

State of Delaware
DELAWARE GEOLOGICAL SURVEY
Robert R. Jordan, State Geologist

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SUMMARY REPORT
THE COASTAL STORM OF DECEMBER 10-14, 1992
DELAWARE AND MARYLAND

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PREFACE

The DGS (Delaware Geological Survey) regularly compiles and evaluates a variety of hydrologic and geologic data. Special efforts are made to obtain detailed measurements, sometimes under difficult conditions, during and following extreme events such as storms, floods, droughts, and earthquakes. Through rapid collection and dissemination of data, the DGS assists those agencies with emergency response responsibilities in evaluating and predicting conditions during specific events. Following such events, the DGS routinely compiles information and prepares reports and maps to help assess the nature and effects of events and to predict the impact of future ones. Although most such reports and maps are not formally published, they are available and are used by officials and citizens.

The DGS encourages the exchange of data about such events collected by various agencies so that as complete record as possible may be assembled for use by each unit.

This report represents the beginning of a cooperative effort with the Maryland Geological Survey to compile and report data for coastal storms that affect the upper Delmarva Peninsula. Data and observations from Maryland were provided by the Maryland Geological Survey and are included in this report.

CLIMATIC CONDITIONS FOR THE STORM OF DECEMBER 10-14, 1992

Summary of Storm Activity¹

On December 10, a low pressure system moved rapidly north-northwest from eastern North Carolina and Virginia, up the Chesapeake Bay to a position just west of Chestertown in Kent County, Maryland by 0700 on December 11. The system then moved irregularly to the southeast, stalled for several hours over Georgetown, Delaware, and proceeded offshore early on December 12. Approximate locations of the storm's track are shown on Figure 1.

The storm had associated rain that contributed to some local stream flooding and high winds that created strong surf and waves. The waves were compounded by an astronomical high tide (full moon) to produce coastal flooding along Delaware Bay and some breaching of the dunes along the Atlantic coast. The position of the storm offshore blew north-northeast winds onto the coast and abnormally high tides continued through December 15.

The following tables (1-8) and figures (1-7) are compilations of data collected after the storm.

Table 1. Precipitation Data - December 10-14, 1992

<u>Location</u>	December					<u>Total (inches)</u>
	10	11	12	13	14	
Salisbury, MD						
FAA - Airport	2.12	0.69	0.09			2.90
Assateague Island National						
Seashore Weather Station	1.60	0.13	0.03			1.76
Lewes, DE	0.17	1.62	0.06	0.05	T	1.90
Georgetown, DE (U of D)	0.00	1.60	0.25	0.21		2.06
Greenwood, DE	0.61	0.67	0.10	0.07		1.45
Dover Air Force Base	1.10	0.43	0.11	T		1.64
Dover, DE (DelDOT)	0.06	1.48	0.09	0.07	0.03	1.73
New Castle, DE (NWS)	1.15	1.50	0.06			2.71
Porter Res., Wilmington, DE	1.03	1.47	0.61	0.01		3.12

¹ Source of information: National Weather Service (NWS)

Figure 1. Track of Storm - December 11-12, 1992.

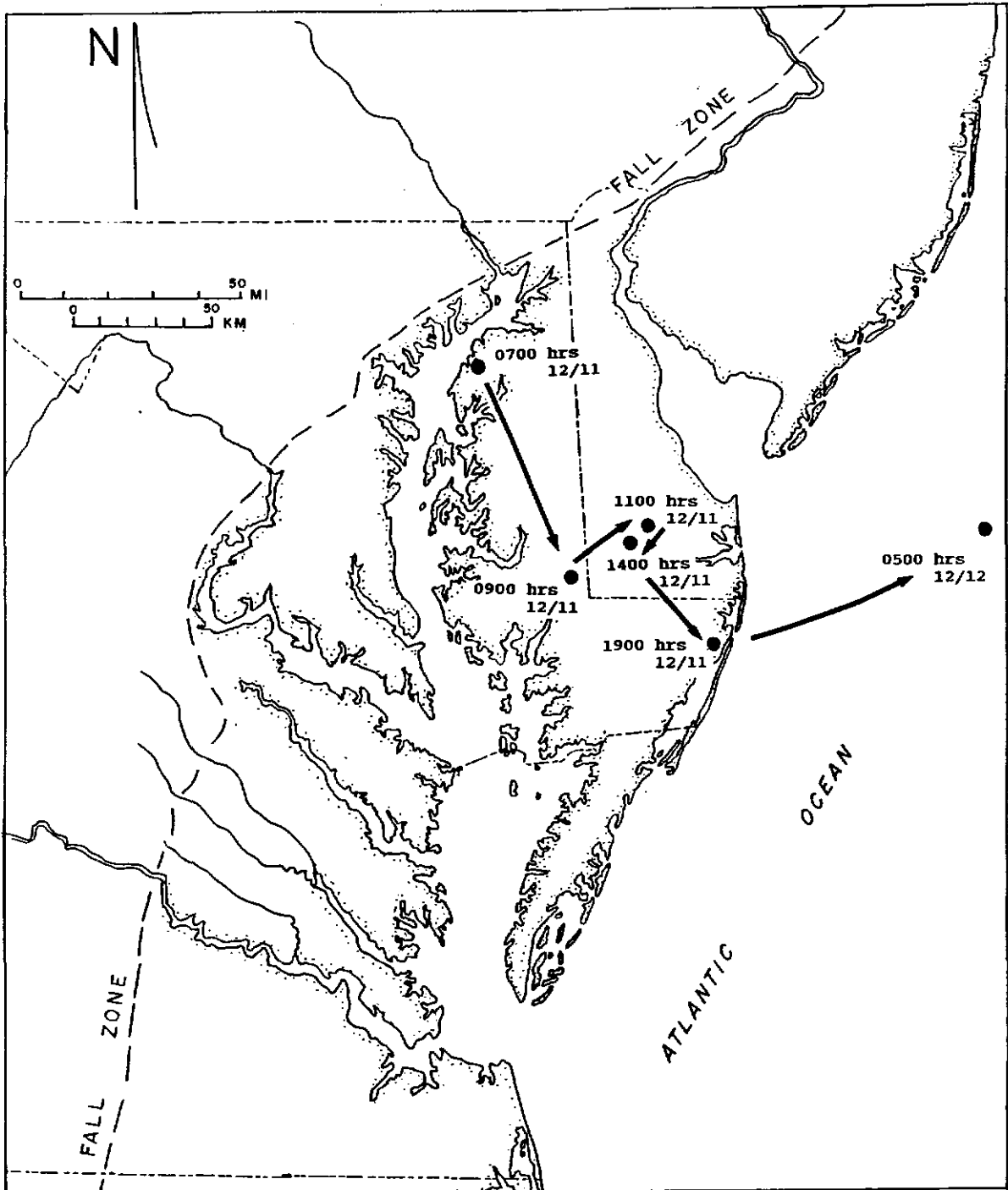


Figure 2. Location of Weather and Tide Gage Stations.

