A Comprehensive Inventory of Surface Water Monitoring Activities in the New Jersey Pinelands Area

STATE OF NEW JERSEY • PINELANDS COMMISSION

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I. Introduction

Currently there exists over one million acres of land in the N.J. Pinelands (Figure 1) (Comprehensive Management Plan, 1980). In this region some of the purest surface water in the nation is found flowing through its many lakes, rivers and streams.

Many unique and endangered plant (Givnish, 1971) and animal species (Moul, 1979) are able to survive in these nutrient poor and acidic waters. However, the surface waters and their surrounding sandy, siliceous and impoverished soils are not able to attenuate the pollutants that are increasingly added to the surface waters as development increases (Durand, 1981). As a result, the fragile chemistry of the surface waters can change significantly, and as a consequence, alter and eliminate the habitats of the many unique and endangered plant and animal species that inhabit the Pinelands (Ehrenfeld, 1981).

In order to protect this valuable national water resource, a coordinated regional surface water monitoring network should be established. Such a network could provide data on stream water contamination to the appropriate agencies who then could take the necessary enforcement measures to protect the stream water quality.

A determination should first be made of the existing surface water monitoring efforts in the Pinelands area. Such a determination is useful in understanding the extent and quality of water monitoring activities in the Pinelands of New Jersey.

It is, therefore, the objective of this inventory to review present and past surface water monitoring activities on the County, State, Federal and academic levels, and determine the quantity and quality of surface water monitoring activities in the New Jersey Pinelands.

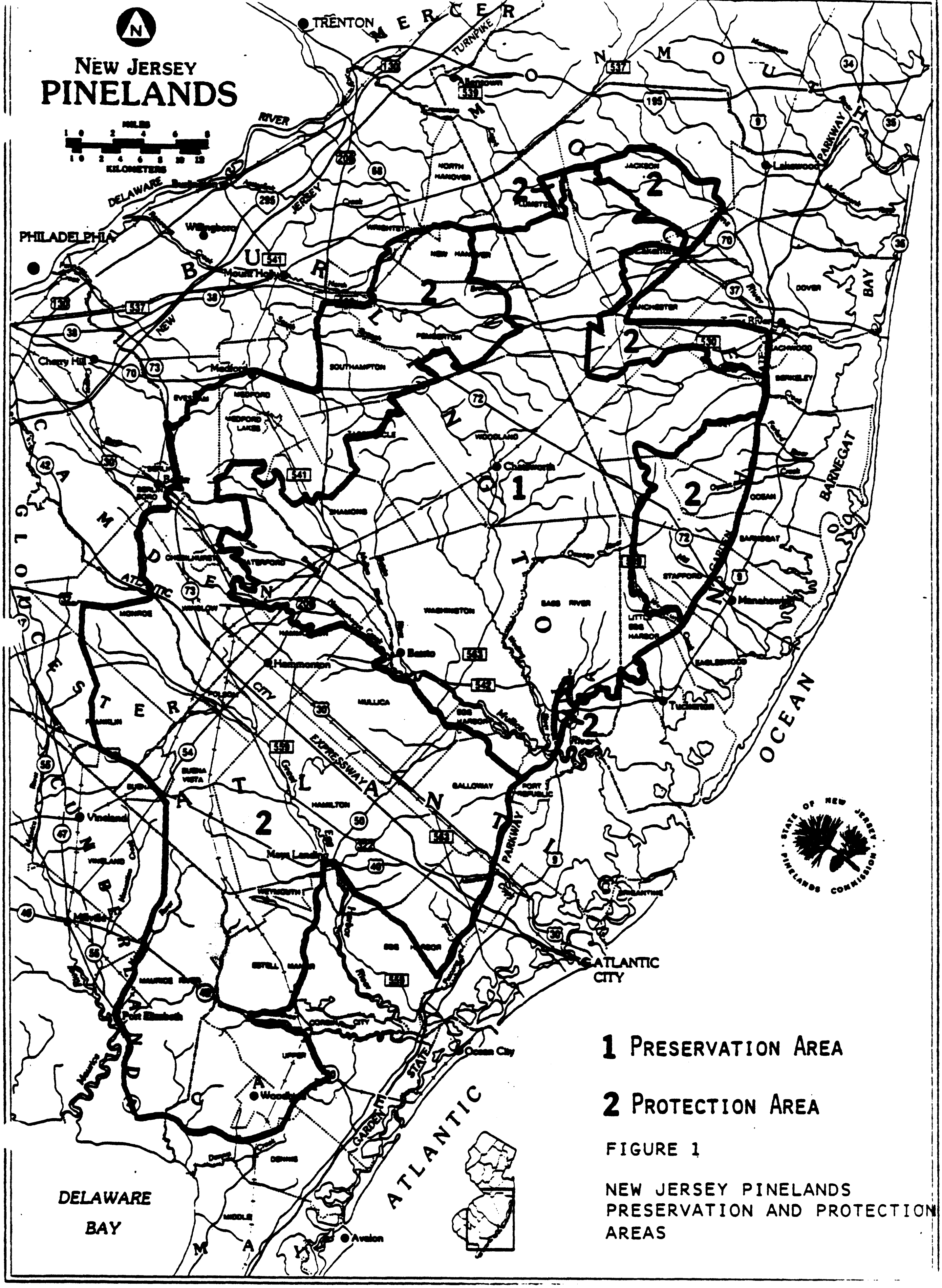


FIGURE 1

NEW JERSEY PINELANDS PRESERVATION AND PROTECTION AREAS

In addition to reviewing surface water monitoring in the Pinelands Area, it is the objective of this report to provide recommendations that will address the organizational problems associated with the development of a coordinated surface water monitoring program in the Pinelands Area.

The data collected in this inventory can then be utilized by appropriate government agencies as a source of information for establishing and implementing a coordinated surface water monitoring network in the N.J. Pinelands Area. Such a network will, hopefully, enable the lead agency to protect the fragile Pinelands ecosystem more effectively.

II. Monitoring Activities

A. County Health Department Studies

There are seven counties within the N.J. Pinelands Area. Of these, only four have undertaken an extensive surface water monitoring effort: Burlington, Ocean, Atlantic and Cape May. As of this writing, Gloucester, Camden and Cumberland Counties have not undertaken surface water monitoring studies.

1. Burlington County Health Department Studies

a. Burrs Mill Creek

Nine sampling stations along Burrs Mill Creek and its tributaries in Southampton Township were selected by the Burlington County Health Department (Figure 2).

Each station was sampled weekly from March, 1978 until March, 1979. The data collected were stored on STORET, the computer filing system currently used by the New Jersey Department of Environmental Protection (N.J.D.E.P.).

Further sampling was performed at these stations for 6 months (March, 1979 - December, 1979). These samples, however, were not collected weekly, but on a more irregular basis. The following parameters, as outlined in Table 1, were studied.

b. Stream Walk Program

CETA workers were employed by Burlington County in 1979 and 1980. They walked the courses of the Mullica, Rancocas and Bass Rivers. Samples were collected once at half mile distances along these rivers. An attempt was made to get baseline water quality data along the major rivers of Burlington

BURLINGTON COUNTY

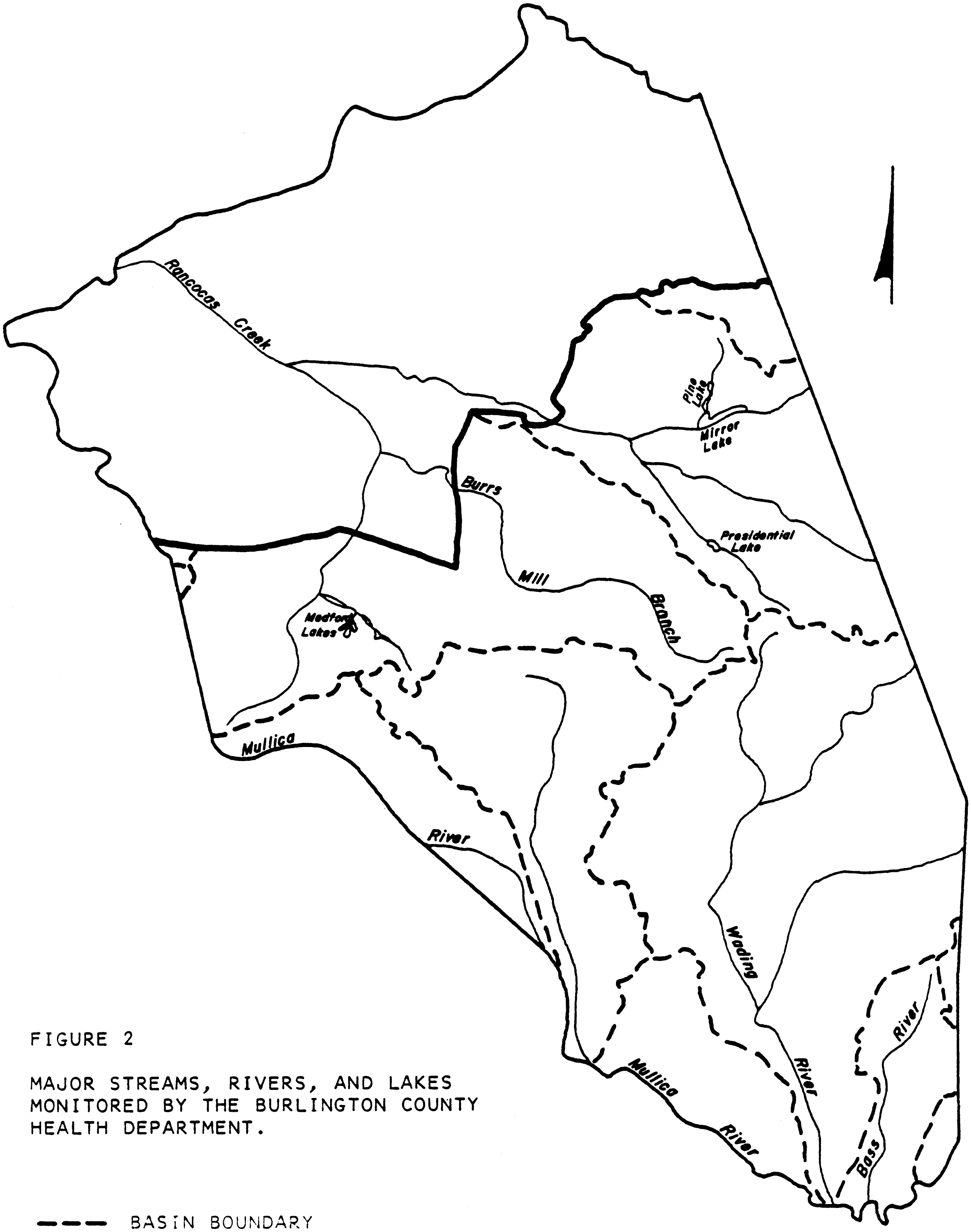
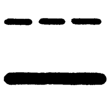


FIGURE 2

MAJOR STREAMS, RIVERS, AND LAKES MONITORED BY THE BURLINGTON COUNTY HEALTH DEPARTMENT.



BASIN BOUNDARY

PINELANDS NATIONAL RESERVE BOUNDARY

Table 1 Parameters measured in Burrs Mill Creek, Southampton Township

Chemical:

pH	alkalinity
turbidity	ammonia
conductivity	nitrite nitrogen
total solids	nitrate nitrogen
suspended solids	orthophosphate
dissolved solids	polyphosphate
chemical oxygen demand	chlorine
biological oxygen demand	

Biological:

Total coliform
Fecal coliform
Fecal streptococcus

County. Also, stream walkers recorded any waste water outfalls entering the rivers.

The water quality parameters measured for the stream walk program are the same as in Table 1. These data, as of this writing, have not been assembled into a formal report. However, these data are currently on file with the Burlington County Health Department.

c. Lake Monitoring

The Burlington County Health Department has been collecting water samples from county lakes on a weekly basis between May and September. Only bacteria levels have been measured; nutrient levels have not. The following lakes in the county are being sampled:

Medford Park Lake (Medford Lakes)
Mirror Lake (Pemberton)
Pine Lake (Pemberton)
Presidential Lake (Pemberton)

Sampling in Medford Park Lake began in 1979. Sampling in Mirror, Pine and Presidential Lakes began in 1977.

In Medford Lakes, the Medford Lakes Colony Club is preparing to sample all major lakes (21) in the borough of Medford Lakes.

2. Atlantic County Health Department Studies

The Atlantic County Health Department has an ongoing water monitoring program for streams and lakes in the county (Figure 3). The parameters measured are listed in Table 2. Not all these parameters were studied at every site.

