ACKNOWLEDGEMENTS

PRIMARY AUTHORS:

Steve Yergeau, Watershed Assessment Specialist
Priya Sankalia, GIS Specialist

CONTRIBUTING AUTHORS:

Noelle MacKay, Director, Watershed Management
Andrew Rowan, Ph.D., Director, The GIS Center
Robert Tucker, Ph.D., Research Director

The Stony Brook-Millstone Watershed Association (SBMWA) would like to thank everyone who helped in the development of this Characterization and Assessment of the Rocky Brook Watershed. The funding for this project was made possible by Federal funds from the Clean Water Action Initiative that has been administered by the **New Jersey Department of Environmental Protection** (NJDEP) through Section 319(h) funds.

We would like to thank the members of our **Clean Water Action Advisory Committee** (James Cosgrove, Donna Drewes, Tod Fairbanks, John Gaston, Nancy Grbelja, Marjorie Kaplan, Tom Kellers, Kerry Kirk-Pflugh, Joe Mattle, Gene McColligan, Janice Mironov, Robert Ortego, Paul Pogorzelski, Kent Scully, William Searing, Stephen Souza, Dan Van Abs, and Michael Wright) for their guidance, for sharing their expertise in watershed management, and providing any available data.

SBMWA's **StreamWatch volunteers** (past and present) for donating their time to collect the chemical, biological, and visual assessment data used in this report.

Summer 2001 Watershed Management and Stony Brook-Millstone Watershed Association interns (Meghan Fehlig, Cynthia Lin, Nick Seifert, Lily Stockman, and Alley Welsh) for performing the visual assessments in the Rocky Brook Watershed.

Brian Rappaport, AmeriCorps Watershed Ambassador, for performing the visual assessments and for videotaping the streams in the Rocky Brook Watershed as part of the visual assessment.

The agencies, organizations and companies that shared their data on the environmental resources of Rocky Brook so that a complete picture of the Rocky Brook Watershed's health could be obtained.

TABLE OF CONTENTS

Acknowledgements	i
Table of Contents	ii
List of Tables	iii
List of Graphs	iii
List of Figures	iv
Introduction	1
Landscape	4
♦ Setting	4
♦ Population	6
♦ Critical Habitats	10
Known Contaminated Sites	13
Point Source Dischargers	18
♦ Dischargers to Surface Water	18
♦ Dischargers to Ground Water	19
Geology	20
Soils	25
♦ Hydrologic Soil Groups	25
♦ Soil Erodibility	25
Land Use	27
♦ Forests	28
♦ Agriculture	29
♦ Urban	29
♦ Wetlands	30
♦ Impervious Cover	31
♦ Riparian Corridors	32
Water Supply	34
♦ Water Withdrawals	34
♦ Wellhead Protection Areas	36
♦ Ground Water Recharge	37
Water Quality	39
♦ Visual Assessments	39
♦ Biological Assessments	41
♦ Chemical Assessments	42
Findings & Recommendations	51
References	56
List of Acronyms	59
Glossary	61
Figures	66

LIST OF TABLES & GRAPHS

TABLE		PAGE
1	Municipalities within the Rocky Brook Watershed.	4
2	Population changes in the municipalities that comprise the Rocky Brook Watershed from 1940 - 2000.	9
3	Population changes in the municipalities that comprise the Rocky Brook Watershed from 1970 - 2000.	9
4	Number of endangered/threatened species in the Rocky Brook Watershed by county.	11
5	Known Contaminated Sites in Rocky Brook Watershed.	17
6	Total water withdrawals in the Rocky Brook Watershed in millions of gallons per year (mgy).	35
7	Visual assessment scores for Rocky Brook 2001.	45
8	Biological assessment data for Rocky Brook Watershed 1993 and 1998 (NJDEP Data).	46
9	Biological assessment data for Rocky Brook Watershed 1999, 2000 & 2001 (MCHD Data).	47
10	Chemical assessment of Rocky Brook Watershed 2000 and 2001 (SBMWA Data).	48
11	Chemical assessment of Rocky Brook Watershed 1999 and 2000 (MCHD Data).	49
12	Chemical assessment of Rocky Brook Watershed 1997 - 2000 (USGS Data).	50

GRAPH		PAGE
1	Percentage of the Rocky Brook Watershed area within each municipality.	4
2	Historical population of the Rocky Brook Watershed by municipality.	7
3	Percentage of total population of the Rocky Brook Watershed by municipality.	7
4	Changes in acreage of land uses in the Rocky Brook Watershed from 1986 to 1995/97.	28
5	Changes in percent of total watershed area of land uses in the Rocky Brook Watershed from 1986 to 1995/97.	29
6	Total water withdrawals in the Rocky Brook Watershed in millions of gallons per year (mgy).	34

LIST OF FIGURES

FIGURE		PAGE
1	Rocky Brook Watershed & Millstone Watershed	67
2	Topography & Major Roads in Rocky Brook Watershed	68
3	Population Density in Rocky Brook Watershed	69
4	Population Distribution in Rocky Brook Watershed	70
5	Critical Habitats in Rocky Brook Watershed	71
6	Land Use Changed to Urban Between 1986 and 1995/97 Near State Threatened Habitats in Rocky Brook Watershed	72
7	Known Contaminated Sites in Rocky Brook Watershed	73
8	Point Source Dischargers in Rocky Brook Watershed	74
9	Physiographic Provinces of New Jersey	75
10	Rocky Brook Watershed Geology	76
11	Rocky Brook Watershed Hydrologic Soil Groups	77
12	Soil Erodibility in Rocky Brook Watershed	78
13	1995/97 Land Use in Rocky Brook Watershed	79
14	Land Use Changed to Urban between 1986 and 1995/97 in Rocky Brook Watershed	80
15	1995/97 Impervious Surfaces in Rocky Brook Watershed	81
16	Riparian Land Cover Conversion in Rocky Brook Watershed	82
17	Community Water Supply Well Head Protection Areas in Rocky Brook Watershed	83
18	Aquifer Regions in Rocky Brook Watershed with High Ground Water Recharge	84
19	Land Use in Areas of High Ground Water Recharge in Rocky Brook Watershed	85
20	Visual Assessment Score for Rocky Brook	86
21	Biological Assessment Sampling Sites in Rocky Brook Watershed	87
22	Chemical Assessment Sampling Sites in Rocky Brook Watershed	88

INTRODUCTION

Sprawl, according to Webster's New Collegiate Dictionary, is defined as: to creep or clamber awkwardly; to spread or develop irregularly; to cause to spread out carelessly or awkwardly. *Awkward*. *Irregular*. *Careless*. These are not words that we want to associate with the planning and development of the towns where we live, work and play. And yet, in Central New Jersey the consequences of this careless development are clear: development is degrading our natural resources, most particularly putting the region's water quality and quantity at risk.

Across America, poor planning is allowing farmlands, forests, wetlands and viewsheds to be devoured at an astounding rate, changing forever the character of the places we call home. Countless acres of open space have become strip malls, roads and detention basins. This consumption of open space by haphazard growth is not merely aesthetically disturbing, but has severe environmental and quality of life costs.

Situated within the metropolitan corridor between New York and Philadelphia, Central New Jersey is on the front line in the battle to stop sprawl, as development threatens to destroy our remaining open space. The consequences are clear: nitrates, phosphates and fecal coliform bacteria are elevated in many of our waterways and our macroinvertebrate populations are showing signs of distress and lack of diversity due to exposure to high levels of pollutants. Roadways and traffic congestion are eroding our sense of place and community.

Many streams in the 265-square-mile Stony-Brook Millstone Watershed (referred to from now on as the Millstone Watershed) have been designated as impaired by the New Jersey Department of Environmental Protection (NJDEP), which cites the pace of development and nonpoint-source pollution as the major causes. Additionally, 65% of the waterways in New Jersey are biologically impaired for drinking, recreational or fishing uses and 50% of the waterways in the Nation are impaired. According to NJDEP data, nearly 11,000 acres of land were developed in the Millstone Watershed between 1986 and 1995/97, a rate of approximately 92 acres per month or over 92 football fields each month (one acre equals approximately one football field). During the years since 1995/97, this area has continued to experience extensive development, as 50 acres of land are lost to development each day in New Jersey.

In order to better identify the causes of declining environmental health, we need an understanding of our watershed and the changes that have occurred within its natural boundaries. The water that flows in a stream arrives there in part by flowing over the land or percolating through the soil. Thus, how we develop the land is reflected in the water quality of the streams.

In the mid-1990's, the NJDEP recognized that to address water quality and quantity issues, regulating point-source pollution alone was not adequate. Nonpoint-source pollution from lawns, agricultural fields, roads and poorly

managed land is a major stress on our streams, rivers and lakes. Emulating programs elsewhere in the United States, NJDEP adopted a new approach, watershed management, to protecting our natural resources. In partnership with local stakeholders, the NJDEP has initiated this watershed-based planning process throughout the State. The Raritan River Basin is one area where this process has begun, and was completed in December 2002. The Millstone Watershed is part of this larger 1,100-square mile basin.

Because of the time frame for the Raritan Basin Project and the large size of both the basin and the 265 square-mile Millstone Watershed, the Stony Brook-Millstone Watershed Association (SBMWA) wanted to initiate a project that combined the data analysis necessary to pinpoint problems with projects that can be implemented to restore and enhance the local environment. Research indicates that the most effective management efforts are generally confined to subwatersheds on the order of 20-50 square miles (Center for Watershed Protection 1998). Such a localized approach allows personal contact with the community and fosters building relationships and trust. Most successful programs changing personal behavior have also cited one-to-one relationships as the key to success. Thus, this project was developed to address problems specific to a smaller subwatershed within the Millstone Watershed.

The first step in this project is to provide a characterization and assessment of an impaired subwatershed in order to understand the causes of the problems and identify appropriate solutions. This report identifies the current status of the environment (characterize) and compares this to community goals and adopted standards in New Jersey (assess). Information is collected on soil types, geology, land use changes, water quality, rare and/or endangered species, critical habitats and population changes. This information is analyzed individually and then integrated with other data from the watershed to pinpoint the potential causes of the water quality problems.

Once the subwatershed is identified and evaluated, the most effective watershed management tools are selected to restore, enhance or protect water quality. For example, if nonpoint-source pollution from residential lawns or a golf course is identified as a concern, the focus should be on implementing education programs for homeowners and golf courses in these areas, rather than for agriculture or businesses. Visual assessments of local streams can also guide management actions. Areas in need of extensive streambank restoration can be identified, as can areas with high water quality that needs to be preserved. The Watershed Association, with 54 years of experience in water quality protection, has a large arsenal of tools that have been utilized successfully in the past. These include:

- Extensive experience in education working with both adults and children;
- Streambank restoration, riparian buffer creation and reforestation;

- Working with the North Jersey Resource Conservation and Development Council to assist farmers in implementing agricultural Best Management Practices (BMPs);
- River Friendly Programs: one-on-one education of residents, businesses, golf courses, schools and municipalities on BMPs for their property;
- StreamWatch: our successful, long-term water quality monitoring program;
- Municipal assessments: working with municipalities to integrate the vision for the municipality into their zoning and ordinances; and
- Open space acquisition planning.

The Rocky Brook Watershed was the second subwatershed chosen to undergo scrutiny and this Characterization and Assessment Report is the result of our investigation. The Beden Brook Watershed was the first subwatershed to be thoroughly assessed. The Rocky Brook Watershed is located in the southeastern portion of the larger Millstone Watershed, in Central New Jersey (Figure 1). The report brings together information and interlinks the data to provide an understanding of why water quality in some areas is impaired. As the SBMWA has done for many years, we are working with the residents, municipal officials, and businesses to understand their concerns and vision for their community, and we will work together to implement the best strategies for improving environmental quality. For this report, when discussing the entire Rocky Brook area, it will be referred to as a watershed.

This report is intended to relay the past and present status of the Rocky Brook Watershed and its environmental resources. The evaluation was used to set priority areas where SBMWA can utilize its effective watershed restoration tools. Goals of watershed restoration include improved water quality, educated local residents, businesses, and municipalities on nonpoint pollution reduction, and a measurable reduction in nonpoint-source pollution in Rocky Brook and its tributaries.

SMBWA is not alone in their efforts. The United States Environmental Protection Agency (USEPA) has stated that nonpoint-source pollution, or pollution from runoff, is currently one of the leading causes of water quality degradation (USEPA 1996). This means that the solution, like recycling, involves everyone – our elected officials, business leaders, golf course superintendents, and each resident. This report summarizes the causes of the problem. It is up to everyone who lives, works and plays in the Rocky Brook Watershed to work together to provide a vision for this area and strive to protect the environment and quality of life that we value.

As with building a sturdy house, a foundation for the Rocky Brook Watershed needs to be laid in order to fully assess its character. That foundation takes the form of the townships that decide what happens within their borders and to the watershed, the streams that meander through, the populations of residents that have an impact of the environment everyday, and the flora and fauna that inhabit the area and rely on it for survival.

SETTING

The Rocky Brook Watershed covers over 9,600 acres (approximately 15 square miles) that lie in part or all of East Windsor Township, Hightstown Borough (both in Mercer County), Monroe Township (Middlesex County), Roosevelt Borough and Millstone Township (both in Monmouth County) (Table 1 and Graph 1). Within the Watershed, the majority of the land is located in two municipalities. Almost half (45.5%) of the area lies within Millstone Township, including the headwaters of Rocky Brook (Graph 1). Millstone Township also contains the headwaters for five watersheds: Assunpink Creek Watershed, Crosswicks Creek Watershed, Manalapan Brook Watershed, Toms River Watershed, and the Millstone Watershed upstream of its confluence with the Rocky Brook. Of the remaining watershed area, 43.1% lies within East Windsor Township, and the rest of the municipalities make up the final 11.4% (Graph 1).

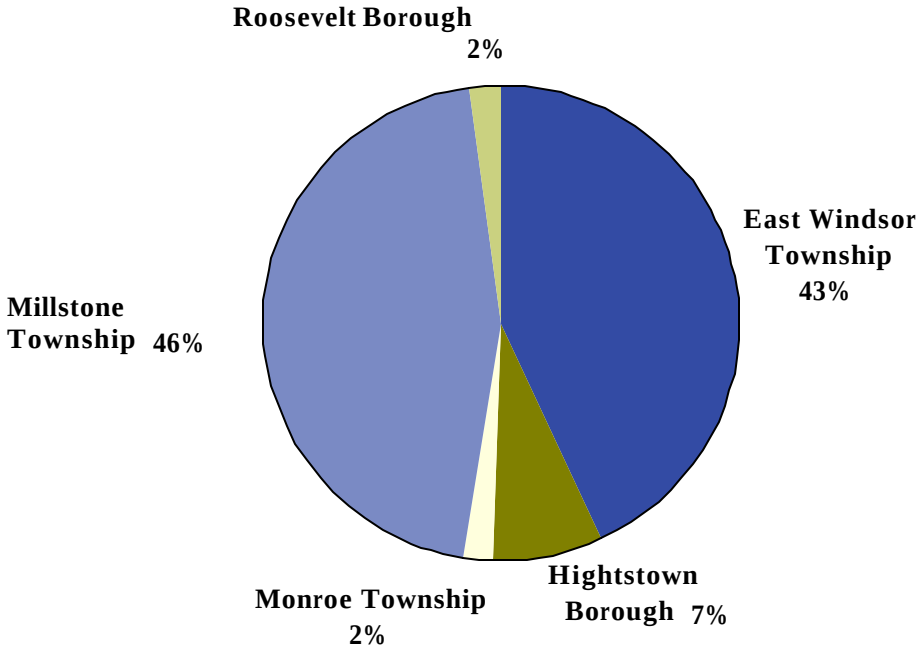
Table 1: Municipalities within the Rocky Brook Watershed.

Municipality	County	Acres in the Rocky Brook Watershed
Millstone Township	Monmouth	4,371
East Windsor Township	Mercer	4,136
Hightstown Borough	Mercer	713
Roosevelt Borough	Monmouth	200
Monroe Township	Middlesex	184
TOTAL	- - -	9,604

In its infancy, Millstone Township was comprised of several historic villages known as Cars Tavern, Holmeson, Smithburg, Sweetman, Bergen Mills, Bairdsville, Stone Tavern, Clarksburg, and Perrineville. The last two remain today as a witness to the town's heritage. A rumor persists that an English tanner named Clark settled Clarksburg in the pre-Revolutionary era. John Perrine purchased a large tract of land north of Clarksburg, which then became known as Perrineville. Roosevelt Borough was founded under President Theodore Roosevelt's "New Deal" in 1937 and bears his name because of it. Roosevelt Borough has the distinction of being the only New Jersey Historic District in the National Register of Historic Places that is an entire town.

