North Jersey Resource Conservation & Development

Water Quality in the Upper Delaware Watershed

A Technical Report for the Upper Delaware Watershed Management Project

May 2002

• Dunnfield Creek - one of the state's stream monitoring network background sites - exhibits excellent water quality

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The North Jersey Resource Conservation and Development Council is a six-county regional nonprofit supported by the Soil Conservation Districts and county governments from Hunterdon, Somerset, Sussex, Morris, Warren, and Union Counties. Though organized by local communities, RC&D Councils nationwide receive technical and administrative support from the United States Department of Agriculture – Natural Resources Conservation Service through the Resource Conservation and Development Program.

This water quality report was developed utilizing the best available data resources from the USGS, DRBC, and NJDEP. A USGS fact sheet titled *Quality of Water in Tributaries to the Upper Delaware River, New Jersey, Water Years 1985-2001* will summarize this data

We would like to acknowledge the Upper Delaware Project Team for their assistance in the creation of this report. The Project Team consists of members from the following agencies or groups:

New Jersey Department of Environmental Protection (NJDEP)
United States Department of Agriculture, Natural Resources Conservation Service (NRCS)
United States Department of the Interior, Geological Survey (USGS)
New Jersey Conservation Foundation

The Water Quality Report is intended to provide detailed information on the water quality status of streams in the Upper Delaware Watershed. This technical report and its associated figures will help to target watershed management efforts to those regions with documented water quality impairments.

May 2002

PRELIMINARY EVALUATION OF WATER QUALITY STATUS OF TRIBUTARIES TO THE UPPER DELAWARE WATERSHED IN NEW JERSEY, WATER YEARS 1985-2001

Data provided by the US Geological Survey

Contents

ABSTRACT 1
INTRODUCTION 2
Purpose and Scope 3
Description of Study Area 3
Previous Studies 8
METHODS OF STUDY 9
Water Quality Data 9
Selection of Constituents 9
Data Review 11
Statistical Methods 11
Presentation of tables appendixes and figures 13
STREAMFLOW DATA 14
WATER QUALITY ANALYSIS 16
Comparison to statewide background sites 17
Comparison to statewide status sites 19
Comparison to Standards 20
Exceedances of Standards analyzed by Season and Flow 22
Exceedances of Standards by watershed 22
Exceedances of Standards at Existing Water Quality Network Sites 24
Relation of Constituents to Season and to Flow at Each Site and Between Sites 24
Trends in Water-Quality Characteristics 29
Trends detected in Previous Studies 32
Relation of Water Quality Constituents to Land Use 32
Comparison of Median Values to Landuse 34
Comparison of all Data grouped by Land Use 34
Changes along stream reaches 35
Water Quality Summary 36
SUMMARY AND CONCLUSIONS 38
GLOSSARY 40
REFERENCES CITED 40

ILLUSTRATIONS

Figure 1. Map showing location of water-quality sampling sites in the Upper Delaware River Watershed study area of New Jersey
2. Map showing Upper Delaware River Watershed study area, 1995/97 landuse, and physiographic province boundaries
3. Boxplots showing distribution of dissolved oxygen, pH and water temperature data at 21 USGS/NJDEP network sites and median values from all samples, statewide background sites, and statewide status sites
4. Boxplots showing distribution of nutrient data at 21 USGS/NJDEP network sites and median values from all samples, statewide background sites, and statewide status sites
5. Boxplots showing distribution of fecal coliform, total dissolved and total suspended solids data at 21 USGS/NJDEP network sites and median values from all samples, statewide background sites, and statewide status sites
6. Cumulative probability curves for un-ionized ammonia concentrations from samples collected at 12 USGS/NJDEP network sites from 1985-2000
7. Cumulative probability curves for un-ionized ammonia concentrations from samples collected at 7 DRBC sites from 1985-2000
8. Cumulative probability curves for dissolved oxygen concentrations from samples collected at 12 USGS/NJDEP network sites from 1985-2000
9. Cumulative probability curves for dissolved oxygen concentrations from samples collected at 9 DRBC sites from 1985-2000
10. Cumulative probability curves for total dissolved solids concentrations from samples collected at 12 USGS/NJDEP network sites from 1985-2000
11. Cumulative probability curves for total dissolved solids concentrations from samples collected at 8 DRBC sites from 1985-2000
12. Cumulative probability curves for fecal coliform counts from samples collected at 12 USGS/NJDEP network sites from 1985-2000
13. Cumulative probability curves for fecal coliform counts from samples collected at 8 DRBC sites from 1985-2000
14. Cumulative probability curves for nitrate plus nitrite concentrations from samples collected at 12 USGS/NJDEP network sites from 1985-2000
15. Cumulative probability curves for nitrate plus nitrite concentrations from samples collected at 6 DRBC sites from 1985-2000
16. Cumulative probability curves for pH from samples collected at 12 USGS/NJDEP network sites from 1985-2000
17. Cumulative probability curves for pH from samples collected at 9 DRBC sites from 1985-2000
18. Cumulative probability curves for total phosphorus concentrations from samples collected at 12 USGS/NJDEP network sites from 1985-2000
19. Cumulative probability curves for total phosphorus concentrations from samples collected at 7 DRBC sites from 1985-2000
20. Cumulative probability curves for total suspended solids concentrations from samples collected at 10 USGS/NJDEP network sites from 1985-2000

21. Cumulative probability curves for total suspended solids concentrations from samples collected at 8 DRBC sites from 1985-2000
22. Cumulative probability curves for water temperature from samples collected at 12 USGS/NJDEP network sites from 1985-2000
23. Cumulative probability curves for water temperature from samples collected at 9 DRBC sites from 1985-2000
24. Relation of median concentrations, fecal coliform counts and pH units from samples collected from 1985-2000 to percent forested land use at the USGS/NJDEP network sites
25. Relation of median concentrations, fecal coliform counts and pH units from samples collected from 1985-2000 to percent agricultural land use at the USGS/NJDEP network sites
26. Relation of median concentrations, fecal coliform counts and pH units from samples collected from 1985-2000 to percent urban land use at the USGS/NJDEP network sites
27. Map showing median of constituents at each site in subwatershed 1 as a percentage of the instream standard
28. Map showing median of constituents at each site in subwatershed 2 as a percentage of the instream standard
29. Map showing median of constituents at each site in subwatershed 3 as a percentage of the instream standard
30. Map showing median of constituents at each site in subwatershed 4 as a percentage of the instream standard
31. Map showing median of constituents at each site in subwatershed 5 as a percentage of the instream standard

TABLES

Table 1. Thirty-nine surface water quality sites sampled by the NJDEP/USGS network, the Delaware River Basin Commission (DRBC)and the NJDEP Existing Water Quality Network (EWQ) in the Upper Delaware River watershed from 1985-2001, drainage watershed characteristics, and historical period of record
2. Streamflow statistics of mean daily flow at sampling sites
3. Statistical summary of data collected by the NJDEP/USGS at 6 New Jersey statewide background sites from 1998-2000
4. Statistical summary of all data collected by the NJDEP/USGS at 21 sites in study area from 1985 – 2000
5. Statistical summary of data collected by the NJDEP/USGS at 109 New Jersey statewide status sites from 1998-2000
6. Summary of data collected by New Jersey Department of Environmental Protection at 15 Existing Water Quality Network sites
7. Summary of trend slopes from Seasonal Kendall tests performed on nine constituents and sampled flow at 10 sites in the Upper Delaware River watershed from 1985-2000
8. Summary of water quality conditions at 12 NJDEP/USGS sites and 10 DRBC sites sampled in the Upper Delaware River watershed from 1985-2000

Appendixes

Appendix 1a. Water quality standards and frequency of samples not meeting standards at the 21 NJDEP/USGS sites sampled in the Delaware River watershed watershed management area 1, from 1985-2000

1b. Water quality standards and frequency of samples not meeting standards at the 15 DRBC sites sampled in the Delaware River watershed watershed management area 1, from 1985-2000

1c. Geometric mean of fecal coliform counts per 100ml and exceedances of the surface water standard

1d. Geometric mean of fecal coliform counts per 100mL and exceedances of the surface water standard for Delaware River Basin Commission (DRBC) sampling sites

2a. Statistical summary of un-ionized ammonia from all samples collected from 1985 to 2000 at the NJDEP/USGS sites

2b. Statistical summary of un-ionized ammonia from all samples collected from 1985 to 2000 at the DRBC sites

2c. Statistical summary and differences in un-ionized ammonia concentrations between seasons and flow conditions using data from NJDEP/USGS sites from 1985-2000

3a. Statistical summary of dissolved oxygen from all samples collected from 1985 to 2000 at the NJDEP/USGS sites

3b. Statistical summary of dissolved oxygen from all samples collected from 1985 to 2000 at the DRBC sites

3c. Statistical summary and differences in dissolved oxygen concentrations between seasons and flow conditions using data from NJDEP/USGS sites from 1985-2000

4a. Statistical summary of total dissolved solids from all samples collected from 1985 to 2000 at the NJDEP/USGS sites

4b. Statistical summary of total dissolved solids from all samples collected from 1985 to 2000 at the DRBC sites

4c. Statistical summary and differences in total dissolved solids concentrations between seasons and flow conditions using data from NJDEP/USGS sites from 1985-2000

5a. Statistical summary of fecal coliform counts from all samples collected from 1985 to 2000 at the NJDEP/USGS sites

5b. Statistical summary of fecal coliform counts from all samples collected from 1985 to 2000 at the DRBC sites

5c. Statistical summary and differences in fecal coliform counts between seasons and flow conditions using data from NJDEP/USGS sites from 1985-2000

6a. Statistical summary of nitrate plus nitrite concentrations from all samples collected from 1985 to 2000 at the NJDEP/USGS sites

6b. Statistical summary of nitrate plus nitrite concentrations from all samples collected from 1985 to 2000 at the DRBC sites

6c. Statistical summary and differences in nitrate plus nitrite concentrations between seasons and flow conditions using data from NJDEP/USGS sites from 1985-2000

7a. Statistical summary of pH data from all samples collected from 1985 to 2000 at the NJDEP/USGS sites

7b. Statistical summary of pH data from all samples collected from 1985 to 2000 at the DRBC sites

7c. Statistical summary of pH data and differences in pH between seasons and flow conditions using data from NJDEP/USGS sites from 1985-2000
8a. Statistical summary of total phosphorus concentrations from all samples collected from 1985 to 2000 at the NJDEP/USGS sites
8b. Statistical summary of total phosphorus concentrations from all samples collected from 1985 to 2000 at the DRBC sites
8c. Statistical summary and differences in total phosphorus concentrations between seasons and flow conditions using data from NJDEP/USGS sites from 1985-2000
9a. Statistical summary of total suspended solids from all samples collected from 1985 to 2000 at the NJDEP/USGS sites
9b. Statistical summary of total suspended solids from all samples collected from 1985 to 2000 at the DRBC sites
9c. Statistical summary and differences in total suspended solids between seasons and flow conditions using data from NJDEP/USGS sites from 1985-2000
10a. Statistical summary of water temperature from all samples collected from 1985 to 2000 at the NJDEP/USGS sites
10b. Statistical summary of water temperature from all samples collected from 1985 to 2000 at the DRBC sites
10c. Statistical summary and differences in water temperature between seasons and flow conditions using data from NJDEP/USGS sites from 1985-2000

WATER QUALITY STATUS OF TRIBUTARIES IN THE UPPER DELAWARE WATERSHED IN NEW JERSEY, WATER YEARS 1985-2001

ABSTRACT

Nine water quality constituents were studied at 39 surface water-quality sites. Eight of the 9 constituents did not meet standards in at least one sample at one or more sites in the study area. The constituents most commonly measured at levels above instream water quality standards were fecal coliform, > 400 MPN/100ml in 23 percent of samples; total phosphorus, > 0.1 mg/L in 22 percent of samples; water temperature in designated trout waters, >20 ^{o} C in 21 percent of samples; and pH, >8.5 or <6.5 in 13 percent of samples. At sites in nontrout waters the percentage of fecal coliform and total phosphorus data not meeting standards was 51 and 31 percent respectively.

In general, the best water quality at the 39 sites in the study area are at sites in the Flat Brook, Dunnfield Creek, Shimers Brook, Van Campens Brook, and Buckhorn Creek subwatersheds. Sites in these subwatersheds usually have the lowest levels of most constituents and highest dissolved oxygen. In contrast, Sites on the Paulins Kill, Musconetcong River, Pequest River, and Pohatcong Creek have the highest median values for more constituents than sites in other subwatersheds. Results from trends tests generally indicate improving water quality on the Musconetcong River, Paulins Kill, and Pohatcong Creek. Un-ionized ammonia, total phosphorus, water temperature, pH are decreasing and dissolved oxygen is increasing at some sites including some with the worst conditions. However, total dissolved solids and nitrate plus nitrite concentrations are increasing at some sites in the Musconetcong River and Pohatcong Creek. Pohatcong Creek has the highest median concentration of nitrate plus nitrite (1.93 mg/L), but highest values at the site are still substantially less than the instream standard.

In general, water quality in the study area is better than water quality in New Jersey as a whole. Streams in the study area have lower total suspended solids, total phosphorus, nitrate plus nitrite, water temperature and fecal coliform counts than data collected at the 109 statewide status sites, those randomly chosen for the USGS/NJDEP cooperative monitoring network to represent the range of water quality in the state. Dissolved oxygen, pH, total dissolved solids, and un-ionized ammonia are higher in the study area than in New Jersey as a whole.

In general, the quality of water in the study area is not as good as the quality of water at 6 sites chosen for the USGS/NJDEP cooperative monitoring network on streams draining predominantly undeveloped areas from across New Jersey. Dissolved oxygen is the only constituent with a median value indicative of better water quality in the study area than at the sites ranked among the best in New Jersey. The median values for all constituents at Dunnfield Creek, all except total dissolved solids at Flat Brook and nitrate plus nitrite concentration and fecal coliform counts at Musconetcong River at the outlet of Lake Hopatcong were lower or statistically comparable to the quality at the sites.

Median values of all constituents, except dissolved oxygen, were significantly related to land use upstream from the sampling site. Sampling sites draining areas of more than 78 percent

undeveloped land had significantly lower values than data collected at sites draining land with more than 19 percent urban or more than 19 percent agricultural land uses. Median values of all fecal coliform, total dissolved solids, and total phosphorus data collected at agricultural sites are significantly higher than median values of data collected from all urban and all undeveloped sites. Water temperature, pH, nitrate plus nitrite, un-ionized ammonia, and total suspended solids are equally high among the data collected at agricultural and urban sites.

Variability in water quality at a site is related to changes in season and/or flow condition. The following constituents were significantly higher in the growing season at one or more sites; water temperature, fecal coliform count, pH, total phosphorus, unionized ammonia and total dissolved solids. The following constituents were significantly higher in the nongrowing season at one or more sites; dissolved oxygen, pH, and nitrate plus nitrite. All constituents were significantly higher at low flow than at high flow at one or more sites except for dissolved oxygen, total suspended solids and nitrate plus nitrite which are higher at high flow.

INTRODUCTION

The Clean Water Act is a 1977 amendment to the Federal Water Pollution Control Act enacted by Congress in 1972 to address the issue of water quality in our nation’s waterways (Jarrell, 1999). One of its goals is to improve water quality in streams to a fishable and swimmable status. Initial efforts for improving in-stream water quality focused on implementing Best-Available-Technology for treating effluent from municipal wastewater treatment plants. Efforts focused on improving the quality of these point source discharges by requiring secondary and advanced treatment. This technology reduced the amount of nutrients, total suspended solids, biochemical oxygen demand, heavy metals and other pollutants discharged to streams.

The effort to upgrade point source discharges has lead to substantial improvements in water quality of many streams during the first 20 years of the CWA. On many streams improving the quality of point source effluent without addressing non point sources of pollution was not enough to attain fishable and swimmable status. During the first 20 years of the CWA nonpoint sources of pollution were rarely evaluated (Jarrell, 1999). Law suits, beginning in the late 1980’s, pushed the U.S. Environmental Protection Agency (USEPA) and state agencys to consider both point and nonpoint sources of pollution on a watershed basis (Jarrell, 1999).

The New Jersey Department of Environmental Protection (NJDEP) has implemented a watershed management approach for characterizing water quality in New Jersey. Watershed management area 1 (WMA1) comprises the upper Delaware River Watershed. To effectively understand the status of water quality, both point and nonpoint source contributions to pollution should be characterized in this area. The watershed approach considers the concerns of many stakeholders including municipal and industrial dischargers, water purveyors, municipal officials, environmental groups, agriculture, and development interests in working toward best management practices for cleaner water in the Upper Delaware Watershed. Results from this study will be used for watershed management planning and to prepare for a preliminary assessment of the nonpoint and point source loads in the study area.

NJDEP, as required by section 303d of the CWA, has identified a number of stream reaches in the Upper Delaware Watershed that exhibit observed or expected violations of surface water quality standards (NJDEP, 1998). The water quality parameters with violations include: pH, temperature, fecal coliform, un-ionized ammonia, and total phosphorus. Moderate biological impairment, based on results from macroinvertabrate studies, occurs at one or more sites in all the subwatersheds except Shimers Brook, Dunnfield Brook, VanCampens Brook, Pophandusing Brook, Pohatcong Creek, and Buckhorn Creek (NJDEP, 1997). Violations of water quality standards occurred in the Paulins Kill, Pequest River, Pohatcong Creek and Musconetcong River (NJDEP, 1997).

Purpose and Scope

The U.S. Geological Survey (USGS) in cooperation with the North Jersey Resource Conservation and Development Council (RC&D), the Natural Resources Conservation Service (NRCS) and NJDEP evaluated the water quality in WMA1. This report documents the results of the analysis of 9 water quality constituents that are among the most important for characterizing the water quality and health of streams in the watershed. The summaries of the results of analyses of 721 samples collected by the USGS/NJDEP cooperative network at 18 sites, 658 samples collected by the Delaware River Basin Commission (DRBC) at 15 sites, 58 samples collected by NJDEP at 15 Existing Water Quality (EWQ) sites, and 6 samples collected at 3 sites by the USGS National Water Quality Assessment Project (NAWQA) in the Upper Delaware River Watershed during the water years 1985 through 2001 are presented. Three DRBC sites and 9 EWQ sites are at the same location as USGS/NJDEP cooperative network sites. This evaluation of water quality includes descriptive statistics of concentrations, analysis of data in relation to water quality standards, comparisons between sites, subwatersheds and along stream reaches, analysis of changes in concentrations by season and flow condition, and a summary of trends over time.

This report also compares water quality in the study area to water quality in other areas of New Jersey. Data for the 9 constituents were compared to data collected by the NJDEP/USGS cooperative ambient stream monitoring network at 109 statewide status sites and 6 background sites located across the state. The statewide status sites are randomly chosen from each watershed management area and represent the variety of physiography and land uses found in New Jersey. The background sites are located on streams from among those with the highest water quality in the state of New Jersey.

The purpose for this initial analysis of water quality is to assess the water quality in streams draining to the Delaware River in Watershed Management Area 1 (WMA1). Results from this study will be used by NJDEP and Natural Resource Conservation Service (NRCS) for watershed management planning and to prepare for a preliminary assessment of the nonpoint and point source loads in the study area.

Description of Study Area

The Upper Delaware Watershed study area is approximately 744 square miles located in portions of Hunterdon, Morris, Sussex and Warren Counties in northwestern New Jersey and an additional 2 square miles of the Clove Brook subwatershed in New York state. The study area encompasses 14 tributaries, over 2 square miles (mi^2), to the Delaware River in WMA1 from the Musconetcong River north to the New York state line (**fig. 1**).

The 14 major subwatersheds are:

- Paulins Kill (177 mi^2)
- Pequest River (157 mi^2)
- Musconetcong River (156 mi^2)
- Flat Brook (65.2 mi^2)
- Pohatcong Creek (57.1 mi^2)
- Lopatcong Creek (14.7 mi^2)
- Buckhorn Creek (11.8 mi^2)
- VanCampens Brook (8.95 mi^2)
- Shimers Brook (7.47 mi^2)
- Pophandusing Creek (5.62 mi^2)
- Delawanna Creek (4.49 mi^2)
- Stony Brook (4.08 mi^2)
- White Brook (2.09 mi^2)
- Dunnfield Creek (3.56 mi^2)

The Clove Brook subwatershed (13.1 mi^2), is located in both New Jersey and New York and drains, to the Neversink River in New York.

The major impoundments in the watershed include:

- Lake Hopatcong (>2,000 acres)
- Merrill Creek Reservoir (6.2 acres)
- Upper and Lower Yards Creek Reservoirs (422 acres)
- Swartswood Lake (500 acres)
- Culvers Lake (550 acres).

Merrill Creek Reservoir is used to store water pumped from the Delaware River and water is released to the Delaware River at low flow conditions. Merrill Creek is a tributary to Pohatcong Creek.

The Upper Delaware study area drains an area encompassing two physiographic provinces. The New England province covers the southern part of the study area including the Musconetcong River, Pohatcong and Lopatcong Creeks and portions of the Pequest River, Pophandusing Creek and Buckhorn Creek subwatersheds. This area is underlain by predominately granite, gneiss, and small amounts of marble of Precambrian age. These rocks are resistant to erosion and create a hilly upland dissected by deep steep-sided valleys of major streams. The Valley and Ridge province covers approximately two thirds of the study area including all tributaries upstream from Pequest River and including portions of the Pequest River, Pophandusing and Buckhorn Creek subwatersheds. The area is underlain by faulted and folded sedimentary layers of sandstone, shale, and limestone. Alternation of belts of erosion resistant sandstone and easily eroded shale and limestone creates the long parellel northeast-southwest trending ridges and valleys characteristic of the province (NJDEP, 1992).

The 39 water-quality sites sampled by the NJDEP/USGS cooperative network, USGS LINJ NAWQA project, and the DRBC, between 1985-2001 and NJDEP EWQ in 2001 and are located throughout the study area (**fig**. **1**). Three sites are sampled in both the NJDEP/USGS and NJDEP networks. Sampling sites are located in 12 of the 14 major subwatersheds. White Brook, the smallest subwatershed, and Stony Brook (4.08 mi^2) are the only tributaries to the Delaware River, in the study area, greater than 2 square miles without any data for the constituents studied. Thirty sites drain watersheds located entirely in one province; eighteen in the Valley and Ridge, and twelve in the New England province. Nine sites along the Paulins Kill, Pequest River, Pophandusing Brook and Lopatcong Creek drain areas located in both provinces (**fig. 2**). The water flowing past the USGS/NJDEP network sites drains 549 mi^2 or 74 percent of the land area in WMA1. The water flowing past the DRBC sites drains 648 mi^2 or 87 percent of WMA1. The EWQ network sampled 15 sites; 9 of which coincide with NJDEP/USGS or NJDEP network sites. Twenty-six sites are located in trout maintanance waters, nine are in trout production waters and 4 are on streams classified as nontrout waters.

The land uses in the study area are derived from a GIS coverage developed from 1995/97 digital infrared aerial photos (NJDEP, 2000) using the Anderson method of classification (Anderson, and others, 1976). Land uses are characterized based on percentages of urban, agriculture, forest, wetland, open water, and barren land for the study area and for each subwatershed. Undeveloped land comprised 67 percent of the land area in WMA1 (**table 1**). Forested areas comprise 53.3 percent, reservoirs, lakes and ponds 3 percent, wetlands 10 percent and barren areas 0.7 percent of the study area. Developed areas account for nearly 33 percent of the study area; 19.0 percent is used for agricultural purposes and 13.6 percent is used for residential, commercial and industrial uses. The highest percentages of undeveloped land (84.6 - 99.9 percent) are located in the Dunnfield Creek, Vancampens Brook, Flat Brook, and Shimers Brook watersheds (**fig 2**). The largest areas of urban land use are located in the vicinity of Lake Hopatcong and Hackettstown in the upper portions of the Musconetcong River watershed, Washington in the headwaters of the Pohatcong Creek watershed, Newton Borough in the Paulins Kill watershed and the Phillipsburg area located at the downstream end of the Lopatcong Creek watershed. The highest percentages of agricultural land uses (30-46%) are found in the Pophandusing Brook, Delawanna Creek, Lopatcong Creek, Pohatcong Creek, and Buckhorn Creek subwatersheds.

Municipal and industrial point source discharges exist in 6 of the 14 subwatersheds (**table 1**). Sampling sites in the Paulins Kill, Pequest River, Pohatcong Creek, Musconetcong River, Pophandusing Creek, and Lopatcong Creek subwatersheds are influenced by point sources. Sampling sites in the Musconetcong River, Paulins Kill, and Pequest River, are influenced by 14, 14 and 10 permitted point sources respectively. The Lopatcong and Pohatcong Creeks and the Pophandusing Brooks are each influenced by discharges from 2 permitted point sources. Flow data from 1994-99 for municipal facilities indicates the following amount of effluent discharged upstream of sampling sites in each watershed; 0.9 cfs to the Pequest River, 1 cfs to the Pohatcong Creek, 1.7 cfs to Paulins Kill, and 5.8 cfs to the Musconetcong River. Effluent is less than 5 percent of median flow at all sites.

