NATURAL RESOURCE INVENTORY

Montgomery Township

Somerset County, New Jersey

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Prepared by

The Montgomery Township Planning Board

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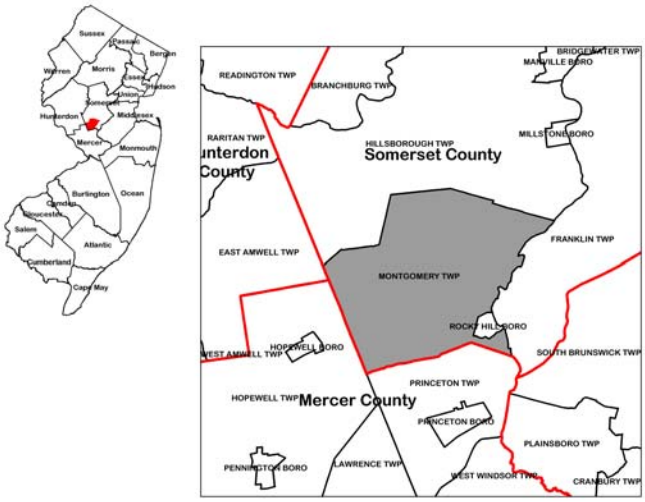
Introduction



Montgomery Township, located in southern Somerset County bordering both Hunterdon and Mercer Counties, is a community with unique natural and scenic resources.

Montgomery Township is also characterized by contrasts; while home to a portion of the fragile Sourland Mountain ecosystem, it is also home to stable suburban neighborhoods and a thriving business community. The local land use mosaic is punctuated by active agricultural operations, with over a quarter of the Township's 20,787 acres in productive farming and scenic stream corridors. These features contribute to the character of the Township, long known as a desirable place to live.

Montgomery Township is also a desirable place to build, and commercial and residential development continues. In the face of this continuing development, the unique resources that characterize the Township are at risk. Identifying these resources and their significance is the first step in affording them protection as development moves forward.

Purpose and Objectives

The Natural Resource Inventory (NRI) identifies, quantifies and describes the environmental resources present in the community. Through the mapping and accompanying narrative, the natural resource base, along with resource conservation issues are portrayed. Many natural resources are worthy of preservation efforts, others merit highlighting or are indicators of larger issues that require further study.

Digital datasets from the Montgomery Township Geographic Information System (GIS) have been used extensively in the preparation of this NRI. The source and original scale of individual datasets utilized in map generation are noted on each map. Generally, the scale of source data for Montgomery Township digital datasets range from 1:9,480 to 1:250,000. The source data scale is an indicator of the overall accuracy of a dataset and its potential utility in making determinations.

National Map Accuracy Standards (NMAS) govern production of datasets; when digitized, source data with a scale of 1:20,000 or smaller must have 90% of tested points within 1/50 of an inch of their location on the map and data presented at a scale greater than 1:20,000 must have 90% of tested points within 1/30 of an inch of their location on the map. Provided a data set meets NMAS, its scale can be translated into ground accuracy. As an example, the source data scale of the bedrock geology information presented in Figure 6 is 1:100,000. NMAS require that 90% of tested points fall within 1/30 of an inch of their location on the map from which they were digitized. This translates to roughly 166 feet on the ground, as noted in the table to the right. This implies that a feature or line can be depicted 165 feet from its actual location on the ground and still meet NMAS. Source data scale and subsequent ground accuracy must therefore be considered in decision-making.

National Map Accuracy Standards

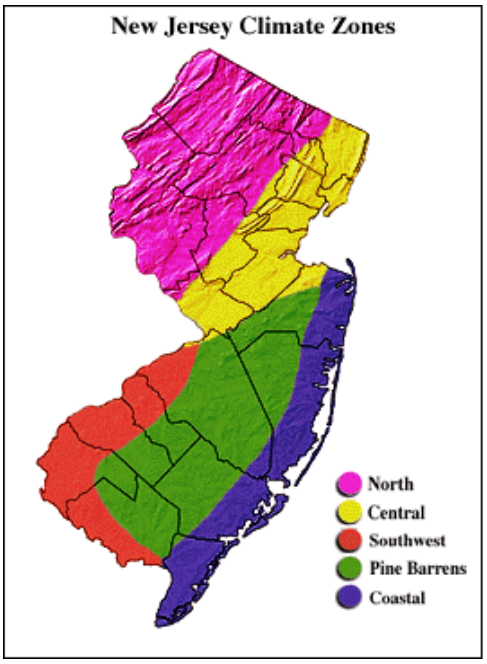
Map Scale	Ground Meters	Ground Feet
1:12,000	10.2	33.5
1:24,000	12.2	40.0
1:100,000	50.8	166.7
1:250,000	127	416.7
1:500,000	254	833.4
1:2,000,000	1,016	3,333.5

GIS digital data has simplified the tasks of identifying, quantifying and describing the resource base of a community. Multiple layers of data can be viewed together within the framework of a digital base map, providing the means to analyze individual resources, along with their role and importance in the overall ecosystem. In this fashion, both competing and synergistic relationships among natural resources can be defined and explored.

Identification, quantification and description are the beginning phases of analysis for the preparation of an NRI. Many of the natural resources and factors that are present play a unique role in planning and community development. An NRI is particularly useful in preparing a land use or conservation plan, key policy documents that spell out goals, objectives and recommendations to protect the natural resources found in a community.

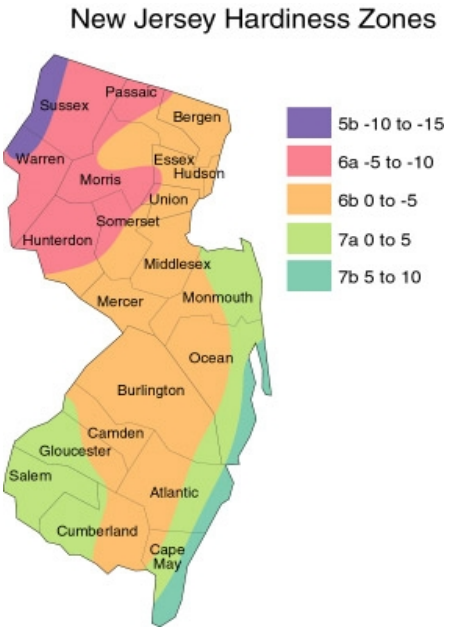
Climate[i]

Montgomery Township is in the central climate zone of New Jersey, comprised mainly of the counties stretching northeast from Trenton to New York City. Somerset County is generally not influenced by the Atlantic Ocean and therefore has a continental type of climate. Prevailing winds are from the southwest in summer and from the northwest in winter. Generally, January is the coldest month with a mean temperature of 28.0 degrees while July is the warmest with a mean temperature of 73.2 degrees Fahrenheit. The annual average temperature is 50.8 degrees Fahrenheit.



Source: *Office of the New Jersey State Climatologist, Rutgers University.*

The continental type of climate means that Montgomery Township generally has colder temperatures and greater snowfall in winter, with a greater average annual precipitation overall as compared to areas in southern New Jersey. Snowfall amounts average 36.5 inches annually, with 45 inches of precipitation throughout the year. Spring and summer months tend to experience temperatures consistent with those found in the rest of the state, averaging between 57 and 70 degrees Fahrenheit.



Source: *Purdue University Center for New Crops and Plant Products*

The difference between the continental and coastal climate types has a profound effect on length of growing season, characterized by the dates of first and last killing frost. Varying within the region as well as from year to year, the growing season can be as short as 148 days to as long as 214 days with an average length of 169 days. The average date of the last killing frost is April 27 and the

average date of the first killing frost is October 13. Areas within the northern climate zone have, however, experienced killing frosts as early as September and as late as June.

Another climate indicator is the hardiness zones established by the United States Department of Agriculture. As depicted on the map below, Montgomery Township falls within Zone 6b, with an average annual minimum temperature range of 0 to -5 degrees Fahrenheit.

Hardiness zones are critical for successful cultivation or maintenance of landscape plant material. Landscape plants are rated by the minimum zone that can be tolerated. As an example, if a shrub is rated as hardy in Zone 7a, it will tolerate an average annual minimum temperature of 0 to 5 degrees Fahrenheit, and can survive in any Zone above 7a. It would likely not survive winters in Montgomery Township, however, as it is rated within Zone 6b. Aside from cold hardiness, a number of other factors affect plant growth. These include soil pH, sun exposure, rainfall and artificial micro-climate factors. Artificial micro-climate factors are those which can be altered by the nature of the built environment; proximity of buildings, artificial landform (severe grading), adjacency to a highway or parking lot and planting of material in planters or other elevated structures can all affect plant growth.

Land Use/Land Cover

Montgomery Township is characterized by contrasting landscapes, divided roughly in thirds among urban, forested and agricultural land cover types. Urban land uses are the most prevalent, comprising 31% of the Township (6,357). Forested land cover comprises 5,725 acres (28%) of the community and agriculture comprises 5,341 acres (26%) of the community.

Urban land uses are present in distinct nodes within Montgomery, the most extensive in the northeastern quadrant of the Township. More compact development (higher density) nodes are found in the southeastern and southwestern corners.

Approximately half of Montgomery's forested acreage is located in the northwestern third of the Township on the Sourland Mountain. The remainder is widely dispersed throughout lower lying elevations. While forested land cover dominates the Sourland Mountain, agricultural land cover is conspicuously absent. The vast majority of agricultural land is located south east of the Sourland ridge. Figure 1 depicts a Level I (generalized) Land Use/Land Cover classification for the Township based on the Anderson classification scheme.

Wetlands and barren lands make up a majority of the remaining land cover found in the Township, at 2,694 acres (13%) and 538 acres (3%) respectively. A majority of the wetlands are found adjacent to stream corridors and are linear in nature. Wetlands located on the Sourland Mountain, however, are generally more expansive, creating large headwaters to the streams which flow off the mountain. The barren lands within the Township, as classified in the NJDEP 1995 Land Use/Land Cover data, are primarily comprised of transition areas under development when the data was interpreted. While these areas have since been permanently established as residential areas, as development continues there are likely new transition areas elsewhere in the Township.

Figure 2 depicts the land use/land cover of the Township in a more detailed fashion, expanding on the 6 general categories contained in the Level I Anderson classification. This breakdown, representing a Level III classification scheme (although terms are slightly modified) details the types of forest, wetland, urban and agricultural land detailed in Figure 1 (barren and water are not further enumerated). Table 1, on the following page, summarizes the acreage and percentage each land use/land cover category represents.

Table 1 – Detailed 1995 Land Use/Land Cover

Land Cover Type	Acres	%
Agricultural	5,341.34	25.7
Brush Covered Field	555.96	2.7
Agricultural Wetlands	456.84	2.2
Barren Land	538.30	2.6
Athletic Fields	49.70	0.2
Recreational Land	510.41	2.5
Commercial	466.72	2.2
Industrial	65.90	0.3
Rural Residential	3,790.47	18.2
Low Density Residential	409.43	2.0
Medium Density Residential	565.07	0.3
High Density Residential	110.58	0.5
Other Urban	779.83	3.8
Coniferous Forest	468.27	2.3
Deciduous Forest	3,697.27	17.8
Mixed Forest	955.56	4.6
Plantation	47.62	0.2
Coniferous Wooded Wetlands	1.94	0.0
Deciduous Wooded Wetlands	1,778.64	8.6
Mixed Wooded Wetlands	63.81	0.3
Herbaceous Wetlands	196.51	0.9
Disturbed Wetlands	112.86	0.5
Managed Wetlands	83.25	0.4
Transportation and Utilities	118.31	0.6
Water	132.38	0.6
Total	**20,787.96**	

While Township growth was significant between 1980 and 1990, when the population rose from 7,360 to 9,612 (30%), Montgomery's population rose even more sharply to 17,481 residents from 1990 to 2000. During this decade, Montgomery experienced the highest rate of growth of any municipality in Somerset County at nearly 82%; the County growth rate for the decade was 24%. This led to precipitous change in the character of the landscape, as evident in comparison of 1986 and 1995 land use/land cover (see Table 2). Comparison of the 1986 and 1995 land use/land cover data reveals that the Township experienced a sharp decline in agricultural land, losing 2,485 acres to other land uses. Urban land uses increased from 4,748 acres in 1986 to 6,357 in 1995, an increase of almost 34%. With the population growth experienced in Montgomery over the past two decades, this should come as no surprise.

Further analysis of land cover change is aided by data compiled by the Center for Remote Sensing and Spatial Analysis (CRSSA) at Cook College, Rutgers University. Historical land cover interpreted from remotely sensed data acquired in 1972 reveals that Montgomery Township was dominated by forest and agricultural land cover types, representing nearly 82% of Montgomery's acreage. Urban land uses were overshadowed by wetland land cover.

The spatial resolution of the 1972 land cover data does not permit direct comparison to the 1986 and 1995 land cover datasets. The smallest area "seen" by the satellite collecting data during this period was 80 square meters; this equates to a box on the ground which is 262.5 feet squared with an area of roughly 1.58 acres. While detailed analysis with data of this spatial resolution is not appropriate, comparison of the general land cover features depicted in a Level 1 Anderson classification scheme provides a meaningful picture of land cover change over time. A Level 1 Anderson classification scheme includes broad categories of land cover; wetlands, urban or developed land, water, agricultural land and forested areas.

Between 1972 and 1995, nearly 5,000 acres (48%) of land in agricultural production was converted to other land uses. As urban land uses grew by 350% (nearly 5,000 acres), this farmland was lost permanently to development. Although forested land increased by almost 300 acres from 1986 to 1995, overall acreage decreased 14% since 1972, a loss of roughly 900 acres. While wetland and barren land cover types showed increases over the 23-year period, this change is likely due to data quality rather than physical change of the landscape. An increase in barren land may also be represented by increased amounts of development, which is categorized as barren land in a Level I Anderson classification scheme. Figure 3 depicts Level I land use/land cover classifications for 1972, 1985 and 1995. Table 2, below, indicates land use/land cover types for these years.

Table 2 – Land Use/Land Cover Change (1972, 1986 and 1995)

LandUse/Land Cover	1972*		1986		1995		Change (1972 – 1995)	
	Acres	*%*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Agriculture	10,277.1	49.6	7,826.7	37.7%	5,341.3	25.7%	-4,935.8	-48.0%
Barren Land	12.1	0.1	373.5	1.8%	538.3	2.6%	526.2	4,348%
Forest	6,631.8	32.0	5,490.5	26.4%	5,724.7	27.5%	-907.1	-13.7%
Urban	1,410.5	6.8	4,747.6	22.8%	6,357.4	30.6%	4,946.9	350.7%
Water	7.9	0.0	121.5	0.6%	132.4	0.6%	-3.0	-38.3%
Wetlands	2,376.6	11.5	2,228.2	10.7%	2,693.8	13.0%	317.2	13.2%

*Acreages were approximated by multiplying the number of grids for each land use/land cover category by the grid size of 262'x262'.

Forested Areas[1]

Including wooded wetlands, Montgomery Township has over 7,500 acres of forested area. This represents 36% of the total acreage of the Township; a significant portion of land cover. Nearly half, 3,487 acres (46.5%), is deciduous forest, and when combined

[1] Forested areas data is taken from the New Jersey Department of Env. Protection 1995 Land Use/Land Cover data

with deciduous wooded wetlands, over 67% of the forested areas in Montgomery are deciduous in nature. Table 3 lists the forest types depicted on Figure 4 and the percentage each type represents.

Table 3 – 1995 Forest Types

Forest Type	Acres	Percentage
Brush Covered Field	555.96	7.4
Coniferous Brush/Shrubland	382.84	5.1
Coniferous Forest	85.43	1.1
Coniferous Scrub/Shrub Wetlands	0.79	0.0
Coniferous Wooded Wetlands	1.15	0.0
Deciduous Brush/Shrubland	210.64	2.8
Deciduous Forest	3,486.63	46.5
Deciduous Scrub/Shrub Wetlands	269.32	3.6
Deciduous Wooded Wetlands	1,509.32	20.1
Mixed Brush/Shrubland	719.09	9.6
Mixed Forest	236.47	3.2
Plantation	47.62	0.6
Total	**7,505.26**	**100.0**

The forested areas of Montgomery Township play a vital role in many ecosystem functions, including:

- Habitat for threatened and endangered species;
- Regulation of stream temperatures to support stability of streams and rivers;
- Provision of nutrients and woody debris to streams and rivers;
- Stabilization of steep slopes and reduction of erosion and sedimentation;
- Wooded wetlands act as headwaters to tributary streams of the Millstone River and watershed;
- Conversion of carbon dioxide to oxygen;

- Dissipation of heat and provision of shade;
- Provision of riparian buffers;
- Reduction of urban heat island effects;
- Regulation of building temperatures and reduction of reliance on heating and cooling systems;
- Reduction of pollution;
- Reduction of noise pollution;
- Provision of privacy and screening;
- Enhancement of groundwater recharge capacities.

The most significant contiguous forest stands in Montgomery are associated with the Sourland Mountain and Pheasant Hill in the western portion of the Township, where they connect with extensive mature forests in Hopewell and East Amwell Townships. This area is characterized primarily by deciduous forest, with deciduous wooded wetlands at the fringe of the mountain. Other smaller areas within the Sourland Mountain are at this point successional and could potentially revert to forested land within coming decades. There are other areas of contiguous forest in the southern portion of the Township, although not as significant as those on the Sourland Mountain. As development has continued since the acquisition of the land use/land cover data in 1995, it is likely that a number of forested areas in the Township have been converted to other developed land uses.

The net cooling effect of a young, healthy tree is equivalent to ten room-size air conditioners operating 20 hours a day. -U.S. Department of Agriculture

Trees can boost the market value of your home by an average of 6 or 7 percent. -Dr. Lowell Ponte

Landscaping, especially with trees, can increase property values as much as 20 percent. -Management Information Services/ICMA

One acre of forest absorbs six tons of carbon dioxide and puts out four tons of oxygen. This is enough to meet the annual needs of 18 people. -U.S. Department of Agriculture

There are about 60-to 200- million spaces along our city streets where trees could be planted. This translates to the potential to absorb 33 million more tons of CO2 every year, and saving $4 billion in energy costs. -National Wildlife Federation

Trees properly placed around buildings can reduce air conditioning needs by 30 percent and can save 20 - 50 percent in energy used for heating. -USDA Forest Service

Trees can be a stimulus to economic development, attracting new business and tourism. Commercial retail areas are more attractive to shoppers, apartments rent more quickly, tenants stay longer, and space in a wooded setting is more valuable to sell or rent. -The National Arbor Day Foundation

Shade from trees could save up to $175 per year (per structure) in air conditioning costs. -Dr. Lowell Ponte

Healthy, mature trees add an average of 10 percent to a property's value. -USDA Forest Service

The planting of trees means improved water quality, resulting in less runoff and erosion. This allows more recharging of the ground water supply. Wooded areas help prevent the transport of sediment and chemicals into streams. -USDA Forest Service

In laboratory research, visual exposure to settings with trees has produced significant recovery from stress within five minutes, as indicated by changes in blood pressure and muscle tension. -Dr. Roger S. Ulrich Texas A&M University

The benefits of trees are fairly well documented, fostering a healthier environment for humans and animals while simultaneously providing economic benefits. It is therefore important to continue to encourage the preservation and wise management of forest resources within the Township. This can be aided through the development review process, establishing strong limits of clearing and making tree and forest preservation a known priority.

Comparison of land use/land cover data from 1986 and 1995 shows that approximately 535 acres of forest land were converted to other land uses, as depicted in Figure 4. The data also indicates that a number of forested areas, primarily brush and shrubland, were converted to recreation uses and athletic fields. Comparison of the land use/land cover data also shows an increase of roughly 600 acres of forested areas between 1986 and 1995. The majority (roughly 500 acres) of these areas were recovered from crop and pastureland and are now successional fields of brush and shrubland (<25% brush covered), not necessarily "forest" in the traditional sense. The remainder (100 acres) was recovered from land uses classified as other urban, residential or recreational land in the 1986 land use/land cover data. Left untouched, these areas will eventually revert to mature forest cover. According to this data, the Township had a net gain of 65 acres of forested land cover over an 8 year period; overall, forested areas have seen significant decline in the last 25 years, as evidenced in Figure 3. And while a gain in forested area is apparent from 1986 to 1995, since 1972 Montgomery has lost 900 acres of forest land, representing a 14% decline.

Typically, forested areas that are converted to other land uses rarely revert to forest. The only gain that can reasonably be expected, as seen in comparison of the 1986 and 1995 land use/land cover information, comes from succession of agricultural land. Most of the lands which reverted to forest cover were fields that were less than 25% brush covered. These lands could easily be tilled and reclaimed for agricultural purposes. This makes the perceived "gain" in forested land cover somewhat suspect, as these

lands could have been reclaimed for agriculture in the year after the data was assembled.

Agricultural Lands[2]

In 1995, Montgomery Township had 5,733 acres of land which could be categorized as agricultural in nature, as depicted in Figure 5. This represents about 28% of the Township's total land area.

