.8667	48.8000
	May-91	0.2166	50.5161	5.6774	218.7903	478.0914	72.4839	50.9677	61.3065
	Jun-91	0.2552	52.7861	5.8000	211.5972	506.2361	77.4000	55.8667	66.1597
	Jul-91	0.2331	56.5323	6.2903	205.7796	435.9409	80.5161	59.7097	69.6895
	Aug-91	0.1950	58.6935	5.9677	215.2285	394.6505	79.0000	59.3871	68.6855
	Sep-91	0.1432	48.1903	5.4667	218.2361	338.6528	69.5667	48.4333	58.5903
	Oct-91	0.0914	40.5390	6.5806	238.2258	220.4301	61.3226	41.4516	50.9220
	Nov-91	0.0448	30.0264	7.8667	231.7639	121.0111	46.2667	32.0333	38.8097
	Dec-91	0.0286	23.1129	7.7419	263.1452	99.2460	37.0968	23.2258	29.7487

Region II (monthly averages from daily data in 1991)

	Date	Evapor. (inch)	Dew Point (deg F)	Cloud Cov (/10)	Wind Speed (meters/hr)	SolarRad (Langleys)	MaxTemp (deg F)	MinTemp (deg F)	AirTemp (deg F)
Stage 1	Jan-91	0.0307	19.0296	7.0968	199.1263	142.9973	36.8387	19.4516	27.7728
	Feb-91	0.0452	22.4033	7.6786	214.1964	183.3036	42.7143	24.7500	33.3839
	Mar-91	0.0860	30.0027	7.1613	240.3898	255.5511	51.4194	32.0323	41.3468
	Apr-91	0.1214	40.0139	7.9667	211.2778	284.6111	62.9000	41.1667	51.6056
	May-91	0.2148	53.6519	6.3226	161.2634	475.1478	81.0968	53.0323	66.5296
	Jun-91	0.2534	56.0764	5.9667	148.4028	508.2778	86.1000	57.0667	70.9486
	Jul-91	0.2276	60.7258	6.4194	145.2419	438.9785	87.9032	62.4839	74.6505
	Aug-91	0.1927	62.0000	6.0645	128.5161	412.8091	86.3871	61.5806	73.3978
	Sep-91	0.1240	52.8833	5.9333	134.1597	346.5417	74.5333	50.7333	62.1542
	Oct-91	0.0802	45.2003	6.4839	183.7097	251.4516	65.6774	42.7742	53.6680
	Nov-91	0.0485	31.4000	7.7333	193.3611	144.9167	50.3000	33.6000	41.6278
	Dec-91	0.0344	24.5712	7.2581	202.3790	123.2070	42.0968	25.9355	33.5202
Stage 2	Jan-91	0.0307	18.9261	7.0968	199.1263	140.7527	36.8387	19.4516	27.7702
	Feb-91	0.0451	22.4033	7.6786	214.1964	181.5476	42.7143	24.7500	33.3824
	Mar-91	0.0855	30.0027	7.1613	240.3898	252.5269	51.4194	32.0323	41.3454
	Apr-91	0.1210	40.0139	7.9667	211.2778	282.5556	62.9000	41.1667	51.6042
	May-91	0.2148	53.6519	6.3226	161.2634	475.0941	81.0968	53.0323	66.5255
	Jun-91	0.2528	56.0764	5.9667	148.4028	506.8333	86.1000	57.0667	70.9458
	Jul-91	0.2274	60.7258	6.4194	145.2419	438.1855	87.9032	62.4839	74.6492
	Aug-91	0.1922	62.0000	6.0645	128.5161	411.6129	86.3871	61.5806	73.3952
	Sep-91	0.1229	52.8833	5.9333	134.1597	343.1528	74.5333	50.7333	62.1514
	Oct-91	0.0796	45.2003	6.4839	183.7097	248.6022	65.6774	42.7742	53.6680
	Nov-91	0.0484	31.4000	7.7333	193.3611	143.4444	50.3000	33.6000	41.6264
	Dec-91	0.0342	24.5712	7.2581	202.3790	120.2325	42.0968	25.9355	33.5094

Comparison of Meteorological Data Development for Stage 1 and Stage 2
Region III (monthly averages from daily data in 1991)

	Date	Evapor. (inch)	Dew Point (deg F)	Cloud Cov (/10)	Wind Speed (meters/hr)	SolarRad (Langleys)	MaxTemp (deg F)	MinTemp (deg F)	AirTemp (deg F)
Stage 1	Jan-91	0.0343	0.1895	6.5484	170.9409	164.3817	40.0323	23.3548	31.3495
	Feb-91	0.0550	0.2098	7.0714	189.5089	205.6250	46.7143	27.9643	36.9762
	Mar-91	0.0981	0.1895	6.3871	211.2769	293.2796	52.8387	34.6452	43.3804
	Apr-91	0.1471	0.1958	6.8667	179.6806	354.4167	64.0667	43.3330	53.3083
	May-91	0.2425	0.1895	5.7419	149.9597	519.9731	81.0000	57.1613	68.6828
	Jun-91	0.2880	0.1958	5.4000	144.0833	540.1111	86.2333	62.0667	73.6208
	Jul-91	0.2464	0.1895	6.4516	129.5995	441.6935	89.4194	67.9032	78.1599
	Aug-91	0.2218	0.1895	5.8387	127.7419	434.3414	87.1935	65.1290	75.6505
	Sep-91	0.1337	0.1958	5.4330	105.2506	351.5278	76.1000	54.5667	64.8875
	Oct-91	0.1008	0.1895	4.7419	164.3548	303.1452	70.0000	43.0645	55.8624
	Nov-91	0.0618	0.1958	6.8667	198.4028	166.8750	56.5667	34.7000	45.2472
	Dec-91	0.0405	0.1895	5.8387	193.2392	151.4516	48.6774	28.2903	37.8804
Stage 2	Jan-91	0.0347	0.1895	6.5484	170.9409	169.8253	40.0323	23.3548	31.3481
	Feb-91	0.0561	0.2098	7.0825	189.5089	211.2351	46.7143	27.9643	36.9732
	Mar-91	0.0989	0.1895	6.3871	211.2769	297.0699	52.8387	34.6452	43.3777
	Apr-91	0.1481	0.1958	6.8667	179.6806	357.7639	64.0667	43.3333	53.3042
	May-91	0.2440	0.1895	5.7419	149.9597	523.2930	81.0000	57.1613	68.6788
	Jun-91	0.2883	0.1958	5.4000	144.0833	540.8472	86.2333	62.0667	73.6181
	Jul-91	0.2475	0.1895	6.4516	129.5995	444.2608	89.4194	67.9032	78.1586
	Aug-91	0.2236	0.1895	5.8387	127.7419	438.4543	87.1935	65.1290	75.6478
	Sep-91	0.1349	0.1958	5.4333	105.2806	355.3750	76.1000	54.5667	64.8792
	Oct-91	0.0983	0.1895	5.2581	146.7876	290.6329	67.0645	46.6129	56.3454
	Nov-91	0.0545	0.1958	7.1667	198.2361	166.2778	52.2333	35.1000	43.3264
	Dec-91	0.0401	0.1895	6.5484	222.7419	147.6210	44.3548	28.5484	35.9530

Region IV (monthly averages from daily data in 1991)

	Date	Evapor. (inch)	Dew Point (deg F)	Cloud Cov (/10)	Wind Speed (meters/hr)	SolarRad (Langleys)	MaxTemp (deg F)	MinTemp (deg F)	AirTemp (deg F)
Stage 1	Oct-91	0.0749	40.5188	6.5484	114.0390	268.1720	67.6774	35.5161	50.7944
	Nov-91	0.0342	30.8167	8.0667	135.2000	142.5417	51.6000	27.2667	39.0417
	Dec-91	0.0262	28.4651	7.7742	160.1747	121.7097	47.1613	24.6774	35.2715
Stage 2	Oct-91	0.0755	40.5188	6.5484	114.0390	271.1022	67.6774	35.5161	50.7567
	Nov-91	0.0345	30.8167	8.0667	135.2000	146.2222	51.6000	27.2667	39.0417
	Dec-91	0.0264	28.4651	7.7742	160.1747	124.1048	47.1613	24.6774	35.2527

Region V (monthly averages from daily data in 1991)

	Date	Evapor. (inch)	Dew Point (deg F)	Cloud Cov (/10)	Wind Speed (meters/hr)	SolarRad (Langleys)	MaxTemp (deg F)	MinTemp (deg F)	AirTemp (deg F)
Stage 1	Oct-91	0.1368	45.9704	4.7419	164.3548	313.2392	70.0000	43.0645	55.8669
	Nov-91	0.0959	33.3264	6.8667	198.4028	175.1528	56.5667	34.7000	45.2472
	Dec-91	0.0723	27.9099	5.8387	193.2392	160.2419	48.6774	28.2903	37.8804
Stage 2	Oct-91	0.1052	45.9704	4.7419	164.3548	320.8199	70.0000	43.0645	55.8320
	Nov-91	0.0639	33.3264	6.8667	198.4028	182.9167	56.5667	34.7000	45.2458
	Dec-91	0.0418	27.9099	5.8387	193.2392	167.0968	48.6774	28.2903	37.8723

Comparison of Meteorological Data Development for Stage 1 and Stage 2
Region VI (monthly averages from daily data in 1991)

	Date	Evapor. (inch)	Dew Point (deg F)	Cloud Cov (/10)	Wind Speed (meters/hr)	SolarRad (Langleys)	MaxTemp (deg F)	MinTemp (deg F)	AirTemp (deg F)
Stage 1	Oct-91	0.1337	42.5806	4.1935	161.0349	338.9113	73.5161	45.2581	58.6976
	Nov-91	0.0739	30.7833	6.1000	183.6806	199.9306	57.2667	36.3333	46.4444
	Dec-91	0.0549	28.4651	5.4516	199.5833	170.0806	52.7742	31.8710	41.7272

Stage 2	Oct-91	0.1384	42.5806	4.1935	161.0349	355.9946	73.5161	45.2581	58.6573
	Nov-91	0.0763	30.7833	6.1000	183.6806	217.0417	57.2667	36.3333	46.4444
	Dec-91	0.0564	28.4651	5.4516	199.5833	185.9005	52.7742	31.8710	41.6989

Region VII (monthly averages from daily data in 1 1991)

	Date	Evapor. (inch)	Dew Point (deg F)	Cloud Cov (/10)	Wind Speed (meters/hr)	SolarRad (Langleys)	MaxTemp (deg F)	MinTemp (deg F)	AirTemp (deg F)
Stage 1	Oct-91	0.1021	48.7513	5.3548	158.7097	301.6532	72.7419	46.9677	59.2487
	Nov-91	0.0675	37.5764	6.1000	203.4444	210.5139	60.8667	38.1667	49.1056
	Dec-91	0.0481	32.8844	5.1290	205.7796	189.0995	55.2581	33.2258	43.6331
Stage 2	Oct-91	0.1026	48.7513	5.3548	158.7097	303.7634	72.7419	46.9677	59.2097
	Nov-91	0.0682	37.5764	6.1000	203.4444	214.6944	60.8667	38.1667	49.1042
	Dec-91	0.0484	32.8844	5.1290	205.7796	191.9892	55.2581	33.2258	43.6599

The numbers in Table D.2.4 are only for the purpose of comparine the agreement of stage 1 and stage 2 data processes. Although the values of intensive variables such as wind speed cannot be simply added to represent the sum of the wind speed in the month, here they were summed up merely to show their values in these two phases for comparison. Therefore, the units should be ignored for the summation in the output files. The units in Table D.2.4 are the units for the hourly or daily Data Set Numbers (SDN) of WDM files.

Fore Regions 4, 5, 6, and 7, the 1/91-9/91 data were not reported in Table D.2.4 because there were some missing data during 1/91-9/91 for these regions, and he missing data were filled in with the nearby stations' data. The stations used to fill in the missing data may be different between stage 1 and stage 2. Therefore, it is not accurate to use the data within the periods with missing data as a base to verify the consistency between the two phases of dta development. For the stage 1 and stage 2 data verification, only 10/91-12/91 data were processed for Regions 4, 5, 6, and 7.

The following is a copy of the PREDY.F program utilized to reformat the NOAA formatted daily data into the HYDDY format in order to make the data compatible with the HSPF software so that it may be inputted into the Phase IV Chesapeake Bay Watershed Model.

```
         character*12 filtat(3), filin, filnam, filin2, filog
         character*3 rectyp1
         character*8 stnid
         character*4 elmtyp1, stnid
         character*2 eunit1, state, stnid1
         character*1 flag11(100), flag21(100), typ, sta1
         character*5 stdumy1
         dimension iday1(100),ihour1(100),ivalue1(100), value(31)
         dimension isumyr(3), isumv2(3), iy(3), iso(100,4)
         dimension isumv3(3), isumv4(3), my(3), PP(1100,4)
         isumv2=0
         isumv3=0
         isumv4=0
         PP = 0
        Write(*,*)'Data extraction from NOAA Daily data'
        Write(*,*)'reformat for HSPF runs'
        filin2 = 'predy.lis'
        open (8, file=filin2, access='sequential',status='old')
        read(8,*) nfil
        read(8,66) filin
66        format(a12)
        open (10, file=filin, access='sequential',status='old')
        filnam = 'xxxxxxx.out'
        filog = 'xxxxxxx.log'
        rewind(10)
        close(10)
        typ = filin(1:1)
          i1 = 1
          i2 = 2
          i3 = 3
          LR = 0
          line = 0
            do 200 m= 1,100
            line = line - 1
         open (10, file=filin, access='sequential',status='old')
200     read(10, 39, end=49, err=49) rectype1
39      format(a3)
33      format (a3, a1, a2, a5, a4, a2, i4, i2, i2, i2, i2
     131(i2, i2, i6, a1, a1))
49        write(*,*) line
        filnam(1:7) = filin(1:7)
```

```
        filog(1:7) = filin(1:7)
        open(24,FILE=filnam,STATUS='unknown')
        open (10, file=filin, access='sequential',status='old')
              do 100 m= 1,line
        read(10, 33, end=301, err=301) rectyp1, sta1, stnid1, stdumy1,
     *  elmtyp1, eunit1, iyear1, imon1, ifil1, inum, numvl,
     *  (iday1(j), ihour1(j),
     *  ivalue1(j), flag11(j), flag21(j), j = 1, 31)
40          iyr = iyear1 - 1900
          do 53 k = 1, 31
           if(abs(ivalue1(k)) .gt. 99998) then
            ivalue1(k) = -999
            endif
53          continue
          do 55 k = 1, 31
          value(k) = float(ivalue1(k)) / 100.
55          continue
          if(sta1 .eq. '18') state='MD'
          if(sta1 .eq. '36') state='PA'
          if(sta1 .eq. '44') state='VA'
          if(sta1 .eq. '46') state='WV'
          if(sta1 .eq. '07') state='DE'
          if(sta1 .eq. '18') state='MD'
          if(sta1 .eq. '30') state='NY'
          write(24,205) stnid1, stdumy1, iyr, imon1, i1,
     1          (value(j), j=1,10)
          write(24,205) stnid1, stdumy1, iyr, imon1, i2,
     1           (value(j), j=11,20)
          write(24,207) stnid1, stdumy1, iyr, imon1, i3,
     1           (value(j), j=21,31)
300         continue
100         continue
301         continue
          close(10)
          close(24)
666         continue
205         format(a2, a5, i2, i2, i1, 10f6.2)
207         format(a2, a5, i2, i2, i1, 11f6.2)
          end
```

Section D.3 Observed Precipitation Database Development

The basic procedure for stage 2 precipitation data development follows the stage 1 method. Hourly stations and daily stations were selected in reference to stage 1. The stage 1 stations were selected based upon their locations within or near the boundary of the Chesapeake Bay watershed. Due to discontinuity in the operation of individual precipitation stations, data from 88 stations and 59 daily precipitation stations (a total of 147 stations) were used in stage 2 database development compared with data from 155 precipitation stations used in stage 1. The data were formatted to Watershed Data Management (WDM) file format.

Data from selected stations were reviewed in an effort to guarantee the integrity of the data. These verified NOAA formatted daily precipitation data sets were then converted to the HYDDY format as previously described (see page 2). The hourly data were reformatted into the HYDHR format using the FORTRAN program PREHR. A copy of this program is found at the end of this section. The conversion for the HYDHR format is as follows:

HYDHR
1. Station identifier (10 digits)
2. Year (last two digits)
3. Month (two digits)
4. Day (two digits)
5. Card number: 1 is for a.m. hours
   2 is for p.m. hours
6. Twelve fields for hourly data.

The HSPF software was utilized to reformat both the HYDDY and HYDHR formats into the WDM format. At this point the files were then applied to the PRECIP.exe program together with information from the Thiessen Polygon network of precipitation stations. The Thiessen polygon network of precipitation is illustrated in Figure D.3.1. The Thiessen polygon method was chosen for this data analysis because it makes it possible to aerially weight the rainfall from each gage. This method is exceptionally useful in those situations in which the stations are not uniformly distributed and when the variations in rainfall amounts are relatively large in comparison to the mean. Although the Thiessen polygon method is the most widely used, it does not account for any elevations effects upon the precipitation distribution. The Thiessen polygon network is created by first drawing lines that connect the stations on a map. In order to form polygons around each gage, perpendicular lines are drawn on the map so that they bisect the before mentioned lines between the stations. Each stations weighted rainfall is calculated as the ratio of the area of each polygon within the model segment boundary to the total area[6].