ATLANTIC COUNTY

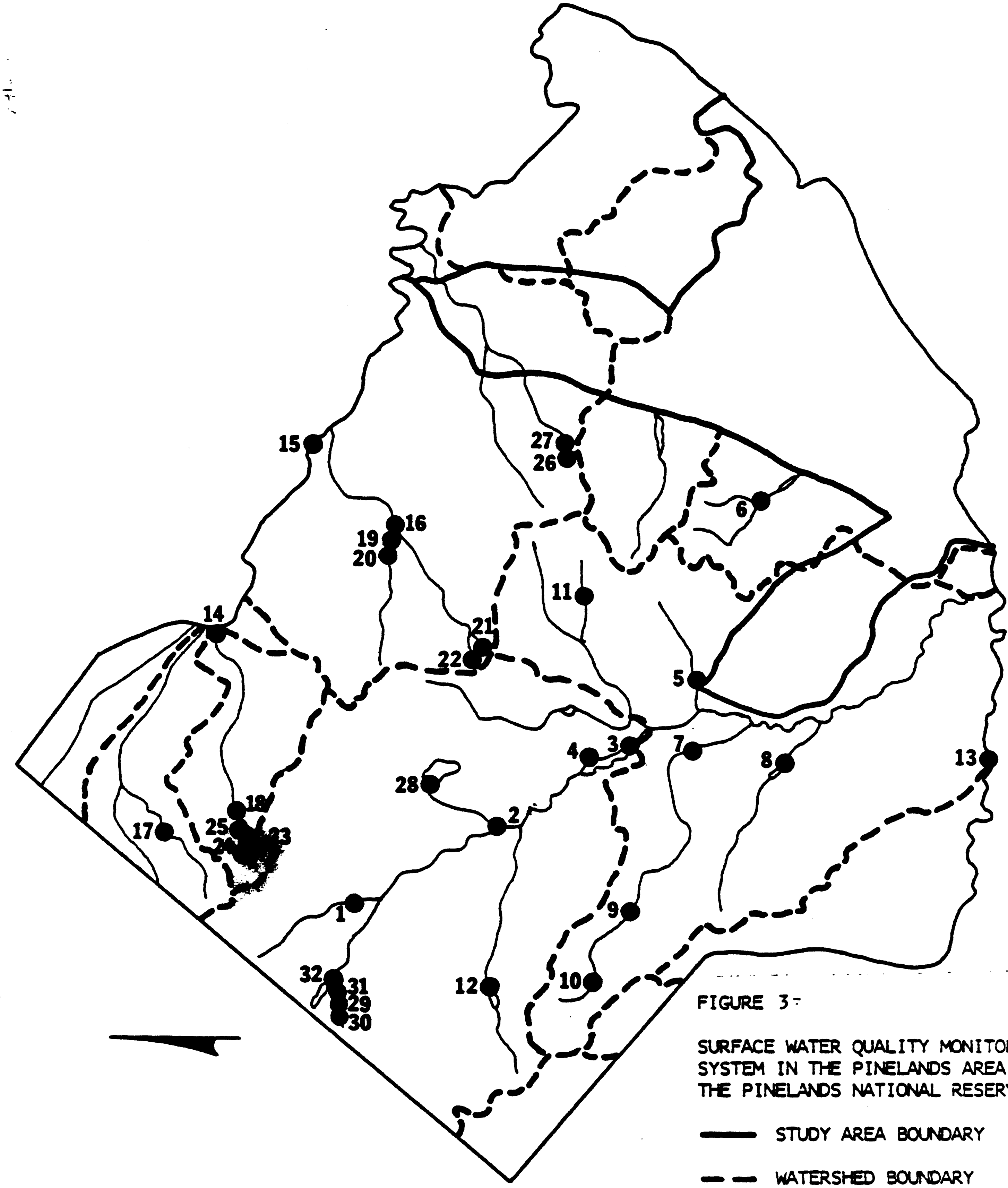


FIGURE 3

SURFACE WATER QUALITY MONITORING SYSTEM IN THE PINELANDS AREA AND THE PINELANDS NATIONAL RESERVE

STUDY AREA BOUNDARY

WATERSHED BOUNDARY

WATER QUALITY STATION

a. Stream Studies

The streams studied in Atlantic County have been divided into watersheds (Figure 3). The following stream sites were monitored in the basins (Table 3) during the summer months of June through August 1980.

b. Inland Lake Studies

A monitoring study was also performed on many of the inland lakes in Atlantic County (Figure 3). They have also been divided into various basins (Table 4) and were monitored also during the summer months of June through August 1980.

The inland lakes have been monitored for primarily total and fecal coliform bacteria. These studies have been performed during the summer to protect bathers. At Collings Lake, sites 29 to 32, (Table 4 and Figure 3) in Folsom, the Atlantic County Health Department in addition to measuring bacteria, also monitored nitrate and phosphate levels in the water.

The Atlantic County Health Department is in the process of purchasing an auto-analyzer that will enable this agency to expand its monitoring program.

3. Ocean County Health Department Studies

In 1976, the Ocean County Health Department developed a 208 surface water quality monitoring program for Ocean County. This 208 funding, however, ended in 1978, but the county has assumed the cost of the project.

Water samples have been collected on a weekly

Table 2. Parameters measured in lakes and streams in Atlantic County

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Chemical:

- pH
- phosphate
- nitrate-nitrogen
- turbidity

Biological:

- Bacteria

Table 3 Streams Monitored in Atlantic County

Site	(Code)	Municipality	Stream
Egg Harbor River Basin			
1.	(1331-01)	Folsom	Penny Pot Stream
2.	(1334-01)	Hamilton	Egg Harbor River
5.	(1345)	Hamilton	Gravelly Run
6.	(1348)	Egg Harbor Twp.	Mill Branch
7.	(1351)	Estell Manor	South River
8.	(1353)	Estell Manor	Stephen Creek
9.	(1356)	Hamilton Twp.	South River
10.	(1358)	Buena Vista Twp.	South River
11.	(1359)	Hamilton Twp.	Jack Pudding Branch
12.	(1370)	Buena Vista	Deep Run
Tuckahoe River Basin			
13.	(1330-01)	Corbin City	Tuckahoe River
Mullica River Basin			
15.	(1329-01)	Egg Harbor City	Mullica River
16.	(1377-01)	Egg Harbor City	Indian Cabin Creek
17.	(1379-01)	Hammonton	Cedar Branch Creek
18.	(1380)	Hammonton	Hammonton Creek

Table 4. Inland Lakes Monitored in Atlantic County

Site (Code)	Municipality	Lake
Egg Harbor River Basin		
3. (1366-01)	Hamilton	Lake Lenape
4. (1366-02)	Hamilton	Lake Lenape
Mullica River Basin		
14. (1325-01)	Mullica Twp.	Lake Nescochague
19. (0178-02)	Egg Harbor City	City Lake
20. (0178-01)	Egg Harbor City	City Lake
21. (1365-01)	Hamilton Twp.	Little Goose Pond
22. (1364-01)	Hamilton Twp.	Big Goose Pond
23. (1368-01)	Hammonton	Hammonton Lake
24. (1368-02)	Hammonton	Hammonton Lake
25. (1368-03)	Hammonton	Hammonton Lake
26. (1372-01)	Galloway	Fred Lake
27. (1373-01)	Galloway	Pam Lake
28. (1374-01)	Hamilton Twp.	Makepeace Lake
Great Egg Harbor River Basin		
29. (1375-01)	Folsom	Collings Lake
30. (1375-02)	Folsom	Collings Lake
31. (1375-03)	Folsom	Collings Lake
32. (1375-04)	Folsom	Collings Lake
Mullica River Basin		
33. (1376-01)	Hamilton Twp.	Reservior

or bi-weekly basis at 29 sites that lie within the Pinelands National Reserve (Figure 4). These collection sites are located on streams, usually upstream of major road crossings from which pollutants may wash.

In Table 5, a list of the chemical and physical parameters measured in this study is given.

The data collected are stored in STORET at the New Jersey Department of Environmental Protection.

The Ocean County Health Department has a certified laboratory that can analyze the chemical, physical and biological constituents as outlined in Table 5. This laboratory is in the process of obtaining a gas chromatograph that will enable the county to measure nonhalogenated hydrocarbons such as benzene, xylene, toulene, and gasoline. The measurement of these parameters will be useful for detecting pollution in streams from such sources as service stations, industrial operations, and landfills.

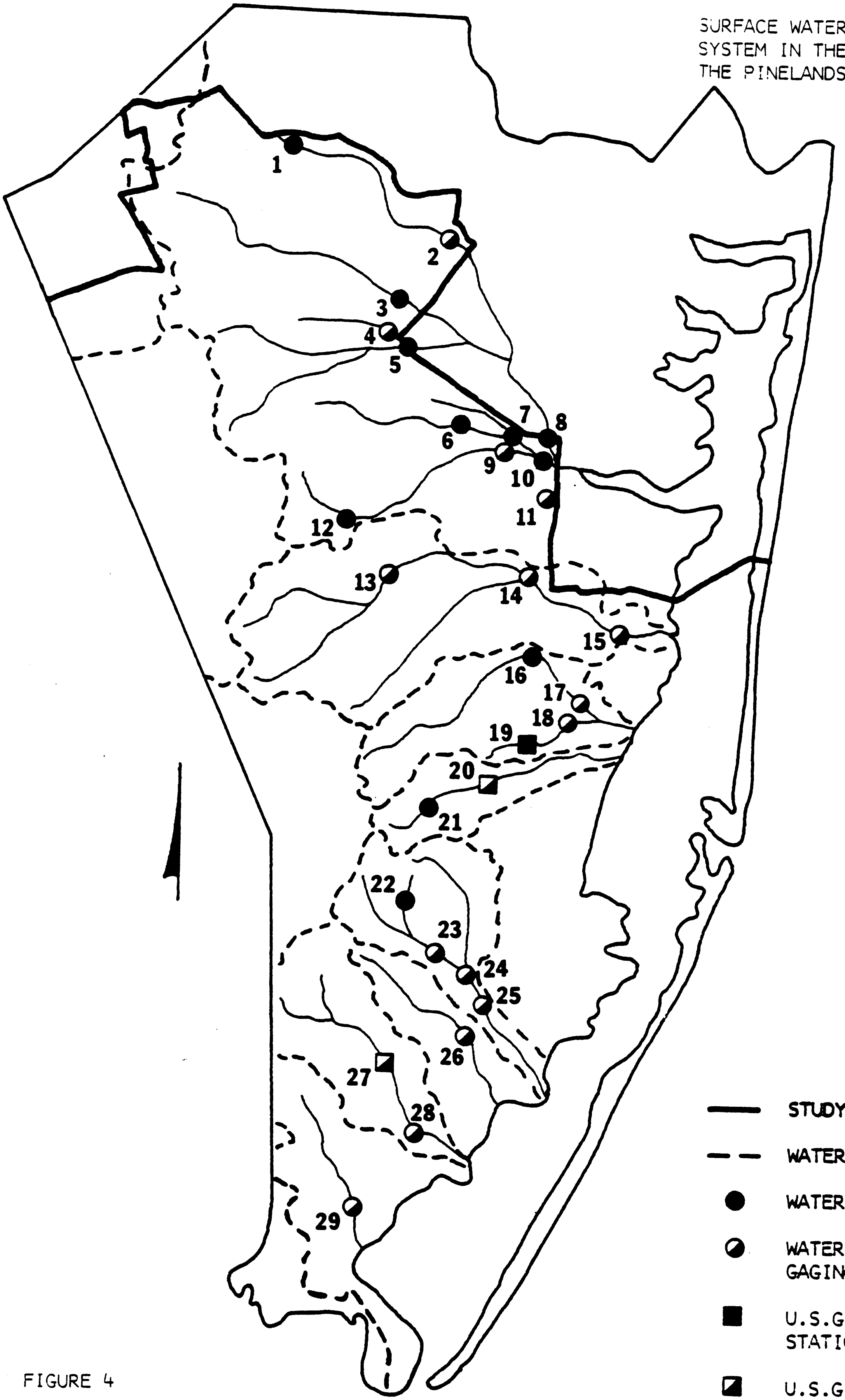
4. Cape May County Health Department Studies

Nine water quality monitoring stations are being sampled in the Pinelands Reserve area (Figure 5) by the Cape May County Health Department. The major sampling stations are those along the Tuckahoe River, Ludlam Pond, and Dennisville Lake. There are also several monitoring stations along some minor tidal creek that flow into the Delaware Bay. These sites are being sampled at various times throughout the year, as a part of a baseline data profile program to study water quality in the Ponds and streams of the County.

Presently, fecal coliform and such chemical parameters as phosphate, ammonia, and dissolved oxygen are being analyzed. Following consultation

OCEAN COUNTY

SURFACE WATER QUALITY MONITORING SYSTEM IN THE PINELANDS AREA AND THE PINELANDS NATIONAL RESERVE.