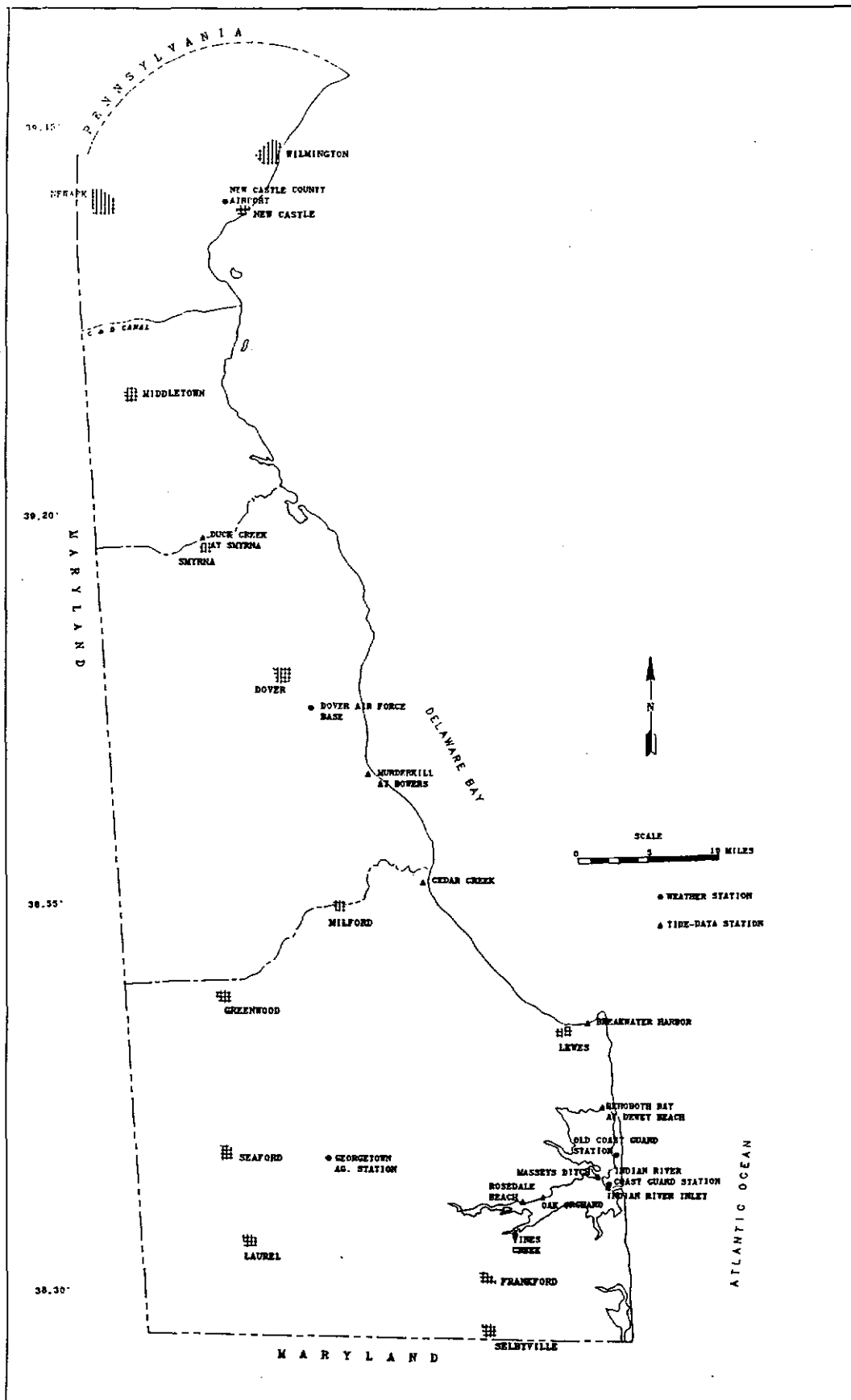


Table 2. Wind and Barometric Pressure Data - December 10-14, 1992

U. S. Coast Guard Station
Indian River, DE

University of Delaware Agricultural Station
Georgetown, DE

Date	Time (EST)	Wind Direction	Wind Velocity (mph)	Maximum Gusts (mph)	Barometric Pressure	Date	Time (EST)	Wind Direction	Wind Velocity (mph)	Maximum Gusts (mph)	Barometric Pressure	
Dec 8	0700	NNW	9	-	30.11	Dec 8	0100	N31°W	7.8	13.2	29.99	
	0900	NNW	9	-	30.16		0400	N31°W	6.2	11.3	30.01	
	1200	NNW	9	-	30.17		0700	N40°W	5.3	9.8	30.05	
	1500	N	10	-	30.19		1000	N16°W	9.8	17.8	30.10	
	1800	NNW	10	-	30.20		1300	N27°W	9.4	19.3	30.06	
	2100	NNW	10	-	30.21		1600	N44°W	9.1	14.9	30.08	
Dec 9	0800	N	13	-	30.33	Dec 9	1900	N47°W	4.1	7.3	30.13	
	1100	N	12	-	30.40		2200	N18°W	2.5	5.1	30.17	
	1400	NE	12	-	30.36		Dec 9	0100	N25°E	6.3	11.4	30.21
	1700	N	7	-	30.38			0400	N 7°W	3.4	6.3	30.24
	2000	NE	7	-	30.38			0700	N15°W	4.1	6.3	30.28
								1000	N	8.7	15.6	30.34
					1300	N21°E		10.9	18.2	30.28		
					1600	N48°E		4.6	8.3	30.28		
Dec 10	0600	SE	24	-	30.22	Dec 10	1900	S85°E	1.5	2.6	30.30	
	0900	SE	32	-	30.14		2200	N24°E	1.2	2.5	30.29	
	1200	ESE	35	-	30.02		Dec 10	0100	N87°E	1.8	3.2	30.26
	1500	SE	35	-	29.88			0400	N61°E	2.8	8.2	30.21
	1800	SE	35	-	29.70			0700	S84°E	4.2	13.8	30.10
	2100	SE	46	-	29.48			1000	S74°E	9.6	17.1	30.04
					1300	S76°E		17.0	27.8	29.86		
					1600	S74°E		20.1	33.3	29.71		
Dec 11	0600	SSW	12	-	29.22	Dec 11	1900	S78°E	21.6	34.5	29.54	
	1000	S	13	-	29.20		2200	N87°E	20.5	37.0	29.35	
	1500	S	12	-	29.20		Dec 11	0100	S79°E	9.3	23.4	27.40
	1800	SE	12	-	29.36			0400	S25°W	9.8	16.9	29.16
	2100	S	12	-	29.36			0500	S49°W	11.2	20.3	29.12
								0700	S13°W	8.4	16.0	29.11
					0900	S11°E		7.8	14.4	29.10		
					1000	S48°E		4.1	9.9	29.10		
Dec 12	0600	N	23	-	29.62	Dec 12	1300	S30°E	7.1	13.2	29.06	
	0900	N	23	-	29.70		1400	S 4°E	9.1	14.9	29.07	
	1200	N	23	-	29.71		1600	S63°E	6.5	10.9	29.12	
	1500	N	23	-	29.74		1900	N41°E	3.5	6.4	29.21	
	1800	N	23	-	29.80		2100	N 5°E	5.6	9.3	29.26	
	2100	N	26	-	29.86		Dec 12	0300	N19°E	11.2	20.2	29.45
					0500	N23°E		14.6	23.4	29.52		
					0600	N14°E		15.4	24.7	29.55		
					0700	N 9°E		14.5	26.4	29.59		
					1000	N 1°E		13.6	25.0	29.68		
					1300	N 2°E		14.6	27.2	29.67		
					1600	N15°W	15.8	26.3	29.69			
					1900	N	14.5	26.1	29.76			
					2200	N 2°E	13.5	22.7	29.83			

Table 2 (continued).

U. S. Coast Guard Station Indian River, DE						University of Delaware Agricultural Station Georgetown, DE					
Date	Time (EST)	Wind Direction	Wind Velocity (mph)	Maximum Gusts (mph)	Barometric Pressure	Date	Time (EST)	Wind Direction	Wind Velocity (mph)	Maximum Gusts (mph)	Barometric Pressure
Dec 13	0000	N	23	-	29.95	Dec 13	0100	N 3°E	13.3	23.7	29.87
	0600	N	17	-	30.07		0400	N 3°E	12.8	21.9	29.91
	0900	N	17	-	30.09		0700	N 9°E	10.6	18.9	29.98
	1200	N	21	-	30.17		1000	N11°E	12.2	20.7	30.06
	1500	N	23	-	30.18		1300	N 4°E	10.5	17.6	30.07
	1800	NNE	29	-	30.25		1600	N25°E	11.5	20.9	30.11
	2100	NNE	29	-	30.28		1900	N21°E	10.6	17.2	30.10
							2200	N29°E	13.4	20.7	30.22
Dec 14	0700	N	23	-	30.31	Dec 14	0100	N21°E	9.3	18.1	30.22
	0800	N	23	-	30.39		0400	N25°E	10.6	16.8	30.24
	1300	N	14	-	30.34		0700	N13°E	9.5	16.2	30.26
	1800	N	16	-	30.32		1000	N16°E	8.6	13.0	30.30
							1300	N18°E	9.6	15.9	30.28
							1600	N 8°E	7.5	13.1	30.26
							1900	N14°E	6.5	9.8	30.28
							2200	N 8°E	4.9	7.6	30.27
Dec 15	0500	N	13	-	30.32	Dec 15	0100	N31°W	4.6	7.8	30.26
	0800	N	9	-	30.32		0400	N36°W	3.6	6.9	30.24
	1100	NW	8	-	30.34		0700	N43°W	2.5	6.8	30.24
							1000	N52°W	5.3	8.5	30.26
Dover Air Force Base Dover, DE						National Weather Service Office New Castle, DE					
Date	Time (EST)	Wind Direction	Wind Velocity (mph)	Maximum Gusts (mph)	Barometric Pressure	Date	Time (EST)	Wind Direction	Wind Velocity (mph)	Maximum Gusts (mph)	Barometric Pressure
Dec 9	0055	N	10	-	30.275	Dec 10	0051	N80°E	6	-	30.37
	0355	N10°W	5	-	30.300		0351	N70°E	9	-	30.34
	0655	N30°W	5	-	30.355		0652	N70°E	8	-	30.25
	0955	N10°W	13	-	30.400		0950	N70°E	12	-	30.18
	1255	N20°E	12	-	30.340		1252	N60°E	16	-	30.01
	1555	N20°W	5	-	30.355		1550	S80°E	23	32	29.84
	1855	N20°E	2	-	30.350		1852	S80°E	20	31	29.74
	2155	N50°E	6	-	30.345		2152	N70°E	18	32	29.56
Dec 10	0055	N60°E	6	-	30.315	Dec 11	0050	N70°E	23	40	29.39
	0355	N50°E	8	-	30.270		0353	N70°E	25	37	29.33
	0655	N80°E	10	-	30.170		0650	N50°E	18	32	29.23
	0955	S70°E	14	21	30.115		0950	N50°E	29	40	29.24
	1255	S80°E	12	23	29.935		1142	N30°E	21	31	29.19
	1555	S70°E	18	37	29.780		1252	N50°E	15	28	29.20
	1855	E	18	36	29.645		1550	N50°E	14	-	29.31
	2155	N80°E	23	37	29.450		1851	N40°E	18	24	29.40
							2151	N50°E	15	21	29.50

Table 2 (continued).

Dover Air Force Base Dover, DE						National Weather Service Office New Castle, DE					
Date	Time (EST)	Wind Direction	Wind Velocity (mph)	Maximum Gusts (mph)	Barometric Pressure	Date	Time (EST)	Wind Direction	Wind Velocity (mph)	Maximum Gusts (mph)	Barometric Pressure
Dec 11	0055	S80°E	23	32	29.290	Dec 12	0052	N40°E	17	30	29.60
	0355	N70°E	22	31	29.210		0352	N20°E	22	30	29.69
	0655	S10°E	9	-	29.145		0653	N20°W	16	28	29.77
	0955	S40°E	6	-	29.165		0952	N10°E	20	-	29.83
	1255	S60°E	12	18	29.125		1250	N10°W	17	-	29.81
	1555	S80°E	12	-	29.230		1550	N10°W	21	30	29.84
	1855	N70°E	14	-	29.315		1851	N	18	24	29.91
	2155	N40°E	14	-	29.405		2151	N10°E	16	24	29.99
Dec 12	0055	N30°E	14	-	29.500	Dec 13	0051	N10°E	18	-	30.03
	0355	N51°E	17	23	29.580		0351	N20°E	17	-	30.05
	0655	N	17	32	29.690		0651	N10°E	15	-	30.13
	0955	N	21	26	29.765		0951	N30°E	15	24	30.20
	1255	N10°W	21	33	29.740		1251	N30°E	13	-	30.21
	1555	N10°W	21	30	29.775		1550	N30°E	12	-	30.25
	1855	N	21	32	29.850		1850	N10°E	13	-	30.31
	2155	N10°W	18	30	29.915		2152	N40°E	10	-	30.36
Dec 13	0055	N	22	31	29.965	Dec 14	0050	N30°E	15	-	30.36
	0355	N10°W	14	-	30.000		0353	N	7	-	30.38
	0655	N	15	-	30.070		0650	N30°E	9	-	30.40
	0955	N10°W	15	-	30.145		0951	N10°E	8	-	30.46
	1255	N20°E	15	-	30.150		1251	N30°E	9	-	30.41
	1555	N10°E	12	23	30.205		1551	N50°W	7	-	30.38
	1855	N20°E	9	-	30.270		1850	N40°W	3	-	30.38
	2155	N30°E	9	21	30.305		2150	N80°W	5	-	30.38
Dec 14	0055	N10°E	10	-	30.300	Dec 15	0055	N30°W	5	-	30.335
	0355	N	12	-	30.320		0355	N60°W	5	-	30.310
	0655	N10°E	10	-	30.350		0655	CALM	-	-	30.300
	0955	N10°E	12	-	30.405		0955	S50°W	5	-	30.330
	1255	N	12	-	30.355		1255	N80°W	5	-	30.260
	1555	N30°W	10	-	30.350		1555	S80°W	5	-	30.235
	1855	CALM	-	-	30.350		1855	S50°W	10	-	30.255
	2155	N40°W	2	-	30.340		2155	S40°W	5	-	30.245

Note: Maximum winds were at 2222 EST, December 10, E at 52 MPH and at 0102 EST, Dec 11, S80°E at 46 MPH.

