AGRICULTURAL PESTICIDES IN SIX DRAINAGE BASINS USED FOR PUBLIC WATER SUPPLY IN NEW JERSEY, 1990

By Tamara Ivahnenko and Debra E. Buxton

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 93-4101

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

Prepared in cooperation with the

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION AND ENERGY

West Trenton, New Jersey
1994

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information
write to:

District Chief
U.S. Geological Survey
Mountain View Office Park
810 Bear Tavern Road
Suite 206
West Trenton, NJ 08628

Copies of this report can be
purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

ILLUSTRATIONS--Continued

TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To Obtain
	Length	
inch (in.)	2.54	centimeter
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	0.4047	hectare
square foot (ft^2)	0.09294	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
	Flow	
cubic feet per second (ft^3/s)	0.0283	cubic meter per second
million gallons per day (Mgal/d)	0.0438	cubic meter per second
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram
pound, avoirdupois (lb)	0.4536×10^6	microgram
	Temperature	
degrees Fahrenheit (°F)	°C = 5/9 (°F-32)	degrees Celsius (°C)
	Other	
pound (avoirdupois) per acre (lb/acre)	1.121	kilogram per hectare

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

AGRICULTURAL PESTICIDES IN SIX DRAINAGE BASINS USED FOR PUBLIC WATER SUPPLY IN NEW JERSEY, 1990

By Tamara Ivahnenko and Debra E. Buxton

ABSTRACT

A reconnaissance study of six drainage basins in New Jersey was conducted to evaluate the presence of pesticides from agricultural runoff in surface water. In the first phase of the study, surface-water public-supply drainage basins throughout New Jersey that could be affected by pesticide applications were identified by use of a Geographic Information System. Six basins--Lower Mine Hill Reservoir, South Branch of the Raritan River, Main Branch of the Raritan River, Millstone River, Manasquan River, and Matchaponix Brook--were selected as those most likely to be affected by pesticides on the basis of calculated pesticide-application rates and percentage of agricultural land.

The second phase of the project was a short-term water-quality reconnaissance of the six drainage basins to determine whether pesticides were present in the surface waters. Twenty-eight surface-water samples (22 water-quality samples, 3 sequentially collected samples, and 3 trip blanks), and 6 samples from water-treatment facilities were collected. Excluding trip blanks, samples from water-treatment facilities, and sequentially collected samples, the pesticides detected in the samples and the percentage of samples in which they were detected, were as follows: atrazine and metolachlor, 86 percent; alachlor, 55 percent; simazine, 45 percent; diazinon, 27 percent; cyanazine and carbaryl, 23 percent; linuron and isophenfos, 9 percent; and chlorpyrifos, 5 percent. Diazinon, detected in one stormflow sample collected from Matchaponix Brook on August 6, 1990, was the only compound to exceed the U.S. Environmental Protection Agency's recommended Lifetime Health Advisory Limit. Correlation between ranked metolachlor concentrations and ranked flow rates was high, and 25 percent of the variance in metolachlor concentrations can be attributed to variations in flow rate. Pesticide residues were detected in samples of pretreated and treated water from water-treatment facilities. Concentrations of all pesticides detected in the treated water were less than the U.S. Environmental Protection Agency's recommended Lifetime Health Advisory Limits.

INTRODUCTION

Agricultural land covers approximately 20 percent of the State of New Jersey and supports a variety of crops. Because of the diversity of crop types, New Jersey farmers use a wide spectrum of insecticides, herbicides, and fungicides to control pests. Few data are available regarding the sources, presence, and transport of pesticides in surface water.

Pesticides from agricultural nonpoint-source runoff have been detected in surface water in a number of states, including New Jersey. A regulatory water-quality monitoring program was mandated by New Jersey's Safe Drinking Water Act (A-280) as part of an effort to examine the issue of pesticide contamination of drinking water and to develop a list of pesticides to be included in the routine monitoring of surface-water quality by water purveyors. Many of the agricultural chemicals currently (1992) used in New Jersey are not included in the monitoring program, however.

In 1990, the U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Environmental Protection and Energy (NJDEPE), conducted a two-phase study to investigate the presence of agricultural pesticides in six drainage basins used for public water supply in New Jersey and to determine if these pesticides threaten sources of potable water. During the first phase, a geographic information system (GIS) was used to evaluate land-use, pesticide, and political-boundary data bases to identify 6 drainage basins most susceptible to pesticide contamination of a total of 45 drainage basins used for public water supply across the State. During the second phase, a short-term, intensive surface-water-quality reconnaissance was conducted in the six basins to verify the presence of selected agricultural pesticides in the surface water.

Purpose and Scope

This report presents the results of a two-phase study conducted during 1990 to investigate the presence of selected pesticides in six drainage basins in New Jersey in which surface water is used for public water supply. The report includes maps of selected calculated pesticide-application rates in New Jersey generated by using a GIS, streamflow hydrographs for each of the six streams in the drainage basins for the sampling period, sampling methods, and results of analyses of 22 surface-water quality and 3 quality-assurance/quality-control samples collected from 7 sites.

Description of the Study Area

The initial study area consisted of 45 drainage basins used for public water supply located throughout New Jersey and 3 water-supply intakes located along the Delaware River (fig. 1). New Jersey's physiography, geology, and land use are described briefly below.

Physiography and Geology

New Jersey is divided by the Fall Line into two regions--northern New Jersey and the Coastal Plain (fig. 1)--which differ geologically, hydrologically, and topographically. Northern New Jersey is subdivided into three physiographic provinces. From northwest to southeast they are the Valley and Ridge (635 mi^2); the New England, or New Jersey Highlands (900 mi^2); and the Piedmont, or Piedmont Lowlands (1,500 mi^2). The Fall Line separates the Piedmont physiographic province from the largest province, the Coastal Plain, which encompasses 4,500 mi^2 (Wolfe, 1977, p. 207) (fig. 2).

The Valley and Ridge physiographic province consists of a series of northeast-southwest-trending ridges and valleys. The ridges are composed of Devonian and Silurian sandstones and conglomerates, whereas the valleys are carved from Devonian, Ordovician, and Cambrian limestones and shales (Wolfe, 1977, p. 204).

The New England physiographic province, also known as the Reading Prong, consists of a series of wide highlands interspersed with long, narrow valleys. The highlands are underlain by Precambrian gneisses and schists.

The valleys are underlain by fault-block inliers of Paleozoic limestones and shales that are bordered by Devonian sandstones, shales, and conglomerates, and Silurian conglomerates (Wolfe, 1977, p. 207).

The Piedmont physiographic province, or lowlands, is underlain by northwestward-dipping Jurassic and Triassic shales, siltstones, and sandstones. The sedimentary rocks form a broad, southeastward-sloping, hilly plateau. Ridges in this province are composed of Jurassic basalt extrusions and diabase intrusions (Wolfe, 1977, p. 207).

The Coastal Plain physiographic province consists of a series of unconsolidated deposits, mainly sand, with some clay, silt, and gravel. The Coastal Plain sediments dip gently to the southeast, toward the Atlantic Ocean, and range from coarse gravel and sand to clay. The mineralogy ranges from mostly quartz to mostly glauconite (Tedrow, 1986, p. 15). The formations range in age from Cretaceous to Tertiary and some areas are covered by Quaternary interglacial fluvial deposits (Wolfe, 1977, p. 207).

Land Use

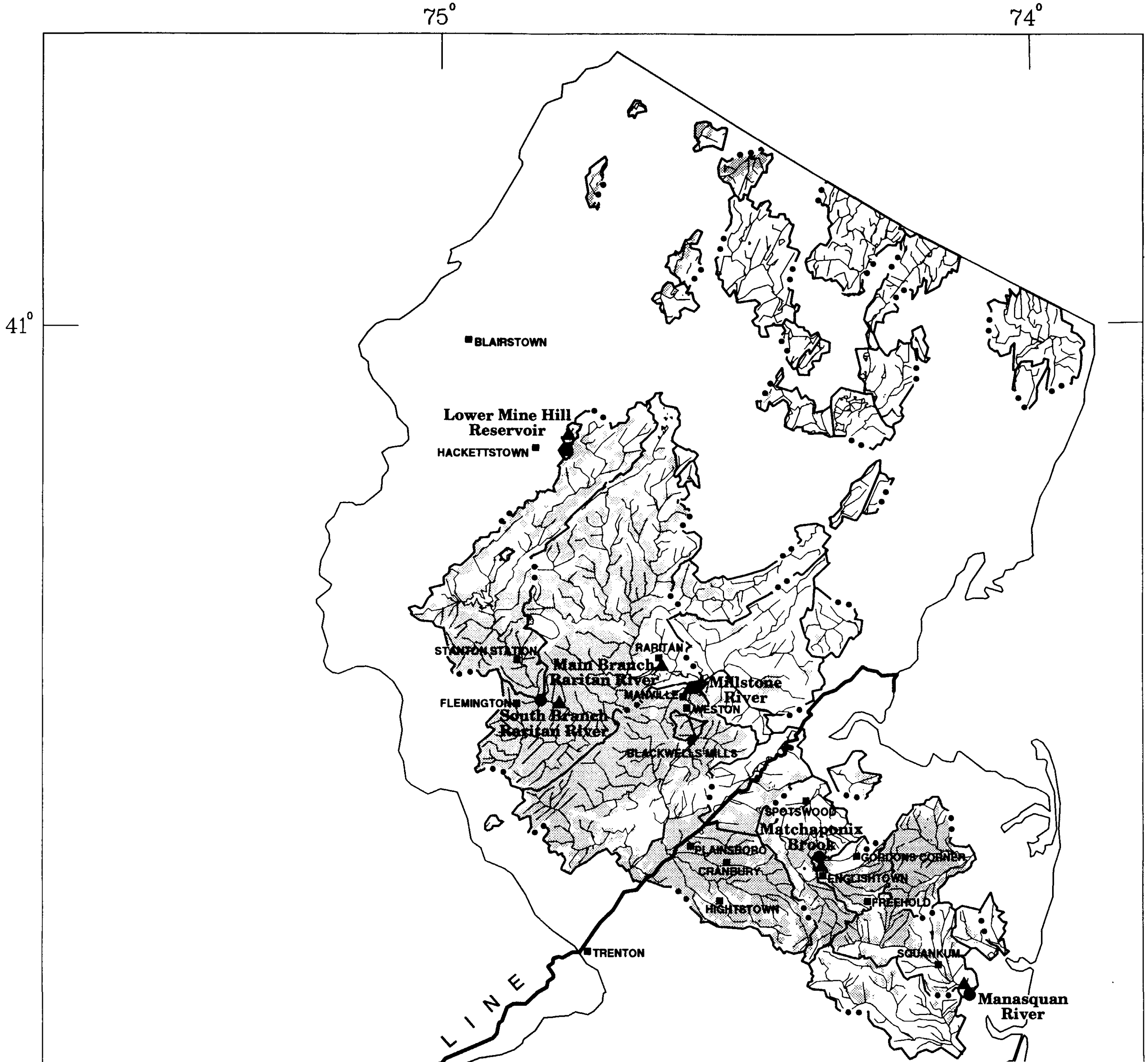
New Jersey is the most densely populated State in the country and demographically is predominantly suburban. Land use in New Jersey has changed through time as residential and industrial development spread out from the cities along the main roads. Service-based businesses are interspersed with residential neighborhoods, and the residential neighborhoods extend into rural areas (New Jersey Planning Commission, 1992, p. 19).

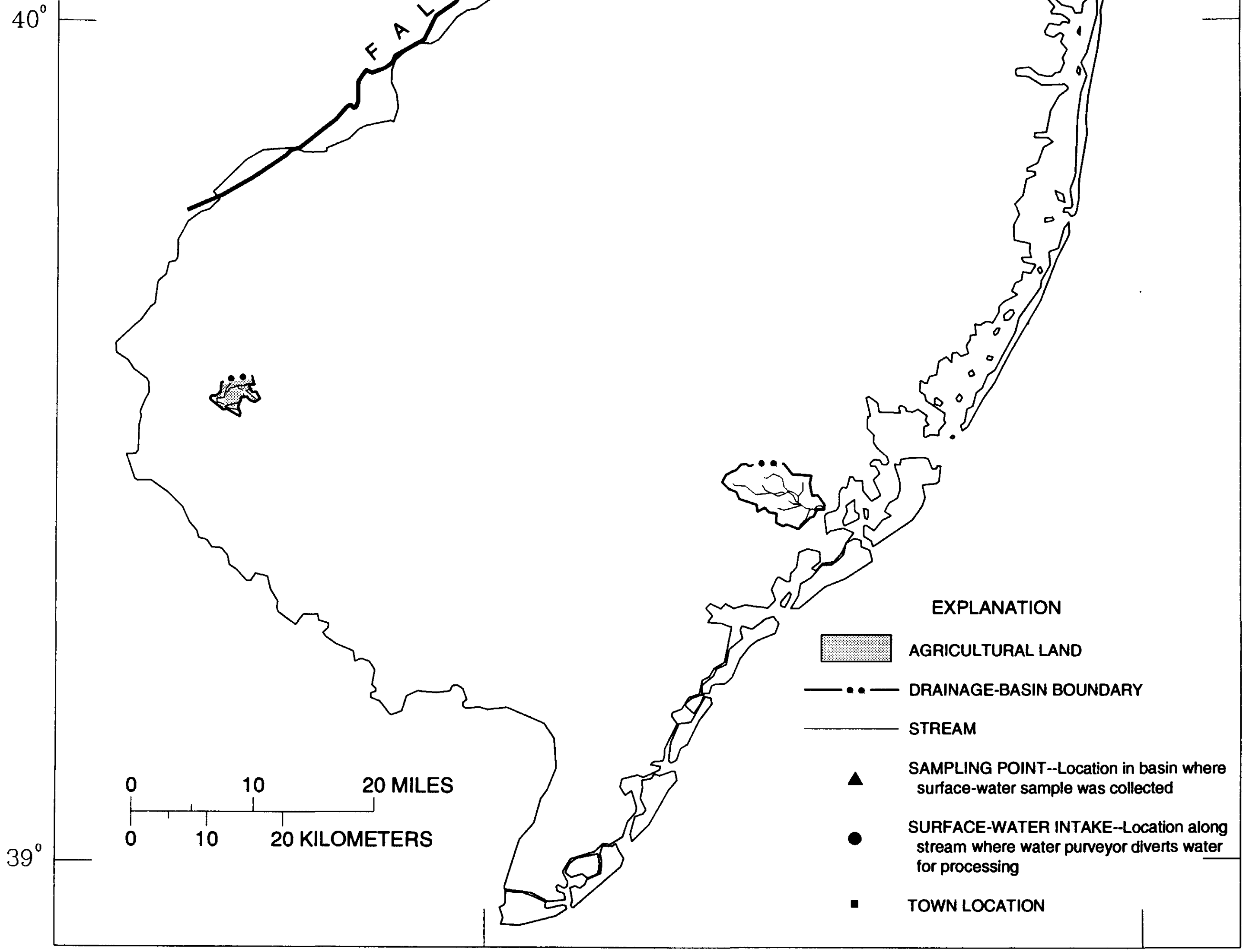
In 1972, residential areas covered 13.4 percent of the State, whereas commercial, industrial, and urban areas covered only 6.1 percent. Forested land covered more than 28.5 percent of the State at that time, surface-water bodies and wetlands covered 30.4 percent, and barren land (beaches and exposed rock) covered 1.5 percent. These percentages were calculated from the Earth Sciences National Cartographic Information Center's digital land-use data base and Anderson and others (1976).

In 1972, only 20 percent of the land in New Jersey was used for agriculture; however, as of 1992 that percentage had decreased to 18 percent (New Jersey State Planning Commission, 1992, p. 79). The intermixing of residential areas with farmland necessitated control of land development and freshwater supplies for drinking and irrigation. Many residential and urban areas throughout the State, especially those north of the Fall Line, obtain their drinking water from surface-water supplies (New Jersey State Planning Commission, 1992, p. 63). Most streams, rivers, and reservoirs that are used as sources of potable water originate in, or flow through, forested areas and agricultural land before they reach a water-treatment plant (fig. 1).

Results of Pesticide-Application Surveys

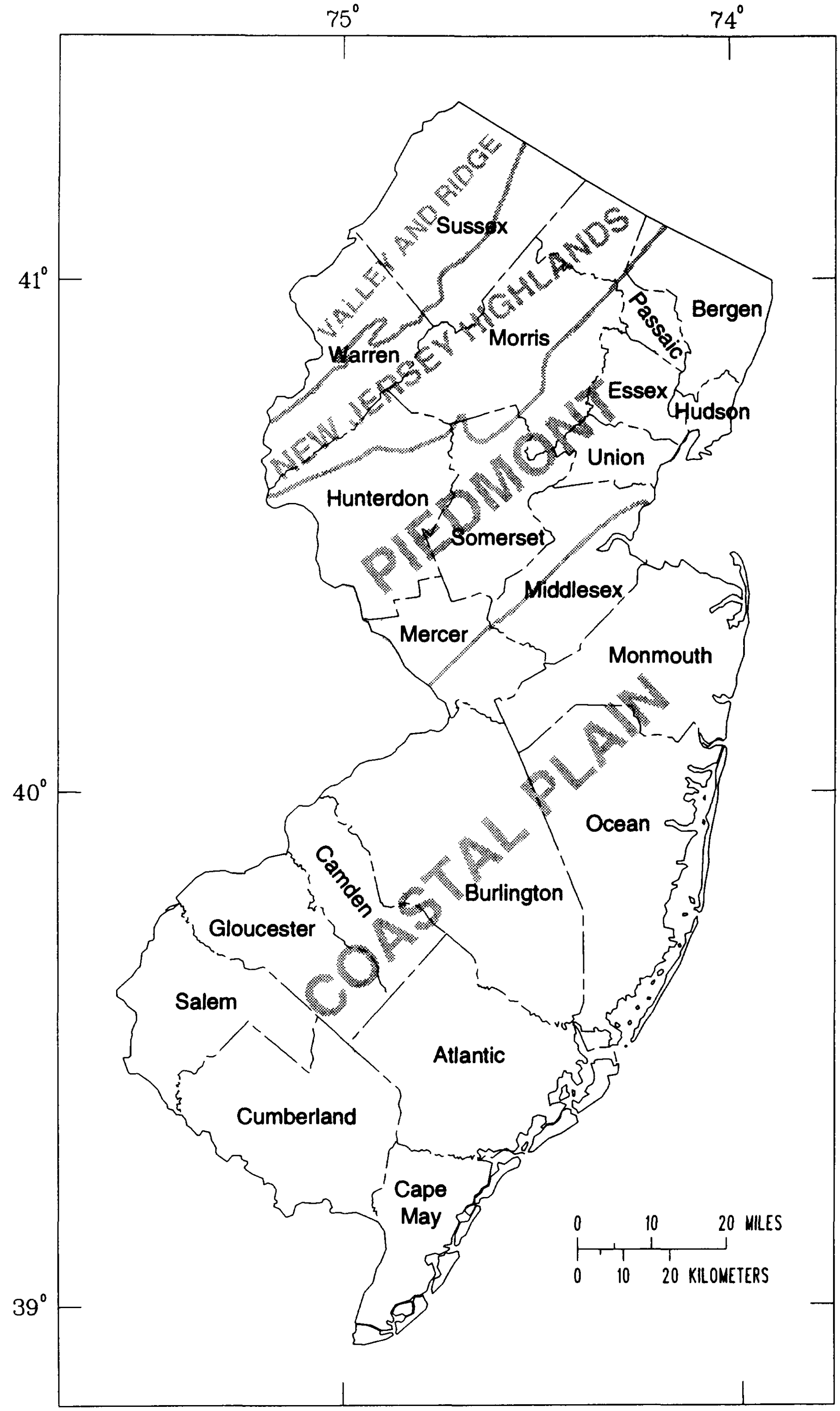
In 1985, NJDEPE, as part of the Pesticide Control Program (PCP), conducted a mail survey of the certified agricultural-pesticide applicators in the State. The questionnaire included type of pesticide applied, number of acres treated, type of crop treated, method of application, and the


75°
74°
41°
BLAIRSTOWN
Lower Mine Hill Reservoir
HACKETTSTOWN
STANTON STATION
Main Branch Raritan River
RARITAN
Millstone River
MANVILLE
WESTON
FLEMINGTON
South Branch Raritan River
BLACKWELLS MILLS
SPOTSWOOD
Matchaponix Brook
PLAINSBORO
GORDONS CORNER
CRANBURY
ENGLISHTOWN
FREEHOLD
HIGHTSTOWN
SQUANKUM
Manasquan River
TRENTON
LINE



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972,
Universal Transverse Mercator projection, Zone 18

Figure 1.--Forty-five surface-water supply basins, six selected intakes and their associated drainage basins, and agricultural land use in New Jersey.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972, Universal Transverse Mercator projection, Zone 18

Figure 2.--County boundaries and the four physiographic provinces in New Jersey.

municipality in which the treated acres were located. A total of 1,721 applicators, or 75 percent of the farmers in the State, returned the questionnaire (Louis and others, 1989, p. 197). Survey data from about 15 percent of the applicators were checked for accuracy. Fungicides were used in the largest quantity, followed by herbicides and insecticides. The most heavily applied pesticides in each category were sulfur, alachlor, and parathion, respectively (Louis and others, 1989, p. 201).

