Smart Growth Planning and Management Project for the Sourland Mountain

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Preface

A Conservation and Open Space Plan for the Sourland Mountain Region

A Natural Resource Inventory for the Sourland Mountain Region

Evaluation of Groundwater for the Sourland Mountain Region of Central New Jersey

Build Out Analysis of the Sourland Mountain Region

Comparison of State, County and Municipal Planning Documents, Ordinances and Board of Health Ordinances

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November 2005

Prepared by:

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M² Associates Inc.

Together with the:
Sourlands Planning Council

The Townships of:
East Amwell
Hillsborough
Hopewell
Montgomery
West Amwell

The Counties of:
Hunterdon
Mercer
Somerset

With additional support from:
D & R Greenway Land Trust
The Stony Brook Millstone Watershed Association

Cover photo by Peg Van Patton

PREFACE

It was May 26, 1999, and the meeting room of the East Amwell Township municipal building was filled with residents of the Sourland Mountain districts from East Amwell and Hopewell Townships. They were gathered there to hear about the history, geology, environment, and culture of the Sourland Mountain region. Jerry Haimowitz, President of the Sourland Planning Council, described the history of this special region, and showed the geology using GIS maps prepared by Joel Coyne, West Amwell. Linda Mead, Executive Director of Delaware & Raritan Greenway Land Trust (D & R), talked about the success that D & R has had with preserving land through conservation easements. Ted Stiles, Professor of Biology at Rutgers, and President of Friends of Hopewell Valley Open Space, showed slides of neo-tropical migrating bird species, some of which are on the threatened and endangered lists, and educated the audience about the plants and animals that depend on the mountain environment. George Hawkins, Executive Director of the Stony Brook Millstone Watershed Association, discussed the water cycle and the importance of coordinated environmental protection to assure adequate clean water supply for citizens. The information presented that evening challenged the human inhabitants of the Sourland Mountain region to become responsible guardians of the environment for a long-term sustainable future for all species of birds, plants and animals.

This was the beginning of the Sourland Mountain Smart Growth project, which has spanned the past six years, and involved many volunteers from five municipalities, three counties, and several non-profit organizations. This document compiles the work products of the consultants into the final report of the Sourland Mountain Smart Growth project. This preface serves as an introduction to how the grant was organized and funded and describes the roles of the various participants on the project's Steering Committee.

Later in 1999, the Sourland Mountain presentation was repeated in Hopewell Township. The enthusiasm of the audience motivated the Planning Board chairmen of East Amwell and Hopewell Townships to seek funding for a study under the auspices of the New Jersey Department of Community Affairs (DCA) Smart Growth grant program. Everyone acknowledged that the fragile environment of the Sourland Mountain, including the limited capacity of the aquifers, did not recognize municipal or county boundary lines. If natural resources were to be available in the long term, conservation efforts on a regional level would be necessary.

The two lead municipalities invited the Sourlands Planning Council (SPC) to work together with them to pursue funding for a smart growth grant and to coordinate the effort among the five towns. Representatives from the other three municipalities with significant land areas on the Sourland Mountain (West Amwell, Hillsborough, and Montgomery) were invited to join the project. The three counties, Mercer, Hunterdon and Somerset, also joined the project. Other non-profit organizations with similar missions, Stony Brook Millstone Watershed Association and the Delaware & Raritan Greenway Land Trust, also lent their expertise.

By the summer of 2000, a Steering Committee was formed with three to four representatives from each of the participating towns, nominated to serve by the mayors. Counties and non-profits also appointed members to the Steering Committee. SPC volunteers completed a draft proposal for a Smart Growth project that would study the characteristics of this region, and propose appropriate conservation strategies and a regional Land Use plan. Public education and outreach were components of the project, so that the residents of the Sourland Mountain region could become better informed about the nature of the fragile area in which they live, and therefore could become better custodians of their own part of the mountain, their own backyards.

Although the initial proposal was submitted for funding in fall 2000, the proposal was not officially funded until the fall of 2003. During the interim period, and due to limited state funding, the scope of the initial work plan was scaled back. The final approved plan for the project provided funding for the following consultant's work products:

- Groundwater Resource Evaluation of the Sourland Mountain (Matt Mulhall and Peter Demicco)
- Natural Resource Inventory for the Sourland Mountain Region (NRI) (Banisch Associates, Inc.)
- Build-out Analysis for the Sourland Mountain Region (Banisch Associates, Inc.)
- Comparison of State, County, and Municipal Planning Documents, ordinances, and Board of Health Ordinances (Banisch Associates, Inc.)
- Conservation and Open Space Plan (Banisch Associates, Inc.)

These documents are reproduced in this final project report.

The Sourland Planning Council assumed responsibility for organizing and facilitating meetings of the Steering Committee, which were held on a rotating basis in all five participating townships. The Steering Committee met approximately two to four times per year during the project, to review, discuss and offer suggestions about the substance of the consultant's work. The Steering Committee also provided an opportunity for colleagues in neighboring towns to share information about similar problems and solutions. This opportunity for discussion of common planning concerns across municipalities is one of the benefits from the organization and process of this project.

The kick-off Steering Committee meeting was a bus tour that visited historic and environmentally unique places – the highlights of the Sourland Mountain region. This marked the official beginning of the project, in October 2003, as soon as the grant funding had been received. Since then the SPC repeated the bus tour in Montgomery and Hopewell townships, and more than 100 citizens have had the opportunity to become better informed about the distinctive features of the Sourland Mountain region.

This report is a compilation of the five consultant's reports, listed above, and represents the final report of the Smart Growth project.

There are some limitations to the report, which need to be mentioned here. The primary source of the published aerial maps and photos of Land Use and Land Cover (LU/LC) is the New Jersey Department of Environmental Protection, (DEP). When the Smart Growth project first began, in 2003, the 1995 editions of the LU/LC maps were available for analysis. At that time, the DEP had a project underway to update the 1995 editions of the LU/LC maps with a 2002 data set. It was projected that the data would be available for analysis prior to the completion of Phase I. Since these maps are still not available at publication date, the NRI, the buildout report, and the Conservation and Open Space Plan are based on the 1995 LU/LC. Once the 2002 LU/LC data are available, the Steering Committee has asked the SPC to obtain funding for a supplement to this project report which would update the maps in the NRI and other documents.

Another limitation of the report is that maps showing preserved farmland and open space were produced as of a certain date, noted with each specific map. Due to the active and on-going farmland preservation and open space acquisition efforts in all of the participating municipalities, the maps showing preserved lands become outdated very quickly. West Amwell Township, for example, has been very successful recently adding hundreds of acres of preserved land to its inventory. It was impossible to keep updating the maps to reflect every new parcel of land as it is preserved – the project would never reach an end.

The best news for the Sourland Mountain environment is that these land preservation activities are continuing and gaining momentum. The most successful and permanent conservation approach to protecting the ground water supply and the integrity of the Sourland Mountain forest is to acquire the sensitive lands for public ownership. Holding lands in private ownership and protecting them with conservation easements is also an important strategy. Land in private ownership with no protections provides the greatest threat of inappropriate development.

A wealth of information is contained in this report. A series of recommendations for subsequent studies and projects are provided in the final report, the Conservation and Open Space Plan. Through a combination of intensive public education and outreach efforts, and appropriate regulations and ordinances, the Sourland Planning Council and the municipalities located in the Sourland Mountain region should continue to pursue the goals of long-term sustainability for this region. Through a concerted effort by local, county and state governments, the region's leading non-profit organizations, and the homeowners and citizens of the Sourland Mountain region, the quality of life offered by this unique Special Resource Area can be preserved for the residents who share the region with the neo-tropical migrating birds and other species of plants and animals.

The quality of this final report is due to the fine work of the consultants to the project: Frank Banisch, Jim Kyle, and Joanna Slagle from Banisch Associates, Inc., and Peter Demicco and Matt Mulhall, hydrogeologists. The Sourlands Planning Council, Jerry Haimowitz, SPC President from 1999– 2003, Jennifer Bryson, project coordinator and subsequently, SPC President from 2003 to 2005, Kathy Bird and Steve Sacks-Wilner,

played an important role in disseminating information about the project to the public, and coordinating the meetings of the Steering Committee. Through the Steering Committee meetings, the municipal representatives had an opportunity to share their different approaches to solving the challenging objectives of environmental protection while allowing for landowner property rights. This laid a framework for inter-municipal cooperation across the region, which may be continued in Phase II of the Smart Growth project. The following planning board representatives were the designated representatives from their towns to the Smart Growth Steering committee: Mick Aucott, Hopewell Township, Marian Fenwick-Freeman, Hillsborough Township, Steve Sacks-Wilner, Montgomery Township, and Ron Shapella, West Amwell Township. The non-profit partners in the project also contributed their time and expertise: Linda Mead and Bill Rawlyk, Delaware and Raritan Greenway Land Trust; and George Hawkins and Jennifer Coffey, Stony Brook Millstone Watershed Association. Many other individuals from the participating municipalities, neighboring boroughs of Hopewell, Pennington and the town of Lambertville, and the three counties (Hunterdon, Mercer, Somerset) participated in Steering Committee meetings, reviewed documents, and provided other assistance. Only through the combined efforts of so many individuals from local and county governments and non-profit associations, has a project of this scope come together. The findings and the recommendations provide a wealth of information that can serve as an important guide to future efforts to preserve the fragile environment of the Sourland Mountain region.

Barbara B. Wolfe, East Amwell Planning Board
on behalf of the Smart Growth Steering Committee
October 2005

A Conservation and Open Space Plan for the Sourland Mountain Region

Prepared by:
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Sergeantsville, NJ

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New Jersey Office of Smart Growth

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We do not inherit the earth from our ancestors,
We borrow it from our children

-Native American Proverb

Executive Summary

The Sourland Mountain region is an island of biodiversity in a sea of encroaching sprawl. Characterized by a fragile ecological balance, where a severely limited water supply strains to support the increasing demands of human habitation and ecosystem functions, the Sourland Mountain region faces unprecedented pressures that threaten to deplete and degrade the water that maintains this delicate ecology and the lifestyles of residents of the mountain.

Alterations to the natural landscape associated with human activity penetrate the canopy of the contiguous forest and invite predators into this once protected sanctuary. Agricultural activities, which create the grasslands that support endangered and threatened species on the flanks of the mountain, also pose direct threats to the survival of these populations as the mowing of hay fields either protects or destroys this habitat, depending upon its timing.

Hydrogeologic investigation suggests that water withdrawal for human use poses severe risks to the Sourlands ecology. Two-thirds of the streams in the region (over 90 stream miles) are “first order” streams, the critical headwaters to the Raritan and Millstone Rivers that provide potable water to downstream users. New homeowners may fail to recognize the region’s severe water constraints and attempt to water lawns, fill swimming pools and wash cars as if water was an unlimited resource. The continuing intrusion of manmade activities and related impervious cover into the sensitive mountain ecology threatens to reduce essential recharge, deplete biological diversity and diminish the Sourland Mountain’s natural buffering functions, which provide uniquely valuable breathing space in this portion of central New Jersey.

This Conservation and Open Space Plan for the Sourland Mountain region recognizes that stewardship and cooperation must be core-operating principals, if the mountain is to have a sustainable future. But balancing the needs of humans with the requirements of a high quality environment is not an easy task. While the inhospitable environment of the

Sourlands discouraged human settlement on a large scale for centuries, modern technological advances have virtually assured that the mountain's ruggedness can be overcome and its sensitive ecology destroyed or dramatically degraded during the 21st Century. This plan recognizes that development in the sensitive core area should be substantially curtailed, and limited development should be managed to protect the water supplies, habitat and rare species of the Sourlands. This plan advances a range of goals and strategies to prevent significant environmental degradation and to maintain the sensitive balance of natural features that currently exist.

The long-term health of the region will depend on the stewardship exercised by those who own, manage or use these lands. This plan seeks to guide these actions toward a sustainable future by developing policies and strategies that will:

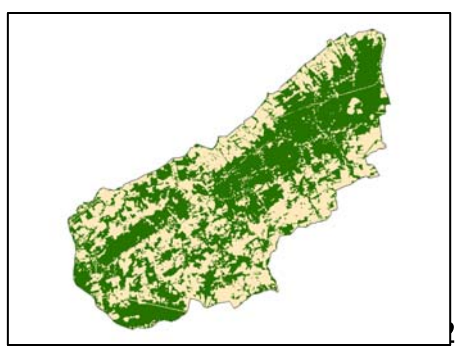
- Maximize the permanent preservation and stewardship of critical resource lands;
- Maintain the quantity and quality of surface waters and groundwater to protect the ecological health of the region;
- Conserve large contiguous areas of forest, grasslands, wetlands and other critical habitat by limiting the effects of man-made activities;
- Manage *limited* growth to respect the region's limited carrying capacity, protect rural character and be compatible with ecological constraints; and
- Promote restoration of degraded landscape features.

Recommended strategies to meet these goals include a variety of planning, management, regulatory and educational activities, including:

- Secure Special Resource Area identification in the State Development and Redevelopment Plan. This designation, previously only applicable to the New Jersey Highlands, will call special attention to the resource conservation needs of the Sourlands.

- Develop a Sourland Mountain municipal alliance modeled on the Ten Towns Great Swamp Watershed Management Committee. This approach recognizes that municipal home rule will continue to shape change on the Mountain, and relies on municipal cooperation in the exercise of municipal planning and regulatory powers. The highly successful Ten Towns Committee has been copied for other regional watershed applications, and its focus on public education and incentives, in tandem with plans and regulations, makes it a worthy model for a Sourland Mountain municipal alliance.

- Identify the forest core and corridors for preservation. This should include the large contiguous interior forest areas where little or no development can be tolerated without significant habitat loss. This area should be protected from further fragmentation, and



corridors of similar habitat should be maintained or restored, and targeted for acquisition or other preservation. Future management of existing land uses should seek to minimize detrimental impacts and phase out inconsistent or deleterious land uses, through a range of policies, regulations and education.

- Identify an agricultural retention area, where continuing agricultural activity, using best management practices, is to be supported. The Sourland Mountain region identified in this plan includes areas well suited to farming as well as those where farming is not appropriate. A coherent regional planning approach will acknowledge the importance of supporting agriculture on prime farmland, while also discouraging or preventing agriculture where it would damage a fragile ecosystem or overstress limited water supplies. Failure to clearly define such areas will create unnecessary adversaries among those with competing visions for the varied landscapes of the Sourland Mountain region.

- Prepare a comprehensive Forestry Management Plan for the region, including detailed forest stand delineation, to actively manage impacts to the forest from development, timber harvests, farming and other activities. Change is inevitable, so change should be harnessed wherever possible to improve the future forest's ability to protect local water supplies, while also protecting and enhancing habitat value and biological diversity. Aesthetic considerations should be appropriately weighted in developing forest management strategies.

- Prioritize open space acquisitions to mirror the level of environmental sensitivity of the resource to be protected.

- Protect surface and groundwater quality and quantity to maintain the ecological integrity of natural ecosystems and human health using Best Management Practices and responsible land use policies.

- Develop a greenway plan for headwater riparian corridors and other conservation areas.

- Prepare a comprehensive cultural resource management plan that integrates local historic preservation plans. This should include an inventory of historic transportation features (bridges, narrow road alignments, etc.) and preservation strategies for cultural landscapes.

- Promote diverse partnerships among governments, non-profit entities and private landowners to assure enhanced stewardship.

- Explore establishment of a "Sourland Mountain Habitat Management Area" identification program, including signage similar to that used in the Great Swamp Watershed.

- Promote coordination of active and passive recreation plans by all sponsoring agencies to maximize the habitat and water conservation benefits of passive open space and minimize any detrimental effects of active recreation facilities.

- Develop a coordinated indicators program to measure and monitor the ecological health of the region, including surveys of stream flow and surface water quality (chemical, physical, biological), regional water levels and groundwater quality (from well records), breeding birds, amphibians and other flora and fauna, including invasive and rare species.

- Promote aggressive deer management strategies at the local, county and State level and conduct studies of the effect of deer harvest on the forest.

- Advocate for enhanced environmental protection standards for the Sourland Mountain's critical core area. DEP requirements applicable throughout the State may fail to adequately protect water resources, native vegetation and wildlife within the Sourland Mountain region. Special Resource Area designation should call attention to the importance of higher standards of protection for these resources.

- Plan for and manage limited growth to be compatible with ecological constraints, with a "zero tolerance" approach to pollution, destruction and degradation.

- Limit anthropogenic demands on the environment through land acquisition and land use policy that minimizes the footprint and water demands of future development.

- Develop equitable strategies to phase out incompatible agricultural activities within the water-poor Sourlands core area, and prevent forest clearing in this area for agriculture.

- Explore use of a Transfer of Development Rights (TDR) program for vacant undersized lots to relocate development from the Sourland Mountain core area to less environmentally constrained areas.

- Minimize impervious cover in aquifer recharge areas and limit water use by new development and agriculture.

- Establish demanding environmental protection strategies and design and performance standards for new development and redevelopment.

- Catalog and disseminate sound habitat management policies that prevent habitat fragmentation, including conservation site designs and coordinated management of upland forest and grassland habitat.

- Develop land stewardship programs for farmers and homeowners (i.e., pesticides, shrubs, land uses, environmental remediation) including habitat management demonstration projects.

- Provide public education including a “pre-purchase advisory” about resource conservation to guide those who will live, work and play on the Sourland Mountain, including “how to” guidelines on lawns, forests, grasslands, etc. Those who wish broad lawns and ornamental landscapes should find suitable locales outside the Sourland region, because these superimposed landscape changes damage the natural environment, and their cumulative external impacts destroy important resources. Sourlands municipalities and counties should join together in developing public education programs and policies and regulations uniquely suited to protect Sourlands resources.

Some of these strategies will require assistance from State legislators or Departments. A concerted effort should be made to secure legislative changes to provide:

- Preferential tax treatment, similar to farmland assessment but without requiring production income, for conservation efforts that preserve wildlife habitat without the need to destroy or damage forest resources for income;

- Effective deer management within the Sourlands region that is essential to healthy regeneration of the forest and its understory;

- Enhanced DEP environmental protection standards applicable within the Sourland Mountain region to reflect the anticipated Special Resource Area status in the amended SDRP;

- Increased funding for open space preservation and habitat protection within the region; and

- Better management of public lands.

The biodiversity of the Sourland Mountain region, and the limited water on which it depends, can only be protected if man-made impacts are minimized and tailored to preserve, protect and enhance this unique environment. This Conservation and Open Space Plan should be viewed as a living document, with strong roots in the essential substratum of the mountain and many branches growing from its multi-focal strategies.

Health is the capacity of the land for self-renewal.
Conservation is our effort to understand and preserve this capacity...

-Aldo Leopold, A Sand County Almanac

Introduction

Every natural landscape is an expression of the unique interaction among wind, water, soil, plants and animals. In the Sourlands, the intersection of these elements has provided a landscape that is uncommon and special. Unlike the Amwell and Hopewell Valleys to the north and south, which share common attributes with other agricultural valleys in the larger region, the Sourland Mountain has no nearby peers. Its uniqueness reflects the geology that formed this relatively small island in central New Jersey, where rare and exceptional flora and fauna flourish in natural conditions not found elsewhere in New Jersey.

This Conservation and Open Space Plan examines the unique ecology and culture of the Sourland Mountain and identifies critical resource issues affecting sustainability within the region. Recognizing the importance of effectively managing growth and change within this fragile ecosystem, the municipalities that share jurisdiction over the Sourland Mountain region (East Amwell, West Amwell, Lambertville, Hopewell Borough, Hopewell Township, Montgomery, Hillsborough), have partnered with the Sourland Planning Council, with the aid of a Smart Growth Planning Grant from the New Jersey Office of Smart Growth, to develop a better understanding of these challenges and effective strategies to manage limited growth and promote conservation.

The characterization phase of this Conservation and Open Space Plan included studies that examined the natural resources of the 56,000-acre Sourlands region study area, and assessed groundwater resources to provide a basis for responsible management policies. Toward that end, municipal regulations were examined and compared throughout the region, and development potential was calculated through build-out analysis, to portray the future extent of development if current policies and regulations remain in effect.

The Sourland Mountain region, situated along the growth corridor between New York and Philadelphia, was largely spared the rapid growth of the post-war era that consumed much of the farmland in the three Sourlands counties (Somerset, Hunterdon and Mercer). In fact, the mostly wooded and environmentally fragile core of the mountain has remained relatively intact. However, this is changing. Between 1972 and 1995, more than 4,200 (21%) of the 20,000 agricultural acres in the Sourland Mountain Region were converted to developed land uses, along with over 1,800 acres (7%) of forest and over 700 acres (9%) of wetlands. The land cover observed in the Sourland region in 1995 (latest available data) showed a largely wooded landscape (24,000 acres or 43.3%) with significant agriculture (16,000 acres or 28.9%) and wetlands (7,000 acres or 12.8%). Development between 1972 and 1995 had consumed 7,700 acres (13.9%), a figure that is somewhat larger today.

As development continues to be redirected away from farmland and other fragile ecological areas, like the 800,000-acre Highlands to the north and the million-acre Pinelands to the south, increasing pressure has mounted to develop the relatively small but fragile mountain. Only careful management of limited development and aggressive protection of critical habitat areas can enable the long-term protection of the Sourlands environment and the survival of the species that depend on the delicate balance of water, soil, plants and animals in the region.

The Sourland Mountain formed over 150,000,000 years ago, during the Triassic and Jurassic Periods, the result of continental separation or rift. The geology that formed the unique topography of the Sourlands is inhospitable to the installation of septic systems and severely limited for the withdrawal of groundwater from two sole source aquifers that underlie the Sourland Mountain region. High bedrock hinders efficient septic installation and a high water table in many areas imposes increased costs for specialized septic systems. When located near wells, septic systems can pose health hazards, as the cracks and fissures in the hard mountain bedrock allow the rapid transport of septic effluent toward wells. This effluent receives little or no renovation after leaving the treatment bed, due to the nature of the soil and parent material, and little dilution of contaminants, since the diabase, argillite and nearby shales, baked by these volcanic intrusions, have very limited water storage capacity. These combined factors make continued residential development a distinct threat to the sensitive ecosystem balance and to existing residents.

Current settlement patterns place human demands on this limited water supply that should be respected and carefully managed. This inhospitable environment discouraged significant settlement by the Europeans who migrated to the area in the 18th century, and had a similar effect during the 19th century. The latter part of the 20th century, however, brought technological advances that aided human settlement of areas previously deemed too harsh. New or improved technologies for disposal of human waste and mechanical devices to maximize extraction of the limited available water, now pose a significant threat to the overall ecological health of the mountain.

In addition to the local importance of adequate volumes of high quality water, the Sourland Mountain region performs an important regional water quality function. The water that flows within headwaters that originate on the mountain travels downstream, diluting the effects of non-point and other downstream pollution and maintaining stream flow and the biotic communities supported by these streams. Having less water in Sourlands aquifers increases the likelihood of well pollution from septic systems, and there is no cure for overpumping limited potable water supplies, except imported water. Exceeding the water supply capabilities of the region will have irreversible consequences.

Wetlands on the mountain perform a variety of functions, retarding storm peak flows, removing contaminants and providing habitat for wildlife. These wooded wetlands, which store and transmit water to streams that flow into other areas of central New Jersey, combine with upland forests to form the largest contiguous remaining forest in central New Jersey**.** The vernal pools and emergent wetlands of the region offer unique habitat to a number of threatened or endangered herptile species.

Riparian areas, surrounding streams and other surface waters, are an important part of the ecosystem that serve a multitude of functions. In addition to controlling water temperature, stabilizing the stream bank, filtering pollutants from runoff, controlling sedimentation and contributing organic matter to the stream ecosystem, these streamside areas are well suited to passive recreation activities and serve as corridors for wildlife migration.

Neotropical migrant songbirds rely on the Sourland Mountain as an ecological island stopover on their long flight from Central America to Canada, and this habitat is critical to the survival of populations of breeding and migrating birds. The richness of bird species, both resident and migrant, relies upon the composition of the expansive contiguous forest, with an understory habitat critical to migrating species, and the successional shrubland and grassland habitats on the Mountain and in the adjoining Amwell and Hopewell valleys.

The geology, soils, wetlands, forest and grasslands combine to form a landscape uniquely suited to sustain an incredibly diverse array of plants and animals, all dependent on adequate water. But the Sourland Mountain region is in danger of overspending its water budget. Loss or degradation of any of these resources, particularly the understory of the contiguous forest canopy, will have a direct effect on the species composition and biodiversity of the area.

The Sourland Mountain region is relied upon to sustain both human and animal populations. The water supply demands of new households will compete directly with the water needed to maintain the seasonal water level that allows rare species to thrive and multiply. Other manmade activities, like agriculture, will compete for the limited available water and, along with the broad green lawns of suburban estate homes, deposit tons of chemical fertilizers and pesticides into this water-poor aquifer system. And while the human population continues to increase, it is rivaled by the overpopulation of deer in destructive impacts on the forest.

A sustainable future for the fragile Sourland Mountain ecosystem will depend on limiting residential, agricultural and commercial expansion, and shaping new development to maintain and reinforce the ecological balance, prevent forest fragmentation and limit competition for scarce water supplies.

The Sourland Mountain is a region at the crossroads. Along the Crossroads of the American Revolution, it chronicles our early life as one of the original Colonies and the critical troop movements that assured American independence. As an essential stopover for Neotropical migrant songbirds, it is an avian crossroads. The country roads that crisscross the Sourlands are also crossroads for commutation between homes and places of employment, which are increasingly widely spaced and disconnected from historic centers. And as the Sourlands region experiences continued pressures, valuable natural resources, including the limited water supply, are threatened by random and piecemeal development, presenting a decision crossroads-continuing development “business as usual” versus effective resource protection and ecological sustainability.

As we face these issues in the 21st century, it is important to recognize that unbridled human activity is not sustainable, particularly in the Sourlands, and will result in exploitation of sensitive and limited resources beyond their limits. With that recognition, this Conservation and Open Space Plan identifies critical areas of conservation concern, and proposes a series of policies, strategies and actions to manage landscape change for the greater ecological benefit of the region and its residents.

Biodiversity of the Sourland Region

Biological diversity is a reflection of the health of an ecosystem. The Sourland Mountain region hosts a wide variety of plant and animal species, within the extensive forest and rural landscape that provide the greatest block of contiguous forest habitat in the State’s Piedmont province. Nonetheless, the habitat that provides shelter, sustenance and a safe place to reproduce, continues to be lost to development despite aggressive public and private preservation efforts. Available biological data and pertinent scientific literature highlight the unique attributes that make the Sourland Mountain Region so important as habitat, including:

- The Sourland Mountain region is one of only three major areas of unbroken habitat in New Jersey, at a strategic location mid-way between the Highlands and the Pinelands.
- The Sourland Mountain region contains a variety of habitat types of high quality and of substantial size, ranging from grassland to mature woodland and including a continuum of successional stages that support a rich diversity of biotic communities. The Nature Conservancy identified 7,737 acres of core forest within their 28,860-acre Sourland Mountain Matrix Block; the New Jersey Landscape Project identifies over 90% of the Sourland Mountain region (51,252 acres) as known habitat or as suitable habitat for species that are endangered, threatened or of special concern.
- The Sourland Mountain region includes the largest contiguous forest in central New Jersey.
- Nearby land use patterns, combined with the size, shape and composition of the forest, contribute to the high quality of Sourlands woodland habitat, especially for forest interior nesting birds.
- The Sourland Mountain region is a critical stopover point for birds migrating along the Atlantic Flyway and is one of New Jersey’s top fall migration stopover sites. Protection of high-quality stopover sites is as essential for long-distance migrants as their breeding and over-wintering habitats.

- The Sourland Mountain region supports a great diversity of bird species, many of which are listed as either threatened or endangered, or are being tracked as species of special concern.
- Vernal pools are isolated wetland depressions that are seasonally filled with water are common in parts of the Sourlands. Some of these are known breeding sites for a number of herptiles who require these pools for egg laying and early life stages.
- The Sourland Mountain region may be the last refuge of some complex plant communities that once flourished in central New Jersey. Sixteen plant species that are either endangered or of special concern in New Jersey have been documented in the Sourlands to date.

The Sourland Mountain region is unparalleled as an ecological island of unbroken habitat in central New Jersey, in part due to geological and hydrological features that hindered human encroachment and aided animals and plants. Past and present agriculture on the more hospitable foothills has exploited productive farmland soils and created a desirable continuum of habitat types - grasslands and meadows, shrub-scrub or old fields and early successional woodland. However, limiting agricultural impacts is also critical to protecting the mountain ecology, since clearing and farming on the hard rock mountain plateau removes forest cover, introduces nutrients and competes for limited water supplies. Thus, while farming is desirable in appropriate areas, it should be avoided on the wooded plateau where water is in very short supply.

Headwaters originating on the mountain provide riparian and aquatic habitat, and perched water table areas supply an ephemeral yet critical habitat for a number of specialized organisms. These habitat types, shaped by the geology and contours of the land, its soils and hydrology, are uniquely suited to sustain a diverse array of plants and animals. Nonetheless, manmade activities can easily impact many of these species and the biodiversity of the area.

The Sourland Mountain region is a reservoir of biodiversity. Not only does it provide prime habitat and a critical migration stopover site but, because it supports larger populations of many organisms, it can serve as a source of genetic diversity for other populations of the same species that utilize smaller habitat patches nearby.

Land use changes over the past hundred years have left the current patchwork of habitats in various stages of succession, ranging from active farmland to nearly-mature woodland, mostly along the lower flanks and in the foothills. The mature forest that now covers the ridge is secondary growth that replaced the virgin old-growth forest that was logged many years ago. This pattern gives an historical record of the use and disuse of the fields and provides a wide variety of habitat types that support a remarkable diversity of animals and plants.

Removing the forest for farming or development, even in small patches, can have impacts extending up to 1,000 feet in all directions, and creates an “edge effect”, where the deep woods habitat of the interior forest is fragmented and breeding bird habitat is threatened by increased nest predation. Many Sourland region species rely on both the quantity and the quality of the forest and understory, and will disappear as the forest becomes fragmented and degraded.

Figure 1: Interior Forest Blocks, illustrates the locations of interior forest blocks that remain after roadway buffers are removed.

Protecting forest habitat capable of supporting the complete suite of forest interior species is a primary goal of this plan. The Nature Conservancy (TNC) has assigned buffer width values ranging from 0 to 500 meters, depending on the degree of disturbance generated, with primary roads significantly affecting forest habitat to a depth of 500 meters, local roads to a 100-meter depth and hiking trails less than 10 meters and having no negative impact. When these buffers are removed, what remains is the forest habitat capable of supporting the forest interior species appropriate for the region.

Sustainability and Stewardship – Core Conservation Concepts

Sustainability is a widely referenced term that merits a fairly precise definition, since it is guiding public policy. In 1987, the World Commission on Environment and Development fashioned a definition of sustainability that was included in its findings, which became known as the Brundtland Report. It stated that:

> *Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.*

Although this definition has become widely publicized, the full meaning of sustainability is somewhat broader, and relates to the overall health of the planet and its occupants. The 1992 Rio Earth Summit and subsequent G7/G8 conferences promoted living, working and ordering society in ways that are environmentally "sustainable", by reducing waste and pollution, re-using resources and promoting biodiversity. In nature conservation terms, sustainability means using natural resources in such a way that the environment's natural qualities can be maintained for the long term.

Stewardship embodies the concept of land as a resource, and recognizes our responsibility to manage it wisely for the benefit of current and future generations.

On the Sourland Mountain, sustainability and stewardship take on a special meaning. Scarce water resources, critical to maintaining the natural ecology, are increasingly sought for human use. Construction of new homes or businesses and the conduct of agricultural operations on the mountain increase the demands on the limited water supply. And when these demands exceed the supply capabilities, the results can be disastrous for people, as well as the environment. Potable water wells have been depleted as new water users drill deeper into the dense rock formations that store very little water, creating a problem that is not readily solved.

Similarly, new water withdrawals can lower the local water table, reducing water volume in streams that rely on groundwater discharge for base flow and even drying up these watercourses during droughts. Unfortunately, these effects may be irreversible if overdevelopment of new homes or excessive agricultural water use overtax these limited supplies.

Lowering the seasonal water table will have serious and possibly permanent impacts on regional biodiversity. Vernal pools, which form temporarily in springtime and to host the egg laying and early life stages of a variety of reptiles and amphibians, occupy a fragile place in the landscape, and one that is highly susceptible to hydrologic changes in landscape ecology. If these features disappear, so do the species that rely upon them for their existence.

Public discourse over land use policy frequently pits the fate of wildlife, including threatened or endangered species, against the human needs for water, shelter, recreation and other activities. This contrast is poorly drawn, since rare species are indicators of a high environmental quality that has value for all living things. Similarly, like the canaries in the mines, when these species can no longer survive because of degraded environmental conditions, their extirpation, or disappearance, is a warning to man.

Effective land stewardship will respect the finite limits of land and water resources, promote the conservation of exceptional resource values and remediate the damages of past manmade activities. Failure to respect these limits by allowing overdevelopment will rob current residents of the adequate water supply needed for daily living. Land use policies and regulations should prevent or limit the damage caused by new development and agriculture to the mountain ecology, and recognize that the very limited carrying capacity of the Sourland Mountain region is a precious resource that is easily squandered, and that economic exploitation by a few can substantially affect the common good.

Open Space in the Sourland Mountain Region

The significant natural resource values of the Sourland Mountain have long attracted preservation efforts from a wide variety of agencies and individuals, reflected on Figure 2: Open Space and Preserved Lands. A network of public non-profit and private partners has anchored the region with significant public holdings (Baldpate Mountain, Pleasant Valley open space, Highfields) and these actions have been aided by significant county initiatives. Somerset County, for instance, has undertaken an aggressive program of acquiring the Somerset County Sourlands Preserve over the past several decades. This substantial open space block anchors the eastern terminus of the Sourland Mountain. The Hunterdon County Sourlands Nature Preserve, adjoining the State Highfields property, is another significant publicly owned land mass in close proximity to the tri-county corner.

Municipal preservation efforts have also added to the evolving mosaic of preserved lands and easements, which are weaving together a protective net on portions of the Sourland Mountain. Public and private open space preservation activity through June 2005 are shown on Table 1.

Table 1: Open Space in the Sourland Mountain Region by Ownership as of June 2005

Township	Ownership Category	Acres	TOTALS
East Amwell Township	Municipal	23	
	County	331	
	State	417	
	Private/Non-Profit	418	
	Conservation Easement	797	
	Preserved Farmland	1,569	**3,555**
Hillsborough Township	Municipal	566	
	County	1,452	
	Private/Non-Profit	139	
	Preserved Farmland	406	**2,563**
Hopewell Township	Municipal	149	
	County	1,718	
	State	573	
	Private/Non-Profit	743	
	Preserved Farmland/Conservation Easement	2,288	**5,471**
Montgomery Township	Municipal	305	
	County	630	
	State	200	
	Private/Non-Profit	26	
	Conservation Easement	70	
	Preserved Farmland	89	
	Other Preserved	1,013	**2,333**
West Amwell	Municipal	380	
	County	217	
	State	1,113	
	Private/Non-Profit	1,645	**3,355**
		TOTAL	**17,277**

The preservation efforts of various public entities have been expanded upon by non-profit partners, like the Delaware and Raritan Greenway Land Trust (D&R Greenway). D&R Greenway has preserved or facilitated the preservation of 3,974 acres of Sourland Mountain lands, carefully selected to expand the base of protected contiguous forest, as well as significant grasslands and other critical habitat areas. Figure 2 illustrates the extent of these preservation efforts, along with the farmland that has been preserved through the cooperative efforts of local property owners, municipalities, the Counties and the State of New Jersey. When viewed together, an impressive array of protected spaces line the Sourlands ridge and its flanks.

Generally speaking, preserved farmlands are found on the flanks and foothills of the Sourland Mountain while preserved open spaces and critical habitat areas have a linear orientation along the ridge. Figure 2 also illustrates those lands that have been preserved by or whose preservation has been facilitated through efforts of the D&R Greenway.

To date, 17,043 acres (31%) of the study area has been preserved. This consists of 2,995 acres of preserved farmland, 10,074 acres of public open space and 3,974 acres of D&R Greenway conservation lands.

D&R Greenway has taken a lead role in creating connections between protected open spaces. Based on a strategy that would create greenbelts around the historic boroughs and other historic settlement areas, D&R Greenway has directly purchased or aided government agencies in land purchases and other open space conservation efforts. Through these efforts, a series of formerly disconnected open spaces are being linked into a network that is expanding to connect with the historic boroughs of Hopewell and Pennington, while also extending an expanding patchwork of preserved farms throughout the Amwell and Hopewell valleys.

Conservation Partnerships

A broad coalition of conservation partners have cooperated to produce the footprint of protected spaces as it exists today. This includes every municipality within and adjoining the study area, the three counties (Somerset, Mercer and Hunterdon), the New Jersey Conservation Foundation, the Lawrence Township Conservation Foundation, Friends of Hopewell Open Space, Sourland Planning Council, Montgomery Friends of Open Space, Hunterdon Land Trust Alliance and Friends of Princeton Open Space. The Nature Conservancy and the Association of New Jersey Environmental Commissions (ANJEC) have also been involved in preservation on the Sourland Mountain, along with a number of private donors.

D&R Greenway Land Trust has played an important role in establishing a “big picture” vision, drawn from a regional perspective. Through its efforts, and those of other nonprofits, the New Jersey Trails Association has embarked on a process of identifying and expanding upon the current trail system. D&R Greenway is developing acquisition objectives designed to protect historic sites, critical habitats and other important natural areas. Among its objectives is to provide open space linkages connecting the Delaware River to the Somerset County Sourlands Preserve, and to develop north-south linkages from this preserved spine into the agricultural valleys and historic settlements. To advance the preservation objectives of county, municipal and nonprofit preservation partnerships, the D&R Greenway cites the need for:

- A stable source of funding from its partners,
- Volunteers to build trails,

- A coherent vision for the Sourlands as an "Adirondack Park-type" public/private open space network,
- A greater State role in teaching stewardship and continuing education efforts by the State, counties and municipalities.

D&R Greenway's partnering efforts have also involved the New Jersey Audubon Society, the Washington Crossing Audubon Chapter and the New Jersey Forestry Association. D&R Greenway promotes a range of protective land management strategies to conserve critical habitat areas and to restore essential elements of the Sourlands ecology, including areas of prior forest loss. Fee ownership of protected open space prevents the loss of forest and other habitat resulting from development and agricultural activities. In this regard, no preservation and conservation approach will be more effective than permanent preservation through acquisition and proper land management.

Partnership efforts are the key to long-term stewardship in the region. To cite one example, in West Amwell Township alone 3,355 acres have been preserved through the leadership of the Township Open Space Committee with the assistance of the Green Acres and Farmland Preservation Programs, Hunterdon County open space grant funds, the D&R Greenway, Hunterdon Land Trust Alliance and landowner donation.

In addition to the open space preservation priorities of the State, counties, municipalities, the D&R Greenway and other nonprofit partners, the New Jersey Water Supply Authority (NJWSA) has highlighted the critical importance of portions of the Sourland Mountain region for water supply purposes.

In 1999, NJSWA teamed with the NJDEP and other stakeholders in the Raritan Basin Watershed Management Project and Millstone Watershed Management Committee to develop a Watershed Management Plan for the basin, where surface water provides drinking water for 1.2 million people, water for agriculture and other processes and critical habitat for wildlife and plants.

Recognizing open space preservation as an effective means of protecting water resources, NJWSA developed ranking criteria to identify lands by importance to water resources protection factors as wellhead protection areas, groundwater recharge, riparian areas, forests and wildlife habitat, preserved open space, land cover and known contaminated sites. This ranking of parcels based on water resource importance level, distinguishes lands most important and appropriate for preservation, and transcends merely being threatened by development

Ranking values were assigned to lands within the Raritan Basin on a percentage basis, from the most important lands for water quality protection (90% and above), to those which are least important (less than 10%). Figure 3: Areas of Critical Importance for Water Resources, reflects NJWSA's mapping of these features.

A regional Stormwater Management Plan for the Sourland Mountain, currently under preparation with municipal participation, will create an updated characterization of the watershed, including water quality and current planning and zoning.

A wide range of water quality and other best management practices has been identified by the Division of Fish and Wildlife. Some that are particularly important in the Sourlands include:

- Minimizing impacts from fertilizers, pesticides, livestock, etc. on waterways by maintaining adequate buffers and, when feasible, enhancing riparian areas through stream bank restoration efforts.
- Protecting endangered and threatened aquatic species by upgrading stream classifications to Category One in critical areas.
- Educating private landowners on the benefits of participating in programs such as Forest Stewardship, LIP, WHIP, US Department of Agriculture programs that advocate best management practices, and best management practices (BMPs) for forestry and agriculture.
- Delaying mowing of hayfields and fallow fields until after July 15 (to permit rare ground-nesting birds to fledge one brood), and retaining standing grass in fields for winter cover.

The acquisition of open space removes the threat of development and the incidental man-made impacts that typically occur along with development. Open spaces that limit these threats protect water resources. As preservation and conservation acquisitions continue into the future, these efforts should focus on better management of public lands as habitat (such as delayed mowing of grasslands, avoidance of "clean-up" techniques that remove woody debris, etc.) and expanded linkages among critical habitats that are key to maintaining regional species biodiversity.

Historic Resources in the Sourland Mountain Region

The Sourland Mountain region has a rich and diverse history that spans from the earliest Lenape Native American settlements to the current suburban expansion. Interpreting the fascinating and unique history of the Sourland Mountain region is not the focus of this Conservation Plan, but it is a worthy subject for further study. Each municipality in the study area has prepared an extensive inventory of historic resources and many have adopted Historic Preservation Master Plan Elements, which provide further detailed information on the history of the region.

Appendix 1, which includes excerpts from *New Jersey's Sourland Mountain,* by T.J. Luce, offers a glimpse into the Sourlands history and local settlements, both remaining and gone. Appendix 1 also identifies historic districts and sites located throughout the Sourland Mountain region as provided by the municipalities.

The Lenape were among the first inhabitants of the region, from 1000 AD to 1650 AD. The Lenape were primarily a farming culture, taking advantage of the rich valley areas for the majority of their food production. The Lenape also used the more mountainous areas for hunting and fishing, but the primary areas of habitation were in the valleys adjacent to the Sourland plateau. As European settlers encroached into the region, they too took advantage of the rich farmland found in the valleys, leaving much of the uplands untouched. It is during the time of the earliest European inhabitation that the Sourlands was named. While the exact reason for the name "Sourlands" is a mystery, it is clear that it was originally identified as such by 1750 by Dutch settlers.

The Revolutionary War brought a great deal of activity to the region. From the earliest days of recruitment for those to fight for patriot causes to strongholds and hideouts throughout the mountain, the Sourlands has been prominent in the storytelling of the Revolutionary War. The Crossroads of the American Revolution Project highlights the historical significance of the Sourland Mountain region, and sites like Hart's Cave, where John Hart, a signer of the Declaration of Independence, hid from the British. The Sourlands location made it an ideal route not only for patriots but for large scale marches, such as Washington's march to the Battle of Monmouth in June 1778 (see Figure 4: Historic Sites and Trails). The region also made an interesting vantage point to monitor the advance of the British and housed a fire signaling system that used large fire pits that spanned from Northern New Jersey to Trenton to Monmouth County. The role of the region in the Revolutionary War is rather extensive, and is detailed in a number of books or by contacting local historical societies and municipalities.

Settlement on the Sourland Mountain began as early as 1725 when the first parcels of land were divided and sold to permanent settlers. By the time of the Revolutionary War much of the outskirts of the Sourland Mountain were dotted with villages providing a wealth of services. The historic villages and habitats of the region are described in Appendix 1, which provides a glimpse into the history of how the region was developed.

Figure 5: Historic Sites and Districts, depicts historic sites and districts as represented on the NJDEP database for the State and National Register. These various sites and districts call attention to the historic significance of the region's human development and help to retain the significant cultural characteristics of the region.

A coordinated conservation and open space strategy should provide appropriate linkages between and among historic sites and districts, and the protected farmland, forestlands and other open spaces that preserve the local context.

Models for Inter-municipal Cooperation

Effective protection of the scarce water resources, fragile ecological balance and critical wildlife habitat areas of the Sourland region will require multi-level partnerships. In a state where municipal Home Rule remains the dominant influence on land use decision-making, inter-municipal cooperative agreements can help to harmonize municipal plans and regulations with regional planning and watershed management objectives.

A model for successful inter-municipal cooperation is found in the Ten Towns Great Swamp Watershed Management Committee (Ten Towns Committee), established in June 1995 to coordinate regional watershed management efforts. The Great Swamp Watershed, located approximately 30 miles west of New York City, was threatened in the late 1960s by the proposed construction of a regional airport which generated strong citizen opposition within this highly sensitive watershed area. When sewer treatment plant expansion within the watershed in the early 1980s was proposed, NJDEP established the Great Swamp Watershed Advisory Committee (GSWAC), which issued recommendations for better stormwater management within the watershed. It also recommended establishment of an independent commission to oversee the Great Swamp Watershed, a concept deemed likely to fail by Morris 2000, a non-partisan planning advocacy organization. Recognizing that a top-down approach would be opposed by local municipalities, Morris 2000 suggested instead harnessing the collective land-use decision-making powers of the affected municipalities. The result was Ten Towns Committee, created through an inter-municipal agreement adopted unanimously by all ten municipal governing bodies.

The Ten Towns Committee that resulted developed a comprehensive program, with broad public participation, resulting in a partnership among all four levels of government (municipal, county, State, and federal), and various private organizations. It also developed a systematic approach for setting goals and establishing priorities, which led to an action-oriented work plan to coordinate cost effective implementation.

The Ten Towns Committee consists of three representatives from each municipality, appointed by the governing body, and including an elected official, an administrative official, and a citizen from each town. The five member executive committee and part-time executive director handle day-to-day activities to coordinate the watershed management program. With a mandate to protect water resources, the Ten Towns Committee was initially given a two-year life span, which included a one-year education program to promote a common base of knowledge and understanding. It also provided for development of a management plan, which was unanimously adopted by watershed municipalities in September 1997. Since adoption of the management plan, the Ten Towns Committee has advocated an ongoing education program for committee members, municipal officials, and the public, addressing issues related to water quality. It has also analyzed environmental regulations and prepared model ordinances that have been presented to municipal governing bodies for adoption. A state of the art chemical water monitoring program has been undertaken to provide baseline data on water quality in the Great Swamp and to aid in evaluating changes over time. A companion macroinvertebrate monitoring program has been undertaken to evaluate the biotic elements of the watershed. During its first ten years, the Ten Towns Committee has found widespread acceptance for its core values, and it continues to advocate for municipal ordinances for environmental protection.

These efforts have led to the establishment of storm water and other regulations at standards higher than those generally applicable throughout the State, in recognition of the unique character of the Great Swamp Watershed and its susceptibility to environmental damage. Model environmental ordinances have been developed to address stormwater management, soil erosion and sediment control, steep slopes, stream corridor buffers, tree preservation and wetlands protection.

The results of this effort are seen on Table 2, which compares the status of "Compliance with Model Ordinances**"** in 1997 and 2003. This comparison provides a dramatic illustration of how local voluntary government actions can be effectively harnessed to achieve regional objectives. As the Ten Towns have harmonized their environmental land use policies and regulations, they stand together to effectively protect the Great Swamp Watershed into the 21st Century and beyond.

Table 2: Ten Towns Ordinance Compliance

1997 Compliance With Model Ordinances								
	Plan	**Septic**	**Slopes**	**Trees**	**Erosion**	**Storm**	**Wetland**	**Stream**
Harding Township								
Mendham Township								
Morris Township								
Bernards Township								
Long Hill Township								
Madison Borough								
Mendham Borough								
Bernardsville Borough								
Chatham Township								
Morristown								
2003 Compliance With Model Ordinances								
	Plan	**Septic**	**Slopes**	**Trees**	**Erosion**	**Storm**	**Wetland**	**Stream**
Harding Township								
Mendham Township								
Morris Township								
Bernards Township								
Long Hill Township								
Madison Borough		N.A.						
Mendham Borough			N.A.					
Bernardsville Borough								
Chatham Township								
Morristown		N.A.						