Table 2 (continued)

Salisbury, MD
 Airport, FAA
 Lat. 38°20'00" Lon. 75°30'02"

Date	Time (EST)	Wind Direction	Wind Velocity (mph)	Maximum Gusts (mph)	Barometric Pressure
Dec 10	0054	-	0	-	30.33
	0355	WNW	28	-	30.24
	0648	ESE	12	-	30.15
	0950	ESE	16	-	30.09
	1247	ESE	17	-	29.91
	-	-	-	-	-
	1752	ESE	21	32	29.62
	2247	ESE	17	24	29.35
Dec 10	0052	WSW	13	-	29.26
	0355	SW	10	-	29.26
	0950	SW	12	-	29.21
	1556	SSW	10	-	29.21
	1856	NNE	7	-	29.26
	2156	N	7	-	29.38
Dec 12	0055	ENE	8	-	29.47
	0353	N	8	-	29.56
	0655	N	17	25	29.68
	0852	NNE	12	18	29.74
	1252	N	12	21	29.77
	1556	NNW	12	23	29.80
	1856	NNW	15	-	29.85
	2156	N	12	23	29.91
Dec 13	0055	N	12	21	29.94
	0353	N	14	-	30.00
	0650	N	12	17	30.06
	0955	N	10	-	30.15
	1255	NNE	12	17	30.15
	1556	NNE	12	-	30.21
	1856	NNE	12	-	30.27
	2156	NNE	14	-	30.30

Table 2 (continued)

National Park Service, Assateague National Seashore
Weather Station located approximately at 38°4.6'N 75°2.6'W

Date	Time (EST)	Wind Direction*	Wind Velocity* (mph)	Maximum Gusts (mph)	Barometric Pressure	Date	Time (EST)	Wind Direction*	Wind Velocity* (mph)	Maximum Gusts (mph)	Barometric Pressure
Dec 10	0100	N87°E	11.6	19	30.26	Dec 12	0100	N85°E	9.2	15	29.37
	0200	S77°E	12.0	18	30.27		0200	N72°E	13.5	22	29.41
	0300	S74°E	10.8	17	30.25		0300	N67°E	15.3	22	29.46
	0400	S81°E	15.3	22	30.21		0400	N62°E	10.4	20	29.49
	0500	S82°E	17.3	25	30.18		0500	N17°W	6.8	13	29.49
	0600	S78°E	21.3	32	30.14		0600	N 2°E	11.3	29	29.52
	0700	S76°E	21.3	32	30.13		0700	N 3°E	13.7	28	29.55
	0800	S77°E	23.4	33	30.10		0800	N 1°W	14.2	27	29.52
	0900	S81°E	23.1	34	30.09		0900	N 4°W	12.7	28	29.50
	1000	S80°E	21.9	30	30.08		1000	N 8°W	13.4	26	29.52
	1100	S85°E	21.7	32	30.01		1100	N11°W	13.7	25	29.54
	1200	S80°E	22.9	33	29.96		1200	N13°W	14.0	26	29.53
	1300	S73°E	24.8	35	29.91		1300	N13°W	13.9	26	29.53
	1400	S74°E	24.5	34	29.86		1400	N13°W	14.5	25	29.53
	1500	S74°E	21.3	32	29.84		1500	N15°W	15.3	28	29.55
	1600	S71°E	20.8	31	29.80		1600	N20°W	15.5	27	29.56
	1700	S78°E	22.7	34	29.72		1700	N21°W	15.3	27	29.58
	1800	S87°E	23.2	35	29.67		1800	N19°W	15.1	26	29.60
	1900	S80°E	28.0	45	29.63		1900	N16°W	15.4	28	29.62
	2000	S75°E	34.7	54	29.65		2000	N12°W	15.1	34	29.63
2100	S68°E	25.0	44	29.68	2100	N 6°W	15.8	30	29.64		
2200	S74°E	22.7	43	29.69	2200	N12°W	16.0	32	29.70		
2300	S56°E	20.0	35	29.65	2300	N10°W	15.3	30	29.72		
2400	S24°E	10.6	26	29.62	2400	N 8°W	13.8	25	29.74		
Dec 11	0100	S50°W	10.5	18	29.60	Dec 13	0100	N 4°W	13.8	27	29.75
	0200	S62°W	7.7	14	29.53		0200	N 1°W	14.1	28	29.76
	0300	S51°W	10.2	18	29.42		0300	N 1°E	13.8	31	29.78
	0400	S52°W	10.6	19	29.33		0400	N	12.3	27	29.79
	0500	S77°W	8.5	18	29.25		0500	N 9°W	11.9	22	29.80
	0600	S46°W	6.2	13	29.20		0600	N 6°W	11.5	22	29.82
	0700	S40°W	8.4	17	29.16		0700	N 2°E	12.2	25	29.85
	0800	S44°W	8.7	17	29.14		0800	N 3°W	11.3	22	29.88
	0900	S42°W	10.9	23	29.12		0900	N 1°W	12.1	24	29.89
	1000	S45°W	12.9	24	29.11		1000	N	11.9	25	29.91
	1100	S54°W	12.7	23	29.12		1100	N 2°W	11.3	22	29.94
	1200	S49°W	14.4	26	29.11		1200	N 7°W	11.8	23	29.93
	1300	S55°W	15.9	27	29.08		1300	N 6°W	11.2	23	29.95
	1400	S55°W	16.4	28	29.13		1400	N 5°W	10.4	20	29.96
	1500	S55°W	16.0	29	29.13		1500	N11°E	12.0	25	30.00
	1600	S54°W	14.8	26	29.16		1600	N 8°E	12.4	25	30.00
	1700	S47°W	12.7	22	29.18		1700	N 7°E	10.9	24	29.98
	1800	S59°W	12.7	23	29.20		1800	N 9°E	12.7	25	30.00
	1900	S54°W	12.0	20	29.22		1900	N 4°E	11.7	24	30.01
	2000	S52°W	12.7	22	29.25		2000	N14°E	12.6	25	30.02
2100	S52°W	10.9	20	29.26	2100	N16°E	13.8	29	30.04		
2200	S29°W	5.7	13	29.27	2200	N13°E	13.0	25	30.05		
2300	S 1°E	2.3	8	29.30	2300	N10°E	11.0	24	30.05		
2400	S74°E	8.1	12	29.33	2400	N 2°E	10.7	20	30.06		

* values represent average of readings taken during one-hour period ending at time given

Table 3. Selected Predicted High and Low Tides -December 9-12, 1992.

	Ocean City, MD (fishing pier)		Indian R. Inlet (C. G. Station)		Breakwater Harbor		Mispillion River (entrance)		Murderkill River at Bowers		Woodland Beach	
	<u>Time</u>	<u>Height</u>	<u>Time</u>	<u>Height</u>	<u>Time</u>	<u>Height</u>	<u>Time</u>	<u>Height</u>	<u>Time</u>	<u>Height</u>	<u>Time</u>	<u>Height</u>
Dec 9												
Low	0007	0.7	0120	0.4	0059	-0.2	0150	0.8	0211	0.7	0325	0.8
High	0624	6.3	0709	6.0	0738	5.1	0801	6.2	0818	6.2	0912	6.9
Low	1300	0.5	1413	0.2	1354	-0.1	1445	0.9	1506	0.8	1613	0.7
High	1856	5.3	1937	5.0	1959	3.7	2022	4.8	2039	4.8	2134	5.8
Dec 10												
Low	0055	0.6	0140	0.3	0144	-0.3	0235	0.7	0256	0.6	0413	0.7
High	0710	6.5	0819	6.2	0822	5.2	0845	6.4	0902	6.3	0954	7.1
Low	1342	0.3	1431	-0.1	1440	-0.2	1531	0.8	1552	0.8	1702	0.6
High	1941	5.3	2050	5.0	2045	3.7	2108	4.8	2125	4.8	2219	5.9
Dec 11												
Low	0141	0.5	0226	0.2	0231	-0.4	0322	0.6	0343	-0.5	0502	0.7
High	0755	6.5	0904	6.2	0908	5.3	0931	6.4	0948	6.4	1038	7.1
Low	1432	0.3	1517	-0.1	1526	-0.3	1617	0.7	1638	0.6	1749	0.6
High	2029	5.3	2138	5.0	2131	3.8	2154	4.9	2211	4.9	2304	6.0
Dec 12												
Low	0229	0.5	0314	0.2	0317	-0.4	0408	0.6	0429	0.5	0551	0.7
High	0843	6.4	0952	6.1	0955	5.2	1018	6.3	1035	6.3	1123	7.2
Low	1517	0.5	1602	-0.2	1613	-0.3	1704	0.7	1725	0.6	1836	0.7
High	2120	5.4	2229	5.1	2222	3.8	2245	4.9	2302	4.9		

Datum is mean lower low water. Times are EST.

Numbers derived from U. S. Department of Commerce, "Tide Tables, 1992, East Coast of North and South America including Greenland."

Figure 3. Tide Gage Data.