A second PCP survey was conducted in 1988. This survey included the same categories as the 1985 survey, with the addition of the applicators' license number and specific categories of crop type. Results of the 1988 survey showed that fungicides were again the most heavily used pesticides, followed by insecticides and herbicides. Fungicides were used mostly on tree and small fruit farms. Use of sulfur, the primary fungicide, increased from 327,099 pounds of active ingredient in 1985 to 448,662 pounds in 1988 (Louis and others, 1990, p. 5).

In 1988, the insecticide sodium alumino fluoride received an emergency exemption under the Federal Insecticide, Fungicide and Rodenticide Act, which raised the limit on the quantity of insecticides that could be applied that year. A total of 158,000 pounds of the insecticide was used to combat the Colorado potato beetle (Louis and others, 1990, p. 15). Metolachlor was the herbicide applied in the largest quantity in 1988 (Louis and others, 1990).

Related Investigations

Several previous studies documented the presence of pesticides in ground water and surface water. A study conducted in the mid-continent by Burkart and others (1988) focuses on the effects of environmental and human factors on the presence of herbicides in ground water and surface waters in nine states from South Dakota to Ohio. Goolsby and Thurman (1990) and Squillace and Engberg (1988) also discussed agricultural nonpoint-source contamination in the mid-continent. Baker (1988) and Baker and Richards (1989) conducted detailed, long-term sediment-transport and pesticide-transport studies of selected lower Great Lakes tributaries. In New Jersey, Vowinkel and Battaglin (1988) and Louis and Vowinkel (1989) investigated the presence of pesticides in ground water in Coastal Plain aquifer systems.

Several studies were conducted to evaluate the effects of field runoff and pesticide content on surface-water quality. Glotfelty and others (1984) studied the movement of atrazine and simazine in Maryland from cornfields to the Wye River estuary. Hall (1974) studied the loss of s-Triazine from Pennsylvania cornfields. Wauchope (1978) summarized current literature on the loss of pesticides from agricultural fields in several States.

Acknowledgments

The authors thank Judy Louis and Paul Sanders of the NJDEPE and Roy Meyer and Curt Brown of the NJDEPE Pesticide Control Program for supplying the information on, and the results of, the pesticide surveys. The authors also thank the Hackettstown Municipal Utilities Authority, Elizabethtown Water Company, and New Jersey Water Supply Authority for allowing the collection of treated-water samples from their treatment plants.

STUDY METHODS

The first phase of the study required the identification of those drainage basins used for public water supply in which concentrations of agricultural pesticides in surface water potentially could be high. Surface-water samples were collected and analyzed to verify the presence of pesticides in selected basins.

Calculation of Pesticide-Application Rate

The first step in calculating the pesticide-application rates was to locate all of the active surface-water public-supply intakes in New Jersey and their associated drainage basins. The NJDEPE provided a list, compiled in 1987, of water purveyors and locations of surface-water intakes in the State. The locations and status (active or inactive) of the intakes were verified by the purveyors. Active intakes totaled 48, three of which are located along the Delaware River. The GIS was used to analyze the land-use data, pesticide-use data, and municipal-boundary data for each basin. The coverages (types of computerized geographic information) used to estimate the rate of pesticide applications in each basin for both the 1985 and 1988 pesticide-survey data are listed in table 1. The locations of the 48 intakes and the associated drainage-basin boundaries used in the study are shown in figure 3. Delaware River intakes 1, 9, and 41 were not included in the analysis because the associated drainage basin receives drainage from neighboring States.

The pesticide-application data were reported as the number of pounds of active ingredient. The basin-selection process required that input data be expressed as a calculated pesticide-application rate, in units of pounds of active ingredient per agricultural square mile.

The 1985 pesticide-application data were inventoried and recorded in a computer data file by matching the address reported by the individual farmer to the appropriate township or municipality; thus, the active ingredient of each compound was totaled by township or municipality.

Agricultural-land-use coverage data stored in the New Jersey District GIS data library (table 1), combined with the basin coverage data, can be used to produce a map showing agricultural land within each basin (fig. 1). The agricultural land-use coverage is classified by using remote sensor land-use data obtained from high-altitude aerial photographs. The classification system is based on work done by Anderson and others (1976). Agricultural land is divided into four subclasses of which only two were of interest in this study. Class 21 includes cropland and pasture, and class 22 includes orchards, groves, vineyards, nurseries, and ornamental horticulture farms.

ARC/INFO[1] was used to combine basin-boundary and agricultural-land-use data with municipal-boundary and pesticide-use data in order to generate a third coverage. The new coverage consists of part of the township that is

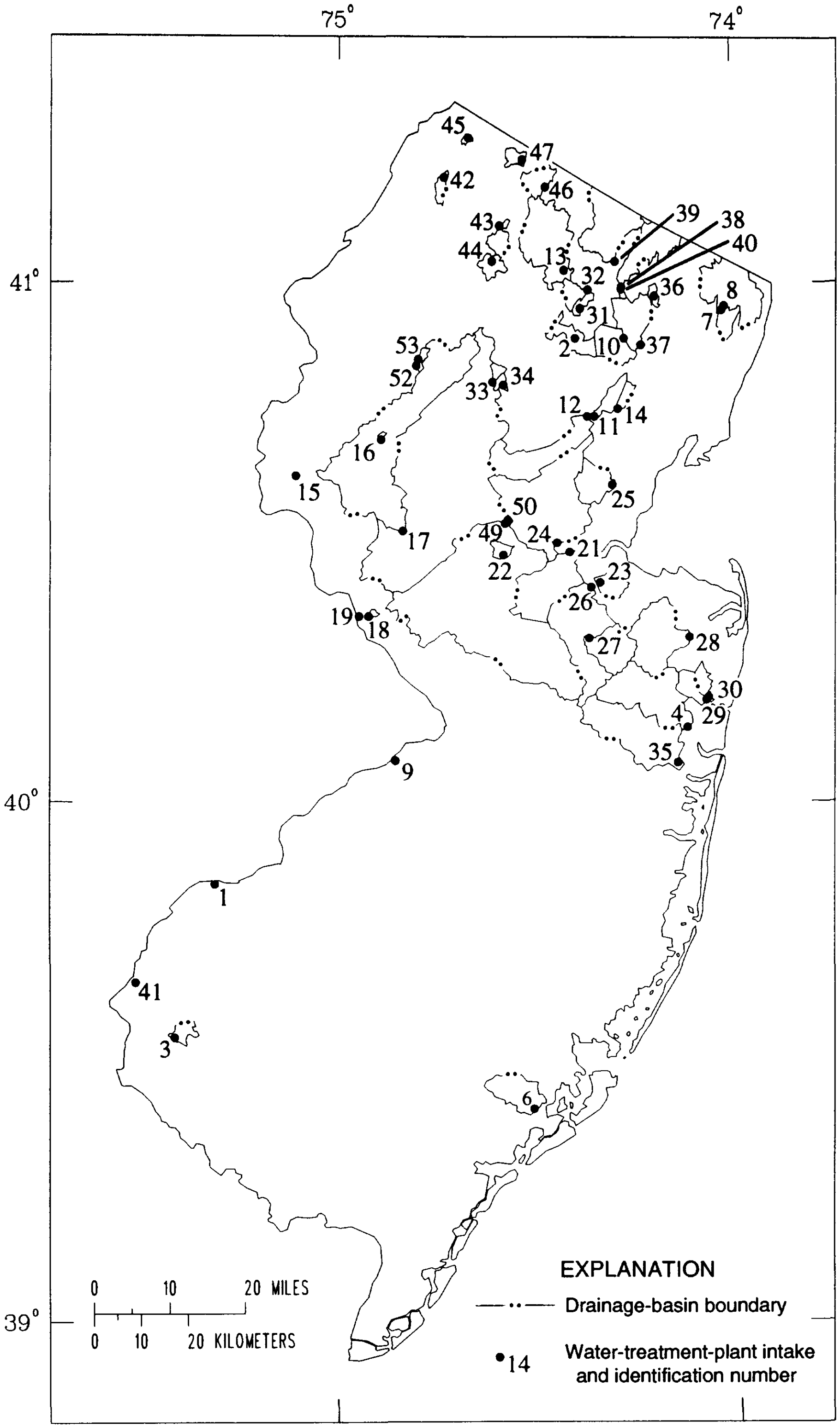
---

[1] Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 1.--Geographic Information System coverages used to determine calculated pesticide-application rates and to select potential surface-water sampling basins

[USGS, U.S. Geological Survey; NJDEPE, New Jersey Department of Environmental Protection and Energy; GIS, Geographic Information System]

GIS coverage and map scale	Source of Information	Description
Land use (1:250,000)	USGS Earth Sciences Information Center	Land-use classification system from Anderson and others, 1976.
Drainage-basin divides and streams	USGS New Jersey District	Interpreted from 1:24,000-scale topographic quadrangles
State, county, and municipal boundaries	USGS New Jersey District	Digitized from 1:24,000-scale topographic quadrangles
Surface-water intakes for public-supply utilites	NJDEPE Bureau of Safe Drinking Water	45 active sites in 1990
Pesticide use	NJDEPE Pesticide Control Program	Compounds reported by farmers in surveys in 1985 and 1988



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972, Universal Transverse Mercator projection, Zone 18

Figure 3.--Locations of public-supply water-treatment-plant intakes and associated drainage basins in New Jersey.

located within each basin boundary, the percentage of land in the basin that is used for agriculture, and the amount of pesticides applied within the townships. The application rates for townships within each individual basin were summed, and this value was divided by the percentage of agricultural land in the basin to produce a calculated average weighted pesticide-application rate. The calculated pesticide-application rates were used to identify the basins in which the greatest amounts of pesticides per agricultural square mile were applied. The land-use calculations were applied to the basin area upstream from the intake, rather than to the basin area upstream from the sampling point. Pesticide concentrations in runoff from the unaccounted-for basin area were assumed to be minimal because land use surrounding the intakes generally is suburban or urban.

Selection of Study Basins

The calculated application rates of pesticides and the percentage of agricultural land within a basin were the primary factors used to select those basins most vulnerable to pesticide contamination. The 1985 calculated pesticide-application rates for selected compounds in the 45 drainage basins are shown in table 2. The 1988 calculated pesticide-application rates (table 3) also were calculated by using the same procedure described above, but the 1988 pesticide-survey data were received too late to be included in the basin-selection process. Although the 1988 pesticide-survey results were not used in the basin-selection process, the results are included in this report to give a more current representation of agricultural conditions during sampling.

Many of the calculated pesticide-application rates for 1988 were much lower--in some basins an order of magnitude lower--than the calculated rates for 1985; however, the same basins would have been selected with the possible exception of the Manasquan River basin. Examples of calculated pesticide-application maps generated from 1985 pesticide-application data--those for alachlor, atrazine, and metolachlor--are shown in figures 4, 5, and 6, respectively. Basins with high calculated application rates for several pesticides and basins with significant rates for only one or two compounds were considered for the study. Rivers or streams with bridge sites or sites convenient for wading were selected for water-quality sampling. In addition, the sampling sites chosen for the study were close to the intakes and streamflow-gaging sites. Surface-water intakes used only part of the year, only in emergency situations, or for recharge purposes were not considered as potential sampling sites.

The six basins chosen for the study--Lower Mine Hill Reservoir, South Branch of the Raritan River, Main Branch of the Raritan River at Raritan, Millstone River, Matchaponix Brook, and Manasquan River--fulfilled all of the selection criteria. The basins, surface-water intakes, and towns in which sampling sites are located are shown on figure 1.

Collection of Surface-Water Samples

Base-flow samples were collected to determine background pesticide concentrations. Several investigators including Baker, 1988; Baker and Richards, 1989; and Wauchope, 1978 reported increased pesticide concentrations during stormflow conditions; therefore, stormflow samples

Table 2.--Selected calculated pesticide-application rates in drainage basins above public surface-water-supply intakes, 1985

[All values in pounds per agricultural square mile]

Intake identification number[1]	Water source	Alachlor	Atrazine	Carbaryl	Cyanazine	Diazinon	Metolachlor	Simazine
2	Boonton Reservoir	0.24	18.55	12.02	0.24	3.56	0.00	0.62
3	Laurel Lake	.00	.00	.00	.00	.00	.00	.00
4	Manasquan River	40.18	4.87	2.27	1.19	.16	7.99	.08
6	Doughty Pond	599.21	23.92	102.46	.00	170.42	.00	.00
7	Hackensack River	.00	.00	.00	.00	.00	.00	.00
8	Oradell Reservoir	4.15	1.36	.07	.00	.00	.00	.28
10	Pompton River	.16	22.48	25.88	.16	.00	1.13	.00
11	Passaic River	10.08	8.39	1.93	.00	.51	.00	.00
12	Canoe Brook	.00	.00	.00	.00	.00	.00	.00
13	Pequannock Watershed	104.73	.00	.64	.00	.64	.57	.00
14	West Branch Rahway River	.00	.00	.00	.00	.00	.00	.00
15	Pine Hollow	6.81	21.81	.07	1.36	.00	81.77	.39
16	Willoughby Brook	.00	.00	1.71	.00	.00	.00	4.68
17	South Branch Raritan River	23.54	13.85	1.32	24.33	.02	9.02	1.81
18	Swan Creek East	4.61	9.47	8.76	19.09	.00	14.43	.00
21	Lawrence Brook	.51	1.98	12.58	.04	4.79	10.03	2.23
22	Delaware Raritan Canal	35.63	17.13	.44	.00	.04	9.48	9.69
23	Tennent's Creek	8.07	73.94	6.99	152.39	.03	12.92	.00
24	Delaware Raritan Canal	7.10	4.77	38.37	.00	.11	3.68	.19
25	Robinsons Brook	.00	.00	.03	.00	.00	.00	.00
26	South River	37.49	26.81	16.39	34.24	1.07	6.12	.15
27	Matchaponix Brook	159.94	52.64	13.08	7.14	.62	3.69	.01
28	Swimming River Reservoir	129.56	47.44	11.54	6.83	4.89	9.13	2.66
29	Shark River	.19	3.36	.14	.19	.70	1.65	.43
30	Jumping Brook	.00	.00	.00	.00	.00	.00	.00
31	Taylortown Reservoir	.51	2.44	22.27	.51	.00	.00	.00
32	Kakeout Reservoir	.03	.16	1.42	.03	.00	.00	.00
33	India Brook	16.62	.00	.10	.00	.00	.00	.00
34	Clyde Potts Reservoir	6.23	.00	.04	.00	.00	.00	.00
35	Metedeconk River	21.82	12.17	10.46	.61	5.02	4.50	3.89
36	Molly Ann's Reservoir	2.08	2.08	115.02	.00	340.61	.00	.00

Table 2.--Selected calculated pesticide-application rates in drainage basins above public surface-water-supply intakes, 1985--Continued

Intake identification number[1]	Water source	Alachlor	Atrazine	Carbaryl	Cyanazine	Diazinon	Metolachlor	Simazine
37	Passaic River	15.05	15.30	77.35	0.00	6.91	0.01	0.00
38	Ramapo River	.39	.39	.20	.00	13.63	.00	.00
39	Wanaque Reservoir	103.39	.00	.00	.00	.00	.00	.00
40	Ramapo River	15.84	15.84	7.95	.00	63.82	.00	.00
42	Dry Brook Reservoir	.00	.00	.00	.00	.01	.00	.00
43	Wallkill River	.00	8.98	.01	.00	.64	.55	.00
44	Lake Morris	.00	.00	.00	.00	2.10	.00	.00
45	Lake Rutherford	.00	.66	2.06	7.87	.00	.00	.00
46	Pochuck Creek Reservoir	.00	.00	.74	.00	1.05	3.16	.00
47	Wallkill Lake	.00	.25	1.32	3.05	.75	2.24	.00
49	Millstone River	403.13	88.55	7.79	5.94	2.86	22.26	2.69
50	Millstone/Raritan	29.70	41.67	1.78	14.84	.46	8.82	4.73
52	Burd Reservoir	15.03	16.35	3.02	34.70	.00	20.39	1.79
53	Lower Mine Hill Reservoir	.00	.00	.00	.00	.00	.00	.00

[1] Intake identification number shown in figure 3.