Crop and pastureland represent nearly 90% of agricultural land in Montgomery, comprising 5,100 acres. While crop and pastureland is present throughout the Township, the larger contiguous fields are located in the southern half. Also of note is the conspicuous absence of agricultural land cover from the Sourland Mountain. This is likely due to limited water supply in the Lockatong formation and the shallow nature of the soils, limiting their ability to sustain crops.

Agricultural wetlands comprise roughly 391 acres (7%) of agricultural land in Montgomery. Agricultural wetlands are wetland areas which have been graded or had drainage structures or tiles installed to keep them relatively dry. When they are actively farmed, they are not considered wetlands in the usual sense. Sometimes they would not be identified as wetlands in field delineation and are better categorized as agricultural land. If drainage tiles or other structures were removed or intercepted, however, it is likely they would revert to wetland areas.

The remaining categories of agricultural land cover are represented by orchards, vineyards and nurseries (65 acres), confined feeding operations (10 acres) and other agriculture (167 acres). Other agricultural uses are characterized by experimental fields, horse farms and isolated dikes and access roads.

[2] Agricultural lands data is taken from the New Jersey Department of Env. Protection 1995 Land Use/Land Cover data

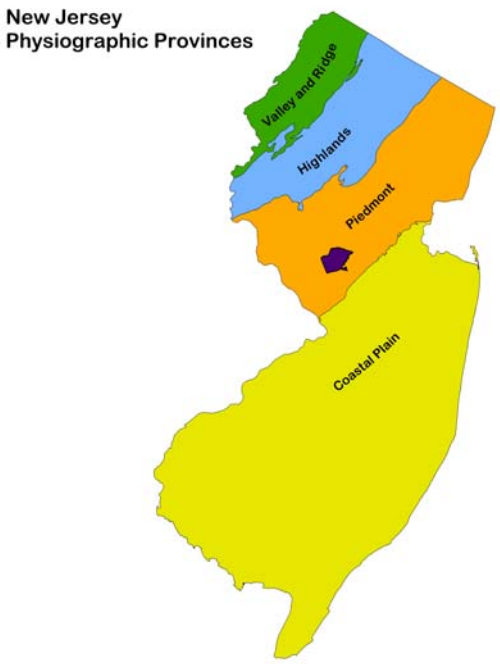
Comparison of the 1986 and 1995 land use/land cover data shows that 2,200 acres of agricultural land has been converted to other uses, as depicted on Figure 3. A majority of these viable agricultural lands were contiguous to other agricultural operations in the central portion of the Township. Over the last 25 years, the Township has seen a 48% decline in acreage devoted to agriculture; in 1972, roughly 10,277 acres were devoted to agriculture. This figure dropped nearly 5,000 acres according to the 1995 land use/land cover data compiled by the NJDEP. Although relatively insignificant, it should be noted that the Township gained roughly 30 acres of agricultural land from 1986 to 1995. The majority of this acreage came from conversion of brush covered fields and shrubland, but did include limited conversion of residential land uses to agriculture.

For the most part, once agricultural land is converted to residential or other developed use, it will not be converted back to agricultural production. As noted above, only 30 acres of land have been reclaimed for agricultural purposes since 1986, with only 6 of those acres reclaimed from residential uses. Even this reclamation is deceiving, as it is unlikely that any residence was demolished to make way for farm fields. More likely, pasture “crept” its way onto an adjacent residential property and consumed a portion of the lot. Another likely scenario is the demolition of a building that was misinterpreted as a residence in the 1986 land use/land cover data, thus being categorized as a residential use being reclaimed for agriculture in the 1995 land use/land cover data.

Conversion of land to agricultural use in Montgomery would come primarily at the expense of remaining forested areas and the Sourland Mountain, the latter likely not able to sustain agriculture in any event. Many of the forested areas that remain in the Township form critical buffers to streams; conversion of these forest areas would have a great impact on surface water quality.

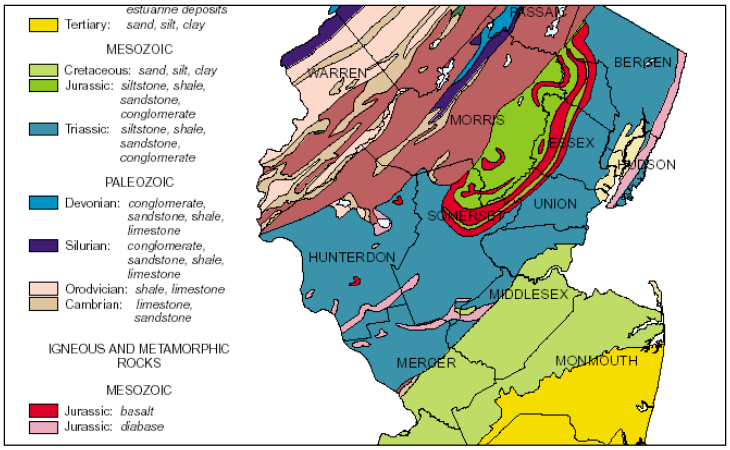
Geology [ii]

Montgomery Township falls within the Piedmont physiographic province of New Jersey, as depicted in the figure at the right. The geology of Montgomery Township is characterized by formations of the upper Triassic and lower Jurassic periods; two periods which came late in New Jersey's geologic history, approximately 190 to 200 million years ago. Only the Cretaceous period of the coastal plain occurred later, roughly 135 to 5.3 million years ago.



Source: *Map prepared byBanisch Associates, Inc., with data provided by the New Jersey Geological Survey.*

The geologic formations which underlie the Township (see Figure 6) are within the Newark Basin, generally characterized by rocks of the Newark Supergroup and the Brunswick Group (a Newark Supergroup subset). The Newark Basin, a rift basin, stretches from Bergen County at the New York/New Jersey border on a northeast to southwest axis (shown in blue on the figure at right). The rocks of the Newark Basin are made up of sedimentary and igneous Jurassic and Triassic rocks. The igneous rocks of the Basin are generally harder and more resistant to weathering, forming topographic highs and ridges, such as the Watchung Ridge (extrusive basalt) and the Sourland Mountain (intrusive diabase), the latter running through the western portion of Montgomery Township.



Source: *"Geologic Map of New Jersey", NJDEP Division of Science, Research and Technology, Geological Survey, 1999.*

The bedrock geology of the Township consists of both sedimentary and intrusive rocks; sedimentary rocks represented by the Lockatong, Stockton and Passaic formations and the intrusive rock represented by Jurassic Diabase. Approximately 81% of the Township is underlain by the Passaic Formation, with 11% underlain by the Lockatong, 5% by the Passaic Gray bed formation, 2% by the Stockton and 2% by the Jurassic Diabase. The mapping depicted in Figure 6 represents revised bedrock geology mapping published by the New Jersey Geological Survey in 2001. This was the first update of bedrock geology maps for the State since originally published in 1910-1912. The only change shown in Montgomery Township was distinction between the Passaic formation and the Passaic gray beds.

The Lockatong, Jurassic Diabase and Stockton formations form the Sourland Mountain along the northwestern boundary of Montgomery. The Sourland Mountain stretches from its beginning in Hillsborough Township, just north of Montgomery, through Montgomery, East Amwell, West Amwell and Hopewell Townships. It terminates at the Delaware River in West Amwell Township. In addition to an area in the Sourland Mountain, there is a wide intrusion of Jurassic Diabase in the southeastern corner of the Township. While the Diabase is closely linked to the Lockatong and Stockton formations in the Sourland Mountain, it is an igneous intrusive formation physically different from these two sedimentary formations. The Diabase was introduced as a lava flow in the already formed Lockatong and Stockton formations.

Most of Montgomery is underlain by the Passaic and Passaic Gray bed formations. These siltstone, sandstone and shale formations are commonly referred to simply as "shales". These formations were deposited cyclically as lacustrine sediments in response to the rise and fall of lake level within the Newark Basin. Older sediments are typically lake-margin sediments, with middle sediments typically lake-bottom sediments and younger sediments typically lake-margin or mudflat sediments. [iii] The Passaic formation was deposited during bundles of Van Houten cycles with periods of 100,000,

400,000 and 2,000,000 years. The Passaic Gray beds correspond to shorter Van Houten cycles of roughly 20,000 years. A Van Houten cycle is represented by a complete cycle of the lake-level rise, lake high-stand, and lake-level fall.

Groundwater Considerations

The Jurassic Diabase and the Lockatong are characterized by poor well yields and subsurface conditions generally unsuitable for septic systems. The diabase is a medium to coarse grained intrusive rock and is dense, hard and sparsely fractured. The Lockatong Formation is composed of dolomitic or silty argillite, mudstone, sandstone, siltstone, and minor silty limestone. In areas where it has been intruded by diabase, as in the Sourland Mountain region, the Lockatong has been chemically altered into hornfels, which are fine grained silicate rocks, dark grey or even green in appearance. When contact metamorphism occurs at shallow levels, as it has here in the Sourland Mountain region, the lack of pressure produces rocks with little foliation. With little foliation and therefore little fracture, water does not move readily through the rock structure or collect in great quantity in any one particular area. As a result, well yields in the Lockatong Formation are very low in places.

Studies on well yields and aquifer characteristics in the fragile Sourland Mountain ecosystem have been completed in adjacent East Amwell Township and Hopewell Township; West Amwell Township commissioned a study that is not yet completed. These studies examined the geologic formations present in the Mountain region, and the effect that rock formation has on the yields of aquifers. These studies also examined the capacity of the land to sustain development, as water availability from domestic wells drilled into these formations is the only source of drinking water. Disposal of effluent via septic system is also affected by underlying geologic formations and other related factors, as will be discussed.

A detailed study of geology and groundwater availability has not been undertaken for Montgomery Township. The studies of other communities, though, are relevant,

particularly in the Sourland Mountain region. The East Amwell and Hopewell groundwater studies both have similar findings in terms of the limited water availability and aquifer recharge, but the East Amwell study has a more detailed analysis of trend factors that could affect water availability in other places. Utilizing well records taken since 1990 under the Township Well Test Ordinance, the East Amwell report and analysis generally indicates that the Diabase and Lockatong formations present in the Sourland Mountain represent some of the poorest yielding aquifers in the State. The report also found that aquifer recharge to these formations is expected to be less than 2.1 inches per year. This is in sharp contrast to a 1995 USGS finding, indicating groundwater recharge of 4.96 inches per year; this has significant carrying capacity implications. The difference in the two figures above stems mainly from the method used to calculate base flow; the East Amwell report utilized the Posten Method while the USGS report utilized the Sliding Interval Method.

The results of the East Amwell groundwater study, as they relate to the Sourland Mountain region, are relevant for Montgomery, where the same formations are found. Analysis of trends evident in the East Amwell well data and application of statistical methods showed that geology is the controlling factor for groundwater availability, not the soils.

The geologic formations of the Sourland Mountain region also have a controlling impact on disposal of effluent utilizing a septic system. While soils have historically been the key factor in determining suitability for septic systems in other areas, the Sourland Mountain geology that shaped soil formation also controls subsurface movement of effluent once it enters the soil. As mentioned, the bedrock of the Sourland Mountain is hard and sparsely fractured, which contributes to limited availability of water. Wells on the mountain with good yields are generally drilled into fractured areas, where water makes rapid downward movement. It is these fractures, however, that present potential hazards for rapid groundwater contamination from septic effluent or other contaminants.

The shallow soils and hard bedrock create great lateral movement of water, where it seeks out fractures as it moves horizontally. Therefore, flow becomes concentrated in the area of fractures as water creates a gradient, moving towards fractures. Septic systems located close to a fracture can tap into the gradient and improperly treated effluent can migrate into fractures. This permits the rapid vertical movement of potentially contaminated water into the aquifer, where it could be taken up in domestic wells. This effect could be amplified if a number of septic systems are located in close proximity to each other and in close proximity to a fracture, especially if closely spaced domestic wells are also tapped into the same fracture.

Other studies have indicated expected groundwater yield for the formations which underlie Montgomery. These include a Hunterdon County study by Kasabach (1966), a 1984 Sourland Mountain ground water report by the Middlesex-Somerset-Mercer Regional Council and a 1995 USGS report by Lewis-Brown and Jacobsen for the Stony Brook, Bedens Brook and Jacobs Creek drainage basins. Generally, these reports found that groundwater yields are greatest from the Passaic formation (typically 15 gpm), with similar results expected from the Stockton formation. Yields from the Stockton formation are slightly lower, ranging from 12 gpm to 15 gpm. Yields from domestic wells drilled in the Lockatong formation, which represents most of the Sourland Mountain, (11% of the Township) are between 5 gpm and 7 gpm. Similar yields can be expected from the Diabase, although recent detailed studies in East Amwell Township indicate expected yields could be lower.

All of the underlying formations in the Township have one characteristic in common, evident in most of the studies completed in the area; shallow wells (less than 75 feet) in these formations typically have higher yields than deeper wells (100-300 feet). One exception can be seen in the Stockton formation, where the USGS study of 1995 indicated that wells drilled to depths greater than 300 feet are likely to encounter more water-bearing fractures. Technical descriptions of the various geologic units are included in Appendix 1.

Soils

The soils of Montgomery Township are varied in terms of their agricultural suitability, depth to bedrock and seasonal high water and suitability for on-site disposal of effluent. All of these characteristics are related by way of soil associations, as mapped in the "Soil Survey of Somerset County", published by the USDA Soil Conservation Service. In addition to the Soil Survey of Somerset County, the US Department of Agriculture Natural Resources Conservation Service published a digital soil survey and supporting data tables in September of 1998, know as the Soil Survey Geographic (SSURGO) database for Somerset County (see table in Appendix 1 for SSURGO Soil Characteristics). This digital data, used to create the maps depicted in Figures 7 through 13, is based on the Soil Survey of Somerset County, published in 1976.

There are five soil associations present in Montgomery, each of which are categorized based on the parent material from which they were formed. They can be described as follows[3]:

Soils formed mainly in glacial till or material weathered from granitic gneiss, diabase or basalt – The nearly level to very steep soils that make up these associations are dominantly gravelly, very stony, or rocky and are underlain by granitic gneiss, diabase, or basalt bedrock. The depth to bedrock is mainly 4 or more feet. In some areas of the steep and very steep soils, outcrops of bedrock are common. The soils of these associations are on ridges and are mostly wooded.

Neshaminy-Mount Lucas-Amwell Association: gently sloping to very steep, deep, well drained to somewhat poorly drained, loamy, gravelly and very stony soils that have bedrock mainly below a depth of 4 feet. This association is found atop the Diabase formation in the Sourland Mountain and along the southern boundary of Montgomery with Mercer County.

[3]Descriptions are taken verbatim from "Soil Survey of Somerset County, New Jersey", USDA Soil Conservation Service, December, 1976.

Soils formed in material weathered mainly from shale, siltstone, or sandstone but partly from conglomerate and argillite- The nearly level to very steep soils that make up these associations formed mainly in material weathered from red shale. In places they formed in material weathered from sandstone, siltstone, argillite, or conglomerate. The soils are mainly nearly level to strongly sloping. They have a surface layer of silt loam. The main farming areas of Somerset County are in these associations.

Penn-Klinesville-Reaville Association: nearly level to very steep, moderately deep and shallow, well drained to somewhat poorly drained loamy and shaly soils underlain mainly by red shale. This association is found throughout the central portion of the Township.

Royce-Penn-Klinesville Association: Gently sloping to very steep, deep to shallow, well-drained loamy and stony soils underlain mainly by red shale. This association is found in pockets in the central portion of the Township, along the base of the Sourland Mountain, along the northern border of the Township with Hillsborough and near Rocky Hill.

Chalfont-Lehigh-Croton Association: Nearly level to steep, deep, poorly drained to moderately well-drained loamy and stony soils underlain mainly by argillite or metamorphosed shale; on uplands. This association is found atop the Lockatong and Stockton formations on the Sourland Mountain, in the western border of the Township with Hillsborough.

Soils formed in recent alluvium and old alluvium- The nearly level to strongly sloping soils that make up these associations are on the flood plains and terraces along the major streams. They were formed predominantly in stream sediment and glacial outwash material. The soils of these associations are mainly farmed or are in pasture.

Rowland-Birdsboro-Raritan Association: nearly level to strongly sloping, deep, well drained to somewhat poorly drained loamy soils formed in alluvial sediment, on floodplains and terraces. This association is present along the banks of the Millstone River.

Farmland Capability

Figure 7 depicts farmland capability for the soils present in Montgomery Township. Farmland capability was mapped by applying designations contained in the State Agriculture Development Board's study entitled "New Jersey Important Farmlands Inventory", prepared in 1990, to the SSURGO digital soils database from the Montgomery Township GIS (see table in Appendix 1 for SSURGO Soil Characteristics).

There is a predominance of highly capable agricultural soils throughout the Township, which includes prime soils, statewide important soils and soils of local importance. The following descriptions of prime farmlands, soils of statewide importance and farmland of local importance are taken directly from the "New Jersey Important Farmlands Inventory", prepared by the State Agriculture Development Committee in 1990. Not included in this description is the category for unique farmlands, the generally poorly drained soils used for specialty crops such as cranberries and blueberries, which do not occur in the Township.

Prime Farmlands - Prime Farmlands include all those soils in Land Capability Class I and selected soils from Land Capability Class II. Prime Farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber and oilseed crops and is also available for these uses. It has the soil quality, growing season, and moisture supply needed to economically produce sustained high yields of crops when treated and managed according to acceptable farming methods. Prime Farmlands are not excessively erodible or saturated with water for a long period of time, and they either do not flood frequently or are protected from flooding.

Soils of Statewide Importance - Farmlands of statewide importance include those soils in Land Capability Classes II and III that do not meet the criteria as Prime Farmland. These soils are nearly Prime Farmland and economically produce high yields of crops when treated and managed according to acceptable farming methods. Some may produce yields as high as Prime Farmland if conditions are favorable.

Farmland of Local Importance - Farmland of local importance includes those soils that are not prime or statewide importance and are used for the production of high value food, fiber or horticultural crops.

Prime agricultural soils make up 36% of all the soils within Montgomery Township. With statewide important soils accounting for 33% and soils of local importance comprising 25%, there are few areas in the Township not capable of supporting some form of agriculture. A majority of the productive soils in the northeastern and southwestern quadrants of the Township have been permanently converted to residential uses. There are, however, large tracts of land which possess the soil resources to continue agricultural production. They are primarily found along the base of the Sourland Mountain ridge west of the railroad, between County Routes 518 and 601 in the core of the Township, south of County Route 518 in the central portion of southern Montgomery Township and north and south of Orchard Road.

Highly productive soils are a finite resource. Once converted to developed uses it is unlikely they will be returned to agricultural uses. In addition, agricultural soils form the backbone of farming, a prized part of the Township's agrarian history. With only one-quarter of the Township's land remaining in some form of agricultural production, protection of remaining undeveloped fertile lands is paramount to the continuation of agriculture in Montgomery.

On-Site Disposal of Effluent

Another property of soils related to community development potential is their ability to dispose of effluent on-site utilizing a septic system. Both the Somerset County Soil Survey and the Standards for Individual Subsurface Sewage Disposal Systems (N.J.A.C. 7:9A) classify soils based on their ability to properly dispose of effluent utilizing a septic system (see table in Appendix 1 for SSURGO Soil Characteristics). The latter statute, adopted by the NJDEP in 1999, represents the most recent scientific information from the Department and is considered the appropriate source when considering suitability for on-site septic disposal. Both are mapped and presented for comparison, Figure 8 depicting Somerset County Soil Survey classification and Figure 9 depicting N.J.A.C. 7:9A classification.

The Somerset County Soil Survey (December of 1976) presents information on the limitations of soils to dispose of effluent from septic systems, which is depicted on Figure 8. An overwhelming majority (84%) of the soils in Montgomery Township have severe limitations for disposal of effluent. The two most important factors that combine to dictate the ability to process effluent are depth to bedrock and depth to seasonal high water, shown on Figures 11 and 12. Other factors that influence the ability of a soil to dispose of septic effluent are permeability, shrink and swell capacity and clay content. Conditions lending to severe limitations for on-site disposal of effluent via a septic system include a perched water table, slow permeability in the subsoil or fragipan layer, hazard of stream overflow, frequent flooding, moderately steep slopes, and pervious shale bedrock at shallow depth. While all of these factors contribute to limitations, depth to bedrock and depth to seasonal high water are the key factors.

Moderate limitations for on-site septic disposal are present on 13% of the soils within the Township. While they are scattered throughout Montgomery, the primary concentrations are in the central portion of the Township, north and east of the railroad line on the western border with Hopewell Township and around Rocky Hill Borough. Conditions lending to moderate limitations for on-site disposal of effluent include rapid

permeability in the substratum, moderate depth to bedrock (3.5 to 6 feet), strong slopes and a hazard of groundwater pollution. Generally, moderate limitations are distinguished from severe limitations by the depth at which contributing conditions occur; a moderate limitation rating exhibits greater depth to limiting characteristics while a severe limitation exhibits shallow depth to limiting characteristics.

Slight limitations to the installation of on-site septic systems occur on only 2% of the soils in Montgomery. A majority of these soils are located in the southeastern portion of the Township, adjacent to Rocky Hill, while isolated pockets are present south of Bedens Brook Road, east and west of Opposum Road, north of Orchard Road and east and west of the railroad line north of County Route 601. The Soil Survey of Somerset County lists hazard of groundwater pollution as a contributing factor to a slight limitation rating.