STATIONS:

1. OCN 031
2. OCN 029
3. OCN 041
4. OCN 042
5. OCN 039
6. OCN 035
7. OCN 034
8. OCN 024
9. OCN 036
10. OCN 033
11. OCN 032
12. OCN 037
13. OCN 045 01408830
14. OCN 044 01408870
15. OCN 043 01409000
16. OCN 047
17. OCN 046
18. OCN 049
19. OCN 048 01409055
20. OCN 051 01409095
21. OCN 052
22. OCN 056
23. OCN 054 01409150
24. OCN 055
25. OCN 053 01409210
26. OCN 057
27. OCN 059 01409280
28. OCN 058 01409282
29. OCN 060 01409310

STUDY AREA BOUNDARY

WATERSHED BOUNDARY

WATER QUALITY STATION

WATER QUALITY AND FLOW GAGING STATION

U.S.G.S. WATER QUALITY STATION

U.S.G.S. WATER QUALITY AND FLOW GAGING STATION

FIGURE 4

Table 5. Parameters measured in surface waters of Ocean County

Parameter	Units
Water Temperature	Degrees Centigrade
Turbidity	
Color	
Conductivity at 25 C	micromhos/cm
Dissolved Oxygen (DO)	mg/l
Biological Oxygen Demand (BOD)	mg/l
Chemical Oxygen Demand (COD)	mg/l
pH	standard units
Total Alkalinity ($CaCO_3$)	mg/l
Acidity (mineral)	mg/l
residue	mg/l
Nitrate-nitrogen	mg/l
Nitrite and nitrate-nitrogen	mg/l
Total Phosphorus	mg/l
Dissolved Phosphorus (ortho)	mg/l
Total Hardness ($CaCO_3$)	mg/l
Chloride	mg/l
Sulfate	mg/l
Iron	mg/l
Fecal Coliform	per 100 ml.
phenols	mg/l
heavy metals (Ag, Zn , Fe, Cu, etc...)	mg/l

CAPE MAY COUNTY

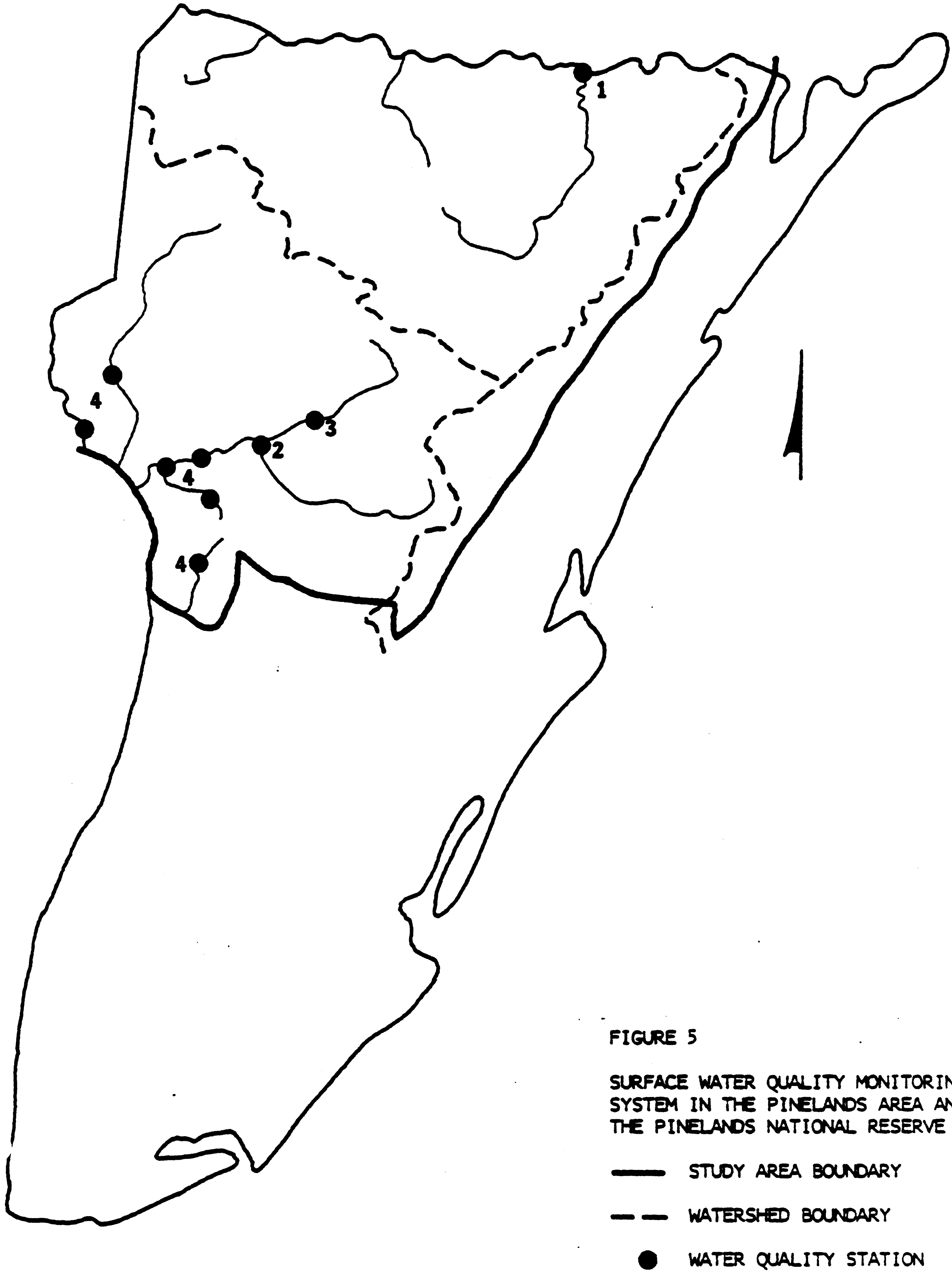


FIGURE 5

SURFACE WATER QUALITY MONITORING SYSTEM IN THE PINELANDS AREA AND THE PINELANDS NATIONAL RESERVE

STUDY AREA BOUNDARY

WATERSHED BOUNDARY

WATER QUALITY STATION

with other State Agencies, other chemical, physical and biological parameters will be studied.

At the present time, the baseline water quality data are not being sent to Data Acquisition (New Jersey Department of Environmental Protection) for storage on STORET.

Presently, water quality monitoring data are not available for Cumberland, Gloucester and Camden County Health Departments.

B. State and Federal Surface Water Monitoring in the New Jersey Pinelands

1. Stream Monitoring

In New Jersey there are four major monitoring networks that have been established by the New Jersey Department of Environmental Protection (D.E.P.) and the United States Geologic Survey (U.S.G.S.) It is the purpose of these networks to establish baseline surface water quality data and identify water quality problems.

a. Primary Surface Water Monitoring Network

In this study which began in 1975, several chemical, physical, and biological parameters have been measured including nitrite, nitrate and total kjedhal nitrogen, phosphate and ammonia to name a few (Table 6). Sampling was done by D.E.P. at a frequency of six times per year at these stations on a routine basis.

In Table 7, a list of surface water monitoring stations, their location, parameters measured, sampling period, and monitoring agency that comprise the Primary Monitoring Network that lies in the Pinelands is given.

b. National Stream Quality Accounting Network (NASQAN)

The U.S.G.S. has also established a National Stream Quality Accounting Network (NASQAN) in the United States. The goal of this program is threefold: to determine the quantity and quality of water moving within the United States; to depict areal variability and changes in stream quality with time; and to assess future changes in stream water quality.

To meet the goals of this program, a bimonthly sampling program has been developed. Two sampling sites have been chosen in the Pinelands National Reserve (U.S.G.S. 1980): station 01409815 on the

Table 6. Parameters Measured in the Primary Surface Water Monitoring Network in the Pinelands.

number	station/number	Parameters	Sampling Time
1.	Mullica River at Pleasant Mills/ 393825074393500	Water Quality stream flow specific conductivity pH-field Temperature Dissolved Oxygen Biological Oxygen Demand Fecal Coliform Fecal Streptococcus Nutrients[1] Alkalinity Suspended Solids Nitrogen Carbon Trace Metals[2] Pesticides[3]	1976+
2.	Toms River/01408500	Water Discharge Water Quality - Specific conductivity - Water temperature	1928+ 1963+ 1974+ 1963-1966, 1974+
3.	Mullica River at Atsion Lake/01409387	Water Quality Same as: 39382507-393500, but no pesticides measured	1976+
4.	Hammonton Creek at Westcoatville/01409416	Water Quality Same as 01409387	1974+
5.	Batsto River at Batsto/01409500	Water Discharge Water Quality	1927+ 1979-1980
6.	West Branch Wading River near Jenkins/ 01409810	Water Discharge Water Quality - Specific Conductivity - Water Temperature	1974+ 1978+
7.	Oswego River at Harrisville/01410000	Water Discharge Water Quality Same as 393825074- 393500	1930+ 1976+
8.	East Branch Bass River near New Gretna/ 01410150	Water Discharge Water Quality Same as 01409416	1978+ 1976+

Table 6 (cont'd)

no.	station/number	Parameters	Sampling Time
9.	Great Egg Harbor River near Blue Anchor/01410820	Water Discharge	1975+
		Water Quality	1972+
		Same as 393825074-393500	
10.	Great Egg Harbor Folsom/01411000	Water Discharge	1925+
		Water Quality	
		Specific Conductance	1969-1975
			1977-1980
		Water Temperature	1960-1975
			1977-1980
		Suspended Sediment	1965-1970
			1978-1979
11.	Great Egg Harbor River at Weymouth/ 01411110	Water Quality	1975+
		Same as 01409387 and:	
		Periphyton Biomass	
		Phytoplankton identification	
		Chlorophyll A and B analysis	
12.	Tuckahoe River at Head of River/ 01411300	Water Discharge	1969+
		Water Quality	1975+
		Same as 01409387	
13.	South Branch Rancocas Creek at Retreat/01465835	Water Quality	1975+
		nitrate-nitrogen	
		nitrite-nitrogen	
		ammonium nitrogen	
		Total Kjedhalnitrogen	
		ortho-phosphate	
14.	North Branch Rancocas Creek at Browns Mills/ 01465970	Water Quality	1975+
		same as 01465835	
15.	North Branch Rancocas Creek at Pemberton/ 01467000	Water Quality	1975+
		same as 01465835	

Notes:

1. List of Nutrients: Sulfide, Sulfate, Chloride, Flouride, Silicon dioxide, nitrite, nitrate and ammonium nitrogen, total kjedhal nitrogen, phosphate and total carbon.
2. List of Trace Metals: Al, As, Be, B, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, Se, and Zn.
3. List of Pesticides: Phenals, PCB, aldrin, chlordane, DDD, DDE, DDT, diazinon, dieldrin, endosulfan, endrin, ethion, heptachlor, lindane, malathion, methoxychlor, methylparathion, methyltrithion, mirex, parathion, perthane, toxaphene, and trithion.

Table 7. Streams Monitored for water quality in the Pinelands by the New Jersey Department of Environmental Protection and the United States Geological Survey as Part of the Primary Monitoring Network

no.	Station	Location	(County)	Latitude/Longitude	Parameters measured	Sampled By[1]	Sampling Period
1.	393825074-393500	Mullica River at Pleasant Mills	Burlington	39°38'25"/74°39'35"	Table 6	DA+A	1976+
2.	01408500	Toms River Basin	Ocean	39°59'10"/74°13'29"	Table 6	USGS	1963+
3.	01409387	Mullica River at Atsion Lake	Burlington	39°44'25"/74°43'37"	Table 6	USGS	1976+
4.	01409416	Hammonton Creek at Westcoat-ville	Atlantic	39°38'02"/74°43'05"	Table 6	USGS	1974+
5.	01409500	Batsto River at Batsto	Burlington	39°38'00"/74°39'00"	Table 6	DA+A	1979-80
6.	01409810	West Branch Wading	Burlington	39°41'17"/74°32'54"	Table 6	USGS	1974+
7.	01410000	Oswego River at Harrisville	Burlington	39°39'47"/74°31'26"	Table 6	DA+A	1976+
8.	01410150	East Branch Bass River near New Gretna	Burlington	39°27'23"/74°26'30"	Table 6	DA+A	1976+
9.	01410820	Great Egg Harbor River near Blue Anchor	Camden	39°40'09"/74°54'49"	Table 6	USGS	1972+
10.	01411000	Great Egg Harbor River at Folsom	Folsom	39°35'42"/74°51'06"	Table 6	USGS	1925+

Table 7 (cont'd)

no.	Station Number	Location	(County)	Latitude/Longitude	Parameters measured	Sampled By[1]	Sampling Period
11.	01411110	Great Egg Harbor River at Weymouth	Atlantic	39°30'50"/74°46'47"	Table 6	USGS	1975+
12.	01411300	Tuckahoe River at Head of River	Cape May	39°18'25"/74°49'15"	Table 6	USGS	1969+
13.	01465835	So. Branch Rancocas Creek at Retreat	Burlington	39°55'23"/74°43'05"	Table 6	USGS	1975+
14.	01465970	No. Branch Rancocas Creek at Browns Mills	Burlington	39°58'04"/74°34'48"	Table 6	USGS	1975+
15.	01467000	No. Branch Rancocas Creek at Pemberton	Burlington	39°58'10"/74°41'04"	Table 6	USGS	1975+

[1]USGS = United States Geological Survey
DA+A = Data Acquisition and Analysis, New Jersey Department of Environmental Protection

Toms River near Toms River and station 01409815 on the Wading River near Maxwell. Sampling at these stations began in October 1975 (U.S.G.S., 1980).

Table 8 lists the parameters measured at these stations. It should be noted that specific conductance and water temperature are recorded hourly while the rest of the parameters except for phytoplankton and trace metals are measured once every two months (November, January, March, May, July and September) Phytoplankton identification was performed on five monthly samples taken during the months of November, March, May, July and September. Trace metals are taken as four monthly samples taken during November, January, May and July.