Table 3.--Selected calculated pesticide-application rates in drainage basins above public surface-water-supply intakes, 1988

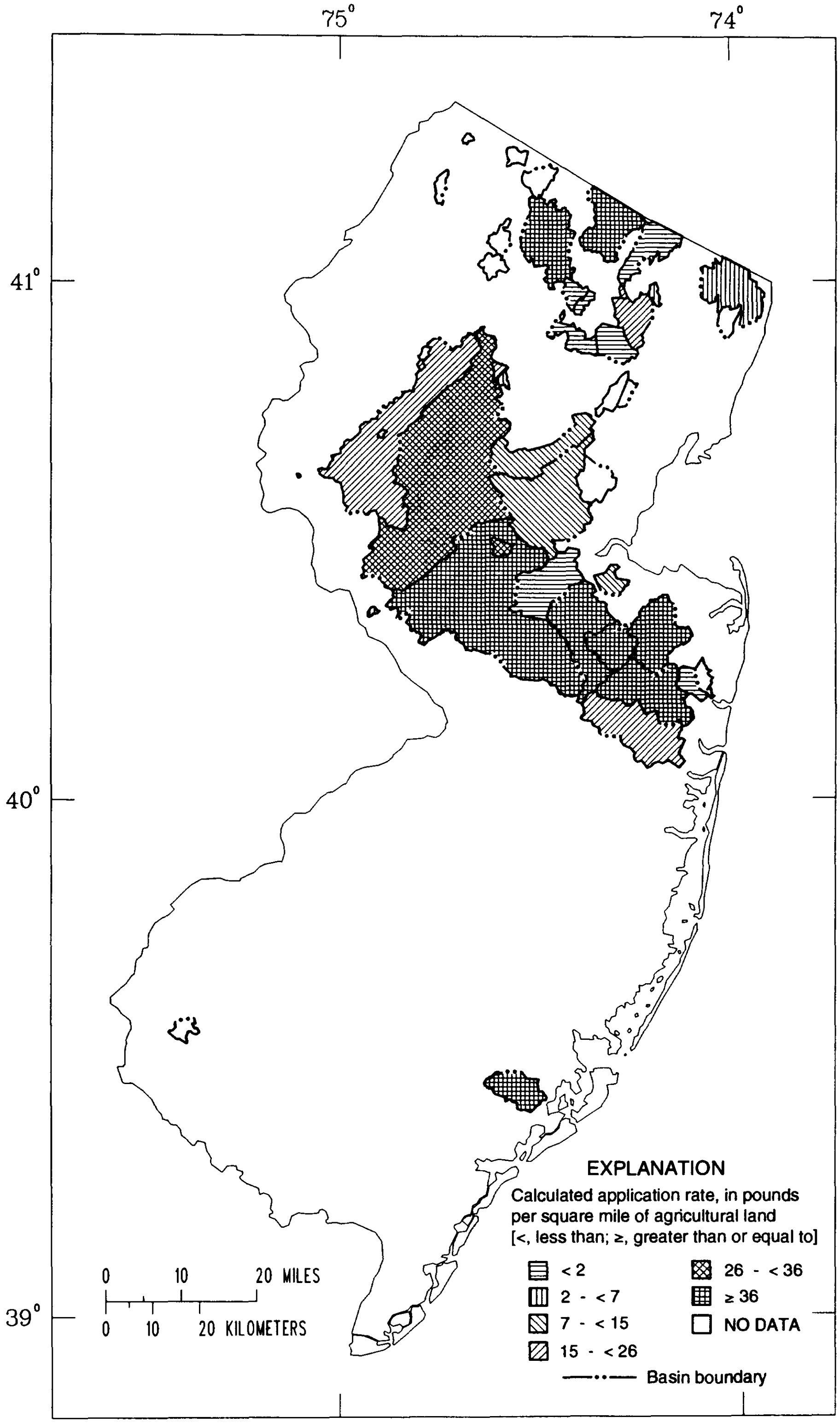
[All values in pounds per agricultural square mile; *, application rate less than 0.01]

Intake identification number[1]	Water source	Alachlor	Atrazine	Carbaryl	Cyanazine	Diazinon	Metolachlor	Simazine
2	Boonton Reservoir	1.10	0.70	22.80	22.80	1.80	6.40	0.60
3	Laurel Lake	.00	.00	*	.00	.00	.00	.00
4	Manasquan River	3.20	6.10	2.70	2.70	3.30	8.30	1.70
6	Doughty Pond	203.9	275.10	*	.00	19.00	.00	*
7	Hackensack River	.00	.00	.00	.00	*	.00	.00
8	Oradell Reservoir	.00	.00	*	.00	*	.00	10.00
10	Pompton River	8.00	7.10	.30	.30	1.30	.00	.00
11	Passaic River	.00	.00	*	.00	.00	.00	3.50
12	Canoe Brook	.00	.00	.00	.00	.00	.00	.00
13	Pequannock Watershed	1.30	4.60	*	.00	.00	.00	.00
14	West Branch Rahway River	*	.00	.00	.00	.00	.00	.00
15	Pine Hollow	*	3.30	*	*	*	2.60	.60
16	Willoughby Brook	.00	.30	.00	.00	.00	.60	.00
17	South Branch Raritan River	15.30	26.90	15.10	15.10	*	32.00	.60
18	Swan Creek East	42.50	17.70	7.80	7.80	*	4.50	.00
21	Lawrence Brook	14.70	6.80	.10	.10	5.20	6.50	1.10
22	Delaware Raritan Canal	6.60	10.30	.00	.00	45.50	24.30	.20
23	Tennent's Creek	.00	.00	*	.00	*	.00	.00
24	Delaware Raritan Canal	.10	2.50	*	.00	*	8.70	.00
25	Robinsons Brook	.00	.00	.03	.00	*	.00	.00
26	South River	26.10	10.80	12.20	12.20	1.60	17.50	.50
27	Matchaponix Brook	16.20	12.90	10.80	10.80	6.90	17.20	1.20
28	Swimming River Reservoir	23.50	10.80	9.50	9.50	5.40	15.60	.30
29	Shark River	1.80	2.30	.30	.30	1.60	3.20	.00
30	Jumping Brook	.00	.00	.00	.00	.00	.00	.00
31	Taylortown Reservoir	2.30	1.40	.90	.90	.00	.00	.00
32	Kakeout Reservoir	.10	.10	.10	.10	.00	.00	.00
33	India Brook	.00	6.90	.00	.00	.00	.00	41.50
34	Clyde Potts Reservoir	.00	2.60	.00	.00	.00	.00	15.60
35	Metedeconk River	12.80	13.20	2.80	2.80	20.30	5.10	.90
36	Molly Ann's Reservoir	.00	.00	*	.00	1.20	.00	.00

Table 3.--Selected calculated pesticide-application rates in drainage basins above public surface-water-supply intakes, 1988--Continued

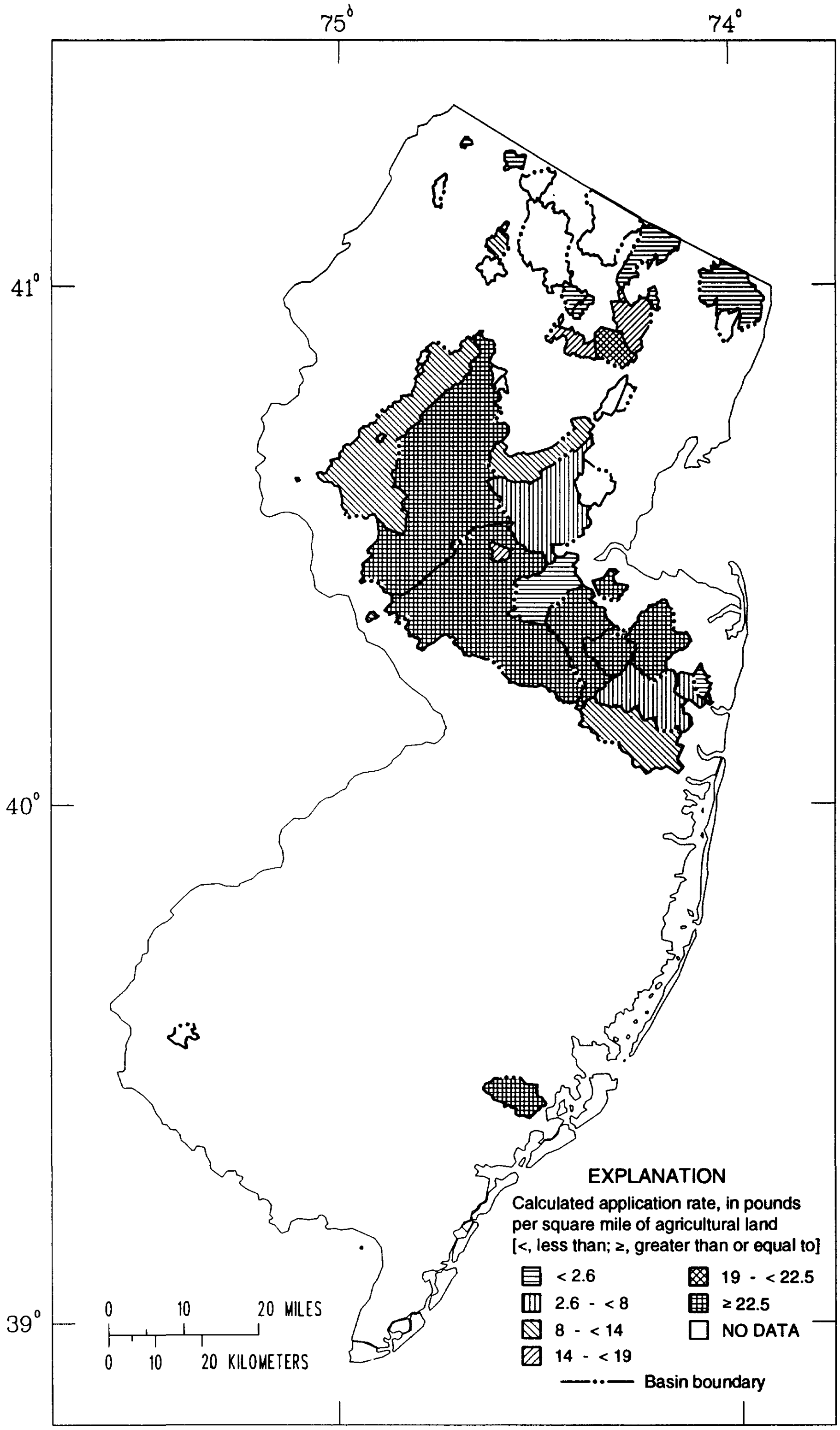
Intake identification number[1]	Water source	Alachlor	Atrazine	Carbaryl	Cyanazine	Diazinon	Metolachlor	Simazine
37	Passaic River	0.10	0.10	0.00	0.00	14.00	0.00	0.00
38	Ramapo River	.00	.00	*	*	.20	.00	.00
39	Wanaque Reservoir	.00	3.70	.30	.30	.00	.00	.00
40	Ramapo River	.00	.00	.00	.00	11.70	.00	.00
42	Dry Brook Reservoir	.00	.00	.00	.00	.02	.00	.00
43	Walkill River	.00	4.80	*	.00	.00	6.30	1.30
44	Lake Morris	.00	.00	.00	.00	.00	.00	.00
45	Lake Rutherford	.10	8.70	2.20	2.20	*	10.00	.10
46	Pochuck Creek Reservoir	7.20	4.30	*	.00	.00	.00	.00
47	Wallkill Lake	5.10	6.40	.90	.90	*	3.90	*
49	Millstone River	30.80	137.70	5.70	5.70	15.30	423.80	1.90
50	Millstone/Raritan	14.60	15.90	7.40	7.40	5.80	19.10	1.20
52	Burd Reservoir	30.40	65.70	15.70	15.70	.00	82.0	.50
53	Lower Mine Hill Reservoir	.00	41.20	*	.00	.00	54.1	.00

[1] Intake identification number shown in figure 3.



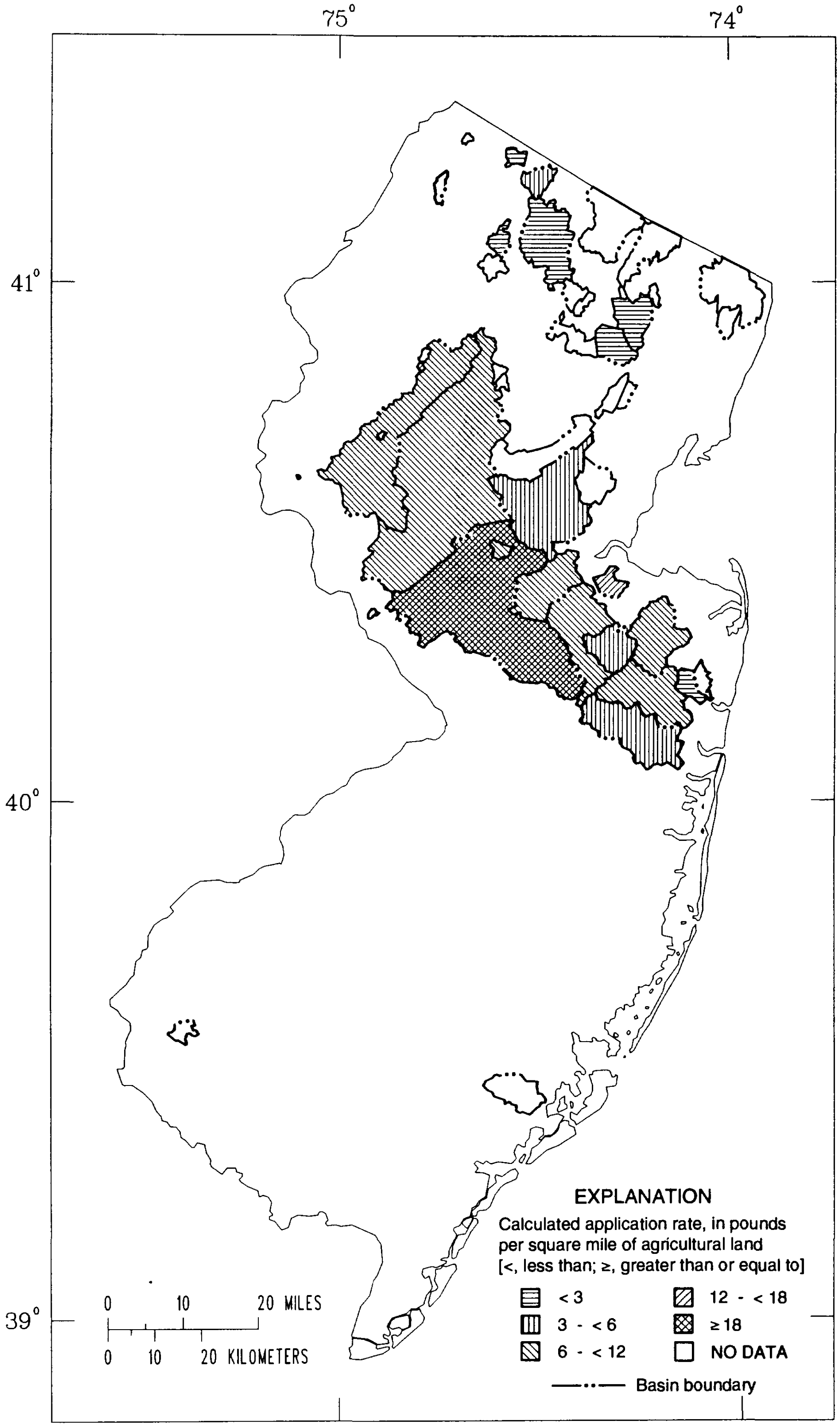
Base from U.S. Geological Survey digital data, 1:2,000,000, 1972, Universal Transverse Mercator projection, Zone 18

Figure 4.--Calculated pesticide-application rates for alachlor in drainage basins used for public supply, 1985.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972,
Universal Transverse Mercator projection, Zone 18

Figure 5.--Calculated pesticide-application rates for atrazine in drainage basins used for public supply, 1985.



Base from U.S. Geological Survey digital data, 1:2,000,000, 1972, Universal Transverse Mercator projection, Zone 18

Figure 6.--Calculated pesticide-application rates for metolachlor in drainage basins used for public supply, 1985.

were collected to determine pesticide concentrations during high flows. Base-flow and stormflow samples were collected by either wading or bridge suspension techniques as described by Guy and Norman (1970) and Ward and Harr (1990).

Sampling points were determined by using the method of equal width increments (EWI) across the stream. A measuring wire was used to mark the sampling points, and an equal-transit-rate (ETR) technique was used to collect samples at all points (Guy and Norman, 1970; Ward and Harr, 1990). Twenty-five surface-water samples--22 water-quality samples and 3 QA/QC samples--were collected at 7 surface-water-sampling sites. Water-quality samples included 14 base-flow samples and 8 stormflow samples.

A DH-48 depth-integrating sampler was used for base-flow or small-stream sampling. A DH-59 depth-integrating sampler was used in conjunction with a bridge board or bridge crane for river and stormflow sampling. (Guy and Norman, 1970). Specific conductance, water temperature, and pH were measured at each site. Silicone gaskets and brass nozzles were used initially in each sediment sampler. Teflon gaskets and nozzles were used to collect the final base-flow sample.

One-pint glass bottles were used in the samplers. A new pint bottle was used at each sampling site. Unfiltered water was composited in a 4-L organic-free baked brown-glass bottle. A glass funnel was used to aid in compositing the sample. The bottle was labeled and chilled on ice, and was transported to the laboratory within 24 hours.

Prior to sampling and upon return from the field, the glass bottles, glass funnels, and sampler were cleaned and decontaminated according to established USGS protocols (Wayne Webb, U.S. Geological Survey, written commun., 1990). The steps are as follows:

1. Wash with low-phosphate detergent;
2. rinse with tap water;
3. rinse with 50-percent methanol;
4. rinse with distilled, deionized water; and
5. air dry.
6. If not used immediately, wrap with aluminum foil.

This procedure was also used to clean and decontaminate the sampler and glass funnels between sampling sites.

Chemical Analysis of Surface-Water Samples

Surface-water quality samples were analyzed at the Rutgers University Food and Science Department Laboratory (hereafter called the Rutgers Lab) in New Brunswick, New Jersey. The laboratory is approved by the NJDEPE for pesticide analyses. Samples were extracted by passing the water through glass-wool plugs to remove large suspended-solid particles. Complete sample-extraction procedures and analytical methods for gas chromatography/chemical ionization mass spectrometry (GC/CIMS) are described in Mattern and Rosen (1991). The 21 pesticides determined in this study were chosen by NJDEPE on the basis of toxicity and high usage. Twenty of the pesticides were determined by means of GC/CIMS, and one pesticide, 2,4-D, was determined by using an immunoassay method. The samples, in order to be representative of water used for drinking-water supply, were not shaken prior to analysis. The compounds detected were those in the dissolved fraction, those in the colloidal fraction, and those adsorbed on the colloidal fraction.

The same samples were analyzed for 2,4-D by means of immunoassay by using the Res-I-Mune test kit. This commercial test kit provides an economical method for determining a pesticide concentration semi-quantitatively by using a colorimetric test. The samples are processed in vials pretreated with reagents that are supplied with the kit. The semi-quantitative concentration of 2,4-D is determined by means of spectrophotometry with absorbance at 450 nanometers (Immunosystems, Inc., 1989). The pesticides determined by using both methods and constituent reporting levels are listed in table 4.

Quality-Assurance/Quality-Control Procedures

Adherence to established quality-assurance/quality-control (QA/QC) procedures is vital to the validation of water-quality data. QA/QC in this project was monitored during sample collection and analysis by means of trip blanks and by comparing differences in concentrations of compounds in the sequentially collected surface-water samples.

Sample Collection

Sequentially collected samples and trip blanks were used for QA/QC. Sequentially collected samples are a type of replicate sample in which the samples are collected consecutively one after the other, typically over a short period of time, whereas a trip blank is a laboratory-provided organic-free, distilled, deionized water that is put in the same type of bottle used for environmental water-quality samples and is kept with the set of sample bottles both before and after sample collection (William Shampine, U.S. Geological Survey, written commun., 1990). Hereafter in this report, the first sample collected in a set of consecutively collected samples is called simply "the sample;" the second sample collected is called "the sequentially collected sample." Field instruments, pH and specific-conductance meters, were calibrated each morning at the first site and were checked for drift at subsequent sites throughout the day. The instruments were recalibrated when necessary.

Chemical Analysis

Rutgers laboratory QA/QC methods for the instruments included recovery studies, sensitivity determinations, and calibration checks. The GC/CIMS was adjusted regularly by use of decafluorotriphenyl phosphine to meet instrument performance specification. Ten percent of the samples were consecutively collected samples that were submitted "blind" (unknown QA/QC sample) to the laboratory. All water-quality samples met the U.S. Environmental Protection Agency (USEPA) recommended holding-time criteria.

Table 4.--Pesticides determined in water-quality samples by means of gas chromatography/chemical ionization mass spectrometry and immunoassay methods and reporting levels, June-September 1990

[All reporting levels in micrograms per liter]

Chemical class and pesticide	Reporting level
Gas Chromatography/Chemical Ionization Mass Spectrometry	
Triazine	
Atrazine	0.03
Cyanazine	.03
Metribuzin	.03
Simazine	.03
Acetanilide	
Alachlor	.03
Linuron	.03
Metolachlor	.03
Pendimethalin	.03
Carbamate	
Butylate	.03
Carboryl	.03
Carbofuran	.03
Organophosphate	
Chlorpyrifos	.03
Diazinon	.03
Fenamiphos	.03
Fonophos	.03
Isofenphos	.03
Parathion	.03
Terbofos	.03
N-Sulfenylphthalimide	
Captan	1.00
Benzonitrile	
Chlorothalonil	1.00
Immunoassay Method	
Chlorophenoxyacetic acid	
2,4-D	.50

Results of Quality-Assurance/Quality-Control Procedures

The results of analyses of water-quality and QA/QC samples for physical properties and pesticides are given in table 5. Maximum and minimum concentrations of pesticides detected in base-flow and stormflow samples are listed in table 6. No contaminants were detected in any of the trip blanks (table 5). Concentrations of compounds that exceeded the USEPA's recommended Lifetime Health Advisory Limits (LHAL) (U.S. Environmental Protection Agency, 1989) also are given in table 6.