With the adoption of N.J.A.C. 7:9A "Standards for Individual Subsurface Sewage Disposal Systems", the NJDEP essentially rewrote the book on classifying soils for their suitability to dispose of effluent via a septic system and the appropriate type of system to be used given certain limitations. In the absence of detailed on-site soil investigation, the Soil Survey mapping is used to determine the location of soil series, and the newly adopted standards specify the types of limiting zones that may be present and the type of system to be used, if any. Figure 9 shows the soils of Montgomery Township as classified by Appendix D of N.J.A.C. 7:9A; Table 4, on the following page, lists the type of septic system permitted given the suitability class. Septic system types include conventional systems, soil replacement bottom-lined systems, soil replacement fill-enclosed systems, mound systems and mounded soil replacement systems.

Table 4 – N.J.A.C. 7:9A Limiting Zones

Type of Limiting Zone	Depth[2], ft.	Suitability Class	Type of Installation Permitted[3]
Fracture Rock or Excessively Coarse Substrata	>5	I	C, (SRB, SRE, M, MSR)
	0-5	IISc	SRE, M, (MSR)
Massive Rock Hydraulically Restrictive Substratum	>9	I	C, (SRB, SRE, M, MSR)
	4-9	IISr	M, (MSR)
	<4	IIISr	UNSUITABLE
Hydraulically Restrictive Horizon, Permeable Substratum	>9	I	C, (SRB, SRE, M, MSR)
	4-9	IIHr	SRB, SRE, M, (MSR)
	<4	IIIHr	SRB, SRE, (MSR)
Excessively Coarse Horizon	>5	I	C, (SRB, SRE, M, MSR)
	0-5	IIHc	SRE, M, (MSR)
Zone of Saturation, Regional	>5	I	C, (SRB, SRE, M, MSR)
	2-5	IIWr	M, (MSR)
	<5	IIIWr	UNSUITABLE
Zone of Saturation, Perched	>5	I	C, (SRB, SRE, M, MSR)
	2-5	IIWp	C[4], (SRB, SRE, M, MSR)
	<5	IIIWp	C[4], (SRB, SRE, M, MSR)

C = Conventional Installation

SRB = Soil Replacement, Bottom-lined Installation

SRE = Soil Replacement, Fill-enclosed Installation

M = Mound Installation

MSR = Mounded Soil Replacement Installation1

(1) Mounded soil replacement systems are generally required only in cases where several limiting zones are present as, for example, in compound soil suitability classes such as IIScWr, IIIHr (IISr) or IIIHr(IIWr).

(2) Depth is measured from the existing ground surface to the top of the limiting zone. In the case of disturbed ground, the depth to the limiting zone shall be measured from the pre-existing natural ground surface, identified as prescribed in N.J.A.C. 7:9A-5.10(c), or the existing ground surface, whichever is lowest.

(3) Installations shown in parentheses are allowed but are generally not the most cost-effective type of installation for the soil suitability class unless other soil limitations are present.

(4) An interceptor drain or other means of removing the perched zone of saturation is required. Note: In soils with a compound soil suitability class, where more than one limiting zone is present in the soil, a disposal field installation shall not be approved unless the type of installation proposed is listed in Table 10.1 as an acceptable option for each of the soil suitability classes which apply.

The 1999 standards adopted by the Department indicate there are certain types of soils with limiting zones that create situations unsuitable for any type of septic system installation. A number of these soil types are present in the Township (primarily on the Sourland Mountain and along stream beds) and are mapped in Figure 10. These soils cover approximately 25% of the Township. Figure 10 is a generalization of soil types based on the mapping in the Soil Survey, with the suitability classes from N.J.A.C. 7:9A

applied. This is the prescribed method in N.J.A.C. 7:9A for making initial determination of soil suitability. Only detailed site investigation, however, can verify the presence or absence of the limiting zones. This map is nonetheless extremely useful for planning purposes, and gives an excellent picture of the types of limitations that may exist and how policy should be shaped to accommodate them to protect the health and safety of residents.

Depth to Bedrock

Figure 11 depicts the depth to bedrock for soils found in the Township, as classified in the SSURGO database from the Montgomery Township GIS (see table in Appendix 1 for SSURGO Soil Characteristics). As noted in the table below, a significant number of soils have relatively shallow depths to bedrock, with 17% of the soils having a depth to bedrock less than 20 inches. These soils are primarily concentrated in the central portion of the Township. Soils with a depth to bedrock of 20 inches to 40 inches can be characterized as moderately deep. These soils represent 33% of those found within Montgomery and are concentrated in the central and northeastern part of the Township. Of the remaining soil types, 39% have what could be considered deep depth to bedrock, ranging from greater than 40 inches to 60 inches. These soil types are primarily found atop and along the base of the Sourland Mountain, in the center of Montgomery, near Rocky Hill and along the Township's southern border with Mercer County. A mere 10% of soils show a clear indication of very deep depth to bedrock, generally greater than 60 inches. These soils are located in the stream and river beds of Montgomery.

Depth to bedrock is one of the components that determine suitability for septic disposal of effluent. The depth (profile) of the soil has a direct relationship to its ability to process effluent effectively, as soils remove nitrates and other organic compounds present in human waste. Generally, the more soil present, the better its processing capabilities. This is of course dependent on the type of soil and its permeability; sandy soils generally drain rapidly and heavy clay soils generally drain slowly, affecting their ability to filter human waste. Depth to bedrock also influences other community development factors such as septic system installation, road construction, basement and foundation

construction, landscaping and drainage. Soils with a depth to bedrock greater than 72 inches are generally unconstrained with respect to the above factors, whereas moderate and shallow depths to bedrock experience varying degrees of limitation, the latter with a tendency towards severe limitations.

Depth to Seasonal High Water

Figure 12 depicts depth to seasonal high water for the soils found in Montgomery Township (see table in Appendix 1 for SSURGO Soil Characteristics). Depth to seasonal high water indicates the highest level below the surface that groundwater reaches in most years, typically occurring between October and June, with variations in the length of time dependent on soil type. Those soils with depth to seasonal high water of 4 feet or less exhibit two water table types; apparent and perched. An apparent water table is illustrated by water standing in a freshly dug hole. These soil types generally coincide with stream beds and wetland areas, but do occur in other locations spread throughout the Township. Of the soils with depth to seasonal high water of 4 feet or less, 21% (4,444 acres) are classified as having an apparent water table. A perched water table is characterized by water standing above an unsaturated zone in the soil horizon, often obstructed by an impermeable or hydraulically restrictive layer within the profile. While a few of these soil types coincide with wetland areas, most are located atop and along the base of the Sourland Mountain, with additional areas stretched along the Township's southern border with Mercer County. These soil types represent 22% (4,654 acres) of the soils with depths to seasonal high water of 4 feet or less.

Depth to seasonal high water is important in determining limitations for development. Potential impacts from a seasonally high water table include flooding of basements, weakening of foundations and serious limitations for on-site disposal of effluent.

Shallow seasonal high water tables, while presenting limitations for development, also support diverse plant and wildlife communities. A majority of soils with depths to seasonal high water less than 4 feet, exhibiting both apparent and perched water tables,

coincide with stream corridors and their associated wetlands or are located on the Sourland Mountain. Moderate or shallow depth to seasonal high water is a good indicator of lands which deserve further study, perhaps warranting protection to limit destruction of private property and fostering of diverse plant and animal communities that may support critical habitat for threatened and endangered species.

Of the soils in the Montgomery, 42% have generally shallow depths to seasonal high water, ranging from 0 to 3 feet. Of these soils, only 3% exhibit depth to seasonal high water of 1 foot or less. Soil types with generally shallow depth to seasonal high water are almost exclusively located on or around the Sourland Mountain, along stream beds or in the southern portion of the Township bordering Mercer County. There are, however, isolated pockets located in the northeastern corner and central core of Montgomery. These seasonally high water tables support wetland systems associated with river and stream systems, deciduous wooded wetlands which act as headwaters for numerous streams and diverse vernal or emergent ecosystems present in the Sourland Mountain region and along rivers and streams.

Shallow depth to seasonal high water presents numerous limitations for development, most notably installation and maintenance of septic systems. Even with soil replacement and other engineering measures, septic systems placed in high water tables have the potential to pollute groundwater. When soils exhibiting shallow depths to seasonal high water are located adjacent to streams, there is also the potential for surface water contamination in periods of flooding. If a system is maintained improperly and ceases to function, effluent from the disposal field that rises to the surface can be carried off in surface water. Even in periods when flooding is not prevalent, a failing septic system can introduce surface contamination into surface waters.

A mere 2% (466 acres) of soils in Montgomery possess what can be characterized as moderate depth to seasonal high water, generally around 4 feet. These soils are primarily located near Rocky Hill, with small pockets east and west of the rail line in the

central portion of the Township and in the southwestern corner bordering Hopewell Township. As compared to soils exhibiting shallow depths to seasonal high water, soils with generally moderate depths have only a few limitations for community development factors. They can have an impact on the installation of foundations and septic systems, depending on site specific conditions and the duration of the high water table.

A majority of the soils in the Township, 56% (11,585 acres), have generally deep depths to seasonal high water at 6 feet. While these soil types are found throughout Montgomery, they are generally found in a swath running from northeast to southwest between the Sourland Mountain and the hills in the southern portion of the Township. They are interlaced with soils exhibiting generally shallow depth to seasonal high water, associated primarily with stream corridors and wetland areas. Most of the soils with generally deep depth to seasonal high water coincide with agriculturally productive soils of prime classification, some of which are currently in agricultural production. The soils in this category are least susceptible to potential problems related to development and any of the minor limitations that may be present can be overcome.

Highly Erodible Lands

The United States Department of Agriculture, Natural Resources Conservation Service rates soils based on their potential for erosion by wind and water. This is referred to as the "Highly Erodible Lands" class. As none of the soils in Montgomery Township are rated as either "highly erodible" or "potentially highly erodible" for wind, they are not mapped. There are, however, soils in the Township rated for erodibility by water, as depicted in Figure 13 (see table in Appendix 1 for SSURGO Soil Characteristics).

Of the soils in Montgomery, 14% (2,819 acres) are rated as "Highly Erodible Land Class" in the SSURGO database. This indicates that the soil will erode when exposed to water, such as heavy rain or surface water runoff. A comparison of the location of "Highly Erodible Lands" and the steep slope mapping in Figure 20 shows that some of the "Highly Erodible Lands" are in areas of slope greater than 15%. Most of the soils in

this category are of the Chalfont, Klinesville, Lawrenceville, Lehigh, Mount Lucas and Penn Series. There are a number of soils designated as "Highly Erodible Lands", however, that are not located in areas of slopes greater than 15%. These include large areas on the Sourland Mountain north and south of Dutchtown-Zion Road and areas north of Cherry Valley Road and west of County Route 601. There are also other areas scattered throughout the Township.

Of the remaining soils in the Township, 75% (15,588 acres) are categorized as "Potentially Highly Erodible". This indicates these soils do not have the component of slope that "Highly Erodible Lands" do, but possess similar texture and surface properties and will experience erosion from heavy rain and swift moving surface water. This class is comprised of the entire spectrum of soils in the Township and is scattered throughout Montgomery. Only 11% (2,381 acres) are classified as "Not Highly Erodible", comprised of the Birdsboro, Bowmanville, Penn and Rowland series primarily found along the banks of streams and rivers.

Soils in the "Highly Erodible Lands" class require careful management in both farming and development. The USDA, under the "Highly Erodible Land and Wetland Conservation Act" restricts participation in certain funding programs for those producing an agricultural commodity on highly erodible land. Mitigation in the form of conservation plans and conservation systems can be implemented to address concerns of farming on highly erodible lands, however. In the course of permitted development, disturbance of highly erodible soils should be avoided unless adequate measures can be implemented to assure that erosion and soil loss will be minimized. Although some equate highly erodible lands with areas of steep slope, there are areas of highly erodible lands that do not coincide with slopes greater than 15%. These areas must be afforded protection, as minimizing soil loss will help eliminate potential surface water quality impairment while maximizing groundwater and aquifer recharge.

Surface Waters and Subwatersheds

The Millstone River is the principal surface water body in Montgomery, ultimately receiving drainage from the entire Township via a network of tributaries comprising 116 miles of surface waters. Surface waters in Montgomery Township are depicted on Figure 14. Table 5 lists the streams and rivers of Montgomery with their length, as well as the percentage of total stream length in the Township they represent.

Table 5 – Streams and Rivers

Stream or River Name	Length (miles)	%
Back Brook	14.55	12.5
Bedens Brook	21.65	18.6
Cherry Brook	6.54	5.6
Cruser Brook	7.63	6.6
Dead Tree Run	2.74	2.4
Millstone River	12.95	11.1
Pike Brook	7.52	6.5
Pike Run	6.26	5.4
Roaring Brook	4.95	4.3
Rock Brook	26.40	22.7
Van Horne Brook	4.96	4.3
Total	116.15	

Surface waters can be categorized by both order and type. Surface waters of first order are considered headwaters, the origin of all other surface waters of higher order. Of the surface waters in Montgomery, 42% (48 miles) are first order. A majority of these surface waters flow off of the Sourland Mountain, making it a significant headwaters region. Surface waters can also be classified by their type; river, stream or tributary. Tributaries make up 73% of the surface waters in Montgomery, with streams making up 35% and rivers 8%. Protection of surface waters assumes increasing importance as downstream waters become degraded.

The streams and tributaries in Montgomery generally flow west to east, with the exception of Pike Brook which flows north to south and Cherry Brook, which flows south to north. Both drain to Bedens Brook, which flows west to east and drains into the Millstone River just east of River Road.

There are a number of lakes and ponds in Montgomery, the most significant of which is Lake Sylvan, located in the central portion of the Township. As with many of the lakes and ponds, Lake Sylvan is part of a stream. Rock Brook flows into the western end of the lake and continues its flow at the east end of the lake. The same situation occurs with Mill Pond, with the Pike Brook as its source of flow. There are very few isolated surface waters in the Township, most being fed in one form or another by flowing streams.

Figure 14 also depicts subwatersheds present in Montgomery. Subwatersheds are smaller drainage basins within larger hydrological units. Water quality impacts are often easier to track in subwatersheds, especially those related to non-point source pollution. Due to their smaller size, it is easier to assess the location of potential pollution sources and determine impacts they may have on water quality.

According to data from the New Jersey Department of Environmental Protection, there are 9 individual subwatersheds within Montgomery, all of which are part of the Millstone River drainage basin, eventually draining to the Raritan River. None of these subwatersheds have their boundaries completely within the Township and some have only a small portion within Montgomery's boundaries. Table 6 lists the subwatersheds within the Township and their acreage.

Table 6 – Subwatersheds

Subwatershed Name	Hydrologic Unit Code (HUC)	Area (Acres)	%
Bedens Brook (above Province Line Rd.)	02030105110040	91.26	0.4
Bedens Brook (below Province Line Rd.)	02030105110050	5,346.34	25.7

Subwatershed Name	Hydrologic Unit Code (HUC)	Area (Acres)	%
Cruser Brook/Roaring Brook	02030105110090	2,423.09	11.7
Millstone River (Bedens Brook to Heathcote Brook)	02030105110030	1,161.28	5.6
Millstone River (Blackwells Mills to Bedens Brook)	02030105110110	1,143.13	5.5
Pike Run (above Cruser Brook)	02030105110080	608.86	2.9
Pike Run (below Cruser Brook)	02030105110100	6,497.83	31.3
Rock Brook (above Camp Meeting Avenue)	02030105110060	1,300.00	6.3
Rock Brook (below Camp Meeting Avenue)	02030105110070	2,216.17	10.7
Total		20,787.97	

Surface Water Quality

Preserving and enhancing surface water quality is of great importance for preserving the scenic and recreational opportunities that the Township's streams, rivers and lakes provide. The primary method of classifying water quality for streams and rivers in New Jersey is offered in the New Jersey Department of Environmental Protection (NJDEP), Division of Environmental Planning "Surface Water Quality Standards" (N.J.A.C 7:9B). Through these statewide standards, a regulatory framework is established and management policies are implemented based on the designation of streams as FW1 and FW2, Category 1 and 2 and either trout-producing, trout-maintenance or non-trout waters.

According to NJDEP, all surface waters within Montgomery are classified as "FW2". "FW2" *means the general surface water classification applied to those fresh waters that are not designated as FW1 or Pinelands Waters* [1]. As a frame of reference, "FW1" *means those fresh waters, as designated in N.J.A.C. 7:9B-1.15(h) Table 6, that are to be maintained in their natural state of quality (set aside for posterity) and not subjected to any man-made wastewater discharges or increases in runoff from anthropogenic activities. These waters are set aside for posterity because of their clarity, color, scenic setting, other characteristic or aesthetic value, unique ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s).*[iv] Possible uses described for FW2 waters include:

1. Maintenance, migration and propagation of the natural and established biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation, and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

In addition to the above classification and for purposes of implementing regulatory policy, surface waters are further categorized by the NJDEP as either "Category 1" or "Category 2". Category 1 waters "*means those waters designated in the tables in N.J.A.C. 7:9B-1.15(c) through (h), for purposes of implementing the antidegradation policies set forth at N.J.A.C. 7:9B-1.5(d), for protection from measurable changes in water quality characteristics because of their clarity, color, scenic setting, other characteristics of aesthetic value, exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s). These waters may include, but are not limited to:*

1. *Waters originating wholly within Federal, interstate, State, county, or municipal parks, forests, fish and wildlife lands, and other special holdings that have not been designated as FW1 at N.J.A.C. 7:9B-1.15(h) Table 6;*
2. *Waters classified at N.J.A.C. 7:9B-1.15(c) through (g) as FW2 trout production waters and their tributaries;*
3. *Surface waters classified in this subchapter as FW2 trout maintenance or FW2 nontrout that are upstream of waters classified in this subchapter as FW2 trout production;*

4. *Shellfish waters of exceptional resource value; or*
5. *Other waters and their tributaries that flow through, or border, Federal, State, county, or municipal parks, forests, fish and wildlife lands, and other special holdings."*[v]

Category 2 waters "*means those waters not designated as Outstanding National Resource Waters or Category One at N.J.A.C. 7:9B-1.15 for purposes of implementing the antidegradation policies set forth at N.J.A.C. 7:9B-1.5(d)."*[vi]

According to NJDEP, all surface waters within Montgomery are classified as Category 2 waters and fall under the general anti-degradation policies of the regulations as well as those specified for Category 2 waters. General anti-degradation policies seek to protect waterways from decline in quality while protecting the designated uses set forth. In addition to general policies, where water quality exceeds levels necessary to support the designated uses, that level shall be maintained unless deterioration would accomplish important social or economic goals. Further categorization of surface water is accomplished through designation as trout-producing, trout maintenance or non-trout waters; the surface waters of Montgomery are classified as non-trout waters.

None of the surface waters within the Township are afforded the protection of either Category 1 designation or designation as trout-producing or trout-maintenance water bodies. NJDEP is proposing, however, to reclassify certain waters within the State, some of which are within Montgomery. Reclassification is based on criteria established by the Department, including surface waters within HUC14's (hydrological unit code) with less than 10% impervious cover draining to water supply areas, surface waters draining to the Delaware and Raritan Canal and certain lands identified as ecologically significant by various departments and agencies with the state and Federal government. Included in the nominations are Bedens Brook, which flows through southern Montgomery, and the Millstone River, which forms the Township's eastern boundary.

The Surface Water Quality Standards adopted by the NJDEP in 1998 also established strict guidelines for the presence of numerous contaminants, both man-made and naturally occurring. Included in these categories are items such as fecal coliform, enterococci, dissolved oxygen, floating colloidal solids, petroleum hydrocarbons, phosphorus, suspended solids, total dissolved solids, sulfates and taste and odor producing substances. Also important, especially to future potential areas of Category 1 waters, are alterations to temperature and the addition of toxic substances.

AMNET Biological Monitoring and Water Quality

The Bureau of Freshwater Biological Monitoring, a division of the NJDEP, currently conducts monitoring of freshwater rivers and streams in New Jersey. The Ambient Biomonitoring Network (AMNET), NJDEP's monitoring program, has an average of 165 monitoring sites in the major drainage basins of the State, with 6 stations located within the borders of the Township.

NJDEP's AMNET monitoring program focuses on populations of macroinvertebrates (benthic communities) present in freshwaters. These biotic communities, which are mainly stationary and cost effective to monitor, integrate the effects of changes in water quality into their life cycle, providing effective indicators of change over time. AMNET has six monitoring stations for waterways in Montgomery, providing data from 1993-1994 and 1998-1999. Figure 15 depicts the location of these monitoring stations, with two along Rock Brook and additional monitoring locations along Bedens Brook, Pike Brook, Back Brook and Cruser Brook. This distribution of locations, along virtually every waterway of the Township except the Millstone River, provides a valuable tool for assessing changes in water quality. With additional sampling planned for 2003, a comprehensive means to monitor changes over time will be in place.