Table 1. Thirty-nine surface water quality sites sampled by the NJDEP/USGS network, the Delaware River Basin Commission (DRBC)and the NJDEP Existing Water Quality Network (EWQ) in the Upper Delaware River watershed from 1985-2001, watershed characteristics, and historical period of record [Site numbers, eight digit numbers are NJDEP/USGS sites, EWQ are EWQ sites, DRBC are DRBC sites; Flow record, G = continuous record, P = partial record; 1995/97 landuse data from New Jersey Department of Environmental Protection; population density from 1990 census; Impairment Status, N= nonimpaired, M= moderate, S=severe; Classification, TP= trout production, TM= trout maintanance, NT= nontrout; land use percentages in bold text represent the predominant land use type at site]

Site Number	Site name	Drain - age Area (mi^2)	Flow Record	Historical period of water-quality record	Number of point sources upstream from site	Surface Water Classification	AMNET biological impairment status	Land Use (in percent)							
								Urban	Agriculture	Forest	Water	Wet-land	Bar-ren	Total Undeveloped	Total Developed
WMA1	Watershed management Area 1	743.65	--	--	--	--	--	13.60	19.00	53.3	10.30	3.00	0.70	67.30	32.6
01439830, EWQ7	BIG FLAT BK AT TUTTLES CORNER NJ	28.3	P	1976-82, 1998	None	TP	N	1.55	0.43	86.5	9.84	1.67	0.00	**98.02**	1.98
01440000	FLAT BROOK NEAR FLATBROOKVILLE NJ	64.0	G	1976-80, 1993, -95, 1997-2000	None	TM	N	3.00	5.20	80.5	9.40	1.70	0.04	**91.11**	8.20
01440010	FLAT BROOK AT FLATBROOKVILLE NJ	65.0	None	1997	None	TM	N	2.90	5.20	80.8	9.30	1.70	0.04	**91.84**	8.10
01442760 /DRBCNPS 0025	DUNNFIELD CREEK AT DUNNFIELD NJ	3.56	P	1998-2000	None	TP	N	0.11	0.00	97.5	2.37	0.00	0.00	**99.89**	0.11
01443290	PAULINS KILL US NJ RT 15 AT LAFAYETTE NJ	26.3	None	1997	7	**TM**	**M**	**22.20**	18.60	34.2	19.50	3.10	2.30	59.10	40.8
01443370, EWQ8	DRY BROOK AT COUNTY ROUTE 519 NEAR BRANCHVILLE NJ	2.69	None	2000	None	NT	N	8.68	**19.77**	60.98	8.71	1.86	0.00	71.55	28.4
01443440, EWQ9	PAULINS KILL AT BALESVILLE NJ	67.1	P	1979-97	9	NT	N	17.47	**23.58**	39.57	15.55	3.83	0.00	58.95	41.0
01443500	PAULINS KILL AT BLAIRSTOWN NJ	126	G	1976-2000	11	TM	N	14.65	**20.11**	49.06	12.14	4.04	0.00	68.65	34.8
01443550	JACKSONBURG CREEK NEAR MILLBROOK NJ	2.43	None	1999	None	TM	N	5.82	0.00	83.78	9.21	1.19	0.00	**94.18**	5.82
01443600	JACKSONBURG CREEK NEAR BLAIRSTOWN NJ	8.34	None	1999	None	TM	N	12.49	9.27	70.47	6.88	0.89	0.00	**78.24**	21.8
01444970	PEQUEST R AT RT 206 BL SPRINGDALE NJ	10.1	None	1998	None	**TM**	**M**	12.76	**24.53**	44.95	15.36	2.40	0.00	62.71	37.3
01445000, EWQ10	PEQUEST RIVER AT HUNTSVILLE NJ	31.0	P	2000	3	TM	N	15.58	15.69	52.17	12.68	3.88	0.00	68.73	31.3
01445500	PEQUEST RIVER AT PEQUEST NJ	106	G	1976-80, 91-97	9	TM	N	12.59	**24.18**	47.32	13.88	2.02	0.00	63.23	36.8
01446400/ DRBCNJ00 33	PEQUEST R AT BELVIDERE NJ	157	P	1976-82, 1998-2000	10	TM	N	12.10	**21.40**	48.00	16.00	1.90	0.60	66.50	33.5
01455200	POHATCONG CREEK AT NEW VILLAGE NJ	33.3	P	1979-97	2	TM	**M**	18.55	**26.07**	45.95	9.12	0.32	0.00	55.4	44.6
01455500	MUSCONETCONG R AT OUT OF LAKE HOPATCONG NJ	25.3	P	1976-91	1	TM	**M**	**28.28**	0.00	47.52	8.01	16.18	0.00	71.7	28.3
01455801	MUSCONETCONG R AT LOCKWOOD NJ	60.1	P	1976-91	3	TM	**M**	**23.00**	0.40	48.00	9.50	9.90	9.20	76.6	23.4

Site Number	Site name	Drain - age Area (mi^2)	Flow Record	Historical period of water-quality record	Number of point sources upstream from site	Surface Water Classification	AMNET biological impairment status	Land Use (in percent)							
								Urban	Agriculture	Forest	Water	Wet-land	Bar-ren	Total Undeveloped	Total Developed
01456200	MUSCONETCONG R AT BEATTYSTOWN NJ	90.3	P	1976-97	7	TM	N	**24.41**	3.00	56.77	8.67	7.15	0.00	72.6	27.4
01456600	MUSCONETCONG RIVER AT HAMPTON N.J	122	None	1997	9	TM	N	**21.00**	11.20	52.60	8.30	5.60	1.20	67.7	32.2
01457000	MUSCONETCONG RIVER NEAR BLOOMSBURY NJ	141	G	1976-80, 1991-97	10	TM	N	**19.90**	16.60	49.70	7.70	5.00	1.10	63.5	36.5
01457400/ DRBCNPS 0025	MUSCONETCONG R AT RIEGELSVILLE NJ	156	P	1976-2000	15	TM	N	**20.83**	18.88	48.91	6.90	4.48	0.00	60.3	39.7
DRBCNPS 0047	SHIMERS BK AT RT 521 AT MONTAGUE NJ	6.95	P	1984-2000	None	TP	N	11.80	3.50	67.00	12.80	4.60	0.25	**84.6**	15.3
DRBCNPS 2251	LITTLE FLAT BK AT PETERS VALLEY, NJ	28.1	None	1990-2000	None	TP	N	7.80	13.60	65.80	11.20	1.50	0.02	**78.5**	21.4
DRBCNPS 2252	BIG FLAT BROOK AT PETERS VALLEY, NJ	32.7	None	1990-2000	None	TP	N	1.70	0.40	85.90	10.00	1.90	0.04	**97.8**	2.10
DRBCNPS 0321	FLAT BROOK AT WALPACK CENTER, NJ	55.8	None	1988-93	None	TM	N	3.40	5.00	79.70	10.10	1.70	0.04	**91.5**	8.40
DRBCNPS 0032	FLAT BK AT OLD MINE RD AT FLATBROOKVILLE, NJ	65.0	None	1984-93	None	TM	N	3.00	5.20	80.80	9.30	1.70	0.04	**91.8**	8.20
DRBCNPS 0031	VAN CAMPENS BK AT OLD MINE RD NR MILLBROOK, NJ	7.6	P	1984-2000	None	TP	N	1.30	0.00	94.10	3.00	1.50	0.02	**98.6**	1.30
DRBCNJ0036	PAULINS KILL AT RT 46 BRIDGE AT COLUMBIA, NJ	165	P	1987, 1999-2000	14	TM	N	7.80	13.60	65.80	11.20	1.60	0.02	**78.6**	21.4
DRBCNJ0035	DELAWANNA CK AT RT 46 AT KNOWLTON TWP, NJ	4.4	None	1987, 1999	None	--	N	13.80	**43.60**	29.10	11.70	1.80	0.00	42.6	57.4
DRBCNJ0031	POPHANDUSING BK AT SPRING ST. AT BELVIDERE, NJ	5.3	None	1999	2	TM	N	11.50	**46.00**	31.90	4.80	0.80	5.00	42.5	57.5
DRBCNJ0030	BUCKHORN CREEK AT HUTCHINSON, NJ	8.5	None	1997-2000	None	TP	N	8.00	**30.00**	55.60	4.80	0.50	1.00	61.9	38.0
DRBCNJ0028	LOPATCONG CK AT MAIN ST AT PHILLIPSBURG, NJ	14.4	None	1987, 1999-2000	2	**NT**	**M**	28.40	**38.20**	27.00	2.50	0.08	3.80	33.4	66.6
DRBCNJ0027	POHATCONG CK AT RT 519 AT POHATCONG TWP, NJ	54.6	None	1987, 1999-2000	2	TM	N	17.10	**32.70**	40.00	7.40	2.30	0.50	50.2	49.8
EWQ1	CLOVE BROOK AT DUTTONVILLE, NJ	--	--	2001	--	--	--	--	--	--	--	--	--	--	--
EWQ2	BEAVER BROOK AT SAREPTA, NJ	--	--	2001	--	--	--	--	--	--	--	--	--	--	--
EWQ3	LOPATCONG CREEK AT PORT WARREN, NJ	--	--	2001	--	--	--	--	--	--	--	--	--	--	--
EWQ4	LUBBERS RUN AT LOCKWOOD, NJ	--	--	2001	--	--	--	--	--	--	--	--	--	--	--
EWQ5	MUSCONETCONG RIVER AT NEW HAMPTON, NJ	--	--	2001	--	--	--	--	--	--	--	--	--	--	--
EWQ6	LITTLE FLAT BK AT SANDYSTON TOWNSHIP, NJ	--	--	2001	--	--	--	--	--	--	--	--	--	--	--

Effluent is less than 5 percent of median flow at all sites. At low flow (95th percentile), municipal effluent accounts for 21 percent of instream flow at Pohatcong Creek and 15 percent at Musconetcong River at Beattystown.

Previous Studies

Relations of water quality to streamflow were determined for 18 water quality constituents at 8 surface-water stations within the Delaware River watershed (WMA1) for the years 1976-93 (Buxton and others, 1999). Trends were evaluated for both high and low flow periods for both concentrations and loads. Median concentrations for 1989-93 were compared to the median value from 1976-93.

Trend tests on values of 24 water-quality characteristics at 83 surface-water quality stations in New Jersey, including 8 stations in the Upper Delaware River Watershed, were conducted on data from 1986-95 (Hickman and Barringer, 1999). The presence of trends in the concentrations of constituents at these stream sites were analyzed for statistical association with watershed characteristics (Robinson and others, 1996).

A study on the presence and distribution of volatile organic compounds in streams in New Jersey included data from 3 stations in the study area. The presence and variability of 86 volatile organic compounds in streams in New Jersey and Long Island New York, including 3 stations in WMA1, was evaluated from data collected during January 27-30, 1997, from stations chosen to represent an urban land-use gradient (O'Brien and others, 1998).

A similar study on the presence and distribution of pesticides at 50 stream sites in New Jersey and Long Island New York, included 3 stations in the study area. The presence and variability of 47 pesticides was evaluated from data collected June 9-18, 1997 (Reiser and O'Brien, 1999). Stations were chosen to represent the gradient of land uses found in the study area and analyses focused on the relation of concentrations to land use.

The presence and distribution of trace elements in bed sediment data from 1976-93 in New Jersey streams, included 5 sites in the Pequest River, Paulins Kill and Pohatcong Creek subwatersheds (O'Brien, 1997). The relation of concentrations to watershed characteristics was evaluated. The presence and distribution of chlorinated organic compounds in bed sediment data from 1976-93 in New Jersey streams, included 4 sites in the Pequest River, Paulins Kill and Pohatcong Creek subwatersheds (Stackelberg, 1997).

The biological assessment of benthic macroinvertebrate communities in New Jersey streams by the NJDEP Ambient Biomonitoring Network (AMNET) has been used to rate water quality. A rating of stream impairment has been assigned to streams in the study area based on the the benthic-macroinvertebrate population at the stream site. The AMNET rating was assigned to 74 stream sites in WMA1 based on 1992 data (NJDEP, 1994). Results showed 1 severely impaired site (1.4% of total sites) at Furnace Brook at Oxford, 19 moderately impaired sites and 54 nonimpaired sites in WMA1. Species of the instream macroinvertebrate community occupy distinct niches based on their tolerance to environmental conditions. An integrated assessment of the benthic community results in an impairment status for each site. The three possible ratings are non-impaired--the benthic community is comparable to communities found in other undisturbed streams within the region and is characterized by a maximum taxa richness, balanced taxa groups, and good representation of intolerant species; moderately impaired --the macroinvertebrate richness and community balance are reduced and intolerant taxa are absent; or severely impaired-- the benthic community has dramatically changed and macroinvertebrates are dominated by a few tolerant taxa (Buxton and others, 1999). Chemical and physical data along with biological impairment status are good indicators of stream quality and possible sources of impairment.

METHODS OF STUDY

Water Quality Data

Water quality and stream flow data used in this study are primarily from the cooperative network of the USGS and NJDEP (Reed and others, 2000). Data from 1,449 samples collected from 39 sites in four data networks was used for this project. Eighteen sites in the Upper Delaware Watershed study area have water quality data from 721 samples available in the USGS database from 1985-2000. Eleven of those sites have data collected routinely five times per year for varying numbers of years between 1985 – 1997 as part of the cooperative network (**table 1**). Seven sites sampled after 1997 have data collected routinely four times per year as part of the statewide cooperative network. Three sites were sampled twice (6 samples) during the study period as part of a data collection effort for the USGS Long Island/New Jersey National Water Quality Assessment (LINJ NAWQA) project. From 1985-2000, 658 samples were collected at the 15 DRBC sampling sites. Three DRBC sites coincide with sites sampled by NJDEP/USGS.

Data from the NJDEP EWQ network was made available for this study. Fifty-eight samples were collected by NJDEP at 15 sites in the study area between November 2000 and August 2001. Nine of the sites are at the same location as USGS/NJDEP or DRBC network sites. The EWQ sites on Clove Brook, Beaver Brook and Lubbers Run sites provide the only available data on those streams. Three other EWQ sampling sites on Little Flat Brook, Lopatcong Creek and Musconetcong River at New Hampton are at different locations on streams sampled by the other networks. The minimum and maximum values reported for the 3 or 4 samples collected at each site and those sites with values greater than the standard were summarized.

The period 1985-2000 was chosen to allow for an adequate amount of data for statistical analysis. Beginning in water year 1998, the NJDEP/USGS network of sites changed and many of the sites included in this study were no longer sampled. New network sites were chosen each year in the study area beginning in 1998 and sampled for one year. A background site was selected on Dunnfield Creek in 1998 and sampled through 2000. Additional samples were collected at sites on the Flat Brook (01440010), Paulins Kill (01443290), and Musconetcong River (01456600) in 1996-97 for the USGS Long Island/New Jersey National Water Quality Assessment (LINJ NAWQA) project. The data collected at these sites during the study period include dissolved oxygen, pH, water temperature, nutrients, major ions, dissolved and suspended solids, and fecal coliform. Pesticides and volatile organic compounds were sampled at the network sites once a year beginning in 1998.

Selection of Constituents

Nine constituents considered to be important indicators of the water quality in the Delaware River Watershed were chosen for analysis in this preliminary evaluation. There is a sufficient amount of data for the chosen constituents during the period 1985-2000 necessary to complete a statistical analysis. The constituents chosen for analysis include dissolved oxygen, fecal coliform, nitrate plus nitrite, pH, total phosphorus, total dissolved, and total suspended solids, un-ionized ammonia and water temperature. All constituents have established surface water-quality standards except nitrate plus nitrite which only has a drinking water standard. The instream standard is for nitrate only.

Un-ionized ammonia concentrations were calculated from total ammonia concentrations provided from the laboratory, and pH and water temperature measured in the field. The following equation was provided by Kevin Berry, NJDEP, written commun., 1999.

$$\text{Un-ionized ammonia-N} = [100/[1+ \text{antilog}((0.09018+2729.92/T)-\text{pH})]*(NH_3)/100] \qquad (1)$$

where T is water temperature in degrees Kelvin (^oK), ^oK = 273.15 + degrees Celsius, and NH_3 is ammonia-N.

Un-ionized ammonia (NH_3) concentrations, calculated from total ammonia, pH, and water temperature, were analyzed for the assessment of water quality conditions in the watershed. Ammonia is very soluble in water. It is an important compound in biological processes and is produced as a normal biological degradation product (Schornick and Fischel, 1980). The toxicity of an aqueous solution of ammonia is attributed to the un-ionized (NH_3) component (Schornick and Fischel, 1980). Un-ionized ammonia has a surface water quality standard not to exceed an average 24-hour concentration of 0.05 milligrams per liter (mg/L) in nontrout streams and 0.02 mg/L in trout streams (NJDEP, 1998). Samples collected from the USGS/NJDEP network are not analyzed for un-ionized ammonia. However, total ammonia concentrations, pH and water temperature were used to compute un-ionized ammonia for this project. Un-ionized ammonia has the lowest detection frequency of the 9 constituents (38 percent) at sampling sites in the watershed. Un-ionized ammonia was found to exceed water quality standards in the Musconetcong River subwatershed in a previous investigation (NJDEP, 1997).

Dissolved oxygen (DO) is a direct measurement of the overall water quality of the river. The concentration of dissolved oxygen in streams depends on physical, chemical and biological characteristics of the water body. Warm temperatures, the presence of organic compounds and biological activitity reduce the amount of dissolved oxygen in water. The presence of organic compounds can cause biological and chemical oxygen demand in water. Turbulence, photosynthesis and decreases in temperature increase the amount of dissolved oxygen in water. A previous analysis of DO concentrations did not report levels below the instream water quality standards on the study area (NJDEP, 1998). Three different surface water standards exist for dissolved oxygen in New Jersey surface waters. The instantaneous criteria are > 4 mg/L in nontrout waters, >5 mg/L in waters classified as trout maintenance and >7 mg/L in waters classified as trout production (NJDEP, 1998).

Fecal coliform levels are a measure of the sanitary quality of water. Fecal coliform bacteria can indicate the presence of untreated human wastewater and animal feces. High numbers can cause streams to be unsuitable for swimming and fishing. Previous studies have found fecal coliform levels exceeding the established criteria at sites in the Paulins Kill, Pequest River, Pohatcong Creek and Musconetcong River watersheds (NJDEP, 1997). Fecal coliform levels have two surface water standards. Levels should not exceed a geometric mean of 200 colonies per 100 milliliters (ml) or 400 colonies/100 ml in more than 10 percent of total samples in a 30-day period (NJDEP, 1998).

Nitrate plus nitrite represents the oxidized form of nitrogen in the stream. Nitrate plus nitrite has a combined drinking water standard of 10 mg/L (USEPA, 1996). An instream standard of 10 mg/L exists for nitrate only. Nitrite is found in very small concentrations in surface waters because it is rapidly oxidized to nitrate. Nitrate enters surface water from wastewater treatment plants, and in fertilizers carried to the stream in storm runoff and groundwater. It is a primary nutrient of rooted aquatic plants and algae. Nitrate is found in surface water in much higher levels than nitrite. Nitrate is considerably less toxic to aquatic organisms than are ammonia and nitrite; however in excess amounts (>10 mg/L), nitrate contributes to methemoglobinemia in small children (Buxton and others, 1999).

The New Jersey surface water standard for pH is > 6.5 and <8.5 (NJDEP, 1998). The pH of water is a measure of the negative logarithm of the hydrogen ion concentration. Values less than 7 are considered acidic and values greater than 7 are considered basic. The aquatic life found in a stream is influenced by the pH. During the day photosynthesis depletes the concentration of carbon dioxide in the water and causes an increase in pH. Samples analyzed for this study were collected in late morning or early afternoon, a time when pH would be expected to be higher than at night.

Total phosphorus concentrations are important to stream health. It is a primary nutrient for algae and aquatic plants and can stimulate excessive growth. The New Jersey standard states that total phosphorus shall not exceed 0.1 mg/L in any stream unless it can be proven that phosphorus is not a limiting nutrient and will not otherwise render the water unsuitable for the designated uses (NJDEP, 1998). Levels over 0.1 mg/L surface are common throughout the Upper Delaware River Watershed. A second surface-water standard of 0.05 mg/L exists for lakes and reservoirs and for streams at the point of entry to these water bodies (NJDEP, 1998). Phosphates are found in solution and associated with particulates. Phosphorus is present in surface water as orthophosphates, condensed phosphates (ie polyphosphates), and organically bound phosphates (Sawyer and McCarty, 1978). Orthophosphorus applied to agricultural land, lawns, and gardens can be washed into streams in runoff. Phosphorus also enters streams from waste-water treatment plants.

Total dissolved solids (TDS) are an important constituent for purveyors and water users. A high concentration of TDS can have impacts on the taste of water and could impact hospitals, industrial facilities and the stream ecosystems. TDS concentrations are increasing over time at some locations in the watershed. The surface water and drinking water standards are both 500 mg/L (USEPA, 1996). Natural factors such as Bedrock and soil are natural sources of TDS in stream water. Human influences from point and nonpoint sources also contribute to TDS in streams.

Total suspended solids (TSS) are regulated and may be one of the more important indicators of non-point source pollution. The health of stream ecosystems are effected by concentrations of TSS. The primary sources of TSS in streams are storm runoff, instream erosion, and resuspension. The surface water standard is not to exceed 40 mg/L in nontrout waters and 25 mg/L in trout waters (NJDEP, 1998).

Water temperature influences the chemical and biological processes in a stream. The amount of sunlight, rainfall, air temperature, the amount of groundwater discharging to a stream and thermal point sources all influence water temperature of a stream. New Jersey surface water criteria for stream temperatures are less than 20^{o} Celsius for trout waters and less than $27.8\ ^{o}$ Celsius for nontrout waters (NJDEP, 1998).

Data Review

All data was reviewed extensively for quality assurance purposes and moved to a data base for data manipulation and statistical analysis. Data for 11 constituents was plotted versus streamflow, plotted to observe seasonal differences and compared with measured levels of other constituents. The review resulted in less than 0.1 percent of the values from the NJDEP/USGS network being changed or removed from the database. Two values of total phosphorus, one value of total suspended solids and one value of dissolved oxygen were removed from the data base. These data points were suspicious outliers that did not match the other data. A total phosphorus samples was an order of magnitude higher than another sample collected at the same site on the next day at the same flow conditions by another project. Phosphorus and total suspended solids were unusually high in the same sample. Sediment was believed to have been stirred up from the bottom. An unusually high dissolved oxygen reading of 15.6 mg/L was believed to be inaccurate.

Some nitrate plus nitrite and phosphorus data collected by the DRBC were derived from field kit determination. The nutrient data collected by the field kit method was footnoted and provided to USGS (written commun. Bob Limbeck, DRBC). The data generated by the field kit analysis were not included in the project database with the laboratory generated results that were used for statistical analysis.

Missing values of total nitrate plus nitrite from the USGS/NJDEP network data were replaced with values of dissolved nitrate plus nitrite. Little difference is observed when both values are present for a sample. Nitrate plus nitrite is present in water almost exclusively as dissolved species (Hem, 1985). Missing values of total suspended solids were substituted with values of total suspended sediment.

Statistical Methods

Water samples were categorized by the season and the hydrologic condition in which they were collected. The growing season is April through October, and the nongrowing season is November through March. The dates for defining these seasons are based on the average times of the first and final frosts in

New Jersey (Ruffner and Bair, 1977). Growing season samples accounted for 491 of the 727 samples collected at NJDEP/USGS network sites. Growing season samples accounted for 627 of the 658 samples collected at the DRBC sampling sites. Ten of the 15 DRBC sites had no nongrowing season samples.

All NJDEP/USGS network samples were grouped into one of two flow categories, lowflow or highflow. A lack of streamflow data at the DRBC sites prohibited analysis of data by flow condition at those sites. Lowflow samples are defined as those collected when the streamflow was less than the fifteen year (1985-2000) median flow at the site. Highflow samples are defined as those collected when the streamflow was greater than the fifteen year median flow. Median flow was computed from mean daily stream flow at gaging stations and from a USGS flow estimating program (MOVE1 correlation) at sites with a partial record of stream flow (Hirsch, 1982). Drainage area adjustment and median flow per square mile from nearby sites was used to estimate median flow at sites without flow data.

Detection frequencies were computed for each constituent. Water quality data that contain concentrations of constituents reported as less than or in some cases greater than an analytical detection limit set by the laboratory are considered censored data or nondetections. Four of the nine constituents contain censored data. Nonparametric methods of statistical analysis are used on these censored data sets.

Percentiles show the percent of samples with concentrations that are less than a particular value. These statistics are used to analyze the distribution of concentrations in a data set. Percentiles of censored data sets are computed using the maximum liklihood estimation (MLE) method developed by Helsel and Cohn (1988). With this method the censored values contain nearly as much information for estimating percentiles as would the same observations had the detection limit been below them (Helsel and Cohn, 1988). Medians of highly censored constituents shown in tables and used for comparisons to land use are derived from this method. Estimates were only used if censored values are less than 50 percent of the population. Percentiles were used to summarize the data and to make comparisons at each site and among sites by season, and flow. The inner quartile range (IQR) was used to measure variability of data. It measures the range of the central 50 percent of the data and is defined as the 75th percentile minus the 25th percentile (Helsel and Hirsch, 1992). IQR was used instead of variance or standard deviation because it is not influenced by outliers.

One-way analysis of variance (ANOVA) using a general linear model for unbalanced datasets, was applied to the ranks of data values to test for differences in median values among 3 or more datasets. The test was used to make comparisons between data from differant groups of sites in the study area. The null hypothesis (H_O) states that mean rank concentrations are equal in each dataset. The alternate hypothesis states that the mean rank concentration from at least one dataset differs from the others. If the null hypothesis is rejected, Tukey’s test was used to determine which mean rank concentrations in the group were significantly different at the 0.05 level. The Tukey’s test takes the mean rank concentrations and shows which groups differ significantly (Helsel and Hirsch, 1992). Two-way ANOVA was applied to ranks of concentrations to simultaneously test whether the significance of season, flow, and season as a function of flow are significant factors contributing to changing concentrations in streams.

A regression technique was used to evaluate the data. Median values of the 9 compounds were evaluated with respect to land use at the 12 sites with 20 or more samples by using least squares linear regression (OLS) (Ott, 1988). Relations between median concentration, temperature, fecal coliform count and pH and percent land use were analyzed. The relation was considered to be significant if the slope of the regression line was different from zero at the 0.05 level of significance. A base-10 logarithm transformation of percent land use and median concentrations were used to normalize the data when necessary before running the regression.

The Wilcoxan rank sum test was used to test for differences in the means of two data sets. It is the nonparametric equivalent to a t-test. Data collected by DRBC was compared to data collected by the NJDEP/USGS network at the same 4 sites in the growing season. This test was performed on all 9 constituents collected at each of the 4 sites. The null hypothesis (H_O) states that mean rank concentrations are equal at each site and assumes that sampling techniques and analytical procedures used by the agencies yields the same result. A p-value of 0.05 was used to minimize the chance that the difference occured by chance alone.