The relative percent difference (RPD) was calculated for constituents detected in concentrations greater than the analytical minimum reporting level. The RPD is the percentage of sampling and laboratory error between concentrations of a detected pesticide in two consecutively collected samples. The RPD is calculated by subtracting the concentration of the pesticide in the sample from the concentration of the pesticide in the sequentially collected sample and dividing the absolute value of the result of the subtraction by the average of the concentration in the sample and the concentration in the sequentially collected sample. The RPD cannot be calculated if one of the samples in the set of two consecutively collected samples contains only a trace concentration of the pesticide. The RPD was calculated for three sets of two consecutively collected samples (table 7). The RPD for the two consecutively collected samples from Matchaponix Brook was the highest (41 percent for carbaryl). The RPD for the Lower Mine Hill Reservoir samples was the next highest (atrazine, 13.3 percent). The RPD's for other compounds in the consecutively collected samples from Matchaponix Brook were less than 5 percent.

Collection of Pretreated- and Treated-Water Samples

Water samples were collected before treatment at a water company's intake and after treatment from a tap within the plant. The Main Branch of the Raritan River, the Millstone River, and the Delaware-Raritan Canal all supply water for the Elizabethtown Water Company. Pretreated water samples were collected at the intake at the confluence of the Raritan and Millstone Rivers, thereby combining two sources in a single sample. Treated water in the plant is derived from a conglomerate of the three sources. Samples also were collected from Lower Mine Hill Reservoir at the Hackettstown Municipal Utilities Authority water-treatment plant and from the New Jersey Water Supply Treatment Plant on the Manasquan River. No samples were collected at the South Branch of the Raritan River or Matchaponix Brook because the intakes were not active.

DESCRIPTION OF STUDY BASINS

The following sections describe the geographic and physiographic characteristics of the six surface-water-supply basins selected for study. Information on sampling sites, streamflow-gaging stations, and agricultural land use in each basin also is provided.

Table 5.--Physical properties and concentrations of pesticides detected in surface-water samples collected from the six study basins, June-September 1990

[ft^3/s, cubic feet per second; --, data not available; *, sample in sequential set 1; **, sample in sequential set 2; ***, sample in sequential set 3; DEG C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; trace, less than 0.03 micrograms per liter; e, estimated value; ND, not detected]

Station name	Station number	Date sampled	Time sampled	Discharge (ft^3/s)	Water Temperature (DEG C)	Specific conductance (µS/cm)	pH	Alachlor (µg/L)	Atrazine (µg/L)	Carbaryl (µg/L)
Lower Mine Hill above reservoir	--	6-18-90	935	2.2e	17.6	176	7.12	0.03	0.15	ND
Lower Mine Hill above reservoir	--	7-13-90	830	4.0e	--	148	7.43	ND	.35	ND
Lower Mine Hill above reservoir	--	8-31-90	815	4.8e	15.5	171	6.99	trace	.06	ND
Lower Mine Hill below reservoir	--	6-18-90	800	2.2e	16.4	186	7.43	ND	.14	ND
Lower Mine Hill below reservoir	--	7-13-90	930	4.0e	--	152	7.84	trace	.61	ND
Lower Mine Hill below reservoir	--	8-31-90	945	4.8e	16.8	183	7.50	ND	.07	ND
Lower Mine Hill below reservoir*	--	8-31-90	945	4.8e	16.8	183	7.50	ND	.08	ND
South Branch Raritan River	01397000	6-18-90	1105	255.0e	--	206	8.00	ND	.06	ND
South Branch Raritan River	01397000	7-13-90	1130	965.0e	--	178	7.10	trace	.26	ND
South Branch Raritan River	01397000	8-20-90	830	138.0e	19.2	238	7.82	trace	.05	ND
Main Branch Raritan River	01400120	6-18-90	1400	480.0e	--	209	7.83	trace	.06	ND
Main Branch Raritan River	01400120	7-13-90	1530	1,400.0e	--	237	7.60	trace	.06	ND
Main Branch Raritan River	01400120	8-20-90	1100	140.0e	20.3	243	7.83	ND	.03	ND
Millstone River	01402000	6-28-90	1240	106.0	24.1	214	7.10	.06	.14	.23
Millstone River	01402000	7-13-90	1645	740.0	--	200	7.10	.13	.18	ND
Millstone River	01402000	8-06-90	1330	1,000.0	23.2	192	7.20	ND	.04	.26
Millstone River	01402000	8-20-90	1330	143.0	22.7	180	6.72	trace	.07	ND
Millstone River**	01402000	8-20-90	1330	143.0	22.7	180	6.72	ND	trace	ND
Matchaponix Brook	--	6-28-90	1030	37.0e	21.4	203	7.07	trace	trace	ND
Matchaponix Brook	--	8-06-90	830	150.0e	22.2	175	6.20	ND	trace	5.48
Matchaponix Brook	--	8-21-90	1000	50.0e	17.9	197	6.88	ND	ND	.33
Matchaponix Brook***	--	8-21-90	1000	50.0e	17.9	197	6.88	ND	trace	.50
Manasquan River	01408030	6-28-90	850	56.0e	19.4	177	7.27	trace	trace	trace
Manasquan River	01408030	8-06-90	1030	175.0e	20.1	150	7.10	ND	ND	ND
Manasquan River	01408030	8-31-90	1430	89.0e	19.1	169	7.22	ND	ND	ND
Trip blank 1	--	6-18-90	--	--	--	--	--	ND	ND	ND
Trip blank 2	--	8-20-90	--	--	--	--	--	ND	ND	ND
Trip blank 3	--	9-04-90	--	--	--	--	--	ND	ND	ND

Table 5.--Physical properties and concentrations of pesticides detected in surface-water samples collected from the six study basins, June-September 1990--Continued

[ft^3/s, cubic feet per second; --, data not available; *, sample in sequential set 1; **, sample in sequential set 2; ***, sample in sequential set 3; DEG C, degrees Celsius; μS/cm, microsiemens per centimeter at 25 degrees Celsius; μg/L, micrograms per liter; trace, less than 0.03 micrograms per liter; e, estimated value; ND, not detected]

Station name	Chlorpyrifos (μg/L)	Cyanazine (μg/L)	Diazinon (μg/L)	Isofenphos (μg/L)	Linuron (μg/L)	Metolachlor (μg/L)	Simazine (μg/L)
Lower Mine Hill above reservoir	ND	ND	ND	ND	ND	0.04	ND
Lower Mine Hill above reservoir	ND	ND	ND	ND	ND	.08	trace
Lower Mine Hill above reservoir	ND	trace	ND	ND	ND	ND	ND
Lower Mine Hill below reservoir	ND	ND	ND	ND	ND	.03	ND
Lower Mine Hill below reservoir	ND	ND	ND	ND	ND	.05	ND
Lower Mine Hill below reservoir	ND	ND	ND	ND	ND	ND	ND
Lower Mine Hill below reservoir*	ND	ND	ND	ND	ND	ND	ND
South Branch Raritan River	ND	ND	ND	ND	ND	.05	trace
South Branch Raritan River	ND	trace	trace	ND	ND	.45	trace
South Branch Raritan River	ND	ND	ND	ND	ND	trace	trace
Main Branch Raritan River	ND	ND	ND	ND	ND	.10	.05
Main Branch Raritan River	ND	.07	ND	ND	.07	.80	.05
Main Branch Raritan River	ND	ND	ND	ND	ND	trace	ND
Millstone River	ND	.06	ND	ND	.25	1.74	trace
Millstone River	ND	ND	ND	ND	ND	2.70	trace
Millstone River	ND	.04	.11	.10	ND	.36	ND
Millstone River	ND	ND	ND	ND	ND	.21	trace
Millstone River**	ND	ND	ND	ND	ND	ND	ND
Matchaponix Brook	ND	ND	.04	ND	ND	.11	trace
Matchaponix Brook	trace	ND	1.11	.61	ND	.13	ND
Matchaponix Brook	ND	ND	.21	ND	ND	.04	ND
Matchaponix Brook***	ND	ND	.22	ND	ND	.04	ND
Manasquan River	ND	ND	ND	ND	ND	.03	ND
Manasquan River	ND	ND	ND	ND	ND	trace	ND
Manasquan River	ND	ND	.05	ND	ND	ND	ND
Trip blank 1	ND	ND	ND	ND	ND	ND	ND
Trip blank 2	ND	ND	ND	ND	ND	ND	ND
Trip blank 3	ND	ND	ND	ND	ND	ND	ND

Table 6.--Maximum and minimum concentrations of pesticides detected in water-quality samples collected from the six study basins, 1990

[Concentrations are in micrograms per liter; <0.03, less than the analytical reporting level; SE, recommended lifetime health advisory limits have not been established]

Pesticide	Maximum	Minimum	USEPA Recommended Lifetime Health Advisory Limits[1]
Alachlor	0.13	<0.03	0.4
Atrazine	.61	< .03	3.0
Carbaryl	5.48	< .03	700.0
Chlorpyrifos	< .03	< .03	20.0
Cyanazine	.07	< .03	10.0
Diazinon	1.11	< .03	.6
Isofenphos	.61	.10	SE
Linuron	.25	.07	SE
Metolachlor	2.70	< .03	100.0
Simazine	.05	< .03	1.0

[1] U.S. Environmental Protection Agency (1989).

Table 7.--Relative percent difference in pesticide concentrations in sequentially collected water-quality samples collected from the Lower Mine Hill Reservoir, Millstone River, and Matchaponix Brook, 1990

[*, compound not detected; --, comparison not possible because all values were less than the analytical detection limit]

	Relative percent difference[1] between sample and sequential concentrations[2]		
Pesticide	sequential set 1[3]	sequential set 2[3]	sequential set 3[3]
Alachlor	*	*	*
Atrazine	13.3	--	--
Carbaryl	*	*	41.0
Diazinon	*	*	4.7
Metolachlor	*	--	.0
Simazine	*	--	*

[1] Relative percent difference = (|S-D|÷((S+D)÷2))x100 where S = concentration of pesticide in sample and D = concentration of pesticide in sequentially collected sample.

[2] Values used to compare pesticide concentrations in samples and sequentially collected samples are provided in table 5.

[3] Sequentially collected samples are identified in table 5.

Lower Mine Hill Reservoir

Lower Mine Hill Reservoir is located in southwestern Morris County; its drainage basin is the smallest of the six study basins, draining only 1.8 mi^2 above the intake. Two sampling sites are located in the basin--one above the reservoir, 4,400 ft upstream from the intake, and one below the reservoir, 3,800 ft downstream from the intake. The reservoir is on Lower Mine Hill Brook, a tributary to the Musconetcong River. The basin, located on Schooley's Mountain in the New Jersey Highlands, is characterized by a steep-sided valley in the lower part of the basin and gentle slopes near the headwaters of the brook. The elevation ranges from 1,020 ft above sea level at the upper sampling point to 620 ft above sea level at the lower sampling point. Because no streamflow-gaging stations are located on Lower Mine Hill Brook, discharge at the streamflow-gaging station on Yards Creek near Blairstown (01443900) was used to represent the discharge of Lower Mine Hill Brook.

Lower Mine Hill Reservoir is used exclusively by the Hackettstown Municipal Utilities Authority (MUA). During July-September 1990, Hackettstown MUA diverted 78.8 million gallons of water for treatment and distribution. In previous years, the following amounts of water were diverted:

1981 - 205.086 Mgal/yr
1982 - 150.46 Mgal/yr
1983 - 149.379 Mgal/yr
1984 - 142.47 Mgal/yr
1985 - 115.99 Mgal/yr
1986 - 105.85 Mgal/yr
1987 - 152.74 Mgal/yr
1988 - 186.48 Mgal/yr
1989 - 227.518 Mgal/yr

Land in the drainage basin is predominantly undeveloped. The basin is approximately 50 percent forested land and 37 percent agricultural land; the remainder is urban land. Most of the agricultural land is located near the headwaters of the brook; the valley, where the brook flows in and out of the reservoir, is heavily forested.

Field corn, sweet corn, fruit trees (other than apples and peaches), grapes, vine crops, and cucurbits are the six main crops grown in the basin, representing the lowest crop diversity of the six basins. According to the results of the 1988 pesticide survey, the following pesticides from the list of 21 determined compounds determined for the study (table 4) were applied in the basin in descending order of amount: metolachlor, atrazine, chlorothalonil, carbofuran, parathion, carbaryl, and captan (table 2).

South Branch of the Raritan River

The South Branch of the Raritan River drains 165.5 mi^2 to the intake (fig. 1). Most of the basin is located in Morris and Hunterdon Counties, and the South Branch headwaters are in the New Jersey Highlands. Two reservoirs, Spruce Run and Round Valley, are situated in the basin. Flow in the Raritan River can be augmented by water released from the reservoirs. Water in the South Branch was sampled from a bridge near Flemington 4,400 ft downstream from the intake and downstream from the streamflow-gaging station at Stanton Station (01397000). Average flow estimated at Stanton Station for the period of record (1919-89) was 246 ft^3/s (Bauersfeld and others, 1990).

Land use in the basin was 65 percent agricultural in 1976 (fig. 1). Most of the agricultural land was used for field corn and soybeans. Other crops include sweet corn; apples; peaches; other fruit trees; grapes, vine crops, cucurbits, solanaceous vegetables (tomatoes, peppers, eggplant); small grains; beans; peas; cole crops (cabbage, cauliflower) and ornamental plants.

Fifteen of the 21 compounds analyzed for in the study (table 4) were applied in the South Branch basin, according to results of the 1988 pesticide survey. The compounds, listed in order of decreasing amount of application, were metolachlor, atrazine, alachlor, carbaryl, cyanazine, linuron, chlorothalonil, carbofuran, captan, parathion, 2,4-D, terbufos, simazine, chlorpyrifos, and pendimethalin.

Main Branch of the Raritan River

The Main Branch of the Raritan River is the largest of the study basins, draining 489 mi^2 above the intake. The Raritan River consists of the Main Branch and several tributaries, the largest of which are the south and north branches of the Raritan River and the Millstone River (fig. 1). The headwaters of the Raritan River begin in the New England Uplands, the intake is located in the Piedmont Lowlands, and the Raritan River empties into the Atlantic Ocean at Raritan Bay. The river was sampled from a bridge in the town of Raritan, 3.9 mi upstream from the intake, at a USGS water-quality-sampling site (01400120). An average flow of 772 ft^3/s was estimated from measurements made at a streamflow-gaging station at Manville, about 3.2 mi downstream from the sampling site (Bauersfeld and others, 1990).

The Elizabethtown Water Company is the primary purveyor in the Main Branch Raritan River basin. The water company processes approximately 138 million gallons on an average day (Glen Johnson, Elizabethtown Water Company, written commun., 1990). Seventy Mgal/d is diverted from the Raritan River; the remaining 68 Mgal/d is diverted from the Delaware-Raritan Canal and the Millstone River. Estimating the number of people and industries served is difficult because water is sold to other water companies.

The drainage basin is highly urbanized near the intake but, like the South Branch, the headwaters are in a rural area. Agricultural land totals about 40 percent of basin acreage. Crops grown in the basin include field and sweet corn, apples, peaches, grapes, cucurbits, solanaceous vegetables, small grains, beans, peas, leafy vegetables, cole crops, potatoes, strawberries, sod, and ornamental plants. The main crop grown in the basin is soybeans.

Metolachlor is the pesticide most heavily applied to the land in the basin, followed by alachlor and atrazine (table 3). Other compounds used in the basin include 2,4-D, captan, carbaryl, carbofuran, chlorothalonil, chlorpyrifos, cyanazine, diazinon, linuron, metribuzin, parathion, simazine, and terbufos.

Millstone River

The Millstone River, which drains 278 mi^2 of central New Jersey, is a tributary to the Raritan River (fig. 1). The basin is unique among the six study basins because the Fall Line divides it nearly in half. The northwestern part of the basin lies in the Piedmont Lowlands, whereas the southeastern part lies in the inner Coastal Plain. The headwaters of the Millstone River lie in the Coastal Plain. The sampling site on the Millstone River is about 1.3 mi downstream from the intake in western New Jersey at a USGS water-quality-sampling site (01402540). Average flow for the period of record, estimated from measurements made at a continuous-record gaging station at Blackwells Mills, is 378 ft^3/s (Bauersfeld and others, 1990).

Two manmade surface-water bodies, the Delaware-Raritan Canal and Carnegie Lake, lie within the basin boundaries. The Delaware-Raritan Canal begins near Trenton and flows past Princeton parallel to the Millstone River until it reaches the confluence of the Millstone and Raritan Rivers at Manville. Carnegie Lake near Princeton is the only manmade impoundment on the Millstone River.

The Millstone River basin is the most developed of all the study basins. In the early 1970's, agricultural land covered about 67 percent of the basin, but in the 1980's, development near the Route 1 corridor reduced the amount of farmland in the Hightstown, Plainsboro, and Cranbury areas by about one-half (fig. 1). The crops grown in the basin include field crops, such as corn, sweet corn, soybeans, and small grains; and orchard fruits and vegetables. The predominant crops in the basin are soybeans, field corn, apples, and cole crops.

Pesticide application was heavier in the Millstone River basin than in any of the other study basins. Eighteen of the 21 pesticides analyzed for were applied in the basin. In 1988, the application rate of the herbicide metolachlor was higher than that of any of the other selected compounds; the application rate of atrazine was the second highest (table 3).

Manasquan River

The Manasquan River drains a basin of 64 mi^2 and empties into the Atlantic Ocean. Estuarine conditions prevail at the mouth, and tidal influences extend about 1 mi upstream. The sampling site in this basin is the intake on Hospital Road near Squankum, New Jersey, which is also a USGS water-quality-sampling site (01408030). Average (1931-90) flow at this site was estimated to be 75.3 ft^3/s (Bauersfeld and others, 1990). Freshwater from the Manasquan River is diverted by the New Jersey Water Supply Authority and treated for drinking water or used to fill two local reservoirs. The water commonly is sold to communities in northern Monmouth and Ocean Counties for consumption.

Agriculture accounts for only 30.7 percent of land use in the Manasquan River basin; this is less than the percentage of agricultural land use in any of the other study basins. The main crops grown in the basin are soybeans, field corn, sweet corn, and tomatoes. Compounds most intensely applied were metolachlor and atrazine (table 3); all of the pesticides selected for analysis (table 4) were applied, except butylate, fenamiphos, and fonophos.

Matchaponix Brook

Matchaponix Brook drains an area of 29 mi^2; the basin is one of the two study basins located completely within the Coastal Plain. The Brook is a tributary to the South River, which eventually empties into the Raritan River (fig. 1). Matchaponix Brook was sampled from a bridge near Englishtown, New Jersey, about 1,000 feet downstream from the intake. Flow at Manalapan Brook (01405400) in Spotswood Borough was used to represent the flow of Matchaponix Brook. The Matchaponix Brook intake was installed but is not yet active. The intake will supply water to Freehold Township, and some of the treated water will be sold to Gordons Corner Water Company.

In 1976, agricultural land covered about 52 percent of the basin. Since 1976, about one-third of the agricultural land has been developed. The most important crops, in order of acreage planted, were leafy vegetables, such as lettuce and endive, soybeans, sod, and field corn. Because of the variety of crops in the basin, many different pesticides were applied. According to the results of the 1988 pesticide survey, all of the 21 selected compounds except fenamiphos and fonophos were applied in the basin.

AGRICULTURAL PESTICIDES IN DRAINAGE BASINS

The results of analyses for pesticides in base-flow and stormflow samples are presented in this section. Results of statistical analyses of surface-water-quality data and concentrations of pesticides in pretreated- and treated-water samples also are included.