BREAKWATER HARBOR, LEWES, DE December 6-17, 1992

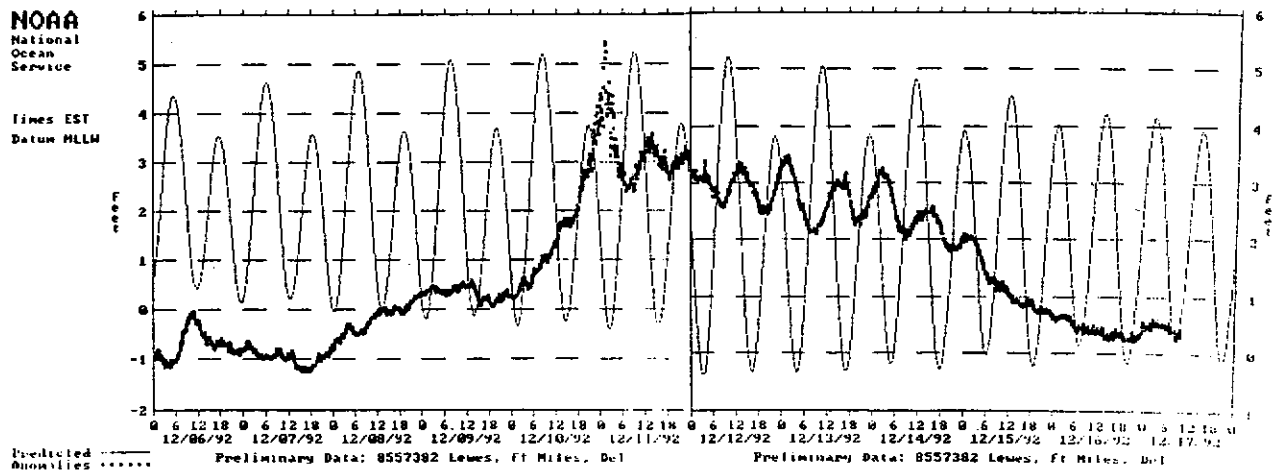
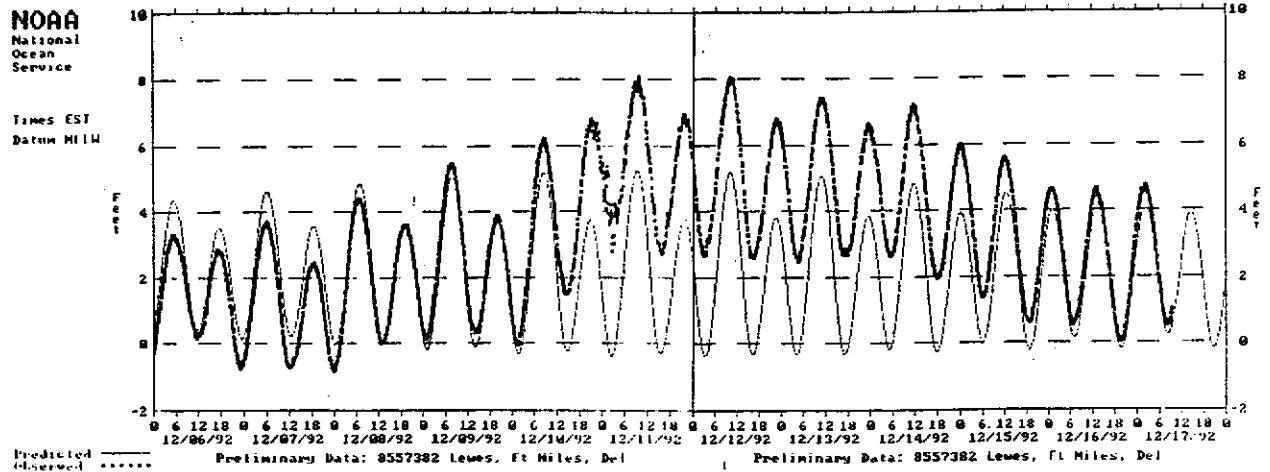


Table 4. Maximum Heights of Tide
Breakwater Harbor, Lewes, DE

Twenty Highest Stages, 1919 TO 1992¹

<u>Rank</u>	<u>Date</u>	<u>Stage (ft.)</u>	<u>Storm type</u>
1	03/06/1962	8.05	NE
2	01/04/1992	7.40	NE
3	09/27/1985	6.61	HUR
4	10/25/1985	6.56	NE
5	10/22/1961	6.56	HUR
6	03/29/1984	6.52	NE
7	12/12/1992	6.33	NE
8	10/14/1977	6.29	HUR
9	10/23/1953	6.24	NE
10	12/22/1972	6.14	NE
11	10/31/1991	6.08	NE
12	01/13/1964	6.03	NE
13	12/09/1973	6.03	NE
14	01/10/1956	5.91	NE
15	01/02/1987	5.89	NE
16	11/10/1969	5.87	NE
17	12/12/1960	5.77	HUR
18	01/29/1922	5.75	NE
19	10/05/1948	5.69	HUR
20	05/24/1967	5.69	NE

NE-northeaster: HUR-hurricane

¹ National Geodetic Vertical Datum (NGVD) 1929. Source: U. S. Army Corps of Engineers.

Table 5. Comparison of historical highest water levels and highest recorded levels during the December, 1992 storm. Water levels were recorded at NOS Tide Stations along the northeastern coast of the United States.¹

Station Location	Highest Water Level December, 1992 Storm				Historical Highest Water Level		
	Date	Time (EST)	Elevation (ft) above		Date	Elevation (ft) above	
			MLLW	NGVD		MLLW	NGVD
Portland, Me.	12/12/92	12:12	12.30	7.71	2/7/78	14.17	9.60
Boston, Mass.	12/12/92	12:42	14.21	9.35	2/7/78	15.25	10.40
Nantucket, Mass.	12/12/92	13:30	6.89	—	10/30/91	8.11	—
New London, Conn.	12/11/92	10:12	6.36	5.31	9/21/38	10.76	9.69
Montauk, N.Y.	12/11/92	09:48	6.04	5.45	8/31/54	8.68	8.10
Bridgeport, Conn.*	12/11/92	11:00	12.14	9.22	9/21/38	12.44	9.52
Willets Pt., N.Y.*	12/11/92	11:00	14.44	11.25	9/21/38	16.90	13.74
Battery, N.Y.*	12/11/92	08:42	9.55	7.68	9/12/60	10.23	8.35
Sandy Hook, N.J.	12/11/92	08:30 09:24	10.47	8.69	9/12/60	10.33	8.56
Atlantic City, N.J.	12/11/92	07:54	8.99	7.35	9/14/44	9.20	7.56
Cape May, N.J.	12/11/92	09:24	8.86	6.86	9/27/85	9.09	7.09
Lewes, Del.	12/12/92	10:12	8.07	6.33	3/6/62	9.49	7.76 ²
Reedy Pt., Del.	12/11/92	14:24	9.45	6.96	10/25/80	9.19	6.68
Philadelphia, Pa.	12/11/92	14:42	10.01	7.72	11/25/50	10.79	8.50
Wachapreague, Va.	12/12/92	10:00	7.68	—	10/25/80	8.33	—
Chesapeake Bay Bridge Tunnel, Va.	12/12/92	09:30	5.94	—	4/26/78	6.36	—
Kiptopeke, Va.	12/12/92	09:30	5.64	4.20	3/7/62	7.41	5.99
Gloucester Pt., Va.	12/12/92	10:12	5.18	4.04	3/7/62	6.63	5.47
Lewisetta, Va.	12/11/92	17:30 19:30	2.89	2.62	3/19/83	3.62	3.34
Solomons Island, Md.	12/11/92	06:30 19:30	3.08	2.76	8/13/55	4.53	4.18
Annapolis, Md.	12/11/92	09:30	3.08	2.92	8/23/33	6.40	6.24
Baltimore, Md.	12/11/92	09:30	4.07	3.79	8/23/33	7.93	7.65

* Gauge limit of the primary gauge at the station was exceeded. The back-up pressure gauge was used and highest water level was extrapolated from a curve plot.

¹ Source of information: Ocean and Lake Levels Division, National Ocean Service (NOS), Rockville, Maryland.

² Difference in numbers at Lewes (Breakwater harbor) for the storm of 3/6/62 between this table and table 4 reflects different base datums used at the time.

Table 6. Selected Tidal Stations - October 31, 1991, January 4, 1992,
December 11, 12, 1992.

Data provided by U.S. Geological Survey, Water Resources Division.
Provisional Data.

<u>Station</u>	<u>Date</u>	<u>Heights (NGVD 1929, ft)</u>	<u>Station Type</u>
Coast Guard Station, Indian River Inlet	Oct. 31, 1991	5.21	b
	Jan. 4, 1992	4.83	
	Dec. 12, 1992	5.10	
Vines Creek near Dagsboro	Oct. 31, 1991	4.83	a
	Jan. 4, 1992	5.35 ¹	
	Dec. 12, 1992	4.76	
Indian River at Oak Orchard	Oct. 31, 1991	5.21	a
	Jan. 4, 1992	5.84	
	Discontinued		
Indian River at Rosedale Beach	Oct. 31, 1991	4.56	b
	Jan. 4, 1992	5.75 ²	
	Dec. 12, 1992	5.08	
Massey Ditch at Massey Landing	Oct. 31, 1991	4.56	b
	Jan. 4, 1992	4.12 ³	
	Dec. 12, 1992	3.76	
Rehoboth Bay at Dewey Beach	Oct. 31, 1991	4.54	b
	Jan. 4, 1992	3.82 ⁴	
	Dec. 12, 1992	3.89	
Cedar Creek near Slaughter Beach	Oct. 31, 1991	5.66	a
	Jan. 4, 1992	6.61	
	Discontinued		
Murderkill River at Bowers	Oct. 31, 1991	6.03	a
	Jan. 4, 1992	8.76	
	Dec. 11 or 12, 1992	7.7	
Duck Creek at Smyrna	Oct. 31, 1991	4.93	a
	Jan. 4, 1992	4.70	
	Dec. 11 or 12, 1992	5.77	

a = Tidal Crest-Stage Gage

b = Digital Water-Stage Recorder

¹ Three additional high-water marks were surveyed at the site to check the crest-stage gage and were found to be at 5.30 ft., 5.37 ft., and 5.42 ft.

² A high water mark for the March 1962 storm was shown to U. S. Geological Survey personnel by John Rogers and was surveyed to NGVD. 1929 on May 13, 1991 and found to be at 6.73 ft. The Rosedale Beach tide gage is on the same property as Gulls Point.

³ High water marks were surveyed to NGVD 1929 for the storm of Jan. 4, 1992 to verify the elevation recorded by the tide gage. They were at 3.86 ft., 3.80 ft., and 3.78 ft.