Key		
Plan	Adoption of Watershed Management Plan	**Compliance**
Septic	Septic system ordinance (if applicable)	**Excellent**
Slopes	Steep slope ordinance	**Good**
Trees	Tree removal ordinance	**Marginal**
Erosion	Soil erosion ordinance	**None**
Storm	Stormwater management ordinance	
Wetland	Wetland regulation ordinance	
Stream	Stream corridor buffer ordinance	

The success of the Ten Towns Committee has led directly to the formation of a sister agency, the Rockaway River Cabinet. Morris 2000 also played a key role in developing this inter-municipal cooperative effort, after the 1996 flood on the Rockaway River, when it visited the mayors of 13 towns along the river corridor to survey their concerns and interests. While three of the towns identified flooding as a problem, the other ten communities were interested in the river for other reasons including recreation, open space, habitat, and water supply.

The Raritan-Highlands Compact, another such inter-municipal cooperative effort, is a joint venture of nine municipalities in the Upper Raritan River basin, the County of Morris, Morris Tomorrow (formerly Morris 2000), the Morris County Municipal Utilities Authority, the New Jersey Water Supply Authority, The Upper Raritan Watershed Association and the South Branch Watershed Association. The Raritan-Highlands Compact shares the natural resource conservation goals reflected in the Ten Towns Committee and Rockaway River Cabinet inter-municipal cooperative agreements, and demonstrates the value and efficacy of inter-municipal alliances.

New Jersey Landscape Project and New Jersey's Comprehensive Wildlife Conservation Strategy

In 1993, the New Jersey Department of Environmental Protection's Endangered and Nongame Species Program (ENSP) developed a landscape database, the *New Jersey Landscape Project***.** This Geographic Information System (GIS) coverage 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 Project 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 (see Table 3), based on the following criteria:

Table 3: 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

The Sourland Mountain region is rich in habitat suitable to support populations of threatened and endangered species (see Figure 6: New Jersey Landscapes Project Habitat Data), including forest, grassland, emergent and forested wetland areas. The highest concentration of valuable habitat is along the Sourland ridge.

The critical forest habitat of the Sourland Mountain that supports State threatened species stretches from the northern boundary of the study area in Hillsborough southwest along the mountain to Route 31. It extends to the lower lying elevations as well, on both the north and south facing slopes. These lands are uniquely suited to reproducing populations of Neotropical migrating birds.

Grasslands that support populations of State endangered species are present on the north side of the Sourland ridge in East Amwell, extending south to the fringe of the study area. Other grassland habitats supporting populations of State threatened species are located along the study area boundary in Hopewell Township and northeast of Hopewell Borough straddling the Montgomery/Hopewell Township border. Grassland habitats are primarily associated with active agricultural operations, which likely involve the production of hay or other grass-like crops. A farmer's profit motivation to cut high quality hay early in the season conflicts with the nesting and fledgling of grassland birds, which requires mowing to be delayed into July.

Emergent habitats are critical to the reproductive cycles of many amphibian species, reliant on both emergent wetlands and spring (vernal) pools. The study area contains critical emergent and forested wetland habitat (south and west of Hopewell Borough), supporting State species of special concern. Areas of emergent habitat are also found north and south of County Route 601 in West Amwell and Hopewell Townships. State regulations adopted in 2001 afford some protection to emergent and vernal habitats, where none previously existed, but these features merit increased protection.

Much of the region's forested wetland habitat supports populations of State threatened and State special concern species. Habitat with documented sightings of State threatened species is present along the Sourland ridge in Hillsborough, East Amwell and Hopewell Townships, and, combined with upland forest critical habitat of the same rank, the area encompasses nearly 20,000 acres. Forested wetland supporting State species of special concern cover 2,661 acres and are located both on the Sourland ridge and on the slopes straddling the mountain. Habitat suitable to support threatened and endangered species but with no field survey covers 1,704 acres, primarily located west of Route 31.

The Landscape Project data is intended to aid municipalities, Counties and State government, 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 to limit development impacts on critical habitat
- Adopting management policies for open space that protect critical habitat
- Permitting flexibility in development techniques to protect critical habitat
- Promoting land stewardship practices that protect critical habitat

In response to a charge from Congress, New Jersey and the other 49 states are currently developing statewide *Comprehensive Wildlife Conservation Strategies* (CWCS) to guide future wildlife conservation policies and expenditures from the State Wildlife Grants Program. State fish and wildlife agencies are developing these strategies by engaging a broad array of partners, including other government agencies, conservation groups, private landowners, the public, and anyone with a stake in fish and wildlife management.

The program seeks to provide conservation strategies with deliverable results, based on directing millions of dollars of federal funds, matched with support from other sources, to ensure their implementation. It also is designed to address the entire diversity of wildlife and habitats.

Each state's CWCS is intended to create a strategic vision for conserving the state's wildlife, not just a plan for targeting resources at preventing wildlife from declining to the point of endangerment. Each state strategy must be completed by October 2005, and reviewed at least every decade.

New Jersey's Department of Environmental Protection has released the "Draft New Jersey Comprehensive Wildlife Conservation Strategy for Wildlife of Greatest Conservation Need" (revised August 2005). This report, referred to the "New Jersey Wildlife Action Plan", cites the "unprecedented challenge facing wildlife conservation in New Jersey" – namely the rapidly changing landscape from encroaching development and the inevitable damaging impacts to wildlife from habitat destruction.

New Jersey residents have overwhelmingly supported important initiatives to protect our wildlife and habitat, and every county has a voter-approved land acquisition program, while the State itself spends more than any other state in our region for important land acquisition. New Jersey also has one of the few statewide programs that protects wetlands, vernal pools and important coastal habitats, and has more land in public ownership than most states, including many that are much larger than New Jersey.

Notwithstanding these significant tools to protect wildlife, the number of species threatened with extinction in New Jersey grows every year, with 14 new species listed since 2001. The NJ Comprehensive Wildlife Conservation Strategy (CWCS) is developing into a blueprint for Statewide protection of priority wildlife and their habitat that will be implemented by all appropriate agencies and groups.

In an effort to better protect New Jersey's wildlife, the NJ Endangered and Non-game Species Program (ENSP) has developed a series of tools in recent years including:

> The *Landscape Project*, a pro-active, ecosystem-level, geographic information systems (GIS) approach to identifying and delineating areas critical for imperiled and priority concern animal species within New Jersey.

> *Delphi Status Review* of the legal status (e.g., endangered, threatened, stable) of wildlife by state wildlife agencies, using a systematic method for reaching consensus among experts, characterized by anonymity among the participating experts and controlled feedback via the principal investigator.
>
> The *State Wildlife Grants*, a federal grant program aimed at preventing wildlife of greatest conservation need from declining to the point of becoming threatened or endangered.
>
> The *Endangered and Nongame Species Advisory Committee (ENSAC)*, established in 1973 to implement the State Endangered Species Act (ESA), was created to review the actions and plans of the Endangered and Nongame Species Program (ENSP) and all recommendations to change the status of species. NJDEP is soliciting peer reviews and public comments on the second draft CWCS, which represents a consensus of what actions wildlife professionals think necessary to protect species of conservation concern.

The CWCS identifies five Landscape Regions in New Jersey with similar land forms, soils, vegetation and hydrological regimes (Skylands, Piedmont Plains, Atlantic Coastal, Pinelands and Delaware Bay). The Sourland Mountain region is within the Central Piedmont Plains. The CWCS cites the Piedmont Plains Landscape, encompassing all or parts of Burlington, Gloucester, Salem, Mercer, Middlesex, Monmouth, Hunterdon, Somerset, Union, Essex, Hudson, Passaic and Bergen counties, as dominated by the Delaware and Raritan rivers, and characterized by farmed areas, extensive grasslands, fragmented woodlands and some of the world's most productive tidal freshwater marshes. Imperiled species within this landscape include grassland birds, such as the endangered Upland sandpiper and woodland raptors, such as the Barred owl and Cooper's hawk.

Since habitats are variable within each landscape region, the CWCS divides the regions into *Conservation Zones*, using landscape and manmade features, to identify specific habitat threats and conservation goals. Figure 7: New Jersey Landscapes Regions, identifies New Jersey's landscape regions and conservation zones within the regions.

The CWCS has also identified New Jersey's most vulnerable wildlife, or "*species of greatest conservation need*". These are so named because continued (or further) habitat degradation or modification would result in population losses detrimental to the species' existence within New Jersey, regionally or nationally.

The wildlife species addressed in the CWCS are those of greatest conservation concern, specifically those with endangered, threatened and special concern status in the State. Species of regional priority for which no harvest is permitted are included among the State's species of special concern.

The CWCS also identifies threats to wildlife and habitats including "National and Interstate Threats" and "Statewide Threats". "National and Interstate Threats" found within the Sourlands region include:

- *Invasive species* requiring swift and significant intervention to avoid permanent losses of natural communities and wildlife.

- *Suburban "sprawl"*, which causes extensive habitat loss and fragmentation.

- *Motorized recreation vehicles* on or near public natural lands and waterways (e.g., off-road vehicles, and personal watercraft), which cause disturbance and habitat destruction and are major threats to wildlife and their habitats.

- *Free-roaming house cats*, which each year kill millions of birds, small mammals and reptiles in the U.S.

- *Contaminants* from point- and non-point sources, which degrade habitat and in wildlife cause developmental and behavioral abnormalities and reproductive failure.

The "Identified Statewide Threats" affecting the region include:

- *Direct Human Impacts,* such as illegal collection of reptiles, butterflies and freshwater mussels, vandalism and recreational use of caves and mines supporting colonies of wintering bats which are highly susceptible to large-scale mortality during hibernation.

- *Development Impacts*, such as erosion, reduction in base flow and pollution of streams and waterways and damage to unspoiled headwater streams, one of the most threatened habitats in North America for fishes and aquatic insects, especially rare dragonflies

- *Road Impacts*, which result in direct mortality of animals and act as barriers to wildlife dispersal, and declines in freshwater biodiversity.

- *White-tailed Deer Impacts,* which pose a significant threat to forest health and regeneration and can eliminate rare plant communities. As the deer population explodes, due to the loss of natural predators, over-browsing of the native shrub layer eliminates breeding habitat for many species, particularly shrub-nesting birds. Over-browsing results in the elimination of native flora as plants cannot become established before being consumed by the deer population. Deer over-browsing and selective browsing on native species also creates a favorable environment for invasive plants to crowd out native species.

- *Invasive Species and Exotic Pathogens*, which include terrestrial and aquatic plants and animals (insects, mollusks) and exotic pathogens, which negatively impact our forests, streams, lakes, bays, marshes and backyards.

- *Unsustainable Land Management Practices* on both private and protected lands, including forestry practices such as unsustainable clear cutting and even-aged stand

> management, which create forests that are low in biological diversity and ecological integrity.

In contrast to this view, several recent studies have concluded that even-aged stand management, carefully implemented through clearcutting, seed-tree cutting (leaving selected “seed trees”) or shelterwood cutting (a series of cuts) has the potential to increase the species richness of forested landscapes and provide important habitat for early successional Neotropical migrants, while effectively meeting demands for marketable timber.

In particular, Keller *et al.* (2003) noted that although development-related forest fragmentation has been at the forefront of recent research,

> “A more widespread pattern of agricultural abandonment, subsequent reforestation, and the resulting consolidation of forest fragments is emerging within the region from Pennsylvania north and east to Maine (DeGraaf and Miller 1996, Stanton and Bills 1996). Odum and Turner (1990) previously noted this same trend in the Southeast. Similarly, the aggregation of remaining agricultural lands into larger active fields with fewer fence rows and fallow fields has further reduced the availability of early successional stages. Collectively, the foregoing processes have resulted in an increasingly simplified landscape in the Northeast; one composed largely of mature forests, agricultural fields, and residentially, commercially, and industrially developed lands (Stanton and Bills 1996). One consequence of landscape simplification in this region is the loss of early successional stages of vegetation and a concomitant decline in numbers of migratory birds associated with these stages (Hagan 1993, Smith et al. 1993, Smith and Gregory 1998). Even-aged forest management, achieved through clearcutting, is one of a number of techniques that can enhance habitats for early successional species of Neotropical migratory birds (Keller 1980, Thompson et al. 1995, Brawn, et al. 2001).”

The Society of American Foresters (SAF) issued a position paper regarding the appropriate use of clear cutting techniques (2002) that suggests clear cutting may be appropriate under specific circumstances. However, the CWCS finds that clear cutting is inappropriate for:

- visually sensitive areas such as forests adjacent to population centers, wilderness areas, or heavily traveled highways;
- areas that support sensitive wildlife species dependent on large contiguous units of forest habitat;
- areas where watershed function has been impaired by the cumulative effects of disturbances; and
- landslide- or erosion-prone areas.

The CWCS highlights unsustainable land management practices that include mowing and herbicide use during the breeding season. These practices increase mortality and reduce productivity of many species, especially birds, invertebrates and small mammals, and some agricultural practices within State Wildlife Management Areas can actually destroy habitat for nongame and game wildlife.

The Draft CWCS identifies "Wildlife of Greatest Conservation Need of the Piedmont Plains Landscape" and the importance of successful landscape management to the conservation of several species including bald eagles, colonial waterbirds and freshwater wetland birds that inhabit riparian forests, brackish and freshwater wetlands and robust grassland bird communities in the Southern Piedmont Zone. CWCS cites significant habitat for bog and wood turtles in the Central and South Piedmont Plains, whose remnant populations are supported in fragmented grassland and woodland, and the patchwork of habitats (forests, grasslands, wetlands, riparian areas) that provide critical stopover sites for migratory birds to rest and refuel. Figure 8: Critical Habitats within the Piedmont Plains, identifies critical habitats within the Piedmont Plains Landscape and associated Conservation Zones, and the extensive core forest and surrounding grasslands of the Sourland Mountain region are prominently seen.

According to CWCS, judicious management of the Piedmont Plains Landscape is essential to conserving some of the most significant natural areas in New Jersey, including the Sourland Mountain, which supports unique and intact ecosystems that are in jeopardy from surrounding land uses, suburban expansion and other human impacts. It also cites the Piedmont Plains Landscape as a critical transition area between the northern deciduous forest ecosystem of the Skylands Landscape and the southern Coastal Plain ecosystem of the Pinelands Landscape.

Areas of Critical Conservation Concern in the Sourland Mountain Region

Surface Water and Groundwater

The Sourland Mountain consists of bedrock formations which are severely limited in their ability to produce clean water. These bedrock formations were deposited in a series of basins during the Triassic and Jurassic Ages, when violent volcanic activity shaped the Sourlands landscape. The sedimentary deposits of the Stockton, Passaic and Lockatong formations formed broad alluvial plains, which were reshaped when volcanic activity baked the sedimentary layers of shale and sandstone and erupted through the surface, forming the Diabase core of the Mountain. These geomorphologic changes created dense hard rocks, with very low water bearing capacities, and heated the adjoining shales and sandstones, significantly reducing their value as groundwater sources.

The groundwater-bearing potential of these bedrock formations, their ability to store and transmit water, is related to the extent of fractures, joints and bedding planes. Fracturing, generally limited to the weathered mantle that extends less than 100 feet below the ground surface, is a key determinant of the potential to yield groundwater. The Passaic and Stockton Formations, with numerous fractures and fairly wide fracture spacing, have better potential to yield potable water supplies and to maintain base flow within the region. Conversely, the lack of significant fracturing in the Lockatong and Diabase formations limits their ability to store substantial groundwater. A detailed review of the water bearing capabilities of these bedrock units is contained in a report prepared by Matthew Mulhall, P.G., and Peter Demicco, P.G., titled Evaluation of Groundwater Resources of the Sourland Mountain Region of Central New Jersey (November 2004).

Protection of groundwater resources requires, in part, that development impacts to aquifers, like impervious surface coverage, are managed in ways that protect recharge areas. Recharge areas, where permeable soils and natural drainage patterns permit the infiltration of surface runoff to replenish the underlying geologic structure, need to be protected from impervious coverage to assure that they remain open to infiltration. Protecting aquifer recharge areas also requires adequate functioning of on-site septic systems.

Groundwater and surface waters are intimately interconnected, since streams recharge aquifers during periods of higher stream flow, while groundwater discharges into stream channels provide the base flow that keeps streams running during dry periods. Groundwater recharge is particularly important for the water-poor diabase and argillite formations, where limited water supplies are counted on for potable use and where changes to the seasonal water table will affect stream flow and ephemeral features like vernal ponds. Maintaining the litter layer on the forest floor is critical to recharge, since this organic mat acts as a giant sponge to hold and slowly release the water that falls on the mountain.

Roughly one-third of the Sourland Mountain region drains westward to the Delaware, while the balance ultimately drains eastward to the Raritan. Two-thirds (67%) of the streams in the Sourland Mountain Region, extending 90 miles in length, are first order streams, or headwaters, the origin of all other surface waters. Nearly all of these headwaters originate on the top of the Sourland Mountain, making it an important area for the management of land use impacts, which will be magnified downstream. Protection of lower order streams assumes increasing importance as downstream waters become degraded.

All surface waters of the Sourland Mountain region are classified as non-trout waters with the exception of Alexauken Creek, Moore Creek and Fiddler's Creek, which are classified as trout maintenance waters. Alexauken Creek is the only stream in the study area currently afforded the protection of Category 1 (C-1) designation, although NJDEP is proposing to reclassify a number of study area streams as C-1, including Fiddler's Creek, Jacob's Creek, Moore Creek, Swan Creek, Bedens Brook, Royce Brook and Stony Brook. All surface waters except Alexauken Creek are classified as Category 2 waters, and fall under the NJDEP anti-degradation policies. Category 1 waters are *waters* *designated 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).* 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).*" Trout maintenance waters are those that are home to native populations of trout, although trout do not breed there.

NJDEP's Ambient Biomonitoring Network (AMNET) samples populations of benthic macroinvertebrates present in freshwaters. These benthic communities are comprised of small animals without backbones (insects, worms, larvae, etc.), visible with the naked eye, living at the bottom of lakes, rivers and streams, that integrate the effects of changes in water quality into their life cycle, and are effective indicators of change over time. The species composition, species diversity and abundance of macro-invertebrates provide valuable information on the relative health and water quality of a waterway, since they are more sensitive to environmental changes and are an important part of the aquatic food chain.

AMNET data from 1993-1994 and 1998-1999 for the 15 monitoring stations in the Sourland Mountain region indicate that seven of the fifteen sites had non-impaired benthic communities in the 1998-1999 monitoring round, compared with only six in 1993. While seven sites showed moderate impairment, a number of sites (Back Brook, Furman's Brook, Rock Brook, Bedens Brook, Jacob's Creek and Moore Creek) showed improvement over the first round of sampling, and Furman's Brook and Moore Creek improved to the level of no impairment. But along with improvement at a number of stations, some stations showed a decline, with Stony Brook and Swan Creek showing moderate signs of impairment and Moore Creek declining in its numerical AMNET rating, which, nonetheless, remained "no impairment".

AMNET monitoring from 1998 includes an assessment of stream habitat (in-stream substrate, channel morphology, bank structural features and riparian vegetation) for seven streams. The Neshanic (Furman's Brook), Stony Brook and Rock Brook sites all scored in the optimal habitat range (160-200) while the Back Brook, Bedens Brook and one Stony Brook site scored in the range of sub-optimal habitat (110-159).

Riparian areas, found along a stream bank or shoreline, are a diverse and important part of the ecosystem that protect water quality by buffering the impacts of surrounding land uses. A forested riparian area reduces water temperature, stabilizes the stream bank, filters pollutants and sediment from runoff, and provides critical nutrients and woody debris, which provide habitat for in-stream organisms. AMNET monitoring shows a correlation between impairment of benthic communities and upstream development.

Development and loss of riparian forest cover degrades surface waters, reducing the filtration of sediment and nonpoint source pollution, and contributing to scouring, which causes bank deterioration and further erosion and sedimentation. Loss of riparian vegetation also reduces the in-stream woody debris that provides critical nutrients and substrate where fish and amphibians reproduce. Riparian areas also provide passive recreation opportunities within an interconnected greenway network of streams and other open spaces. Figure 9: Suggested Greenway Linkages, illustrates “Suggested Greenway Linkages” among preserved lands, oriented along the riparian corridors.

Wetlands

Wetland habitats characteristically include swamps, bogs, marshes and bottomland areas between well-drained upland areas and low-lying, permanently flooded areas, lakes or streams, although they may occur on slopes with groundwater seeps or in perched water table areas, as is typical on the Sourland Mountain. Wetlands account for one-eighth of the study area, consisting of over 7,000 acres, with nearly 6,000 acres in deciduous wooded wetlands, including a large expanse along the Sourland ridge. Remaining wetlands are deciduous scrub/shrub and herbaceous wetlands, found on the fringes of larger deciduous wooded wetlands, and agricultural wetlands, found at the edge of wetland areas next to farm fields and concentrated on the flanks of the Sourland ridge. Minor areas of mixed wooded and coniferous wooded wetland are also found in the Sourland Mountain region.

Wetlands serve as aquifer recharge areas and trap and filter nonpoint source pollutants through natural bio-chemical processes, helping to improve stream quality. Wetlands play a particularly valuable role on the Sourland Mountain, filtering clean water into headwaters streams and capturing and retaining precipitation to recharge water-poor aquifers, a critical function on the mountain, where recharge is extremely low.

Steep Slopes and Ridgelines

The Sourland Mountain is more of a hill than a mountain, with its highest elevation around 567’ above mean sea level and its ridge a relatively flat plateau, more than 3 miles wide and over 15 miles long. Steep slopes, which represent transitional areas in the landscape, are mostly found along the eastern face of the Sourland Mountain, around Baldpate Mountain, Pennington Mountain and Pheasant Hill, and in limited areas on the north facing slope. Often created by the erosion effects of water scouring along stream corridors, the most dramatic slopes surround Alexauken Creek, Moore Creek and Swan Creek.

Slopes exceeding 25% present serious development limitations, often requiring extensive and costly engineering and construction. Development on slopes in excess of 15% can degrade the environment, if not properly managed, and since most slopes occur in and around the banks of streams and rivers, clearing in these areas results in water quality degradation from erosion and stream sedimentation.

Agricultural operations, which may include the grazing of animals near steep slopes and the stream courses they typically surround, can seriously degrade and destabilize stream banks, increasing erosion and sedimentation and introducing manure directly into surface waters.

Ridgelines are topographic features that are often prominent in the visual landscape, depending on the surrounding terrain. However, within the Sourland Mountain region, where there are only moderate elevation changes from the surrounding landscape, the Sourland ridge is only clearly seen from at least several miles away, and is most prominent from the opposite sides of the Amwell and Hopewell valleys.

From an individual homeowner's perspective, ridgelines offer impressive views and are desirable locations for residential homesites, and, as a result, forest vegetation is routinely cleared to make way for homes capitalizing on views to the surrounding landscape. From a broader perspective, however, ridgelines are communal assets that merit protection.

Forest

Among its many habitat types, the expansive mature deciduous forest in the Sourlands is its most unique ecological treasure. The nearly 12,000 acres of predominantly mixed oak forest on the Sourland Mountain comprise the largest remaining contiguous woodlands in central New Jersey, the most significant remnant of the vast forest that once covered the State's Piedmont region. It is the size, shape, composition and adjacent land use that make the relatively unfragmented forest of the Sourlands a haven for so many woodland birds. It is not just the acreage of a patch that makes it suitable habitat, but also its shape. Thus, maintaining wide unbroken patches of forest has more habitat value than the same patch size in a linear arrangement, where the edge effect is heightened.

Forest fragmentation due to development produces obstacles to breeding birds, particularly those that rely on interior forest habitat for breeding. As fragmentation occurs, more edge is created relative to forest interior and the number of species of forest interior nesting birds is reduced.

Nest parasitism is another serious obstacle to breeding success in fragmented forests. Cowbirds, a nest parasite that lays its eggs in the nests of other species, have increased in numbers in the East as edge habitat has increased, and some Neotropical species are being driven to near survival threshold levels by cowbird parasitism. It is important to note that edge effects that result from development are generally permanent, as they usually cannot be reversed; while edge effects from logging activities can be reversed and even avoided with appropriate management.

The size and shape of forest patches on Sourland Mountain and Baldpate Mountain minimize edge impacts on interior nesting Neotropical migratory birds. Protection of these landscape characteristics is particularly important to maintaining the critical habitat that supports these long distance visitors, without which many would not survive their long migration from Central America to the northern fringes of North America.

Abundant populations of deer, another consequence of human impacts, inhabit forest edges and deer browsing of tree seedlings is driving the composition of our forests from mixed oak-hickory to red maple. If native plant populations, critical forest understory and seedling trees needed for forest regeneration are to survive, effective deer management is critical. A deer management plan was initiated on Baldpate Mountain in January 2000, and participants holding special permits had harvested about 650 deer as of the 2003-2004 hunting season. Though several observers report that the ground layer vegetation appears to be regenerating since deer management began, there has not been a controlled study to evaluate the effect of the harvest on the herbaceous and understory layers of the forest. Such a study would aid in mapping out a deer management plan.

Despite a vigorous deer population in the area, a healthy understory of native shrubs and saplings remains in parts of the forest, along with a varied herbaceous layer. This complex woodland structure is vital for many bird species, whether for breeding, migration stopover, or over-wintering. Browsing white-tailed deer can decimate this layer where they are numerous, but their populations tend to be less dense in the deep woods than along forest edges.

The forest is also significantly impacted by the tree-cutting incentives of the Farmland Assessment Act. Landowners qualify for dramatic tax reductions when they conduct eligible harvesting activities, yet these practices can serve to further fragment the mature forest. Preferential tax treatment for conservation practices should be advocated at the State level instead of income production in sensitive areas, to prevent unnecessary or inappropriate tree harvesting impacts on the forest.

Grasslands

Grasslands in New Jersey, other than marshes, are typically agricultural fields, either maintained as pasture or mowed regularly for hay. In modern times, the woodlands of the lower flanks and foothills of the Sourlands region were cleared when the area was settled and farming was widespread. Grassland bird species readily took advantage of the open fields, particularly when warm season native grasses flourished. However, their replacement with European cold season species, such as timothy, bluegrass and tall fescue, calls for an early summer mowing regimen, that is detrimental to many grassland species. Habitat conservation must compete with a market preference for cool season grasses for feeding horses and livestock, just one of many detrimental impacts of agriculture on habitat. D&R Greenway notes that landowners can grow and manage warm season grasses for profit, eliminating traditional row crops.

The grasslands that flank the Sourland ridge in the Amwell and Hopewell valleys provide critical habitat for a number of bird species. Grassland species are the most severely threatened birds in New Jersey based on habitat preference, because the meadows and hayfields used for nesting and breeding are prime land for conversion to housing subdivisions and corporate parks. And while hay and livestock farming continue on the fringes of the Sourland Mountain, better outreach is needed to acquaint landowners with government programs providing technical assistance and funding for soil, water and habitat conservation, such as NRCS “Conservation Reserve Program”, and “Landowner Incentive Program for Endangered Species”.

Other Sourlands Habitats

While less important than interior forest or grasslands to the region’s ecology, other habitat types support a range of birds and other wildlife, although only temporarily. When cultivated fields are abandoned, secondary succession begins. In the Sourlands, early pioneers like Eastern red cedar provide choice shelter for nesting birds that breed in shrub-scrub habitat, as well as food for over-wintering birds. In time, other shrubs and vines join to form small thickets, creating a favored habitat of bird species such as yellow warbler, field sparrow and American goldfinch. Ultimately, native hardwoods begin to shade and crowd out the earliest volunteers in a long-abandoned field, although the last remnants of the earlier successional stage, including Eastern red cedar, panicled dogwood and gray birch may survive.

Sourlands Birds

The complex of grasslands, old fields, shrub lands and mature forest offers a remarkable richness of bird species, both resident and migrant, that can be directly linked to the broad spectrum of high quality habitats. One researcher found that as succession progresses in fields abandoned at different points in time, habitat becomes more diverse, supporting a greater variety of birds.

__Bird Migration in the Sourlands__

The Neotropical, or long-distance, migrants have severely declined locally and regionally and are the group most severely affected in recent decades as habitat has been converted to other land uses in both the United States and Central and South America. Most migratory birds arrive in central New Jersey between mid-April and late May, where the mixed oak forests of the Sourlands provide a favorite but brief stopover for passage migrants, such as Cape May warbler and Blackburnian warbler. Many of the breeding migrants, such as wood thrush and red-eyed vireo settle in at the same time.

The New Jersey Audubon Society identifies the Sourlands as a key Migratory Bird Corridor in New Jersey. The New Jersey Piedmont location provides a smooth transition between the low, flat coastal plain and the highest elevations and ridges of the New Jersey Highlands, midway between the Pinelands and the Highlands. This makes it a critical stopover for migrating species using the Atlantic Flyway, which generally extends from Greenland southward along the eastern coast of Canada and the United States. The Sourland region had a frequency of stopover use between 21 and 26 days, the highest range possible, and found in no other area outside the Pinelands. According to New Jersey Audubon, suitability for use as a stopover site is solely related to the quality of available habitat, and its ability to provide fresh water, shelter and fuel. Maintaining the quantity and quality of habitat types is critical to continued use of the Sourland region as a stopover point for migratory birds, both spring and fall.

Breeding Birds of the Sourlands and Their Habitats

Birds can be grouped based on the habitat type they require for breeding. Some are grassland specialists; others nest only in deep woodlands. Still others prefer the early successional stage known as shrub-scrub or savannah-like habitat while some build their nests in edge habitat—the margin where woodland meets a farm field, park, lawn or other non-forested opening.

Habitat fragmentation results when a once-contiguous habitat is disrupted and broken up into smaller remnants of different sizes and shapes, interrupted by an altered landscape. Birds are affected in all life stages by fragmentation, and Neotropical migratory birds are most sensitive to habitat fragmentation.

The variety of habitat patches of substantial size within the Sourlands region supports a robust complex of avian populations. Most of the species that historically have bred in central New Jersey still breed successfully in the Sourlands, even though they may have disappeared from other parts of the surrounding area, contributing further to the region's importance.

Birds in Peril

Many of the bird species found in the Sourlands region are listed as either threatened or endangered, or are being tracked because their numbers are on a steep downward trajectory. These species have diverse food and habitat requirements and most are very sensitive to environmental change. What makes the Sourlands region so critical to avian diversity and abundance is the variety of intact habitats of impressive size that, for various reasons, remain despite human disturbance to date. However, these resources are increasingly threatened by development.

Critical habitat is essential to a number of bird species in crisis that are finding safe harbor in the Sourlands. A review of available lists of birds found in the Sourlands indicates the region provides shelter and refuge to many bird species in peril. Table 4 identifies Special Concern Species Listing Documented in the Sourlands:

Table 4 - NJ Endangered and Nongame Species Program
Special Concern Species Listing Documented in the Sourlands

Endangered	Special Concern
Upland sandpiper	Northern harrier
	Sharp-shinned hawk
Threatened	American kestrel
	Winter wren
Red-shouldered hawk	Veery
Cooper's hawk	Gray-cheeked thrush
Barred owl	Kentucky warbler
Grasshopper sparrow	Canada warbler
Bobolink	Yellow-breasted chat
	Eastern meadowlark

WatchList

This list (Table 5) calls attention to birds at conservation risk before they require federal listing and stresses preventive action over last-ditch intervention. The WatchList is based on the Partners in Flight conservation priority scoring system designed to conserve viable populations of birds and the biological systems on which they depend. Partners in Flight is a cooperative effort involving partnerships of many federal, state and local agencies, philanthropic foundations, professional organizations, conservation groups, the academic community and private individuals.

Table 5 - WatchList Birds Documented as Breeding in the Sourlands

American woodcock
Willow flycatcher
Wood thrush
Blue-winged warbler
Prairie warbler
Worm-eating warbler
Kentucky warbler
Canada warbler

In addition, two other WatchList species, Bicknell's thrush and Prothonotary warbler, have been documented as migrants in the Sourlands region.

Additionally, Table 6 identifies species documented in the Sourlands listed in the Mid-Atlantic Piedmont Area Plan's Priority Habitats and Suites of Species:

Table 6 –Mid-Atlantic Piedmont Area Plan Priority Habitats and Suites of Species Documented in the Sourland Region

Deciduous Forest	Agricultural Grassland
Wood thrush	Upland sandpiper
Kentucky warbler	
Eastern screech owl	
Chimney swift	Freshwater Wetland
Prothonotary warbler	
Acadian flycatcher	Green heron
Scarlet tanager	
Louisiana waterthrush	
Canada warbler	
Worm-eating warbler	
Shrub - Early Successional	
American woodcock	
Prairie warbler	
Northern bobwhite	
Field sparrow	
Eastern towhee	
Blue-winged warbler	
Willow flycatcher	

The Mid-Atlantic Piedmont Plan, prepared by the American Bird Conservancy, notes that the "future of wildlife habitat depends on protection of patches of conservation significance and the manner in which inevitable continuing growth alters the environment. Forest habitat remains relatively abundant, but is very heavily fragmented. Identification and maintenance of those blocks large enough to support the full array of breeding birds should be a priority." The species lists indicate that Sourland Mountain fits the definition of a priority habitat site.

Reptiles and Amphibians

The region also supports diverse populations of amphibians and reptiles that reproduce in vernal pools, which are "confined wetland depressions, either natural or man-made, that hold water for at least two consecutive months out of the year, and are devoid of breeding fish populations." Currently, only certified vernal ponds receive protection under the State wetland regulations, and many of the pools that are certified are on lands that are already protected from development. An inherent problem lies in documenting pools that are not on public land, and public education should focus on preventing their loss or alteration.

The rock outcrops and rock piles of Sourland Mountain and Baldpate Mountain offer excellent habitat for basking snakes, with reported sightings of Northern copperhead snakes on both Sourland and Baldpate Mountains and in the Alexauken Creek Watershed Management Area. Several turtle species appear in the survey lists as well.

Mammals

The region is also home to a host of animals representing a number of mammalian families and habitat preferences, along with the occasional anecdotal report of a black bear, bobcat and Eastern coyote.

Insects

A thriving, diverse insect population can be an indicator of a healthy environment, as they fulfill a vital role in maintaining biological communities by serving as pollinators for many plant species and as a food source for many birds, reptiles and amphibians and small mammals. Butterflies and dragonflies were identified in the biological surveys, and the insect species lists represent a broad range of insect families.

Plants

The Sourlands region supports diverse plant communities including wet and dry meadows, old fields in succession, young second growth forest, riparian and wetland forests and older second growth forest. The forest that covers the Diabase ridges of Sourland and Baldpate Mountains is the mixed oak type. Flowering dogwood, sassafras, ironwood and other small trees fill the understory layer and native vines are abundant in some locations. Native shrubs such as several species of virburnum and dogwood thrive in areas that have not been over-browsed by deer. Many of these trees, shrubs and vines are important food sources for southward migrating birds in the fall and for over-wintering birds.

The Piedmont exhibits a diverse variety of plants, since many southern species reach their northern climatic limit and some northern species reach their southern limit here. The Sourlands region may be the last refuge of some of the complex plant communities that once flourished here, and the sheer number and range of plant species overall attests to the diversity of habitat types that have not been overwhelmed by invasive alien plants, probably due to the size of the intact habitat patches and lack of intense development in the region.

Invasive and exotic species continue to be a problem associated with clearing of the forest. As holes open in the canopy, the increased amount of sunlight reaching the forest floor aids perpetuation of opportunistic non-native plants. Most of these species have little or no value to native wildlife and compete with native plants for habitat. Many of our rarest wildflowers are fragile woodland species that can be overwhelmed by aggressive alien plants such as garlic mustard, stiltgrass and barberry.

While invasive species are problematic when the forest canopy is thinned, they are more of a problem when trees are clear cut, as it takes decades for the canopy to close enough to provide the shade that eliminates problem vegetation. Even careful logging activity aids invasive species; selective cutting can still thin the canopy enough to change light conditions and make the environment favorable for their growth. And while deer increasingly destroy desirable native vegetation in the understory of the forest, they tend to avoid many of the invasive plants, which also present a challenge in grassland habitats.

Table 7 identifies New Jersey Endangered Plant Species and Plant Species of Concern Documented in the Sourlands Region. As New Jersey rapidly loses its rich botanical heritage to development, inappropriate management and browsing by deer, the importance of preserving what remains of central New Jersey's native flora in the Sourlands region cannot be overstated.

Table 7 - New Jersey Endangered Plant Species and Plant Species of Concern Documented in the Sourlands Region

Allegheny vine	Adlumia fungosa	SMP, B
Arrow-leaved aster	Aster sagittifolius	B
Britton's grooveburr	Agrimonia striata	ACWMA
Giant yellow hyssop	Agastache nepitoides	SMP, B
Ginseng	Panax quinquefolius	SMP, B
Green violet	Hybanthus concolor	B
Hairy rock cress	Arabis hirsuta	B
Pennywort	Obolaria virginica	SMP
Redbud	Cercis canadensis	SMP, B
Slender toothwort	Cardamine angustata	SMP
Smooth hedge-nettle	Stachys tenuifolia	B
Spreading chervil	Chaerophyllum procumbens	B
Strict blue-eyed grass	Sisyrinchium montanum	ACWMA
Warty spike rush	Eleocharis tenuis var. Verrucosa	SMP
Wild comfrey	Cynoglossum virginianum	SMP
Winged monkey flower	Mimulus alatus	SMP

ACWMA = Alexauken Creek Wildlife Management Area
B = Baldpate Mountain
SMP = Sourland Mountain Preserve

Habitat Management

Every landowner who engages in property maintenance is affecting habitat, for better or worse. Careful management of Sourland Mountain region habitats will be critical to maintaining the biodiversity that exists, since the interplay of habitat types is what supports the incredible richness of plants and animals. Habitat management plans for both public and private lands should be designed to preserve biological diversity.

Grassland habitat will require the most intensive management, and former hayfields may need to be supplemented with native cool and warm season grasses and herbs, and a strict mowing regimen put in place to protect grassland birds. Invasive plants such as Canada thistle and crown vetch may need to be eliminated.

Effective deer management is crucial if native plant populations, critical forest understory and seedling trees needed for forest regeneration are to thrive. State deer control efforts have shown hunting to be the most effective deer management strategy.

The stewardship of habitat, Sourlands migratory bird, for which the region is a critical stopover site, requires maintenance of the existing high-quality habitats, as well as enhancement of those of lesser quality.

Habitat management has advanced to a point where long-standing land management practices by public agencies (mowing, clearing, fertilizing, etc) have been reconsidered, due to their impacts on wildlife. As a result, improved management approaches are being advanced by Federal, State, County agencies and non-profit conservation organizations that will aid habitat and resource conservation in the Sourland Mountain.

Forest Management for Habitat Improvement

The range of timber harvesting approaches includes some which extend throughout a forest and others that have more localized effects. Selective cutting and single tree harvests, for instance, have an expansive scope as they remove selected trees, or groups of trees that meet certain criteria over a wide area. Block cuts, like clear cutting or seed tree cuts, remove all or most mature trees over a smaller area, with seed tree cuts retaining some healthy mature trees to influence reforestation. While single tree harvests are common and deemed more aesthetically appealing than block cuts, they are far less useful to the maintenance and enhancement of a diverse landscape and the wildlife habitat it provides. These block cut areas return to forest over time and create the early successional habitat important to some neotropical songbirds.

The major impacts associated with timber harvesting fall into two categories: 1) ecological impacts such as habitat loss / modification, which encompass a wide array of changes in species composition, resource distribution and abundance, and species interactions such as competition and predation, and 2) associated physical impacts such as erosion, sedimentation, forest fragmentation and increased stormwater runoff. Considering the potential ecological impacts in terms of birds, the subject of extensive scientific data, suggests a series of policy approaches.

<u>Ecological Impacts</u>

To understand the ecological changes associated with timber harvest, it is useful to first understand several fundamental species-habitat relationships. One of the most fundamental of these is the species-area relationship (MacArthur and Wilson, 1967); that is, larger areas tend to support more species (i.e., increased biodiversity) than smaller areas. This relationship was first noted on oceanic islands and it is often useful to think of the mosaic of plant communities (e.g., forests, pastures, etc.) on the landscape in this fashion. The relationship of biodiversity to island size is primarily a function of the fact that larger species need more area to meet their energy requirements and thus, as island size increases, more and more species can be accommodated (Schoener 1968, Keller

1986). Secondly, some species, regardless of their body size, are area-sensitive (Robbins *et al*. 1989) and only occur within extensive areas of their preferred habitat type. Lastly, some species are associated with contiguous areas of a single plant community type such as closed canopy forest or open grassland, while others are associated with structural discontinuities such as field-forest edge or the canopy openings created by treefalls. The first type are contiguous-area species, while the latter types are commonly known as "edge" species. Thus, both large contiguous areas of a single plant community type and edges between community types are important for biodiversity.

Many species of wildlife are found only within closed canopy mature forests (i.e., they are contiguous-area species) and many of them are area sensitive. One of the key features of the Sourland Mountain is its extensive and relatively unbroken forest community (i.e., it represents a large "habitat island"), which provides habitats for forest interior species. Disturbances such as cutting, which both remove canopy and create edges within the forest, impact forest interior species in several ways. First, canopy openings caused by cutting break up the contiguity of the forest – a phenomenon commonly referred to as forest fragmentation. Some mature forest bird species, such as red-eyed vireos (*Vireo olivaceous*, Robinson and Robinson 1999, ovenbirds (*Seiurus aurocapillus*, Annand and Thompson 1997), and wood thrushes, (*Hylocichla mustelina,* Annand and Thompson 1997) are less abundant in stands managed by selective or small group harvesting (Webb *et al*. 1977). Even the small canopy gaps created by selection cutting displace territories of these and other forest species away from harvest areas (Germaine et al. 1997, King et al. 2001). Secondly, the creation of edge favors a number of species that are either nest predators or nest parasites of forest interior birds. This reduces the reproductive success of those individuals that remain (King et al. 1998) resulting in long-term population declines of forest interior species in highly fragmented areas.

As with all habitat manipulations, there are positive effects for wildlife as well as negative ones. One of the benefits of cutting is that it creates shrub habitats for early successional species of birds. However, the patches created by single tree harvesting are not large enough to support many of the species associated with this habitat type (i.e., the islands are too small) (Keller 1986, King *et al*. 2001).

<u>Physical Impacts</u>

The very nature of the single-tree harvesting proposed under typical forest management plans would likely cut trees across an extensive portion of a given property. This frequently requires a network of roads and skid trails to reach each individual harvest location with associated disturbance and resulting erosion and sedimentation. The usual removal of most branches (in addition to harvest of the trunks) further increases erosion and impacts from stormwater runoff. Furthermore, because trees cannot fall within their own dripline, there are additional disturbances to the adjacent forest with each tree cut. The scattered distribution of single tree harvesting over large portions of a particular forested property often includes cutting within wetlands and wetlands buffers as well as resulting in the fragmentation-associated impacts discussed above.

Forest Management Recommendations

Forest management is a group activity in the Sourlands, with myriad property owners making separate, uncoordinated decisions about how to manage the landscape. The future health of the forest would be enhanced if these individual harvesting decisions were coordinated through a centralized oversight process, where the long-term resource management goals for the region could be advanced. The regulatory authority of Sourland Mountain municipalities, if harnessed toward these ends through an intermunicipal cooperative agreement, could offer such oversight.

The results of a number of studies (e.g., Webb et al. 1977, Titterington, et al. 1979, Keller 1986, King, et al. 2001, Keller *et al.* 2003) suggest that forest managers should maintain a large core area of mature forests if forest interior and area-sensitive species are of management concern, while providing small (5-35 hectares or 12 to 86 acres), peripherally located clearcuts or, preferably, seed-tree cuts (i.e., with a small percentage of residual canopy) every 10 years to maintain patches for species of Neotropical migrants associated with early successional even-aged stands. The retention of some canopy trees (c.f., Williamson 1970) increases the number of patch types and provides habitat during forest succession for additional species of birds associated with mature trees (e.g., bark probers and gleaners) or canopy-opening edges (e.g., some flycatchers). This strategy appears especially appropriate for regions like Sourland Mountain and much of the northeastern United States where an increasingly simplified landscape has led to declines in numbers of migratory birds associated with the early stages of forest regeneration.

The habitat created by typical selective cutting does not satisfy the habitat requirements of a substantial portion of early successional shrubland birds, and the scattered gaps created by this harvest method disrupt the remaining mature forest. As such, selective harvesting represents an ineffective management scheme for both early successional and mature forest birds (King *et al*. 2001, Keller *et al*. 2003).

Following the guidelines of Hagan *et al*. 1997, King *et al*. 2001 and Keller *et al*. 2003, a more effective long-term coordinated forest management strategy than one based on the typical individual tree harvest plans in New Jersey would be to:

1. Maintain undisturbed or infrequently harvested core areas of mature forest that are centered on conservation easement or publicly-held lands, wetlands, and wetland buffers. Figure 10: Interior Forest Areas and Preserved Open Space, which identifies preserved open space and interior forest blocks within the Sourland Mountain region, can aid in identifying and prioritizing interstitial areas that would be valuable to add as additional core areas or connecting corridors.

2. Provide for regional-scale review of individual harvest plans by an agency to be identified, for the purpose of maximizing the long term health and regeneration of the forest. An intermunicipal cooperative agreement could advance this objective, which can be significantly advanced using municipal regulatory authority.

3. When harvest plans are submitted, consolidate proposed cutting into shelterwood cuts, seed tree cuts or clearcuts of up to 25 acres. Shelterwood or seed tree cuts are preferred, where the retention of some canopy trees (e.g., Williamson 1970), especially in small (3-4 trees), scattered, open clusters, increases heterogeneity of the stand and provides habitat for additional types of birds during succession (Keller *et al*. 2003).

4. Harvest boles and the largest limbs only. Leave some trunks (e.g., beech) and all slash on the ground. Minimize logging trails.

5. Where aesthetics are of concern, retain screens of mature forest between cuts and adjacent private lands and public roads.

6. Strive to cut approximately 10% of the total managed forest during each 10-year management period. This will maintain sufficient habitat for early successional species, which begin to decline in richness and density by post-cut year 10 (Keller *et al*. 2003). Maintain non-core areas on an 80-100 year cutting rotation.

7. Educate the public on the value of these techniques and provide brochures and signage for cut areas on publicly-held lands.

Monitoring Environmental Health in the Sourland Mountain Region

Effective protection of the Sourlands will be aided by development of an indicators program, which identifies and measures a variety of indicators of environmental health. Some suggested indicators would include:

1. Stream chemical and physical quality - This could include pH, nitrate, total dissolved solids (TDS) and chloride of selected area streams and other surface water bodies, and could be expanded to include specific markers of human-caused pollution, e.g. from septic systems, such as, perhaps, caffeine, pharmaceuticals or bacteria. The DEP, in concert with USGS and other organizations, already samples a number of streams for some of the above parameters. Any additional monitoring should coordinate with and augment existing efforts.

2. Stream biomonitoring - The NJDEP has a well-developed approach to monitoring benthic macroinvertebrates in streams, and to gauging the degree of stream impairment through these results. Additional sampling sites within the Sourlands could be chosen and operated consistent with the NJDEP methodology.

3. Groundwater quantity - Some wells in the area are monitored by the United States Geologic Survey (USGS) for water levels. More detail is needed on the status of groundwater quantities, and more well records are needed. Hydrogeologists can assist in identifying useful locations and setting up routine, electronic monitoring.

4. Groundwater quality - Through New Jersey's Private Well Testing Act, much data are now becoming available on groundwater quality in the State. The data for the Sourlands region include nitrate, arsenic, fecal coliform, and a variety of other parameters, and some municipalities collect data. While data are generally available only at relatively broad geographic scale, at least routine reporting of the data relevant to the Sourlands should be considered. Ideally, these data will be augmented with local-scale data.

5. Breeding bird surveys - Such surveys are conducted by the Audubon Society and periodically by NJDEP. The establishment of a routine monitoring program for the Sourlands could augment these efforts and provide important detail on trends of key species that are especially important in the Sourlands (e.g. Ovenbird and others that need relatively large contiguous forests for breeding success).

6. Survey for alien invasive flora and fauna - These species threaten the long term health of the Sourland Mountain region. The establishment of such a program in the Sourlands would highlight the region's importance and could serve as the impetus for further efforts elsewhere and possibly additional funding opportunities.