Pesticides in Base Flow and Stormflow

Thirty-four surface-water samples, including 22 water-quality samples, 3 sequentially collected samples, 3 trip blanks, and 6 samples from water-treatment facilities were collected. The pesticides detected in the samples, excluding the trip blanks, water-treatment facility samples, and sequentially collected samples, and the percentage of samples in which they were detected, were as follows: atrazine and metolachlor, 86 percent; alachlor, 55 percent; simazine, 45 percent; diazinon, 27 percent; cyanazine and carbaryl, 23 percent; linuron and isofenphos, 9 percent; and chlorpyrifos, 5 percent.

In this section, results of the 1988 pesticide survey are compared to the results of the analyses of water-quality samples collected during 1990. The 1988 survey results may not accurately represent 1990 agricultural practices because crop rotation, changes in crop type, and leaving fields fallow are common agricultural practices. Seasonal as well as short-term fluctuations in weather conditions can affect weed growth and insect life cycles, thereby controlling the types of pesticides used and rates of application. Results of the 1985 pesticide survey are less valid for this study than the 1988 data because of changes in land use and the banning or restricted use of selected pesticides since 1985.

Lower Mine Hill Reservoir

The first base-flow samples were collected near Lower Mine Hill Reservoir, on June 18, 1990, 5 days after a storm (fig. 7). Three pesticides--alachlor, atrazine, and metolachlor--were present in the sample collected above the reservoir (fig. 8), whereas only atrazine and metolachlor (fig. 9) were present in the sample collected below the reservoir. According to the results of the 1988 pesticide survey, alachlor was not applied in the basin. The concentrations of atrazine, alachlor, and metolachlor were below the USEPA's recommended LHAL of 3 μg/L, 0.4 μg/L, and 100 μg/L, respectively. Slightly greater concentrations of pesticides were present in the samples collected above the reservoir than below.

On July 13, 1990, during a storm with an estimated peak flow of 23 ft^3/s, a sample was collected above the Lower Mine Hill Reservoir. The timing of the sampling coincided with the falling limb of the storm hydrograph. Concentrations of atrazine and metolachlor in this sample were double their respective concentrations in base-flow samples. Simazine was detected in trace amounts in the stormflow sample. Results of the pesticide surveys indicated that no simazine had been used in the Lower Mine Hill basin (tables 2 and 3).

Concentrations of pesticides in samples collected below the reservoir were nearly identical to the concentrations of the same pesticides in samples collected above the reservoir. Concentrations of atrazine and metolachlor in samples collected during a storm were at least double the concentrations of these pesticides in base-flow samples (figs. 7 and 8). Alachlor, which was not found in the stormflow sample collected above the reservoir, was detected in trace amounts in the stormflow sample below the reservoir; simazine, detected in trace amounts above the reservoir, was not detected below the reservoir. Concentrations of atrazine in the stormflow samples above and below the reservoir were 0.35 μg/L and 0.61 μg/L, respectively. Four of the 21 compounds determined (table 4) that had been applied in the basin according to results of the 1988 pesticide survey--captan, carbofuran, chlorothalonil, and parathion--were not detected in any of the samples collected from Lower Mine Hill Reservoir.

The base-flow sample collected in late August contained alachlor and cyanazine in trace amounts, and atrazine was present in the sample collected above the reservoir at concentrations of 0.06 μg/L. According to results of the 1988 pesticide survey, no cyanazine had been applied in the basin.

South Branch of the Raritan River

The first base-flow (fig. 10) sample collected from the South Branch of the Raritan River contained atrazine, metolachlor, and simazine; simazine was present in trace amounts (fig. 11). This sample was not collected during true base-flow conditions (fig. 10); the storm-recession curve had not yet reached base-flow conditions, but this was not determined until hydrographs were produced subsequent to sampling.

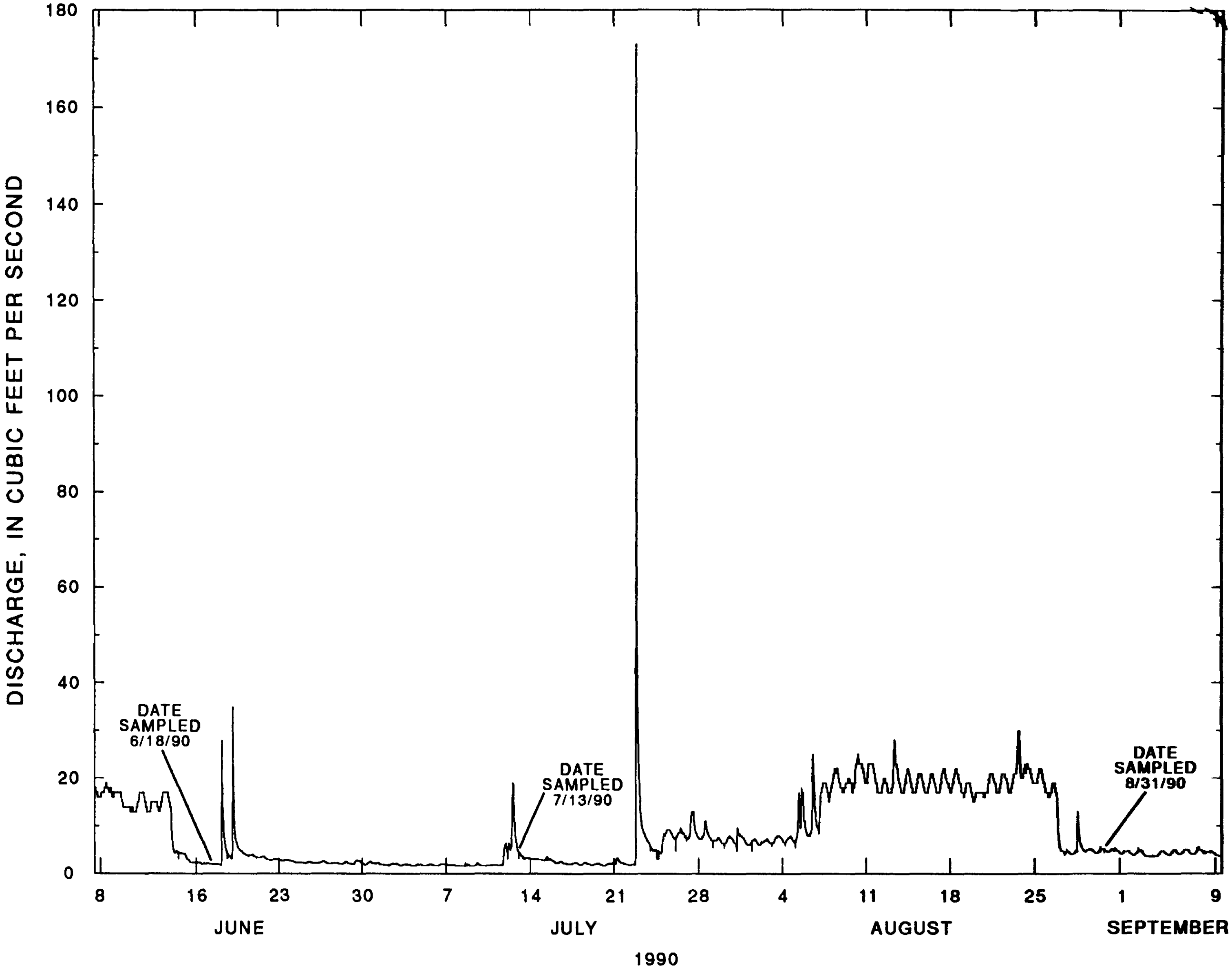


Figure 7.--Streamflow hydrograph of Yards Creek near Blairstown (01443900) for the period June 8, 1990, through September 9, 1990, used to represent discharge of Lower Mine Hill Brook.

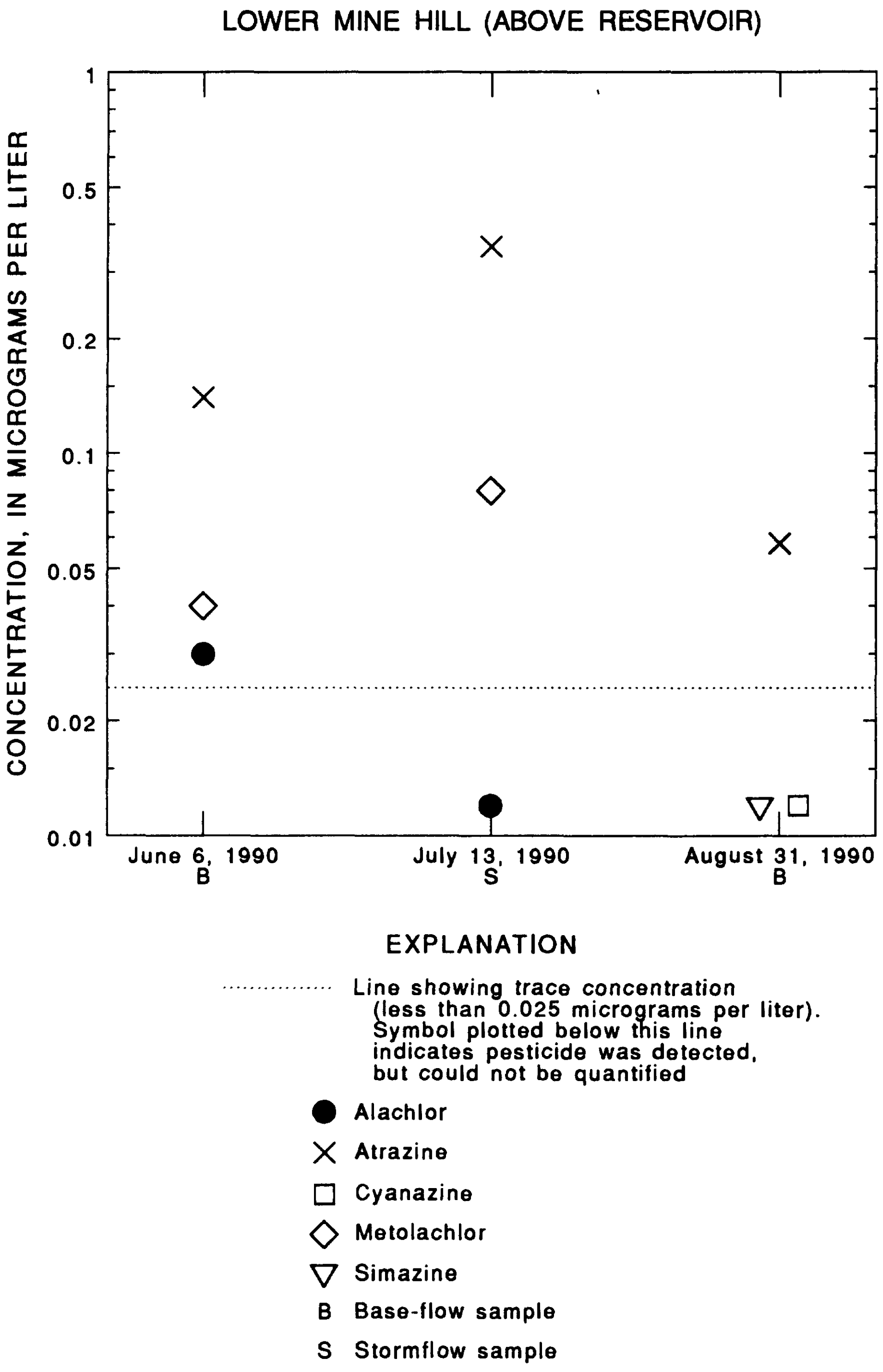


Figure 8.--Concentrations of pesticides in three water samples collected above Lower Mine Hill Reservoir, June-August 1990.

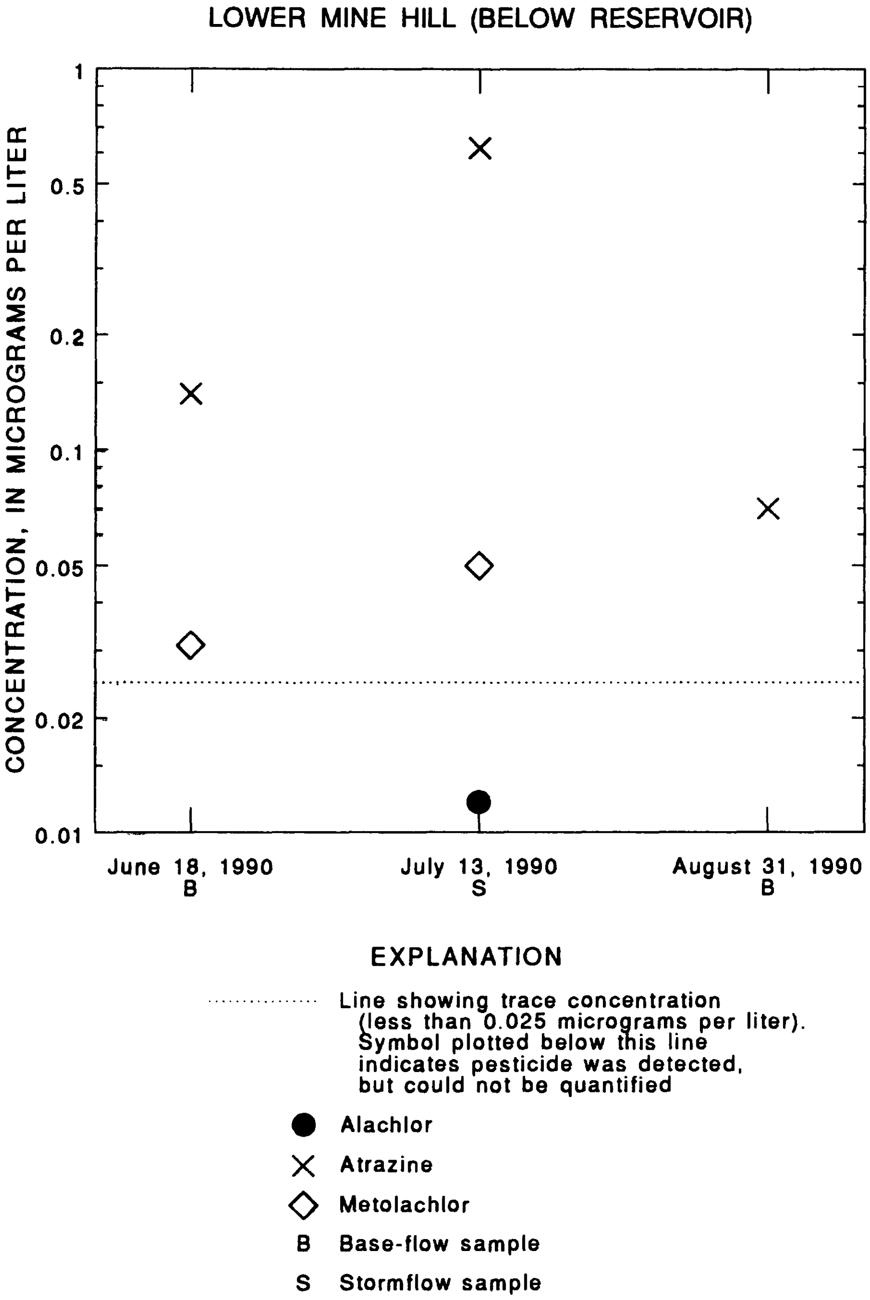


Figure 9.--Concentrations of pesticides in three water samples collected below Lower Mine Hill Reservoir, June-August 1990.

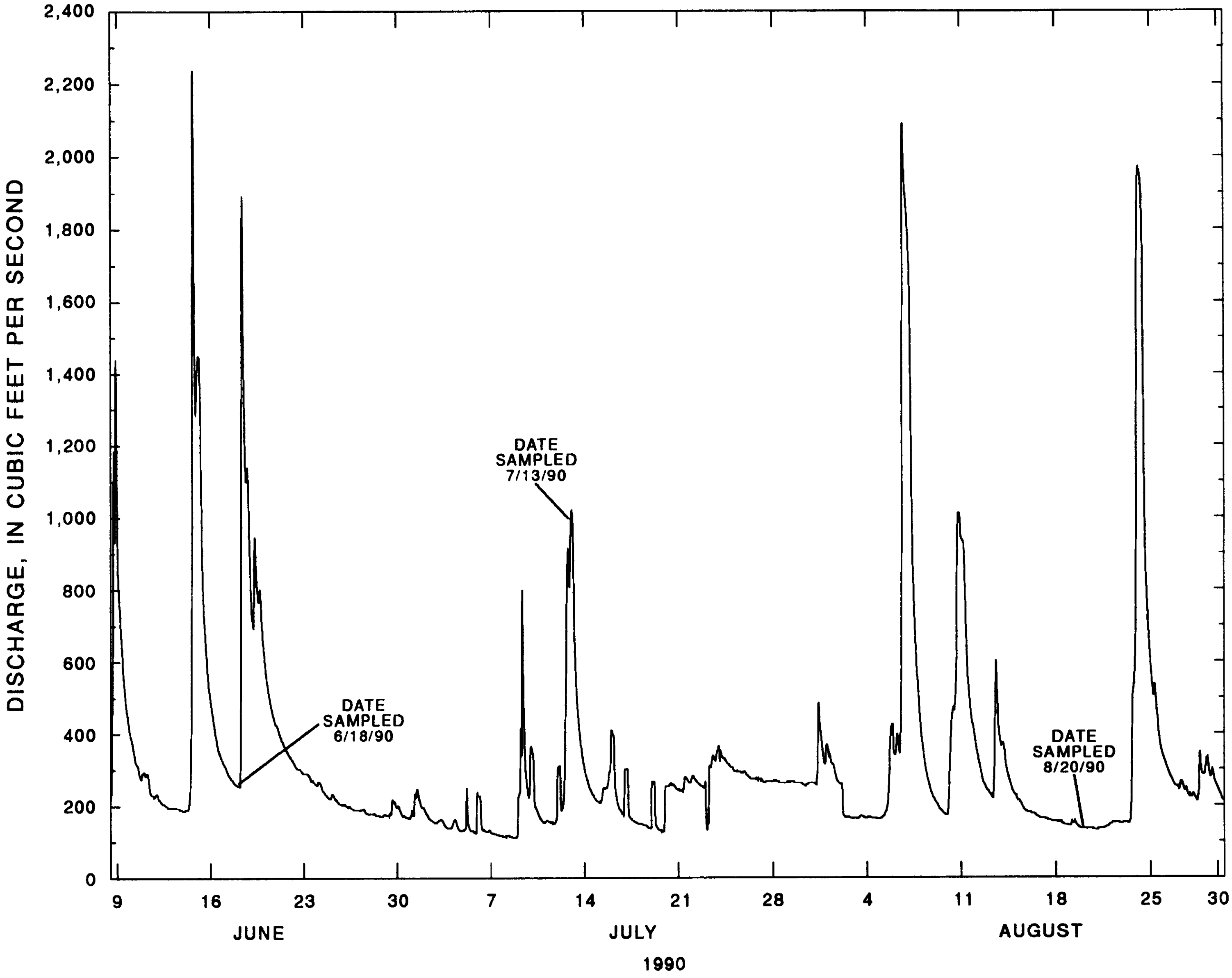


Figure 10.--Streamflow hydrograph of the South Branch of the Raritan River at Stanton Station (01397000) for the period June 9, 1990, through August 30, 1990.