⁴ Two high water marks of 6.94 ft. and 7.04 ft. for the storm of March 1962 were shown to U.S.G.S. personnel by I. G. Burton. They are in his beach house at the tide gage site. They were surveyed to NGVD 1929 on August 6, 1984.

Table 7. Tidal Crest Stage Stations
(Maximum recorded heights of tide 1966 to 1992)

Murderkill River at Bowers, DE

Elevation NGVD 1929 (ft)		Date
8.76		04-Jan-92
8.74		06-Mar-62
8.19		29-Mar-84
8.13		25-Oct-80
7.70		11 or 12-Dec-92
7.18		14-Oct-77
7.10	(Gloria)	27-Sept-85
6.91		19-Oct-89
6.81	Between	18-Nov-86 & 04-Dec-86
6.68		09-Dec-73
6.64	Between	20-Dec-77 & 30-Jan-78
6.63		18-Aug-89
6.53	Between	15-Nov-83 & 07-Dec-83
6.48		23-Dec-72
6.47		26-Dec-79
6.35	Between	17-Dec-86 & 04-Feb-87
6.26		24-May-67
6.24		15-Nov-81
6.22		24-Apr-83
6.22	Between	07-Apr-87 & 08-May-87
6.21	Between	29-Aug-79 & 09-Oct-79
6.19		13-Dec-85
6.16	Between	26-Jan-67 & 30-Mar-67
6.16		10-Nov-69
6.13		19-Feb-72
6.10		12-Nov-68

A plaque attached to a door frame at Paskey's Wharf marks the high tide location for the storm of March 1962. This mark was surveyed to National Geodetic Vertical Datum (NGVD) of 1929 on December 16, 1980 and was found to be at an elevation of 8.75 ft.

At the residence of Donald Wujtewicz at Bowers, DE, a high water mark is shown in a photo for the March 1962 storm. The mark is on a garage near the fire station and at the house next door to the Bowers Maritime Museum. The photo shows the 1962 storm to be about 2 inches higher than the January 4, 1992 storm.

Table 7 (continued).

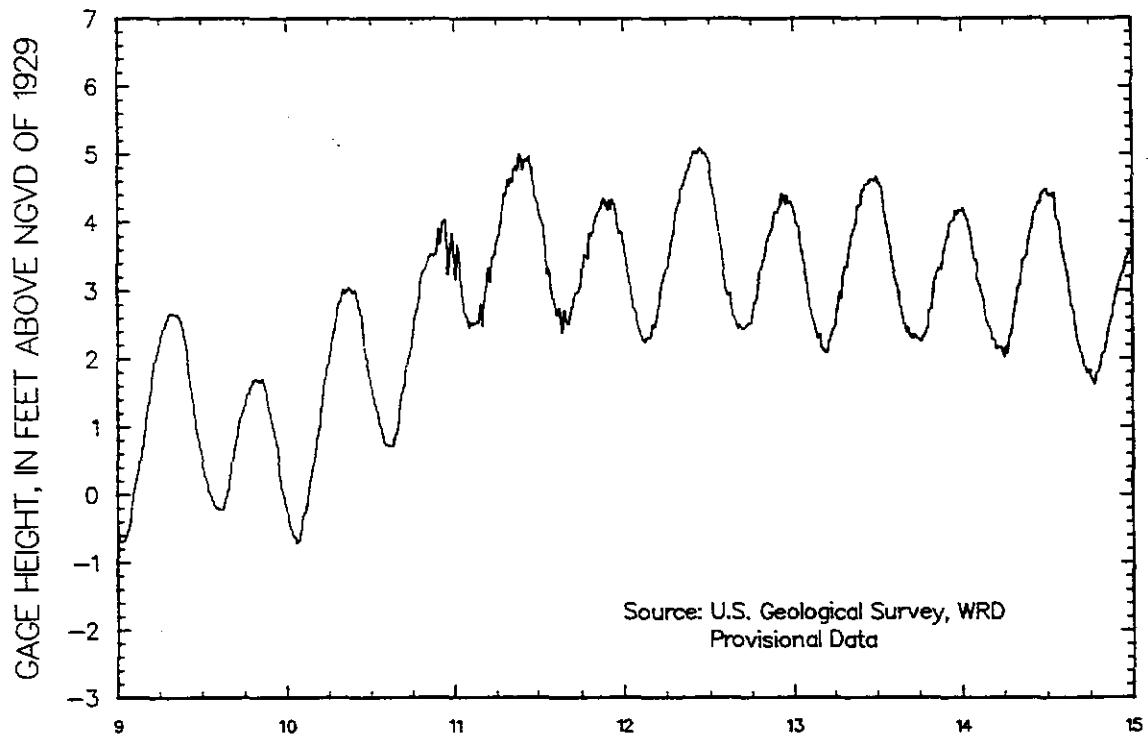
Duck Creek (Smyrna River) at U.S. Rt. 13

<u>Elevation</u> <u>NGVD 1929 (ft)</u>		<u>Date</u>	
6.82		23-Jun-72	
5.86		29-Mar-84	
5.77		11 or 12-Dec-92	
5.55		26-Feb-79	
5.53		29-Jul-80	
5.33	Between	29-Jul-80	& 04-Aug-80
5.11		01-Dec-74	
5.00		18-Aug-89	
4.93		31-Oct-91	
4.88		12-Nov-68	
4.80	(Gloria)	27-Sep-85	
4.74		18-Mar-83	
4.73		19-Oct-89	
4.72	Between	22-Jul-69	& 23-Aug-69
4.70		03-Nov-85	
4.70		04-Jan-92	
4.57	Between	12-Oct-82	& 15-Oct-82
4.54		28-Aug-71	
4.53		23-Dec-72	
4.50	Between	10-Nov-86	& 08-Dec-86
4.48	Between	08-Dec-86	& 06-Jan-87
4.44	Between	21-Aug-79	& 04-Oct-79
4.44	Between	16-Apr-90	& 18-Jun-90
4.43	Between	22-Jan-88	& 14-Mar-88
4.43	Between	04-Jan-84	& 10-Feb-84
4.42	Between	15-Nov-82	& 20-Dec-82

(References supplied by R. H. Simmons, USGS, Water Resources Division (WRD).)

Figure 4. Digital Tide Gage Station Records - December 9-15, 1992.

INDIAN R. AT INDIAN R. INLET NR BETHANY BEACH, DELAWARE



MASSEY DITCH AT MASSEY LANDING, DELAWARE

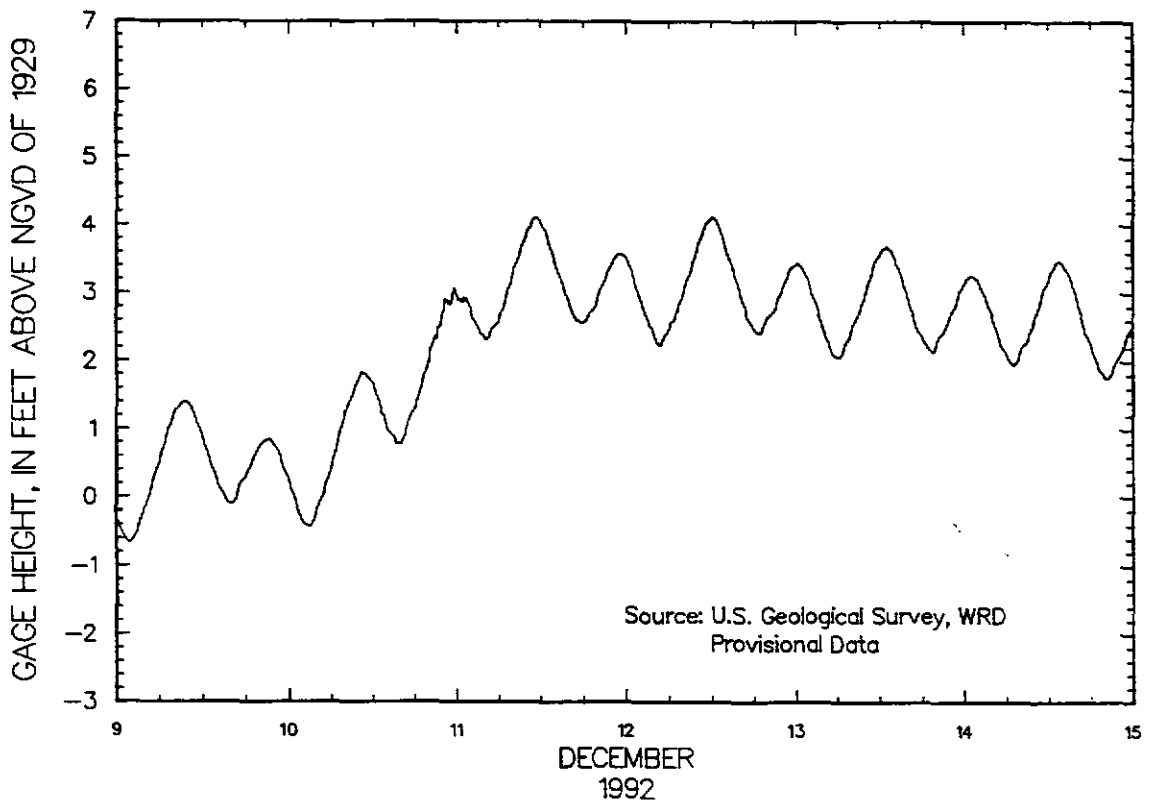
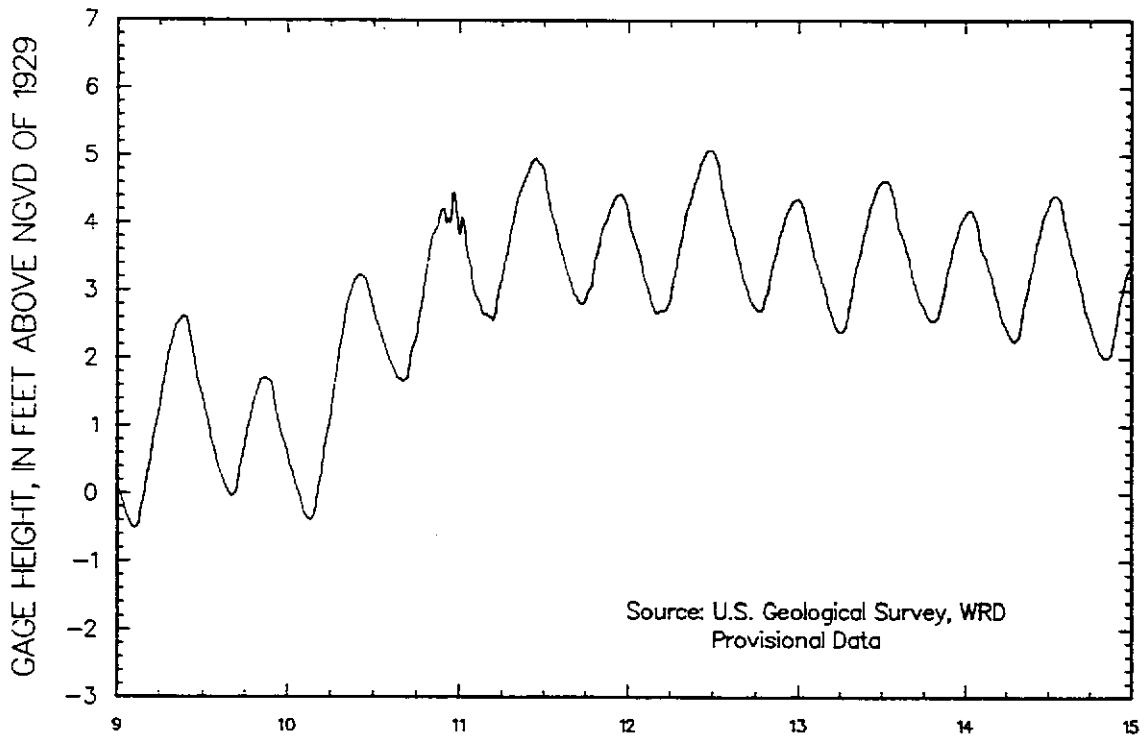