7. Survey for presence of threatened flora and fauna - (Overlaps with breeding bird surveys) While important habitats are increasingly being delineated, routine surveys of the status of known threatened flora and fauna in the Sourlands could highlight the Sourlands and stimulate additional survey efforts.

8. Land use/land cover – Available interpretations rely on the aerial photos and satellite-based imagery available through the State and from regional and national organizations. Trends in these data, especially any significant changes in extent of impervious cover, could be routinely examined and reported on a Sourland-specific basis to area organizations and municipalities. An ongoing database of land cover alterations, documenting changes between aerial photo interpretations, could be developed to track emergent change.

9. Other land use measurements - Such measures as traffic counts on selected, representative roads, issuance of building permits or septic installation or repair permits, could be routinely tracked in the Sourlands.

10. Stream flow – While USGS monitors points at some streams, there is a need for more detailed data, particularly on some of the headwaters streams that are, increasingly, intermittent or ephemeral. Additional monitoring stations could be established in the Sourlands under the guidance of hydrogeologists.

11. Amphibian monitoring - The North American Amphibian Monitoring Program (NAAMP) is a collaborative effort among regional partners (state natural resource agencies, nonprofit organizations and the USGS) to monitor populations of vocal

amphibians. Observers are trained to identify their local species by these unique vocalizations or "frog calls". The USGS provides central coordination and database management, while the regional partners recruit and train volunteer observers to collect amphibian population data, following the protocol of the NAAMP. This could be expanded along the same lines with additional sites in the Sourlands, and would likely generate much useful data.

12. Other - Other measures, e.g. location, extent and functioning of detention basins in the region, location and status of easements and various other prohibitions on certain types of land use, e.g. preserved stream corridors, could be routinely monitored in the Sourlands.

Stewardship Goals and Strategies for the Sourland Mountain Region

The long-term health of the region will depend on the stewardship exercised by those who own, manage or use these lands. This plan seeks to guide these actions toward a sustainable future by developing policies and strategies that will:

- Maximize the permanent preservation and stewardship of critical resource lands;
- Maintain the quantity and quality of surface waters and groundwater to protect the ecological health of the region;
- Conserve large contiguous areas of interior forest, grasslands, wetlands and other critical habitat by carefully managing man-made activities;
- Manage *limited* growth to respect the region’s limited carrying capacity and be compatible with ecological constraints; and
- Promote restoration of degraded landscape features.

Recommended strategies to meet these goals include a variety of planning, management, regulatory and educational activities, including:

Planning

- Secure Special Resource Area identification in the State Development and Redevelopment Plan. This designation, previously only applicable to the New Jersey Highlands, will call special attention to the resource conservation needs of the Sourlands.

- Develop a Sourland Mountain municipal alliance modeled on the Ten Towns Great Swamp Watershed Management Committee. This approach recognizes that municipal home rule will continue to shape landscape changes on the Mountain, and relies on municipal cooperation in the exercise of municipal planning and regulatory powers. The highly successful Ten Towns Committee has been copied for other regional watershed applications, and its focus on public education and incentives, in tandem with plans and regulations, makes it a worthy model for a Sourland Mountain municipal alliance.

- Identify the forest core and corridors for preservation. This should include the forest core area where little or no development can be tolerated without significant environmental damage, along with linkage corridors where restoration efforts should be directed. This area should be targeted for acquisition or other preservation efforts and future management of existing land uses should seek to minimize detrimental impacts and phase out inconsistent or deleterious land uses, through a variety of techniques, which may include amortization payments.

- Identify an agricultural retention area, where continuing agricultural activity, using best management practices, is to be supported. The Sourland Mountain region identified in this plan includes areas well suited to farming as well as those where farming is not appropriate. A coherent regional planning approach will acknowledge the importance of supporting agriculture on prime farmland where water is relatively abundant, while also discouraging or preventing agriculture where it would damage a fragile ecosystem or overstress limited water supplies. Failure to clearly define such areas will create unnecessary adversaries among those with competing visions for the varied landscapes of the Sourland Mountain region.

- Prepare a comprehensive Forest Management Plan for the region, including detailed forest stand delineation, to actively manage impacts to the forest from development, timber harvests, farming and other activities. Change is inevitable, so change should be harnessed wherever possible to improve the future forest's ability to protect local water supplies, while also protecting and enhancing habitat value and biological diversity. Aesthetic considerations should be appropriately weighted in developing forest management strategies.

- Prepare a comprehensive cultural resource management plan for the region incorporating local historic preservation plans.

- Prioritize open space acquisitions to mirror the level of environmental sensitivity of the resource to be protected.

- Develop a greenway plan for headwater riparian corridors and other conservation areas.

- Promote diverse partnerships among governments, non-profit entities and private landowners to assure enhanced stewardship.

- Develop a coordinated indicators program to measure and monitor the ecological health of the region, including surveys of stream flow and surface water quality (chemical, physical, biological), regional water levels and groundwater quality (from well records), breeding birds, amphibians and other flora and fauna, including invasive and rare species.

Management

- Promote aggressive deer management strategies at the local, county and State level and conduct studies of the effect of deer harvest on the forest.

- Promote use of best management practices to conserve critical woodland, grassland and wetland habitat.

- Protect surface and groundwater quality and quantity to maintain the ecological integrity of natural ecosystems and human health using best management practices and effective land use management.

- Prepare a comprehensive cultural resource management plan.

Regulation

- Explore enhanced environmental protection standards. DEP requirements applicable throughout the State may fail to adequately protect water resources, native vegetation and wildlife within the Sourland Mountain region. Special Resource Area designation should call attention to the importance of higher standards of protection for these resources.

- Manage limited growth to be compatible with ecological constraints. This would involve a "zero tolerance" approach to pollution, destruction and degradation and would require a "custom fit" for new development within the Sourlands environment. Require all new development to include remediation strategies to limit or obviate its attendant environmental impacts.

- Explore use of a Transfer of Development Rights (TDR) program for vacant undersized lots to relocate development from the Sourland Mountain core area to less environmentally constrained areas.

- Limit anthropogenic demands on the environment through land acquisition and land use policy that minimizes the footprint of future development and the water demands of new development.

- Develop equitable strategies to phase out incompatible agricultural activities within the water-poor Sourlands core area.

- Minimize impervious coverage in aquifer recharge areas and limit water use by new development and agriculture.

- Establish demanding environmental protection strategies and design and performance standards for new development and redevelopment.

- Require each buildable lot to have a primary and a reserve septic field.

Education

- Catalog and disseminate sound habitat management policies that prevent habitat fragmentation, including conservation site designs and coordinated management of upland forest and grassland habitat.

- Develop land stewardship programs for farmers and homeowners (re: pesticides, shrubs, land uses).

- Provide public education about resource conservation to guide those who will live, work and play on the Sourland Mountain, including "how to" on lawns, forests, grasslands, etc. Those who wish broad lawns and ornamental landscapes can find suitable locales outside the Sourland region, where these superimposed landscape changes damage the natural environment and their cumulative external impacts destroy important resources.

Some of these strategies will require assistance from State legislators or Departments. A concerted effort should be made to secure needed legislative changes to provide:

- Preferential tax treatment, like farmland assessment, for conservation efforts that preserve wildlife habitat without the need to destroy or damage forest resources;

- Effective deer management within the Sourlands region that can permit needed regeneration of the forest and its understory;

- Enhanced DEP environmental protection standards applicable within the Sourland Mountain region to reflect the anticipated Special Resource Area status in the amended SDRP;

- Increased funding for open space preservation and habitat protection within the region; and

- Better management of public lands.

Conclusion

The Sourland Mountain region faces increasing pressures from human activity that threaten to deplete the water supply, damage the environment and degrade the ecology and quality of life. This Conservation and Open Space Plan recognizes that cooperation among individual landowners, municipal, county and State governments and non-profit organizations is the key to a sustainable future for a region in the path of inevitable regional expansion.

The long term health of the region will depend on the stewardship of those who own, manage, and use these lands. A variety of planning, management, regulatory and education functions have been identified that can significantly improve the long term outlook. Through coordinated efforts, the Sourland Mountain stakeholders, sharing a common vision and goals, can prevent significant environmental degradation and maintain the sensitive balance of natural features and the impressive biodiversity of the region.

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Figure 1

Interior Forest Blocks

Sourland Mountain District
A Portion of Central New Jersey

November 2005

Legend

Interior Forest Blocks

Other Forest Areas

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Miles

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Source:
NJDEP
D&R Greenways

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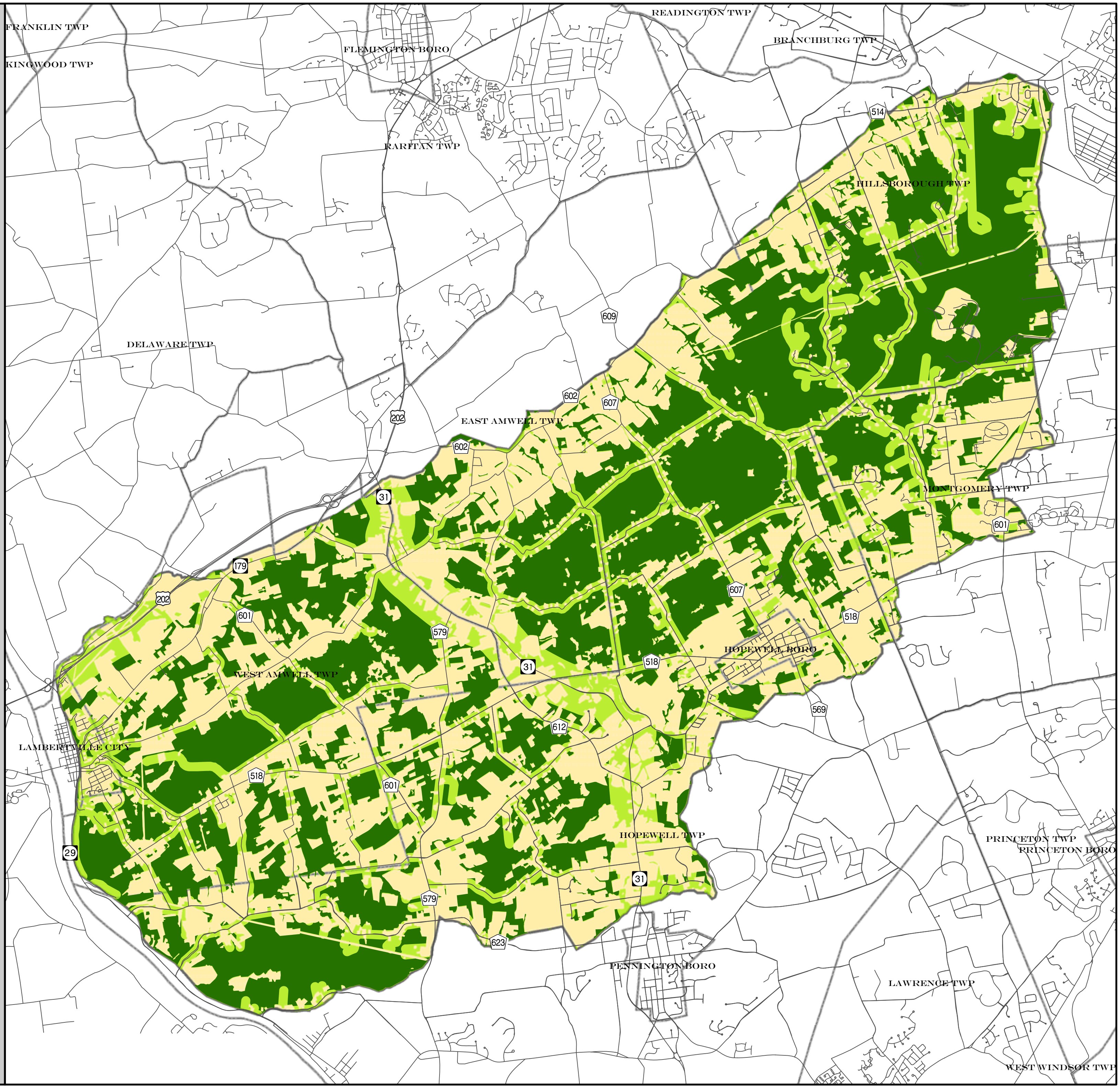
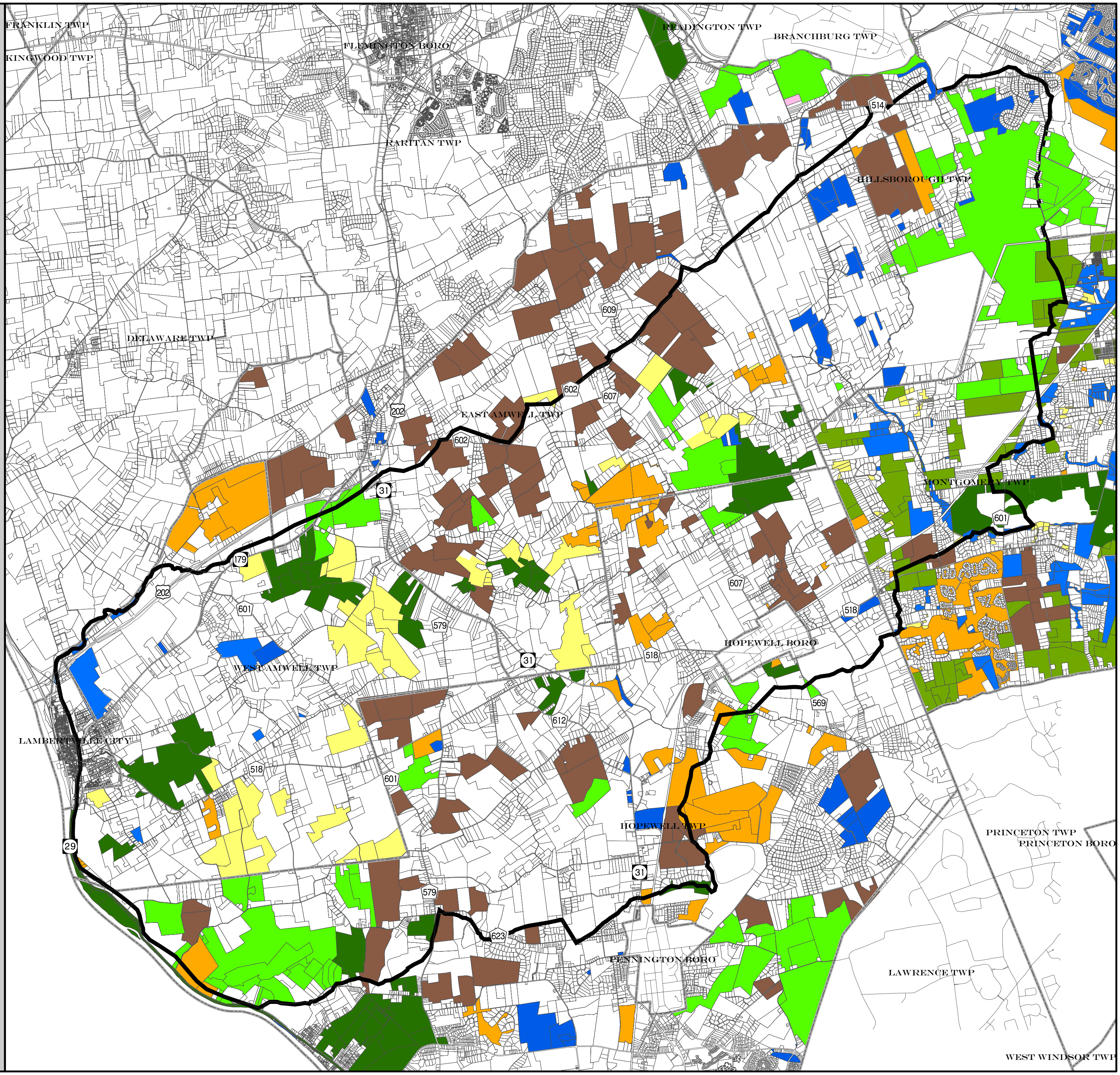


Figure 2

Open Space and Preserved Lands

Sourland Mountain District
A Portion of Central New Jersey

November 2005



Legend

- Sourlands Boundary
- Municipally Owned
- Board of Education
- County Owned
- State Owned
- Non-Profit/Private Preserved Land
- Conservation Easement
- Preserved Farmland
- Other Preserved Land

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This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Source:
NJDEP
D&R Greenways

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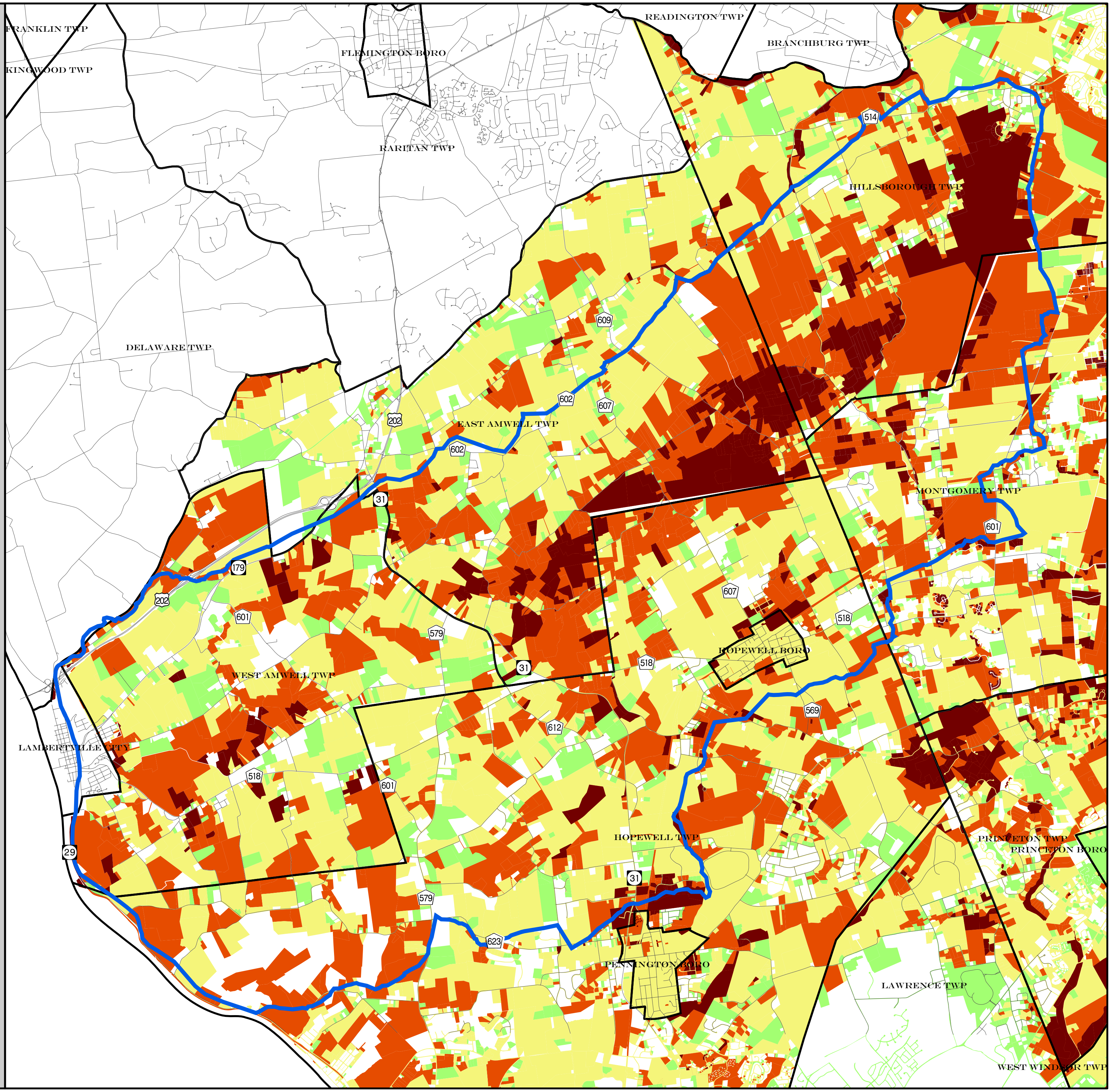
Figure 3

Areas of Critical Importance for Water Resources

Sourland Mountain District

A Portion of Central New Jersey

November 2005



Legend

- 10% or Less Critical Importance
- 10%-50% Critical Importance
- 50%-90% Critical Importance
- 90%+ Critical Importance

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Data Source:
New Jersey Water Supply Authority
NJDEP
D&R Greenways

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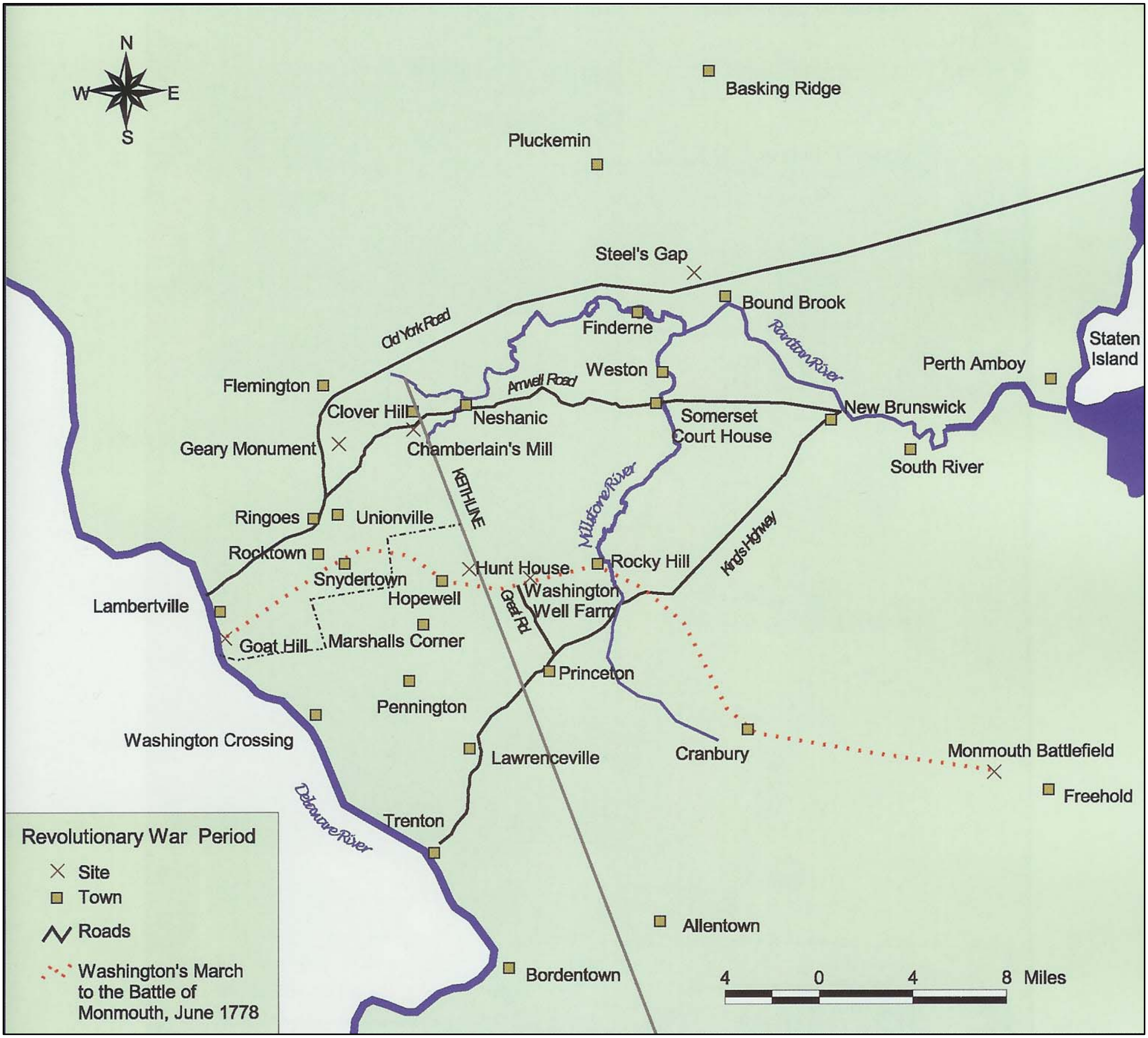
Figure 4: Historic Sites and Trails



Source: Luce, J.T. New Jersey's Sourland Mountain. Hamilton, NJ: White Eagle Printing, 2001

Figure 5

Historic Sites and Districts

Sourland Mountain District
A Portion of Central New Jersey

November 2005

Legend

Historic Sites
Historic Districts

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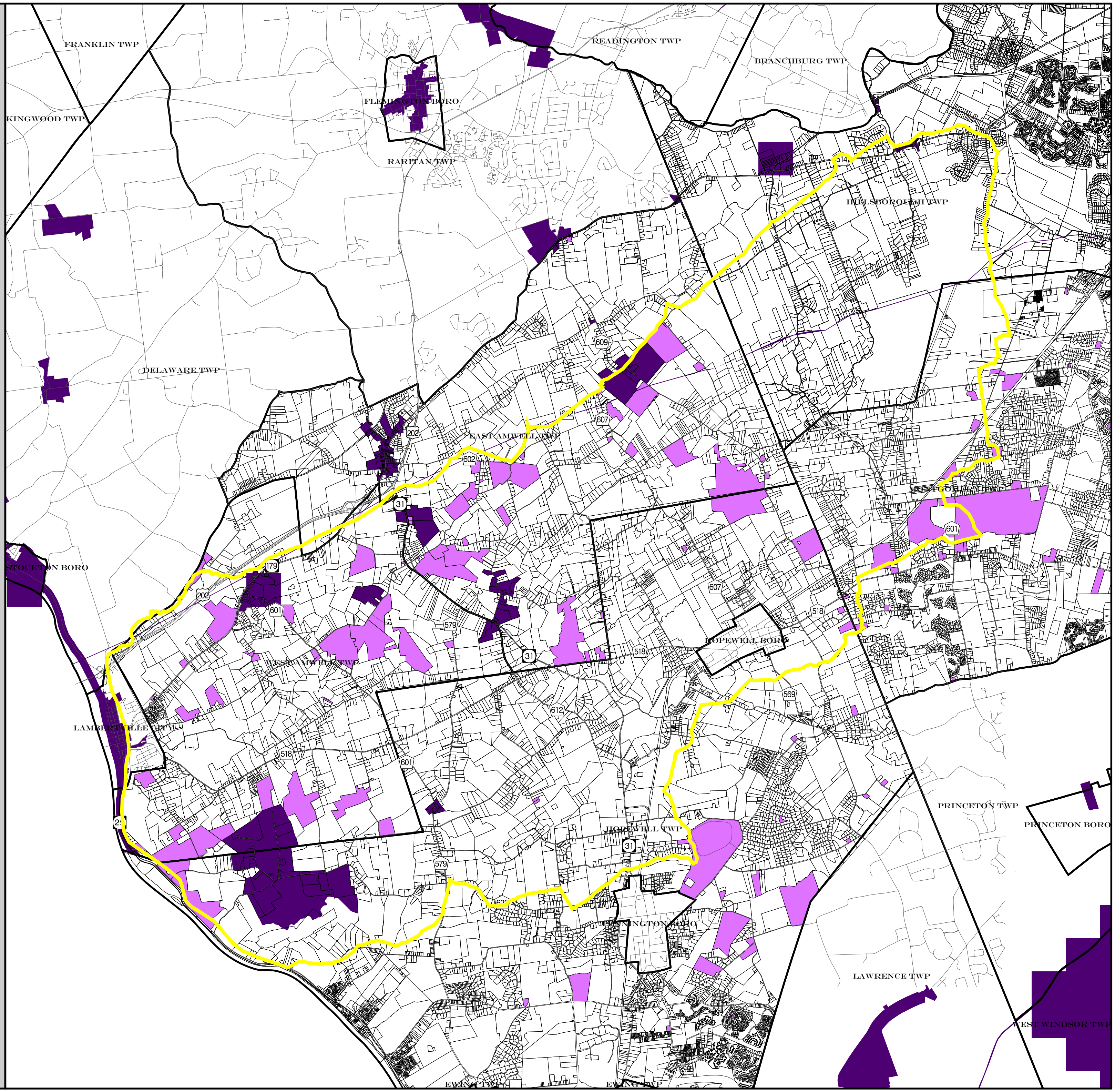

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Source:
NJDEP
Municpal Historic Data

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Figure 6

New Jersey Landscape Project Habitat Data

The Sourland Mountain District
A Portion of Central New Jersey

November 2005

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Rank	Indication
1	Suitable habitat with no field survey conducted
2	Habitat patch with State special concern species 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

Legend

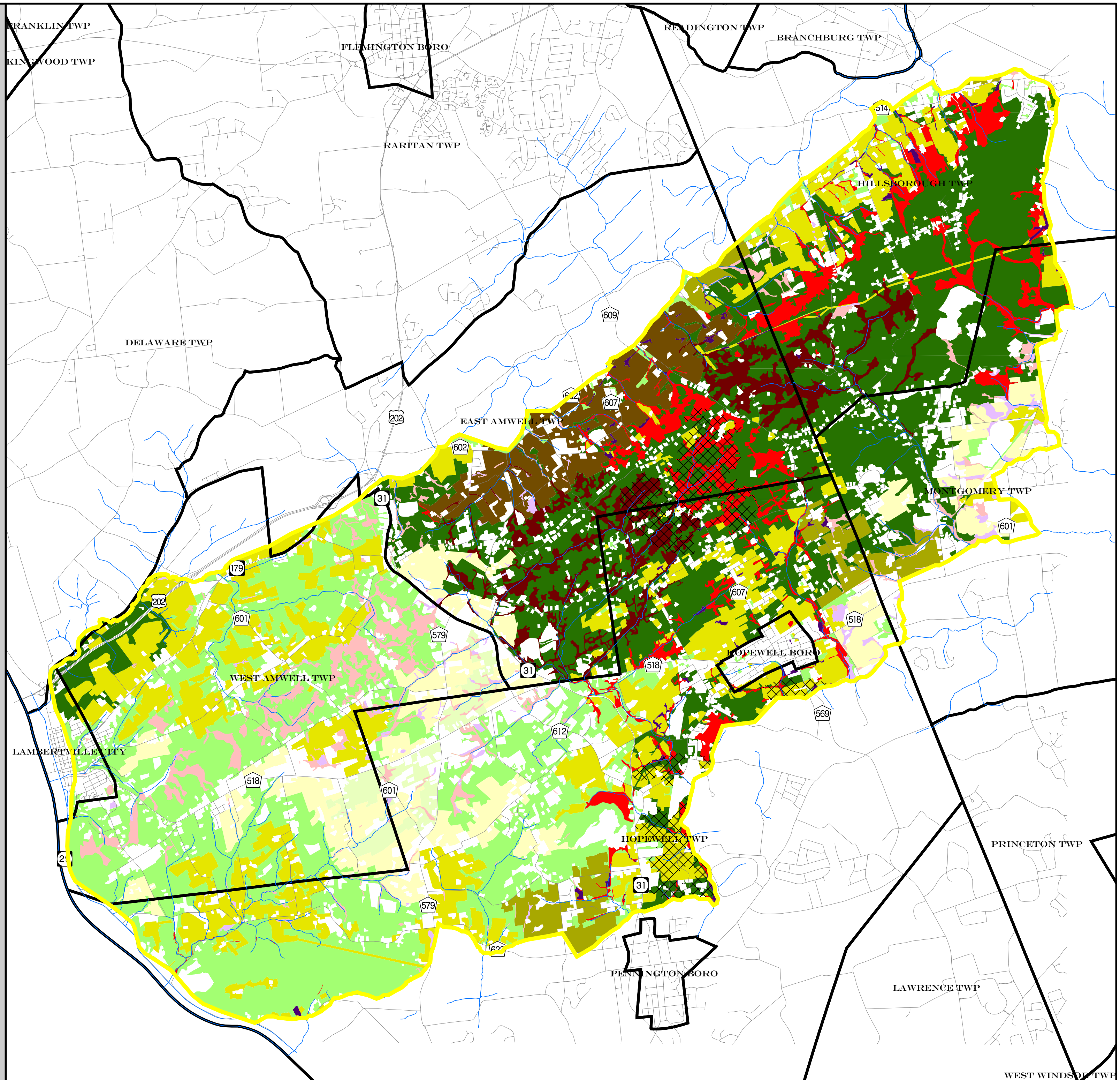
Wood Turtle Foraging

Forest
- Rank 1
- Rank 2
- Rank 3
- Rank 4

Emergent
- Rank 1
- Rank 2

Grassland
- Rank 1
- Rank 2
- Rank 3
- Rank 4

Forested Wetland
- Rank 1
- Rank 2
- Rank 3



This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
NJDEP Landscape Project Critical Habitat Data, Originator - NJDEP, Division of Fish and Wildlife, Endangered NonGame Species Program, Source Data Scale - 30 Meter Resolution. 2/04

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Figure 7: New Jersey Landscapes Regions

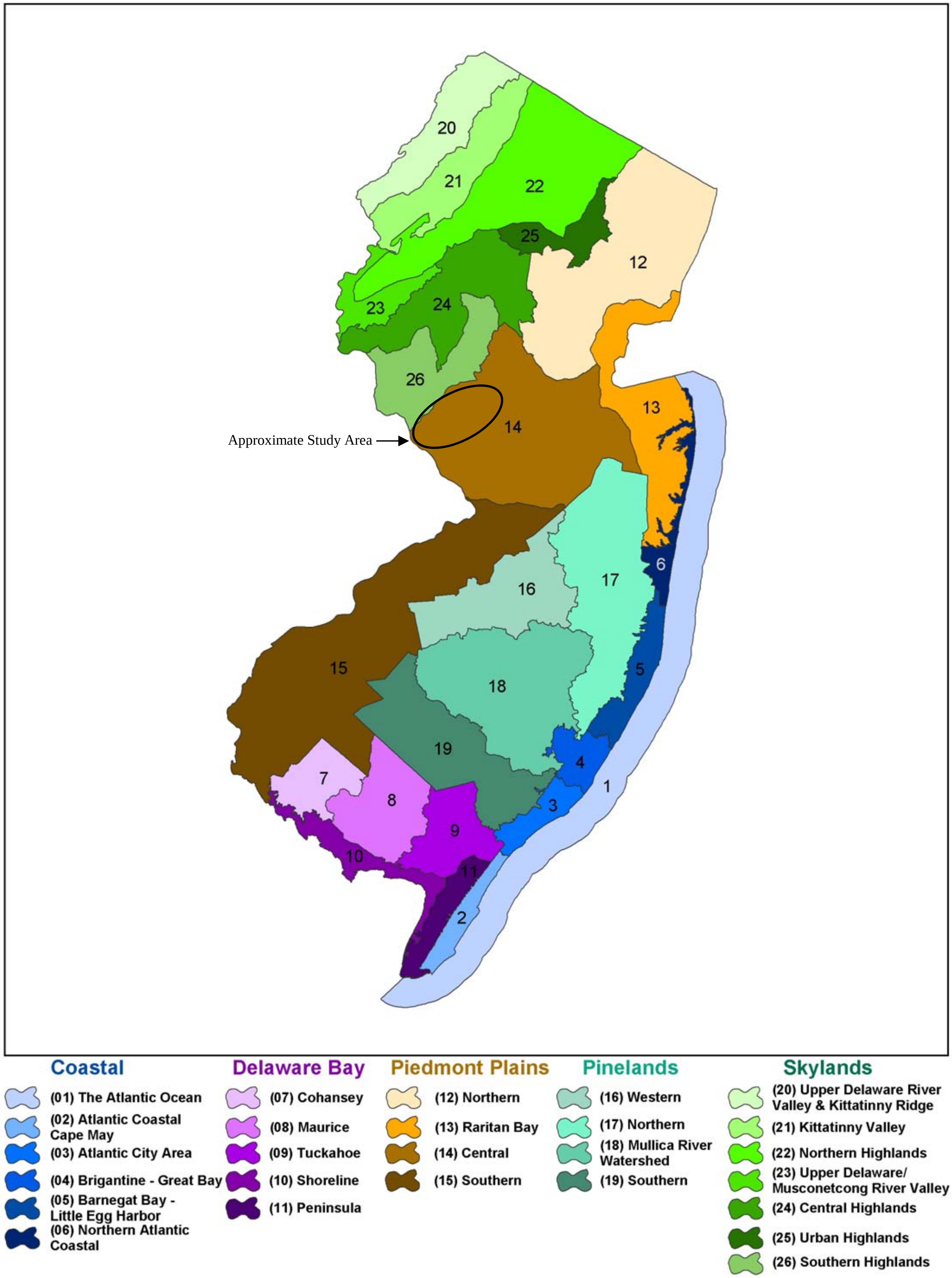

Figure 8: Critical Habitats within the Piedmont Plains

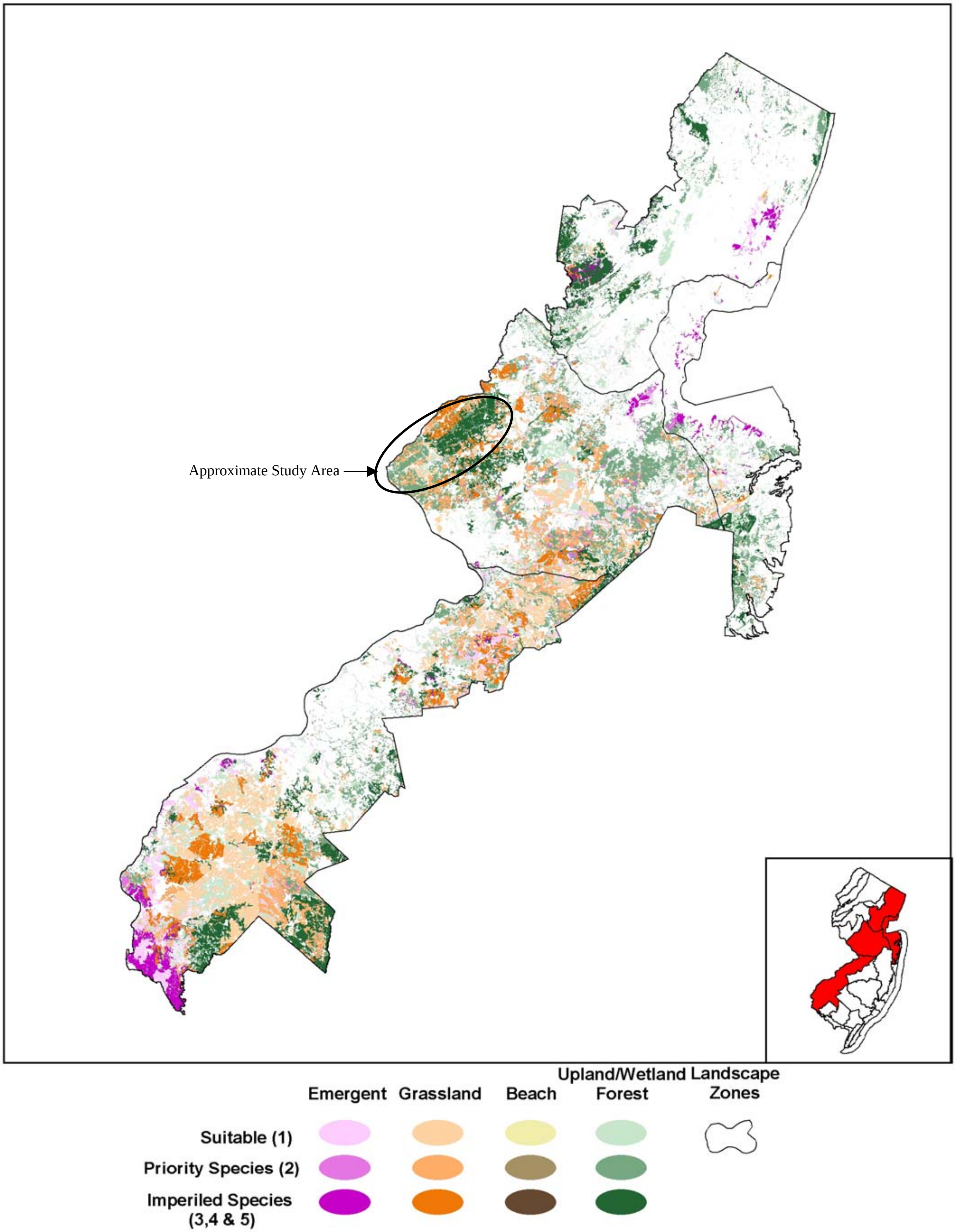

Figure 9

Suggested Greenway Linkages

Sourland Mountain District
A Portion of Central New Jersey

November 2005

Legend

Suggested Greenway Linkages
Preserved Open Space

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This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Source:
NJDEP
D&R Greenways

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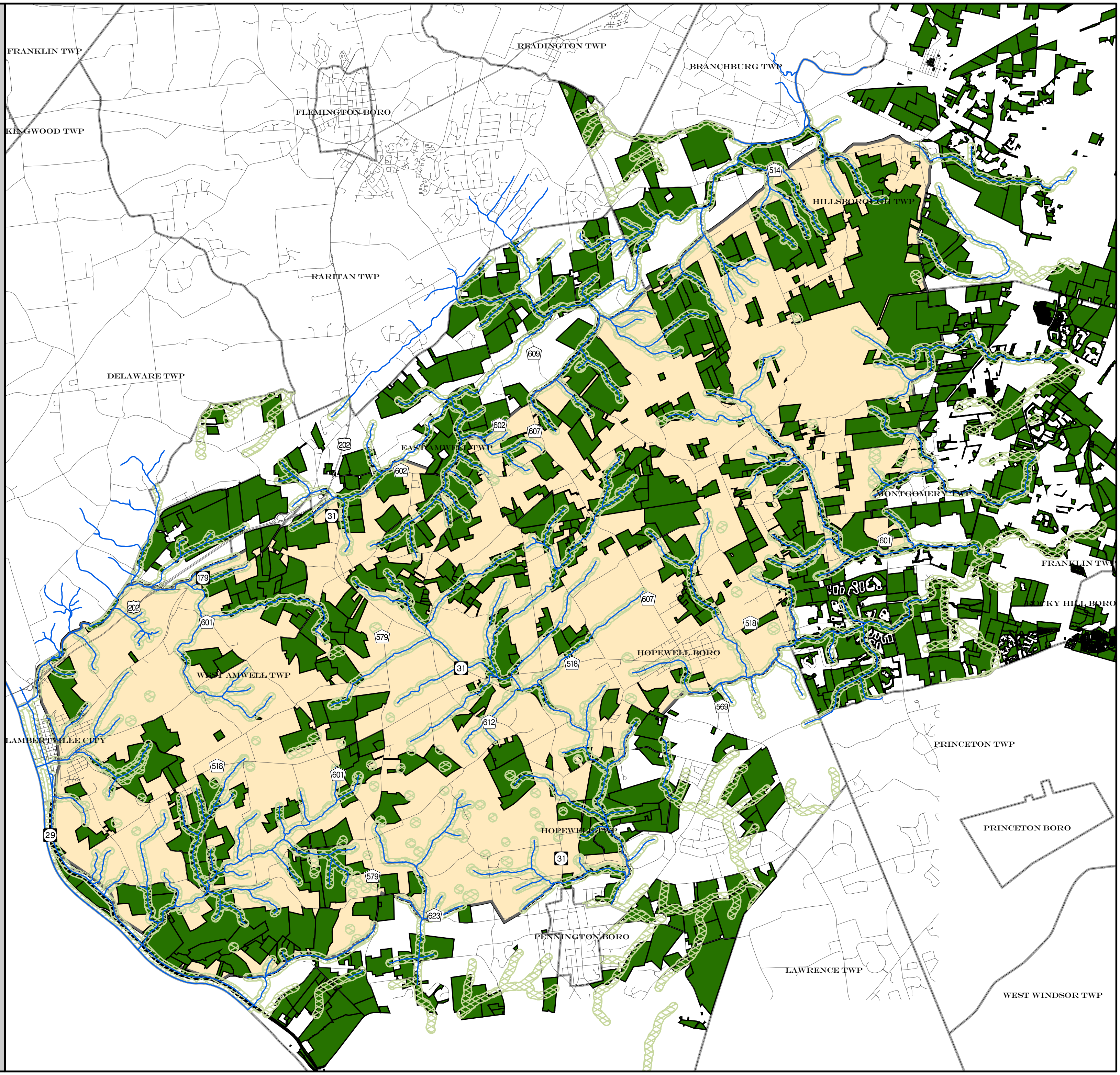

Figure 10

Interior Forest Areas and Preserved Open Space

Sourland Mountain District

A Portion of Central New Jersey

November 2005

Legend

Interior Forest Areas

Preserved Open Space

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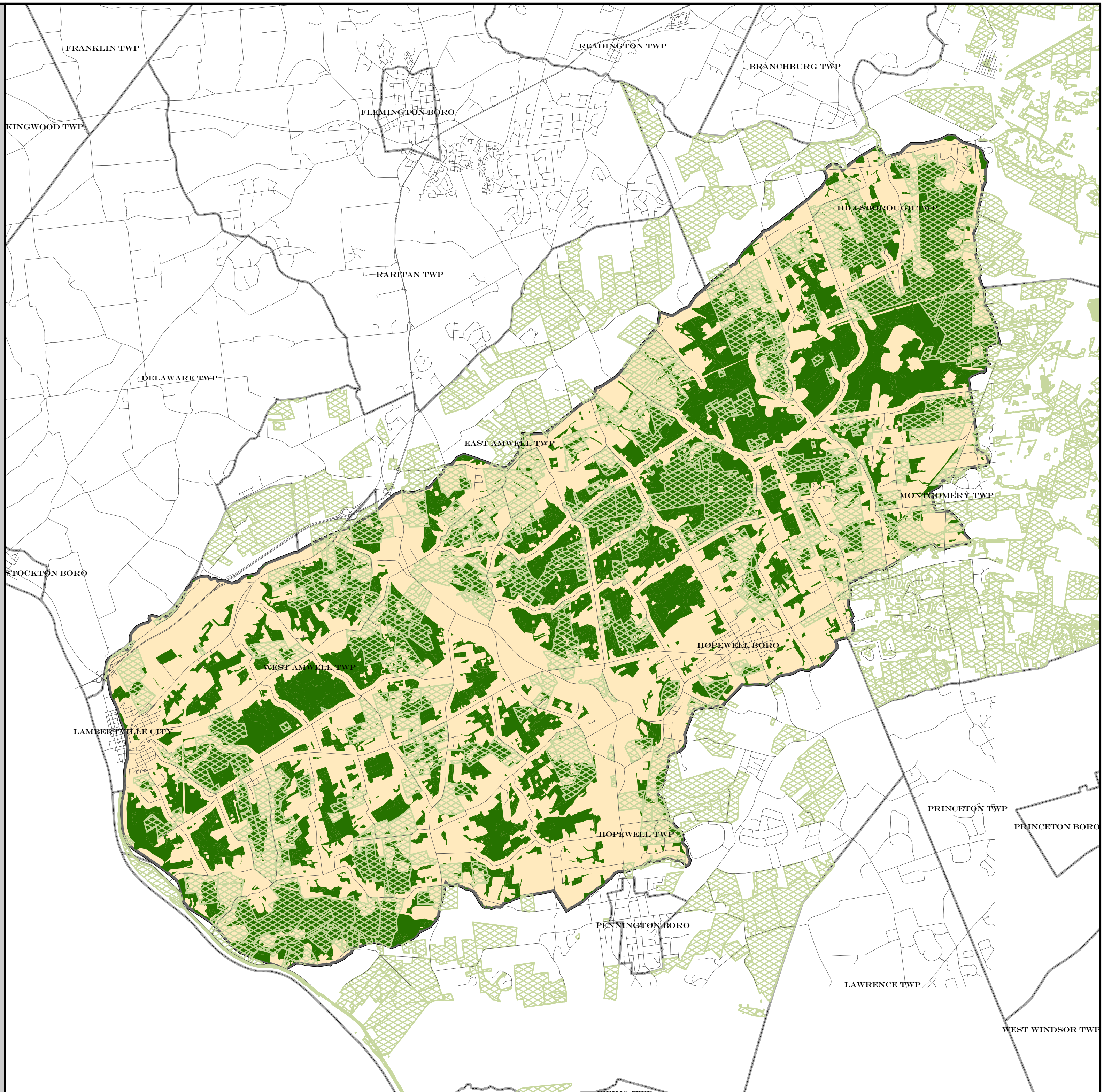

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Source:
NJDEP
D&R Greenways

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Planning and Design

A Natural Resource Inventory for the Sourland Mountain Region

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November 2004

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New Jersey Department of Community Affairs
Smart Growth Grant Program
New Jersey Office of Smart Growth

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"We cannot solve problems by using the same kind of thinking we used when we created them."