Once the home of potato farmers, East Windsor was incorporated in 1798 after residents disagreed over public road maintenance and separated the land into what are now East Windsor and West Windsor. From 1770 – 1773, Etra Lake was created as a way to power a gristmill on Rocky Brook. Hightstown was founded in 1721 and is well known for the Victorian homes that line many of its streets.

Graph 1: Percentage of the Rocky Brook Watershed area within each municipality.



Rocky Brook, running 10½ miles long, originates in Millstone Township and crosses the northern half of Roosevelt Borough and bisects Hightstown Borough as it travels to its confluence with the Millstone River northwest of Route 130 and north of Route 33 in East Windsor Township (Figure 2). Many smaller tributaries drain into Rocky Brook, but are unnamed.

The Rocky Brook Watershed also has many recreational lakes that are important to the area. Peddie Lake provides recreation to local residents and educational opportunities to students at The Peddie School in Hightstown Borough. The recreational values of Peddie Lake include two launches for canoes and small watercraft and fishing along its shores. The NJDEP recently developed a management plan for Peddie Lake. As part of the plan, the fishery resources of Peddie Lake were surveyed and it was found to have a healthy and balanced population of fish (NJ Bureau of Freshwater Fisheries 1998). A major park in East Windsor is located at Etra Lake, where 160 acres provide a popular spot for fishing, hiking and other outdoor activities. Around Perrineville Lake in Millstone Township, Monmouth County is planning to purchase land for a 535-acre park, an area already heavily used by residents.

POPULATION

People within a watershed have both direct and indirect impacts on water quality and therefore, also have opportunities to responsibly manage and improve water quality. Increasing populations in the Rocky Brook Watershed are adding to the pressures of waste disposal and water treatment, an increased need for housing to be built, and increased water usage. Development pressure increases with growing populations as the infrastructure needed to support more residents needs to be in place.

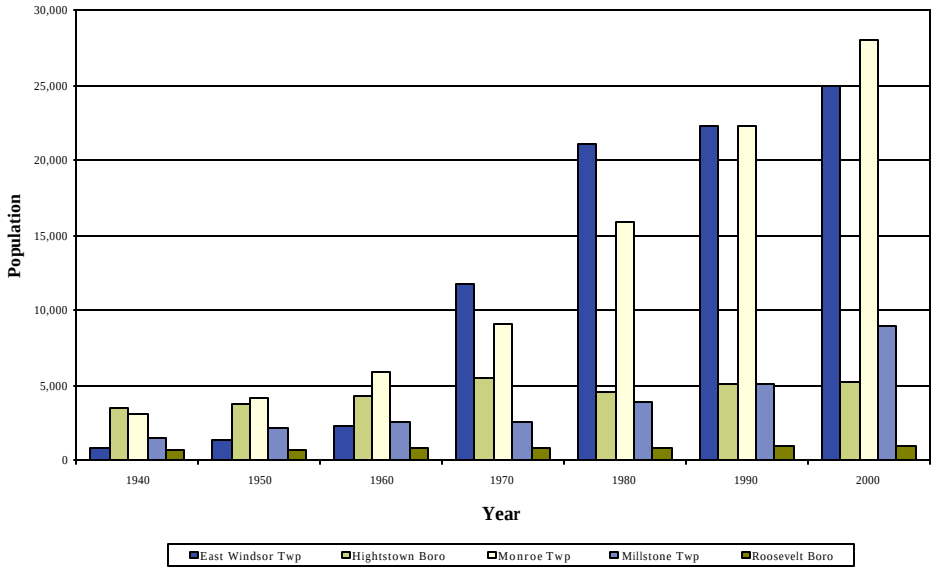
Population is increasing and development is progressing rapidly in the Rocky Brook Watershed. The current trend is in spreading out over the landscape, instead of clustering in hamlets, villages, town centers or the boroughs. Residents are moving away from established centers in order to live in more rural settings. People's dependence on the automobile and the lack of reliable public transportation have encouraged this pattern of development in the area, and throughout the State.

Within those municipalities that make up the Rocky Brook Watershed, the total population for the towns has increased more than seven-fold in 60 years, from 9,529 people in 1940 to 68,037 in 2000 (Graph 2 and Table 2). This population increased at an average rate of 975 people per year. Between 1940 and 2000, population changes for people living within the five (5) municipalities found partially or fully within the Watershed show that overall growth occurred in each of the municipalities (Figure 3, Table 2, and Graph 2).

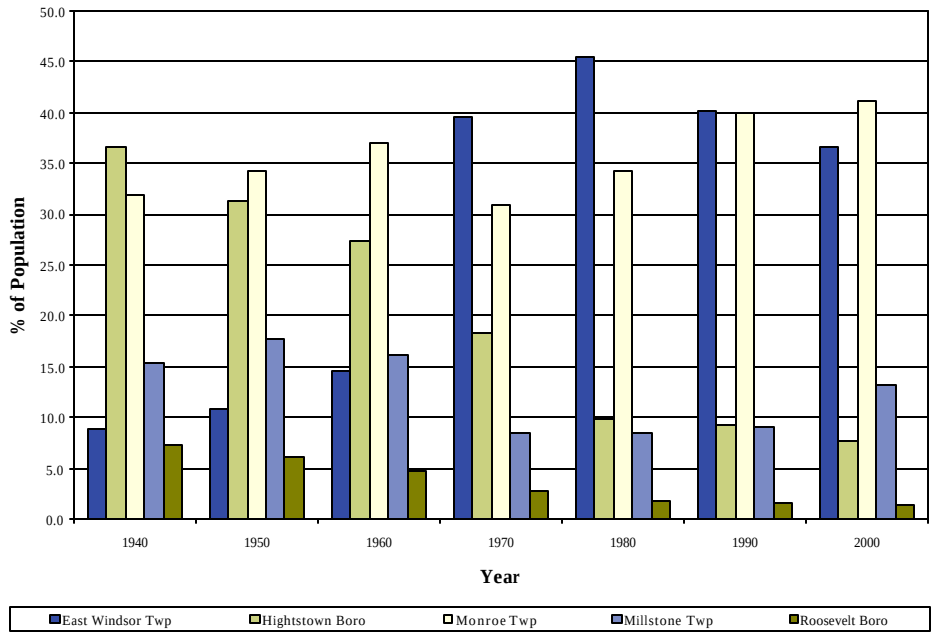
The largest population increase occurred in East Windsor Township. East Windsor experienced a 2,849% increase in residents between 1940 and 2000, as it went from 845 residents in 1940 to a population of 24,919 in 2000 (Table 2). East Windsor makes up a large portion of the Rocky Brook Watershed (making up 43.1% of the overall watershed's area) and contributes a comparable 36.6% of the population for the municipalities found all or part in the Rocky Brook Watershed (Graph 3). With such an increasing

population in one municipality that constitutes a major portion of the Rocky Brook Watershed, local governance needs to thoughtfully plan out the future direction of development within East Windsor.

Graph 2: Historical population of the Rocky Brook Watershed by municipality. *



Graph 3: Percentage of total population of the Rocky Broo4k Watershed by municipality. *



* The population figures listed are for the entire municipality and not just for the portion found in the Rocky Brook Watershed.

The smallest change in population was found in Roosevelt Borough with only a 34% increase in population over 60 years (Table 2, Graph 2). Hightstown Borough also has attracted new residents, with a 50% increase in the number of people living there (Table 2 and Graph 2). In fact, over the last 30 years, Hightstown Borough lost residents while the other municipalities gained residents (Table 3). Between the years 1970 and 2000, Hightstown Borough lost 215 residents, or 4% of its residents, as the population went from 5,431 to 5,216. Even with the slow population growth rate and a loss of residents over the past 30 years, Hightstown Borough still has the highest density of residents in the Rocky Brook Watershed with an average of 4,206 residents per square mile (Regional Planning Partnership 2001; Figure 3). Much of that density is distributed near State Route 33 where many businesses and direct connections to the New Jersey Turnpike are also located (Figure 4). It is important to note that Hightstown is small in size, covering only 1.24 square miles (Regional Planning Partnership 2001). Growth patterns are occurring in the larger, less developed townships and not the centrally developed boroughs, because of a desire to own more land or that the boroughs are currently built out or near buildout.

Population density is also high at the Twin Rivers development in East Windsor Township, on the border with Monroe Township, with densities of over 4,000 people per square mile (Figure 3). This development was completed in 1969 and was the state's first planned unit development. A planned unit development is a zoning designation for property developed at a higher density than conventional development in an area. Much of Twin Rivers design incorporated the needs of the community: schools, library, recreational facilities, retail establishments and light industry. All of these are connected by walkways for easy access by the 10,000 residents of Twin Rivers.

Because they incorporate many of the everyday needs of their residents, high-density areas like Hightstown and Twin Rivers allow for the opportunity to combat sprawl by concentrating populations within developed centers that reduce commuting time, and therefore pollutant emissions, to commonly-used facilities, compact infrastructure and utilities in one centralized area, and reduce impervious cover over the landscape (see Land Use section for more information on impervious cover).

The other municipalities within the Rocky Brook Watershed have also increased their populations (Table 2). Monroe Township experienced the second highest population growth, with an increase of 823% of its residents over 60 years, as the residents increase from 3,034 in 1940 to 27,999 in 2000, and an increase of 206% over the last 30 years alone (Table 2 and Table 3).

Millstone Township contributes the largest portion of land to Rocky Brook Watershed, with 45.5% of the Watershed in that one municipality. Millstone Township's importance also lies in that the headwaters for the Rocky Brook are located there.

Table 2: Population changes in the municipalities that comprise the Rocky Brook Watershed from 1940 - 2000. *

Municipality	1940 Population	2000 Population	% Population Change
East Windsor Township	845	24,919	+ 2,849%
Hightstown Borough	3,486	5,216	+ 50%
Monroe Township	3,034	27,999	+ 823%
Millstone Township	1,466	8,970	+ 512%
Roosevelt Borough	698	933	+ 34%
TOTAL	9,529	68,037	+ 614%

Table 3: Population changes in the municipalities that comprise the Rocky Brook Watershed from 1970 - 2000. *

Municipality	1970 Population	2000 Population	% Population Change
East Windsor Township	11,736	24,919	+ 112%
Hightstown Borough	5,431	5,216	- 4%
Monroe Township	9,138	27,999	+ 206%
Millstone Township	2,535	8,970	+ 254%
Roosevelt Borough	814	933	+ 15%
TOTAL	29,654	68,037	+ 129%

* The population figures listed are for the entire municipality and not just for the portion found in the Rocky Brook Watershed.

CRITICAL HABITATS

NJDEP's Division of Fish and Wildlife has developed a planning tool, The Landscape Project, to help land managers, planners and regulatory agencies integrate wildlife protection into their overall land use goals. The Landscape Project establishes "accurate boundaries around critical wildlife habitats and then comparatively ranks them to offer prioritization options for varying levels of conservation and management" (Niles, Myers and Valent no date). The ranking is based upon the presence or absence of animal species of concern, state threatened and endangered species, and federally threatened and endangered species.

Due to the loss of specific habitats, pollution, invasive plants and development, many species of plants and animals are losing the basic materials they need to survive in our area (food, shelter, and clean water.). Loss of animal species can be linked to loss in the resources that are necessary for survival of that species. Endangered species are those whose survival in New Jersey is in immediate danger. Threatened species are those who may become endangered if conditions that harm them continue to accumulate.

The portion of Millstone Township covered by critical habitats in the Rocky Brook Watershed is 49.2%. Much of the critical habitat in Millstone Township is forested areas of importance to wildlife, ranging from Suitable Habitat (suitable for fulfilling the habitat requirements of species of concern, but no such species documented there) to State Threatened (habitat where state threatened species have been documented) (Figure 5). East Windsor, 52.7% covered by critical habitats, contains mostly grassland habitats for state listed threatened or endangered species (Figure 5). Much of the critical habitat is located near stream corridors (Figure 5).

Extensive critical habitats exist in the Rocky Brook Watershed, especially habitat that has been valued as threatened. Just like the non-critical areas of the Watershed, these areas are susceptible to future development, especially those critical habitats near or adjacent to lands developed between 1986 and 1995/97 (Figure 6). Many urban developments have appeared in the Rocky Brook Watershed between 1986 and 1995/97, including a large urban area and several smaller areas in Millstone Township (Figure 6).

In the Rocky Brook Watershed, two known recorded state threatened species are found: the wood turtle (*Clemmys insculpta*) and the redheaded woodpecker (*Melanerpes erythrocephalus*). The surrounding counties support a large diversity of endangered or threatened vertebrate, invertebrate, and vascular plant species (Table 4).

Table 4: Number of endangered/threatened species in the Rocky Brook Watershed by county. *

County	Vertebrates	Invertebrates	Vascular Plants
Mercer	18	12	60
Middlesex	15	20	58
Monmouth	21	18	55

* NJDEP's Natural Heritage Program gives the general area where the endangered or threatened species is located. This reduces the ability of people to pinpoint the location of the organism's habitat, and thus reduce the impact on that particular organism.

Assessment –

The sprawling population growth of the Rocky Brook Watershed has a more detrimental impact on water quality than clustering development in town centers. As agricultural lands, forested areas, and lands adjacent to wetlands are developed into residences and office buildings, they create residential and business destinations that attract more development (Center for Watershed Protection 1998). These developed areas tend to have a higher percentage of impervious cover, material that prevents water from percolating back into the ground. Among other things, this increase in impervious cover alters flooding patterns, heightens pollutant loads to streams, raises water temperatures, and also reduces baseflow in streams during drought (Center for Watershed Protection 1998; see Land Use section for more information). Development that sprawls over the landscape makes systematic stormwater control extremely difficult, as well as fragmenting forests and other habitats thereby causing a decline in ecological health. Established centers that concentrate populations and impervious cover allow for more effective and efficient stormwater practices and minimize habitat fragmentation. In addition, infrastructure needs and costs increase as development occurs further and further away from established sewer and water systems. Municipalities need to manage the additional infrastructure and development patterns such that water quality is protected.

Developing areas as planned unit developments is one way to reduce sprawl in New Jersey. Other innovative ways to plan developments include re-zoning (changing zoning classifications to permit development that is less dense or restrictive), mixed-use development (projects that integrate different land uses, such as restaurants, residences, offices and parks), conservation

design and town-center designation (centralized growth areas through incentives and allows for developing at higher densities). These alternatives need to be based on accurate scientific information, the carrying capacity of available water supplies, sewer systems and other infrastructure, and the goals and objectives of the municipality's Master Plan and decision-making committees. Municipalities must incorporate these alternatives into their Master Plans in order to slow down sprawl.

By providing alternatives to traditional development, municipalities will protect the environment and especially the sensitive habitats and the wildlife that lives in them. These critical habitats are being threatened by development and municipalities need to incorporate this information on critical habitats in order to effectively slow sprawl, improve the environment and protect wildlife.

In addition to providing habitat for the conservation of rare species, protecting important wildlife habitats will result in more open space for outdoor recreation. Open spaces provide places where people can escape the confines of urban and suburban living. Many recreational areas currently exist in the Rocky Brook Watershed. Etra Lake Park, Peddie Lake and Perrineville Lake can only maintain the interest of outdoorsmen if they maintain good water quality for canoeing and boating and preserve habitat for fishing and bird watching.

The headwaters for Rocky Brook are contained entirely in Millstone Township. Because of this, the residents in Millstone Township need to be especially aware of their roles in impacting and improving water quality in Rocky Brook. Millstone Township has the lowest population density in the Rocky Brook Watershed, with only 240 people per square mile (Millstone Township 2002; Figure 4).

KNOWN CONTAMINATED SITES

Contaminated sites are generally the result of spills, leaks, or careless practices with chemicals or other hazardous materials such as biological or radioactive wastes. It is important to be aware of these sites because the substances involved can be highly toxic, and, therefore, can become hazards to human health as well as to the natural environment. Common contaminants found on these sites include metals, petroleum products and by-products, organic solvents, and pesticides. Once discovered and evaluated, several different branches of the NJDEP regulate and oversee these sites.

Note that the listing of contaminated sites gives the name of the current owner of the property where the contaminated site is located. The current site owner and the potentially responsible party (PRP) for the contamination are not necessarily the same. Site managers at NJDEP are currently overseeing the investigation of sites found on this list. There are also many residential sites that contain underground storage tanks (USTs) that have not been described or mapped. This lack of information may prove risky as the status, leaking or intact, for these USTs is unknown, and therefore whether or not they are contaminating surrounding areas is unknown. For privacy and cost-benefit reasons, SBMWA has not made any further effort to enumerate, locate, or identify residential USTs, either intact or leaking, in this subwatershed.