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[6]Bedient, P.B., Huber, W.C. (1992). *Hydrology and Floodplain Analysis*. 2nd ed. Addison-Wesley Publishing Co., New York: 26-27.

The precipitation segments illustrated in Figure D.3.2, are primarily based upon the Phase IV Chesapeake Bay Watershed Model Segments (Figure D.2.1). Since some of the model segments were too small to have sufficient hourly stations fall within them, some aggregation, determined by the number of hourly precipitation stations, of model segments occurred to form precipitation segments.

The location of hourly and daily precipitation stations are shown in Figure D.3.3. Each station was assigned a DSN number for WDM file development. A Thiessen polygon network was generated using Arc/Info with the geographical locations of precipitation stations.

The resultant Thiessen polygon network (Figure D.3.1) and Phase IV Watershed Model segmentation (Figure D.3.2) were overlapped to calculate the measurement of Thiessen polygon distribution within a precipitation segment, and then the areal percentage of each Thiessen polygon in a precipitation segment. Table D.3.1 lists precipitation stations and their areal percentage weights for each precipitation segment.

Some of the areal percentage weights were converted to zero, because these stations actually had no precipitation data during 1991-1994 and they were not included in the input files when running the PRECIP.exe program. It is also acceptable for the calculation if the weight percentage still keeps the measured areal percentage in a precipitation segment.

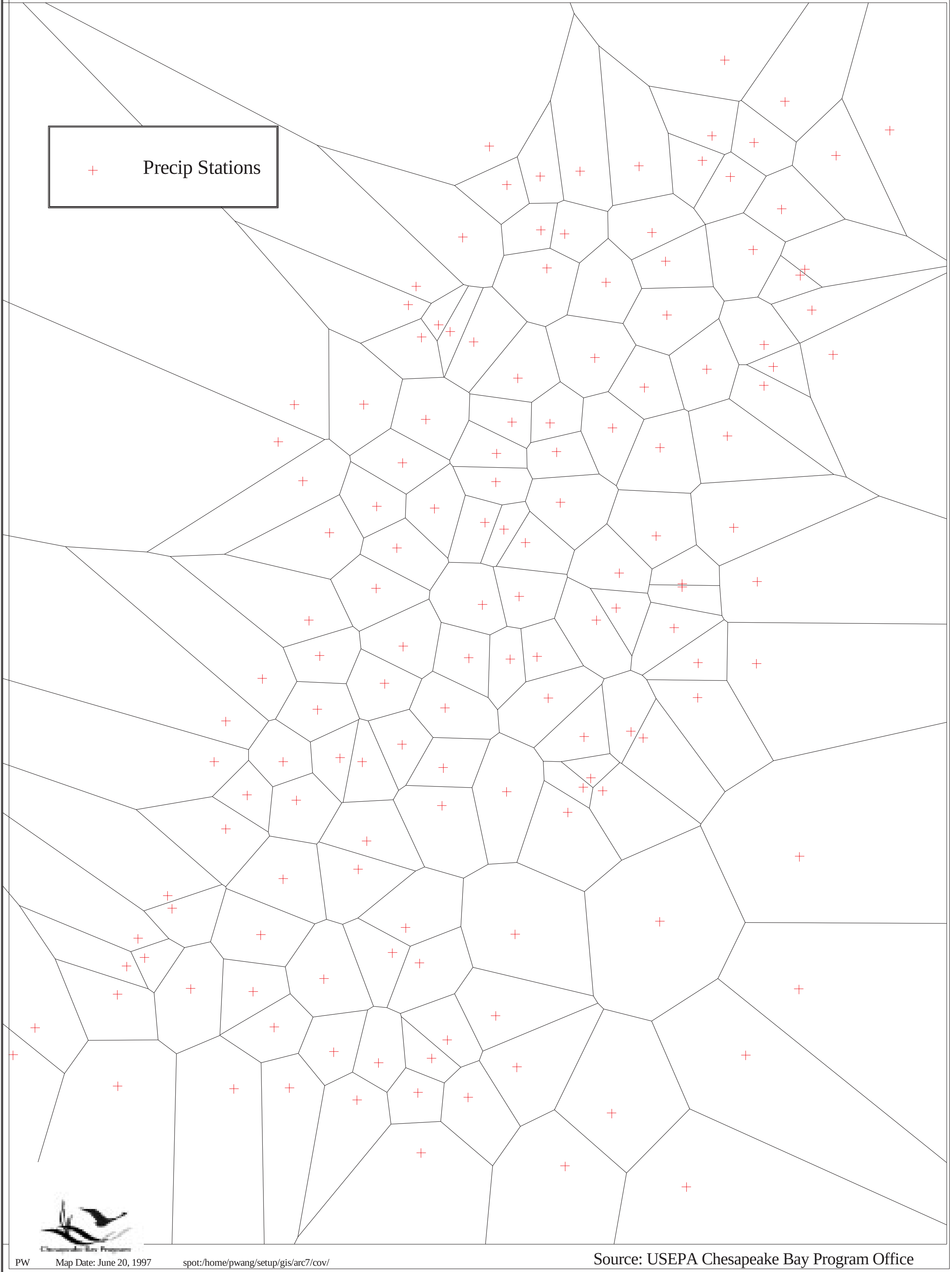
Additional adjustment to the Thiessen polygon network was required for precipitation segments 60, 80 and 100. All three of these segments had more than ten hourly stations falling within their boundaries. The PRECIP.exe program allows a maximum of ten hourly stations for the calculation of estimated precipitation. As a result, the data were manually inspected and stations with the least information based on the period of operation or Thiessen weight were selectively culled.

Precipitation segments 700 and 750 are small segments with only three hourly precipitation stations each. Data from all six stations were missing for April 1994. Precipitation stations near segments 700 and 750 were selected and a new Thiessen polygon network was developed, which was then overlapped with both segments. The exposed area was used for Segments 700 and 750 to calculate April 1994 precipitation.

The weight for precipitation stations in segments were then used to generate the input files (as the weight of precipitation contributing to certain segment) for PRECIP.exe program. The PRECIP.exe program read the input file (with ".inp" extension) and read from and wrote to the WDM. Table D.3.2 is the format for input files.

The PRECIP.exe program operates by calculating the sum of a single day's precipitation using the respective weights for both hourly (hourly precipitation is summed to a daily value) and daily DSNs. The total daily weighted volume was then compared against the hourly stations total daily volumes. The hourly station that had a total daily volume closest to the weighted

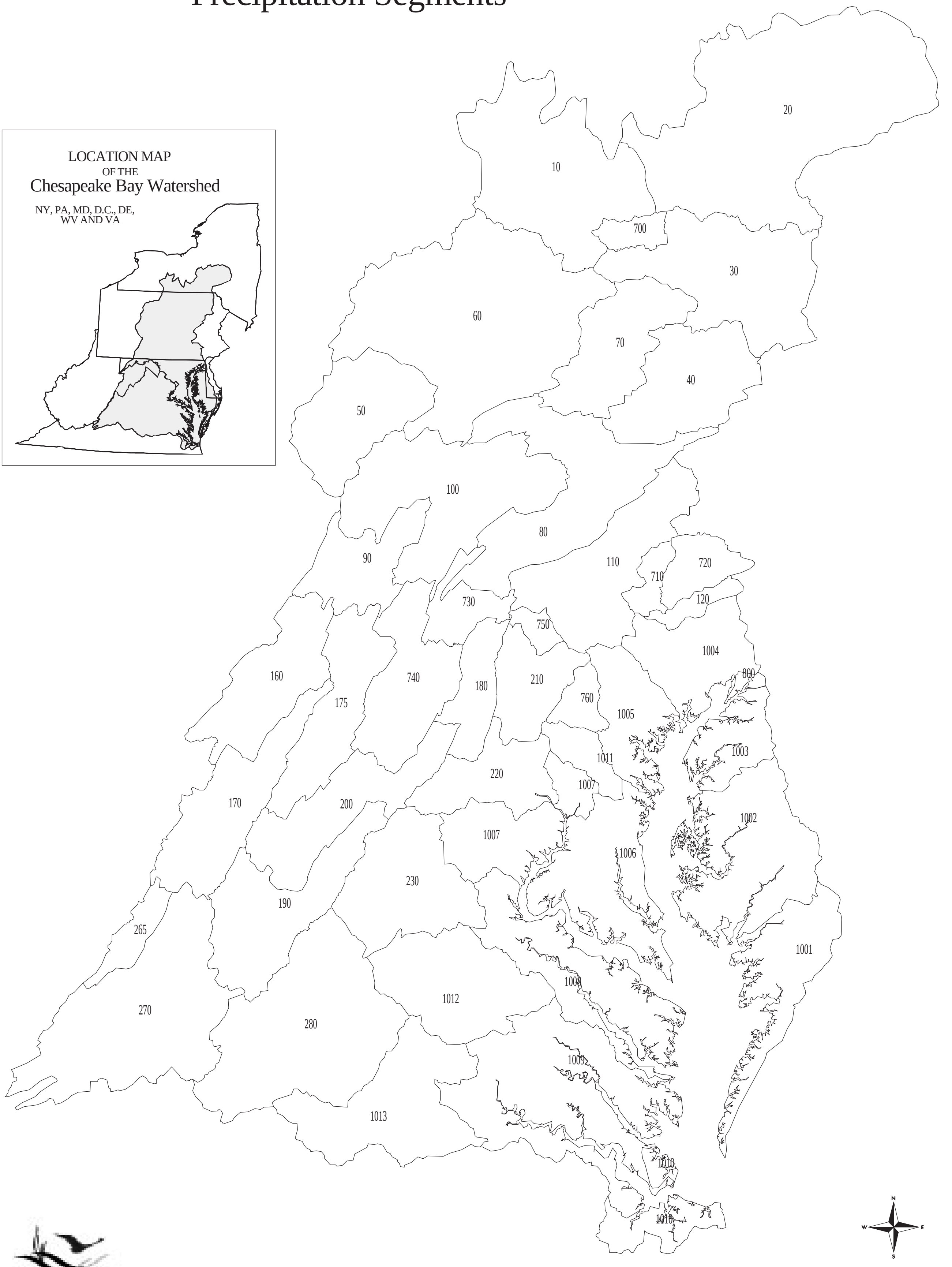
Thiessen Polygon of Phase IV Chesapeake Bay Watershed Model Precipitation Stations



PW Map Date: June 20, 1997 spot:/home/pwang/setup/gis/arc7/cov/

Source: USEPA Chesapeake Bay Program Office

Phase IV Chesapeake Bay Watershed Model Precipitation Segments

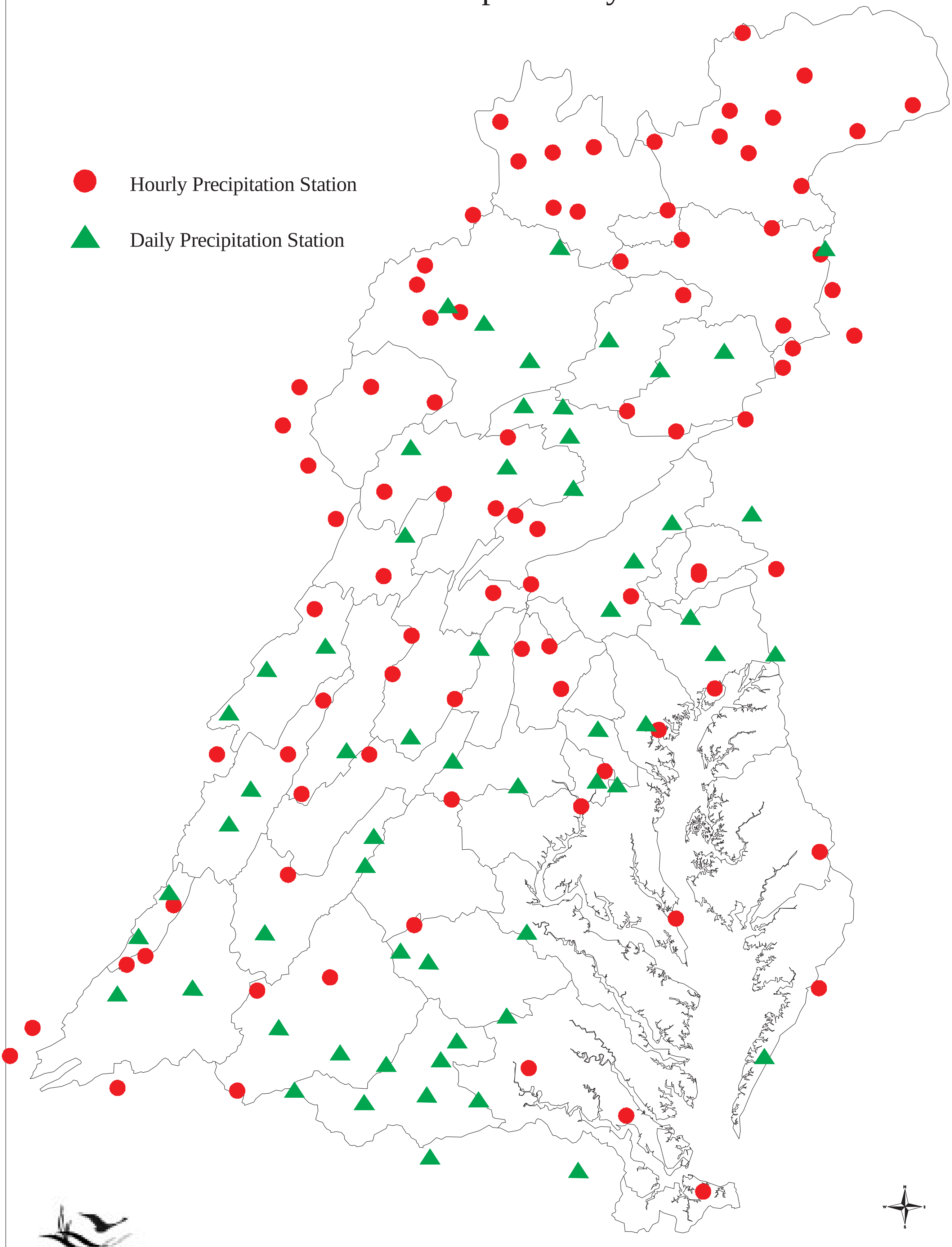


PW Map Date: June 20, 1997 spot:/home/pwang/setup/gis/arc7/cov/

Source: USEPA Chesapeake Bay Program Office

Figure D.3.3

Location of Hourly and Daily Precipitation Stations Used in the Phase IV Chesapeake Bay Watershed Model



PW Map Date: June 20, 1997 spot:/home/pwang/setup/gis/arc7/cov/

Source: USEPA Chesapeake Bay Program Office

Table D.3.1
Precipitation Stations and Their Weights for Precipitation Segments

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observation Time ** (if daily)
10	10	1	NYHR0270	0.0492	
		9	NYHR3979	0.1692	
		10	NYHR3983	0.155	
		18	NYHR8498	0.1353	
		20	NYHR9229	0.0995	
		108	PAHR1212	0.0386	
		142	PAHR5731	0.0733	
		152	PAHR6627	0.1006	
		160	PAHR7310	0.0162	
		179	PAHR8868	0.1309	
		336	PADY9408	0.0322	07:00
20	20	1	NYHR0270	0.0508	
		2	NYHR0687	0.0851	
		3	NYHR1987	0.1872	
		5	NYHR2454	0.1015	
		11	NYHR4070	0.0621	
		15	NYHR5682	0.0649	
		16	NYHR6685	0.2057	
		17	NYHR7830	0.0849	
		19	NYHR8625	0.0711	
		22	NYHR9522	0.078	
		300	PADY7029	0.0087	08:00
30	30	108	PAHR1212	0.0682	
		117	PAHR2325	0.1176	
		130	PAHR3521	0.0037	
		141	PAHR5601	0.0248	
		142	PAHR5731	0.0152	
		147	PAHR5915	0.2108	
		170	PAHR8275	0.0449	
		173	PAHR8491	0.085	
		181	PAHR8905	0.1797	
		187	PAHR9705	0.1966	
		300	PADY7029	0.0261	08:00
		315	PADY8057	0.0274	07:00
40	40	117	PAHR2325	0.0397	
		124	PAHR3018	0.0354	
		149	PAHR6004	0.1809	
		166	PAHR7931	0.1054	
		177	PAHR8763	0.0824	
		187	PAHR9705	0.0229	