The AMNET data for the Montgomery shows that none of the six sites depicted on Figure 15 have non-impaired benthic communities. This was not the case when the first round of sampling was completed in 1993, when the stations at Cruser and Back Brook

showed no impairment. The monitoring completed in 1998 indicated that benthic communities in both of these waterways were subject to moderate impairment, with the Cruser Brook rating dropping from 27 to 21 and the Back Brook rating dropping from 24 to 21. The monitoring station at Pike Brook showed serious decline, having a moderate rating of 15 in 1993, dropping to a severe rating of 3 in 1998. Benthic communities present in this stretch of waterway indicate rapid decline in water quality. Two of the remaining sample sites, located along Bedens Brook and Rock Brook, indicated improved health in benthic communities; the Rock Brook monitoring location received a rating of 12 in 1993 and 18 in 1998 while the Bedens Brook monitoring location received a rating of 12 in 1993 and 15 in 1998. All of these scores indicate moderate impairment to the benthic communities present. The second sample site along Rock Brook received a rating of 21 in 1993, but no comparison can be made as a sample was not taken in 1998. The data for each AMNET site in Montgomery is indicated in the table below.

AMNET Biological Monitoring Program Data

Site	Stream	1993 Score	1993 Impairment Rating	1998 Score	1998 Impairment Rating	1998 Habitat Rating
AN0399	Rock Bk	12	Moderate	18	Moderate	161
AN0400	Rock Bk	21	Moderate	No Sample	No Sample	No Rating
AN0401	Bedens Bk	12	Moderate	15	Moderate	160
AN0403	Cruser Bk	27	None	21	Moderate	133
AN0404	Back Bk	24	None	21	Moderate	150
AN0405	Pike Run	15	Moderate	3	Severe	89

Note: Impairment rating is out of a possible 30, habitat rating is out of a possible 200.

The data for AMNET monitoring also includes an assessment of habitat within a 100-200 foot radius of the sampling site. This assessment, available only in the 1998 data, provides information on in-stream substrate, channel morphology, bank structural

features and riparian vegetation. Habitat assessment is done independent of biological monitoring and did not factor into the final impairment score for the monitoring sites for Montgomery. Both the Bedens Brook and Rock Brook sites scored 160 and 161 (out of 200) in the habitat assessment, indicating optimal habitat. The Cruser Brook (133) and Back Brook (150) sites scored in the range of sub-optimal habitat (110-159). The Pike Run monitoring site was rated 89 for habitat, indicating marginal habitat.

With data collected on a five year cycle, the AMNET monitoring program will continue to provide useful data for assessing the health of waterways statewide. With samples to be collected this year, the Township can continue to assess the health of surface waters through comparative assessment of macroinvertebrate communities. Once this data is released from the NJDEP, the Township should assess changes in water quality and determine if regulatory guidance at the local level is appropriate. As the main impact to water quality comes from surface runoff related to increased impervious surface, examination of impervious cover limitations would be an appropriate first step. This could be followed by creation of requirements for water quality buffers, water quality treatment methods (bio-retention and filtering basins as opposed to detention basins) and stricter requirements for infiltration; the latter would ultimately eliminate new surface runoff sources.

Wetlands

Wetland habitats generally occur between well-drained upland areas that rarely receive floodwater and low-lying, permanently flooded waters of lakes or streams. Wetlands characteristically include swamps, bogs, marshes and bottomland areas. Although they usually lie along rivers and lakes, wetlands may occur on slopes where they are associated with groundwater seeps or in areas of a perched water table, as is typical on the Sourland Mountain. Wetlands depicted on Figure 16 are taken from the New Jersey Department of Environmental Protection's Land Use/Land Cover information from 1995. Wetland features from this data set were derived from the Freshwater Wetlands (FWW) data from the New Jersey Freshwater Wetlands Mapping Project, which was combined

with the 1986 Integrated Terrain Unit Mapping (ITUM) to create the 1986 Land Use/Land Cover data.

The NJDEP wetland mapping in Figure 16 indicates that 2,915 acres of wetlands exist in Montgomery. The predominant wetland type is deciduous wooded, comprising just over 54% of the total acreage of wetlands at 1,580 acres. They are located primarily along stream corridors and in isolated pockets on the Sourland Mountain and in the southern portion of the Township. Agricultural wetlands represent the second largest type of wetland, comprising 18% (527 acres) of all wetland areas. Agricultural wetlands are wetland areas that have been modified for crop production, generally by the installation of drainage features such as ditches or tiles. When drainage features are removed and the land is allowed to fall into succession, these areas will generally revert to wetlands. Agricultural wetlands are typically located at the edge of existing wetland areas which abut field fringes. They are located throughout the Township, with a large expanse of farmed wetlands south of County Route 601 in the central portion of Montgomery.

Deciduous scrub/shrub and herbaceous wetlands make up the remainder of the significant wetland types, representing 12% (349 acres) and 8% (221 acres) respectively. Deciduous scrub/shrub wetlands are typically successional areas where vegetation is in early stages of growth. Left untouched, these areas will eventually likely become deciduous wooded wetland areas. Herbaceous wetlands are typically emergent-like habitats located along stream corridors where vegetation can be frequently flooded and run down by moving water. In late summer, vegetation is typically stable and hardy, maintaining a vegetative state below scrub/shrub.

The wetlands found along the Millstone River are dominated by deciduous wooded and herbaceous wetland types. These areas serve as valuable riparian zones, offering recreation opportunities for humans as well as valuable habitat and migration corridors for wildlife. These areas also serve as a water quality protection buffer. Additionally,

the wooded areas along stream and river corridors also offer protection from temperature fluctuations.

Thirteen wetland types are identified in Figure 16 and listed in Table 7 below.

Table 7 – Wetland Types

Type	Acres	Percentage
Mixed Forested Wetlands (Coniferous Dominant)	0.94	0.0
Mixed Forested Wetlands (Deciduous Dominant)	12.53	0.4
Mixed Scrub/Shrub Wetlands (Deciduous Dominant)	18.92	0.6
Coniferous Wooded Wetlands	1.82	0.1
Natural Lakes	3.38	0.1
Artificial Lakes	27.90	1.0
Disturbed Wetlands	37.65	1.3
Managed Wetlands	43.04	1.5
Streams and Canals	90.17	3.1
Herbaceous Wetlands	221.25	7.6
Deciduous Scrub/Shrub Wetlands	349.20	12.0
Agricultural Wetlands	527.28	18.1
Deciduous Wooded Wetlands	1,580.49	54.2
Total	**2,914.57**	**100.0**

A majority of the wetlands found in Montgomery are designated as Palustrine and can be described as marshy, boggy or swampy. The types of Palustrine wetlands in the Township are further defined according to the dominant types of vegetation found in each, or according to the form and composition of the substrate material of each wetland. The Palustrine Forested Broad Leaf Deciduous wetland, for example, is at least 50% forested and forested predominately with deciduous trees having broad leaves, such as oak or maple. The other classifications of palustrine wetlands include emergent, open water and scrub/shrub broad leaved deciduous. The open water classification refers to wetland areas that appear wet, as in ponded areas. The

emergent designation means that most of the characteristic vegetation is rooted in shallow water. Small trees and shrubs dominate the scrub/shrub type of wetland.

The importance of wetlands is multi-faceted. They serve as aquifer recharge areas and as areas that trap and filter pollutants through natural bio-chemical processes. The filtering capabilities of wetlands are particularly useful along waterways where protection of existing water quality is desirable. Wetlands in these areas may serve as a buffer to harmful non-point source pollutants.

Wetlands play a particularly valuable role on the Sourland Mountain, acting as headwaters to Rock Brook, Roaring Brook and Cruser Brook. While the wetlands that serve this function are limited in extent within the Township, they are nonetheless part of the larger Sourland Mountain region and a valuable piece of the ecosystem. As none of the streams which flow off the mountain are classified as trout-producing or trout maintenance, the wetlands in this area are not classified as being exceptional in value. In addition to acting as headwaters, the wetland systems of the Sourland Mountain capture and retain precipitation, slowly releasing it into the ground and recharging aquifers. This is critical as recharge on the mountain is extremely low.

Although State regulations afford protection for wetlands, they do not prevent destruction or disturbance per se, and it is prudent to consider additional environmental resource protection strategies that can build upon State protections. More and more, the importance of wetlands in flood control and water quality is becoming known. The importance of careful management of wetlands and their environs was highlighted by Hurricane Floyd in 1999, which destroyed millions of dollars worth of property and even claimed lives. Careful planning and location of development can avoid loss from such disasters in the future.

Floodplains and Floodprone Areas

The Federal Emergency Management Agency (FEMA) has prepared maps of the 100-year floodplain found along a majority of the streams and rivers in the Township, as taken from the Q3 Flood Digital database and depicted on Figure 17. This mapping is prepared to provide information to homeowners, floodplain managers, engineers and flood insurance providers on the flooding risks associated with the location of dwellings and structures. It should be noted that the digital floodplain data that FEMA provides was created by digitizing the existing Flood Insurance Rate Maps (FIRM) with varying scales. In most cases, the data is distorted to varying degrees and is useful only for generalized floodplain location and magnitude.

Montgomery Township participates in the National Flood Insurance Program (NFIP), whereby the Township has adopted standards regarding development in the floodplain. A Flood Hazard Study was completed for the Township in 1981, initiating their participation in the Program. Montgomery has implemented development regulations to prohibit or limit development in the floodplain to reduce the risk of flood damage and protect public safety.

FEMA requires all persons with improved property within a special flood hazard area as certified by the Township Flood Search Official and shown on the Flood Insurance Rate Maps (FIRM) to purchase flood insurance. They recommend that even those not directly in a flood hazard area purchase insurance, as flood damage can occur outside the flood hazard areas as well.

The mapping of floodplains provided by FEMA carries a number of different designations. The 100-year floodplain is delineated for most streams though some do not have base flood elevations (BFE's) determined, as indicated. Streams that do not have BFE's determined have not been subject to detailed hydraulic study to determine potential flood extent, and water levels during the 100-year storm have not been determined.

The Millstone River has an expansive 100-year floodplain, encroaching 1,500' in some areas of the Township. Significant 100-year floodplains are also depicted for Bedens Brook and Pike Brook, spanning 800' in places. The other streams in the Township also have floodplains mapped, although floodplain areas are reduced as you travel further upstream.

The USGS also compiles data on areas potentially subject to flooding, mapped in Figure 18 as areas documented as floodprone and areas that are floodprone and undocumented. Comparison to the FEMA mapping shows that the two data sets are generally consistent; however, the USGS data is spatially more reliable. Typically, the FEMA mapping will depict areas of potential flooding more expansive than the USGS data, as can be seen.

A majority of the streams and rivers in the Township have documented floodprone areas, with upstream reaches indicated as undocumented floodprone areas. These areas are generally consistent with the FEMA 100 year floodplain, but do vary.

The FIRM mapping of the 100-year floodplain and data provided by the USGS on floodprone areas are an essential resource that identifies the hazard of flood associated with areas in the Township. There are a number of areas not depicted as floodplain or floodprone which flood on a regular basis; this points to the need for creation of more complete and accurate flood data. The extent of the 100-year flood plain and floodprone areas impose severe limitations on development and sound policy is to prohibit development throughout these mapped areas, as the Township generally tries to do.

Riparian Areas

The health of surface waters within the Township is relative to the health of the areas that surround them, commonly known as riparian areas. The term riparian is derived

from the Latin "ripa", which means *bank* or *shore.* Riparian areas can be further defined in a number of ways, including:

> *The aquatic ecosystem and the portions of the adjacent terrestrial ecosystem that directly affect or are affected by the aquatic environment. This includes streams, rivers, lakes and bays and their adjacent side channels, flood plain and wetlands. In specific cases, the riparian area may also include a portion of the hillslope that directly serves as streamside habitats for wildlife.* – USDA Forest Service

> *Vegetated ecosystems along a waterbody through which energy, materials and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent water body. These systems encompass wetlands, uplands or some combination of these two landforms. They will not in all cases have all the characteristics necessary for them to be classified as wetlands.* - Coastal Zone Management Handbook

> *The lands adjacent to streams, rivers or other bodies of water where vegetation is strongly influenced by the presence of water.* - American Fisheries Society

Riparian areas are a diverse and important part of the ecosystem. Due to their position in the landscape, they are conveyed a great amount of energy and nutrients. But this position at the same time makes them most vulnerable, subject to a combination of effects which can be related directly to anthropogenic activities.

Riparian Area Functions

- **Maintenance of biodiversity**
- **Provision of forage and other food sources**
- **Protection of water quality**
- **Regulation of stream temperature**
- **Flood storage and release**
- **Provision of wildlife corridors**
- **Aquifer recharge and baseflow maintenance**
- **Terrestrial and amphibian habitat**
- **Recreation sites**
- **Stream bank stabilization**
- **Habitat for threatened and endangered species**

Riparian areas serve a multitude of functions for surface waters, the most critical of which is to provide a transition area from surrounding land uses. A forested riparian area acts as a stream or river stabilizer in many ways, controlling water temperature, stabilizing the stream bank, filtering pollutants from runoff, controlling sedimentation and contributing organic matter to the

stream ecosystem. Riparian forests are among the most healthy forest types, uniquely positioned to take advantage of abundant available water and receive the benefits of nutrient flow. They, in-turn, provide critical nutrients and woody debris which enhance stream health by providing habitat for in-stream organisms. This in turn enhances the overall health of the riparian ecosystem through ripple effects.

Careful delineation of riparian areas and implementation of appropriate management strategies can insure continued maintenance and potential enhancement of existing water quality. This is especially critical in more developed portions of the Township, where water quality will continue to decline if riparian areas are not better protected. Figure 19 depicts riparian areas for Montgomery Township, comprised of streams and their required buffer (including the 100-year floodplain), wetlands and slopes greater than 15% which are adjacent to required stream corridor buffers. This should be considered the minimum area of regulatory protection for riparian areas. Forested areas depicted on Figure 19 indicate where potential exists to extend riparian protection into non-wetland areas. Protection of portions of these adjacent forested areas will enhance water quality and stream health.

Also depicted in Figure 19 are AMNET monitoring locations where impairment of benthic communities has increased since 1993 (refer to table on Page 42 for detailed data). The monitoring location along Pike Brook at County Route 533 now shows benthic communities in a severe state of impairment, with rapid decline experienced since 1993. While the other two monitoring locations, along Back Brook and Cruser Brook, showed decline, they can still be classified as moderately impaired. Looking at development patterns, it should come as no surprise that water quality is declining at these locations, given the amount of upstream development. The Pike Brook monitoring location is downstream of the other two, located just upstream of the confluence of Pike Brook with Bedens Brook. The pattern evident in the data would suggest a synergistic effect, with impairment increasing as you progress further downstream.

Development and subsequent loss of riparian areas can have a number of negative impacts on surface waters. First and foremost, loss of riparian areas eliminates filtration of sediment and non-point source pollution, greatly impacting waterways. In addition to sediment which enters the stream from off-site sources, deterioration and elimination of stream-side and stream bank vegetation lends to scouring, which causes bank deterioration and contributes to further erosion and sedimentation. Streams lacking forested or even vegetative riparian areas also lack habitat provided by woody debris. In-stream woody debris not only provides areas for fish and amphibians to reproduce, it also provides critical nutrients and substrate. Road crossings, which include bridges and culverts, are also destructive to riparian areas and stream channels. Crossings create breaks in an otherwise uninterrupted corridor, making wildlife migration difficult. Bridges are also prime sources of non-point pollution, often washed directly into the stream from the bridge deck.

Proposed amendments to New Jersey's stormwater management regulations will likely provide future guidance and additional protection measures for riparian areas. The "special resource protection" area requirement proposed to be implemented for Category 1 waters in the State would require a 300' buffer (minimum 150') around such streams. The special resource protection area is to be left in a natural state, with no installation of structural stormwater management facilities. The New Jersey Department of Environmental Protection is seeking to implement this requirement in order to protect surface water quality from new stormwater discharges, which often carry non-point source pollution and eroded sediment into waterways. Currently, regulations focus on moving stormwater runoff efficiently into surface waters. The proposed regulations will implement a vegetative buffer which will offer filtration of run-off, reducing non-point source pollutants and sediment reaching streams. As noted previously, Bedens Brook and the Millstone River have been nominated by the NJDEP for reclassification as Category 1 waters, which would be subject to the special resource area requirement.

In addition to the physical characteristics of riparian areas, there are intrinsic social and economic contributions which riparian areas make. Riparian areas provide passive recreation sites which can be enjoyed by the community. An interconnected stream network and its associated riparian areas present the opportunity for greenways which can span the entire Township. Homes located along riparian areas and stream corridors have a perceived aesthetic value which can be enhanced by the permanent protection of streamside lands.

Steep Slopes and Topography

Montgomery Township is characterized by two general landforms; flat to gently rolling expanses in the lower elevations, and the higher elevation areas of the prominent Sourland Mountain. Since areas of Montgomery east and south of the Mountain are relatively flat, the mountain is clearly visible on the western horizon from a majority of locations. Figure 20, which depicts the topography of the Township, was derived from a digital elevation model and "hillshaded" to add depth to the visualization. The Sourland Mountain and Pheasant Hill, in the western portion of the Township, have their highest elevation around 465' and represent the most prominent topographic features in Montgomery. The Rock Brook stream corridor offers a dramatic element, forming a ravine in the area of Hollow Road, surrounded by two high mounds where it flows out of the Sourland Mountain. Another such feature is present where the Roaring Brook flows off the Mountain in the northeastern corner of the Township, although not as dramatic. The remainder of the Township is relatively flat and rolling, with the exception of some minor hills in southern Montgomery.

Steep slopes, depicted on Figure 21, represent transitional areas in the landscape; transition from higher terrain to lower terrain and transition into areas of stream corridors. The latter are often created by the erosional effects of water scouring the landscape. The most extensive areas of steep slope are found along the eastern face of the Sourland Mountain in two distinct areas. The first is in the vicinity of Rock Brook near Hollow Road. This area extends roughly from Hillside Terrace to the Township's

western border, running parallel to the rail line. The second extends from Back Brook to the Township's northern border with Hillsborough. Both of these areas represent the broadest expanses of slopes greater than 25%, the most critical for protection.

Steep slopes are not confined to the area surrounding the Sourland Mountain, where one might expect. A majority of stream corridors possess areas of steep slopes leading up to or as part of their banks. The most prominent streamside slopes are along Bedens Brook. The minor hills that form the southern portion of the Township have distinct ridgelines in relatively close proximity to streams with steep transitional slope areas. Beyond the Sourland Mountain, Back Brook and Cruser Brook have little in the way of streamside slopes. The same is true for Pike Brook. The Millstone River has extensive steep slopes north and south of Rocky Hill in Montgomery near Hillsborough.

Steep slopes have a number of implications for community development and the environment. Slopes in excess of 25% present serious limitations for development, often requiring extensive and costly engineering for construction. Development on slopes in excess of 15% can degrade the environment, if not properly managed. Since most slopes occur in and around the banks of streams and rivers, clearing in these areas creates the potential for erosion and stream sedimentation. With many of the steep slopes in the Township occurring near the banks of rivers and streams, protection of steep slope areas becomes more critical. The clearing of trees and vegetation that stabilizes the slope not only causes erosion and sedimentation problems, it can also contribute to increased water temperatures in streams and rivers.

Another potential area of concern relates to agricultural operations near steep slopes and stream courses. Agricultural operations include the grazing of animals and use of pesticides and fertilizers. Where grazing occurs along steep stream banks, animals can seriously degrade and destabilize these banks when seeking water. Animals accessing streams through areas of steep banks can destroy vegetation while increasing erosion and sedimentation and introducing manure directly into surface waters.

Ridgelines

Ridgelines are valuable topographic features often prominent in the visual landscape. Simply defined, a ridgeline is *a horizontal line or demarcation representing the intersection of two slopes having generally opposing aspects, usually representing the highest common elevation of both.* The prominence of ridgelines varies depending on the surrounding terrain, and a ridgeline may not be visible from the surrounding landscape if there are only moderate elevation changes. Its visual impact is therefore diminished, as in much of Montgomery.

Figure 21 depicts the ridgelines in Montgomery, delineated based on the above definition. Utilizing the Township's 10 Foot digital elevation model, contour information and 3-dimensional visualizations of terrain, ridgelines were delineated manually. The most prominent ridgelines in the Township are associated with the Sourland Mountain and Pheasant Hill. The area southwest and northeast of Hollow Road has three ridgelines which run parallel to the rail line. The southern portion of the Township is characterized by the presence of ridgelines, although not as pronounced as those on the Sourland Mountain and Pheasant Hill. These hills, their highest elevation reaching roughly 260', stretch west to east along the Township border with Mercer County. A majority of these ridgelines run west to east as well, with some projecting to the north.

There are a number of other ridgeline features in the central part of the Township, which is characterized by rolling terrain. The most apparent of these relatively minor ridgeline features stretches west to east between County Route 518 and Rock Brook, extending from Spring Hill Road to the confluence of Rock Brook and Bedens Brook. Many of the other ridgelines in the lower elevations of Montgomery are barely noticeable, although they do fit the definition of a ridgeline.