There are currently 15 known contaminated sites in the Rocky Brook Watershed (Figure 7 and Table 5). Seven sites are located in each of East Windsor Township and Hightstown Borough, and one in Millstone Township (Figure 7 and Table 5). Most of these are commercial establishments consisting of closed USTs of varying sizes, which were used to store petroleum products. Closure of a UST involves draining the tank and supply lines, excavation around the tank and testing the soil for contamination, and often subsequent monitoring of ground water for likely contaminants (such as lead, base neutral organics, petroleum hydrocarbons, and volatile organics). The contamination from each tank may range from no contamination to large-scale ground water and potable water contamination.

In Hightstown Borough, the Agway Petroleum Corporation was a fuel oil distributing facility with historic ground water problems. Benzene was found in the ground water and there was a surface discharge from the fuel oil tank into the soil and water in 2000. The soil has since been removed and storm drains have been replaced and monitoring wells installed. The extent of the contamination has not yet been determined, but the NJDEP is monitoring the site and working on determining the extent and seriousness of the contamination.

A problematic site, the Carduners Liquor Store in East Windsor Township has been an active site since 1994. The site is on a strip mall owned by the same owner as the liquor store and the original contamination was from the

dry cleaners in the mall. The dry cleaners were dumping the chemical waste resulting in perchloroethylene (PCE) and trichloroethylene (TCE) contamination of ground water and soil. The contamination is moderate and different treatments have been tried to correct the problem.

The Citgo Service Station in Hightstown Borough appears to be a low priority site. A leak of gasoline from a 4,000-gallon UST was reported in 1990. Since then, four monitoring wells were installed and some ground water sampling was done, which resulted in the reporting of some benzene and toluene contamination.

The Cumberland Farms of Hightstown Borough site was a gas station that had a gasoline and fuel oil UST leak in 1996. There is evidence of ground water contamination. The UST has since been removed and remediation work is in progress. Thirteen monitoring wells have been installed and sampling has been done on a yearly basis starting in 1996. Sampling events show the ground water flow to be in an easterly direction. The wells near the tank fields show the highest level of contaminants. The contamination has spread to neighboring properties. Monitoring wells have been installed in two neighboring properties and one shows contamination. The PRP needs to delineate the extent of the contamination better since there is a very large plume. They need to put in few more wells for this purpose. In September 2000, high intensity treatment (HIT) of the site, where water is extracted at high vacuum pressure, was proposed and approved. The current remediation status is unknown.

There are six leaking USTs at the East Windsor Department of Public Works site, which were for waste oil, diesel and gasoline. A sheen was observed in the ground water associated with two of these tanks. Contaminants include chlorinated solvents, benzene, tetrachloroethene, arsenic, chromium and lead. The tanks were removed in 1996 and soil has been excavated at the site, with soil samples continuing to be collected. Ground water monitoring wells have been installed. The ground water flow is toward the east and delineation of the plume is being undertaken. Many of the contaminants are not in high concentrations while some, tetrachloroethene for example, are below the State Water Quality Standards.

In East Windsor Township, the Exxon Service Station is a gas station that had a leaking gas tank, which was removed in 1991. Ground water contamination was detected but was confined to the site, and samples taken across from the site showed no contamination. The contaminated soil was removed and monitoring is continuing regularly with the eight wells that have been installed at the site. There is no active remediation planned. After removal of the soil, natural remediation is anticipated.

A gasoline UST leak in 1991 places Hess Service Station as a known contaminated site in East Windsor Township. The tank has been replaced, and many remediation treatments have been tried, but have proven

unsuccessful. The remediation is difficult because of the significant deep ground water and soil contamination at this site. The PRP has been compliant with efforts to clean up this site.

Historically an old distribution facility, the Hightstown Oil Company has some metal contamination, the source of which is unknown. The metal contaminants include lead and arsenic. They had gasoline and fuel oil tanks that were leaking and have since been removed. There is a ground water plume, which has been partially delineated, but additional samples need to be taken to determine its exact extent. There are several monitoring wells in place at the site and the PRP has been compliant with NJDEP. The site will probably be left to natural remediation but this will be accepted only after the PRP has given NJDEP a receptor evaluation.

A leaking diesel and gasoline UST was removed from the JCP&L Hightstown Central District/GPU Energy site in Hightstown Borough. The original discharge took place in 1992. The extent of the contamination is limited to the entire, approximately 200 square foot, site. The organic contamination includes benzene, toluene, ethylbenzene, and xylenes (BTEX). Five monitoring wells have been set up, which are sampled on a regular basis. High vacuum extraction treatment was used to remediate the site in summer 2000, which appears to have been successful. Currently, the site is being left to natural remediation.

The contamination in East Windsor Township at the NJ Turnpike Authority Central Shops site occurred in 1994. There were six USTs for heating oil, diesel, gasoline, and waste oil tanks, three of which were responsible for the contamination. The contamination was limited to the area around the tanks. Eight monitoring wells are in place and the contamination appears to be delineated. There is soil contamination and possibly some water contamination at the time of the leak, but the levels were very low and are most likely acceptable now.

The North American Phillips Lighting site in Hightstown Borough is an old site, where ground water contamination had been noticed. The contaminants are chlorinated organics such as trichloroethane (TCA) and have been contained and the PRP has been compliant with NJDEP. The PRP has been using remediation where the chlorinated organics are pumped to the sewer through a trench system. NJDEP reevaluated the site in August 2001 to determine if additional monitoring at the site is necessary.

There is little information on the Orchard Terrace site in East Windsor Township. In 1991, the site was assigned to the Bureau of USTs (BUST), but the information trail ends there. BUST says it is with the Bureau of Field Operations (BFO) Southern Office, who in turn says it should be with Bureau of Case Assignment. In 1991, the site was reported to have a leaking fuel oil tank with soil and ground water contamination, but no reports have been submitted since then.

The Perrineville Deli in Millstone Township had gas tanks at the site, which have since been removed. There was soil and ground water contamination detected. The soil has been excavated and wells have been installed to monitor the contamination. The PRP is trying to determine the extent of the contamination and is continuing to take samples from the monitoring wells.

There was a heating oil tank at the senior citizen center at the Presbyterian Homes at Meadow Lakes in East Windsor Township, which is not regulated by BUST and so has been transferred to the BFO. The database at NJDEP however, still lists it as a BUST site. According to BUST, there were chlorinated compounds at low concentrations at the site, but contamination was not extensive. This site will most likely be left to natural remediation.

The Pullen Fuel Company site in Hightstown Borough has been archived. This could mean one of two things: the site has been worked on but there are outstanding issues which need resolving but do not have high priority, or there are no oversight documents associated with the site.

Assessment –

There are a large number of known contaminated sites in the Rocky Brook Watershed and this warrants that the PRPs clean up any contamination present. This is especially true for those sites with certain or possible ground water contamination. The Rocky Brook Watershed has many areas with high recharge to ground water (see Water Supply section). These areas not only allow for quick movement of water to ground water supplies but also those pollutants traveling with that water.

Ground water contamination is a concern at four of the known contaminated sites: North American Phillips Lighting, Hightstown Oil Company, Pullen Fuel Company and Citgo Service Station (see Water Supply section for more detail). These sites are located within a half-mile of two public wells in Hightstown Borough. Special attention needs to be given to the monitoring of these four sites to ensure that public safety is maintained.

Table 5: Known Contaminated Sites in Rocky Brook Watershed.

Site Identification Number	Site Name	Address	City	Remedial Level *
NJL800223075	East Windsor Department of Public Works	Ward Street & Etra Road	East Windsor Township	C2
NJL000040311	Orchard Terrace	60 One Mile Road	East Windsor Township	B
NJD986596336	Presbyterian Homes at Meadow Lakes	Etra Road	East Windsor Township	C2
NJL880000385	Carduners Liquor Store	Routes 130 & 571	East Windsor Township	C2
NJC876025586	Hess Service Station	Route 33	East Windsor Township	C2
NJD982740359	Exxon Service Station	Route 33 & Monmouth Road	East Windsor Township	N/A
NJD986586667	NJ Turnpike Authority Central Shops	New Jersey Turnpike Mile Maker 67.6	East Windsor Township	C2
NJD043290659	North America Philips Lighting	Bank Street	Hightstown Borough	C2
NJD000767988	Hightstown Oil Company	Broad & Monmouth Streets	Hightstown Borough	C2
NJL000059394	Cumberland Farms	315 Mercer Street	Hightstown Borough	C2
NJL000069286	Citgo Service Station	164 Mercer Street	Hightstown Borough	C2
NJD980646905	JCP&L	401 Mercer Street	Hightstown Borough	C2
NJD980766372	Agway Petroleum Corporation	Maxwell Street	Hightstown Borough	C2
NJL800476103	Pullen Fuel Company	Broad & Monmouth Streets	Hightstown Borough	N/A
NJL800369043	Perrineville Deli	866 Perrineville Road	Millstone Township	N/A

* Remedial Level: Level of site complexity to remediate the contamination, as outlined in Case Assignment Manual by the NJDEP's Site Remediation Program.

The intent of the remedial level is to reflect the overall degree of contam ination at a site recognizing that different areas may involved varying levels of action.

A = Emergency or single-phase, short-term clean up.

B = Single phase clean up of soils only.

C1 = Single source/contaminant affecting both soils and groundwater.

C2 = Multiple sources/contaminants affecting soil/groudwater - moderate.

C3 = Multiple sources/contaminants affecting soil/groudwater - severe.

C4/D = Superfund site.

N/A = Known sites not adequately assessed to a rank.

KNOWN CONTAMINATED SITES

Point source dischargers are facilities that discharge treated waste directly into surface water or ground water. These discharges can have powerful effects on the quality and quantity of water in a stream or aquifer. Because flow from these sources is independent of storm events, the quality of effluent in surface water discharges is crucial to habitat quality. The NJDEP regulates these facilities and several federal and state laws govern their discharges. Each facility is assigned a case manager, and is classed according to its type of discharge (i.e., land application, a pipe discharge to surface water, a percolation lagoon, a stormwater detention basin, etc.). Discharges may combine waters from more than one source (storm water and cooling water combinations are common). If this is done, then the permit is classified according to the major component of the discharge. Regular monitoring of the discharge is required for all permits.

Note that the information presented in this section was derived from the U.S. Environmental Protection Agency's (USEPA) EnviroFacts Warehouse: Water Discharge Permits' Permit Compliance System database at http://www.epa.gov/enviro/html/pcs/pcs_query_java.html, downloaded in the summer of 2002 and updated in the fall of 2002. Any inconsistencies between the actual permit and the data presented here, should be reported to the USEPA EnviroFacts website.

PERMITTED DISCHARGERS TO SURFACE WATER

There are currently three licensed point source dischargers in the Rocky Brook Watershed (Figure 8). The point source dischargers to surface water in the Rocky Brook Watershed consist of a water treatment plant (WTP), the Hightstown Borough WTP, a wastewater treatment plant, the Hightstown Advanced WTP, both discharging less than 1 million gallons per day (MGD) in volume and one industrial discharger, the Coca-Cola Foods-owned Minute Maid Company (Figure 8).

The Minute Maid Company and Hightstown Borough WTP are both working under permits issued in 2002. The Minute Maid Company permit (NJPDES # NJ0004561) expires on August 31st, 2007 and the Hightstown Borough WTP permit (NJPDES # NJ0003832) expires on March 31st, 2007. The only violations that both these facilities have experienced have been due to non-receipt of the facilities' monthly discharge monitoring reports (DMRs). However, the Hightstown Borough WTP was cited for these violations in 1980, 1981 and 1983. These violations were corrected by eventual submittal of the DMRs. The Hightstown Advanced WTP is working under a permit issued in 2000 (NJPDES # NJ0029475), which expires on June 30th, 2005.

It is important not to understate the impact of the sanitary discharges to Rocky Brook. Streams experience reduced flows after prolonged dry spells in the summer. The ratio of effluent water to baseflow, particularly in these summer months, may be a problem. Since the baseflow is lowered, the

majority of the stream water is discharged, treated effluent. If problems happen at the discharge point and treatment of the effluent does not take place, then water quality degradation due to higher levels of contaminants in the effluent will happen.

In some streams, however, the only flow during the summer months may be due to treatment facilities. By adding water to a completely dry system, treatment plants may help to sustain stream life.

PERMITTED DISCHARGERS TO GROUND WATER

There are no active permitted discharges to ground water in the Rocky Brook Watershed.

Assessment –
The point source discharges in the Rocky Brook Watershed have been compliant with their permits.

GEOLOGY

The Rocky Brook Watershed lies near the inner (Western) edge of the Coastal Plain Physiographic Province (Figure 9). The Coastal Plain in New Jersey is characterized by extensive sedimentary deposits of Cretaceous (<145 million years ago) to Pliocene (>5 million years ago) age. The deposits are mostly unconsolidated, that is, they have not been cemented into rock but rather are relatively loose sediments. Because of this, the material is easily eroded, and the present landscape of the Coastal Plain is largely the result of this erosion (Owen et al. 1998).

In cross-section, the unconsolidated sediments of the Coastal Plain lie in a wedge shape, thickening to the southeast. The wedge thins to nothing along the northwestern boundary of the Coastal Plain, giving way to the consolidated rocks of the Piedmont Physiographic Province. At its southernmost extent in New Jersey, under Cape May, the wedge of sediment reaches a thickness of over 6000 feet (Vowinkel and Foster 1981). The sedimentary units are essentially undeformed, except for a moderate dip to the southeast. Several of the coarser-grained units in the sequence serve as major aquifers for the region. Over 75% of the fresh water supplies for the Coastal Plain comes from groundwater, with high-capacity public supply wells commonly yielding over 500 gallons per minute (USGS 2001).

Five discrete major aquifers exist in the New Jersey Coastal Plain: the Potomac-Raritan-Magothy aquifer system, Englishtown aquifer, Wenonah-Mount Laurel aquifer, lower "800 foot" sand aquifer of the Kirkwood Formation, and the Kirkwood-Cohansey aquifer. All but the Kirkwood-Cohansey are confined aquifers for most of their extent, being overlain by relatively impermeable layers of fine sediment that impede the vertical movement of water between the aquifers (USEPA 1988). Because of the southeast dip of the formations, layers that are below the surface in the southeastern portion of the Coastal Plain crop out at the surface to the northwest. Since the lower formations are confined aquifers throughout most of their extent, their only source of recharge is infiltration through the surface soil and sediment in these areas of outcrop; very little water passes through the confining layers from one aquifer to another below it. Despite the small size of the Rocky Brook watershed, four of the five aquifers reach the surface within its extent. (The Lower Member of the Kirkwood Formation does crop out here as well, but the sandy portion of the unit that serves as an aquifer, exists only further to the south.) The watershed is therefore a crucial area in terms of recharge for these regionally important aquifer systems. Impervious surfaces in the recharge areas within the watershed have an incremental negative effect on the water supply for the whole region, and contaminants entering the groundwater here have the potential of traveling great distances and impacting drinking water quality for large areas.

Following are brief descriptions of the sedimentary units occurring in the Rocky Brook Watershed, listed in stratigraphic order from highest to lowest (from Owen et al. 1998; Figure 10).

Cohansey Formation (Middle Miocene): A narrow band of the Cohansey Formation underlies the uppermost headwaters portion of the watershed, in the southeast. The Cohansey is the youngest of the major sedimentary units of the Coastal Plain and therefore is the uppermost in the vertical sequence of the five major aquifers. It is predominantly a moderately-sorted, medium-grained sand, but does range from fine- to very coarse-grained sand with interbedded layers of clay and silty clay. The Cohansey is as much as 350 feet thick in some locations in New Jersey, but has been extensively eroded. The area containing the erosional remnants of the Cohansey at the surface is described as the Upland Subprovince, and has the hilliest terrain of the Coastal Plain.

Kirkwood Formation, Lower Member (Lower Miocene): The Lower Member is a complex unit, with variations in sediment types (and the depositional environments they represent) from place to place. In the northern portion of its extent in New Jersey (including Rocky Brook), it consists primarily of massive to finely laminated, dark gray clay. It occurs in an irregular band in the eastern, headwaters portion of the Rocky Brook, just below the Cohansey.

Hornerstown Formation (Lower Paleocene): The Hornerstown Formation is a very thin deposit, generally less than 25 feet in vertical thickness. The sediments are glauconite sand at the base of the unit, overlain by a thin laminated sequence of dark gray clay and silt layers, which grade upward into a fine-grained, glauconite-quartz sand with clay intermixed.