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observ. Time ** (if daily)
230	230	747*	VAHR8906	0.0001	
		612*	MDHR6915	0.0001	
		999*	XXHR0000	0.0001	
		760	VADY0720	0.2531	08:00
		776	VADY2009	0.0325	09:00
		792	VADY3466	0.0176	07:00
		807	VADY5096	0.1838	08:00
265	265	713	VAHR3310	0.096	
		714	VAHR4128	0.0767	
		724	VAHR5880	0.254	
		503*	WVHR1393	0.0001	
		513*	VAHR9011	0.0001	
		707*	VAHR2208	0.0001	
		722*	VAHR5690	0.0001	
		735*	VAHR7285	0.0001	
		999*	XXHR0000	0.0001	
		813	VADY5595	0.2625	07:00
		817	VADY5756	0.3102	07:00
270	270	506	WVHR5284	0.0155	
		513	WVHR9011	0.0599	
		707	VAHR2208	0.0002	
		713	VAHR3310	0.0259	
		714	VAHR4128	0	
		720	VAHR5120	0.0371	
		722	VAHR5690	0.0633	
		724	VAHR5880	0.1082	
		735	VAHR7285	0.1354	
		999*	XXHR0000	0.0001	
		525	WVDY3215	0.0001	08:00
		778	VADY2044	0.2057	17:00
		798	VADY4565	0.2809	07:00
		813	VADY5595	0.0159	07:00
		817	VADY5756	0.0001	07:00
		836	VADY8062	0.0427	08:00
		843	VADY8600	0.009	06:00
280	280	707	VAHR2208	0.0071	
		720	VAHR5120	0.1053	
		722	VAHR5690	0.087	
		726	VAHR6178	0(-.25)	
		729	VAHR6712	0.0005	

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observation Time ** (if daily)
		141*	PAHR5601	0.0001	
		146*	PAHR5825	0.0001	
		181*	PAHR8905	0.0001	
		999*	XXHR0000	0.0001	
		284	PADY5817	0.2045	07:00
		315	PADY8057	0.3284	07:00
50	50	113	PAHR1961	0.4211	
		114	PAHR2245	0.0171	
		116	PAHR2298	0.0018	
		133	PAHR4001	0.073	
		134	PAHR4027	0.0177	
		155	PAHR6916	0.2206	
		159	PAHR7217	0.0102	
		175	PAHR8589	0.1344	
		999*	XXHR0000	0.0001	
		333	PADY9022	0.104	07:00
60	60	101	PAHR0147	0.0594	
		113	PAHR1961	0.0314	
		117	PAHR2245	0.0022	
		120	PAHR2629	0.1034	
		146	PAHR5825	0.0172	
		152	PAHR6627	0.0001	
		155	PAHR6916	0.073	
		160	PAHR7310	0.0669	
		168	PAHR8155	0.0533	
		999*	XXHR0000	0.0001	
		268	PADY4853	0.0001	17:00
		274	PADY5109	0.133	07:00
		283	PADY5790	0.037	07:00
		306	PADY7409	0.1304	08:00
		323	PADY8469	0.0704	08:00
		336	PADY9408	0.1486	07:00
		342	PADY9728	0.0751	24:00
70	70	108	PAHR1212	0.0517	
		117	PAHR2325	0.2471	
		166	PAHR7931	0.1115	
		2*	NYHR0687	0.0001	
		142*	PAHR5731	0.0001	
		147*	PAHR5915	0.0001	
		155*	PAHR6916	0.0001	
		181*	PAHR8905	0.0001	
		101*	PAHR0147	0.0001	
		999*	XXHR0000	0.0001	

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observ. Time ** (if daily)
		724*	VAHR5880	0.0001	
		735*	VAHR7285	0.0001	
		999*	XXHR0000	0.0001	
		756	VADY0243	0.0717	07:00
		760	VADY0720	0.0336	08:00
		765	VADY1136	0.1953	07:00
		782	VADY2160	0.1247	07:00
		792	VADY3466	0.1363	07:00
		806	VADY5050	0.0375	18:00
		843	VADY8600	0.2007	06:00
700	700	108	PAHR1212	0.3213	
		142	PAHR5731	0.4548	
		179	PAHR8868	0.0089	
		181	PAHR8905	0.215	
710	710	137	PAHR4763	0.1089	
		138	PAHR4778	0.1552	
		189	PAHR9938	0.2671	
		103*	PAHR0605	0.0001	
		119*	PAHR2537	0.0001	
		123*	PAHR2838	0.0001	
		129*	PAHR3321	0.0001	
		149*	PAHR6004	0.0001	
		615*	MDHR9030	0.0001	
		999*	XXHR0000	0.0001	
		253	PADY4019	0.0852	07:00
		269	PADY4896	0.2141	15:00
		345	PADY9950	0.1688	08:00
720	720	129	PAHR3321	0.1116	
		137	PAHR4763	0.1894	
		138	PAHR4778	0.4663	
		119*	PAHR2537	0.0001	
		177*	PAHR8763	0.0001	
		189*	PAHR9938	0.0001	
		149*	PAHR6004	0.0001	
		999*	XXHR0000	0.0001	
		253	PADY4019	0.0133	07:00
		269	PADY4896	0.0823	15:00
		305	PADY7322	0.1366	07:00
730	730	104	PAHR0725	0.0234	
		109	PAHR1354	0.6995	
		123	PAHR2838	0.1386	
		154	PAHR6852	0.0609	

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observation Time ** (if daily)
		268	PADY4853	0.1038	17:00
		274	PADY5109	0.0005	07:00
		284	PADY5817	0.1493	07:00
		342	PADY9728	0.3354	24:00
80	80	104	PAHR0725	0.0581	
		105	PAHR0763	0.1457	
		109	PAHR1354	0.0468	
		123	PAHR2838	0.0371	
		146	PAHR5825	0.0288	
		149	PAHR6004	0.1125	
		166	PAHR7931	0.088	
		177	PAHR8763	0.0101	
		999*	XXHR0000	0.0001	
		196	PADY0482	0.1146	07:00
		268	PADY4853	0.0594	17:00
		269	PADY4896	0.0368	15:00
		283	PADY5790	0.0635	07:00
		289	PADY6297	0.1984	07:00
		345	PADY9950	0.0001	08:00
90	90	116	PAHR2298	0.1455	
		122	PAHR2721	0.4343	
		127	PAHR3295	0.0683	
		133	PAHR4001	0.0002	
		161	PAHR7312	0.0887	
		608	MDHR4030	0.0003	
		134*	PADY4027	0.0001	
		175*	PADY8589	0.0001	
		502*	WVHR1323	0.0001	
		999*	XXHR0000	0.0001	
		312	PADY7846	0.2623	07:00
100	100	104	PAHR0725	0.0983	
		105	PAHR0763	0.0034	
		109	PAHR1354	0	
		113	PAHR1961	0.0001	
		116	PAHR2298	0.0075	
		133	PAHR4001	0.1737	
		146	PAHR5825	0.0781	
		155	PAHR6916	0.07	
		161	PAHR7312	0.2221	
		999*	XXHR0000	0.0001	
		196	PADY0482	0.0344	07:00
		268	PADY4853	0.0001	17:00
		273	PADY4992	0.1453	08:00

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observ. Time ** (if daily)
		105*	PAHR0763	0.0001	
		119*	PAHR2537	0.0001	
		161*	PAHR7312	0.0001	
		605*	MDHR1530	0.0001	
		999*	XXHR0000	0.0001	
		281	PADY5662	0	08:00
		643	MDDY3975	0.0771	18:00
740	740	122	PAHR2721	0.0234	
		502	WVHR1323	0.173	
		505	WVHR4763	0.2085	
		608	MDHR4030	0.2063	
		737	VAHR8046	0.0221	
		123*	PAHR2838	0.0001	
		127*	PAHR3295	0.0001	
		508*	WVHR5739	0.0001	
		509*	WVHR6163	0.0001	
		999*	XXHR0000	0.0001	
		281	PADY5662	0	08:00
		312	PADY7846	0.0002	07:00
		643	MDDY3975	0.1245	18:00
		856	VADY9186	0.2414	08:00
750	750	119	PAHR2537	0.6449	
		123	PAHR2838	0.3549	
		605	MDHR1530	0.0002	
760	760	119	PAHR2537	0.001	
		615	MDHR9030	0.5421	
		123*	PAHR2838	0.0001	
		189*	PAHR9938	0.0001	
		604*	MDHR0700	0.0001	
		605*	MDHR1530	0.0001	
		601*	MDHR0015	0.0001	
		602*	MDHR0465	0.0001	
		138*	PAHR4778	0.0001	
		999*	XXHR0000	0.0001	
		320	PADY8379	0.0442	08:00
		620	MDHR0470	0.015	24:00
		629	MDHR1862	0.3969	17:00
1001	420	401	DEHR3570	0.2589	
	430	612	MDHR6915	0.0284	
	440	725	VAHR6139	0.0064	
		745	VAHR8849	0.5244	
		749	VAHR9151	0.0001	

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observation Time ** (if daily)
		281	PADY5662	0	08:00
		283	PADY5790	0.0029	07:00
		289	PADY6297	0.0754	07:00
		312	PADY7846	0.0887	07:00
110	110	103	PAHR0605	0.0078	
		119	PAHR2537	0.0051	
		123	PAHR2838	0.0686	
		149	PAHR6004	0.0613	
		189	PAHR9938	0.0981	
		109*	PAHR1354	0.0001	
		137*	PAHR4763	0.0001	
		138*	PAHR4778	0.0001	
		999*	XXHR0000	0.0001	
		269	PADY4896	0.2693	15:00
		305	PADY7322	0.0051	07:00
		320	PADY8379	0.2391	08:00
		345	PADY9950	0.2452	09:00
120	120	129	PAHR3321	0.1758	
		137	PAHR4763	0.3912	
		138	PAHR4778	0.0037	
		189	PAHR9938	0.0021	
		103*	PAHR0605	0.0001	
		119*	PAHR2537	0.0001	
		177*	PAHR8763	0.0001	
		601*	MDHR0015	0.0001	
		615*	MDHR9030	0.0001	
		999*	XXHR0000	0.0001	
		253	PADY4019	0.4266	07:00
160	160	122	PAHR2721	0.0028	
		127	PAHR3295	0.1818	
		503	WVHR1393	0.0112	
		509	WVHR6163	0.063	
		510	WVHR7730	0.1001	
		116*	PAHR2298	0.0001	
		175*	PAHR8589	0.0001	
		502*	WVHR1323	0.0001	
		608*	MDHR4030	0.0001	
		999*	XXHR0000	0.0001	
		516	WVDY0527	0.1672	07:00
		633	MDDY2282	0.2188	07:00
		662	MDDY8065	0.2546	08:00
170	170	502	WVHR1323	0.0001	

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observ. Time ** (if daily)
		999*	XXHR0000	0.0001	
		822	VADY6475	0.1817	16:00
1002	400	401	DEHR3570	0.6525	
	820	601	MDHR0015	0.0502	
	390	602	MDHR0465	0.0648	
	830	612	MDHR6915	0.211	
	770	602*	MDHR0465	0.0001	
	780	749*	VAHR9151	0.0001	
		604*	MDHR0700	0.0001	
		747*	VAHR8906	0.0001	
		129*	PAHR3321	0.0001	
		999*	XXHR0000	0.0001	
	840	409	DEDY6410	0.0002	17:00
	410	642	MDDY3675	0.0207	16:00
1003	370	601	MDHR0015	0.6506	
	380	602	MDHR0465	0.115	
	800	129*	PAHR3321	0.0001	
	810	137*	PAHR4763	0.0001	
		138*	PAHR4778	0.0001	
		401*	DEHR3570	0.0001	
		745*	VAHR8849	0.0001	
		999*	XXHR0000	0.0001	
		409	DEDY6410	0.2338	17:00
1004	140	129	PAHR3321	0.0357	
	450	137	PAHR4763	0.0243	
	850	189	PAHR9938	0.0439	
		601	MDHR0015	0.1725	
		602	MDHR0465	0.0001	
		119*	PAHR2537	0.0001	
		138*	PAHR4778	0.0001	
		605*	MDHR1530	0.0001	
		747*	VAHR8906	0.0001	
		999*	XXHR0000	0.0001	
		253	PADY4019	0.2493	07:00
		320	PADY8379	0.0026	08:00
		409	DEDY6410	0.1214	17:00
		631	MDDY2060	0.3497	24:00
1005	510	189	PAHR9938	0.0004	
	870	601	MDHR0015	0.0525	
	470	602	MDHR0465	0.2394	
	480	604	MDHR0700	0.0085	
	860	615	MDHR9030	0.0032	

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observation Time ** (if daily)
		503	WVHR1393	0.0475	
		508	WVHR5739	0.0253	
		509	WVHR6163	0.1684	
		510	WVHR7730	0.105	
		707	VAHR2208	0.0026	
		724	VAHR5880	0.0004	
		127*	PAHR3295	0.0001	
		999*	XXHR0000	0.0001	
		516	WVDY0527	0.0057	07:00
		525	WVDY3215	0.3803	08:00
		535	WVDY6960	0.1973	08:00
		633	MDDY2282	0.004	07:00
		813	VADY5595	0.0632	07:00
175	175	122	PAHR2721	0.0625	
		127	PAHR3295	0.0094	
		502	WVHR1323	0.1985	
		508	WVHR5739	0.0955	
		509	WVHR6163	0.04	
		510	WVHR7730	0.1269	
		608	MDHR4030	0.133	
		737	VAHR8046	0.041	
		707*	VAHR2208	0.0001	
		999*	XXHR0000	0.0001	
		544	WVDY9281	0.2035	08:00
		633	MDDY2282	0.0884	07:00
		856	VADY9186	0.0011	08:00
180	180	109	PAHR1354	0.0543	
		123	PAHR2838	0.0103	
		505	WVHR4763	0.2589	
		605	MDHR1530	0.1778	
		119*	PAHR2537	0.0001	
		123*	PAHR2838	0.0001	
		502*	WVHR1323	0.0001	
		742*	VAHR8396	0.0001	
		999*	VAHR0000	0.0001	
		623	MDDY1032	0.04	18:00
		640	MDDY3355	0.1377	07:00
		643	MDDY3975	0.2429	18:00
		818	VADY5851	0.0776	08:00
190	190	707	VAHR2208	0.3168	
		722	VAHR5690	0.0548	
		726	VAHR6178	0.0051	
		737	VAHR8046	0.008	

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observ. Time ** (if daily)
	490	119*	PAHR2537	0.0001	
		612*	MDHR6915	0.0001	
		747*	VAHR8906	0.0001	
		999*	XXHR0000	0.0001	
		253	PADY4019	0.0239	07:00
		320	PADY8379	0.1541	08:00
		631	MDDY2060	0.0001	24:00
		620	MDDY0470	0.4498	24:00
		629	MDDY1862	0.0371	17:00
		642	MDDY3675	0.0306	16:00
1006	880	612	MDHR6915	0.361	
	500	747*	VAHR8906	0.3048	
	910	602*	MDHR0465	0.0001	
	920	604*	MDHR0700	0.0001	
	990	749*	VAHR9151	0.0001	
		729*	VAHR6712	0.0001	
		999*	XXHR0000	0.0001	
		642	MDDY3675	0.2497	16:00
		776	VADY2009	0.084	09:00
1007	550	604	MDHR0700	0.05	
	890	612	MDHR6915	0.0001	
	900	742	VAHR8396	0.1325	
	970	747	VAHR8906	0.3211	
		602*	MDHR0465	0.0001	
		615*	MDHR9030	0.0001	
		729*	VAHR6712	0.0001	
		999*	XXHR0000	0.0001	
		624	MDDY1125	0	24:00
		630	MDDY1995	0.1193	09:00
		642	MDDY3675	0.0111	16:00
		776	VADY2009	0.0105	09:00
		849	VADY8903	0.355	24:00
1008	980	612	MDHR6915	0.3363	
	580	734	VAHR7201	0.005	
	930	749	VAHR9151	0.0873	
		604*	MDHR0700	0.0001	
		729*	VAHR6712	0.0001	
		747*	VAHR8906	0.0001	
		745*	VAHR8849	0.0001	
		725*	VAHR6139	0.0001	
		999*	XXHR0000	0.0001	
		757	VADY0327	0.0326	18:00
		776	VADY2009	0.4957	09:00

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observation Time ** (if daily)
		742	VAHR8396	0.0011	
		508*	WVHR5739	0.0001	
		724*	VAHR5880	0.0001	
		729*	VAHR6712	0.0001	
		503*	WVHR1393	0.0001	
		999*	XXHR0000	0.0001	
		525	WVDY3215	0.0117	08:00
		760	VADY0720	0.1195	08:00
		807	VADY5096	0.135	08:00
		836	VADY8062	0.3475	08:00
200	200	505	WVHR4763	0.0752	
		707	VAHR2208	0.0979	
		737	VAHR8046	0.306	
		742	VAHR8396	0.0557	
		502*	WVHR1323	0.0001	
		509*	WVHR6163	0.0001	
		724*	VAHR5880	0.0001	
		999*	XXHR0000	0.0001	
		525	WVDY3215	0.0089	08:00
		535	WVDY6960	0.0073	08:00
		544	WVDY9281	0.0545	08:00
		807	VADY5096	0.1108	08:00
		818	VADY5851	0.1867	08:00
		842	VADY8448	0(.2343)	18:00
		856	VADY9186	0.0966	08:00
210	210	119	PAHR2537	0.3897	
		123	PAHR2838	0.0084	
		605	MDHR1530	0.2442	
		615	MDHR9030	0.3199	
		109*	PAHR1354	0.0001	
		189*	PAHR9938	0.0001	
		138*	PAHR4778	0.0001	
		999*	XXHR0000	0.0001	
		320	PADY8379	0.0374	08:00
220	220	742	VAHR8396	0.2044	
		747	VAHR8906	0.0491	
		505*	WVHR4763	0.0001	
		604*	MDHR0700	0.0001	
		605*	MDHR1530	0.0001	
		737*	VAHR8046	0.0001	
		602*	MDHR0465	0.0001	
		999*	XXHR0000	0.0001	
		630	MDHR1995	0.0279	09:00