Trend tests were conducted for this study on data from 1985 through 2000 by using the Seasonal Kendall test (Helsel and Hirsch, 1992). This is a nonparametric test designed for water quality data that are not normally distributed. The test also accounts for seasonal variability in the data by only comparing data collected in the same season. The test was performed on all constituents, those with and without censored data. All censored values in the dataset were used in the analysis by substituting a value of one half the censored value. A significant trend exists if the test statistic tau was significantly different from zero at the 0.05 level. The seasonal kendall test was performed for this study on all data at sites with a regular sampling interval of 4 times per year for 7 or more consecutive years.

Presentation of tables appendixes and figures

The tables and figures presented in this report summarize much of the statistical analysis of the water quality data. **Figures 1 and 2** are maps showing the location of the sampling sites, land use and physiographic provinces.

Boxplots presented in **figures 3-5**, show the distribution of the central 50 percent of data at each site. The boxplots are sorted in the figures in downstream order by subwatershed from left to right. The first boxplot on the left is the sampling site closet to the New York state border. The horizontal line through the middle of the rectangle represents the median value at the site. The horizontal line at the top of the box indicates the 75th percentile--75 percent of the data are less than this value--and the horizontal line at the bottom of the rectangle represents the 25th percentile. Outliers are not presented. For example, in **figure 3**, the inner quartile range (IQR) for dissolved oxygen at the first site on the left is 2.7 mg/L (13.1 minus 12.4). The horizontal lines in blue and green represent the median values of the constituent at randomly selected statewide and background sites respectively. The black line represents the median value of the medians at each site in the study area. The red lines indicate the New Jersey surface water standard.

The cumulative probability curves presented in **figures 6-23** , are another way to analyze the distribution of data at each site. Curves with steeper slopes indicate a wider range of values. The y axis is a range of values covering all the samples analyzed. The x axis is the percent of time samples are below a given value. For example, **figure 6** shows that 100 percent of samples are less than 0.05 mg/L at all 12 NJDEP/USGS sites and only a small percent of samples at Pohatcong Creek and two of the Musconetcong River sites are greater than 0.02 mg/L un-ionized ammonia. Horizontal lines representing the values of instream water quality standards are included in the figures to show the percentage of values at each site below the standard.

The scatter plots presented in **figures 24-26** show the median values of selected constituents at 12 NJDEP/USGS sites. The median values are sorted by the percentage of a given land use at each site. The scatter plots shown in the figures are only for those constituents with a significant relation to land use. The line in each scatter plot represents the OLS linear regression relation. The stacked bar chart at the top of each figure shows the percentage of each major land use category at the 12 sites.

Figures 27-31 are maps showing the location of sampling sites in each subwatershed. The tributaries are sorted into 5 subwatersheds; Flat Brook, Paulins Kill, Pequest River, Pohatcong/Lopatcong Creeks, and Musconetcong River. The Flat Brook subwatershed includes the Flat Brook, Shimers Brook, Van Camperns Brook, and Dunnfield Creek. The Pohatcong/Lopatcong subwatershed includes Lopatcong Creek, Pohatcong Creek, Delawanna Creek, and Buckhorn Creek. A bar chart is associated with each sampling site. Each bar in the chart represents the median value of that constiteunt as a percentage of the New Jersey surface water standard. The median of pH is not included because there is an upper and lower limit. The other constituents are referenced to a single limit. The goal for dissolved oxygen is to be above the standard while the goal for the other 7 constituents in the bar chart is to be below the standard. The bars for dissolved oxygen over 100 percent imply the median value in meeting the instream standard. Bars over 100 percent for other constituents imply median values not meeting the standard.

In **appendix 1, tables 1a-1c** list the New Jersey surface water and drinking water standards for the 9 constituents. The tables list the percentage of samples not meeting the standards in streams designated as nontrout , trout maintanance, and trout production waters (NJDEP, 1998). **Table 1a** includes a summary of all samples at NJDEP/USGS sites not meeting standards by season and flow condition. **Table 1b** shows the percentage of samples not meeting the standards at DRBC sites. **Table 1b** does not show a summmary by flow condition because the vast majority of samples collected at DRBC sites are not associated with flow data. **Table 1c** lists the geometric mean of fecal coliform counts for water years 1985-2000 at the network sites. Tbale 1d lists the geometric mean of fecal coliform counts for the DRBC sites.

In **appendices 2** through **10, Tables 2a-c** through **10a-c** list the statistical summary of values for each of the 9 water-quality constituents and the summary of statistical differences in median values by season and flow condition. The tables include the number of data points at each site, the standard deviation, inner quartile range, minimum and maximum value observed at the site and the 25th, 50th, and 75th percentile values. The percentile statistics represent the percentage of data points that are less than the number indicated. For example, in **table 2a**, the 75th percentile indicates that 75 percent of the values of un-ionized ammonia calculated for site 01440000 are less than 0.0005 mg/L.

Tables 2c, 3c, 4c, 5c, 6c, 7c, 8c, 9c, and 10c list a comparison of median values by season and flow condition at each site, significant differences in concentrations between seasons and between flow conditions, and the results showing if there is a significant interaction between season and flow. Significantly higher values in a season are indicated by a “G” for growing season and a “NG” for nongrowing season. Significantly higher values for a flow condition are indicated by a “LO” for low flow and a “HI” for high flow. Significantly higher values at high flow in the growing season are designated G@HI.

The column titled “flow and season interaction” lists results of a 2-way ANOVA on season and flow. The column indicates whether values collected from a particular flow condition in a single season is significant or not. For example, in **table 2c** , un-ionized ammonia values at site 01440000 are shown to be significantly higher in the growing season than in the nongrowing season. Flow alone was not a significant variable in predicting variability. However, when season and flow were considered together, samples collected in the nongrowing season at high flow had a significantly higher median value than those collected under other conditions.

Table 2 shows a summary of streamflow statistics at the sampling sites. **Tables 3, 4, 5**, and **6** show statistical summaries of data collected at all statewide background, NJDEP/USGS network, statewide status, and existing water quality sites, respectively. **Table 7** shows the results of the seasonal kendall tests for trends. The numbers in the table represent slopes of significant trend lines. The numbers indicate the change in units per year. **Table 8** is a summary of water quality conditions. The color of the table cells indicate the median value represented as a percentage of the instream standard.

STREAMFLOW DATA

Streamflow is measured at each of the NJDEP/USGS network water quality sites in the Upper Delaware River Watershed. Instantaneous streamflows prior to 1998 are determined for the mean time recorded for each sample from ratings that relate water level elevation to streamflow. Streamflow is measured at the same time as the water quality sample is collected for all samples from 1998 through 2000. Four of the 21 sites have a continuous 15 minute record of streamflow. The other 17 sites have instantaneous streamflow measurements that are correlated to mean daily streamflows at nearby continous-record gaging stations to estimate flow at the time of the sample and for estimating streamflow statistics. Streamflow data was available at 5 of the 15 sites sampled by the DRBC. None of the 5 sites have a continous record of streamflow and streamflow was not measured at these sites during each water quality sample. Therefore streamflow was not used in the analysis of water quality data at the DRBC sites.

Streamflow data at the NJDEP/USGS sites was used to develop a flow-duration curve summarizing magnitude and frequency of flow at each site. Flow duration curves showing the percentage of time that a particular flow is equaled or exceeded at a site were developed at each of the sampling sites (**table 2**). Flow durations at the sites with continuous streamflow records were computed from a statistical package associated with the USGS database. Flow and water quality at median flow was compared between sites. Median flow was the flow duration used to separate samples into two groups. Samples collected when flows were greater than the median were classified as high flow samples and those collected at flows less than the median were classified as low flow samples. Statisical tests were used to compare and contrast the data in both groups.

Correlation procedures were used to estimate flow duration at the 17 sites without a continuous record of streamflow from streamflow records at nearby gaging stations. A streamflow record extension technique, maintenance of variance extension (MOVE1), was used to develop a correlation between instantaneous flow at the sampling site and mean daily flow at a nearby continuous-record gaging station (Hirsch, 1982). The log of flow is used to normalize the data before the relation is developed. This technique is good for estimating low to median flow conditions. A test for base-flow conditions excludes high flow measurements from the correlation. For the purpose of this study the correlation procedure was used to estimate the median flow at the sampling sites from median daily flow at nearby gaging stations.

Samples at all sites covered the range of approximately 10 to 90 percent flow duration with some sites having high-flow samples that exceed the 0.1 percent duration and others with samples at flows as low as approximately the 99 percent duration. The majority of the samples collected at high flows are during the receding portion of the hydrograph. These samples are not representative of water quality conditions throughout the entire hydrograph. Samples were random and no sampling was conducted throughout a storm hydrograph.

The median of the average daily flow at the 4 sites with continuous streamflow records for 1985-2000 was compared to the long term median flow at those sites. Daily mean streamflow has been recorded at the Pequest River at Pequest and Paulins Kill at Blairstown gages from 1922-2000. Streamflow record at Musconetcong River near Bloomsbury is from 1904-06, 1922-2000, and from 1924-2000 at Flat Brook at Flatbrookville. The median of the daily mean streamflow was higher at each of the 4 sites during the study period than during the entire period of stream flow record. The median daily flow during the period 1985-2000 was from 4.1 to 4.7 percent higher at the Musconetcong River, Pequest River and Paulins Kill gages and 8.4 percent higher at the Flat Brook gage.

Table 2. Streamflow statistics of mean daily flow [flow is in cubic feet per second; flow durations are based on gage records from 1985 through 2000; median flows at ungaged sites were estimated using regression and drainage area adjustment]

USGS Site	Period of gage record	Flow Duration values of mean daily flow			Streamflow measured			
		95%	median	5%	Number of measurements	Minimum	Median	Maximum
Big Flat Brook (01439830)			32.5		0			
Flat Brook (01440000)	1985-2000	12.5	78.5	339.8	30	8.400	66.50	1210
Flat Brook (01440010)			79.7		2	40.00		112.0
Dunnfield Creek (01442760)			4.3		12	.3110	3.250	14.90
Paulins Kill (01443290)			30.8		2	18.60		55.00
Dry Brook (01443370)			2.8		0			
Paulins Kill (01443440)			81.2		71	14.00	75.00	880.0
Paulins Kill (01443500)	1985-2000	28.9	140.1	587.4	84	16.90	134.0	1390
Jacksonburg Creek (01443550)			2.6		0			
Jacksonburg Creek (01443600)			8.8		0			
Pequest River (01444970)			11.5		0			
Pequest River (01445000)			35.3		0			
Pequest River (01445500)	1985-2000	33.5	117.5	456.9	31	33.00	107.0	1210
Pequest River (01446400)			175		12	23.00	175.0	820.0
Pohatcong Creek (01455200)			23.2		71	4.400	25.00	340.0
Musconetcong River (01455500)			32.3		39	2.400	19.00	156.0
Musconetcong River (01455801)			61.5		41	16.00	76.00	334.0
Musconetcong River (01456200)			122		68	33.00	128.0	1600
Musconetcong River 01456600			165		2	118.0		310.0
Musconetcong River 01457000	1985-2000	75.9	191.9	615.2	31	71.00	194.0	1240
Musconetcong River 01457400			211		85	72.60	195.0	1650

WATER QUALITY ANALYSIS

This section presents an analysis of water quality data from the NJDEP/USGS stream sampling network, DRBC sampling sites, LINJ NAWQA sites, and EWQ sites in the study area. Data was evaluated with respect to instream standards, variability between sites in the study area and landuses at those sites, comparisons to data from statewide sampling networks, trends at sites, variability at sites between seasons and flow conditions, and changes in quality along stream reaches.

Comparison to statewide background sites

The NJDEP/USGS cooperative ambient stream monitoring network includes six background sites draining undisturbed areas on New Jersey state lands. There were 72 samples collected at these sites from 1998-2000. The data from these sites is summarized in **table 3** . The six sampling sites are located on streams with the highest water quality in the state of New Jersey. The sites are classified by NJDEP as non-degraded. Dunnfield Creek at Dunnfield, from this study area, is one of the six sites. Data collected at NJDEP/USGS network sites was compared to data collected at these sites. Data from DRBC sites were collected mainly in the growing season and therefore were not comparable to data collected at the background sites.

Table 3. Statistical summary of data collected by the NJDEP/USGS at 6 statewide background sites from 1998 – 2000 [concentrations are in milligrams per liter; pH is in standard units; temperature is in degrees celcius; fecal coliform are most probable number per 100 ml; *, Site also sampled by USGS/NJDEP]

Constituent	Number of samples	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maximum
Ammonia, un-ionized	68	0.00014	0.009	<0.00001	<0.00001	.00003	.0001	.0006
Dissolved Oxygen	72	4.2	3.1	2.3	7.65	9.65	11.8	14.4
Dissolved Solids, Total	56	72.8	37.2	14.5	22.3	75	95	123
Fecal Coliform	52	90	355	<20	5.5	20	110	2,400
Nitrate plus Nitrite	72	0.22	0.17	0.018	0.036	0.09	0.28	0.85
pH	68	2.6	1.4	3.9	4.9	6.85	7.5	8.0
Phosphorus, Total	72	0.04	0.02	0.004	0.005	0.009	0.015	0.064
Suspended Solids, Total	60	2.0	2.5	<1	0.74	2.0	3.0	15
Water Temperature	72	11	6.3	0.0	5.5	10	16.5	24.5

The median values of the nine constituents from all samples at the six background sites were compared to the median values of all the data analyzed at network sites in the study area (**figures 3-5**). The median values of all samples at background sites for water years 1998 to 2000 are lower than median values of data for water years 1985 to 2000 from all NJDEP/USGS network sites in the WMA1 for all constituents (**table 4**).

Table 4. Statistical summary of all data collected by the NJDEP/USGS at 21 sites in study area from 1985 – 2000 [concentrations are in milligrams per liter; pH is in standard units; temperature is in degrees celcius; fecal coliform are most probable number per 100 ml; *, median values are a median of all the medians at each site]

Constituent	Number of samples	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maximum
Ammonia, un-ionized	578	0.0035	0.004	<0.00002	0.0006	0.003 0.0008*	0.004	0.033
Dissolved Oxygen	602	3.8	2.24	4.6	9.1	10.8 10.7*	12.9	16.3
Dissolved Solids, Total	592	82	62.4	19	135	174 172*	217	345
Fecal Coliform	563	740	2,772	<20	50	170 202*	790	>24,000
Nitrate plus Nitrite	599	1.20	0.73	<0.02	0.42	0.96 0.42*	1.62	2.93
pH	603	0.5	0.46	5.8	7.7	8.0 7.8*	8.2	9.2
Phosphorus, Total	593	0.06	0.06	0.004	0.03	0.05 0.03*	0.09	0.81
Suspended Solids, Total	180	6.0	7.54	<1.0	1.0	4.0 3.0*	7.0	72
Water Temperature	607	13	7.44	0	6.0	10.8 12*	19.0	29.0

In general, water quality at the background sites is better than the overall water quality at WMA1. Dissolved oxygen is the only constituent with a median value indicative of better water quality in the study area than at background sites. The median concentration is 10.6 mg/L in the study area and 9.6 mg/L at background sites. The inner quartile range (IQR) (between the 25^{th} and 75^{th} percentile) of each constituent from all samples at the six background sites was compared to medians at each of the12 sites with 8 or more data points. The IQR measures the range of the central 50 percent of the data. Median values at study sites that are within the range of the central 50 percent of data at background sites are considered to have comparable data. The median values for all constituents at Dunnfield Creek were within the IQR of the background data. Median values for all constituents except TDS at Flat Brook are also within the central 50 percent of the data. The nitrate plus nitrite concentration and fecal coliform counts at Musconetcong River at the outlet of Lake Hopatcong are the only other constituents at any site that are comparable to the low levels observed at the background sites. Median values at the other sites are all higher than the 75^{th} percentile at the background sites for nitrate plus nitrite and fecal coliform.

Comparison to statewide status sites

The NJDEP/USGS network includes statewide status sites which represent a randomly selected population of New Jersey streams (DeLuca and others, 2000). Two sites were selected from each of the 20 watershed management areas. There were 476 samples collected at 109 sites from 1998 through 2000. The data from these sites is summarized in **table 5** . Data collected at NJDEP/USGS network sites in the study area was compared to data collected at these sites. Data from DRBC sites were collected mainly in the growing season and therefore were not comparable to data collected at the status sites.

Table 5. Statistical summary of data collected by the NJDEP/USGS at 109 Statewide Status Sites from 1998 – 2000 [concentrations are in milligrams per liter; pH is in standard units; temperature is in degrees celcius; fecal coliform are most probable number per 100 ml; *, Site also sampled by USGS/NJDEP]

Constituent	Number of samples	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maximum
Ammonia, un-ionized	462	0.00046	0.0022	<0.00001	<0.00001	0.0001	0.00047	0.04
Dissolved Oxygen	473	3.6	2.53	1.1	7.6	9.3	11.2	16.3
Dissolved Solids, Total	408	135	121	18.5	64.6	111	200	1,054
Fecal Coliform	146	750	5,070	<20	40	220	790	>24,000
Nitrate plus Nitrite	475	1.02	1.03	0.02	0.13	0.52	1.15	7.6
pH	473	1.4	1.22	3.5	6.2	7.1	7.6	9.0
Phosphorus, Total	475	0.06	0.14	0.004	0.02	0.05	0.07	1.36
Suspended Solids, Total	388	4	10.3	<1.0	1.0	3.0	5.0	128
Water Temperature	476	12	7.1	0.0	5.5	12	17.5	28

The median values of the nine constituents from all the data collected at the 109 status sites were compared to the median values of all the data analyzed at network sites in the study area (**figures 3-5**). Median values of samples from streams located in WMA1 have lower total suspended solids, total phosphorus, nitrate plus nitrite, water temperature and fecal coliform counts than from randomly selected streams in New Jersey as a whole (**table 4**). Median values of dissolved oxygen, pH, total dissolved solids, and un-ionized ammonia are higher in WMA1 than in New Jersey as a whole. Higher median pH and total dissolved solids concentrations in WMA1 than in some other areas of New Jersey, are a result of the lithology in the area. The highest TDS values observed are during low flow conditions. In many other streams in New Jersey the highest TDS values are observed during high flow events in the nongrowing season, as a result of nonpoint source runoff. In general water quality, based on these 9 constituents, is better in WMA1 than in New Jersey as a whole.

Median values at study sites that are within the range of the central 50 percent of data at background sites are considered to have comparable data.The central 50 percent of the data from all samples at the six statewide status sites was compared to medians at each of the 12 sites with 8 or more data points. A few sites in WMA1 have higher median values for some constituents than the 75th percentile and others have lower median values than the 25th percentile for the statewide status sites. Median values of pH, TSS, TP, nitrate plus nitrite, fecal coliform, and un-ionized ammonia are higher at Pohatcong Creek than the central 50 percent of data collected statewide. Median values of pH, TSS, TDS, fecal coliform, and un-ionized ammonia are higher at Pequest River sites than the central 50 percent of data collected statewide. Median values of pH, TSS, nitrate plus nitrite and un-ionized ammonia are higher at Pequest River sites than the central 50 percent of data collected statewide. Also Paulins Kill sites have higher median values of pH, TDS, and un-ionized ammonia than the central 50 percent of data collected statewide. Dunnfield Creek, Flat Brook, Van Campens Brook and Shimers Brook sites have lower medians for one or more constituents and higher dissolved oxygen than the central 50 percent of statewide data.

Sites on the Pequest River, Pohatcong River, Musconetcong River, and Paulins Kill have higher median values than the statewide median for one or more constituents. Median values of total suspended solids, nitrate plus nitrite, un-ionized ammonia, and fecal coliform counts are higher at the Pohatcong Creek and Pequest River at Pequest sites for water years 1985-2000 than the statewide median for water years 1998-2000. Higher median total suspended solids were observed at the most downstream Musconetcong River sites at Bloomsbury and Reigelsville than statewide. TDS was higher at the two Paulins Kill and Pequest River sites, total phosphorus was higher at Pohatcong Creek and un-ionized ammonia was higher at 3 Musconetcong River sites than the statewide median.

Comparison to Standards

Water quality standards establish the water quality goals and policies underlying the management of New Jersey's waters (NJDEP, 1997). The numeric criteria are set by the NJDEP to protect public health and welfare and to enhance the quality of water. The Federal Clean Water Act requires wherever attainable that surface-water quality standards should provide for protection and propagation of fish, shellfish and wildlife and to provide for recreation in and on the water (NJDEP, 1997). Drinking water standards are set by USEPA and NJDEP. These standards, known as maximum contaminant levels (MCL's) are the maximum permissible levels allowed in public drinking water (USEPA, 1996). The standard is set for water being delivered to public water supply users, after it has been treated. The MCL for nitrate plus nitrite is used in this study as a reference to instream measurements because no instream surface water standard exists in New Jersey.

Surface water quality criteria for many of the constituents do not apply to instantaneous values derived from one sample. The standards are used simply as a level of reference for evaluating water quality conditions in the study area. Surface water quality standards exist for eight of the nine constituents analyzed. The drinking water standard for nitrate plus nitrite is used as a reference level in the absence of surface water quality criteria. Data from each sample was compared to these reference levels.

The surface water quality standards for New Jersey (NJDEP, 1998) streams represent a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use (NJDEP, 1998). The standards for total phosphorus, total suspended solids, total dissolved solids, dissolved oxygen, and pH applies to the quality in the stream at all times. The un-ionized ammonia standard is for a 24-hour average concentration. The standards for fecal coliform are not to exceed a geometric mean or 10 percent of the total samples in a 30-day period (NJDEP, 1998). The standards for water temperature are set so that point source discharges do not cause the stream temperature to exceed the designated levels.

Standards for dissolved oxygen, total suspended solids, un-ionized ammonia, and water temperature are stricter for trout waters than for streams designated as nontrout waters. In addition, dissolved oxygen has a stricter standard in trout production streams (>7 mg/L) than in trout maintenance streams (>5 mg/L). Each DRBC station had at least one sample with a value that did not meet a standard. Each NJDEP/USGS station had at least one sample with a value that did not meet a standard, except for Flat Brook at Flatbrookville, Paulins Kill upstream of route 15 at Lafayette and Musconetcong River at Hampton. These three sites were only sampled twice and data did not include fecal coliform and un-ionized ammonia.

The percentages of samples that do not meet the established criteria are listed by site and for all samples in trout and nontrout streams by flow condition and season (**appendix 1**, **tables 1a-1b).** The percentage of samples exceeding the standard at each site during both high flow and low flow conditions are also listed in **table 1a**. The comparison between flow conditions is not available at the DRBC sites because of lack of stream flow data at these sites. The percentage of samples not meeting standards is also presented by site in cumulative probability plots (**figs 6-23**). The cumulative probability plots show the percentage of data at each site that is less than a given concentration, fecal coliform count, or water temperature. Horizontal lines across the plots represent established water quality or drinking water standards. The intersection of the cumulative probability line with the horizontal line representing the standard indicates the percentage of data meeting the standard. The exception is for dissolved oxygen. The intersection of the lines indicates the percentage not meeting the standard.

The most common violations of standards at NJDEP/USGS sites were for fecal coliform, above 400 MPN/100mL in 51 percent of all samples at nontrout sites and 35 percent at trout sites and total phosphorus above 0.1 mg/L in 31 percent of samples at nontrout sites and 24 percent of samples at trout sites. The fecal coliform standards for streams are not to exceed a geometric mean of 200 MPN/100mL (**table 1c)** and are not to exceed 400 MPN/ 100mL for more than 10 percent of samples collected during a 30-day period (**table 1a**). Water temperature was above 20.0 degrees Celsius in 20 percent of samples at trout sites, however no samples exceeded the

27.8 degree Celsius limit at nontrout sites. Only samples from Dunnfield Creek were less than a pH of 6.5 and only 11 percent of all samples from trout sites exceeded 8.5. Samples from both the DRBC and NJDEP/USGS were less than 6.5. All pH data at nontrout sites were within standards. Fewer than 3 percent of samples did not meet standards for total suspended solids, un-ionized ammonia and dissolved oxygen. Results from data collected at DRBC sites (**table 1b)** are similar to those from network sites (**table 1c**). Only one sample collected by DRBC at Pequest River at Belvidere exceeded 500 mg/L TDS. No samples from either group of sites exceeded the standard for nitrate plus nitrite.

Exceedances of Standards analyzed by Season and Flow

A seasonal comparison was made of all samples not meeting water quality standards. All violations of dissolved oxygen concentration, and water temperature were in the growing season (**table 1a**). The percentage of fecal coliform samples exceeding 400 MPN/100 ml was substantially higher in the growing season than in the nongrowing season at sites in both trout and nontrout waters. Lower counts in the nongrowing season may be related to lower water temperatures. A slightly higher percentage of total phosphorus concentrations exceeded surface water standards in the growing season. A slightly higher percentage of pH samples were less than 6.5 and greater than 8.5 in the nongrowing season. The percentages of total suspended solids and un-ionized ammonia samples not meeting standards were less than 3 percent of the total in both seasons.

Samples at DRBC sites were collected mainly in the growing season. Four constituents --un-ionized ammonia, total dissolved solids, total phosphorus, and total suspended solids-- were not sampled in the nongrowing season (**table 1b**). Results for four of the five constituents –dissolved oxygen, fecal coliform, nitrate plus nitrite, and water temperature-- sampled in each season are comparable to the results at network sites. A difference was found for pH. A higher percentage of pH samples were greater than 8.5 at trout sites in the growing season. A higher percentage (5.1%) of total suspended solids samples exceeded the standard in the growing season at DRBC trout sites than at network sites.

All data not meeting water quality standards were analyzed with respect to streamflow conditions at the time the sample was collected. This comparison could not be made at DRBC sampling sites because only 5 sites have flow data. Two of the five sites with flow data were also sampled by the USGS/NJDEP network and comparison of data to flow conditions was performed on the USGS/NJDEP network data. The flow data that exists at the other 3 DRBC sites indicates nearly all samples were collected at conditions less than median flow.