Albert Einstein

Executive Summary

This Natural Resource Inventory has been prepared as part of an overall study funded by the New Jersey Department of Community Affairs and the New Jersey Office of Smart Growth. With the Sourland Planning Council as a sponsor and project partner, the five municipalities that share the core of the Sourland region (East and West Amwell Townships, Hopewell Township, Montgomery Township and Hillsborough Township) applied for grant funding to prepare a variety of studies to better understand the region. The first phase of the project is to provide a characterization of the natural resources of the region and assess groundwater resources; phases that will follow will summarize and compare municipal regulations as they relate to the region, assess development potential through build-out analysis and provide a Conservation and Open Space Plan that will identify policies and actions that promote sustainability for the region.

The Sourland Mountain region possesses a number of unique natural features and resources that combine to form what can only be characterized as a fragile ecosystem. While situated between New York and Philadelphia in a corridor that has experienced tremendous population growth in the last 30 years, the core of its fragile resources has remained relatively intact and continues to thrive. But careful management of development and protection of habitat are the only measures that will ensure the long-term survival of the region.

Most development that occurred in the region between 1972 and 1995 came at the expense of agricultural land, as evidenced in land use/land cover information provided by Rutgers University (Grant F. Walton Center for Remote Sensing and Spatial Analysis) and the New Jersey Department of Environmental Protection (NJDEP). More than 4,200 of the 20,000 acres (21%) of agricultural land present in 1972 were converted to developed land uses by 1995. Additionally, the region experienced a loss of 7% of forest present in 1972, roughly 1,800 acres. Given the inter-relationship of these land cover types in providing habitat for both resident and migrating birds, these losses are deemed significant.

The geology that created the unique topographic features known as the Sourlands also brings about limitations for the installation of septic systems and the withdrawal of groundwater through domestic wells. The hard bedrock present at shallow depths creates limited opportunity to install septic systems that will properly treat effluent. Most of the groundwater that reaches bedrock aquifers does so through cracks and fissures; with limited cracks and fissures present in the hard bedrock types of the region, infiltration is also limited. There are also concerns that improperly treated septic effluent could flow along the boundary between soil and bedrock and enter fissures, mixing with groundwater and creating health hazards.

The soils of the study area are varied in composition. The majority are favorable for agriculture, with over 58% of the soils classified as prime or of statewide importance. Most of the agriculture present in the region is on the fringe of the study area, however. In terms of suitability for septic systems, more than 46% of soils are considered unsuitable for the installation of septic systems, according to regulations adopted by the NJDEP in 1999. This is largely due to the shallow depth to bedrock and seasonal high water that a number of soils in the region exhibit.

The Sourland Mountain region acts as headwaters to a number of streams which flow into other areas of Central New Jersey. While only the Alexauken Creek is currently designated a Category One (C-1) water by the NJDEP, there are a number of other streams that could potentially qualify for C-1 designation based on the limited impervious cover in their drainage areas and the nature of their fragile surroundings. A number of streams have been proposed for designation through both the NJDEP and the public and will be considered over the next few months. In terms of existing water quality, a number of the streams within the study area exhibit moderate impairment in their ability to support macro organisms. Through analysis of NJDEP water quality monitoring data, it appears that some streams are tending towards improving quality.

The wetlands present in the study area play an important role in providing habitat for wildlife. Many of the wetland areas are also forested and combine with uplands areas to form the largest contiguous forest remaining in Central New Jersey. These wooded wetlands also store and transmit water to streams which flow into other areas of Central New Jersey.

Riparian areas, or the areas immediately surrounding surface waters, are an important part of the ecosystem that serves a multitude of functions. In addition to controlling water temperature, stabilizing the stream bank, filtering pollutants from runoff, controlling sedimentation and contributing organic matter to the stream ecosystem, they are uniquely suited to passive recreation activities and can serve as corridors for wildlife migration.

The Sourland Mountain region is an ecological island in Central New Jersey, essential to the survival of populations of breeding and migrating birds. The geology, soils, wetlands, forest and grasslands combine to create an environment uniquely suited to sustain an incredibly diverse array of plants and animals that call the region home. Loss of or impact to any of these resources, particularly the understory of the contiguous forest canopy, will have a direct effect on these species and the biodiversity of the area. Although anthropogenic, or manmade, activities have the most impact, natural forces can prolong and often enhance the effect that humans initiate through development.

Data on the importance of the Sourland region continues to become available, as more scientists and organizations focus their attention on identifying the resource factors that make the area unique. Of particular interest is the richness of bird species, both resident and migrant. Composition of the old-growth forest, including the understory habitat critical to migrating species is unique, making the Sourland forest an important stopover along migratory routes. Also important are successional shrubland and grassland habitats that are present on the mountain proper and its flanks, which lead to the Amwell and Hopewell valleys. The vernal pools and emergent wetlands of the region also serve as habitat to a number of threatened or endangered herpetile species.

Introduction

The Sourland Mountain is a region at the crossroads. As a crossroads of the American Revolution, it holds secrets and can tell tales from our early life as one of the original Colonies. As an essential stopover for Neotropical migrants in the flyway between Central America and Canada, it is an avian crossroads. The Sourlands are also a crossroads for commutation between homes and places of employment, which are increasingly widely spaced and disconnected from historic centers. And as the Sourlands region enters the 21st century, valuable natural resources, including the limited water supply, are threatened by random and piecemeal development.

Set amid productive agricultural valleys to the north and south, the Sourlands are situated midway between New York and Philadelphia, in a region which has been dramatically altered by development. A place rich in history that extends far beyond the Lindbergh kidnapping, the lower elevations of the mountains were first settled by the Lenape Indians, whose Unami tribes farmed the agricultural valleys that flank the mountain. However, the hostile environment of hard rock and scarce water limited their exploitation of the mountaintop.

The Sourland Mountain formed over 150,000,000 years ago, during the Triassic and Jurassic Periods, the result of continental separation or rift. This inhospitable environment discouraged significant settlement by the Europeans who migrated to the area in the 18th century, and had a similar effect during the 19th century. The latter part of the 20th century, however, brought technological advances that aided human settlement of areas previously deemed too harsh. These new or improved technologies, which provided techniques for disposal of human waste and devices to extract the limited available water, now pose a significant threat to the overall ecological health of the mountain.

As we deal with these issues in the 21st century, it is important to recognize that unbridled human activity will provoke exploitation of sensitive and limited resources beyond their limits. A sustainable future for the Sourland Mountain and the fragile ecosystem that it encompasses will depend on limiting residential and commercial expansion and shaping new development to maintain and reinforce the ecological balance and prevent forest fragmentation and competition for limited water supplies.

Sensitive environmental features, like the vernal pools that support rare species, are highly susceptible to being lost or compromised. Increasing consumer demands for potable water can also have the effect of robbing the base flow from streams whose biota are indicative of high environmental quality. Limiting the demands we place on these resources will be essential to the long term health of the region.

This Natural Resource Inventory provides data that will help to coordinate the resource protection efforts and concerns of the municipalities and three counties that together will shape the fate of this fragile landscape. It recognizes that geography, not political boundaries, defines the Sourlands.

The Study Area

The study area for this Natural Resource Inventory expands on a 64 square mile (40,886 acre) boundary previously defined by Joel Coyne and Jerry Haimowitz for study undertaken by the Sourland Planning Council. This boundary was based largely on the extent of the forest canopy and was meant to incorporate the majority of the Jurassic Diabase formation that comprises the Sourland ridge and other topographic highs of the region. More recent study of the Sourland region has focused primarily on the issue of water supply, vis-à-vis groundwater resource studies prepared for East Amwell, West Amwell and Hopewell Townships. As such, for this more detailed analysis of natural resource factors affecting the region, the study area was expanded to 87 square miles (55,731 acres) to encompass recharge areas and other important habitat types on the flanks of the Sourland ridge. For the most part, the study area boundary represents the limit water flowing out of the Sourland region would reach.

While the expanded boundary may not represent what many feel is the essence of the Sourland region, it will aid in further identifying the extent of impact that land uses in these areas have on the resources of the Sourland Mountain. Analysis of a larger study area will also permit determination of the true core of the region, allowing for prioritization and protection of critical resource factors to aid future planning efforts.

Throughout this Natural Resource Inventory, a number of terms are used to describe a variety of geographic areas. "The Sourlands" refers to all of the topographic formations within the study area, including the Sourland Mountain, Baldpate Mountain, Pheasant Hill and Pennington Mountain (see Figure 22). "The Sourland Region" refers to the entire 87 square mile study area. "The Sourland Ridge" refers to the Diabase formation that forms the Sourland Mountain itself. These terms are interchanged throughout this document and are important to defining the context of the discussion presented.

Purpose and Objectives

A Natural Resource Inventory (NRI) identifies, quantifies and describes the environmental resources present in the community. Through mapping and description, critical factors can be identified and highlighted; this process forms the basis for determining relative importance for future planning efforts.

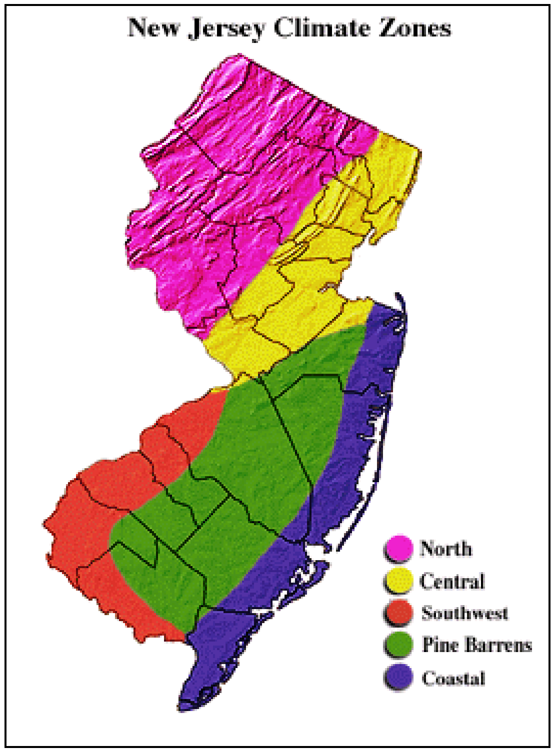
GIS digital data has simplified the quantification and description of resource factors. The ease with which data can be analyzed and displayed allows detailed study to be undertaken for a large area. The inter-relationship of physical features and their relative importance can be identified. In this fashion, both competing and synergistic relationships among natural resources can be defined and explored.

An NRI is particularly useful in identifying and describing many of the natural resources and factors that play a unique role in planning and community development. It is often the basis for future efforts to establish land use and preservation policies in community planning documents; these documents will shape the future of the region.

The purpose of this Natural Resource Inventory is to document in detail the resources and importance of what most intuitively view as an extremely fragile ecosystem. The objective is to provide a firm basis for the establishment of sustainable policy and land use regulation by the communities that share the Sourland Region. This study will likely point to larger issues that require action at higher levels. The objective is to provide enough information to initiate more in depth study where required.

Climate[i]

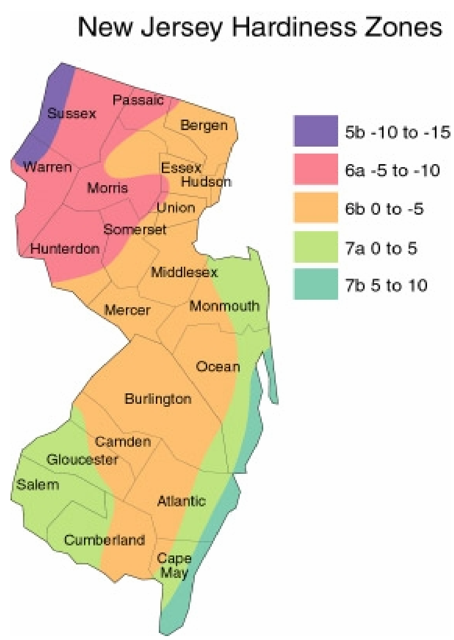
While the study area for the Sourland Mountain region is in both the central and north climate zones of New Jersey, the majority and core of the mountain is in the north climate zone, as depicted at right. Neither climate zone is generally influenced by the Atlantic Ocean and thus have a continental type of climate. Prevailing winds are from the southwest in summer and from the northwest in winter. The continental type of climate means the Sourland Mountain region generally has colder temperatures and greater snowfall in winter, with a greater average annual precipitation overall as compared to areas in southern New Jersey.



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

Based on 30 years of data from weather stations in Flemington and Lambertville, snowfall amounts average 20.9 to 29.1 inches annually, with 48.77 to 49.79 inches of precipitation throughout the year. Generally, January is the month with the most snowfall, averaging 7.5 to 9.5 inches, while May averaged the most precipitation (4.86 inches) over 30 years in Flemington and July averaged the most precipitation in Lambertville (5.06 inches). Spring and summer months tend to experience temperatures consistent with those found in the rest of the state, averaging between 49 and 73 degrees Fahrenheit.

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 136 days to as long as 235 days with an average length between 158 and 191 days 9 years in 10 (based on data from Flemington weather station). 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 north climate zone have, however, experienced killing frosts as early as September and as late as June.



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

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

Fahrenheit.

Hardiness zones are critical for successful cultivation and maintenance of plant material. 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 the Sourland region, 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

According to 1995 data on land use/land cover published by the New Jersey Department of Environmental Protection (NJDEP), the Sourland Mountain region is primarily characterized by forest (43.3%) and agriculture (28.9%) land cover types. Urban land cover accounts for 13.9% of the region while wetlands (12.8%), barren land (0.7%) and water (0.3%) account for the remainder. Figure 1 depicts a Level I (generalized) Land Use/Land Cover classification for the region based on the Anderson classification scheme, which was developed in the late 1970's as a standard for land use/land cover interpretation. The Anderson scheme classifies all land uses first on a general level (urban, agriculture, forest, wetland, barren and water), then provides further general distinction along with detailed distinction There are three levels of classification possible, Level III being the most detailed.

Urban land uses are generally scattered throughout the Sourland Mountain region, with concentrated nodes found on the flanks of the ridge itself (see Figure 1). The majority of land classified as urban is found in Hopewell Borough, at the base of the Mountain in Montgomery, Hopewell, Hillsborough and West Amwell townships and concentrated along the Route 31 corridor in the central part of the study area. The pattern of development has, for the most part, left many of the forested areas which comprise much of the region intact. The Sourland ridge itself, comprised of the Diabase is dotted with limited development.

The Sourland Mountain's forested acreage is concentrated in three distinct areas; two of these areas are separated by the Route 31 corridor, which divides the region roughly in half. The third area is Baldpate Mountain, in the southwest portion of the study area in the northwest corner of Hopewell Township. And while wetlands comprise only 12.8% of the land cover types found in the region, in relative terms this is a fairly large part. A majority of the wetlands on the Sourland Mountain itself are deciduous wooded wetlands, which could be duly classified as forest as well.

But what general figures illustrating land cover characteristics for the region do not express is its essence; deep forest, grassland and forested wetlands. These factors lend to the feeling that people get from this place, both those who live here and those who visit. They are the critical elements that together define what is important about the Sourland region. The interrelationship of these macro-level features provide continuity that promotes incredible diversity.

Figure 2 depicts the 1995 land use/land cover of the region in a more detailed fashion, expanding on the 6 general categories contained in the Level I Anderson classification. This breakdown, generally representative of 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	15,345.74	27.8
Agricultural Wetlands	388.35	0.7
Altered Lands	3.27	0.0
Brush Covered Field	1,345.96	2.4
Brush/Shrubland	3317.36	6.0
Commercial	275.41	0.5
Coniferous Forest	467.36	0.8
Coniferous Wooded Wetlands	4.72	0.0
Deciduous Forest	18,263.47	33.1
Deciduous Wooded Wetlands	5,879.73	10.6
Disturbed Wetlands	66.34	0.1
Exposed Rock	3.73	0.0
Industrial	103.86	0.2
Managed Wetland	27.12	0.0
Mining	344.38	0.6
Mixed Forest	528.99	1.0
Mixed Wooded Wetlands	161.24	0.3
Other Agriculture	595.53	1.1
Other Urban	724.09	1.3
Recreational Land	280.42	0.5
Residential	5,933.95	10.7
Residential, High Density	45.59	0.1
Transitional Areas	33.96	0.1
Transportation and Utilities	341.32	0.6
Water	183.08	0.3
Wetlands	568.32	1.2
Total	**55,233.26**	

Table 2– Population Change (1970 to 2000)

MUNICIPALITY	1970	1980	1990	2000	Change 1970-2000	% Change 1970-2000
East Amwell Township	2,568	3,468	4,332	4,455	1,887	73.5%
West Amwell Township	2,142	2,299	2,251	2,383	241	11.3%
Hillsborough Township	11,061	19,061	28,808	36,634	25,573	231.2%
Montgomery Township	6,353	7,360	9,612	17,481	11,128	175.2%
Hopewell Township	10,030	10,893	11,590	16,105	6,075	60.6%
Total	**34,124**	**45,061**	**58,583**	**79,058**	**44,934**	**131.7%**

While growth in the municipalities which share the Sourland Mountain region was significant between 1970 and 2000 (see Table 2), when the population rose from 34,124 to 79,058 (131.7%), it is clear from comparison of land use/land cover data for roughly the same period that growth occurred on the fringe of the study area and not on the mountain itself. Historical land cover interpreted from remotely sensed data reveals that in 1972, the Sourland Mountain region was dominated by forest and agricultural land cover types, representing nearly 83.5% of the study area's acreage. Wetlands comprised 14.2% of the region's land cover and urban land uses represented a mere 1.7%. In 1986, developed land uses began to appear in the region as more of New Jersey's population expanded into the western part of the state. Land dedicated to agriculture decreased by more than 2,000 acres, forested land declined by more than 2,500 acres and roughly 660 acres of wetlands were converted to other land uses. Simultaneously, urban land uses increased by 5,500 acres (574%).

Table 3 – Land Use/Land Cover Change (1972, 1986 and 1995)

LandUse/Land Cover Type	1972*		1986		1995		Change (1972 – 1995)	
	Acres	*%*	*Acres*	*%*	*Acres*	*%*	*Acres*	*%*
Agriculture	20,207.5	36.7	18,010.9	32.6	15,941.3	28.9	-4,266.2	-21.2
Barren Land	186.0	0.3	350.5	0.6	385.3	0.7	199.3	107.2
Forest	25,766.0	46.8	23,066.6	41.8	23,923.1	43.3	-1,842.9	-7.2
Urban	959.8	1.7	6,464.1	11.7	7,704.6	13.9	6,744.8	702.7
Water	59.9	0.1	178.3	0.3	183.1	0.3	123.2	205.7
Wetlands	7,826.4	14.2	7,162.9	13.0	7,095.8	12.8	-730.6	-9.3

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

The study area was marked by a decline in agricultural land uses (-21.2%) and a precipitous increase in urban land uses (702.7%) from 1972 to 1995. Roughly 4,266 acres of agricultural land was converted to other uses while urban land cover increased by 6,745 acres. Figure 3 reveals that the majority of conversion to urban land uses occurred in the valleys which surround the Sourland Mountain and not on the mountain proper; Montgomery, Hillsborough and

Hopewell Townships all show new residential growth that occurred post-1972. Figure 3 also illustrates that most conversion was from agricultural land directly to urban land. This is supported by the fact that forest cover declined a mere 7.2% (1,842 acres) from 1972 to 1995.

When considering changes in land use/land cover, it is important to consider factors that may not be apparent in the raw data; these factors are closely linked to the methods by which the data is compiled. As an example, what the data does not readily quantify is the replacement of old-growth forest with old fields in the forest category. Both are classified the same in a Level I land use/land cover scheme. Gross comparison of land cover characteristics, such as above, must be tempered with an understanding of their general nature. While useful for broad comparison, they cannot detail the true nature of change occurring at finer levels.

Forested Areas[1]

Including wooded wetlands, the study area has nearly 30,000 acres of forested areas. This represents 54% of the total acreage of the region and a significant portion of land cover. More than half (60.9%) is deciduous forest, which when combined with deciduous wooded wetlands, makes over 80% of the forested areas in the region deciduous in nature. Table 4 below lists the forest types depicted on Figure 4 and the percentage each type represents.

Table 4 – 1995 Forest Types

Forest Type	Acres	Percentage
Brush Covered Field	1,345.96	4.5
Brush/Shrubland	3,317.36	11.1
Coniferous Forest	467.36	1.6
Coniferous Wooded Wetlands	4.72	0.0
Deciduous Forest	18,263.47	60.9
Deciduous Wooded Wetlands	5,879.73	19.6
Mixed Forest	528.99	1.8
Mixed Wooded Wetlands	161.24	0.5
Total	**29,968.82**	

The forested areas of Sourland Mountain region play a vital role in many ecosystem functions, including:

- Habitat for threatened and endangered species;
- Breeding habitat for Neotropical migrant bird 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 and Delaware River watersheds;

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

- 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;
- Stopover between and linkage to other ecosystems and greenways such as the Highlands, Pinelands, Duke Estate, Neshanic Greenway, D&R Greenway, and the Amwell and Hopewell valleys
- Enhancement of groundwater recharge capacities.

The most significant contiguous forest stand in the study area is found along the Sourland ridge stretching from Hillsborough and northern Montgomery into the southernmost part of East Amwell and the northern fringe of Hopewell (see Figure 5). At roughly 11,800 acres, this patch of forest represents the largest remaining contiguous forest in Central New Jersey (see Figure 6).

Another reasonably intact linear forest is found just west of the Route 31 corridor, which divides the forests of the Sourland ridge roughly in half. Bound by Rocktown-Lambertville Road to the north and Rock Road and County Route 518 to the South, this 1,200 acre, four thousand foot wide patch of forest is interrupted only by sparse residences until it intersects County Route 518 as it reaches to Lambertville City. (see Figure 7)

The forest found at Baldpate Mountain consists of roughly 1,500 acres of deciduous woodland. Although traversed by a utility right-of-way and home to an area of agriculture, this forest is uninterrupted by urban land uses. (see Figure 7)

The forests of the study area are characterized by a number of tree species that can be considered important, based on a 1990 study prepared by Douglas W. White, PhD of Rutgers University. The study, entitled “Woodlands of Hopewell Valley”, highlighted the characteristics of forests in the northern half of the Township; most are within the study area. Ash, Tulip, Red Oak, Beech, White Oak, Hickory and Red Maple had the highest basal area, relative density and relative frequency (White, 1990). The importance of these species extends to other forested areas of the Sourland region.

Comparison of land use/land cover data from 1986 and 1995 shows that 683.8 acres of forest were converted to other land uses, primarily residential (66%, including other urban). Forest areas cleared for agriculture accounted for 12.8% (87.6 acres) of forest lost, while expansion of mining (10.4%) and industrial areas (3.6%) accounted for the majority of the remainder. Considering the amount of new forested areas since 1986, however, there was a net gain of 826 acres. Succession of crop and pastureland accounts for 90% (1,359 acres) of new forested areas identified in 1995. Surprisingly, conversion of residential and other urban land uses comprised 90.6 acres of new forest (6%).

Typically, forested areas converted to other land uses rarely revert to forest, especially when converted to residential uses. 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, the study area had 15,941.3 acres of land categorized as agricultural in nature. This acreage represents 29% of the region. For the most part, these lands are located on the flanks of the Sourland ridge stretching into the Amwell and Hopewell valleys, as depicted on Figure 8. There are, however, areas of agriculture interspersed among forested areas on the Mountain itself.

Crop and pastureland represent nearly 95% of agricultural land in the Sourland region. The remaining categories of agricultural land cover are represented by orchards, vineyards and nurseries (230 acres) and other agriculture (602.4 acres). Other agricultural uses are characterized by confined feeding operations, experimental fields, horse farms and isolated dikes and access roads.

Reviewing land cover data from 1986 and 1995, 2,211 acres of agricultural land was converted to other land uses over the nine year period. The majority (62%) was converted to brush covered field and brush/shrubland, representative of cropland and pasture that went fallow for an extended period of time. New residential and other urban uses comprised 33% (730 acres) of agricultural land converted. New agricultural areas evident since 1986 amounted to 141 acres, composed primarily of conversion of brush/shrubland and deciduous forest (70.7% together) to cropland. There was, however, conversion of residential and recreational land to agricultural use, accounting for 11.4% and 5.7% respectively.

The agricultural lands which flank the Sourland Mountain play an important role as grassland habitat for breeding birds, including a number of endangered species (see Appendix 4). Much of the crop and pastureland of the Amwell and Hopewell valleys are hay and pasture ideal for birds. But the agricultural management of these fields is what ultimately determines their suitability as breeding grounds. Generally, hay or pasture which is mowed prior to mid-July is not suitable for breeding. Depending on weather, most farmers will harvest the first crop of hay well before mid-July, especially in years with generous precipitation in late spring.

Geology [ii]

The study area falls within the Piedmont physiographic province of New Jersey. The Sourland Mountain consists of bedrock formations which are severely limited in their ability to produce clean water. These bedrock formations, depicted on Figure 9, were deposited in a series of basins during the Triassic and Jurassic Ages, when violent volcanic activity shaped the Sourlands

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

landscape. The sedimentary deposits of the Stockton, Passaic and Lockatong formations formed broad alluvial plains, which were reshaped when volcanic activity baked the sedimentary layers of shale and sandstone and erupted through the surface, forming the Diabase core of the Mountain.

The Stockton Formation, which occupies 2,679 acres or roughly 5 percent of the study area, is the oldest sedimentary deposit, consisting of sand, gravel and silt. The Lockatong Formation, consisting of fine grain silts, clays and sands were deposited over the Stockton Formation in lakebeds, and account for 12,632 acres, or roughly 23 percent of the study area. Later sedimentary deposits (Late Triassic-Early Jurassic) of fine grain sands, silts and clay deposited in lakes and mudflats were later cemented into the red to gray colored shales, siltstones, mudstones and sandstones of the Passaic Formation. The Passaic Formation occupies the largest area within the Sourland Mountain study area at 25,080 acres (45.4 percent of study area), and when combined with the Passaic Formation graybed (3,376 acres, or 6.1 percent of study area), Passaic bedrock accounts for over half of the study area.

The Diabase, which forms the hard rock core of the mountain, represent the youngest bedrock formation on the mountain, having intruded as magmas that produced dense, hard and poorly fractured crystalline Diabase and baked, or metamorphosed, the adjacent sediments in relatively close proximity.

The groundwater-bearing potential of these bedrock formations relates to their ability to store and transmit water, and is related to the extent of fractures, joints and bedding planes. Fracturing, generally limited to the weathered mantle that extends less than 100 feet below the ground surface, is a key determinant of the potential to yield groundwater. As compared to Jurrasic Diabase, the Passaic and Stockton Formations, with numerous fractures and fairly wide fracture spacing, have better potential to yield potable water supplies and to maintain base flow within the region. Conversely, the lack of significant fracturing in the Lockatong and Diabase formations limits their ability to store substantial groundwater. A detailed review of the water bearing capabilities of these bedrock units is contained in the Hydrogeology Report prepared by Matthew Mulhall, PG and Peter Demicco, PG.

Soils

Soils are formed by the weathering and break up of parent material (rock). They bear a strong relationship to the rock from which they are formed and are often times greatly influenced by this relationship, especially in the Sourland region. A variety of factors related to community development are limited by the soils present in the region. With their shallow depth to hard bedrock and presence of layers which restrict infiltration of precipitation, their properties must be considered carefully.

The soils of the Sourland Mountain region have significant limitations 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 Surveys published by the United States Department of Agriculture (USDA) Soil Conservation Service for the three counties in which the study area is located. In addition to

Soil Surveys, the USDA Natural Resources Conservation Service published digital soil surveys and supporting data tables known as Soil Survey Geographic (SSURGO) databases (see the table in Appendix 1 for SSURGO Soil Characteristics). This digital data, used to create the maps depicted in Figures 10 through 15, is based on the Soil Surveys of Somerset County, published in 1976, Hunterdon County, published in 1974 and Mercer County, published in 1972.

There are a number of different soil associations present in the Sourland Mountain region, each of which are categorized based on the parent material from which they were formed. They can be described as follows and are presented by county for the region:

Somerset County (Hillsborough and Montgomery Townships)[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 with Mercer County.

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 on the north and south flanks of the Sourland Mountain.

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 adjacent to the Sourland Mountain, extending east into Hillsborough and Montgomery Townships.

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.

[3] "General Soil Map," Somerset County, New Jersey, prepared by the USDA Soil Conservation Service, 1975.

Hunterdon County (East and West Amwell Townships)[4]

Soils of the Highlands and Adjacent Part of Piedmont Plateau– On the adjacent part of the Plateau, the soils are mostly deep, gently sloping to moderately steep, gravelly, stony or rocky. Included are narrow areas of flood plains. Most of the Piedmont Plateau of the County is used for the production of general crops.

Washington-Berks-Athol Association: Deep and moderately deep, gently sloping to moderately steep, well-drained soils; on uplands. This association is found in the southern part of West Amwell Township along the border with Mercer County.

Soils of the Piedmont Plateau- The dominant soils of the Piedmont Plateau are moderately deep or deep over shale, sandstone, or argillite. Slopes are mostly gently rolling. Most of the soils are well drained but some range to poorly drained. Minor areas are underlain by Diabase rock. These areas are very stony.

Penn-Klinesville-Bucks Association: Shallow to deep, gently sloping to moderately steep, well-drained soils. This association is present in only a small portion of the study area immediately adjacent to the Amwell Valley and Neshanic River.

Penn-Bucks-Reaville Association: Moderately deep and deep, gently sloping to moderately steep, well-drained to somewhat poorly drained soils. This association is found at the northern fringe of the study area in West and East Amwell Townships, extending along the Alexauken Creek into Lambertville City.

Lehigh-Chalfont-Lawrenceville Association: Deep, nearly level to moderately steep, moderately well drained and somewhat poorly drained, non-stony to very stony soils. This association is located on the north and south flanks of the Sourland ridge.

Neshaminy-Mount Lucas-Legore Association: Deep, nearly level to very steep, well-drained to somewhat poorly drained, mostly very stony soils. This association is found atop the Diabase of the Sourland ridge.

Mercer County (Hopewell Township)[5]

Soils of the Northern Piedmont – In the part of the county that lies within the Northern Piedmont Lowland, the soils are dominantly silty and commonly are shaly or stony. Most of the soils are underlain by hard bedrock at a depth of 2 to 20 feet. Ground water is generally scarce in the five soils association of the Piedmont area. Ground water is stored in fractured zones of the rock, and in many places the supply is barely adequate for private wells.

Neshaminy-Mount Lucas-Lehigh Association: Mainly deep, well-drained to somewhat poorly drained, moderately sloping to steep, stony soils that have a silty subsoil and overlie Diabase; but partly moderately deep, nearly level, non-stony soils that overlie shale or siltstone. This

[4] "General Soil Map", Hunterdon County, New Jersey, prepared by the USDA Soil Conservation Service, 1973.
[5] "General Soil Map", Mercer County, New Jersey, prepared by the USDA Soil Conservation Service, 1970.

association is located atop the Diabase along the northern border of the Township with Hunterdon County.

Quakertown-Chalfont-Doylestown Association: Moderately deep to deep, well-drained to poorly drained, nearly level to moderately steep soils that have a silty subsoil; mainly over sandstone and argillite but partly over red shale and siltstone. This association is located on the north and south flanks of the Sourland ridge.

Bucks-Penn-Readington Association: Moderately deep and shallow, well-drained and moderately well drained, gently undulating or gently sloping soils that have a silty sub-soil; over red shale or siltstone. This association is found between Baldpate Mountain and the border of the Township with Hunterdon County.

Soil Characteristics

Agricultural Suitability

As discussed in the section of this Natural Resource Inventory detailing the land use/land cover, roughly 30% of the study area is devoted to active agricultural land uses. This is not surprising given the fact that the region is characterized by soils uniquely suited to agricultural production.

The predominance of highly capable agricultural soils throughout the study area 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 study area.

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 comprise 20.3% (11,236.3 acres) of the study area. While most are located in Hopewell Township, there are additional pockets of prime soils in all of the municipalities sharing the region (see Figure 10). Statewide important soils make up the majority (38.4 % or 21,207.1 acres) of agriculturally productive soils in the region and have just 153 less acres than soils not classified as agriculturally productive, which represent 38.7% of the study area (21,360.5 acres). While most of the prime agricultural soils are located closer to the Amwell and Hopewell valleys, the statewide important soils of the study area are primarily concentrated adjacent to the Sourland Ridge. The baking of the shale which resulted from the intruding Diabase and weathering of both the Passaic and Lockatong formations produced large areas of soils suitable for agricultural production. Farmland of local importance makes up a mere 2.6% (1,429.9 acres) of the study area. They are interspersed and adjacent to areas of prime and statewide important soils.

On-Site Disposal of Effluent

With the adoption of *N.J.A.C.* 7:9A "Standards for Individual Subsurface Sewage Disposal Systems" in 1999, the New Jersey Department of Environmental Protection (NJDEP) revised their methods for classifying soils based on 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 standards specify the types of limiting zones that may be present and the type of system to be used, if any. Figure 11 shows the soils of study area 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 5 – 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 0-5	I IISc	C, (SRB, SRE, M, MSR) SRE, M, (MSR)
Massive Rock Hydraulically Restrictive Substratum	>9 4-9 <4	I IISr IIISr	C, (SRB, SRE, M, MSR) M, (MSR) UNSUITABLE
Hydraulically Restrictive Horizon, Permeable Substratum	>9 4-9 <4	I IIHr IIIHr	C, (SRB, SRE, M, MSR) SRB, SRE, M, (MSR) SRB, SRE, (MSR)
Excessively Coarse Horizon	>5 0-5	I IIHc	C, (SRB, SRE, M, MSR) SRE, M, (MSR)
Zone of Saturation, Regional	>5 2-5 <5	I IIWr IIIWr	C, (SRB, SRE, M, MSR) M, (MSR) UNSUITABLE
Zone of Saturation, Perched	>5 2-5 <5	I IIWp IIIWp	C, (SRB, SRE, M, MSR) C[4], (SRB, SRE, M, MSR) 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 certain soils with limiting zones that are unsuitable for any type of septic system installation. A number of these soil types are present in the study area and are mapped in Figure 12. According to *N.J.A.C* 7:9A approximately 46.2% (25,495.9 acres) of the study area could have soils unsuitable for any type of septic system installation. These generally coincide with soils underlain by the baked margins of the Passaic formation. Interestingly, none of these soils types are immediately underlain by the Diabase itself.

Depth to Bedrock

Depth to bedrock is one factor which affects a soils' ability to process septic effluent via a septic system. Generally the shallower the depth to bedrock, the less soil is present to properly treat human waste. Excluding mounded systems, a four foot zone of treatment is required to propertly treat septic effluent.

Figure 13 depicts the depth to bedrock for soils in the study area, as classified in the SSURGO database from the USDA NRCS (see table in Appendix 1 for SSURGO Soil Characteristics). The majority (68%) of soils in the region have a depth to bedrock between 40 and 60 inches, while 18% have depths 40 inches or less and the remainder (14%) have depths to bedrock 48 to 99 inches and 60 inches and greater. Many of the categorizations in the SSURGO database exhibit great variety, where the range presented could be part of another range based on site specific investigation.

Depth to bedrock for soils along the Sourland ridge itself is generally 48 to 60 inches and 48 to 99 inches. This is characteristic of soils underlain by Diabase. The soils which immediately straddle the ridge, corresponding to those underlain by the baked margins of the Passaic formation, have depths to bedrock of at least 40 inches, with pockets of soils exhibiting ranges from 20 to 40 inches. Many of the soils on the fringe of the study area have depth to bedrock ranging from 20 to 40 inches, with the majority of soils with shallow depths to bedrock underlain by the Passaic formation.

Depth to Seasonal High Water

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 leach 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.

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 are good indicators 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.

Figure 14 depicts depth to seasonal high water for the soils in the study area (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 study area. Of the soils with depth to seasonal high water of 4 feet or less, 10.6% (5,858.4 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 flanks of the Sourland Mountain. These soil types represent 48.5% (26,774.3 acres) of the soils in the study area with depths to seasonal high water of 4 feet or less. The majority of soils with a perched water table exhibit standing water above the hydraulically restrictive zone from November until March.

Of the soils in the study area, the majority (67.6%) have generally shallow depths to seasonal high water, ranging from 0 to 3 feet. Of these soils, only 36.6% exhibit depth to seasonal high water of 1.5 feet or less. Soil types with generally shallow depth to seasonal high water are almost exclusively located atop or on the flanks of the Sourland Mountain, along stream beds or in isolated pockets in Hopewell Township. There are, however, isolated pockets north of the Sourland ridge in East and West Amwell Townships. A number of 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.

A mere 0.2% (106.9 acres) of soils in the study area possess what could be characterized as moderate depth to seasonal high water, generally around 4 feet. These soils are primarily located north of Baldpate Mountain (on permanently preserved parkland), with small pockets east of Hopewell Borough and in the eastern part of the study area in Montgomery. 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.

The remainder of soils, comprising 32.2% of the study area (17,795.7 acres), exhibit generally deep depths to seasonal high water at 6 feet. These soil types are generally found along the north and south fringes of the study area. 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. None of the soils in the region are susceptible to erosion by wind. With respect to water, there are soils in the region rated for erodibility, as depicted in Figure 15 (see Table 11 in Appendix II for SSURGO Soil Characteristics). These soil types are discussed in detail below.

Of the soils in the study area, 25.7% (14,183.4 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 22 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 Birdsboro, Chalfont, Doylestown, Hazleton, Klinesville, Lawrenceville, Legore, Lehigh, Mount Lucas, Neshaminy, Penn, Quakertown, Readington and Reaville series. There are a number of soils designated as "Highly Erodible Lands", however, that are not located in areas of slopes greater than 15%.

Of the remaining soils in the region, 75% (15,588 acres) are categorized as "Potentially Highly Erodible". While these soils do not have the component of slope that "Highly Erodible Lands" do, they 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 study area and are scattered throughout region. Only 4.9% (2,702.3 acres) are classified as "Not Highly Erodible", comprised of the Birdsboro, Bowmanville, Bucks, Penn, Pope, Rowland and Tioga series primarily located along the banks of streams and rivers.

Soils in the "Highly Erodible Lands" class require careful management in farming, logging 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. In order to address concerns of farming on highly erodible lands, mitigation in the form of conservation plans and conservation systems can be implemented. 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. This is especially important atop the Sourland Mountain, where all streams are headwater streams.

Surface Waters and Subwatersheds

The Stony Brook is the principal surface water body in Sourland region, ultimately receiving drainage from 22.5% of the land within the study area. Table 5 lists the streams and rivers of study area with their length, as well as the percentage of total stream length in the region they represent; surface waters, including lakes, are depicted on Figure 16.

Table 6 – Streams and Rivers

Stream or River Name	Designated C-1	Nominated C-1	Length (miles)	%
Alexauken Creek	Yes	N/A	13.9	10.4
Back Brook	No	Public	11.4	8.5
Baldwins Creek	No	Public	3.3	2.5
Bedens Brook	No	NJDEP, Public	7.3	5.5
Cat Tail Brook	No	Public	1.5	1.1
Cruser Brook	No	Public	1.2	0.9
D&R Canal	No	Public	2.1	1.6
Fiddler's Creek	No	NJDEP, Public	0.7	0.5
Jacob's Creek	No	NJDEP, Public	5.0	3.7
Moore Creek	No	NJDEP, Public	19.9	14.9
Neshanic River	No	Public	15.3	11.5
Peter's Brook	No	Public	2.0	1.5
Pleasant Run	No	Public	1.9	1.4
Roaring Brook	No	Public	2.0	1.5
Rock Brook	No	Public	10.7	8.0
Royce Brook	No	NJDEP, Public	0.2	0.1
Stony Brook	No	NJDEP, Public	27.9	20.9
Swan Creek	No	NJDEP, Public	5.6	4.2
Woodsville Brook	No	Public	1.7	1.3
Total			**133.6**	

Surface waters can be categorized by their order. Surface waters of first order are considered headwaters, the origin of all other surface waters of higher order. Of the surface waters in the region, 67% (89.5 miles) are first order. The vast majority of these surface waters originate on the Sourland Mountain, making it a significant headwaters region. Of the remaining surface water courses, 21.2% (28.3 miles) are second order, 9.7% (13 miles) are third order and 2.1% (2.8 miles) are fourth order waterways. Protection of lower order surface waters assumes increasing importance as downstream waters become degraded.

Figure 17 depicts subwatersheds of the study area, all draining to two main watersheds, the Delaware River and the Raritan River. The major drainage basins divide the region with roughly 1/3 draining to the Delaware and 2/3 draining to the Raritan. The Sourland ridge again divides these two major drainage areas, with the streams on the north side of the ridge draining mostly east and west then flowing north off the mountain and the streams on the south draining mostly east and west then flowing south off the mountain. Some of the watercourses simply drain due south, north, east or west with no other patterns evident. For the most part, streams of the subwatersheds exhibit dendritic (branching and treelike) patterns, with the exception of the Stony Brook, which can be best described as a hybrid between a trellis
and dendritic drainage pattern. A number of the first order tributaries flow into the main stem as right angles, characteristic of a trellis pattern. The subwatersheds are smaller drainage basins within larger hydrological units. Water quality impacts are often easier to track in subwatersheds, especially those related to nonpoint 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 22 HUC 14 (Hydrologic Unit Code) drainage areas within the study area that are part of the Delaware River drainage basin and 15 within the Raritan River Basin. Table 7 lists the HUC 14's within the study area, the watercourses within them and the HUC14 acreage.

Table 7 – HUC14 Subwatersheds

Subwatershed Name	Hydrologic Unit Code (HUC)	Area (Acres)	%
Back Brook (Raritan)	02030105030050	3,590.0	6.5
Neshanic River(Raritan)	02030105030060	5,421.3	9.8
Pleasant Run(Raritan)	02030105040010	765.4	1.4
Stony Brook(Raritan)	02030105090010	3,561.4	6.4
Stony Brook(Raritan)	02030105090020	6,174.2	11.2
Stony Brook(Raritan)	02030105090030	2,684.1	4.9
Baldwins Creek(Raritan)	02030105090040	1,265.9	2.3
Stony Brook(Raritan)	02030105090050	9.2	0.0
Beden Brook(Raritan)	02030105110040	3,880.8	7.0
Beden Brook(Raritan)	02030105110050	376.6	0.7
Rock Brook(Raritan)	02030105110060	3,875.7	7.0
Back Brook(Raritan)	02030105110070	490.4	3.2
Rock Brook(Raritan)	02030105110070	1,266.8	2.3
Pike Run(Raritan)	02030105110080	821.0	1.5
Cruser Brook(Raritan)	02030105110090	1,833.7	3.3
Back Brook(Raritan)	02030105110100	957.6	1.7
Royce Brook(Raritan)	02030105110150	328.8	0.6
Alexauken Creek(Delaware)	02030105110010	4,021.6	7.3
Alexauken Creek(Delaware)	02030105110020	1,042.6	1.9
D&R Canal(Delaware)	02030105110030	912.8	6.0
Swan Creek(Delaware)	02030105110030	2,404.7	4.4
Moore Creek(Delaware)	02030105110040	6,537.5	11.8
Fiddler's Creek(Delaware)	02030105110050	1,155.6	2.1
Jacob's Creek(Delaware)	02030105110060	1,856.0	3.4
Total		**55,233.7**	

Surface Water Quality

Preserving and enhancing surface water quality is of great importance for preserving the environmental health of water bodies as well as the scenic and recreational opportunities that the region'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 the study area are currently 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).*[iii] 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 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."* [iv]

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)."* [v]

According to NJDEP, with the exception of Alexauken Creek, all surface waters within the study area 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; all surface waters of the Sourland Mountain region are classified as non-trout waters with the exception of Alexauken Creek, Moore Creek and Fiddler's Creek, which are classified as trout maintenance waters. Trout production waters are those that are home to breeding populations of native trout while trout maintenance waters are those that are home to native populations of trout, although trout do not breed there.

With the exception of Alexauken Creek, none of the surface waters within the study area are currently afforded the protection of Category 1 designation. NJDEP is proposing, however, to reclassify certain waters within the State, some of which are within the study area (see Table 6). 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 Fiddler's Creek, Jacob's Creek, Moore Creek, Swan Creek, Beden Brook, Royce Brook and Stony Brook. The NJDEP also solicited nominations for reclassification to Category 1 designation from the public and other agencies.

The Surface Water Quality Standards adopted by NJDEP in 2003 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 15 stations located within or in close proximity to the study area.

NJDEP's AMNET monitoring program focuses on populations of macroinvertebrates (invertebrates which can be seen without the aid of a hand lens or microscope) 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 fifteen monitoring stations for waterways in the

Sourland region, providing data from 1993-1994 and 1998-1999. Figure 18 depicts the location of these monitoring stations, with two along Alexauken Creek, two along Stony Brook, two along Moore Creek, one along Jacob's Creek, two along Rock Brook, one along Beden Brook, two along Alexauken Creek, one along Swan Creek, two along Back Brook and one along the Neshanic River. This distribution of locations, along virtually every waterway in the region, 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 study area shows that for the 1998-1999 monitoring round, seven of the fifteen sites depicted on Figure 18 had non-impaired benthic communities. This is an improvement over the six non-impaired communities identified when the first round of sampling was completed in 1993. Seven of the remaining sites showed moderate impairment, with ratings ranging from 12 to 18.

A number of sites showed improvement over the first round of sampling. This included one site along the Back Brook, (AN0334), a site along the Neshanic (Furman's Brook – AN0336) a site along Rock Brook (AN0399), a site along Beden Brook (AN0398), a site along Jacob's Creek and a site along Moore Creek (AN0101). The sites at the Neshanic (Furman's Brook) and Moore Creek improved to such a degree that their rating was changed to indicate no impairment. But along with improvement at a number of stations, some stations showed a decline. Station AN0390 along the Stony Brook declined from a rating of 24 to a rating of 15, showing moderate impairment in the second round of monitoring. Station AN0100 along Moore Creek declined from a rating of 27 to a rating of 24 but maintained a no impairment rating. Station AN 0099 along Swan Creek declined from a rating of 21 to a rating of 18, continuing to show moderate signs of impairment. The data for each AMNET site in the region is indicated in the table on the following page.

Table 8 – AMNET Biological Monitoring Sites

Site #	Water Course	1992 Score	1992 Rating	1998 Score	1998 Rating	Habitat Score
AN0097	Alexauken Ck	24	NONE	24	NONE	999
AN0096	Alexauken Ck	27	NONE	27	NONE	999
AN0098	Alexauken Ck	30	NONE	30	NONE	999
AN0334	Back Bk	15	MODERATE	18	MODERATE	120
AN0335	Back Bk	21	MODERATE	12	MODERATE	118
AN0336	Furmans Bk	18	MODERATE	27	NONE	161
AN0390	Stony Bk	24	NONE	15	MODERATE	157
AN0399	Rock Bk	12	MODERATE	18	MODERATE	161
AN0400	Rock Bk	21	MODERATE	99	NOSAMPLE	999
AN0398	Bedens Bk	15	MODERATE	21	MODERATE	126
AN0100	Moores Ck	27	NONE	24	NONE	999
AN0101	Moores Ck	18	MODERATE	27	NONE	999
AN0099	Swan Ck	21	MODERATE	18	MODERATE	999
AN0102	Jacobs Ck	24	NONE	27	NONE	999
AN0391	Stony Bk	12	MODERATE	12	MODERATE	135

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 the region. Of the 15 sites in the region, 8 were not rated for habitat. Of the 7 sites remaining, the Neshanic (Furman's Brook), Stony Brook and Rock Brook sites all scored in the optimal habitat range (160-200) while the Back Brook, Beden Brook and one Stony Brook site scored in the range of sub-optimal habitat (110-159).