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observ. Time ** (if daily)
		822	VADY6475	0.0425	16:00
1009	600	725	VAHR6139	0.0297	
	610	734	VAHR7201	0.3208	
	590	749	VAHR9151	0.3773	
	940	612*	MDHR6915	0.0001	
		747*	VAHR8906	0.0001	
		745*	VAHR8849	0.0001	
		999*	XXHR0000	0.0001	
		757	VADY0327	0.1246	18:00
		776	VADY2009	0.0013	09:00
		780	VADY2142	0.0018	08:00
		822	VADY6475	0.0016	16:00
		830	VADY6906	0.0062	07:00
		845	VADY8800	0.0454	07:00
		857	VADY9213	0.0909	07:00
1010	950	725	VAHR6139	0.7701	
	630	749	VAHR9151	0.0679	
	960	612*	MDHR6915	0.0001	
	620	734*	VAHR7201	0.0001	
		999*	XXHR0000	0.0001	
		845	VADY8800	0.1617	07:00
1011	330	604	MDHR0700	0.2692	
	340	615	MDHR9030	0.0532	
		119*	PAHR2537	0.0001	
		602*	MDHR0465	0.0001	
		605*	MDHR1530	0.0001	
		734*	VAHR7201	0.0001	
		742*	VAHR8396	0.0001	
		747*	VAHR8906	0.0001	
		999*	XXHR0000	0.0001	
		624	MDDY1125	0	24:00
		629	MDDY1862	0.4485	17:00
		642	MDDY3675	0.2284	16:00
1012	235	729	VAHR6712	0.0827	
	250	726*	VAHR6178	0.0001	
	260	734*	VAHR7201	0.0001	
		742*	VAHR8396	0.0001	
		747*	VAHR8906	0.0001	
		612*	MDHR6915	0.0001	
		999*	XXHR0000	0.0001	
		757	VADY0327	0.2494	18:00
		776	VADY2009	0.2487	09:00

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observation Time ** (if daily)
		818	VADY5851	0.2685	08:00
		849	VADY8903	0.4495	24:00
230	230	729	VAHR6712	0.3089	
		742	VAHR8396	0.2033	
		604*	MDHR0700	0.0001	
		707*	VAHR2208	0.0001	
		722*	VAHR5690	0.0001	
		726*	VAHR6178	0.0001	
		737*	VAHR8046	0.0001	

Precip Seg	Model Seg	DSN	Station Name	Station Weight	Observ. Time ** (if daily)
		780	VADY2142	0.0609	08:00
		792	VADY3466	0.0652	07:00
		806	VADY5050	0.2925	18:00
1013	290	734	VAHR7201	0.0012	
	300	720*	VAHR5120	0.0001	
	310	729*	VAHR6712	0.0001	
		749*	VAHR9151	0.0001	
		722*	VAHR5690	0.0001	
		999*	XXHR0000	0.0001	
		755	VADY0187	0.1788	07:00
		756	VADY0243	0.0663	07:00
		767	VADY1322	0.0513	08:00
		757	VADY0327	0.0001	18:00
		765	VADY1136	0.0001	07:00
		780	VADY2142	0.1637	08:00
		782	VADY2160	0.082	07:00
		786	VADY2941	0.2324	07:00
		830	VADY6906	0.1191	07:00
		857	VADY9213	0.1045	07:00

(*indicates stations which possess Thiessen polygons outside of the segment, but are used to minimize skipped hourly precipitation events)

(**indicates time of data that precipitation data was observed at those stations subject to daily inspection)

Table D.3.2

Format of Input Files for PRECIP.exe Program

Line	FORTRAN Format	Variable Name	Definition
1	7I4	NGAGES	Total number of hourly and daily stations
		IDAILY	Number of daily stations
		IHRLY	Number of hourly stations
		TYPE	Set to 2, for Thiessen method
		COMP	Set to 1
		DIS	Set to 0
		AVG	Set to 1
2	A64	WDNAME	WDM file name and extension
3	I4	DSN(21)	WDM data set number for the output time series generated by PRECIP.exe
4	20I4	DSN(1-NGAGES)	WDM data set numbers of the input hourly and daily precipitation time series. Enter hourly stations DSNs first, then daily station DSNs
5	6I4	SDATE(1-3)	Start date in year, month,day format
		EDATE(1-3)	End date in year, month, day format
6	10I4	IOBST(11-IDAYT)	Observation times of the daily stations in the same order as they appear in line 4. If there are no daily stations to be included omit this line, do not leave a blank line
7+	10F8.2	WGT(1-NGAGES)	Thiessen weights of the observed precipitation stations in the same order as line 4. Enter a maximum of ten values per line, then start a new line immediately below following the same format

volume was used to distribute that event by employing a proportional distribution pattern on an hourly basis. A data gap occurs when daily precipitation stations have precipitation recorded, but the hourly stations either have zero or missing precipitation. As no hourly distribution is available, for these instances the precipitation hourly record will contain data gaps.

To eliminate hourly data gaps an ideal hourly station that rained every hour of every day for the period of the record. This ideal station (DSN999) had an extremely low precipitation volume (0.00042 inches per hour, or 0.01 inches per day) and was set to a weight of 0.0001 which was a negligable weight assigned to other nearby hourly stations not in the Thiessen precipitation segment but close by and used for hourly weights of the precipitation volume. The ideal station had no impact on a segment's calculated precipitation volume, but was selected when no other hourly station had precipitation registered for that day. This ideal station was included for all precipitation segments that missed more than one inch of calculated precipitation over the 1991-1994 run time. For those stations with less than one inch missed, all events were reviewed and determined to be less than 0.20 inch in depth. Table D.3.1 is the final draft with Thiessen weights with the augmented hourly stations marked with an asterisk and the inclusion of the ideal hourly station identified by an asterisk and a "999" in the DSN column.

Both 1991 data from the above development and from the earlier 1984-1991 dataset were compared to verify the consistency between them. Table D.3.3 lists the monthly precipitation in 1991 for the 1984-1991 data set and for verification with the 1991-1995 data set, and in 1992-1995.

In comparing 1991 precipitation of stage 1 and stage 2, there are only minor (<1%) differences between them. The differences may be due to any of the following reasons: 1) 1984-91 used one decimal place for daily precipitation, while 1991-1995 used two decimal places, and 2) 1991-95 used eight fewer precipitation stations than 1984-91 did.

From the above analysis, the 1991-95 precipitation data development was shown to be in agreement with 1984-91 precipitation data.

Finally, the 1992-95 precipitation data were combined with 1984-1991 data using ANNIE.exe software, yielding 1984-95 precipitation data for application in the Phase IV Chesapeake Bay Watershed Model.

TABLE 3.3
Summary of 1991 Precipitation Data from Stage 1 WDM Files

	Jan-91	Feb-91	Mar-91	Apr-91	May-91	Jun-91	Jul-91	Aug-91	Sep-91	Oct-91	Nov-91	Dec-91
DSN 1010	1.67	1.24	2.96	2.97	1.05	0.92	2.53	2.61	2.45	1.81	2.86	2.76
DSN 1020	2.22	1.79	3.63	4.44	2.54	1.55	3.12	3.72	3.09	1.85	3.91	2.8
DSN 1030	1.87	1.58	3.33	3.11	2.34	1.13	2.84	2.29	3.15	2.14	3.52	2.81
DSN 1040	2.59	1.68	3.64	2.91	2.57	2.34	3.31	4.48	3.63	2.71	3.49	3.19
DSN 1050	3.10	1.82	5.20	3.52	1.95	2.64	3.33	1.78	3.00	1.31	2.49	2.83
DSN 1060	1.97	1.43	4.15	2.89	1.83	1.51	2.80	2.76	3.29	1.69	2.86	3.01
DSN 1070	2.20	1.79	3.59	2.72	2.16	1.37	3.23	3.6	4.18	2.26	3.12	3.18
DSN 1080	2.39	1.62	3.97	2.48	2.03	0.84	2.06	4.58	2.32	2.09	2.95	2.93
DSN 1090	1.97	1.66	4.12	2.67	1.46	1.28	2.61	2.47	1.49	1.16	2.73	3.06
DSN 1100	1.90	1.66	4.62	2.70	1.45	1.37	2.37	2.93	2.32	1.42	2.76	2.62
DSN 1110	2.59	1.12	3.61	2.00	2.82	0.66	1.92	3.77	3.65	2.96	2.27	3.41
DSN 1120	3.01	1.13	3.52	2.25	1.64	1.65	3.24	2.40	4.43	2.48	2.22	3.7
DSN 1160	2.63	1.72	4.01	3.04	2.12	1.48	2.69	2.32	1.19	1.09	2.68	3.97
DSN 1170	3.02	0.96	5.06	2.03	2.15	1.22	4.02	2.35	1.31	0.5	2.22	3.88
DSN 1175	2.66	1.20	4.43	1.93	1.81	2.25	2.43	2.32	0.94	0.91	2.48	3.64
DSN 1180	2.94	1.09	4.25	2.11	1.95	1.27	1.93	2.23	1.78	2.62	1.92	4.1
DSN 1190	3.09	1.45	5.20	1.88	1.69	3.56	7.31	2.26	0.80	0.99	2.43	4.46
DSN 1200	3.12	1.01	4.70	1.93	1.63	2.48	2.74	1.71	1.33	1.47	2.13	4.29
DSN 1210	3.20	1.34	4.04	2.02	1.85	0.90	2.08	5.54	4.29	2.17	2.11	3.86
DSN 1220	3.01	0.82	4.94	1.80	1.30	3.98	2.65	1.07	2.56	1.71	2.32	4.6
DSN 1230	3.64	1.04	5.01	2.48	1.71	3.47	5.30	1.43	1.67	1.73	2.71	4.73
DSN 1265	4.07	1.74	6.04	2.14	2.16	2.33	5.74	2.89	0.60	1.11	3.38	5.63
DSN 1270	3.76	2.00	6.81	2.25	2.91	2.65	6.00	2.13	0.77	0.63	3.42	4.79
DSN 1280	3.67	1.94	5.56	2.42	2.36	3.22	8.24	2.51	1.29	1.13	2.67	5.36
DSN 1700	1.28	1.27	2.99	2.99	0.98	0.67	2.05	1.63	2.40	1.37	3.47	2.47
DSN 1710	2.46	1.15	3.55	1.85	2.36	0.81	1.90	3.39	3.67	2.8	2.04	3.44
DSN 1720	2.79	1.16	3.74	2.28	2.50	1.92	3.06	3.41	3.53	2.78	1.96	3.35
DSN 1730	2.54	1.44	4.31	2.87	2.79	0.58	2.03	2.75	1.46	2.81	2.44	3.42
DSN 1740	2.81	1.11	4.17	2.04	1.88	1.61	1.63	2.21	1.79	1.55	2.3	3.72
DSN 1750	3.00	1.50	4.12	2.36	2.50	0.50	2.32	4.61	2.10	2.69	2.25	3.73
DSN 1760	3.38	1.15	4.03	1.73	1.92	1.43	1.67	4.63	3.85	1.87	2.36	4.23
DSN 2001	4.59	0.87	4.89	2.96	0.72	2.62	3.89	5.48	2.89	3.62	0.86	3.54
DSN 2002	4.55	0.86	5.56	2.64	1.23	3.22	4.34	4.10	4.09	3.04	0.98	4.37
DSN 2003	3.68	1.08	4.92	2.66	2.14	1.34	3.18	3.39	4.42	1.83	2.18	4.21
DSN 2004	3.50	1.19	4.34	2.34	2.17	1.73	3.19	3.21	4.25	1.93	2.18	4.1
DSN 2005	3.26	0.78	4.89	1.91	1.34	0.80	2.47	2.53	3.68	2.55	2.02	4.38
DSN 2006	3.31	0.80	4.71	1.66	1.62	2.45	3.58	2.08	3.11	2.77	1.11	5.28
DSN 2007	2.98	0.80	4.92	1.67	1.64	3.46	3.66	1.69	2.98	1.94	1.86	4.89
DSN 2008	3.62	0.96	4.48	1.60	1.49	3.39	4.12	1.17	3.01	2.74	1.15	5.82
DSN 2009	3.90	1.19	5.40	1.67	0.98	4.82	5.91	2.86	2.74	2.92	0.85	3.93
DSN 2010	4.55	0.88	4.63	5.41	0.67	4.22	7.15	4.10	2.27	4.26	1.46	2.5
DSN 2011	3.24	0.94	5.34	1.92	2.02	1.95	2.25	3.21	3.42	2.59	2.16	4.73
DSN 2012	3.71	1.08	4.11	1.59	1.36	3.72	7.61	1.20	2.47	1.83	1.42	5.36
DSN 2013	4.17	2.22	5.44	1.39	1.93	2.88	6.30	4.13	2.83	1.87	1.23	4.68

Summary of 1991 Precipitation Processed by Stage 2 for Verification with Stage 1

	Jan-91	Feb-91	Mar-91	Apr-91	May-91	Jun-91	Jul-91	Aug-91	Sep-91	Oct-91	Nov-91	Dec-91
DSN 1010	1.68	1.26	2.96	2.97	1.05	0.92	2.52	2.61	2.46	1.81	2.86	2.76
DSN 1020	2.22	1.79	3.63	4.44	2.54	1.55	3.12	3.72	3.09	1.85	3.91	2.8
DSN 1030	1.87	1.59	3.31	3.11	2.33	1.12	2.85	2.30	3.16	2.14	3.51	2.81
DSN 1040	2.54	1.74	3.53	2.84	2.57	2.31	3.39	4.48	3.67	2.71	3.39	3.21
DSN 1050	3.10	1.59	5.20	3.08	1.95	2.32	3.33	1.71	3.24	1.32	2.59	2.94
DSN 1060	2.00	1.54	4.11	2.88	1.87	1.53	2.80	2.79	3.34	1.74	2.87	3.04
DSN 1070	2.22	1.79	3.56	2.70	2.14	1.40	3.20	3.62	4.23	2.26	3.18	3.22
DSN 1080	2.41	1.60	3.97	2.49	2.01	0.96	2.04	4.59	2.30	2.12	3.01	2.93
DSN 1090	2.01	1.68	4.08	2.67	1.45	1.32	2.58	2.44	1.47	1.14	2.82	2.98
DSN 1100	1.97	1.63	4.58	2.66	1.49	1.39	2.42	2.85	2.19	1.38	2.80	2.57
DSN 1110	2.63	1.14	3.61	1.96	2.83	0.65	1.83	3.81	3.70	2.96	2.33	3.57
DSN 1120	2.90	1.23	3.45	2.60	1.79	1.67	3.78	2.10	4.53	2.15	2.28	3.63
DSN 1160	3.27	1.65	4.10	3.06	2.11	1.45	2.69	2.34	1.14	1.08	2.69	4.00
DSN 1170	2.81	0.96	5.12	2.06	2.13	1.18	4.06	2.36	1.33	0.55	2.92	3.88
DSN 1175	2.75	1.16	4.45	1.98	1.84	2.35	2.38	2.33	1.02	0.97	2.46	3.69
DSN 1180	3.61	1.18	4.21	2.22	1.41	1.22	1.87	2.03	---	2.07	1.69	3.02
DSN 1190	3.48	1.47	5.17	1.92	1.76	3.53	7.30	2.24	0.77	1.06	2.51	4.43
DSN 1200	3.25	1.02	4.78	1.93	1.55	2.49	2.80	1.69	1.14	1.32	2.00	4.35
DSN 1210	3.21	1.45	4.04	2.02	1.85	0.90	2.07	5.55	---	2.17	2.11	3.86
DSN 1220	2.89	0.85	5.02	1.76	1.33	4.02	2.57	1.04	2.61	1.75	2.40	4.53
DSN 1230	3.57	1.00	5.01	2.46	1.73	3.49	5.34	1.43	1.61	1.76	2.75	4.67
DSN 1265	3.46	1.75	5.64	2.02	2.12	2.16	5.89	2.72	0.63	1.10	3.36	5.59
DSN 1270	3.75	2.01	6.75	2.19	2.94	2.65	6.15	2.14	0.79	0.63	3.49	4.82
DSN 1280	3.51	2.04	5.61	2.33	2.50	3.43	7.12	2.62	1.51	0.96	2.61	5.53
DSN 1700	1.28	1.27	2.99	2.99	0.98	0.67	2.05	1.63	2.40	1.37	3.47	2.47
DSN 1710	2.45	1.16	3.54	1.84	2.49	0.68	1.80	3.50	3.66	2.78	2.11	3.53
DSN 1720	2.73	1.27	3.77	2.40	2.93	2.11	3.24	3.69	3.44	2.81	2.06	3.14
DSN 1730	2.69	1.45	4.32	2.93	2.75	0.60	2.03	2.79	---	2.77	2.43	3.26
DSN 1740	2.84	1.11	4.17	2.01	1.83	1.72	1.62	2.19	---	1.64	1.20	3.66
DSN 1750	3.00	1.50	4.12	2.36	2.50	0.50	2.32	4.61	---	2.69	2.25	3.73
DSN 1760	3.32	1.11	4.12	1.69	1.86	1.36	1.66	4.62	3.93	1.91	2.34	4.35
DSN 2001	4.60	0.88	4.87	2.98	0.73	2.64	3.90	5.46	2.89	3.63	0.86	3.56
DSN 2002	4.55	0.86	5.56	2.64	1.23	3.22	4.37	4.10	4.09	3.04	0.98	4.37
DSN 2003	3.68	1.08	4.94	2.64	2.15	1.34	3.17	3.35	4.38	1.80	2.08	4.18
DSN 2004	3.34	1.19	4.36	2.42	2.26	1.72	3.22	3.24	4.16	1.92	2.10	4.09
DSN 2005	3.25	0.84	4.92	1.86	1.35	0.84	2.36	2.46	3.72	2.57	2.01	4.36
DSN 2006	3.32	0.83	4.75	1.70	1.61	2.45	3.59	2.09	3.12	2.77	1.14	5.31
DSN 2007	2.95	0.84	4.98	1.63	1.64	3.49	3.61	1.70	3.04	1.99	1.90	4.84
DSN 2008	3.59	0.96	4.47	1.76	1.56	3.43	4.18	0.96	3.20	2.76	1.14	5.76
DSN 2009	3.90	1.16	5.82	1.71	0.98	4.85	5.92	2.87	2.73	2.95	0.88	3.89
DSN 2010	4.56	0.84	6.08	5.42	0.66	4.50	7.06	4.08	2.26	4.25	1.45	2.49
DSN 2011	3.18	1.01	5.46	1.88	1.98	1.86	2.30	3.25	3.48	2.62	2.15	4.88
DSN 2012	3.63	1.05	4.09	1.70	1.40	3.76	7.69	1.23	2.46	1.88	1.39	5.44
DSN 2013	4.19	2.23	5.44	1.32	1.96	2.86	6.23	4.18	2.84	1.87	1.15	4.70

Note: There are no values for segments 1180, 1210, 1730, 1740, and 1750 due to unacceptable raw data for those segments.