Visual interest, like beauty, is in the eye of the beholder. The view from a ridge-top home, while spectacular, degrades the view of the natural ridgeline. Frank Lloyd Wright

admonished us to never build on top of a hill, because we "lose" the hill. Development of ridgelines can have major impacts on visual resources. They represent desirable locations for residential home sites, taking advantage of views to the surrounding landscape. Many times, forested ridgelines are cleared to make way for homes. Selective cutting of trees and careful placement of the building envelope can minimize disturbance to the visual landscape. Ridgelines should be considered valuable community assets. Development on ridgelines replaces these community assets to the benefit of few.

Wildlife and Critical Habitat

In 1993, the New Jersey Department of Environmental Protection Endangered and Non-game Species Program (ENSP) initiated a move to a landscape level approach for endangered species protection. With suburbanization and development occurring in all areas of the State, an increasing amount of habitat that could potentially support threatened and endangered species was being lost daily.

In order to address habitat loss, ENSP needed to grasp the extent and suitability of remaining resources in the State. To accomplish this, they partnered with the Center for Remote Sensing and Spatial Analysis (CRSSA) at Cook College, Rutgers University. Utilizing LandSat Thematic Mapper satellite imagery, CRSSA mapped land cover for the entire State of New Jersey, broken down into 20 different habitat/land cover types. After generalized cover types were classified, detailed methodologies were developed to address the habitat suitability issues for each focus category, including beach/dunes, emergent landscapes, forested wetlands, forested areas and grasslands.

After reclassifying data based on standards developed for each category, the habitat data was intersected or combined with the Natural Heritage Program's Biological Conservation Database (BCD). This database is a Geographic Information System (GIS) coverage that provides information on the sighting of threatened and endangered species, based on the field work of ENSP scientists and sightings reported by members

of the public. It is the most comprehensive data available in digital form on the location of threatened and endangered species.

The Landscape Program data provides users with scientifically sound, peer-reviewed information on the location of critical habitat based on the conservation status of the species that are present. Habitats are ranked on a scale of 1 to 5, based on the following criteria:

Table 8 - NJ Landscape Program Ranking System

Rank	Indication
1	Suitable habitat, no special concern, threatened or endangered species sighted
2	Habitat patch with species of special concern present
3	Habitat patch with State threatened species present
4	Habitat patch with State endangered species present
5	Habitat patch with Federal threatened or endangered species present

Montgomery is rich in habitat suitable to support populations of threatened and endangered species, as depicted on Figure 22. This includes forest, grassland, emergent and forested wetland areas that canvas the Township. The highest concentrations of valuable habitat are associated with the Sourland Mountain and Pheasant Hill and the agricultural lands in the central and western portions of the Township. Forest and grassland habitat comprise the majority of critical habitat in Montgomery.

The critical forest habitat of the Sourland Mountain supporting state endangered species stretches from the northern boundary of the Township with Hillsborough southwest along the mountain into East Amwell and Hopewell Townships. It penetrates a portion of the lower lying elevations as well. Forest habitat in the southeastern corner of the Township directly south of Rocky Hill also has the documented presence of state endangered species. Additional forest resources in the southern part of the Township

along the border of Mercer County have the documented presence of state threatened species.

Grasslands supporting populations of state endangered species are present north of County Route 518 west of County Route 601. Other grassland habitats supporting populations of state threatened species are located north and south of County Route 518 east of County Route 601 in the central portion of southern Montgomery and are more expansive than grassland areas supporting state endangered species. The foot of the Sourland Mountain has grassland of a similar nature. All of these grasslands habitats are primarily associated with active agricultural operations which likely involve the production of hay or other grass-like crops. These lands are uniquely suited to reproducing populations of neo-tropical migrating birds.

Montgomery also has critical emergent and forested wetland habitat. These habitats are not as high ranking and expansive as the forest and grassland habitats, yet are nonetheless worthy of noting. Emergent habitats are critical to the reproductive cycles of many amphibian species, reliant on both emergent wetlands and spring (vernal) pools for this process. The NJDEP, in cooperation with The Center for Remote Sensing and Spatial Analysis (CRSSA) at Cook College developed a project to identify and monitor vernal habitats, which will eventually be incorporated into the Landscape Project data. New regulations adopted in 2001 afford protection to emergent and vernal habitats where previously none existed. This lack of protection was largely due to the size of pools and isolated emergent areas, as many are less than 1 acre and could be drained and filled with a general wetland permit. CRSSA and NJDEP are developing maps of both potential and certified vernal and emergent habitats.

The forested wetland habitat depicted on Figure 22 is primarily suitable habitat, with isolated areas of habitat which has the documented presence of state threatened species. Suitable habitats are located along the central part of the Millstone River and at the headwaters of Van Horne Brook. Areas of habitat with documented sightings of

state threatened species are located along the northern part of Millstone River and along Bedens Brook west of Route 206.

The Landscape Project data is intended to aid municipalities, County and State governments, conservation agencies and citizens in determining the extent of critical habitat within their respective jurisdictions and communities. After identifying critical habitat, a variety of means can be employed to protect it, including the following:

- Prioritizing open space acquisitions based on the presence of habitat for threatened and endangered species
- Adopting regulations aimed at protecting critical habitat
- Adopting management policies for open space that are consistent with protection of critical habitat
- Permitting flexibility in development techniques that can accommodate the protection of critical habitat
- Promoting land stewardship practices that are consistent with the protection of critical habitat

Many of the habitat areas identified by the Landscape Project from the 1995 land use/land cover information have since been converted to other land uses, primarily residential. This is evident from comparison of the parcel base map and the land cover data. In order for critical habitat information to be utilized in the ways suggested by the Landscape Project, updated land use/land cover information should be compiled and an assessment of remaining habitat areas completed.

Areas of Scenic and Recreational Importance

Montgomery Township is rich in recreational opportunities, scenic vistas and viewsheds. While the quality of these is subjective, the basic elements which combine to bring them about are readily identifiable and mapped and presented in Figure 23.

Open space and other publicly owned lands are the foundation of recreational opportunities. Combined with natural features such as hills and mountains, forests, streams and rivers and lakes and ponds, these open spaces define the experience a person will have while engaging in recreation activities. Significant recreational opportunities are present in the Sourland Mountain, along the Millstone River and Delaware and Raritan Canal and at other Township parks including Hobler Park, Montgomery Park, Mill Pond Park and others.

In addition to being a prime spot for recreation opportunities, the Sourland Mountain is one of the prominent scenic resources in the Township. Standing out in the rolling landscape, it also provides a vantage point for view of the pastoral landscapes that spread out across much of Montgomery. Many of the ridgelines depicted in Figure 23 present scenic view opportunities, although not to the extent of the Sourland Mountain.

Riparian areas represent both significant recreation opportunities and viewshed and vista enjoyment opportunities. The enclosure felt in a forested stream corridor can often give the sense of calm and tranquility, effectively closing out surrounding ambient noise. And while the extent of vistas and viewsheds is often limited, their presence is enjoyed nonetheless.

Forested areas, taken from the NJDEP's 1995 Land Use/Land Cover data and depicted on Figure 23, contribute greatly to scenic and recreational enjoyment. In addition to their important role in ecosystem stabilization, they often provide separation for open spaces and developed areas. As seen in Figure 23, many of the riparian areas in the Township remain forested, providing opportunities for the creation of greenways and

walking paths along streams and rivers. The riparian and forested areas depicted also provide logical targets for open space acquisition, whether in fee or through easement purchase.

Somerset County published a scenic corridor and roadway study in July of 1992. The study developed ranking criteria for County roadways, their application intended to highlight those worthy of designation as "scenic". The scenic corridors in Montgomery Township included County Route 601(in its entirety in Montgomery), County Route 604 (from Route 206 west to County Route 601) and County Route 518 (from County Route 601 west to Hopewell Township and from Route 206 east to Rocky Hill). A scenic corridor, as defined in the study, is where "the area of influence is generally extended beyond the properties immediately adjacent to the road and includes the entire landscape visible form the right-of-way." The only scenic roadway in Montgomery Township was River Road (from Hillsborough south to Route 206). A scenic roadway, as defined in the study, is where "the area of influence is generally limited to the adjacent property or right-of-way and concentrates on the visual foreground adjacent to the roadway edge."

Roadways designated in the County plan as either Scenic Corridors or Scenic Roadways greatly contribute to the scenic experience in Montgomery Township. Land use controls were recommended as the most effective means to protect and enhance scenic resources; creative site planning and arrangement can permit development in a way that does not compromise scenic resources. This is critical to preserving the bucolic sense which remains in parts of Montgomery.

Regional Relationships

State Plan

The State Planning Act (NJSA 52:18A-196 et seq.) included a finding that as the nation's most densely populated state, New Jersey requires coordinated State, local and regional planning in order to conserve its natural resources. The New Jersey State Development

and Redevelopment Plan (SDRP), adopted in March of 2001 by the State Planning Commission, sets forth State policy and management objectives for various portions of the State.

The State Plan Policy Map, depicted on Figure 24, shows that Montgomery Township is predominantly characterized by Planning Areas 4 and 5 in its western half and Planning Areas 2 and 3 in its eastern half. This is indicative of the contrast between the developed portions of the Township and the portions that remain relatively rural, dominated by agriculture and forested areas.

The State Plan espouses a number of goals and policy objectives for the Planning Areas in Montgomery, indicated below.

PA-2 (Suburban Planning Area)- **2,942 Acres (14.2%)**

Planning Area 2 is characterized by existing "suburban" type development, typically occurring on lands with available infrastructure such as public sewer and water. These areas of the State are intended to absorb the market demand for additional housing, allowing protection to be afforded to other areas not appropriate for development. The intent of the State Plan for PA-2 is:

- provide for much of the state's future development;
- promote growth in Centers and other compact forms;
- protect the character of existing stable communities;
- protect natural resources;
- redesign areas of sprawl;
- reverse the current trend toward further sprawl; and,
- revitalize cities and towns.

While it is the intent for Planning Area 2 to absorb some of the State's growth, it is not intended to promote further sprawl. Development should occur in centers and utilize

efficient development patterns and a mix of uses to promote less dependence on automobiles.

Many of the policy objectives for Planning Area 2 are relevant to resource based planning and offer appropriate guidance. As identified in this NRI, there are areas within PA-2 which require careful attention in the face of continuing development. The specific policy objectives for PA-2 applicable to this document are:

Natural Resource Conservation: Conserve continuous natural systems, strategically locate open space, and buffer Critical Environmental Sites. Use open space to reinforce neighborhood and community identity, and protect natural linear systems, including regional systems that link into other Planning Areas.

Agriculture: Guide development to ensure the continued viability of agriculture and the retention of productive farmland in strategically located agricultural areas and in other adjacent Planning Areas. Actively promote more intensive, new-crop agricultural enterprises and meet the needs of agricultural industry for intensive packaging, processing, value-added operations, marketing, exporting and other shipping through development and redevelopment.

PA-3 (Fringe Planning Area) – **6,156 Acres (29.6%)**

Planning Area 3 represents a transition area between the environmentally sensitive and rural areas of the Township and the more dense suburbs. While it represents almost 30% of the land in Montgomery, it represents a mere 3% in the entire State. The Fringe Planning Area generally lacks significant investment in public roads and other infrastructure and are not characterized by critical environmental features or prime and statewide important agricultural soils. The intent for PA-3 is:

- protect the Environs primarily as open lands;
- revitalize cities and towns;

- protect the character of existing stable communities;
- protect natural resources;
- provide a buffer between more developed Metropolitan and Suburban Planning Areas and less developed Rural and Environmentally Sensitive Planning Areas; and,
- confine programmed sewers and public water services to Centers.

The specific policy objectives for PA-3 applicable to this study include:

Natural Resource Conservation: Strategically acquire open space to define Centers and to maintain contiguous open space corridors that link to other Planning Areas and Centers.

Agriculture: Guide development to ensure the viability of agriculture and the retention of productive farmland in strategically located agricultural areas and in other adjacent Planning Areas. Encourage farmland retention and minimize conflicts between agricultural practices and the location of Centers. Actively promote more intensive, new crop agricultural enterprises and meet the needs of the agricultural industry for intensive packaging, processing, value-added operations, marketing, exporting and other shipping through development and redevelopment.

PA-4 (Rural Planning Area) – **7,516 Acres (36.2%)**

Planning Area 4 is represented by areas of contiguous farmland and interspersed residential and commercial development at low densities. These areas are not intended to be urban or suburban in nature and act as the gateway to the more developed portions of the state. Planning Area 4 is comprised of the prime soils of the State and is intended to be the focus of farmland preservation efforts and strengthening of the rural economy. The intent for PA-4 is:

- revitalize cities and towns;

- accommodate growth in Centers;
- promote a viable agricultural industry;
- protect the character of existing, stable communities; and
- confine programmed sewers and public water services to Centers.

Specific policy objectives of the State Plan related to this NRI include:

Natural Resource Conservation: Minimize potential conflicts between development, agricultural practices and sensitive environmental resources. Promote agricultural management practices and other agricultural conservation techniques to protect soil and water resources. Protect and preserve large, contiguous tracts and corridors of recreation, forest or other open space land that protect natural systems and natural resources.

Agriculture and Farmland Preservation: Guide development to ensure the viability of agriculture and the retention of farmland in agricultural areas. Encourage farmland retention and minimize conflicts between agricultural practices and the location of Centers. Ensure the availability of adequate water resources and large, contiguous tracts of land with minimal land-use conflicts. Actively promote more intensive, new crop agricultural enterprises and meet the needs of the agricultural industry for intensive packaging, processing, value-added operations, marketing, exporting and other shipping through development and redevelopment.

PA-5 (Environmentally Sensitive Planning Area) – **3,811 Acres (18.3%)**

Planning Area 5 is representative of lands which contain critical environmental features and habitats including contiguous forests, unique geologic features, wetlands and other ecosystems. The delineation of PA-5 in Montgomery roughly corresponds to the area of the Sourland Mountain. The intent of PA-5 in the State Plan is:

- accommodate growth in Centers;

- protect the character of existing stable communities;
- confine programmed sewers and public water services to Centers; and,
- revitalize cities and towns.

The State Plan recommends balancing the capacity of the land with planned development. Protection should be extended to critical resources, especially those identified in this NRI. Specific policy objectives for PA-5 pertinent to this study include:

Natural Resource Conservation: Protect and preserve large, contiguous tracts and corridors of recreation, forest or other open space land that protects natural systems and sensitive natural resources, including endangered species, ground and surface water resources, wetland systems, natural landscapes of exceptional value, critical slope areas, scenic vistas and other significant environmentally sensitive features.

Agriculture: Promote agricultural practices that prevent or minimize conflicts with sensitive environmental resources. Guide development to ensure the viability of agriculture and the retention of farmland in agricultural areas. Encourage farmland retention and minimize conflicts between agricultural practices and the location of Centers. Ensure the availability of adequate water resources and large, contiguous tracts of land with minimal land use conflicts. Actively promote more intensive, new-crop agricultural enterprises and meet the needs of the agricultural industry for intensive packaging, processing, value-added operations, marketing, exporting and other shipping through development and redevelopment.

County Planning

The Somerset County Planning Board is the body responsible for planning initiatives at the County level. With the assistance of the County Planning Board staff, they prepare and adopt studies which identify and discuss issues of regional planning significance. In addition, the County Planning Board analyzes municipal planning policy in order to determine the degree of consistency with regional plans, both State and County.

The last Master Plan prepared for Somerset County was adopted in 1987. Since that time, the County has embarked on a process to adopt a "Somerset County Smart Growth Strategic Plan", involving the public and municipalities in the formulation of general strategies.

The Guiding Principles of the Plan provide support for conservation policies and environmental protection which are applicable to Montgomery Township. Listed below the relevant guiding principles are specific planning objectives[vii].

1. Protect Natural Systems
   - Protect natural systems and maximize their ability to maintain water supply and quality; provide flood control
   - Promote energy conservation and the use of alternative energy technologies that minimize air pollution
   - Restore the ecological integrity, scenic and recreational value of damaged river and stream corridors, wetlands, forests and other natural systems
     1) Identify, prioritize and coordinate the preservation of adequate amounts and types of natural and undeveloped lands needed to sustain water supply and natural habitats with the implementation of open space, parks, recreation, agricultural, watershed management and historic preservation goals.
     2) Preserve a variety of natural landscapes, ecosystems and topographic features throughout all areas of the county to make their benefits more widespread.
     3) Protect and enhance biodiversity by preserving natural habitats of suitable size and type to sustain existing threatened and endangered species; and by employing humane methods for dealing with species imbalance

4) Enforce compliance with local, state and federal environmental regulations, and strengthen monitoring and enforcement programs

2. Reduce the Environmental Impacts of Development

- Repair and maintain wastewater collection and treatment facilities
- Utilize water recycling and other conservation strategies to enhance water supply and minimize drought impacts
- Incorporate water-quality technologies into the design of storm water management facilities; and retrofit existing facilities to include water quality controls where needed

1. Utilize site design, building and landscape materials and land development practices that facilitate groundwater recharge; enhance surface and ground water quality; minimize downstream impacts; and preserve critical habitats, wetlands and other environmentally sensitive features
2. Expand septic management and well-testing programs in areas served by on-site wastewater systems and residential wells
3. Encourage energy efficient community and building design, and the use of alternative energy technologies
4. Apply “best management practices” to minimize non-point source pollution, noise, flooding, traffic congestion and other adverse impacts of development
5. Implement policies and technologies that reduce spills of toxic and hazardous substances during transport, transfer, use, storage and processing, in order to prevent risks to public health and the environment; and reduce emergency response and cleanup costs
6. Promote and facilitate the clean up of contaminated “brownfield” sites; make cleanup of sites that are a threat to public health and the environment the top priority
7. Address the impact of airports, including noise, air pollution, safety concerns and traffic generation

8. Prevent unhealthy build-up of heat and air pollution in developed areas by integrating natural systems and landscaping, advancing "green building" technologies, using alternative energy options and minimizing traffic congestion

3. Preserve Rural Resource Areas, Farmland and Agriculture
   - Protect and preserve adequate agricultural resources and land base needed to support and sustain the agricultural industry, both short and long term
   - Implement policies and programs that enable farm operations to continue and expand, i.e. encourage the application of new agricultural technologies, promote agricultural tourism and increase marketing opportunities for local farm products
   - Encourage the establishment of local agriculture-related support industries, such as distributors and equipment suppliers, while assuring that facility design is compatible with the rural landscape, infrastructure and natural system capacity
     1. Discontinue sprawl development patterns
     2. Identify and implement strategies that increase labor force participation in, and the attractiveness of, agricultural occupations in the county
     3. Encourage the use of agricultural "best practices"

4. Preserve the Beauty and Function of the County's Scenic Corridors and Major Highways
   - Preserve views of significant topographic features, natural, rural and historic landscapes and landmarks

"The Somerset County Parks, Recreation and Open Space Master Plan Update", completed in December of 2000, also provides broad support for the environment and

conservation strategies. Of particular note is the goal to protect the critical environmental resources of the County, including critical environmental features delineated in the State Development and Redevelopment Plan (SDRP), preserving floodplains and facilitating flood protection projects, and promotion of regional solutions to stormwater management and water quality protection.

The Somerset County Parks, Recreation and Open Space Master Plan Update also refers to the Sourland Mountain Preserve Master Plan. This Master Plan proposes the introduction of passive and limited active recreation facilities while providing opportunities to protect and preserve the areas natural resources. It also notes that significant environmental constraints exist and that it is imperative that park development is sensitive to the mature native forests, critical habitat and critical slopes that are characteristic of the region.

"The Somerset County Agriculture Retention and Development Master Plan" provides broad support for protecting the agricultural resources of the Township and the County as a whole. Although agriculture has continued to decline, agriculture retention has a range of open space and rural character benefits that are increasingly important to the quality of life in the State's fastest growing County. Aside from quality of life benefits, preservation of farmland provides important areas for aquifer recharge. It also protects the prime and statewide important agricultural soils that form the basis of agriculture in the County and in Montgomery.

Adjacent Municipalities

Montgomery Township, one of five communities that share the Sourland Mountain, is involved in a unique regional planning project funded by a State Smart Growth Grant. The common goal of resource conservation in the Sourland Mountain region, spanning Montgomery, Hillsborough, Hopewell and East and West Amwell Townships in Hunterdon, Mercer and Somerset Counties, will be aided by a regional conservation plan prepared jointly by the five towns.

The Sourland Mountain is home to one of the largest remaining contiguous forests in Central New Jersey. The unique nature of this pristine ecosystem makes it especially susceptible to anthropogenic activities. Shallow soils have limited ability to process effluent using septic systems; hard, dense geologic formations allow very limited aquifer recharge and are characterized, for the most part, by low dependable yields of drinking water; the forest is home to a number of threatened and endangered species; the mountain is characterized by perched water tables and emergent and forested wetland systems; all of the streams on the Mountain act as headwaters to the Millstone, Raritan and Delaware Rivers.

The goal of this cooperative planning project is to prepare a comprehensive conservation and open space plan, with shared resource protection goals and objectives for each plan element. As part of the planning process, a groundwater evaluation study will be prepared for the region, providing insight into the implications of water resources on development densities in the region. Additionally, a build-out study will be completed for the Sourland Mountain, providing the means to assess the impact of current zoning policy in the five participating communities.