The parameters listed in Table 8 are only measured by the U.S.G.S. at the sampling station on the Wading River. However, at the Toms River station only specific conductance and water temperature are measured. These parameters are measured on a hourly basis by automatic means.

c. Benchmark Monitoring Network

The third type of surface water monitoring program that has been developed by the U.S.G.S. is called the Benchmark Network. Selected stream basins have been chosen that are likely to remain in their present or natural condition. Of the 57 Benchmark Stations that the U.S.G.S. has chosen in the United States, only one, the McDonald's Branch in Lebanon State Forest is located in the New Jersey Pinelands (Cobb and Biesecker, 1971), U.S.G.S. sampling station number 01466500 (Table 9).

At this Benchmark Station specific conductance and water temperature are measured on an hourly basis. Stream flow, pH, dissolved oxygen, fecal coliform, fecal streptococcus, biological oxygen demand, suspended sediments, common ions, nutrients

Table 8. Parameters Measured and Sampling Frequency of Streams in the Pinelands as Part of NASQAN (USGS)

Sampling Frequency	Parameter
Hourly	Specific Conductance Water Temperature
Six Samples per Year (Nov, Jan, Mar, May, Jul, Sep)	Specific Conductance Streamflow pH Dissolved Oxygen Water Temperature Fecal Coliform Fecal Streptoccus Suspended Sediment Sand-Silt Fraction. Common Ions Nutrients
Five Samples per Year (Nov, Mar, May, Jul, Sep)	Phytoplankton Identification
Four Samples per Year (Nov, Jan, May, Jul)	Trace Metals

and dissolved solids are measured bimonthly.

2. Lake Monitoring

In addition to the streams that are monitored in the Pinelands by the New Jersey Department of Environmental Protection, baseline data are maintained for many lakes. Table 10 lists the parameters that have been measured in the lake water. This program began in 1975 and continues. One hundred samples are collected per station per year.

In Table 11, the lakes that have been monitored by the N.J.D.E.P. are listed along with their acreage and location.

Not only do these data provide the N.J.D.E.P. with a baseline to measure chemical changes in the lake water, but are useful for determining whether the lakes have safe levels of bacteria.

3. Oyster Creek Study

Fusillo et al, (1980) while working for the U.S.G.S. began collecting water quality data in 1968 in upper Oyster Creek, near Brookville (Figure 6).

Initially, a stream-gaging station was installed. In 1974, a strip-chart pH recorder that was originally installed was replaced by a four-parameter water-quality monitor that measured pH, specific conductance, temperature, and dissolved oxygen. This monitor remained in operation until April, 1977.

Weekly field visits were begun in January, 1974 to complement the automatic data collection. In November 1975, the field data collection was expanded to include additional sampling sites on the main stem of Oyster Creek and its tributaries.

Temperature and pH were measured in the field at six stations on the main channel and on seven tributary streams. Additional water-quality data were collected at these stations during two intensively studied sampling periods: April 13, 1978, during baseflow conditions, and the second on May 25, 1978, after a

Table 9. Parameters Measured and Sampling Frequency of a Pineland Stream as Part of the U.S.G.S. Benchmark Program, Station Number 01466500, McDonalds Branch at Lebanon State Forest.

Frequency	Parameters
Hourly	Specific Conductance Water Temperature
Six times per year	Stream flow pH Dissolved Oxygen Fecal Coliform Fecal Streptococcus Biological Oxygen Demand Suspended Sediments Common Ions Nutrients Dissolved Solids

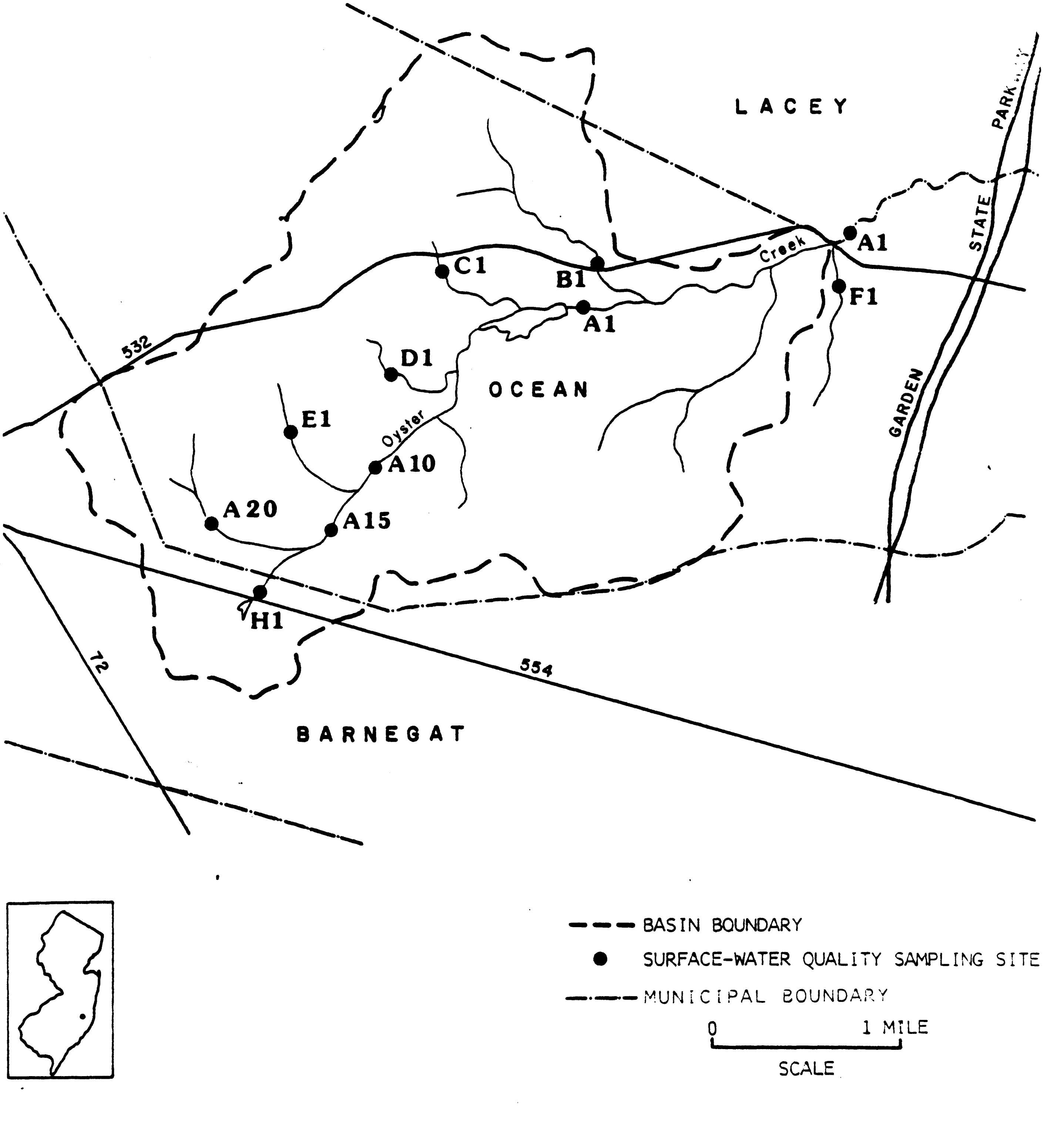
Table 10. Parameters Measured in Selected Lakes of the Pinelands by the D.E.P.

Parameters
Nitrite
Nitrite and Nitrate
Ammonia
Total Kjedhal Nitrogen
Total Phosphorus
Ortho-phosphate
Fecal Coliform
Fecal Streptococcus
Total Coliform
Turbidity
Suspended Solids
Total Solids

Table 11. Lakes Monitored by the New Jersey Department of Environmental Protection in the Pinelands of New Jersey.

County	Lake	Acres	Municipality
Atlantic	Egg Harbor Lake	35	Egg Harbor City
	Hammonton Lake	75	Hammonton
	Hunters Mill Pond	8	Estell Manor
	Lake Fred	50	Galloway
	Lake Pam	8	Galloway
Burlington	Absegami Lake	92	Bass River
	Atsion Lake	90	Shamong
	Batsto Lake	62	Washington
	Goshen Pond	10	Shamong
	Harrisville Pond	40	Washington
	Indian Mills Lake	42	Shamong
	Lebanon Lake	42	Woodland
	Mirror Lake	129	Pemberton
	Oswego Lake	90	Washington
	Pakin Pond	8	Woodland
	Presidential Lakes		Pemberton
Camden	New Brooklyn Lake	40	Winslow
Cape May	Nummi Lake	26	Dennis
	Tuckahoe Lake	11	Upper
Ocean	Bamber Lake	51	Lacey
	Barnegat Lake	61.2	Lacey
	Brindle Lake	30.0	Plumsted
	Deer Head Lake	37.3	Lacey
	Horicon Lake	63.7	Lakehurst
	Manahawkin Lake	45.5	Stafford
	Success Lake	19	Jackson
	Bauer Pond		Manchester

FIGURE 6: LOCATION OF DATA COLLECTION SITES IN OYSTER CREEK STUDY AREA.



3-inch rainfall. Specific conductance, pH, temperature, and dissolved oxygen were measured in the field. Samples were collected for analysis of dissolved solids, total hardness, ferrous and total iron, sulfate, chloride and total nitrogen.

Continuous streamflow records have been collected at the U.S. Geological Survey Gaging station, Oyster Creek near Brookville, New Jersey since July, 1965. Water samples for chemical analysis were collected periodically at the station from September 1965 to September 1977.

Results

The water quality of Oyster Creek is relatively low in pH, nutrients and dissolved solids (Table 12). The average total nitrogen concentration was 0.15 mg/l and nitrate-nitrogen averaged 0.03 mg/l. The mean concentration of total phosphorus was 0.01 mg/l.

Dissolved oxygen levels were high in Oyster Creek with a mean concentration of 8.7 mg/l. The pH ranged from 3.9 to 5.8, dissolved aluminum from 0.08 mg/l to 0.5 mg/l, dissolved iron from 0 to 0.37 mg/l. These values are characteristic of surface water in the Pinelands.

The levels of fecal coliform and fecal streptococci bacteria, which indicate fecal contamination and the presence of pathogens, were generally low.

The mean concentrations of bi-carbonate, 0.8 mg/l, and alkalinity, 0.5 mg/l, illustrate the low-buffering capacity of the water in Oyster Creek.

The water quality in Oyster Creek was found to be relatively unchanged in its chemical composition during the study period. However, the tributaries of Oyster Creek had more variability in terms of the parameters used to measure the water quality than the main stem of Oyster Creek. Tributaries draining swampy areas tended to have higher levels of total iron

Table 12. Water Quality of Oyster Creek near Brookville, New Jersey

Parameter	Value
Total Nitrogen	0.15 mg/l
Nitrate-Nitrogen	0.03 mg/l
Total Phosphorus	0.01 mg/l
Dissolved Oxygen	8.7 mg/l
pH	3.9 to 5.8
Dissolved Aluminum	0.08 to 0.5 mg/l
Dissolved Iron	0 to 0.37 mg/l
Fecal Coliform	Low
Fecal Streptococci	Low
Bicarbonate	0.8 mg/l
Alkalinity	0.5 mg/l

and nitrogen, and lower pH values than tributaries draining upland areas. Fusillo et al (1980) attribute the low pH associated with the swamps to the acidity formed by the decomposition of organic matter, and the formation of humic acids. Also, it is believed that living Sphagnum and the peat material in the bog areas have the ability to absorb the bases from dissolved salts, releasing acids.

These factors may be responsible for the decrease in pH in Oyster Creek as it flows downstrem, and after a rainfall event when water from swampy areas drain into the stream.

4. Streamflow Studies

The U.S.G.S. (1980) in addition to monitoring water quality has several stations located in the Pinelands that monitor water discharge only. In Table 13, a list of these stations is given along with the location and time of sampling.

These data help determine the rate of water discharge from the streams of the Pinelands into the ocean. Such measurements are of special concern during wet and dry periods.

5. Pinelands Study

In 1977-1978, the New Jersey Department of Environmental Protection performed a special study to measure the water quality of the Pinelands. The Pinelands were divided into the following drainage basins: Toms River, Rancocas Creek, Cedar Creek, Forked River, Mullica River, Great Egg Harbor River, Maurice River, Tuckahoe River, Dennis Creek, and Patcong Creek. The water quality data from this study, pH, Biochemical Oxygen Demand, Total Nitrogen (TN), Suspended Solids (SS), Total Dissolved Solids (TDS), and Fecal coliform (FL) were then used to construct a water quality index by the Pinelands Commission N.J. Pinelands (Comprehensive Management Plan, 1980). Table 14 lists the stations monitored

Table 13. Streams Monitored for only stream discharge in the New Jersey Pinelands

no.	Station/identification number	Location Latitude/ Longitude	Monitoring Period
1.	Oyster Creek near Brookville/01409095	39°47'54"/ 74°15'02"	1965+
2.	Westecunk Creek at Stafford Forge/01409280	39°40'00"/ 74°19'12"	1973+
3.	Mullica River at Batsto/ 01409400	39°40'28"/ 74°39'55"	1957+
4.	Batsto River at Pleasant Mills/01409510	39°37'55"/ 74°38'40"	1958+

for this study.