Figure 4 (continued).

INDIAN RIVER AT ROSEDALE BEACH, DELAWARE



REHOBOTH BAY AT DEWEY BEACH, DELAWARE

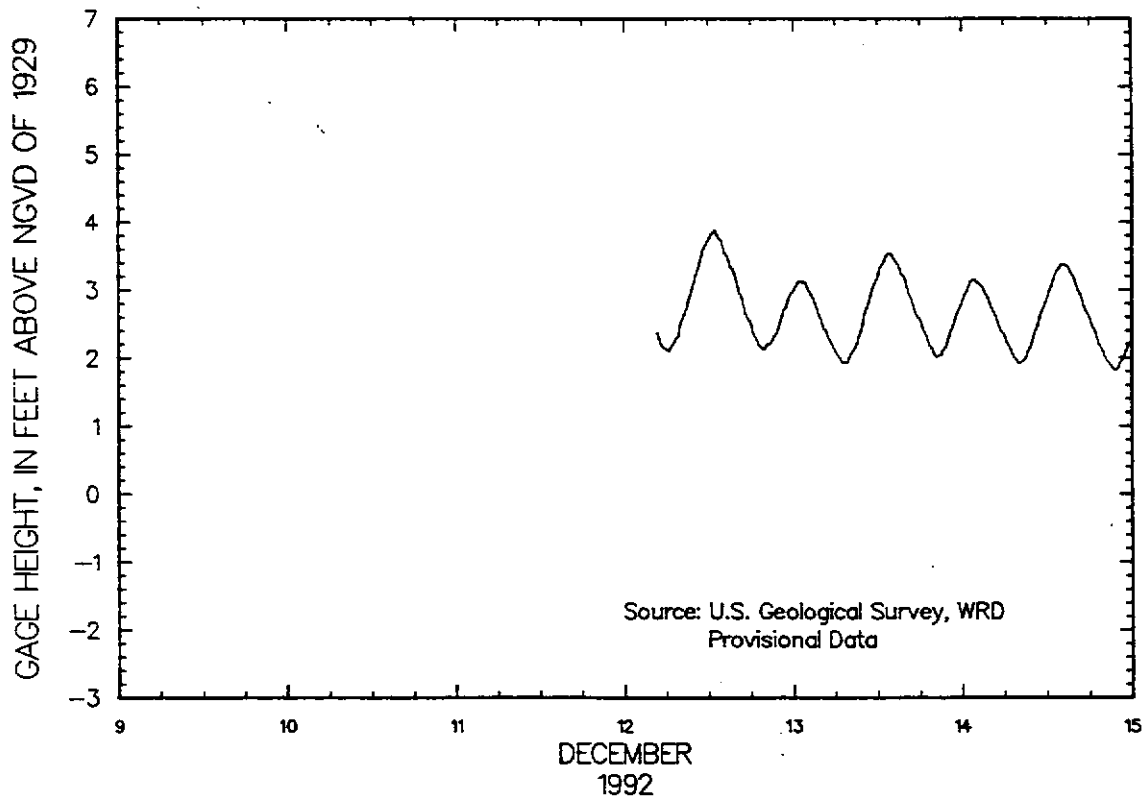


Table 8. Wave heights and wave periods recorded during the December storm by the wave gage located offshore Ocean City, Maryland.¹ The gage was located at 38°24'N, 75°2.24'W. The gage was damaged during the December storm.

Date	Time (EST)	Wave Height (H_mO)		Wave Period (T_p) (seconds)	Water Depth	
		meters	feet		meters	feet
Dec. 9, 1992	1900	0.68	2.23	6.0	12.0	39.4
	2000	0.76	2.49	5.7	11.8	38.7
	2100	0.67	2.20	5.7	11.7	38.4
	2200	0.64	2.10	6.0	11.4	37.4
	2300	0.62	2.03	5.4	11.1	36.4
Dec. 10, 1992	0000	0.61	2.00	5.4	10.8	35.4
	0100	0.59	1.94	4.3	10.8	35.4
	0200	0.71	2.33	6.0	11.0	36.1
	0300	0.67	2.20	5.7	11.3	37.1
	0400	0.78	2.56	5.4	11.7	38.4
	0500	0.81	2.66	4.2	12.1	39.7
	0600	1.24	4.07	4.5	12.4	40.7
	0700	1.52	4.99	4.5	12.6	41.3
	0800	1.73	5.68	5.0	12.6	41.3
	0900	1.83	6.00	5.7	12.3	40.4
	1000	2.17	7.12	5.7	12.1	39.7
	1100	2.57	8.43	6.9	11.7	38.4
	1200	2.63	8.63	7.3	11.4	37.4
	1300	3.05	10.01	7.8	11.2	36.7
	1400	2.99	9.81	7.8	11.1	36.4
	1500	3.09	10.14	7.3	11.3	37.1
	1600	3.58	11.75	7.8	11.5	37.7
	1700	3.78	12.40	8.3	11.8	38.7
	1800	4.43	14.53	8.3	12.2	40.0
1900	4.22	13.84	8.8	12.5	41.0	
2000	4.22	13.84	9.5	12.4	40.7	
2100	4.12	13.52	10.2	12.4	40.7	
2200	4.70	15.42	11.1	12.1	39.7	
2300	4.76	15.62	10.2	12.0	39.4	
Dec. 11, 1992	0000	4.69	15.39	11.1	11.8	38.7
	0100	3.94	12.93	11.1	11.4	37.4
	0200	4.22	13.84	13.5	11.2	36.7
	0300 ²	---	---	---	---	---

¹ Source of information: U.S. Army Corps of Engineers, Baltimore District

² Wave gage had stopped functioning.

GEOLOGIC OBSERVATIONS

Observations are based on reconnaissance of the area by Kelvin W. Ramsey of the Delaware Geological Survey on December 15, 1992.

1. Washovers and breaches in the dune system occurred at scattered locations along the Atlantic Coast.
 - Dunes in Fenwick remained intact and were only marginally eroded. The beachface was steep and a bar system had formed just offshore.
 - The dunes in Fenwick Island State Park were barely breached in scattered spots. Only minor washover was associated with the breaches.
 - Some beach loss occurred in South Bethany and Bethany Beach. Only minor damage to the boardwalk was noted. No breaches in the dunes were observed north of Ocean Village up to Indian River Inlet.
 - No observations were made along the Inland Bays. Some local flooding was reported along areas normally flooded during extreme high tides.
 - Breaches in the dunes were noted south and north of the Old Coast Guard Station in Delaware Seashore State Park. Washovers associated with the breaches were minor.
 - Washover occurred throughout much of Indian Beach north to Dewey Beach. Damage to structures was observed throughout the area. The most severe area of washover, as in the January 4 storm, occurred in the vicinity of Read Street in Dewey Beach. Damage to some structures was substantial.
 - Some loss of beach occurred in Rehoboth Beach; no damage to the boardwalk or structures was observed.
2. Washovers and breaches in the dunes occurred at scattered locations along Delaware Bay.
 - The dunes were flattened from north of Primehook Beach to the south end of Slaughter Beach. An artificial earthen berm at the end of Rd. 199 at Fowler Beach was almost completely removed. Artificial plastic structures added to stabilize the dunes at Fowler Beach were almost completely removed and scattered along the beach and into the marsh. Washovers in the area were common. Based on the position of a concrete structure at the south end of

Fowler Beach, the beach may have retreated an additional five feet since the January 4, 1992 storm.