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 in 2004 and 2005, determining the health of surface waters through comparative assessment of macroinvertebrate communities can continue. Once this data is released from the NJDEP, further changes in water quality should be assessed and the communities sharing the region should 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. With the NJDEP's proposal to reclassify a majority of the surface waters in the Sourland region as Category 1, the special resource area requirements would be implemented. This will no doubt makes strides to improving surface water quality as buffers are created.

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 19 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 19 indicates that 7,068.7 acres of wetlands exist in study area. The predominant wetland type is deciduous wooded, comprising just over 83% of the total acreage of wetlands at 5,879.7 acres. While a number of these wooded wetland areas are located along stream corridors, a large expanse is present along the Sourland ridge. Deciduous scrub/shrub and herbaceous wetlands (aggregated as "wetlands") represent the second largest type of wetland, comprising 8% (568.3 acres) of all wetland areas. 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. Both of these wetland types are primarily located along water courses, but are present along the fringes of larger areas of deciduous wooded wetlands spread across the study area.

Agricultural wetlands represent 5.5% (388.4 acres) of those in the region. 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 Sourland Mountain region, but are mainly focused on the flanks of the ridge itself.

Mixed wooded (2.3% or 161.2 acres) and coniferous wooded (0.1% or 4.72 acres) comprise the remaining wetland areas found in the Sourland Mountain region. Mixed wooded wetlands are found atop the Sourland ridge, along the flanks of the ridge and on the fringe of the study area. The majority is in one location at the fringe of the study area southeast of Hopewell Borough in Hopewell Township. The lone patch of coniferous wooded wetland in the study area is located north of Hopewell-Amwell Road, northeast of Hopewell Borough.

Six general wetland types are identified in Figure 19 and listed in Table 9 below.

Table 9 – Wetland Types

Type	Acres	Percentage
Agricultural Wetlands	388.35	5.5
Coniferous Wooded Wetlands	4.72	0.1
Deciduous Wooded Wetlands	5,879.73	83.2
Disturbed Wetlands	66.34	0.9
Mixed Wooded Wetlands	161.24	2.3
Wetlands	568.32	8.0
Total	**7,068.7**	

A majority of the wetlands found in the region are designated as Palustrine and can be described as marshy, boggy or swampy. Types of Palustrine wetlands 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 nonpoint source pollutants.

Wetlands play a particularly valuable role on the Sourland Mountain, acting as headwaters to all of the water courses in the study area. As none of the streams which flow off the mountain are classified as trout-producing or trout maintenance, many of the wetlands in this area are not classified as being exceptional in value. There are, however, wetlands classified as exceptional due to the presence of threatened or endangered species. 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 some protection to 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 these State protections. More and more, the importance of wetlands in flood control and water quality is becoming known.

<u>Floodplains</u>

The Federal Emergency Management Agency (FEMA) has prepared maps of the 100-year floodplain found along a number of the streams and rivers in the study area, as taken from the Q3 Flood Digital database and depicted on Figure 20. 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.

All five communities in the study area participate in the National Flood Insurance Program (NFIP), whereby they have adopted standards regarding development in the floodplain. A Flood Hazard Study initiated each community's participation in the Program; all have 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) 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 FIRM mapping of the 100-year floodplain is an essential resource that identifies the hazard of flood associated with areas in the region. There are a number of areas not depicted as floodplain which flood on a regular basis, pointing to the need for creation of more complete and accurate flood data. The extent of the 100-year flood plain imposes severe limitations on development and sound policy is to prohibit development throughout these mapped areas, as the Townships in the study area generally try to do.

Riparian Areas

The health of surface waters within the study area 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 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. At the same time, this position makes them most vulnerable, subject to a combination of effects which can be related directly to anthropogenic activities.

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 vigorous 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 region, where water quality will continue to decline if riparian areas are not better protected. Figure 21 depicts riparian areas for the Sourland Mountain region, comprised of streams and a 150' foot buffer, wetlands and slopes greater than 15% which are adjacent and drain to stream corridors. A 150' buffer was utilized as it is the minimum buffer permitted by the NJDEP for Category One surface waters. Forested areas are depicted on Figure 21 to indicate where the potential exists to extend riparian protection into non-wetland areas. Protection of portions of these adjacent forested areas will only further enhance water quality and stream health.

Also depicted in Figure 21 are AMNET monitoring locations where impairment of benthic communities has increased since 1993 (refer to table on Page 41 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 nonpoint 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 nonpoint pollution, often washed directly into the stream from the bridge deck.

New Jersey's recently adopted stormwater management regulations 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 nonpoint source pollution and eroded sediment into waterways. The former regulations focused on moving stormwater runoff efficiently into surface waters. The newly adopted regulations will implement a vegetative buffer for Category 1 waters which will offer filtration of run-off, reducing nonpoint source pollutants and sediment reaching streams. As noted previously, a majority of the surface waters in the study area have been nominated by 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 great distances.

Steep Slopes and Topography

The study area is characterized by two general landforms; gently sloping expanses in the lower elevations, and the higher elevation areas of the prominent Sourland Mountain ridge and plateau. Figure 22, which depicts the topography of the study area, was derived from a digital elevation model and "hillshaded" to add depth to the visualization. The Sourland Mountain ridge has its highest elevation around 567'.

The Sourland Mountain is best described as more of a hill or ridge than a mountain, a minor bump as you progress north through the state to the more dramatic topographic features of the New Jersey Highlands and the Ridge and Valley. The ridge or peak of the Sourland Mountain is more a flat plateau, a broad expanse of relatively homogenous composition that extends for more than 3 miles in places. Many of the areas where water courses flow off the mountain create dramatic topographic features, as is the case with Swan Creek, Rock Brook, Roaring Brook, Stony Brook and Moore Creek, where the erosive force of water has carved ravine-like elements into the landscape. There are also the less dramatic features of Baldpate Mountain, Pennington Mountain, Pheasant Ridge and the Princeton Ridge, which begins just south of Hopewell Borough and stretches southeast to Princeton Township.

Steep slopes, depicted on Figure 23, 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 of the landscape. The most extensive areas of steep slope are found along the eastern face of the Sourland Mountain in Montgomery and Hillsborough Townships, around Baldpate Mountain, Pennington Mountain and Pheasant Hill in Hopewell Township and in limited areas on the north facing slope of the mountain. Aside from these areas, the remainder of steep slopes is located along stream corridors. The most dramatic surround Alexauken Creek, Moore Creek and Swan Creek.

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 and 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 of the region 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 the study area.

Figure 24 depicts the ridgelines in the study area, delineated based on the above definition. Utilizing the NJDEP's 10 meter digital elevation model, contour information and three-dimensional visualizations of terrain, ridgelines were delineated manually. The most prominent ridgelines in the region are associated with the Sourland Mountain ridge, Baldpate Mountain, Pennington Mountain and Pheasant Hill. The majority of ridgelines in the study area run parallel to each other. There are a number of other minor ridgelines throughout the study area, as depicted on Figure 24.

Development of ridgelines can have major impacts on visual resources as many times, forested ridgelines are cleared to make way for homes.. From an individual perspective they represent desirable locations for residential home sites, taking advantage of views to the surrounding landscape. From a community perspective, ridgelines are desirable places to protect. 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.

Animals, Plants and Habitats of the Sourland Region

New Jersey is endowed with a remarkable wealth of biological diversity. Its coastal location in temperate latitude, its diverse topographical elements with their unique ecological attributes and its position along a major bird migration corridor provide for an abundant array of plant and animal species. The Sourland Mountain region hosts an ample share of this rich natural heritage. Its extensive forest and rural landscape provide the greatest block of intact habitat in the state's Piedmont province, which stretches diagonally across the middle of the state at the interface of northern and southern ecosystem types.

Protective stewardship of New Jersey's cherished natural heritage presents extraordinary challenges. Habitat—the place where a species finds shelter, sustenance and a place to reproduce and perpetuate its kind—continues to be lost to development despite aggressive public and private efforts to preserve it. Over the last few decades, there has been an astonishingly rapid consumption of habitat in central New Jersey; Land Use/Land Cover maps spanning nearly thirty years reveal that the integrity of habitat in the Sourlands region is in jeopardy.

This section provides an overview of the habitats of the Sourlands and how the requirements of animals and plants that occupy the region are met by those diverse habitats. Review of the available biological data and of pertinent scientific literature highlights a number of attributes that make the Sourland Mountain Region biologically unique and precious.

- The Sourland Mountain region is one of only three major areas of unbroken habitat in New Jersey and is a critical location mid-way between the Highlands and the Pinelands.
- The Sourland Mountain region contains a variety of habitat types of high quality and of substantial size, ranging from grassland to mature woodland and including a continuum of successional stages which support a rich diversity of biotic communities. The Nature Conservancy identified 7,737 acres of core forest within their 28,860-acre Sourland Mountain Matrix Block; the New Jersey Landscape Project identifies 24,582.14 acres of critical habitat.
- The Sourland Mountain region includes the largest contiguous forest in central New Jersey.
- Nearby land use patterns, combined with the size, shape and composition of the forest contribute to the high quality of Sourlands woodland habitat, especially for forest interior nesting birds.
- The Sourland Mountain region is a critical stopover point for migrating birds using the Atlantic Flyway and is one of New Jersey's top fall migration stopover sites. Protection of high-quality stopover sites is as necessary for long-distance migrants as their breeding and over-wintering habitats.
- The Sourland Mountain region supports a great diversity of bird species, many of which are listed as either threatened or endangered, or are being tracked as species of special concern.
- Vernal pools—isolated wetland depressions that are seasonally filled with water—are common in parts of the Sourlands. Some of these are known breeding sites for a number of herptiles who require these pools for egg laying and early life stages.
- The Sourland Mountain region may be the last refuge of some of the complex plant communities that once flourished in central New Jersey. Sixteen plant species that are either endangered or of special concern in New Jersey have been documented in the Sourlands to date.

The Sourland Mountain region is an ecological island in central New Jersey. Nowhere else in the state's rapidly developing mid-section can one find such a vast swath of unbroken habitat. Unique geological and hydrological features of the Sourlands have presented challenges to human encroachment and opportunities for animals and plants. The forest that covers the ridge and slopes has been largely untouched for many years. Past and present agricultural activity on the more hospitable lower flanks and foothills has created a continuum of habitat types ranging from grasslands and meadows, to shrub-scrub or old fields, to early successional woodland. Freely flowing water courses originating on the mountain and its foothills provide riparian and aquatic habitat. The perched water table supplies an ephemeral yet critical habitat for a number of specialized organisms. This suite of habitat types combine with the geology and contours of the land, its soils and hydrology and even with the aspect of the ridge to create an environment uniquely suited to sustain an incredibly diverse array of plants and animals. Loss of or impact to any of these resources will have a direct effect on many of these species and the overall biodiversity of the area. Although anthropogenic, or manmade, activities have the most impact, natural forces can prolong and often enhance the effect that humans initiate through development.

The very traits that render the Sourlands an island of biodiversity also make the area a desirable, if challenging, place for human habitation. The forested slopes and bucolic valleys are tempting to those who seek a rural setting for a new home. It is not unusual to see real estate ads with statements such as, "…nestled in the Sourland Mountains." Residential development, egged on by commercial development along the Route 1 and I-95 corridors, is pressing in and already threatens the lower flanks of Sourland Mountain itself. Long held at bay by lack of public utilities, scarce groundwater, and soil percolation too poor to support septic systems, newer technology and importation of drinking water can open the doors for development of what had been a virtually pristine environment.

But to the exhausted migrating bird nearing the end of a 3,000-mile journey from South America, the Sourlands are not just a coveted piece of real estate. To one who has just traversed a good part of the northeast corridor, with its cities, industrial and commercial parks, and endless suburban tracts and who has perhaps touched down briefly in the Pinelands, the Sourlands are a critical oasis in an impervious desert. To a scarlet tanager, for instance, this may be its destination—a suitable place to call for its mate and make a home. To a bay-breasted warbler, it is a refueling stopover, where it feeds on the tiny caterpillars that emerge on the oaks and tulip poplars to build up fat stores for a few days before continuing its long northward flight.

The Sourland Mountain region is a reservoir of biodiversity. Not only does it provide prime habitat and a critical migration stopover site but, because it supports larger populations of many organisms, it can serve as a source of genetic diversity for other populations of the same species that utilize smaller habitat patches nearby.

Appendices 4 through 7 contain lists of birds, mammals, reptiles and amphibians, insects and plants assembled in the course of several biological surveys. The existing species lists are not a complete inventory of the flora and fauna of the Sourlands but, rather, are representative of the abundance and diversity of the biota of the region. In addition to the species whose presence has been documented, The Nature Conservancy has identified numerous species that could be expected to be present in the region based on the extent and quality of habitat. Data on the ecological importance of the Sourland region will continue to become available as more scientists and volunteer naturalists focus their attention on identifying the resource factors that make the area unique.

Habitat Diversity and Quality in the Sourlands

At the time of first human settlement, the vegetation covering the Sourland region was most likely a fairly homogeneous deciduous forest. Native Americans in the area practiced limited agriculture and field rotation, creating openings in the vast forest canopy which invited some non-forest dwelling creatures to occupy the land and eventually led to some isolated patches of successional growth as fields were abandoned. Beginning in the mid- 17th century, European settlers and their descendants brought with them more intensive agriculture, including opening up large segments of the forest in the valleys and on the lower flanks of the mountain for villages, pastureland and row crops. Trees were harvested from woodlots on the higher elevations. In time, the face of agriculture in the region changed and fields were abandoned, either because of changing demographics or because the type of farming eventually proved unsuited to the region. Over the course of several decades, fallow fields underwent a series of predictable and relatively rapid changes in the composition of their vegetation, a process known as ecological succession. Meanwhile, new areas were cleared to make way for new farms. Such land use changes that have occurred irregularly over the past hundred years or so have led to the current patchwork of habitats in various stages of succession, ranging from active farmland to nearly-mature woodland, mostly along the lower flanks and in the foothills. The mature forest that now covers the ridge is secondary growth that replaced the virgin old-growth forest that was logged many years ago. This pattern gives an historical record of the use and disuse of the fields and provides a wide range of habitat types that support a remarkable diversity of animals and plants.

Land use/land cover mapping clearly shows the extent of the Sourlands forest, the most dramatic feature of the region; it also reveals how development intruded upon this habitat block between 1972 and 1995. The effects of human activity are not always immediately evident from the air or the ground. To the layperson, it may appear that a small opening in the forest canopy to accommodate a house would have little effect on the large contiguous forest, as there is so much of it covering the area. The area disturbed might not even create a gap in the canopy. But each time the forest is disturbed, even in small patches, the impact can stretch for up to 1,000 feet in all directions (Flaspohler, Temple and Rosenfield, 1999.) The hotspots created by clearing result in the edge effect, where the integrity of habitat is diminished in a gradient. Even though relatively large lots are required as a minimum in the region, the separation they create between dwellings does not mitigate the effects of forest clearing and removal of the understory. And the fact is that many of the species that live in or make use of the Sourland region rely on both the quantity and the quality of the forest and understory; as it becomes degraded and disappears, so will these species.

The Nature Conservancy (TNC) identified 7,737 acres of core acreage in their 28,860-acre Sourland Mountain Matrix Block, the region east of Route 31 and north of Route 518. TNC included as core forest only that acreage not fragmented by any break in the forest canopy equal to or greater than 10 meters in width. Linear corridors, including roads, utility rights-of-way and hiking trails are major contributors to fragmentation effects in forest matrix blocks. Disturbances include habitat edge effects, pollution, collisions, visual stimuli and noise and vary depending on the type of corridor. Based on extensive review of scientific literature, TNC has assigned buffer width values ranging from 0 to 500 meters, depending on the degree of disturbance generated. Primary roads are considered to influence forest habitat to a depth of 500 meters, local roads 100 meters. Hiking trails less than 10 meters wide are not considered a canopy break of sufficient width to have a negative impact. The buffers are not included in the core forest acreage. What remains is considered forest habitat that is capable of supporting the complete suite of forest interior species appropriate for the region. Along with other forest patches that are not included as core forest, the Sourland Mountain Matrix Block also contains significant grasslands in the form of hay pasture, covering 27% of the matrix block. Only 5% of the matrix block is developed cover. TNC also identified 55 total stream miles in the block. These estimates do not include the parts of the Sourland Mountain region west of Route 31; nor do they include Alexauken Creek, which was designated a Category 1 stream in July of 2004. The New Jersey Landscape Project identifies 24,582 acres in the Sourlands either as known habitat of species that are either endangered, threatened or of special concern, or as suitable habitat for such species.

Sourlands Birds

Among the many animals in the Sourland region, of particular interest is the richness of bird species, both resident and migrant, for whom the complex of grasslands, old fields, shrublands and mature forest offer an exceptional opportunity to either make their home or refuel for continued migration. This incredible avian diversity can be directly linked to the broad spectrum of high quality habitats. One study undertaken in the region supports the theory that the wide range of habitats and their juxtaposition is what makes the Sourland region unique in its ability to support a rich variety of both resident and migrant birds (Suthers, 1988.) While conducting a long term study of the succession of old hayfields adjacent to a variety of wooded areas (wet woods, early successional and climax woods), Suthers found that as succession progresses in fields abandoned at different points in time, habitat becomes more diverse, supporting a greater variety of birds. Altogether in this particular study, 51 species of stopover migrants and 70 species of resident and breeding birds were noted.

Bird Migration in the Sourlands

Birds can be classified as either permanent residents or migrants, with short-distance migrants wintering in the continental United States and long-distance migrants wintering in Central and South America. This classification can further be broken down into passage migrants and locally breeding species. Passage migrants are those whose breeding grounds are in the northern tier of states or Canada. Most migratory birds arrive in central New Jersey between mid-April and late May, with the peak occurring around the second week in May. The mixed oak forests of the Sourlands are a favorite stopover for passage migrants such as Cape May warbler and Blackburnian warbler, who will stay only briefly to gorge themselves on the caterpillars that favor this type of woodland. Many of the breeding migrants, such as wood thrush and red-eyed vireo settle in at the same time. The Neotropical, or long-distance, migrants are the group most severely affected in recent decades by human manipulation of the environment. As development has continued and habitat has been converted to other land uses in both the United States and Central and South America, the numbers of long-distance migrants has severely declined locally (Floyd, 1990) and regionally (Terborgh, 1989.)

New Jersey Audubon Society in *New Jersey at the Crossroads of Migration* identifies the Sourlands as one of the key portions of New Jersey that have been designated Migratory Bird

Corridors. The Sourland Mountain is located on the New Jersey Piedmont physiographic region, which presents a smooth transition between the relatively low and flat coastal plain and the highest elevations and ridges of the New Jersey Highlands. It is situated midway between the Pinelands and the Highlands and provides a critical stopover point for migrating species using the Atlantic Flyway, which generally extends from the western coast of Greenland south along the eastern coast of Canada and the United States. Studies undertaken by the New Jersey Audubon Society in fall of 2001 using NEXRAD Radar showed that the Sourland region had a frequency of stopover use between 21 and 26 days, the highest range possible. No other area outside the Pinelands exhibited so high a frequency. And, although the bird density for the entire season was not as great as in the Pinelands, the frequency of stopover use was as great (New Jersey Audubon, 2001.) New Jersey Audubon identifies the fact that suitability of an area for use as a stopover site is solely related to the quality of available habitat that is present. Stopover migrants require a place that provides shelter and fuel. If those requirements are not met, then the utility of an area diminishes. A study published by Suthers, Bickal and Rodewald in June 2000 shows that use of particular habitat types, in this case open shrubland during fall migration, depended largely on the availability of fruit. As high quality fruit supplies begin to diminish, so does the appearance of certain species of birds.

In their Issue Paper, “Protecting Stopover Sites for Forest-Dwelling Migratory Landbirds,” The Nature Conservancy states that ideal migration stopover sites “provide fresh water, protection from predation, and food resources acquired easily enough that birds can survive and regain mass lost through catabolism during their travels.” They go on to list criteria for defining important stopover sites, including relative abundance of all or a subset of migrants; resource-rich sites where birds regain lost energy; and, spatial relationship to other sites (The Nature Conservancy, 2001.) Available species data shows that the Sourlands region meets these criteria. Maintaining the quantity and quality of habitat types is critical to continued use of the Sourland region as a stopover point for migratory birds, both spring and fall. New Jersey Audubon Society’s *New Jersey at the Crossroads of Migration* states, “Protect all of the breeding woodland in North America and all of the rain forest in Central and South America and tanagers will still decline *unless the habitat they need during migration is also preserved.”*

Breeding Birds of the Sourlands and Their Habitats

Birds can also be grouped based on the habitat type they require for breeding. Some are grassland specialists; others nest only in deep woodlands. Still others prefer the early successional stage known as shrub-scrub or savannah-like habitat while some build their nests in edge habitat—the margin where woodland meets a farm field, park, lawn or other non-forested opening. Even within habitat types some species need or prefer a certain minimum patch size. Land use adjacent to a habitat patch will also influence its suitability for usage by some sensitive species. While some bird species may be tolerant of human disturbance, or even thrive in its presence, most suffer negative impacts on breeding success because of it. The house wren is a familiar species that will readily build a nest and successfully raise a brood in a nest box at the edge of a patio and American robins flourish in landscaped suburban neighborhoods. But by and large, birds do not adapt well to perturbations in the environment and are rather rigid in their habitat requirements. They are genetically and behaviorally programmed to build their nests of the same materials in the same type of habitat at the same level relative to the ground as they have done over thousands of generations. There is even a tendency for offspring to return to their ancestral homes to seek out a territory when it is their turn to breed.

Habitat fragmentation is the condition that results when a once-contiguous habitat is disrupted and broken up into smaller remnants of different sizes and shapes interrupted by altered landscape. Birds are affected in all life stages by fragmentation. There has been considerable research into the reasons why the size of a habitat patch is critical to the breeding success of a species. Overall, Neotropical migratory birds seem to be most sensitive to habitat fragmentation. One reason seems to be that most of these species have only one brood per season, unlike short-distance migrants such as American robins who may have as many as three broods (Faaborg, 2002.) There also is a relationship between migration distance and mortality during the journey, especially for young birds on their first trip. Intra-species competition can be a factor; a breeding pair simply will not tolerate another of the same species in proximity to its own nesting territory. This territory varies widely among species. Inter-species competition, on the other hand, does not seem to be a consideration. Availability of preferred foods could be another determinant. But vulnerability of the eggs, nestlings and brooding parents to predators is probably the most important factor. Most long-distance migrants build open nests, while many short-distance migrants and permanent residents such as Eastern bluebirds nest in cavities. An open, cup type nest built on the ground by a black-and-white warbler carries more predation risk than a Baltimore oriole's pendulous nest hanging from the tip of a branch 20 feet from the ground at the edge of a small woodland. A house wren's nest in a tree cavity or nest box is safer still, thus their tolerance of activity on the patio.

The variety of habitat patches of substantial size within the Sourlands region supports a robust complex of avian populations. Most of the species that historically have bred in central New Jersey still breed successfully in the Sourlands even though they may have disappeared from other parts of the area. Among the 10 species with 30% or more of their statewide breeding range in the Piedmont, five are noted in the surveys referenced in this report: black-capped chickadee, bobolink, ring-necked pheasant (non-native species), rose-breasted grosbeak and warbling vireo. These are included among results of the New Jersey Breeding Bird Atlas published by New Jersey Audubon in their landmark book, *Birds of New Jersey*, which documents the distribution of all of the state's breeding birds.

<u>Mature Forest</u>

Among its many habitat types, the largely intact mature deciduous forest that resides in the Sourlands is arguably its most unique ecological treasure. The nearly 12,000 acres of predominantly mixed oak forest on Sourland Mountain and the large forest blocks west of Route 31 comprise the largest remaining contiguous woodlands in central New Jersey, the most significant remnant of the vast forest that once covered the state's Piedmont region. Other forest patches of sufficient size to support populations of interior woodland species are found to the west of Route 31 and on Baldpate Mountain. The primeval stands of trees were harvested long ago and some managed woodlots remain. But widespread timber harvest ceased well over a hundred years ago and the forest is at or near climax, the stage at which composition of the forest changes at a very slow rate compared to the earlier successional stages. Using a tree diameter calculation method, Dr. Henry Horn of Princeton University estimated that some trees in what he refers to as a “majestic tulip woods” on Baldpate Mountain are up to 120 years of age. Many ash, oak, hickory and beech trees were estimated to be from 60 to 75 years of age (Dr. Henry S. Horn, personal communication, 1990.) His method involved extrapolation based on a Princeton University B.A. thesis that plotted diameter versus growth rings of cored or previously sawn trees in the Sourland Mountain Preserve. That study tabulated some beech and tulip trees well over 150 years of age and several white oaks 200 or more years old (P.G. Newman, 1987.)

Despite a vigorous deer population in the area, itself a consequence of human impacts, a healthy understory of native shrubs and saplings is flourishing in many parts of the forest, accompanied by a varied herbaceous layer. This complex woodland structure is vital for many bird species, whether for breeding, migration stopover, or over-wintering. Browsing white-tailed deer can decimate this layer where they are numerous, but their populations tend to be less dense in deep woods than along edges.

It is the size, shape, composition and adjacent land use that make the relatively unfragmented forest of the Sourlands a haven for so many woodland birds. It is not just the acreage of a patch that makes it suitable habitat, but also its shape. A long and thin woodland may provide a wildlife corridor, but the entire piece may be exposed to edge effects, whereas the same acreage in a somewhat circular shape would contain an interior core free from those effects (Faaborg, 2002.) A comparative study of two forest patches, the Institute Woods in Princeton Township consisting of 155 hectares (383 acres) and Baldpate Mountain in Hopewell Township, consisting of 509 hectares (1,258 acres) showed that the larger of the properties supported a greater density of forest interior breeding birds. Using a transect census method, the study documented 198 pairs of forest interior breeding birds per 100 hectares on Baldpate versus 51 in the Institute Woods (Floyd, 1990.) In addition to the size of the habitat, there is good evidence that the landscape within which a forest patch is located affects the intensity of edge effects. Predation pressure varies according to the predators supported by the matrix surrounding the forest (Faaborg, 2002.)

Forest fragmentation due to development produces obstacles to breeding birds, particularly those that rely on interior forest habitat for breeding. As fragmentation occurs, more edge is created relative to forest interior. As the core becomes smaller, certain sensitive species will tend to cluster their territories in the area farthest from the edge. Patch size is critical for a number of species of forest interior nesting birds, which have been severely impacted in their breeding grounds by loss of forest mass and the ever-increasing creation of edge due to expanding development. But studies show that it is not forest size and edge, *per se*, that are causing the decline of these birds but rather factors associated with edge. In his book, *Where Have All the Birds Gone*, Dr. John Terborgh cites the Princeton University Ph.D. thesis work of David Wilcove. As part of this work, Dr. Wilcove found that forest interior birds bred right up to the edge of a large reservoir surrounded by forest. This research seems to imply that certain properties of edge, such as what is on the other side of the forest-field interface, are impacting the birds. A clue lies in the fact that many of these birds lay their eggs in open cup nests on or near the ground, making them vulnerable to predation. Cavity nesters and those who build their nests in high branches are less vulnerable to predation than ground nesters. Wilcove found that the most common nest predators are raccoon, opossum, striped skunk, dog, cat and blue jay. All of these are animals associated with human habitation and are more likely to prowl a forest edge than penetrate into the interior. Development has resulted in increased breeding success and population sizes of the predators that far exceed those found in pristine areas. In looking at forest patches of various sizes in several different settings, Wilcove found that nest predation rates in small suburban woodlots neared 100 percent as opposed to just 2 percent in a large national park. Predation rates were intermediate between these two patch size extremes.

Nest parasitism is another serious obstacle to breeding success created when forests are fragmented and edge is increased. Cowbirds, a known nest parasite common only in the Great Plains when the American colonies were first settled, are dramatically increasing in numbers in the east as the extent of edge habitat increases. Their frequency is greatly diminished in the forest interior as they rely primarily on short grass pastures for feeding and have a confined range (Faaborg, 2002.) These birds lay their eggs in the nests of other species, often smaller than themselves, who are then burdened with the task of raising these larger cowbird nestlings at the expense of their own. Some Neotropical species are being driven to near survival threshold levels by cowbird parasitism. It is thought that they used the nests of about 50 species before European settlement; they now use around 200, many of which lack an evolutionary tendency to recognize and remove the alien eggs from their nests (Terborgh 1989.) Studies referenced by Terborgh provide alarming statistics; one study found 37 cowbird eggs in 11 wood thrush nests and only 12 wood thrush eggs. 29 of 30 wood thrush nests had been parasitized.

Edge is suitable, even preferred habitat for birds that nest in trees but forage in fields, such as brown thrashers and eastern towhees. And the fact that birds are easier to spot at the edge of a woodland as they fly back and forth gathering food for their young may give the impression that bird life there is abundant. But the important fact is that certain species, because of the type of nest they build and its location, are losing ground as forests shrink in size and predators and parasitic birds gain access. It is important to note that edge effects that result from development are particularly harmful, as they usually cannot be reversed; edge effects from logging activities can be reversed and even avoided with appropriate management.

The forest patches on Sourland Mountain and Baldpate Mountain are of sufficient size and appropriate dimensions to minimize edge impacts on interior nesting Neotropical migratory birds. A 2004 study conducted on Baldpate as part of the Birds in Forested Landscapes Project of the Cornell Lab of Ornithology is reassuring. Data collected at two survey points within the core of the 1200+-acre forest in late May and early June noted no cowbirds were seen or heard. This same study did reveal the presence of several forest interior species, including hooded warbler, Kentucky warbler, Canada warbler, veery, wood thrush and yellow-billed cuckoo. This study employed a different method (point count) from Floyd’s 1990 breeding bird census (transect method) so direct comparison of numbers of pairs cannot be made. However, this data and other observations indicate that the Baldpate forest still hosts the same forest interior specialists as it did 14 years before.

Grasslands

Typically, grasslands in New Jersey other than marshes are agricultural fields, either maintained as pasture or mowed regularly for hay. There is some debate as to when grassland birds first occupied New Jersey and other eastern states that were mostly covered with a vast, contiguous forest before European settlement. Much of the state was, indeed, a savannah-like landscape in the immediate post-glacial (late Pleistocene) period. Fossilized skeletons of grassland birds from 14,000 to 20,000 years ago have been found (NJ Audubon Grassland Habitat Symposium, 2004.) It is likely that, as the forest filled in, grassland pockets were intermittently established by lightning initiated fires, the activity of beavers or severe flood events, leaving isolated relict populations of grassland birds. More pockets were created when Native Americans who first occupied the land cleared patches for small-scale agriculture.

In modern times, the woodlands of the lower flanks and foothills of the Sourlands region were cleared when the area was settled and farming was widespread. Grassland bird species readily took advantage of the fields, particularly those where warm season native grasses were flourishing. In time, these native grasses were replaced by the European species such as timothy, bluegrass and tall fescue, which were considered more productive in spite of the fact that they are less drought resistant and require more nutrients than the native clumping grasses such as bluestem, Indian grass and switch grass. These imported cool season grasses call for an early summer mowing regimen, which has proven detrimental to many grassland species. Habitat conservation must compete with a market preference for cool season grasses for feeding horses and livestock.

The grasslands that flank the Sourland ridge in the Amwell and Hopewell Valleys provide critical habitat to a number of bird species. Some of these species require an expansive viewspace—considerable distance from the forest edge and a low horizon—for nesting, which aids reproductive success by reducing the threat of predators that lurk at the edge (Mattice, 2004.) It is noteworthy that, in New Jersey, grassland species as a group are the most severely threatened birds when considered by habitat preference. More of our state's threatened and endangered bird species are grassland habitat specialists than any other habitat group—41% in all. Species surveys and anecdotal reports list bobolink, meadowlark, upland sandpiper, grasshopper sparrow and American kestrel among those seen in the Sourlands. These birds are declining because the meadows and hayfields they have used for nesting for generations are also prime land for housing subdivisions and corporate parks. Grasslands are being swallowed up at an incredible rate. Fortunately, hay and livestock farming continue to prosper in the Sourland region and some farms of sufficient size to support these sensitive species remain. Fields of at least 100 acres are best for maintaining populations of grassland birds. A large field may support several breeding pairs, averaging 10 acres per pair. However, a 10 or 20-acre field will support none (Maryland Partners in Flight, 1999.) At the same time, these farms present a habitat management challenge that will require education and economic incentive if the fields are to provide optimum breeding habitat. The preferred cool-season grasses typically are mowed in June. For the sake of birds that nest in the grasslands, it should not be cut before mid-July. For birds that raise a second brood, such as Eastern meadowlark, only a first mowing after mid-August would spare the second clutch of young. Several federal and state funding incentives are available for habitat preservation and enhancement for grassland species.

<u>Other Habitats in the Sourlands</u>

When cultivated fields are abandoned, secondary succession begins. Initially, forbs or flowering herbaceous plants will colonize a fallow field, providing nectar and pollen for butterflies and other insects. These creatures, in turn, provide food for some species of birds. In fall and winter, the seeds of the flowering plants provide food for southward-bound migrants and over-wintering birds. Prime examples of such fields were found at Alexauken Creek Wildlife Management Area.

Randomly scattered shrubs and young trees take hold in suitable microhabitats throughout a field that has been fallow for three years or more. In the Sourlands, among the first of these pioneers would be Eastern red cedar which provides choice shelter for nesting birds that breed in shrub-scrub habitat, as well as food for over-wintering birds. In time, other shrubs and vines join them to form small thickets. This is the favored habitat of bird species such as yellow warbler, field sparrow and American goldfinch.

Native hardwoods begin to shade and crowd out the earliest volunteers in a long-abandoned field. Trees typically are just a few inches in diameter and closely packed together. The last remnants of the earlier successional stage, including Eastern red cedar, panicled dogwood and gray birch may continue to survive. This stage has been thoroughly studied by Hannah Suthers at the Featherbed Lane Bird Banding Station and her data on birds in this and earlier successional stages are listed in Appendix 4.

Birds in Peril

The Sourlands region is providing essential habitat for a great diversity of bird species as shown in Appendix 4. Many of these are species who are listed as either threatened or endangered, or are being tracked because their numbers are on a steep downward trajectory. The avifauna consist of more species than any other vertebrate class. These species are incredibly diverse in their food and habitat requirements and most are very sensitive to environmental perturbations. What makes the Sourlands region so critical to avian diversity and abundance is that it consists of a variety of habitats of impressive size that, for various reasons, are relatively untrammeled by human disturbance. From the aerial perspective of a bird in flight, it is a welcome refuge and a place to call home.

Data collected so far indicates that a number of bird species in crisis are finding safe harbor in the Sourlands. Bird populations have been tracked for a number of years by federal and state agencies and conservation organizations. In New Jersey, the New Jersey Endangered and Nongame Species Program maintains listings of species of special concern. In addition to data collected by state biologists, documentation by skilled volunteer naturalists provides important tracking information. The New Jersey Natural Heritage Program database is a vital repository of information on sightings of threatened and endangered species. The New Jersey Breeding Bird Atlas research was conducted from 1993 through 1997 and published by New Jersey Audubon Society in the book *Birds of New Jersey* in 1999. Surveys were conducted on specific sites by volunteer organizations in the Sourlands in 1990, 1994 and 2003. Some parts of the Sourlands are included in annual Christmas Bird Counts. One citizen scientist has been compiling her own lists of breeding birds on Baldpate Mountain and in 2004 did so as part of the Cornell Lab of Ornithology's "Birds in Forested Landscapes" project. And birders often make note of special sightings that are not part of a particular project—anecdotal notations that round out the body of knowledge on birds of the Sourlands.

Currently available lists of birds found in the Sourlands indicate the region provides shelter and refuge to many bird species in peril, identified in three separate sources.

New Jersey Endangered and Nongame Species Program

According to New Jersey Endangered and Nongame Species Program status definitions, "Endangered" applies to a species whose prospects for survival within the state are in immediate danger. "Threatened" applies to species that may become Endangered if conditions surrounding it begin to or continue to deteriorate. "Special Concern" applies to species that warrant special attention because of some evidence of decline, inherent vulnerability to environmental deterioration, or habitat modification that would result in their becoming Threatened.

Table 10 - NJ Endangered and Nongame Species Program – Special Concern Species Listing Documented in the Sourlands

Endangered	Special Concern
Upland sandpiper	Northern harrier
	Sharp-shinned hawk
Threatened	American kestrel
	Winter wren
Red-shouldered hawk	Veery
Cooper's hawk	Gray-cheeked thrush
Barred owl	Kentucky warbler
Grasshopper sparrow	Canada warbler
Bobolink	Yellow-breasted chat
	Eastern meadowlark

WatchList

This list calls attention to birds at conservation risk before they require federal listing and stresses preventive action over last-ditch intervention. The WatchList is based on the Partners in Flight conservation priority scoring system designed to conserve viable populations of birds and the biological systems on which they depend. Partners in Flight is a cooperative effort involving partnerships of many federal, state and local agencies, philanthropic foundations, professional organizations, conservation groups, the academic community and private individuals.

Table 11 - WatchList Birds Documented as Breeding in the Sourlands

American woodcock
Willow flycatcher
Wood thrush
Blue-winged warbler
Prairie warbler
Worm-eating warbler
Kentucky warbler
Canada warbler

In addition, two other WatchList species, Bicknell's thrush and prothonotary warbler, have been documented as migrants in the Sourlands region.

Partners in Flight Physiographic Areas Plans – Mid-Atlantic Piedmont

This plan lists species by habitat type within each physiographic region and assigns scores to the species, lists population trends and recommends action levels. The following are species documented in the Sourlands listed in the Mid-Atlantic Piedmont Area Plan's Priority Habitats and Suites of Species.

Table 12 – Partners in Flight Mid-Atlantic Piedmont Area Plan

Priority Habitats and Suites of Species -Species Documented in the Sourland Region

Deciduous Forest	Agricultural Grassland
Wood thrush	Upland sandpiper
Kentucky warbler	
Eastern screech owl	
Chimney swift	Freshwater Wetland
Prothonotary warbler	
Acadian flycatcher	Green heron
Scarlet tanager	
Louisiana waterthrush	
Canada warbler	
Worm-eating warbler	
Shrub - Early Successional	
American woodcock	
Prairie warbler	
Northern bobwhite	
Field sparrow	
Eastern towhee	
Blue-winged warbler	
Willow flycatcher	

The Executive Summary of the Mid-Atlantic Piedmont Plan states, "The future of wildlife habitat depends on protection of patches of conservation significance and the manner in which inevitable continuing growth alters the environment. Forest habitat remains relatively abundant, but is very heavily fragmented. Identification and maintenance of those blocks large enough to support the full array of breeding birds should be a priority." The species lists indicate that Sourland Mountain fits the definition of a priority habitat site.

Reptiles and Amphibians

The region also supports diverse populations of amphibians and reptiles (see Appendix 5.) Critical to the continued success of amphibian populations in particular are vernal pools. Vernal pools are "confined wetland depressions, either natural or man-made, that hold water for at least two consecutive months out of the year, and are devoid of breeding fish populations." (Tesauro, 2003) Many amphibian species, frogs and salamanders in particular, are obligate to early spring pools for breeding (see Appendix 5.) One study of a vernal pool in the Sourland region revealed that no less than 500 spotted salamanders and 700 wood frogs visited one pond to breed (Heilferty.) Currently, only certified vernal ponds receive protection under the State wetland regulations. Many of the pools that are certified are on lands that are already protected from development. The Heilferty study found that individuals had come from as far as 600 yards from the pool under observation; as such, the maximum wetland buffer of 150 feet for exceptional resource value wetlands would do little to protect the critical area surrounding a vernal pool. Currently, NJDEP and Rutgers University are providing training for individuals who wish to survey and certify vernal pools. As pools are certified, they are documented in an internet mapping application and afforded protection. An inherent problem lies in documenting pools that are not on public land.

The rocky terrain of Sourland Mountain and Baldpate Mountain offers excellent habitat for some snakes. Rock outcrops and rock piles are perfect for basking snakes. Residents, including a Somerset County naturalist, have reported sightings of Northern copperhead snakes on both Sourland and Baldpate Mountains and the species had been noted in the past at what is now Alexauken Creek Watershed Management Area. This species was sought for but not seen in the course of the two Washington Crossing Audubon biological surveys, nor in the Baldpate Mountain survey. A variety of other snake species were documented. Several turtle species appear in the survey lists as well.

Mammals

The region is also home to a host of animals representing a number of mammalian families and habitat preferences (see Appendix 6 and lists included in the biological surveys.) In addition to these lists, there is the occasional anecdotal report of a black bear, bobcat and Eastern coyote.

Insects

A thriving, diverse insect population can be an indicator of a healthy environment. They fulfill a vital role in maintaining biological communities by serving as pollinators for many plant species and as a food source for many birds, reptiles and amphibians and small mammals. Except for butterflies and dragonflies, there was no concerted effort to identify insects in the biological surveys but incidental sightings were noted. Nevertheless, the species lists represent a broad range of insect families.

Plants

The Sourlands region supports diverse plant communities including wet and dry meadows, old fields in succession, young second growth forest, riparian and wetland forests and older second growth forest (McCormick and Peifer, 1990.) The forest that covers the Diabase ridges of Sourland and Baldpate Mountains is the mixed oak type (Collins and Anderson, 1994.) White, red, black, scarlet and chestnut oaks dominate this type of forest but, in the areas surveyed, shagbark, bitternut and pignut hickory, tulip poplar and American beech are very well represented, creating a spectacular mixed hardwood forest. Flowering dogwood, sassafras, ironwood and other small trees fill the understory layer and native vines such as Virginia creeper, grape and poison ivy are abundant in some locations. Native shrubs such as several species of virburnum and dogwood thrive in areas that have not been over-browsed by deer. Many of these trees, shrubs and vines are important food sources for southward migrating birds in the fall and for over-wintering birds (Suthers, Bickal and Rodewald, 2000.)

New Jersey is botanically very interesting. The historic composition of its flora contains species characteristic of both southeastern and northeastern states. This is especially true of the Piedmont, where many southern species reach their northern climatic limit and some northern species reach their southern limit. Central New Jersey is also a region where a growth explosion has obliterated much of the natural botanical habitat. The Sourlands region may be the last refuge of some of the complex plant communities that once flourished here. One indication of the integrity of habitat in the Sourlands is the number of species listed by the State of New Jersey as threatened or endangered that have been documented there (see below.) The sheer number and range of plant species overall attests to the diversity of habitat types. The fact that the bulk of these are native species that have not been overwhelmed by invasive alien plants may be attributable to the size of the habitat patches and lack of intense development in the region.

It is worth noting that many invasive species are landscape plants that have jumped the interface between homestead and natural lands. Invasive and exotic species continue to be a problem associated with clearing of the forest. As holes open in the canopy, the increased amount of sunlight reaching the forest floor aids perpetuation of opportunistic non-native plants. Many invasive species begin as prized ornamentals used in landscaping around new homes and include a host of trees, shrubs, groundcovers and herbaceous perennials (see Appendix 3.) Most of these species have little or no value to native wildlife and compete with native plants for habitat. Many of our rarest wildflowers are fragile woodland species that can be overwhelmed by aggressive alien plants such as garlic mustard, stiltgrass and barberry. While invasive species are problematic when the forest canopy is thinned, they are more of a problem when trees are clear cut, as it takes decades for the canopy to close enough to provide the shade that eliminates problem vegetation. Even careful logging activity aids invasive species; selective cutting can still thin the canopy enough to change light conditions and make the environment favorable for their growth. The rapacious mile-a-minute vine and Asiatic bittersweet retard early successional growth and even native wild grapes that flourish in forest openings can inhibit closing of the canopy. And while deer are effective at eliminating desirable native vegetation in the understory of the forest, they tend to avoid many of the invasive plants. Invasive plants such as Canada thistle and multiflora rose present a challenge in grassland habitats.

New Jersey is rapidly losing its rich botanical heritage to development, inappropriate management or misuse of preserved lands, and to browsing by deer, which are crowded into ever-diminishing habitat. The importance of preserving what remains of central New Jersey's native flora in the Sourlands region cannot be overstated.

Table 13 - New Jersey Endangered Plant Species and Plant Species of Concern Documented in the Sourlands Region

Allegheny vine	Adlumia fungosa	SMP, B
Arrow-leaved aster	Aster sagittifolius	B
Britton's grooveburr	Agrimonia striata	ACWMA
Giant yellow hyssop	Agastache nepitoides	SMP, B
Ginseng	Panax quinquefolius	SMP, B
Green violet	Hybanthus concolor	B
Hairy rock cress	Arabis hirsuta	B
Pennywort	Obolaria virginica	SMP
Redbud	Cercis canadensis	SMP, B
Slender toothwort	Cardamine angustata	SMP
Smooth hedge-nettle	Stachys tenuifolia	B
Spreading chervil	Chaerophyllum procumbens	B
Strict blue-eyed grass	Sisyrinchium montanum	ACWMA
Warty spike rush	Eleocharis tenuis var. Verrucosa	SMP
Wild comfrey	Cynoglossum virginianum	SMP
Winged monkey flower	Mimulus alatus	SMP

ACWMA = Alexauken Creek Wildlife Management Area
B = Baldpate Mountain
SMP = Sourland Mountain Preserve

Habitat Management

Careful management of the habitat in the Sourland region is critical to maintaining the biodiversity that exists. The interplay of habitat types in the area is what supports the incredible richness of plants and animals (Appendices 3 through 7.) As land acquisition continues, management plans should be developed to support habitat that preserves diversity. In some cases, this may include the creation of grassland habitat from cropland or pastureland. In other cases, old fields may need to be maintained at their early successional stage to provide shrub/scrub habitat. Other old fields will need to be left alone to progress to forest.

Of these management scenarios, grassland habitat maintenance will require the most intensive management plans. Former hayfields may need to be burned and replanted with native warm season grasses and a strict mowing regimen put in place. Invasive plants such as Canada thistle and crown vetch may need to be eliminated. Conversion to proper grassland habitat takes 3 or 4 growing seasons. Shrub-scrub habitat must be vigorously managed by selective mowing unless targeted for eventual succession to woodland. Typically, a new second growth forest requires 40 to 50 years to close its canopy sufficiently to eliminate invasive species that appear in almost every woodland in the region.

If native plant populations, critical forest understory and seedling trees needed for forest regeneration are to thrive, the complex and sensitive question of deer management needs to be addressed. Current deer populations far exceed those that existed before the eastern United States was converted from a vast forest to woodland patches amidst a sea of development and farmland. Deer inhabit forest edges more than they do the deep interior and exploit the banquet laid out for them by man. They are having a profound impact on our native vegetation. Studies in the northeastern states have shown that deer browsing of tree seedlings is driving the composition of our forests from mixed oak-hickory to red maple. In other words, deer are eating our hardwoods to potential extinction, and are creating a monoculture of red maple. There is a huge body of literature that supports this theory. And in a study conducted in the Sourlands as part of her 1995 Master's Thesis for Princeton University's Department of Ecology and Evolutionary Biology, S. E. Graham found that deer are effecting change in the composition of the forest.

Deer have decimated the ground covers of trillium, orchids and other wildflowers that used to carpet the forest floors in our state and that provided hiding places for ground-nesting Neotropical birds. According to Hannah Suthers, who has conducted extensive botanical studies at her bird banding station in Hopewell Township, deer have eaten the fringed orchis colony before it could go to seed, and have eaten down the cardinal flowers, a favorite nectar plant of hummingbirds, in bud. These plants lost their reproductive potential as a result. Suthers states that colonies of trout lily and ferns, which deer are more likely to avoid, actually indicate deer degenerated areas. A resident whose homestead is on the edge of the Sourland Mountain forest provides a graphic description of deer damage on his 16-acre property. Emmerson Bowes tells of the "complete disappearance of a stand of Ground Pine about 150' x 200' feet solid, all the Cardinal flowers from the edges of the rocky vernal ponds, and all Partridgeberry and Dwarf Ginseng have gone." He also reports near-extirpation of May apple, bloodroot, baneberry, wood anemone and rue anemone—all native woodland plants. He adds, "For the first time all Showy Orchis were eaten down to the ground this year as soon as the flowers opened." On his property, even "acres and acres of Trout Lily that one could not avoid treading on are down to miserable looking leaves and this year I spotted, instead of hundreds, just four flowers and those in a sheltered spot."