Summary of 1992 Precipitation Data Processed by Stage 2

	Jan-92	Feb-92	Mar-92	Apr-92	May-92	Jun-92	Jul-92	Aug-92	Sep-92	Oct-92	Nov-92	Dec-92
DSN 1010	1.73	1.21	3.24	2.88	2.56	2.03	7.34	3.32	3.87	2.17	3.13	2.74
DSN 1020	1.70	2.07	3.30	3.17	4.68	1.73	6.17	2.71	3.43	3.34	4.06	2.6
DSN 1030	1.69	1.70	3.52	2.53	4.11	1.64	5.27	2.83	3.30	2.52	3.75	3.18
DSN 1040	1.34	2.00	4.97	2.68	2.45	2.82	5.32	2.97	3.02	2.15	3.52	2.17
DSN 1050	1.84	1.76	3.22	2.45	2.63	1.58	6.98	4.92	4.34	1.45	4.14	3.39
DSN 1060	1.93	1.42	3.59	2.58	2.72	2.22	8.09	3.98	4.09	1.77	4.30	3.29
DSN 1070	1.76	1.66	4.74	2.30	3.44	2.82	7.97	2.64	2.60	1.20	3.65	1.94
DSN 1080	1.62	1.90	4.73	2.64	3.09	2.15	4.87	2.48	3.00	1.75	4.31	3.57
DSN 1090	1.87	1.96	3.96	1.91	2.59	1.99	5.28	2.77	3.10	0.68	3.66	4.21
DSN 1100	1.53	1.64	3.79	2.02	2.77	1.83	4.02	1.82	3.21	0.85	4.03	4.09
DSN 1110	1.37	1.58	4.54	2.36	3.97	2.30	4.67	1.88	4.75	1.58	4.96	2.87
DSN 1120	1.87	1.47	3.90	1.70	4.18	2.60	2.74	2.15	3.78	2.50	3.57	3.79
DSN 1160	1.79	2.88	4.07	2.33	3.28	2.12	7.43	2.93	1.75	0.59	3.28	4.59
DSN 1170	1.35	1.49	2.76	2.52	3.49	2.01	3.09	1.65	1.96	0.29	1.65	2.56
DSN 1175	1.36	1.82	3.08	2.35	3.60	2.78	5.14	2.56	2.60	0.47	3.03	4.25
DSN 1180	1.47	1.29	3.86	4.09	3.93	3.21	4.81	2.55	4.96	0.65	3.74	4.49
DSN 1190	2.57	2.05	3.01	4.44	4.16	3.27	4.19	2.00	4.38	1.57	4.06	5.68
DSN 1200	2.26	1.77	3.11	4.01	3.79	3.10	4.70	2.08	4.83	0.75	3.42	5.81
DSN 1210	1.52	1.84	5.09	3.53	3.29	3.32	6.55	2.51	4.81	1.32	4.78	3.81
DSN 1220	2.38	2.07	3.49	3.73	4.09	2.81	6.78	1.68	5.39	2.11	5.26	4.73
DSN 1230	3.03	2.19	3.05	4.23	4.49	4.09	4.80	2.60	6.03	1.97	5.82	7.69
DSN 1265	1.49	4.01	4.04	3.46	4.61	4.61	3.94	2.22	2.18	1.06	4.81	3.00
DSN 1270	2.28	2.82	3.48	4.39	4.43	4.60	3.12	2.27	2.95	1.54	4.54	2.85
DSN 1280	2.80	2.99	3.20	3.34	4.84	3.62	3.35	2.05	5.46	1.87	5.60	4.60
DSN 1700	1.69	1.36	3.59	2.40	3.54	1.52	6.02	3.54	2.78	2.72	3.07	3.06
DSN 1710	1.50	1.55	4.26	1.97	3.99	2.01	4.21	1.81	4.44	1.50	4.31	2.87
DSN 1720	1.56	1.45	3.83	1.48	4.36	2.94	4.01	2.36	4.17	1.82	4.11	3.75
DSN 1730	1.66	1.99	5.13	3.26	4.14	2.75	4.11	2.08	4.24	0.68	5.28	5.63
DSN 1740	1.38	1.95	3.63	3.52	4.15	3.65	4.41	2.32	3.82	0.41	2.20	4.65
DSN 1750	1.65	1.98	5.49	3.18	4.08	2.81	5.69	1.60	4.69	1.26	6.18	4.30
DSN 1760	2.04	2.50	4.29	2.76	3.45	1.77	5.81	2.14	4.19	1.98	5.22	4.87
DSN 2001	1.57	2.76	3.42	1.56	4.15	2.78	4.81	5.16	5.59	1.45	4.65	4.46
DSN 2002	1.06	3.12	3.59	1.36	3.57	3.50	8.24	4.85	5.20	1.65	2.77	4.61
DSN 2003	1.14	2.57	4.67	1.67	4.30	3.51	5.94	2.95	5.62	1.86	4.04	4.85
DSN 2004	1.57	1.26	4.26	0.98	4.10	1.64	3.47	2.33	2.42	2.14	2.24	3.73
DSN 2005	1.43	2.35	4.38	1.98	3.19	2.29	4.61	2.48	5.45	2.18	4.20	4.11
DSN 2006	1.92	2.72	4.50	2.19	3.54	2.67	7.14	4.14	4.17	1.82	3.28	4.08
DSN 2007	2.38	2.25	3.50	2.78	3.91	2.48	6.79	2.03	4.81	2.04	4.30	3.88
DSN 2008	2.17	2.95	4.42	1.77	3.96	2.48	6.15	5.76	3.87	1.93	3.09	4.40
DSN 2009	2.41	2.75	4.88	2.44	4.55	2.86	5.76	7.49	2.29	2.37	3.03	3.53
DSN 2010	4.37	2.09	2.72	1.70	3.78	2.36	4.77	12.97	2.31	2.82	4.00	3.44
DSN 2011	2.06	2.58	4.27	2.62	4.04	1.72	7.55	2.41	4.45	2.17	4.88	4.53
DSN 2012	2.03	2.8	4.22	2.04	3.94	2.47	3.48	4.03	4.15	2.09	4.09	4.83
DSN 2013	2.37	3.03	4.02	2.72	4.87	2.90	3.34	3.86	3.12	2.25	3.69	3.94

Summary of 1993 Precipitation Data Processed by Stage 2

	Jan-93	Feb-93	Mar-93	Apr-93	May-93	Jun-93	Jul-93	Aug-93	Sep-93	Oct-93	Nov-93	Dec-93
DSN 1010	1.78	1.28	3.81	6.72	1.47	2.36	1.56	3.08	4.42	2.10	4.17	1.84
DSN 1020	2.39	1.77	3.98	6.95	1.63	3.52	1.65	3.03	3.69	2.84	3.91	2.97
DSN 1030	1.80	1.45	4.36	7.59	1.58	2.82	2.09	3.71	5.42	3.61	4.13	3.16
DSN 1040	1.85	1.37	3.63	7.49	1.61	2.42	1.70	4.42	4.56	2.90	2.99	2.85
DSN 1050	2.95	2.10	4.77	6.98	2.47	2.69	3.83	2.55	5.50	3.03	5.38	2.78
DSN 1060	2.48	1.75	5.18	7.45	1.86	3.23	2.88	3.93	5.10	3.30	4.86	2.50
DSN 1070	1.53	1.14	3.9	6.17	1.65	2.62	1.71	3.68	4.21	2.52	3.53	2.17
DSN 1080	2.24	1.66	6.25	6.89	2.31	2.44	3.41	4.29	4.34	3.32	3.45	3.23
DSN 1090	1.75	2.08	5.93	8.77	2.39	2.74	3.89	2.57	4.63	2.81	4.90	2.84
DSN 1100	1.88	1.90	5.31	7.81	2.09	2.43	3.13	2.14	4.27	2.47	4.77	2.50
DSN 1110	1.94	2.40	6.10	6.90	2.45	2.96	3.44	4.16	6.47	3.47	4.46	4.30
DSN 1120	1.77	2.40	6.63	6.08	1.75	1.70	2.19	3.33	6.09	2.93	3.97	4.35
DSN 1160	1.81	2.42	7.16	6.59	2.23	2.74	3.48	2.48	5.04	2.78	3.46	3.14
DSN 1170	1.32	1.52	6.62	3.60	1.30	2.33	1.78	2.11	4.09	2.08	3.29	2.37
DSN 1175	1.41	1.83	6.94	6.26	1.48	2.65	3.49	1.88	4.29	2.25	4.15	3.07
DSN 1180	1.73	2.14	5.57	4.91	2.21	2.16	2.07	2.28	6.97	1.92	3.21	3.00
DSN 1190	2.39	2.29	7.38	4.34	2.84	2.02	2.65	2.18	4.23	2.32	3.87	3.71
DSN 1200	1.81	1.84	7.85	4.08	1.56	3.04	2.66	2.25	4.13	2.38	4.47	3.69
DSN 1210	2.08	3.26	7.81	6.07	2.24	2.15	2.12	3.48	8.84	2.91	4.61	4.10
DSN 1220	2.50	2.44	7.67	3.76	2.58	3.12	1.68	3.68	4.22	2.41	5.86	4.12
DSN 1230	2.88	2.56	7.75	4.98	3.46	2.69	3.03	2.71	3.60	2.79	5.74	3.90
DSN 1265	1.94	2.18	5.69	3.69	4.20	2.00	2.16	2.32	4.98	2.64	2.87	4.69
DSN 1270	2.70	3.00	7.49	3.67	3.02	3.27	2.47	2.05	4.31	2.11	2.80	3.82
DSN 1280	4.38	3.45	8.25	4.57	4.92	2.15	2.86	2.32	3.88	2.44	5.96	4.88
DSN 1700	1.41	1.13	3.61	7.43	1.61	3.65	1.32	3.24	3.76	2.23	3.50	2.50
DSN 1710	1.76	2.08	5.60	6.54	1.85	2.74	3.09	3.75	6.70	3.35	4.46	4.42
DSN 1720	1.97	2.39	5.97	6.62	1.68	2.27	2.68	2.48	7.46	3.41	4.50	4.78
DSN 1730	2.08	2.76	6.99	8.06	2.25	2.59	3.40	2.57	5.57	3.10	5.11	3.72
DSN 1740	1.67	1.67	6.73	5.81	1.20	2.73	2.75	1.86	5.39	2.49	4.29	3.89
DSN 1750	2.27	3.20	7.77	6.97	2.08	2.65	2.78	3.44	7.79	3.12	4.68	3.94
DSN 1760	2.41	2.54	1.28	6.32	2.49	3.37	1.58	4.04	5.16	2.98	4.72	4.52
DSN 2001	3.62	1.64	5.87	2.88	4.22	1.71	0.44	3.00	2.76	4.02	1.78	3.51
DSN 2002	3.21	2.84	7.81	2.99	3.60	2.06	1.27	4.73	2.58	2.46	3.23	4.53
DSN 2003	2.80	3.11	7.57	4.85	3.94	2.81	2.43	2.93	6.09	3.08	2.94	4.56
DSN 2004	2.02	1.44	7.17	3.24	2.44	1.10	1.86	3.54	6.59	3.86	3.64	4.70
DSN 2005	2.55	2.75	7.92	4.39	2.87	2.66	2.11	3.60	4.99	3.22	3.61	4.50
DSN 2006	3.27	2.53	7.38	3.43	3.86	1.85	1.10	4.54	3.24	2.65	4.89	4.41
DSN 2007	2.84	2.46	7.53	4.64	3.21	1.96	1.56	4.36	4.26	2.51	5.70	4.31
DSN 2008	3.65	2.72	8.08	4.20	4.48	2.05	1.10	3.44	4.25	2.60	4.33	4.41
DSN 2009	4.66	2.48	6.86	3.75	5.02	2.26	1.48	2.50	2.78	2.78	2.98	3.89
DSN 2010	4.93	2.23	6.23	3.57	3.57	2.70	0.36	1.34	3.95	3.45	1.25	3.38
DSN 2011	2.86	2.30	4.24	4.95	3.51	2.40	1.37	4.84	4.17	3.35	5.13	4.81
DSN 2012	3.99	2.83	8.08	4.74	4.75	1.87	1.58	2.35	4.14	2.39	6.57	4.53
DSN 2013	4.81	3.24	7.90	6.20	5.15	2.07	1.93	2.54	4.30	2.75	6.40	5.56