Tinton Formation (Upper Cretaceous): This unit is a quartz and glauconite sand, reddish-brown to dark gray in color. Unlike most Coastal Plain formations, the Tinton deposits have been indurated with siderite cement, imparting hardness to the unit and reducing its porosity. However, extensive erosion removed most of the Tinton sediments before the overlying Hornerstown Formation was deposited, and the unit can only be traced (in cores) as far south as Freehold. Where it does occur, it is 20-40 feet thick. Within the Rocky Brook watershed, Tinton sediments occur at the surface in only a very small area in the eastern headwaters.

Red Bank Formation, Shrewsbury Member (Upper Cretaceous): Shrewsbury deposits are fine- to coarse-grained sand, primarily quartz with some clay and mica. Color ranges from light yellow to red and dark brown. Near the base of the unit the sand contains some glauconite. Maximum thickness of the Shrewsbury is approximately 100 feet near Matawan, but it thins to the southwest and pinches out completely near Arneytown in Ocean County. In the upper (eastern) portion of the watershed, Shrewsbury Formation is the dominant unit.

Navesink Formation (Upper Cretaceous): A medium-grained, glauconite sand with some clay and silt. It can contain large calcareous shells, and mica

sand is abundant in some areas. The Navesink is 10-25 feet thick and, with the overlying Red Bank, represents a transgressive-regressive (advance and retreat of the shoreline) cycle of sedimentation. The contact between Navesink and Red Bank sediments is gradational. The basal sediments of the Navesink are quartz sand deposits formed by reworking of the underlying Mount Laurel Formation.

Mount Laurel Formation (Upper Cretaceous): The Mount Laurel is typically quartz sand with minor amounts of glauconite and feldspar, finer at the base and coarsening upward. Mica (both biotite and muscovite) is abundant near the base. Deposits are described as massive to crudely bedded, with interbedded thin layers of clay. Granules and gravel are abundant in the upper beds. This formation ranges from 15 to 33 feet thick and is gradational with the underlying Wenonah sands. Together, the Wenonah and Mount Laurel form a major aquifer in the region.

Wenonah Formation (Upper Cretaceous): The Wenonah occurs in a relatively wide band through the central portion of the watershed. This unit is fine-grained, silty and clayey sand. Composition is quartz and mica with minor amounts of feldspar, but locally it can contain high concentrations of sand-sized, lignitized wood. Thickness ranges from 25 to 66 feet. The base of the Wenonah is a gradual transition over several feet into the underlying Marshalltown Formation, with the transition marked by a decrease in mica and an increase in glauconite.

Marshalltown Formation (Upper Cretaceous): The Marshalltown occurs in a narrow belt in the middle of the watershed. Deposits are fine- to medium-grained, silty and clayey sand composed primarily of glauconite and quartz. Glauconite concentration is very high at the base and decreases to approximately half in the upper portion. Other components are feldspar, mica, pyrite, and phosphatic fragments. The Marshalltown and overlying Wenonah and Mount Laurel Formations together represent a transgressive-regressive sedimentation cycle similar to that of the Navesink and Red Bank.

Englishtown Formation (Upper Cretaceous): The Englishtown, which serves as one of the five major aquifers of the Coastal Plain, has the largest surface exposure within the watershed of all the geologic units. It occurs in a broad band through the middle-lower portion of the watershed. Englishtown sediments are predominantly quartz, ranging in size from fine to coarse, gravelly sand locally interbedded with thin to thick layers of dark clay. In some places carbonaceous matter is abundant, including large, lignitized logs. Feldspar, glauconite, and muscovite are minor constituents in the sand, and pyrite occurs as well, especially in the carbonaceous deposits. The Formation ranges in thickness from 50 feet in the south to 150 feet in the central Coastal Plain. The basal contact is transitional, grading into the Woodbury Formation (or the Merchantville in some locations outside the watershed).

Woodbury Formation (Upper Cretaceous): Downstream of the Englishtown at the surface, and below it in the stratigraphic sequence, Woodbury clays form a moderate band across the watershed. The unit is a dark gray clay-silt, weathering to brown and orange-pink. It contains mica throughout, and finely dispersed pyrite, carbonaceous matter, and small pieces of carbonized wood. Thin layers of quartz sand occur near the base, and small amounts of glauconite are found locally near the top. Iron oxides are found in layers or filling fractures in the most weathered beds. The Woodbury Formation is generally about 50 feet thick over its entire extent. The Woodbury is notable for containing fossils of the dinosaur *Hadrosaurus foulkii* in an outcrop in Camden County.

Merchantville Formation (Upper Cretaceous): The Merchantville is a very clayey and silty, glauconite and glauconite-quartz sand. Deposits are massive to thickly bedded, grayish-green in color and weathering to brown or yellow-brown. Minor amounts of mica, feldspar, and pyrite occur in the sand, except at the base, which is very micaceous. Iron incrustations can be extensive in weathered beds near the surface. The Formation ranges in thickness from 20 to 66 feet. The base of the Merchantville forms a sharp contact over an erosional surface at the top of the Magothy Formation, with a zone of reworked sediment 1-3 feet thick at the base of the Merchantville. The Merchantville and overlying Woodbury and Englishtown Formations together form a transgressive-regressive depositional cycle.

Magothy Formation (Upper Cretaceous): The sands of the Magothy Formation, together with the contiguous Raritan and Potomac Formations, serve as an extensive and regionally very important aquifer system underlying nearly all of the New Jersey Coastal Plain and reaching 4100 feet in thickness in southernmost New Jersey (USEPA 1988). The recharge area for the entire system occurs in a belt along the inner (western) edge of the Coastal Plain, where the formations reach the surface before thinning out and giving way to the Piedmont rocks to the northwest. The Magothy occurs at the surface in a small area in the lowermost (western) portion of the Rocky Brook Watershed. The sediments of the Magothy are fine- to coarse-grained, locally gravelly, quartz sand, interbedded with thin layers of clay or clay-silt, mostly at the top of the Formation. Minor amounts of muscovite and feldspar occur in the sand, and large wood fragments are found in the clay layers. The unit reaches a thickness of 260 feet near Raritan Bay, thinning to 80 feet or less to the south.

Assessment –

The geology has a large influence on the water resources of the Rocky Brook Watershed. The unconsolidated nature of the sediments has two major implications from the standpoint of water resources. First, streams and rivers of the Coastal Plain are typified by large amounts of alluvial sediment (considering their shallow gradients and relatively sluggish flows) because of the erodibility of the underlying deposits. The soils are easily eroded and carried to other areas of the Watershed (see the Soils section for more

information). This results in water quality degradation through sedimentation of streams (see the Water Quality section for more information). Smothering of aquatic macroinvertebrate habitat and subsequent loss of biological diversity, clogging of fish gills, reducing photosynthetic productivity by reducing sunlight penetration into water and increasing water treatment costs, can impact waterways experiencing heavy sedimentation.

Second, the lack of cementation of the buried sediments means that the sandy units retain a high porosity, making them very productive aquifers. Increasing urbanization in the Rocky Brook Watershed also increases the amount of impervious cover (see Land Use section for more details). This has the effect of decreasing the amount of water flowing into the aquifer by diverting precipitation over the landscape to streams and not downward into the soil. Placement of new development, and therefore impervious cover, out of areas that have high value for recharging the aquifers will help to maintain water levels for drinking, irrigation, and industrial use (see Water Supply section for more details).

The soils that underlay a watershed exert an influence on the types of vegetation that grow, agriculture that can be performed, drainage patterns, water transportation, water supply, and types of suitable land use.

HYDROLOGIC SOIL GROUPS

Soils are classified based upon their textures, composition and ability to drain water. Soil surveys have been performed and mapped by the U.S. Department of Agriculture's (USDA) Natural Resource Conservation Service (NRCS). The Rocky Brook Watershed falls in the Coastal Plain Physiographic Province, where the soil is dominated by sands, silts, clays and gravel (New Jersey Water Supply Authority 2000). The dominant soil in the Rocky Brook Watershed is the Freehold-Connington-Adelphia series (New Jersey Water Supply Authority 2000). This series is located in the southeastern portion of the Watershed. Another extensively occurring series in the Rocky Brook Watershed is the Downer-Sassafras-Hammonton series (New Jersey Water Supply Authority 2000). Both series consist of well-drained soils, with a moderately coarse texture.

Based upon their various compositions, these soil series have varying degrees to which they can infiltrate water. Their ability to drain water, especially from precipitation, is evaluated and reports as the hydrologic soil group. Much of the Rocky Brook is classified as hydrologic soil group B, covering 4,498.5 acres out of a total of 9,604.0 acres in the entire Watershed (Figure 11). Hydrologic soil group B represents soils with a moderate infiltration rate, and is representative of the moderately coarse soils seen in the Coastal Plain Physiographic Province. Most of this soil underlies the agricultural areas in East Windsor and Millstone Townships (Figure 11).

The second most common hydrologic soil group in the Rocky Brook Watershed is group A, representing high infiltration rates and the gravel and sandy soils in the area (Figure 11).

The hydrologic soils in group D are found primarily as streambeds and wetlands in the Rocky Brook Watershed (Figure 11). Category D soil groups have very slow infiltration rates since most of these soils are clayey or are shallow to an impervious layer (Figure 11).

SOIL ERODIBILITY

Soil erodibility defines the susceptibility of soil to erosion and largely depends on soil structure. Therefore, maintaining a good soil structure will help to build healthy soils, reducing the detachability of soil particles and the susceptibility of soil crusting. Soil management is an important component in preventing soil erosion, improving water management, encouraging plant growth, and improving water quality on our farms and in urban land uses.

The erodibility is based upon the 'K-factor,' a measure of bare surface soil erosion. Different soils are given different K-factors based upon land use, an area's slope, and distance to nearest stream (Maryland Department of Natural Resources 2001). The majority of the soils in the Rocky Brook Watershed are classified as having medium erodibility (Figure 12). Highly erodible soils are found in the northwestern portion of the Watershed, in East Windsor Township and Hightstown Borough (Figure 12).

Assessment –

The characteristics of the soils in the Rocky Brook Watershed are aligned to their overall composition in the Coastal Plain (see Geology section for more detail). These soils are moderately coarse to fine and infiltrate water into the subsurface at a moderate rate. The Coastal Plain in New Jersey is characterized by extensive sedimentary deposits of Cretaceous (<145 million years ago) to Pliocene (>5 million years ago) age. The deposits are mostly unconsolidated, that is, they have not been cemented into rock but rather are relatively loose sediments. These loosely aggregated soils allow for infiltration of varying rates, but are not a major impediment to subsurface water flow.

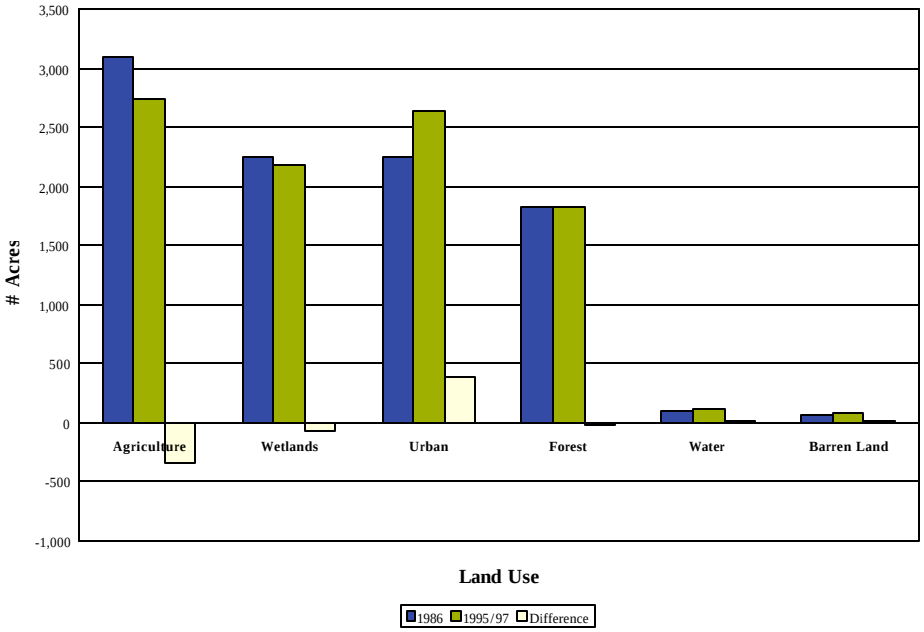
Based on the relative unsolidified nature of the soils, a large proportion of the Rocky Brook Watershed is categorized as having medium or high erodibility. The result of erodible soils is sedimentation of streams. In conjunction with the visual assessment data and observations during the biological assessments (see the Water Quality section for more details), this is already happening in the Watershed. Smothering of aquatic macroinvertebrate habitat and subsequent loss of biological diversity, clogging of fish gills, reducing photosynthetic productivity by reducing sunlight penetration into water and increasing water treatment costs, can impact waterways experiencing heavy sedimentation. Maintenance of soil integrity in areas with medium to highly erodible soils can be accomplished by restricting earth moving activities, promoting and implementing soil and erosion control BMPs and encouraging forested areas.

Another aspect of soils is their ability to provide on-site septic systems to drain wastes: their septic suitability. The septic suitability needs to be considered when determining whether or not a septic system is a viable option for new residential areas in the Rocky Brook Watershed. The major limiting factor of septic suitability is based on the fact that the underlying soils may percolate too slowly or not at all, which lower the capacity of a residential septic system to perform properly. Soil data to determine septic suitability at the time of this report was reviewed and found to be limited in it ability to provide an accurate assessment. Future planning efforts should still consider septic systems as an option and review newer soils data for septic suitability as it becomes available.

Populations in the Rocky Brook Watershed are on the rise, and appropriate residential areas and necessary infrastructure continue to be built to accommodate this increasing population. These changes are reflected in the different land use categories between 1986 and 1995/97 (Figure 13 and Figure 14). Land use was interpreted from photographs that were taken during flyovers of the State in 1986, and again in 1995/97.

The information for land use comes from the NJDEP land use/land use cover data from 1986 and 1995/97, but much development has occurred within the last seven years. Forests, agriculture, urban/developed land and wetlands will be discussed in more detail as they make up the majority of land usage in the Watershed. The remainder of the land use in the watershed is made up of either water (121.0 acres, or 1.3% of the Rocky Brook Watershed) in the form of streams, lakes, ponds, reservoirs and other waterbodies, or barren land (89.2 acres, or 0.9% of the Rocky Brook Watershed) as developing land, quarries and mines (Graph 4 and Graph 5).

Graph 4: Changes in acreage of land uses in the Rocky Brook Watershed from 1986 to 1995/97.



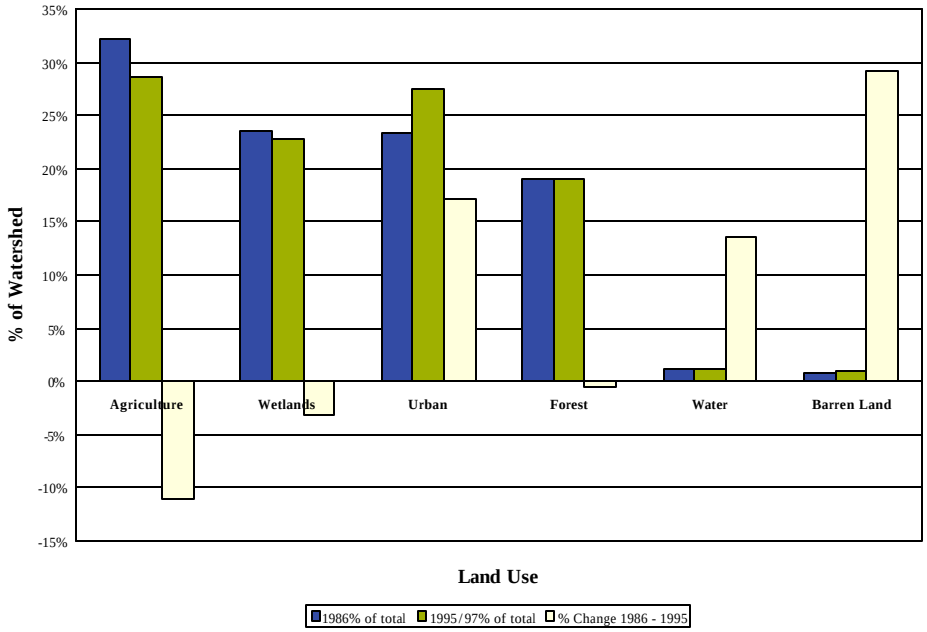
Source: NJDEP Land Use/Land Cover Data 1986 & 1995/97.
Negative percent changes represent a loss in acreage while positive numbers represent a gain in acreage.