A deer management plan was initiated on Baldpate Mountain in January 2000. Each season since then, 85 to 90 participants holding special permits have harvested about 120 deer. As of the 2003-2004 hunting season, approximately 650 deer have been taken. There are about 33 hunting days in each season under the plan. Though several observers report that the ground layer vegetation appears to be regenerating since deer management began, there has not been a controlled study to evaluate the effect of the harvest on the herbaceous and understory layers of the forest. Such a study would have merit in mapping out a management plan.

Maintenance of the existing high-quality habitats in the Sourlands, as well as enhancement of those of lesser quality and even creation of new areas of suitable habitat will be of tremendous benefit to central New Jersey's native flora and fauna and essential to the stewardship of habitat for migratory birds for which the Sourlands region is a critical stopover site.

New Jersey Landscape Project

In 1993, the New Jersey Department of Environmental Protection's Endangered and Nongame 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. Version 2 of the Landscape Project data, released in February of 2004 and presented in Figure 25, replaced the land cover information compiled by Rutgers with the 1995 land use/land cover data prepared by the New Jersey Department of Environmental Protection. Once the 2002 land use/land cover data for New Jersey is complete, it will replace the 1995 information.

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 14 - 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

The Sourland Mountain region is rich in habitat suitable to support populations of threatened and endangered species, as depicted on Figure 25. This includes forest, grassland, emergent and forested wetland areas that canvas the study area. The highest concentration of valuable habitat is along the Sourland ridge. Table 11 summarizes the area of each habitat type by rank.

Table 15 - NJ Landscape Project Habitat Summary

Habitat Type	Rank	Acres	% of Total Acres of Habitat Type
Grassland	1 – Suitable habitat	3,282.0	22.5
	2 – Species of Special Concern sighted	8,210.7	56.2
	3 – State Threatened Species sighted	1,236.8	8.5
	4 – State Endangered Species sighted	1,869.2	12.8
	Total	**14,598.7**	
Forested Wetland	1 – Suitable habitat	1,704.2	26.7
	2 – Species of Special Concern sighted	2,660.8	41.6
	3 – State Threatened Species sighted	2,024.6	31.7
	Total	**6,389.7**	
Forest	1 – Suitable habitat	752.4	2.5
	2 – Species of Special Concern sighted	11,557.8	39.0
	3 – State Threatened Species sighted	17,323.7	58.5
	4 – State Endangered Species sighted	3.41	0.0
	Total	**29,637.4**	
Emergent	1 – Suitable habitat	425.7	68.0
	2 – Species of Special Concern sighted	200.67	32.0
	Total	**626.34**	

The critical forest habitat of the Sourland Mountain supporting state threatened species stretches from the northern boundary of the study area in Hillsborough southwest along the mountain to

Route 31. It penetrates a portion of the lower lying elevations as well, situated on both the north and south facing slopes. Altogether, forested areas with documented sighting of state threatened species cover 17,323.7 acres and account for 31.4% of the study area. West of Route 31, the forest areas are documented as supporting a number of species of special concern. Comprising 11,557.8 acres (21%) of the study area, these forested areas stretch along the Sourland ridge just south of Lambertville City and cover Baldpate and Pennington Mountains. These lands are uniquely suited to reproducing populations of Neotropical migrating birds.

Grasslands supporting populations of state endangered species are present on the north side of the Sourland ridge in East Amwell extending south to the fringe of the study area. Part of the Natural Heritage Program's East Amwell Grasslands Macrosite, this habitat patch contains 1,869.2 acres. Other grassland habitats supporting populations of state threatened species are located along the study area boundary in southern Hopewell Township and northeast of Hopewell Borough straddling the Montgomery/Hopewell Township border. Together, these areas cover 1,236.8 acres. There are also large areas of grasslands which support state species of special concern (8.210.7 acres) and those which are suitable to support threatened or endangered species (3,282.0 acres) but have had no field survey incorporated into the Natural Heritage Program databaseAll grassland habitats are primarily associated with active agricultural operations which likely involve the production of hay or other grass-like crops.

The study area 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 habitat supporting state species of special concern cover 200.6 acres in the study area and are situated south and west of Hopewell Borough. Additional areas of emergent habitat identified by the Landscape Project as suitable to support threatened and endangered species yet lacking in field survey are found north and south of County Route 601 in both West Amwell and Hopewell townships. 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 in 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. In addition to study underway by NJDEP and CRSSA, volunteer organizations and experts from non-profit groups have taken on the issue of identifying vernal pools in the Sourland region, although no map products are available and documentation is lacking at this point.

Much of the forested wetland habitat depicted on Figure 25 supports populations of threatened and state special concern species. Covering 2,024.6 acres, habitat with documented sightings of state threatened species are present along the Sourland ridge in Hillsborough, East Amwell and Hopewell townships. When combined with upland forest critical habitat of the same rank, the area encompasses nearly 20,000 acres. Forested wetland supporting state species of special concern covers 2,660.8 acres and is located both on the Sourland ridge and on facing slopes straddling the mountain itself. Habitat suitable to support threatened and endangered species but with no field survey covers 1,704.2 acres primarily located west of Route 31.

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

APPENDICES

APPENDIX 1 - Geologic Units – Technical Descriptions[vi]

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 Data for Soils in the Sourland Mountain Region

Symbol	Soil Name	Highly Erodible Lands Class(1)	Total Acres	Farmland Capability	N.J.A.C. 7:9A Soil Suitability Classifications	Depth to Seasonal High Water	Depth to Bedrock
AbrA	Abbottstown silt loam, 0 to 3 percent slopes	2	160.0	Statewide Important Soil	IIIHr, Wp(IISc); IISr, Wp (IISc)	0.5 to 1.5 Feet	40 to 60 Inches
AbrB	Abbottstown silt loam, 3 to 8 percent slopes	2	668.5	Statewide Important Soil	IIIHr, Wp(IISc); IISr, Wp (IISc)	0.5 to 1.5 Feet	40 to 60 Inches
BhmB	Birdsboro loam, 3 to 8 percent slopes	2	49.2	Prime Soil	I; IIWr; IISc; IIWrSc	0 Feet	0 Inches
BhmB2	Birdsboro loam, 3 to 8 percent slopes, eroded	2	45.2	Prime Soil	I; IIWr; IISc; IIWrSc	0 Feet	0 Inches
BhmC2	Birdsboro loam, 8 to 15 percent slopes, eroded	1	6.8	Statewide Important Soil	I; IIWr; IISc; IIWrSc	0 Feet	0 Inches
BhnA	Birdsboro silt loam, 0 to 3 percent slopes	3	34.1	Prime Soil	I; IIWr; IISc; IIWrSc	0 Feet	0 Inches
BhnB	Birdsboro silt loam, 3 to 8 percent slopes	2	106.9	Prime Soil	I; IIWr; IISc; IIWrSc	4 Feet	60 Inches
Boy	Bowmansville silt loam	3	776.7	Statewide Important Soil	IIIWr	0 to 1 Feet	72 to 99 Inches
BucA	Bucks silt loam, 0 to 3 percent slopes	3	218.7	Prime Soil	IISc; IISr	0 Feet	40 Inches
BucB	Bucks silt loam, 3 to 8 percent slopes	2	2,324.7	Prime Soil	IISc; IISr	6 Feet	40 Inches
BucB2	Bucks silt loam, 3 to 8 percent slopes, eroded	2	128.0	Prime Soil	IISc; IISr	0 Feet	40 Inches
BucC	Bucks silt loam, 8 to 15 percent slopes	2	233.6	Statewide Important Soil	IISc; IISr	0 Feet	40 Inches
BucC2	Bucks silt loam, 8 to 15 percent slopes, eroded	2	520.3	Statewide Important Soil	IISc; IISr	6 Feet	40 Inches
CakBb	Califon loam, 0 to 8 percent slopes, very stony	2	25.2		IIIHrWp	0.5 to 2.5 Feet	60 Inches
ChcA	Chalfont silt loam, 0 to 3 percent slopes	2	996.4	Statewide Important Soil	IIISrWp	0.5 to 1.5 Feet	40 to 60 Inches
ChcB	Chalfont silt loam, 3 to 8 percent slopes	2	5,552.6	Statewide Important Soil	IIISrWp	0.5 to 1.5 Feet	40 Inches
ChcB2	Chalfont silt loam, 3 to 8 percent slopes, eroded	2	510.0	Statewide	IIISrWp	0 Feet	40 Inches

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Symbol	Soil Name	Highly Erodible Lands Class(1)	Total Acres	Farmland Capability	N.J.A.C. 7:9A Soil Suitability Classifications	Depth to Seasonal High Water	Depth to Bedrock
				Important Soil			
ChcBa	Chalfont silt loam, 0 to 8 percent slopes, stony	2	510.3		IIISrWp	0.5 to 1.5 Feet	40 Inches
ChcBb	Chalfont silt loam, 0 to 8 percent slopes, very stony	2	105.6		IIISrWp	0 Feet	40 Inches
ChcC	Chalfont silt loam, 8 to 15 percent slopes	1	621.3	Statewide Important Soil	IIISrWp	0.5 to 1.5 Feet	40 Inches
ChcC2	Chalfont silt loam, 8 to 15 percent slopes, eroded	1	2,190.3	Statewide Important Soil	IIISrWp	0.5 to 1.5 Feet	40 to 60 Inches
ChcCa	Chalfont silt loam, 8 to 15 percent slopes, stony	1	778.8		IIISrWp	0.5 to 1.5 Feet	40 Inches
ChcCb	Chalfont silt loam, 0 to 15 percent slopes, very stony	2	147.4		IIISrWp	0.5 to 1.5 Feet	40 to 60 Inches
ChcDa	Chalfont silt loam, 15 to 25 percent slopes, stony	1	630.2		IIISrWp	0.5 to 1.5 Feet	40 Inches
CheCb	Chalfont-Lehigh silt loams, 8 to 15 percent slopes, very stony	2	695.3		IIISrWp	0.5 to 1.5 Feet	40 to 60 Inches
ChfB	Chalfont-Quakertown silt loams, 0 to 8 percent slopes	2	26.5	Statewide Important Soil	IIISrWp	0.5 to 1.5 Feet	40 to 60 Inches
CoxA	Croton silt loam, 0 to 3 percent slopes	2	233.0	Statewide Important Soil	IIISrWp; IIISrWr	0 to 0.5 Feet	42 to 60 Inches
CoxB	Croton silt loam, 3 to 8 percent slopes	2	149.9	Statewide Important Soil	IIISrWp; IIISrWr	0 to 0.5 Feet	42 to 60 Inches
CoxBb	Croton silt loam, 0 to 8 percent slopes, very stony	2	3.5		IIISrWp; IIISrWr	0 to 1 Feet	40 to 60 Inches
DOZA	Doylestown silt loam and Reaville Variant silt loam, 0 to 3 percent slopes	2	404.3		IIISrWr	0 to 0.5 Feet	40 Inches
DOZB	Doylestown silt loam and Reaville Variant silt loam, 3 to 8 percent slopes	2	451.8		IIISrWr	0 to 0.5 Feet	40 Inches
DOZB2	Doylestown silt loam and Reaville Variant silt loam, 3 to 8 percent slopes, eroded	2	47.0		IIISrWr	0 to 0.5 Feet	40 Inches
DOZC	Doylestown silt loam and Reaville Variant silt loam, 8 to 15 percent slopes	1	42.5		IIISrWr	0 to 0.5 Feet	40 Inches
HdyB	Hazelton channery loam, 3 to 8 percent slopes	2	27.7		IISc	6 Feet	48 to 60 Inches
HdyB2	Hazelton channery loam, 8 to 15 percent slopes, eroded	2	98.4		IISc	6 Feet	48 to 60 Inches
HdyD	Hazelton channery loam, 15 to 25 percent slopes	1	91.0		IISc	6 Feet	48 to 60 Inches

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Symbol	Soil Name	Highly Erodible Lands Class(1)	Total Acres	Farmland Capability	N.J.A.C. 7:9A Soil Suitability Classifications	Depth to Seasonal High Water	Depth to Bedrock
HdzEb	Hazelton loam, 25 to 45 percent slopes, very stony	1	74.6		IISc	6 Feet	48 to 60 Inches
KkoC	Klinesville channery loam, 8 to 15 percent slopes	2	1,246.1		IISc; IISr	6 Feet	10 to 20 Inches
KkoD	Klinesville channery loam, 15 to 25 percent slopes	1	287.2		IISc; IISr	6 Feet	10 to 20 Inches
KkoE	Klinesville channery loam, 25 to 45 percent slopes	1	173.9		IISc; IISr	6 Feet	10 to 20 Inches
LDXA	Lawrenceville and Mount Lucas silt loams, 0 to 3 percent slopes	2	21.1	Prime Soil	IIISrWp; IIIHrWp	0 Feet	48 Inches
LDXB	Lawrenceville and Mount Lucas silt loams, 3 to 8 percent slopes	2	328.3	Prime Soil	IIISrWp; IIIHrWp	0 Feet	48 Inches
LDXB2	Lawrenceville and Mount Lucas silt loams, 3 to 8 percent slopes, eroded	2	94.6	Prime Soil	IIISrWp; IIIHrWp	0 Feet	48 Inches
LDXC2	Lawrenceville and Mount Lucas silt loams, 8 to 15 percent slopes, eroded	1	113.6	Statewide Important Soil	IIISrWp; IIIHrWp	0 Feet	48 Inches
LbhB	Lansdale sandy loam, 3 to 8 percent slopes	2	57.6	Prime Soil	IISc	0 Feet	42 to 60 Inches
LbmB	Lansdale loam, 3 to 8 percent slopes	2	20.6	Prime Soil	IISc	6 Feet	40 to 60 Inches
LbmCb	Lansdale loam, 0 to 15 percent slopes, very stony	2	48.4		IISc	0 Feet	40 to 60 Inches
LbmEb	Lansdale loam, 25 to 45 percent slopes, very stony	1	3.7		IISc	0 Feet	40 to 60 Inches
LbnC2	Lansdale channery loam, 8 to 15 percent slopes, eroded	2	81.6	Statewide Important Soil	IISc	0 Feet	42 to 60 Inches
LbnD2	Lansdale channery loam, 15 to 25 percent slopes	1	51.8		IISc	0 Feet	42 to 60 Inches
LbtA	Lansdowne silt loam, 0 to 3 percent slopes	2	53.5	Statewide Important Soil	IISc	1 to 2.5 Feet	48 Inches
LbtB	Lansdowne silt loam, 3 to 8 percent slopes	2	23.4	Statewide Important Soil	IISc	1 to 2.5 Feet	48 Inches
LdmB	Lawrenceville silt loam, 3 to 8 percent slopes	2	1,822.6	Prime Soil	IIISrWp; IIIHrWp	1.5 to 3 Feet	48 Inches
LdmC	Lawrenceville silt loam, 8 to 15 percent slopes	1	285.4	Statewide Important Soil	IIISrWp; IIIHrWp	1.5 to 3 Feet	48 Inches
LdmC2	Lawrenceville silt loam, 8 to 15 percent slopes, eroded	1	287.7	Statewide Important Soil	IIISrWp; IIIHrWp	1.5 to 3 Feet	40 to 60 Inches
LegB	Legore gravelly loam, 3 to 8 percent slopes	2	6.5	Prime Soil	I; IISr	6 Feet	48 to 60 Inches
LegC	Legore gravelly loam, 8 to 15 percent slopes	2	313.7	Statewide Important Soil	I; IISr	6 Feet	48 to 60 Inches
LegD	Legore gravelly loam, 15 to 25 percent slopes	1	414.3		I; IISr	6 Feet	48 to 60 Inches

APPENDIX 2 - SSURGO Data for Soils in the Sourland Mountain Region

Symbol	Soil Name	Highly Erodible Lands Class(1)	Total Acres	Farmland Capability	N.J.A.C. 7:9A Soil Suitability Classifications	Depth to Seasonal High Water	Depth to Bedrock
LegE	Legore gravelly loam, 18 to 30 percent slopes	1	713.9		I; IISr	0 Feet	48 to 60 Inches
LemB	Lehigh silt loam, 3 to 8 percent slopes	2	1,557.1	Statewide Important Soil	IIISrWp; IIIHrWp(IISc)	0.5 to 2 Feet	40 to 60 Inches
LemB2	Lehigh silt loam, 3 to 8 percent slopes, eroded	2	71.8	Statewide Important Soil	IIISrWp; IIIHrWp(IISc)	0 Feet	40 to 60 Inches
LemBb	Lehigh silt loam, 0 to 8 percent slopes, very stony	2	139.4		IIISrWp; IIIHrWp(IISc)	0.5 to 2 Feet	40 to 60 Inches
LemC	Lehigh silt loam, 8 to 15 percent slopes	1	289.4	Statewide Important Soil	IIISrWp; IIIHrWp(IISc)	0.5 to 2 Feet	40 to 60 Inches
LemC2	Lehigh silt loam, 8 to 15 percent slopes, eroded	1	1,196.6	Statewide Important Soil	IIISrWp; IIIHrWp(IISc)	0.5 to 2 Feet	40 to 60 Inches
LemD2	Lehigh silt loam, 15 to 25 percent slopes, eroded	1	320.6		IIISrWp; IIIHrWp(IISc)	0.5 to 2 Feet	40 to 60 Inches
LemDb	Lehigh silt loam, 8 to 15 percent slopes, very stony	2	168.8		IIISrWp; IIIHrWp(IISc)	0.5 to 2 Feet	40 to 60 Inches
MORCB	Mount Lucas and Neshaminy soils, 8 to 15 percent slopes, very stony	2	120.5		IIIWp(IISr)	0 Feet	48 to 99 Inches
MonB	Mount Lucas silt loam, 3 to 8 percent slopes	2	244.6	Prime Soil	IIIWp(IISr)	0.5 to 2.5 Feet	48 to 60 Inches
MonBb	Mount Lucas silt loam, 0 to 8 percent slopes, very stony	2	175.6		IIIWp(IISr)	0 Feet	48 to 99 Inches
MonCb	Mount Lucas silt loam, 8 to 15 percent slopes, very stony	1	75.8		IIIWp(IISr)	0 Feet	48 to 99 Inches
MopBb	Mount Lucas-Watchung silt loams, 0 to 8 percent slopes, very stony	2	3,163.3		IIIWp(IISr)	0.5 to 2.5 Feet	48 to 60 Inches
MopCb	Mount Lucas-Watchung silt loams, 8 to 15 percent slopes, very stony	2	609.2		IIIWp(IISr)	0.5 to 2.5 Feet	48 to 99 Inches
NehB	Neshaminy silt loam, 3 to 8 percent slopes	2	982.5	Prime Soil	IISr	6 Feet	48 to 99 Inches
NehC	Neshaminy silt loam, 8 to 15 percent slopes	2	81.1	Statewide Important Soil	IISr	6 Feet	48 to 99 Inches
NehC2	Neshaminy silt loam, 8 to 15 percent slopes, eroded	2	318.5	Statewide Important Soil	IISr	6 Feet	48 to 60 Inches
NehCb	Neshaminy silt loam, 8 to 15 percent slopes, very stony	2	587.8		IISr	6 Feet	48 to 60 Inches
NehDb	Neshaminy silt loam, 15 to 25 percent slopes, very stony	1	679.2		IISr	6 Feet	48 to 60 Inches
NehEb	Neshaminy silt loam, 25 to 45 percent slopes, very stony	1	570.7		IISr	6 Feet	48 to 60 Inches

APPENDIX 2 - SSURGO Data for Soils in the Sourland Mountain Region

Symbol	Soil Name	Highly Erodible Lands Class(1)	Total Acres	Farmland Capability	N.J.A.C. 7:9A Soil Suitability Classifications	Depth to Seasonal High Water	Depth to Bedrock
NehEc	Neshaminy silt loam, 25 to 45 percent slopes, extremely stony	1	31.1		IISr	0 Feet	48 Inches
NemCb	Neshaminy-Mount Lucas silt loams, 8 to 15 percent slopes, very stony	2	2,838.2		IISr	0.5 to 3 Feet	48 to 99 Inches
NemDb	Neshaminy-Mount Lucas silt loams, 15 to 25 percent slopes, very stony	1	228.7		IISr	0.5 to 3 Feet	48 to 99 Inches
NotB	Norton loam, 3 to 8 percent slopes	2	79.7	Prime Soil	IIIHr	6 Feet	42 Inches
PHF	Pits, gravel	3	1.9		Disturbed Ground	6 Feet	60 Inches
PHG	Pits, sand and gravel	3	57.1		Disturbed Ground	0 Feet	0 Inches
PenB	Penn silt loam, 3 to 8 percent slopes	2	251.1	Prime Soil	IISc; IIISr	6 Feet	20 to 40 Inches
PenC	Penn silt loam, 8 to 15 percent slopes	1	10.7	Statewide Important Soil	IISc; IIISr	6 Feet	20 to 40 Inches
PeoB	Penn channery silt loam, 3 to 8 percent slopes	2	1,767.1	Prime Soil	IISc; IIISr	6 Feet	20 to 40 Inches
PeoC	Penn channery silt loam, 8 to 15 percent slopes	1	1,182.1		IISc; IIISr	6 Feet	20 to 40 Inches
PeoC2	Penn channery silt loam, 8 to 15 percent slopes, eroded	2	1,164.2		IISc; IIISr	6 Feet	20 to 40 Inches
PeoD	Penn channery silt loam, 15 to 25 percent slopes	1	385.7		IISc; IIISr	6 Feet	20 to 40 Inches
PepB	Penn-Bucks complex, 3 to 8 percent slopes	2	205.1	Prime Soil	IISc; IIISr	6 Feet	40 to 60 Inches
PepC2	Penn-Bucks complex, 8 to 15 percent slopes, eroded	2	76.3	Statewide Important Soil	IISc; IIISr	6 Feet	40 to 60 Inches
PomA	Pope fine sandy loam, high bottom, 0 to 3 percent slopes	3	3.8	Prime Soil	I; IISc	6 Feet	60 Inches
QY	Quarry	3	27.1		Disturbed Ground	6 Feet	0 Inches
QukB	Quakertown silt loam, 3 to 8 percent slopes	2	1,610.6	Prime Soil	IISc; I	6 Feet	40 to 60 Inches
QukB2	Quakertown silt loam, 3 to 8 percent slopes, eroded	2	165.9	Prime Soil	IISc; I	0 Feet	42 to 60 Inches
QukC	Quakertown silt loam, 8 to 15 percent slopes	2	583.2	Statewide Important Soil	IISc; I	6 Feet	42 to 60 Inches
QukC2	Quakertown silt loam, 8 to 15 percent slopes, eroded	1	511.8	Statewide Important Soil	IISc; I	6 Feet	40 to 60 Inches
QukD	Quakertown silt loam, 15 to 25 percent slopes	1	247.4		IISc; I	6 Feet	42 to 60 Inches
QukD2	Quakertown silt loam, 15 to 25 percent slopes, eroded	1	40.6		IISc; I	6 Feet	40 to 60 Inches
QumB	Quakertown channery silt loam, 3 to 8 percent slopes	2	224.8	Prime Soil	IISc	0 Feet	42 to 60 Inches

APPENDIX 2 - SSURGO Data for Soils in the Sourland Mountain Region

Symbol	Soil Name	Highly Erodible Lands Class(1)	Total Acres	Farmland Capability	N.J.A.C. 7:9A Soil Suitability Classifications	Depth to Seasonal High Water	Depth to Bedrock
QumC	Quakertown channery silt loam, 8 to 15 percent slopes	1	131.2	Statewide Important Soil	IISc	0 Feet	42 to 60 Inches
QumC2	Quakertown channery silt loam, 8 to 15 percent slopes, eroded	1	177.7	Statewide Important Soil	IISc	0 Feet	42 to 60 Inches
QumD2	Quakertown channery silt loam, 15 to 25 percent slopes, eroded	1	122.7		IISc	0 Feet	42 to 60 Inches
REFA	Readington and Abbottstown silt loams, 0 to 3 percent slopes	2	62.2	Prime Soil	IIIHrWp(IISc); IIWpSrSc; IIWrSc	0 Feet	40 Inches
REFB	Readington and Abbottstown silt loams, 3 to 8 percent slopes	2	87.6	Prime Soil	IIIHrWp(IISc); IIWpSrSc; IIWrSc	0 Feet	40 Inches
REFB2	Readington and Abbottstown silt loams, 3 to 8 percent slopes, eroded	2	33.3	Prime Soil	IIIHrWp(IISc); IIWpSrSc; IIWrSc	0 Feet	40 Inches
REFC2	Readington and Abbottstown silt loams, 8 to 15 percent slopes, eroded	1	37.8	Statewide Important Soil	IIIHrWp(IISc); IIWpSrSc; IIWrSc	0 Feet	40 Inches
RNG	Rough broken land, shale	1	696.6		Excessively Stony	6 Feet	0 Inches
RarA	Raritan silt loam, 0 to 3 percent slopes	2	3.4	Prime Soil	IIIHrWp; IIIHrWp(IISc); IIIHrWp(IISr)	0.5 to 2.5 Feet	60 Inches
RarB	Raritan silt loam, 3 to 8 percent slopes	2	19.6	Prime Soil	IIIHrWp; IIIHrWp(IISc); IIIHrWp(IISr)	0.5 to 2.5 Feet	60 Inches
RedB	Readington silt loam, 3 to 8 percent slopes	2	103.3	Prime Soil	IIIHrWp(IISc); IIWpSrSc; IIWrSc	1.5 to 3 Feet	40 Inches
RedC2	Readington silt loam, 8 to 15 percent slopes, eroded	1	30.3	Statewide Important Soil	IIIHrWp(IISc); IIWpSrSc; IIWrSc	1.5 to 3 Feet	40 to 60 Inches
RehA	Reaville silt loam, 0 to 3 percent slopes	2	290.4	Statewide Important Soil	IIISrWp(IIHc)	0.5 to 3 Feet	20 to 40 Inches
RehB	Reaville silt loam, 3 to 8 percent slopes	2	1,650.1	Statewide Important Soil	IIISrWp(IIHc)	0.5 to 3 Feet	20 to 40 Inches
RehB2	Reaville silt loam, 3 to 8 percent slopes, eroded	2	83.7	Statewide Important Soil	IIISrWp(IIHc)	0 Feet	20 to 40 Inches
RehC2	Reaville silt loam, 8 to 15 percent slopes, eroded	1	301.9	Statewide Important Soil	IIISrWp(IIHc)	1 to 2 Feet	20 to 40 Inches
RepwA	Reaville Wet Variant silt loam, 0 to 3 percent slopes	2	140.6		IIISrWp(IIHc)	0 to 1 Feet	20 to 40 Inches
RepwB	Reaville Wet Variant silt loam, 3 to 8 percent slopes	2	28.9		IIISrWp(IIHc)	0 to 1 Feet	20 to 40 Inches

APPENDIX 2 - SSURGO Data for Soils in the Sourland Mountain Region

Symbol	Soil Name	Highly Erodible Lands Class(1)	Total Acres	Farmland Capability	N.J.A.C. 7:9A Soil Suitability Classifications	Depth to Seasonal High Water	Depth to Bedrock
RksC	Riverhead gravelly sandy loam, 8 to 15 percent slopes	2	2.7	Statewide Important Soil	I; IISc	6 Feet	60 Inches
Ror	Rowland silt loam	3	1,429.9	Farmland of Local Importance	IIIWr	1 to 3 Feet	72 Inches
RoyB	Royce silt loam, 3 to 8 percent slopes	2	129.2	Prime Soil	IISc	6 Feet	40 to 72 Inches
ThoA	Tioga fine sandy loam, 0 to 3 percent slopes	3	4.4	Prime Soil	I; IIWr:IIWrSc; IISc	0 Feet	0 Inches
UR	Urban land	3	51.7		Disturbed Ground	2 Feet	10 Inches
Udt	Udorthents, bedrock substratum	3	96.9			0 Feet	48 to 72 Inches
WATER	Water	1	147.8		Water	0 Feet	0 Inches
Was	Watchung silt loam	2	151.6		IIIHrWpWr	0 to 1 Feet	60 Inches
Wasb	Watchung silt loam, very stony	2	35.8		IIIHrWpWr	0 to 1 Feet	0 Inches
			55,233.8				

(1) 1= Highly Erodible, 2= Potentially Highly Erodible, 3= Not Highly Erodible

APPENDIX 3 – Exotic Invasive Plants[vii]

LARGE TREES

Common Name	***Scientific Name***
Amur Maple	*Acer ginnala*
Japanese Red Maple	*Acer japonica*
Norway Maple	*Acer platanoides*
Sycamore Maple	*Acer psuedoplatanus*
Tree-of-Heaven	*Ailanthus altissima*
Black Alder	*Alnus glutinosa*
Paper Mulberry	*Broussonetia papyrifera*
Autumn Olive	*Eleagnus umbellatus*
Russian Olive	*Eleagnus angustifolia*
Golden Rain Tree	*Koelreuteria paniculata*
Chinaberry	*Melia Azedarach*
White Mulberry	*Morus alba*
Empress Tree	*Paulownia tomentosa*
Amur Corktree	*Phellodendron amurense*
White Cottonwood	*Populus alba*
Sweet Cherry	*Prunus avium*
Siberian Elm	*Ulmus pumila*
Chinese Tallow Tree	*Sapium sebiferum*

SHRUBS & SMALL TREES

Common Name	***Scientific Name***
Mimosa	*Albizia julibrissin*
Barberry	*Berberis japonica*
Barberry	*Berberis thunbergii*
Scotch Broom	*Cystisus scoparius*
Russian Olive	*Elaeagnus angustifolia*
Thorny Olive	*Elaeagnus pungens*
Autumn Olive	*Eleagnus umbellata*
Winged Euonymus	*Euonymus alatus*
Rose-of-Sharon	*Hibiscus syriacus*
Border Privet	*Ligustrum obtusifolium*
Chinese Privet	*Ligustrum sinense*
Amur Honeysuckle	*Lonicera maackii*
Morrow's Honeysuckle	*Lonicera morrowii*
Tartarian Honeysuckle	*Lonicera tatarica*
Belle Honeysuckle	*Lonicera x bella*
Common Buckthorn	*Rhamnus cathartica*
European Buckthorn	*Rhamnus frangula*
Multiflora Rose	*Rosa multiflora*
Cut Leaved Blackberrry	*Rubus laciniata*
Wineberry	*Rubus phoenicolasius*
Japenese Spirea	*Spiraea japonica*

VINES AND GROUNDCOVERS

Common Name	***Scientific Name***
Fiveleaf Akebia	*Ampelopsis brevipedunculata*
Chinese Bittersweet	*Celastrus orbiculatus*
Climbing Euonymus	*Euonymus fortunei*
English Ivy	*Hedera helix*
Hops	*Humulus japonica*
Japanese Honeysuckle	*Lonicera japonica*
Silver Fleece Vine	*Polygonum aubertii*
Kudzu	*Pueraria lobata*
Bittersweet Nightshade	*Solanum dulcamara*
Periwinkle	*Vinca minor*
Wisteria	*Wisteria floribunda*
Chinese Wisteria	*Wisteria sinensis*

HERBACEOUS PLANTS

Common Name	***Scientific Name***
Yarrow	*Achillea millefolium*
Goutweed	*Aegopodium podagraria*
Rhode Island Bent Grass	*Agrostis capillaries*
Redtop	*Agrostis gigantean*
Bugleweed	*Ajuga reptans*
Garlic Mustard	*Alliara officinalis*
Wild Onion	*Allium vineale*
Burdock	*Arctium spp.*
Oatgrass	*Arrenatherum elatius*
Mugwort	*Artemisia vulgaris*
Giant Reed	*Arunddonaz*
Smooth Brome	*Bromus inermis*
Musk Thistle	*Carduus nutans*
Asiatic Sand Sedge	*Carex kobomugi*
Brown Knapweed	*Centaurea jucea*
Knapweed	*Centaurea nigrescens*
Chicory	*Cichorium intybus*
Bull Thistle	*Cirsium vulgare*
Canada Thistle	*Cirsium arvense*
Water Hemlock	*Conium macalatum*
Field Bindweed	*Convolvuus arvensis*
Tickseed	*Coreopsis lanceolata*
Crown Vetch	*Coronilla varia*
Bermuda Grass	*Cynodon dactylon*
Orchard Grass	*Dactylis glomerata*
Queen Anne's Lace	*Daucus carota*
Cut Leaf Teasel	*Dipsacus laciniatus*
Common Teasel	*Dipsacus sylvestris*
Chinese Yam	*Dioscorea batatas*
Quackgrass	*Elytrigia repens*
Hairy Willow Herb	*Epilobium hirsutum*
Weeping Lovegrass	*Eragrostis curvula*
Cypress Spurge	*Euphorbia cyparissias*
Leafy Spurge	*Euphorbia esula*

Common Name	***Scientific Name***
Tall Fescue	*Festuca arundinacea*
Fescue	*Festuca elatior*
Sheep Fescue	*Festuca ovina*
Fennel	*Foeniculum vulgare*
Field Madder	*Galium mollugo*
Ground Ivy	*Glechoma hederacea*
Day Lily	*Hemerocallis fulva*
Velvet Grass	*Holcus lanatus*
Hops	*Humulus japonica*
St. John's Wort	*Hypericum perforatum*
Cogan Grass	*Imperata cylindrical*
Yellow Iris	*Iris pseudacorus*
Chinese Lespedeza	*Lespedeza cuneata*
Butter & Eggs	*Linaria vulgaris*
Birdsfoot Trefoil	*Lotus corniculatus*
Money Wort	*Lysimachia nummularia*
Purple Loosestrife	*Lythrum salicaria*
Purple Loosestrife	*Lythrum virgatum*
White Sweet Clover	*Melilotus alba*
Yellow Sweet Clover	*Melilotus officinalis*
Miscanthus	*Miscanthus sinensis*
Wild Parsnip	*Pastinaca sativa*
Reed Canary Grass	*Phalaris arundinacea*
Timothy	*Phleum prantense*
Narrow Leave Plantain	*Plantago lanceolata*
Broad Leaved Plantain	*Plantago major*
Canada Bluegrass	*Poa compressa*
Rough Bluegrass	*Poa trivialis*
Lesser Calandine	*Ranunculus ficaria*
Japanese Knotweed	*Reynoutria japonica*
Broad Leaved Dock	*Rumes obtusifolia*
Johnson Grass	*Sorghum halepense*
Stinging Nettle	*Urtica dioica*
Flannel Leaved Mullein	*Verbascum thapsus*

APPENDIX 4 – Bird Species in the Sourland Region

Birds of Featherbed Lane Bird Banding Station
Sommer Park, Hopewell Sourlands
Hannah Suthers

Permanent Residents

Black-capped Chickadee	Carolina Chickadee
Eastern Tufted Titmouse	White-breasted Nuthatch
Carolina Wren	Canada Goose
Eastern Bluebird	Red-tailed Hawk
Northern Mockingbird	Bobwhite
Cedar Waxwing	Wild Turkey
Northern Cardinal	Ruffed Grouse
House Finch	House Sparrow
American Goldfinch	Hybrid Chickadee
Ring-necked Pheasant	Eastern Screech Owl
Great Horned Owl	Red-bellied Woodpecker
Downy Woodpecker	Northern Cardinal
Hairy Woodpecker	Pileated Woodpecker
American Crow	

Neotropical Migrants That Breed Here

Black-billed Cuckoo	Yellow-billed Cuckoo
Chimney Swift	Ruby-throated Hummingbird
Eastern Wood Pewee	Willow Flycatcher
Eastern Phoebe	Great Crested Flycatcher
Eastern Kingbird	Barn Swallow
Purple Martin	Blue-gray Gnatcatcher
Veery	Wood Thrush
Gray Catbird	White-eyed Vireo
Red-eyed Vireo	Yellow-throated Vireo
Blue-winged Warbler	

Short Distance Migrants That Breed Here

Turkey Vulture	some overwinter
Black Vulture	some overwinter
Red-shouldered Hawk	some overwinter
Am. Kestrel	
Am. Woodcock	
Killdeer	
Mourning Dove	some overwinter
C. Flicker	some overwinter
Blue Jay	some overwinter
European Starling	some overwinter
House Wren	
Am. Robin	northern subspecies overwinter
Brown Thrasher	
Eastern Towhee	some overwinter
Chipping Sparrow	

Field Sparrow	
Song Sparrow	some overwinter
Red-winged Blackbird	
Common Grackle	
Brown-headed Cowbird	

Stopover Migrants, Spring and Fall

Red-shouldered Hawk	some overwinter
Sharp-shinned Hawk	some overwinter
Broad-winged Hawk	
Cooper's Hawk	
Yellow-bellied Sapsucker	some overwinter
Acadian Flycatcher	
Alder Flycatcher	
Least Flycatcher	
Tree Swallow	
Brown Creeper	
Red-breasted Nuthatch	
Winter Wren	some overwinter
Golden-crowned Kinglet	
Ruby-crowned Kinglet	some overwinter
Gray-cheeked Thrush	
Bicknell Thrush	
Swainson's Thrush	
Hermit Thrush	some overwinter
Philadelphia Vireo	
Blue-headed Vireo	
Yellow-rumped Warbler (Myrtle)	some overwinter
Pine Warbler	
Palm Warbler	
Black-throated Green Warbler	
Black-throated Blue Warbler	
Worm-eating Warbler	
Louisiana Waterthrush	
Northern Waterthrush	
Kentucky Warbler	
Hooded Warbler	
Northern Parula	
Chestnut-sided Warbler	
Prothonotary Warbler	
Canada Warbler	
Prairie Warbler	
Yellow-breasted Chat	
Tennesee Warbler	
Mourning Warbler	
Connecticut Warbler	
Nashville Warbler	
Magnolia Warbler	
Blackpoll Warbler	
Blackburnian Warbler	
Orchard Oriole	

Lincoln's Sparrow
Swamp Sparrow
White-throated Sparrow
Slate-colored Junco
Purple Finch
American Tree Sparrow

APPENDIX 5 – Amphibians and Reptiles

Spotted Salamander	*Ambystoma maculatum*
Red-backed Salamander (red & gray phases)	*Plethodon cinereus*
Slimy Salamander	*Plethodon glutinosus*
Northern Two-lined Salamander	
Northern Red Salamander	
Northern Dusky Salamander	
Jefferson Salamander	
American Toad	
Fowler's Toad	*Bufo fowleri*
Spring Peeper	*Hyla crucifer*
Bullfrog	*Rana catesbeiana*
Green Frog	*Rana clamitans*
Wood Frog	*Rana sylvatica*
Pickerel Frog	*Rana palustris*
Northern Gray Tree Frog	*Hyla versicolor*
Common Musk Turtle	
Spotted Turtle	*Clemmys guttata*
Box Turtle	*Terrapene carolina*
Eastern Painted Turtle	*Chrysemys marginata*
Snapping Turtle	*Chelydra serpentina*
Black Rat Snake	
Common Garter Snake	*Thammophis sirtalis*
Ribbon Snake	*Thamnophis sauritus*
Ringneck Snake	
Black Racer	*Coluber constrictor*
Milk Snake	*Lampropeltis triangulum*
Northern Water Snake	*Natrix sipedon*

APPENDIX 6 – Mammals

Big Brown Bat	*Epesicus fuscus*
Little Brown Myotis	*Myotis lucifugus*
House Mouse	*Mus Muscus*
White-footed Mouse	*Peromyscus leocopus*
Meadow Vole	*Microtus pennsylvanicus*
Eastern Chipmunk	*Tamias striatus*
Red Squirrel	*Tamiasciurus hudsonicus*
Gray Squirrel	*Scirus carolinensis*
Eastern Cottontail	*Sylvilagus floridanus*
Woodchuck	*Marmota monax*
Eastern Mole	*Scalopus aquaticus*
Star-nosed Mole	*Condylura cristata*
Opossum	*Didelphis marsupialis*
Raccoon	*Procyon lotor*
Striped Skunk	*Mephitis mephitis*
Long-tailed Weasel	*Mustela frenata*
White-tailed Deer	*Odocoileus virginianus*
Red Fox	*Vulpes fulva*

APPENDIX 7 – Plants

OBLW	Obligate wetland species
FACW	Facultative wetland species
FACU	Facultative upland species
FAC	Likely to occur
*	Imported
**	Protected

APRIL

Northern White Violet	*Viola pallens*	OBLW
Common Winter Cress	*Brassica rapa*	
Common Blue Violet	*Viola papilionacea*	FAC
Round-leafed Yellow Violet	*Viola rotundifolia*	FAC+
Spring Beauty	*Claytonia virginica*	FACU
May Apple	*Podophyllum peltatum*	FACU
Coltsfoot*	*Tussilago farfara*	
Common Strawberry	*Fragaria virginiana*	FACU
Common Cinquefoil	*Potentilla simplex*	FACU-
Wild Geranium	*Geranium maculatum*	FACU
Cut-leaf Toothwort	*Dentaria laciniata*	
Small Jack-in-the pulpit	*Arisaema triphyllum*	
Jack-in-the-pulpit	*Arisaema atrorubens*	
Blood Root**	*Sanguinaria canadensis*	
Trout-lily	*Erythronium americanuum*	
Wild Leek	*Allium tricoccum*	FACU+
Field Garlic	*Allium vineale*	FACU-
Skunk Cabbage	*Symplocarpus faetidus*	OBLW
Speedwell, American	*Veronica Americana*	OBLW
Rue Anemone	*Anemonella thalictroides*	
Dandelion	*Taraxacum officinale*	
Buttercup	*Ranunculus species*	some OBLW
Virginia Waterleaf	*Hydrophyllum virginianum*	
Smaller Forget-me-not	*Myosotis laxa*	
Yellow Stargrass	*Hypoxis hirsuta*	
Japanese Silverberry*	*Eleagnus umbellata*	

MAY

Poison-ivy	*Rhus radicans*	
Virginia Creeper	*Parthenocissus quinquefolia*	FACU
Partridge Berry	*Mitchella repens*	FACU
Common Highbush Blueberry	*Vaccinium croymbosum*	FACW-
Common Lowbush Blueberry	*Vaccinium angustifolium*	FACU-
Common Ragwort	*Senecio obovatus*	FACU-
Common Groundsel	*Senecio vulgaris*	FACU
Multiflora Rose	*Rosa multiflora*	

Common Blackberry (Highbush)	*Rubus allegheniensis*	FACU-
Commom Dewberry	*Rubus flagellaris*	
Black Raspberry	*Rubus occidentalis*	
Wine Raspberry*	*Rubus phoenicolasius*	
Fox Grape	*Vitis species labrusca*	FACU
Summer Grape	*Vitis species aestivalis*	FACU
Frost Grape	*Vitis species vulpina*	
New England Grape	*Vitis species novae-angliae*	
Japanese Honeysuckle*	*Lonicera japonica*	
Wild Rose	*Rosa carolina*	UPL
Common Greenbriar**	*Smilas rotundifolia*	FAC
Poison Ivy	*Rhus radicans*	
Northern Bayberry	*Myrica pensylvanicum*	FAC
Common Milkweed	*Asclepias syriaca*	
Broad Leafed Milkweed	*Asclepias amplexicaulis*	
Swamp Milkweed	*Asclepias incarnata*	OBLW
Devil's Paintbrush	*Hieracium aurantiacum*	
Jewelweed (Spotted Touch-me-not)	*Impatiens capensis*	FACW
Hairy Beardtongue	*Penstemon hirsutus*	
Common Chick Weed	*Stellaria media*	
White Campion	*Lychnis alba*	
Ground Ivy	*Glechoma hederacea*	FACU
Purple Milkwort	*Polygala species*	FACW
Moth Mullein	*Verbascum thapsus*	
Field Pennycress*	*Thlapsi arbvense*	
Golden Ragwort	*Senecio aureus*	
Garlic Mustard	*Alliaria petiolata*	
JUNE		
Field Daisy	*Chrysanthemum leucanthemum*	
Field Hawkweed	*Hieracium pratense*	
Daisy Fleabane	*Erigeron annuus*	FACU
Whorled Loosestrife	*Lysimachia quadrifolia*	FACU-
Two-flowered Cynthia	*Krigia biflora*	FACU
Bouncing Bet*	*Saponaria officinalis*	
Sundrop	*Oenothera fruticosa*	FACU-
Black-eyed Susan	*Rudbeckia hirta*	FACU-
Sow Thistle*	*Sonchus species*	
Canada Thistle*	*Circium arvense*	
American Elderberry	*Sambucus canadensis*	FACW-
Cow Vetch*	*Vicia cracca*	
Wild Pea	*Lathyrus palustris*	FACW+
Dayflower	*Commelina species*	FACW
Cow Parsnip	*Heracleum maximum*	
Sasaparilla**	*Aralia nudicalis*	FACU
Sheep Sorrel*	*Rumex acetosella*	

White Clover	*Melilotus alba*	FACU
Red Clover*	*Trifolium pratense*	
Yellow Sweet Clover*	*Melilotus officinalis*	FACU-
Hop (Yellow Clover)*	*Trifolium agrarium*	
Tick Trefoil	*Desmodium canadense*	FAC
Blue Vervain	*Verbena hastata*	FACW+
Common St. Johnswort*	*Hypericum perforatum*	
Cardinal Flower**	*Lobelia cardinalis*	FACW+
Spiked Lobelia	*Lobelia spicata*	
Wild Pink	*Silene caroliniana*	
Long-leafed Stitchwort	*Stellaria longifolia*	
Wild Balsam Apple	*Echinocystis Lobata*	
Eastern Blue-eyed Grass	*Sisyrinchium atlanticum*	FACW
Stout Blue-eyed Grass	*Sisyrinchium angustifolium*	
Common Blue-eyed Grass	*Sisyrinchium montanum*	
Yellow Stargrass	*Hypoxis hirsuta*	
Horse Nettle	*Solanum carolininse*	
Fringed Loosestrife	*Lysimachia ciliata*	
Common Plantain	*Plantago major*	
Black Cohosh	*Cimicifuga racemosa*	
JULY		
Yarrow*	*Achillea millefolium*	FACU
Purple Milkweed	*Asclepias purpurescens*	OBLW
Tall Meadow Rue	*Thalictrum polygamum*	
White Avens	*Geum canadense*	
Indian Hemp (Clasping-leaf Dogbane)	*Apocynum cannabinum*	FACU
Early Goldenrod	*Solidago juncea*	
Birdfoot Trefoil	*Lotus corniculatus*	FACU-
Narrow-leafed Mountain Mint	*Pycanthemum tenuifolium*	FACW
Yellow Bedstraw	*Galium verum*	
Hounds Tongue Forget-me-not	*Cynoglossum officinale*	
Galinsoga (Quickweed)	*Galinsoga ciliata*	
Virginia Knotweed	*Tovara virginiana*	
Raggid Fringed Orchis	*Habenaria lacera*	
Wild Basil	*Satureja vulgaris*	
AUGUST		
Pickerelweed	*Pontedaria cordata*	OBLW
Slender Gerardia	*Agalinis tenuifolia*	FACU
Queen Ann's Lace	*Daucus carota*	FACU
Boneset	*Eupatorium perfoliatum*	FACW+
Bur Marigold	*Bidens laevis*	OBLW
Heal-all*	*Prunella vulgaris*	
Bull Thistle	*Cirsium vulgare*	
New York Aster	*Aster novae-belgii*	FACW+

New England Aster	*Aster novae-angliae*	FACW-
Small White Aster	*Aster vivineus*	FACW
Arrow-leafed Tearthumb	*Polygonum sagittatum*	OBLW
Long-bristled Smartweed	*Polygonum cespitosum*	
Rough-stemmed Goldenrod	*Solidago rugosa*	FAC
Grass-leafed Goldenrod	*Euthamia graminifolia*	FACW
Field Thistle	*Cirsium discolor*	
Pilewort	*Erectites hieracifolia*	FACU
Pokeweed	*Phytolacca americana*	FACU+
New York Ironweed	*Vernonia noveboracensis*	FACW+
Common Ragweed	*Ambrosia artemisiifolia*	FACU
Joe-pye-weed	*Eupatoriadelphus dubius*	FACW
Hyssop Skullcap	*Scutellaria integrifolia*	
Agrimony	*Agrimony spp.*	
Purple Milkwort	*Polygala sanguiena*	
Indian Tobacco	*Lobelia inflata*	

SEPTEMBER

Heart-leafed Aster	*Aster cordifolius*	
Lawrie's Aster	*Aster lowrieanus*	
Slender Gerardia	*Agalinis tenuifolia*	
White Wood Aster	*Aster divaricatus*	
Panicled Aster	*Aster simplex*	FACW
Heath Aster	*Aster ericoides*	FACU
Bushy Aster	*Aster dumosus*	FAC
Pennsylvania Smartweed	*Polygonum pensylvanicum*	FACW
Cocklebur	*Xanthium pensylvanicum*	FAC
Common Burdock*	*Arctium minus*	
Giant Goldenrod	*Solidago gigantea*	FACW
Beechdrops	*Epifagus virginiana*	

FERNS AND ALLIES

New York Fern	*Thelypteris noveboracensis*	
Sensitive Fern	*Onoclea sensibilius*	FACW
Christmas Fern	*Polystichum acrostichoides*	FACU
Lady Fern	*Athyrium Felix-femina*	FAC
Cut-leaved Grape Fern	*Botrychium dissectum Spreng.*	
Hay-scented Fern	*Dennstaedia punctilobula*	
Common Polypody	*Polypodium virginianum*	
Ground Pine/Running Pine	*Lycopodium tristachyjm (clavatum)*	FAC
Moss	*Pollytrichum* sp.	
Moss	*Atricum* sp.	