This resource protection based project represents a unique regional planning approach, transcending political boundaries to protect the sensitive mountain ecology through local level initiatives. The Montgomery Township Natural Resource Inventory will provide information useful to this regional planning effort.

Appendix 1

Geologic Units – Technical Descriptions[viii]

Jd, Jg Diabase and granophyre (Early Jurassic) – Fine-grained to aphanitic dikes; medium- to coarsegrained, subophitic discordant stock-like intrusions of dark-greenish-gray to black diabase; and plugs of dark gray, concordant to discordant sheetlike, medium- to coarse-grained, quartz-rich to albite-rich granophyre (map unit Jg). The chilled margins of diabase masses are aphanitic to very fine grained. Diabase is dense, hard, and sparsely fractured. It is composed mostly of plagioclase (An50-70), clinopyroxene (mostly augite) and magnetite±ilmenite. Accessory minerals include apatite, quartz, alkali feldspar, hornblende, titantite, and zirocon. Olivine is rare. Within about 200 m (655 ft) above and 150 m (490 ft) below the large diabase sheets, red mudstones are typically metamorphosed into indurated, bluish-gray hornfels commonly with clots or crystals of tourmaline or cordierite, whereas argillitic siltstone is metamorphosed into brittle, black, very fine grained hornfels, Sheetlike intrusions are as much as 360 to 400 m (1,180-1,310 ft) thick. Dikes range in thickness from 3 to 15 m (10-50 ft) and several kilometers (miles) long. Thickness of the stocklike bodies is unknown.

JTrp, JTrpms, JTrps, JTrpsc, JTrpcq, JTrpcl, Trpg Passaic Formation (Lower Jurassic and Upper Triassic) (Olsen, 1980) - Reddish-brown to brownish-purple and grayish-red siltstone and shale (JTrp) maximum thickness 3,600 m (11,810 ft). At places contains mapped sandy mudstone (JTrpms), sandstone (JTrps), conglomeratic sandstone (JTrpsc) and conglomerate containing clasts of quartzite (JTrpcq), or limestone (JTrpcl). Formation coarsens up section and to the southwest. Quartzite conglomerate unit (JTrpcq) is reddish-brown pebble conglomerate, pebbly sandstone, and sandstone, in upward-fining sequences 1 to 2 m (3-6 ft) thick. Clasts are subangular to subrounded, quartz and quartzite in sandstone matrix. Sandstone is medium to coarse grained, feldspathic (up to 20 percent feldspar), and locally contains pebble and cobble layers. Conglomerate thickness exceeds 850 m (2,790 ft). Limestone conglomerate unit (JTrpcl) is medium-bedded to massive, pebble to boulder conglomerate. Clasts are subangular dolomitic limestone in matrix of brownish- to purplish-red sandstone to

mudstone; matrix weathers light-gray to white near faults. Maximum thickness unknown.

Trl, Trlr, Trla, Trls, Trlcq Lockatong Formation (Upper Triassic) (Kümmel, 1897) - Cyclically-deposited sequences consisting of light- to dark-gray, greenish-gray, and black, dolomitic or analcime-bearing silty argillite, laminated mudstone, silty to calcareous, argillaceous, very-fine-grained pyritic sandstone and siltstone, and minor silty limestone (Trl). Grayish-red, grayish-purple, and dark-brownish-red sequences (Trlr) common in upper half. Two types of cycles are recognized: detrital and chemical. Detrital cycles average 5.2 m (17 ft) thick and consist of basal, argillaceous, very fine grained sandstone to coarse siltstone; medial, dark-gray to black, laminated siltstone, silty mudstone, or silty limestone; and upper, light- to dark-gray, silty to dolomitic or analcime-rich mudstone, argillitic siltstone, or very-finegrained sandstone. Chemical cycles are similar to detrital cycles, but thinner, averaging 3.2 m (10.5 ft). Cycles in northern Newark basin are thinner and have arkosic sandstone in lower and upper parts. Upper part of formation in northern basin composed mostly of light-gray to light-pinkish-gray or light-brown, coarse- to fine-grained, thick- to massive-bedded arkosic sandstone (Trla). Thermally metamorphosed into hornfels where intruded by diabase (Jd). Interfingers laterally and gradationally with quartz sandstone and conglomerate (Trls) and quartzite conglomerate (Trlcq) near Triassic border fault in southwestern area of map. Maximum thickness of Lockatong Formation about 1,070 m (3,510 ft).

Trs, Trss, Trscq Stockton Formation (Upper Triassic) (Kümmel, 1897) - Light-gray, light-grayishbrown, yellowish- to pinkish-gray, or violet-gray to reddish-brown, medium- to coarse-grained arkosic sandstone and reddish- to purplish-brown mudstone, silty mudstone, argillaceous siltstone, and shale. Mudstone, siltstone and shale beds thicker and more numerous in central Newark basin west of Round Valley Reservoir. Sandstones mostly planar-bedded, with scoured bases containing pebble lags and mudstone rip-ups. Unit is coarser near Newark basin border fault, where poorly exposed, reddish-brown to pinkish-white, medium- to coarse-grained, feldspathic pebbly

sandstone and conglomerate (Trss) and pebble to cobble quartzite conglomerate (Trscq). Maximum thickness of formation about 1,240 m (4,070 ft).

Appendix 2

SSURGO Soil Characteristics

Symbol	Series	Soil Name	Acreage	Farmland Capability	Septic Limitations	Soil Suitability Classification N.J.A.C. 7:9A	Depth to Bedrock	Depth to Seasonal High Water	Hydric Soil	Erodible Land Class
AbrA	ABBOTTSTOWN	Abbottstown silt loam, 0 to 3 percent slopes	125.79	Soil of Statewide Importance	Severe	IIIHr, Wp(IIISc); IISr, Wp(IIISc)	40 to 72 inches	0.5 to 3 Feet	No	Potentially Highly Erodible
AbrB	ABBOTTSTOWN	Abbottstown silt loam, 3 to 8 percent slopes	345.00	Soil of Statewide Importance	Severe	IIIHr, Wp(IIISc); IISr, Wp(IIISc)	40 to 72 inches	0.5 to 3 Feet	No	Potentially Highly Erodible
BhnA	BIRDSBORO	Birdsboro silt loam, 0 to 3 percent slopes	31.34	Prime Farmland	Slight	I; IIWr; IISc; IIWrSc	40 to 60 Inches	4 Feet	No	Not Highly Erodible
BhnB	BIRDSBORO	Birdsboro silt loam, 3 to 8 percent slopes	434.31	Prime Farmland	Slight	I; IIWr; IISc; IIWrSc	40 to 60 Inches	4 Feet	No	Potentially Highly Erodible
Boy	BOWMANSVILLE	Bowmansville silt loam	194.79	Soil of Statewide Importance	Severe	IIIWr	72 Inches or Greater	Less than 1 Foot	Yes	Not Highly Erodible
BucB	BUCKS	Bucks silt loam, 3 to 8 percent slopes	345.06	Prime Farmland	Moderate	IISc; IISr	40 Inches	6 Feet	No	Potentially Highly Erodible
BucC2	BUCKS	Bucks silt loam, 8 to 15 percent slopes, eroded	62.07	Soil of Statewide Importance	Moderate	IISc; IISr	40 Inches	6 Feet	No	Potentially Highly Erodible
ChcB	CHALFONT	Chalfont silt loam, 3 to 8 percent slopes	387.35	Soil of Statewide Importance	Severe	IIISrWp	40 Inches	0.5 to 3 Feet	No	Potentially Highly Erodible
ChcBa	CHALFONT	Chalfont silt loam, 0 to 8 percent slopes, stony	139.53	No Rating	Severe	IIISrWp	40 Inches	0.5 to 3 Feet	No	Potentially Highly Erodible
ChcC	CHALFONT	Chalfont silt loam, 8 to 15 percent slopes	459.68	Soil of Statewide Importance	Severe	IIISrWp	40 Inches	0.5 to 3 Feet	No	Highly Erodible
ChcCa	CHALFONT	Chalfont silt loam, 8 to 15 percent slopes, stony	183.28	Soil of Statewide Importance	Severe	IIISrWp	40 Inches	0.5 to 3 Feet	No	Highly Erodible
ChcDa	CHALFONT	Chalfont silt loam, 15 to 25 percent slopes, stony	213.76	No Rating	Severe	IIISrWp	40 Inches	0.5 to 3 Feet	No	Highly Erodible
CoxA	CROTON	Croton silt loam, 0 to 3 percent slopes	251.14	Soil of Statewide Importance	Severe	IIISrWp; IIISrWr	42 to 60 inches	Less than 1 Foot	Yes	Potentially Highly Erodible
CoxB	CROTON	Croton silt loam, 3 to 8 percent slopes	254.56	Soil of Statewide Importance	Severe	IIISrWp; IIISrWr	42 to 60 inches	Less than 1 Foot	Yes	Potentially Highly Erodible
KkoC	KLINESVILLE	Klinesville channery loam, 8 to 15 percent slopes	3,303.52	No Rating	Severe	IISc; IISr	Less than 20 Inches	6 Feet	No	Potentially Highly Erodible
KkoD	KLINESVILLE	Klinesville channery loam, 15 to 25 percent slopes	188.25	No Rating	Severe	IISc; IISr	Less than 20 Inches	6 Feet	No	Highly Erodible
KkoE	KLINESVILLE	Klinesville channery loam, 25 to 45 percent slopes	78.91	No Rating	Severe	IISc; IISr	Less than 20 Inches	6 Feet	No	Highly Erodible
LbtA	LANSDOWNE	Lansdowne silt loam, 0 to 3 percent slopes	436.92	Soil of Statewide Importance	Severe	IIIHrWp(IISc); IIIHrWp(IISr)	48 Inches or Greater	0.5 to 3 Feet	No	Potentially Highly Erodible
LbtB	LANSDOWNE	Lansdowne silt loam, 3 to 8 percent slopes	184.97	Soil of Statewide Importance	Severe	IIIHrWp(IISc); IIIHrWp(IISr)	48 Inches or Greater	0.5 to 3 Feet	No	Potentially Highly Erodible
LdmB	LAWRENCEVILLE	Lawrenceville silt loam, 3 to 8 percent slopes	507.20	Prime Farmland	Severe	IIISrWp; IIIHrWp	48 Inches or Greater	0.5 to 3 Feet	No	Potentially Highly Erodible
LdmC	LAWRENCEVILLE	Lawrenceville silt loam, 8 to 15 percent slopes	194.18	Soil of Statewide Importance	Severe	IIISrWp; IIIHrWp	48 Inches or Greater	0.5 to 3 Feet	No	Highly Erodible
LemB	LEHIGH	Lehigh silt loam, 3 to 8 percent slopes	427.63	Soil of Statewide Importance	Severe	IIISrWp; IIIHrWp(IISc)	40 to 72 inches	0.5 to 3 Feet	No	Potentially Highly Erodible
LemC	LEHIGH	Lehigh silt loam, 8 to 15 percent slopes	219.07	Soil of Statewide Importance	Severe	IIISrWp; IIIHrWp(IISc)	40 to 72 inches	0.5 to 3 Feet	No	Highly Erodible
MopCb	WATCHUNG	Mount Lucas-Watchung silt loams, 8 to 15 percent slopes, very stony	83.94	No Rating	Severe	IIIWp(IISr)	48 Inches or Greater	0.5 to 3 Feet	No	Potentially Highly Erodible
NehB	NESHAMINY	Neshaminy silt loam, 3 to 8 percent slopes	51.84	Prime Farmland	Moderate	IISr	48 Inches or Greater	6 Feet	No	Potentially Highly Erodible
NehC	NESHAMINY	Neshaminy silt loam, 8 to 15 percent slopes	0.41	Soil of Statewide Importance	Moderate	IISr	48 Inches or Greater	6 Feet	No	Potentially Highly Erodible
NehEb	NESHAMINY	Neshaminy silt loam, 25 to 45 percent slopes, very stony	52.62	No Rating	Severe	IISr	48 Inches or Greater	6 Feet	No	Highly Erodible
NemCb	MOUNT LUCAS	Neshaminy-Mount Lucas silt loams, 8 to 15 percent slopes, very stony	105.52	No Rating	Moderate	IISr	48 Inches or Greater	0.5 to 3 Feet	No	Potentially Highly Erodible
NemDb	NESHAMINY	Neshaminy-Mount Lucas silt loams, 15 to 25 percent slopes, very stony	17.47	No Rating	Severe	IISr	48 Inches or Greater	0.5 to 3 Feet	No	Highly Erodible
NotB	NORTON	Norton loam, 3 to 8 percent slopes	164.84	Prime Farmland	Severe	IIIHr	42 to 60 inches	6 Feet	No	Potentially Highly Erodible
PenA	PENN	Penn silt loam, 0 to 3 percent slopes	254.19	Prime Farmland	Severe	IISc; IIISr	20 to 40 Inches	6 Feet	No	Not Highly Erodible
PenB	PENN	Penn silt loam, 3 to 8 percent slopes	1,508.73	Prime Farmland	Severe	IISc; IIISr	20 to 40 Inches	6 Feet	No	Potentially Highly Erodible
PenC	PENN	Penn silt loam, 8 to 15 percent slopes	229.71	Soil of Statewide Importance	Severe	IISc; IIISr	20 to 40 Inches	6 Feet	No	Highly Erodible
PeoB	PENN	Penn channery silt loam, 3 to 8 percent slopes	2,294.24	Prime Farmland	Severe	IISc; IIISr	20 to 40 Inches	6 Feet	No	Potentially Highly Erodible
PeoC	PENN	Penn channery silt loam, 8 to 15 percent slopes	709.16	No Rating	Severe	IISc; IIISr	20 to 40 Inches	6 Feet	No	Highly Erodible
QukC	QUAKERTOWN	Quakertown silt loam, 8 to 15 percent slopes	313.23	Soil of Statewide Importance	Moderate	IISc; I	42 to 60 inches	6 Feet	No	Potentially Highly Erodible
QukD	QUAKERTOWN	Quakertown silt loam, 15 to 25 percent slopes	218.59	No Rating	Severe	IISc; I	42 to 60 inches	6 Feet	No	Highly Erodible
RarA	RARITAN	Raritan silt loam, 0 to 3 percent slopes	64.90	Prime Farmland	Severe	IIIHrWp; IIIHrWP(IISc); IIIHrWp(IISr)	40 to 60 Inches	0.5 to 3 Feet	No	Potentially Highly Erodible
RedB	READINGTON	Readington silt loam, 3 to 8 percent slopes	52.08	Prime Farmland	Severe	IIIHrWp(IISc); IIWpSrSc; IIWrSc	40 Inches	0.5 to 3 Feet	No	Potentially Highly Erodible
RehA	REAVILLE	Reaville silt loam, 0 to 3 percent slopes	499.59	Soil of Statewide Importance	Severe	IISrWp(IIHc)	20 to 40 Inches	0.5 to 3 Feet	No	Potentially Highly Erodible
RehB	REAVILLE	Reaville silt loam, 3 to 8 percent slopes	1,434.22	Soil of Statewide Importance	Severe	IISrWp(IIHc)	20 to 40 Inches	0.5 to 3 Feet	No	Potentially Highly Erodible

SSURGO Soil Characteristics

Symbol	Series	Soil Name	Acreage	Farmland Capability	Septic Limitations	Soil Suitability Classification N.J.A.C. 7:9A	Depth to Bedrock	Depth to Seasonal High Water	Hydric Soil	Erodible Land Class
Ror	ROWLAND	Rowland silt loam	1,849.40	Soil of Local Importance	Severe	IIIWr	72 Inches or Greater	0.5 to 3 Feet	No	Not Highly Erodible
RoyB	ROYCE	Royce silt loam, 3 to 8 percent slopes	1,809.09	Prime Farmland	Moderate	IISc	40 to 72 inches	6 Feet	No	Potentially Highly Erodible
UR	URBAN LAND	Urban land	51.68	No Rating	Variable	Distrubed Ground	Less than 20 Inches	0.5 to 3 Feet	No	Not Highly Erodible
WATER	WATER	Water	54.04	No Rating	Water	Water	Water	Water	Yes	Potentially Highly Erodible
Was	WATCHUNG	Watchung silt loam	0.19	No Rating	Severe	IIIHrWpWr	40 to 60 Inches	Less than 1 Foot	Yes	Potentially Highly Erodible

Appendix 3

Nitrate Dilution Modeling of Montgomery Township

Somerset County,

Nitrate Dilution Modeling of Montgomery Township, Somerset County, NJ

Prepared for:
Montgomery Township Environmental Commission
Somerset County, NJ
2261 Route 206
Belle Mead, NJ 08502

Prepared by:
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Pennington, NJ 08534

April 8, 2004

Introduction

Nitrate from natural sources generally only occurs in ground water at low levels but anthropogenic sources can lead to elevated concentrations. Sources include fertilizers, animal waste, and sewage effluent. Nitrate is considered a contaminant in ground water because of various impacts to human health and aquatic ecology. For instance, high levels of nitrate intake in infants can lead to methemoglobinemia, or blue baby syndrome (Hem, 1985; U.S. EPA, 1991). Because of its low natural occurrence and solubility and stability in groundwater, nitrate can also serve as an indicator for possible bacterial, viral, or chemical contaminants of anthropogenic origin.

Nitrogen is present in septic system effluent and is converted to nitrate through biological processes active in the soil below the drain field. Once this nitrification process is complete, nitrate is a stable and mobile compound in ground water under normal conditions (Hoffman and Canace, 2001). Nitrate concentrations resulting from septic effluent are mitigated by dilution if the septic effluent is combined over time with water entering the ground through infiltration during and after storm events. The extent of this dilution effect is clearly dependent on long-term rates of both infiltration and nitrate loading from septic system sources. The density of septic systems relative to infiltration rates in a particular area is therefore a critical factor controlling the ultimate nitrate level in ground water.

The purpose of this report is to present the results of nitrate dilution calculations for Montgomery Township in Somerset County, New Jersey. Two different methods were explored, and the results of both are presented and explained.

Physical Setting: Montgomery Township

Montgomery Township lies entirely in the Piedmont physiographic province of New Jersey. Bedrock formations within the Piedmont are of Late Triassic and Early Jurassic age (230 to 190 million years old) and are part of the Newark Supergroup. Three formations of the Newark Supergroup are present in Montgomery: from oldest to youngest, the Stockton, Lockatong, and Passaic, which is part of the Brunswick Group (Figure 1). These formations crop out as a northeast-striking belt of rocks, with a gentle northwesterly dip of about 15 degrees. The sequence of three sedimentary units (Stockton, Lockatong and Passaic) is disrupted in the area surrounding Montgomery as a result of vertical displacement along the Hopewell Fault, which extends northeast through the area and passes through the western portion of the Township. In addition, later diabase rocks of Jurassic age cut through the sequence of sedimentary rocks within the Township (USGS, 1998).

The Stockton Formation consists of red and gray thin-bedded to thick-bedded, very fine-grained to coarse-grained sandstone, siltstone, and shale. The Lockatong Formation is composed of dark gray and reddish-brown beds of siltstone and shale with minor amounts of fine-grained sandstone. Many of the siltstone and sandstone beds are extremely hard, chemically cemented siltstone and sandstone (argillite). Rocks of the Lockatong Formation are generally more resistant to erosion than are adjacent units and therefore form ridges, such as the face of the Sourland Mountains. The youngest and most abundant rock in the region is the Passaic Formation. It consists of reddish brown, thin-bedded to thick-bedded shale, siltstone, and very fine-grained to coarse-grained sandstone. In addition, some zones of dark gray siltstone are present, similar to those of the underlying Lockatong Formation. The diabase (trap rock) is a fine-grained to coarse-grained, dark gray to black igneous rock, which has intruded between the beds of the Newark Supergroup sediments. It is extremely hard and resistant to weathering. Diabase is found at the top of the Sourland Mountains and also forms a topographic feature known as the Princeton Ridge, which extends east-west from Rocky Hill to Mount Rose (Lewis-Brown and Jacobsen, 1995).

Soils of the Northern Piedmont Lowland are dominantly silty and commonly shaly or stony. Most of the soils are underlain by hard bedrock at a depth of 2 to 20 feet (USDA SCS, 1972). The dominant soil in Montgomery Township is the Penn (Figure 2). It consists of reddish-brown, moderately deep (20 to 40 inches to bedrock), well-drained soils formed in materials weathered from noncalcareous reddish shale, siltstone, and fine-grained sandstone normally of Triassic age. Penn soils are on nearly level to steep and moderately dissected uplands.

Other soils derived from shale, siltstone, slate and/or sandstone, associated with the Penn series are the shallow (10 to 20 inches to bedrock) Klinesville series, the moderately deep (20 to 40 inches to bedrock) Reaville series, and the very deep (depth to stratified sand and gravel more than 40 inches) Rowland series formed in alluvial sediments. These reddish brown soils fall into the group of soils with moderately fine to fine textures, impeding the downward movement of water. Another extensively occurring series in the Township is the Chalfont series. These soils, found on the slopes of the Sourland Mountains, are deep to very deep (3½ to 8 feet or more), soils formed in a loess mantle overlying a weathered residuum of shale and sandstone. They are somewhat poorly drained with medium to fast runoff and slow permeability (USDA NRCS, 2003).