The Pinelands Commission Staff drew several conclusions from this study:

a. A relatively consistent relationship exists between pH and water quality. Areas exhibiting higher pH values generally have lower water quality. In many cases, high pH waters were found downstream from point sources of agricultural areas.

b. Streams with low average flows are sensitive to pollution. Streams with small catchment areas, usually less than 20 square miles, have low average flows and do not have the capacity to assimulate large waste loads.

c. Land uses impact surface water quality. Stream stretches with pristine or good water quality generally drain areas of natural vegetation which have few point sources of pollution. Stream stretches draining areas in row-crop agriculture generally have higher levels of pH, nitrogen, and dissolved solids than undisturbed forested areas. This is due to fertilization and liming activities.

   Stream draining areas of suburban and urban development generally contain elevated pH, suspended solids, nitrogen and oxygen demand levels. These levels are due to septic systems, stormwater runoff, and other point and nonpoint discharges associated with development (N.J. Pinelands Comprehensive Management Plan, 1980).

Table 14. Water Quality Stations Monitored in 1977-1978 for Drainage Basin Assessment by the Pinelands Commission (New Jersey Pinelands Comprehensive Management Plan, 1980).

Drainage Basin	Water Quality Station Number	Water Quality Station Location
Toms River	OCN031	Toms River off Cassville Rd.
	OCN030 (01408260)	Toms River near Van Hiseville
	OCN029	Toms River off Lakehurst-Whitesville Rd.
	OCN028	Toms River near Lakehurst
	(01408310)	
	OCN041	Ridgeway branch off Lakehurst-Whitesville Rd.
	OCN040 (01408492)	Ridgeway Branch off Route 70 near Lakehurst
	OCN027	Toms River off Rt. 571 (Manchester-Dover Border)
	OCN042	Manapaqua Branch off Lakehurst - Ridgeway Rd.
	OCN039	Union Branch off Colonial Drive
	OCN038	Union Branch off Brookville Rd.
	OCN026	Toms River below confluence of Union and Ridgeway
	OCN025 (01408500)	Toms River near Toms River
	OCN024	Toms River off Lakehurst Rd.
	OCN034	Wrangle Brook off S. Barbados Dr.
	OCN035	Wrangle Brook off Fort de France Rd.
	OCN037	Davenport Branch off Whiting-Lacey Rd.
	OCN036	Davenport Branch between Holiday City and Dover Rd.
	OCN033	Wrangle Brook at end of Gem Ave.
	OCN032	Jakes off Double-Trouble Rd.

Table 14 (cont'd)

Rancocas Creek		
	01465970	North Branch at Browns Mills
	01466500	McDonald's Branch in Lebanon State Forest
	01466900	Greenwood Branch at New Lisbon
	01467000	North Branch at Pemberton
	01467003	North Branch at Ewansville
	01467006	North Branch on Pine Street in Mt. Holly
	01465835	South Branch at Retreat
	01465850	South Branch at Vincentown
	01465900	South Branch at Eayrestown
	01465915	South Branch at Hainesport
Cedar Creek		
	OCN045 (01408830)	Cedar Creek off Whiting - Lacey Road
	OCN044 (01408870)	Cedar Creek off Double Trouble Road
	OCN043 (0140900)	Cedar Creek at Lanoka Harbor
Forked River		
	OCN047	North Branch Forked River
	OCN046	North Branch Forked River at Forked River
	OCN048	Middle Branch Forked River at Rt. 9
	OCN049	South Branch Forked River at Rt. 9.
Oyster Creek	OCN052	Oyster Creek outflow of Brookville Bog
	OCN051 (01409095)	Oyster Creek at Rt. 532
Mill Creek	OCN056	Eight Mile Branch at Rt. 72.
	OCN054 (01409150)	Mill Creek at Rt. 72
	OCN055	Fourmile Branch at Oxycoccus-Littleville Mill Rd.
	OCN053	Mill Creek at Rt. 180.
	01409210	Mill Creek at Manahawkin
Westecunk Creek		
	OCN059	Westecunk Creek at Martha Rd.
	OCN058 (01409282)	Westecunk Creek off Rt. 9 near West Creek

Table 14 (cont'd)

Bass River		
	01401050	E. Br. Bass River near New Gretn
	01410200	W. Br. Bass River near New Gretn
Wading River		
	01409810	W. Br. Wading River near Jenkins
	01409815	W. Br. Wading River near Maxwell
	01410000	Oswego River at Harrisville
	01410070	Wading River at Wading River
Batsto River		
	01409450	Springers Brook near Indian Mill
	01409470	Batsto River at Quaker Bridge
	01409500	Batsto River at Batsto
Atsion - Mechesoctauxin Creek		
	01409375	Mullica River near Atco
	01409383	Mullica River at Jackson Rd. near Indian Mills
	01409387	Mullica River at outlet
	01409400	Mullica River near Batsto
	01409403	Wild Cat Branch at Chesilhurst
	39382507-4393500	Mullica River at Pleasant Mills
Nescochague Creek		
	01409411	Nescochague at Pleasant Mills
Hammonton Creek	01409412	Hammonton Creek off Rt. 30 at Hammonton
	01409414	Hammonton Creek at Hammonton
	01409416	Hammonton Creek at Westcoatville
Lower Mullica River	01409535	Mullica River at Green Bank

Great Egg Harbor River		
	01410775	GEHR at Berlin
	01410784	GEHR near Sicklerville
	01410787	GEHR at Sicklerville
	39420307 - 4562901	GEHR at New Brooklyn Lake, west outlet
	01410803	Fourmile Branch at Winslow Crossing
	01410810	Fourmile Branch at New Brooklyn
	01410820	GEHR near Broad Lane (near Blue Anchor)
	01410865	Squankum Br. at Malaga Rd.
	01411000	GEHR at Folsom
	01411503	Hospitality Branch at Berryland
	01411110	GEHR at Weymouth
	01411140	Deep Run Branch at Weymouth
	01411196	Babcock Creek at Rt. 322 near Mays Landing
	01411170	GEHR at Mays Landing
Manumuskin River	01412100	Manumuskin River near Manumuskin
Maurice River		Below Station 01412100.
Tuckahoe River		
	11411290	Tuckahoe River near Estell Manor
	11411300	Tuckahoe River at Head of River

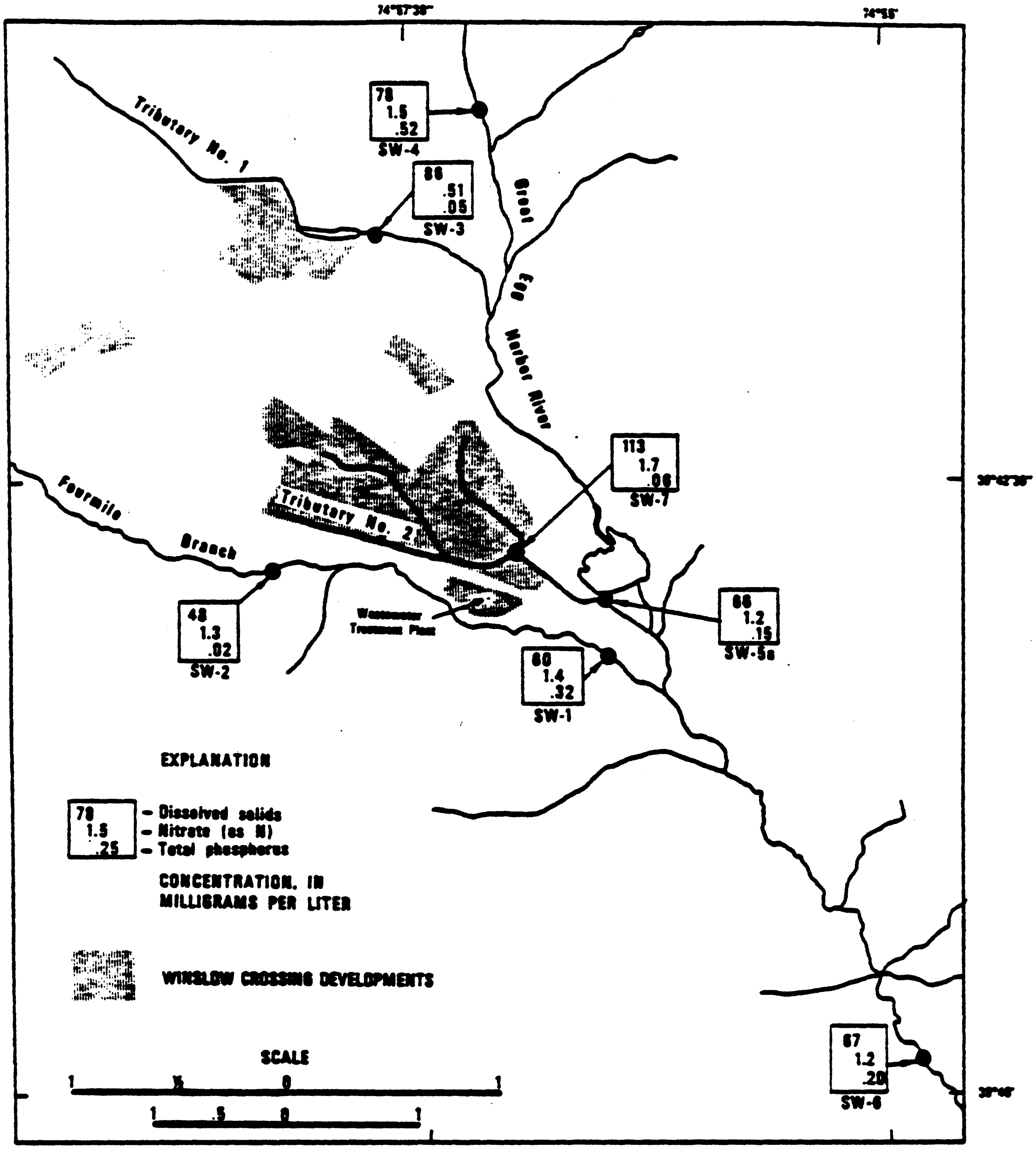
6. Winslow Township Study

The U.S.G.S. (1981) studied the impact of the suburban residential development of Winslow Crossing in Camden County upon the stream water quality. Continuous streamflow at four sites, and monthly stream water quality at seven sites were monitored from 1972 to 1978 on the tributaries and the main stem of the Great Egg Harbor River (Figure 7).

Two surface-water sampling sites were established on Fourmile Branch. The drainage area of Fourmile Branch consists mostly of forested areas and cultivated fields, with slight urbanization. However, the water quality of the stream is affected by the Winslow wastewater treatment plant, which discharges effluent into the shallow water table, which slopes toward the stream. Site SW-2 is on the Fourmile Branch above the treatement plant and has a drainage area of 6.22 mile^2. This site was sampled monthly from January 1972 to December 1978 for inorganic compounds and nutrients. It was also sampled yearly from 1972 to 1975 and during 1978, for pesticides and metals in bottom material.

Site SW-1 is below the treatment plant and has a drainage area of 7.74 mile^2. This site was sampled monthly for inorganic compounds and nutrients and yearly from 1972 to 1978 for pesticides and metals in bottom material. Continuous gage-height and discharge data were obtained from June 1972 to September 1979.

Stream-gage data and water quality samples were collected at sites along two small tributaries to the Great Egg Harbor River. Site SW-3 has a drainage area of 1.64 mi^2. This area consisted of woodland and fields until the construction of single-family homes on 0.23 mi^2 at the lower end of the drainage



Base from U.S. Geological Survey, Williamstown 1:24,000, 1966

Figure 7 —Mean concentrations of total phosphorus, nitrate-nitrogen, and dissolved solids at seven surface-water sampling sites after development, water years 1976-78.

basin. This site was sampled monthly from January 1972 to December 1978 for inorganic constituents and nutrients, and yearly from 1972 to 1978 for pesticides and metals in the bottom material. Continuous gage-height and discharge records were collected at this site from January 1972 to September 1979.

Site SW-7 was used to measure the quantity and quality of streamflow from a residential area. This site was sampled monthly from April 1972 to December 1978 for inorganic constituents and nutrients and yearly from 1972 to 1978 for pesticides and metals in the bottom material. Continous gage-height and discharge data were collected from 1973 to 1979.

Three surface-water sites were established on the Great Egg Harbor River. Site SW-6, near Blue Anchor, drains 37.3 mi^2 and is downstream from Winslow Crossing. This site was sampled monthly from February 1972 to January 1979 for inorganic compounds and nutrients and yearly from 1972 to 1978 for metals and pesticides in the bottom material. Continuous gage-height and discharge records were collected from June 1972 to September 1979.

Site SW-4 is a water-quality sampling site upstream from the Winslow Crossing Development, with a drainage area of 15.1 mi^2. This site was sampled monthly from January 1972 to January 1979 for inorganic compounds and nutrients and yearly from 1972 to 1978 for metals and pesticides in the bottom material. Sites SW-5 and SW-5a are water-quality-sampling sites on the Great Egg Harbor River at the outlets of New Brooklyn Lake. Site Sw-5 was sampled at various intervals between January 1972 and January 1975 for nutrients and inorganic constituents and yearly between 1972 and 1974 for metals and pesticides in the bottom material. Site SW-5a was sampled monthly between December 1972 and December 1978 for nutrients and inorganic constituents and several times during 1973 and 1974 for metals and pesticides in the bottom material.