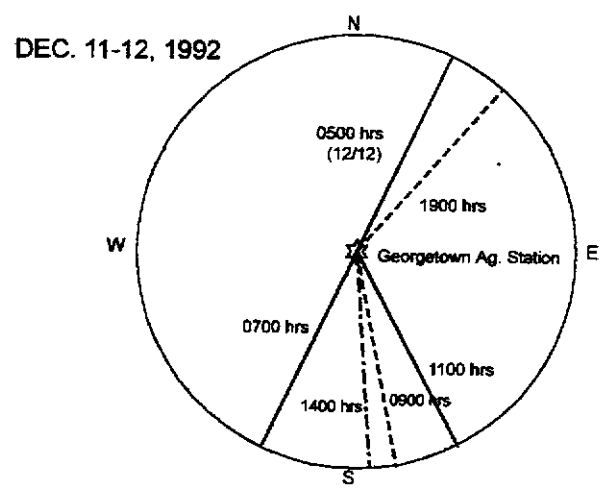
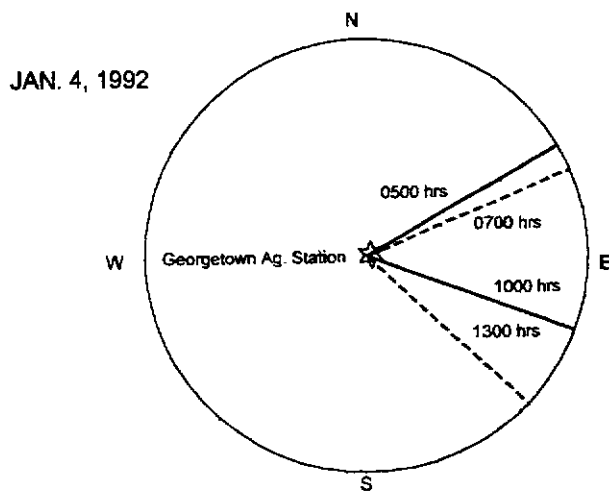
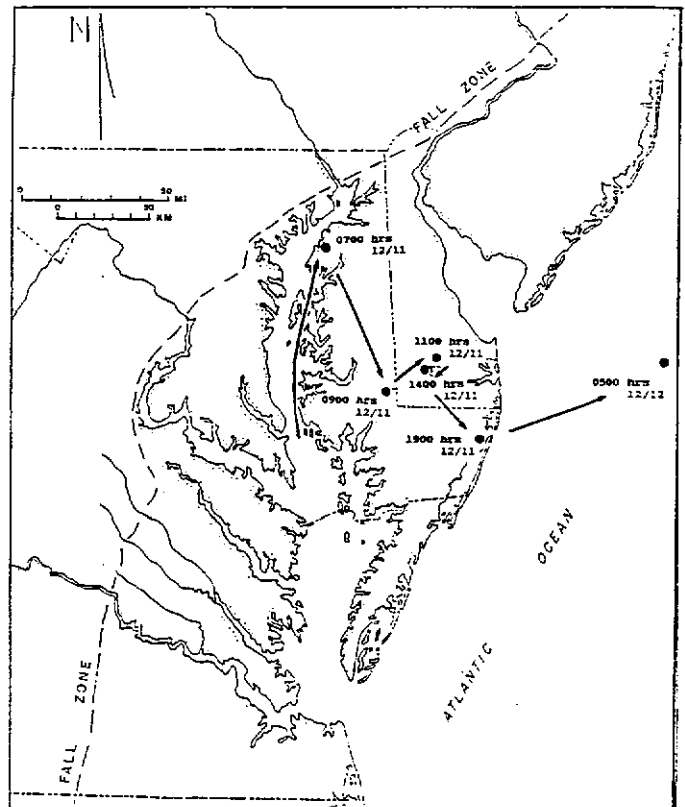
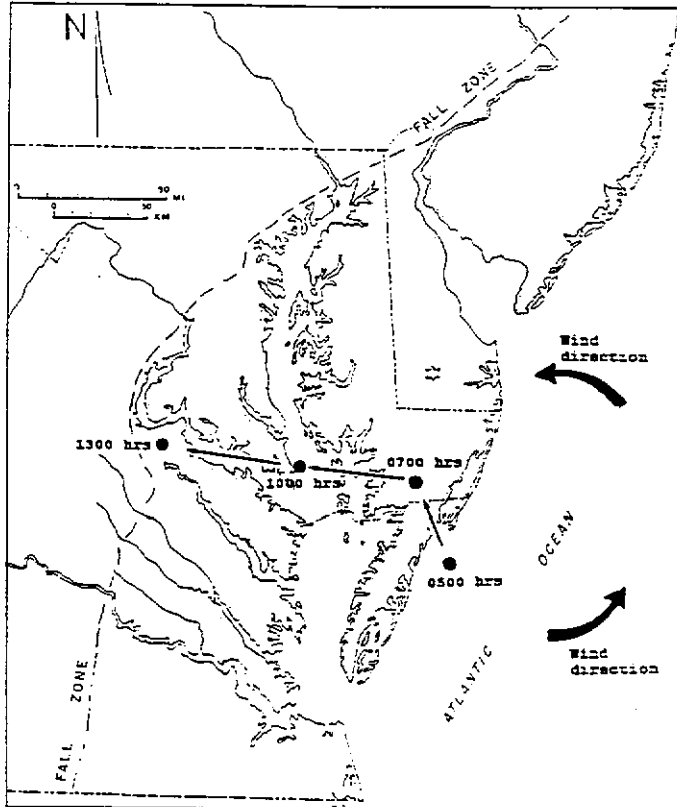
- No washovers were observed along Slaughter Beach or Cedar Beach.
- Flooding occurred at the Mispillion River light with some damage to the docks and structures damaged in the January 4, 1992 storm. The spit and small island observed between a breach north of the north jetty and the jetty after the January 4, 1992 storm was almost gone. At the time of observation flooding was still occurring during high tide.
- Dunes were flattened at scattered locations from the north end of the Mispillion Inlet to Bennetts Pier. At Big Stone Beach some moderate washover and flooding occurred. The marshes were still flooded at the time of observation.
- Washovers occurred along the southern end of South Bowers up to about the fourth house. The marshes were still flooded, but marsh vegetation was not flattened as in the January 4, 1992 storm. Flooding in the marsh at the bridge closest to the beach is estimated to have been one to two feet above road level. Some erosion of the highway was noted at the boat landing.
- No observations were made north of South Bowers. Newspaper accounts reported flooding at North Bowers, Kitts Hummock, Port Mahon, and Woodland Beach.

SUMMARY

The storm of December 10-14, 1992 was fundamentally different from that of the January 4, 1992 storm and as a result, even though it was of longer duration, it was less severe. The track of the storm was up the Chesapeake Bay, southeast across the Delmarva Peninsula, and then offshore to the east-northeast. The January 4 storm moved rapidly from offshore to onshore on the Delmarva Peninsula south of Delaware, placing the Delaware coast in the northeast quadrant of the storm during landfall but only for a period of one tidal cycle. In the December storm, the Delaware coast did not come under the influence of east-northeast winds until the storm moved to the southeast and then offshore (Figure 5).

Highest wind speeds were as high as the January storm (up to 52 mph in gusts). These were from a south-southeast direction rather than from the east-northeast of the January storm. Wave buildup from the winds was minimized due to the lower distance of storm fetch (distance over which the waves build up). This was especially significant for

Figure 5. Storm track locations and wind directions at the University of Delaware Agricultural Station near Georgetown, DE, January 4, 1992 and December 11-12, 1992.



Delaware Bay, which experienced winds from due east with a long wave fetch in the January storm that produced high waves and significant damage along the shoreline. During the December storm, waves built in the Atlantic from southeast winds were blocked by Cape Henlopen and the rest of the coast and were less severe than in the January storm.

Also unlike the January storm, the December storm had significant rainfall associated with it. Some stream flooding was reported in New Castle County and at scattered locations in Kent and Sussex counties. The rainfall, in addition to an astronomical high tide and east-northeast winds after December 11, contributed to abnormally high tides along the streams and marshes along Delaware Bay and the Inland Bays until December 15. Rainfall discharge may have been a contributing factor to the third highest tide of record at Duck Creek at Smyrna, approximately a foot higher than the January 4 storm.

CONCLUSIONS

The storm of December 10-14, 1992 was typical of "northeasters" that produce flooding along the Delaware coast. The severity of the storm was mitigated by the fact that it proceeded up the Chesapeake Bay and moved from land offshore. As a result, Delaware's coast was not in the northeast quadrant of the storm until it had moved offshore. New Jersey, however, was in the northeast quadrant for most of the storm's duration and as a result had more flooding, beach migration, and property damage. The duration of the storm over several days coinciding with an astronomical high tide and rainfall, contributed to flooding of coastal marshes and some additional coastal washover in areas most severely affected such as at Dewey Beach.

The severity of the problem at Dewey Beach is in part due to the lack of a dune system in front of the buildings, the progressive loss of beach sand due to beach migration inland, the lack of a significant natural source of sand in the surf zone and just offshore to naturally replenish the beach, such as is found at Rehoboth Beach, and the impact of a migrating coastline on structures not designed to be affected by waves and surf.

Fewer data stations were available for this storm than for the January storm including the loss of two tidal crest stations at Cedar Creek and at Indian River at Oak Orchard due to lack of funding. The data from these stations are useful in assessing the severity of the storms and to compare storms. The weather station at the Old Coast Guard station was not operational and is being replaced by a system to be located near Indian River Inlet. The discontinued tidal crest stations need to be replaced as well as new stations added on the Murderkill River at Bowers, on the St. Jones River, at Woodland Beach, and on Little Assawoman Bay.

Presently, there are no tidal stations or stream gages in Maryland's Atlantic coastal area. The wave gage operated by the U. S. Army Corps of Engineers was lost during this storm. The NOS tide station at the city pier in Ocean City, Maryland, was destroyed during the January 1992 storm. Without tide or storm surge data, the effects of storms on Maryland's coast are difficult to assess.

As was stated in the report of January 4, 1992 (DGS Open File Report No. 36), the worst case scenario for a coastal storm impacting Delaware's coast that would produce severe and life-threatening conditions is as follows:

1. A slow-moving storm with tropical- to hurricane-force winds.
2. Landfall over the southern Delmarva Peninsula that places the Delaware coast in the storm's northeast quadrant.
3. Continuation of the storm over several tidal cycles.
4. Landfall during high tide or an astronomical high tide.

GEOLOGIC OBSERVATIONS- MARYLAND

Observations based on a reconnaissance of Ocean City, Maryland and Assateague State Park by Darlene Wells and Robert Conkwright of the Maryland Geological Survey on January 8 and 9, 1993. Assateague State Park beach profiles were collected on January 8, 1993. Profile locations are shown in Figure 6.

1. The newly placed dune system at Ocean City suffered widespread damage.
 - Approximately a third of the dune was eroded. As much as half of the dune was missing along several areas including 30th to 32nd streets, 78th Street, and 135 to 145th streets (Maryland/Delaware Line). Erosion was restricted to the eastern flank of the dune, with the dune cross-section truncated in many areas by a three- to four-foot escarpment.
 - Much of the sand fencing marking the eastern edge of the dune was damaged or missing.
 - Evidence suggested that waves overtopped the dune (washover) along areas between 78th and 86th streets. Dune fencing along the west side of the dune was damaged or missing. Deposits of sand were observed on several side streets.