In the context of septic system operation and nitrate dilution, a significant characteristic of the soils of much of Montgomery Township is that they very often do not have sufficient percolation rates in the soil horizons to support septic drain fields. In response to this, septic fields are often installed by excavating deeper than usual into a zone that is predominantly weathered bedrock to achieve the necessary percolation rates. This is important because it means that the septic system effluent is being released very near the upper surface of the fractured bedrock that serves as an aquifer. In this situation, there is a significant possibility that septic system effluent will migrate to a fracture in the

bedrock and pass downward into the aquifer (Mulhall, pers. comm.). The impact of this on nitrate dilution is discussed below.

Methods

Recharge and Nitrate Dilution Processes

The hydrologic cycle describes the balance and distribution of water as it moves through various processes between the atmosphere, surface water, and ground water. Precipitation forms in the atmosphere and falls to the earth's surface, moves through streams, rivers, and groundwater, flows to the ocean, and is returned to the atmosphere through evaporation and transpiration by plants. It is the part of this cycle in which water enters the ground that is of interest in evaluating nitrate dilution. Precipitation reaching the ground enters several pathways in the cycle.

- Plant leaves intercept a portion and it is either taken up by the plants or immediately returned to the atmosphere by evaporation.
- Of the remainder that reaches the ground, some flows away as overland runoff and eventually flows into streams.
- Some water remains on the surface and evaporates back to the atmosphere.
- The rest infiltrates into the soil, but does not necessarily enter an aquifer. A great deal of the infiltrated water is taken up by plant roots and ultimately returned to the atmosphere by the plants through transpiration.
- Beyond the root zone, water continues to move downward if conditions allow. For this report, the quantity of water that moves downward beyond the root zone is called **soil recharge**.
- In conditions such as those found in Montgomery Township, some of this water finds its way into fractures in the bedrock and moves downward into the bedrock aquifer. This quantity of water is referred to as **aquifer recharge**.
- Because the amount of water that can enter through fractures is limited, a significant amount stays above the top of the bedrock and moves laterally through the soil, eventually discharging back to surface water through seeps or directly into streambeds. This process is known as **interflow**.

The central assumption of nitrate dilution calculations is that over the long term, septic system effluent is diluted by fresh water infiltrating the ground after a storm. But in order to properly calculate the dilution, we must correctly identify where in the hydrologic cycle the dilution is occurring. The key question is whether the septic system effluent is diluted by the full quantity of soil recharge water and eventually divided into interflow and aquifer recharge, or whether the effluent does not move as interflow and is only diluted by the quantity of recharge water that actually enters the aquifer.

NJGS Method

New Jersey Geological Survey (NJGS) has produced a model for calculating nitrate dilution from septic systems that is documented in Hoffman and Canace, 2001. The NJGS model is a synthesis of two independent models: one for calculating "ground water" recharge, published by NJGS and known as GSR-32 (Charles, et al., 1993) and a modified version of the Trela-Douglas mass dilution model (Trela and Douglas, 1978).

The GSR-32 method estimates soil recharge based on soil type, impervious cover, and annual rainfall. Although the GSR-32 publication uses the term "ground water," the term soil recharge is used here in an attempt to avoid confusion that commonly occurs in discussing the various models. The GSR-32 method is designed to estimate how much of the annual rainfall enters the soil and infiltrates past the root zone. In other words, it estimates how much of the rainwater is left after the amount that runs off over land and the amount that is returned to the atmosphere through evapotranspiration. It does not include any mechanism for estimating how much of the infiltrated water reaches the bedrock aquifer and how much moves laterally in the soil zone and ultimately returns to surface water bodies (the process known as interflow). As we will see, this difference can be substantial, particularly in areas with fractured bedrock aquifers.

The NJGS nitrate dilution method uses GSR-32 recharge values as a starting point. It then calculates nitrate dilution and from that a minimum number of acres per septic system necessary to provide adequate dilution to stay below a target maximum nitrate concentration in groundwater, which is a value specified by the user. (The default configuration of the model uses a target value of 10 mg/liter, which coincides with the primary drinking water standard.) Based on the minimum lot size, a resulting value of impervious cover is calculated. Since impervious cover reduces recharge and therefore affects the dilution calculation, that value is then used to repeat the calculations, and an iterative process is used until the model reaches a stable solution (Hoffman and Canace, 2001).

Aquifer Recharge Method

With a traditional septic system installation, the effluent from the drain field is released into the soil zone. From there it migrates downward and possibly laterally, depending on local conditions. But whereas a significant portion of the rainwater infiltrating the soil zone ends up moving laterally as interflow and never reaching the aquifer, the same does not necessarily happen with the septic system effluent. During dry periods, the septic system effluent is the only water moving down through the soil zone. Because the quantity of water percolating down is so much less than during rainfall periods, in some settings, nearly all of it may enter the aquifer.

In addition to this, as mentioned above, septic system drain fields in many cases in Montgomery (and in the region in general) are essentially installed at the bottom of the soil zone, and the septic effluent discharges into a zone of weathered bedrock. In these

circumstances, the possibility exists in any given case for the effluent to reach a fracture in the bedrock directly. This would lead to an even higher percentage of the effluent entering the bedrock aquifer (especially in dry periods) and a lower percentage being diverted as interflow. In such a case, it is more appropriate to calculate nitrate dilution based on the quantity of recharge entering the bedrock aquifer rather than the quantity that enters the soil. Therefore, this report also includes the results of nitrate dilution calculations that are based on *aquifer* recharge rates rather than the *soil* recharge rates that come from the GSR-32 method. The rates of aquifer recharge used here are from analyses performed by M2 Associates (Mulhall, 2001 and Mullhall, pers. comm.).

Mulhall (2001) derived values for aquifer recharge for the formations that underly Hopewell Township, and has since refined the results of that analysis and extended it to include Montgomery (Mulhall, pers. comm.). The recharge estimates are based on a mass balance approach in which evapotransipiration and surface runoff are subtracted from precipitation. This is similar to the basic approach of GSR-32, except that interflow, the lateral movement of water within the soil zone, is considered as surface water runoff along with the overland flow component. Interflow and overland flow are combined in the analysis because neither can be measured directly but both ultimately contribute to stream flow, which can be measured directly. Overland flow contributes to stream flow during and immediately after a storm event. Interflow through the soil is what causes stream flows to remain high for a number of days after a storm event. Long after a storm, the flow in streams is provided by discharge from groundwater. By analyzing long-term climate and stream flow records and interpreting the results of computer models of groundwater flow, Mulhall arrived at estimates for evapotranspiration and the combination of overland runoff and interflow. Subtraction of these values then yields an estimate for aquifer recharge.

The difference between this approach and the one taken by GSR-32 is that GSR-32 considers that any water that infiltrates the soil zone and isn't taken up by plants is a contribution to ground water. But stream flow records clearly show that most of that soil recharge does ultimately end up back in the surface water and never reaches the water table aquifer in bedrock.

Aquifer recharge values were used with the Trela-Douglas formula for nitrate dilution, the same formula that is the basis for the NJGS method. One modification to the original Trela-Douglas formula that is incorporated in the NJGS method was not used, however. The NJGS method adjusts the formula to account for the reduction in soil recharge caused by impervious cover. In the case of aquifer recharge, however, this relationship is less clear. In the setting in question, with a fractured bedrock aquifer covered by layers of soil, most of the water that enters the soil travels laterally along the soil-rock interface as interflow and never enters the aquifer. If the volume of water entering the soil is reduced by a small percentage, it is not clear how much the volume that enters the aquifer will be reduced, and at the housing densities in question here, the impervious cover percentages would be relatively low. We therefore base the dilution calculations on the aquifer recharge estimates that reflect current conditions, without a reduction for a projected effect of increased impervious cover.

The equations from the Trela-Douglas model start from the basic assumption that nitrate entering into the site from septic systems on an annual basis is equal to nitrate leaving the site in groundwater, diluted by recharge (Hoffman and Canace, 2001). The equation takes the form of

$$HM = ARC$$

Where

H = People per home
M = Per capita nitrate loading rate (10 lbs/year)
A = Area of land over which recharge occurs
R = Recharge rate
C = Concentration of nitrate in groundwater (5.2 mg/liter)

After the appropriate conversion factors are applied to equalize the units involved, and incorporating the constant values listed above and rearranging the equation to solve it for area, it becomes

$$A = 25.48 / R$$

Where

A = Area of land, in **acres**
R = Recharge rate, in **inches/yr**

This form of the equation provides a straightforward relationship between the rate of aquifer recharge and the minimum land area necessary to provide adequate dilution for one septic system (assuming three people per household and the other constants listed above).

Results and Discussion

NJGS Method

Soil recharge values produced using version 5.0 of the NJGS method are displayed in Figure 3; projected values for minimum average lot size per septic system are in Figure 4. These are based on the following parameter selections. Number of people per home was set at 3, based on data from the 2000 census. The target nitrate concentration after dilution was 5.2 mg/l, which is the default value recommended by the model's authors as consistent with the antidegradation approach defined in New Jersey's ground water quality regulations (N.J.A.C 7:9-6). Climate values were the standard values in the model for Montgomery Township, and nitrate loading rate was 10 pounds per person annually, also the model's standard value.

Because the NJGS method is based primarily on soil type, and most of the soils in the Township have similar drainage characteristics, there is very little variability in the

results from place to place within the Township. Excluding areas with wetlands or hydric soil (for which the NJGS method cannot compute results), values of minimum lot size range from 2.0 to 2.4 acres per septic system.

It is important to keep in mind that the NJGS model is not designed to estimate nitrate concentrations in specific places arising from individual systems; rather, it is meant for estimating on a regional basis what the cumulative impact is of a number of systems taken together. It is designed to be applied at a map scale of 1:24,000, which means that it is not appropriate to use the model to discern fine differences occurring over small distances. For this reason, it would be appropriate to use a statistical function to smooth out some of the fine-scale variations in the results. We have not presented results of that process here for two reasons. First, there is very little variation in the results to begin with. Second, and much more important, the specific conditions that exist in the Township are such that the model is simply not appropriate to the setting. As described above, site conditions often lead to situations where septic system effluent can ultimately move primarily into the bedrock aquifer with very little diverted as interflow. But of the quantity of recharge water estimated to enter the soil by the GSR-32 method, the great majority does ultimately get diverted as interflow and a relatively small proportion enters the aquifer where it would serve to dilute the septic effluent (compare Figures 3 and 5). Furthermore, there is evidence from streamflow records for the area that the estimates of soil recharge produced using GSR-32 are too high, even leaving out the question of soil recharge vs. aquifer recharge (Mulhall, 2001.) For these reasons, it is more appropriate to use aquifer recharge estimates as the quantity of water available to dilute septic system effluent.

Aquifer Recharge Method

As described earlier, there are four geologic formations underlying Montgomery Township. From oldest to youngest, they are the Stockton, Lockatong, and Passaic Formations and intrusions of Jurassic Diabase. Median annual recharge rates for these aquifers are as follows. These values are also shown as they are distributed over the Township in Figure 5.

Geology	Aquifer Recharge
Stockton Formation	5.5 inches/yr
Lockatong Formation	2.2 inches/yr
Passaic Formation	5.5 inches/yr
Jurassic Diabase	2.2 inches/yr

Using the methodology described above, the resulting values for the land area necessary to provide adequate dilution for each septic system are as follows. Figure 6 shows these values as they occur within the township.

Geology	Maximum Septic System Density
Stockton Formation	4.6 acres/system
Lockatong Formation	12 acres/system
Passaic Formation	4.6 acres/system
Jurassic Diabase	12 acres/system

It should be noted that the recharge values listed above are average values for the geologic formations. Since the recharge is occurring through fractures in the rock, site-specific conditions can have a large effect on the process. Areas that have a higher density of fractures will have higher recharge rates than those with lower fracture densities. In particular, the Hopewell Fault has been identified as an area with substantially higher recharge than the surrounding areas. Recharge through this approximately 500-foot-wide fracture zone into the Passaic Formation has been estimated to be as high as 95 inches per year (Lewis-Brown and Jacobsen, 1995; Mulhall, 2001). Purely on the basis of nitrate dilution, it might be tempting to conclude from this that the fault zone would be able to support very high development densities, but an area with such high recharge is an extremely valuable and sensitive resource. The fault zone and the area upslope (northwest) from it should be protected from overdevelopment because of its regional importance as a recharge area.

Existing Housing Densities

To assess existing conditions in light of the nitrate dilution results, housing densities were calculated for areas not served by sanitary sewers. This was accomplished by using the Township's GIS-based parcel data (dated July 2003) in conjunction with the bedrock geology information. Each property in the Township's database is flagged with the ID number of the sewer service area (if any) that it falls within, and there is also a count of existing dwelling units on each property. From this data, the number of dwelling units not served by sewers within each of the four outcrop areas was calculated. This number of dwelling units was divided into the total area to arrive at an overall density value for that geologically defined region of the Township.

Geology	Existing Septic System Density
Lockatong and Diabase (NW)	9 acres/system
Passaic and Stockton (Central)	7 acres/system
Diabase in SE	160 acres/system

The developed portions of the diabase area in the southeast portion of the Township are served by sewers; our analysis only revealed two dwelling units in that area that are not in a sewer service area. Therefore the contributing area per septic system is quite large and nitrate dilution is not an issue. In the central portion of the Township that is underlain by the Passaic and Stockton Formations, there is 7 acres of contributing area for each septic system, a value safely above the recommended minimum of 4.6 acres. But in the northwestern portion of the Township, which is underlain by Lockatong

Formation and Jurassic Diabase, the existing density yields a figure of 9 acres per septic system. The minimum area needed to provide adequate dilution is calculated to be 12 acres per system. This indicates that existing conditions in this area may be leading to degradation of groundwater quality. The actual situation is much more complex than the assumptions incorporated into the nitrate dilution model, but these results are a source of concern. Particular attention should be paid to groundwater issues in this portion of the Township.

Conclusions

One component of ground water protection is limiting the amount of nitrate that enters ground water from septic systems. The density of septic systems that can be supported in an area depends on how much recharge enters the ground water to provide dilution of the nitrate load. Nitrate dilution calculations for Montgomery Township were performed using two different methods. The NJGS method (Hoffman and Canace, 2001) uses a mass dilution method based on the annual rate at which water enters the soil and infiltrates past the root zone. Calculations are based on soil type, impervious cover, and climate (rainfall) data. The NJGS method estimates that soil recharge in the Township ranges from 11.8 to 14.8 inches/yr. The corresponding values for the minimum area necessary to provide adequate dilution range from 2.4 to 2.0 acres/system.

The problem with applying the NJGS method in Montgomery Township is that the specific conditions present in the Township cause the ground water system to behave in a way that violates the assumptions inherent in the NJGS method. The NJGS method assumes that both septic effluent and recharge water are subject to the same partitioning that causes some water to move laterally through the soil above the soil-rock interface and ultimately return to surface water bodies, and some water to move downward into fractures in the bedrock and thus enter the aquifer. If the same proportion of recharge water and septic system water follow these two pathways, then the dilution calculations are valid and should properly reflect the dilution effect of the recharge water. But in locations where the septic systems are installed very low in the soil profile, the discharge from the drain field enters directly into a horizon of weathered bedrock. Depending on the specific geometry of the situation, this effluent may preferentially move into fractures in the rock and then into the aquifer. In this case, the more appropriate calculation to use is one based on aquifer recharge volumes rather than soil recharge. Furthermore, there are indications that the soil recharge calculations arising from the NJGS method are too high for Montgomery in any case, based on analysis of stream flow records.

For these reasons, a second set of results is presented, based on calculations using aquifer recharge volumes determined from analysis of the regional groundwater system by Mulhall (2001). The volume of water that enters the fractured bedrock aquifer is much less than the volume of soil recharge calculated by the NJGS method, and as a result, the land area necessary to provide dilution for each septic system is significantly higher. Values for this minimum land area are 4.6 acres per system in areas underlain by Stockton and Passaic Formation rocks and 12 acres per system in areas underlain by

Lockatong Formation and Jurassic Diabase. An exception to these values exists in the area of the Hopewell Fault. The fault zone has very much higher recharge rates than the surrounding areas, and although nitrate dilution is not a particular issue there, the fault zone is a special resource that should be protected.

It should be noted that these numbers represent what the overall density of septic systems in an area should be to protect ground water. Requiring this amount of land as a minimum lot size for each system is one way to achieve this goal but certainly not the only way; the important thing is that the overall density target be reached in a given area.

In the portions of the Township underlain by Passaic and Stockton Formation geology, the distribution of existing septic systems is less dense than the threshold values yielded by the aquifer recharge modeling method, but planning of future growth in this area should be done with the nitrate dilution issue in mind. In the northwest portion of the Township, however, the existing development already indicates a potential problem. Existing septic system density is such that there is 9 acres of land area per septic system contributing to nitrate dilution, but the model yields a recommended minimum of 12 acres per system. This part of the Township may already be developed beyond the capacity of the groundwater system to assimilate the septic effluent. The geology in that region is especially complex, and the model may not adequately represent that complexity, but the results indicate that there is an issue that requires further attention.

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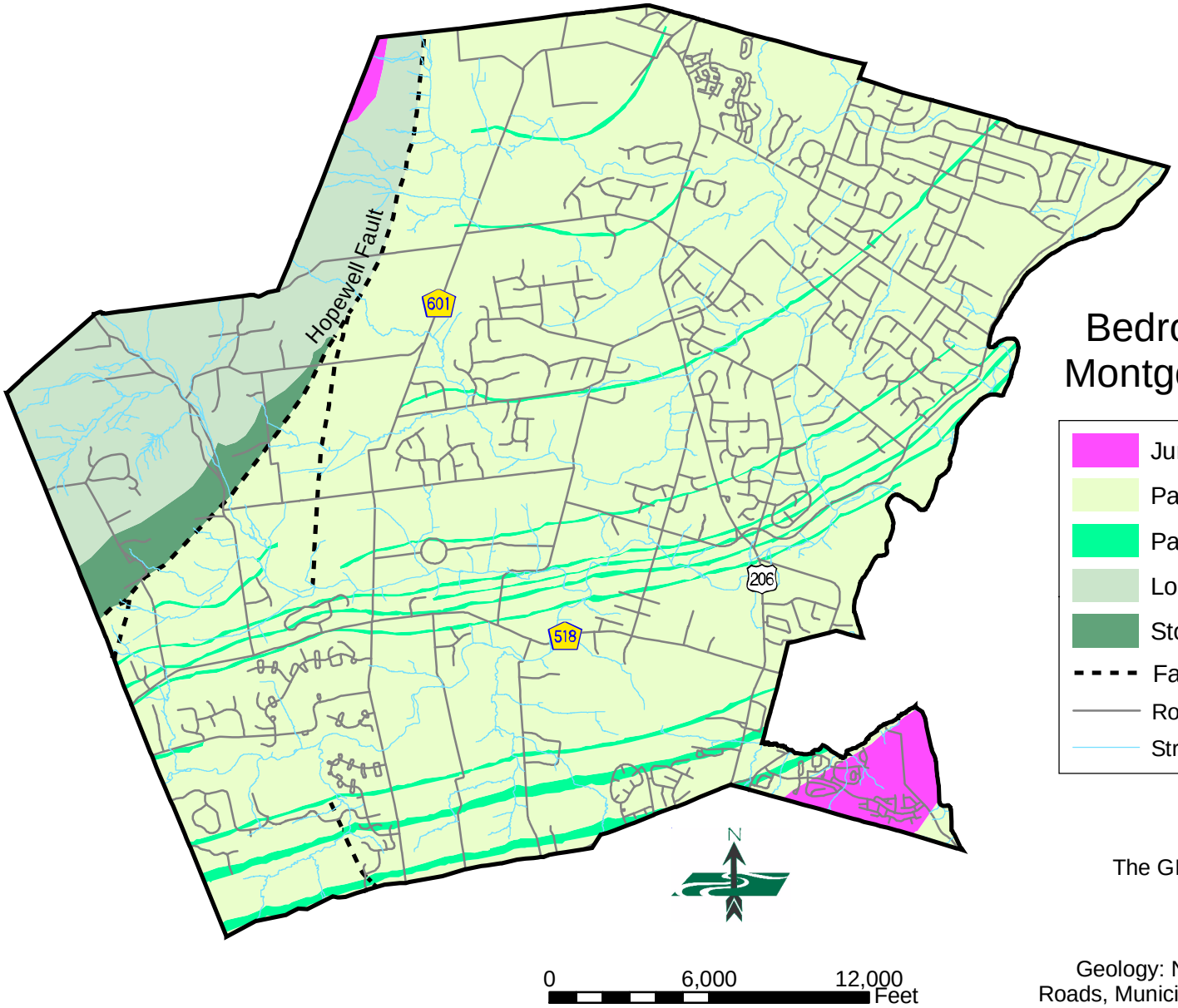

Figure 1: Bedrock Geology of Montgomery Township

- Jurassic Diabase
- Passaic Formation
- Passaic Formation Gray bed
- Lockatong Formation
- Stockton Formation
- Faults
- Roads
- Streams