MUSHROOMS, LICHENS

British Soldiers	*Cladonia cristatella*
Stalked Scarlet Cup	*Sarcoscypha occidentalis*
Bird's Nest Fungi	*Cyathus striatus*
Bird's Nest Fungi	*Crucibulum laeve*
Witches' Jelly	*Tremella* sp
Common Scleroderma	*Scleroderma* sp.

SEDGES AND RUSHES

Trianglestem Spikerush	*Eleocharis robbinsii*	OBLW
Four Square	*Eleocharis species*	OBLW
Spike Rush	*Eleocharis species*	OBLW
Wool Grass	*Scirpus cyperinus*	
Dark Green Bulrush	*Scirpus atrovirens*	
Path Rush	*Scirpus tenuis*	
Umbrella Sedge	*Cyperus strigosus*	
Twig Rush	*Scirpus species*	
Tussock Sedge	*Carex stricta*	
Wooly Sedge	*Carex lanuginosa*	OBLW
Sedge, one of the ovales	*Carex scoparia*	
Sedge	*Carex intumescens*	
Bottle Brush Sedge	*Carex lurida*	
Sedge	*Carex Lupulina*	
Soft Rush	*Juncus effusus*	
Rush	*Juncus canadensis*	
Cattail	*Typha latifolia*	OBLW

GRASSES

Orchard Grass*	*Dactylis glomerata*	
Red-topped Grass	*Agrostis alba*	FACW
Meadow Foxtail Grass	*Alopecurus geniculatus*	OBLW
Bristly Foxtail	*Setaria*	

Switch Grass	*Panicum virgatum*
Deer-tongue Grass	*Panicum clandestinum*
Panic Grass	*Panicum lanuginosum*
Reed Canary Grass*	*Phalaris arundinacea*
Tall Oats Grass	*Arrhenatherum elatius*
Brome Grass*	*Bromus ciliatus*
Little Bluestem	*Andropogon scoparius*
Sweet Vernal Grass	*Antheroxanthum odoratum*
Quack Grass	*Agropyron repens*
Indian Grass	*Sorghastrum nutans*
Wirestem Muhly	*Muhlenbergia frondosa*
Meadow Fescue	*Festuca elatior*
Red Fescue	*Festuca rubra*
Stilt Grass*	*Microstegium vimineum*
Barnyard Grass*	*Echinochloa crusgalli*

SHRUBS

Panicled Dogwood	*Cornus foemina ssp. racemosa*	FACW+
Silky Dogwood	*Cornus amomum*	
Northern Spicebush	*Lindera benzoin*	FACW-
Steeple Bush	*Spirea tomentosa*	FACW
Northern Bayberry	*Myrica pensylvanicum*	FAC
Arrowwood	*Viburnum dentatum*	
Shadbush	*Amelanchier arborea*	
Nannyberry	*Viburnum lentago*	FAC
Japanese Silverberry, Autumn Elaeagnus	*Elaeagnus umbellata*	
Winged Euonymus	*Euonymus alata*	
Staghorn Sumac	*Rhus typhina*	
Red Chokeberry	*Pyrus arbutifolia*	
Winterberry	*Ilex verticillata*	
Privit	*Ligustrum vulgare*	
Japanese Barberry	*Berberis thunbergii*	
Amur Honeysuckle	*Lonicera Maackii*	
Morrow Honeysuckle	*Lonicera morrowi*	

TREES

Red Maple	*Acer rubrum*	FAC
Sugar Maple	*Acer saccharum*	
Silver Maple	*Acer saccharinum*	FACW
Crab Apple	*Pyrus species*	
Gray Birch	*Betula populifolia*	
Black Birch	*Betula lenta*	
Flowering Dogwood	*Cornus florida*	
Eastern Red Cedar	*Juniperus virginiana*	
Red Mulberry	*Morus rubra*	FACU
Slippery Elm	*Ulmus rubra*	FAC
Osage Orange	*Maclura pomifera*	
Staghorn Sumac	*Rhus typhina*	
Swamp White Oak	*Quercus bicolor*	FACW+
White Oak	*Quercus alba*	
Pin Oak	*Quercus paulistris*	FACW
Swamp Chestnut Oak	*Quercus michauxii*	FACW
Black Oak/Red Oak	*Quercus species*	
Basswood	*Tilia americana*	
Tuliptree	*Liriodendron tulipifera*	
White Ash	*Fraxinus americana*	
Shagbark Hickory	*Carya ovata*	
Mockernut Hickory	*Carya tomentosa*	
Black Walnut	*Juglans nigra*	

Sassafras	*Sassafras albidum*
Ironwood	*Carpinus caroliniana*
Sycamore	*Platanus occidentalis*
American Beech	*Fagus grandifolia*
Persimmon	*Diospyros virginiana*
Common Catalpa	*Catalpa bignonioides*

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[ii] "Geology of the Newark Rift Basin", Roy Schlische, Department of Geological Sciences, Rutgers University.

[iii] "Surface Water Quality Standards", N.J.A.C. 7:9B, New Jersey Department of Environmental Protection, pg. 4.
[iv] Ibid, pgs. 2-3
[v] Ibid, pg. 3
[vi] "Bedrock Geology and Topographic Base Maps of New Jersey", New Jersey Geological Survey CD Series CD 00-1, New Jersey Geological Survey, 2001.

[vii] "Building Greener Communities – Planning for Woodland Conservation (Appendix D", Marybeth H. Carter, ASLA, AICP, June 2003.

Figure 1

Level I Classification
1995 Land Use/
Land Cover

The Sourland Mountain
A Portion of Central New Jersey

0 0.5 1
Miles

Legend

- AGRICULTURE
- BARREN LAND
- FOREST
- URBAN
- WATER
- WETLANDS

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
1995 Land Use/Land Cover Edition 1.3 - WMA 10 (Millstone Watershed Management Area), Originator - NJDEP, OIRM, BGIA, Source Scale 1:12,000.

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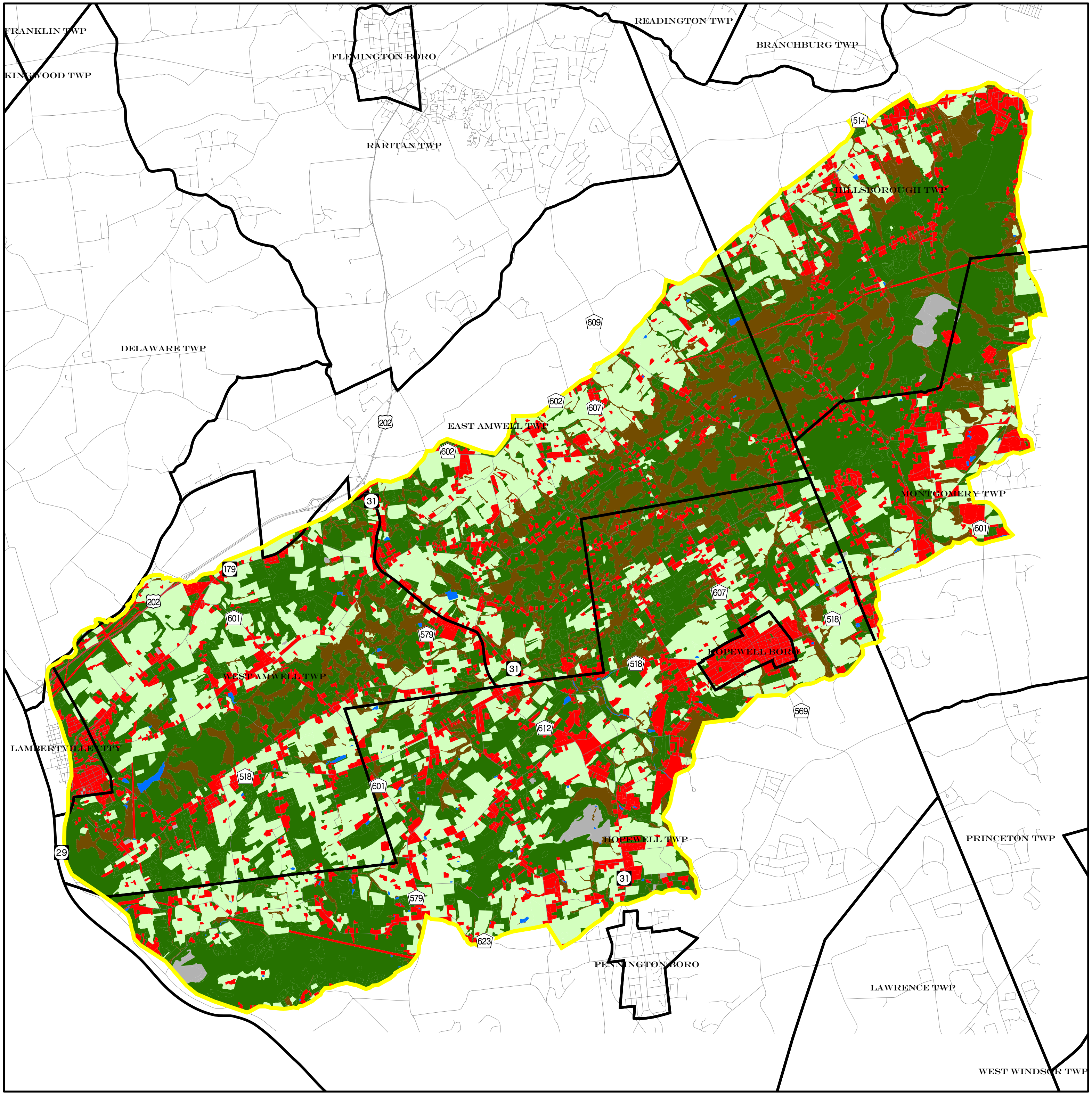

Figure 2
1995 Land Use/ Land Cover

The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 2 Miles

Legend

- Agricultural Land
- Agricultural Wetlands
- Other Agriculture
- Brush Covered Field
- Altered Lands
- Commercial
- Industrial
- Brush/Shrubland
- Coniferous Forest
- Deciduous Forest
- Mixed Forest
- Coniferous Wooded Wetlands
- Deciduous Wooded Wetlands
- Mixed Wooded Wetlands
- Disturbed Wetlands
- Managed Wetland
- Exposed Rock
- Mining
- Other Urban
- Recreational Land
- Residential
- Residential, High Density
- Transitional Areas
- Transportation and Utilities
- Water
- Wetlands

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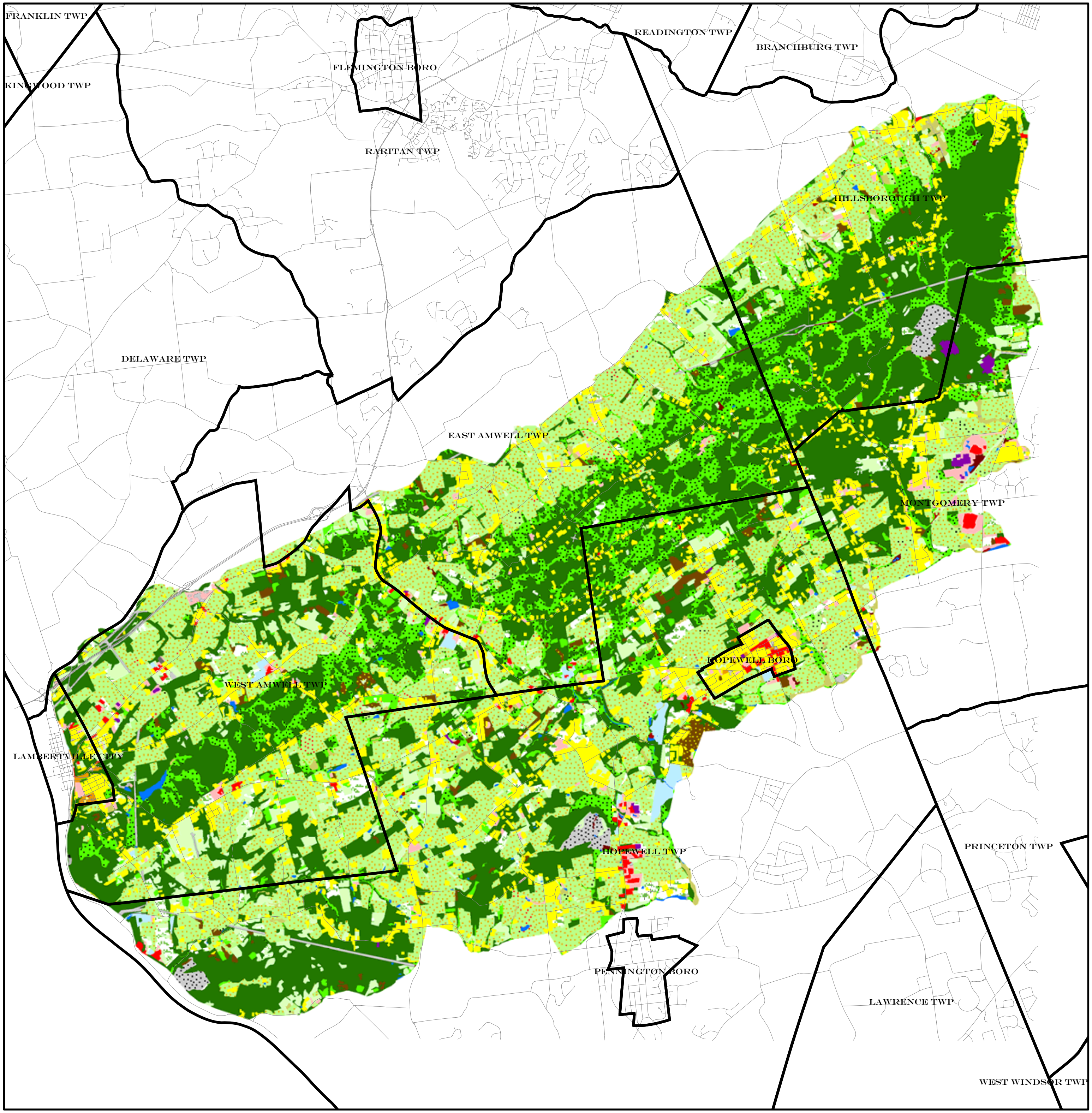

Figure 3
Land Use/Land Cover Comparison 1972, 1986 and 1995

The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 2 3 4 Miles

Legend

- Bare Land
- Cultivated/Grassland
- Developed
- Palustrine Wetland
- Upland Forest
- Water

Data Sources 1972:
New Jersey 1972 Level ILand Cover Classification,
Originator - Grant F. Walton Center for Remote
Sensing and Spatial Analysis Rutgers University,
Source Data Resolution - 80 meters x 80 meters.

Data Sources 1986:
1986 Land Use/Land Cover for Somerset County,
New Jersey, Originator - NJDEP, OIRM, BGIA,
Source Scale 1:24,000.

Data Sources 1995:
New Jersey 1995 Level ILand Cover Classification,
Originator - Grant F. Walton Center for Remote
Sensing and Spatial Analysis Rutgers University,
Source Data Resolution - 80 meters x 80 meters.

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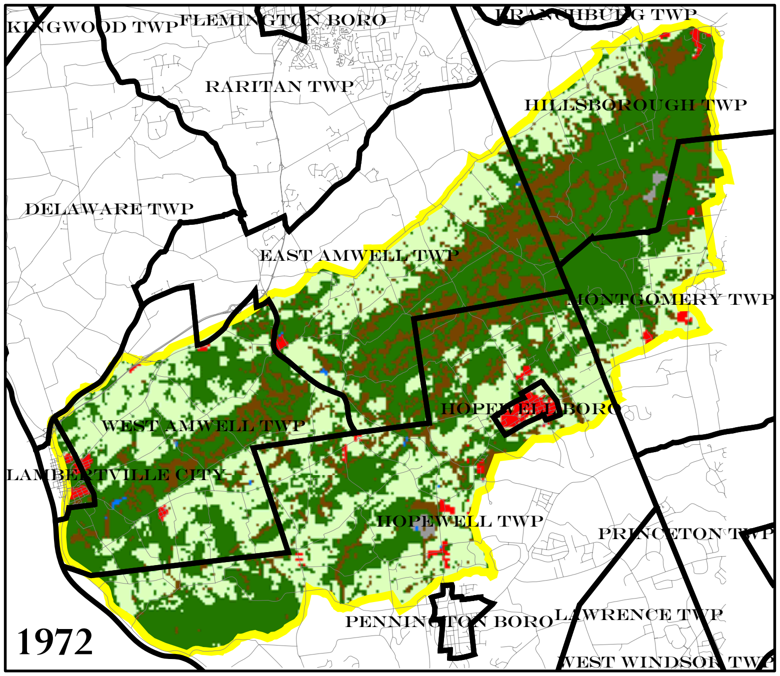

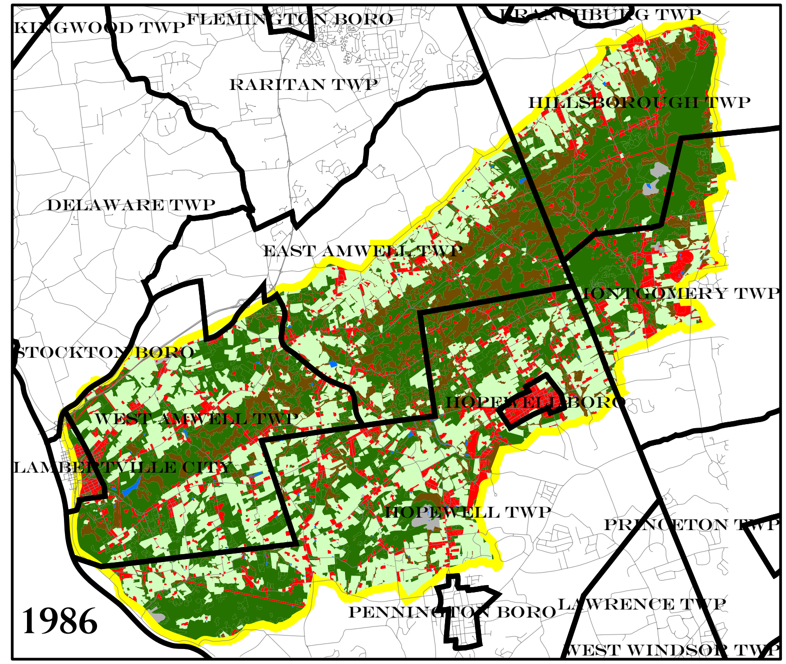

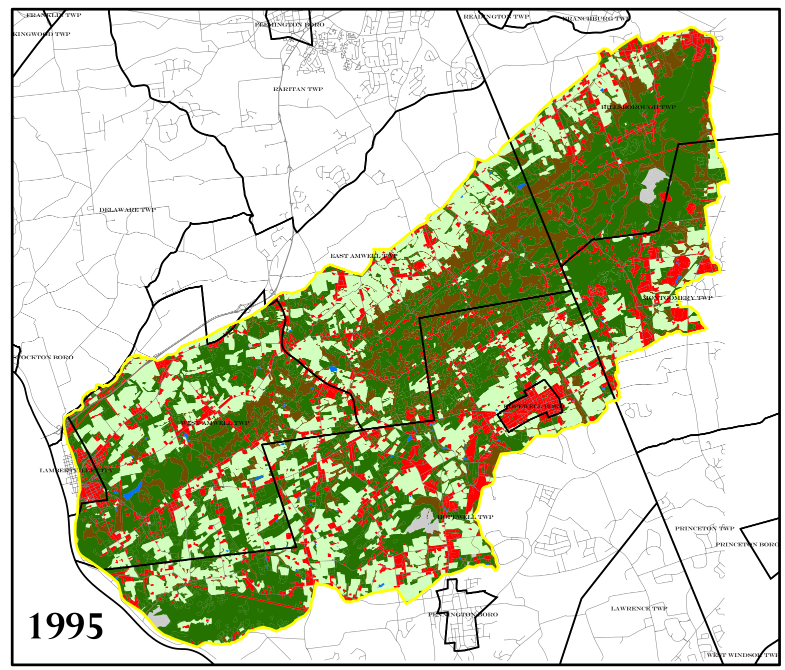

Figure 4

1995 Forested Areas and Forested Area Change

The Sourland Mountain Region
A Portion of Central New Jersey

0 0.5 1 2 Miles

Legend

- New Forest Areas Since 1986
- Forested Areas Converted to Other Uses
- Brush Covered Field
- Brush/Shrubland
- Coniferous Forest
- Deciduous Forest
- Mixed Forest
- Coniferous Wooded Wetlands
- Deciduous Wooded Wetlands
- Mixed Wooded Wetlands

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Data Sources:
1995 Land Use/Land Cover Edition 1.3 - WMA 10 (Millstone Watershed Management Area), Originator - NJDEP, OIRM, BGIA, Source Scale 1:12,000.

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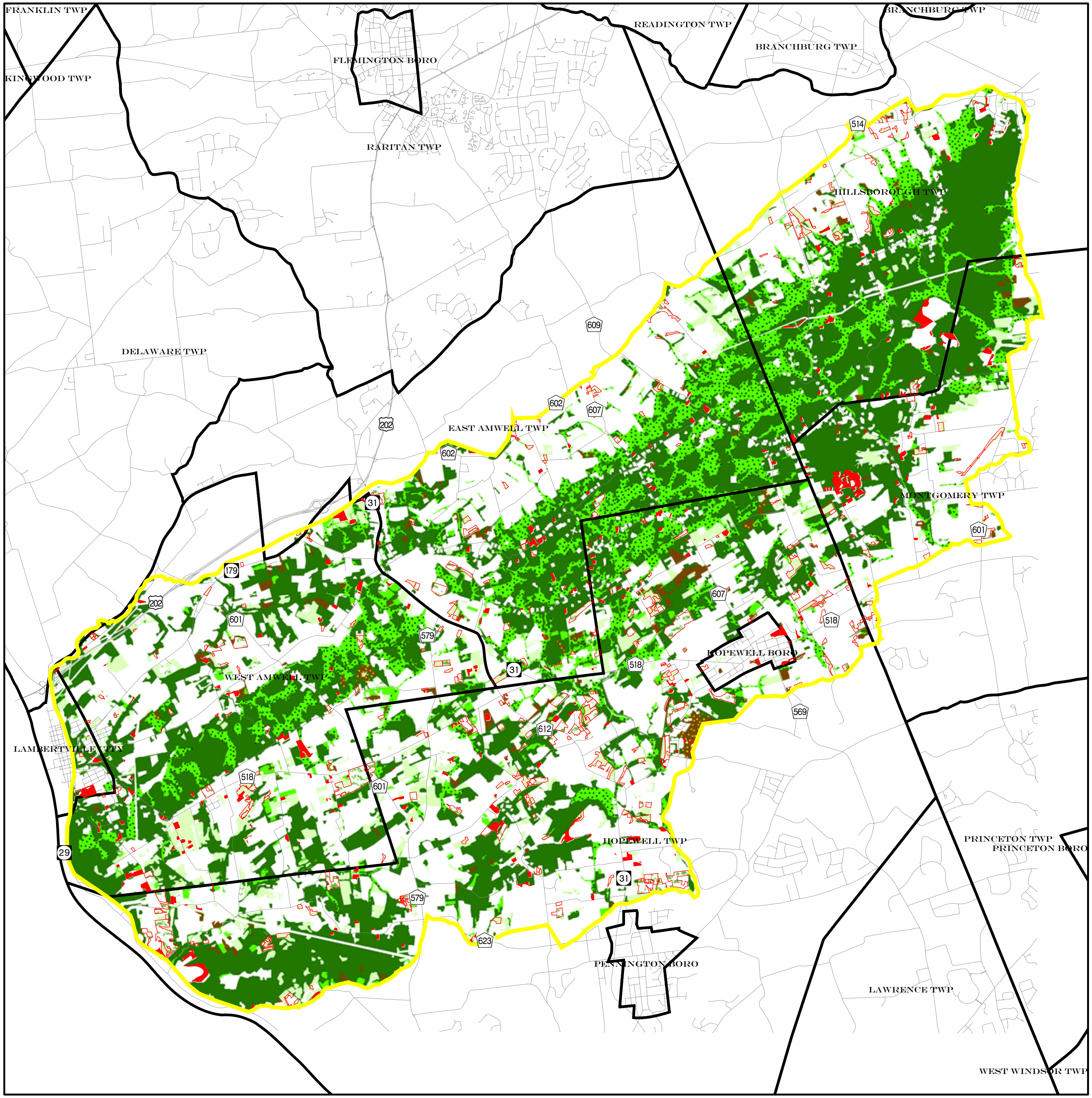

Figure 5
Forest Patch 1
East of State Route 31

The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1
Miles

Legend

- Brush Covered Field
- Brush/Shrubland
- Coniferous Forest
- Deciduous Forest
- Mixed Forest
- Coniferous Wooded Wetlands
- Deciduous Wooded Wetlands
- Mixed Wooded Wetlands

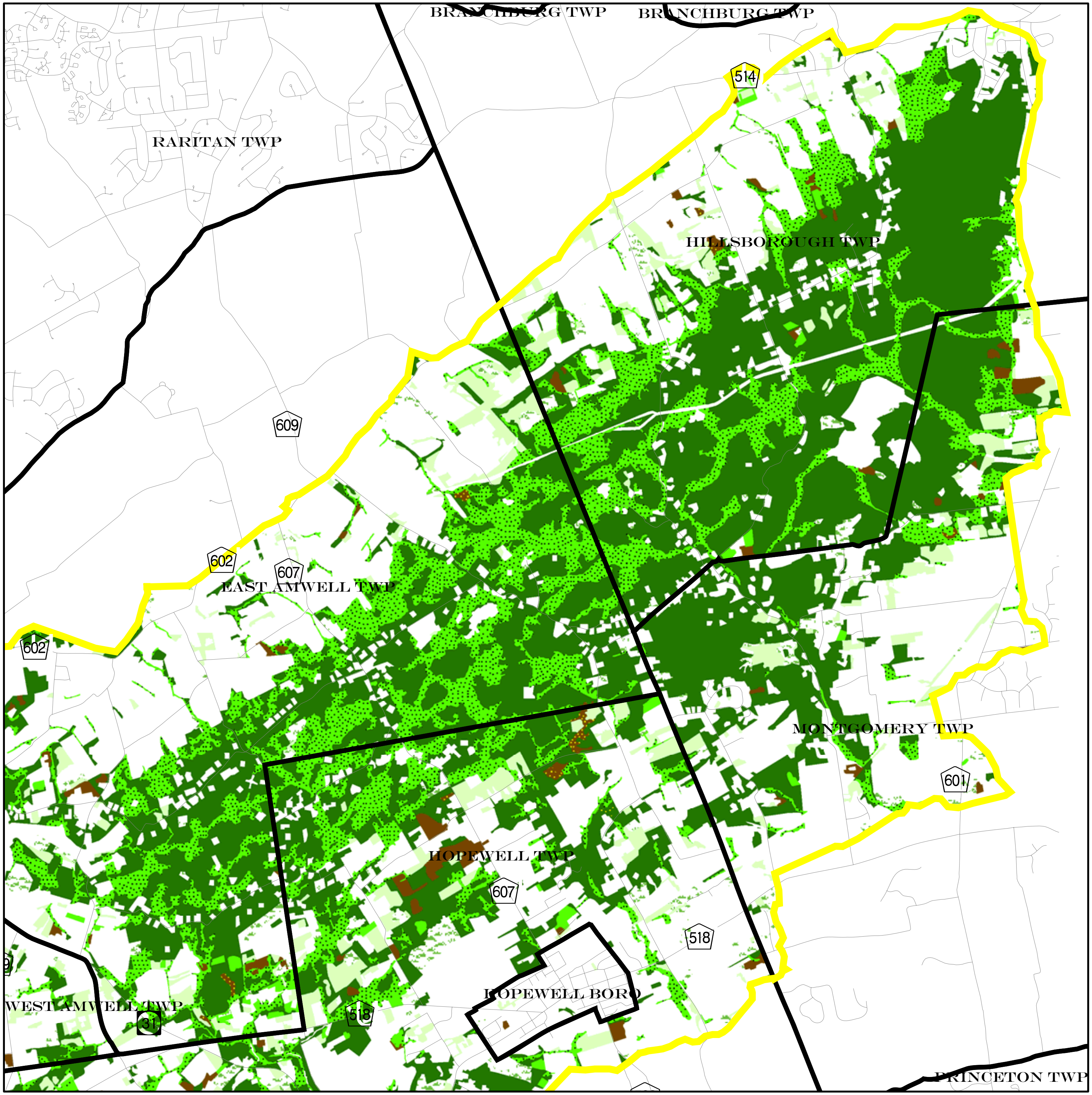

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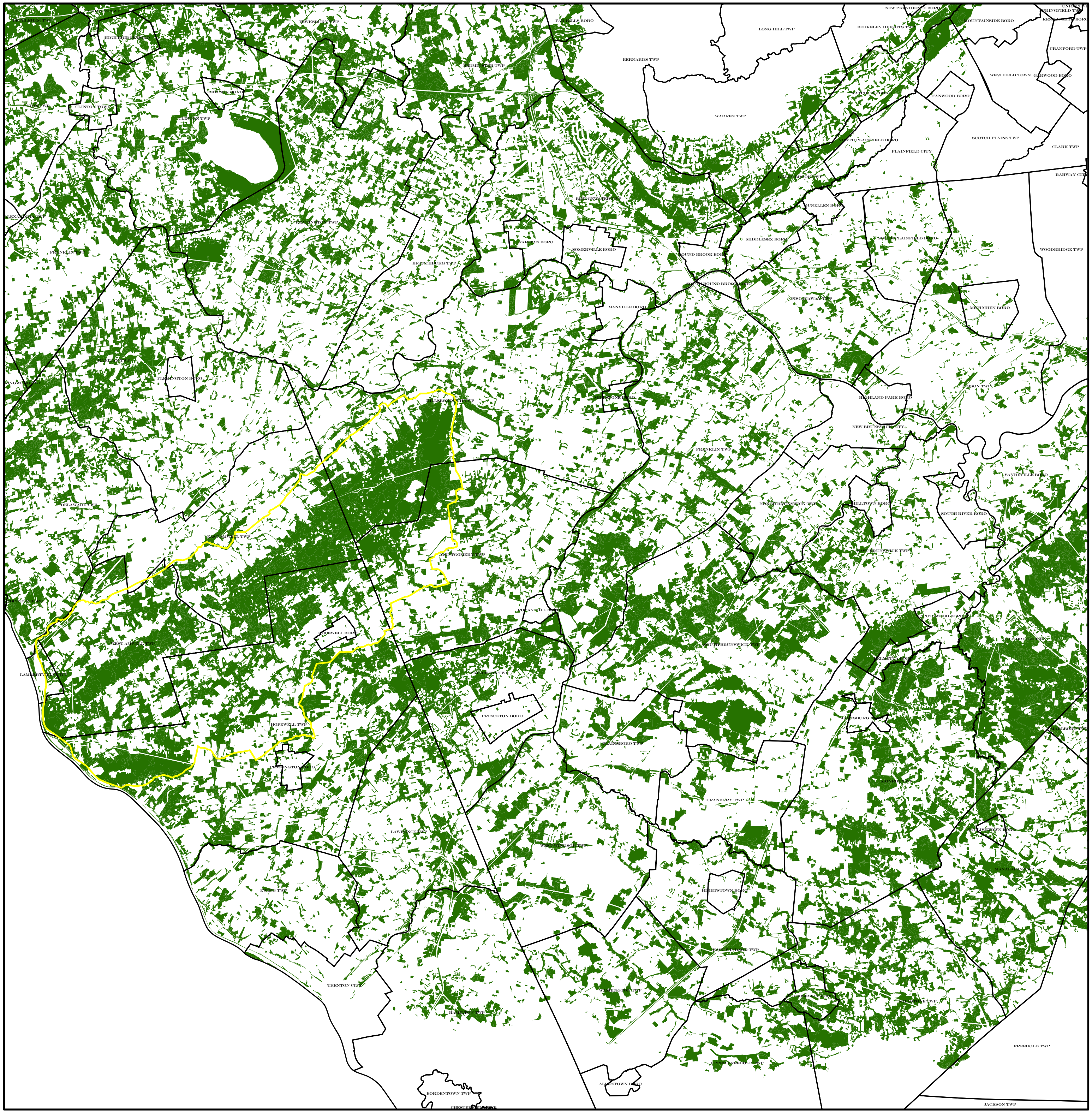
Figure 6
Forested Areas of Central New Jersey

The Sourland Mountain Region
A Portion of Central New Jersey

0 0.5 1 2 3 4 5
Miles

Legend

Forested Areas



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Data Sources:
1995 Land Use/Land Cover Edition 1.3 - WMA 10 (Millstone Watershed Management Area), Originator - NJDEP, OIRM, BGIA, Source Scale 1:12,000.

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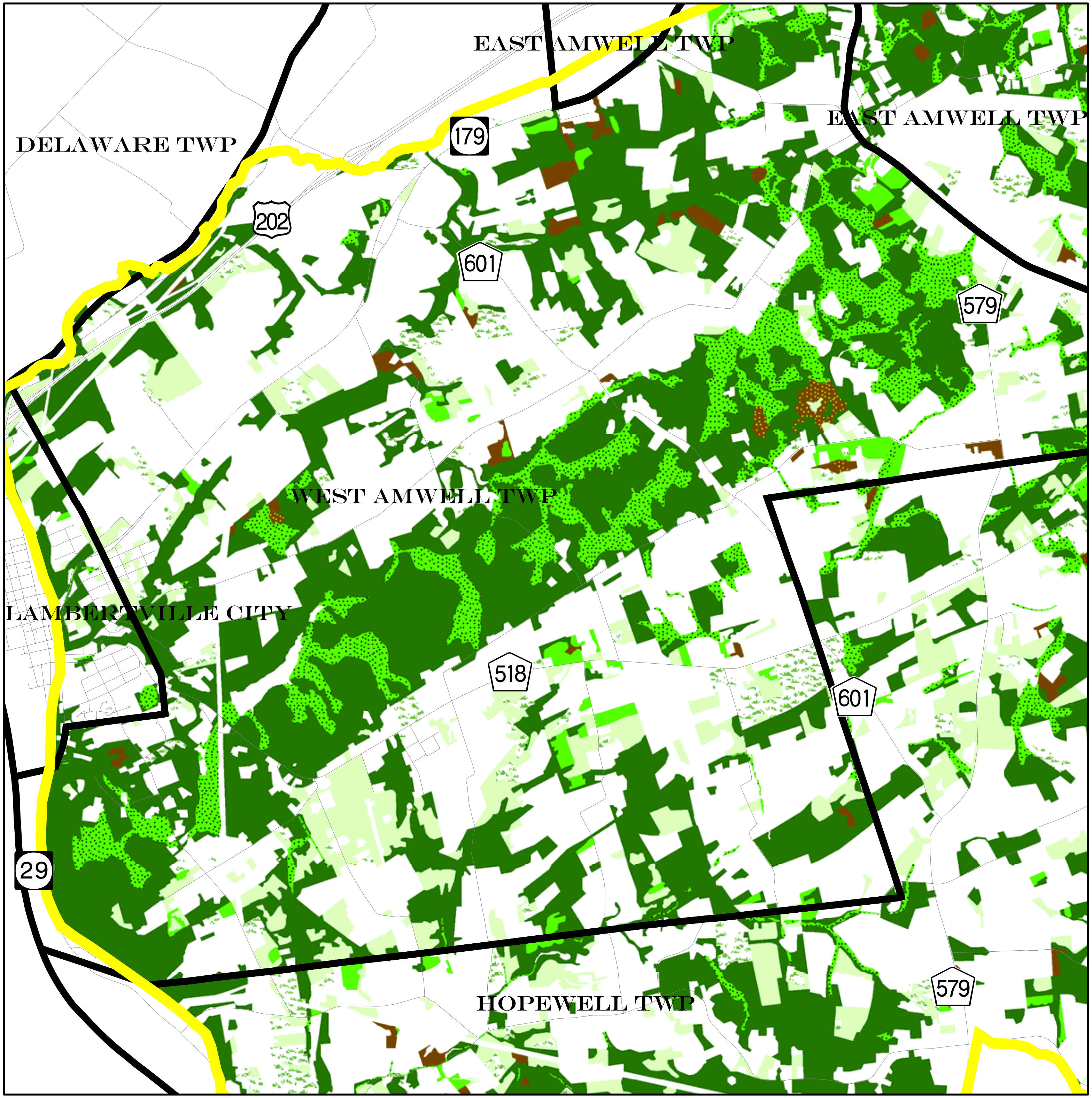
Figure 7
Forest Patch 2
West of State Route 31

The Sourland Mountain Region
A Portion of Central New Jersey

0 0.5 1 Miles

Legend

- Brush Covered Field
- Brush/Shrubland
- Coniferous Forest
- Deciduous Forest
- Mixed Forest
- Coniferous Wooded Wetlands
- Deciduous Wooded Wetlands
- Mixed Wooded Wetlands



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Data Sources:
1995 Land Use/Land Cover Edition 1.3 - WMA 10 (Millstone Watershed Management Area), Originator - NJDEP, OIRM, BGIA, Source Scale 1:12,000.

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Figure 8

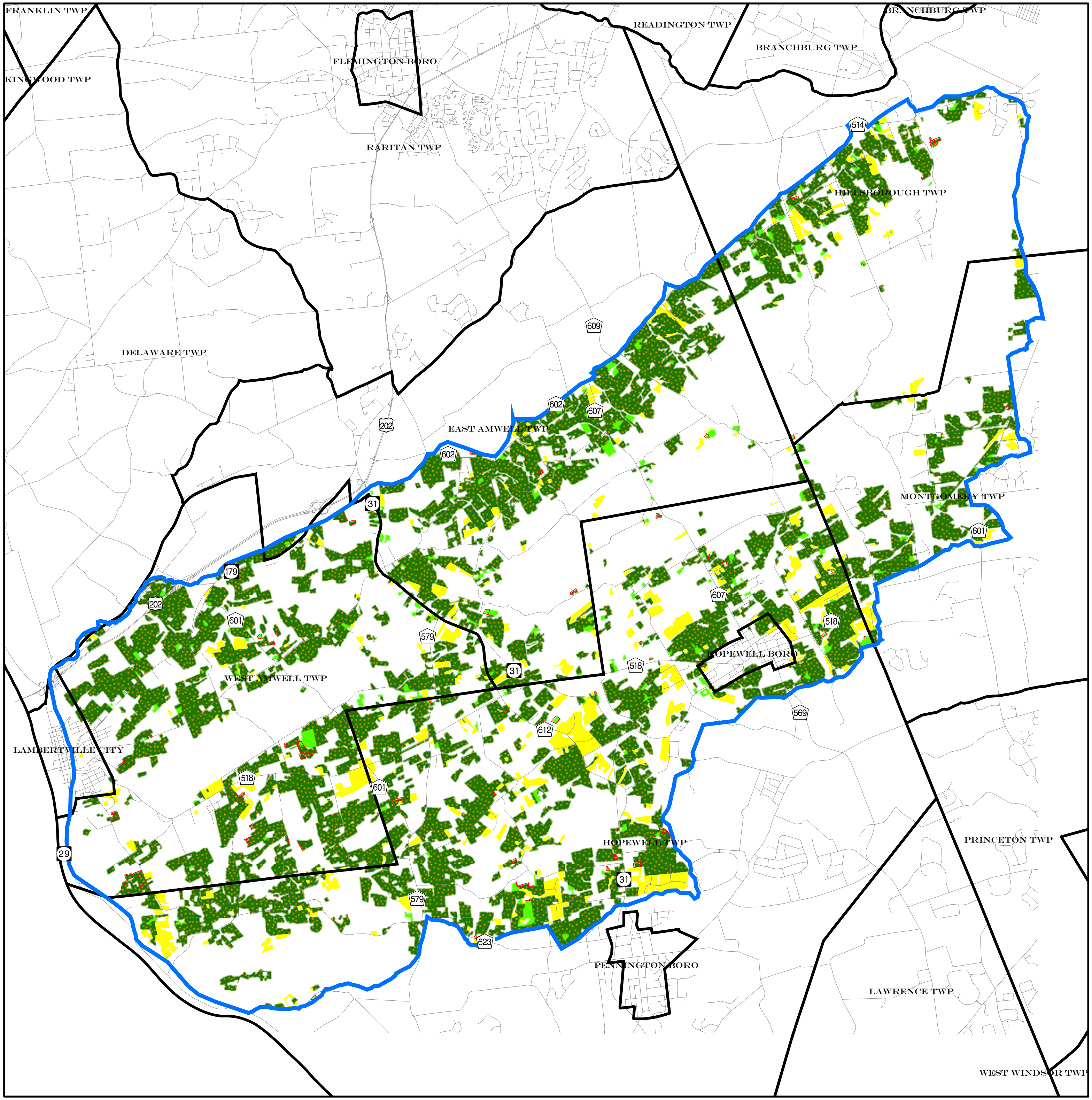
1995 Existing Agriculture and Agricultural Change

The Sourland Mountain Region
A Portion of Central New Jersey

0 0.5 1 2 Miles

Legend

- New Agriculture Since 1986
- Agriculture Converted to Other Use Since 1986
- Agricultural Land
- Other Agriculture



This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
1995 Land Use/Land Cover Edition 1.3 - WMA 10 (Millstone Watershed Management Area), Originator - NJDEP, OIRM, BGIA, Source Scale 1:12,000.

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Figure 9

Bedrock Geology

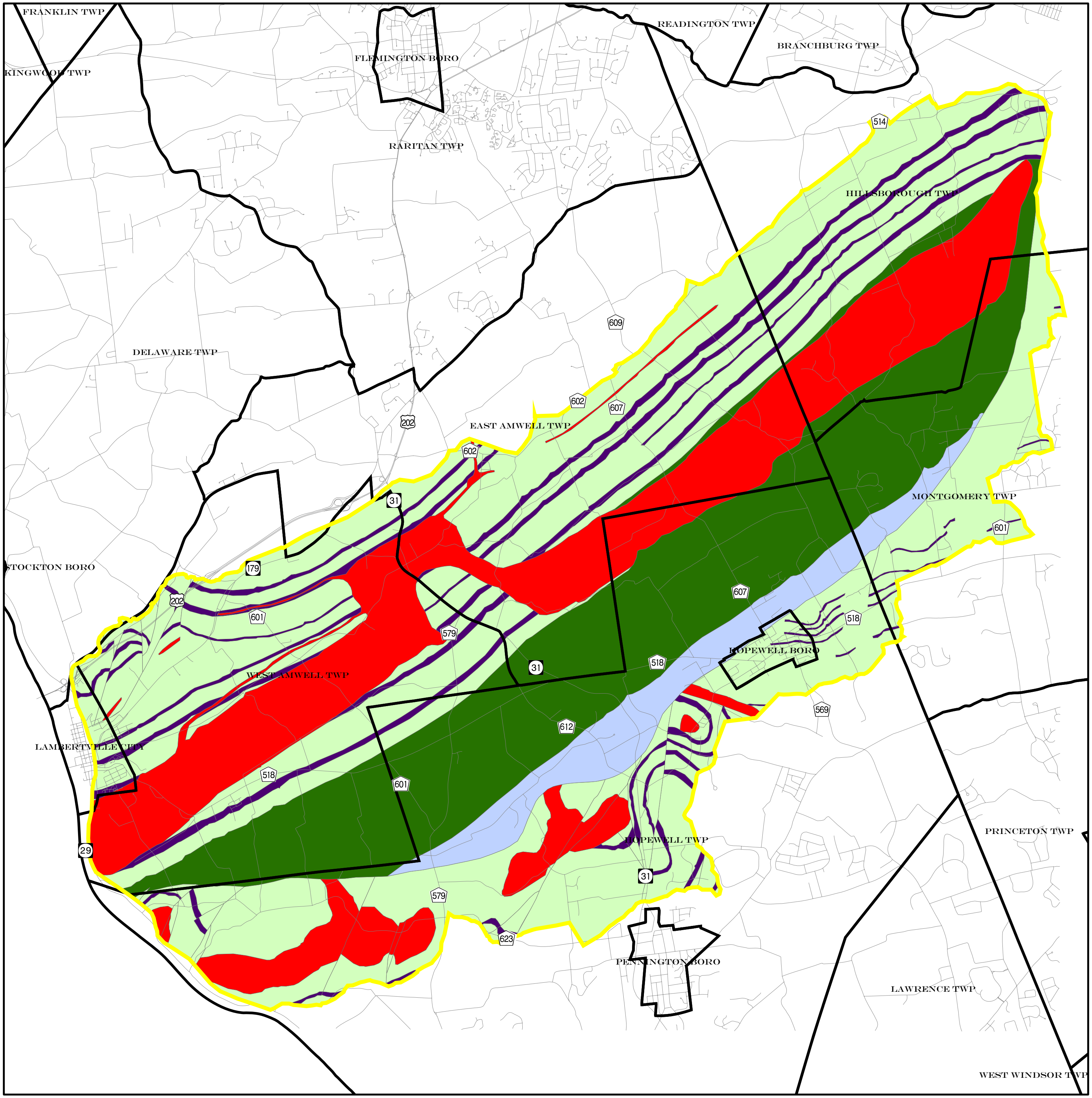
The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 Miles

Legend

- Jurassic Diabase
- Lockatong Formation
- Passaic Formation
- Passaic Formation Gray bed
- Stockton Formation



This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
"Bedrock Geology and Topographic Base Maps of NJ",
CD Series CD 00-1, Originator - New Jersey Geological Survey,
Source Data Scale - 1:100,000

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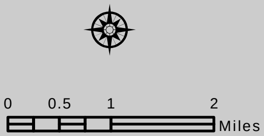
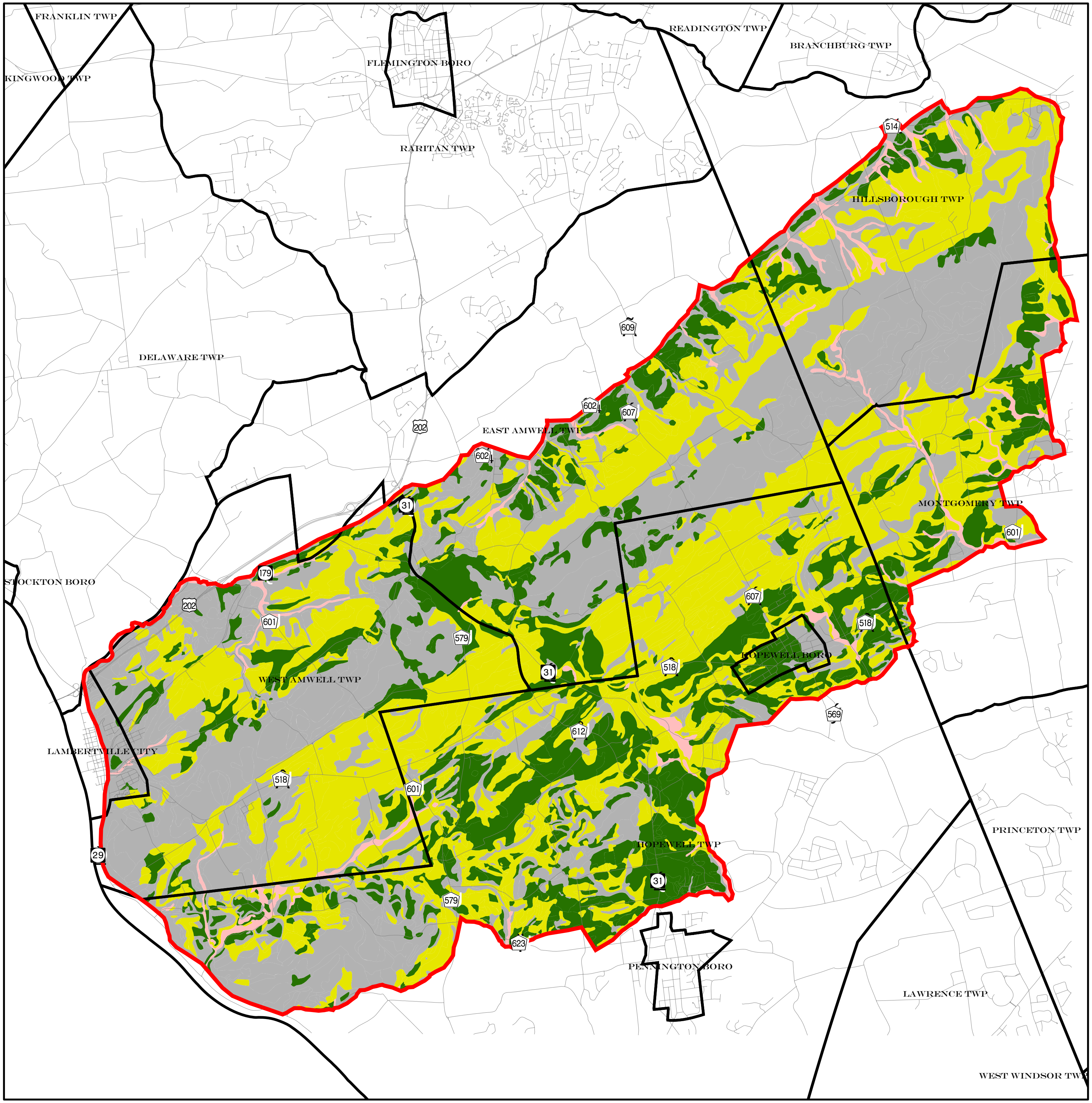
Figure 10
Agriculturally Significant Soils
The Sourland Mountain Region
A Portion of Central New Jersey



Legend

- Prime Soil
- Statewide Important Soil
- Farmland of Local Importance
- No Class



Data Sources:
Soil Survey Database for Somerset County, Originator - U.S. Department of Agriculture, Natural Resources Conservation Service, Source Data Scale - 1:15,840
"New Jersey Important Farmlands Inventory", Originator - New Jersey Natural Resources Conservation Service, September 24, 1990.