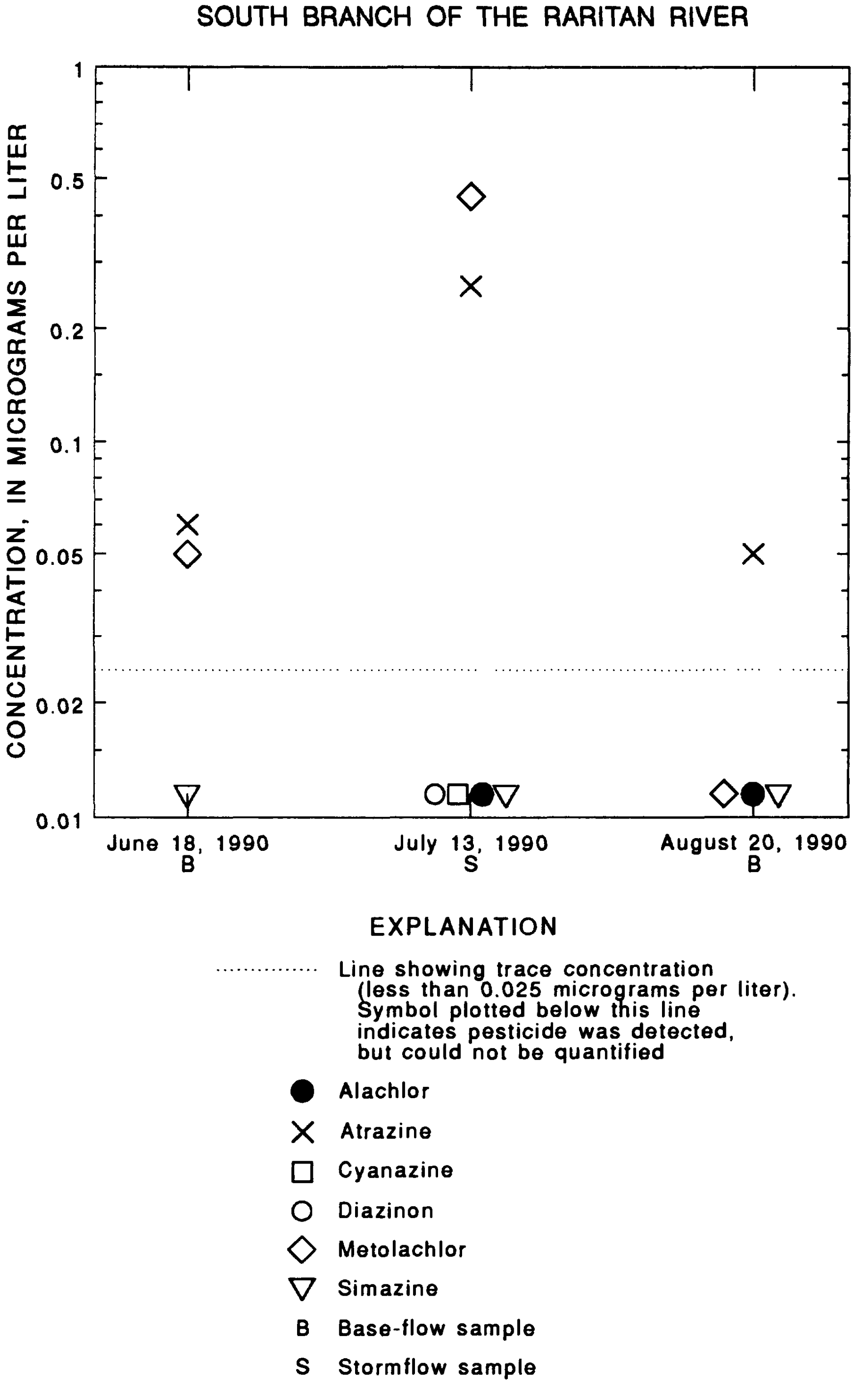


Figure 11.--Concentrations of pesticides in three water samples collected on the South Branch of the Raritan River near Flemington, June-August 1990.

The stormflow sample contained a greater variety of pesticides than the base-flow sample, but only atrazine and metolachlor were present in concentrations greater than trace amounts. Although diazinon was detected in trace amounts, results of the 1988 pesticide survey (table 3) indicate that it was not applied in the basin. The concentrations of atrazine were higher in the stormflow sample than in the base-flow sample (0.26 μg/L and 0.06 μg/L, respectively); the same was true for metolachlor 0.45 μg/L in the stormflow sample and 0.05 in the base-flow sample (fig. 10). Atrazine was the only pesticide detected above trace concentrations in the final base-flow sample collected. Alachlor, metolachlor, and simazine were all found in trace amounts.

Ten of the 21 compounds determined that were applied in 1988 were not detected in the 1990 sampling. These 10 compounds were captan, carbaryl, carbofuran, chlorothalonil, chlorpyrifos, linuron, parathion, pendimethalin, terbufos, and 2,4-D (table 8).

Main Branch of the Raritan River

Results of analyses of samples from the Main Branch of the Raritan River were similar to those of samples from the South Branch. The first base-flow sample (fig. 12) contained the herbicides atrazine, metolachlor, and simazine above trace concentrations and alachlor in trace quantities. The highest concentration of any of the detected pesticides was that for metolachlor, 0.10 μg/L (fig. 13).

The pesticides detected in the stormflow sample from the Main Branch also were similar to those detected in the stormflow sample from the South Branch. Five pesticides (alachlor, atrazine, cyanazine, metolachlor, and simazine) detected in the South Branch also were detected in the Main Branch. Diazinon was present in the South Branch sample but was absent from the Main Branch sample; linuron was present in the Main Branch sample but was absent from the South Branch sample. The Main Branch sample contained higher concentrations of cyanazine, metolachlor, and simazine than the South Branch sample.

Ten of the compounds applied in 1988, according to the results of the pesticide survey, were not detected in samples from either the Main Branch or the South Branch in 1990. The undetected compounds were butylate, metribuzin, captan, carbaryl, carbofuran, chlorothalonil, chlorpyrifos, parathion, terbufos, and 2,4-D (table 8).

Millstone River

The Millstone River was the only site at which two stormflow and base-flow samples were collected. The stormflow samples were collected successively; no base-flow sample was collected between them (figs. 14 and 15).

Table 8.--Calculated pesticide-application rates in drainage basins above selected public surface-water-supply intakes, 1988

(Values in pounds per agricultural square mile)

Pesticide	Lower Mine Hill Reservoir	South Raritan River	Main Branch Raritan River	Millstone River	Manasquan River	Matchaponix Brook
Alachlor	0.00	15.30	14.60	30.80	3.20	16.20
Atrazine	41.20	26.90	15.90	137.70	6.10	12.90
Butylate	.00	.00	.84	2.46	.00	8.00
Captan	.88	2.17	6.04	76.00	1.17	1.64
Carbaryl	.00	15.10	7.40	5.70	2.70	10.80
Carbofuran	6.84	2.29	2.40	12.10	1.45	14.40
Clorothalonil	7.13	2.42	1.91	41.40	9.50	22.10
Chlorpyrifos	.00	.50	2.74	7.13	2.55	1.50
Cyanazine	.00	15.10	7.40	5.70	2.70	10.80
Diazinon	.00	.00	5.80	15.30	3.30	6.90
Fenamiphos	.00	.00	.00	.00	.00	.00
Fonophos	.00	.00	.00	.00	.00	.00
Isofenphos	.00	.00	.00	.00	.02	.07
Linuron	.00	2.77	3.90	102.80	6.96	9.02
Metolachlor	54.10	32.00	19.10	423.80	8.30	17.20
Metribuzin	.00	.00	.01	.31	.12	.10
Parathion	3.56	1.40	1.27	9.20	5.20	5.98
Pendimethalin	.00	.10	.00	.50	.10	.01
Simazine	.00	.60	1.20	1.90	1.70	1.20
Terbufos	.00	.75	1.22	81.10	.79	3.56
2,4-D	.00	1.35	2.75	12.60	14.40	25.00

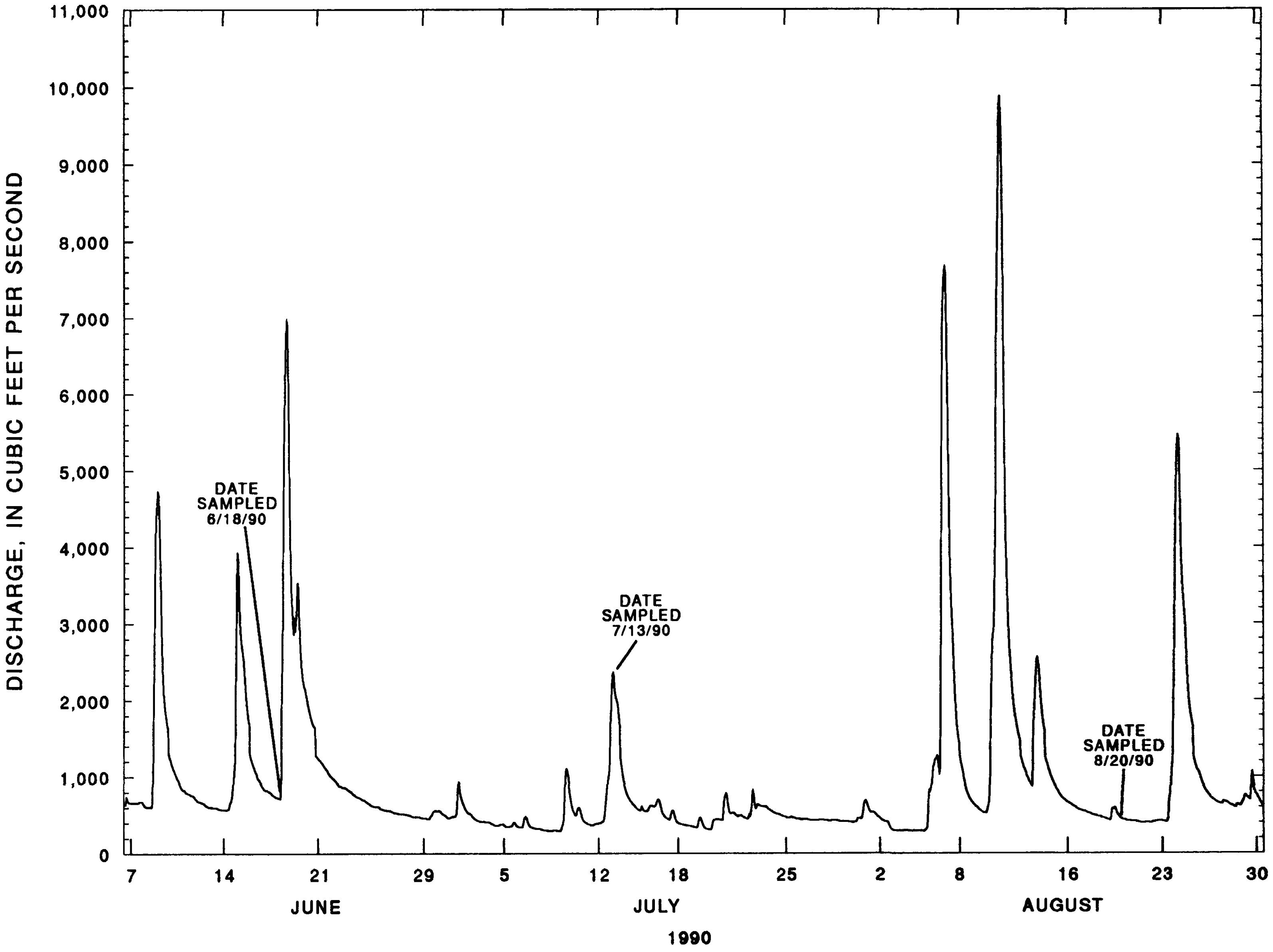


Figure 12.--Streamflow hydrograph of the Raritan River at Manville (01400500) for the period June 7, 1990, through August 30, 1990.

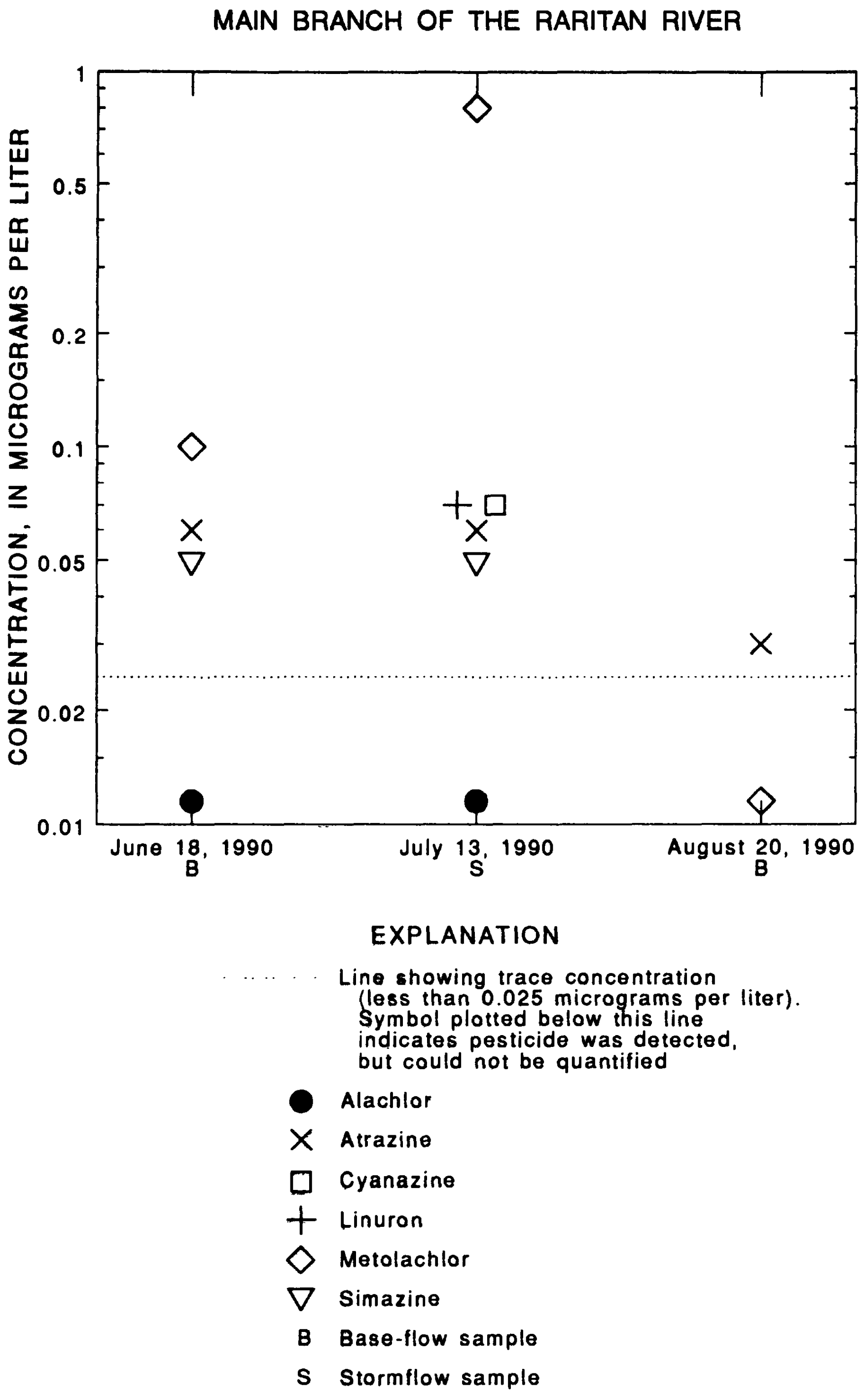


Figure 13.--Concentrations of pesticides in three water samples collected on the Main Branch of the Raritan River at Raritan, June-August 1990.

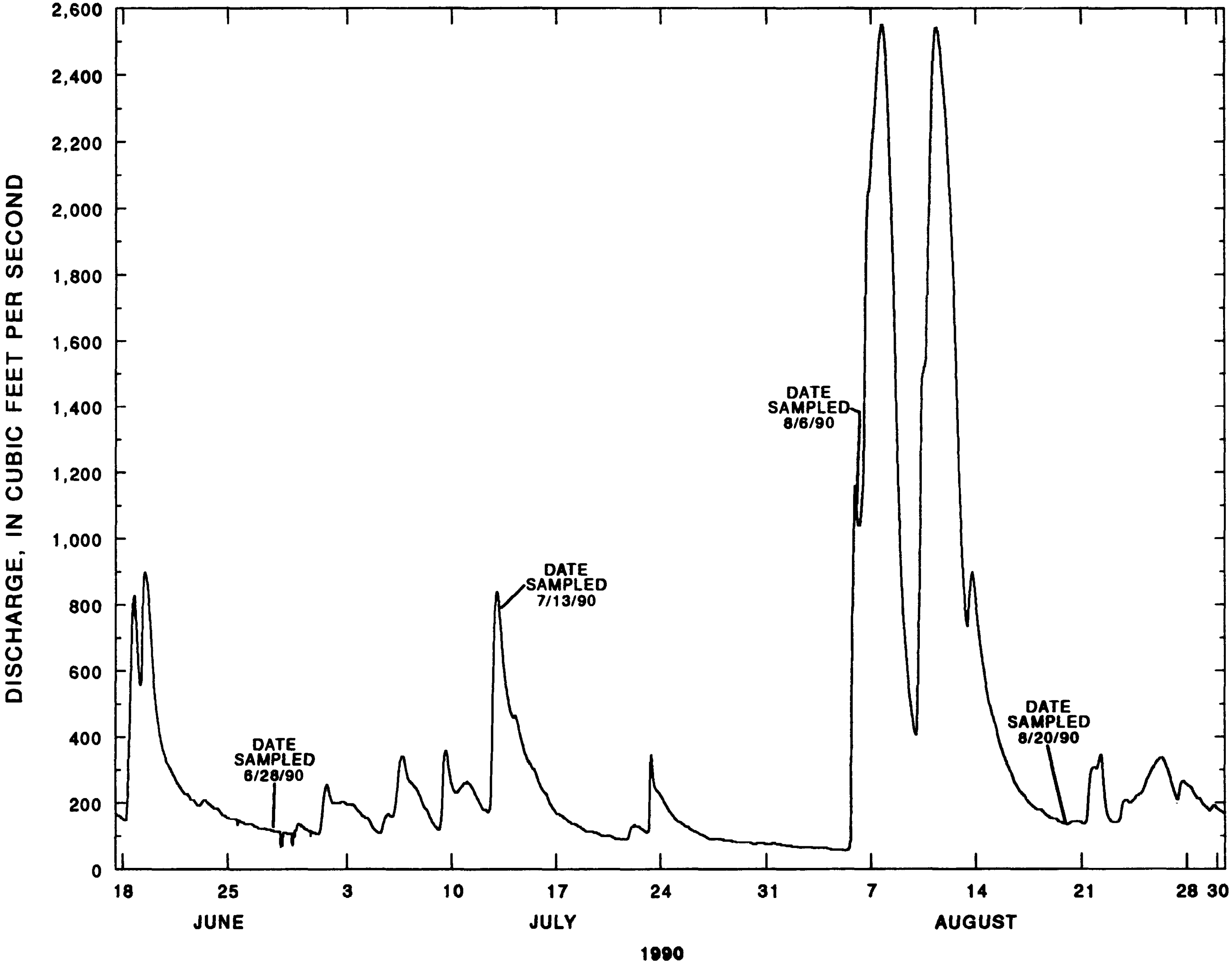


Figure 14.--Streamflow hydrograph of the Millstone River at Blackwells Mills (01402000) for the period June 18, 1990, through August 30, 1990.