Summary of 1994 Precipitation Data Processed by Stage 2

	Jan-94	Feb-94	Mar-94	Apr-94	May-94	Jun-94	Jul-94	Aug-94	Sep-94	Oct-94	Nov-94	Dec-94
DSN 1010	2.57	1.56	4.11	2.67	2.47	5.64	2.88	6.82	2.19	1.63	3.36	1.89
DSN 1020	3.59	1.91	5.09	3.36	2.52	6.30	4.19	6.46	2.68	0.91	3.05	2.72
DSN 1030	3.82	1.45	4.46	4.57	2.45	5.03	4.34	7.16	3.96	1.10	4.26	2.54
DSN 1040	4.04	1.65	4.78	3.18	2.03	4.66	4.14	4.84	3.07	0.66	4.01	2.15
DSN 1050	4.03	2.75	6.54	5.01	3.41	4.61	3.73	8.84	3.12	0.89	4.74	3.04
DSN 1060	3.00	2.11	4.93	3.71	2.40	5.90	4.42	8.29	2.89	0.74	4.36	2.70
DSN 1070	3.07	1.73	4.32	3.23	2.25	4.39	4.61	5.47	3.60	0.59	4.01	2.45
DSN 1080	4.73	2.27	6.34	2.70	2.87	3.51	4.80	6.95	2.33	0.78	3.70	2.74
DSN 1090	4.55	3.44	6.37	2.99	3.00	2.09	4.50	7.58	2.12	0.97	4.04	2.91
DSN 1100	4.05	2.98	5.78	2.66	2.66	1.91	3.50	6.60	2.31	0.72	4.16	2.71
DSN 1110	4.10	3.40	5.68	2.08	3.01	2.21	6.40	5.31	2.67	1.04	5.39	2.93
DSN 1120	4.75	4.14	5.51	2.82	3.80	2.16	5.69	5.94	3.12	1.10	3.16	1.81
DSN 1160	4.72	5.65	6.47	3.91	4.34	3.36	5.29	5.02	1.03	0.79	3.38	2.99
DSN 1170	2.28	3.81	4.66	1.92	2.86	2.00	4.85	4.28	0.78	0.40	2.06	1.78
DSN 1175	3.92	4.30	6.03	2.90	3.20	2.63	5.40	4.56	1.26	0.96	3.63	2.88
DSN 1180	2.70	2.56	4.20	1.75	2.16	1.78	3.36	4.16	2.85	0.79	2.15	2.47
DSN 1190	4.55	3.65	7.01	2.54	2.53	2.83	4.42	5.20	1.67	1.28	2.47	2.12
DSN 1200	3.62	3.96	6.65	2.73	3.02	2.89	4.70	5.72	2.54	0.80	2.93	2.54
DSN 1210	3.78	3.74	6.41	2.16	2.75	4.15	3.73	4.08	3.65	0.91	4.89	2.53
DSN 1220	4.12	3.80	6.98	2.19	3.15	4.06	5.52	5.34	3.47	1.06	2.33	2.62
DSN 1230	4.34	3.81	7.61	3.08	2.24	3.77	6.82	5.54	3.51	1.20	3.01	2.51
DSN 1265	4.49	4.84	6.64	2.69	4.12	2.84	6.88	3.73	0.57	0.97	1.72	2.54
DSN 1270	4.17	3.78	6.30	3.28	2.63	3.20	5.53	5.64	1.06	1.49	1.45	2.32
DSN 1280	4.42	5.10	8.73	2.09	2.14	3.45	6.81	5.10	3.11	1.63	2.21	1.66
DSN 1700	3.32	1.51	4.31	0.00	1.81	7.63	5.29	6.25	3.05	1.27	2.76	2.13
DSN 1710	3.44	3.36	5.45	0.00	3.41	1.96	7.34	4.93	2.60	1.04	5.14	2.97
DSN 1720	5.05	3.06	5.52	3.12	4.11	2.61	6.67	5.81	2.78	1.10	4.69	3.06
DSN 1730	4.69	3.40	5.80	0.37	2.86	1.92	3.84	7.39	3.84	0.80	5.27	3.30
DSN 1740	4.03	4.14	6.19	2.51	3.95	1.56	4.45	6.28	2.02	1.13	3.68	3.04
DSN 1750	3.90	3.39	5.56	0.00	2.71	3.55	3.78	5.21	3.84	0.94	5.29	2.64
DSN 1760	3.72	4.22	7.29	1.81	3.25	2.19	4.98	4.95	2.89	1.08	4.06	3.13
DSN 2001	3.35	5.13	9.72	0.94	2.89	2.82	6.90	3.23	3.55	2.28	3.90	1.54
DSN 2002	4.62	4.00	9.78	3.09	3.07	1.86	6.32	3.93	3.09	1.56	2.07	1.49
DSN 2003	4.32	2.57	7.66	3.01	3.40	0.90	9.28	3.83	2.23	0.82	2.52	2.13
DSN 2004	5.33	3.52	6.06	2.72	3.27	1.68	6.46	4.04	2.56	0.93	3.26	2.28
DSN 2005	4.42	4.17	8.24	2.12	2.83	2.45	5.22	4.47	2.98	1.29	2.71	2.05
DSN 2006	4.50	4.25	9.36	2.51	2.12	2.19	5.97	5.11	3.14	1.44	2.11	1.71
DSN 2007	4.28	3.88	7.76	1.84	2.57	3.71	5.12	4.92	3.05	1.14	1.91	2.42
DSN 2008	4.29	5.52	9.69	2.65	1.91	2.87	7.57	4.86	4.02	1.67	2.75	1.16
DSN 2009	3.31	4.40	8.29	2.44	2.96	1.69	7.67	3.35	3.43	2.36	3.54	0.89
DSN 2010	3.89	3.64	10.01	0.70	3.24	1.36	12.46	3.62	2.59	2.52	4.95	1.22
DSN 2011	4.56	3.65	8.69	2.57	2.94	2.61	8.47	7.61	3.10	1.35	2.39	2.31
DSN 2012	3.92	5.06	9.37	3.45	2.33	2.33	7.62	5.46	4.38	1.79	2.41	1.53
DSN 2013	3.32	5.40	9.10	2.51	3.09	3.79	5.52	3.71	3.86	2.16	3.45	0.80

Summary of 1995 Precipitation Data Processed by Stage 2

	Jan-95	Feb-95	Mar-95	Apr-95	May-95	Jun-95	Jul-95	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95
DSN 1010	2.83	0.95	0.91	1.76	1.56	1.87	1.79	3.02	2.08	6.41	3.09	1.29
DSN 1020	2.43	2.50	1.13	2.38	1.91	1.88	2.32	2.55	3.15	6.51	3.72	2.14
DSN 1030	2.97	1.38	1.03	2.47	1.93	2.00	3.38	1.72	2.81	6.78	4.35	1.42
DSN 1040	3.87	1.46	1.24	2.40	2.31	3.88	3.83	0.72	2.04	7.87	5.15	1.38
DSN 1050	2.78	1.96	1.44	2.67	4.30	5.12	3.16	1.73	1.34	6.30	4.26	1.77
DSN 1060	3.47	1.47	1.17	2.67	3.48	3.23	2.31	1.25	1.39	7.27	4.51	1.74
DSN 1070	4.23	1.37	1.11	2.36	2.46	3.59	2.50	0.75	1.57	7.42	4.57	1.33
DSN 1080	4.52	1.74	1.16	2.31	2.91	5.50	2.47	0.83	1.79	8.23	4.51	1.92
DSN 1090	3.16	1.68	1.34	2.37	3.36	5.02	2.12	1.28	1.72	6.58	3.98	2.49
DSN 1100	3.50	1.59	1.21	2.45	3.59	5.84	2.10	1.16	1.70	7.18	4.14	2.10
DSN 1110	4.18	1.81	1.38	2.10	4.39	3.51	5.92	1.29	2.48	6.67	4.49	2.56
DSN 1120	4.13	2.04	2.41	1.33	3.40	2.42	3.98	1.13	3.70	7.14	4.55	1.78
DSN 1160	3.71	1.89	0.89	2.35	4.33	6.29	2.71	3.71	1.77	4.46	3.34	2.37
DSN 1170	4.70	0.66	1.33	2.11	4.06	6.78	4.10	3.23	1.67	3.65	2.48	1.81
DSN 1175	3.45	0.83	1.33	1.81	3.55	5.84	2.95	3.42	1.68	5.50	3.85	1.92
DSN 1180	3.37	0.92	1.45	2.29	3.48	8.23	3.32	4.10	3.15	6.54	3.79	2.17
DSN 1190	6.56	1.19	1.51	1.65	4.81	10.44	2.48	2.00	3.40	7.15	3.39	2.33
DSN 1200	4.06	0.90	1.31	1.76	4.13	6.68	2.25	3.90	2.38	6.24	3.66	2.07
DSN 1210	4.48	1.68	0.81	1.00	3.70	7.72	2.84	1.54	2.95	5.09	3.72	1.79
DSN 1220	3.97	1.51	1.58	2.15	4.76	5.19	3.78	2.78	2.93	6.41	4.54	2.06
DSN 1230	5.28	1.47	2.28	1.83	5.31	10.60	3.38	2.42	3.17	7.50	4.34	2.26
DSN 1265	6.20	1.80	1.82	1.88	4.30	7.71	2.54	1.23	2.37	4.15	3.05	2.22
DSN 1270	7.24	1.78	1.57	1.45	4.47	11.11	3.03	0.94	2.37	4.70	4.02	2.15
DSN 1280	5.60	2.31	1.70	1.65	5.83	9.56	4.17	1.38	3.27	8.29	4.16	2.28
DSN 1700	2.14	0.66	0.63	2.33	1.49	1.93	2.53	3.22	3.22	6.12	3.02	1.34
DSN 1710	4.08	1.87	1.42	1.94	3.76	3.76	6.73	0.77	2.80	6.80	4.70	2.39
DSN 1720	3.61	1.98	1.94	1.95	3.29	3.21	5.68	0.50	2.99	8.27	5.18	2.22
DSN 1730	4.17	1.34	1.29	1.95	3.05	6.26	2.97	0.79	1.75	8.89	4.87	2.11
DSN 1740	3.64	0.62	1.59	1.92	4.87	6.46	3.73	3.70	2.08	7.06	3.96	2.23
DSN 1750	4.54	1.10	0.98	1.33	3.47	7.10	3.03	1.26	2.68	6.50	3.81	1.84
DSN 1760	3.89	1.93	1.44	1.68	5.88	2.94	6.05	3.06	2.79	6.05	4.88	1.81
DSN 2001	2.82	1.82	1.98	3.86	4.06	2.56	4.10	1.59	5.15	4.74	2.88	2.22
DSN 2002	3.08	2.16	2.26	2.48	4.22	2.73	6.45	2.37	3.65	6.61	3.92	2.86
DSN 2003	3.80	2.12	1.36	2.09	3.89	1.53	3.02	1.96	3.81	6.46	4.62	2.26
DSN 2004	4.46	2.29	2.26	1.83	3.63	3.09	2.65	1.45	4.34	6.38	4.63	2.13
DSN 2005	3.41	1.89	1.67	1.63	4.08	1.88	4.34	2.71	3.20	6.27	4.38	1.52
DSN 2006	3.61	1.89	2.55	2.22	4.39	2.95	3.57	1.02	3.26	7.37	3.79	2.55
DSN 2007	3.67	1.71	1.89	2.07	4.91	3.34	3.90	1.71	3.16	7.18	4.83	2.10
DSN 2008	3.94	1.70	2.81	2.66	4.23	4.02	5.77	1.08	2.99	6.89	3.64	2.47
DSN 2009	3.25	1.68	3.11	2.34	4.61	3.17	4.00	1.65	3.76	5.47	2.75	1.89
DSN 2010	2.58	2.67	3.28	2.94	2.68	4.80	2.27	1.43	4.63	4.95	3.02	1.83
DSN 2011	3.87	2.07	1.90	2.20	6.15	2.48	3.32	2.02	3.38	7.44	4.32	2.25
DSN 2012	4.60	1.48	2.46	2.39	5.31	6.48	5.26	1.25	3.14	8.39	3.67	2.50
DSN 2013	4.41	1.77	2.67	2.29	5.97	4.94	6.43	0.92	3.49	7.24	3.27	2.02

The following is a copy of the PREHR.F program which was used to reformat the hourly data from the NOAA format into a more compatible HYDHR format:

```
         character*12 filtat(3), filin, filnam, filin2, filog
         character*3 rectyp1
         character*8 stnid
         character*4 elmtyp1, stnid
         character*2 eunit1, state, stnid1
         character*1 flag11(100), flag21(100), typ, sta1
         character*5 stdumy1
         dimension iday1(100),ihour1(100),ivalue1(100), value(31)
         dimension isumyr(3), isumv2(3), iy(3), iso(100,4)
         dimension isumv3(3), isumv4(3), my(3), PP(1100,4)
         isumv2=0
         isumv3=0
         isumv4=0
         PP = 0
        Write(*,*)'Data extraction from NOAA Hourly data'
        Write(*,*)'reformat for HSPF runs'
        filin2 = 'prehr.lis'
        open (8, file=filin2, access='sequential',status='old')
        read(8,*) nfil
        read(8,66) filin
66        format(a12)
        open (10, file=filin, access='sequential',status='old')
        filnam = 'xxxxxxx.out'
        filog = 'xxxxxxx.log'
        rewind(10)
        close(10)
        typ = filin(1:1)
         i1 = 1
         i2 = 2
         i3 = 3
         LR = 0
         line = 0
         do 200 m= 1,2000
         line = line - 1
         open (10, file=filin, access='sequential',status='old')
200       read(10, 39, end=49, err=49) rectype1
39        format(a3)
49        write(*,*) line
         filnam(1:7) = filin(1:7)
filog(1:7) = filin(1:7)
        open(24,FILE=filnam,STATUS='unknown')
        open (10, file=filin, access='sequential',status='old')
          do 100 m= 1,line
```

```
      read(10, 33, end=40,err=40) ir, iyr, imn, idy, idum, Vdum,
     1(value(j), j = 1, 12)
33    format (i2, i2, i2, i2, i8, F8.0, 12f8.0)
40    write(24,205) filin(1:7), iyr, imn, idy, i1,
     1(value(j), j=1,12)
      write(24,205) filin(1:7), iyr, imn, idy, i2,
     1(value(j), j=1,12)
205         format(a7, 3x, i2, 1x, i2, 1x,i2,1x,i1, 12f5.2)
           if(sta1 .eq. '18') state='MD'
           if(sta1 .eq. '36') state='PA'
           if(sta1 .eq. '44') state='VA'
           if(sta1 .eq. '46') state='WV'
           if(sta1 .eq. '07') state='DE'
           if(sta1 .eq. '18') state='MD'
           if(sta1 .eq. '30') state='NY'
100         continue
          close(10)
          close(24)
666         continue
           end
```

Section D.4 Simulation of the Atmospheric Deposition of Nutrients

D.4.1 Introduction

The atmospheric nutrient deposition inputs for the Phase IV Chesapeake Bay Watershed Model consist of wet nitrate (NO_3), dry NO_3, organic nitrogen (OrN), organic phosphorus (OrP), and dissolved inorganic phosphorus (DIP). The total amount of dry ammonia (NH_4) deposited is assumed to be negligible.

D.4.2 Wetfall Atmospheric Deposition of NO_3 and NH_4 for the Phase IV Chesapeake Bay Watershed Model Precipitation Segments

The wetfall atmospheric deposition of NO_3 and NH_4 for the Phase IV Chesapeake Bay Watershed Model precipitation segments was calculated according to a regression model which was developed by the Chesapeake Bay Program's Air Subcommittee[7]. The regression model is based principally on the logarithmic relationship between the amount of precipitation and the NH_3 and NO_3 concentrations in the precipitation. The regression relationship was developed using weekly data collected over an eight year period at fifteen National Air Deposition Program (NADP) sites. Due to the weekly pooled sampling protocol of NADP and concerns over transformation of the nutrient species over time, the data were quality controlled by selecting those data where the precipitation event occurred only on the last day of the weekly sample. Using this criteria, 265 samples were selected from the approximately 5,000 samples collected at the NADP sites. These selected data were then treated as daily samples and employed in developing the regression model.

The regression equation expresses the wetfall deposition of NO_3 and NH_4 as a function of daily precipitation, latitude, and month of the year:

$$N[NO_3] = 0.226 * \exp(-0.3852 * \ln(ppn) - 0.0037 * month^2 + 0.0744 * latitude - 1.289)$$

$$N[NH_4] = 0.7765 * \exp(-0.3549 * \ln(ppn) + 0.3966 * month - 0.0337 * month^2 - 1.226)$$

where: [] is the concentration (in milligrams/liter) as N,
ppn is the precipitation (in millimeters),
the month is expressed as an integer, and
the latitude is the centroid Y component (in decimal degrees) of precipitation segments.

Load of N (in kg/ha) = N[NO_3 or NH_4] * precipitation = (mg/L * ppn) / 100.

The regression model was applied to the precipitation data to produce daily deposition rates with the same spatial resolution as the Theissen distributed daily precipitation inputs. The annual average wet nitrate and ammonia atmospheric deposition loads during 1984-1994 for the Phase IV Chesapeake Bay Watershed Model precipitation segments are listed in Table D.4.1. Information regarding the model segments and their corresponding precipitation segments can be found in Table D.3.1.

[7]Valigura, R.A., Luke, W.T., Artz, R.S., Hicks, B.B. (1996). *Atmospheric Nutrient Input to Coastal Areas -- Reducing the Uncertainties*. NOAA Coastal Ocean Program Decision Analysis Series No. 9. Silver Spring, MD.

Table D.4.1
Average Annual Atmospheric Wet NO_3 and Wet NH_4 Depositions for the Phase IV Chesapeake Bay Watershed Model Precipitation Segments, 1984-1994

Bay Watershed Model Precipitation Segments	Average Annual Wet NO_3 Deposition Pound/acre	Average Annual Wet NH_4 Deposition Pound/acre
010	4.27	2.08
020	4.95	2.33
030	4.37	2.23
040	4.22	2.26
050	4.36	2.31
060	4.50	2.33
070	4.00	2.11
080	4.21	2.34
090	3.74	2.09
100	4.09	2.23
110	3.87	2.18
120	3.60	2.06
160	3.83	2.24
170	3.26	2.02
175	3.36	2.01
180	3.40	2.00
190	3.33	2.15
200	3.26	2.01
210	3.63	2.12
220	3.35	2.04
230	3.54	2.26
265	3.30	2.14
270	3.36	2.26
280	3.46	2.34
700	3.64	1.84
710	3.69	2.08
720	3.80	2.16
730	3.73	2.16
740	3.49	2.06
750	3.53	2.03
760	3.45	2.03
1001	3.10	2.00
1002	3.40	2.10
1003	3.39	2.05
1004	3.71	2.14
1005	3.44	2.03
1006	3.20	2.00
1007	3.25	2.02
1008	3.20	2.10
1009	3.10	2.11
1010	2.92	2.11
1011	3.46	2.09
1012	3.27	2.17
1013	3.16	2.18

D.4.3 Annual Wet Deposition of NO_3 and NH_4

The observed measurements of wetfall NO_3 and NH_4 as reported by the NADP for twelve sites in and around the Chesapeake Bay watershed are listed in Table D.4.2[8]. The average annual wet NO_3 and NH_4 depositions derived from the regression equations (Table D.4.1.) are in the same ranges of magnitude as the observed data (Table D.4.2). Of those values obtained through the regression equations, watershed model precipitation segments 10-100 have the highest annual average wet NO_3 and NH_4 deposition loading rates. These precipitation segments are located in the states of New York and Pennsylvania portions of the Susquehanna River basin. The NADP data (Table D.4.2) show that most of the atmospheric air deposition stations in New York and Pennsylvania generally have higher observed wet NO_3 and NH_4 deposition loading rates. The close agreement of the NADP values to those obtained from the regression equations verifies the application of the Chesapeake Bay Program Air Subcommittee regression simulation for the wet NO_3 and NH_4 atmospheric deposition inputs for the Phase IV Chesapeake Bay Watershed Model.

