LAKE WALLENPAUPACK
WATER QUALITY MANAGEMENT STUDY

FINAL REPORT
DECEMBER 1982

PREPARED FOR
LAKE WALLENPAUPACK WATERSHED
MANAGEMENT DISTRICT

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VOLUME I

LAKE WALLENPAUPACK
WATER QUALITY MANAGEMENT STUDY

(EPA Phase 1 Diagnostic-Feasibility Study)

Final Report, December 1982

PREPARED FOR

Lake Wallenpaupack Watershed Management District
c/o Pike County Planning Commission
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Special appreciation is extended to those organizations which contributed significantly to the success of this study including Pike and Wayne Counties, Palmyra Township, Pennsylvania Power and Light Company, the Lake Wallenpaupack Watershed Association, and the townships in the watershed.

Special thanks are due those individuals who contributed significantly of their time in providing administrative and technical assistance throughout the study, including Bill Bergstresser, Slim Petrasek, Carson Helfrich, Paul Buehler, Jerry Ehrhardt, and Jimmy Coccodrilli.

PREFACE

The draft report for the Lake Wallenpaupack Water Quality Management Study was first submitted to the Lake Wallenpaupack Watershed Management District (LWWMD) in June 1982. This final edition of the report presents a number of revisions and corrections based on comments provided by representatives from the following organizations:

- Lake Wallenpaupack Watershed Management District
- Lake Wallenpaupack Watershed Association
- Technical Review Committee (LWWMD)
- Pennsylvania Department of Environmental Resources
- U.S. Environmental Protection Agency
- Pennsylvania Power and Light Company

Comments were also received from local residents and other concerned officials. A formal public meeting was held on August 27, 1982 to discuss the conclusions and recommendations of the report. A summary of the public participation activities conducted by the LWWMD is presented in Appendix C.

Portions of the report that were significantly changed include the following sections:

2.4 Recommendations - Conservation Districts
2.6 Recommendations - LWWMD
2.8 Recommendations - Priority Action Plan
5.5.1 Point Source Loads
6.2 Lake Operations
6.4.10 Fisheries Resources
6.8 Possible Effects of Lake Operations
7.6 Earthmoving Activities Controls

Some of the questions raised by reviewers of the draft Water Quality Management Study will be addressed in further detail in the supplemental report due in May 1983. That report, commissioned under a separate contract with LWWMD, will present revised watershed management and lake restoration plans based on additional data which has been collected during 1982.

This report has been published in two volumes:

Volume I - Water Quality Management Study

Volume II - Data Appendices

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1.0 CONCLUSIONS

1.1 LAKE WATER QUALITY

1. Lake Wallenpaupack is eutrophic as evidenced by high nutrient levels in the lake, algal blooms, low water transparency, and depleted oxygen in the bottom waters of the lake during warm weather months.

2. Despite the eutrophic condition of Lake Wallenpaupack, the recreational uses of the lake have not been diminished. If the rate of eutrophication is not abated, however, the recreational uses of the lake may be impaired.

3. No water related human health problems were reported during 1980 and 1981.

4. Based on limited water quality data from 1973 to the present, water quality in Lake Wallenpaupack has decreased continuously over the years.

5. Algal blooms in Lake Wallenpaupack are dominated by blue-green algae that can cause unaesthetic conditions, odors, and toxins.

6. Phosphorus is the nutrient that limits algal growth during most of the year. Consequently, phosphorus entering the lake from point and nonpoint sources should be controlled.

7. Based on a fisheries study by the Pennsylvania Fish Commission, eutrophication-related problems in Lake Wallenpaupack may have adversely affected the fishery in the lake. Adverse temperature and dissolved oxygen conditions in the lake during periods of warm weather appear to stress cold water fish populations in the lake.

8. The present water quality data base for Lake Wallenpaupack is inconsistent and insufficient for evaluating long-term water quality trends. Annual water quality monitoring of the lake is needed to evaluate long-term water quality trends in the lake.

9. The timing of PP&L's hydroelectric discharges may have a beneficial affect on water quality. Further study is needed to evaluate the impact of lake drawdown on water quality.

1.2 POLLUTANT SOURCES

1. Nutrients and sediments enter Lake Wallenpaupack from many sources including runoff from various land uses and activities (e.g. cropland, pasture, development, resorts, roadways, and construction), point sources (wastewater treatment plants), septic system, rain, and streambank erosion.

2. Streams tributary to Lake Wallenpaupack account for most of the nutrients and sediments entering the lake. Streams account for 84%, 88%, and 98% of the phosphorus, nitrogen and sediments entering the lake, respectively. Most of these stream pollutant loads (67 to 83%) enter the lake during rain events, indicating that stormwater runoff and erosion are significant pollutant sources.

3. West Branch subbasin and the area around the lake have the highest nonpoint pollutant loadings <u>per acre</u> of land as shown below:

	Pollutant Loading (lb/acre/year)	
Basin	Total Phosphorus	Total Suspended Solids
Area Around Lake	0.38	122
West Branch	0.26	101
Purdy Creek	0.19	37
Ariel Creek	0.18	35
Main Stem	0.16	37
Mill Brook	0.15	56

The actual loading amounts for each subbasin are shown in Table 17.

The lakes and wetlands in Ariel Creek and Purdy Creek appear to effectively remove nutrients and sediments from the streams by sedimentation and biological uptake. Although these lakes appear to reduce the pollutant loadings to Lake Wallenpaupack, the pollutant accumulation in these lakes probably causes localized eutrophication problems in these lakes. Upstream lakes and regional sedimentation basins may effectively reduce the pollutant loadings to Lake Wallenpaupack.

Main Stem and Mill Brook had the lowest pollutant loadings per acre of land.

4. Based on a comprehensive literature review, cropland and developed land (including roadways) produce relatively high nutrient and sediment loadings per acre of land. Construction activities, although temporary, generally produce the highest nutrient and sediment loadings per acre of land. Runoff and erosion from these land use activities should be controlled.

5. Septic systems throughout the watershed are a significant source of phosphorus to Lake Wallenpaupack. Soils in the watershed are generally not suitable for septic systems.

6. Wastewater treatment plants (point sources) account for less than 2% of the nutrients entering the lake each year.

7. The relative importance of phosphorus discharged by wastewater treatment plants and septic systems, however, may be greater than their numerical value since wastewater discharges from treatment plants and septic systems increase significantly during the summer when algae problems occur and when stream flow is low; thus, the relative magnitude of treatment plants and septic systems is increased.

   Also, the phosphorus discharged by treatment plants and septic systems is generally in a form more readily usable by algae.

8. High fecal bacteria levels, indicative of fecal pollution and possibly pathogenic (disease producing) bacteria, were repeatedly measured in West Branch, Ariel Creek and Purdy Creek.

9. Further monitoring of stream water quality is necessary to refine the annual pollutant budget calculated in this study and to further identify specific pollutant sources.

2.0 RECOMMENDATIONS

2.1 GENERAL

1. The Lake Wallenpaupack Watershed Management District (LWWMD) and the townships and counties in the watershed should adopt and implement the watershed management plan proposed in this report.

2. Watershed management activities should be coordinated by the Lake Wallenpaupack Watershed Management District.

3. A Management Plan Implementation Committee should be formed within LWWMD to assist in the adoption and implementation of the management plan.

4. The counties and townships in the watershed should continue to provide technical and financial support to LWWMD.

2.2 COUNTIES

1. The counties in the watershed should jointly develop a stormwater management plan in accordance with the requirements of Pennsylvania Act 167. The Stormwater Management Act, passed in October 1978, requires counties to adopt a watershed stormwater management plan for <u>each</u> watershed in the county. The Lake Wallenpaupack watershed has been designated by DER to be studied as an Act 167 watershed. The LWWMD and the counties should consider petitioning DER to allow a phased approach to implementing Act 167. Phase 1 would consist of identifying runoff characteristics, floodplains and land use patterns. It would also include the development of stormwater control criteria and ordinances. Phase 2 would involve "site-specific" investigations based on the results of Phase 1.

2. Each county should enact an ordinance requiring licensing of septage haulers.

2.3 Townships

1. Each township in the watershed should develop a comprehensive plan and zoning for the township.

2. Each township should adopt a septic system ordinance that provides greater power for septic system inspection and enforcement activities (including requiring system maintenance and upgrading).

3. Each township should adopt a runoff control ordinance to control runoff from new developments. As an alternative, each township should amend existing subdivision regulations to include runoff control requirements.

4. Each township should adopt an erosion control ordinance similar to DER's erosion control regulations to control erosion during construction. As an alternative, each township should amend existing subdivision regulations to include erosion control requirements.

2.4 Conservation Districts

1. The Wayne and Pike County Conservation Districts should actively enlist more farm cooperators. The plans of all landowners who are not required to obtain erosion control permits should be routinely inspected.

2. The Wayne County Conservation District should advance to Level 5 (voluntary and induced compliance) in its administration of the soil erosion and sedimentation control plan review and permitting process. Presently the Wayne County Conservation District is at Level 3 (complaint handling) while Pike County is at Level 5.

3. The Conservation Districts should petition the DER to reduce the present 25 acre size limitation for requiring erosion control permits. The size limitation should be reduced to 5 to 10 acres to include more developments in the permitting process.

4. To handle the increased work load produced by implementing the above recommendations, the Soil Conservation Service (SCS) should increase the size of their technical staff.

2.5 Department of Environmental Resources

1. The Pennsylvania Department of Environmental Resoruces (DER) should maintain the present phosphorus limit of 0.5 mg/l for all wastewater treatment plants in the watershed.

2. The DER should require formal laboratory quality assurance procedures for all laboratories analyzing wastewater treatment plants in the watershed.

2.6 Lake Wallenpaupack Watershed Management District

1. The LWWMD should continue to monitor water quality in Lake Wallenpaupack and its tributaries. A long-term data base for water quality in Lake Wallenpaupack should be developed.

2. The LWWMD should conduct field investigations of land use activities in the watershed.

3. The LWWMD should review the effluent monitoring reports (NPDES reports) of the wastewater treatment plants in the watershed.

4. The LWWMD should provide technical assistance to the townships and counties in the watershed.

5. The LWWMD should assist the townships and counties in regulating septage haulers in the watershed.

6. The LWWMD should conduct workshops for Sewage Enforcement Officers (SEOs) and treatment plant operators.

7. The LWWMD should pursue funding for a 201 Facilities Plan to study community wastewater treatment and sludge disposal alternatives, and to design remedial measures. An EPA 201 Grant would pay 75% of the construction costs and a portion of the planning and design costs.

8. The LWWMD should continue its public education program via fact sheets, signs, and presentations.

9. The LWWMD should encourage homeowner practices designed to improve water quality in Lake Wallenpaupack (e.g. a voluntary phosphate detergent limitation; proper lawn fertilization).

10. The LWWMD should channel information concerning watershed problems and violations to appropriate officials and follow up on enforcement actions.

11. The LWWMD should investigate funding sources for implementing Best Management Practices (BMPs) in the watershed.

12. The LWWMD should work closely with the Pennsylvania Fish Commission and PP&L on the management of the fishery in Lake Wallenpaupack.

2.7 PP&L

1. PP&L should continue to provide technical, administrative and financial support to LWWMD.

2. PP&L should assist LWWMD in evaluating the affect of lake level drawdown on water quality in Lake Wallenpaupack.

2.8 Priority Action Plan

1. Control of nonpoint sources from land use activities and septic systems throughout the entire watershed should be given high priority.

2. Nonpoint source control efforts should be concentrated in the West Branch subbasin and in the area immediately around the lake.

3. Both physical and institutional nonpoint source pollution control measures should be implemented.

ACTION PLAN

LWWMD Sets Up Management Plan Implementation Committee

↓

LWWMD Makes Presentations to Counties, Townships Conservation Districts and Other Groups

↓

LWWMD Develops & Submits 201 Septage/Sludge Disposal Grant Application	LWWMD Develops Model Runoff & Septic System Control Ordinances	Conservation Districts Petition DER to Reduce 25 Acre Limitation	LWWMD Investigates 167 Stormwater Study Funding
↓	↓	↓	↓
LWWMD Performs 201 Study and Design	LWWMD Presents Ordinances to Townships	Wayne County Accepts Level 5 Erosion Control Status	LWWMD Submits Act 167 Application
↓	↓	↓	↓
Construct Septage/Sludge Facilities	Townships Adopt Ordinances	SCS Increase Staff Size	LWWMD Performs Act 167 Study

3.0 Project Description

3.1 Background

Lake Wallenpaupack is a vital resource in the northeastern Pennsylvania region. Over the past years, the water quality of Lake Wallenpaupack has deteriorated. The 1975 EPA National Eutrophication Survey (NES) Study stated that the lake was mesotrophic, but the appearance of blue-green algal blooms indicated that it was becoming eutrophic. In addition to the algal blooms, evidence of the oncoming eutrophic condition of the lake was found in reduced water clarity, increased nutrient concentrations, the appearance of excessive rooted plants around the lake, and the outbreak of water-borne infections. Recent data and lake problems indicate that Lake Wallenpaupack is now eutrophic. In August 1979, a bloom of the blue-green alga, Anabaena, reportedly caused numerous cases of algae-related infections that produced such symptoms as allergic reactions and gastro-intestinal disorders. This outbreak of water-contact dermatitis and other symptoms led to the posting of warning signs around the lake.

3.2 Formation of Watershed Management District

Because of the importance of the lake as a natural and economic resource, the Pennsylvania Comprehensive Water Quality Management Plan (COWAMP, 1977) recommended the formation of a watershed management district for Lake Wallenpaupack. Recognizing the need for such a district, the Wayne and Pike County Commissioners and the supervisors of the 14 townships in the watershed established the Lake Wallenpaupack Watershed Management District (LWWMD) in September 1979. The District was formed because of the complexity of the lake problems, requiring a strong management organization backed by local government. The organization plan for the LWWMD was devised by F. X. Browne Associates, Inc. in 1979.

The general objectives of the watershed management district include, but are not limited to, the following:

1. To protect or improve Lake Wallenpaupack and its tributaries.

2. To protect public health and welfare.
3. To protect public rights.
4. To promote environmental values.
5. To provide for orderly lake and watershed management.

Specific objectives include the performance of diagnostic studies to evaluate lake and watershed problems, determine pollutant sources, develop a watershed management plan, and implement a continuing watershed management program. Specific objectives also include the implementation of best management practices (BMPs) to control pollutant loadings to the lake. Such pollutants include, but are not limited to, sediments, nutrients (especially phosphorus), organic materials, heavy metals, pesticides, fecal bacteria, and other toxic or harmful materials.

As described in the organization plan, specific powers and responsibilities of the LWWMD include the following:

1. Conduct lake and watershed monitoring programs.
2. Provide technical assistance, review, and advisory service.
3. Develop public educational programs and model ordinances.
4. Coordinate watershed management activities.
5. Provide financial management of the District.

Members of the LWWMD Board of Directors include representatives from Wayne and Pike Counties, the various townships in the watershed, and a representative from the Lake Wallenpaupack Watershed Association.

3.3 PROJECT OBJECTIVES

This study was conducted under the EPA 314 Clean Lakes Program. As described in the EPA Clean Lakes Program Guidance Manual, grants can be provided for Phase 1 or Phase 2 projects. A Phase 1 project, such as this one, is defined as a diagnostic-feasibility study. The diagnostic portion of the study is conducted to determine the lake's water quality condition, identify existing problems, and determine the pollutant sources which are causing the problem(s). The feasibility part of the study involves the development of alternative management programs based on the results of the diagnostic study. These alternatives can include watershed management practices, and/or lake restoration methods.

After completing a Phase 1 study, if funding is available, a Phase 2 grant can be applied for and used to implement the recommended management practices.

The primary objectives of this Phase 1 Diagnostic-Feasibility Study were:

1. To evaluate the trophic conditions in the lake and determine their relative impacts on recreational uses of the lake and its watershed.
2. To determine the location and magnitude of point and nonpoint sources of pollution to the lake and develop a nutrient budget.
3. To develop a feasible watershed management plan to abate both point and nonpoint sources of pollutants and thereby allow for the natural rehabilitation of the lake.
4. To collect the appropriate information to be used for the implementation of specific watershed management practices.

Other secondary objectives of the study included: (1) determining the magnitude of nonpoint pollutant loadings from certain land uses; (2) evaluating the significance of septic tank leachate as a nutrient source; and (3) providing for the proper education of the general public as to matters which affect the water quality in Lake Wallenpaupack.

This project was administered by the Pennsylvania Department of Environmental Resources (PaDER). In-kind services for the performance of the study were contributed by the various organizations and municipalities comprising the LWWMD, and the Pennsylvania Power and Light Company (PP&L).

4.0 Demographic Information

4.1 Watershed Description

Lake Wallenpaupack is one of the largest lakes in northeastern Pennsylvania. Its watershed covers 219 square miles and includes the following major tributaries: Wallenpaupack Creek (East Branch, Main Stem, and West Branch), Ariel Creek, Purdy Creek, and Mill Brook. The watershed is comprised of portions of four counties and 14 townships as shown in Figure 1, and as listed below:

<u>Wayne County</u>

- Paupack Township
- Salem Township
- Dreher Township
- Lake Township
- Sterling Township
- Lehigh Township
- Palmyra Township

<u>Pike County</u>

- Palmyra Township
- Greene Township
- Blooming Grove Township

<u>Monroe County</u>

- Coolbaugh Township
- Barrett Township

<u>Lackawanna County</u>

- Jefferson Township
- Madison Township

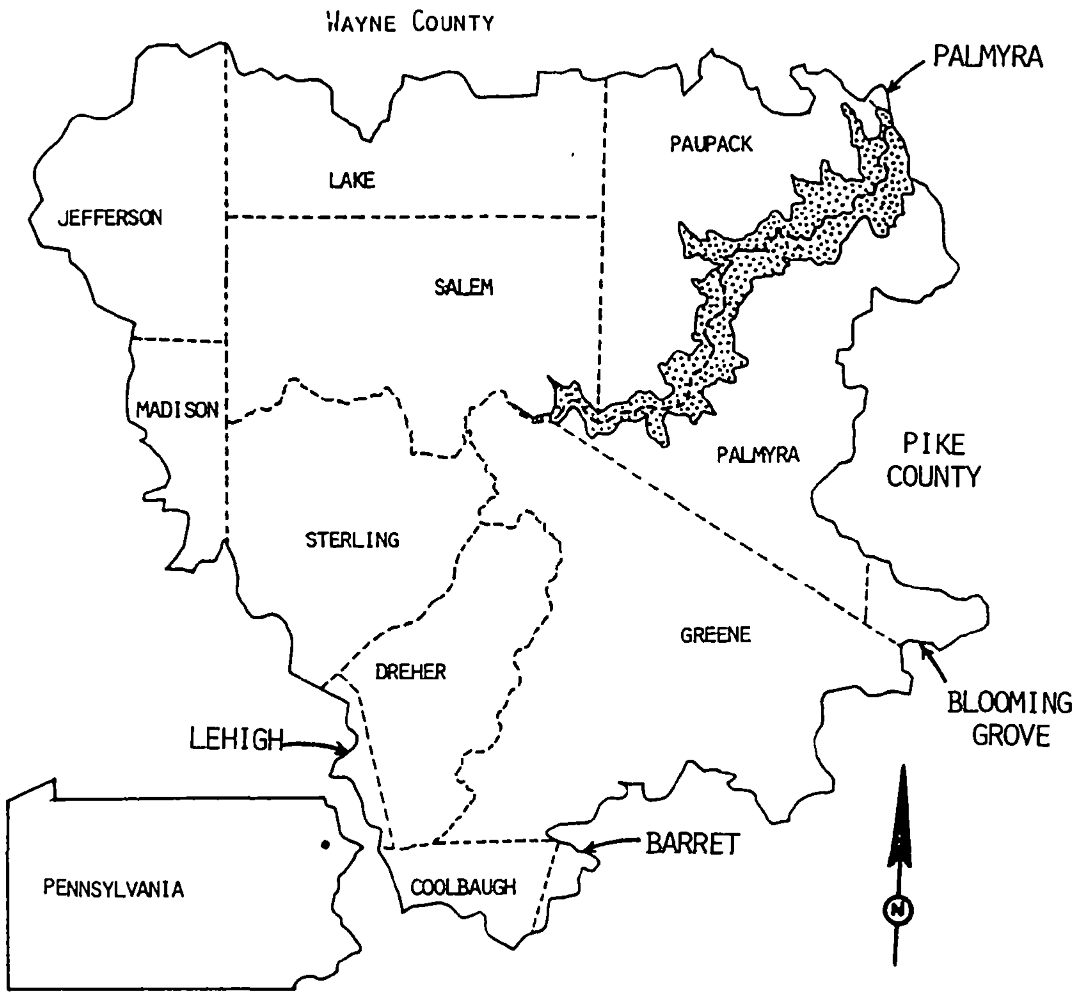


Figure 1. Lake Wallenpaupack Watershed

4.2 Land Use

Existing land uses for the monitored and unmonitored subbasins within the watershed are given in Table 1. These figures were developed by the Pike and Wayne County planning staffs. Sources of information for the land use evaluation included subdivision surveys, aerial photographs, PP&L computer maps, and field investigations. All of the land within the watershed was classified into one of the following categories: residential, commercial, cropland, pasture, wetlands, water, and forest. Resorts and recreational areas were usually included in the commercial category.

For the monitored subbasins, Ariel Creek and Purdy Creek have the highest percentages of residential development and cropland. These subbasins also have the highest percentage of water surface area. The West Branch and Ariel Creek subbasins have the largest relative areas of pasture land. Main Stem and Mill Brook have the highest percentages of undeveloped land.

The unmonitored subbasins primarily include all of the smaller streams around the lake in addition to those areas which drain directly into the lake. These subbasins combined contain the highest percentage of residential and commerical development. The Waynewood Lake subbasin consists of approximately 29% cropland. Overall, the same percentage (approximately 70%) of the combined monitored subbasins and combined unmonitored subbasins is undeveloped.

In general, cropland and residential development are the land use activities which most impact tributary water quality. Therefore the subbasins of potential concern from a pollutant loading standpoint should be Ariel Creek, Purdy Creek, and all of the unmonitored drainage area. Also of concern should be the West Branch subbasin based on its size and amount of cleared area.

Table 1

Existing Land Use In Lake Wallenpaupack Watershed

	Total		Residential		Commercial		Cropland		Pasture		Wetlands		Water		Forest	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Monitored Subbasins																
Main Stem	48,115	100	1,804	3.7	47	0.1	718	1.5	3,824	7.9	1,665	3.5	1,087	2.3	38,970	81.0
West Branch	43,536	100	1,103	2.5	212	0.5	2,153	4.9	10,364	23.8	546	1.3	1,273	2.9	27,885	64.1
Ariel Creek	9,899	100	587	5.9	78	0.8	1,508	15.2	1,177	11.9	277	2.8	831	8.4	5,441	55.0
Purdy Creek	5,778	100	280	4.9	19	0.3	877	15.3	129	2.2	488	8.4	488	8.4	3,497	60.5
Mill Brook	2,998	100	73	2.4	<1	0	<1	0	51	1.7	47	1.6	36	1.2	2,791	93.1
Subtotal	110,326	100	3,847	3.5	356	0.3	5,256	4.8	15,545	14.1	3,023	2.7	3,715	3.4	78,584	71.2
Unmonitored Subbasins																
Spinner Brook	1,741	100	89	5.1	6	0.3	82	4.7	128	7.4	19	1.1	169	9.7	1,248	71.7
Goose Pond	2,843	100	148	5.2	50	1.8	171	6.0	395	13.9	162	5.7	243	8.5	1,674	58.9
Waynewood Lake	3,636	100	65	1.8	1	0	1,059	29.1	300	8.3	96	2.6	96	2.6	2,019	55.6
Kleinhans Creek	2,553	100	221	8.7	<1	0	<1	0	28	1.1	71	2.8	37	1.4	2,196	86.0
Minor Tributaries & Immediate Drainage	18,809	100	2,905	15.4	319	1.7	293	1.6	1,102	5.9	343	1.8	441	2.3	13,406	71.3
Subtotal	29,582	100	3,428	11.6	376	1.3	1,605	5.4	1,953	6.6	691	2.3	986	3.3	20,543	69.5
Total	139,908	100	7,275	5.2	732	0.5	6,861	4.9	17,498	12.5	3,714	2.7	4,701	3.4	99,127	70.8

Another measure of the amounts of development in different subbasins is the number of miles of primary roadway. Roads are important with respect to water quality because they increase the amount of impervious area. Also, significant quantities of pollutants can be washed off road surfaces during storms. The number of road-miles (including Interstate 84) per acre for each subbasin are presented in Table 2. The subbasins do not significantly differ from one another. The West Branch subbasin had the highest percentage of road-miles; whereas Purdy Creek had the lowest percentage.

Most of the past large scale land subdivision occurred in the late 1960's and early 1970's when economic conditions were more favorable. At that time, subdivisions of over 100 lots were not uncommon. Recently, however, smaller subdivisions with larger lot sizes have become more common. As has been the case throughout the Poconos, time-share developments and condominiums are also becoming more prevalent.

Since only a few of the townships in the watershed have comprehensive plans or zoning ordinances, it is difficult to project which areas might be developed as future growth occurs. It is likely that as the economy improves, lots in existing subdivisions will be sold and improved rather than raw land being developed into new subdivisions. Another possibility for future development involves subdivisions which are currently classified as recreational developments. The lots in these developments, located mainly in the Main Stem subbasin, are currently to be used for recreational purposes only and not for permanent residence. There is a potential, however, for this status to be changed in the future.

Estimated ultimate acreages for residential development are presented in Table 3. On an areal basis, the Main Stem and Immediate Drainage subbasins have the most potential for development. On a percentage basis, it is estimated that the Ariel Creek and Purdy Creek subbasins will experience the most growth.

Table 2

Number of Primary Road-Miles in Each Subbasin

Subbasin	No. of Primary Road-Miles	Road-Miles per Acre
Main Stem	123.5	0.003
West Branch	160.1	0.004
Ariel Creek	30.1	0.003
Purdy Creek	8.0	0.001
Mill Brook	7.0	0.002
Spinner Brook	4.2	0.002
Goose Pond	8.5	0.003
Waynewood Lake	9.6	0.003
Kleinhans Creek	6.9	0.003
Minor Tributaries & Immediate Drainage	58.9	0.003
Total Watershed	416.8	0.003

Table 3

Potential Ultimate Residential Development for the Watershed

	Residential Development (acres)		Percent
	Existing	Est. Ultimate	Increase
Main Stem	1,804	4,649	158
West Branch	1,103	1,685	53
Ariel Creek	587	2,320	295
Purdy Creek	280	1,086	288
Mill Brook	73	84	15
Spinner Brook	89	250	181
Goose Pond	148	311	110
Waynewood Lake	65	198	205
Kleinhans Creek	221	588	166
Minor Tributaries & Immediate Drainage	2,905	5,894	103
Total	7,275	17,605	135

Source: Information provided by Wayne and Pike County Planners.

Table 4 shows that 8% of the total watershed is publicly owned land. This land is comprised mainly of State Forest and Game Lands, and is located solely within Pike County. There are several relatively minor quasi-public lands in Wayne County including the Lacawac Sanctuary and four PP&L recreational areas. The amount of public owned land in a given subbasin is important since it is unlikely that these areas will be changed from their undeveloped states.