The Winslow wastewater treatment plant had a significant effect on surface-water quality in the vicinity of the plant originally. Nitrate-nitrogen concentrations in Fourmile Branch were higher below the treatment plant than above it. However, after the treatment process at the plant was modified in October 1974 to increase denitrification, nitrate concentrations in Fourmile Branch since 1974 have been the same upstream and downstream from the treatment plant (Figure 7).

Phosphorus levels, however, have remained high and have increased in Fourmile Branch since 1973 below the plant (Figure 7).

Site SW-2 on the upper Fourmile Branch, in the least urbanized area, had the lowest concentrations of most constituents.

Winslow Crossing's development has had only a slight effect on the quality of water in Great Egg Harbor River. Water quality was found to be poorer at site SW-4 upstream from Winslow Crossing than downstream, because of point and non-point inputs in the headwaters of the river.

Water quality improves below New Brooklyn Lake at site SW-5a because the lake acts as a sink for nutrients and suspended matter. Farther downstream at site SW-6, the water quality was similar to that at SW-5a, except for a slightly higher level of phosphate from 1976 to 1978 because of the inflow from Fourmile Branch.

The impact of the development of Winslow Crossing on the water resources of the area has been relatively small owing to the slow development and improved wastewater facilities. U.S.G.S. plans to continue monitoring this site.

C. Academic Investigations

1. Yuretich, Crerar, Kinsman, Means and Boresik

Yuretich et al, (1981) working in conjunction with the U.S.G.S. conducted a research program to study the hydrochemistry of the New Jersey Pine Barrens.

The field data were collected in 1971 and 1972. Stream water sampling stations were established in two distinct networks (Figure 8). The first network comprised 11 stations along Cedar Creek and its tributaries. These stations were maintained for the first year of the study and subsequently reduced to 5 for the second year. Samples were collected at approximately four week intervals. In addition, 22 other sites were located in the Mullica River basin, along the Tuckerton, Westecunk, Cedar Run, Mill and Oyster Creeks, as well as the Forked and Toms River, and the Wrangle Branch of the Toms River. All these stations were sampled approximately every four weeks during the course of this study as well.

Water samples were collected in polyethylene bottles which were rinsed with river water immediately before sampling. Water temperature was recorded and pH measurements were done in the field.

<u>Findings</u>

Surface waters were found to be unusually low in total dissolved solids (25 ppm), and pH (4-5). The streams contained relatively high concentrations of organic carbon and iron. Liquid chromatographic analyses show that a significant proportion of the total iron in the river water is associated with dissolved organic carbon which is primarily humic and fulvic acid. Stream borne Fe and Al is also colloidal Fe - oxyhydroxide admixed with insoluble organic material.

The streams and rivers of the Pinelands were found to be soft, pure and easily passed federal drinking

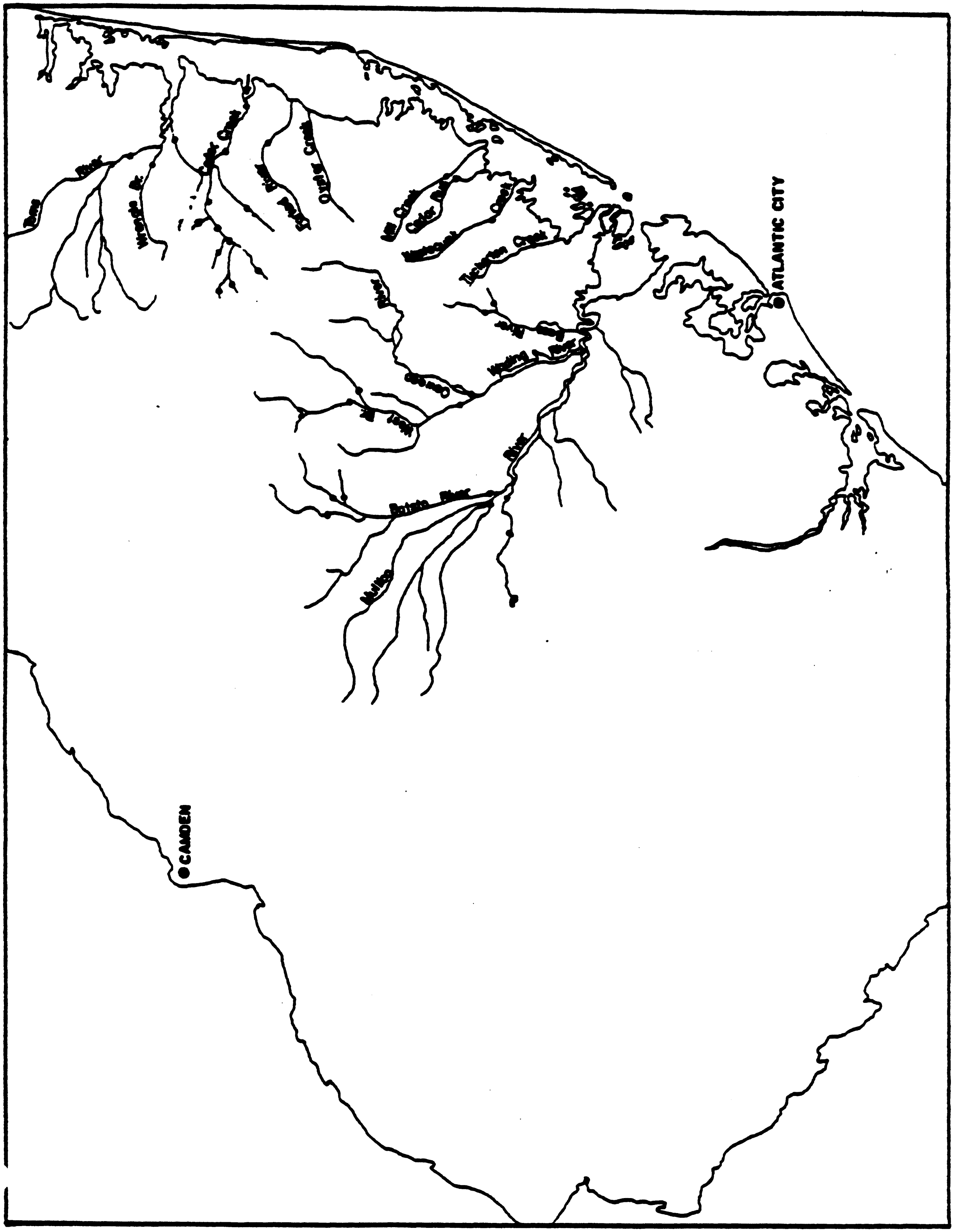


Fig. 8 – River water sampling sites monitored during 1971-72.

water standards. However, because these waters are low in total dissolved solids, they are as a consequence weakly buffered and bear little resistance to chemical change. Yuretich et al, (1981) conclude that human development will rapidly degrade the quality of stream water. They attribute this degradation to the fragility of the stream water chemistry and the inability of the sandy and inert Pinelands soils to attenuate undesirable wastes and to prevent the contamination of the streams.

2. Durand

Durand (1979) has done extensive monitoring in the streams that comprise the Mullica River Basin in the Pinelands. He has investigated such phenomena as nutrient cycling in water and sediments, and the correlation between stream nutrient levels and land use.

In 1961-1963 Durand (1979) measured ammonium-nitrogen and nitrate-nitrogen concentrations in samples taken from eight stations along the Mullica River. Samples were collected and measured approximately once a week during the period of September to May and twice weekly during the period of June to August.

In the summer of 1976 and in January 1977, ammonium and nitrate-nitrogen were measured in the uppermost part of the Mullica River drainage basin. Durand (1979) classified the stations on the basis of the degree to which the drainage of each was subject to agricultural or urban influence.

Durand (1979) found several trends in the distribution of nitrogen and nutrients in the streams and bays of the Mullica River Basin.

a. Stream nitrogen levels as a function of degree of development

Durand found that the highest nitrogen concentrations; particularly nitrate-nitrogen (3.77 ppm) occurred at those stations along streams which drained urban and agricultural areas. Those streams draining undisturbed forested areas had the lowest levels of nitrogen (0.04 ppm).

b. Stream nitrogen levels as a function of proximity to swamps.

Another observation that Durand made from his studies in the Mullica River Basin was that lower nitrogen concentrations were found in stream water downstream of connecting swamps and bogs than in stream water upstream of the bogs and swamps. Durand attributes this decrease in nitrogen levels to dilution which occurs when relatively pure groundwater enters the swamp or bog from the Cohansey aquifer and then flows into the stream (Durand, 1982, personal communication).

c. Stream nitrogen levels as a function of time.

Durand (1979) found that nitrate-nitrogen levels increased in the streams of the Mullica Basin during the winter months. He attributes this increase to excess nitrate-nitrogen in the soil being leached into the streams during the winter months.

d. Stream nitrogen levels as a function of stream depth.

Another factor that needs to be considered in any stream water monitoring program is the depth in the stream from which the sample was taken.

Durand (1979) reports that the concentration of nutrients such as nitrogen was higher when samples were taken in deeper streams than in shallower streams or bays. Durand attributes this increase to the inability of nutrient-removing phytoplankton to inhabit the deeper and darker reaches of the streams. In the shallower streams and bays, sunlight can penetrate more and provide a more suitable habitat for the nutrient-absorbing phytoplankton. Because of this relationship between phtyoplankton growth, depth of water and nutrient levels, the data sampler should note the depth of the stream and the depth from which the sample was taken in the stream.

e. Stream nutrient levels as a function of stream flow.

A sampler should also note the volume of stream flow and the occurrence of the last storm event. Since nutrient levels may vary considerably prior to and after a storm event, all of these factors need to be considered in any surface water quality monitoring program (Durand, 1979).

3. Durand and Zimmer (1981)

The purpose of their study was to compare surface water quality in the Pine Barrens for drainage of pristine areas and developed areas, both domestic and agricultural.

Stations were divided into groups: one group was sampled weekly, and the other group less frequently. Sampling was carried on throughout the year to obtain seasonal data.

In later phases of the study stations were added in certain areas, either upstream or downstream from existing stations, to permit study of changes that occur along a segment of the stream and its drainage. Measurements of nitrogen cycling were also instituted, particularly ammonification and nitrification in water samples and in sediments. All sites that were intensively and not so intensively sampled are shown in Figure 9.

During the period from July 1977 through June 1978, eight stations were sampled monthly. These have been designated low intensity sites. The other eight sites were sampled weekly until May, 1979. These sites have been designated as high intensity sites.

During May 1979, three additional sites were added to the eight high priority sites, and three sites were shifted from high priority status to low priority status. During summer 1979 (May through September), high priority sites were sampled once per month, and subsequent to

SAMPLING SITES IN THE UPPER MULLICA BASIN

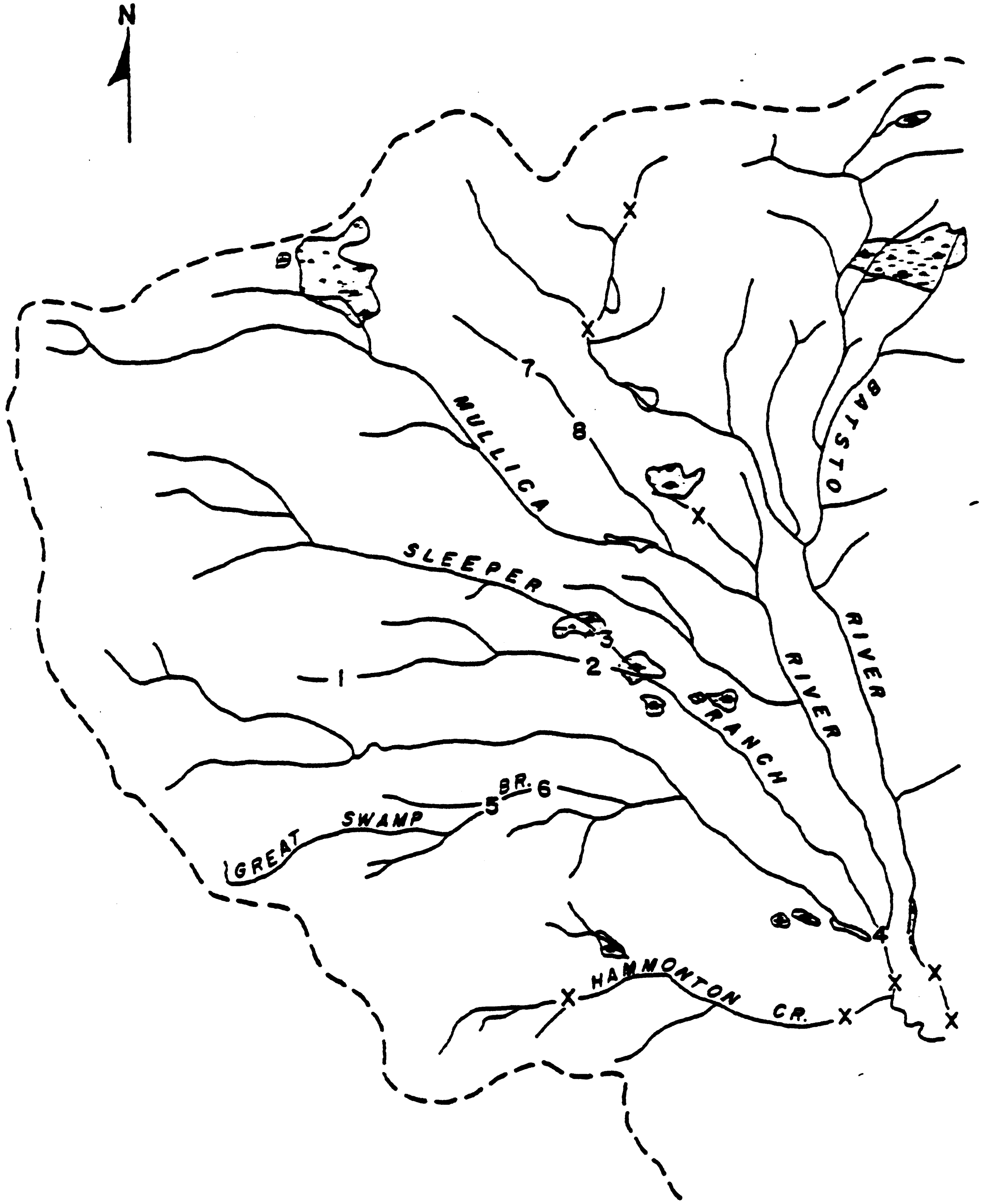


FIG. 9

- - - MULLICA BASIN

CRANBERRY BOG

X LOW INTENSITY STUDY SITE

HIGH INTENSITY STUDY SITE

0 2 4 MILES

SCALE

September 1979 (October 1979 through May 1980), all sites were sampled once per month.