Dissolved oxygen, fecal coliform, total phosphorus, un-ionized ammonia and water temperatures did not meet the standard in a higher percentage of samples at low flow than at high flow conditions (**table 1a**). All total suspended solids concentrations above the standard were sampled during high flow conditions. Measurements of pH above the standard of 8.5 were more commonly found at low flow conditions and those below the standard of 6.5 were more commonly found at high flow conditions. Comparisons of the percentage of samples not meeting standards during high and low flow at each site are presented in **table 1a.**

Exceedances of Standards by watershed

Sites on the Pohatcong Creek and Musconetcong River have more constituents not meeting standards than sites in the other subwatersheds with sampling sites studied. Fecal coliform, total phosphorus, water temperature, pH, total suspended solids and un-ionized ammonia values exceeded the standards in one or more samples collected in these watersheds. Fecal coliform exceeded the 400 MPN/100ml standard in more than half the samples at the two Pohatcong River sites and the two Musconetcong River sites furthest downstream. However, usually there was no more than one sample collected in a 30-day period. Most exceedences at the NJDEP/USGS sites occurred at low flow conditions. Low flow samples on the Pohatcong Creek exceeded 400 MPN/100ml in 82 percent of the samples.

The geometric mean of fecal coliform counts was highest on the Pequest River at Belvidere, Pohatcong Creek, and Dry Brook sites; 880, 660 and 652 counts/100ml respectively (**table 1c**). The geometric mean at Pohatcong Creek was highest (903 counts/100ml) at low flow but also exceeded the 200 counts/100ml standard at high flow (487 counts/100ml). Samples of fecal coliform bacteria were only collected at low flow at Pequest River at Belvidere and Dry Brook. The New Jersey surface water standard was also exceeded at five other sites; Paulins Kill at Balesville, Pequest River near Springdale, Pequest River at Pequest, Musconetcong River near Bloomsbury, and Musconetcong River at Riegelsville. Pequest River near Springdale was only sampled at low flow. The geometric mean of Fecal coliform counts exceeded 200 counts/100ml at both low and high flow conditions at Pequest River at Pequest and Musconetcong River at Riegelsville. The geometric mean at Paulins Kill at Balesville and Musconetcong River near Bloomsbury did not exceed during high flow but exceeded during low flow.

The geometric mean of fecal coliform counts from data collected at DRBC sites is summarized in **table 1d**. The geometric mean exceeded the standard of 200 counts/100mL at sites on the Musconetcong River, Pohatcong Creek, Lopatcong Creek, Buckhorn Creek, Pophandusing Brook, Pequest River and Delawanna Creek. Flow data is not available for the majority of these samples. The highest geometric mean counts were 709 counts/100mL at Pohatcong Creek and 512 counts/100mL at Pophandusing Creek. The lowest geometric means were on Shimers Brook (25.4), Big Flat Brook (26.7), Dunnfield Creek (28.2), VanCampens Brook (29.6) and Flat Brook at Flatbrookville (34.7).

Fecal coliform counts exceeded standards in more than half the samples collected at 11 of the 33 sites in the NJDEP/USGS and DRBC networks (**tables 1a-1b**). In addition to the Pohatcong Creek and Musconetcong River sites, a high percentage of samples exceeded standards at Delawanna Creek, Pophandusing Creek, Lopatcong Brook, Buckhorn Creek, Dry Brook, Pequest River at Belvidere, and Paulins Kill at Balesville.

The standard for phosphorus was exceeded in a much greater percentage of samples at Pohatcong Creek at New Village than at any other site (**table 1a**). Eighty percent of all samples exceeded 0.1 mg/L and 97 percent exceeded that level at low flow, indicating a constant base-flow or point source. Phosphorus values over 0.1 mg/L did not account for more than 35 percent of the data at other sites. All sites with values over 0.1 mg/L, except for the DRBC site at the mouth of Flat Brook, were classified as urban or agricultural sites and received flow from one or more permitted point sources.

Dunnfield Creek (01442760 & DRBCNPS0025) and Jacksonburg Creek (01443550) are the only sites with pH data less than 6.4. Data below the 6.5 instream standard accounts for 65 percent of the DRBC data and 33 percent of the USGS/NJDEP data at the Dunnfield Creek site and 25 percent of the data at the most upstream Jacksonburg Creek site. The watersheds at both sites are over 94 percent undeveloped with no agricultural land uses. Both sites drain areas of steep mountainous terrain along the Kittatinny mountain ridge. The geology upstream of these sites consists of erosion resistant layers of sandstone, siltstone and quartzite –Shawangunk and

Bloomberg Red Beds Formations-- unique to the Kittatinny Mountain and Walpack Ridge (Drake and others, 1996). Soil pH in this area ranges from extremely acid to moderately acid with values ranging from 3.5 to 5.5 (U.S. Department of Agriculture, 2002).

The pH data from a second sampling site near the mouth of Jacksonburg Creek is more consistent with other sites in the study area, with values ranging from 7.5 to 8.1. The second site is approximately 5 miles downstream from the site with the low pH. The creek flows through a valley underlain by limestone and shale and consisting of some areas of agricultural and urban land use before reaching the downstream sampling site.

The surface water standard of pH less than or equal to 8.5 was not met in more streams and in a higher percentage of samples than the low-end standard of greater than or equal to 6.5. Greater than 20 percent of samples exceeded a pH of 8.5, mostly at low flow in the summer, at Pequest River at Belvidere, Pohatcong Creek, Musconetcong River near Bloomsbury and two Flat Brook sites sampled by the DRBC. These sites are in areas with the highest percentages of agricultural and urban land uses of the sites sampled.

The higher pH may be a result of a diurnal fluctuation caused by algal growth in eutrophic waters. The rate of assimilation of dissolved carbon dioxide (CO_2) by algae on sunny days can exceed the rate at which CO_2 from the air can be brought into solution (Hem, 1985). As a result, the pH of water near the surface may increase as the ratio of bicarbonate (HCO_3) to carbonate (H_2CO_3) becomes greater. At night, the pH declines.

Un-ionized ammonia concentrations rarely exceeded standards. Only 9 samples, mainly at low flow conditions, collected at sites on the Musconetcong River, Pohatcong Creek and Paulins Kill had values exceeding 0.02 mg/L. TDS exceeded 500 mg/L in one sample at low flow at the mouth of the Pequest River. Eleven samples exceeded the total suspended solids standard at high flow conditions at Pequest River at Pequest, the Pohatcong Creek sites, Paulins Kill at Blairstown and Shimers Brook; all agricultural sites except Shimers Brook. Dissolved oxygen was less than 5 mg/L once during low flow in the summer at a Pequest River site and less than 7 mg/L once during the summer at Buckhorn Creek. Water temperature at Musconetcong River sites and Paulins Kill at Blairstown exceeded 20^{o} C more frequently than any other sites sampled routinely throughout the year.

Exceedances of Standards at Existing Water Quality Network Sites

Fifty-eight samples were collected at the 15 EWQ sites in the study area from November 2000 to August 2001 (**table 6**). Four samples were collected at 13 of the sites. Three samples were collected at Dry Brook at Branchville and Paulins Kill at Balesville. A statistical summary of the EWQ data at each site is not provided because of the limited number of data points. **Table 6** shows only the minimum and maximum values for each constituent and the sites with values exceeding the reference level. Total phosphorus exceeded the 0.10 mg/L instream standard in one sample at Pohatcong Creek at New Village. One sample at Pequest River at Oxford exceeded the standard for total suspended solids and total dissolved solids (**table 6**). The range in EWQ data is similar to the USGS/NJDEP network data at these sites.

Relation of Constituents to Season and to Flow at Each Site and Between Sites

Changes in streamflow conditions and season of the year were factors found to contribute to the variability of water quality of streams in WMA1. Concentrations may increase or decrease with an increase in stream flow depending on the source of the constituent. Seasonal changes, related to water temperature and human activities may influence concentrations in streams. Tests relating changes in levels of constituents to changes in flow conditions and season were only performed at the NJDEP/USGS sites. Summaries of lowest and highest median values in the study area generally included summaries from both networks.

Concentrations of nine constituents, fecal coliform counts and water temperature were compared at each site by season, flow, and season as a function of flow to explain variability in the data. Statistically significant differences in levels of constituents between seasons were found to occur for each constituent at one or more of the 12 sites with a sufficient amount of data for one-way ANOVA. Significant differences in levels of constituents between flow conditions were found for each constituent except TSS. A test was also performed to see if the significant differences were related to an interaction of flow and season. At many sites the median values of a constituent varied significantly between the subsets of data collected in the growing season at high-flow, the nongrowing season at high flow, the growing season at lowflow and the nongrowing season at low flow **(appendices 2-10, tables 2c, 3c, 4c, 5c, 6c, 7c, 8c, 9c, and 10c**).

The results of the analysis are presented in tables showing summary statistics and significant differences by season and flow condition (**tables 1a-10c**). A summary of the distributions of constituents at each site and a comparison between sites is presented in cumulative probability plots (**figures 6-23**).

Table 6. Summary of data collected by New Jersey Department of Environmental Protection at 15 Existing Water Quality Network sites [numbers in **bold** font are those exceeding the instream standard; *;trout maintanance sites; **, trout production sites; other sites are in nontrout waters; (n), NJDEP/USGS network site; (d) DRBC sampling sites;

				Water Temperatu		pH		Dissolved Oxygen		Nitrate		Total Phos-phor		Total Dis-solved Solids		Total susp ende d solids		Un-ionized am-monia	
AMNET Site	Stream	Municipality	Number of samples	Mini-mum	Maxi-mum	Mini-mum	Maxi-mum	Mini-mum	Max-imum	Mini-mum	Maxi-mum	Mini-mum	Maxi-mum	Mini-mum	Maxi-mum	Mini-mum	Maxi-mum	Mini-mum	Maxi-mum
**AN0002	Clove Bk	Duttonville	4	0.70	19.80	7.90	8.10	7.08	13.60	0.14	0.23	<0.02	<0.02	142.00	280.00	1.00	4.00	<0.0004	0.00160
**AN0005A	Little Flat Bk	Sandyston Twp	4	1.4	12.4	7.84	8.2	9.4	12.71	0.35	0.65	<0.02	<0.02	163.00	321.00	<1.0	3	<0.0002	0.00036
**AN0006 (n)	Big Flat Bk	Tuttles Corner	4	1.10	11.50	7.30	8.05	9.33	13.52	0.10	0.18	<0.02	<0.02	57.00	108.00	<1.0	4.00	<0.0003	<0.0007
AN0020 (n)	Dry Bk	Branchville	3	1.50	13.60	7.80	8.30	9.30	14.20	0.38	1.62	<0.02	<0.02	161.00	223.00	1.00	5.00	<0.0001	<0.0006
AN0021 (n)	Paulins Kill	Balesville	3	0.30	26.00	7.84	8.30	7.50	13.05	0.22	1.45	<0.02	0.05	310.00	481.00	1.00	13.00	0.00050	0.01000
*AN0037 (n)	Pequest R	Huntsville	4	2.10	19.60	7.90	8.10	7.20	14.95	0.62	0.87	<0.02	<0.02	281.00	379.00	<1.0	8.00	<0.0002	0.00200
*AN0043 (n)	Pequest R	Oxford	4	2.50	19.30	8.20	8.51	7.90	12.82	1.29	1.66	0.05	**0.22**	313.00	**514**	4.00	**102.0**	0.00260	0.01300
AN0047	Beaver Bk	Sarepta	4	1.2	21.4	8.25	8.42	5.73	13.66	0.6	1.27	<0.02	0.03	95	285	1	5	<0.0009	0.00600
**AN0050 (d)	Buck Horn Ck	Hutchinson	4	1.5	16.3	7.9	8.2	8.3	13.8	1.2	1.95	<0.02	0.05	130	244	4	12	<0.0005	0.00120
**AN0052	Lopatcong Ck	Port Warren	4	2.00	17.80	7.52	7.90	10.10	13.60	0.51	1.97	<0.02	0.06	127.00	163.00	2.00	14.00	<0.0001	0.00078
*AN0055 (d)	Pohatcong Ck	Washington Twp	4	2.30	20.90	7.40	7.70	5.90	12.60	0.32	0.82	<0.02	0.03	72.00	108.00	<1.0	11.00	<0.0003	0.00060
*AN0058 (n)	Pohatcong Ck	New Village	4	2.00	21.20	7.88	8.43	9.90	13.10	1.40	2.04	0.05	**0.16**	140.00	224.00	4.00	11.00	<0.0002	0.00500
*AN0066	Lubbers Run	Lockwood	4	1.90	20.50	7.85	8.05	7.84	13.45	0.31	0.59	<0.02	<0.02	163.00	286.00	<1.0	8.00	<0.0002	0.00020
AN0069 (n)	Musconetcong R	Beattystown	4	4.2	19.6	7.71	8.3	9.6	12.31	1.24	1.93	<0.02	0.04	231	361	2	8	<0.0002	0.00120
AN0072	Musconetcong R	New Hampton	4	3.8	18.7	8.1	8.34	9.53	12.87	1.52	2.39	<0.02	<0.02	208	332	<1.0	10	<0.001	0.00060

Median values of constituents were compared between sites. Data from sites sampled by the NJDEP/USGS network could not be compared directly with data collected at the DRBC sites. DRBC sites were sampled primarily in the growing season and mainly at low flow, while the network sites were sampled at fixed times throughout the year. Statistical comparisons were performed on data collected in the growing season and at low flow in the growing season between all sites. Four streams are sampled at or near the same location by both networks. The Wilcoxan rank sum test was used to compare a subset of both datasets containing growing season data. Water temperature, dissolved oxygen, fecal coliform, un-ionized ammonia and total dissolved solids from the two datasets were statistically different at one or more sites. Because of these observed differences in datasets, comparisons between all the sites in both networks were not considered valid.

Sites sampled by both the NJDEP/USGS and DRBC networks on the Musconetcong River and Paulins Kill were among the sites with the lowest median dissolved oxygen and highest median values for seven of the eight other constituents. Median values of pH were not among the highest or the lowest at Paulins Kill sites and TDS at the Musconetcong River sites was not among the highest in the study area.

Median un-ionized ammonia concentrations were low and did not exceed 0.0046 mg/L at any sites (**appendix 2**, **tables 2a-2b**). Highest median values (>0.001 mg/L) were at the Beattystown and Lockwood sites on Musconetcong River, Pequest River, and Pohatcong Creek. Lowest median values (<0.0001 mg/L) were at sites on the Flat Brook, Dunnfield Creek, and Van Campens Brook. Concentrations at half the sites were significantly higher in the growing season than in the nongrowing season and most sites were significantly higher at low flow (**table 2c**). The highest concentrations measured at most sites were during low flow in the growing season.

Median concentrations of dissolved oxygen were fairly uniform at sites across the study area (**appendix 3**, **tables 3a-3b**). Median concentrations at sites sampled throughout the year were lowest (< 10.4 mg/L) at Paulins Kill and Musconetcong River sites. At sites sampled only in the growing season, median values were lowest (<9.0 mg/L) at Paulins Kill, Delawanna Creek, Pophandusing Creek and Van Campens Brook. In contrast, the highest median concentrations were on the Flat Brook, Dunnfield Creek and Pequest River at Belvidere from samples collected year round and in the growing season.

Changes in season and the subsequent change in stream temperature is the dominant factor causing the variability of dissolved oxygen concentrations in streams. All USGS/NJDEP sites had significantly higher concentrations of dissolved oxygen in the nongrowing season (**table 3c**). Median concentrations were highest at all sites at high flow, however only six sites were significantly higher at high flow than at low flow. Highest concentrations measured at all sites were in the nongrowing season, but not always at high flow (**table 3c**). Algal blooms were not thought to be the cause for dissolved oxygen values over 15 mg/L at 8 NJDEP/USGS network sites because these high readings occurred in the nongrowing season.

Median concentrations of TDS were highest (>220 mg/L) at sites on the Pequest River, Paulins Kill and Pohatcong Creek. The lowest median concentrations (< 100 mg/L) were on Dunnfield Creek and Flat Brook sites (**appendix 4**, **tables 4a-4b**). The median concentration of 22 mg/L at Dunnfield Creek is much lower than at other sites. The low value is a result of the lithology and the absence of urban and agricultural land uses in the watershed. The 4 samples at the upstream Jacksonburg Creek site are also much lower than other sites as a result of the same lithology. All sites except Musconetcong River at the outlet of Lake Hopatcong had significantly higher concentrations of TDS at low flow than at high flow and half the sites had higher concentrations in the growing season (**table 4c**). The highest concentrations measured were at low flow in the growing season. In many other areas of New Jersey the highest concentrations measured in streams are during high flow events in the winter. These spikes in concentration caused by runoff containing deicing salts were not observed in the study area. This could be because the timing of high flow samples did not coincide with the time of peak concentrations of deicing salts.

Median fecal coliform counts were highest (>400 counts per 100/ml) at sites in the Pohatcong Creek, Musconetcong River and Lopatcong Creek and Paulins Kill (**appendix 5**, **tables 5a-5b).** The lowest median concentrations ($\leq$ 20 counts per 100ml) were on Dunnfield Creek, Shimers Brook, Flat Brook sites, and Musconetcong River at the outlet of Lake Hopatcong. Season is the dominant factor related to variability of fecal coliform counts at sites (**table 5c**). Most sites have significantly higher counts in the growing season than in the nongrowing season. Median counts were significantly higher during low flow than during high flow at only 2 sites. The highest counts recorded are generally during high flow events in the growing season.

Median concentrations of nitrate plus nitrite were highest (>1.0 mg/L) at Pohatcong Creek, the two downstream Musconetcong River sites, the three downstream Pequest River sites and the upstream Paulins Kill site (**appendix 6**, **table 6a**). The lowest median concentrations of nitrate plus nitrite were less than 0.1 mg/L at Dunnfield Creek, Van Campens Brook, Flat Brook sites and Musconetcong River at the outlet of Lake Hopatcong (**tables 6a-6b).** The highest concentrations measured were greater than 2 .0 mg/L at Musconetcong River sites, Pohatcong Creek, Pequest River and Buckhorn Creek sites. These concentrations were at low flow except at Pequest River at Pequest. Variability in median concentrations was related to changes in flow and/or season at 10 of the 12 sites, the exception being the two Pequest River sites (**table 6c**) Flat Brook, Musconetcong River at the outlet of Lake Hopatcong, and Paulins Kill at Blairstown had significantly higher concentrations at high flow while the other sites were higher at low flow. Season was a factor in the variability at four sites.

Median measurements of pH were highest (>8.0 standard units) at Pequest River sites, the Musconetcong River excluding the two upstream most sites and Paulins Kill at Blairstown (**appendix 7, tables 7a-7b**). The lowest median measurement was 6.75 at Dunnfield Creek. No measurements exceeded 7.0 at Dunnfield Creek and Jacksonburg Creek near Millbrook. The lowest readings (<6.0) at these two sites were during the winter and during high flow at Dunnfield Creek. Flow data was not available at Jacksonburg Creek. The highest readings (>9.0 standard units) were detected at Pohatcong Creek and Musconetcong River at Reigelsville at low flow in the spring. The majority of sites did not show significant variability in pH data with changes in flow or season. Flow however, was a more significant factor than season. All sites with significant changes in pH had highest median values in the growing season or at low flow (**table 7c**). A previous water quality study on the Raritan River watershed found significant drops in alkalinity concentrations at high flow at all sites. The decrease was great enough to drop the buffering capacity causing lower pH readings at high flow at most of the sites. This may be a factor contributing to lower pH at high flow at five sites in WMA1.

Median total phosphorus concentrations were highest ($\geq$ 0.07 mg/L) at the Pohatcong Creek, Musconetcong River at Beattystown, Pequest River at Pequest, and Paulins Kill at Balesville sites (**appendix 8**, **tables 8a-8b**). Median total phosphorus concentrations were lowest (<0.02 mg/L) at Dunnfield Creek and Flat Brook sites. Highest concentrations detected were at low flow in the growing season. The majority of sites did not show significant variability in total phosphorus data with changes in flow or season (**table 8c**). Pohatcong Creek and Paulins Kill at Balesville, two sites with the highest median concentrations and among the highest concentrations detected were significantly higher at low flow than at high flow. Five sites were highest in the growing season.

Median total suspended solids concentrations were highest (> 8.0 mg/L) at the most downstream sites on the Pequest and Musconetcong Rivers (**appendix 9, tables 9a-9b**). Median concentrations were lowest (<3.0 mg/L) at sites in the Flat Brook watershed. Highest concentrations (>100 mg/L) were detected at sites on the Pequest River, Musconetcong River, Pohatcong Creek and Shimers Brook. All these concentrations were detected at high flow conditions. Median concentrations were higher at high flow than at low flow at all sites. However, no sites showed median concentrations varying significantly with a change in flow or season (**table 9c**).

At sites sampled in both the growing and nongrowing seasons, median water temperatures were highest (>12.0^{o} C), at the two Musconetcong River sites closest to Lake Hopatcong, and the Musconetcong River site near the mouth, and Paulins Kill at Blairstown (**appendix 10**, **table 10a**). At sites sampled by DRBC mainly in the growing season, the highest median water temperatures were greater than 20^{o} C at Musconetcong River at the mouth, Pophandusing Brook, Delawanna Creek and Paulins Kill at the mouth (**table 10b**). The lowest median temperature was 7.2^{o} C at Dunnfield Creek. The lowest median water temperatures (< 18.0^{o} C) at sites sampled mainly in the growing season were at Van Campens Brook, Dunnfield Creek, Flat Brook sites and Pohatcong Creek. Season was the dominant factor causing the variability of water temperature in streams. All sites had significantly higher water temperature in the growing season and half the sites were significantly higher at low flow than at high flow (**table 10c**).

Trends in Water-Quality Characteristics

The Seasonal Kendall Trend test was run on data collected routinely throughout the year at sites with at least 7 years of record. Ten sites in the USGS/NJDEP network were found to have an adequate amount of data for trends tests during the study period 1985-2000 (**table 7**). The ten sites include:

1) Flat Brook at Flatbrookville (01440000)
2) Paulins Kill at Balesville (01443440)
3) Paulins Kill at Blairstown (01443500)
4) Pequest River at Pequest (01445500)
5) Pohatcong Creek at New Village (01455200)
6) Musconetcong River at outlet of Lake Hopatcong (01455500)
7) Musconetcong River at Lockwood (01455801)
8) Musconetcong River at Beattystown (01456200)
9) Musconetcong River at Bloomsbury (01457000)
10) Musconetcong River at Reigelsville (01457400)

Five DRBC sites were sampled for at least seven consecutive years, primarily in the growing season. Since samples were not collected on a routine schedule throughout the year, and nongrowing season data does not exist or is very sparse at these sites, trends tests were not performed on DRBC data.

Three of the five sites on the Musconetcong River had significant trends for more constituents than sites on the other streams. There were decreases in un-ionized ammonia and total phosphorus concentrations and increases in total dissolved solids concentrations at three of the five sites. Nitrate plus nitrite concentrations increased at two sites and dissolved oxygen increased at one site. Water temperature decreased at the Reigelsville site from 1985-2000. The two Paulins Kill sites showed decreases in un-ionized ammonia and total phosphorus with a decrease in water temperatures sampled at the Blairstown site.

The Pohatcong Creek site showed increases in nitrate plus nitrite and decreases in total phosphorus concentrations in samples collected from 1985-97. The Pequest River at Pequest showed a significant decreasing trend in pH, which may be influenced by the significant increase in the stream flow during sampling events from 1991-97. There were no significant changes in data collected at the Flat Brook site during the study period.

Total phosphorus and un-ionized ammonia concentrations, showed trends at more sites than the other constituents. Trends tests indicate decreases in un-ionized ammonia at three of the six sites with the highest concentrations recorded (**table 8**). Tests also show significant decreases in total phosphorus concentrations at four of the five sites with the highest concentrations sampled (**appendix 8**, **table 8a**).

Total dissolved solids concentrations increased at three of the five Musconetcong River sites. The highest concentrations at each of these sites have occurred at low flow conditions and have not exceeded 243 mg/L. Even if the trend continues, it does not appear that the instream standard will be approached in the near future. The highest observed total dissolved solids concentrations are from a constant base-flow source and not from nonpoint sources during runoff events in the nongrowing season as has been observed in some other streams in New Jersey.

Nitrate plus nitrite concentrations have increased at 3 of the 5 sites with the highest concentrations sampled (**appendix 6**, **table 6a**) The highest concentrations observed at these sites however, did not exceed 2.8 mg/L. Nitrate plus nitrite is increasing at Pohatcong Creek at New Village, the site with the highest median concentration (1.93 mg/L). These increasing trends do not appear to be an indication that the instream reference level (10mg/L) will be approached. There were no trends observed for fecal coliform and total suspended solids.

The results of tests on nutrient values -- ammonia, nitrate plus nitrite, and phosphorus-- are consistent with the expected changes in concentrations in treated wastewater discharged from sewage treatment plants (STP's) because of upgrades to plants (Hickman and Barringer, 1999). Un-ionized ammonia has decreased at five sites tested and total phosphorus has decreased at six sites. At the same time, three of these sites have shown increases in nitrate plus nitrite and none have shown decreases. This is also consistent with STP upgrades, which tend to oxidize the nitrogen in the effluent, which decreases concentrations of ammonia and increases concentrations of nitrate plus nitrite. All trends in nutrient values occurred at stations with STP's upstream from the site, while concentrations at Flat Brook, a stream without STP's, did not change significantly.