In the Rocky Brook Watershed, land use has changed dramatically in the years between 1986 and 1995/97, as there has been a gain in urban areas and a loss of primarily agricultural land. Between 1986 and 1995/97, the landscape draining to Rocky Brook has changed due to shifts in land use as

well as increases in population and local preservation efforts (Figure 13). To accommodate the increasing population, the agricultural lands are being developed to provide housing and services for new residents. The changes in land use were a loss of 341.8 acres, or 11.1%, of agricultural lands, and an increase of 386.8 acres, or 17.2%, in urban areas (Graph 4 and Graph 5).

Of special note is the increase in barren lands within the Rocky Brook Watershed. Between 1986 and 1995/97, there was a 29.2% increase, but barren lands make up a very small percentage of the entire Rocky Brook Watershed (0.9% in 1995/97) (Graph 5). This represents a temporary condition, as the increase was most likely due to clearing of land in the process of becoming part of the developed or urban land use category.

Graph 5: Changes in percent of total watershed area of land uses in the Rocky Brook Watershed from 1986 to 1995/97.



Source: NJDEP Land Use/Land Cover Data 1986 & 1995/97.
Negative percent changes represent a loss in acreage while positive numbers represent a gain in acreage.

FORESTS

Forests improve water quality by filtering pollutants, reduce flooding by slowing stormwater, and providing habitat to a variety of plant and animal species. It has been shown that the best predictor of the presence of an unimpaired benthic macroinvertebrate community is the total area of forested land located upstream of a sampling site (USGS 1998).

Since 1986, there has been a minimal loss of 0.6% forested land (Graph 5). In 1986, over 32% of the Watershed, or 3,087.8 acres, was forested (Graph 4 and Graph 5). In 1995/97, approximately 29% of the Watershed, or 2,745.9 acres, was covered with forests (Graph 4 and Graph 5). The majority of the woodlands are found in the southeastern portion of the Rocky Brook Watershed (Figure 13). Millstone Township remains heavily forested and contains this Watershed's headwaters (Figure 13).

AGRICULTURE

In both 1985 and 1995/97, the largest land use category within the Rocky Brook Watershed was agriculture (Graph 4 and Graph 5). Up until twenty years ago, the land was primarily used for orchards and agriculture was a major source of employment in the region. Corn, soybeans and small grains are grown today and there is also some rearing of livestock (cattle and horses).

In 1986, 32.2% of the Rocky Brook Watershed, or 3,087 acres, was in agricultural use (Graph 4 and Graph 5). According to the 1995/97 data, there is approximately 29%, or 2,745.9 acres, of farmed lands in the Rocky Brook Watershed. This represents a loss of over 11% of the available agricultural lands (Graph 5). This loss is particularly concentrated in the area of Millstone Township north of Roosevelt Borough in an area that was a former orchard (Figure 14).

Most of the current agriculture is found in the central part of the Rocky Brook Watershed, especially in East Windsor Township. Most of the agriculture is also located near the streams and wetlands found in the Watershed (Figure 13). In the past, these streams were used to irrigate the crops or water the livestock on many of the region's farms.

URBAN

Approximately 27% of the Watershed, or 2,635.3 acres, is developed into urban areas, those areas providing residential, recreational, and industrial uses, in 1995/97 (Graph 4 and Graph 5). This is a gain of over 17% from 1986, when there were 2,248.5 acres of urban land use in the Rocky Brook Watershed (Graph 4 and Graph 5). Hightstown Borough represents a major area of residential development, as most of the 1.25 square miles it occupies is built up.

In the Watershed, urban development generally falls into one of four categories:

- Older villages such as Hightstown Borough;
- Older, scattered strip frontage lots found along rural roads;
- Isolated farm homes or homes on large lots in the agricultural areas; and

- More recent developments that occur on flat farmland and as small subdivisions.

The majority of the urban areas lie along major roadways, such as Route 33 and near the NJ Turnpike (Figure 13). East Windsor Township experienced the greatest increase in population, but not the greatest amount of development of urban areas between 1986 and 1995/97. The Twin Rivers development, built in 1969 in East Windsor Township on the border with Monroe Township, is the largest residential subdivision in the Rocky Brook Watershed (Figure 13; see Landscape section for more details).

In Millstone Township, several smaller developments have been built between 1986 and 1995/97 (Figure 14). One large development, on a former orchard, has been built northeast of Roosevelt Borough (Figure 14). Residents of Millstone Township need to made aware of the their role in affecting water quality, especially as they are in the headwaters of the Rocky Brook Watershed.

WETLANDS

Wetlands are those areas inundated or saturated by surface water or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (University of North Carolina WATERSHEDSS 2001). Wetlands vary widely because of regional and geographic differences in soil types and climate and therefore have a variety of essential functions and values associated with their roles in the environment. Water quality is improved as wetlands filter excessive nutrients, sediment, and other pollutants through abundant plant life and help reduce flooding and storm surges by acting as natural retention basins. Wetlands are also excellent nurseries for a variety of wildlife, since wetlands process nutrients efficiently and retain those nutrients. These nutrients become essential building blocks for wildlife and vegetation.

Of the total 9,603.5 acres in the Rocky Brook Watershed, there are 2,187.0 acres of wetlands, representing 22.8% of the entire Watershed area in 1995/97 (Graph 4 and Graph 5). Most of the wetlands surrounding Rocky Brook and its tributaries are forested wetlands.

The majority of the wooded wetlands found in the Rocky Brook Watershed are found in central Rocky Brook at the border of East Windsor and Millstone Townships, with a few located at the headwaters in Millstone Township (Figure 13). The location of these areas is critical to maintaining healthy streams in the Watershed, as riparian forests are important sinks for polluted runoff. Many studies have determined the effectiveness of riparian forests in improving water quality:

- A 50-meter wide riparian forest in an agricultural watershed of the Chesapeake Bay removed about 89% of the nitrogen that entered the forest from runoff (Peterjohn and Correll 1984).
- Riparian forests can reduce phosphate levels in runoff and floodwater by 50% (Gilliam 1994).
- A forested wetland overlaying permeable soil may infiltrate up to 100,000 gallons of water per acre per day (Anderson and Rockel 1991).

IMPERVIOUS COVER

Impervious cover is any surface that prohibits the movement of water from the land surface into the underlying soil. Buildings, paved surfaces (such as driveways, roofs, roads, airport tarmacs, cemented walkways), exposed bedrock, and even severely compacted soils and lawns are considered impervious.

An increase in impervious surfaces in a watershed interferes with the natural flow of water into the aquifers and local waterbodies. Areas that are impervious could prevent the percolation of water into the aquifer and can impair local ground water resources due to decreased recharge. Impervious surfaces could also increase the amount of stormwater runoff, which increases the frequency and intensity of local stream flooding. Because this stormwater runs directly into streams, often with no filtration through a streamside buffer, these floods can cause accelerated erosion. Since water does not have time to percolate into the soil naturally, substances carried by the runoff get carried to streams and lakes and contribute to water quality degradation. Research has shown that stream ecosystems and water quality degrade as the amount of impervious surface within an area increases (Center for Watershed Protection 1998). The first limit to impervious areas appears at approximately 10% impervious cover, where sensitive elements are lost from the system. A second limit appears at approximately 25% impervious cover, where there is a shift to poor stream conditions that include diminished aquatic diversity, water quality, and habitat functioning (Center for Watershed Protection 1998).

Rocky Brook Watershed has an average impervious cover of 13.9% with some areas much higher, suggesting some water quality degradation (Figure 15). The highest percentages of impervious areas are found in Hightstown Borough and the larger residential development, Twin Rivers, in East Windsor. Much of the impervious area is rated at 26% or higher for the Borough (Figure 15). This shows that the borough is heavily developed and could be contributing to water quality problems in the downstream portions of Rocky Brook as it flows to the Millstone River. The best predictor of the presence of a severely impaired benthic macroinvertebrate community is the total area of urban land in close proximity to sampling sites (USGS 1998).

The majority of the lands covered with higher impervious area are congregated closer to streams (Figure 15). This may be due to the conversion of agricultural lands, which are traditionally located near streams for irrigation, into urban lands.

RIPARIAN CORRIDORS

Of special note are riparian corridors, which are those vegetated areas that lie along the side of streams. These areas are usually transitional zones between wetland and upland areas and are generally comprised of grasses, shrubs, trees, or a mix of vegetation types. Riparian corridors can be found in agricultural, forested, suburban and urban landscapes. These areas are the first and last lines of defense for the streams they surround in terms of nonpoint source pollution control. When left as natural areas, riparian corridors provide erosion control by plant root growth, stormwater control by slowing water flow, and habitat for many species of plants and animals. Land use changes to these areas can have the most detrimental effects on water quality.

In the Rocky Brook Watershed, the riparian area is based on the width of the 100-year flood prone areas, streamside hydric soils, streamside wetlands and associated transition areas, and a 150-foot or 300-foot wildlife passage corridor, depending on stream order (New Jersey Water Supply Authority 2000c). Many of these lands have undergone conversion between 1986 and 1995/97 (Figure 16). There are a total of 2,730.4 acres of riparian corridor in the Rocky Brook Watershed. Of that, 1,232.8 acres (or 45.1%) have been converted to agricultural or urban areas, leaving 1,497.6 acres (or 54.9%) remaining. Most of these areas were developed into urban lands, as urban lands in 1986 in the riparian corridor increased from 574.4 acres to 680.9 acres in 1995/97 (an 18.5% increase). Riparian areas used for agriculture increased by only 2.1% from 540.5 acres in 1986 to 551.9 acres in 1995/97.

Assessment –

Land uses change constantly to reflect the needs of the municipality. As more residents move into an area, the more homes and infrastructure are needed to provide basic services to these residents. This is reflected in both the increasing population within the Rocky Brook Watershed (see Landscape section for more detail) and the increasing developed areas from 1986 to 1995/97 (Figure 14). Many of the newly developed areas are being placed on former agricultural areas. Water quality becomes a concern for the urbanizing regions in the Rocky Brook Watershed because of the proximity to the streams and brooks of the agricultural lands being converted and the increase in impervious surfaces. Decreasing the rate of conversion of farmlands in the Rocky Brook Watershed to urban areas through participation in the State's farmland preservation programs, adopting and enforcing a stream corridor ordinance, or protecting riparian areas with conservation easements would help to protect water quality. An area of concern is Millstone Township as the increasing urban areas in town between

1986 and 1995/97 are surrounding many of the tributaries that make up the headwaters of the Rocky Brook Watershed.

Increasing urbanization in the Rocky Brook Watershed also increases the amount of impervious cover. This has the effect of decreasing biological diversity in nearby streams, increasing the frequency of flooding, and decreasing the amount of water recharging the ground water supply. Placement of new development, and therefore impervious cover, out of areas that have high value for recharging ground water supplies will help to maintain water levels for drinking, irrigation, and industrial use (see Water Supply section for more details). This strategy should be used in conjunction with water conservation education programs to proactively protect water supplies.

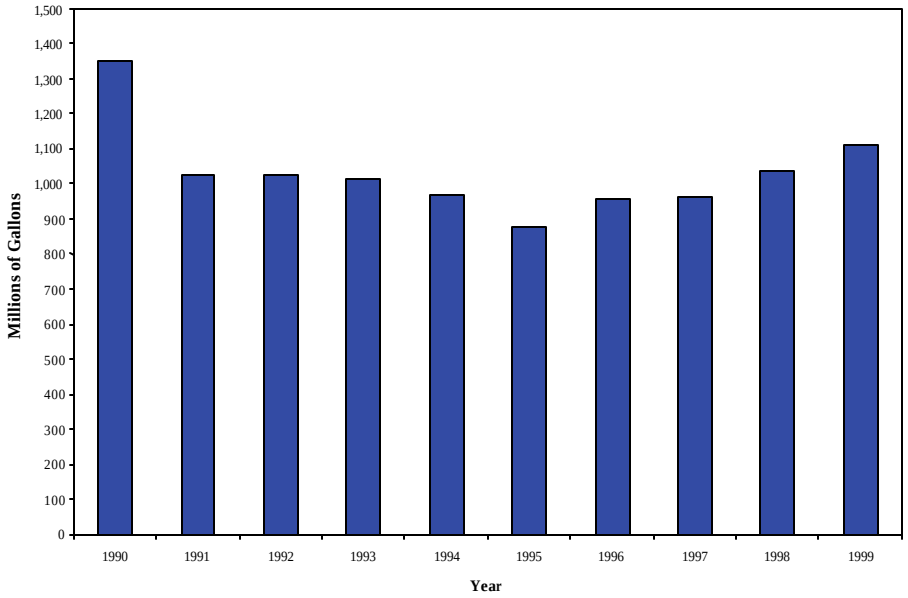
Riparian corridors are being increasingly encroached upon for developed areas in the Rocky Brook Watershed (Figure 16). These areas are particularly sensitive to land use changes, as they are the natural buffers that protect the stream itself from a variety of pollution sources. Placing of new construction in the Rocky Brook Watershed needs to be sensitive to or avoid altogether the riparian corridors in order to maintain ecological integrity.

Water is the necessary component for life on Earth. Aquatic ecosystems, however, are competing for the very resource that forms the basis of their existence. Multiple uses of water for irrigation for agriculture, recreation through fishing and boating, and commercial uses in industry have severely strained a resource that cannot be easily replenished. Less than 3% of all water on the planet is fresh water (U.S. Geological Survey 1999). Most freshwater is frozen in the polar ice caps. Less than 15% of the total freshwater is available in surface and ground water (U.S. Geological Survey 1999).

Watersheds are not comprised of surface water alone. The ground water present in the pore spaces of soil and rock is an important component of the watershed. Evaluating the health of one alone only presents a partial picture of the true quality of water in an area.

WATER WITHDRAWALS

Graph 6: Total permitted water withdrawals in the Rocky Brook Watershed in millions of gallons per year (mgy).



According to NJDEP data, water use in the Rocky Brook Watershed is primarily to supply the residents with drinking water, as the largest water withdrawals are by the East Windsor Municipal Utilities Authority (EWMUA), Hightstown Water Department, and private wells (Table 6). The largest water user is the EWMUA, which withdrew 5,696.2 million gallons between 1990 and 1999, representing 55.2% of all water withdrawals in that time (Table 6). It is important to note that the EWMUA is supplying water for the entire township of East Windsor and not just that portion in the Rocky Brook Watershed.

Table 6: Total permitted water withdrawals in the Rocky Brook Watershed in millions of gallons per year (mgy).

Permit Holder	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
East Windsor Municipal Utilities Authority	901.0	538.5	586.6	514.8	513.9	461.1	569.2	458.5	576.7	576.0	5,696.2
Hightstown Water Department	387.9	388.1	371.1	394.2	351.2	334.2	324.2	347.3	370.0	448.7	3,716.9
Private Home Wells	51.6	52.4	53.3	54.3	55.3	56.2	57.2	58.4	59.6	61.1	559.4
New Sun Sang Farm	0.9	1.1	1.6	31.0	35.9	6.5	N/A	10.2	21.6	17.7	126.6
Forman Farms	N/A	N/A	N/A	N/A	N/A	N/A	N/A	84.1	N/A	N/A	84.1
Peddie School Golf Course	3.9	10.9	4.7	8.7	6.2	10.8	4.5	2.1	9.0	8.8	69.7
Millstone Board of Education	N/A	24.8	0.5	0.4	0.4	8.0	0.1	0.4	0.5	0.5	35.6
Holland, Harvey/Cancelled	4.8	8.5	6.4	9.9	3.9	N/A	N/A	N/A	N/A	N/A	33.4
H&M Estates	1.2	1.7	1.8	2.4	1.7	4.4	1.5	2.0	2.6	2.4	21.9
Sahara Sand, Inc.	14.3	0.1	0.1	0.1	0.2	1.0	0.2	0.0	0.0	0.0	16.0
Holland Greenhouses, Inc.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.2	N/A	0.2
Total Withdrawals	1,350.1	1,024.3	1,024.2	1,013.4	966.8	876.7	955.2	961.0	1,037.4	1,112.8	10,321.9

WATER SUPPLY

Water supply demands within the Watershed have actually decreased between 1990 and 1999 (Graph 6). The total water withdrawals dropped from 1,350.1 million gallons per year (mgy) in 1990 to 1,112.8 mgy in 1999, a decrease of 18.3% (Graph 6). This occurred despite a 22.2% increase in population, which went from 55,687 residents in 1990 to 68,037 in 2000 (Graph 2).