Ammonification and nitrification studies were conducted at various sites from July 1978 through May 1980. Sediment samples were obtained at various sites from July 1979 through March 1980.

Table 15 lists the sampling sites, drainage basin type, vegetation type and sampling frequency in the upper Mullica Basin of this study.

Table 16 summarizes some of the parameters measured at high intensity sampling sites from June 1978 through May 1980.

Water temperature, dissolved oxygen, pH, organic carbon, orthophosphate-P, ammonium-N, nitrate-N, total organic-N, C/N ratios, suspended solids, chlorinity, ammonium-N load, nitrate-N load, total-N load, swamp input of nitrate-N and ammonium-N were measured.

Also, in June 1978, stream water discharge studies began for all eight intensively sampled sites. The month of February 1979 was excluded because many streams were frozen in early February, and heavy rains in late February made access to some streams impossible due to flooding.

The total monthly discharge/km^2 and the total monthly discharge were measured. At the less intensively studied sites the following parameters were measured: surface water pH, chlorinity, ortho-phosphate-P, total organic carbon, ammonium-N, and nitrate-N.

To summarize the work of Durand and Zimmer (1981), they investigated several aspects of nitrogen dynamics in the disturbed and undisturbed watersheds in the Mullica River drainage basin in the Pine Barrens during 1978-1980. These included nutrient concentrations in the surface water, discharge rates, concentrations of nutrients in the ground water at streamside, organic content of sediments, rate of ammonium-N release from the sediments, rate of

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Table 15. Sampling sites, listing location code, drainage basin type, vegetation type, and sampling frequency in the upper Mullica River

Site	Location Code	Drainage Type	Vegetation Type	Sampling Frequency
Clark	1	Undeveloped	Hardwood swamp	H
Clark 206	2	Developed swamp	Hardwood swamp	H
Sleeper 206	3	Developed swamp	Hardwood swamp	H
Sleeper	4	Undeveloped	Cedar Swamp Hardwood Swamp	H
Great Swamp Myrtle	5	Developed	Agricultural	H
Great Swamp 206	6	Developed	Agricultural, Hardwood Swamp	H
Wesickman	7	Developed	Agricultural	H
Wesickman	8	Developed swamp	Hardwood swamp	H
Friendship	x	Undeveloped	Hardwood swamp	L
Mullica 542	x	Undeveloped	Hardwood swamp	L
Batsto 542	x	Undeveloped	Hardwood swamp	L
Rolwey Land-ing	x	Undeveloped	Hardwood Swamp	L
Hampton	x	Undeveloped	Hardwood swamp	L
Cedar Bog		Undeveloped	Cedar Swamp	L
Muskingham	x	Developed	Agricultural	L
Indian Mills	x	Developed	Residential	L
Hammonton Sewage	x	Developed	Residential	L
Hammonton Nescochague	x	Developed	Residential, Agricultural	L
Nescochague Lake	x	Developed	Residential, Agricultural	L

H - high intensity sampling; L - Low intensity sampling

Table 16. Summary of some parameters measured at high intensity sampling sites from June 1978 through May 1980.

Parameter	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Stream Water																								
NH_4-N	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NO_3-N	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Org-N	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
TOC	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
PO_4-P	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Discharge	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Sediment	*	*	*	*																				
Ammonifi-cation																								
Precipitation																								
NH_4-N									*								*		*	*		*	*	
NO_3-N									*								*		*	*		*	*	
Org-N																			*	*		*		
DOC									*										*	*		*		
PO_4-P																						*	*	

*indicates at least one sample taken per month.

nitrification in the water column, and rate of nitrate-N and ammonium-N loss from the water in sediment/water microcosms.

Surface Water Nutrients

Concentrations of organic carbon and ortho-phosphate were generally low at all sites. Organic carbon concentrations were slightly elevated at pristine sites during the summer months when the peak concentration of cedar strain occurred in the water. Organic carbon concentrations ranged from 3 - 20 ppm; ortho-phosphate concentrations ranged from 0 - 5 ugat PO_4-P/liter.

Nitrate-N showed a distinct seasonal increase in disturbed watersheds. Summer concentrations ranged from 20 - 60 ugat NO_3-N/l, while winter concentrations ranged from 80 - 150 ugat NO_3-N/l. Nitrate-N concentrations at undisturbed sites ranged from 0-10 ugat NO_3-N/l.

Ammonium-N concentrations in the stream water were generally below 20 ugat NH_4-N/l, with no seasonal variation. Ammonium-N concentrations at Great Swamp ranged from 0-175 ugat NH_4-N/l, with a distinct wintertime peak. This peak was due to upstream inputs of ammonium-N.

Organic-N concentrations ranged from 0-225 ugat N/l. High values were measured at Great Swamp Branch which corresponded with the high wintertime ammonium-N values. High values were measured at undisturbed sites which corresponded with the high summer organic carbon.

A significant shift of more than 1 pH unit was consistently measured at disturbed sites compared to undisturbed sites. The pH at undisturbed sites ranged from 2.7 - 5.1, and from 4.1 - 6.4 at disturbed sites. The increase in pH at disturbed sites was due to application of lime for agricultural use.

Discharge was dependent on the immediately preceding precipitation history, with maxima occurring after storm events. The nutrient load was dependent on discharge, with higher loads occurring during times of peak discharge.

The primary input of water and nutrients into the stream systems occurred in the swamp segments of the stream. The swamp functions as the boundary between ground water and stream, so that the water and nutrients enter the stream in swamp areas. This tendency was most pronounced at Great Swamp Branch.

The substrate underlying the stream water is low in organic content, ranging from 0.1 - 6.5% dry weight. The amount or organic matter in the sediment was slightly higher at disturbed sites than at undisturbed sites.

Ammonium-N levels were low in the sediments. Ammonification was limited by low levels of organic-N and low pH which inhibits bacterial activity. Similarly, nitrification rates in the water column were not detected due to the low pH inhibiting bacterial activity. Low rates of nitrification were occassionally measured at disturbed sites.

4. Ehrenfeld

A study was performed to determine whether lowland communities subject to nutrient enrichment from development suffered changes in their species composition. Thirty-two wetland sites were sampled in June 1979 for species composition and pH, half of which were in undeveloped watersheds and half were in watersheds that were predominantly urban or agricultural (Figure 10, Table 17).

Since Durand and Zimmer (1981) showed that elevated pH was correlated with elevated nutrient levels, Ehrenfeld sampled the pH of surface water in the wetland as a measure of nutrient enrichment.

It was found that the pristine lowlands, i.e. those with low pH values in the surface water had some carnivorous species (*Drosera* and *Sarracenia*), a number of ericaceous shrub species, and a sedge found only in pristine areas.

Enriched sites in contrast, contain a number of herbaceous species common to the Coastal Plain but rare or absent in the Barrens, as well as woody plants, such as *Sambucus*, characteristic of nutrient-rich habitats. Also, enriched sites contain an abundance of vines among the constant species.

The mean pH in the enriched sites was found to be 5.17$\pm$ 0.35 standard error, while the mean pH in the pristine sites was found to be 3.82$\pm$0.17 standard error.

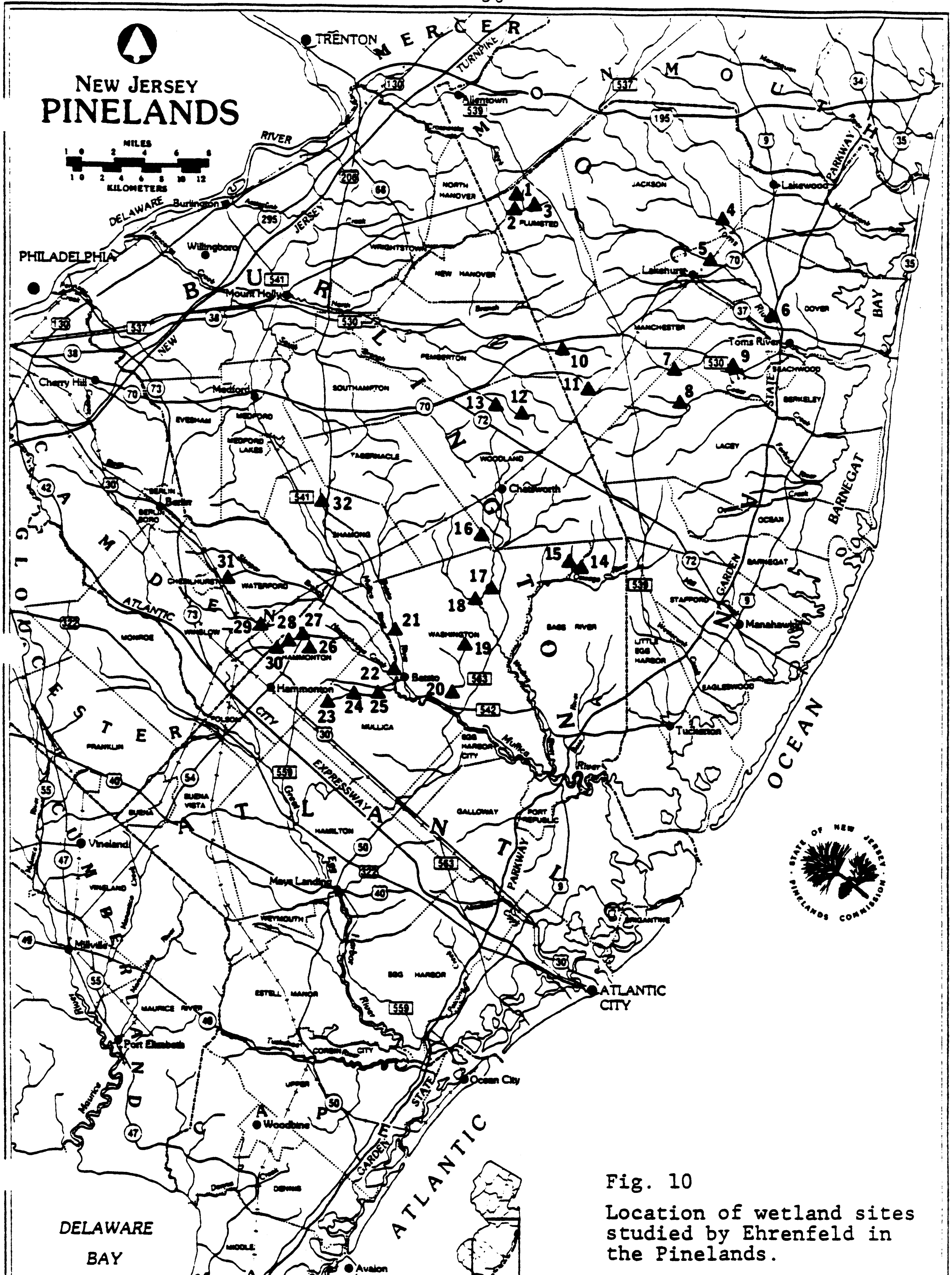

Fig. 10

Location of wetland sites studied by Ehrenfeld in the Pinelands.

Table 17. Summary of sites used in a vegetation community composition study. J. Ehrenfeld

Enriched		Pristine
Archertown (1)		Batsto (21)
Cedar Brook (26)		Bulltown (20)
Collings (31)		Butler (11)
Cookstown (2)		Cedar Crest (8)
Ezaldeen Village (29)		Cedar Swamp Branch (7)
Grawtown Road (4)		McDonald Branch (12)
Great Swamp Branch at 206 (27)		Mile Branch (16)
Indian Mills (32)		Nescochaque (22)
Jumping Branch (3)		Papoose Branch (15)
Myrtle Branch (28)		Pole Branch (10)
Oak Spring Branch (30)		Rte. 530 (9)
Ridgeway Branch (5)		Shinn Branch (13)
Hammonton Creek at Columbia Road (24)		Sim Place (14)
Hammonton Creek at Nesco Road (25)		Tulpehocken Creek (18)
Toms River (6)		Washington Road (19)
		W. Branch Wading River (17)
mean pH ± s.e.	5.17 ± 0.35	3.82 ± 0.17

III. Recommendations for a Pinelands Water Quality Monitoring Program

A. Sampling and Analysis Techniques

From the data in this report, a large body of data exist on water quality monitoring efforts for the major streams, lakes and rivers of the Pinelands. However, the efforts, for the most part, have not been coordinated.