4.3 POPULATION

Table 5 presents current populations and future population estimates for the townships in the watershed. The figures for 1970 and 1980 were obtained from US Census information. The projections for 1990 were developed by the Wayne County and Pike County planning staffs. They were based upon assumed buildout rates for improved and unimproved vacant lots. The projections also included the estimated conversion of second homes into permanent residences. Two different growth rates were assumed in order to provide for a range of possibilities depending on future economic conditions.

Perhaps even more important than the permanent population, is the number of persons living in the watershed during the summer months. A summer peak population, as shown in Table 6, has been developed by assuming that all available seasonal homes are occupied by an average maximum of five individuals. Although this situation could probably only occur on a holiday weekend, it is possible that the resident population in the watershed nearly quadruples during certain portions of the summer.

4.4 SOCIO-ECONOMIC STRUCTURE

The Lake Wallenpaupack area is dependent upon a recreation-based economy with the lake itself being the economic backbone of the region. The economies of both Wayne and Pike Counties are heavily supported by recreational and

Table 4

Amount of Publicly Owned Land in Watershed

Subbasin	Area (acres)	Percent of Subbasin
Main Stem	8,293	17.2
Kleinhans Creek	1,442	56.5
Mill Brook	285	9.5
Minor Tributaries & Immediate Drainage	1,125	6.0
Total Watershed	11,145	8.0

Table 5

Existing and Projected Populations for Townships

Township	Permanent Population			
	1970	1980	Estimated 1990	
			10% Growth	25% Growth
Pike County				
Greene	1,023	1,462	1,780	2,383
Palmyra	1,204	1,722	2,215	3,156
Wayne County				
Dreher	705	743	828	1,053
Lake	1,755	2,453	2,554	2,711
Lehigh	637	884	1,102	1,635
Palmyra	528	773	837	954
Paupack	644	1,379	1,836	2,733
Salem	1,581	2,538	2,804	3,364
Sterling	526	730	826	1,113
Total	8,658	12,684	14,782	19,102

Table 6

Assumed 1982 Summer Peak Population

Township	Summer Peak
Pike County*	
Greene	7,807
Palmyra	12,632
Wayne County	
Dreher	1,613
Lake	2,813
Lehigh	4,254
Palmyra	1,313
Paupack	8,969
Salem	6,278
Sterling	1,440
Total	47,120

*Note: Blooming Grove Township was not included due to its distance from the lake, and the relatively small amount of populated land area located within the watershed boundary.

resort activities. Although tourism is most significant during the summer months, growing interest in autumn and winter sports provides year-round revenue to many of the local businessmen.

In the portions of Wayne and Pike Counties located within the watershed, industry is primarily service-related. The major services include construction, restaurants, resorts, realtors, and retail establishments. This service group is reflective of an environment which caters to the second homeowner and tourist trade. In Pike County overall, for example, the composition of the work force is as follows:

	Pike County Work Force
Craftsmen, foremen	20%
Service workers, operative	29%
Professionals, managers	24%
Clerical, labor	27%
Total	100%

Pike County employment figures show that the total labor force increased by 1000 to 7200 from January to June 1981, with the unemployment rate dropping from a high of 12.9% in Feburary to a low of 5.5% in August. These numbers indicate the fluctuation of employment conditions in the Lake Wallenpaupack area.

In addition to the recreation-related businesses, Wayne County also has a fair percentage of agriculture. Most of the farms primarily practice dairy and/or livestock production.

Compared to statewide figures, average per capita incomes for the townships in the watershed are in the low to medium range; as shown below:

Pike*	
Palmyra	$6,303
Greene	5,792

*1979 estimates (US Dept. of Commerce)

Wayne County**	
Paupack	$3,664
Salem	$2,868
Dreher	$3,881
Lake	$3,223
Sterling	$3,421
Lehigh	$4,383
Palmyra	$4,219

**1975 estimates (Wayne County Data Book)

Data for Greene and Palmyra Townships in Pike County show that the median ages in these townships are high among those for the State (40.5 and 47.5, respectively). This high median age is mainly due to the inward imigration of retired persons to the second homes in the area.

Property values in the watershed are strongly connected to the health of the lake.

4.5 LAKE USES

Since its construction in 1926, Lake Wallenpaupack has been an important recreational resource in northeastern Pennsylvania. The lake has 52 miles of shoreline, and is used extensively for the following purposes: swimming, fishing, boating, water-skiing, and snowmobiling.

In addition to the numerous private resorts and marinas located around the shoreline, there are a number of other public access sites. The following recreation areas provide public boat ramps:

Mangan Cove Access Area (PP&L and Pennsylvania Fish Commission)
Caffrey Campground (PP&L)
Wilsonville Campground (PP&L)
Ironwood Point Campground (PP&L)
Ledgedale Campground (PP&L)

There are also several picnic and nature areas located around the lake, including:

Five Mile Point
Tafton Dike Observation Area
Lake Wallenpaupack Overlook
Beech House Creek Wildlife Refuge
Shuman Point Natural Area
Ledgedale Natural Area
PP&L Visitors Center
Palmyra Township Swimming Beach

As shown in Figure 2, Lake Wallenpaupack is within convenient vacationing distance of millions of inhabitants of the mid-Atlantic states. According to the Pocono Mountains Vacation Bureau, approximately 34% (2.7 million) of the region's 8 million annual visitations occur in the Pike/Wayne area (visitation is defined as the number of separate times that an individual travels to the area).

The main access routes to the watershed include Interstates 84, 81, and 80, and US Route 6. Bus transportation to the lake area is also available.

Lake Wallenpaupack is the largest lake in northeastern Pennsylvania. Although, there are a number of other lakes (both public and private) in the region, Lake Wallenpaupack receives the most usage. Examples of other Pennsylvania lakes located within a 30 mile (50 kilometer radius) are provided in Table 7.

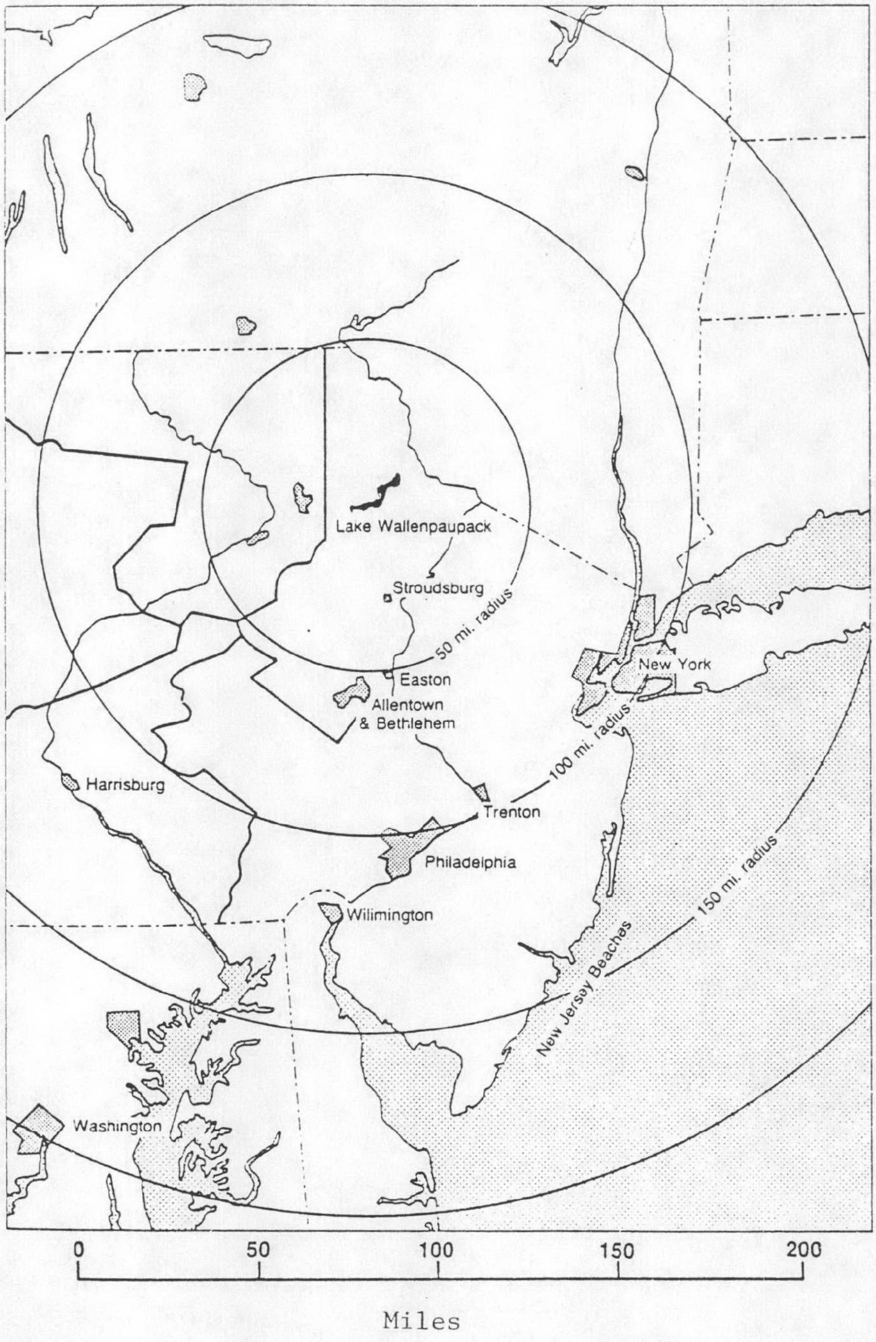


Figure 2. Regional Location of Lake Wallenpaupack

Table 7

Example Pennsylvania Lakes
within a 50 km Radius of Lake Wallenpaupack

Pocono Lake	Corilla Lake
Lake Naomi	Jadwin Reservoir
Stillwater Lake	Glass Pond
Trait Lake	Tagoin Lake
Gouldboro Lake	Blue Heron Lake
Promised Land Lake	Peck's Pond
Lake Henry	Lake Maskenozha
Scranton Reservoir	Salus Lake
Crystal Lake	Mountain Lake
Newton Lake	Fairview Lake
Duck Harbor Pond	Lake Laura
Stanton Pond	Francis E. Walter Lake
Teedyuskung Lake	Lake Ariel

5.0 POLLUTANT SOURCE ANALYSIS

5.1 WATERSHED CHARACTERISTICS

The physical characteristics of a watershed have a direct bearing on the types and quantities of pollutants which enter a lake. Pertinent factors include topography, soils, and geology.

5.1.1 TOPOGRAPHY

There are two physiographic provinces within the northeast region of Pennsylvania: the Ridge and Valley; and the Allegheny Plateau. The southeastern portion of the Allegheny Plateau is a distinct subsection in and of itself. Commonly referred to as the Pocono Plateau, it covers all of Monroe, Pike, and most of Wayne Counties. Its landscape is more diverse than the main body of its province. It is characterized by rough terrain and an abundance of lakes and streams created by glacial scouring of the land which disrupted the internal drainage.

The Lake Wallenpaupack watershed is bound along the northwest by the Moosic Mountains. Elevations in the watershed vary from 2300 feet mean sea level (MSL) in the northwest and 2200 feet MSL in the south to 1190 feet MSL at the dam (top of spillway gates).

5.1.2 GEOLOGY AND SOILS

Since the beginning of the Pleistocene, the Upper Delaware area has been affected by three glacial episodes which have influenced the landforms, mineral resources, and drainage of the area. Glaciated areas are characterized by poor drainage, abundance of wetlands, and stony to extremely stony soils. Glacial deposits consisting of unsorted clay, gravel, pebbles, sand, mud, and boulders, form a patchy cover over most of Wayne and Pike Counties (PaDER, 1981).

In Pike County, the soils are mainly from the Culvers-Cattaraugua-Morris Associations (US Soil Conservation Service, 1969). This soil association is gently sloping to moderately steep. The soils are generally deep and are well-drained to somewhat poorly drained. The soils were formed in reddish or brownish glacial till that was derived from red sandstone and shale. Large areas of the association are very stony. Much of the association is underlain by a well-developed fragipan that slows movement of water through the soil. In general, the soils are of moderate fertility.

The soils of Wayne County are relatively young with slight or weak development. They are all acid and are not very fertile. Most of the soils are formed on material deposited by the Wisconsin glacier. Bedrock outcrops and ledges are numerous. The soils on the mountains and plateaus contain many boulders, stones, and rock fragments. Most of the soils are wet, shallow, slowly permeable, and steep. In general, they are not suitable for septic systems.

5.2 RAINFALL

The available rainfall data for the watershed during the monitoring period is presented in Table 8. Since the records are maintained by volunteers, the data are not complete. The estimated total rainfall over the entire watershed for 16 months was 44.9 inches. This was considerably shy of the average annual rate of 47.2 inches. The rainfall was not evenly distributed over the watershed, as more rain appeared to fall in the southern and western portions.

5.3 HYDROLOGY

Daily tributary flows for each of the streams were modelled using the limited flow and rain data available, along with USGS records for several similar stations in the nearby Lackawaxen River basin. The resulting flow estimates are summarized in Table 9. The Main Stem, West Branch, and

Table 8

Lake Wallenpaupack Watershed Area

Rainfall Distribution for Monitoring Period

Month	Palmyra Township Pike County (inches)	Paupack Township Wayne County (inches)	Sterling Township Wayne County (inches)	Lake Township Wayne County (inches)	Dreher Township Wayne County (inches)
Aug. 1980	2.01	1.70	1.01	-	-
Sept. 1980	1.15	0.88	1.10	-	-
Oct. 1980	3.16	2.18	2.55	-	-
Nov. 1980	2.96	2.86	-	-	-
Dec. 1980	0.82	1.36	-	-	-
Jan. 1981	0.58	-	-	-	-
Feb. 1981	8.31	-	-	-	8.83
March 1981	0.44	-	-	-	0.93
April 1981	4.31	2.87	-	-	4.86
May 1981	4.45	3.66	3.36	-	3.93
June 1981	3.57	3.21	4.83	-	4.56
July 1981	3.62	3.46	2.81	-	2.96
Aug. 1981	1.26	1.13	0.95	0.21	0.91
Sept. 1981	6.33	5.19	4.93	3.43	2.95
Oct. 1981	3.52	3.09	-	-	-
Nov. 1981	1.76	1.95	-	-	-
Totals	48.25	-	-	-	-

Estimated Average for Watershed = 44.90 inches

Table 9

Estimated Tributary Flows into Lake Wallenpaupack for Monitoring Period

Subbasin	Total Volume (ft^3)	Mean Flow (cfs)	Mean Flow (cfs/mi^2)
Main Stem	3.88×10^9	92.2	1.23
West Branch	3.71×10^9	88.2	1.30
Ariel Creek	0.37×10^9	8.7	0.56
Purdy Creek	0.19×10^9	4.6	0.51
Mill Brook	0.22×10^9	5.1	1.09
Minor Tributaries and Immediate Drainage	1.50×10^9	35.6	0.77
Total Watershed	9.87×10^9	234.4	1.07

Table 10

Total Number of Storm Hydrographs in Each Subbasin for Monitoring Period

Subbasin	No. of Storm Hydrographs
Main Stem	36
West Branch	33
Ariel Creek	31
Purdy Creek	26
Mill Brook	28

and Mill Brook subbasins produced the most runoff per square mile. Ariel Creek and Purdy Creek experienced considerably less runoff during the monitoring period. This was probably due to the rainfall distribution in the watershed, as discussed above. The actual number of modeled storm hydrographs for each subbasin is shown in Table 10. Main Stem and West Branch had the most storm hydrographs.

Monthly flows into and out of the lake are given in Table 11. The largest flows into the lake occurred during February 1981. The largest withdrawals from the lake occurred during May and September 1981. More water was discharged from the lake than entered it during the overall monitoring period. Accurate discharge records for the hydroelectric outlet are maintained by PP&L and the USGS. Table 12 presents a water budget for the lake for the monitoring period. The table indicates a difference between total inputs and total outputs of 12.4%. This error could be due to the following possible reasons:

1) tributary flows into the lake were overestimated,

2) evaporation was underestimated,

3) there may be a net groundwater outflow from the lake.

This error is considered acceptable, however, based on the amount of data available.

5.4 WATERSHED MONITORING PROGRAM

Tributary monitoring was performed for dry and wet weather conditions at six stations as shown in Figure 3. For much of the study, instantaneous flow readings had to be manually obtained using the existing USGS wire-weight staff gages at each of the five stream stations. Continuous, automatic monitoring equipment was installed at the three major stream stations (Main Stem, West Branch, and Ariel Creek) by the LWWMD in the summer of 1981. This equipment included recording flow meters, automatic water samplers, activation switches, and protective housings.

Table 11

Monthly Inflows and Outflows for Lake Wallenpaupack

Month/Year	Tributary Flows into Lake (cfs)	Outlet Flow from Lake (cfs)
August 1980	55.6	286.1
September	42.8	373.7
October	51.8	48.1
November	80.1	97.6
December	211.0	91.4
January 1981	244.6	27.5
February	1320.5	29.4
March	263.0	235.5
April	304.5	249.3
May	516.8	630.9
June	185.6	371.4
July	109.8	341.0
August	51.7	245.4
September	62.6	434.2
October	124.9	87.0
November	213.4	279.0
Weighted Average	234.4	239.8

Table 12

Hydraulic Budget for Lake Wallenpaupack
for Monitoring Period

	Volume (ft^3)
Inputs	
Tributary Flows*	9.87×10^9
Direct Precipitation	0.94×10^9
Net Storage Loss	1.91×10^9
Total	12.72×10^9
Outputs	
PP&L Discharge	10.09×10^9
Evaporation*	1.05×10^9
Total	11.14×10^9

*Estimated Values

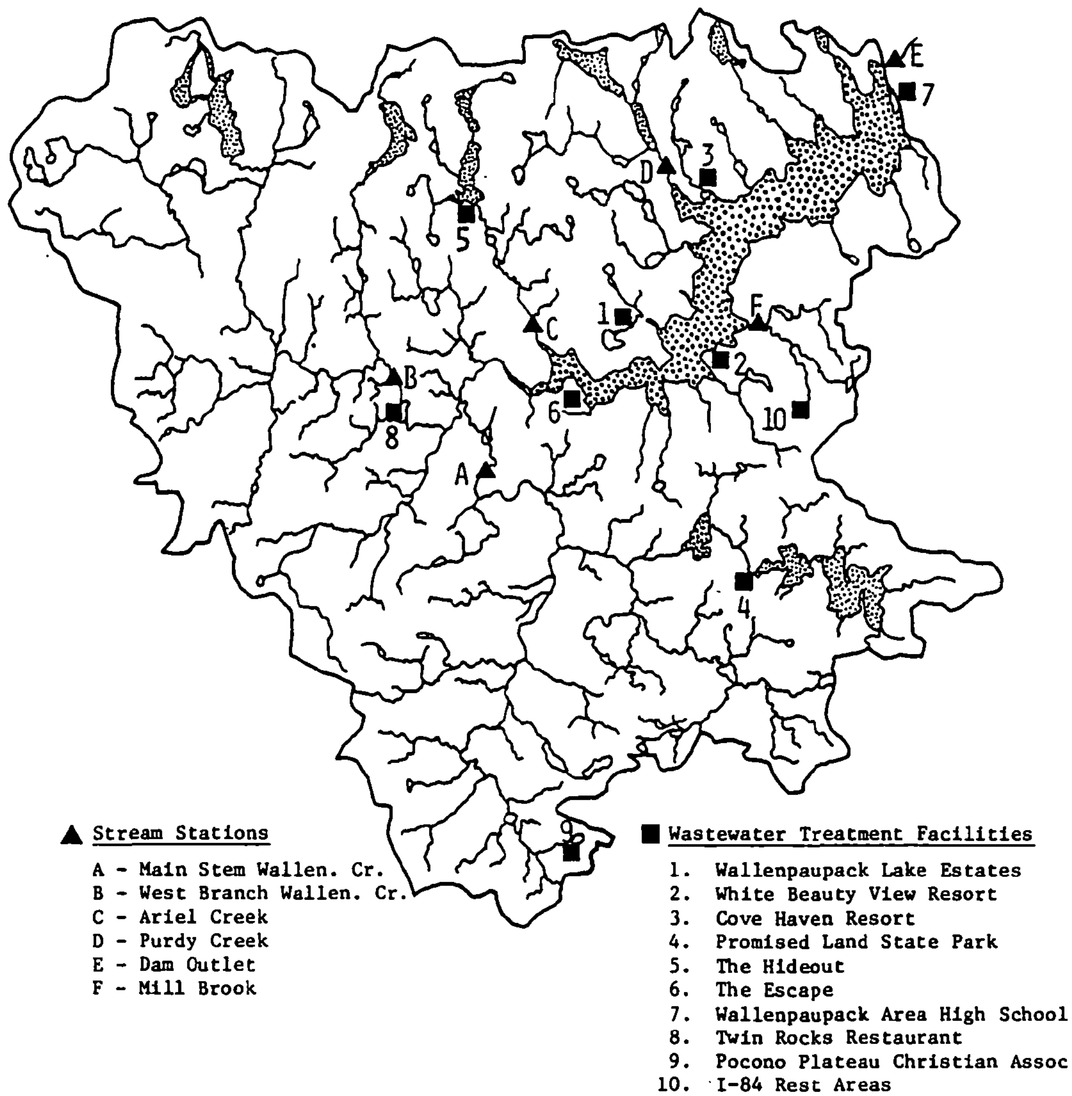


Figure 3. Location of Stream Monitoring Stations and Wastewater Treatment Facilities in Watershed.

Dry weather samples were collected once per month for 16 months (August 1980 through November 1981) in order to establish base load conditions. Wet weather samples were collected over the storm hydrograph at each stream station for eight rain events. The storm events monitored represented a variety of storms with respect to intensity, duration, and season of the year. Wet weather samples were flow-composited for analysis. Grab samples were collected at the PP&L hydroelectric plant during periods when water was being discharged from the lake.

Tributary samples were analyzed for the following parameters:

- Total Phosphorus (total and dissolved)
- Orthophosphate (total and dissolved)
- Total Kjeldahl Nitrogen
- Nitrate/Nitrite
- Fecal Streptococcus (periodically)
- Suspended Solids
- pH
- Fecal Coliform (periodically)
- Ammonia

5.5 POLLUTANT LOADS

Pollutant loads occur from both point and nonpoint sources. Point sources are defined as all of the wastewater effluent discharges (including domestic and/or industrial discharges) within the watershed. Nonpoint sources are all other pollutant sources which effect the lake via the tributaries or immediate drainage areas. Examples of nonpoint sources include: stormwater runoff, groundwater inflow, channel erosion, and precipitation. Nonpoint sources usually contribute the most significant portion of nutrients to a lake.

Calculating pollutant loads requires large amounts of data analyses, and hydrological and engineering assumptions. In performing such analyses, many sources of error may be incorporated into the results. Obvious sources of error include built-in errors in flow measurements, water quality analyses and sampling. These sources of error cannot be avoided because they are inherent in the analytical methodologies presently available. Errors caused by statistical and hydrological analyses and engineering assumptions can only be avoided or minimized by continuous monitoring of all tributaries to the lake. Such a program would be technically impractical and economically infeasible. Therefore, the loads presented in this report should be considered as "best possible estimates", and not absolute values.

5.5.1 POINT SOURCE LOADS

The known wastewater dischargers in the Lake Wallenpaupack watershed are shown in Figure 3. The receiving waters for each wastewater discharger are listed below:

Wastewater Treatment Facility	Receiving Water
1. Wallenpaupack Lake Estates	Tributary to Lake Wallenpaupack
2. White Beauty View Resort	Lake Wallenpaupack
3. Cove Haven Resort	Lake Wallenpaupack
4. Promised Land State Park	East Branch Wallenpaupack Creek
5. The Hideout	Ariel Creek
6. The Escape	Lake Wallenpaupack
7. Wallenpaupack Area High School	Lake Wallenpaupack
8. Twin Rocks Restaurant	Tributary to West Branch
9. Pocono Plateau Christian Assoc.	Tributary to Main Stem
10. I-84 Rest Areas	Tributary to Mill Brook

The above facilities treat domestic and/or commercial wastewater. There are no known industrial dischargers located within the watershed. All of the facilities have NPDES Permits, with the exception of Wallenpaupack Lake Estates, White Beauty View Resort, and the Escape, which are currently certified under the Pennsylvania Clean Streams Law. At least two of these three dischargers (White Beauty View and Wallenpaupack Lake Estates) have applied for NPDES Permits. Those treatment facilities which discharge directly to the lake theoretically have a greater impact on the lake water quality.

Wastewater effluents from the above facilities were monitored twice during the study through the combined efforts of F. X. Browne Associates, Inc. and the PaDER. These data were combined with data from monthly monitoring reports available from the PaDER to estimate the loads shown in Table 13. In a review of the data for all treatment facilities, only infrequent violations of effluent requirements were detected.

The Hideout wastewater treatment facility has the largest capacity, but it did not have the highest phosphorus loads due to its extensive phosphorus removal practices. White Beauty View Resort and Wallenpaupack Lake Estates discharged slightly higher phosphorus loads. The Hideout discharged the largest quantities of suspended solids and nitrogen.

5.5.2 Nonpoint Source Loads

Nonpoint sources are comprised of tributary, groundwater, septic system, and atmospheric inputs to the lake. Nonpoint sources of pollutants are much more difficult to regulate.

Tributary Loads

Tributary loads are divided into base (dry weather) loads and storm (wet weather) loads. A comparison of nutrient concentrations between dry and wet weather conditions is presented in Table 14. Few general patterns can be distinguished between the different streams. Total suspended solids and total phosphorus concentrations increased at all of the stations during storm periods. This was due to the larger amounts of particulate matter which are eroded from the land and stream banks during storms. These higher concentrations coupled with higher flows result in greatly increased stream loads during storm periods. West Branch had the highest total suspended solids concentrations during both base and storm periods. The nitrate/nitrite concentrations in Mill Brook were low compared to the other stations. Ammonia, which is a soluble parameter, decreased during storm runoff at Ariel Creek, indicating that the high concentrations of ammonia found during base flows at Ariel Creek were produced by the treatment facility at the Hideout. This ammonia is actually diluted during storm events.

Table 13

Pollutant Loads from Wastewater Dischargers during Monitoring Period

	Average Flow (MGD)	Total Phosphorus (lbs as P)	Total Suspended Solids (lbs)	Total Nitrogen(c) (lbs as N)
White Beauty View Resort	0.036	247	1,900	1,548
Promised Land State Park(a)	0.025	89	257	3,468
The Hideout	0.115	133	5,091	5,063
The Escape	0.012	71	2,633	727
Twin Rocks Restaurant	0.004	44	81	772
Wallenpaupack High School	0.011	37	268	992
Wallenpaupack Lake Estates	0.043	160	4,244	1,317
Cove Haven Resort	0.038	128	1,412	2,083
Pocono Plateau Christian Association(a)	0.001	9	4	7
I-84 Rest Areas(b)	0	0	0	0
Total	0.284	918	15,890	15,977

Notes: (a) Facility in operation during only portion of the year.

(b) Not in operation during study.

(c) Does not include organic nitrogen (not measured by wastewater treatment plants).