Most of the decrease in water withdrawal came between 1990 and 1991, when withdrawals decreased by 24.1% or 325.8 mgy (Table 6). The EWMUA alone withdrew 40.2%, or 362.5 mgy, less water between those years (Table 6). This was due to the construction of a new treatment facility in 1991 that withdraws water from the Millstone River outside the Rocky Brook Watershed. After this sharp decrease, from 1991 to 1999 water withdrawals actually increased by 88.5 mgy or 8.6% (Table 6).

WELLHEAD PROTECTION AREAS

In order to retrieve water for use in everyday life, wells are drilled to a desired depth into an aquifer containing potable water. This water is pumped out of the wells for household, agricultural or commercial uses. There are different types of wells regulated by the State. Individual domestic wells are used for single homes for potable purposes. Public community wells (PCWs) supply water systems that service at least 15 connections used on a year-round basis or supply at least 25 year-round residents (South Branch Watershed Association 1998). The source of a well and the structure built over it are referred to as the wellhead.

Protecting the wellhead from future and present contamination will protect the population from deleterious health effects. Wellhead protection areas (WHPAs) are delineated at the surface and represent the area that contributes water to a well in a defined time period (New Jersey Water Supply Authority 2002). The WHPA is divided into three tiers based upon the time of travel (TOT) that it takes for water at a given point to reach the well when pumped. TOTs are helpful in determining the risk of contamination to a well from ground water. A Tier 1 WHPA has a TOT of two years, Tier 2 has a TOT of five years, and Tier 3 has a TOT of 12 years (New Jersey Water Supply Authority 2002)

Within the Rocky Brook Watershed, there are two WHPAs surrounding two PCWs and four Tiers from outside the Watershed that reach into the Watershed (Figure 17). (Note that water traveling below the ground's surface can travel outside the surface-delineated watershed.) Two PCWs, located within Hightstown Borough, have four known contaminated sites (KCSs) located within differing Tiers (Figure 17). The KCSs are: North American Phillips Lighting, Hightstown Oil Company, Pullen Fuel Company and Citgo Service Station (Figure 17). These sites are detailed in the Known Contaminated Sites section of this report.

GROUND WATER RECHARGE

Ground water is not in an inexhaustible supply. Water needs to enter the land's subsurface in order to recharge and reinvigorate ground water. Land use activities can disrupt the natural water cycle, the flow of water back into the soil, and diminish water supplies. As impervious covers increase with developed areas, water that would normally go back into ground water supplies is diverted as runoff. In an area preserved with natural cover (forests, fields, and wetlands), it has been estimated that approximately 50% of precipitation infiltrates into the ground, 10% flows over the land as runoff, and 40% is evaporated back into the atmosphere (Schueler and Holland 2000). In an area with up to 20% impervious cover, like the Rocky Brook Watershed at 13.9%, these numbers may drop to 20% of the precipitation flows away as runoff, 42% goes to infiltration, and 38% evaporates into the atmosphere (Schueler and Holland 2000). For the Millstone Watershed, it has been shown that 14.2% of precipitation infiltrates into the ground, 31.6% flows over the land as runoff, and 54.2% is evaporated back into the atmosphere (New Jersey Water Supply Authority 2000b).

Therefore, not all areas, even if left in their natural state, infiltrate water into the subsurface water equally. Different types of land use allow for different rates of infiltration. The underlying geology also plays a role in the capacity of water to percolate. In a developing watershed like the Rocky Brook Watershed, the location of suburbanization and urbanization becomes important. Water quality also is an issue. Locating heavy development near areas that contain highly permeable soils can cause increased pollution of ground water from runoff.

Three distinct major aquifers occur in areas of the Rocky Brook Watershed that have high recharge rates: the Kirkwood-Cohansey, the Englishtown, and Potomac-Raritan-Magothy systems (Figure 18). The Kirkwood-Cohansey aquifer underlies the surficial soils in the southeastern portion of the Watershed in Millstone Township (Figure 18). The Englishtown aquifer is found in the middle of the Rocky Brook Watershed, in East Windsor and Monroe Townships. Finally, the Potomac-Raritan-Magothy aquifer system comes to the surface in the northwestern part of the watershed in East Windsor Township (Figure 18). These areas represent that portion of the geologic formation where soil and land use allow for increased recharge at the rate of 11 – 19 inches per year.

It was noted in the New Jersey Water Supply Authority's Raritan Basin Watershed Management Project report, *Ground Water in the Raritan Basin*, that between 1986 and 1995, the Raritan Basin (of which both the Millstone Watershed and the Rocky Brook Watershed are part) lost 5% of its recharge capability (New Jersey Water Supply Authority 2002). Much of the loss was concentrated outside of the confines of the Rocky Brook Watershed, however. The Rocky Brook Watershed was below this overall average, losing

2.5% of its ground water recharge capability between 1986 and 1995 (New Jersey Water Supply Authority 2002).

Assessment –

Water withdrawals in the Rocky Brook Watershed are growing at a slower rate than the population. But to ensure that the populations continues to have access to plentiful water, the municipalities need to limit residential development within their borders and focus growth in established centers, such as the Twin Rivers development and Hightstown Borough.

The two WHPAs in Hightstown Borough are important, as there is the potential for ground water contamination due to their proximity to four known contaminated sites (KCSs). The KCSs need to consistently be monitored to ensure that any contamination is noted quickly and clean-up efforts can be implemented immediately. These four KCSs also need to be the top priorities for remediation in the Rocky Brook Watershed.

There are many areas of the Rocky Brook Watershed that contain areas with high ground water recharge. These areas need to be protected by their respective townships (East Windsor and Millstone, in particular) to prevent their development. East Windsor Township needs to develop and enforce regulations on the use of chemicals (especially harmful chemicals like pesticides) in the agricultural areas above ground water recharge zones to prevent contamination (Figure 19).

The small loss of ground water recharge in the Rocky Brook Watershed as reported by the Raritan Basin Watershed Management Project shows planning efforts are slowing down impacts to ground water recharge areas. Much needs to be done to continue these efforts to protect recharge areas. Close attention needs to be paid to any increases in impervious surfaces in the Watershed, as possible mitigation efforts may need to be performed in order to prevent further decline of recharge areas.

Assessing water quality is an important way to gauge the response of streams and lakes to surrounding land uses, pollutant loadings, seasonal changes, and increased community awareness on the importance of clean and healthy water.

Nonpoint source pollution, associated with suburban development and activities, is of particular concern in this Watershed. Nonpoint source pollution comes from numerous, diverse, or widely scattered sources that together have an adverse effect on the environment. The United States Environmental Protection Agency (USEPA) has stated that nonpoint-source pollution, or pollution from runoff, is currently one of the leading causes of water quality degradation (USEPA 1996). Fertilizers and pesticides from yards, farms and golf courses, animal wastes (both farm animals, pets and wildlife), sediments from construction and erosion, detergents, and toxic chemicals from cars and household cleaning and yard care products are all examples of nonpoint pollution.

Water quality data was gathered from a variety of sources (Figure 20, Figure 21 and Figure 22). The U.S. Geological Survey (USGS), NJDEP, Stony Brook-Millstone Watershed Association, and the Monmouth County Health Department (MCHD) have conducted chemical monitoring at various sites within the Rocky Brook Watershed. The biological assessment data was gathered from the NJDEP's Ambient Biomonitoring Network (AMNET) 1994 and 1999 data for the Raritan River drainage basin and from the MCHD. Visual assessments were collected from reports by trained SBMWA employees and interns.

VISUAL ASSESSMENTS

Visual assessments are a valuable tool in obtaining a gross evaluation of impacts and health of the environment. Observational data can be difficult to compare between areas, however. An effort to quantify these observed characteristics was used, based upon visual assessment protocols used by the USDA's NRCS, the Upper Raritan Watershed Association (URWA), and the Maryland Department of Natural Resources (MDDNR) (USDA 1998; URWA 1997; MDDNR 2000). During the visual assessments, a score was given to each of ten parameters (i.e., water color, erosion, man-made structures, etc.) on a scale of 1 to 4. A score of 1 represents severe problems while a score of 4 represents pristine conditions. These ten parameters were then averaged to determine the overall value for the entire stream segment. It should be noted that the results be used with caution, since the data are based on qualitative judgments and observations.

Information presented for the visual assessments was developed from the collected reports of several trained SBMWA employees and interns. Five navigable stream segments, called "beats", are located in the Rocky Brook Watershed the main stem of the Rocky Brook (Figure 20). All assessments were completed in the summer of 2001, in July and August. SBMWA staff

and interns walked their "beat" after being trained in what information to look for and how to assess water quality problems in an area based upon their observations. Notable or interesting sites or problems were photographed and recorded to aid in determining stream health.

It should be noted that the information gathered through the visual assessments is most directly applicable to the health of the riparian corridor. The overall health of these stream-buffering areas does indirectly aid in determining water quality.

Note: The stream segment from Etra Road to Etra Lake (RYB3) wasn't navigable during the time of the surveys, so results are not included in this assessment.

The visual assessment scores ranged from 2.90 along the segment of Rocky Brook (RYB2) that flows from Perrineville Road to Etra Road to a score of 3.00 on the remaining "beats" (RYB1, RYB4, and RYB5) (Table 7). The average score for all stream segments in the Rocky Brook Watershed is 2.98 (Table 7). Through these assessments, the Rocky Brook is rated as having overall good riparian corridor quality (Figure 20).

The highest rated parameters dealt with assessment of the riparian corridor and vegetation. Scores for canopy cover, surrounding vegetation, and width of the riparian zone were high for the Rocky Brook (either rated 3 or 4) showing that much of the area along the streams is buffered from surrounding land uses and impacts.

The most common problems seen on the visual surveys were the result of sedimentation. The lowest rated parameter was for the stream bottom. Three out of the four stream segments surveyed rated stream bottom as 1, indicating that gravel, cobble and boulders present in the stream were at least 40% covered by sediment (Stony Brook-Millstone Watershed Association 2000). Conversely, erosion scores on the visual assessments were rated 3 or higher at all four "beats", indicating that the streambanks are relatively stable and have less than 30% of their lengths showing signs of erosion (Stony Brook-Millstone Watershed Association 2000). Most of the sedimentation may be due to the nature of the Coastal Plain geology and associated soil types (see Soils section and Geology section for more information). The depositional environment of the Coastal Plain formation has higher soil erodibility than other geological formations in the Millstone Watershed. Advanced sedimentation of streams causes loss of habitat for aquatic macroinvertebrates, clogging of fish's gills, and increasing the concentration of metals and organic toxins, which easily combine with sediments (Center for Watershed Protection no date).

During their biological evaluations, MCHD surveyed the substrate composition of Rocky Brook at Fairplay Road (biological assessment Site 70). It was determined that the most common components were silt and

sand making up 55% of the substrate in 1999 and 80% in 2000 (MCHD 2002).

BIOLOGICAL ASSESSMENTS

The organisms that live within a stream system can convey much information about the health of the waterway. One such group of organisms is the aquatic macroinvertebrates. They are used as indicator organisms by the varying sensitivities to pollution each species exhibits. For example, mayfly nymphs are very sensitive to pollution and are only abundant where water quality is good, while leeches and worms are tolerant to pollutants and can survive waters with poor water quality.

Streams are rated numerically and then categorized as "non-impaired," "moderately impaired," or "severely impaired" based on the following biological criteria:

- Pollution-tolerance of families collected;
- Number of different families collected;
- Number of pollution-intolerant ("sensitive") families collected;
- Percent of the sample composed of pollution-intolerant individuals; and
- Percent of the sample dominated by one family.

Biological data has been collected from NJDEP's AMNET monitoring program and MCHD's Environmental Protection program (Figure 21). At least 100 organisms are required from each sampling event for that event to be statistically valid for interpretation of results in this report. The organisms from these samples are identified to the family level and the data are entered into a database and rated in a scoring system to determine the level of stream impairment.

The two NJDEP sampling sites in the Rocky Brook Watershed are (NJDEP 2000) (Figure 21):

- Rocky Brook at Perrineville Road in Millstone Township (AN0380).
- Rocky Brook at Route 33 in Hightstown Borough (AN0381).

According to the AMNET reports from 1994 and 1999, three (3) of the four (4) sampling events were rated as "moderately impaired" (Table 8; NJDEP 1995; NJDEP 2000). At Route 33, site AN0381 was rated "severely impaired" when sampled in 1998, possibly due to runoff from the adjacent roadway (NJDEP 2000). The most recent 303(d) list published by the NJDEP (1998), ranks the biological health of Rocky Brook as "moderately impaired" (NJDEP 2002). The schedule for TMDL development for Rocky Brook is listed as December 31, 2003 for submittal of the TMDL for arsenic, chromium, lead and zinc (NJDEP 2002).

The four MCHD sites in Millstone Township are (Figure 21):

- Rocky Brook at Fairplay Road (Site 70).
- Rocky Brook at Bittner Road (RB1).
- Rocky Brook at Millstone Road (RB2).
- Rocky Brook at Hampton Hollow Drive (RB3).

The MCHD data indicates that at Fairplay Road there is "moderate impairment" to the macroinvertebrate communities in Rocky Brook in both 1999 and 2000 (Table 9). These results should be viewed generally as the sample from 1999 contained only 91 organisms and the 2000 sample only had 67 organisms (Table 9). Sites RB1 and RB2 were rated as "non-impaired" in 2001, and RB3 was rated as "severely impaired" (Table 9). RB1 and RB2 are in the headwaters of Rocky Brook, which contains most of the forested areas in the watershed (Figure 14, Figure 21). RB3 is located along an unnamed tributary, which drains into the Rocky Brook along RYB1, the uppermost "beat" walked during the visual assessment (Figure 20; Figure 21). If the stream follows a pattern similar to the others as part of the biological and visual assessments, then the stream bottom is undergoing sedimentation and smothering out habitat for macroinvertebrates to properly survive.

CHEMICAL ASSESSMENTS

Visual assessments provide an overall sense of water quality through qualitative surveys. Biological assessments give information on long-term water quality, but do not reveal the source of impairments. Chemical assessments reveal detailed information on the quality of waterways. However, chemical assessments give a snapshot of a particular time and location and only long-term monitoring is able to reveal significant trends.

Under Section 303(d) of the Clean Water Act, each state is required to monitor the health of its waterways, produce a list of waterways not meeting Surface Water Quality Standards, and report these to the U.S. Environmental Protection Agency. These lists are produced every two years and are used to establish the timeline in developing a total maximum daily load (TMDL) for the impaired waterways. A TMDL is the maximum quantity of a particular pollutant that can enter a waterway without affecting the designated use of that waterway (Jarrell 1999).

The New Jersey 303(d) list has determined that Etra Lake is impaired due to nutrients, organic enrichment, sedimentation, and excessive algal growth (NJDEP 2002). The 303(d) list implicates stormwater runoff as the source of these problems, which is associated with land use activities. As increased development occurs, and recreational and residential areas appear in the Watershed, larger amounts of lawn and turf landscaping, and associated fertilizers and chemicals, add to excess algal growth and increased toxicity of the waterways.

Rocky Brook itself is also listed as an impaired waterway due to metals (NJDEP 2002). Chromium, lead, zinc, and iron levels were found to be higher than the State Water Quality Standard established by the NJDEP. These metals can have severely detrimental effects on the environment and people including neurological damage and allergic reactions.

In the last part of the 19th century and well into the 20th, many agricultural pesticides were compounds of metals such as mercury, arsenic, and lead, and such use has left a legacy of soil and water contamination because these elements do not break down in the environment. Most of the Rocky Brook Watershed (29% in 1995) is made up of agricultural lands, which may account for many of the sources of contamination (Figure 14 and Graph 5).

Before the banning of lead in gasoline, air levels of this toxic metal often exceeded standards in New Jersey. Although air-borne levels of lead are now much lower, sources from incineration, power plants, disturbance of contaminated soils, and industrial processes still contribute some lead to the atmosphere where it can be widely distributed and added to waterways.

SBMWA's chemical action teams (CATs) monitor one chemical monitoring site in the Rocky Brook Watershed (Figure 22). Chemical monitoring is conducted every other weekend throughout the year. Volunteers monitor six parameters: dissolved oxygen (DO), pH, nitrate-nitrogen, orthophosphates, water temperature and turbidity. For this assessment, water quality was determined for three of these six parameters: DO, nitrates and orthophosphates. These three are indicative of nonpoint pollution and eutrophication in waterways.

The site in the Rocky Brook Watershed currently monitored by SBMWA's volunteers is (Figure 22):

- Peddie Lake at Route 33, sampled at the Hightstown Memorial Branch of the Mercer County Library (PL1).