A workshop sponsored by the Chesapeake Bay Program's Scientific and Technical Advisory Committee evaluated more recent NADP data through 1994 showed that 1983-1994 average annual inorganic nitrogen deposition at the NADP sites within or near the Chesapeake Basin range from 3.5kg N/ha-yr in southwestern Virginia to 7.7 kg N/ha-yr in northwestern Pennsylvania[9]. The wet NO_3 + NH_4 atmospheric deposition loading rates ranged from 6 to 7 lb/ac-yr and the ratio of NO_3-N to NH_4-N in wet deposition ranged from 1.3 to 2.5. These are consistent with Phase IV Chesapeake Bay Watershed Model adopted wet NO3 and NH4 deposition values presented in Table D.4.1.

D.4.4 Dry Atmospheric Deposition for NO_3 and NH_4

The wet/dry ratios of NO_3 atmospheric deposition was determined through the wet/dry NO_3 ratio estimated by the RADM model cells distributed tot he Phase IV Chesapeake Bay Watershed Model segments and are listed in Table D.4.3. The annual average dry NO_3 deposition, calculated by dividing the annual average (1984-94) wet NO_3 deposition by the corresponding wet/dry ratio, is also presented in Table D.4.3. The wet-NO_3 deposition was associated with precipitation, and, therefore, was differentiated among precipitation segments (as presented in Table D.2.1). Each of the precipitation segments either corresponds to one model segment, or is aggregated from several model segments (see Section D.3).

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8 Valigura, R.A., Luke, W.T., Artz, R.S., Hicks, B.B. (1996). *Atmospheric Nutrient Input to Coastal Areas -- Reducing the Uncertainties*. NOAA Coastal Ocean Program Decision Analysis Series No. 9. Silver Spring, MD.

9 Gardner, R.H., Castro, M.S., Morgan R.P., Seagle, S.W. (1996). *Perspectives on Chesapeake Bay: Nitrogen Dynamics in Forested Lands of the Chesapeake Basin*. Chesapeake Bay Program Office. Annapolis, MD.

Table D.4.2.a
Annual Wet Deposition of NO_3 at NADP Sites (Pounds Nitrogen / Acre)

NADP Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
White Rock, MD	2.65	3.27	3.27	3.50	3.96	3.43	2.77	3.11	4.03	3.70	2.58
Wye, MD	2.63	2.77	2.23	2.33	3.85	3.14	3.01	2.49	3.14	3.38	2.66
Lewiston, NC	1.76	2.05	2.19	2.34	2.54	2.06	2.05	2.20	2.05	1.67	2.13
Finely Farms, NC	1.82	--	2.26	2.65	3.35	2.03	1.98	1.64	1.93	1.74	2.26
Chautauqau, NY	5.17	5.30	3.47	3.85	3.63	4.25	3.19	3.55	3.50	3.09	3.09
Jasper, NY	2.15	2.77	2.68	2.54	2.70	2.69	2.06	2.74	2.60	3.04	1.84
Penn State, PA	3.52	3.74	4.03	2.90	3.72	4.03	3.49	3.70	4.03	3.84	2.85
Leading Ridge, PA	3.83	4.89	4.89	3.60	4.81	4.73	3.56	3.60	4.20	3.75	2.84
Milford, PA	3.93	--	4.05	3.69	4.06	4.52	3.22	3.78	3.96	4.56	2.93
Charlottesville, VA	3.35	2.97	3.15	2.65	--	3.22	2.93	3.28	3.52	3.21	3.18
Babcock State Park, WV	3.03	3.51	2.76	1.86	3.54	2.80	2.52	2.82	3.56	2.71	2.87
Parsons, WV	4.90	5.58	3.63	3.46	4.70	3.80	3.54	3.74	3.99	4.43	3.61

Table D.4.2.b
Annual Wet Deposition of NH_4 at NADP Sites (Pounds Nitrogen / Acre)

NADP Site	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
White Rock, MD	1.21	1.67	1.77	1.53	2.40	2.00	1.57	1.75	2.34	2.25	1.67
Wye, MD	1.42	1.50	1.21	1.05	2.36	1.91	1.83	1.53	1.95	2.11	1.90
Lewiston, NC	1.13	1.22	1.45	0.72	1.53	1.67	1.28	1.58	1.85	1.32	1.58
Finely Farms, NC	1.27	--	1.78	1.33	3.89	2.29	2.28	1.80	2.13	1.80	2.41
Chautauqau, NY	3.04	3.73	1.92	2.16	2.17	2.58	1.78	1.99	2.05	1.64	2.05
Jasper, NY	1.21	1.27	1.50	1.16	1.79	1.54	1.03	1.57	1.14	1.81	1.15
Penn State, PA	1.61	1.50	1.78	1.26	2.27	2.08	1.70	1.80	1.64	1.89	1.57
Leading Ridge, PA	1.83	2.27	2.29	1.58	2.71	2.56	1.77	1.78	1.84	1.83	1.39
Milford, PA	1.95	--	1.39	1.04	1.58	2.06	1.42	1.69	1.69	2.17	1.51
Charlottesville, VA	1.60	1.57	1.45	0.97	–	2.20	1.66	1.72	2.34	2.01	2.17
Babcock State Park, WV	1.41	1.78	1.59	0.77	1.89	1.77	1.05	1.42	1.91	1.55	1.85
Parsons, WV	2.36	2.69	1.92	1.25	2.58	1.98	1.52	1.65	1.71	2.48	2.21

Constant annual dry NO_3 deposition applied on a daily basis are used as the inputs of dry NO_3 deposition for the Phase IV Chesapeake Bay Watershed Model.

Table D.4.3

Average Annual Wet & Dry NO_3 Atmospheric Deposition Loading Rates (Pounds-Nitrogen / Acre-Year)

Phase IV Watershed Model Segment	1984-1994 Annual Average Wet NO_3 Atmospheric Deposition	Wet/Dry Ratio of NO_3 Atmospheric Deposition	Estimated Annual Average Dry NO_3 Atmospheric Deposition
10	4.27	0.99	4.32
20	4.95	1.07	4.63
30	4.37	1.08	4.04
40	4.22	1.07	3.95
50	4.36	1.14	3.82
60	4.50	1.08	4.17
70	4.00	1.05	3.81
80	4.21	1.07	3.93
90	3.74	1.17	3.20
100	4.09	1.13	3.62
110	3.87	1.05	3.69
120	3.60	1.01	3.56
140	3.71	1.01	3.67
160	3.83	1.18	3.25
170	3.26	1.14	2.86
175	3.36	1.13	2.98
180	3.40	1.05	3.24
190	3.33	1.02	3.27
200	3.26	1.08	3.02
210	3.63	1.02	3.56
220	3.35	1.01	3.31
230	3.54	1.01	3.50
235	3.27	0.96	3.40
240	3.27	0.93	3.51
250	3.27	0.95	3.44
260	3.27	0.93	3.51
265	3.30	0.99	3.34
270	3.36	0.88	3.82
280	3.46	0.91	3.81
290	3.16	0.90	3.51
300	3.16	0.87	3.63
310	3.16	0.87	3.63

Table D.4.3 Continued

Phase IV Watershed Model Segment	1984-1994 Annual Average Wet NO_3 Atmospheric Deposition	Wet/Dry Ratio of NO3 Atmospheric Deposition	Estimated Annual Average Dry NO_3 Atmospheric Deposition
330	3.46	0.99	3.49
340	3.46	0.99	3.49
370	3.39	0.99	3.42
380	3.39	0.99	3.42
390	3.40	0.99	3.44
400	3.40	0.99	3.44
410	3.40	0.97	3.51
420	3.10	0.95	3.26
430	3.10	0.94	3.30
440	3.10	0.90	3.45
450	3.71	1.00	3.71
470	3.44	1.01	3.40
480	3.44	0.99	3.47
490	3.44	0.99	3.47
500	3.20	0.97	3.30
510	3.44	0.99	3.47
540	3.25	0.98	3.32
550	3.25	0.99	3.28
560	3.20	0.92	3.48
580	3.20	0.90	3.56
590	3.10	0.90	3.45
600	3.10	0.88	3.53
610	3.10	0.90	3.45
620	2.92	0.86	3.40
630	2.92	0.84	3.48
650	3.44	1.00	3.44
700	3.64	1.01	3.60
710	3.69	1.03	3.58
720	3.80	1.03	3.69
730	3.73	1.10	3.40
740	3.49	1.10	3.18
750	3.53	1.05	3.37
760	3.45	1.00	3.45
770	3.40	0.99	3.44
780	3.40	0.99	3.44
800	3.39	0.99	3.42
810	3.39	0.99	3.42

Table D.4.3 continued

Phase IV Watershed Model Segment	1984-1994 Annual Average Wet NO_3 Atmospheric Deposition	Wet/Dry Ratio of NO_3 Atmospheric Deposition	Estimated Annual Average Dry NO_3 Atmospheric Deposition
820	3.40	0.99	3.44
830	3.40	0.98	3.47
840	3.40	0.96	3.54
850	3.71	1.00	3.71
860	3.44	0.99	3.47
870	3.44	0.99	3.47
880	3.20	0.98	3.26
890	3.25	0.98	3.32
900	3.25	0.98	3.32
910	3.20	0.97	3.30
920	3.20	0.95	3.37
930	3.20	0.90	3.56
940	3.10	0.89	3.49
950	2.92	0.86	3.40
960	2.92	0.86	3.40
970	3.25	0.97	3.35
980	3.20	0.94	3.41
990	3.20	0.94	3.40

D.4.5 Atmospheric Deposition for Organic Nitrogen

Organic nitrogen is only represented as wet atmospheric deposition of dissolved organic nitrogen (DON). This is because the magnitude of the dry fall organic nitrogen is currently unknown and, therefore, not accounted for separately. Organic nitrogen remains the least well characterized of all the nitrogen species in atmospheric deposition.

It is useful to utilize previous studies' data to understand the magnitude of the values being incorporated into the Phase IV Chesapeake Bay Watershed Model. Dissolved organic nitrogen has considerable seasonal variability with the seasonal high occurring from April to June and the seasonal low from July to March[10]. Organic nitrogen measurements from Bermuda collected by Knap and co-workers (1986) were calculated at about 100 µg/l (as N)[11]. Moper and Zika (1987) reported an average DON concentration from the western Atlantic and Gulf of Mexico of about 100 µg/l (as N)[12]. This is consistent with the reported range of concentrations from the North Sea and Northeast Atlantic of between 90 µg/l to 120 µg/l [13]. A

[10] Smullen, J.T., Taft, J.L., Macknis, J. (1982). *Nutrient and Sediment Loads to the Tidal Chesapeake Bay System*. U.S. EPA Chesapeake Bay Program Technical Studies. Chesapeake Bay Program Office, Annapolis, MD.

[11] Knap, A., Jickells, T., et al. (1986). Significance of atmospheric-derived fixed nitrogen on productivity of the Sargasso Sea. *Nature* 320 (3/13): 158-160.

[12] Moper, K., Zika, R.G. (1987). Free amino acids in marine rain: Evidence for oxidation and potential role in nitrogen cycling. *Nature* 325: 246-249.

[13] Scudlark, J.R., Church, T.M. (1993). Atmospheric input of inorganic nitrogen to Delaware Bay. *Estuaries*

recent study reported an annual volume weighted avereage DON concentration in the mid-Atlantic coastal areas to be about 130 µg/l (as N)[14]. The measurements in this study are consistent with the interannual variation (maximum in spring) reported in previous studies[15].

According to the studies focused on the mid-Atlantic coastal areas, 130 ug/l (as N) is regarded as representative of an average annual DON wet deposition concentration[14]. Based on these studies, an average concentration of 98 ug/l for July to March rainfall and an average concentration of 224 ug/l for April to June rainfall were applied to the Chesapeake Bay watershed and tidal surface waters as part of the Phase IV model. Table D.4.4 summarizes the 1984-1991 average annual DON loading rates by the Phase IV watershed model precipitation segments.

D.4.6 Atmospheric Deposition for Organic P and Inorganic Phosphate

Daily atmospheric deposition loads of organic phosphorous (OrP) and inorganic phosphate (DIP) are employed in the Phase IV Chesapeake Bay Watershed Model. The annual loading rates are 0.423 lb/ac for P[Organic P] and 0.143 lb/ac for P[Phosphate][16]. The yearly loads were evenly allocated as daily loads for model input throughout all of the Phase IV watershed model segments.

D.4.7 Atmospheric Deposition to Chesapeake Bay Water Quality Model Cells

Inputs of atmospheric deposition of nutrients to the mainstem Bay and tidal tribuaries' surface waters--Chesapeake Bay Water Quality Model--utilizes the atmospheric deposition data for the coastal Phase IV Chesapeake Bay Watershed Model. As mentioned in Sections D.4.2-D.4.5, the atmospheric NO_3, NH_4, and DON depositions were calculated and associated with precipitation, therefore, in order to utilize the atmospheric nutrient deposition of the Watershed Model for the Chesapeake Bay Water Quality Model, a development or allocation of the watershed precipitation to the 3D water quality model cells is necessary.

Arc/Info software was applied to data supplied by the Waterways Experimental Station of the U.S. Army Corps of Engineers on a grid with 2100 surface cells in order to divide the 3D-cells into eight precipitation regions. The 3D-cells were divided based upon the NADP station's proximity to the Chesapeake Bay and the boundaries of the precipitation regions. Figure D.4.2 illustrates the eight precipitation regions for the 3D model cells. Each of the Bay Water Quality Model precipitation regions is associated with one coastal Chesapeake Bay Watershed Model precipitation segment (Table D.4.5, Figure D.4.3).

16(4): 747-754.

[14] Scudlark, J.R., Russel, K.M., et al. (1996) *Dissolved Organic Nitrogen in Precipitation: Collection, Analysis, and Atmospheric Flux.* Report to: Maryland Department of Natural Resources, Annapolis, MD.

[15] Smullen, J.T., Taft, J.L., Macknis, J. (1982). *Nutrient and Sediment Loads to the Tidal Chesapeake Bay System*. U.S. EPA Chesapeake Bay Program Technical Studies. Chesapeake Bay Program Office, Annapolis, MD.

[16] _____.(1982). *Technical Studies: A Synthesis*. U.S. Environmental Protection Agency. Chesapeake Bay Program Office. Annapolis, MD.

Table D.4.4
Phase IV Chesapeake Bay Watershed Model Precipitation Segments 1984-1991 Average Annual Atmospheric Dissolved Organic Nitrogen Atmospheric Deposition Loading Rates (Pounds Nitrogen/Acre-Year)

Phase IV Watershed Model Precipitation Segment	Average Annual DON Deposition Loading Rate	Phase IV Watershed Model Precipitation Segment	Average Annual DON Deposition Loading Rate
10	1.02	700	1.00
20	1.18	710	1.15
30	1.19	720	1.24
40	1.24	730	1.24
50	1.26	740	1.10
60	1.19	750	1.22
70	1.14	760	1.17
80	1.19	1001	1.13
90	1.13	1002	1.17
100	1.13	1003	1.24
110	1.19	1004	1.16
120	1.17	1005	1.15
160	1.19	1006	1.16
170	1.00	1007	1.17
175	1.06	1008	1.21
180	1.10	1009	1.22
190	1.18	1010	1.25
200	1.07	1011	1.24
210	1.21	1012	1.27
220	1.19	1013	1.26
230	1.30		
265	1.18		
270	1.23		
280	1.34		

Table D.4.5 shows the atmospheric nitrogen deposition to the Chesapeake Bay Watershed based upon 1991 landuse data and 1984-1994 annual average loads.