Table 14

Comparison of Average Nutrient Concentrations
for Base and Storm Conditions

Station	Total Phosphorus (mg/l as P)		Nitrate/Nitrite (mg/l as N)		Ammonia (mg/l as N)		Total Suspended Solids (mg/l)	
	Base	Storm	Base	Storm	Base	Storm	Base	Storm
Main Stem	0.024	0.030	0.229	0.300	0.019	0.037	3.8	10.6
West Branch	0.030	0.045	0.276	0.319	0.038	0.024	7.9	14.3
Ariel Creek	0.032	0.041	0.282	0.264	0.073	0.032	4.4	6.9
Purdy Creek	0.036	0.037	0.227	0.248	0.033	0.034	5.6	5.5
Mill Brook	0.023	0.030	0.055	0.075	0.017	0.024	3.2	5.1

Note: Base conditions = discrete samples
Storm conditions = composite samples

Pollutant loads for base flow conditions were calculated by taking the average base flow concentrations for each month and multiplying by the base volume. Where applicable, point source loads were subtracted from the monthly nonpoint base loads.

Eight storms were monitored at each station by flow-compositing samples taken throughout the storm hydrographs. The relationships between the monitored loads and the volume of runoff were statistically analyzed using a log-log regression method. The resulting regression curves are shown in Figures 4, 5, and 6 for total phosphorus, total nitrogen, and total suspended solids, respectively.

The steeper curves in Figures 4, 5, and 6 represent the basins with more severe storm runoff problems. For example, in all cases, West Branch produces more pounds of pollutant per volume runoff than Main Stem. This would be expected since the West Branch subbasin contains about three times as much agricultural land on a percentage basis. The Main Stem subbasin, on the other hand, is comprised of 81% forest land. Runoff from agricultural and developed land usually produces higher loadings than undeveloped areas. These land use relationships, however, do not seem to apply as readily to the smaller subbasins. Based on their percentages of agricultural and developed land, it would be expected that the Ariel Creek and Purdy Creek subbasins would exhibit much higher loadings than Mill Brook, which is mainly forested. More data need to be collected to explain these discrepancies.

A summary of the tributary loads to the lake for the monitoring period is presented in Table 15. Loads for the unmonitored storm periods were estimated using the load/runoff regression curves. The modeled storm loads were then superimposed on the base loads to develop total tributary loads for each subbasin. A proration technique based on land use characteristics was used to estimate the nonpoint source loads from the unmonitored areas. The West Branch contributed by far the largest quantities of nutrients and suspended solids to Lake Wallenpaupack during the monitoring period.

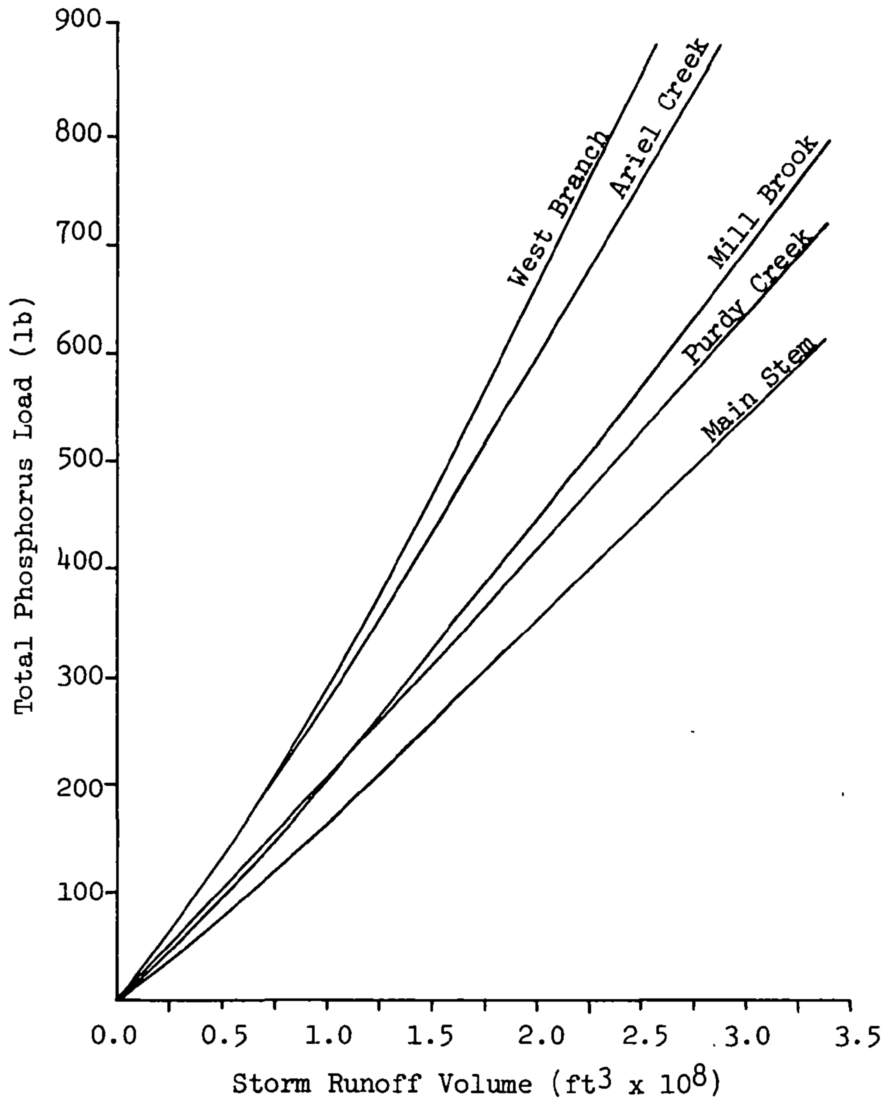


Figure 4. Total Phosphorus Load versus Storm Runoff Volume Relationships for Monitored Subbasins.

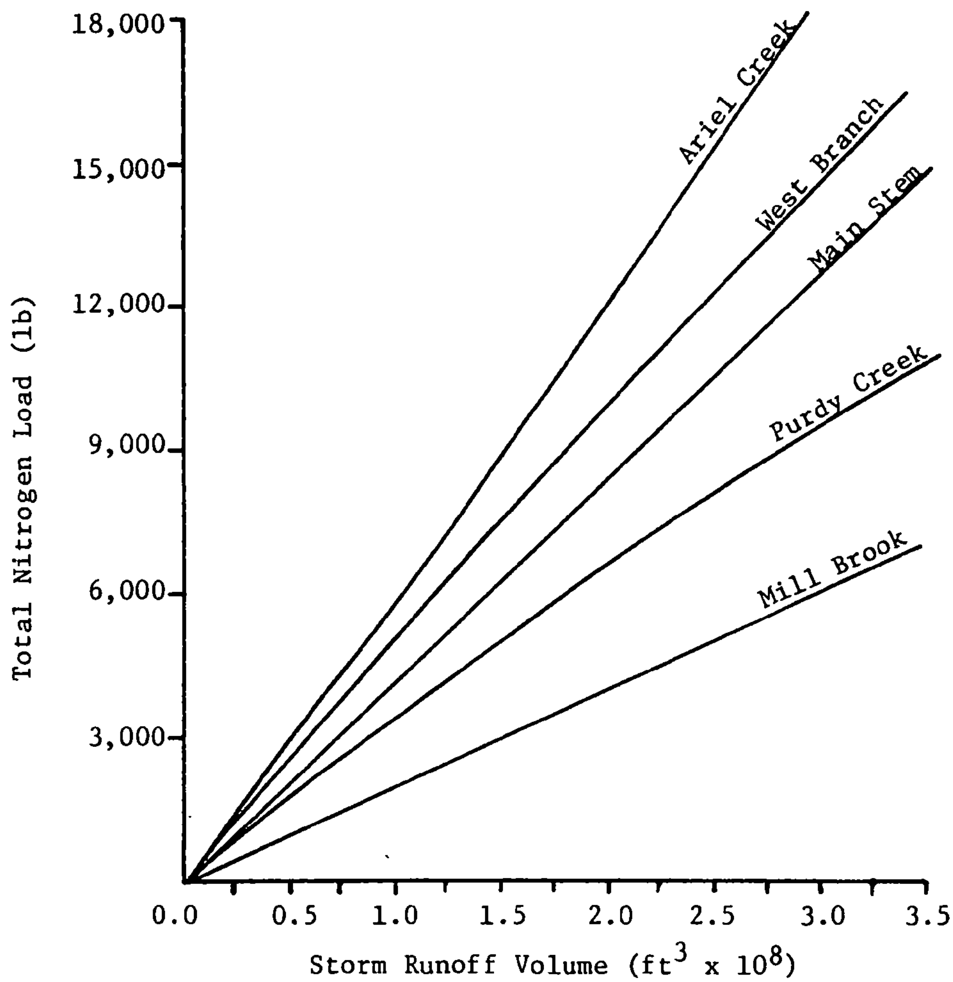


Figure 5. Total Nitrogen Load versus Storm Runoff Volume Relationships for Monitored Subbasins

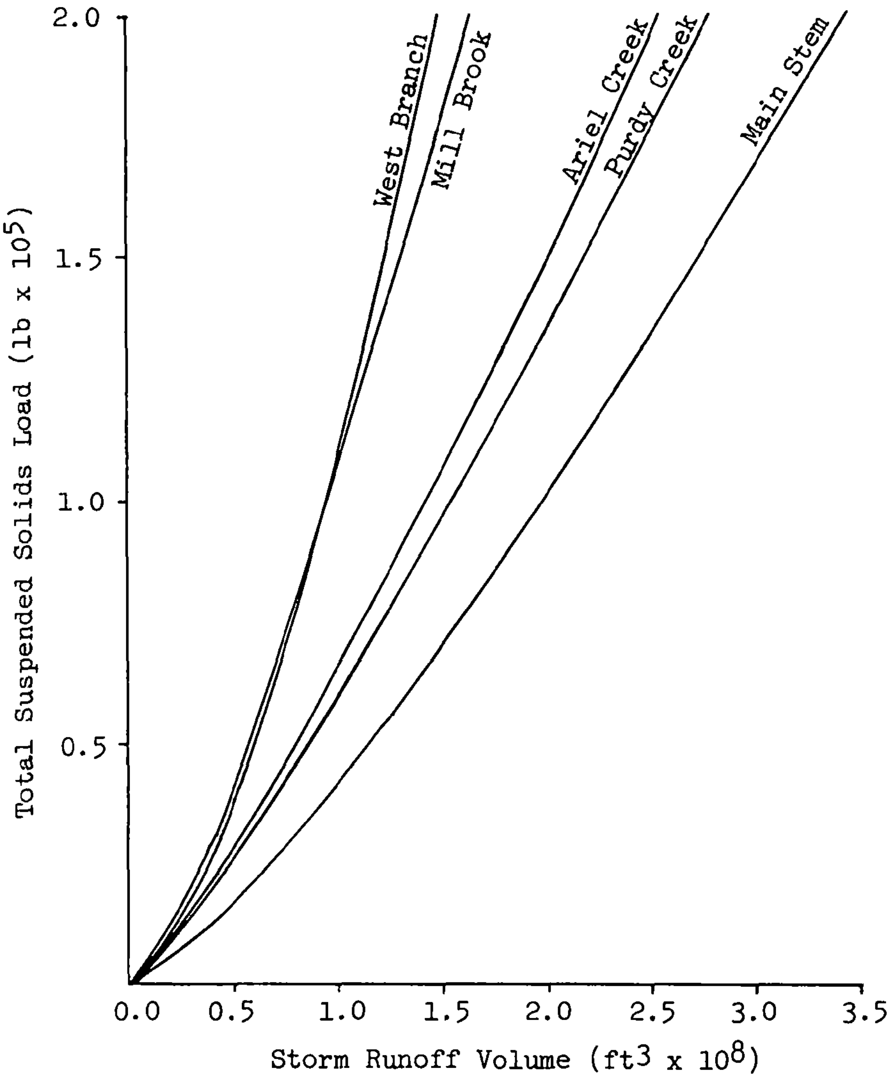


Figure 6. Total Suspended Solids Load versus Storm Runoff Volume Relationships for Monitored Subbasins.

Table 15

Summary of Tributary Pollutant Source Loads
for the Monitoring Period

Subbasin	Total Phosphorus (lbs as P)	%	Total Nitrogen (lbs as N)	%	Total Suspended Solids (lbs)	%
Main Stem	6,420	27.0	164,240	34.4	1,487,000	19.8
West Branch	10,040	42.2	178,900	37.5	3,857,900	51.4
Ariel Creek	700	2.9	14,930	3.1	131,800	1.7
Purdy Creek	380	1.6	7,810	1.7	73,700	1.0
Mill Brook	330	1.4	3,950	0.8	58,400	0.8
Minor Tributaries and Immediate Drainage	5,920	24.9	107,210	22.5	1,897,000	25.3
Total	23,790	100.0	477,040	100.0	7,505,800	100.0

Since the rainfall distribution over the watershed was not uniform, the relationships between the pollutant loads for each subbasin are not necessarily indicative of the relative magnitudes which would occur under more homogeneous rainfall conditions.

Septic System Loads

In some watersheds, pollutant loads from septic tank leachate are a significant source of nutrients and/or bacteria to a lake. In the Lake Wallenpaupack watershed, many of the individual septic systems were either designed or built improperly. For example, many of the systems were installed before regulations were instituted establishing criteria for acceptable soils, slopes, and bedrock conditions. In addition, many vacation homes have been upgraded to year-around residences without a concurrent increase in septic system capacity.

Nutrient loads from septic systems can occur in two forms: (1) surface breakthrough, and (2) groundwater contamination. The first form indicates a failing septic system which should be immediately repaired. The second source is much more difficult to control. Phosphorus compounds are usually removed to some degree in most soils due to precipitation and adsorption reactions. Nitrogen compounds, however, are usually readily transported through most soils. Suspended solids are only a factor for systems experiencing a direct breakthrough to the ground surface.

A detailed evaluation of soils and geology was performed for the watershed area. The suitability of each soil type for septic systems was determined based on the following considerations:

- depth to water table
- depth to bedrock
- percolation rate
- slope

Most of the areas in the watershed have severe limitations for septic systems.

Data from the above analysis were combined with information from field investigations in order to estimate total septic systems loadings to the lake. There are approximately 5400 septic systems in the watershed. These systems contribute the following estimated annual loads:

Total phosphorus	-	3,970 lbs as P
Total nitrogen	-	29,000 lbs as N
Total suspended solids	-	24,150 lbs

Atmospheric Sources

Another source of nutrients is the direct precipitation of rain and dust onto the lake. Rain and snow contain measurable amounts of nutrients and particulate matter. Several samples of rain water were collected and analyzed. The following annual loads are estimated for direct precipitation:

Total phosphorus	-	1,850 lbs as P
Total nitrogen	-	56,080 lbs as N
Total suspended solids	-	184,900 lbs

5.5.3 TOTAL WATERSHED LOADS

The overall pollutant budget for Lake Wallenpaupack for the 1980 to 1981 monitoring period is presented in Table 16. For each parameter, tributary sources accounted for the major portion of the pollutants entering the lake. Tributary sources were responsible for 96.2% of the total suspended solids load, 78.7% of total nitrogen, and 73.3% of total phosphorus. Septic systems were the second largest contributor of phosphorus to the lake. Point sources were the least significant contributors for all three parameters As a matter of fact, the relatively low amounts of rainfall which occurred during the monitoring period may have actually caused an overemphasis in the relative proportions of the loads attributed to point sources.

Table 16

Pollutant Budget for Lake Wallenpaupack
for 1980 to 1981 Monitoring Period *

	Total Phosphorus (lbs as P)	%	Total Nitrogen (lbs as N)	%	Total Suspended Solids (lbs)	%
Inputs						
Tributaries	23,790	73.3	477,040	78.7	7,505,800	96.2
Point Sources	920	2.8	15,980	2.6	15,900	0.2
Septic Systems	5,290	16.3	38,660	6.4	32,200	0.4
Direct Precipitation	2,460	7.6	74,770	12.3	246,500	3.2
Total	32,460	100.0	606,450	100.0	7,800,400	100.0
Output						
PP&L Discharge	17,590	-	415,730	-	3,294,500	-
Accumulation	14,870		190,720		4,505,900	-

*Represents 16 month period.

All loads are presented in weight units (pounds), which are the product of pollutant concentration times the volume of water. Despite relatively low pollutant concentrations, the tributary loads are higher because of the large volumes of water which enter the lake from streams. For example, an average stream flow of one cubic foot per second is equivalent to greater than 235 million gallons of water per year.

Tributary loads are generally the highest during the winter and spring when stream flows are high. (On the contrary, point source and septic system loads are generally higher in the summer when the area's population is at its peak.) The largest tributary loads during the study period occurred during February 1981; whereas the smallest loads occurred during August 1981.

5.5.4 POLLUTANT ACCUMULATION IN LAKE WALLENPAUPACK

According to the accumulation rates shown in Table 16, the following percentages were retained in the lake during the monitoring period:

Parameter	Percent Retained
Total phosphorus	45.8
Total nitrogen	31.4
Total suspended solids	57.8

Since most of the solids entering the reservoir are settleable, a high retention is expected. A relatively high retention of phosphorus is also expected since over 50% of the total phosphorus load to the lake is in the particulate (i.e. settleable) form. Low nitrogen retention is expected since most of the nitrogen is in the soluble form. The amounts of nutrients and solids discharged from the lake depend partly on the timing and quantity of PP&L withdrawals during the year.

5.5.5 NORMALIZED POLLUTANT LOADS

Table 17 presents normalized annual pollutant loads to the lake. The tributary loads were normalized to reflect average annual runoff conditions, assuming a uniform rainfall distribution throughout the watershed. The annual point source loads were assumed to remain constant. Hence, the normalized loads more accurately reflect the relative significance of each subbasin and of each pollutant source. As would be expected, tributary sources are even more significant under normalized conditions (i.e. 84% of total phosphorus, 88% of total nitrogen, and 98% of total suspended solids loads come from tributary sources).

5.5.6 COMPARISON OF TRIBUTARY LOADINGS

The normalized tributary loads measured for this study were higher than the phosphorus and nitrogen loads which were estimated in the 1975 US EPA National Eutrophication Survey (NES) Report for Lake Wallenpaupack. This is mainly due to the more extensive watershed monitoring program conducted as part of this study; particularly during storm runoff events. The NES report did not provide a loading estimate for total suspended solids.

<u>Subbasin Loadings</u>

Unit areal loading rates for the tributary loads in each of the subbasins are presented in Table 18. The loading rates (in pounds/acre/year) for Main Stem, Ariel Creek, Purdy Creek, and Mill Brook were approximately the same. Mill Brook had a slightly higher total suspended solids loading rate. The West Branch and Immediate Drainage subbasins had the highest loadings for all three parameters. For the Immediate Drainage area, the high loads are due to the relatively large percentages of residential and commercial development. The higher loads in the West Branch subbasin are due to the high percentage of agricultural land, including cropland and pasture.

Table 17

Normalized Annual Pollutant Loadings
for the Lake Wallenpaupack Watershed

	Total Phosphorus (lbs/yr)	Total Phosphorus (%)	Total Nitrogen (lbs/yr)	Total Nitrogen (%)	Total Suspended Solids (lbs/yr)	Total Suspended Solids (%)
Inputs						
Tributaries						
Main Stem	7,685	19.1	196,770	25.6	1,781,000	16.6
West Branch	11,385	28.3	202,760	26.3	4,372,000	40.8
Ariel Creek	1,825	4.5	38,970	5.1	344,000	3.2
Purdy Creek	1,090	2.7	22,510	2.9	213,000	2.0
Mill Brook	445	1.1	11,380	1.5	169,000	1.6
Immediate Drainage	11,300	28.1	204,680	26.6	3,622,000	33.7
Subtotal	33,730	83.8	677,070	88.0	10,501,000	97.9
Point Sources						
White Beauty View Resort	185	0.5	1,160	0.2	1,400	<0.1
Promised Land State Park	70	0.2	2,600	0.3	200	<0.1
The Hideout	100	0.2	3,800	0.5	3,800	<0.1
The Escape	50	0.1	550	0.1	2,000	<0.1
Twin Lakes Rest.	30	<0.1	580	0.1	100	<0.1
Wallenpaupack H.S.	30	<0.1	740	0.1	200	<0.1
Wallenpaupack Lake Estates	120	0.3	990	0.1	3,200	<0.1
Cove Haven Resort	100	0.2	1,560	0.2	1,100	<0.1
Pocono Plateau Christian Assoc.	10	<0.1	10	<0.1	<10	0
Subtotal	695	1.7	11,990	1.6	12,000	0.1
Septic System Leachate	3,970	9.9	24,150	3.1	29,000	0.3
Direct Precipitation	1,850	4.6	56,080	7.4	184,900	1.7
TOTAL	40,245	100.0	769,290	100.0	10,726,900	100.0

Table 18

Unit Areal Subbasin Loadings for Normalized Tributary Loads

Subbasin	Total Phosphorus (lb/ac/yr)	Total Nitrogen (lb/ac/yr)	Total Suspended Solids (lb/ac/yr)
Main Stem	0.16	4.1	37
West Branch	0.26	4.7	101
Ariel Creek	0.18	3.9	35
Purdy Creek	0.19	3.9	37
Mill Brook	0.15	3.8	56
Minor Tributaries & Immediate Drainage	0.38	6.9	122

Table 19

Synopsis of Subbasin Land Uses

Subbasin	Residential/ Commercial (%)	Cropland (%)	Pasture (%)	Undeveloped Forest (%)
Main Stem	3.8	1.5	7.9	81.0
West Branch	3.0	4.9	23.8	64.1
Ariel Creek	6.7	15.2	11.9	55.0
Purdy Creek	5.2	15.3	2.2	60.5
Mill Brook	2.4	0	1.7	93.1
Minor Tributaries & Immediate Drainage	17.1	1.6	5.9	69.5

Based on the land use synopsis presented in Table 19, much higher loadings would be expected from the Ariel Creek and Purdy Creek subbasins. These basins both contain relatively high percentages of developed and agricultural land use. However, as was shown in Table 1, these subbasins also contain the largest percentages of wetlands and surface waters. For example, these subbasins contain the following lakes:

Ariel Creek	Purdy Creek
Lake Ariel	Paupackan Lake
Wildwood Lake	Locklin Pond
Roamingwood Lake	Butler Pond
Lake Genero	Craft Pond

It is hypothesized that these lakes act as retention basins for much of the nutrients and solids eroded from the land in these subbasins. Also, these lakes dampen storm flows in the tributary systems by storing portions of the runoff during rain events. This serves to reduce stream velocities, which in turn reduces the magnitude of channel erosion.

Land Use Loadings

Loading rates for individual land uses have been obtained from a literature review and are summarized in Table 20. Due to the soils and geological conditions in the Lake Wallenpaupack watershed, the lower ends of these ranges apply. The actual pollutant loadings from specific land uses in various subbasins will vary based on actual land use activities and the amounts and intensities of rainfall received.

The loadings in Table 20 can be used to compare the relative nutrient and sediment contributions of different land uses. In general, cropland and developed land are the most significant contributors of pollutants. These loadings can also be used to estimate the potential effects of future land use changes on the annual pollutant budget.

Table 20

Range of Literature Values for
Land Use Loadings

	Export Coefficients (lb/ac/yr)		
Land Use	Total Phosphorus	Total Nitrogen	Total Suspended Solids
Undeveloped	0.1 - 0.4	1 - 3	50 - 150
Pasture	0.5 - 1.0	3 - 9	100 - 340
Cropland	1.5 - 4.6	9 - 26	800 - 2000
Developed	0.8 - 1.8	5 - 10	420 - 900

Sources: (a) Browne and Grizzard, 1979.

(b) Northern Virginia Planning District Commission *et al.*, 1978.

(c) Reckhow *et al.*, 1980.

(d) Rast and Lee, 1978.

5.5.7 LAND USE MONITORING

In an effort to verify the above relationships, three locations were selected for specific land use monitoring, as listed below:

Land Use Category	Location	Drainage Area
Residential	Wallenpaupack Lake Estates	739 acres
Agricultural	Little Chapel Area	687 acres
Bungalow Resort	Hemlock Grove Cottages	160 acres

The locations of these monitoring sites are shown in Figure 7. Each of the sites represents a small subbasin with relatively homogeneous land use of the type described. The agricultural subbasin contained both pasture and cropland. The residential subbasin was not fully developed.

An intermittent stream which flows only after a storm is located at each site. Grab samples and flow measurements were taken at each site during four storms. These data were used to develop the instantaneous pollutant loads in Table 21. The loads shown are a product of the quantity of runoff and the pollutant concentrations measured. Although the results are inconclusive, the following observations were made:

1. Due to the relatively large amount of impervious area, the bungalow resort generated the greatest runoff flows per unit area.
2. Despite lower flows, high pollutant concentrations at the agricultural site caused that station to have the highest loadings for most of the parameters.

5.5.8 PHOSPHORUS AVAILABILITY

The impact of phosphorus loads to the lake, whether from point or nonpoint sources, depends on many factors including the chemical state of the phosphorus (i.e. organic phosphorus, polyphosphate, or orthophosphate) and whether the phosphorus is in the particulate or soluble form. In general,

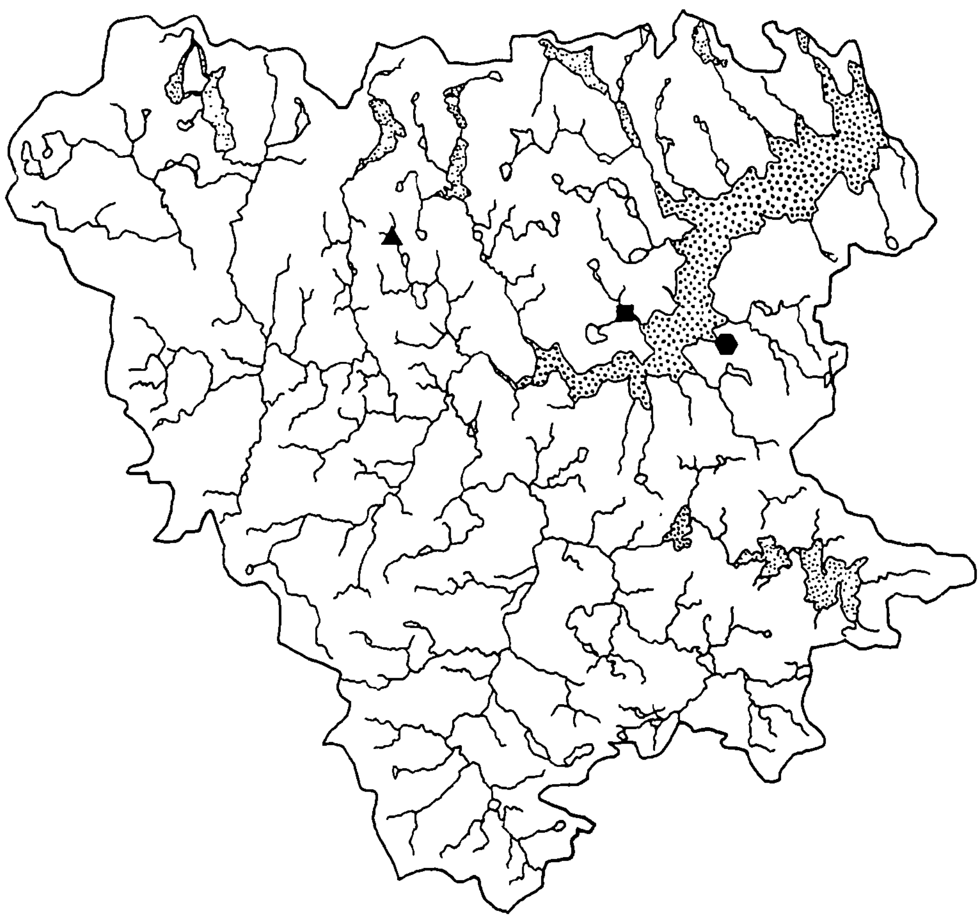


Figure 7. Location of Land Use Monitoring Sites

Table 21

Instantaneous Storm Loads for Selected Land Use Monitoring Sites

		Instantaneous Loads (lbs/ac/hr)					
Storm Date	Average Flow (cfs/ac)	Total Phosphorus ($x 10^{-7}$)	Total Orthophosphate ($x 10^{-7}$)	Total Kjeldahl Nitrogen ($x 10^{-6}$)	Ammonia ($x 10^{-7}$)	Nitrate/ Nitrite ($x 10^{-6}$)	Total Suspended Solids ($x 10^{-5}$)
10/6/81							
Residential	0.0009	1.3	0.6	0.8	0.8	8.9	1.7
Agricultural	0.0002	2.7	0.8	1.6	0.7	1.8	4.6
Bungalow Resort	0.0023	2.9	1.2	8.9	4.9	2.9	5.9
10/26-27/81							
Residential	0.0005	0.9	0.2	1.6	0.2	0.9	0.7
Agricultural	0.0001	30.0	1.4	4.8	1.1	8.9	1.4
Bungalow Resort	0.0014	1.9	0.5	2.7	0.2	7.1	2.0
11/16-17/81							
Residential	0.0005	1.0	0.2	1.8	0.9	1.8	1.0
Agricultural	0.0008	31.0	1.4	5.7	3.1	19.0	1.9
Bungalow Resort	0.0009	1.5	0.4	1.8	0.5	8.0	1.4
12/2-3/81							
Residential	0.0005	0.5	0.2	1.0	1.3	6.3	0.9
Agricultural	0.0005	11.0	6.3	1.5	3.4	9.8	1.5
Bungalow Resort	0.0006	1.0	0.2	0.9	0.2	7.1	1.4

algae utilize phosphorus in the orthophosphate chemical state. Soluble orthophosphate is more readily available for algal uptake than particulate phosphorus. The amount of soluble orthophosphate entering the lake, therefore, is a good indicator of the readily available phosphorus. Other phosphorus forms may not be available for algal growth or they may require significant time and chemical transformations before they are available for algal growth. Organic phosphorus, for example, needs to be chemically transformed into orthophosphate by bacterial decomposition or enzymatic reactions before it becomes available for algal growth.