Site PL1 has been monitored sporadically since the fall of 2000, but results have been collected throughout the year. The results show that Peddie Lake is maintaining good water quality, as all of the tests are above the State Water Quality Standard for each parameter (Table 10).

The MCHD also took water quality measurements when performing biological assessments at Site #70 (Rocky Brook at Fairplay Road) (Figure 22 and Table 11). At Site #70, water quality is good, as all of the tests are above the State Water Quality Standard for each parameter (Table 11).

USGS has one monitoring station (01400585) at the area where Perrineville Drains into Rocky Brook (Figure 22 and Table 12). This site coincides with NJDEP's AMNET site AN0380 (Figure 21). Water quality at station

01400585 is also good in that all parameters are above the State Water Quality Standard (Table 11).

It should be noted that MCHD Site #70 and USGS station 01400585 are both upstream of Etra Lake, where runoff problems are causing water quality degradation. SBMWA station PL1 is downstream of Etra Lake. Much on the land use between the sampling sites and Etra Lake is composed of agriculture and urban development (Figure 14 and Figure 22).

Assessment –

To best assess water quality, the need is to determine trends in particular indicators. Water quality information for the Rocky Brook Watershed is limited in terms of visual, biological and chemical assessments. This means that there needs to be obtained a long-term set of reliable data. Measurements of the environment can be highly valuable, yet very specific to the time and place where the measurements were taken. A long-term (10 - 20 years) dataset helps to reduce this specificity and increase the likelihood that the measurements are reflecting the actual water quality conditions in the stream.

The chemical data available shows that upstream and downstream of Etra Lake there is very little impacting water quality (Table 10, Table 11 and Table 12). Etra Lake itself is listed by the NJDEP as impaired due to stormwater runoff. Increasing the sampling effort in tributaries draining into Etra Lake or in stations closer to the Lake will help to clarify the impacts affecting its water quality. By increasing the number and frequency that samples are taken, the actual nature of the chemical constituents in the stream can be reliably assessed.

In general, Rocky Brook does not fully support the breadth and diversity of aquatic life representative of a healthy stream ecosystem (Table 8 and Table 9). This means that there are one or many stressors that are suppressing the numbers and varieties of aquatic macroinvertebrate populations and creating opportunities for pollution-tolerant varieties of macroinvertebrates to thrive.

The most likely stressor affecting the macroinvertebrate communities in Rocky Brook is the heightened sedimentation seen in both SBMWA's visual assessments and MCHD's biological assessment (Table 7 and Table 9). The basis for this heightened sedimentation may be due to the soil composition and erodibility of the Rocky Brook Watershed itself (see Geology section and Soils section for more details). The majority of soils in the Watershed are classified as "medium" in terms of their erodibility (Figure 12). This classification is based upon the "k-factor" and measures ability of bare soil to erode. This moderate erodibility combined with the sandy geology seen in much of the southeastern portion of the Watershed probably accounts for much of the sedimentation observed.

Table 7: Visual assessment scores for Rocky Brook 2001.

Visual Assessment "Beat"	Flooding Score	Water Odor Score	Water Color Score	Stream Bottom Score	Aquatic Vegetation Score	Surrounding Vegetation Score	Man-Made Structures Score	Erosion Score	Riparian Zone Width Score	Canopy Score	Overall Assessment Score
RYB1	4	3	2	1	3	4	3	3	3	4	3.00
RYB2	4	3	3	1	3	3	2	3	3	4	2.90
RYB3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RYB4	4	3	3	1	3	3	3	3	3	4	3.00
RYB5	4	2	3	4	3	3	2.5	3.5	1.5	3.5	3.00
Overall Stream Score								2.98			

WATER QUALITY

Table 8: Biological assessment data for Rocky Brook Watershed 1993 and 1998 (NJDEP Data).

Site	Date	Number in Sample	FBI	Total Taxa Richness	EPT Richness	% EPT	% Dominance	Scoring for Stream Impairment Biological Assessment
AN0380	8/31/1993	100	4.6	6	1	71%	71%	Moderately Impaired
AN0380	8/20/1998	100	0.0	13	1	16%	25%	Moderately Impaired
AN0381	10/6/1993	100	4.9	10	1	48%	71%	Moderately Impaired
AN0381	10/1/1998	100	0.0	9	1	3%	81%	Severely Impaired

FBI = Family Biotic Index: Index of the average pollution-tolerance ("sensitivity") of individuals in the sample.

Total Taxa Richness: Number of different families in the sample

EPT Richness: Number of families in *Ephemeroptera*, *Plecoptera*, and *Tricoptera* Orders

% EPT: Percent of sample in the *Ephemeroptera*, *Plecoptera*, and *Tricoptera* Orders

% Dominance: Percent of sample composed of individuals from one family.

Samples should include at least 100 organisms for statistical evaluation. Samples with fewer than 100 were included in this table for interest, but would not be included in a rigorous evaluation of stream health.

Table 9: Biological assessment data for Rocky Brook Watershed 1999, 2000 & 2001 (MCHD Data).

Site	Date	Number in Sample	FBI	Total Taxa Richness	EPT Richness	% EPT	% Dominance	Scoring for Stream Impairment Biological Assessment
70	11/3/1999	91	4.8	11	2	2%	63%	Moderately Impaired
70	5/16/2000	67	4.7	7	0	0%	69%	Moderately Impaired
RB1	3/19/2001	100	4.8	17	6	30%	34%	Non-Impaired
RB2	4/10/2001	103	5.0	17	5	16%	39%	Non-Impaired
RB3	4/17/2001	104	5.7	10	2	5%	70%	Severely Impaired

FBI = Family Biotic Index: Index of the average pollution-tolerance ("sensitivity") of individuals in the sample.

Total Taxa Richness: Number of different families in the sample

EPT Richness: Number of families in *Ephemeroptera, Plecoptera,* and *Tricoptera* Orders

% EPT: Percent of sample in the *Ephemeroptera, Plecoptera,* and *Tricoptera* Orders

% Dominance: Percent of sample composed of individuals from one family.

Samples should include at least 100 organisms for statistical evaluation. Samples with fewer than 100 were included in this table for interest, but would not be included in a rigorous evaluation of stream health.

Table 10: Chemical assessment of Rocky Brook Watershed 2000 and 2001 (SBMWA Data).

Station	Date	Water Temperature (^oC)	Dissolved Oxygen (ppm)	NO_3-N (ppm)	Orthophosphate (ppm)	pH
PL1	10/15/00	15.00	9.50	1.76	<0.2	6.50
PL1	10/27/00	15.00	9.40	1.76	<0.2	6.50
PL1	11/12/00	N/A	8.50	1.32	<0.2	6.50
PL1	4/28/01	14.00	10.50	1.76	<0.2	7.00
PL1	5/13/01	N/A	7.90	1.76	<0.2	N/A
PL1	6/23/01	25.00	8.80	1.32	<0.2	7.00
PL1	8/19/01	25.00	8.25	1.32	<0.2	7.00
PL1	9/1/01	24.50	6.10	1.32	<0.2	7.00
PL1	10/28/01	12.00	8.00	0.88	<0.2	6.50
PL1	11/11/01	9.50	10.00	0.88	<0.2	7.00
PL1	11/25/01	10.00	10.10	1.76	N/A	7.00

Table 11: Chemical assessment of Rocky Brook Watershed 1999 and 2000 (MCHD Data).

Site	Date	Water Temperature (^{o}C)	Dissolved Oxygen (ppm)	pH	Total Dissolved Solids* (ppm)
70	11/3/1999	10.40	6.60	6.70	127.60
70	5/16/2000	15.30	6.80	7.00	107.30

* Total Dissolved Solids (TDS) was derived from Conductivity measurements taken by the MCHD using the formula:

TDS = Conductivity X 0.67 (Campbell and Wildberger 1992)

WATER QUALITY

Table 12: Chemical assessment of Rocky Brook Watershed 1997 - 2000 (USGS Data).

Station Number	Date	Water Temperature (°C)	Dissolved Oxygen (ppm)	NO3-N (ppm)	Total Phosphorus (ppm)	pH	Total Dissolved Solids* (ppm)
1400585	12/16/97	2.50	11.70	0.02	0.01	6.60	83.08
1400585	3/5/98	8.00	9.70	0.01	0.02	6.90	83.08
1400585	5/20/98	15.00	5.20	0.01	0.02	7.00	85.76
1400585	9/9/98	22.00	8.70	0.01	0.02	7.30	84.42
1400585	11/18/99	6.00	12.80	<0.003	0.01	8.20	94.47
1400585	2/29/00	7.50	11.20	0.01	0.02	6.80	139.36
1400585	5/16/00	20.00	8.40	0.01	0.04	7.20	93.80
1400585	8/10/00	27.00	7.80	0.01	0.05	7.40	76.38

* Total Dissolved Solids (TDS) was derived from Conductivity measurements taken by the MCHD using the formula:

TDS = Conductivity X 0.67 (Campbell and Wildberger 1992)

The results of this characterization and assessment represent an opportunity to properly plan the landscape of the Rocky Brook Watershed in an environmentally responsible way and to work proactively to protect water quality. Overall, waterways are experiencing moderate degradation due to sedimentation in Rocky Brook and stormwater is impacting the health of Etra Lake. Increased sedimentation is due to the makeup of the underlying soils and geology. While this condition is natural, many other factors are amplifying this problem. Increases in populations in the Rocky Brook Watershed, and associated land use changes, are adding to the amount of impervious surfaces, which augment the frequency and intensity of stormwater, flooding and erosion.

Landscape –

Populations in the Rocky Brook Watershed, like the rest of New Jersey, are on the rise. The population went from 55,687 residents in 1990 to 68,037 in 2000, increasing by 22.2%. From 1986 to 1995/97, developed lands increased from 2,248.5 acres to 2,635.3 acres, a gain of 17.2%. The rate of change for developed areas may be slower than the increase in population due to areas such as Hightstown Borough (which was already mostly developed in 1986) and the Twin Rivers development. Hightstown Borough needs to look at redeveloping areas within its town to aid in preventing populations from spreading over the rest of the Rocky Brook Watershed.

- One way to keep the rate of population growth and rate of development comparable is to plan for and build mixed-use developments (projects that integrate different land uses, such as restaurants, residences, offices and parks), such as the Twin Rivers development in East Windsor. This development was completed in 1969 and was the State's first planned unit development. A planned unit development is a zoning designation for property developed at a higher density than conventional development in an area. Much of Twin Rivers design incorporated the needs of the community: schools, library, recreational facilities, retail establishments and light industry. The only question remains after 34 years is whether or not Twin Rivers is efficiently working to reduce sprawl. A more thorough study needs to be conducted to determine Twin Rivers' impact on population growth and what percent of the residents utilize the facilities associated with the development.

- Rocky Brook Watershed contains many critical habitats for a variety of threatened and endangered species. Many of these critical areas are adjacent to increasing development, putting them under pressure to be built upon. The municipalities that make up the Watershed should review their zoning and rezone their municipality to coincide with these environmentally important areas and restrict development and fragmentation of these habitats.

Known Contaminated Sites –
There are 15 KCSs in this 15 square mile watershed. Seven sites are found within the 1.2 square mile boundary of Hightstown Borough alone. This large number of KCSs in the Rocky Brook Watershed warrants that the PRPs clean up any contamination present.

- There is one WHPA in Hightstown Borough that is in close proximity to a public community drinking water well. This WHPA is important as there is the potential for ground water contamination due to their proximity to four KCSs: North American Phillips Lighting, Hightstown Oil Company, Pullen Fuel Company and Citgo Service Station. These sites are located within a half-mile of two public water supply wells in Hightstown Borough. Because of this, these four KCSs need to be the top priorities for remediation in the Rocky Brook Watershed. Special attention needs to be given to the monitoring of these four sites to ensure that public safety is maintained.

Point Source Dischargers –
The point source discharges in the Rocky Brook Watershed have been compliant with their permits.

- The dischargers need to stay vigilant of their monitoring efforts to maintain the health of local waterways.

Geology –
The nature of Coastal Plain geology has a large influence on the water resources of the Rocky Brook Watershed. The unconsolidated nature of the sediments has two major implications from the standpoint of water resources. First, streams and rivers of the Coastal Plain are typified by large amounts of alluvial sediment (considering their shallow gradients and relatively sluggish flows) because of the erodibility of the underlying deposits. The soils are easily eroded and carried to other areas of the Watershed. Second, the lack of cementation of the buried sediments means that the sandy units retain a high porosity, making them very productive aquifers.

- Increasing urbanization in the Rocky Brook Watershed also increases the amount of impervious cover. This has the effect of decreasing the amount of water flowing into the aquifer by diverting precipitation over the landscape to streams and not downward into the soil. Placement of new development, and therefore impervious cover, out of areas that have high value for recharging the aquifers will help to maintain water levels for drinking, irrigation, and industrial use.

Soils –
Much of the Rocky Brook is classified as hydrologic soil group B, covering 4,498 acres out of a total of 9,604 acres in the entire Watershed. Hydrologic soil group B represents soils with a moderate infiltration rate, and is

representative of the moderately coarse soils seen in the Coastal Plain Physiographic Province. Most of this soil underlies the agricultural areas in East Windsor and Millstone Townships. This aids in both creating extensive aquifers in the region and allowing for much ground water to be recharged to the soil.

- In conjunction with the visual assessment data and observations during the biological assessments, the most likely stressor affecting the macroinvertebrate communities in Rocky Brook is heightened sedimentation. The basis for this heightened sedimentation may be due to the soil composition and erodibility of the Rocky Brook Watershed itself. This moderate erodibility combined with the sandy geology seen in much of the southeastern portion of the Millstone Watershed probably accounts for much of the sedimentation observed. The nature of the Coastal Plain soils in the Rocky Brook Watershed is an important factor impacting water quality of Rocky Brook (especially macroinvertebrate communities).

Land Use –

Newly developed lands are being placed in headwaters of Rocky Brook in Millstone Township. Much of the conversion was from separate pieces of forested area to urban land uses. Forests improve water quality by filtering pollutants and reduce flooding by slowing stormwater. Forests also provide habitat to a variety of plant and animal species, and many of the forests in Millstone Township are critical habitat for State Threatened species. It has been shown that the best indicator of the presence of an unimpaired benthic macroinvertebrate community is the total area of forested land located upstream of a sampling site (USGS 1998).

- Millstone Township should review their zoning to determine if more suitable areas away from headwater streams are available for new development or redevelopment in their town and to keep forested areas intact.

- Riparian corridors are being increasingly encroached upon for developed areas in the Rocky Brook Watershed. These areas are particularly sensitive to land use changes, as they are the natural buffers that protect the stream itself from a variety of pollution sources. Placing of new construction in the Rocky Brook Watershed needs to be sensitive to or avoid altogether the riparian corridors in order to maintain ecological integrity.

- East Windsor Township has had an ordinance to protect stream corridors since 2000. Millstone Township proposed a stream corridor protection ordinance in early 2003. Stream corridor ordinances will preserve the riparian corridor and prevent further development to these critical areas. The other municipalities that do not have such protection

for area streams should develop and implement such a strategy, if feasible. For example, Hightstown Borough is nearly built out, so a stream corridor ordinance may not be the best solution to protecting the portion of Rocky Brook that flows through its borders.

Impervious cover prevents the movement of water into the soil. The Rocky Brook Watershed is only covered by 13.9% impervious cover. While this is below the 25% impervious cover limit, where there is a shift to poor stream conditions that include diminished aquatic diversity, water quality, and habitat functioning, it is above the 10% impervious cover limit, where sensitive elements are lost from the stream system. The municipalities need to be aware that much of the underlying soils in the Rocky Brook Watershed are moderately erodible. Water quality impacts have been noted due to the erodible nature of the soils in this region.

- Increasing impervious cover will only exacerbate the problem by increasing the frequency and intensity of storm flows and flooding. Municipalities need to incorporate innovative ways to plan developments including re-zoning (changing zoning classifications to permit development that is less dense or restrictive), mixed-use development (projects that integrate different land uses, such as restaurants, residences, offices and parks), conservation design and town-center designation (centralized growth areas through incentives and allows for developing at higher densities).

Water Supply –
There are many portions of the Rocky Brook Watershed that contain areas with high ground water recharge. These areas need to be protected by ordinances by their respective townships (East Windsor and Millstone, in particular) to restrict development. Reduced development in the high ground water recharge areas will ensure that there are plentiful supplies of water for many years to come.

- Since the majority of high ground water recharge areas are located in East Windsor and Millstone Townships, these municipalities need to develop and enforce regulations on the use of chemicals in the agricultural areas above ground water recharge zones to prevent potential contamination of drinking water.