Table 7. Summary of trend slopes from Seasonal Kendall tests performed on nine constituents and sampled flow at 10 sites in the Upper Delaware River Watershed, from 1985 through 2000 [+, positive slope indicates values increase with time; -, negative slope indicates concentration decreases with time; --, no significant change; slopes indicate change in units per year; NA, not enough data]

Station number	Period of Record	Ammonia, Un-ionized	Dissolved Oxygen	Dissolved solids, Total	Fecal Coliform	Flow	Nitrate + Nitrite	pH	Phosphorus, total	Suspended solids, total	Water temper-ature
Big Flat Brook (01439830)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Flat Brook (01440000)	1993-2000	--	--	--	--	--	--	--	--	--	--
Flat Brook (01440010)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dunnfield Creek (01442760)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Paulins Kill (01443290)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dry Brook (01443370)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Paulins Kill (01443440)	1985-97	-0.00015	--	--	--	--	--	--	-0.01	--	--
Paulins Kill (01443500)	1985-2000	-0.000065	--	--	--	--	--	--	-0.26	--	-0.28
Jacksonburg Creek(01443550)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Jacksonburg Creek(01443600)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pequest River (01444970)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pequest River (01445000)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pequest River (01445500)	1991-97	--	--	--	--	+21.8	--	-0.05	--	--	--
Pequest River (01446400)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pohatcong Creek (01455200)	1985-97	--	--	--	--	--	+0.038	--	-0.012	--	--
Musconetcong River (01455500)	1985-91	-0.00028	+0.25	+2.1	--	--	--	--	--	--	--
Musconetcong River (01455801)	1985-91	--	--	--	--	--	+0.073	--	-0.011	--	--
Musconetcong River (01456200)	1985-97	-0.00063	--	+4.1	--	--	+0.057	--	-0.013	--	--
Musconetcong River (01456600)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Musconetcong River (01457000)	1991-97	--	--	--	--	--	--	--	--	--	--
Musconetcong River (01457400)	1985-2000	-0.0017	--	+2.3	--	--	--	--	-0.005	--	-0.19

Trends detected in Previous Studies

Similar trend results for the nine constituents were found during three previous USGS studies at eight of the 10 sites tested. Musconetcong River sites at Lake Hopatcong and Lockwood were not included in the previous studies. The results of trends tests for seven of the nine constituents for the period 1986 through 1995 are summarized from Hickman and Barringer, 1999. A trends test was not performed on total suspended solids or un-ionized ammonia data in that study. Results from another study (Buxton and others, 1999) of trends at high- and at low flows from 1976-93, for all nine constituents are also summarized. Trends in constituents measured during 1975-86 at four sites in the Upper Delaware River watershed were included in an analysis of 60 sites for statistical association with watershed characteristics (Robinson and others, 1996).

The results from Hickman and Barringer, 1999 show trends existing for at least two parameters at each of the eight sites. Every constituent except for fecal coliform counts showed a trend at one or more stations. Total phosphorus, total ammonia, and dissolved oxygen decreased at three or more sites. Water temperature, pH, and total dissolved solids increased at two sites. Nitrate plus nitrite decreased at Paulins Kill at Blairstown and increased at Pohatcong Creek, and the Musconetcong River sites at Beattystown and Riegelsville.

The results of tests on total dissolved solids from all studies show an increasing trend at most sites in the Musconetcong River. These increases could be caused by changes in point source discharges, watershed land use or other watershed characteristics.

Results are summarized from another study (Buxton and others, 1999) of trends at high and at low flows for all constituents analyzed in this study, except pH and water temperature. The tests were performed on datasets with long-term data from 1976 through 1993. Positive trends during low flow conditions indicate increases in concentrations from ground water and (or) point sources. Positive trends during high flow conditions indicate increases in concentrations from storm runoff. Results from trends tests performed by Buxton and others showed similar but much fewer significant trends than results from this study and the Hickman and Barringer study. Flat Brook at Flatbrookville had an increasing trend in dissolved oxygen at high flow, fecal coliform decreased at high flow at Paulins Kill at Blairstown, and total dissolved solids increased at low flow at Musconetcong River at Reigelsville.

Trends in the concentrations of seven chemical constituents and two physical parameters measured during 1975-86 at 60 sites including four in the Upper Delaware River study area were analyzed for statistical association with watershed characteristics (Robinson and others, 1996). Urbanized subwatersheds were associated with increasing concentrations of sodium, chloride, magnesium and pH. Trends in total dissolved solids were strongly associated with application rates of road deicing salts. Upward trends in dissolved oxygen were associated with effluent discharged by nonmunicipal wastewater-treatment facilities. Trends in nutrients showed little association with the amount of effluent discharged to streams. Trends during 1975-86 in total ammonia at sites influenced by agricultural land use seem to indicate that nonpoint sources may be more of an influence than effluent discharge.

Relation of Water Quality Constituents to Land Use

Concentrations of constituents, water temperature, pH and fecal coliform were evaluated with respect to land use at 12 USGS/NJDEP network sites and at 6 of 13 DRBC sites, depending on the data available for each constituent. Variations in the levels of the constituents at the sites was significantly related to the land use in the watershed upstream from the sampling site. Each of the 9 constituents was significantly related to one or more land use categories. Forested land use was related to the median values of seven constituents, more than any other land use category.

Undeveloped land uses account for 67 percent of the land area in WMA1 (**table 1**). Total undeveloped land use was computed by adding forest, water, wetland and barren land use categories. Forested land accounts for 53.3 percent of the study area while reservoirs, lakes and ponds account for 3 percent, wetlands 10.3 percent and barren areas 0.7 percent of the study area. Developed areas, consisting of urban and agricultural land uses, account for nearly 33 percent of the study area; 19.0 percent is used for agricultural purposes and 13.6 percent is used for residential, commercial and industrial uses. The 33 sites at which land use was computed, have watersheds that reflect this mix of land uses. Land use was not calculated at the watersheds drained by the EWQ sites. Thirty of the 33 sites are more than 50 percent undeveloped, twelve sites have more than nineteen percent of their watershed in agricultural land uses and fourteen sites have at least 13 percent of their watershed in urban land uses including residential, commercial and industrial uses (**table 1**).

The land uses are derived from a 1995/97 GIS coverage (NJDEP, 2000). The percentage of forested land in the watersheds studied varies from 97.5 percent at Dunnfield Creek at Dunnfield to 29.1 percent at Delawanna Creek at Knowlton Township. The percentage of land consisting of urban land uses varies from 28.4 percent in the Lopatcong Creek at Phillipsburg watershed to 0.1 percent in the Dunnfield Creek at Dunnfield watershed. Agricultural land use varies from 46 percent at Pophandusing Creek to 0.0 percent in the Musconetcong River at the outlet of Lake Hopatcong and Dunnfield Creek at Dunnfield. The percentage of wetlands varies from 16.1 percent in the Musconetcong River at outlet of Lake Hopatcong watershed to 0.0 percent in the Dunnfield Creek at Dunnfield watershed. The percentage of total developed land use varied from 66.6 percent at Lopatcong Creek at Phillipsburg (33.4 percent undeveloped) to 0.1 percent at Dunnfield Creek (99.9 percent undeveloped).

Ordinary least squares regression was used to study relations between the percentage of major land use categories at each site (forest, urban, agriculture, wetlands, total developed and total undeveloped) and median concentrations of the six constituents, water temperature, pH and fecal coliform at these sites. Medians were computed at sites with at least eight data points. Data from the USGS/NJDEP sites and DRBC sites were studied separately because the DRBC data is mainly from the growing season only. Median values of each constituent were significantly related to one or more land use categories (**figures 24-26)**.

Analysis of variance on the ranked data was also used to examine differences in data collected at sites in different land-use categories. Data from the sites in each land use was grouped together and comparisons were made between the groups. The data from all sites, even those with too few data points to compute a median value, was used in this analysis. Sites were categorized into one of three groups according to the predominant land use in the watershed. Sites with watersheds consisting of greater than nineteen percent urban land were classified as urban. Those sites with more than nineteen percent agricultural lands were classified as agricultural and those sites with greater than or equal to 78 percent undeveloped land were classified as undeveloped. These land use percentages were used to get an even amount of sites in each category and lessen the number of sites that do not fit into a category. Only one site does not fit into one of the three categories.

Results from these analyses may indicate that nonpoint sources are related to particular land uses, however the volume of permitted point source effluent discharged above each sampling sites was not considered in this preliminary analysis. In this analysis, it was not determined whether the differences in concentrations between developed and undeveloped areas are from land use or from point source influences. Streamflow at all the sites classified as urban include discharges from NJPDES point sources. No NJPDES sites discharge to streams upstream from USGS/NJDEP network sites classified as undeveloped. Discharges to groundwater were not included in this analysis. Land use for the entire watershed was calculated at each site, not just the land use in a closer proximity to the sampling site.

Comparison of Median Values to Landuse

Median concentrations, water temperatures, fecal coliform counts, and pH were compared to percentages of urban, agriculture, forest, wetland, total developed, and total undeveloped land uses at the sampling sites by using OLS regression. Median values of all nine constituents, studied in the preliminary evaluation of water quality in the watershed, were significantly related to at least one land use category. The variability in median levels of all constituents were related to the percentage of agricultural or urban land use in the watersheds sampled.

Forested land use was significantly related to the variability in the data for eight constituents in the study area. Seven constituents at USGS/NJDEP sites (**fig. 24**) and six constituents at DRBC sites were related to the amount of forested land in the watershed. As the percentage of forested land in a watershed increased the median concentrations of un-ionized ammonia, total phosphorus, total suspended solids, total dissolved solids, fecal coliform count, and pH signicantly decreased (**figure 24**). Concentrations of dissolved oxygen increased with an increase in forested land.

Seven constituents were related to urban land use. Four constituents at the USGS/NJDEP network sites (**figure 26**) and 5 constituents at the DRBC sites. As the percentage of urban land use increased in a watershed the median total phosphorus, un-ionized ammonia, total suspended solids, total dissolved solids concentrations, water temperature, and fecal coliform increased. Concentrations of dissolved oxygen decreased as urban land increased.

Agricultural land use in a watershed was related to increases in six constituents; total dissolved and total suspended solids, total phosphorus, nitrate plus nitrite, fecal coliform and pH (**figure 25**).

The percentages of total developed and total undeveloped land use were each related to seven constituents. Median values related to total undeveloped land use were the same as those related to forested land, except there was no relation with dissolved oxygen. The same constituents showed significant opposite relations to developed land use (**figure 25**).

The median concentrations of only 2 constituents were related to the percentage of wetlands. Both TDS and pH significantly increased as the percentage of wetlands increased at NJDEP/USGS network sites. At DRBC sites, only pH increased with an increase in wetlands upstream from a sampling site.

Comparison of all Data grouped by Land Use

Data values from all sites were grouped together into one of three land use categories in an effort to include all network data in this analysis, even data from sites with too few data points to compute a median value. The entire drainage area contributing to a sampling site was classified as either undeveloped, urban or agricultural. There was a significant difference between data collected from sites in each of the three landuse areas. Data for 8 of the 9 constituents collected at sampling sites draining areas of more than 78 percent undeveloped land had significantly lower values than data collected at sites draining land with higher percentages of urban and agricultural land uses. Only concentrations of dissolved oxygen did not vary between categories.

Median values of fecal coliform, total dissolved solids, and total phosphorus are significantly higher at agricultural sites than the data collected at urban and undeveloped sites. Water temperature, pH, nitrate plus nitrite, un-ionized ammonia, and total suspended solids are equally high among the data collected at agricultural and urban sites. The data collected for these 5 constituents is significantly lower at undeveloped sites.

Changes along stream reaches

To facilitate regional discussion of the subwatershed area's issues and water quality along stream reaches, the subwatersheds in the Upper Delaware have been grouped into 5 larger units in this watershed characterization effort. For reports developed as part of this effort, smaller subwatersheds that have similar natural resource and human-based elements were considered. The subwatershed breakdown used is as follows:

1) Flat Brook Watershed Group
Including Big and Little Flat Brook, Shimers Brook, Clove Brook, Van Campens Brook, Stony Brook and Dunnfield Creek (**fig. 27**)

2) Paulins Kill Watershed Group
Including Paulins Kill, Trout Brook, Delawanna Brook, and Stony Brook (**fig. 28**)

3) Pequest River Watershed Group
Including Pequest River, Bear Creek and Beaver Brook (**fig. 29**)

4) Pohatcong-Lopatcong Creek Watershed Group
Including Pohatcong Creek, Lopatcong Creek, Buckhorn Creek and Pophandusing Brook (**fig. 30**)

5) Musconetcong Watershed (**fig. 31**)

Multiple stations along the Musconetcong River, Pequest River, and Paulins Kill allowed for an analysis of water quality along these stream reaches. Five sites along the Musconetcong River(**fig. 31**), and 2 sites along the Pequest River (**fig. 29**), and Paulins Kill (**fig. 28**) were used for comparison.

Five of the six sites along the Musconetcong River have a sufficient amount of data for comparison. Lake Hopatcong is in the headwaters of the watershed. Sampling sites exist along the river from the outlet of the lake to the mouth (**figure 1**). Agricutural land use increases from 0 percent at the most upstream site to 18.8 percent at the site at the mouth. Urban land use is fairly constant with the highest percentage at the most upstream site (**table 1**). Forested land varies from 47 to 57 percent. All sites are influenced by permitted point sources. Discharge from municipal facilities varies from 0.003 cfs discharged to an unnamed tributary to Lake Shawnee upstream from the site at the outlet of Lake Hopatcong to over 6 cfs at the downstream site.

Water temperature and dissolved oxygen did not vary significantly between any of the sites. Median values of fecal coliform, total dissolved solids, and nitrate plus nitrite increase progressively and significantly from upstream to downstream. Total suspended solids data is not available at the two upstream sites. Concentrations increase slightly in downstream order at the other sites. Median pH values were significantly lower at the two sites in the upper portion of the watershed than at the 3 sites furthest downstream. Un-ionized ammonia and total phosphorus are equally low at the outlet of Lake Hopatcong and the Bloomsbury site. Concentrations at Lockwood, Beattystown and Reigelsville are significantly higher.

Median total phosphorus concentrations were the lowest at the most upstream site at the outlet of Lake Hopatcong (01455500) and at Bloomsbury (01457000) and among the highest at Lockwood (01455801) and Beattystown (01456200). The increase in median total phosphorus concentrations between the outlet of Lake Hopatcong and Beattystown may be influenced by point source discharges and the proximity of the Beattystown site to the urban area surrounding Hackettstown. Over 5.8 cfs of municipal effluent is discharged to the river between the sites in addition to a smaller unknown quantity of effluent discharged by 3 industrial facilities. The observed drop in median phosphorus between Beattystown and Bloomsbury may to related to the dilution of point source effluent, distance from the Hackettstown urban area, and to a difference in the period of record at the sites. The period of record at Beattystown is from 1985 through 1997. The record at the downstream site at Bloomsbury is from 1991-97. Results from trends tests have shown a significant drop in total phosphorus concentrations at 3 of the 5 sites on the Musconetcong River from 1985-97.

Few significant changes were observed between the Pequest River sites at Pequest (upstream site) and Belvidere (downstream site) which are approximately 6 miles apart. Fecal coliform was significantly higher at the downstream site at Belvidere and total suspended solids were significantly higher at Pequest. Land use is similar in both watersheds. No municipal point sources discharge to the river between the sites.

Five constituents vary significantly between the upstream most site at Balesville and downstream site at Blairstown on the Paulins Kill which are approximately 15 miles apart. The upstream site at Balesville has higher total phosphorus, total dissolved solids, nitrate plus nitrite, and fecal coliform than Blairstown. The median pH is higher at Blairstown than at Balesville. Higher percentages of agricultural and urban landuses and a larger percentage of instream flow from municipal point sources may contribute to the higher values at Balesville.

Water Quality Summary

Twelve sites from the NJDEP/USGS network and 10 DRBC sites were summarized based on the median value as a percent of the surface water quality standard. **Figures 27-31** are maps showing the sampling sites and bar charts representing the median value as a percent of the surface water quality standard. The sites are also summarized with respect to the best and worst water quality in **table 8** by color-coding the table cells to represent the median value as a percent of the instream standard. The most desirable rating for each constituent at a site is designated by a white cell that represents a median value of less than or equal to 20 percent of the surface water standard. A yellow cell represents a median value of 21 to 50 percent, an orange cell 51-100 percent and a brown cell greater than 100 percent of the standard. Median values of fecal coliform exceeded the 400 MPN/100 ml standard at seven sites, the 2 downstream Musconetcong River sites, the 2 Pohatcong Creek sites, Lopatcong Creek, Paulins Kill at Balesville and Pequest River at Belvidere. Median total phosphorus exceeded 0.1 mg/L at Pohatcong Creek and the median water temperature in the growing season exceeded 20^{o} C at the DRBC site at the mouth of the Paulins Kill.

Table 8. Summary of water quality conditions at 12 NJDEP/USGS sites and 10 DRBC sites sampled in the Upper Delaware River watershed from 1985-2000 [Colored cells represent the median as a percent of the surface water standard; White cells = ≤ 20 percent, **Yellow** = 21-50 percent, **Orange** = 51-100 percent, **Brown** = Median greater than standard; Ratings for pH are based pH units above 6.5 or below 8.5; Ratings for dissolved oxygen are based on standard as a percent of the median; *, trout maintenance; ** trout production; NA, median value not available]

Station Number	Nutrients		Inorganics		Other Constituents					
	Ammonia Un-ionized	Nitrite plus Nitrate	Phosphorus, total	Dissolved solids, total	Dissolved Oxygen	Fecal coliform	pH		Suspended solids, total	Water temper-ature
							6.5	8.5		
Subwatershed 1: Flat Brook, Shimers Brook, Van Campens Brook, and Dunnfield Creek										
**01440000 Flat Brook										
**01442760 Dunnfield Creek										
**DRBC2251 Little Flat Brook										
**DRBC2252 Big Flat Brook										
**DRBC32 Flat Brook										
**DRBC321 Flat Brook	NA		NA	NA						
**DRBC47 Van Campens Brook										
**DRBC31 Shimers Brook			NA	NA					NA	
Subwatershed 2: Paulins Kill										
01443440 at Balesville										
*01443500 at Blairstown										
*DRBC36 at Columbia		NA								
Subwatershed 3: Pequest River										
*01445500 at Pequest										
*01446400 at Belvidere										
Subwatershed 4: Pohatcong Creek, Lopatcong Creek, Buckhorn Creek, and Pophandusing Creek										
*01455200 Pohatcong Creek										
*DRBC27 Pohatcong Creek		NA								
*DRBC28 Lopatcong Creek	NA	NA	NA	NA						
**DRBC30 Buckhorn Creek	NA	NA	NA	NA		NA				
Subwatershed 5: Musconetcong River										
*01455500 at Lk Hopatcong									NA	
*01455801 at Lockwood									NA	
*01456200 at Beattystown										
*01457000 near Bloomsbury										
*01457400 at Reigelsville										

SUMMARY AND CONCLUSIONS

Water quality data was analyzed for nine constituents collected from 1985-2001 at NJDEP/USGS, DRBC, LINJ NAWQA, and EWQ network sites on tributaries to the Upper Delaware River watershed in New Jersey. Data was evaluated with respect to instream standards, trends at sites, variability at sites between seasons and flow conditions, variability between sites in the study area and landuses at those sites, comparisons to data from statewide sampling networks, and changes in quality along stream reaches.

In general, water quality in the study area compares favorably to water quality in New Jersey as a whole. Streams in the study area have lower total suspended solids, total phosphorus, nitrate plus nitrite, water temperature, and fecal coliform counts and higher dissolved oxygen and pH than streams from across the state. These seven constituents would indicate better overall quality in WMA1 than in other areas of the state. Total dissolved solids were higher, most likely as a result of geology and agriculture in the area. The highest levels are found at low flow in the summer and are not a result of higher amounts of road salt during runoff events in the winter. Un-ionized ammonia was slightly higher in the study area than in New Jersey as a whole.

Water quality data in the study area was compared with data collected at 6 sites on streams among those with the highest quality in the state of New Jersey. In general, water quality at the statewide background sites is better than the overall water quality at WMA1. Dissolved oxygen is the only constituent with a median value indicative of better water quality in the study area than at background sites. Data from sites draining undeveloped areas in the Dunnfield Creek, and Flat Brook have comparable or lower median values for all constituents except total dissolved solids at Flat Brook.

Data was compared to the surface water standard for 8 of the 9 constituents. The drinking water maximum contaminant level was used as a reference for nitrate plus nitrite concentrations because no instream standard exists. The most commonly occuring constituents measured above standards were fecal coliform, > 400 MPN/100ml in 23 percent; total phosphorus, > 0.1 mg/L in 22 percent; water temperature in designated trout waters, >20 ^{o} C in 21 percent; and pH, >8.5 or <6.5 in 13 percent of samples collected at USGS/NJDEP and DRBC sampling sites. At sites in nontrout waters the percentage of fecal coliform and total phosphorus data not meeting standards was 51 and 31 percent respectively. Eight of the 9 constituents did not meet standards in at least one sample at one or more sites in the study area. Nitrate plus nitrite was the only constituent that met the reference level in every sample.

Sites on the Pohatcong Creek and Musconetcong River have more constituents not meeting standards than sites in the other subwatersheds. Six of the nine constituents exceeded the level set for standards in one or more samples on these streams. Eighty percent of all samples at Pohatcong Creek at New Village exceeded 0.1 mg/L and 97 percent exceeded that level at low flow, indicating a constant base-flow or point source. Phosphorus values over 0.1 mg/L did not account for more than 35 percent of the data at other sites. Fecal coliform exceeded the 400 MPN/100ml standard in more than half the samples at 11 of the 33 sampling sites including the two Pohatcong Creek sites and the two Musconetcong River sites furthest downstream. Most exceedences at the NJDEP/USGS sites occurred at low flow conditions. Low flow samples on the Pohatcong Creek exceeded 400 MPN/100ml in 82 percent of the samples.

Dunnfield Creek and Jacksonburg Creek (01443550) are the only sites with pH data less than 6.4. Data below the 6.5 instream standard accounts for 65 percent of the DRBC data and 33 percent of the USGS/NJDEP data at the Dunnfield Creek site and 25 percent of the data at the upstream most Jacksonburg Creek site. The drainage watersheds at both sites are over 94 percent undeveloped with no agricultural land uses. Both sites drain areas of steep mountainous terrain along the Kittatinny mountain ridge. The geology upstream of these sites consists of erosion resistant layers of sandstone and siltstone unique to the Kittatinny Mountain and Walpack Ridge.

Results from trends tests indicate improving water quality in the study area. Un-ionized ammonia, total phosphorus, water temperature, pH are decreasing and dissolved oxygen is increasing at some sites including some with the worst conditions. However, total dissolved solids and nitrate plus nitrite concentrations are increasing at some sites in the Musconetcong River and Pohatcong Creek. Pohatcong Creek has the highest median concentration of nitrate plus nitrite (1.93 mg/L), but highest values at the site are still substantially less than the drinking water maximum contaminant level. Total suspended solids and fecal coliform counts did not change significantly at any sites.

Median values of all constituents, except dissolved oxygen, were significantly related to land use upstream from the sampling site. Sampling sites draining areas of more than 78 percent undeveloped land had significantly lower values than data collected at sites draining land with higher percentages of urban and agricultural land uses. Median values of fecal coliform, total dissolved solids, and total phosphorus are significantly higher at agricultural sites than the data collected at urban and undeveloped sites. Water temperature, pH, nitrate plus nitrite, un-ionized ammonia, and total suspended solids are equally high among the data collected at agricultural and urban sites.

Variability in water quality at a site is related to changes in season and/or flow condition. The following constituents were significantly higher in the growing season at one or more sites; water temperature, fecal coliform count, pH, total phosphorus, unionized ammonia and total dissolved solids. The highest observed total dissolved solids concentrations are from a constant base-flow source and not from nonpoint sources during runoff events in the nongrowing season as has been observed in some other streams in New Jersey. The following constituents were significantly higher in the nongrowing season at one or more sites; dissolved oxygen, pH, and nitrate plus nitrite. All constituents were significantly higher at low flow than at high flow at one or more sites except for dissolved oxygen, and total suspended solids which are higher at high flow at all sites and nitrate plus nitrite which is higher at a few sites.

Sites on the Musconetcong River and Pohatcong Creek were among the sites with the lowest median dissolved oxygen and highest median values for six of the eight other constituents. Sites on these streams drain areas with some of the highest percentages of urban and agricultural land in the study area. Effluent from point source discharges accounts for over 4 percent of median stream flow at Pohatcong Creek and up to 5 percent at a Musconetcong river site. In contrast, sites on the Flat Brook and Dunnfield Creek have among the highest dissolved oxygen and lowest values for the other 8 constituents. Van Campens Brook also had among the lowest median values for 5 constituents. These sites drain areas over 90 percent undeveloped with no permitted point sources.

Sites along the Musconetcong River were among those with both the highest and lowest levels of nitrate plus nitrite, total phosphorus, total suspended solids, dissolved oxygen and pH in the study area. Dissolved oxygen, nitrate plus nitrite, total suspended solids, and pH were lower at the upstream sites than at the downstream sites. Total phosphorus is among the lowest at the outlet of Lake Hopatcong (01455500) and at Bloomsbury (01457000) and among the highest at Beattystown (01456200) (**figure 1**). The increase in median total phosphorus concentrations between the outlet of Lake Hopatcong and Beattystown may be influenced by point source discharges and the proximity of the Beattystown site to the urban area surrounding Hackettstown.

GLOSSARY

Background Sites—Locations sampled for the USGS/NJDEP cooperative monitoring network on streams draining predominantly undeveloped areas from across New Jersey.

Base-flow—Sustained, low flow in a stream; ground water is the source of base-flow in most streams.

Lithology--The character of a rock formation

Median--The middle value from a group of samples arranged from lowest to highest.

Statewide Status Sites--Locations randomly chosen from streams across New Jersey for the USGS/NJDEP cooperative monitoring network to represent the range of water quality in the state

Streamflow—The rate at which surface water moves through a stream channel. Often referred to as discharge in reports by the USGS.

Stream reach--A distance along a stream.

Water purveyors--Those who supply water to municipalities for residential, commercial and industrial uses.

Watershed—The land area that drains all the streams and rainfall to a common outlet, such as the outflow of a reservoir, the mouth of a bay, or any point along a stream channel. Sometimes referred to as drainage basin or catchments.