Total phosphorus loads from tributary sources are generally comprised of a relatively low percentage of soluble orthophosphate. Average stream concentrations of total phosphorus and soluble orthophosphate are shown in Table 22 for both base and storm flow conditions. Total phosphorus concentrations were high at all stations for storm conditions indicating the erosion of particulate matter which takes place. During base flow conditions, soluble orthophosphate accounted for 21 to 33% of the total phosphorus, with an average of 28%. During storm conditions, soluble orthophosphate accounted for 19 to 23% of the total phosphorus, with an average of 20%. These results indicate that the phosphorus in dry weather stream flow is generally more available for algal growth than the phosphorus in wet weather flow. This should be expected since wet weather flows carry eroded soils and impervious surface washoff into the lake. Dry weather flows, however, generally consist of groundwater and point source discharges, both of which usually have higher percentages of soluble phosphorus. Overall, approximately 25% of the tributary phosphorus loads are comprised of soluble orthophosphate.

Wastewater effluent and septic system leachate both usually contain fairly high percentages of available phosphorus. Based on a review of the scientific literature, these combined sources could therefore effectively account for approximately 15.8% of the readily available annual phosphorus load to the lake. This is considerably more than the 11.6% of the total phosphorus

Table 22

Average Total Phosphorus and Soluble Orthophosphate Concentrations in Stream

Stream	Avg. Total Phosphorus (mg/l as P)	Avg. Soluble Orthophosphate (mg/l as P)	Percent Soluble Orthophosphate (%)
Main Stem			
Base Flow	0.024	0.005	21
Storm Flow	0.030	0.006	20
West Branch			
Base Flow	0.030	0.007	23
Storm Flow	0.045	0.009	20
Ariel Creek			
Base Flow	0.032	0.009	28
Storm Flow	0.041	0.008	20
Purdy Creek			
Base Flow	0.036	0.012	33
Storm Flow	0.037	0.007	19
Mill Brook			
Base Flow	0.023	0.007	30
Storm Flow	0.030	0.007	23

load shown in the normalized load section (Table 17). This phenomenon could be particularly important during the summer algae season when tributary loads to the reservoir are generally lower.

In general, results of the watershed monitoring program indicate that both point and nonpoint sources of phosphorus should be controlled to protect Lake Wallenpaupack.

5.5.9 Detergent Phosphate Loads

The average phosphorus content of household laundry detergents in non-regulated areas of the country is approximately 5.5%. This is about half as much as the average for a decade ago. According to the Soap and Detergent Association (Sedlak, 1980), laundry detergents currently account for about 35% of the phosphorus in the annual wastewater loads from an average home in non-regulated areas. This is broken down as follows;

Source	Quantity	Percent
Human Wastes	1.2 lbs/capita/year	46.2
Laundry Detergents	0.9 lbs/capita/year	34.6
Dishwasher Detergents	0.2 lbs/capita/year	7.7
Kitchen Wastes	0.3 lbs/capita/year	11.5
Total	2.6 lbs/capita/year	100.0

These percentages will vary for other living units such as second-homes, resorts, and campgrounds.

Since septic systems and point sources are collectively responsible for 11.6% of the annual phosphorus load to the lake, the complete elimination of phosphorus detergents could result in as much as a 4% reduction in the phosphorus load. Such a reduction could be even more significant when considering the factor of phosphorus availability. The exact amount of reduction depends on the phosphorus removals obtained in individual treatment facilities and septic systems. Although the overall amount may not be substantial enough to warrant a detergent phosphorus ban, the voluntary use of low-phosphate products should definitely be encouraged. Besides having a positive effect on the loads entering the lake, such a recommendation provides a tangible action for homeowners in the watershed.

5.6 BACTERIOLOGICAL DATA

Table 23 presents the bacteriological data for the stream stations for both dry and wet weather conditions. No fecal coliform violations (i.e. coliform bacteria count greater than 200/100 ml) were measured in Mill Brook. Main Stem exhibited only two fecal coliform violations; whereas West Branch, Ariel Creek, and Purdy Creek all exhibited numerous violations. Fecal streptococcus counts were also often high in West Branch, Ariel Creek and Purdy Creek.

Fecal coliform and fecal streptococcus bacteria are indicator organisms; that is, they indicate the possible presence of pathogenic (disease producing) bacteria. Coliform and streptococcus bacteria are harmless, they only indicate the possible presence of harmful bacteria. The ratio of fecal coliform to fecal streptococcus can be used to indicate whether the observed bacteria levels are caused by human activities (wastewater discharges, septic tanks) or stormwater runoff (animal wastes). Fecal coliform/fecal streptococcus ranges and their use as indicators are listed below (Geldreich, 1972):

FC/FS	< 0.7	-	Ratio less than or equal to 0.7 indicates pollution derived from livestock or poultry.
FC/FS	0.7-1.0	-	Ratio between 0.7 and 1.0 suggests a predominance of livestock or poultry wastes in mixed pollution.
FC/FS	1-2	-	Ratio bewteen one and two represents a "gray" area of uncertain interpretation. Samples should be taken nearer the suspected source of pollution.
FC/FS	2-4	-	Ratio between two and four suggest a predominance of human wastes in pollution.

Table 23

Stream Bacteriological Data

Station	Dry Weather 6-15-81 FC	6-15-81 FS	6-15-81 FC/FS	7-07-81 FC	7-07-81 FS	7-07-81 FC/FS	8-4/5-81 FC	8-4/5-81 FS	8-4/5-81 FC/FS	9-30-81 FC	9-30-81 FS	9-30-81 FC/FS	11-09-81 FC	11-09-81 FS	11-09-81 FC/FS
Main Stem	TNTC	TNTC	≈1	90	2	45.0	5	21	0.2	17	11	1.5	39	296	0.1
West Branch	TNTC	100	>2.0	TNTC	1	>4.0	45	7	6.4	TNTC	38	>4.0	72	312	0.2
Purdy Creek	TNTC	100	>2.0	TNTC	1	>4.0	93	87	1.1	TNTC	TNTC	≈1	10	1320	<0.1
Ariel Creek	TNTC	110	>2.0	TNTC	1	>4.0	228	71	3.2	18	TNTC	<0.7	23	322	0.1
Mill Brook	2	37	0.1	12	1	12.0	21	78	0.3	12	306	<0.1	1	244	<0.1

Station	Wet Weather 5-12-81 FC	5-12-81 FS	5-12-81 FC/FS	10-28-81 FC	10-28-81 FS	10-28-81 FC/FS	11-16-81 FC	11-16-81 FS	11-16-81 FC/FS	12-02-81 FC	12-02-81 FS	12-02-81 FC/FS
Main Stem	210	108	1.9	20	46	0.4	102	50	2.0	54	10	5.4
West Branch	TNTC	172	>2.0	1200	430	2.8	346	874	0.4	120	62	1.9
Purdy Creek	160	95	1.7	490	360	1.4	66	429	0.2	114	66	1.7
Ariel Creek	TNTC	134	>2.0	650	310	2.1	59	86	0.7	342	46	7.4
Mill Brook	70	47	1.5	10	23	0.4	36	56	0.6	29	13	2.2

Notes: FC = Fecal Coliform (#/100 ml)
FS = Fecal Streptococcus (#/100 ml)
TNTC = Too Numberous To Count (>200/100 ml)

FC/FS >4.0 - Ratio greater than or equal to four indicates pollution derived from human wastes.

This method of analysis may not always be accurate, particularly when fecal streptococcus counts are below 100/100 ml.

The ratio data indicate that the bacteria in the West Branch and Ariel Creek are probably from human wastes. This is supported by the fact that higher bacterial concentrations were measured in these streams during base flow periods. Since wastewater effluents are usually heavily disinfected, these bacteria are more likely to be from septic system wastes. The data for Purdy Creek are less conclusive, but seem to indicate a combination of human and animal contamination.

Table 24 presents the bacteriological data collected at the land use monitoring sites. Only one fecal coliform violation was detected at Wallenpaupack Lake Estates, and that was probably caused by animal wastes (perhaps pets). Several violations were detected in the stream which flows through Hemlock Grove. These appeared to be caused by a combination of contamination sources. Repeated fecal coliform violations were measured at the agricultural monitoring site. The fecal coliform-to-fecal streptococcus ratios indicate that the bacteria came from livestock.

Table 24

Land Use Bacteriological Data

	10-06-81			10-26-81			11-16-81			12-02-81		
	FC	FS	FC/FS	FC	FS	FC/FS	FC	FS	FC/FS	FC	FS	FC/FS
Wallenpaupack Lake Estates												
Tributary 1	122	1250	0.1	20	115	0.2	47	249	0.2	78	10	7.8
Tributary 2	438	1500	0.3	5	125	<0.1	75	286	0.3	108	21	5.1
Hemlock Grove Cottages	280	720	0.4	222	45	4.9	37	142	0.3	152	73	2.1
Little Chapel Area	309	TNTC	<0.7	1610	5000	0.3	610	1100	0.6	470	9800	<0.1

Notes: FC = Fecal Coliform (#/100 ml)

FS = Fecal Streptococcus (#/1oo ml)

TNTC = Too Numerous To Count (>200/100 ml)

6.0 Lake Water Quality

Water quality is determined by a complex system of chemical, physical, and biological interactions. A primer on these ecological processes can be found in the Clean Lakes Program Guidance Manual (US EPA, 1980). The actual definition of water quality must be based on lake usage. For example, the primary uses of Lake Wallenpaupack are for hydroelectric power generation and recreation. Since hydroelectric power generation does not require high water quality, the main objective of future management activities will be to protect the recreational uses of Lake Wallenpaupack. These include fishing, swimming, boating, and general aesthetics.

6.1 Lake Characteristics

Lake Wallenpaupack is relatively large and deep. The lake has a moderate drainage area to water surface area ratio of 24.3:1. This ratio indicates the need for proper watershed management to protect water quality in the lake. Physical characteristics of the lake are listed in Table 25 .

The elevation of the top of the dam spillway gates is 1190 ft MSL. The outlet pipe is over 14 feet in diameter and is located at the bottom of the dam (invert elevation = 1140 MSL).

6.2 Lake Operations

There are several factors which govern PP&L's operation policies for the lake. These include:

- lake user needs
- peak periods for power demand
- downstream flow augmentation
- prevention of ice buildup in outlet pipe

Table 25

Physical Characteristics of Lake Wallenpaupack

Normal Maximum Summer Elevation*	1187 ft MSL
Surface Area	2.47×10^8 ft^2
Volume	7.31×10^9 ft^3
Mean Depth	29.5 ft
Maximum Depth	52.0 ft
Mean Annual Discharge**	366 ft^3/sec
Mean Residence Time	231 days
Mean Flushing Rate	1.6 times/year

*All values given are for this elevation.

**From USGS records for PP&L discharge at Wilsonville.

In general, PP&L discharges large quantities of water during the winter months in order to accomodate inflows during the spring runoff period. This practice is advantageous since the utility experiences a high power demand during the winter. PP&L then attempts to maintain a maximum elevation of approximately 1187 feet MSL through June 1 (this is the maximum elevation which can be attained without substantially increasing the possibility of having to release water over the dam during a significant storm event). The lake is drawn down steadily over the summer to a minimum recreational elevation of 1179 feet MSL by October 1. This annual cycle was temporarily altered in 1980 and 1981 when the lake was drawn down more than usual during September in order to perform repairs on the dam structure.

6.3 LAKE MONITORING PROGRAM

Lake monitoring was performed for 14 months from August 1980 through October 1981. A contract extension funded by local sources enabled the monitoring of one complete algal growing season in 1981. A total of 21 regular lake sampling surveys was performed for the study. Monitoring was conducted on a bi-weekly basis during the summer and on a monthly basis during the winter. Samples for phytoplankton analysis were collected at several cove and beach locations on five additional monitoring dates.

The locations of the lake monitoring stations are shown in Figure 8. At each station, chemical samples were collected at three depths: surface, middle, and bottom. Phytoplankton samples were collected at the surface (0.5 meters) and at the Secchi disk depth for that date. Temperature and dissolved oxygen profiles and Secchi disk depth measurements were made at each of the regular lake monitoring stations. Ambient conditions were recorded including general weather, air temperature, percent cloud cover, wind speed and direction, and antecedent rainfall.

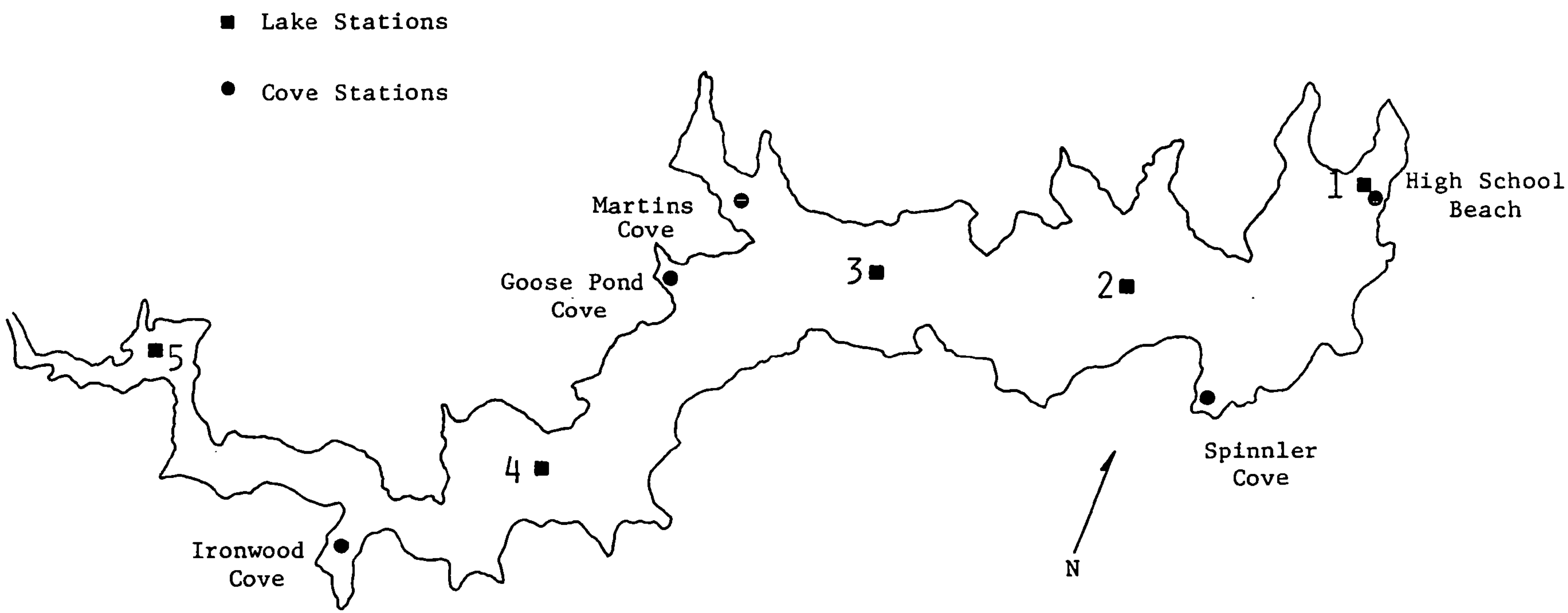


Figure 8. Location of Lake Sampling Stations

Parameters measured in the laboratory included:

- Total Phosphorus (total and dissolved)
- Orthophosphate (total and dissolved)
- Total Kjeldahl Nitrogen
- Nitrate/Nitrite
- Ammonia
- Total Suspended Solids
- Alkalinity
- pH
- Chlorophyll a and Pheophytin a
- Phytoplankton
- Fecal Coliform
- Fecal Streptococcus

6.4 LAKE DATA

6.4.1 GENERAL

The annual water quality response in a lake is determined by a number of factors. The major factor is the amount of nutrients and sediments delivered to the lake via the tributaries. These pollutant loads are mainly determined by the amount and distribution of rainfall over a given period. Other factors which affect lake response include variations in ambient temperature and sunlight. Physical, chemical, and biological characteristics of the lake are discussed in the following sections.

6.4.2 PH AND ALKALINITY

The pH, alkalinity and hardness of a water are interrelated. pH is a term used to express the intensity of the acidity or alkalinity of a water. It is important because most chemical and biological reactions are controlled or affected by the pH. The alkalinity of a water is a measure of its buffering capacity; that is, its capacity to neutralize acids. Alkalinity of natural waters is due primarily to salts of weak acids such as bicarbonates, carbonates, borates, silicates and phosphates. Although many materials contribute to the alkalinity of a water, most of the alkalinity in natural waters is caused by hydroxides, carbonates and bicarbonates. The bicarbonates represent the major form of alkalinity in runoff because they are formed by the action of carbon dioxide with basic materials in the soil.

In lake ecosystems, interactions between pH and alkalinity occur when phytoplankton utilize carbon dioxide in their photosynthetic activity. As carbon dioxide is removed by algae, the pH of the water increases, transforming both carbonate and bicarbonate forms of alkalinity into carbon dioxide, which the algae use for further growth. Thus, alkalinity acts as a food source for the algae, supplying carbon dioxide as a carbon source for algal growth.

Alkalinity values in the lake varied from 9 to 50 mg/l as $CaCO_3$, with an overall lake average of 15 mg/l as $CaCO_3$. This level of alkalinity is relatively low for surface water. Hence, the lake has a low buffering capacity and can be sensitive to fluctuations in pH such as those caused by algae.

Most pH readings in the lake were in the neutral range from 6.5 to 7.5 pH units. The lowest reading was 6.0 units and the highest was 7.9 units. In general, higher pH values occurred at the surface where they would be expected due to algal photosynthetic activity. The measured pH range during the monitoring period was acceptable for fish habitat.

6.4.3 Temperature and Dissolved Oxygen

Presented in Figure 9 are representative temperature and dissolved oxygen profiles for Station 3 during 1981. The surface elevation of the lake

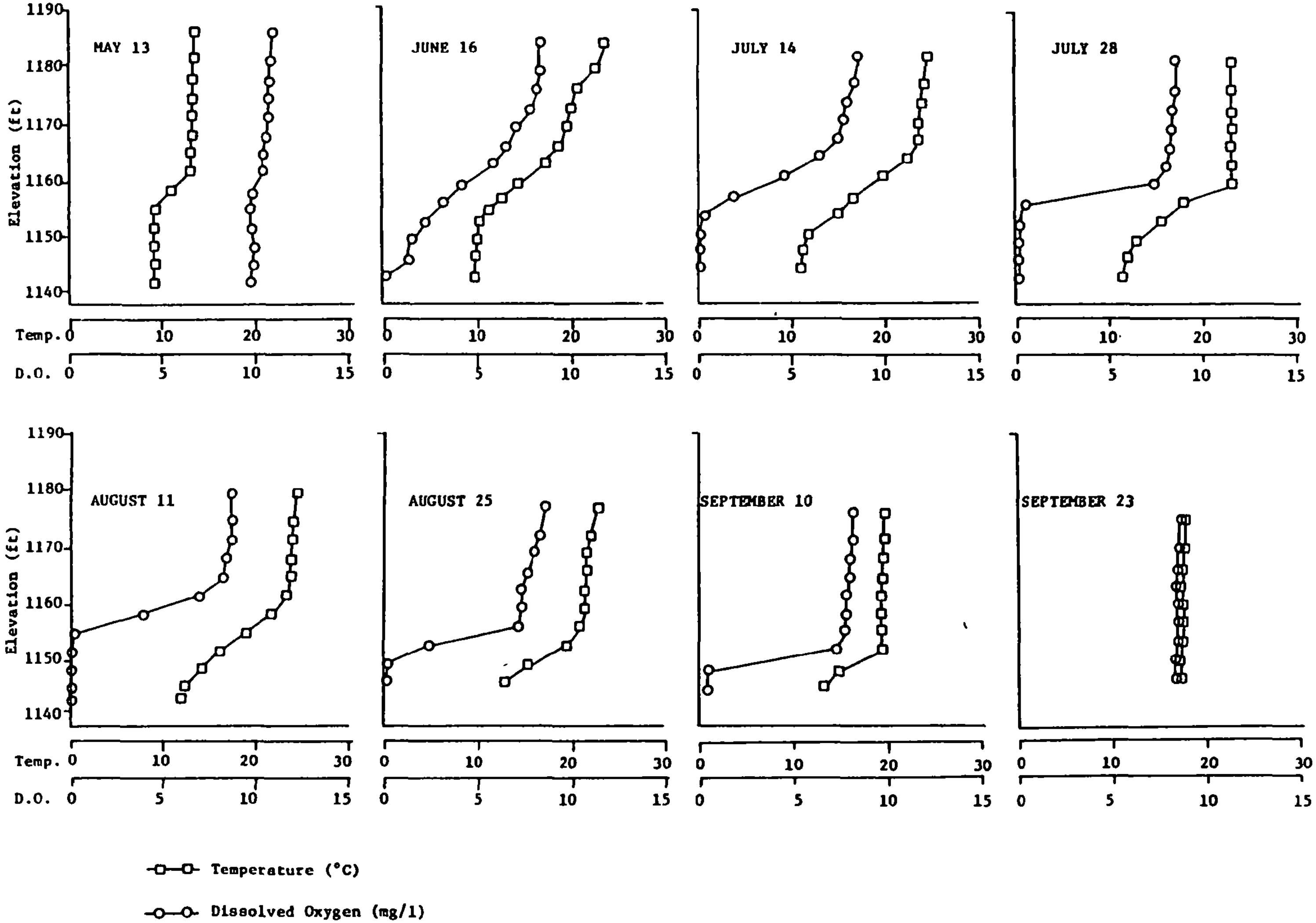


Figure 9. Representative Temperature and Dissolved Oxygen Profiles for Station 3 during 1981.

(and therefore the depth of the lake) declined throughout the summer as shown in the profiles. Thermal stratification began to form in May and was well pronounced by the middle of June. The elevation of the top of the thermocline decreased from 1167 ft MSL in the middle of July to 1152 ft MSL on September 10th after the initiation of bottom withdrawal by PP&L. Maximum temperatures in the epilimnion (surface waters) reached 24°C (75°F) in July and August of 1980. Surface temperatures for the same period in 1980 exceeded 24°C(79°F). Destratification (fall turnover) occurred during mid-September in both years. This phenomenon which would normally occur during October was induced by PP&L drawdown practices for those years. In the periods following destratifcation, the lake was very turbid and had visible algae blooms.

Dissolved oxygen concentrations in the lake were greater than 10 mg/l before the onset of thermal stratification. Severe oxygen depletion occurred in the hypolimnion by the June 29th sampling date (not shown). Oxygen depletion is caused by bacterial decomposition of dead algae and other organic matter as they settle into the bottom waters of the lake. Anoxic conditions persisted in the hypolimnion until the time of fall turnover. When bottom waters become devoid of oxygen (anoxic), there is an alteration of the chemical properties of the sediments. Increased rates of phosphorus release from sediments to the water column occur during anoxic conditions. The sediments can therefore become another source of nutrients to the lake during summer periods.

During daylight hours, algal photosynthesis exceeds respiration causing dissolved oxygen concentrations to increase. When high algal concentrations are present this can cause oxygen supersaturation of the surface waters. Extreme fluctuations in dissolved oxygen content can also cause water quality problems. However, no significant supersaturation values were detected for Lake Wallenpaupack during 1981.

Cold water fish species (such as trout) generally need temperatures less than 22°C and dissolved oxygen concentrations greater than 5 mg/l in order to survive and grow. These required conditions were not present at any depth in the lake during the period from July 28 through August 11. Therefore, trout populations were stressed during this period and were probably forced to oscillate above and below the thermocline in order to survive.

6.4.4 Total Suspended Solids

Total suspended solids is a measure of the amount of particulate matter in the water column. Suspended solids are comprised of both organic (e.g. algae) and inorganic (e.g. minerals) matter. Suspended solids concentrations for three depths at Station 1 are shown in Figure 10. Concentrations at the surface and middle depths were responsive to the suspended solids loads entering the lake, and to increasing and decreasing algae levels. Suspended solids concentrations were generally higher in the bottom waters due to the settling of particulate matter from the surface (note that the vertical scale of the bottom plot is different from the other two plots). A large peak occurred in the bottom waters during August 1981 indicating the settling of large quantities of algal biomass after a significant bloom in July.

6.4.5 Transparency

An indirect measurement of the total amount of organic and inorganic turbidity in a lake is the Secchi disk depth. This measurement is taken by lowering a special disk into the water until it can no longer be clearly seen. Therefore, higher Secchi disk depths represent better water transparency. This testing method probably best represents the conditions which are most readily visible to the common lake user.