1984-1994 Annual Average Atmospheric Nitrogen Deposition Loads to the Chesepeake Bay Watershed

(based on 1991 landuse as analyzed on March 16, 1997 at the Chesapeake Bay Program Office)

Model Segment	Wet-NO3 thousand lbs/yr	Wet-NH4 thousand lbs/yr	Dry-NO3 thousand lbs/yr	DON thousand lbs/yr	TN thousand lbs/yr
10	7223	3512	7296	1738	19770
20	15733	7407	14704	3764	41609
30	6114	3121	5661	1673	16569
40	4015	2148	3753	1188	11104
50	3985	2113	3496	1160	10754
60	12270	6350	11361	3246	33228
70	3400	1794	3239	975	9408
80	6142	3418	5740	1748	17047
90	2245	1256	1919	678	6097
100	6326	3443	5599	1748	17116
110	4385	2463	4176	1358	12382
120	475	271	470	154	1370
140	689	397	682	217	1986
160	3311	1932	2806	1030	9080
170	3093	1917	2714	959	8683
175	2710	1616	2398	855	7580
180	1392	820	1326	454	3992
190	3466	2239	3398	1228	10330
200	2939	1814	2721	971	8445
210	1862	1089	1826	623	5400
220	2042	1244	2022	732	6041
230	3635	2324	3599	1344	10901
235	537	357	559	209	1662
240	705	468	758	274	2205
250	698	464	735	272	2169
260	1539	1022	1655	599	4815
265	738	477	745	264	2224
270	6289	4236	7147	2316	19987
280	6692	4513	7353	2593	21151
290	1040	717	1156	418	3331
300	2415	1664	2776	970	7825
310	320	220	367	128	1036
330	294	177	297	106	875
340	475	287	480	172	1414
370	128	78	129	47	382
380	898	544	907	330	2680
390	196	121	198	68	582
400	1025	633	1035	355	3048
410	1575	974	1624	546	4719
420	423	272	446	155	1296
430	1482	953	1576	541	4552
440	637	410	708	232	1987
450	1758	1014	1758	553	5082

Model Segment	Wet-NO3 thousand lbs/yr	Wet-NH4 thousand lbs/yr	Dry-NO3 thousand lbs/yr	DON thousand lbs/yr	TN thousand lbs/yr
470	1000	590	990	335	2916
480	271	160	273	91	795
490	341	201	345	114	1002
500	1068	666	1101	388	3223
510	104	61	105	35	306
540	336	209	343	121	1009
550	1301	810	1315	470	3896
560	2003	1311	2177	761	6251
580	133	87	147	50	417
590	1826	1239	2029	722	5817
600	2650	1798	3012	1048	8508
610	492	334	547	195	1568
620	414	298	481	178	1371
630	53	38	63	23	178
650	358	211	358	122	1049
700	564	285	559	156	1563
710	572	323	555	180	1630
720	1153	656	1120	377	3305
730	1191	688	1082	395	3356
740	3060	1802	2781	967	8609
750	379	218	361	131	1090
760	272	160	272	93	798
770	243	150	245	84	722
780	154	95	156	54	459
800	173	105	175	63	515
810	366	222	370	134	1092
820	91	56	92	32	272
830	296	183	302	103	884
840	942	582	981	326	2831
850	204	117	204	64	589
860	203	120	205	68	596
870	94	55	95	31	275
880	369	230	377	134	1111
890	189	118	193	68	568
900	461	287	470	166	1385
910	515	321	530	187	1553
920	1258	785	1324	457	3824
930	102	67	113	39	320
940	778	528	874	308	2487
950	184	133	214	79	611
960	450	324	523	193	1489
970	119	74	123	43	360
980	1229	804	1307	467	3807
990	67	42	71	24	205
	======	======	======	======	======
Total	155347	89838	152277	49067	446530

Table D.4.6
Correspondence of Phase IV Chesapeake Bay Watershed Model Precipitation Segments with the Chesapeake Bay Water Quality Model Precipitation Regions

Chesapeake Bay Water Quality Precipitation Regions	Phase IV Watershed Model Precipitation Segments
1	1001
2	1009
3	1010
4	1004
5	1005
6	1006
7	1007
8	1008

Building on the above established linkages between the grouping of Bay Water Quality model cells and Chesapeake Bay Watershed Model precipitation segments, the same loading rates (lb/ac-yr) for NO_3, NH_4, and DON atmospheric deposition developed for each respective Chesapeake Bay Watershed Model precipitation segment is applied to the corresponding Bay Water Quality Model precipitation region (Table D.4.6).

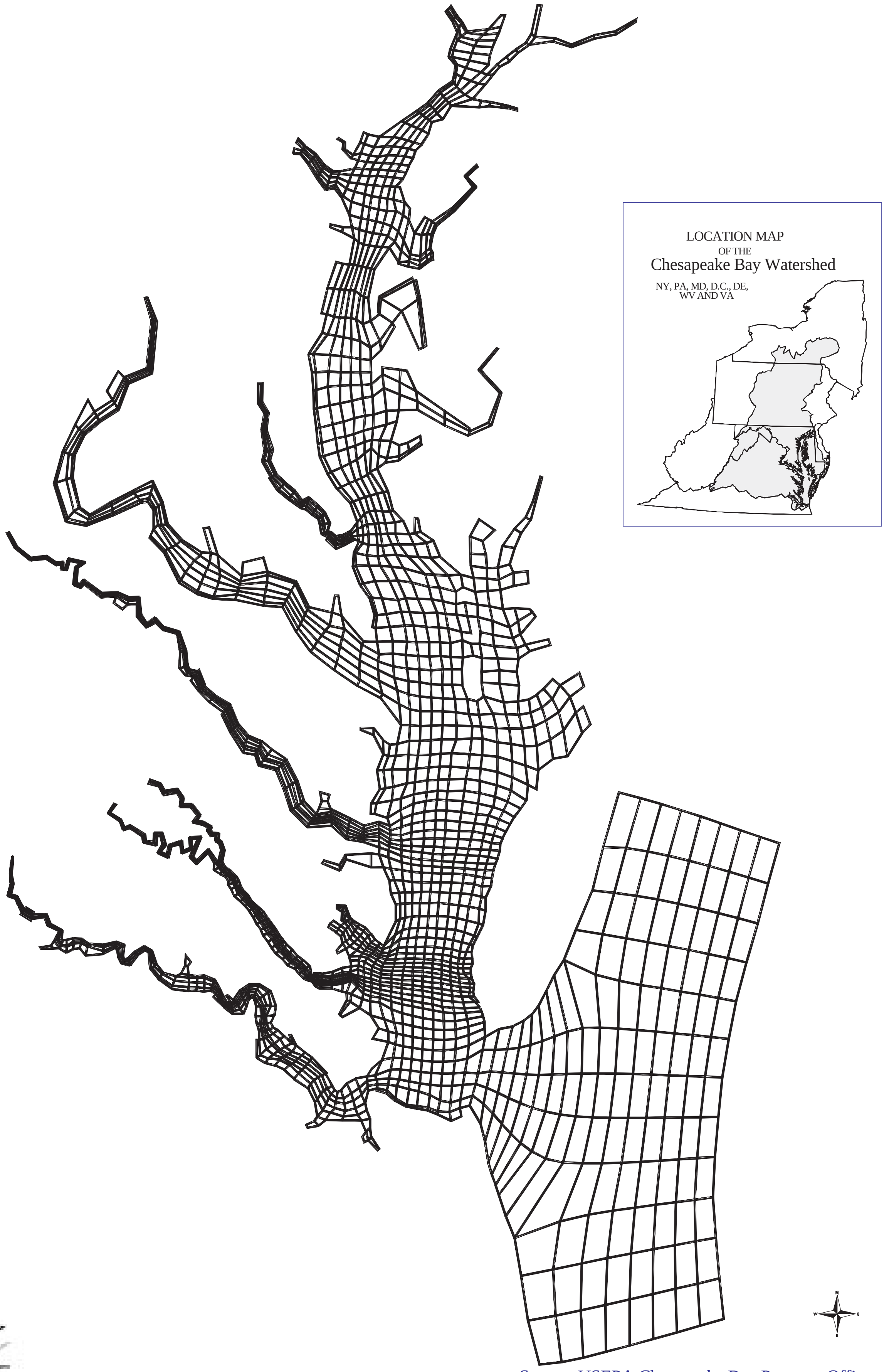
As determined for the Phase IV Chesapeake Bay Watershed Model segments, OrP and PO_4 atmospheric deposition loading rates were assumed to be constant (P [Organic P] at 0.423 lb/ac, and P [PO_4] at 0.143 lb/ac), and the yearly loads were evenly allocated as daily load for input into all Chesapeake Bay Water Quality Model Cells.

As with all Chesapeake Bay Watershed Model segments, the dry NH_4 atmospheric deposition loading rate is assumed to be zero for all the Chesapeake Bay Water Quality Model cells.

The dry NO_3 atmospheric deposition loading rates for each Chesapeake Bay Water Quality Model cell were calculated as thirty percent of their corresponding watershed precipitation segment's 1984-1994 annual average wet NO_3 deposition, because a long-term average of wet/dry fall nitrate to open water that is wider than about 5 meters is 3.33[17]. Table D.4.3 lists the dry-NO_3 versus wet-NO_3 ratios for the eight precipitation regions of the Chesapeake Bay Water Quality Model cells.

[17] Valigura, R.A., Luke, W.T., Artz, R.S., Hicks, B.B. (1996). *Atmospheric Nutrient Input to Coastal Areas -- Reducing the Uncertainties*. NOAA Coastal Ocean Program Decision Analysis Series No. 9., MD.

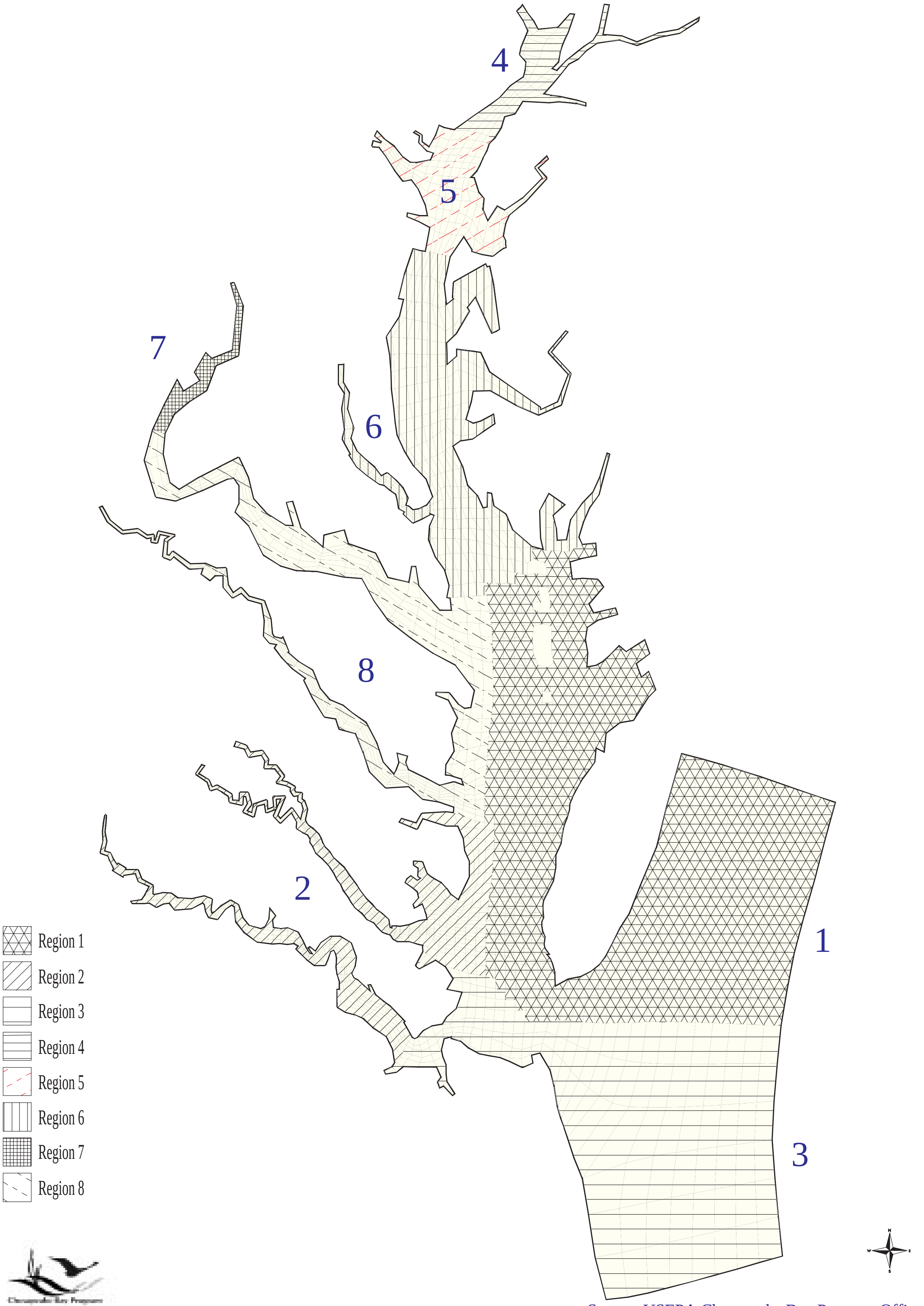
Fig. D.4.1. The 3D Model Cells



PW Map Date: July 24, 1997 spot:home/pwang/setup/gis/arc7/cov/

Source: USEPA Chesapeake Bay Program Office

Chesapeake Bay Water Qaulity Model Precipitation Regions



PW Map Date: July 24, 1997 spot:home/pwang/setup/gis/arc7/cov/

Source: USEPA Chesapeake Bay Program Office

Chesapeack Bay Water Qaulity Model Precipitation Region with the Corresponding Coastal Phase IV Chesapeake Bay Watershed Model Precipitation Regions

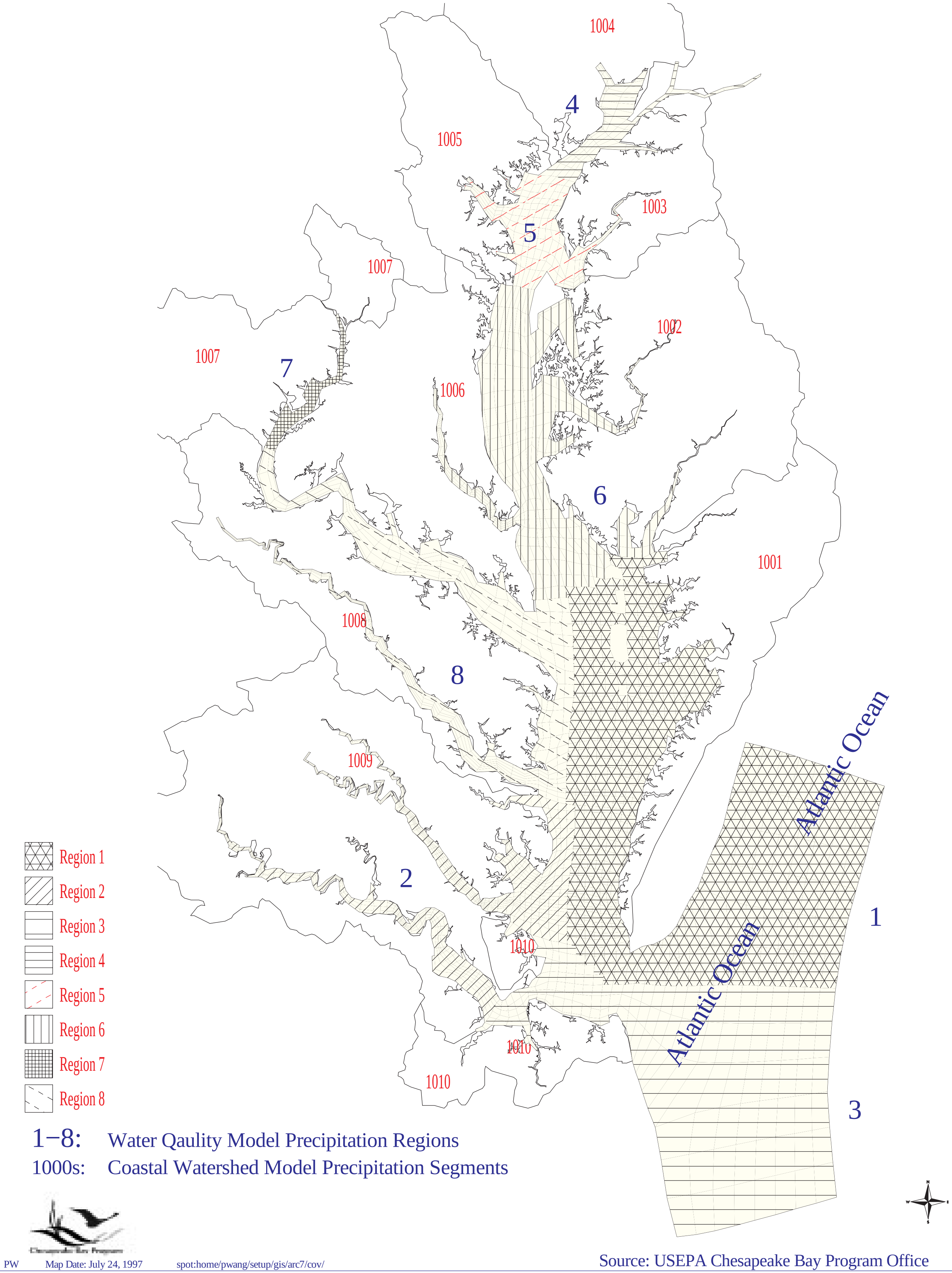


Table D.4.7
Wet and Dry NO_3 Atmospheric Deposition Loading Rates for the Chesapeake Bay Water Quality Model Precipitation Regions

Chesapeake Bay Water Quality Model Precipitation Region	1984-1994 Annual Average Wet NO_3 (Pounds-Nitrogen/ Acre-Year)	Wet/Dry Ratio	1984-1994 Annual Average Dry NO_3 (Pounds-Nitrogen/ Acre-Year)
Region 1	3.10	3.33	0.93
Region 2	3.10	3.33	0.93
Region 3	2.92	3.33	0.88
Region 4	3.71	3.33	1.11
Region 5	3.44	3.33	1.03
Region 6	3.20	3.33	0.96
Region 7	3.25	3.33	0.97
Region 8	3.20	3.33	0.96

This report is cited in the following way:
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