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Appendix 1. Water quality standards and frequency of samples not meeting standards at USGS/NJDEP and DRBC sites and geometric mean of fecal coliform counts sampled from 1985-2000

Table 1a. Water quality standards and frequency of samples not meeting these reference levels at the 21 USGS sites sampled in the Delaware River watershed, watershed management area 1, from 1985-2000 [Standards: concentrations are in milligrams per liter, coliform is in most probable number, pH is in standard units, and temperature is in degrees celsius; <, less than the standard; >, greater than the standard; *, trout maintenance; ** trout production; L, criteria in lakes, and reservoirs and tributaries at point of entry to such water bodies; G, geometric average; Blue shaded cells = high flow; **Bold text** = greater than 50% not meeting standards; --, no data available; Numbers in the table are percentages of data not meeting the standard]

Standards	Ammonia, un-ionized	Dissolved Oxygen	Dissolved solids, total	Fecal coliform	Nitrite plus Nitrate	pH	Phosphorus total	Suspended solids, total	Water temperature
Drinking water	--	--	500	--	10	--	--	--	--
New Jersey Surface Water	*0.02 0.05	> 4 *> 5 **> 7	500	G200 400	--	>6.5 <8.5	L0.05 0.1	*25 40	*20 27.8

Stream sampling sites	**Percent of samples not meeting the standard**								
All Trout Sites	*1.8	*0.2, 0**	0	35	0	<1.3 , >11	24, L54	*2.5	*22
All Nontrout Sites	0	0	0	**51**	0	0	31, L**63**	0	0
**Big Flat Brook (01439830)	0	0	0	0	0	0	0	0	0
*Flat Brook (01440000)	0	0	0	4.2	0	<0, >9.4	0, L23	0	16
*Flat Brook (01440010)	--	0	0	--	0	0	0	0	50
**Dunnfield Creek (01442760)	0	0	0	0	0	<33, >0	0, L33	0	8.3
**Paulins Kill (01443290)	--	0	0	--	0	0	0	0	0
Dry Brook (01443370)	0	0	0	**60**	0	0	0, L25	0	0
Paulins Kill (01443440)	0	0	0	**51**	0	0	32, L**65**	0	0
*Paulins Kill (01443500)	1.2	0	0	21	0	<0,>4.8	4.8, L46	0	29
*Jacksonburg Creek (01443550)	0	0	0	--	0	<25,>0	0, L**50**	0	0
*Jacksonburg Creek (01443600)	0	0	0	--	0	0	0, L**100**	0	0
*Pequest River (01444970)	0	25	0	40	0	0	0	0	25
*Pequest River (01445000)	0	0	0	0	0	0	0	0	0
*Pequest River (01445500)	0	0	0	26	0	0	29, L**74**	14	0
*Pequest River (01446400)	0	0	0	**80**	0	0, >33	17, L42	0	17
*Pohatcong Creek (01455200)	4.5	0	0	**72**	0	<1.4, >20	**80**, L**96**	7.1	20

Standards	Ammonia, un-ionized	Dissolved Oxygen	Dissolved solids, total	Fecal coliform	Nitrite plus Nitrate	pH	Phosphorus total	Suspended solids, total	Water temperature
Drinking water	--	--	500	--	10	--	--	--	--
New Jersey Surface Water	*0.02 0.05	> 4 *> 5 **> 7	500	G200 400	--	>6.5 <8.5	L0.05 0.1	*25 40	*20 27.8
*Musconetcong River (01455500)	0	0	0	2.7	0	<2.6, >5.3	0, L7.7	--	38
*Musconetcong River (01455801)	0	0	0	23	0	0	27, L**68**	--	34
*Musconetcong River (01456200)	6.2	0	0	23	0	<0, >12	32, L**65**	0	25
*Musconetcong River 01456600	--	0	0	--	0	0	0	0	0
*Musconetcong River 01457000	0	0	0	**55**	0	<0, >26	10, L26	0	13
*Musconetcong River 01457400	1.3	0	0	**52**	0	<0, >11	24, L**60**	4.3	24
By season									
Growing season, trout sites	*1.9	*0.6, **0	0	44	0	<0.9, >10	27, L59	2.2	35
Nongrowing season, trout sites	*1.6	*0, **0	0	14	0	<2.1, >13	19, L45	2.7	0
Growing Season, nontrout sites	0	*0, **0	0	65	0	0	37, L**72**	0	0
Nongrowing season, nontrout sites	0	*0, **0	0	27	0	0	21, L48	0	0
By flow									
All high flow samples, at trout sites	0.9	*0, **0	0	31	0	<1.6, >7.8	22, L**52**	5.4	12
All low flow samples, at trout sites	2.6	*0.7, **0.4	0	37	0	<1.1 ,>13	25, L**56**	0	31
All high flow samples, at nontrout sites	0	*0, **0	0	32	0	<0, >0	21, L**52**	0	6.1
All low flow samples, at nontrout sites	0	0	0	65	0	<0, >0	38, L**71**	0	0
**Big Flat Brook (01439830)	--	--	--	--	--	--	--	--	--
	0	0	0	0	0	0	0	0	0
*Flat Brook (01440000)	0	0	0	0	0	0	0, L7.7	0	0
	0	0	0	5.9	0	<0, >16	0, L31	0	26
*Flat Brook (01440010)	--	--	--	--	--	0	--	--	0
	--	0	0	--	0	0	0	0	0
**Dunnfield Creek (01442760)	0	0	0	--	0	<**60**, >0	0, L20	0	0
	0	0	0	0	0	<14, >0	0, L43	0	14
**Paulins Kill (01443290)	--	--	--	--	--	0	--	--	0
	--	0	0	--	0	0	0	0	0

Standards	Ammonia, un-ionized	Dissolved Oxygen	Dissolved solids, total	Fecal coliform	Nitrite plus Nitrate	pH	Phosphorus total	Suspended solids, total	Water temperature
Drinking water	--	--	500	--	10	--	--	--	--
New Jersey Surface Water	*0.02 0.05	> 4 *> 5 **> 7	500	G200 400	--	>6.5 <8.5	L0.05 0.1	*25 40	*20 27.8
Dry Brook (01443370)	--	--	--	--	--	--	--	--	--
	0	0	0	**60**	0	0	0, L25	0	0
Paulins Kill (01443440)	0	0	0	32	0	0, 0	21, L**52**	0	0
	0	0	0	**66**	0	0	42, L**76**	0	0
*Paulins Kill (01443500)	2.5	0	0	29	0	<0, >4.9	2.4, L39	5.0	15
	0	0	0	16	0	<0, >4.7	7.0, L**54**	0	42
*Jacksonburg Creek (01443550)	--	--	--	--	--	--	--	--	--
	0	0	0	--	0	<25, >0	0, L50	0	0
*Jacksonburg Creek (01443600)	--	--	--	--	--	--	--	--	--
	0	0	0	--	0	0	0	0	0
*Pequest River (01444970)	--	--	--	--	--	--	--	--	--
	0	25	0	40	0	0	0	0	25
*Pequest River (01445000)	--	--	--	--	--	--	--	--	--
	0	0	0	0	0	0	0	0	0
*Pequest River (01445500)	0	0	0	20	0	<0, >13	33, L**60**	22	0
	0	0	0	31	0	<0, >19	25, L**88**	0	0
*Pequest River (01446400)	0	0	0	--	0	0	17, L33	0	17
	0	0	0	**80**	0	<0, >**67**	17, L50	0	17
*Pohatcong Creek (01455200)	2.9	0	0	**63**	0	<2.8, >14	**65**, L**94**	11	5.4
	6.1	0	0	**82**	0	<0, >26	**97**, L**97**	0	35
*Musconetcong River (01455500)	0	0	0	10	0	0	0, L9.1	--	27
	0	0	0	0	0	<3.6, >7.1	0, 7.1	--	43
*Musconetcong River (01455801)	0	0	0	16	0	0	18, L**63**	--	26
	0	0	0	36	0	0	42, L**79**	--	50
*Musconetcong River (01456200)	0	0	0	20	0	<0, >11	30, L**60**	0	16
	13	0	0	26	0	<11, >13	36, L**71**	0	36
Musconetcong River 01456600	--	--	--	--	--	0	--	--	0
	0	0	0	--	0	0	0	0	0
Musconetcong River 01457000	0	0	0	38	0	<0, >19	6.3, L25	0	0
	0	0	0	**73**	0	<0, >33	13, L27	0	27
Musconetcong River 01457400	0	0	0	41	0	<0, >8.6	21, L**53**	9.1	11

Standards	Ammonia, un-ionized	Dissolved Oxygen	Dissolved solids, total	Fecal coliform	Nitrite plus Nitrate	pH	Phosphorus total	Suspended solids, total	Water temperature
Drinking water	--	--	500	--	10	--	--	--	--
New Jersey Surface Water	*0.02 0.05	> 4 *> 5 **> 7	500	G200 400	--	>6.5 <8.5	L0.05 0.1	*25 40	*20 27.8
	2.1	0	0	**58**	0	<0, >12	25, L**65**	0	33

Table 1b. Water quality standards and frequency of samples not meeting these reference levels at the 15 DRBC sites sampled in the Delaware River watershed, watershed management area 1, from 1985-2000 [concentrations are in milligrams per liter, coliform is in most probable number, pH is in standard units, and temperature is in degrees celsius; <, less than the standard; >, greater than the standard; *, trout maintenance; ** trout production; L, criteria in lakes, and reservoirs and tributaries at point of entry to such water bodies; G, geometric average; **Bold text** = greater than 50% not meeting standards; --, no data available]

Standards	Ammonia, un-ionized	Dissolved Oxygen	Dissolved solids, total	Fecal coliform	Nitrite plus Nitrate	pH	Phosphorus, total	Suspended solids, total	Water temperature
Drinking water	--	--	500	--	10	--	--	--	--
New Jersey Surface Water	*0.02 0.05	> 4 *> 5 **> 7	500	G200 400	--	>6.5 <8.5	L0.05 0.1	*25 40	*20 27.8

Stream sampling sites	Percent of samples not meeting the standard								
Trout Sites	*0	**0.3	0.8	9.9	0	<2.9, >12	8.5, L26	*5.1	*36
Nontrout Sites	0	0	0	**69**	0	<0, >4.3	25, L**50**	15	0
*Musconetcong River DRBCNPS0025	0	0	0	44	0	<0, >4.2	18, L54	25	52
**Shimers Brook DRBCNPS0047	0	0	0	2.2	0	<0, 12>	0, L9.4	4.8	47
**Little Flat Brook DRBCNPS2251	0	0	0	3.3	0	<0, >8.6	0	0	25
**Big Flat Brook DRBCNPS2252	0	0	0	0	0	<0, >1.7	0	0	6.3
*Flat Brook DRBCNPS0321	--	0	--	5.7	0	<0, >29	0	--	50
*Flat Brook DRBCNPS0032	0	0	0	2.6	0	<0, >34	4.5, L4.5	0	64
**Van Campens Brook DRBCNPS0031	0	0	0	1.3	0	<2.0, >0	0	0	6.9
*Paulins Kill DRBCNJ0036	0	0	0	21	0	<0, >8.7	20, L**80**	0	**70**
*Delawanna Creek DRBCNJ0035	--	0	--	**75**	0	<0, >20	--	--	0
Pophandusing Brook DRBCNJ0031*	--	0	--	**67**	0	0	--	--	**67**
Buckhorn Creek DRBCNJ0030**	--	8.3	0	**57**	0	<0, >8.3	0	0	42
Lopatcong Creek DRBCNJ0028	0	0	0	**64**	0	<0, >19	0, L**60**	0	0
Pequest River DRBCNJ0033*	0	0	8.3	35	0	<0, >22	27, L**64**	0	39
Pohatcong Creek DRBCNJ0027	0	0	0	**69**	0	<0, >4.3	25, L**50**	15	0
Dunnfield Creek DRBCNPS0025**	0	0	--	6.3	0	<**65**, >0	0	0	4.3
By season									
Growing season, trout sites	0	**0.3	0.8	10	0	<3.0, >13	8.5	5.1	38
Nongrowing season, trout sites	--	0	--	0	0	<0, >3.4	--	--	6.9

Standards	Ammonia, un-ionized	Dissolved Oxygen	Dissolved solids, total	Fecal coliform	Nitrite plus Nitrate	pH	Phosphorus, total	Suspended solids, total	Water temperature
Drinking water	--	--	500	--	10	--	--	--	--
New Jersey Surface Water	*0.02 0.05	> 4 *> 5 **> 7	500	G200 400	--	>6.5 <8.5	L0.05 0.1	*25 40	*20 27.8
Growing Season, nontrout sites	0	0	0	64	0	<0, >19	0, L60	0	0
Nongrowing season, nontrout sites	--	--	--	--	--	--	--	--	--

Table 1c. Geometric Mean of Fecal coliform counts per 100/mL and exceedances of surface water standard [Bold text = exceeds New Jersey surface water standard, geometric mean > 200 counts/ 100mL]

Station number	Number of samples			Geometric mean		
	Total	High Flow	Low Flow	All samples	High Flow	Low Flow
**Big Flat Brook (01439830)	5	0	8	20.9	--	20.9
*Flat Brook (01440000)	24	7	17	28.5	< 20	36.4
*Flat Brook (01440010)	0	0	0	--	--	--
**Dunnfield Creek (01442760)	10	0	10	< 20	--	< 20
**Paulins Kill (01443290)	0	0	0	--	--	--
Dry Brook (01443370)	5	0	5	**652**	--	**652**
Paulins Kill (01443440)	69	33	38	**435**	199	**826**
*Paulins Kill (01443500)	79	34	45	114	103	124
*Jacksonburg Creek (01443550)	0	0	0	--	--	--
*Jacksonburg Creek (01443600)	0	0	0	--	--	--
*Pequest River (01444970)	5	0	5	**555**	--	**555**
*Pequest River (01445000)	4	0	4	187	--	187
*Pequest River (01445500)	31	15	16	**247**	**213**	**284**
*Pequest River (01446400)	10	0	10	**880**	--	**880**
*Pohatcong Creek (01455200)	69	35	34	**660**	**487**	**903**
*Musconetcong River (01455500)	37	10	27	28.5	55	22.4
*Musconetcong River (01455801)	19	5	14	133	101	**215**
*Musconetcong River (01456200)	66	35	31	128	107	155
*Musconetcong River 01456600	0	0	0	--	--	--
*Musconetcong River 01457000	31	16	15	**351**	192	**669**
*Musconetcong River 01457400	79	27	52	**364**	**243**	**450**

Samples from all sites by season		
Season	Number of Samples	Geometric Mean
Growing	388	**320**
Nongrowing	175	63.7

Samples from all sites by flow condition		
Flow Condition	Number of Samples	Geometric Mean
High Flow	235	158
Low Flow	328	**225**

Table 1d. Geometric Mean of Fecal coliform counts per 100/mL and exceedances of surface water standard for Delaware River Basin Commission sampling sites [Bold text = exceeds New Jersey surface water standard, geometric mean > 200 counts/ 100mL]

Station number	Number of samples				Geometric mean			
	Total	High Flow	Low Flow	Flow Unknown	All samples	High Flow	Low Flow	Flow Unknown
Little Flat Brook DRBCNPS2251	60	--	--	60	51.9	--	--	51.9
Big Flat Brook DRBCNPS2252	64	--	--	64	26.7	--	--	26.7
Van Campens Brook DRBCNPS0031	80	2	30	48	29.6	4.0	29.0	32.6
Flat Brook DRBCNPS0032	78	--	--	78	34.7	--	--	34.7
Flat Brook DRBCNPS0321	35	--	--	35	98.0	--	--	98.0
Shimers Brook DRBCNPS0047	134	--	19	116	25.4	--	23.5	25.7
*Musconetcong River DRBCNPS0025 (01457400)	16	2	6	8	**392**	232	169	**839**
Pohatcong Creek DRBCNJ0027	16	--	--	16	**709**	--	--	**709**
Lopatcong Creek DRBCNJ0028	11	--	--	11	**386**	--	--	**386**
Buckhorn Creek DRBCNJ0030	7	--	--	7	**205**	--	--	**205**
Pophandusing Brook DRBCNJ0031	3	--	--	3	**512**	--	--	**512**
*Pequest River DRBCNJ0033 (01446400)	17	--	5	7	**246**	--	**225**	**279**
Delawanna Creek DRBCNJ0035	4	--	--	4	**438**	--	--	**438**
Paulins Kill DRBCNJ0036	14	2	6	6	169	66.9	**597**	**282**
*Dunnfield Creek DRBCNPS0025 (01442760)	32	--	--	32	28.2	--	--	28.2

Samples from all sites by season		
Season	Number of Samples	Geometric Mean
Growing	538	50.6
Nongrowing	29	17.2
Samples from all sites by flow condition		
Flow Condition	Number of Samples	Geometric Mean
High Flow	6	82.2
Low Flow	66	42.5
Flow Unknown	495	48.4

Appendix 2. Statistical summaries of un-ionized ammonia data from NJDEP/USGS and DRBC sites and comparison of data between different season and flow conditions

Table 2a. Statistical summary of un-ionized ammonia measured in samples collected from 1985 – 2000 [concentrations are in milligrams per liter]

USGS Site Number	Number of samples	Percent Censored	Inner quartile range	Standard Deviation	Mini-mum	25th	median	75th	Maxi-mum
Big Flat Brook (01439830)	4	100			<0.0001				<0.0003
Flat Brook (01440000)	27	70	0.0004	0.0007	<0.0001	0.0001	0.0002	0.0005	0.0027
Flat Brook (01440010)	0	--							
Dunnfield Creek (01442760)	12	100	0.0000	0.0000	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Paulins Kill (01443290)	0	--							
Dry Brook (01443370)	4	75			<0.0001				0.0004
Paulins Kill (01443440)	70	23	0.0023	0.0019	<0.0001	0.0006	0.0011	0.0029	0.0092
Paulins Kill (01443500)	82	45	0.0024	0.0032	<0.0002	0.0003	0.0011	0.0027	0.0208
Jacksonburg Creek (01443550)	4	100			<0.0001				<0.0001
Jacksonburg Creek (01443600)	4	75			<0.0001				0.0006
Pequest River (01444970)	4	75			<0.0002				0.0005
Pequest River (01445000)	4	75			<0.0002				0.0011
Pequest River (01445500)	31	19	0.0044	0.0037	<0.0001	0.0010	0.0022	0.0054	0.0166
Pequest River (01446400)	12	58	0.0009	0.0009	0.0029	0.0007	0.0011	0.0016	0.0037
Pohatcong Creek (01455200)	67	10	0.0037	0.0064	<0.0001	0.0007	0.0022	0.0044	0.0332
Musconetcong River (01455500)	37	24	0.0020	0.0024	<0.0001	0.0003	0.0008	0.0023	0.0131
Musconetcong River (01455801)	40	0	0.0053	0.0031	0.0005	0.0017	0.0042	0.0071	0.0121
Musconetcong River (01456200)	65	24	0.0084	0.0067	<0.0002	0.0007	0.0046	0.0091	0.0310
Musconetcong River (01456600)	0	--							
Musconetcong River (01457000)	31	74	0.0016	0.0016	<0.0002	0.0004	0.0008	0.0017	0.0075
Musconetcong River (01457400)	80	30	0.0043	0.0043	<0.0001	0.0005	0.0013	0.0041	0.0258

Table 2b. Statistical summary of un-ionized ammonia computed from total ammonia, pH and water temperature measured in samples collected by the Delaware River Basin Commission from 1990 – 2000 [concentrations are in milligrams per liter; *, Site also samples by USGS/NJDEP]

DRBC Site Number	Number of samples	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maximum
DRBC/ NPS2251	9	.00007	.00050	<.00010	.000096	.0001	.00038	.00165
DRBC/ NPS2252	8	.00010	.00015	<.00002	.00002	.00003	.00014	.00049
DRBC/ NPS31	9	.00001	.00005	<.00001	<.00003	<.00004	.00004	.00015
DRBC/ NPS32	19	.00066	.00060	<.00004	.00023	.0003	.00098	.00234
DRBC/ NPS321	0	.	.	.	.	.	.	.
DRBC/ NPS47	23	.00091	.00075	<.00009	.0003	.0004	.00126	.00253
*DRBCNJ 0025 (01457400)	10	.00120	.00213	<.00003	.000036	.000045	.00137	.00704
DRBCNJ 0027	11	.00045	.00083	<.00003	<.00018	<.00030	.00064	.00250
DRBCNJ 0028	5	.00031	.00020	<.00001	.	.	.	<.00048
DRBCNJ 0030	0	.	.	.	.	.	.	.
DRBCNJ 0031	0	.	.	.	.	.	.	.
*DRBCNJ 0033 (01446400)	11	.00215	.00150	<.00007	<.00058	<.00067	<.00273	.00440
DRBCNJ 0035	0	.	.	.	.	.	.	.
DRBCNJ 0036	10	.00192	.00125	<.00015	.00048	.00053	.00220	.00394
*DRBCNP S0025 (01442760)	1	.00000	.	<.00001	.	.	.	<.00001

Table 2c. Statistical summary and differences in un-ionized ammonia concentrations between seasons and flow conditions using all data from 1991 -1997 water years [un-ionized ammonia is in milligrams per liter; NS, indicates the distribution of un-ionized ammonia during the growing season and nongrowing season or during high flow and low flow conditions did not differ at the 0.05 significance level; G, significant differences occur between seasons and highest un-ionized ammonia occurs in the growing season (April- October); NG, significant differences occur between seasons and highest un-ionized ammonia occurs in the nongrowing season (November-March); LO, significant differences occur between flow conditions and largest un-ionized ammonia occur at low flow (less than median flow); HI, significant differences occur between flow conditions and highest un-ionized ammonia occurs at high flow (greater than median flow); Season(flow), indicates interaction of flow and season with highest median; ND, not enough data to perform an analysis of variance]

Station Number	UN-IONIZED AMMONIA							
	Number of samples	Seasonal Comparison			Flow Comparison			Flow and season inter-action (highest median)
		Median Un-ionized Ammonia		Statistically signi-ficant	Median Un-ionized Ammonia		Statistically signi-ficant	
		Growing	Non-growing		Low flow	High flow		
Big Flat Brook (01439830)	4			ND			ND	ND
Flat Brook (01440000)	27	.00064	.00020	G	.00064	.00021	LO	G@LO
Flat Brook (01440010)	0			ND			ND	ND
Dunnfield Creek (01442760)	12	<.00005	<.00001	G	<.00005	<.00001	LO	G@LO
Paulins Kill (01443290)	0			ND			ND	ND
Dry Brook (01443370)	4			ND			ND	ND
Paulins Kill (01443440)	70	.00160	.00080	NS	.00165	.00086	LO	NG@LO
Paulins Kill (01443500)	82	.00208	.00065	G	.00183	.00106	NS	G@LO
Jacksonburg Creek (01443550)	4			ND			ND	ND
Jacksonburg Creek (01443600)	4			ND			ND	ND
Pequest River (01444970)	4			ND			ND	ND
Pequest River (01445000)	4			ND			ND	ND
Pequest River (01445500)	31	.00448	.00098	G	.00497	.00101	LO	G@LO
Pequest River (01446400)	12	.00213	.00135	NS	.00229	.00125	NS	NS
Pohatcong Creek (01455200)	67	.00299	.00164	NS	.00408	.00164	LO	NS
Musconetcong River (01455500)	37	.00117	.00057	NS	.00104	.00088	NS	NS
Musconetcong River (01455801)	40	.00440	.00233	NS	.00575	.00277	LO	G@LO
Musconetcong River (01456200)	65	.00459	.00371	NS	.00847	.00242	LO	NG@LO
Musconetcong River (01456600)	0			ND			ND	ND
Musconetcong River (01457000)	31	.00184	.00078	G	.00189	.0079	LO	ND
Musconetcong River (01457400)	80	.00235	.00076	G	.00373	.00074	LO	G@LO

Appendix 3. **Statistical summaries of dissolved oxygen data from NJDEP/USGS and DRBC sites and comparison of data between different season and flow conditions**

Table 3a. Statistical summary of dissolved oxygen measured in samples from 1985 – 2000 [concentrations are in milligrams per liter]

Site	Number of sam-ples	Percent Censored	Range	Standard Devia-tion	Minimum	25th	Median	75th	Maxi-mum
Big Flat Brook (01439830)	4	0			10.20				14.00
Flat Brook (01440000)	31	0	2.700	1.916	8.260	10.40	11.60	13.10	15.60
Flat Brook (01440010)	1	0			9.100				9.100
Dunnfield Creek (01442760)	12	0	3.100	1.784	8.500	9.800	11.50	12.90	13.80
Paulins Kill (01443290)	1	0			8.300				8.300
Dry Brook (01443370)	4	0			6.300				15.60
Paulins Kill (01443440)	71	0	4.300	2.354	7.100	8.600	10.10	12.90	15.50
Paulins Kill (01443500)	84	0	4.200	2.448	7.100	8.800	10.45	13.00	16.20
Jacksonburg Creek (01443550)	4	0			7.800				12.60
Jacksonburg Creek (01443600)	4	0			8.900				13.40
Pequest River (01444970)	4	0			4.600				11.80
Pequest River (01445000)	4	0			8.900				13.40
Pequest River (01445500)	31	0	3.000	1.939	7.900	9.300	10.70	12.30	14.50
Pequest River (01446400)	12	0	3.900	2.137	8.610	9.400	11.40	13.30	14.60
Pohatcong Creek (01455200)	70	0	3.600	2.184	7.100	9.400	11.15	13.00	16.20
Musconetcong River (01455500)	39	0	4.000	2.511	7.300	8.400	10.40	12.40	15.90
Musconetcong River (01455801)	41	0	4.400	2.485	6.800	8.400	10.00	12.80	15.10
Musconetcong River (01456200)	68	0	3.750	2.164	8.000	9.500	10.60	13.25	16.30
Musconetcong River (01456600)	1	0			9.100				9.100
Musconetcong River (01457000)	31	0	3.200	1.795	8.700	9.600	11.40	12.80	14.90
Musconetcong River (01457400)	85	0	3.300	2.062	7.400	9.100	10.70	12.40	15.70

Table 3b. Statistical summary of dissolved oxygen measured in samples collected by the Delaware River Basin Commission from 1985 – 2000 [concentrations are in milligrams per liter; *, Site also samples by USGS/NJDEP]