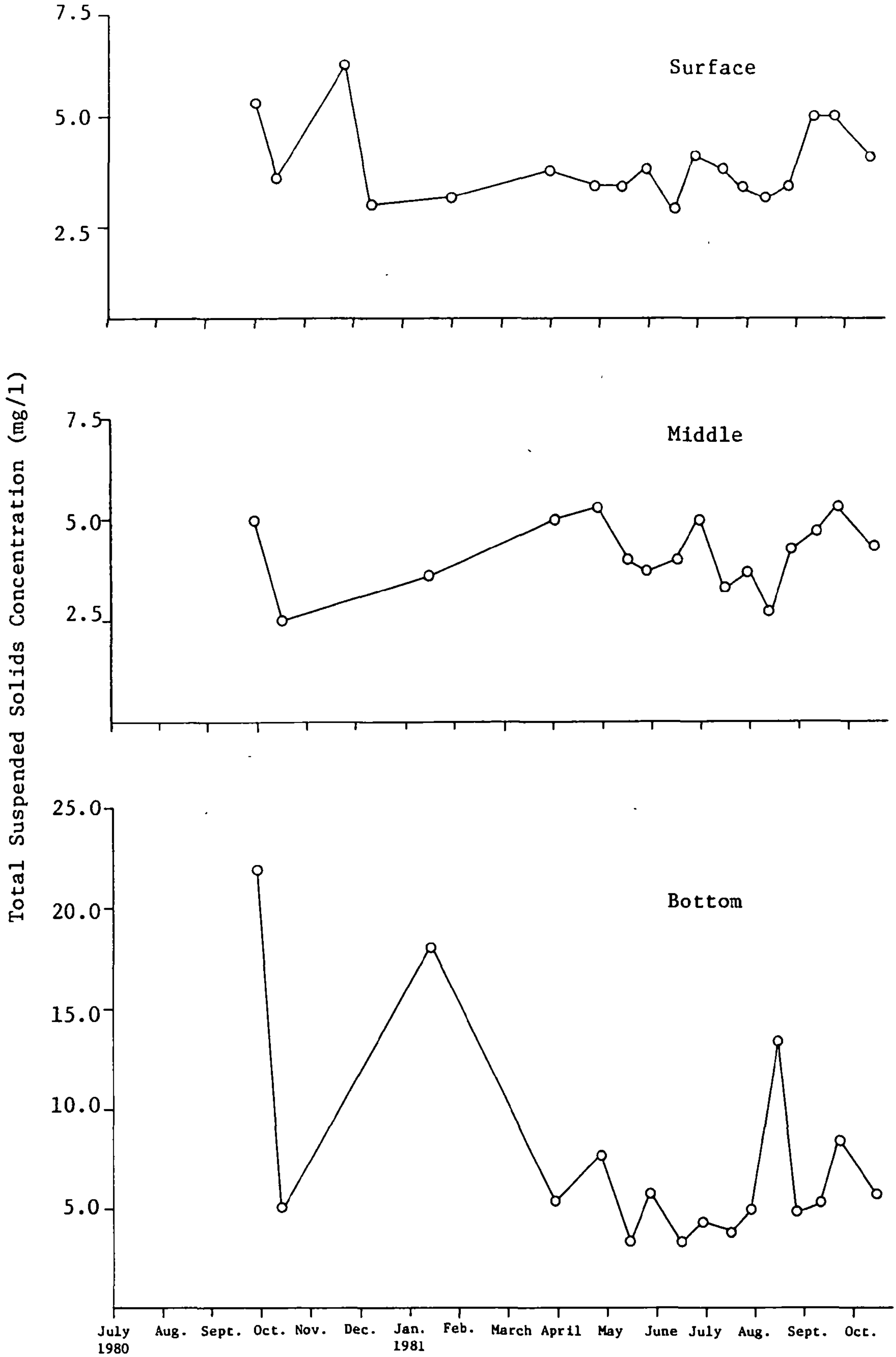


Figure 10. Total Suspended Solids Concentrations at Three Depths for Station 1.

The mean Secchi disk readings for the overall lake are shown in Figure 11. The mean values ranged from 1.0 to 2.0 meters and were well correlated with the patterns displayed by surface suspended solids concentrations. Secchi disk depths less than 2.0 meters are generally considered undesirable for recreational lake uses.

Mean Secchi disk depths for individual stations are presented in Table 26 for 1980 and 1981. These values show that transparency improved as water flowed through the lake. Average water transparency was lowest at the upstream lake stations. This indicates that much of the particulate matter settles out as water flows through the lake.

6.4.6 NUTRIENT CONCENTRATIONS

Phosphorus and nitrogen compounds are important for the growth of algae. Figure 12 shows the temporal and spatial variations in total phosphorus and soluble orthophosphate during the monitoring period. Total phosphorus represents the sum of all forms of phosphorus, including both soluble and particulate forms. Total phosphorus also includes both the organic and inorganic forms of phosphorus. Thus, total phosphorus includes live algae, dead algae, other microorganisms, organic phosphorus, polyphosphates and orthophosphate. Soluble orthophosphate is the form most readily used by algae. Total phosphorus levels depend on the phosphorus loads entering the lake. Soluble orthophosphate levels, however, are affected by algal consumption during the growing season. This is illustrated by the decline of soluble orthophosphate to the minimum detectable limit on June 29, 1981 and August 25, 1981 when significant increases in phytoplankton were measured.

As illustrated in Figure 12, phosphorus concentrations throughout the lake were usually higher at the bottom and middle depths, especially during July through September (note that the vertical scale of the bottom plot is different from the other two plots). Higher phosphorus levels occur in

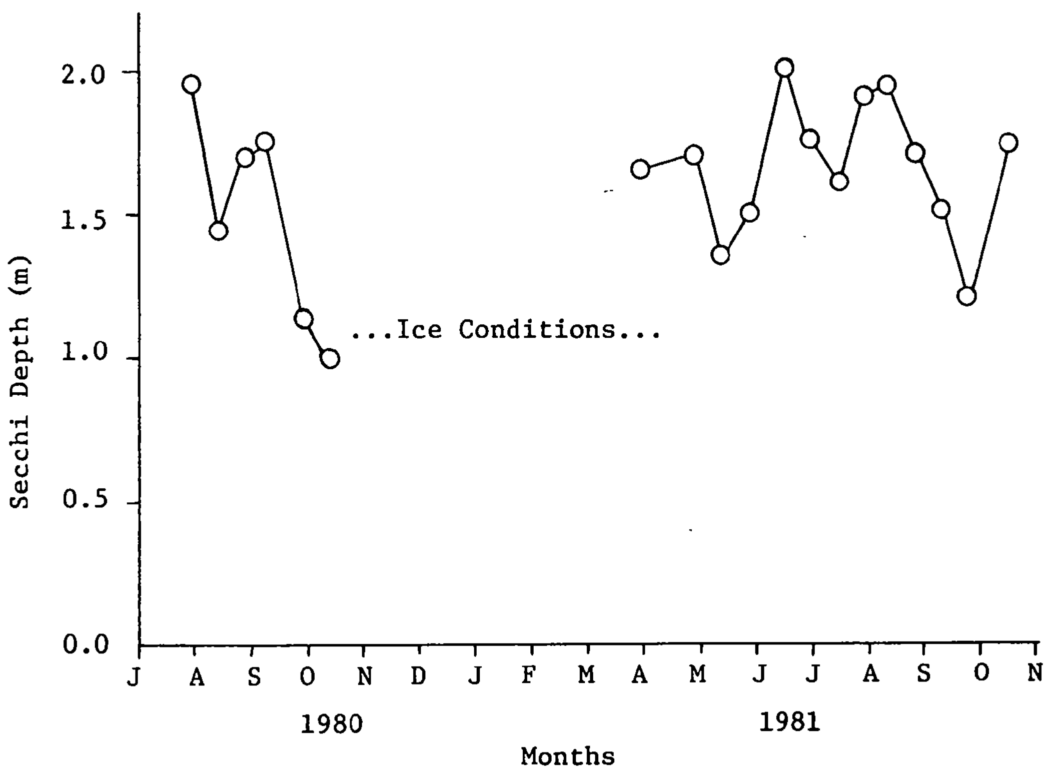


Figure 11. Mean Secchi Depths for All Lake Stations

Table 26

Mean Secchi Disk Depth for
Individual Lake Stations

Station	Secchi Disk Depth(m) 1980*	Secchi Disk Depth(m) 1981**
1	1.7	2.0
2	1.5	1.7
3	1.5	1.7
4	1.5	1.6
5	1.1	1.4

*Data represents 6 sampling dates.

**Data represents 13 sampling dates.

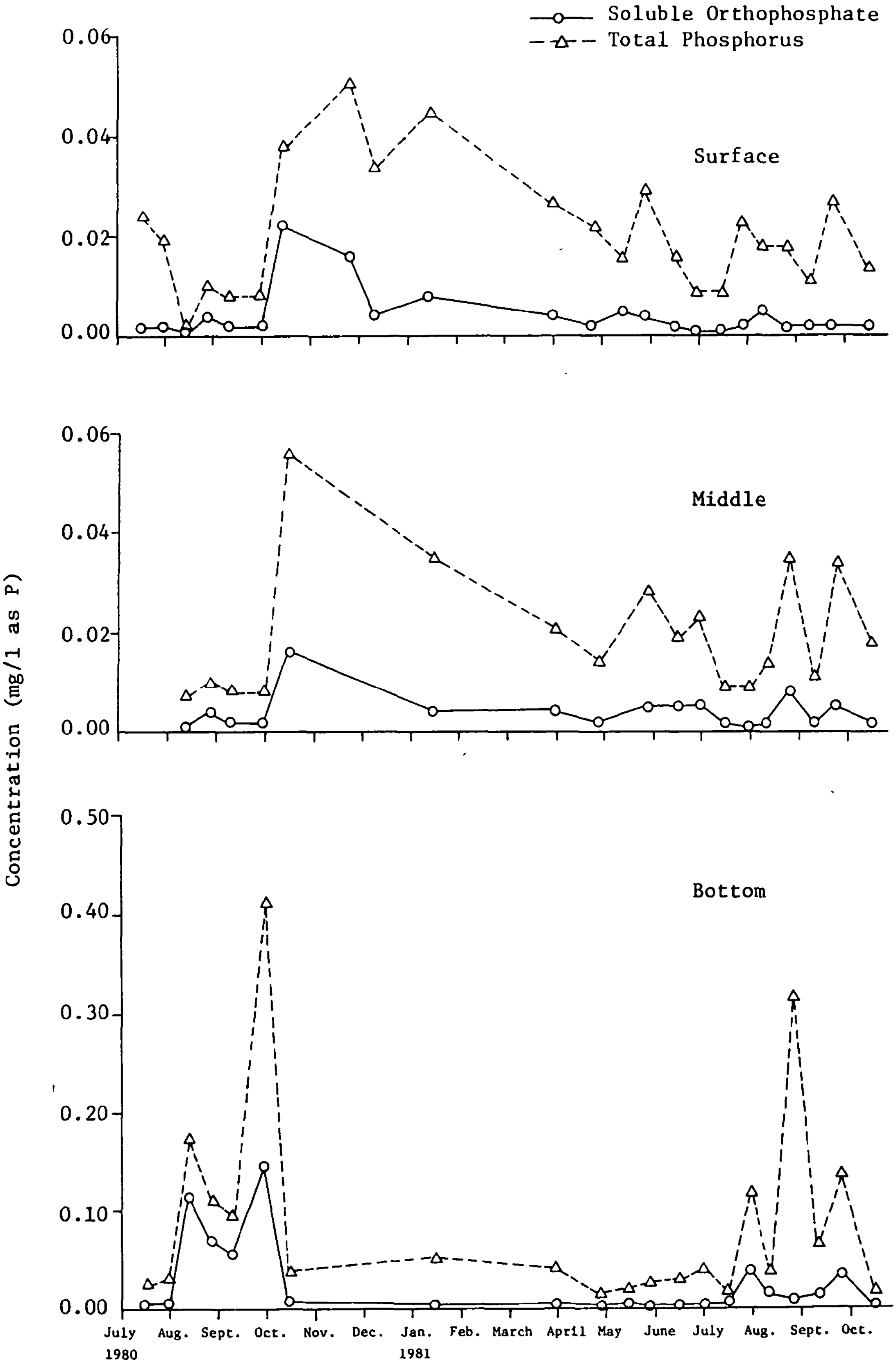


Figure 12. Total Phosphorus and Soluble Orthophosphate Concentrations at Three Depths for Station 1.

the bottom waters of the lake because algae and other microorganisms settle to the bottom, and because the bottom sediments become anoxic (void of oxygen) and release phosphorus to the bottom waters.

Mean total phosphorus and orthophosphate concentrations for each lake station, presented in Table 27, are relatively similar throughout the lake except for Station 5, located upstream near Ledgedale. The Ledgedale station is atypical and is more representative of a stream than a lake station. The mean total phosphorus concentration for all stations exceeded 0.02 mg/l, a level usually considered indicative of eutrophic conditions.

Limiting Nutrient

Phytoplankton growth depends on a variety of nutrients including phosphorus, nitrogen, carbon, iron, manganese, and certain trace minerals. According to the law of the minimum, biological growth is limited by the substance that is present in minimal quantity with respect to the needs of the organism. Nitrogen and phosphorus are usually the elements in least relative supply in most natural water systems. Depending on the species, algae require approximately 15 to 26 atoms of nitrogen for every atom of phosphorus. On a mass basis, this ratio converts to 7 to 12 mg of nitrogen per each 1 mg of phosphorus. Therefore, the following ratios can be used to define nutrient limiting conditions:

TIN:SOP (mg/1 N: mg/1 P)	Nutrient Limiting Phytoplankton Yield
<7	Nitrogen
7-12	Nitrogen and/or Phosphorus
>12	Phosphorus

TIN = Total inorganic nitrogen

SOP = Soluble orthophosphate

Table 27

Mean Lake Concentrations for
Total Phosphorus and Orthophosphate

Station	Parameter	Mean (mg/l as P)	Minimum (mg/l as P)	Maximum (mg/l as P)
1	Total Phosphorus	0.042	0.002	0.312
	Soluble Orthophosphate	0.025	0.002	0.395
2	Total Phosphorus	0.040	0.007	0.348
	Soluble Orthophosphate	0.025	0.002	0.313
3	Total Phosphorus	0.039	0.002	0.328
	Soluble Orthophosphate	0.026	0.002	0.300
4	Total Phosphorus	0.046	0.009	0.289
	Soluble Orthophosphate	0.024	0.002	0.150
5	Total Phosphorus	0.039	0.014	0.146
	Soluble Orthophosphate	0.013	0.002	0.049

Figure 13 shows the mean TIN:SOP ratios for samples collected at the surface and over the total depth. There was considerable variation in the ratios throughout the monitoring period. The TIN:SOP ratios varied considerably throughout the year due to complex algae/nutrient interactions and periodic tributary nutrient inputs during storm events. In general, the ratios were high early in the growing season, indicating phosphorus limitation. This period is critical in determining the phytoplankton levels for the rest of the summer. As phosphorus limitation is reached in the early summer, a competitive edge is given to the blue-green algal species which require less phosphorus per unit of nitrogen. As the blue-green algae increase, nitrogen compounds are consumed and the TIN:SOP ratios drop to below 12. During the middle of the summer, nutrient conditions vary between nitrogen and phosphorus limitation, with short periods of absolute nitrogen limitation. Under these conditions, however, some species of blue-green algae can fix dissolved elemental nitrogen (not included in TIN) which is present in the water from contact with the atmosphere. During the nitrogen fixation period, phosphorus again becomes limiting.

In summary, the pattern of nutrient limitation in Lake Wallenpaupack is similar to other eutrophic lakes where phosphorus is limiting for much of the time, but temporary nitrogen limitation develops as blue-green algae populations increase. Since it is usually not feasible to control nitrogen sources, watershed management practices must concentrate on reducing phosphorus loads to the lake. If phosphorus is reduced sufficiently, overall phytoplankton levels can be decreased on an average annual basis.

6.4.7 PHYTOPLANKTON

Phytoplankton densities for the surface depths and the Secchi disk depths at Station 1 are shown in Figure 14. This station was represenative of the phytoplankton dynamics for the rest of the lake. The vertical scale in the figure is logarithmic, rather than linear. Algal densities frequently exceeded a total of 10,000 cells/ml indicating eutrophic conditions. The peak algal density occurred on July 28, 1981 when the average for the

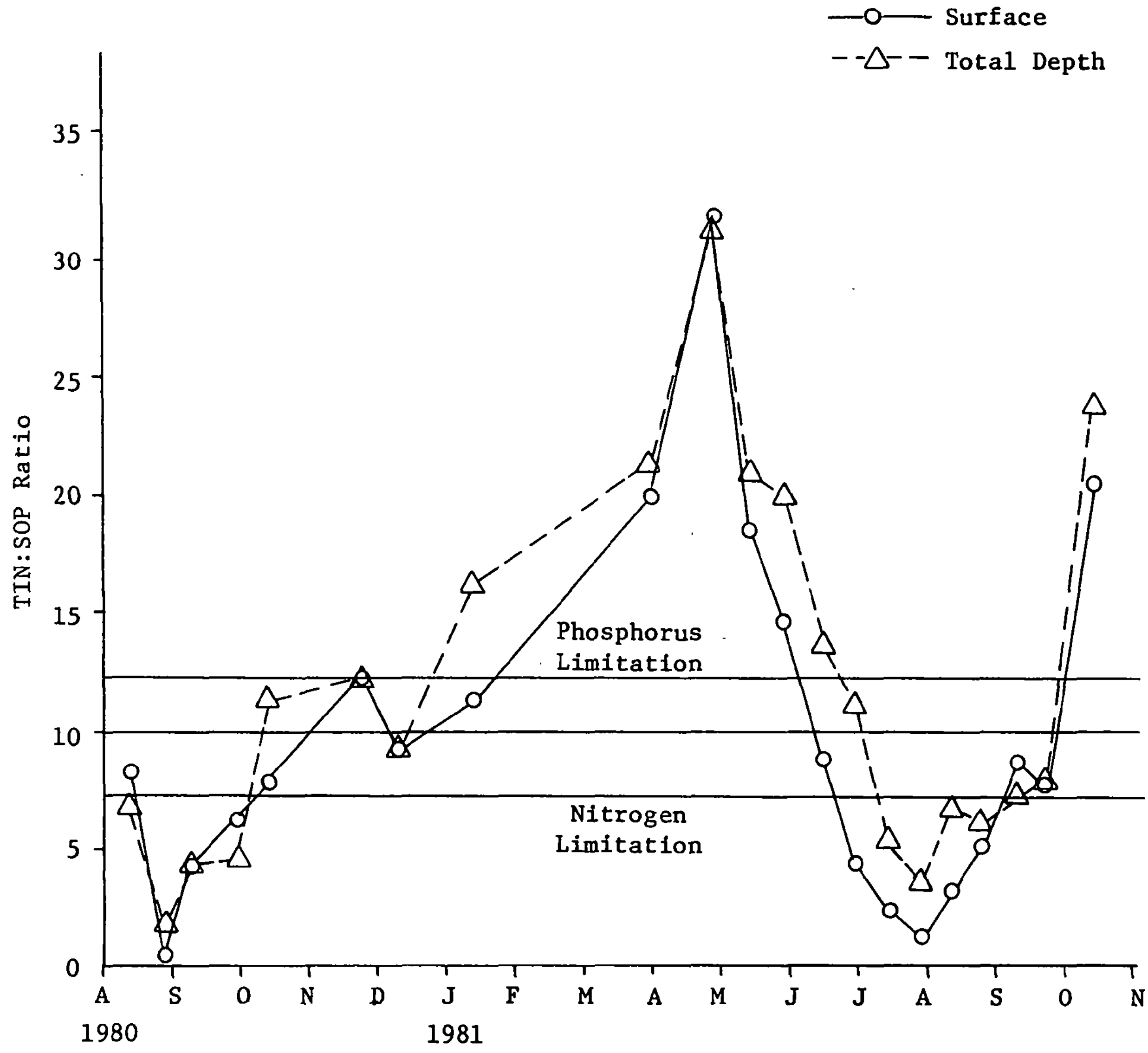


Figure 13. Mean Total Inorganic Nitrogen:Soluble Orthophosphate Ratios for All Sampling Stations

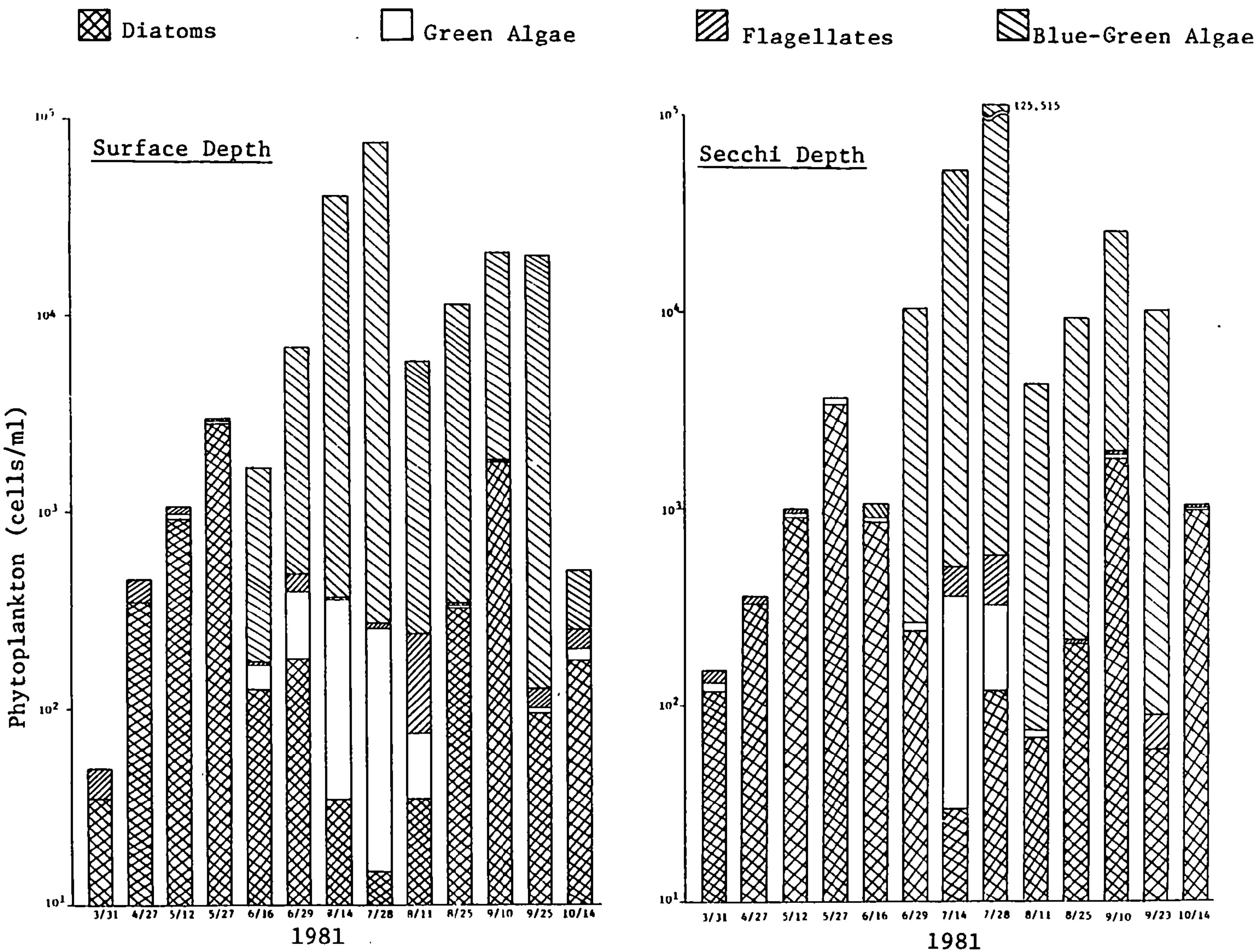


Figure 14. Phytoplankton Data for Station 1

lake reached 78,000 cells/ml. A second bloom occurred on September 10, 1981 when the lake average peaked again at 26,000 cells/ml. Both blooms were comprised primarily of blue-green algal species. With few exceptions, there was little significant difference between the algal types and densities for the two sampling depths.

In the spring of 1981 the dominant alga in Lake Wallenpaupack was Asterionella formosa, a diatom. Diatoms are often the representative algae during the spring when weather conditions are cool and water temperatures are beginning to increase above 5°C. The diatoms remained the dominant algal form through mid-June when there was a shift in species predominance. Asterionella formosa receded in number and Tabellaria fenestrata replaced it as the representative species. By the end of June, as the lake temperatures continued to increase, the diatoms rapidly decreased in number dropping from 80-100% of the total phytoplankton count to 6-13%. In July the only diatom that appeared in any number was Synedra delicatissima.

Green algae in Lake Wallenpaupack were present in a wide variety of species, yet they never became the dominant genera, and rarely exceeded 15% of the algal population. By the end of July they were essentially absent from the lake, falling below 1% in most stations.

With the decline of the diatoms in June there was a marked increase in blue-green algae. This steady increase in blue-greens is common and is due to their favoring of warmer waters (18-24°C) and longer periods of light due to increased day-length. The blue-green algae comprised 86-99.5% of the phytoplankton count by the end of June. Low species diversity and high biomass characterize blue-green algae blooms. In Lake Wallenpaupack three bloom forming algae accounted for 100% of the blue-green count in June and July. These three algae were Anabaena sp., Aphanizomenon flos-aquae and Oscillatoria acuminata. Succession among the blue-greens started off with Oscillatoria being the primary alga during the end of June and throughout most of July. Anabaena followed Oscillatoria in dominance but was quickly succeeded by Aphanizomenon which remained the representative alga through the end of September. Coelosphaerium naegilianum, another bloom forming species, appeared occasionally in significant quantities but was confined to three stations in the downstream half of the lake. The blue-greens continued to comprise 80-100% of the phytoplankton count through the end of the summer and into the fall.

Statistical analysis of the phytoplankton data collected for the coves sampled indicates that there were no significant differences between the types and numbers of algae present (F. X. Browne Associates, Inc., 1982). Also, cross-sectional sampling done at 0.5 meters at Stations 2 and 4 showed relatively consistent phytoplankton concentrations across the lake. This is exemplified in the data shown below for September 4, 1981:

Transect	Station 2	Station 4
A	33,450 cells/ml	29,595 cells/ml
B	35,610	41,110
C	37,185	17,475
D	29,010	32,100
E	32,475	32,700
Average	33,546 cells/ml	30,596 cells/ml

Wind speed and direction for the above date were 8 mph from the southwest. On no sampling dates did the wind seem to have an effect on the distribution of algal populations in the lake.

6.4.8 CHLOROPHYLL A

Samples collected at the surface depth and at the Secchi depth were also analyzed for chlorophyll a and pheophytin a. Chlorophyll a is the green pigment which causes photosynthesis to take place in algal cells. Pheophytin a is the degradation product of chlorophyll a which is found in dead algal cells. Therefore chlorophyll a and pheophytin a are indicators of the amounts of live and dead algal biomass, respectively. Not all algal species, however, contain the same relative proportions of chlorophyll a.

Mean epilimnetic chlorophyll a and pheophytin a concentrations for the lake monitoring period are plotted in Figure 15. The mean chlorophyll a concentrations followed the same general patterns as the phytoplankton counts, although there were a few exceptions. The discrepancies may have been due to the varying chlorophyll a contents of different algal species. Also, the algae present during September 1980 may have been larger in cell size, thereby containing more chlorophyll a per cell. The peak summer concentration for 1980 occurred on October 16 at 15.3 ug/l. The peak summer concentration for 1981 was 15.8 ug/l on September 10.

The mean epilimnetic chlorophyll a and pheophytin a concentrations for each of the lake stations are presented in Table 28. The average levels for both parameters were generally lower during 1981. This occurred, however, because sampling began in mid-summer of 1980 and therefore did not include any late winter or spring values. The highest chlorophyll a concentrations were measured at Station 4 indicating that the largest algal populations developed at the upper end of the main body of the lake. The algae then slowly decreased as the nutrients were consumed in the lower portion of the lake. Pheophytin a concentrations were relatively constant throughout the lake for both years.