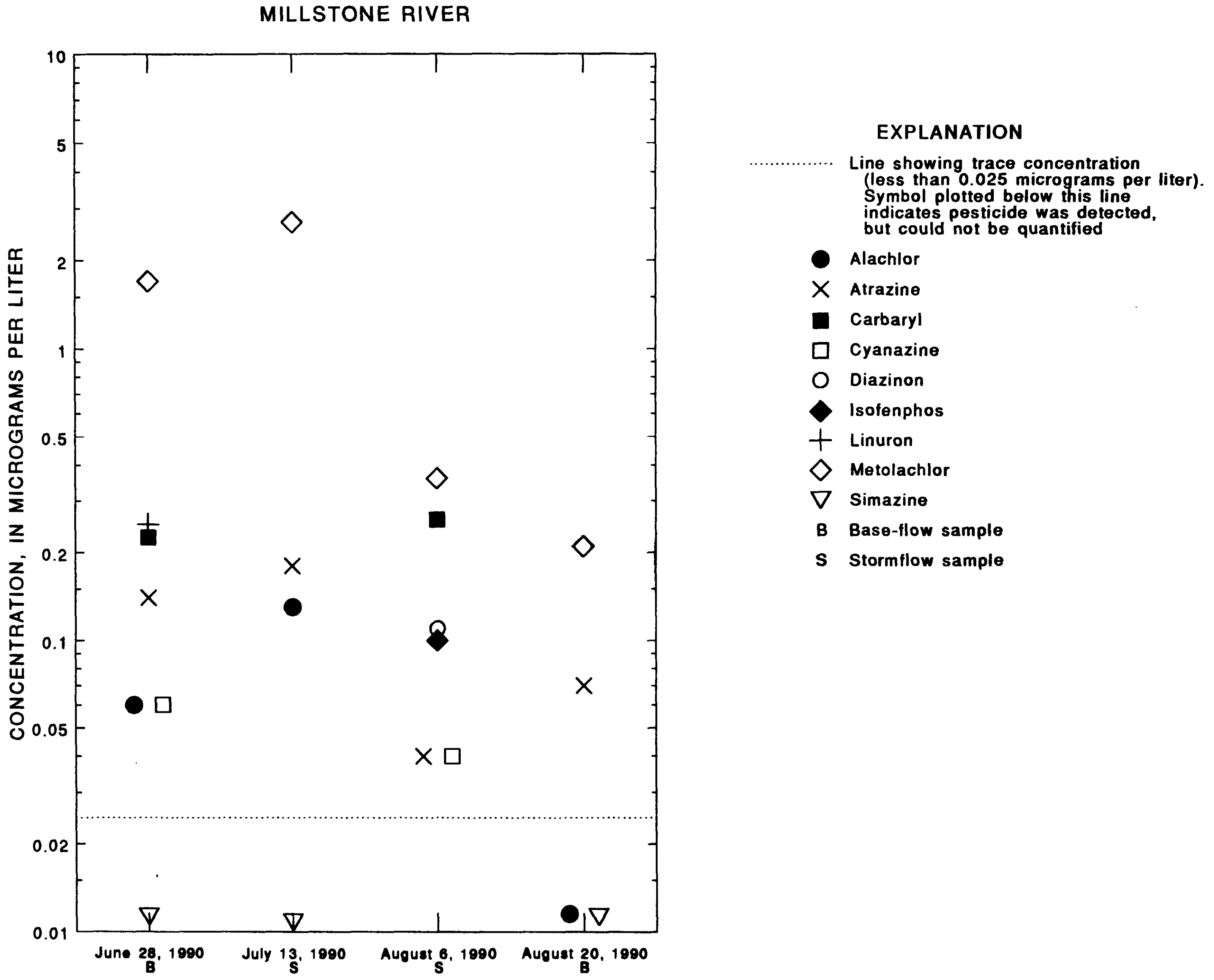


Figure 15.--Concentrations of pesticides in four water samples collected on the Millstone River at Weston, June-August 1990.

The base-flow sample, collected on June 28, 1990, contained alachlor, atrazine, carbaryl, cyanazine, linuron, metolachlor, and simazine; metolachlor was present in the highest concentration, 1.74 μg/L (fig. 15). Stormflow was sampled about 2 weeks later; this sample contained only half the compounds present in the first base-flow sample. The herbicides alachlor, atrazine, simazine, and metolachlor were detected in this stormflow sample; again, metolachlor was present in the highest concentration, 2.7 μg/L (table 5).

The stormflow sample collected on August 6, 1990, contained two compounds not detected previously; diazinon and isofenphos were detected in concentrations greater than trace amounts. According to results of the 1988 pesticide survey, isofenphos was the only compound on the list of 21 pesticides (table 4) that was not applied in the basin. Isofenphos is an insecticide that is used extensively by homeowners and sod growers (Murphy and Fenske, 1987, p. 119). The base-flow sample collected on August 20, 1990, contained atrazine, metolachlor, alachlor, and simazine. All of these pesticides were detected in low to trace concentrations (table 5).

According to the results of the 1988 pesticide survey, 18 of the 21 compounds determined were applied in the Millstone River basin; however, 10 of these compounds were not detected in the 1990 water-quality sampling. These compounds were butylate, captan, carbofuran, chlorothalonil, chlorpyrifos, metribuzin, parathion, pendimethalon, terbufos, and 2,4-D (table 8).

Manasquan River

Samples from the Manasquan River, in general, contained the fewest of the 21 pesticides and the lowest concentrations of those pesticides detected. Alachlor, atrazine, and carbaryl were detected in trace amounts in the base-flow sample (fig. 16), and metolachlor was the only compound detected at concentrations greater than trace amounts (fig. 17). The stormflow sample, collected during the rising limb of the hydrograph (fig. 16), contained metolachlor in trace amounts. The second base-flow sample contained the insecticide diazinon (fig. 17).

Eighteen pesticides were applied in the Manasquan River basin; only five of these pesticides were detected in water samples. The 13 pesticides that were applied but not detected were captan, carbofuran, chlorothalonil, chlorpyrifos, cyanazine, isofenphos, linuron, metribuzin, parathion, pendimethalin, simazine, terbufos, and 2,4-D (table 8).

Matchaponix Brook

Concentrations of pesticides in samples from Matchaponix Brook, located in the New Jersey Coastal Plain, were among the highest concentrations of pesticides in all the study basins. The first base-flow sample (fig. 18), collected on June 28, 1990, contained metolachlor and diazinon in concentrations greater than trace concentrations and alachlor, atrazine, and simazine in trace concentrations (fig. 19). The second base-flow sample, collected on August 21, 1990, contained metolachlor, diazinon, and carbaryl, all in concentrations greater than trace concentrations.

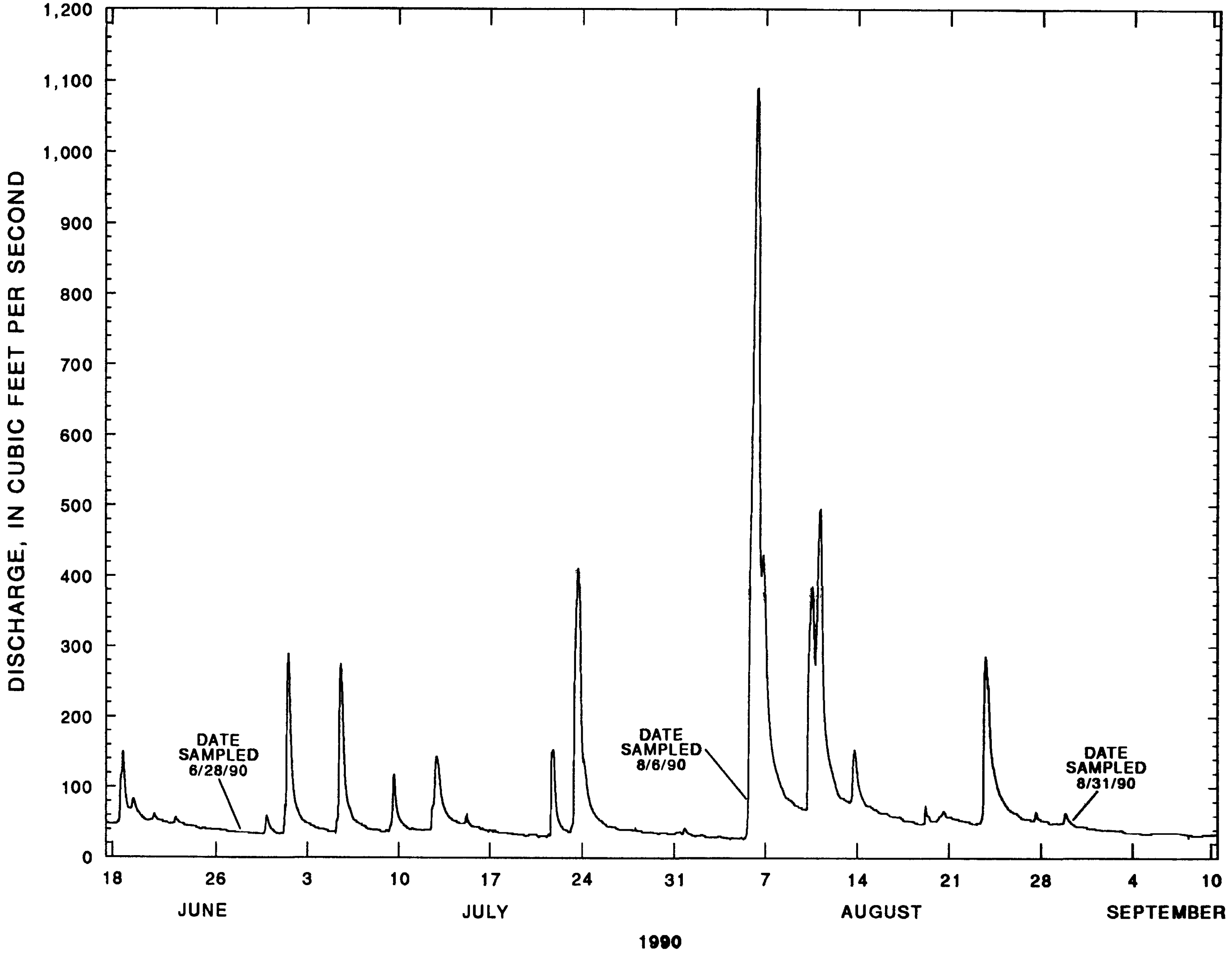


Figure 16.--Streamflow hydrograph of the Manasquan River at Squankum (01408000) for the period June 18, 1990, through September 10, 1990.

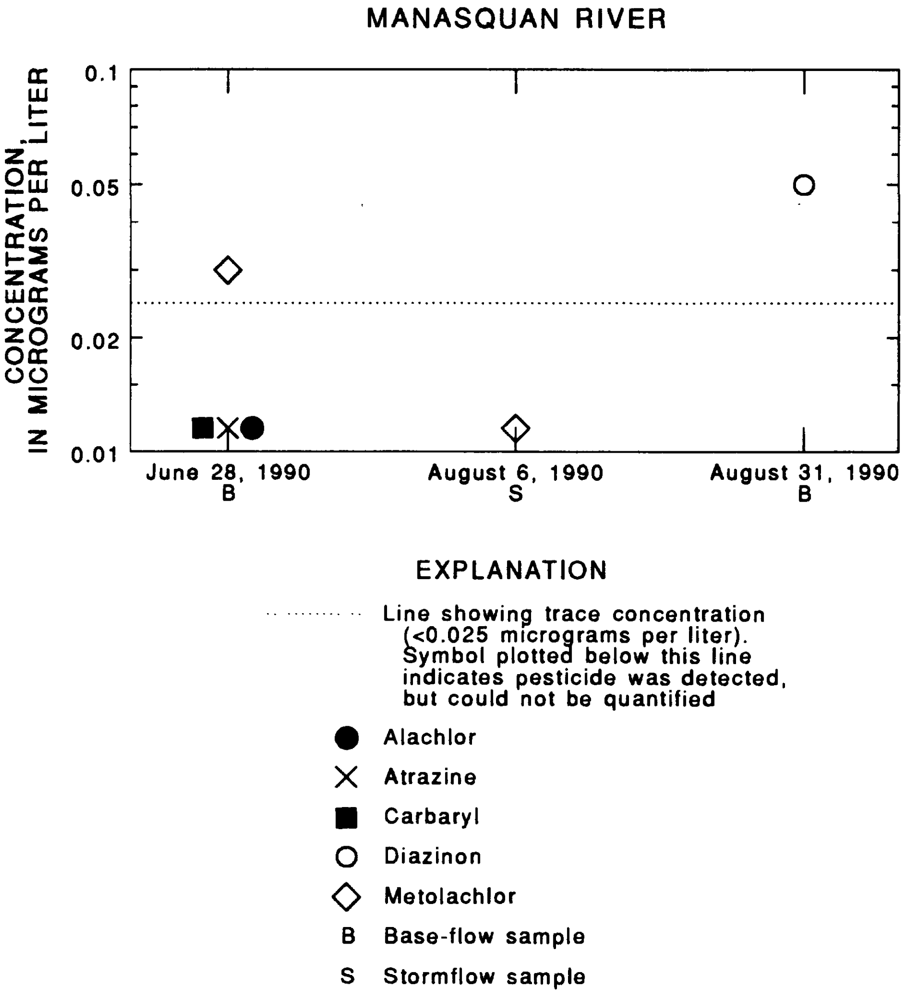


Figure 17.--Concentrations of pesticides in three water samples collected on the Manasquan River near Squankum, June-August 1990.

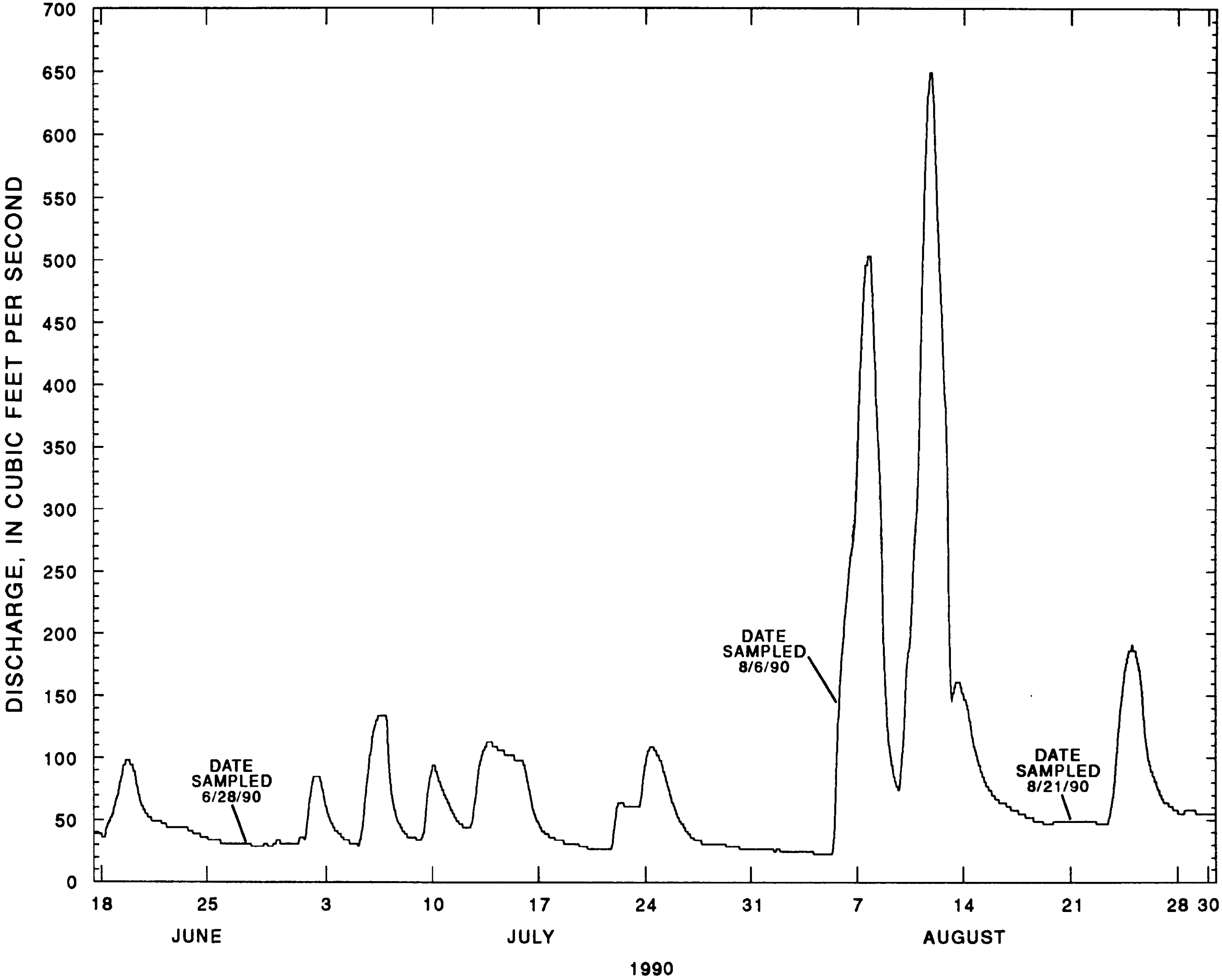


Figure 18.--Streamflow hydrograph of the Manalapan Brook near Spotswood (01405400) for the period June 18, 1990, through August 30, 1990, used to represent discharge of Matchaponix Brook.

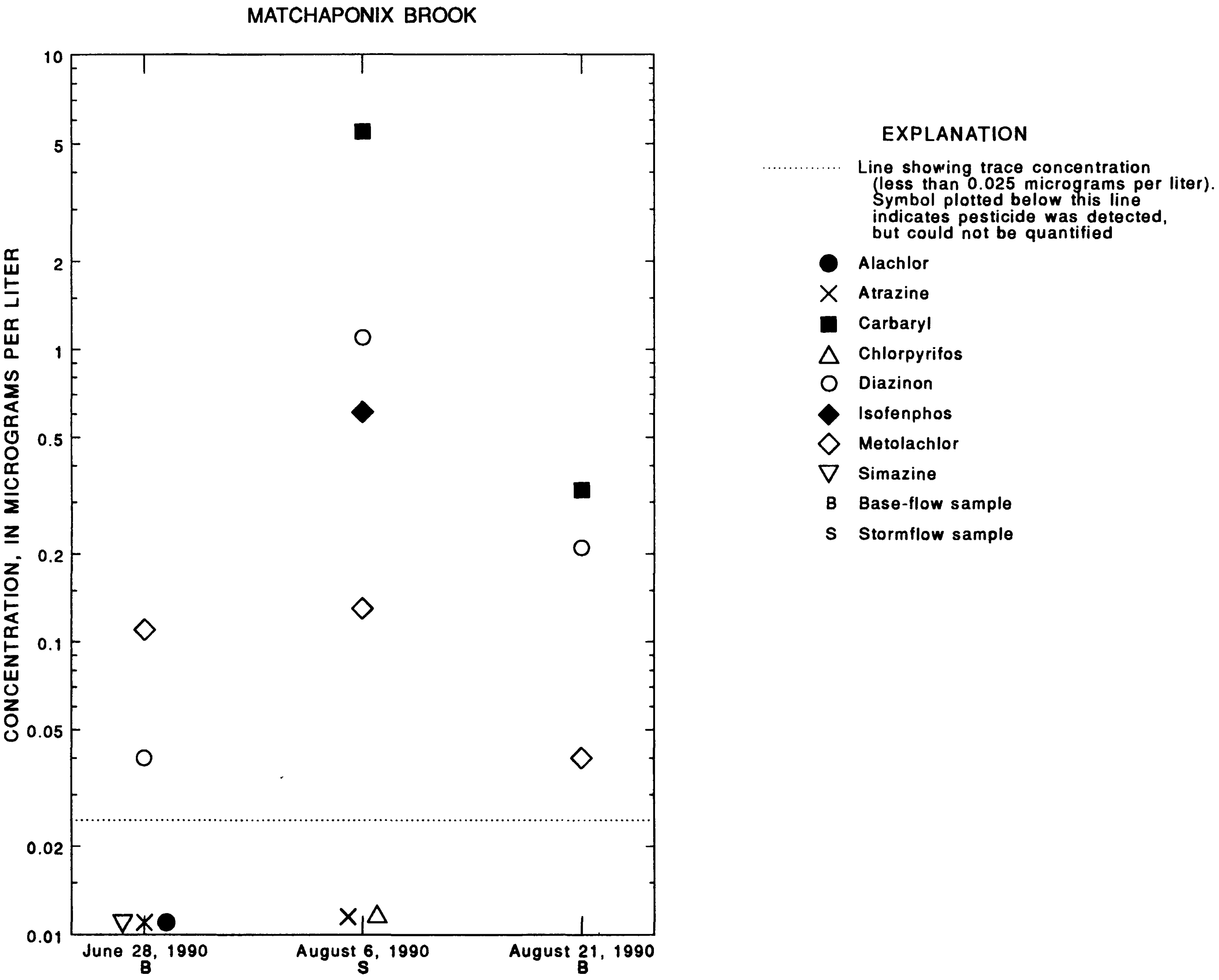


Figure 19.--Concentrations of pesticides in three water samples collected on Matchaponix Brook near Englishtown, June-August 1990.