Site	Number of samples	Range	Standard Deviation	Mini--mum	25th	Median	75th	Maxi-mum
Little Flat Brook DRBCNPS2251	60	2.10	3.85	8.0	8.60	9.80	10.70	13.20
Big Flat Brook DRBCNPS2252	64	1.65	3.45	7.6	8.65	9.35	10.30	13.70
Van Campens Brook DRBCNPS0031	70	2.00	3.42	8.2	8.60	9.50	10.60	13.80
Flat Brook DRBCNPS0032	65	0.90	2.18	8.6	8.90	9.30	9.80	11.50
Flat Brook DRBCNPS0321	36	0.70	2.57	8.3	9.15	9.55	9.85	11.90
Shimers Brook DRBCNPS0047	121	1.00	3.06	7.1	8.20	8.70	9.20	13.60
*Musconetcong River DRBCNPS0025 (01457400)	23	1.40	1.40	7.30	8.60	9.10	10.00	14.00
Pohatcong Creek DRBCNJ0027	23	1.40	1.71	8.20	9.20	9.80	10.60	16.50
Lopatcong Creek DRBCNJ0028	16	0.95	1.63	7.20	9.50	9.85	10.45	14.20
Buckhorn Creek DRBCNJ0030	12	0.95	1.06	6.00	8.55	9.15	9.50	10.10
Pophandusing Brook DRBCNJ0031	3	2.70	1.56	6.00	6.00	8.70	8.70	8.70
*Pequest River DRBCNJ0033 (01446400)	27	1.7	1.55	7.20	9.20	9.90	10.90	15.80
Delawanna Creek DRBCNJ0035	5	1.30	0.90	6.30	6.90	8.10	8.20	8.30
Paulins Kill DRBCNJ0036	23	1.90	1.24	6.20	7.00	7.80	8.90	11.20
*Dunnfield Creek DRBCNPS0025 (01442760)	23	0.80	0.74	7.00	8.40	8.80	9.20	10.00

Table 3c. Statistical summary and differences in dissolved oxygen concentrations between seasons and flow conditions using all data from 1991 -1997 water years [dissolved oxygen is in milligrams per liter; NS, indicates the distribution of temperatures during the growing season and nongrowing season or during high flow and low flow conditions did not differ at the 0.05 significance level; G, significant differences occur between seasons and highest dissolved oxygen occurs in the growing season (April- October); NG, significant differences occur between seasons and highest dissolved oxygen occurs in the nongrowing season (November-March); LO, significant differences occur between flow conditions and highest dissolved oxygen occurs at low flow (less than median flow); HI, significant differences occur between flow conditions and highest dissolved oxygen occurs at high flow (greater than median flow); Season@flow, indicates interaction of flow and season with highest median; ND, not enough data to perform an analysis of variance]

Station Number	DISSOLVED OXYGEN							
	Number of samples	Seasonal Comparison			Flow Comparison			Flow and season interaction (highest median)
		Median Dissolved Oxygen		Statistically significant	Median Dissolved Oxygen		Statistically significant	
		Growing	Non-growing		Low flow	High flow		
Big Flat Brook (01439830)	4			ND			ND	ND
Flat Brook (01440000)	31	10.90	13.15	NG	11.30	11.6	NS	NG@HI
Flat Brook (01440010)	1			ND			ND	ND
Dunnfield Creek (01442760)	12	9.80	12.90	NG	10.10	13.1	HI	NG@HI
Paulins Kill (01443290)	1			ND			ND	ND
Dry Brook (01443370)	4			ND			ND	ND
Paulins Kill (01443440)	71	8.90	13.10	NG	8.95	12.8	HI	NG@HI
Paulins Kill (01443500)	84	9.20	13.40	NG	9.50	12.2	HI	NG@HI-
Jacksonburg Creek (01443550)	4			ND			ND	ND
Jacksonburg Creek (01443600)	4			ND			ND	ND
Pequest River (01444970)	4			ND			ND	ND
Pequest River (01445000)	4			ND			ND	ND
Pequest River (01445500)	31	9.70	12.85	NG	9.75	11.7	HI	NG@HI
Pequest River (01446400)	12	9.40	13.30	NG	11.55	11.4	NS	NG@HI
Pohatcong Creek (01455200)	70	10.00	13.10	NG	10.80	11.5	NS	NG@LO
Musconetcong River (01455500)	39	8.70	13.85	NG	9.90	11.2	NS	NG@LO
Musconetcong River (01455801)	41	8.65	13.30	NG	9.00	10.3	NS	NG@LO
Musconetcong River (01456200)	68	9.70	13.85	NG	10.10	12.0	NS	NG@LO
Musconetcong River (01456600)	1			ND			ND	ND
Musconetcong River (01457000)	31	10.20	13.40	NG	10.40	12.6	HI	NG@HI
Musconetcong River (01457400)	85	9.80	13.20	NG	9.80	11.8	HI	NG@HI

Appendix 4. **Statistical summaries of total dissolved solids data from NJDEP/USGS and DRBC sites and comparison of data between different season and flow conditions**

Table 4a. Statistical summary of total dissolved solids measured when samples were collected from 1985 – 2000 [concentrations are in milligrams per liter]

USGS Site Number	Number of samples	Percent Censored	Inner quartile range	Standard Devia-tion	Mini-mum	25th	median	75th	Maxi-mum
Big Flat Brook (01439830)	4	0			35.0				62.0
Flat Brook (01440000)	30	0	33.00	30.25	39.0	86.0	100	119.	158
Flat Brook (01440010)	1	0			113				113
Dunnfield Creek (01442760)	12	0	2.000	1.960	19.0	21.0	22.0	23.0	27.0
Paulins Kill (01443290)	1	0			345				345
Dry Brook (01443370)	4	0			90.0				117
Paulins Kill (01443440)	71	0	78.00	52.59	122	201	230	279	343
Paulins Kill (01443500)	82	0	49.00	35.72	121	181	205	230	291
Jacksonburg Creek (01443550)	4	0			35.0				50.0
Jacksonburg Creek (01443600)	4	0			67.0				102
Pequest River (01444970)	4	0			189				313
Pequest River (01445000)	4	0			194				264
Pequest River (01445500)	31	0	56.00	38.87	166	243	269	299	321
Pequest River (01446400)	12	0	34.50	38.38	161	250	276	285	293
Pohatcong Creek (01455200)	70	0	32.00	23.08	75.0	105	122	137	183
Musconetcong River (01455500)	37	0	16.00	12.72	109	122	128	138	164
Musconetcong River (01455801)	40	0	43.50	35.02	107	140	154	184	253
Musconetcong River (01456200)	66	0	57.00	36.74	105	158	172	215	269
Musconetcong River (01456600)	1	0			217				217
Musconetcong River (01457000)	30	0	36.00	27.46	105	171	192	207	222
Musconetcong River (01457400)	84	0	34.50	25.26	115	166	182	200	243

Table 4b. Statistical summary of total dissolved solids measured in samples collected by the Delaware River Basin Commission from 1990 – 2000 [concentrations are in milligrams per liter; *, Site also samples by USGS/NJDEP]

DRBC Site Number	Number of samples	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maxi-mum
Little Flat Brook DRBCNPS2251	10	42.00	55.46	70.00	192.0	202.0	234.0	280.0
Big Flat Brook DRBCNPS2252	10	78.00	50.44	50.00	77.00	116.0	155.0	217.0
Van Campens Brook DRBCNPS0031	4	8.00	5.20	48.00	.	.	.	60.00
Flat Brook DRBCNPS0032	12	27.50	17.74	101.0	118.5	126.5	146.0	154.0
Flat Brook DRBCNPS0321	0	.	.	.	.	.	.	.
Shimers Brook DRBCNPS0047	22	66.00	49.97	60.00	156.0	197.5	222.0	266.0
*Musconetcong River DRBCNPS0025 (01457400)	12	102.0	63.36	206.0	230.0	252.5	332.0	408.0
Pohatcong Creek DRBCNJ0027	13	109.0	84.33	180.0	211.0	262.0	320.0	446.0
Lopatcong Creek DRBCNJ0028	7	168.0	78.52	270.0	.	.	.	454.0
Buckhorn Creek DRBCNJ0030	7	48.00	51.25	142.0	.	.	.	288.0
Pophandusing Brook DRBCNJ0031	0	.	.	.	.	.	.	.
*Pequest River DRBCNJ0033 (01446400)	12	89.50	113.2	78.00	304.5	344.0	394.0	556.0
Delawanna Creek DRBCNJ0035	0	.	.	.	.	.	.	.
Paulins Kill DRBCNJ0036	12	89.00	106.3	44.00	244.0	292.0	333.0	416.0
*Dunnfield Creek DRBCNPS0025 (01442760)	0	.	.	.	.	.	.	.

Table 4c. Statistical summary and differences in total dissolved solids concentrations between seasons and flow conditions using all data from 1991 -1997 water years [total dissolved solids are in milligrams per liter; NS, indicates the distribution of total dissolved solids during the growing season and nongrowing season or during high flow and low flow conditions did not differ at the 0.05 significance level; G, significant differences occur between seasons and highest total dissolved solids occur in the growing season (April- October); NG, significant differences occur between seasons and highest total dissolved solids occur in the nongrowing season (November-March); LO, significant differences occur between flow conditions and highest total dissolved solids occur at low flow (less than median flow); HI, significant differences occur between flow conditions and highest total dissolved solids occur at high flow (greater than median flow); Season@flow, indicates flow as a function of season]

Station Number	TOTAL DISSOLVED SOLIDS							
	Number of samples	Seasonal Comparison			Flow Comparison			Flow and season interaction (highest median)
		Median Total Dissolved Solids		Statistica lly signi-ficant	Median Total Dissolved Solids		Statistically signi-ficant	
		Growing	Non-growing		Low flow	High flow		
Big Flat Brook (01439830)	4			ND			ND	ND
Flat Brook (01440000)	30	107.0	98.5	NS	119.0	80.0	LO	G@LO
Flat Brook (01440010)	1			ND			ND	ND
Dunnfield Creek (01442760)	12	22.5	22.0	NS	23.00	21.0	LO	G@LO
Paulins Kill (01443290)	1			ND			ND	ND
Dry Brook (01443370)	4			ND			ND	ND
Paulins Kill (01443440)	71	251.0	211.0	G	275.0	198.0	LO	G@LO
Paulins Kill (01443500)	82	214.5	191.0	G	225.0	180.0	LO	NG@LO
Jacksonburg Creek (01443550)	4			ND			ND	ND
Jacksonburg Creek (01443600)	4			ND			ND	ND
Pequest River (01444970)	4			ND			ND	ND
Pequest River (01445000)	4			ND			ND	ND
Pequest River (01445500)	31	282.0	250.0	G	292.5	243.0	LO	NG@LO
Pequest River (01446400)	12	260.5	282.0	NS	285.0	250.5	LO	NG@LO
Pohatcong Creek (01455200)	70	131.5	108.0	G	135.0	107.0	LO	G@LO
Musconetcong River (01455500)	37	128.0	125.0	NS	130.5	126.0	NS	NS
Musconetcong River (01455801)	40	157.5	151.5	NS	196.5	146.0	LO	G@LO
Musconetcong River (01456200)	66	183.0	162.0	G	215.0	162.5	LO	G@LO
Musconetcong River (01456600)	1			ND			ND	ND
Musconetcong River (01457000)	30	202.0	172.5	G	205.0	171.0	LO	G@LO
Musconetcong River (01457400)	84	183.0	175.0	NS	194.0	166.0	LO	G@LO

Appendix 5. **Statistical summaries of fecal coliform counts from NJDEP/USGS and DRBC sites and comparison of data between different season and flow conditions**

Table 5a. Statistical summary of fecal coliform measured in samples from 1985 – 2000 [measured as most probable number]

Site	Number of samples	Percent censored	Range	Standard Deviation	Minimum	25th	Median	75th	Maximum
Big Flat Brook (01439830)	5	40			<20.00				50.00
Flat Brook (01440000)	24	33.3	30.00	220.7	2.000	<20.00	20.00	50.00	1100
Flat Brook (01440010)	0	--							
Dunnfield Creek (01442760)	10	100	.0000	5.692	<2.000	<20.00	<20.00	<20.00	<20.00
Paulins Kill (01443290)	0	--							
Dry Brook (01443370)	5	0			330.0				2800
Paulins Kill (01443440)	69	3	1570	3228	20.00	130.0	490.0	1700	>24000
Paulins Kill (01443500)	79	11	310.0	2887	<20.00	20.00	120.0	330.0	>24000
Jacksonburg Creek (01443550)	0	--							
Jacksonburg Creek (01443600)	0	--							
Pequest River (01444970)	5	0			170.0				5400
Pequest River (01445000)	4	0			80.00				330.0
Pequest River (01445500)	31	0	410.0	2060	20.00	80.00	170.0	490.0	9200
Pequest River (01446400)	10	0	1740	832.7	170.0	460.0	1045	2200	2400
Pohatcong Creek (01455200)	69	7	2030	4685	<20.00	170.0	1100	2200	24000
Musconetcong River (01455500)	37	51	50.00	87.35	<20.00	<20.00	20.00	70.00	490.0
Musconetcong River (01455801)	39	18	290.0	1285	<20.00	40.00	170.0	330.0	5400
Musconetcong River (01456200)	66	7	290.0	749.2	<20.00	40.00	130.0	330.0	3500
Musconetcong River (01456600)	0	--							
Musconetcong River (01457000)	31	7	860.0	3269	<20.00	80.00	490.0	940.0	16000
Musconetcong River (01457400)	79	5	810.0	2749	7.000	130.0	490.0	940.0	16000

Table 5b. Statistical summary of fecal coliform measured in samples collected by the Delaware River Basin Commission from 1985 – 2000 [data is in colonies per 100 milliliters; *, Site also sampled by USGS/NJDEP]

Site	Number of samples	Range	Standard Deviation	Minimum	25th	Median	75th	Maximum
Little Flat Brook DRBCNPS2251	60	66	88	<1	26	65	92	>400
Big Flat Brook DRBCNPS2252	64	54	58	<1	17	34	70	346
Van Campens Brook DRBCNPS0031	80	57	67	<1	16	34	72	400
Flat Brook DRBCNPS0032	78	47	89	<1	18	30	65	538
Flat Brook DRBCNPS0321	35	78	112	27	62	98	140	594
Shimers Brook DRBCNPS0047	134	46	144	<1	12	22	58	>1000
*Musconetcong River DRBCNPS0025 (01457400)	16	1493	1966	12	142	245	1635	5980
Pohatcong Creek DRBCNJ0027	16	1383	977	30	368	715	1750	3500
Lopatcong Creek DRBCNJ0028	11	1920	1749	13	80	460	2000	5100
Buckhorn Creek DRBCNJ0030	7	770	426	1	.	.	.	>1200
Pophandusing Brook DRBCNJ0031	3	880	482	320	.	.	.	>1200
*Pequest River DRBCNJ0033 (01446400)	17	420	1034	15	120	310	540	4100
Delawanna Creek DRBCNJ0035	4	1525	1021	31	.	.	.	2380
Paulins Kill DRBCNJ0036	14	130	970	25	80	104	210	3300
*Dunnfield Creek DRBCNPS0025 (01442760)	32	60	689	3	6	22	66	3900

Table 5c. Statistical summary and differences in fecal coliform counts between seasons and flow conditions using all data from 1991 -1997 water years [fecal coliform is in counts per 100 milliliters; NS, indicates the distribution of fecal coliform during the growing season and nongrowing season or during high flow and low flow conditions did not differ at the 0.05 significance level; G, significant differences occur between seasons and highest fecal coliform counts occur in the growing season (April- October); NG, significant differences occur between seasons and highest fecal coliform counts occur in the nongrowing season (November-March); LO, significant differences occur between flow conditions and highest fecal coliform counts occur at low flow (less than median flow); HI, significant differences occur between flow conditions and largest fecal coliform occur at high flow (greater than median flow); Season@flow, indicates flow as a function of season]

Station Number	FECAL COLIFORM							
	Number of samples	Seasonal Comparison			Flow Comparison			Flow and season compari s on
		Median Fecal Coliform Count		Statistic ally signi- ficant	Median Fecal Coliform Count		Statistic ally signi- ficant	
		Growing	Non- growing		Low flow	High flow		
Big Flat Brook (01439830)	5			ND			ND	ND
Flat Brook (01440000)	24	40.00	20.00	NS	40.0	20.0	NS	NS
Flat Brook (01440010)	0			ND			ND	ND
Dunnfield Creek (01442760)	10	<20.00	NS	ND	<20.0	NS	ND	ND
Paulins Kill (01443290)	0			ND			ND	ND
Dry Brook (01443370)	5			ND			ND	ND
Paulins Kill (01443440)	69	1100	105.0	G	1020	170	LO	G@LO
Paulins Kill (01443500)	79	130.0	20.00	G	130.0	50	NS	G@HI
Jacksonburg Creek (01443550)	0			ND			ND	ND
Jacksonburg Creek (01443600)	0			ND			ND	ND
Pequest River (01444970)	5			ND			ND	ND
Pequest River (01445000)	4			ND			ND	ND
Pequest River (01445500)	31	230.0	80.00	G	230.0	110	NS	G@HI
Pequest River (01446400)	10	1045	NS	ND	1045	NS	ND	ND
Pohatcong Creek (01455200)	69	1700	150.0	G	1350	490	NS	G@HI
Musconetcong River (01455500)	37	20.0	<20.0	NS	<20.0	20	NS	G@HI
Musconetcong River (01455801)	39	230.0	20.00	G	195.0	130	NS	G@LO
Musconetcong River (01456200)	66	195.0	35.00	G	170.0	130	NS	G@HI
Musconetcong River (01456600)	0			ND			ND	ND
Musconetcong River (01457000)	31	700.0	150.0	G	700.0	130	LO	NS
Musconetcong River (01457400)	79	595.0	110.0	G	490.0	170	NS	G@LO

Appendix 6. **Statistical summaries of nitrate plus nitrite data from NJDEP/USGS and DRBC sites and comparison of data between different season and flow conditions**

Table 6a. Statistical summary of nitrate plus nitrite measured when samples were collected from 1985 – 2000 [concentrations are in milligrams per liter]

USGS Site Number	Number of samples	Percent Censor-ed	Inner quartile range	Standard Deviation	Mini-mum	25th	median	75th	Maxi-mum
Big Flat Brook (01439830)	4	0			0.050				0.457
Flat Brook (01440000)	30	3.3	0.0770	0.0976	<0.02	0.0500	0.0910	0.1300	0.420
Flat Brook (01440010)	1	0			0.127				0.127
Dunnfield Creek (01442760)	12	0	0.0335	0.1110	0.018	0.0435	0.0500	0.0770	0.407
Paulins Kill (01443290)	1	0			1.662				1.662
Dry Brook (01443370)	4	0			0.037				0.239
Paulins Kill (01443440)	70	0	0.4900	0.2958	0.400	0.7700	1.000	1.260	1.640
Paulins Kill (01443500)	84	1	0.3595	0.2621	<0.03	0.3855	0.5400	0.7450	1.190
Jacksonburg Creek (01443550)	4	0			0.040				0.050
Jacksonburg Creek (01443600)	4	0			0.131				0.358
Pequest River (01444970)	4	0			0.159				0.616
Pequest River (01445000)	4	0			0.290				0.471
Pequest River (01445500)	31	0	0.3500	0.3682	0.730	1.010	1.200	1.360	2.660
Pequest River (01446400)	12	0	0.2935	0.2279	0.655	0.9050	1.015	1.199	1.476
Pohatcong Creek (01455200)	69	0	0.5200	0.4441	0.850	1.680	1.930	2.200	2.800
Musconetcong River (01455500)	39	26	0.1100	0.0966	<0.02	0.0400	0.0700	0.1600	0.400
Musconetcong River (01455801)	41	0	0.3700	0.4838	0.123	0.2700	0.4200	0.6400	1.958
Musconetcong River (01456200)	68	0	0.5700	0.5060	0.410	0.7000	0.8750	1.270	2.600
Musconetcong River (01456600)	1	0			1.815				1.815
Musconetcong River (01457000)	31	0	0.7200	0.4656	0.980	1.480	1.850	2.200	2.930
Musconetcong River (01457400)	85	0	0.5300	0.4757	0.230	1.570	1.790	2.100	2.900

Table 6b. Statistical summary of nitrate plus nitrite data measured by the Delaware River Basin Commission from 1985 – 2000 [data is in cubic feet per second; *, samples also collected at this site by USGS/NJDEP]

Site	Number of samples	Percent Censored	Inner quartile range	Standard Deviation	Minimum	25th	Median	75th	Maximum
Little Flat Brook DRBCNPS2251	31	3.2	0.33	0.23	<0.02	0.23	0.40	0.56	0.87
Big Flat Brook DRBCNPS2252	48	16.7	0.27	0.17	<0.02	0.09	0.21	0.36	0.56
Van Campens Brook DRBCNPS0031	26	77.8	0.09	0.14	<0.02	0.02	0.05	0.11	0.73
Flat Brook DRBCNPS0032	26	26.9	0.13	0.16	<0.01	0.04	0.07	0.18	0.75
Flat Brook DRBCNPS0321	7	0	0.06	0.08	0.11	.	.	.	0.37
Shimers Brook DRBCNPS0047	57	7	0.10	0.09	<0.01	0.12	0.16	0.22	0.58
*Musconetcong River DRBCNPS0025 (01457400)	3	0	5.02	2.84	0.38	.	.	.	5.40
Pohatcong Creek DRBCNJ0027	4	0	2.30	1.65	0.06	.	.	.	3.60
Lopatcong Creek DRBCNJ0028	2	0	1.15	0.81	0.60	.	.	.	1.75
Buckhorn Creek DRBCNJ0030	6	0	0.90	0.48	0.96	.	.	.	2.10
Pophandusing Brook DRBCNJ0031	3	0	0.70	0.35	0.90	.	.	.	1.60
*Pequest River DRBCNJ0033 (01446400)	13	0	0.50	0.53	0.20	0.70	1.05	1.20	2.00
Delawanna Creek DRBCNJ0035	3	0	0.94	0.53	0.96	.	.	.	1.90
Paulins Kill DRBCNJ0036	3	0	1.06	0.55	0.63	.	.	.	1.69
*Dunnfield Creek DRBCNPS0025 (01442760)	1	0	0.00	.	0.24	.	.	.	0.24

Table 6c. Statistical summary and differences in nitrate plus nitrite concentrations between seasons and flow conditions using all data from 1991 -1997 water years [nitrate plus nitrite is in milligrams per liter; NS, indicates the distribution of concentrations during the growing season and nongrowing season or during high flow and low flow conditions did not differ at the 0.05 significance level; G, significant differences occur between seasons and highest nitrate plus nitrite occurs in the growing season (April- October); NG, significant differences occur between seasons and highest nitrate plus nitrite occurs in the nongrowing season (November-March); LO, significant differences occur between flow conditions and highest nitrate plus nitrites occur at low flow (less than median flow); HI, significant differences occur between flow conditions and highest nitrate plus nitrite occurs at high flow (greater than median flow); Season(flow), indicates interaction of flow and season with highest median; ND, not enough data to perform an analysis of variance]

Station Number	NITRATE PLUS NITRITE							
	Number of samples	Seasonal Comparison			Flow Comparison			Flow and season interaction (highest median)
		Median Nitrate plus nitrite		Statistically significant	Median Nitrate plus nitrite		Statistically significant	
		Growing	Non-growing		Low flow	High flow		
Big Flat Brook (01439830)	4			ND			ND	ND
Flat Brook (01440000)	30	0.08	0.15	NG	0.07	0.11	HI	G@HI
Flat Brook (01440010)	1			ND			ND	ND
Dunnfield Creek (01442760)	12	0.08	0.05	NS	0.05	0.05	LO	G@LO
Paulins Kill (01443290)	1			ND			ND	ND
Dry Brook (01443370)	4			ND			ND	ND
Paulins Kill (01443440)	70	1.02	1.00	NS	1.18	0.92	LO	NG@LO
Paulins Kill (01443500)	84	0.45	0.79	NG	0.45	0.62	HI	NG@HI
Jacksonburg Creek (01443550)	4			ND			ND	ND
Jacksonburg Creek (01443600)	4			ND			ND	ND
Pequest River (01444970)	4			ND			ND	ND
Pequest River (01445000)	4			ND			ND	ND
Pequest River (01445500)	31	1.20	1.23	NS	1.2	1.20	NS	NG@LO
Pequest River (01446400)	12	1.07	1.01	NS	1.1	1.00	NS	NS
Pohatcong Creek (01455200)	69	2.03	1.82	NS	2.1	1.70	LO	G@LO
Musconetcong River (01455500)	39	0.07	0.15	NS	0.07	0.10	HI	G@HI
Musconetcong River (01455801)	41	0.50	0.27	G	0.87	0.39	LO	G@LO
Musconetcong River (01456200)	68	1.01	0.79	G	1.25	0.76	LO	G@LO
Musconetcong River (01456600)	1			ND			ND	ND
Musconetcong River (01457000)	31	1.92	1.60	NS	2.02	1.60	LO	NS
Musconetcong River (01457400)	85	1.86	1.77	NS	2.01	1.56	LO	NG@LO

Appendix 7. **Statistical summaries of pH data from NJDEP/USGS and DRBC sites and comparison of data between different season and flow conditions**

Table 7a. Statistical summary of pH measurements collected from 1985 – 2000 [measurements are in standard units]

USGS Site Number	Number of samples	Percent Censored	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maximum
Big Flat Brook (01439830)	4	0			7.30				7.70
Flat Brook (01440000)	32	0	0.3500	0.3741	7.19	7.65	7.90	8.00	8.90
Flat Brook (01440010)	2	0			7.43				8.10
Dunnfield Creek (01442760)	12	0	0.3500	0.3303	5.80	6.45	6.75	6.80	6.90
Paulins Kill (01443290)	2	0			7.23				7.90
Dry Brook (01443370)	4	0			7.10				8.00
Paulins Kill (01443440)	71	0	0.3000	0.2699	7.30	7.80	8.00	8.10	8.40
Paulins Kill (01443500)	84	0	0.2000	0.2654	7.20	8.00	8.10	8.20	8.70
Jacksonburg Creek (01443550)	4	0			5.90				7.00
Jacksonburg Creek (01443600)	4	0			7.50				8.10
Pequest River (01444970)	4	0			7.30				8.00
Pequest River (01445000)	4	0			7.70				8.10
Pequest River (01445500)	31	0	0.3000	0.2233	7.60	8.10	8.30	8.40	8.70
Pequest River (01446400)	12	0	0.3000	0.2234	8.00	8.20	8.35	8.50	8.70
Pohatcong Creek (01455200)	70	0	0.7000	0.5697	6.40	7.50	7.85	8.20	9.20
Musconetcong River (01455500)	38	0	0.4000	0.4405	6.40	7.50	7.70	7.90	8.80
Musconetcong River (01455801)	41	0	0.4000	0.2937	6.80	7.50	7.70	7.90	8.10
Musconetcong River (01456200)	67	0	0.4000	0.2935	7.40	7.90	8.10	8.30	8.70
Musconetcong River (01456600)	2	0			7.34				7.99
Musconetcong River (01457000)	31	0	0.5000	0.3285	7.60	8.00	8.20	8.50	9.00
Musconetcong River (01457400)	84	0	0.5000	0.3854	6.90	7.80	8.10	8.30	9.20