Unlike the phytoplankton data, the chlorophyll a data showed higher concentrations at the Secchi depth indicating that some light inhibition of the algae occurred at the lake surface.

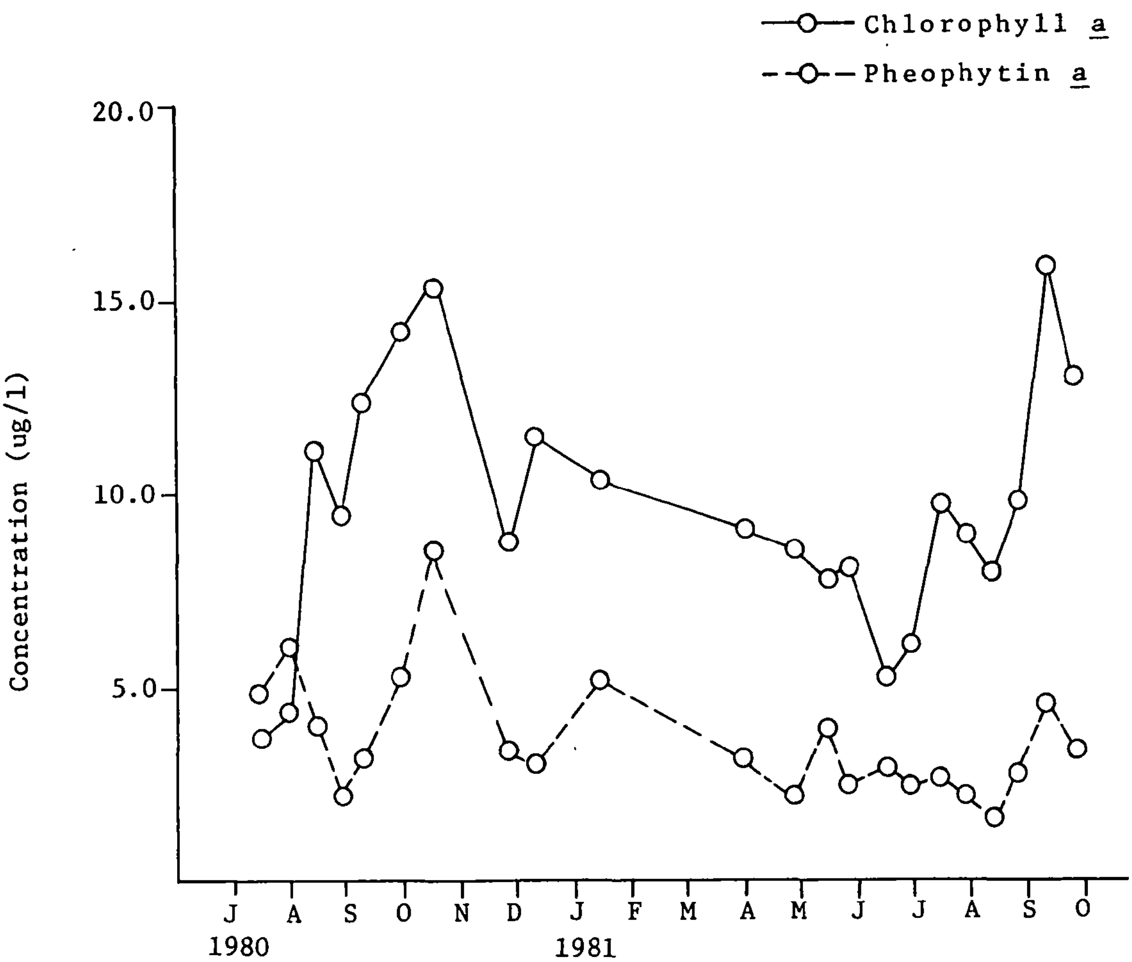


Figure 15. Mean Epilimnetic Chlorophyll a and Pheophytin a Concentrations

Table 28

Mean Epilimnetic Chlorophyll *a* and Pheophytin *a*
Concentrations for Lake Stations

	1980*		1981**	
	Mean Chlorophyll *a* (ug/l)	Mean Pheophytin *a* (ug/l)	Mean Chlorophyll *a* (ug/l)	Mean Pheophytin *a* (ug/l)
Station 1	8.8	4.6	8.9	2.9
Station 2	10.0	4.9	8.8	2.9
Station 3	11.8	4.1	9.6	3.1
Station 4	13.5	4.7	10.0	2.8
Station 5	9.0	5.1	9.1	3.4
All Stations	10.9	4.6	9.3	3.0

* Represents 9 sampling dates

** Represents 13 sampling dates

6.4.9 BACTERIA

Fecal coliform and fecal streptococcus data for the lake are presented in Table 29. No significant levels of bacteria were found at any regular lake station. Bacteria samples were not collected at any beaches or coves as part of this study.

6.4.10 FISHERY RESOURCES

After collecting data in 1980, the Pennsylvania Fish Commission (Billingsley and Bourke, 1981) prepared a report on fisheries management for Lake Wallenpaupack. The report concludes that the predominant fish populations in the lake include walleye (Stizostedion vitreum), alewife (Alosa pseudoharengus), pumpkinseed (Lepomis gibbosus), and perch (Perca flavescens). Smaller populations include smallmouth bass (Micropterus dolomieui), largemouth bass (Micropterus salmoides), brown trout (Salmo trutta), chain pickerel (Esox niger), and tiger muskellunge (Esox masquinongy x lucius). Cisco (Coregonus artedii) populations have declined since the early 1950's.

History of the Fishery

There is a long-term record of fish stocking in Lake Wallenpaupack, extending from 1932 to the present, with most stocking done under the auspices of the Pennsylvania Fish Commission. Many species of fish have been stocked, including percids, centrarchids, esocids and salmonids. In addition, various forage fish and non-piscine forage species (such as frogs, crayfish and Daphnia) have been stocked. Until 1954, the stocking program emphasized warmwater fish, primarily percids and centrarchids. From 1954 until the early 1970's a mixture of salmonids and warmwater species (mainly trout and walleye) were stocked. During the 1970's the number of species and quantities of fish stocked declined, with trout and walleye continuing as the major species stocked. In 1981 the Pennsylvania Fish Commission began stocking striped bass yearlings along with a small number of trout fingerlings.

Over the past twenty years, fishermen have been actively seeking a great variety of fish species in Lake Wallenpaupack, including walleye, yellow perch, bass, sunfish, trout, catfish and carp. Fishermen are now reported to be anxious for the start of good striped bass fishing. However, there appears to have been a decline in fishing pressure over the past decade, most notably during the ice fishing season. For the steadfast Wallenpaupack fisherman, a decline in catch per unit effort has been noted. The fish that have been taken have been observed to possess full stomachs, and were generally larger than fish of the same species taken in past years. The Pennsylvania Fish Commission reports higher than average growth rates for all species investigated. While an accurate assessment is made difficult by the reluctance of many fishermen to discuss their cathces, it appears that fish populations have not noticeably declined, and that piscivores are simply harder to catch due to an overabundance of forage fish. Large schools of the alewife (Alosa pseudoharengus), not observed prior to about 1975, have been reported in the lake in recent years.

Unfortunately, organized surveys of the fish community of Lake Wallenpaupack have been few and sporadic. Interpretation of the data acquired through the organized surveys is complicated by inconsistent methods and survey timing. This is a universal problem in fisheries biology and is by no means a reflection of the quality of the surveys performed. Obtaining representative samples of fish populations is simply a very difficult task. With this in mind, the results of fish surveys performed, the stocking record, the more reliable fishing reports, and observations by local residents and officials have been integrated to produce a general assessment of the fish community over time.

Until about 1970 Lake Wallenpaupack afforded a diverse and apparently well-balanced fishery. Populations were reportedly large with a desirable size distribution, and reproduction was supplemented through stocking. During the 1970's increased phytoplankton levels, consisting largely of blue-green species, were apparently caused by higher nitrient concentrations in the lake. Also, the alewife became established in the early 1970's, probably after repeated introduction by bait fishermen. It was not intentionally stocked by any group with the authority to do so. The alewife became abundant by 1975, and is presently the dominant planktivore and forage fish in the lake. The filterfeeding habit of the alewife makes it a superior competitor for zooplankton under conditions of low zooplankton biomass or low visibility. Analyses conducted over the past few years suggest that these conditions do indeed exist in Lake Wallenpaupack. Therefore, it appears that the alewife population has increased at the expense of other planktivores. This would include adult planktivores, such as sunfish, and the young of the year of most gamefishes (notably walleye and perch). While total elimination of the visually feeding planktivores by alewife competition is not likely, reduced recruitment to the piscivore populations is undoubtedly occurring, causing the age distribution of the piscivore populations to be skewed toward older, larger fish. While no obvious decline in gamefish abundance has been noted, such a decline will eventually occur. The decline in actual catches appears related to the overabundance of food for piscivores and the inability of the piscivore populations to expand in response to the increased food base. As a result, there has been a slight decline in the quality and popularity of the Lake Wallenpaupack fishery.

Environmental stresses on the gamefish of Lake Wallenpaupack might provide an alternative explanation for the lack of a population surge in response to increased alewife abundance. The anoxic condition of the lake's hypolimnion during the summer is certainly not a benefit to any fish species, and in conjunction with the high summer temperatures in the epilimnion could adversely affect salmonids. However, most Wallenpaupack fish species spawn before or after the anoxic hypolimnion period, or out of the lake entirely, moving into tributary streams to spawn. Damage to certain tributary streams as a result of inadequate erosion control has been reported, and has apparently reduced successful salmonid spawning. Great success by spawning walleye has been noted, however, and no significant fishkills have been reported for the lake. Therefore, it does not appear that the present situation can be explained strictly in terms of abiotic environmental variables. The large alewife population does appear to be the major disruptive force in the Lake Wallenpaupack fishery.

Based on the limited information available, the following standing crop hierarchy can be tentatively established for Lake Wallenpaupack fish species, in decreasing order:

Alewife > Walleye, Perch > Bass, Sunfish > Other Species

Management Response

It is generally considered desirable to have a self-regulating fish community. In most cases this takes the form of a set of piscivore populations preying primarily on the young of that same set of species. Environmental and food resource constraints will set an upper limit for young of the year survival, with that limit reduced by predation. If predation is too great, recruitment to the piscivore population declines, reducing predation pressure the next year. Too little predation will result in greater recruitment to the adult piscivore populations and greater predation pressure in the following year. Fishing pressure on the adult piscivores becomes the major disruptive force, and regulations are generally promulgated so as to minimize the effects of fishing mortality.

The occurrence of a large alewife population in addition to increased phytoplankton concentrations in Lake Wallenpaupack has upset whatever balance previously existed, providing increased food supplies for adult piscivores but preventing concurrent population expansion through competition with the young of the piscivore species. The logical solution is to artifically increase the number of piscivores in the system, either by adding adults or piscivorous juveniles of an existing species (walleye would be the logical choice) or by introducing a new piscivore species.

The Pennsylvania Fish Commission has chosen the latter route, and is currently stocking Lake Wallenpaupack with striped bass (Morone saxatilis). The rationale behind this selection is based on the ravenous appetite of striped bass, their popularity among fishermen, and their inability to reproduce in freshwater lake systems such as Lake Wallenpaupack. Two critical assumptions are involved here. The first is that the striped bass will make the alewife its primary prey, and the second is that overstocking will not occur. Assuming the above to be true, the stocking of striped bass should result in a decrease in the alewife population, an increase in survival of young of the year gamefish, and an increase in recruitment to piscivore populations.

After two years of striped bass stocking, it remains to be seen if the above sequence will take place. This is a relatively short period, but it must be remembered that assumptions have been made that are not necessarily true. If the above sequence does occur, at some point the striped bass and other piscivore populations will come into direct competition for a limited food base, which should include a significant fraction of young of the year gamefish, exclusive of striped bass, which are being stocked as yearlings. At that point a decision will have to be made regarding future stocking of striped bass. Some reduction in stocking or an increase in catches by fishermen will be necessary if other gamefish populations are to be maintained. The potential popularity of striped bass may outweigh at least some reduction in other piscivore populations. Public discussion of preferences and alternatives should be encouraged.

The problems in the lake are magnified by the depletion of dissolved oxygen during the summer. Severe temperature and dissolved oxygen conditions stress both the survival and growth rates of salmonids. Hence, these species are forced to live within a limited zone, outside of which they do not compete well.

Another problem involves the monitoring of fish populations over time. The Pennsylvania Fish Commission is expected to continue their work with the lake until at least 1985, but no provisions have been made for time thereafter. Successful management of the fishery will require an ongoing monitoring program. Also, present Fish Commission monitoring efforts do not include all species of interest or all trophic levels. Additional monitoring is warranted. Records of fishing clubs and voluntary angler reports should be solicited in an organized fashion, and some assessment of zooplankton populations should be made. Additional parameters of interest include the diet of striped bass in the lake, the survival of young of the year fish, and recruitment to various piscivore populations.

Defining Fishery Priorities

Lake Wallenpaupack will have to be managed as a warm water fishery until eutrophic conditions in the lake are significantly improved. At the present time there is no official fishery policy in effect for Lake Wallenpaupack. While a formalized policy is not essential, it will greatly minimize confusion over management goals and provides a framework for evaluating potential management actions. Discussions with representatives of parties with an interest in the Lake Wallenpaupack fishery has suggested the following unofficial priorities:

1. Many catchable fish - Everyone should be a successful angler.
2. A fair proportion of large fish - There are many trophy fishermen.
3. A high species richness - Diverse preferences among fishermen exist.

The general order of preference should probably be:

1. Striped Bass, Walleye, Perch
2. Trout, Smallmouth and Largemouth Bass
3. Sunfish
4. Catfish, Carp, other species

The current management response is consistent with these priorities. Further interaction between lake managers and the concerned public is desirable, with a resultant open formulation of priorities and goals with respect to fishing and other recreational uses of Lake Wallenpaupack.

Table 29

Bacteriological Data for Lake Stations

	4-27-81		5-27-81		5-16-81		7-14-81		8-25-81		9-23-81	
	FS	FC	FS	FC	FS	FC	FS	FC	FS	FC	FS	FC
Station 1	<2	<2	<2	<2	<1	<1	<1	<1	>1	>1	<1	<1
Station 2	<2	<2	<2	<2	<1	<1	3	1	>1	>1	5	<1
Station 3	<2	<2	<2	4	<1	<1	<1	<1	>1	>1	<1	<1
Station 4	<2	<2	<2	<2	<1	8	<1	<1	>1	>1	<1	<1
Station 5	4	22	<2	6	<1	2	4	2	17	>1	<1	1

Notes: FC = Fecal Coliform (#/100 ml)
FS = Fecal Streptococcus (#/100 ml)

6.4.11 Sediment Analyses

Three lake sediment samples were collected for analysis by the Lake Wallenpaupack Watershed Association. The results of these analyses are shown in Table 30. No criteria have been established for most of these parameters in sediments. The values for lead and chromium appear to be high. Most of the other parameters were present in concentrations below the minimum detectable limit.

If performed again in the future, the same parameters should be measured at each location so that comparisons can be made. In addition, the EP Toxicity testing procedure should be used since criteria have been established by the US EPA with respect to landfill requirements for dredged spoils (see Federal Register; May 19, 1980).

Table 30

Lake Sediments Data

	Ledgedale	White Beauty View	Ariel Creek Outlet
Total Phosphorus (mg/kg)	-	92.4	-
Mercury (mg/kg)	-	0.0085	-
Lead (mg/kg)	-	6.04	-
Cadmium (mg/kg)	<0.0001	0.134	-
Phenols (mg/kg)	<0.001	<0.001	-
Cyanide (mg/kg)	<0.01	-	-
Arsenic (mg/kg)	0.4	-	0.76
Chromium (mg/kg)	-	-	2.49
Lindane (ug/kg)	-	-	<0.7
Endrin (ug/kg)	-	-	<0.4
Toxaphene (ug/kg)	-	-	<8.0
Methoxychlor (ug/kg)	-	-	<3.0
2,4-D (ug/kg)	<0.7	-	-
2,4,5-TP Silvex (ug/kg)	<1.0	-	-

Note: Dash indicates that the parameter was not analyzed.

6.5 Trophic State Determination

Eutrophication is a natural process whereby sediments and nutrients from the watershed accumulate in the lake. Ultimately, all lakes evolve into bogs and eventually become extinct. This process is often accelerated by the activities of man in a given watershed. Contrary to the popular opinion that a eutrophic lake is "dead", it is actually suffering from an over abundance of living organisms (plant and animal). These organisms are usually comprised of relatively few species. An oligotrophic lake, on the other hand, contains small populations of many diverse organisms. The term "mesotrophy" refers to a condition in-between oligotrophy and eutrophy.

The 1975 US EPA study concluded that Lake Wallenpaupack was progressing from a mesotrophic to a eutrophic state. The data collected for this Phase 1 Study during 1980 to 1981 indicate that the lake is eutrophic. As shown in Table 31, nutrient concentrations were excessive, chlorophyll *a* concentrations were high, and water transparency was low. Algal densities often exceeded 10,000 cells/ml, and were dominated by blue-green algae. Dissolved oxygen concentrations in the hypolimnion became severely depleted by early summer.

Another commonly accepted method of determining the trophic status of a lake is demonstrated in Figure 16. This classification approach, developed by Vollenweider (1975), is based on the areal phosphorus loading to the lake and the physical and hydrologic characteristics of the lake. Using the normalized phosphorus load presented in Chapter 5.0, the areal phosphorus loading to the lake is 0.783 $gm/m^2/yr$. This loading places Lake Wallenpaupack into the "eutrophic" zone. A phosphorus load reduction of about 30% would be required to bring the lake below the "Excessive loading" line. It should be noted, however, that this line represents a general guideline based on data from a number of lakes. The exact excessive loading limit for Lake Wallenpaupack may be slightly higher or lower.

Table 31

Comparison of Lake Wallenpaupack Data to
Eutrophic Classification Criteria

Parameter	Eutrophic Criteria*	1981 Mean Concentrations
Total Phosphorus (mg/l as P) (winter)	>0.020-0.030	0.029
Chlorophyll a (ug/l) (summer)	>6-10	9.2
Secchi Depth (m) (summer)	<1.5-2.0	1.65

*US EPA, 1980

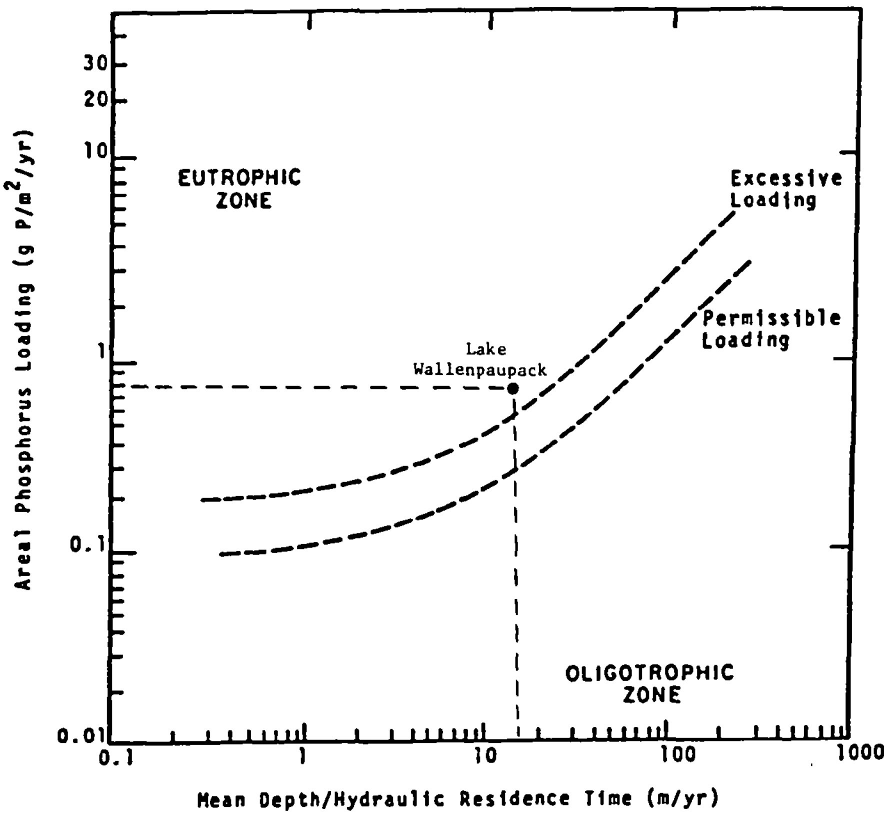


Figure 16. Vollenweider Phosphorus Loading Curves for Trophic State Classification.

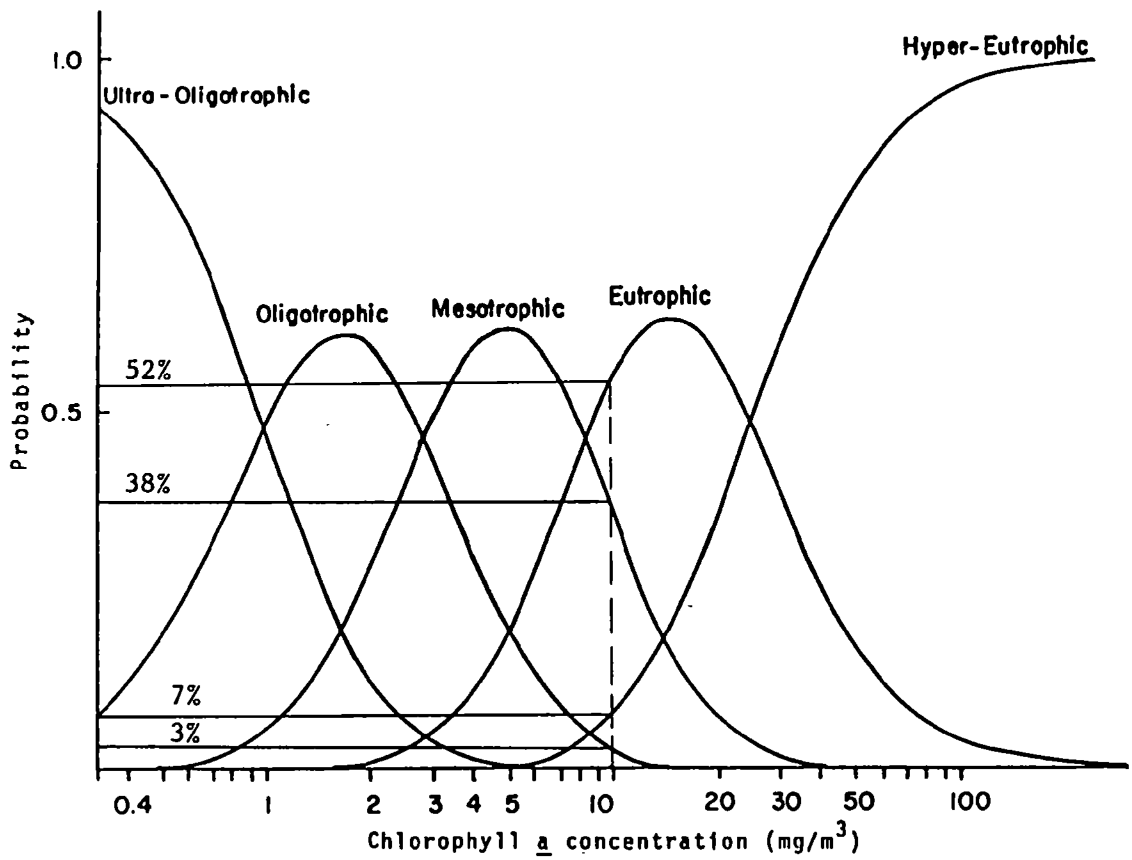
In actuality, the classification of trophic state is a subjective determination based on the most important uses of a lake. The primary uses of Lake Wallenpaupack (in addition to hydroelectric power generation) are for recreation. A probability distribution for trophic classification is shown in Figure 17, as developed by Vollenweider (1979). This distribution indicates that based on the average annual chlorophyll a concentration for 1980 to 1981 (9.8 ug/l), lake observers would perceive water quality according to the following breakdown:

3% - Oligotrophic
38% - Mesotrophic
52% - Eutrophic
7% - Hyper-Eutrophic

6.6 Potential Human Health Effects

In August 1979, a bloom of the blue-green alga, Anabaena, reportedly caused numerous cases of algae-related infections that produced such symptoms as allergic reactions and gastrointestinal disorders. This outbreak of water-contact dermatitis and other symptoms led to the posting of warning signs around the lake. However, the outbreak was not well documented. It should be emphasized that no such outbreaks have been reported since 1979.

Certain genera of blue-green algae, particularly Anabaena, Aphanizomenon, Microcystis, and Oscillatoria, have been shown to produce endotoxins which are toxic to animals. Documented cases of algal toxicity have usually involved livestock, waterfowl, or domestic animals. However, a review of the literature (Kadis et al.) indicates that there have been several recorded cases of human health impacts caused by these species. Blue-green algal effects, as they relate to humans, can be classified as gastrointestinal, respiratory, and dermatological in nature. In the case of drinking water, ordinanry water treatment procedures apparently have little effect on the toxins.



After Vollenweider (1979)

Figure 17. Probability Distribution for Trophic Classification

In order for an algal bloom to be poisonous to humans, it must be predominatly composed of a known toxic species, possessing 80 to 90% toxic algal strains (Gorham, 1977). The conditions under which these toxic strains form are impossible to predict. Should another outbreak be suspected, area physicians should be alerted and requested to maintain detailed records. Also, the LWWMD should initiate a short-term extensive sampling survey in the lake in order to detect the cause of the problem.

Another possible source of human health problems is pathenogenic bacteria. Fecal bacteria tests are used to indicate whether possible human contamination of a given lake or stream has occurred. High bacterial counts are often associated with blue-green algal blooms. However, no significant fecal bacterial concentrations were detected at the regular lake stations. Bacteriological samples for beaches and coves are collected by local municipalities or private organizations and are reported to PaDER officials.

6.7 WATER QUALITY TRENDS

Although much data has been collected over the years for Lake Wallenpaupack, monitoring strategies have been somewhat inconsistent with respect to sampling stations, types of parameters, number of dates, and laboratory methods. This has been particularly true for those parameters which measure lake response, such as phytoplankton counts, chlorophyll a concentration, and turbidity. For example, the identification and counting of phytoplankton has not been performed since 1973 when samples were analyzed on one date by the Academy of Natural Sciences of Philadelphia, and on three dates by the US EPA.

Chlorophyll a data were collected by PP&L during the period from June through October in 1978 and 1979 at the same five stations as for this study. The mean for that data is compared below to the mean for the same period in 1981:

	Mean Chlorphyll a (surface)
Summer, 1978	7.5 ug/l
Summer, 1979	9.0
Summer, 1981	9.6

Water transparency data has been collected by several observers over the last decade. Mr. Aurel Petrasek (an LWWMD Director) took a Secchi depth reading at the same point in the lake every June between the years of 1973 and 1979. PP&L took Secchi disk measurements at numerous stations in the years 1975, 1976, 1978, and 1979. The mean values for these data are compared to the FXB mean data for 1980 and 1981 in Figure 18. There has been a significant decrease in water transparency since 1973.

Dissolved oxygen data collected by PP&L each year between 1975 and 1979, show that hypolimnetic oxygen depletion has also become more severe in recent years. Whereas only one or two meters of the lake bottom were devoid of oxygen in the mid-summers of 1975 and 1976, zero dissolved oxygen concentrations were measured for five to six meters above the bottom in 1977, 1978, and 1979.