The stormflow sample, collected on the rising limb of the hydrograph (fig. 18), contained 1.11 μg/L of diazinon, which exceeded the USEPA's recommended LHAL (table 5). Diazinon is an insecticide that is used primarily on field corn, vegetables, and fruit crops (Murphy and Fenske, 1987, p. 72). Carbaryl was detected at concentrations of 5.48 μg/L. Although this concentration is below the USEPA's recommended LHAL, it is the highest pesticide concentration measured in any of the study basins. The stormflow sample also contained two insecticides, chlorpyrifos and isofenphos (fig. 19). Chlorpyrifos was detected in trace amounts and isofenphos was detected at a concentration of 0.61 μg/L. No USEPA recommended LHAL has been established for either compound.

According to results of the 1988 survey, 19 of the 21 pesticides determined were applied in Matchaponix Brook basin. Eleven of these compounds were not detected in samples collected in 1990. These compounds were butylate, captan, carbaryl, chlorothalonil, cyanazine, linuron, metribuzin, parathion, pendimethalin, terbufos, and 2,4-D.

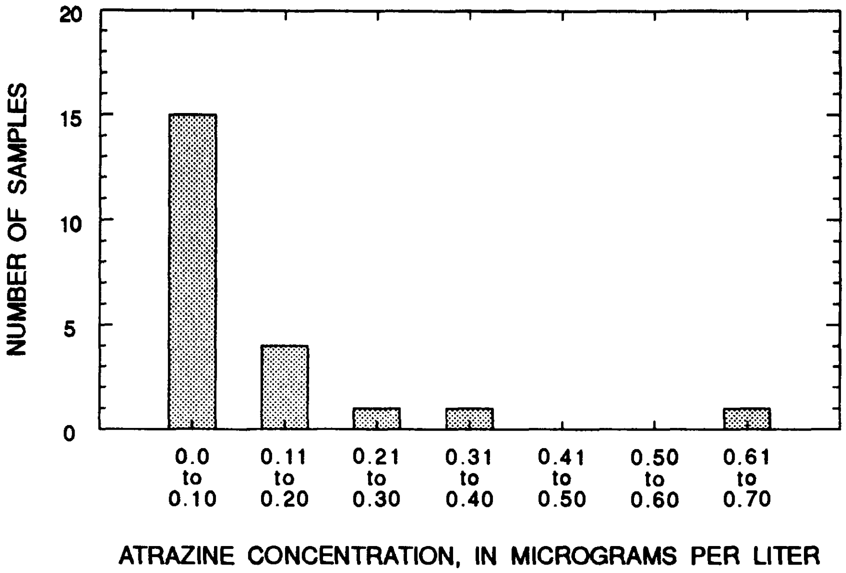
Statistical Analysis of Pesticide Concentrations in Base Flow and Stormflow

The surface-water-quality data set contained 22 samples, and a total of 21 pesticides were measured in each set of samples. Methods of statistical analysis of data--mean, median, standard deviation, quartiles, and histograms--were all used to describe the data distribution and any outlying data points from the distribution. The mean, median, and standard deviation of the concentrations of the 10 detected pesticides are listed in table 9. The mean concentrations of atrazine, metolachlor, and carbaryl were 0.11, 0.32, and 0.29 μg/L, respectively; mean concentrations of the remaining 7 pesticides were less than 0.1 μg/L. The greatest standard deviation calculated for all the pesticides was that for concentrations of carbaryl (1.164); this wide spread in the data can be attributed to the high concentration of carbaryl in a stormflow sample from Matchaponix Brook (5.48 μg/L). Concentrations of carbaryl in other samples were less than or equal to 0.5 μg/L.

Histograms showing concentrations of atrazine and metolachlor are skewed toward the low concentrations (fig. 20). Data sets for atrazine and metolachlor are nearly complete; each pesticide was detected in 19 samples (including trace values) and thus was used in the statistical analysis. The other eight pesticides were detected less often and predominantly at trace concentrations. About 46 percent of the entire data set is censored (large number of trace values), and is, therefore, not appropriate for more rigorous statistical analysis.

Table 9.--Mean, median, and standard deviations of concentrations of pesticides detected in water-quality samples, June-September 1990

	Number of samples	Mean	Median	Standard deviation
Alachlor	22	0.01	0.00	0.02985
Atrazine	22	.11	.06	.1442
Carbaryl	22	.29	.00	1.164
Chlorpyrifos	22	.00	.00	.00064
Cyanazine	22	.01	.00	.02037
Diazinon	22	.07	.00	.2377
Isofenphos	22	.03	.00	.1308
Linuron	22	.01	.00	.0547
Metolachlor	22	.32	.05	.662
Simazine	22	.01	.00	.01447



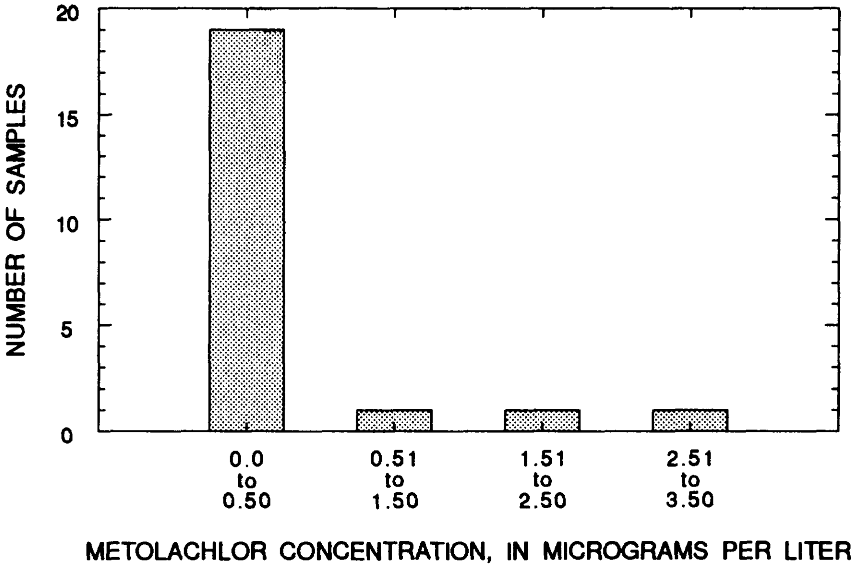


Figure 20.--Concentrations of atrazine and metolachlor in water samples collected at seven sampling sites.

Association analysis, such as bivariate plots and correlation, are used to indicate a possible relation between variables in the data. Because the concentrations of metolachlor and atrazine have outlying data points (fig. 20), the data were ranked as described by Conover (1971). Figure 21 is a plot of ranked metolachlor concentrations as a function of ranked flow rate. The correlation between the two variables is 0.533. A regression of the ranked values yielded an adjusted r^2 of 25 percent; however, results of the t-test showed that the correlation was significant. These results indicate that 25 percent of the variance in metolachlor data can be attributed to the flow rate in the sampled rivers. The remaining variance can be attributed to other climatic, topographic, and geologic factors. A similar correlation test was conducted on ranked atrazine concentrations and ranked flow rates, but the resulting correlation (0.084) was extremely low.

Pesticides in Pretreated and Treated Public-Supply Water Samples

Treatment of surface water prior to human consumption involves several steps. Pretreated water enters the treatment facility at the intake, where large debris, such as branches, are screened out; then water flows through fine screens to remove leaves and twigs. Next, aluminum sulfate is added as a flocculent to remove impurities; chemical treatments to adjust pH and control odor also are added. The coagulated floc is allowed to settle in large basins and chlorine is added as a disinfectant. Finally, water from the basins is pumped through sand and gravel filters. More chemicals are added to adjust pH and complete the disinfection process, and the water is ready for distribution. Samples of pretreated and treated water were collected from three treatment plants that are operated by the Elizabethtown Water Company (Main Branch Raritan River and Millstone River), the Hackettstown Municipal Utilities Authority (Lower Mine Hill Reservoir), and the New Jersey Water Supply Authority (Manasquan River).

The results of analyses of pretreated and treated water samples are listed by the basin name in table 10. Samples from the Hackettstown Municipal Utility Authority (Lower Mine Hill Reservoir) contained low concentrations of atrazine in both pretreated and treated water (0.08 μg/L and trace concentrations, respectively) (table 10), although atrazine was detected at the highest concentrations (0.14, 0.15, 0.35, and 0.61 μg/L) of all compounds detected at Lower Mine Hill Reservoir during field sampling (table 5). Six of the eight water-quality samples collected from the Main Branch Raritan and Millstone Rivers contained higher concentrations of atrazine than samples of pretreated and treated water from the associated treatment plants (table 5). Simazine was detected in higher concentrations (0.25 and 0.32 μg/L) in pretreated and treated water than in the water-quality samples, but these concentrations were still below the USEPA's recommended LHAL. No pesticides were detected in pretreated or treated water samples from the New Jersey Water Supply Authority (Manasquan River). These findings are consistent with the low concentrations measured in the water-quality samples (table 5).

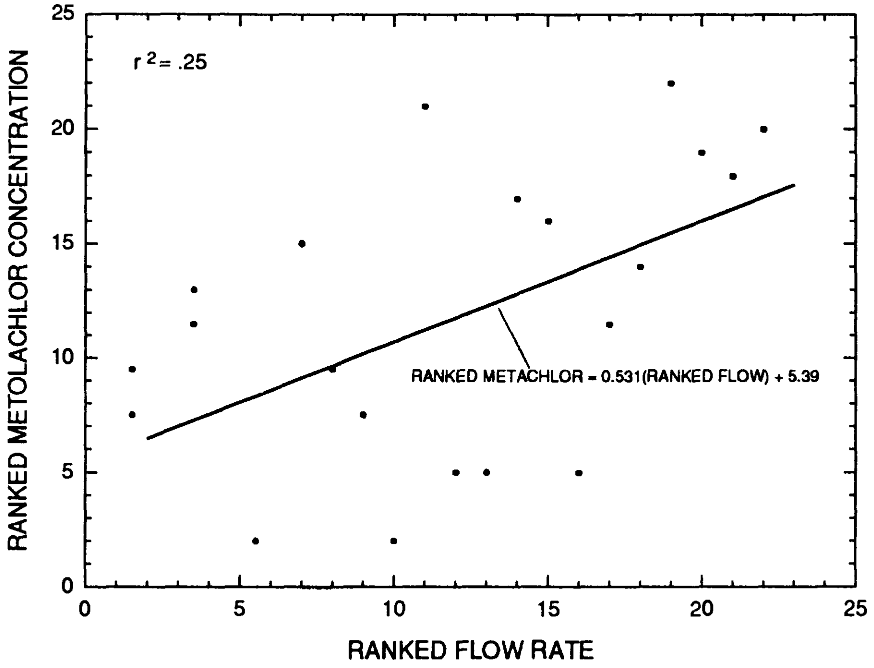


Figure 21.--Relation between ranked concentration of metolachlor in water samples and ranked flow rate.

Table 10.--Physical properties and concentrations of pesticides detected in water samples collected from water-treatment facilities, September 1990

[--, data not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; trace, less than 0.03 micrograms per liter; ND, not detected]

Station name	Date sampled	Time sampled	Specific conductance (µS/cm)	pH	Atrazine (µg/L)	Simazine (µg/L)
Lower Mine Hill, untreated water	9-05-90	1130	--	7.39	0.08	ND
Lower Mine Hill, treated water	9-05-90	1130	--	6.51	trace	ND
Main Branch Raritan River, untreated water	9-04-90	1400	248	9.06	trace	.25
Main Branch Raritan River, treated water	9-04-90	1400	--	7.18	.03	.32
Manasquan River, untreated water	9-06-90	900	--	7.42	ND	ND
Manasquan River, treated water	9-06-90	900	--	8.00	ND	ND

SUMMARY AND CONCLUSIONS

The U.S. Geological Survey, in cooperation with the New Jersey Department of Environmental Protection and Energy, investigated the presence of agricultural pesticides in surface-water sources of potable-water supplies. In the first phase of the study, drainage basins used for public water supply in New Jersey that might be affected by agricultural runoff were identified by analyzing pesticide-use data that were collected by surveying licensed pesticide applicators. A Geographic Information System (GIS) was used to analyze agricultural-land-use, hydrographic, basin-delineation, and municipal-boundary data. In the second phase, a short-term water-quality reconnaissance was conducted in six drainage basins used for public supply most likely to be affected by pesticide application.

Base-flow and stormflow samples were collected from Lower Mine Hill Reservoir, with sampling sites above and below the reservoir; South Branch of the Raritan River at Flemington; Main Branch of the Raritan River at Raritan; Millstone River at Raritan; Matchaponix Brook at Englishtown; and Manasquan River at Squankum. The basins were selected on the basis of calculated pesticide-application rate and percentage of agricultural land.

Pesticides were detected in all samples except the trip blanks and the pretreated and treated samples from the Manasquan River. Only one compound (diazinon) exceeded the USEPA's recommended Lifetime Health Advisory Limit; diazinon was present in the stormflow sample from Matchaponix Brook at a concentration of 1.11 μg/L. Results of analyses of water-treatment-plant samples showed detectable pesticide residues in both pretreated and treated samples.

Atrazine and metolachlor were detected in 86 percent of the samples; alachlor, in 55 percent; simazine, in 45 percent; diazinon, in 27 percent; cyanazine and carbaryl, in 23 percent; linuron and isophenfos, in 9 percent; and chlorpyrifos, in 5 percent. About 46 percent of the data are censored because pesticides were detected in trace concentrations. Correlation between ranked metolachlor concentrations and flow rates is 0.533, and 25 percent of the variance in metolachlor concentrations can be attributed to the flow rate. Other climatic, topographic, and geologic factors apparently affect metolachlor concentrations in surface water in the study basins. The correlation between ranked atrazine concentrations and flow rate is poor.

Most of the pesticides detected in 1990 in surface water from the six study basins were applied in the basins, according to results of the 1988 pesticide survey. The exceptions were simazine, alachlor, and cyanazine in samples collected above the Lower Mine Hill reservoir; isofenphos in samples from the Millstone River; and diazinon in samples from the South Branch of the Raritan River. Nine of the 21 pesticides selected for study reportedly were applied in 1988 in at least three of the six study basins, but were not detected in the 1990 samples. These compounds were butylate, captan, carbofuran, chlorothalonil, metribuzin, parathion, pendimethalin, terbufos, and 2,4-D.

REFERENCES CITED

Anderson, J.R., Hardy, E.E., Roach, J.T., and Wiemer, R.E., 1976, A land use and land cover classification system for use with remote sensor data: U.S. Geological Survey Professional Paper 964, 28 p.

Baker, D.B., 1988, Sediment, nutrient, and pesticide transport in selected Lower Great Lakes tributaries: U.S. Environmental Protection Agency, EPA-905/4-88-001, 173 p.

Baker, D.B., and Richards, R.P., 1989, Pesticides in terrestrial and aquatic environments: Proceedings of the National Research Conference, Virginia Water Resources Research Center, Richmond, Va., p. 11.

Bauersfeld, W.R., Moshinsky, E.W., Pustay, E.A., and Jones, W.D., 1990, Water Resources Data New Jersey Water Year 1989, Water-Data Report NJ-89-1, v. 1, p. 436.

Burkart, M.R., Ragone, S.E., Thurman, M.E., and Perry, C.A., 1988, Planned studies of herbicides in ground and surface water in the midcontinental United States: U.S. Geological Survey Water-Resources Investigations Report, 88-4220, 445 p.

Conover, W.J., 1971, Practical nonparametric statistics: New York, John Wiley and Sons, 493 p.

Glotfelty, D.E., Taylor, A.W., Ibensee, A.R., Jersey, J. and Glenn, S., 1984, Atrazine and simazine movement to Wye River estuary: Journal of Environmental Quality, v. 13, p. 115-121.

Goolsby, D.A., and Thurman, M.E., 1990, Herbicides in rivers and streams of the upper midwestern United States, in Proceedings of the 46th Annual Meeting of the Upper Mississippi River Conservation Committee, Bettendorf, Iowa, p. 6.

Guy, H.P., and Norman, V.W., 1970, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C2, 59 p.

Hall, J.K., 1974, Erosional losses of s-Triazine herbicides: Journal of Environmental Quality, v. 3, p. 174-180.

Immunosystems, Inc., 1989, Res-I-Mune use manual: Scarborough, Me., unpublished, 5 p.

Louis, J.B., Robsen, M.G., and Hamilton, G.C., 1989, New Jersey pesticide use survey, in Pesticides in terrestrial and aquatic environments: Proceedings of the National Research Conference, Virginia Water Resources Research Center, Richmond, Va., p. 194-204.

Louis, J.B., and Vowinkel, E.F., 1989, Effect of agricultural chemicals on ground-water quality in the New Jersey Coastal Plain, in Pesticides in terrestrial and aquatic environments: Proceedings of the National Research Conference, Virginia Water Resources Research Center, Richmond, Va., p. 80-89.

Louis, J.B., Robsen, M.G., and Meyer, L.W., 1990, Trends in the agricultural use of pesticides in New Jersey: 1978 through 1988, in Pesticides in the next decade: The challenges ahead: Proceedings of the National Research Conference, Virginia Water Resources Research Center, Richmond, Va., p. 675-691.

Mattern, G.C., and Rosen, J.D., 1991, Trace pesticide determination in surface water by XAD extraction and gas chromatography/chemical ionization mass spectrometry: Journal of the Association of Official Analytical Chemists, v. 74, no. 6, p. 982-986.

Murphy, E., and Fenske, R., 1987, Pesticide use in New Jersey: Implications for ground water quality: Trenton, N.J., New Jersey Department of Environmental Protection, 214 p.

New Jersey State Planning Commission, 1992, The New Jersey State development and redevelopment plan, Trenton, N.J., 183 p.

Squillace, P.J., and Engberg, R.A., 1988, Surface-water quality of the Cedar River basin, Iowa, with emphasis on the occurrence and transport of herbicides, May through November 1985: U.S. Geological Survey Water-Resources Investigations Report 88-4060, 82 p.

Tedrow, J.C.F., 1986, Soils of New Jersey: Malabar, Fla., Robert E. Kriegler Publishing Company, 479 p.

U.S. Geological Survey, 1991, National water summary 1988-89--Florida floods and droughts: U.S. Geological Survey Water-Supply Paper 2375, p. 231-238.

Vowinkel, E.F., and Battaglin, W.A., 1988, Methods of evaluating the relation of ground-water quality to land use in a New Jersey Coastal Plain aquifer system: U.S. Geological Survey Water-Resources Investigations Report 88-4220, p. 405-410.

Ward, J.R., and Harr, A.C., eds., 1990, Methods for collection and processing of surface-water and bed-material samples for physical and chemical analyses: U.S. Geological Survey Open-File Report 90-140, 71 p.

Wauchope, R.D., 1978, The pesticide content of surface water draining from agricultural fields--A review: Journal of Environmental Quality, v. 7, no. 4, p. 459-472.

Wolfe, Peter E., 1977, The geology and landscapes of New Jersey: New York, Crane, Russak, and Company, Inc., 351 p.