2. No observations were made along the bay side of Ocean City (Isle of Wight and Assawoman bays) at the time of the reconnaissance. City engineers reported that water elevations during the December storm probably did not exceed 2.5 ft above NGVD. The bay water levels during the December storm were minimal compared to those reached during the October, 1991 (Halloween) storm. Peak water levels during the Halloween storm were measured at 1st, 15th, 87th and 142nd streets and were found to be at 4.31 ft., 4.15 ft., 4.0 ft., and 3.80 ft. above NGVD (1929, adjusted in 1977), respectively. NGVD has been determined to be 1.03 ft above MLW at a NOAA tide station located in Isle of Wight Bay at Talbot Street in South Ocean City and 0.69 ft above MLW at 9th street. Tide range (MHW - MLW) measured at both sites were 2.24 ft. and 1.55 ft., respectively.¹

¹ On the bay side of Fenwick Island (Isle of Wight Bay), NGVD relative to the tidal datums for the bay are based on tide data from NOAA tide stations MD 857 0282 and MD 857 0255, both of which are no longer in place.

3. The established dune system within Assateague Island State Park experienced widespread erosion.
 - Much of the erosion was restricted to the central portion of the State Park where as much as a third of the dune was eroded. Comparisons of January, 1993 dune profiles to profiles collected prior to the storm (November, 1992) indicate that an average of 12 to 13 cubic yards per linear foot of beach were removed from the seaward flank of the dune and beach (Figure 7).
 - Along the more heavily eroded areas, fencing marking the east boundary of the dune was destroyed. North of the day use area, dune fencing appeared to be largely intact.
 - The dune appeared to have been breached at the vehicle cross-over located just south of profile 3 (in front of the campers recreation area). Some minor washovers occurred at other areas, primarily at pedestrian crossovers. However, the amount of sand deposited west of the dune appeared to be minimal.
4. Reconnaissance survey did not include the National Park area on Assateague Island. However, according to the National Park Service (NPS) the storm caused significant changes within the National Park. Complete washover occurred along the north end of the island and near the visitor's center at the southern end of the park (in Virginia). Severe flooding and washovers occurred at the latter location. Along the central portion of the island, washovers occurred at existing washover sites with some sediment being carried to the back side of the island.

Figure 6. Location of profile lines within Assateague Island State Park. The State Park is located approximately six miles south of Ocean City Inlet, Lat. 38°13'30", Lon. 75°08'00".

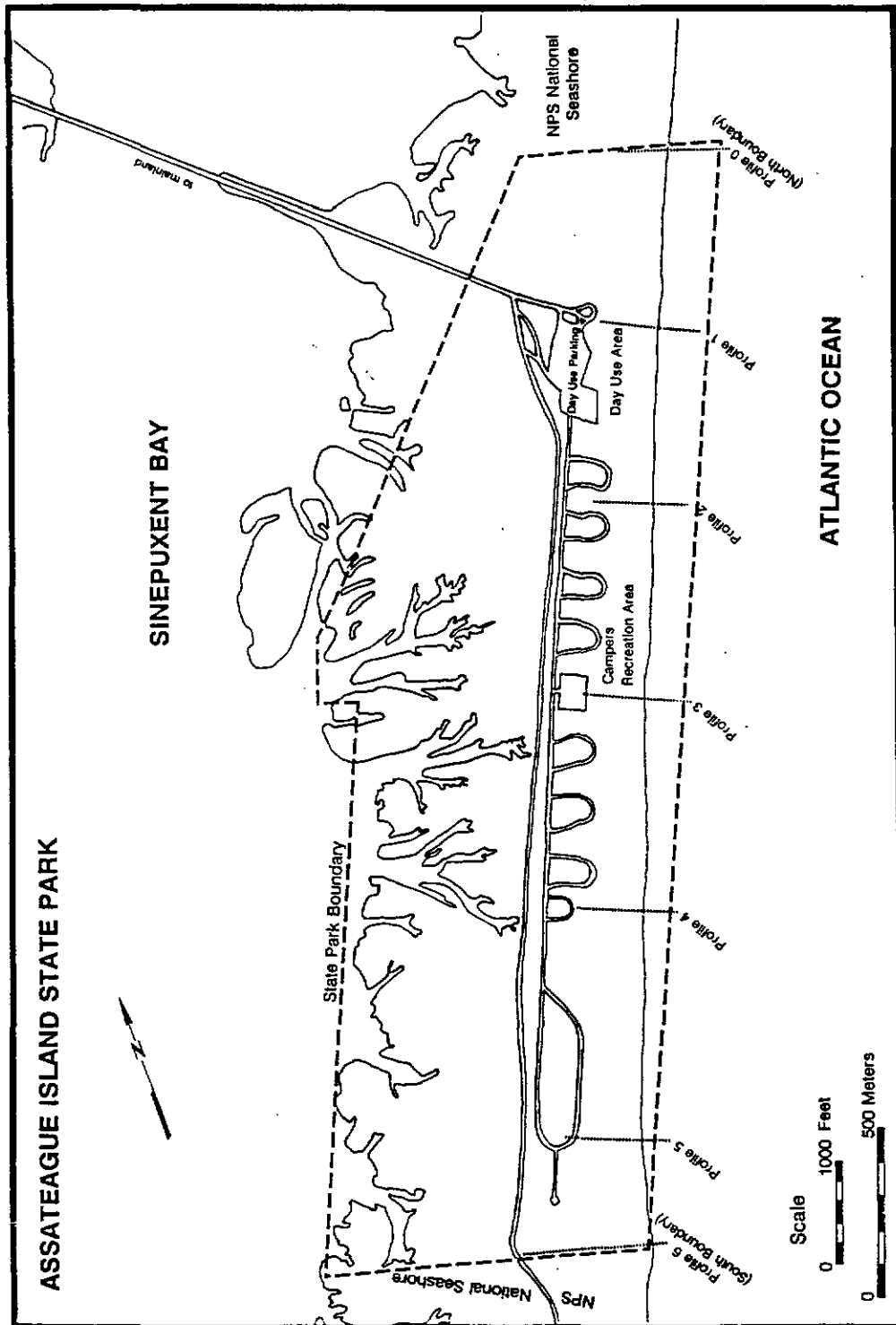
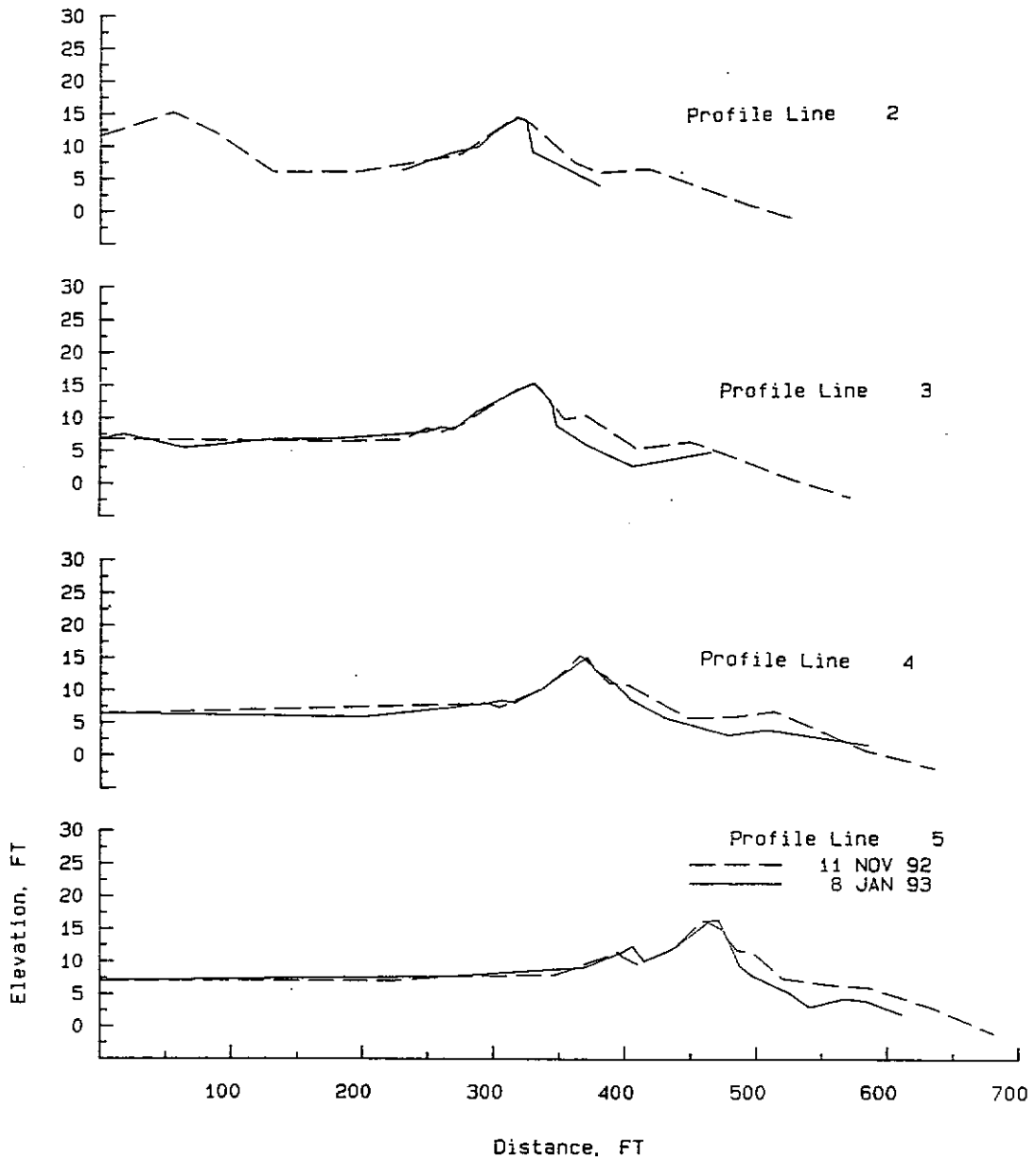


Figure 7. Pre- and post-storm beach profiles collected in Assateague Island State Park. Distance is from profile bench mark. Datum is NGVD (NAV 88). Profile locations are shown in Figure 6.



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Raw data from which tables in this report were generated are available from the Delaware Geological Survey or from the agencies cited.