6.8 Possible Effects of Lake Operations

The manner in which water is withdrawn from the lake by PP&L may also have an impact on water quality. It has been PP&L policy in the past to wait until mid-winter to withdraw large quantities of water from the lake in order to accomodate spring inflows. In 1980 and 1981, however, the lake was lowered substantially in September in order to perform repairs on the dam. Due to the high concentrations of nutrients and suspended solids in the hypolimnion before fall turnover (See Figures 10 and 12), the latter practice may actually benefit water quality in the lake since the outlet is located at the bottom of the dam. The greatest quantities of phosphorus discharged during the monitoring period occurred in September of both years.

Hence, discharging large quantities of water from the lake before and during fall turnover may actually cause reduced phosphorus concentrations during the following summer. This practice has also reportedly reduced the amount of rooted plants around the lake shore. This situation is being studied further in order to make specific recommendations to PP&L regarding their lake operation policy. Another alternative which is being investigated is the possibility of increasing the discharge around the time of spring turnover.

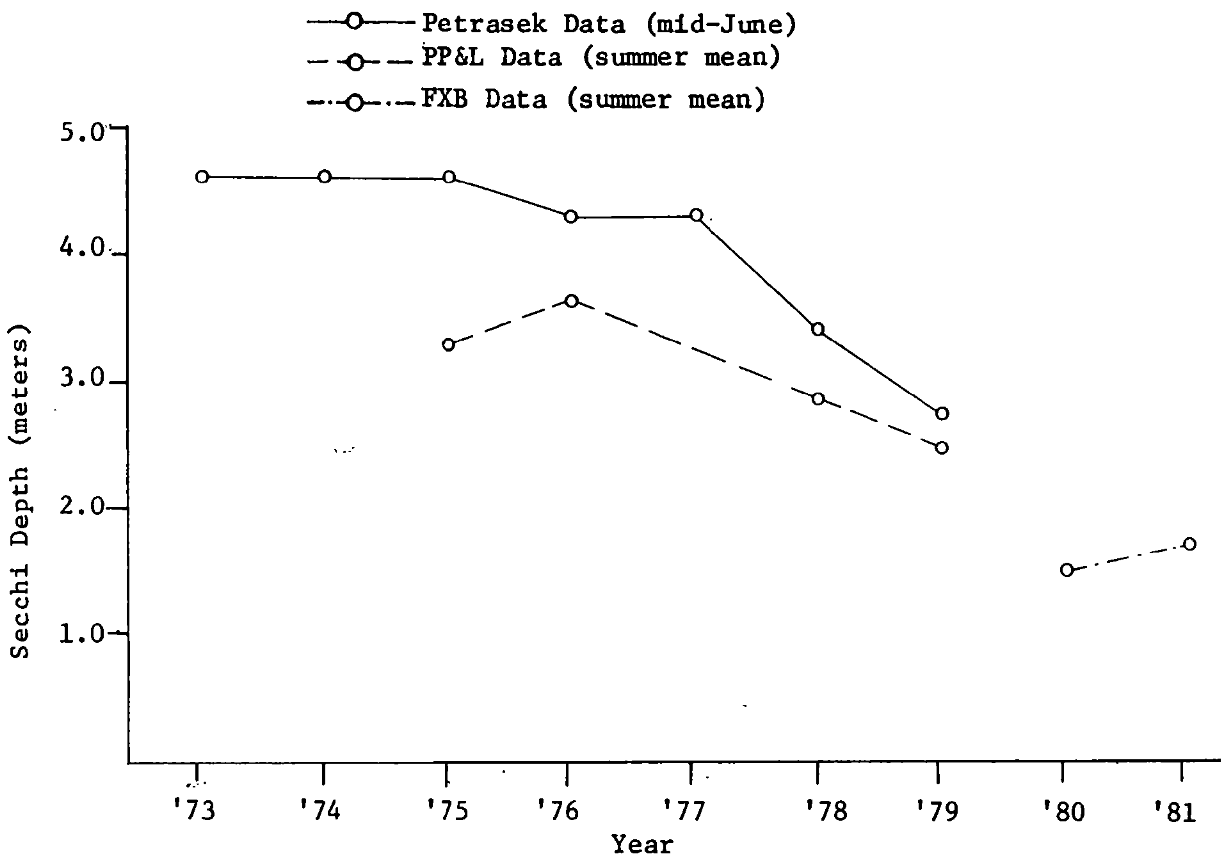


Figure 18. Historical Secchi Depth Measurements

6.9 Lake Modeling

The US OECD (Organization for Economic Cooperation and Development) relationship for chlorophyll a versus phosphorus load (Rast and Lee, 1978) is presented in Figure 19. This empirical relationship was developed from phosphorus load and chlorophyll a data for 38 US lakes. The relationship can be used to predict the change in chlorophyll a which should result from a decrease in the phosphorus load to a lake. The terms used in the relationship are defined below:

$L(P)$ = Surface areal total phosphorus loading rate ($mg\ P/m^2/yr$).

q_s = Hydraulic loading rate (m/yr) = z/τ_ω.

z = Mean depth (m) = water body volume (m^3)/surface area (m^2).

τ_ω = Hydraulic residence time (yr) = water body volume (m^3)/annual inflow volume (m^3/yr).

The mean chlorophyll a concentration for Lake Wallenpaupack during the monitoring period (9.8 ug/l) was higher than would be predicted by the US OECD line of best fit. Therefore, a line parallel to the US OECD line was used in order to determine the relative changes in chlorophyll a which can be expected for assumed changes in phosphorus load. Using this line, it was determined that a 30% reduction in the normalized annual load (as discussed in Section 6.5) would result in a 24% reduction in the mean epilimnetic chlorophyll a concentration. The actual predicted concentrations are shown below:

	Chlorophyll a
Normalized Annual Load	10.9 ug/l
30% Load Reduction	8.3 ug/l

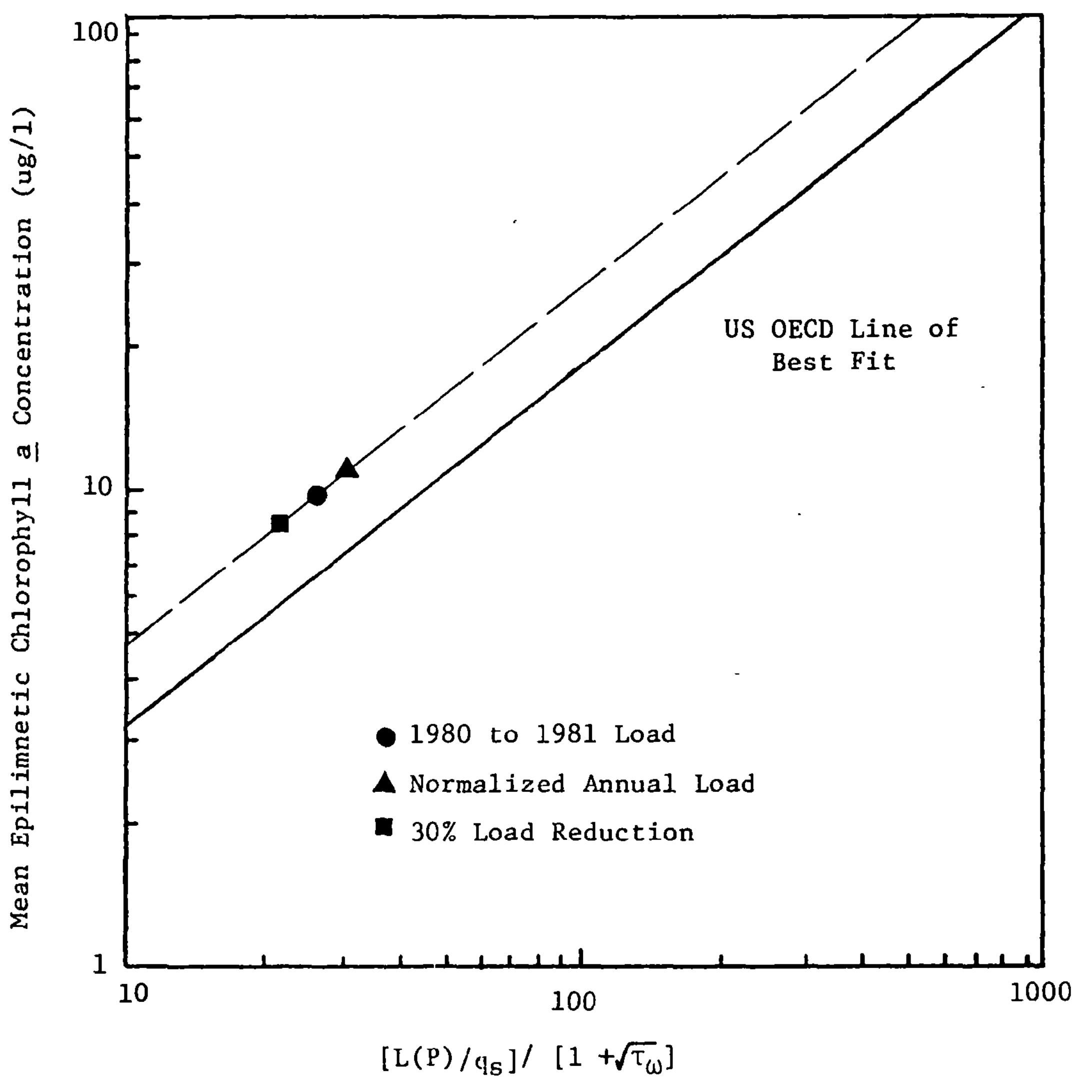


Figure 19. US OECD Relationship for Mean Epilimnetic Chlorophyll a versus Phosphorus Loading Term

According to the probability distribution presented in Figure 17, a chlorophyll a concentration of 8.3 ug/l represents water quality which equal percentages of lake observers would classify as mesotrophic or eutrophic.

7.0 WATERSHED MANAGEMENT PLAN

7.1 INTRODUCTION

Management practices available to reduce the effects of nutrients and sediments entering Lake Wallenpaupack include in-lake treatment and management practices and point and nonpoint source control practices. A successful watershed management plan must incorporate all of the above controls. If the eutrophication process within the lake is not abated, the recreational uses of the lake could be jeopardized.

7.2 IN-LAKE TREATMENT AND MANAGEMENT

Available lake treatment and management techniques include algal control, nutrient control, dredging, lake aeration, dilution-flushing, lake level drawdown, and biological controls.

Algal Control

Algae in the lake can be controlled by the addition of chemicals or by algal harvesting. The primary purpose of these controls is to reduce the number of algae in the lake.

Algal harvesting consists of the removal of algae by physical techniques. Although shown to be successful on small lakes and impoundments, algal harvesting is impractical for large impoundments such as Lake Wallenpaupack.

Chemical control of algae by the addition of algicides is the most common lake management technique. Available algicides include copper sulfate, potassium permanganate, triazine derivatives, organic mercurial compounds, resin amines, and mixtures of copper sulfate, silver nitrate and ammonia. Of these, the most promising algicides are copper sulfate, potassium permanganate, and Cutrine-Plus (a brand name compound containing copper aklanolamine). When used properly, these algicides can be added to a lake without causing health problems or detrimental effects to aquatic organisms. Commercial literature indicates that Cutrine-Plus applied at a rate of one gallon per acre of lake is effective in reducing planktonic, benthic and filamentous algae. The application of Cutrine-Plus, however, is significantly more costly than copper sulfate or potassium permanganate.

Copper sulfate is the most commonly used general algicide. The solubility of copper sulfate and subsequently its effectiveness is influenced by pH, alkalinity and temperature. Copper sulfate is most effective in soft, mildly acidic waters such as Lake Wallenpaupack. If added in excessive amounts, copper sulfate can be toxic to fish and other aquatic life. It can also accumulate in the lake sediments. One of the problems with the use of copper sulfate is its specificity for only certain algae (McKnight, 1981). It is successful in causing a change in the dominant species of algae in a body of water. There are times when the algae replacing the original problem species cause problems of their own, and these latter algae are not controlled by usual treatments of copper sulfate (Fitzgerald and Faust, 1963; Fitzgerald, 1966, 1971; Funk and Gaufin, 1965; Allen, 1966).

Potassium permanganate is a general algicide that is rapidly gaining in popularity since it is toxic to more algal species than copper. In addition, since potassium permanganate is an oxidant, it not only inactivates algae, but it also raises the dissolved oxygen level of the water. Potassium permanganate, like copper sulfate, can be potentially harmful to fish and other aquatic organisms.

Algal control in the lake can be maintained by adding either copper sulfate or potassium permanganate to the lake during the algal growth periods. The selected algicide should be added periodically during the warm weather months to control the algae population prior to the formation of algal blooms. Algicides should only be used to control severe algal blooms, and they should only be applied to select areas of the lake where the blooms occur and cause the most severe problem for lake users.

Nutrient Control

The magnitude of the algal problems in Lake Wallenpaupack could be significantly reduced through control of nutrients. The best method is to limit the nutrients entering the lake by controlling them at their source with watershed management practices such as land use controls, septic system maintenance, and erosion control. In-lake nutrient controls, however, are also effective but are usually not cost-effective for large lakes. In-lake nutrient control practices include nutrient inactivation, sediment sealing, and physical-chemical treatment.

1. Nutrient Inactivation

Nutrient inactivation usually consists of adding alum (aluminum sulfate) to the lake surface to chemically precipitate phosphorus. Removal of the phosphorus from the water column usually increases the water transparency by removing particulate phosphorus, organic material and algae. Precipitation of phosphorus also removes the nutrient most needed for algal growth, resulting in a temporary reduction in the algae population. If sufficient alum is added, the chemical floc can cover the bottom sediments, reducing the release and recycling of sediment nutrients to the water column.

Chemical precipitation of phosphorus has several significant disadvantages: (1) it is considerably more costly than algicide application (even though it is applied in a similar manner using a chemical-dispensing system and a boat), (2) the beneficial results are temporary and depend on the rate at which phosphorus enters the lake, (3) several applications may be needed during one growing season if sufficient phosphorus enters the lake during the warm weather months, and (4) the beneficial results of chemical precipitation are inconclusive; conflicting results have been reported in the scientific literature. Based on these disadvantages, chemical precipitation of nutrients is not a viable management technique for Lake Wallenpaupack.

2. Sediment Sealing

Sediment sealing consists of sealing the lake sediments with various materials such as plastic sheets, sand, clay or fly ash. The purpose of sediment sealing is to prevent the release of nutrients from the sediment to the lake water. Sediment sealing has the following disadvantages: (1) it is costly, (2) the beneficial results are inconclusive, and (3) it may adversely affect bottom organisms and fish spawning. Sediment sealing is not a viable management technique.

3. Physical-Chemical Treatment

A relatively novel approach to nutrient control is to install a physical-chemical treatment plant at the inlet to the lake and to chemically remove phosphorus from the water entering the lake. This approach was used to treat the water entering the Wahnbach Reservoir, a highly eutrophic reservoir in West Germany (Bernhardt and Schell, 1982). An energy-input controlled direct filtration system with phosphorus precipitation was used. The Wahnbach plant, in operation since 1977, has reduced the average total phosphorus concentration to below 0.01 mg/l; increased the transparency from an average of 3 meters to one of 6 meters; significantly reduced the algae population (reduction of 99% in the chlorophyll concentration during algal development periods); and changed the algal composition (small blue-green algae disappeared). The reservoir is now described as oligotrophic to mesotrophic rather than eutrophic.

This approach, combined with watershed management practices, may be a viable management technique for Lake Wallenpaupack. Further study of the technical and financial aspects of a physical-chemical treatment system is needed.

Dredging

Dredging can be used to remove the nutrients in the bottom sediments, increase the lake depth, and reduce the rooted aquatic plants in the lake.

Dredging has the following disadvantages: (1) it is extremely costly, (2) the bottom biological community is destroyed, (3) dredging operations increase the turbidity in the lake, and (4) nutrients and organic matter can be released into the lake water.

Dredging of the entire lake is not feasible; dredging of select areas in the lake, such as small inlets, coves or marinas, however, is a viable management technique.

Lake Aeration

Lake aeration consists of adding air to the lake water during critical warm weather conditions. The air is usually added to the lake area near the dam. Lake aeration has the following advantages: (1) the dissolved oxygen level is increased, and (2) anaerobic conditions near the lake bottom are eliminated or reduced, resulting in a reduction in the release of nutrients from the sediments. Allegedly, lake aeration also reduces the algal biomass and produces a shift in algal dominance from blue-green algae to green algae. These changes, however, have not been substantiated. A recent study of the Rivanna Reservoir in Virginia indicated that aeration had no observable effects on water quality, algal population or algal diversity (F. X. Browne Associates, Inc., 1982). The aeration system increased the dissolved oxygen level of the bottom waters during periods of severe oxygen depletion, but did not improve water quality. Lake aeration, therefore, is not a viable management technique.

Dilution-Flushing

Dilution-flushing is a lake management technique that consists of reducing the amount of algae or nutrients in a lake by introducing large volumes of low nutrient water into a lake. Since there is no low nutrient water supply available in the Lake Wallenpaupack area, dilution-flushing is not a viable management technique.

Lake Level Drawdown

Lake level drawdown is a multipurpose lake management technique that has been used to attempt control of nuisance aquatic weeds, to manage fish, to consolidate flocculent sediments, and to remove algae and nutrients from the lake. Negative aspects of lake level drawdown can include the occurrence of algal blooms caused by mineralization of nutrients in organic-rich sediments; the occurrence of fish kills, especially during a summer drawdown; and the destruction of food animals used by fish.

Lake level drawdown is performed every year by PP&L. The timing and magnitude of this drawdown may significantly affect water quality in Lake Wallenpaupack. In theory, if the timing of lake drawdown was properly selected based on the thermal and nutrient characteristics of the lake, significant amounts of algae and nutrients would be removed from the lake, enhancing water quality. Further study is needed to evaluate the potential impact of lake level drawdown on Lake Wallenpaupack.

Biological Controls

Biological controls of nuisance plants and algae are still in the experimental stage. Most scientists view biological controls with caution since the introduction of a different organism to a water body may cause more problems than it solves.

Two promising biological controls are: (1) the introduction of herbivorous fish which eat algae and certain rooted plants; and (2) the use of biomanipulation, the alteration of the food web to favor that portion of the animal community that grazes on algae. Although these are promising techniques, they are still in the experimental stage and are not viable management techniques for Lake Wallenpaupack at this time.

7.3 POINT SOURCE CONTROLS

The current effluent requirements for phosphorus removal should be maintained for all wastewater dischargers in the watershed. This is particularly necessary due to the proportion of biologically available phosphorus which is discharged from wastewater treatment facilities compared to non-point pollutant sources. The laboratories performing analyses for each of the treatment facilities should be tested for quality assurance at least once per year. These laboratories should be required to maintain a formal documented quality assurance program that includes the periodical analysis of standard solutions, spiked samples, duplicates and known samples. The laboratories should be allowed to use only those analytical methods and equipment approved by the US Environmental Protection Agency (EPA) and the Pennsyvlania Department of Environmental Resources (DER).

7.4 DEVELOPMENT CONTROL

Development of an area increases the quantity of runoff by removing protective vegetative cover, disturbing the earth , modifying natural drainage contours, and increasing the impervious ground area. Runoff from developing and developed areas contains significant amounts of sediments and nutrients which are detrimental to Lake Wallenpaupack. The basic concept in the control of runoff from development is that the runoff characteristics after development should be the same or similar as those existing before development. Water falling on a given site should, under ideal conditions, be absorbed or retained on-site to the extent that after development the quantity, rate and quality of water leaving the site would not be significantly different than if the site had remained undeveloped. A major new emphasis should be placed on the application of natural engineering techniques to preserve the natural features of a site and maximize economical-environmental benefit. Emphasis should be placed on onsite detention storage and the use of land treatment systems for handling and disposal of stormwater. There is a need to recognize that temporary ponding on an individual lot is a potential solution rather than a problem in many situations.

Control of runoff from development can best be accomplished by enactment of a comprehensive runoff control ordinance based on environmental performance standards.

Environmental Performance Standards

Traditionally, specification standards have been used to control land use. Specification standards determine the desired pattern of land use activities by specifying locations and development standards through zoning, subdivision controls, building codes, and other devices. Specification standards, by indicating what one can or cannot do, restrict innovation and are aimed at controlling man-made features rather than at protecting the environment.

Environmental performance standards, unlike specification standards, set specific goals to be obtained. The stipulation that post-development runoff characteristics be the same or similar to pre-development characteristics, for instance, is an environmental performance standard. A performance standard eliminates the need for the enforcing agency to know about and test all available runoff control processes. Instead, the developer must prove that the proposed control processes will perform as required. Performance standards, in effect, are concerned with results and not with the type of process used.

Runoff Control Ordinance

It is beyond the scope of this study to develop a site-specific runoff control ordinance. Such an ordinance would require intensive evaluation of existing and proposed land uses in the watershed. However, this section describes various components that should be incorporated into a runoff control ordinance.

An effective runoff control ordinance should include the following components:

1. Environmental performance standards
2. Submittal of a runoff control plan

3. Permit requirements

4. Control of construction on steep slopes

5. Provisions for field inspection and review of control facilities

The environmental performance standards should, in general, stipulate that post-development runoff characteristics should be the same or similar to pre-development characteristics.

A runoff control plan should be required for all land use activities except the following:

1. Farming and forestry

2. Existing developed lots

3. Wells and sewage disposal systems

4. Small developments (e.g., less than one-half acre, less than 500 square feet of impervious coverage, less than 100 cubic yards of earthmoving)

The runoff control plan should include the following:

1. Topographic features of project area

2. Soil and slope characteristics

3. Proposed development or alteration of the area

4. Projected runoff quantity and characteristics

5. Staging of earthmoving and construction activities

6. Temporary control measures and facilities for use during earthmoving and construction activities

7. Permanent control measures and facilities for long-term protection

8. Maintenance program for the control facilities.

The runoff control plan should be thoroughly reviewed and evaluated prior to the issuance of a construction permit. If various proposed control processes are questionable, the applicant should be required to submit additional information. Development should not be permitted on slopes greater than 25%. For slopes between 15 to 25%, strict runoff control measures should be required.

An alternative to adopting a separate runoff control ordinance would be to integrate runoff control requirements into existing subdivision regulations.

Existing Development

For existing developments with known stormwater runoff problems, there are a number of Best Management Practices (BMPs) that can be installed to reduce the quantities of water and pollutants entering nearby tributaries. These BMPs include:

- sedimentation ponds
- detention basins
- infiltration pits and trenches
- french drains
- level spreaders
- grass swales
- terraces
- porous pavement

Under current legal conditions, these BMPs would have to be installed either voluntarily by the homeowners or at the expense of the township.

Besides the above onsite BMPs, another possible management practice is the construction of regional sedimentation ponds. Sedimentation ponds are effective in removing large percentages of particulate matter, including nutrients, from the tributaries before they reach the lake. Regional sedimentation ponds can be used in subbasins containing all types of land use, including development and agriculture.

7.5 Agricultural Controls

Produce farms and dairy farms generally contribute significant quantities of nutrients, suspended solids, and bacteria to nearby streams. Crop production can generate nonpoint source pollution by the following activities:

1. Disturbance of the soil by tillage operations or the compaction of the soil with large equipment.
2. Disturbance of natural vegetation and the substituting of crop plants in its place, and leaving the soil bare during periods of the year.
3. Addition of commercial fertilizers or animal wastes as fertilizers.
4. Application of pesticides.
5. Application of surface or groundwaters as irrigation water.

Livestock activities can generate nonpoint source pollution in the following ways:

1. Concentration of animals and their wastes in holding areas for extended periods of time and improper methods of waste disposal.
2. Overgrazing that results in inadequate vegetation protection for the soil.
3. Concentration of animals along streambanks in such numbers that streambank erosion occurs along with direct deposition of manure into the streams.

According to Title 25, Chapter 102 of the Pennsylvania Administrative Code, all earthmoving activities, including plowing and tilling, must be conducted in such a way as to prevent accelerated erosion and the resulting sedimentation.

The methods proposed to control accelerated erosion must be developed by an experienced person and set forth in a conservation plan. The plan must be available from the landowner or his lessee at all times. However, no earth disturbance permit is required for agricultural activities, regardless of the size of the disturbed area.

In an effort to preserve the soil and water resources of the Commonwealth, conservation districts have been established in every county. The main purpose of these districts is to assist farmers and other individuals in preventing soil erosion. This goal benefits both the farmer and downstream users of the effected tributary. Each conservation district formulates and carries out its own conservation program. Individual landowners may receive assistance in preparing their farm conservation plans by becoming conservation district cooperators. The conservation district requests a representative of the US Soil Conservation Service (SCS) to provide technical assistance in preparing a conservation plan to meet the needs of the landowner and the standards of the SCS. The plan covers all agricultural land activities and is approved by the conservation district. This assistance is provided at no direct cost to the landowner but is subject to priority assignments by the conservation district.

Based on the results of the watershed monitoring program, it is necessary to intensify control efforts directed toward the reduction of agricultural pollutant loadings. Specific recommendations for the conservation districts in both counties include:

- districts should actively pursue the enlistment of more cooperators
- districts should call for the inspection of conservation plans for non-cooperators
- districts should pursue federal and state funding for the implementation of agricultural BMP projects in the watershed

The objective of the first two recommendations is somewhat obvious. A district conservation program cannot be successful if only a small percentage of the farmers cooperate. The third recommendation realizes that some farm management practices are beyond the economic means of many farmers. Therefore the conservation districts and the LWWMD need to investigate possible sources of funding to assist the farmers. More information will be presented on this topic in a later section.

A number of BMPs, both structural and non-structural, have been developed and tested for the control of runoff and pollutants from agricultural sources. These include BMPs for both cropping practices and livestock practices, as listed below:

Cropping Practices

- crop rotation
- cover cropping
- contour farming
- strip cropping
- crop residue management
- minimum tillage
- cropland terraces
- fertilizer and pesticide management

Livestock Practices

- pasture management
- barnyard diversions
- manure storage pits
- streamside fencing
- controlled feed and water access points

Both Practices

- grassed waterways
- buffer strips
- sedimentation ponds
- drainage channels
- streambank protection

A number of handbooks describing specific agricultural BMPs are available from the SCS and PaDER.

7.6 Earthmoving Activities Controls

As discussed previously, Pennsylvania law requires that every earthmoving activity (regardless of size) within the state develop, implement, and maintain a plan for the control of erosion resulting from the activity. According to the regulations, the following factors must be considered in the plan:

- the topographic features of the project area
- the types, depth, slope, and areal extent of the soils
- the proposed alteration to the area
- the amount of runoff from the project area and the upland watershed area
- the staging of earthmoving activities
- temporary control measures and facilities for use during earthmoving
- permanent control measures for long-term protection
- a maintenance program for the control facilities including disposal of materials from the control facilities or project area

In general, every earthmover is required to obtain a permit except:

1) those activities involving plowing or tilling for agricultural activities,

2) those activities affecting less than 25 acres,

3) those activities affecting more than 25 acres, but which are subdivided into parcels of less than 25 acres that are non-contiguous and where each parcel is stabilized before the next parcel is disturbed,

4) those activities which have acquired a permit under the Water Obstruction Act, the Surface Mining and Reclamation Act, the Clean Streams Law, or Chapters 91-101 of the PaDER's Rules and Regulations.