Water Quality –
The chemical data available shows that upstream and downstream of Etra Lake there is very little impacting water quality. Etra Lake itself is listed by the NJDEP as impaired due to stormwater runoff. Increasing the sampling effort in tributaries draining into Etra Lake or in stations closer to the Lake will help to clarify the impacts affecting its water quality. By increasing the number and frequency that samples are taken, the actual nature of the chemical constituents in the stream can be reliably assessed.

- In order to accurately assess the environmental health of Rocky Brook, long-term trends in water quality need to be determined. Currently, there is a lack of reliable monitoring data on the water resources in this region, especially basic water quality information for many of the area's tributaries, which also have an impact on Rocky Brook. Intensive monitoring needs to occur to determine the health of Rocky Brook and its tributaries.

- Since stormwater runoff has been targeted as the pollution source for Etra Lake, BMPs should be enacted around Etra Lake in order to control the stormwater runoff and preserve this piece of open space. NJDEP needs to make Etra Lake a priority for restoration efforts. BMPs ranging from simple vegetated filters and extended forest buffers, to bioretention systems or wet ponds are examples of what can be implemented to improve stormwater quality.

- To help alleviate the runoff entering the tributaries of Etra Lake and the Lake itself, local residents and businesses need to incorporate environmentally sensitive landscaping practices into their properties. Programs such as the SBMWA's River-Friendly Resident and Business Programs can offer guidance and expertise to properly implement everyday strategies to protect water quality.

REFERENCES

Anderson and Rockel, 1991. *Economic Valuation of Wetlands. Discussion Paper #065*, Washington, D.C: American Petroleum Institute.

Campbell, G. and S. Wildberger, 1992. *The Monitor's Handbook.* LaMotte Company, Chestertown, MD.

Center for Watershed Protection, 1998. *Rapid Watershed Planning Handbook: A Comprehensive Guide for Managing Urbanizing Watersheds*. Maryland: Center for Watershed Protection.

Center for Watershed Protection, No Date. *Environmental Indicator Profile Sheet No. 5: Sediment Contamination*. Maryland: Center for Watershed Protection.

Gilliam, J.W., 1994. "Riparian Wetlands and Water Quality." *Journal of Environmental Quality*, 23: 896-900.

Jarrell W.M. 1999. *Getting Started With TMDLs.* YSI, Inc.

Maryland Department of Natural Resources, 2000. *Stream Corridor Assessment Survey: Survey Protocols*.

Maryland Department of Natural Resources, 2001. "Maryland's Surf Your Watershed" [Online WWW]. Available URL: "http://www.dnr.state.md.us/watersheds/surf/index.html."

Millstone Township, 2002. "Millstone Township – Monmouth County, New Jersey" Online WWW. Available URL: "http://www.millstone.nj.us/index1.htm."

Monmouth County Health Department, 2002. "Rapid Bioassessment" [Online WWW]. Available URL: "http://www.shore.co.monmouth.nj.us/health/labpages/rba.htm."

New Jersey Bureau of Freshwater Fisheries, 1998. *Lake Management Plan: Peddie Lake.* New Jersey Department of Environmental Protection, Trenton, NJ.

New Jersey Department of Environmental Protection, July 1995. *Ambient Biomonitoring Network: Raritan River Drainage Basin, 1993-1994 Macroinvertebrate Data*.

New Jersey Department of Environmental Protection. 1997. *The Clean Water Book*. New Jersey Department of Environmental Protection, Trenton, NJ.

New Jersey Department of Environmental Protection, Office of Policy and Planning, 1998. *Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey.* September 1998.

REFERENCES

New Jersey Department of Environmental Protection, 2000. *Ambient Biomonitoring Network: Raritan Region, 1999 Macroinvertebrate Data*. NJDEP, June 2000.

New Jersey Department of Environmental Protection, 2002. *New Jersey's 2002 Integrated List Of Waterbodies And Their Categorization Regarding Support Of Designated Uses And Compliance With Water Quality Standards.*

New Jersey Water Supply Authority, 2000a. *Setting of the Raritan River Basin*. NJWSA, July 2000.

New Jersey Water Supply Authority, 2000b. *Water Budget in the Raritan River Basin*. NJWSA, September 2000.

New Jersey Water Supply Authority, 2000c. *Riparian Methodology: A Methodology for Defining and Assessing Riparian Areas in the Raritan River Basin*. NJWSA, June 2000.

New Jersey Water Supply Authority, 2002. *Ground Water of the Raritan River Basin.* NJWSA, May 2001.

Niles, L., J. Myers, and M. Valent, No Date. *The Landscape Project.* New Jersey Department of Environmental Protection, Division of Fish and Wildlife, New Jersey Endangered and Nongame Species Program.

Owens, James P., Sugarman, Peter J., Sohl, Norman F., Parker, Ronald A., Houghton, Hugh F., Volkert, Richard A., Drake, Avery A., Jr., and Orndorff, Randall C., 1998. *Bedrock Geologic Map of Central and Southern New Jersey,* Scale 1 to 100,000, 8 cross sections, 4 sheets, each size 58x41, I-2540-B. Published in digital format in 2000 in New Jersey Geological Survey CD Series CD 00-1, Bedrock Geology (1:100,000-scale) and Topographic Base Maps (1:24,000- and 1:100,000-scales) of New Jersey.

Peterjohn and Correll, 1984. "Natural Dynamics in an Agricultural Watershed Observations on the Role of a Riparian Forest." *Ecology*, 65: 1466.

Regional Planning Partnership, 2001. *Regional Data Book*.

Schueler, T.R. and H.K. Holland, 2000. *The Practice of Watershed Protection*. Center for Watershed Protection, Ellicott City, MD.

South Branch Watershed Association, 1998. *Highlands Wellhead Protection Project.*

Stony Brook-Millstone Watershed Association, 2000. *Volunteer Monitors Handbook*.

Stony Brook-Millstone Watershed Association, 2002. *River-Friendly Resident.* Stony Brook-Millstone Watershed Association.

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), 1998. *Stream Visual Assessment Protocol*. National Water and Climate Center Technical Note 99-1.

U.S. Environmental Protection Agency, 1988. *New Jersey Coastal Plain Aquifer: Support Document*. On the web at http://www.epa.gov/region02/water/aquifer/coast/coastpln.htm.

U.S. Environmental Protection Agency, 1996. *Nonpoint Pointers #4: The National Nonpoint Source Management Program.* USEPA Fact Sheet EPA-841-F-96-004D.

U.S. Geological Survey, 1998. *Relation of Benthic Macroinvertebrate Community Impairment to Basin Characteristics in New Jersey Streams*. USGS Fact Sheet FS-057-98.

U.S. Geological Survey, 1999. *Ground Water and Surface Water: A Single Resource*. Circular 1139, U.S. Geological Survey, Denver, CO.

U.S. Geological Survey. 2001. *Major Aquifers in New Jersey.* On the web at http://wwwnj.er.usgs.gov/gw/aquifer.html.

University of North Carolina, 2001. "WATERSHEDSS Wetland Management" [Online WWW]. Available URL: "http://h2osparc.wq.ncsu.edu/info/wetlands/manage.html." Initiated August 1994 and last updated May 2001.

Upper Raritan Watershed Association, 1997. *Physical Stream Monitoring Guide*.

Vowinkel, Eric F. and Foster, W. Rendall, April 1981. *Hydrogeologic Conditions in the Coastal Plain of New Jersey,* Open File Report 81-405. U.S. Geological Survey, West Trenton, NJ.

REFERENCES

LIST OF ACRONYMS

AMNET	Ambient Biomonitoring Network
BAT	Biological Action Team
BFO	Bureau of Field Operations
BMPs	Best Management Practices
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
BUST	Bureau of Underground Storage Tanks
CAT	Chemical Action Team
CWA	Clean Water Action
CWP	Center for Watershed Protection
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
EPT	Ephemeroptera Plecoptera Tricoptera
EWMUA	East Windsor Municipal Utilities Authority
FBI	Family Biotic Index
GIS	Geographic Information System
GSA	General Services Administration
HIT	High Intensity Treatment
KCS	Known Contaminated Site
MCHD	Monmouth County Health Department
MDDNR	Maryland Department of Natural Resources
MGD	Million Gallons per Day
ND	No Date
NJDEP	New Jersey Department of Environmental Protection
NJGS	New Jersey Geological Survey

LIST OF ACRONYMS

NJPDES	New Jersey Pollution Discharge Elimination System
NJWSA	New Jersey Water Supply Authority
NO_3	Nitrate
NRCS	Natural Resources Conservation Service
PCE	Perchloroethylene
PCW	Public Community Well
PO_4	Phosphate
PRP	Potentially Responsible Party
RAT	River Action Team
RPP	Regional Planning Partnership
SBMWA	Stony Brook-Millstone Watershed Association
STP	Sewage Treatment Plant
SWQS	Surface Water Quality Standard
TCA	Trichloroethane
TCE	Trichloroethylene
TMDL	Total Maximum Daily Load
TOT	Time of Travel
URWA	Upper Raritan Watershed Association
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	Underground Storage Tank
WHPA	Wellhead Protection Area
WTP	Water Treatment Plant

GLOSSARY

alluvial: Relating to mud and/or sand deposited by flowing water.

anaerobic: Describing an organism (especially a bacterium) that can survive in the absence of oxygen.

aquifer: An underground geological formation, or group of formations, containing usable amounts of groundwater that can supply wells and springs.

baseflow: The sustained or fair-weather flow of a stream regardless of human-induced inputs.

benthic organism: Any of a diverse group of aquatic plants and animals that lives on the bottom of bodies of water; the presence or absence of certain benthic organisms is used as an indicator of water quality.

biotite: A rock-forming mineral of the mica group.

calcareous: Containing calcium carbonate.

carbonaceous: Describes sediment that contains organic matter or is rich in carbon.

clay: A rock or mineral fragment or particle of decayed matter smaller than a very fine silt grain, having a diameter less than 1/256 of a millimeter.

confluence: A place of meeting of two or more streams; the point where a tributary joins the main stream.

Cretaceous: The last period of the Mesozoic era, covering 135 to 65 million years ago.

deciduous: Describes a tree that loses its leaves during autumn.

detention basin: An impoundment or excavated basin for the short-term detention of stormwater runoff from an area.

dip direction: The vertical angle, measured at an observation point in surveying, between the plane of the true horizon and a line of sight to the apparent horizon.

dissolved oxygen: The volume of oxygen that is contained in water.

endangered species: Living organisms threatened with extinction by man made or natural changes in the environment.

erodibility: The tendency of soil to become detached and washed away during erosion.

GLOSSARY

erosion: The physical removal of rock or soil particles by a transport agent such as running water, wind, glacial ice, and gravity.

eutrophication: The slow aging process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears; during the later stages of eutrophication the water body is choked by abundant plant life due to higher levels of nutritive compounds such as nitrogen and phosphorous; human activities can accelerate this process.

evapotranspiration: The loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil.

feldspar: A group of rock-forming minerals that are the most widespread of any mineral group; usually white or nearly white and clear or translucent.

floodplain: Area adjacent to a stream or river that is subject to flooding or inundation during severe storm events; often called a 100-year floodplain, it would include the area of flooding that occurs, on average, once every 100 years.

Geographic Information System (GIS): A computer system designed to manipulate, analyze, and display information that is tied to a geographic location.

glauconite: A dull-green earthy or granular mineral of the mica group.

gravel: An unconsolidated natural accumulation of rounded rock fragments resulting from erosion, consisting primarily of particles larger than sand grains.

ground water: The portion of water beneath the land surface that is below the water table and the pore spaces are filled with water.

habitat: The environment in which a plant or animal tends to live.

Hadrosaurus foulkii: A duck-billed dinosaur discovered in New Jersey in 1858.

headwater stream / headwaters: The beginnings or sources for watercourses; typically, the point in the landscape where sufficient runoff collects in intermittent streams.

hydrology: The science that deals with water (both surface and ground water), its properties, circulation and distribution.

impervious cover / impervious surface: Any surface in the landscape that cannot effectively adsorb or infiltrate rainfall; usually associated with urban

development; the amount of impervious surfaces has been used as an indicator to predict the severity of water quality impairments to local waterways.

infiltration: The movement of water into soil or porous rock.

infrastructure: The underlying system or network used for organization; most often refers to the road systems, sewer networks, school systems, etc. in a municipality.

lignitized wood: Mineral coal retaining the texture of the wood from which it was formed; also called wood coal.

macroinvertebrates: These are organisms that do not have a backbone and are visible to the naked eye (for example, certain insect larvae); they are most often used as indicator organisms in water bodies as they exhibit varying sensitivities to pollution.

mica: A mineral that is characterized by low hardness and the readily splitting into thin sheets; a prominent rock-forming constituent of igneous and metamorphic rock.

Miocene: A time period of the upper Tertiary before the Pliocene.

muscovite: A mineral of the mica group.

nitrate-nitrogen: The amount of nitrogen found in the form of nitrates.

nonpoint-source pollution: Any source of pollution not associated with a distinct discharge point; pollution from a diffuse source; includes sources such as rainwater runoff from agricultural lands, industrial sites, parking lots, and timber operations, as well as escaping gases from pipes and fittings.

nutrient: Any substance that is assimilated by organisms and promotes growth. Nitrogen and phosphorous are nutrients which promote the growth of algae. There are other essential and trace elements, which are also considered nutrients.

orthophosphate: Chemical parameter monitored for water quality assessment. A form of reactive phosphorus primarily found in fertilizer applied to agricultural and residential lands.

outcrop: The part of a geological formation or structure that appears at the surface of the Earth.

Paleocene: A time period of the early Tertiary before the Eocene.

percolation: The slow movement of water through small openings within a porous material.

pervious surface: Any surface with the capacity for transmitting a fluid; also called permeable surface.

phosphatic: Any rock or mineral containing phosphates or phosphoric acid.

Physiographic Province: The distribution of land area in New Jersey into distinct divisions determined by New Jersey's geological history.

Pliocene: A time period of Tertiary, between the Miocene and Pleistocene.

point-source pollution: A stationary location or fixed facility such as an industrial or municipal plant that discharges pollutants into air or surface water through pipes, ditches, lagoons, wells, or stacks; a single identifiable source of pollution such as a ship or mine.

porosity: The ratio of the volume of interstices of a material to the volume of its mass; the quality of being porous.

potable water: Raw or treated water that is considered safe to drink; also called drinking water.

pyrite: A common, pale-bronze or brass-yellow mineral that is an important ore of sulfur.

quartz: Crystalline silica; an important rock-forming mineral that forms the major proportion of sand.

recharge: The process of the absorption and addition of water to the zone of saturation or aquifer.

retention basin: A large depression built as a barrier to reduce flooding and storm surges.

riparian area: Land situated on or adjacent to a stream bank.

runoff: The portion of rainfall, melted snow or irrigation water that flows across the ground's surface and is eventually returned to streams; runoff can pick up pollutants from air or land and carry them to receiving waters; also called stormwater.

sand: A rock fragment or particle of detritus smaller than gravel but larger than silt.

sediment: Solid fragmented material that originates from weathering of rocks and is distributed by air, water or ice.

sedimentation: The act or process of forming or accumulating sediment in layers.

septic system: A system designed to treat waste and wastewater by the use of bacteria; most often associated with individual residences.

siderite: A yellow-brown, brown-red, or brown-black mineral containing calcite.

silt: A rock fragment or particle of detritus smaller than fine sand but larger than clay.

soil: The upper layer of the Earth's surface that may be dug up or plowed and in which vegetation grows.

succession: The process of plant life maturation over a landscape.

surface water: All water found in rivers, streams, ponds, lakes, marshes, wetlands, as ice and snow, and transitional, coastal and marine waters.

threatened species: Species that may become endangered if conditions that harm them continue to accumulate.

tillable land: Land suitable for agricultural use.

total maximum daily load: The maximum quantity of a particular pollutant that can enter a waterway without affecting the designated use of that waterway.

turbidity: A measure of the ability of a suspended material to disturb or diminish the penetration of light through a fluid.

wastewater: Water that has been used for industrial, domestic, or agricultural practices and has not yet been treated.

watershed: A hydrologic unit in which all surface water runoff egresses through a single, natural hydrologic outlet, and as delineated in the statewide Water Quality Management Plan. Also, all the land area, which contributes runoff to a particular point along a waterway.

wellhead: The source of a well and the structure built over it.

wetlands: Areas that are soaked or flooded by surface or ground water frequently enough or for sufficient duration to support plants, birds, animals, and aquatic life. Wetlands generally include swamps, marshes, bogs, estuaries, and other inland and coastal areas, and are federally protected.