Prepared by:
The GIS Center at Stony Brook
December 2003

Data Sources:
Geology: NJ Geologic Survey CD 00-1
Roads, Municipal Boundary: Montgomery Twp

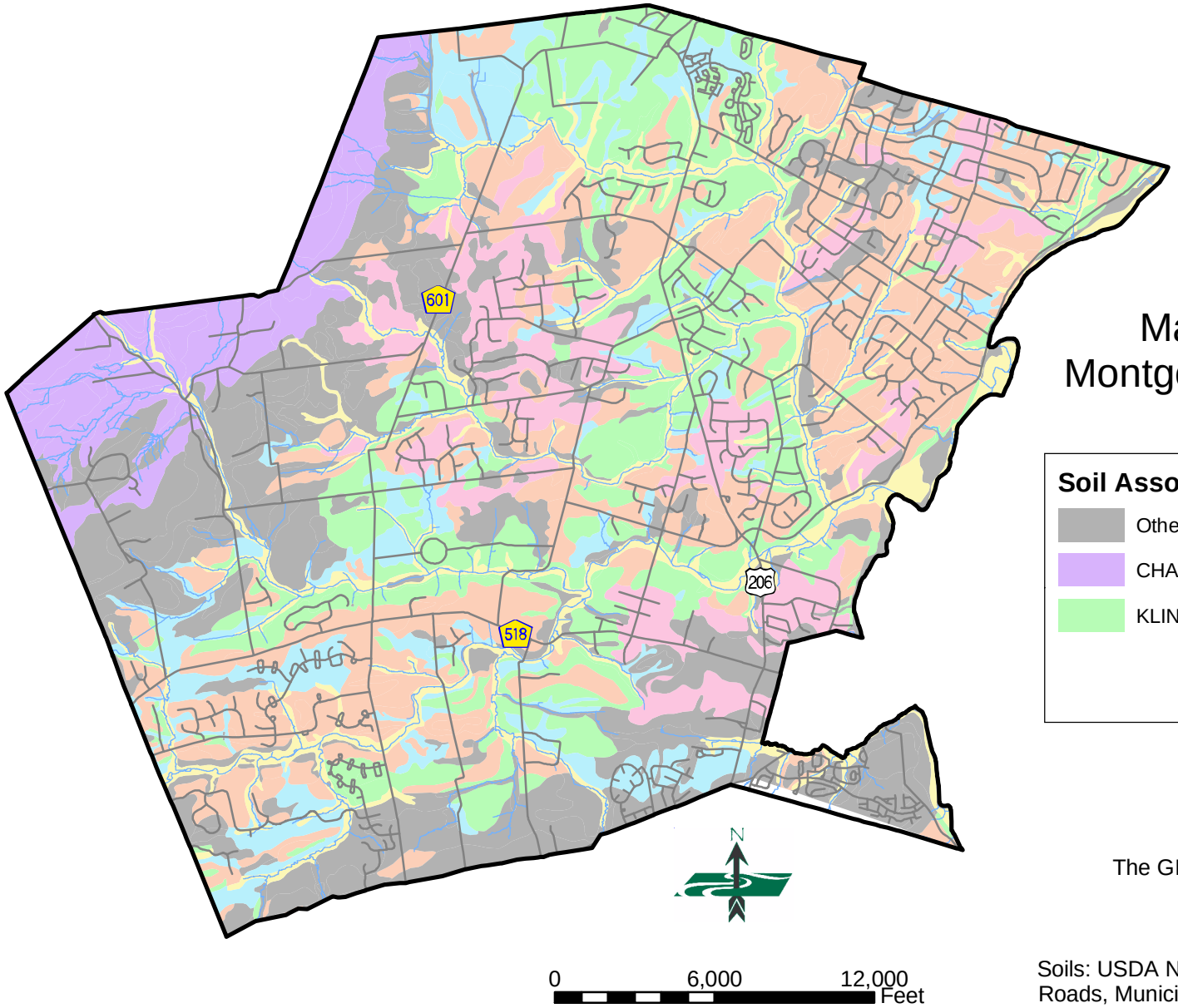

Figure 2: Major Soils of Montgomery Township

Soil Associations

- Other Soils
- CHALFONT
- KLINESVILLE
- PENN
- REAVILLE
- ROWLAND
- ROYCE
- Roads
- Streams

Prepared by:
The GIS Center at Stony Brook
December 2003

Data Sources:
Soils: USDA NRCS Somerset County soil data
Roads, Municipal Boundary: Montgomery Twp

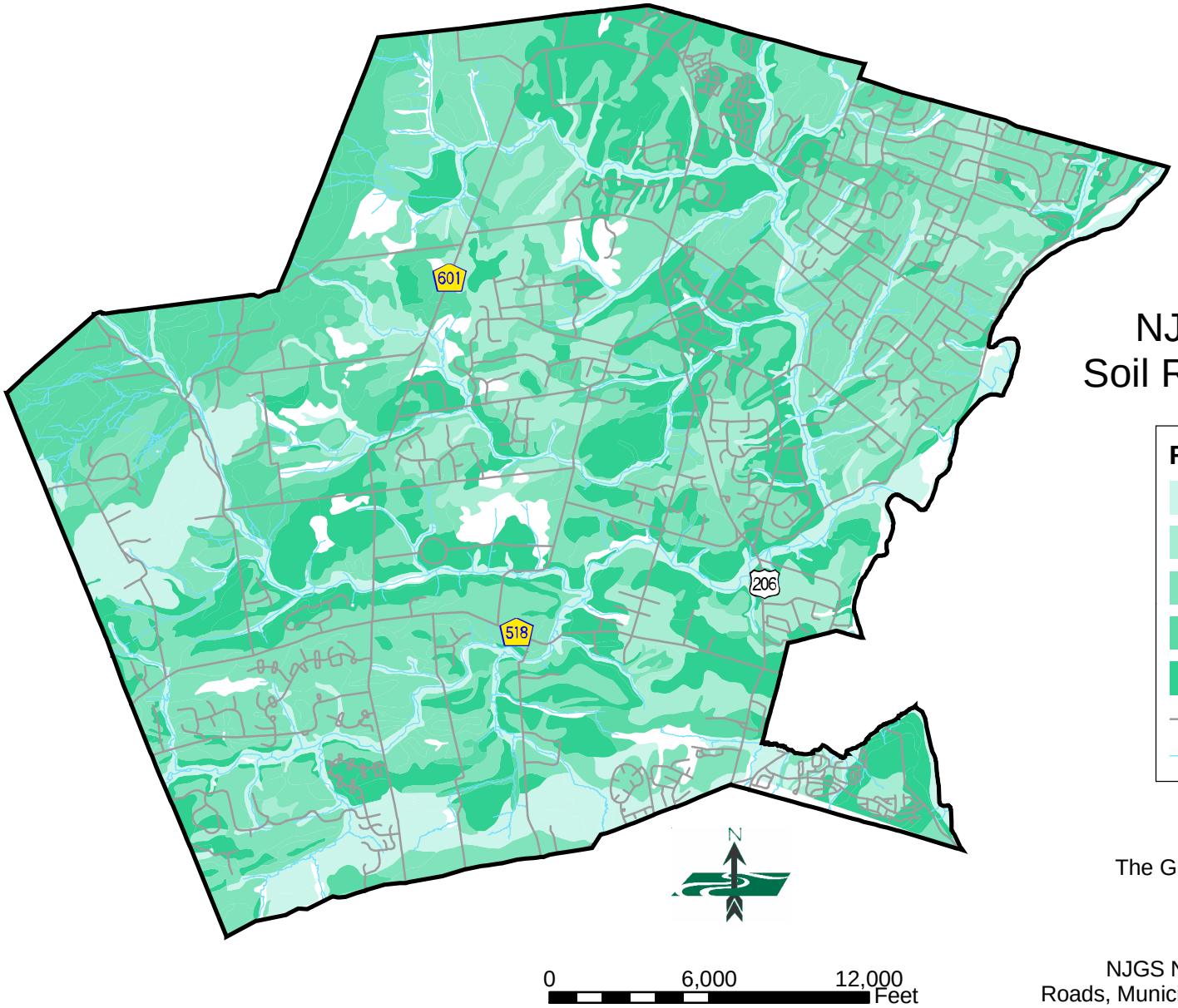

Figure 3:
NJGS Method:
Soil Recharge Rates

Recharge, in/yr

- 11.8 - 12.0
- 12.1 - 12.3
- 12.5 - 12.6
- 12.7 - 12.8
- 14.4 - 14.8
- Roads
- Streams

Prepared by:
The GIS Center at Stony Brook
December 2003

Data Sources:
NJGS Nitrate Dilution Model v5.0
Roads, Municipal Boundary: Montgomery Twp

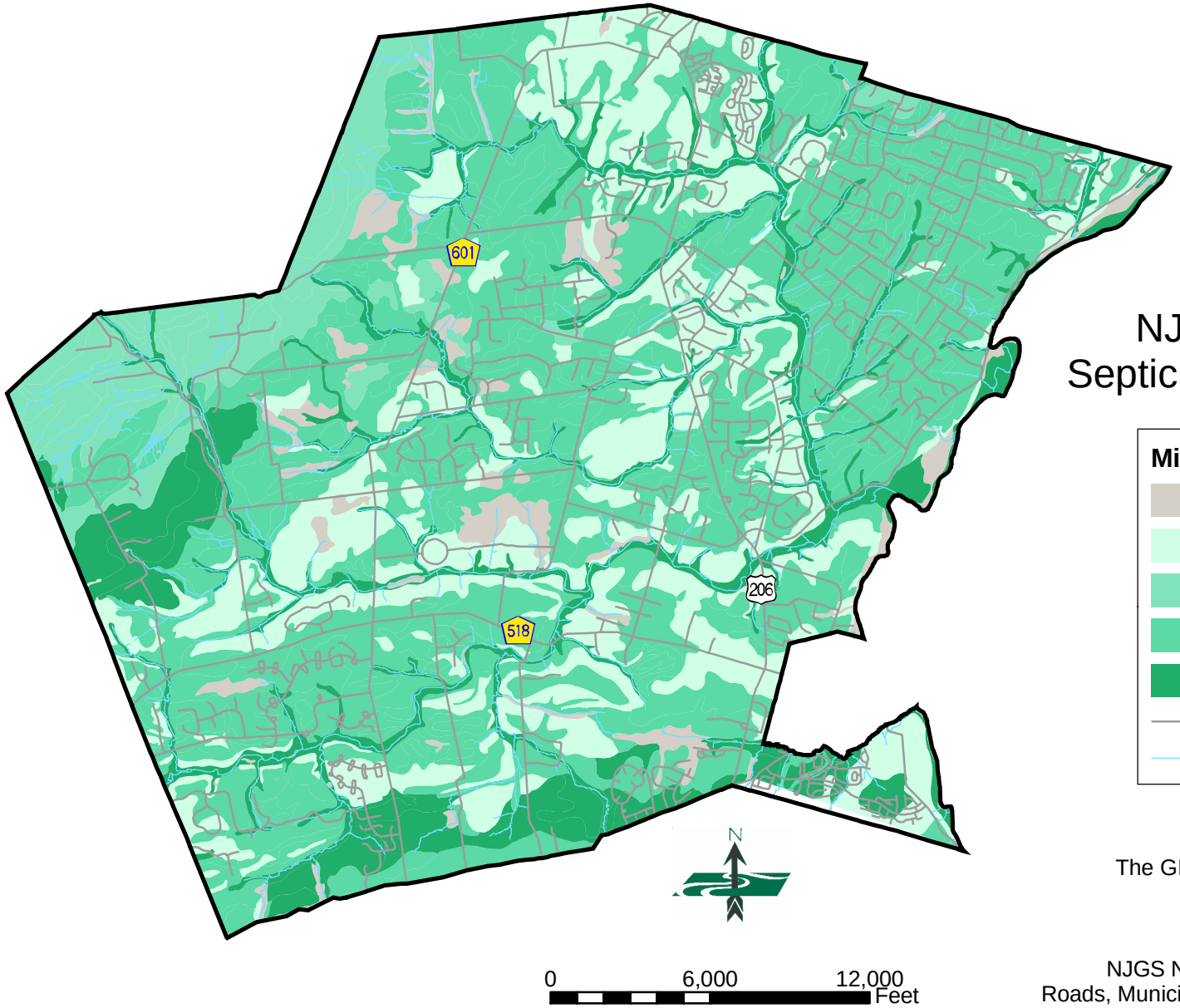

Figure 4:
NJGS Method:
Septic System Density

Min Acres/System

- N/A
- 2
- 2.2
- 2.3
- 2.4
- Roads
- Streams

Prepared by:
The GIS Center at Stony Brook
December 2003

Data Sources:
NJGS Nitrate Dilution Model v5.0
Roads, Municipal Boundary: Montgomery Twp

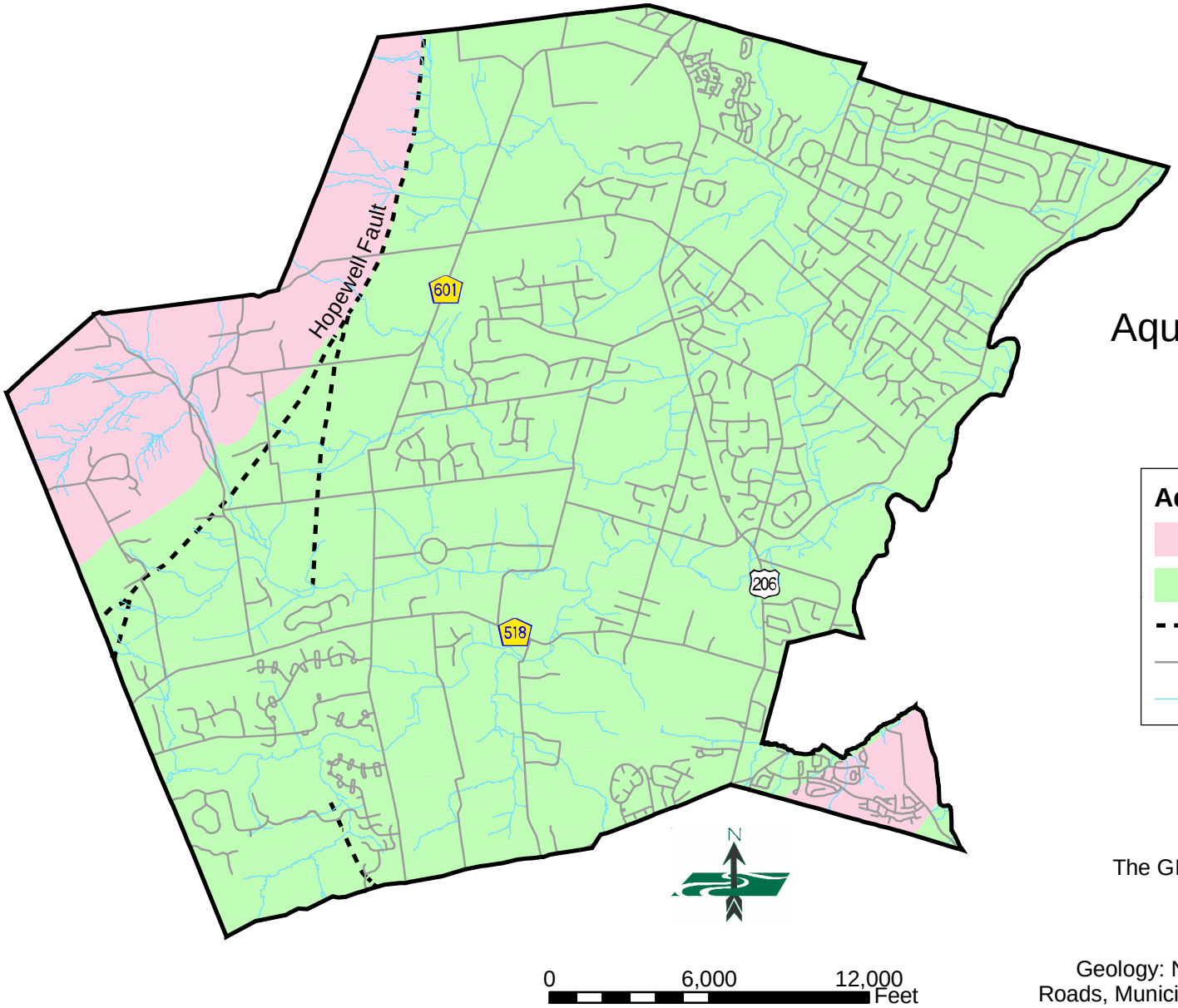

Figure 5: Aquifer Recharge Rates

Aquifer Recharge

- 2.2 in/yr
- 5.5 in/yr
- Faults
- Roads
- Streams

Prepared by:
The GIS Center at Stony Brook
December 2003

Data Sources:
Geology: NJ Geologic Survey CD 00-1
Roads, Municipal Boundary: Montgomery Twp

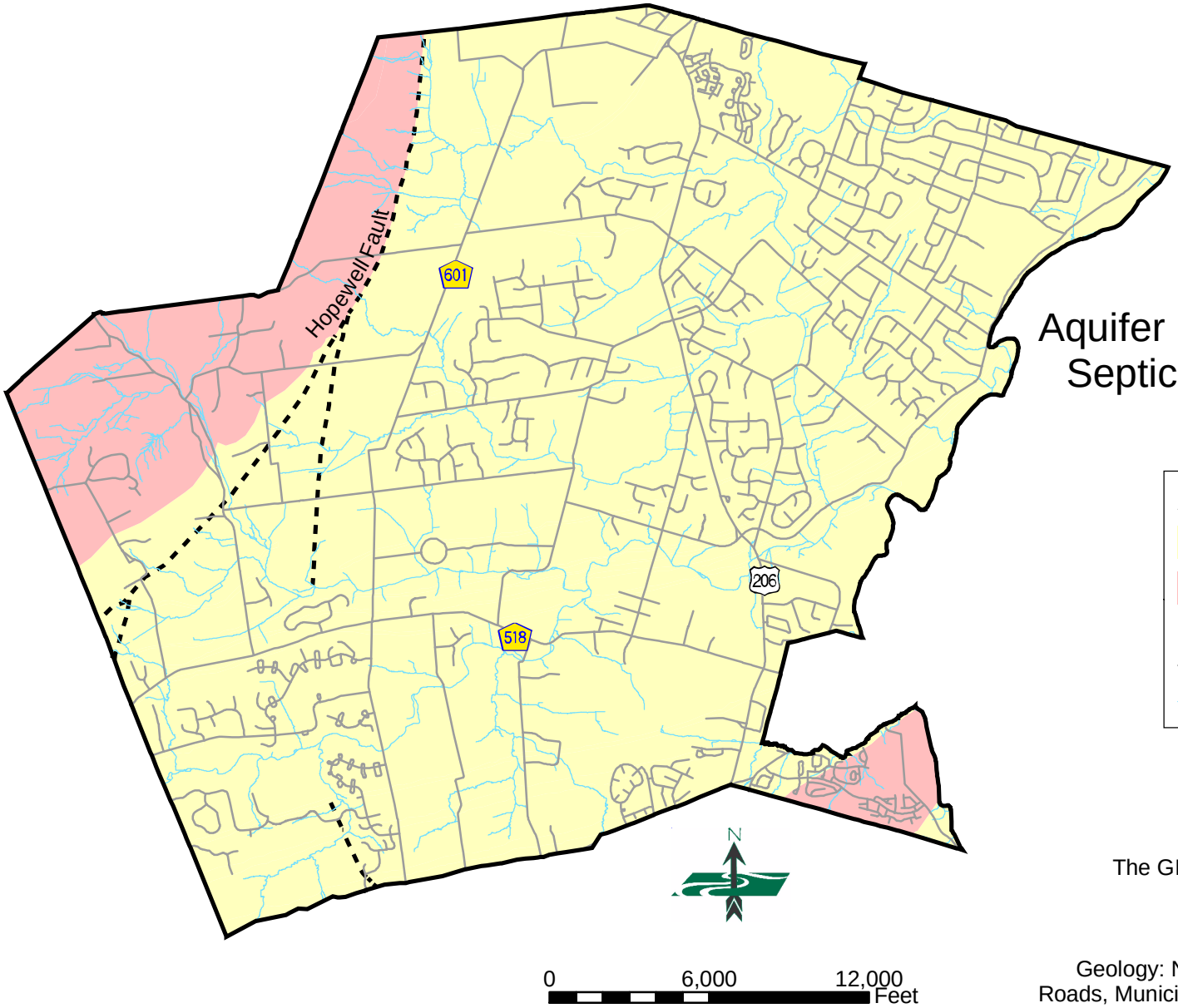

Figure 6:
Aquifer Recharge Method
Septic System Density

Acres/System

- 4.6
- 12
- Faults
- Roads
- Streams

Prepared by:
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[iii] "Evaluation of Groundwater Resources of Hopewell Township", M2 Associates, March 2001.
[iv] "Surface Water Quality Standards", N.J.A.C. 7:9B, New Jersey Department of Environmental Protection, pg. 4.
[v] Ibid, pgs. 2-3
[vi] Ibid, pg. 3
[vii] "Draft Guiding Principles for "Creating Quality Communities Together", Somerset County Planning Board, June, 2003, pgs 3-8.
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