Due to the high nutrient and sediment loadings which can be discharged from construction sites, the 25 acre exclusion criteria is too liberal and should be reduced. Many of the construction activities which were recently undertaken in the watershed involved less than 25 acres. These activities can still have a significant impact on water quality in the streams and in the lake. A more suitable range for the maximum area exclusion criteria might be between five and ten acres. This revision can be accomplished by petitioning the PaDER.

Depending on the county, earthmoving permit applications are reviewed and enforced to varying degrees of involvement by conservation district and/or PaDER personnel as outlined below:

Level 1 - Public Education
Level 2 - Permit Plan Review
Level 3 - Complaint Handling (office procedure)
Level 4 - Problem Assessment (field procedure)
Level 5 - Compliance (voluntary and induced)
Level 6 - Legal Enforcement

The Pike County Conservation District has recently advanced to Level 5; whereas the Wayne County Conservation District is currently at Level 3. Due the generally accepted premise that more effective administration can be achieved at the local level, as opposed to the state level, it is recommended that the Wayne County Conservation District take the appropriate steps to progress to Level 5. The conservation district would therefore be responsible for the field assessment and compliance tasks.

An even more effective approach for the control of erosion from construction activities would be for the townships to adopt their own soil erosion and sedimentation control ordinances. These ordinances could be as restrictive or more restrictive than the state regulations.

7.7 Septic System Waste Controls

Another nonpoint source which needs to be controlled is septic system wastes. Due to poor soil and geological conditions, many portions of the watershed are unsuitable or only moderately suitable for septic system disposal. While current Pennsylvania regulations are helping to avoid the future installation of improper systems, a number of existing septic systems in the watershed are contributing large quantities of nutrients to the lake. Where possible, these systems should be upgraded to meet current standards. In addition, all townships should implement ordinances requiring the routine maintenance and pumping of septic tanks in order to improve their operation and prevent clogging of the drainage fields.

The COWAMP Study (PaDER, 1981) recommended that local municipalities consider the formation of septic system management districts for areas where septic system pollution is an acknowledged problem. The appropriate mechansims for dealing with this problem in the Lake Wallenpaupack watershed already exist between the townships and the LWWMD. However, if the programs recommended in this report are not successful at controlling the problem it may be desirable to investigate the formation of a formal septic system district at a future date.

Because of the number of suspected septic system problem areas within the watershed, the LWWMD should investigate potential funding sources for the performance of a facilities planning study. Such a study would include the following elements:

- identify wastewater treatment problem areas,
- evaluate possible solutions such as sewers, aerated septic systems, community systems, and holding tanks

- further assess the impact of septic system effluent on the lake, and
- evaluate septage sludge disposal alternatives

Such a study for the Lake Wallenpaupack area has been given a high priority by the PaDER in their 1982 statewide inventory of municipal sewerage construction needs (PA Bulletin, January 16, 1982). Recent changes in EPA construction program regulations provide for 75% federal funding of the actual construction cost. Local funds must be used for planning and design of wastewater and sludge facilities, but, if the facilities are constructed, EPA will reimburse a portion of the planning and design costs.

7.8 INDIVIDUAL HOMEOWNER PRACTICES

There are a number of practices which private residents of the watershed can follow in order to supplement the above watershed management activities. These include:

- the proper maintenance of septic tanks and drain fields, including regular cleaning of the system
- the maintenance of a good vegetative cover in order to avoid exposed soil areas
- the installation of terraces or retaining walls on steep slopes
- the installation of splash blocks below gutters and pipe outlets
- the washing of cars over grassy areas where phosphates will be partially absorbed
- the protection of drainage channels using stone, tall grass, or logs
- the planting of trees and shrubs to protect the ground and to induce evapotranspiration
- the controlled use of lawn fertilizers with respect to both time and quantity of application (clippings and leaves should be mulched and left on the lawn)

- the limited use of pesticides and herbicides
- the maintenance of an uncleared buffer strip along stream channels
- the diversion of runoff to grassy areas rather than directly to drainage channels
- the proper disposal of animal wastes
- the avoidance of trash and litter disposal in stream channels
- the voluntary use of low-phosphate detergents

7.9 INSTITUTIONAL IMPLEMENTATION

When planning for watershed management, it is important to emphasize local solutions. Many of the state and local institutions necessary for the management of activities in the Lake Wallenpaupack watershed already exist. For some of these institutions, a certain amount of strengthening or re-focusing is necessary in order to address the objective of improving water quality in the lake. The following sections discuss the recommended roles and responsibilities of each municipality or agency concerned. In order for watershed management to be effective it is important that all of the municipalities involved (Pike and Wayne Counties, and the 13 townships) follow the recommendations in this plan.

Lake Wallenpaupack Watershed Management District

The LWWMD should assume primary responsibility for the implementation of the watershed management plan. In order to accomplish this, the LWWMD will have to expand its role according to the existing authorities established in the Organization Plan (F. X. Browne Associates, Inc., 1979). Also, certain additional authorities will have to be given to the LWWMD by townships and/or county resolutions.

Specific recommendations for future LWWMD activities include:

1. Continue field monitoring and laboratory analysis activities.
2. Inspect wastewater treatment facilities, provide operational assistance, review monthly monitoring reports and quality control results.
3. Conduct field investigations of land use activities such as construction, agriculture, and silviculture.
4. Provide technical assistance to township officials including assistance in developing ordinances.
5. Implement the watershed management plan through meetings with local officials.
6. Conduct workshops for sewage enforcement officers and wastewater treatment operators.
7. Regulate septage haulers.
8. Perform a more detailed study on the affects of septic systems on the lake, using the following possible approaches:
   - groundwater monitoring program
   - Septic Snooper survey for lake
   - aerial infra-red photography
   - septic system survey and/or public questionnaire
9. Pursue funding for a facilities planning study to evaluate wastewater treatment alternatives for portions of the watershed; the study to include the following elements:
   - identification of septic system problem areas
   - evaluation of community treatment alternatives
   - evaluation of sludge disposal alternatives

10. Continue public education program through the use of news releases, fact sheets, signs, civic presentations, and meetings.

11. Channel complaints and formally follow up on actions by enforcement officials including:
    - sewage enforcement officers
    - conservation district inspectors
    - waterways patrolmen
    - PaDER representatives
    - PP&L lake superintendent

12. Investigate funding sources for the implementation of agricultural and roadway BMPs in the watershed.

The Pike County Planner would still be needed by the LWWMD for administrative and planning tasks.

Wayne and Pike Counties

Both Wayne and Pike Counties should continue to provide technical and financial support to the LWWMD. The Counties should also implement the following specific recommendations:

1. Wayne and Pike Counties should jointly develop a stormwater management plan for the Lake Wallenpaupack watershed according to the requirements of the Pennsylvania Stormwater Management Act (P.L. 864, No. 167). Although this Act is directed mainly at controlling runoff quantity, such a stormwater management plan will inherently help to improve the quality of the waters entering the lake.

2. Each County should enact an ordinance requiring all septage haulers who operate within the watershed boundaries to be permitted. This program could be administered by the LWWMD if no appropriate department exists at the county level.

Townships

Like the counties, all townships within the watershed should continue to actively support the objectives of the LWWMD. Specific recommendations for the townships are listed below:

1. Townships should continue to influence the quality of development in the watershed through the use of existing subdivision ordinances. Each township should adopt runoff control and erosion control ordinances or integrate these ordinances into their existing subdivision ordinance.

2. Townships should develop master plans and zoning ordinances to channel growth toward suitable areas which will not have an adverse impact on the lake.

3. Townships should pass septic system ordinances which include the following elements:
   - provide sewage enforcement officers with more authority where needed
   - require regular septic system maintenance including cleaning at a rate of at least once every two to four years.
   - require upgrading of existing systems which are determined to be a potential hazard to public or environmental health

Many of these ordinances will probably be required after the development of a stormwater management plan for the watershed according to Pennsylvania Act No. 167.

Conservation Districts

The Wayne County and Pike County Conservation Districts must continue to play a major role in preventing soil erosion from earthmoving and agricultural activities in the watershed. The following specific recommendations apply to the conservation districts:

1. Both districts should attempt to increase the number of agricultural cooperators. The farm plans of non-cooperating landowners should be inspected for compliance with the Clean Streams Law.

2. Wayne County should make an agreement with the PaDER to advance to Level 5 in the soil erosion and sedimentation control plan review and permitting process. The PaDER does not have the resources to effectively administer this program at the regional level. Additional financial assistance is available from the state for districts accepting Level 5 responsibilities.

3. Both districts should petition the PaDER to have the maximum acreage for exclusion from the earthmoving permit requirement reduced for the Lake Wallenpaupack watershed. The current statewide requirement allows persons conducting earthmoving activities up to 25 acres (250 acres for forestry activities) to proceed without obtaining a permit. This requirement should be made more restrictive by reducing the limit to a range of from five to ten acres (50 to 100 acres for forestry). To offset this more restrictive requirement, it may be desirable to arrange the process such that only applications for earthmoving activites of more than 25 acres need to be sent to the PaDER for permit approval. All other permit applications could be reviewed and approved by the conservation district.

US Soil Conservation Service

In order to manage the additional administrative and technical workload which is expected to be generated by the recommendations stated in this watershed management plan, the number of SCS staff members assigned to Wayne and Pike Counties should be increased. Due to their common boundaries and interests, the two counties should continue to be serviced from the same SCS office.

Pennsylvania Fish Commission

Waterways patrolmen should use the fullest extent of their enforcement powers under the Clean Streams Law. They should also notify the LWWMD of actual or suspected violators.

Pennsylvania Department of Transportation

If not already practiced, the following provisions should be included in all private contracts:

- All contractors should adhere strictly to soil erosion and sedimentation control plans.
- A cited violation of the Clean Streams Law should be grounds for immediate termination of the contract.

PennDOT roadway maintenance procedures should be reviewed to evaluate their impact on water quality.

7.10 POTENTIAL ASSISTANCE SOURCES

The implementation of watershed management practices can be expensive and often requires funding assistance from state and federal programs. The LWWMD should actively pursue funding assistance in cooperation with other concerned agencies.

The EPA Clean Lakes Program (under which this Phase 1 Study was partially funded) has been re-authorized for FY83 but funds have not been appropriated. If funds are appropriated for the program, the LWWMD should submit a Phase 2 Grant Application to obtain partial funding for the implementation of Best Management Practices (BMPs) throughout the watershed.

There are a number of assistance programs directed at financially helping farmers to install BMPs. Several of these programs are listed below:

- Rural Clean Water Program
- Agricultural Conservation Program (ACP)
- Resource Conservation and Development Program (RC&D)
- Small Watershed Protection Program

These programs are administered by the US Agricultural Stabilization and Conservation Service (ASCS). Loans for landowners to make watershed improvements can be obtained from the Farmers Home Administration (FmHA).

Funding for a 201 Facilities Planning Study to evaluate wastewater and sludge disposal needs in the watershed may be available through the EPA/PaDER Construction Grants Program. Other possible funding sources for the construction of wastewater treatment systems are:

- Rural Water and Waste Disposal Systems Program (Farmers Home Administration).
- Economic Development Grants for Public Works and Facilities (Economic Development Administration).
- Appalachian Region Development Grants (Appalachian Regional Commission).

According to the Stormwater Management Act, (Act 167), the PaDER is authorized to provide grants up to 50% of the allowable costs of preparing stormwater management plans. Although no funds were authorized for fiscal year 1982, grants may become available in the future.

7.11 MONITORING PROGRAM CONTINUATION

The LWWMD is currently conducting a continuation study which includes monitoring of the lake and watershed. The study is aimed at identifying specific problem areas in each of the subbasins relating to land use activities, point source discharges and septic systems. The current monitoring program is scheduled to end by December 1982.

The LWWMD should continue the monitoring efforts for Lake Wallenpaupack and its watershed on an annual basis. Water quality data for the lake are needed establish long-term water quality trends. Also, the lake data should be used in an attempt to develop an early detection system with respect to the potential occurrence of algae-related water quality problems. Eventually, it might be possible to develop a water quality response model specifically for Lake Wallenpaupack.

The automatic stream stations should be maintained in continuous operation. Watershed data should be used to refine the pollutant load budget and to detect any improvements in water quality caused by the implementation of watershed management practices.

APPENDIX A

GLOSSARY

(Taken from EPA Clean Lakes Program Guidance Manual, EPA-440/5-81-003, 1980)

Appendix A

GLOSSARY OF LAKE AND WATERSHED MANAGEMENT TERMS

Aeration: A process in which water is treated with air or other gases, usually oxygen. In lake restoration, aeration is used to prevent anaerobic condition or to provide artificial destratification.

Algal bloom: A high concentration of a specific algal species in a water body, usually caused by nutrient enrichment.

Algicide: A chemical highly toxic to algae.

Alkalinity: A quantitative measure of water's capacity to neutralize acids. Alkalinity results from the presence of bicarbonates, carbonates, hydroxides, salts, and occasionally of borates, silicates, and phosphates. Numerically, it is expressed as the concentration of calcium carbonate that has an equivalent capacity to neutralize strong acids.

Allochthonous: Describes organic matter produced outside of a specific stream or lake system.

Alluvial: Pertaining to sediments gradually deposited by moving water.

Artificial destratification: The process of inducing water currents in a lake to produce partial or total vertical circulation.

Artificial recharge: The addition of water to the groundwater reservoir by activities of man, such as irrigation or induced infiltration.

Assimilation: The absorption and conversion of nutritive elements into protoplasm.

Autochthon: Any organic matter indigenous to a specific stream or lake.

Autotrophic: The ability to synthesize organic matter from inorganic substances.

Background loading of concentration: The concentration of a chemical constituent arising from natural sources.

Base flow: Stream discharge due to groundwater flow.

Benthic oxygen demand: Oxygen demand exerted from the bottom of a stream or lake, usually by biochemical oxidation of organic material in the sediments.

Benthos: Organisms living on or in the bottom of a body of water.

Best management practices: Practices, either structural or non-structural, which are used to control nonpoint source pollution.

Bioassay: The use of living organisms to determine the biological effect of some substance, factor, or condition.

Biochemical oxidation: The process by which bacteria and other microorganisms break down organic material and remove organic matter from solution.

Biochemical oxygen demand (BOD), biological oxygen demand: The amount of oxygen used by aerobic organisms to decompose organic material. Provides an indirect measure of the concentration of biologically degradable material present in water or wastewater.

Biological control: A method of controlling pest organisms by introduced or naturally occurring predatory organisms, sterilization, inhibiting hormones, or other nonmechanical or nonchemical means.

Biological magnification, biomagnification: An increase in concentration of a substance along succeeding steps in a food chain.

Biomass: The total mass of living organisms in a particular volume or area.

Biota: All living matter in a particular region.

Blue-green algae: The phylum Cyanophyta, characterized by the presence of blue pigment in addition to green chlorophyll.

Catch basin: A collection chamber usually built at the curb line of a street, designed to admit surface water to a sewer or subdrain and to retain matter that would block the sewer.

Catchment: Surface drainage area.

Chemical control: A method of controlling pest organisms through exposure to specific toxic chemicals.

Chlorophyll: Green pigment in plants and algae necessary for photosynthesis.

Circulation period: The interval of time in which the thermal stratification of a lake is destroyed, resulting in the mixing of the entire water body.

Coagulation: The aggregation of colloidal particles, often induced by chemicals such as lime or alum.

Coliform bacteria: Nonpathogenic organisms considered a good indicator of pathogenic bacterial pollution.

Colorimetry: The technique used to infer the concentration of a dissolved substance in solution by comparison of its color intensity with that of a solution of known concentration.

Combined sewer: A sewer receiving both stormwater runoff and sewage.

Compensation point: The depth of water at which oxygen production by photosynthesis and respiration by plants and animals are at equilibrium due to light intensity.

Cover crop: A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of permanent vegetation.

Crustacea: Aquatic animals with a rigid outer covering, jointed appendages, and gills.

Culture: A growth of microorganisms in an artificial medium.

Denitrification: Reduction of nitrates to nitrites or to elemental nitrogen by bacterial action.

Depression storage: Water retained in surface depressions when precipitation intensity is greater than infiltration capacity.

Design storm: A rainfall pattern of specified amount, intensity, duration, and frequency that is used as a basis for design.

Detention: Managing stormwater runoff or sewer flows through temporary holding and controlled release.

Detritus: Finely divided material of organic or inorganic origin.

Diatoms: Organisms belonging to the group Bacillariophyceae, characterized by the presence of silica in its cell walls.

Dilution: A lake restorative measure aimed at reducing nutrient levels within a water body by the replacement of nutrient-rich waters with nutrient-poor waters.

Discharge: A volume of fluid passing a point per unit time, commonly expressed as cubic meters per second.

Dissolved oxygen (DO): The quantity of oxygen present in water in a dissolved state, usually expressed as milligrams per liter of water, or as a percent of saturation at a specific temperature.

Dissolved solids (DS): The total amount of dissolved material, organic and inorganic, contained in water or wastes.

Diversion: A channel or berm constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

Drainage basin, watershed, drainage area: A geographical area where surface runoff from streams and other natural watercourses is carried by a single drainage system to a common outlet.

Dry weather flow: The combination of sanitary sewage and industrial and commercial wastes normally found in the sanitary sewers during the dry weather season of the year; or, flow in streams during dry seasons.

Dystrophic lakes: Brown-water lakes with a low lime content and a high humus content, often severely lacking nutrients.

Enrichment: The addition to or accumulation of plant nutrients in water.

Epilimnion: The upper, circulating layer of a thermally stratified lake.

Erosion: The process by which the soils of the earth's crust are worn away and carried from one place to another by weathering, corrosion, solution, and transportation.

Eutrophication: A natural enrichment process of a lake, which may be accelerated by man's activities. Usually manifested by one or more of the following characteristics: (a) excessive biomass accumulations of primary producers; (b) rapid organic and/or inorganic sedimentation and shallowing; or (c) seasonal and/or diurnal dissolved oxygen deficiencies.

Fecal streptococcus: A group of bacteria normally present in large numbers in the intestinal tracts of humans and other warm-blooded animals.

First flush: The first, and generally most polluted, portion of runoff generated by rainfall.

Flocculation: The process by which suspended particles collide and combine into larger particles or floccules and settle out of solution.

Gabion: A rectangular or cylindrical wire mesh cage (a chicken wire basket) filled with rock and used to protect against erosion.

Gaging station: A selected section of a stream channel equipped with a gage, recorder, and/or other facilities for determining stream discharge.

Grassed waterway: A natural or constructed waterway covered with erosion-resistant grasses, used to conduct surface water from an area at a reduced flow rate.

Green algae: Algae characterized by the presence of photosynthetic pigments similar in color to those of the higher green plants.

Heavy metals: Metals of high specific gravity, including cadmium, chromium, cobalt, copper, lead, mercury. They are toxic to many organisms even in low concentrations.

Hydrograph: A continuous graph showing the properties of stream flow with respect to time.

Hydrologic cycle: The movement of water from the oceans to the atmosphere and back to the sea. Many subcycles exist including precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hypolimnion: The lower, non-circulating layer of a thermally stratified lake.

Intermittent stream: A stream or portion of a stream that flows only when replenished by frequent precipitation.

Irrigation return flow: Irrigation water which is not consumed in evaporation or plant growth, and which returns to a surface stream or groundwater reservoir.

Leaching: Removal of the more soluble materials from the soil by percolating waters.

Limiting nutrient: The substance that is limiting to biological growth due to its short supply with respect to other substances necessary for the growth of an organism.

Littoral: The region along the shore of a body of water.

Macrophytes: Large vascular, aquatic plants which are either rooted or floating.

Mesotrophic lake: A trophic condition between an oligotrophic and an eutrophic water body.

Metalimnion: The middle layer of a thermally stratified lake in which temperature rapidly decreases with depth.

Most probable number (MPN): A statistical indication of the number of bacteria present in a given volume (usually 100 ml).

Nannoplankton: Those organisms suspended in open water which because of their small size, cannot be collected by nets (usually smaller than approximately 25 microns).

Nitrification: The biochemical oxidation process by which ammonia is changed first to nitrates and then to nitrites by bacterial action.

Nitrogen, available: Includes ammonium, nitrate ions, ammonia, and certain simple amines readily available for plant growth.

Nitrogen cycle: The sequence of biochemical changes in which atmospheric nitrogen is "fixed," then used by a living organism, liberated upon the death and decomposition of the organism, and reduced to its original state.

Nitrogen fixation: The biological process of removing elemental nitrogen from the atmosphere and incorporating it into organic compounds.

Nitrogen, organic: Nitrogen components of biological origin such as amino acids, proteins, and peptides.

Nonpoint source: Nonpoint source pollutants are not traceable to a discrete origin, but generally result from land runoff, precipitation, drainage, or seepage.

Nutrient, available: That portion of an element or compound that can be readily absorbed and assimilated by growing plants.

Nutrient budget: An analysis of the nutrients entering a lake, discharging from the lake, and accumulating in the lake (e.g., input minus output = accumulation).

Nutrient inactivation: The process of rendering nutrients inactive by one of three methods: (1) Changing the form of a nutrient to make it unavailable to plants, (2) removing the nutrient from the photic zone, or (3) preventing the release or recycling of potentially available nutrients within a lake.

Oligotrophic lake: A lake with a small supply of nutrients, and consequently a low level of primary production. Oligotrophic lakes are often characterized by a high level of species diversification.

Orthophosphate: See phosphorus, available.

Outfall: The point where wastewater or drainage discharges from a sewer to a receiving body of water.

Overturn, turnovers: The complete mixing of a previously thermally stratified lake. This occurs in the spring and fall when water temperatures in the lake are uniform.

Oxygen deficit: The difference between observed oxygen concentrations and the amount that would be present at 100 percent saturation at a specific temperature.

Peak discharge: The maximum instantaneous flow from a given storm condition at a specific location.

Percolation test: A test used to determine the rate of percolation or seepage of water through natural soils. The percolation rate is expressed as time in minutes for a 1-inch fall of water in a test hold and is used to determine the acceptability of a site for treatment of domestic wastes by a septic system.

Perennial stream: A stream that maintains water in its channel throughout the year.

Periphyton: Microorganisms that are attached to or growing on submerged surfaces in a waterway.

Phosphorus, available: Phosphorus which is readily available for plant growth. Usually in the form of soluble orthophosphates.

Phosphorus, total (TP): All of the phosphorus present in a sample regardless of form. Usually measured by the persulfate digestion procedure.

Photic zone: The upper layer in a lake where sufficient light is available for photosynthesis.

Photosynthesis: The process occurring in green plants in which light energy is used to convert inorganic compounds to carbohydrates. In this process, carbon dioxide is consumed and oxygen is released.

Phytoplankton: Plant microorganisms, such as algae, living unattached in the water.

Plankton: Unattached aquatic microorganisms which drift passively through water.

Point source: A discreet pollutant discharge such as a pipe, ditch, channel, or concentrated animal feeding operation.

Population equivalent: An expression of the amount of a given waste load in terms of the size of human population that would contribute the same amount of biochemical oxygen demand (BOD) per day. A common base is 0.17 pounds (7.72 grams) of 5-day BOD per capita per day.

Primary production: The production of organic matter from light energy and inorganic materials, by autotrophic organisms.

Protozoa: Unicellular animals, including the ciliates and nonchlorophyllous flagellates.

Rainfall intensity: The rate at which rain falls, usually expressed in centimeters per hour.

Rational method: A means of computing peak storm drainage runoff (Q) by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the average rainfall intensity, and A is the size of the drainage area.

Raw water: A water supply which is available for use but which has not yet been treated or purified.

Recurrence interval: The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus, a 10-year storm can be expected to occur on the average once every 10 years. Sewers are generally designed for a specific design storm frequency.

Riprap: Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves).

Saprophytic: Pertaining to those organisms that live on dead or decaying organic matter.

Scouring: The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt, usually during a flood.

Secchi depth: A measure of optical water clarity as determined by lowering a weighted Secchi disk into a water body to the point where it is no longer visible.

Sediment basin: A structure designed to slow the velocity of runoff water and facilitate the settling and retention of sediment and debris.

Sediment delivery ratio: The fraction of soil eroded from upland sources that reaches a continuous stream channel or storage reservoir.

Sediment discharge: The quantity of sediment, expressed as a dry weight or volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended load and bedload.

Septic: A putrefactive condition produced by anaerobic decomposition of organic wastes, usually accompanied by production of malodorous gases.

Standing crop: The biomass present in a body of water at a particular time.

Sub-basin: A physical division of a larger basin, associated with one reach of the storm drainage system.

Substrate: The substance or base upon which an organism grows.

Suspended solids: Refers to the particulate matter in a sample, including the material that settles readily as well as the material that remains dispersed.

Swale: An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and provide some groundwater recharge.

Terrace: An embankment or combination of an embankment and channel built across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

Thermal stratification: The layering of water bodies due to temperature-induced density differences.

Thermocline: See metalimnion.

Tile drainage: Land drainage by means of a series of tile lines laid at a specified depth and grade.

Total solids: The solids in water, sewage, or other liquids, including the dissolved, filterable, and nonfilterable solids. The residue left when a sample is evaporated and dried at a specified temperature.

Trace elements: Those elements which are needed in low concentrations for the growth of an organism.

Trophic condition: A relative description of a lake's biological productivity. The range of trophic conditions is characterized by the terms oligotrophic for the least biologically productive, to eutrophic for the most biologically productive.

Turbidity: A measure of the cloudiness of a liquid. Turbidity provides an indirect measure of the suspended solids concentration in water.

Urban runoff: Surface runoff from an urban drainage area.

Volatile solids: The quantity of solids in water, sewage, or other liquid, which is lost upon ignition at 600° C

Waste load allocation: The assignment of target pollutant loads to point sources so as to achieve water quality standards in a stream segment in the most effective manner.

Water quality: A term used to describe the chemical, physical, and biological characteristics of water, usually with respect to its suitability for a particular purpose.

Water quality standards: State-enforced standards describing the required physical and chemical properties of water according to its designated uses.

Watershed: See drainage basin.

Weir: Device for measuring or regulating the flow of water.

Zooplankton: Protozoa and other animal microorganisms living unattached in water.

APPENDIX B

REFERENCES

REFERENCES

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APPENDIX C

SUMMARY OF

PUBLIC PARTICIPATION ACTIVITIES

SUMMARY OF PUBLIC PARTICIPATION ACTIVITIES

The LWWMD actively participated in numerous public education activities. Presentations regarding the study were made at civic meetings including those for clubs, business groups, community associations, and marina owners. A detailed fact sheet was distributed to all property owners in the watershed at the initiation of the Water Quality Management Study. Signs describing the existence of the LWWMD and the importantce of maintaining acceptable water quality have been printed courtesy of the Lake Wallenpaupack Watershed Association (LWWA, a local citizens' group which has been active in watershed matters for over a decade). These signs some large, and some small, are currently being posted at various locations throughout the watershed at the time of this report revision.

The activities of the LWWMD have been reported frequently in newspaper articles and on local radio programs. A video documentary of the condition of Lake Wallenpaupack was prepared by the State College Public Broadcasting Station and was telecast statewide on at least two separate occasions.

All meetings of the LWWMD are open to the general public. The LWWMD and LWWA jointly sponsored annual public meetings on August 2, 1980 and August 14, 1981. The status of this study was the main topic at each of those meetings.

In addition to the meeting at which the final draft report was formally presented to the LWWMD on June 23, 1982, an official public meeting was held on August 27, 1982 to discuss the proposed conclusions and recommendations of the study. The format for the latter meeting included a slide presentation, handouts, and a question and answer period. Formal notification for both meetings was provided via advertisements in two local newspapers.