Table 7b. Statistical summary of pH measured in samples collected by the Delaware River Basin Commission from 1984 – 2000 [concentrations are in milligrams per liter; *, Site also sampled by USGS/NJDEP]

DRBC Site Number	Number of samples	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maximum
Little Flat Brook DRBCNPS2251	58	0.30	0.26	7.50	8.00	8.00	8.30	8.60
Big Flat Brook DRBCNPS2252	59	0.35	0.34	6.80	7.40	7.60	7.75	8.80
Van Campens Brook DRBCNPS0031	68	0.60	0.36	6.50	7.00	7.40	7.60	8.20
Flat Brook DRBCNPS0032	64	0.50	0.50	7.00	8.00	8.00	8.50	9.00
Flat Brook DRBCNPS0321	35	0.70	0.50	7.00	7.80	8.00	8.50	9.00
Shimers Brook DRBCNPS0047	131	0.30	0.32	7.13	7.80	8.00	8.10	9.00
*Musconetcong River DRBCNPS0025 (01457400)	24	0.60	0.41	6.90	7.60	7.90	8.20	8.60
Pohatcong Creek DRBCNJ0027	23	0.40	0.32	6.90	7.80	7.90	8.20	8.50
Lopatcong Creek DRBCNJ0028	16	0.55	0.47	6.70	7.80	8.00	8.35	8.50
Buckhorn Creek DRBCNJ0030	12	0.70	0.43	7.10	7.50	7.90	8.20	8.50
Pophandusing Brook DRBCNJ0031	3	1.50	0.79	6.90	.	.	.	8.40
*Pequest River DRBCNJ0033 (01446400)	27	0.40	0.40	6.90	8.00	8.20	8.40	9.00
Delawanna Creek DRBCNJ0035	5	0.40	0.73	6.90	.	.	.	8.90
Paulins Kill DRBCNJ0036	23	0.30	0.39	6.90	7.70	7.90	8.00	8.70
*Dunnfield Creek DRBCNPS0025 (01442760)	23	0.30	0.42	6.40	6.50	6.50	6.80	8.10

Table 7c. Statistical summary and differences in pH units between seasons and flow conditions using all data from 1991 -1997 water years [pH is in standard units; NS, indicates the distribution of pH data during the growing season and nongrowing season or during high flow and low flow conditions did not differ at the 0.05 significance level; G, significant differences occur between seasons and highest pH values occur in the growing season (April- October); NG, significant differences occur between seasons and highest pH values occur in the nongrowing season (November-March); LO, significant differences occur between flow conditions and largest pH values occur at low flow (less than median flow); HI, significant differences occur between flow conditions and largest pH values occur at high flow (greater than median flow); Season(flow), indicates interaction of flow and season with highest median; ND, not enough data to perform an analysis of variance]

Station Number	pH							
	Number of samples	Seasonal Comparison			Flow Comparison			Flow and season inter-action (highest median)
		Median Temperature		Statistic a lly signi-ficant	Median Temperature		Statistic ally signi-ficant	
		Growing	Non-growing		Low flow	High flow		
Big Flat Brook (01439830)	4			ND			ND	ND
Flat Brook (01440000)	32	8.00	7.70	NS	8.00	7.70	LO	G@LO
Flat Brook (01440010)	2			ND			ND	ND
Dunnfield Creek (01442760)	12	6.80	6.50	G	6.80	6.50	NS	NS
Paulins Kill (01443290)	2			ND			ND	ND
Dry Brook (01443370)	4			ND			ND	ND
Paulins Kill (01443440)	71	8.00	7.90	NS	8.00	7.90	NS	NS
Paulins Kill (01443500)	84	8.10	8.10	NS	8.20	8.10	NS	NS
Jacksonburg Creek (01443550)	4			ND			ND	ND
Jacksonburg Creek (01443600)	4			ND			ND	ND
Pequest River (01444970)	4			ND			ND	ND
Pequest River (01445000)	4			ND			ND	ND
Pequest River (01445500)	31	8.30	8.15	G	8.40	8.20	LO	G@LO
Pequest River (01446400)	12	8.40	8.30	NS	8.50	8.30	LO	NS
Pohatcong Creek (01455200)	70	7.85	7.85	NS	8.05	7.75	LO	NS
Musconetcong River (01455500)	38	7.65	7.70	NS	7.70	7.70	NS	NS
Musconetcong River (01455801)	41	7.70	7.80	NS	7.80	7.70	NS	NS
Musconetcong River (01456200)	67	8.10	8.25	NS	8.20	8.00	LO	NG@LO
Musconetcong River (01456600)	2			ND			ND	ND
Musconetcong River (01457000)	31	8.25	8.20	NS	8.30	8.20	NS	ND
Musconetcong River (01457400)	84	8.10	8.20	NS	8.20	8.00	NS	NG@LO

Appendix 8. **Statistical summaries of Total Phosphorus data from NJDEP/USGS and DRBC sites and comparison of data between different season and flow conditions**

Table 8a. Statistical summary of total phosphorus measured in samples collected from 1985 – 2000 [concentrations are in milligrams per liter; *, site also sampled by DRBC]

USGS Site Number	Number of samples	Percent Censored	Inner quartile range	Standard Deviation	Mini-mum	25th	median	75th	Maxi-mum
Big Flat Brook (01439830)	4	100			<0.01				<0.01
Flat Brook (01440000)	29	0	0.0300	0.018	0.004	0.005	0.0110	0.0300	0.063
Flat Brook (01440010)	1	100			<0.01				<0.01
Dunnfield Creek (01442760)	12	83	0.0420	0.0196	<0.008	<0.008	<0.008	0.0100	0.018
Paulins Kill (01443290)	1	0			0.015				0.015
Dry Brook (01443370)	4	0			0.015				0.078
Paulins Kill (01443440)	71	7	0.0800	0.0784	<0.01	0.04	0.0700	0.1200	0.379
Paulins Kill (01443500)	84	10	0.0390	0.0318	<0.01	0.03	0.0415	0.0690	0.21
Jacksonburg Creek (01443550)	4	50			<0.01				0.05
Jacksonburg Creek (01443600)	4	100			<0.05				<0.05
Pequest River (01444970)	4	25			<0.01				0.049
Pequest River (01445000)	4	0			0.013				0.028
Pequest River (01445500)	31	0	0.0800	0.0750	0.01	0.03	0.0700	0.1100	0.40
Pequest River (01446400)	12	0	0.0270	0.0853	0.021	0.04	0.0425	0.0665	0.329
Pohatcong Creek (01455200)	66	0	0.1800	0.1593	0.03	0.11	0.1850	0.2900	0.808
Musconetcong River (01455500)	39	26	0.0200	0.0124	<0.01	0.017	0.0240	0.0400	0.07
Musconetcong River (01455801)	41	2	0.0640	0.0515	<0.01	0.04	0.0600	0.1040	0.22
Musconetcong River (01456200)	68	3	0.1135	0.0873	<0.01	0.036	0.0700	0.1500	0.38
Musconetcong River (01456600)	1	0			0.032				0.032
Musconetcong River (01457000)	31	29	0.0500	0.0455	<0.01	0.01	0.0200	0.0700	0.21
Musconetcong River (01457400)	82	11	0.0600	0.1004	<0.01	0.03	0.0500	0.0900	0.48

Table 8b. Statistical summary of total phosphorus measured in samples collected by the Delaware River Basin Commission from 1990 – 2000 [concentrations are in milligrams per liter; *, Site also samples by USGS/NJDEP]

DRBC Site Number	Number of samples	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maxi-mum
Little Flat Brook DRBCNPS2251	10	0.01	0.01	<0.01	0.02	0.02	0.03	0.03
Big Flat Brook DRBCNPS2252	10	0.01	0.00	<0.01	0.013	0.016	0.02	0.02
Van Campens Brook DRBCNPS0031	5	0.00	0.00	<0.01	.	.	.	0.02
Flat Brook DRBCNPS0032	22	0.01	0.04	0.01	0.003	0.01	0.02	0.19
Flat Brook DRBCNPS0321	3	0.02	0.01	<0.03	.	.	.	0.05
Shimers Brook DRBCNPS0047	32	0.02	0.01	<0.01	0.02	0.03	0.04	0.07
*Musconetcong River DRBCNPS0025 (01457400)	11	0.08	0.05	<0.01	0.026	0.05	0.09	0.16
Pohatcong Creek DRBCNJ0027	12	0.09	0.09	<0.01	0.02	0.05	0.10	0.25
Lopatcong Creek DRBCNJ0028	5	0.06	0.03	<0.01	.	.	.	0.07
Buckhorn Creek DRBCNJ0030	0	.	.	.	.	.	.	.
Pophandusing Brook DRBCNJ0031	0	.	.	.	.	.	.	.
*Pequest River DRBCNJ0033 (01446400)	11	0.10	0.06	<0.01	0.01	0.07	0.11	0.21
Delawanna Creek DRBCNJ0035	0	.	.	.	.	.	.	.
Paulins Kill DRBCNJ0036	10	0.02	0.06	<0.01	0.05	0.07	0.07	0.21
*Dunnfield Creek DRBCNPS0025 (01442760)	1	0.00	.	<0.01	.	.	.	<0.01

Table 8c. Statistical summary and differences in total phosphorus concentrations between seasons and flow conditions using all data from 1991 -1997 water years [total phosphorus is in milligrams per liter; NS, indicates the distribution of total phosphorus during the growing season and nongrowing season or during high flow and low flow conditions did not differ at the 0.05 significance level; G, significant differences occur between seasons and highest total phosphorus occurs in the growing season (April- October); NG, significant differences occur between seasons and highest total phosphorus occur in the nongrowing season (November-March); LO, significant differences occur between flow conditions and highest total phosphorus occurs at low flow (less than median flow); HI, significant differences occur between flow conditions and highest total phosphorus occur at high flow (greater than median flow); Season(flow), indicates interaction of flow and season with highest median; ND, not enough data to perform an analysis of variance]

Station Number	TOTAL PHOSPHORUS							
	Number of samples	Seasonal Comparison			Flow Comparison			Flow and season interaction (highest median)
		Median Total Phosphorus		Statistically significant	Median Total Phosphorus		Statistically significant	
		Growing	Non-growing		Low flow	High flow		
Big Flat Brook (01439830)	4			ND			ND	ND
Flat Brook (01440000)	29	0.01	0.01	NS	0.02	0.01	NS	NS
Flat Brook (01440010)	1			ND			ND	ND
Dunnfield Creek (01442760)	12	0.01	<0.01	NS	<0.01	0.05	NS	NS
Paulins Kill (01443290)	1			ND			ND	ND
Dry Brook (01443370)	4			ND			ND	ND
Paulins Kill (01443440)	71	0.08	0.05	G	0.08	0.05	LO	G@LO
Paulins Kill (01443500)	84	0.06	0.03	G	0.05	0.04	NS	G@LO
Jacksonburg Creek (01443550)	4			ND	0.04		ND	ND
Jacksonburg Creek (01443600)	4			ND	0.05		ND	ND
Pequest River (01444970)	4			ND	0.03		ND	ND
Pequest River (01445000)	4			ND	0.02		ND	ND
Pequest River (01445500)	31	0.07	0.06	NS	0.08	0.06	NS	NS
Pequest River (01446400)	12	0.07	0.04	G	0.05	0.04	NS	NS
Pohatcong Creek (01455200)	66	0.21	0.12	G	0.25	0.12	LO	G@LO
Musconetcong River (01455500)	39	0.03	0.02	G	0.03	0.02	NS	NS
Musconetcong River (01455801)	41	0.07	0.04	NS	0.08	0.06	NS	NS
Musconetcong River (01456200)	68	0.07	0.06	NS	0.07	0.05	NS	NS
Musconetcong River (01456600)	1			ND			ND	ND
Musconetcong River (01457000)	31	0.02	0.03	NS	0.02	0.03	NS	NS
Musconetcong River (01457400)	82	0.06	0.05	NS	0.06	0.05	NS	NS

Appendix 9. **Statistical summaries of total suspended solids data from NJDEP/USGS and DRBC sites and comparison of data between different season and flow conditions**

Table 9a. Statistical summary of total suspended solids measured in samples collected from 1985 – 2000 [concentrations are in milligrams per liter]

USGS Site Number	Number of samples	Percent Censored	Inner quartile range	Standard Deviation	Mini-mum	25th	median	75th	Maxi-mum
Big Flat Brook (01439830)	4	0			1.00				1.00
Flat Brook (01440000)	21	0	3.00	5.710	0.80	1.00	3.00	4.00	28.0
Flat Brook (01440010)	1	0			2.50				2.50
Dunnfield Creek (01442760)	5	0			1.30				4.00
Paulins Kill (01443290)	1	0			6.30				6.30
Dry Brook (01443370)	3	0			1.80				12.3
Paulins Kill (01443440)	27	0	3.00	3.786	<1.00	4.00	5.00	7.00	17.0
Paulins Kill (01443500)	41	0	3.90	11.20	<1.00	3.10	5.00	7.00	75.0
Jacksonburg Creek (01443550)	3	0			<1.00				2.00
Jacksonburg Creek (01443600)	3	0			<1.00				5.00
Pequest River (01444970)	3	0			<1.00				4.00
Pequest River (01445000)	4	0			1.00				7.00
Pequest River (01445500)	29	0	5.00	46.55	<1.00	6.00	8.00	11.0	189.0
Pequest River (01446400)	10	0	6.00	28.70	<1.00	4.00	8.45	10.0	95.7
Pohatcong Creek (01455200)	28	0	6.00	26.44	<1.00	4.00	6.50	10.0	140.0
Musconetcong River (01455500)	0	--							
Musconetcong River (01455801)	2	0			3.00				3.00
Musconetcong River (01456200)	26	0	3.00	6.458	<1.00	3.00	4.00	6.00	34.0
Musconetcong River (01456600)	1	0			6.40				6.40
Musconetcong River (01457000)	29	0	9.00	25.54	1.00	3.00	6.00	12.0	142.0
Musconetcong River (01457400)	42	0	8.00	23.79	1.00	5.00	8.00	13.0	144.7

Table 9b. Statistical summary of total suspended solids measured in samples collected by the Delaware River Basin Commission from 1990 – 2000 [concentrations are in milligrams per liter; *, Site also sampled by USGS/NJDEP]

DRBC Site Number	Number of samples	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maxi-mum
Little Flat Brook DRBCNPS2251	10	1.80	6.116	.3500	1.000	1.700	2.80	20.9
Big Flat Brook DRBCNPS2252	10	.920	.7554	<1.000	<1.000	1.300	1.92	3.40
Van Campens Brook DRBCNPS0031	3	.600	.3464	<1.000	.	.	.	1.60
Flat Brook DRBCNPS0032	12	2.025	1.305	<1.000	<1.000	1.480	3.025	4.38
Flat Brook DRBCNPS0321	0	.	.	.	.	.	.	.
Shimers Brook DRBCNPS0047	21	5.00	21.87	<1.000	3.400	6.200	8.40	105
*Musconetcong River DRBCNPS0025 (01457400)	12	15.0	10.22	3.000	6.000	9.000	21.0	31.0
Pohatcong Creek DRBCNJ0027	13	8.00	16.81	2.000	5.000	7.000	13.0	52.0
Lopatcong Creek DRBCNJ0028	7	4.00	1.915	<1.000	.	.	.	6.00
Buckhorn Creek DRBCNJ0030	7	2.00	7.868	<1.000	.	.	.	23.0
Pophandusing Brook DRBCNJ0031	0	.	.	.	.	.	.	.
*Pequest River DRBCNJ0033 (01446400)	12	7.00	7.378	<1.000	4.000	6.000	11.0	24.0
Delawanna Creek DRBCNJ0035	0	.	.	.	.	.	.	.
Paulins Kill DRBCNJ0036	12	5.00	5.071	3.000	5.000	7.500	10.0	22.0
*Dunnfield Creek DRBCNPS0025 (01442760)	0	.	.	.	.	.	.	.

Table 9c. Statistical summary and differences in total suspended solids concentrations between seasons and flow conditions using all data from 1991 -1997 water years [total suspended solids is in milligrams per liter; --, indicates the distribution of total suspended solids during the growing season and nongrowing season or during high flow and low flow conditions did not differ at the 0.05 significance level; G, significant differences occur between seasons and highest total suspended solids occur in the growing season (April- October); NG, significant differences occur between seasons and highest total suspended solids occur in the nongrowing season (November-March); LO, significant differences occur between flow conditions and largest total suspended solids occur at low flow (less than median flow); HI, significant differences occur between flow conditions and highest total suspended solids occur at high flow (greater than median flow); Season(flow), indicates interaction of flow and season with highest median; ND, not enough data to perform an analysis of variance]

Station Number	TOTAL SUSPENDED SOLIDS							
	Number of samples	Seasonal Comparison			Flow Comparison			Flow and season inter-action (highest median)
		Median total suspended solids		Statistically signi-ficant	Median total suspended solids		Statistically signi-ficant	
		Growing	Non-growing		Low flow	High flow		
Big Flat Brook (01439830)	4			ND			ND	ND
Flat Brook (01440000)	21	1.0	1.0	NS	1.00	2.50	NS	NS
Flat Brook (01440010)	1			ND			ND	ND
Dunnfield Creek (01442760)	5			ND			ND	ND
Paulins Kill (01443290)	1			ND			ND	ND
Dry Brook (01443370)	3			NS			ND	ND
Paulins Kill (01443440)	27	3.0	3.5	NS	3.00	3.50	NS	NS
Paulins Kill (01443500)	41	6.0	3.0	NS	3.50	5.00	NS	NS
Jacksonburg Creek (01443550)	3			NG			ND	ND
Jacksonburg Creek (01443600)	3			NS			ND	ND
Pequest River (01444970)	3			NS			ND	ND
Pequest River (01445000)	4			ND			ND	ND
Pequest River (01445500)	29	7.0	8.0	NS	5.50	11.0	NS	NS
Pequest River (01446400)	10	7.0	2.0	NS	3.00	5.00	NS	NS
Pohatcong Creek (01455200)	28	6.0	6.0	NS	6.00	6.00	NS	NS
Musconetcong River (01455500)	0			ND			ND	ND
Musconetcong River (01455801)	2			ND			ND	ND
Musconetcong River (01456200)	26	4.0	3.0	NS	3.50	5.00	NS	NS
Musconetcong River (01456600)	1			ND			ND	ND
Musconetcong River (01457000)	29	5.5	3.0	NS	4.00	7.00	NS	NS
Musconetcong River (01457400)	42	8.0	3.0	NS	5.50	9.00	NS	NS

Appendix 10. **Statistical summaries of water temperature data from NJDEP/USGS and DRBC sites and comparison of data between different season and flow conditions**

Table 10a. Statistical summary of water temperatures measured from 1985 – 2000 [measurements are in degrees celcius]

USGS Site Number	Number of samples	Percent Censored	Inner quartile range	Standard Deviation	Mini-mum	25th	median	75th	Maxi-mum
Big Flat Brook (01439830)	4	0			1.50				18.5
Flat Brook (01440000)	32	0	13.25	7.333	0.00	4.75	12.0	18.0	24.5
Flat Brook (01440010)	2	0			0.00				20.4
Dunnfield Creek (01442760)	12	0	10.00	6.008	2.50	4.00	7.25	14.0	20.5
Paulins Kill (01443290)	2	0			0.30				19.2
Dry Brook (01443370)	4	0			0.00				22.0
Paulins Kill (01443440)	71	0	14.00	7.412	0.00	5.00	10.8	19.0	25.0
Paulins Kill (01443500)	84	0	14.50	7.981	0.00	6.00	13.0	20.5	26.0
Jacksonburg Creek (01443550)	4	0			1.50				16.5
Jacksonburg Creek (01443600)	4	0			3.00				16.5
Pequest River (01444970)	4	0			3.50				22.0
Pequest River (01445000)	4	0			2.00				16.0
Pequest River (01445500)	31	0	11.50	6.132	1.50	5.50	11.5	17.0	19.0
Pequest River (01446400)	12	0	11.25	6.872	2.00	6.00	10.25	17.25	20.5
Pohatcong Creek (01455200)	71	0	12.00	7.218	0.00	7.00	12.0	19.0	25.0
Musconetcong River (01455500)	39	0	16.50	8.794	1.00	6.50	15.5	23.0	29.0
Musconetcong River (01455801)	41	0	14.00	7.860	1.00	7.00	15.0	21.0	26.0
Musconetcong River (01456200)	68	0	13.50	7.535	0.50	6.25	11.25	19.75	24.0
Musconetcong River (01456600)	2	0			1.80				16.5
Musconetcong River (01457000)	31	0	11.00	6.734	2.00	7.50	11.0	18.5	22.5
Musconetcong River (01457400)	85	0	12.50	6.965	0.00	7.00	12.5	19.5	24.5

Table 10b. Statistical summary of water temperatures collected by the Delaware River Basin Commission from 1984 – 2000 [data is in degrees celcius; *, Site also sampled by USGS/NJDEP]

DRBC Site Number	Number of samples	Inner quartile range	Standard Deviation	Minimum	25th	median	75th	Maximum
Little Flat Brook DRBCNPS2251	59	9.00	4.92	2.00	11.00	17.00	20.00	23.00
Big Flat Brook DRBCNPS2252	63	7.00	4.87	1.50	11.00	16.20	18.00	27.00
Van Campens Brook DRBCNPS0031	72	6.20	4.49	2.00	12.00	16.75	18.20	22.00
Flat Brook DRBCNPS0032	66	2.90	2.72	12.00	18.30	20.00	21.20	27.00
Flat Brook DRBCNPS0321	38	3.00	2.83	13.00	18.00	19.90	21.00	25.00
Shimers Brook DRBCNPS0047	**	5.00	4.54	2.50	17.00	19.00	22.00	25.50
*Musconetcong River DRBCNPS0025 (01457400)	23	4.10	3.12	12.60	17.50	20.30	21.60	25.00
Pohatcong Creek DRBCNJ0027	23	2.70	3.39	9.80	16.10	17.20	18.80	25.40
Lopatcong Creek DRBCNJ0028	15	2.00	3.96	10.80	13.40	14.10	15.40	25.00
Buckhorn Creek DRBCNJ0030	12	4.50	3.63	11.70	17.35	18.95	21.85	24.20
Pophandusing Brook DRBCNJ0031	3	3.50	1.82	19.50	19.50	22.10	23.00	23.00
*Pequest River DRBCNJ0033 (01446400)	28	4.80	2.98	10.20	16.9	19.30	21.8	22.90
Delawanna Creek DRBCNJ0035	5	0.00	0.50	20.90	22.00	22.00	22.00	22.10
Paulins Kill DRBCNJ0036	23	5.20	3.73	13.30	18.80	21.70	24.00	27.50
*Dunnfield Creek DRBCNPS0025 (01442760)	23	1.50	2.36	14.70	16.50	17.10	18.00	27.00

Table 10c. Statistical summary and differences in water temperatures between seasons and flow conditions using all data from 1991 -1997 water years [temperature is in degrees celsius; --, indicates the distribution of temperatures during the growing season and nongrowing season or during high flow and low flow conditions did not differ at the 0.05 significance level; G, significant differences occur between seasons and largest temperatures occur in the growing season (April- October); NG, significant differences occur between seasons and highest temperatures occur in the nongrowing season (November-March); LO, significant differences occur between flow conditions and largest temperatures occur at low flow (less than median flow); HI, significant differences occur between flow conditions and largest temperatures occur at high flow (greater than median flow); Season(flow), indicates interaction of flow and season with highest median; ND, not enough data to perform an analysis of variance]

Station Number	WATER TEMPERATURE							
	Number of samples	Seasonal Comparison			Flow Comparison			Flow and season inter-acti on (highest median)
		Median Temperature		Statistically signi-ficant	Median Temperature		Statistically signi-ficant	
		Growing	Non-growing		Low flow	High flow		
Big Flat Brook (01439830)	4			ND			ND	ND
Flat Brook (01440000)	32	15.85	2.75	G	14.70	7.0	LO	G@LO
Flat Brook (01440010)	2			ND			ND	ND
Dunnfield Creek (01442760)	12	14.00	4.00	G	12.50	3.50	NS	G@LO
Paulins Kill (01443290)	2			ND			ND	ND
Dry Brook (01443370)	4			ND			ND	ND
Paulins Kill (01443440)	71	18.00	3.50	G	18.00	7.00	LO	G@LO
Paulins Kill (01443500)	84	19.50	3.50	G	18.00	8.50	LO	G@LO
Jacksonburg Creek (01443550)	4			ND			ND	ND
Jacksonburg Creek (01443600)	4			ND			ND	ND
Pequest River (01444970)	4			ND			ND	ND
Pequest River (01445000)	4			ND			ND	ND
Pequest River (01445500)	31	15.50	3.50	G	16.25	6.00	LO	G@LO
Pequest River (01446400)	12	17.25	6.00	G	10.50	9.75	NS	G@LO
Pohatcong Creek (01455200)	71	18.00	4.25	G	17.25	NS	ND	G@LO
Musconetcong River (01455500)	39	21.50	3.25	G	18.25	12.0	NS	G@HI
Musconetcong River (01455801)	41	19.75	4.50	G	19.00	12.0	NS	G@LO
Musconetcong River (01456200)	68	18.25	3.75	G	16.00	10.0	NS	G@LO
Musconetcong River (01456600)	2			ND			ND	ND
Musconetcong River (01457000)	31	16.50	3.00	G	18.00	7.50	LO	G@LO
Musconetcong River (01457400)	85	17.95	4.50	G	17.50	8.00	LO	G@LO