It is felt that three phases of monitoring are required in order to adequately determine baseline conditions, to define the developer's responsibilities and to evaluate water quality changes. The three phases are:

1. sub-watershed analysis
2. localized water quality analysis
3. post-development monitoring

Sub-Watershed Analysis

The objective of a sub-watershed monitoring program is to determine a baseline condition that can be compared with post-development water quality in order to monitor changes. The lead monitoring agency can accomplish this by refering to existing data that is being collected or has been recently collected that is contained in a central data storage system such as STORET.

If few data exist or are presently being collected for a particular sub-watershed, or group of streams that flow into one common river, the lead monitoring agency must direct and coordinate local and county agencies to begin a monitoring program for a data deficient, yet potentially developable subwatershed area.

The lead agency should recommend which parameters must be measured; where, for how long, at what frequency and under what field conditions should the collection of samples take place.

The following parameters may be included in the monitoring program:

- pH
- acidity
- temperature

- o dissolved oxygen
- o BOD
- o Nitrate Nitrogen
- o Total Nitrogen
- o Total Phosphorus
- o Fecal Coliform
- o Dissolved Solids
- o Suspended Solids
- o Flow

Methods

The analysis of chemical parameters should comply with methods in the following publications:

- o <u>Standard Methods for the Examination of Water and Wastewater</u>

  APHA, AWWA, and WPCF (latest edition)

- o <u>Methods for Chemical Analysis of Water and Wastes</u>

  U.S. Environmental Protection Agency (latest edition).

- o "Guidelines Establishing Test Procedures for the Analysis of Pollutants"

  Federal Register Vol. 44 (244) p. 75028, Tuesday, December 18, 1979.

pH, temperature, dissolved oxygen and flow should be tested in the field; all other chemical parameters should be determined by a certified analytical laboratory. The following are recommended accuracy limits and units for expression of results:

Parameters	Units	Detection Limits
pH	pH units	0.1
acidity	mg/l $CaCO_3$	0.1
temperature	^oC	1^o
dissolved oxygen	mg/l	0.1
BOD	mg/l	2 to 4
nitrate-nitrogen	mg/l	0.01
total nitrogen	mg/l	0.01
total phosphorus	mg/l	0.01
fecal coliform	No./100 ml.	1
dissolved solids	mg/l	1
suspended solids	mg/l	1
flow	CFS	0.1

Field Notes

Samples should be collected in a clean liter bottle (glass or plastic) and kept on ice until delivered to the laboratory. A separate sample should be collected in a sterile glass bottle (at least 300 ml.) for fecal coliform analysis. Samples should be delivered to the laboratory no later than 6 - 8 hours after collection.

The field measurements of pH, temperature and dissolved oxygen should be performed first, then the water samples collected approximately one foot below the surface as close to the middle of the stream as possible. Care should be taken to minimize stirring of the bottom sediments and collection of debris.

At each station, the following information should be recorded:

- o name of water body
- o location of station
- o date of collection
- o time of collection
- o Flow of level (visual or stream gage)
- o name of collector
- o weather conditions
- o any other factors that may affect chemical quality (eg. surface runoff or point source discharge present)

During the first sampling period, the following information should also be reported:

- o Width of stream
- o Substrate type
- o notes on local vegetation
- o surrounding land uses

Miscellaneous Notes

The following are comments on particular parameters:

- o acidity - in order to determine the response of the system to pH change, a titration curve is required as well as the actual acidity level.

- o fecal coliform - either the membrane filter or most probable number (mpn) method can be used for coliform analysis, however, it is recommended that one method be chosen and used throughout the monitoring program for a particular subwatershed.
- o flow - specific flow levels are required in order to calculate loading factors for use in predicative models. Measurements of stream cross-sectional area and velocity should be made at each sampling station. The cross-sectional area has to be measured only once if velocity is measured at the same location each sampling period. There are a number of methods that can be used for this analysis, and a standard hydrology text should be consulted. The labor involved in velocity measurement can be reduced if a staff gage is established. A staff-gage should be installed if long-term sampling is anticipated. After a series of observations relating stream velocity to stream height, a rating curve can be generated.

Sampling Location

Sampling stations should be established at the following locations within the sub-watershed.

- o at the base of every major tributary
- o above and below lakes and bogs
- o at the base of a subwatershed

Sampling Frequency

In order to meet the objectives of the baseline monitoring program, water quality samples must be taken at high and low flow conditions. It is recommended that the major effort be placed on monitoring baseflow conditions during the summer months since these represent the most critical times for the biological community. In the months June through August, low flow conditions stress the biota because the dilution factor is reduced and biological productivity is high. A baseline developed during the summer months represents the conditions that must be tolerated by the majority of the biological community.

High flows during storm events must also be considered. During a storm event, surface runoff with its pollutant load is a major factor in stream flow. Depending on land use, concentrations of chemical and physical parameters will change considerably throughout a storm hydrograph. It is important to monitor water quality during storm events in order to determine the range of water quality levels in the sub-watershed and to use in calibration of stormwater quality predictive models.

Summer Baseflow

It is recommended that the water quality stations be sampled five (5) times during June, July and August. Each sampling period should be at least 72 hours after the most recent precipitation event, and there should be at least one week between sampling period.

Storm Hydrograph/Pollutograph

An intensive survey of water quality at the base of sub-watershed is recommended during a storm hydrograph. A summer storm should be selected which is predicted to have at least one-inch of rainfall. Perhaps a Pineland's Commission staff member could be responsible for selecting the storm event for the stream monitors and coordinating the efforts among the sub-watersheds.

For the selected storm event, ten (10) sampling periods should be established. Flow should be measured and water samples collected and analyzed for pH, acidity, nitrate, total nitrogen, total phosphorus and suspended solids. Every other sampling period (5) water samples should also be tested for temperature, dissolved oxygen, BOD, fecal coliform and dissolved solids. Sampling periods should be spaced so that representative samples are taken during the rising limb, peak, and receding limb of the hydrograph. The flow hydrograph and water quality samples will be used to develop the pollutograph.

Localized Water Quality Analysis

During and post construction large developers should be required to monitor the nearest surface water body immediately upstream and downstream of the project site. Parameters should include those chemical parameters selected in the sub-watershed analysis, as well as additional parameters considered applicable on a case-by-case basis (e.g. heavy metals, pesticides, etc.). Samples should be taken during baseflow and storm events. At least three samples should be taken during construction, and four in the year following construction. The findings of this analysis can be used to determine if the developer is conforming to his prescribed water quality allotment.

Post Development Monitoring

The sub-watershed monitoring program should be continued after development has occurred in order to monitor change throughout the basin. The same chemical and biological parameters should be monitored as in the preliminary monitoring program, however, the program can be reduced to three (3) summer baseflow sampling periods and one (1) storm hydrograph/pollutograph. Tributaries which have had no development activity should be sampled at the same frequency to increase the data base and to provide data upstream of developed areas.

B. Organizational Recommendations

1. Introduction

In order to develop a regional, coordinated surface water monitoring program for the Pinelands Area, an organizational plan must be formulated. Such a plan could then be used by appropriate government officials for the implementation of such a program.

2. Objectives

The Pinelands Commission has chosen to organize a conference to be held at the Commission office or any other suitable place. This conference which will bring together various Federal, State and local officials will serve as the vehicle to develop the framework of an organizational plan that would outline a regional, coordinated surface water monitoring program in the Pinelands National Reserve - this country's first Reserve. This conference will more specifically:

a. review prior and existing surface water monitoring efforts. This comprehensive inventory will serve as a source of information for the participants in the conference. This inventory will be presented at the outset of the conference by its author. This inventory together with the experience of the conference participants will enable the participants to:

(1) identify some of the technical and organizational problems associated with and inherent to surface water monitoring activities;

(2) present solutions to these technical and organizational problems;

(3) select which specific geographical locations within the Pinelands area need to be studied most intensively;

(4) recommend which sampling methods, chemical, physical and biological parameters should be utilized and measured; and

(5) estimate the cost and effectiveness of such a long-term surface water monitoring program.

b. determine which government agency is most suitable to coordinate the monitoring, analysis, evaluation, storage and dissemination of water quality data from the streams, lakes and other surface water bodies in the Pinelands Area; and

c. draft a formal plan of implementation that will be submitted to various managing agencies. Such a plan will outline the goals of the surface water monitoring program and the role of the various government agencies which currently monitor surface water in the Pinelands of New Jersey.

3. Pinelands Commission Recommendations

a. Lead Agency

It appears appropriate for the United States Geological Survey (U.S.G.S.) to assume the lead agency role in this program. This agency has the technical and organizational capabilities to accomplish successfully the goals of such an extensive monitoring program. Currently they are monitoring in the Pinelands (see text) and have a cooperative monitoring program with the Ocean County Health Department. However, the Department of Environmental Protection also has extensive expertise and experience in this area and also appears to be an appropriate candidate to assume the lead agency role.

b. Coordination

The lead agency could coordinate the monitoring activities of the six other County Health Departments in the Pinelands Reserve. That is, determine:

(1) the location of the study sites;

(2) the sampling techniques to be followed that will ensure the accuracy of the data;

(3) the analytical methodology that should be uniformily used and provide reliable and accurate data

From time to time the lead agency would review the sampling and analytical techniques being performed on the local level for quality assurance purposes. The lead agency would serve as the data collection center, that is, the local health departments would send data to the lead agency office once a week or biweekly. These data would then be filed according to location, that is, county Watershed, stream, tributary or lake and stored on a computer file.

A monthly report or data sheet could then be forwarded to the Pinelands Commission office which could then distribute this water quality data to the public.

c. Problems

One of the problems facing the implementation of such a program is funding. At the conference a better idea of the costs of such a program will be determined, and who will bear what share of the costs.

The other problem is determining the actual means by which this coordinated plan shall be implemented. These and other problems will be addressed at the conference.

d. Conference Schedule

1. Some time prior to the conference a comprehensive inventory describing surface water monitoring activities in the Pinelands Area will be disturbed to selected participants.
2. The participants will then prepare summary papers that will address the technical and organizational problems associated with the implementation of a coordinated surface water

monitoring program.

3. These summary papers will be presented as short seminars by the various participants at the conference with discussions following.
4. The participants will together formulate the conceptual framework that will establish a coordinated surface water monitoring program for the Pinelands Area.
5. Once conceptual agreement is reached, the plan will be submitted by appropriate decision-makers to the various state and federal agencies for implementation.

IV. Bibliography

1. Cobb, E.C. and J.E. Biesecker. 1971. The national hydrologic bench-mark network: U.S. Geological Survey. Circular 460-D 38 p.

2. Department of Environmental Protection. 1980. Detailed workplan for an integrated ground water monitoring strategy. Division of Water Resources, Trenton, New Jersey.

3. Durand, J.B. 1979. Nutrient and hydrological effects of the Pine Barrens on neighboring estuaries. In: Pine Barrens Ecosystem and Landscape. R.T.T. Forman ed. Academic Press, New York. pp. 195-211.

4. Durand, J.B. and B. Zimmer. 1981. Pinelands surface water quality. Part 1. Center for Coastal and Environmental Studies, Rutgers University, New Brunswick, New Jersey.

5. Ehrenfeld, J. "The effects of changes in land use on swamps in the New Jersey Pine Barrens (unpublished).

6. Fusillo, T.V. 1981. Impact of suburban residential development on water resources in the area of Winslow Township, Camden County, New Jersey. U.S. Geological Survey. Water Resources Investigations 81-27. Trenton, N.J. 38 pp.

7. Fusillo, T.V.; J.C. Schornick, Jr.; H.E. Koester, and D.A. Harriman. 1980. Investigation of acidity and other water-quality characteristics of upper Oyster Creek, Ocean County, New Jersey. U.S. Geological Survey. Water-Resources Investigations 80-10.

8. Givnish, T. 1971. A study of New Jersey Pine Barrens Cedar swamps. 1971 report of the Princeton N.S.F. Cedar Swamp Study Group. Princeton U., Princeton, New Jersey.

9. Moul, E.T. and H.F. Buell. 1979. "Algae of the Pine Barrens." In: Pine-Barrens-Ecosystem and Landscape, R.T. Forman, ed. Academic Press.

10. U.S. Geological Survey. 1980. Water Resources Data vol. 1. Atlantic Slope Basins, Hudson River to Cape May. Water-Data Report N.J. 80-1. Water Year 1980. Trenton, New Jersey. 362 pp.

11. Yuretich, R.F.; D.A. Crerar, D.J.J. Kinsman, J.L. Means, and M.P. Boresik. 1981. Hydrogeochemistry of the New Jersey Coastal Plain. 1. Major-element cycles in precipitation and river water. Bulletin 76. Department of Environmental Protection, New Jersey Geological Survey, Trenton, New Jersey. 107 pp.