Note:
This map was created by recoding data contained in the SSURGO database created by U.S. Department of Agriculture, Natural Resources Conservation Service. Information in the "New Jersey Important Farmlands Inventory", published by the New Jersey Natural Resources Conservation Service in September 24, 1990, is the source applied to the SSURGO database to determine soils which are prime, statewide important or locally important in nature.

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Figure 11

Soil Suitability Classes - N.J.A.C. 7:9A

The Sourland Mountain

A Portion of Central New Jersey

0 0.5 1 2 Miles

Legend

- I; IISc
- I; IISr
- I; IIWr:IIWrSc; IISc
- I; IIWr; IISc; IIWrSc
- IISc
- IISr
- IISc; I
- IISc; IISr
- IISc; IIISr
- IIIHr
- IIIHr, Wp(IISc); IISr, Wp (IISc)
- IIIHrWp
- IIIHrWp(IISc); IIWpSrSc; IIWrSc
- IIIHrWp; IIIHrWp(IISc); IIIHrWp(IISr)
- IIIHrWpWr
- IIISrWp
- IIISrWp(IIHc)
- IIISrWp; IIIHrWp
- IIISrWp; IIIHrWp(IISc)
- IIISrWp; IIISrWr
- IIISrWr
- IIIWp(IISr)
- IIIWr
- Udorthents
- Water
- Disturbed Ground
- Excessively Stony

Data Sources:
Soil Survey Database for Somerset County, Originator - U.S. Department of Agriculture, Natural Resources Conservation Service, Source Data Scale - 1:15,840
"Standards for Individual Subsurface Disposal Systems", State of New Jersey Administrative Code, N.J.A.C. 7:9A, New Jersey Department of Environmental Protection, Division of Water Quality, Bureau of Non-Point Pollution Control, August 15, 1999.

Note:
In order to display soil suitability classes as defined in N.J.A.C 7:9A, soil polygons as mapped by the USDA NRCS were recoded by soil series. Specific data on soil suitability classes was derived from Appendix D of "Standards for Individual Subsurface Disposal Systems", State of New Jersey Administrative Code, N.J.A.C. 7:9A, New Jersey Department of Environmental Protection, Division of Water Quality, Bureau of Non-Point Pollution Control, August 15, 1999.

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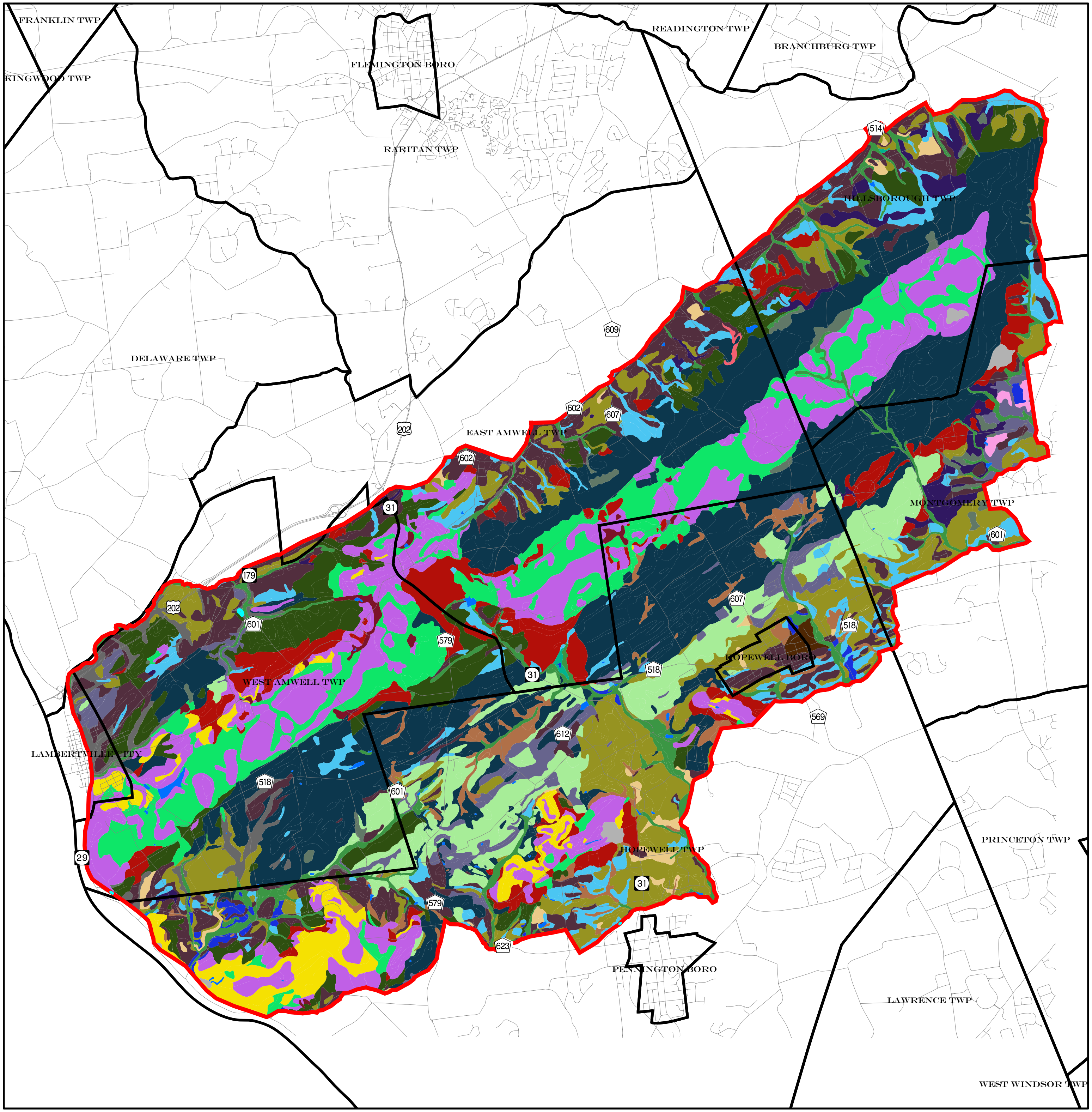


Figure 12
Soils Generally Unsuitable for Septic Systems - N.J.A.C. 7:9A

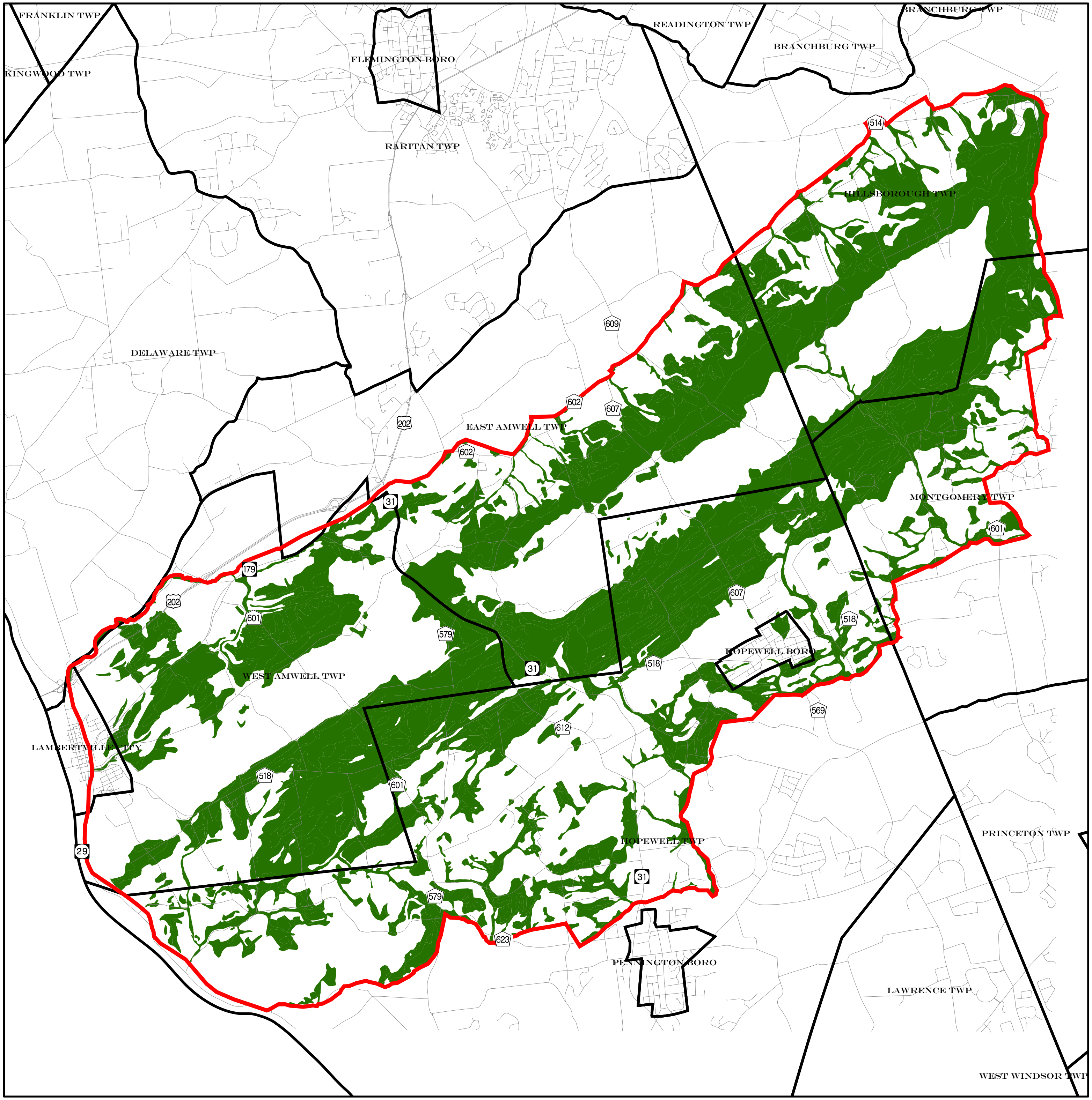
The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 2 Miles

Legend

Soils Generally Unsuitable for Septic



Data Sources:
Soil Survey Database for Somerset County, Originator - U.S. Department of Agriculture, Natural Resources Conservation Service, Source Data Scale - 1:15,840
"Standards for Individual Subsurface Disposal Systems", State of New Jersey Administrative Code, N.J.A.C. 7:9A, New Jersey Department of Environmental Protection, Division of Water Quality, Bureau of Non-Point Pollution Control, August 15, 1999.

Note:
"Soils Generally Unsuitable for Septic Systems", as depicted on this map, were derived from Table 10.1 of "Standards for Individual Subsurface Disposal Systems", State of New Jersey Administrative Code, N.J.A.C. 7:9A, New Jersey Department of Environmental Protection, Division of Water Quality, Bureau of Non-Point Pollution Control, August 15, 1999. Table 10.1 lists soils which the Department classifies as unsuitable for septic system installation based on soil suitability class.

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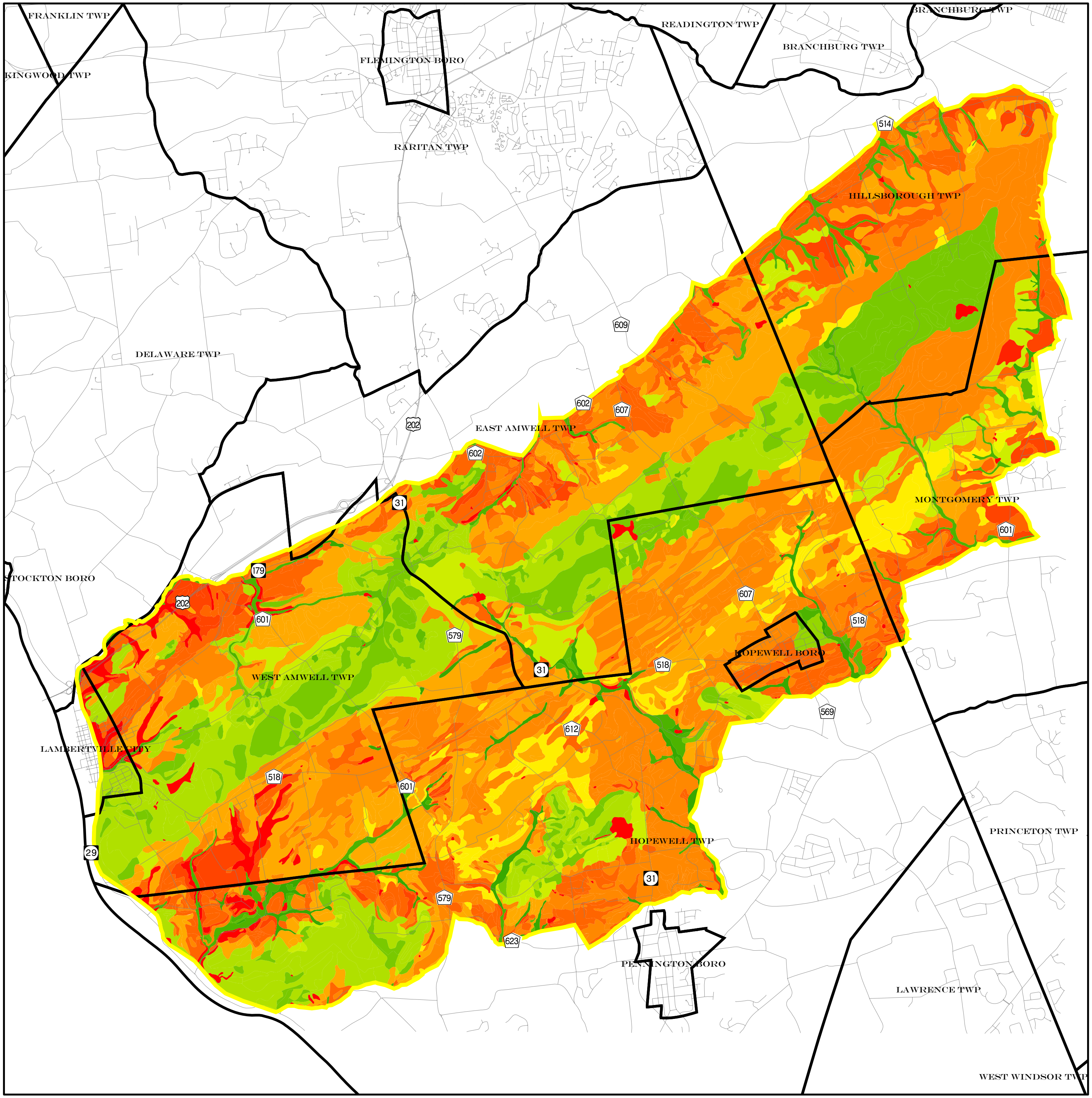
Figure 13
Depth to Bedrock

The Sourland Mountain Region
A Portion of Central New Jersey

0 0.5 1
Miles



Legend

- 0 Inches
- 10 Inches
- 10 to 20 Inches
- 20 to 40 Inches
- 40 Inches
- 40 to 60 Inches
- 40 to 72 Inches
- 42 Inches
- 42 to 60 Inches
- 48 Inches
- 48 to 60 Inches
- 48 to 72 Inches
- 48 to 99 Inches
- 60 Inches
- 72 Inches
- 72 to 99 Inches

Data Sources:
Soil Survey Database for Somerset County, Originator - U.S. Department of Agriculture, Natural Resources Conservation Service, Source Data Scale - 1:15,840

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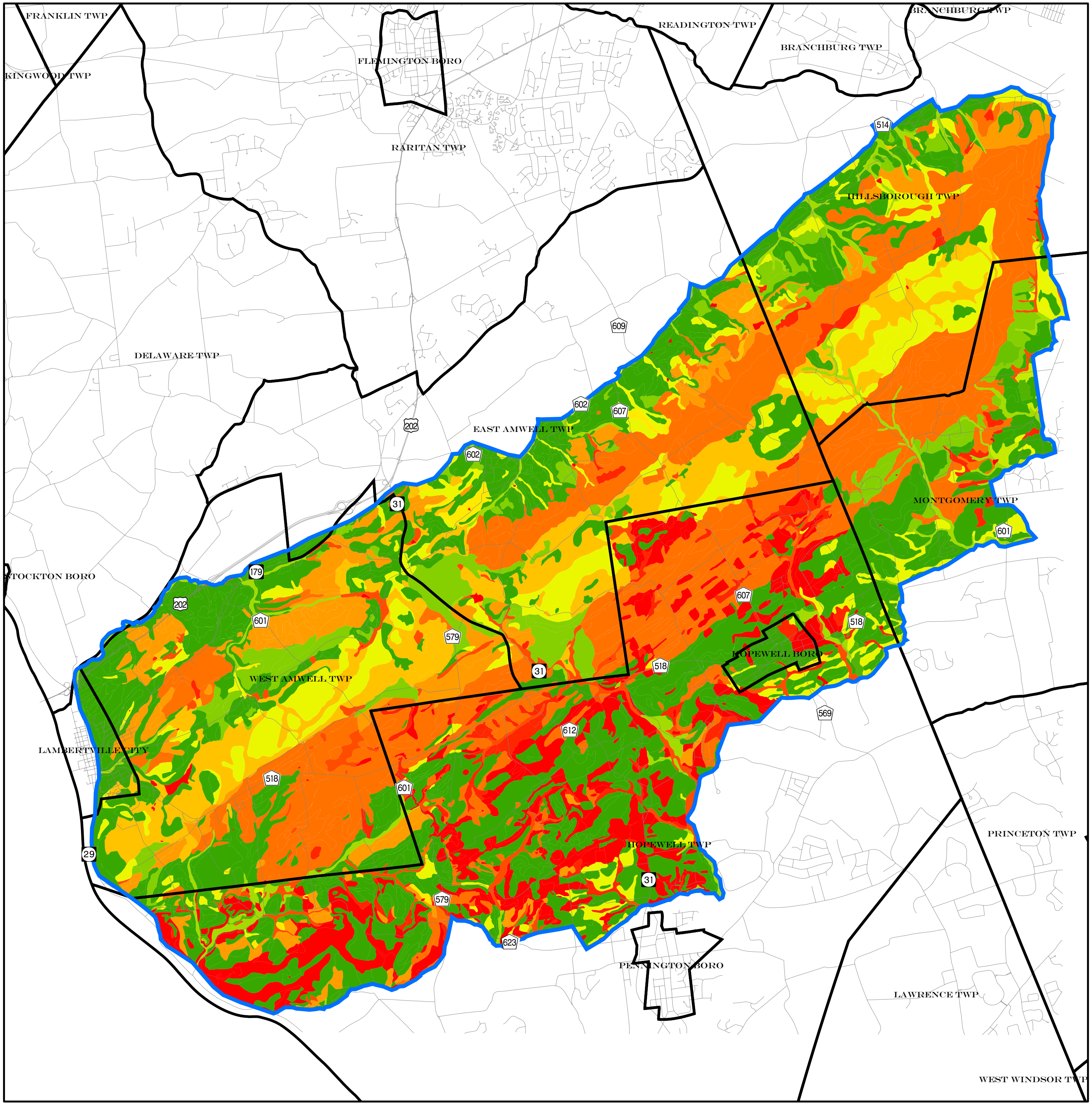
Figure 14
Depth to Seasonal High Water

The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 2 Miles



Legend

- 0 Feet
- 0 to 0.5 Feet
- 0 to 1 Feet
- 0.5 to 1.5 Feet
- 0.5 to 2 Feet
- 0.5 to 2.5 Feet
- 0.5 to 3 Feet
- 1 to 2 Feet
- 1 to 2.5 Feet
- 1 to 3 Feet
- 1.5 to 3 Feet
- 2 Feet
- 4 Feet
- 6 Feet

Data Sources:
Soil Survey Database for Somerset County, Originator - U.S. Department of Agriculture, Natural Resources Conservation Service, Source Data Scale - 1:15,840

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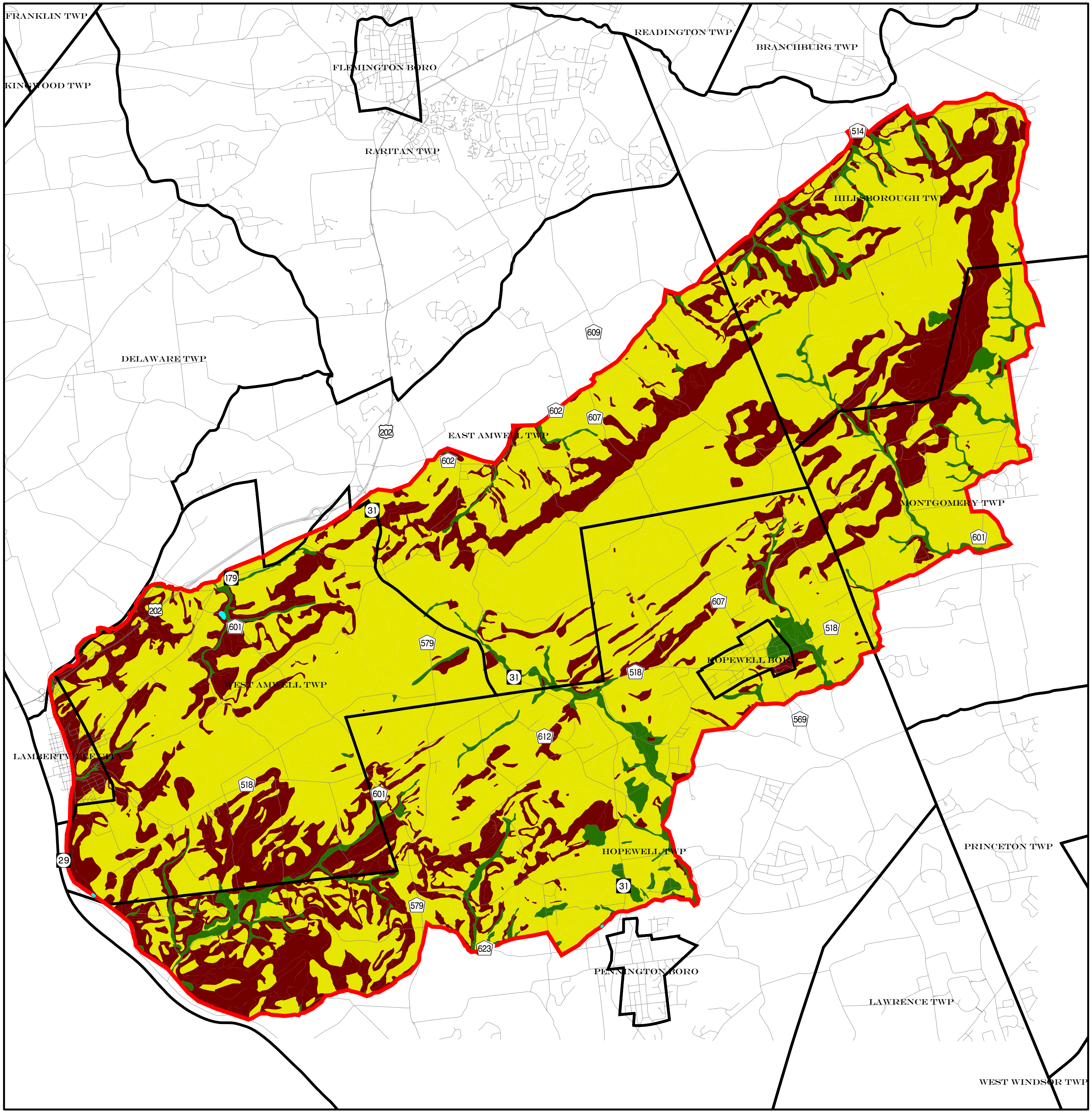
Figure 15

Highly Erodible Lands Class

The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 2 Miles



Legend

- Highly Erodible
- Potentially Highly Erodible
- Not Highly Erodible

Data Sources:
Soil Survey Database for Somerset County, Originator - U.S. Department of Agriculture, Natural Resources Conservation Service, Source Data Scale - 1:15,840

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Figure 16
Surface Waters and Drainage Areas

The Sourland Mountain

A Portion of Central New Jersey

0 0.5 1 2 Miles

Legend

- Major Drainage Basin Divide
- Alexauken Creek
- Back Brook
- Back Brook (Somerset)
- Baldwins Creek
- Beden Brook
- Cruser Brook
- D&R Canal
- Fiddler's Creek
- Jacob's Creek
- Moore Creek
- Neshanic River
- Pike Run
- Pleasant Run
- Rock Brook
- Royce Brook
- Stony Brook
- Swan Creek

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
"NJDEP 14 Digit Hydrologic Unit Code delineations for New Jersey", Originator - NJDEP and NJGS, Source Data Scale - 1:24,000.

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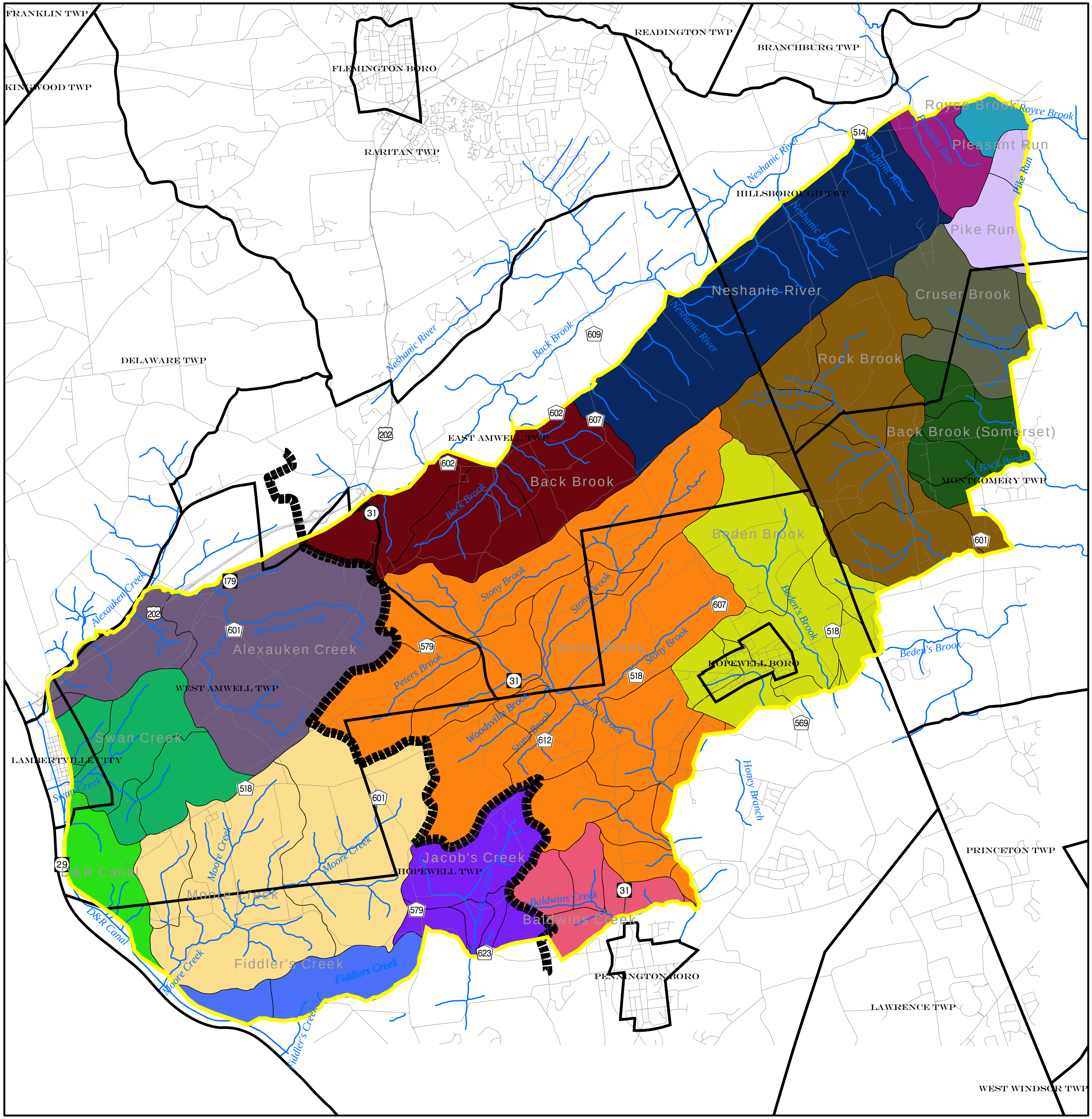

Figure 17

HUC 14 Subwatershed Boundaries

The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 Miles

Legend

- Major Drainage Basin Divide
- 02030105030050
- 02030105030060
- 02030105040010
- 02030105090010
- 02030105090020
- 02030105090030
- 02030105090040
- 02030105090050
- 02030105110040
- 02030105110050
- 02030105110060
- 02030105110070
- 02030105110080
- 02030105110090
- 02030105110100
- 02030105110150
- 02040105210010
- 02040105210020
- 02040105210030
- 02040105210040
- 02040105210050
- 02040105210060

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Source:
"NJDEP 14 Digit Hydrologic Unit Code delineations for New Jersey", Originator - NJDEP and NJGS, Source Data Scale - 1:24,000.

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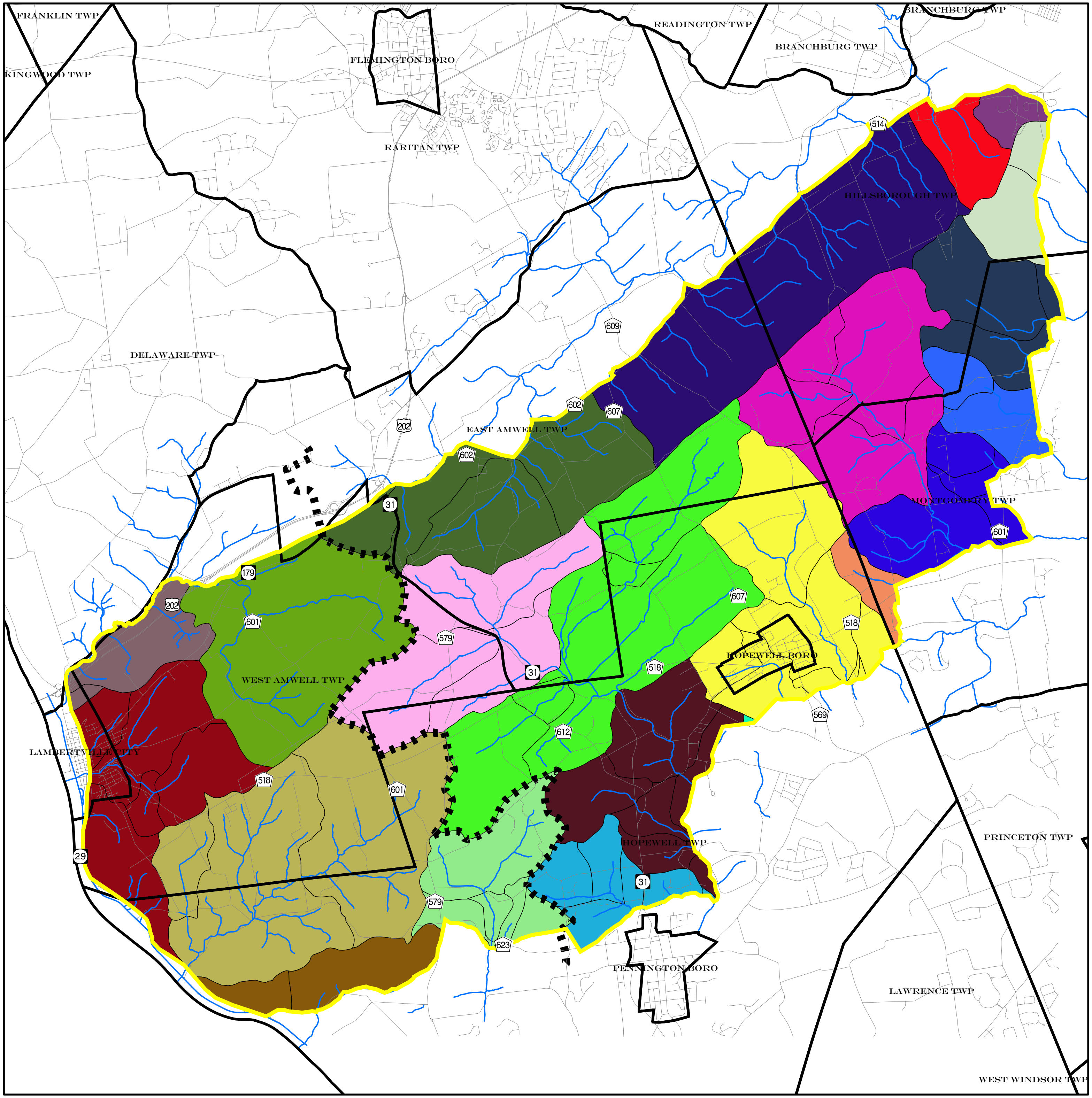

Figure 18
AMNET Biological Monitoring Sites

The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 2 Miles

Legend

AMNET Monitoring Site

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Source:
"NJDEP Ambient Biomonitoring Network (AMNET) 2000", Originator - New Jersey Department of Environmental Protection (NJDEP), Bureau of Freshwater Biological Monitoring (BFBM), Source Data Scale - 1:24,000

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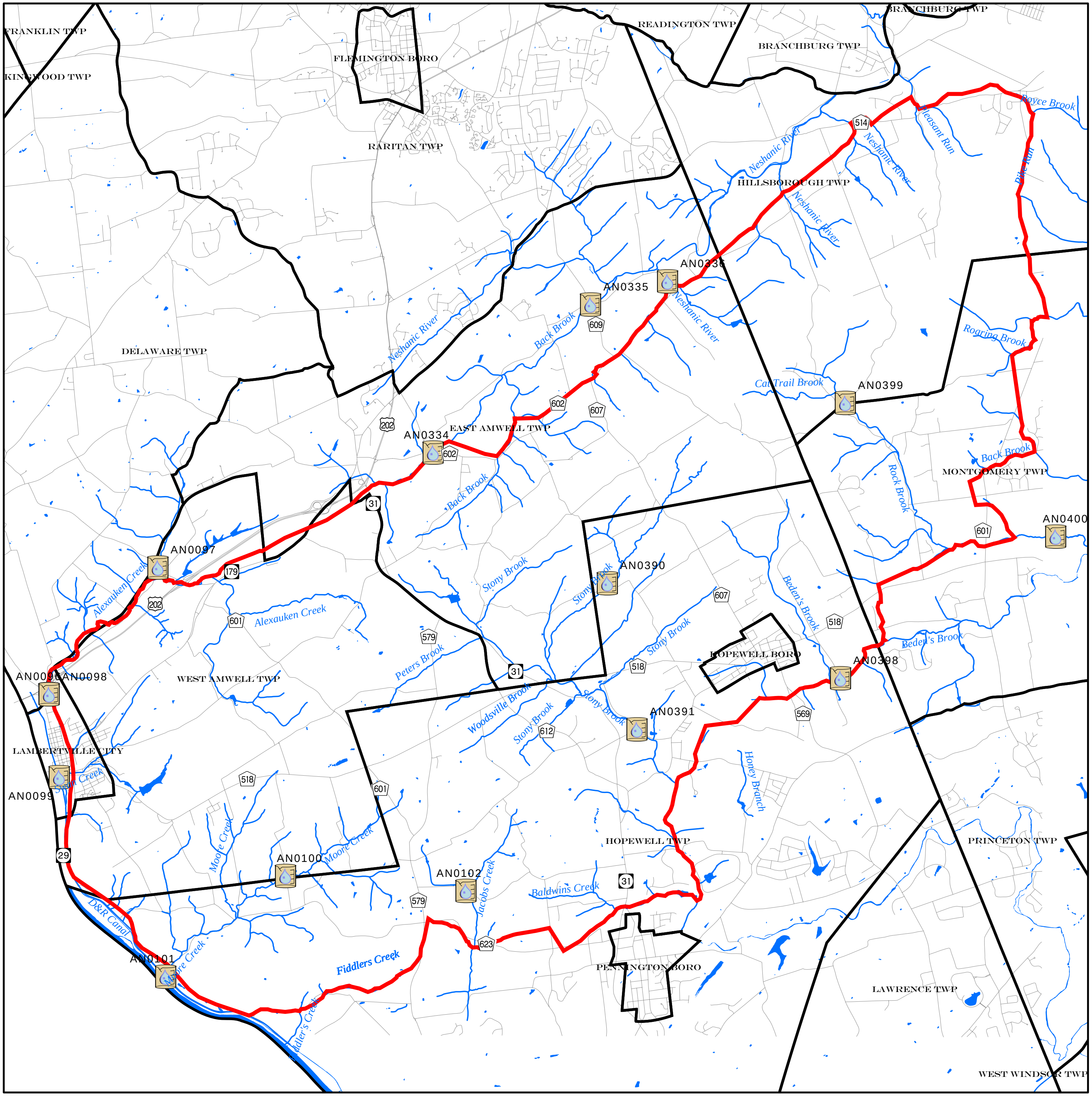
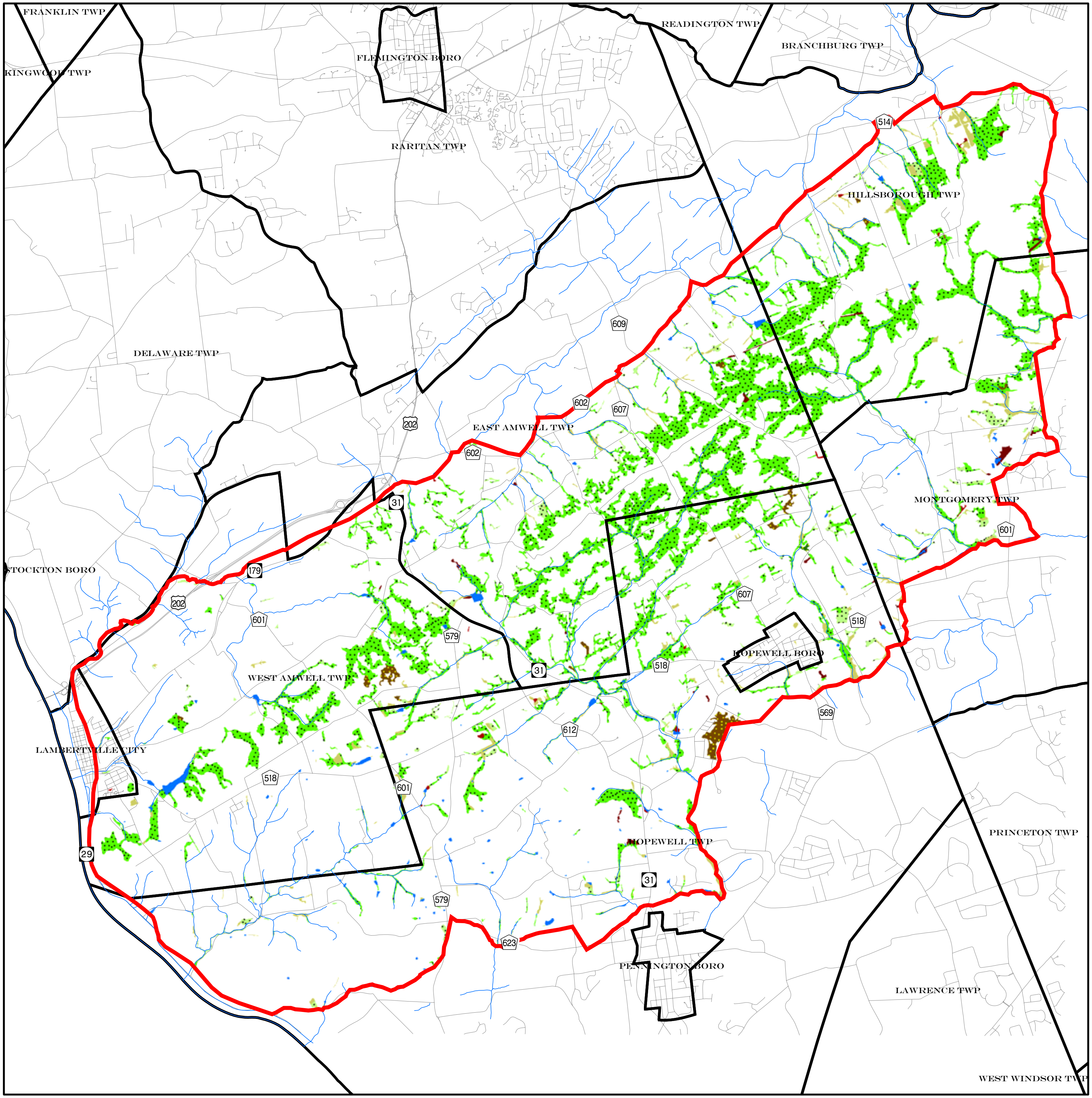


Figure 19
Wetlands
The Sourland Mountain Region
A Portion of Central New Jersey

0 0.5 1 Miles



Legend

- Agricultural Wetlands
- Coniferous Wooded Wetlands
- Deciduous Wooded Wetlands
- Mixed Wooded Wetlands
- Disturbed Wetlands
- Managed Wetland
- Water
- Wetlands

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
1995 Land Use/Land Cover Edition 1.3 - WMA 10 (Millstone Watershed Management Area), Originator - NJDEP, OIRM, BGIA, Source Scale 1:12,000.

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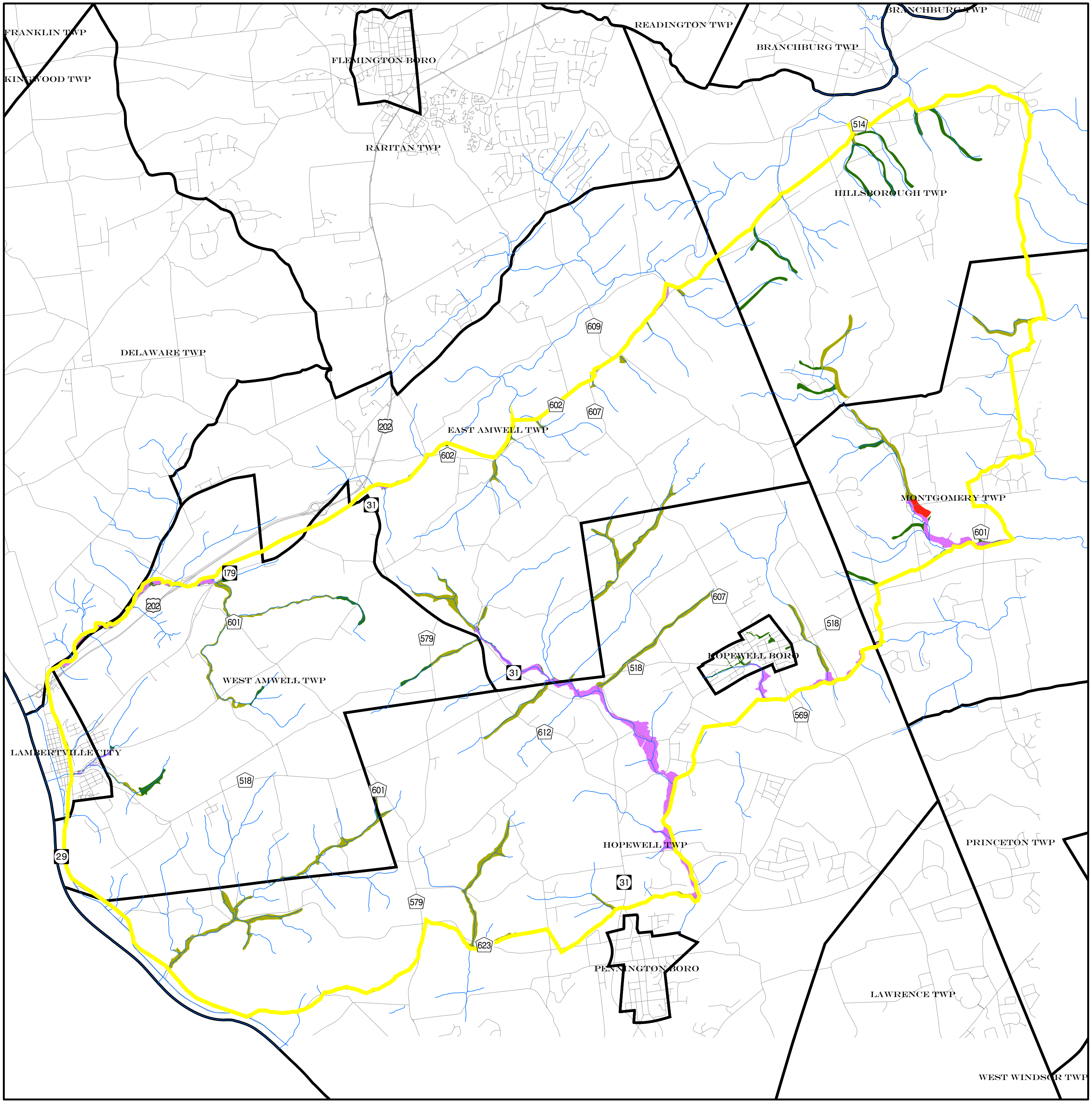
Figure 20

FEMA Floodzones

The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 2 Miles



Legend

- 100-Year Floodplain - No BFE's Determined
- 100-Year Floodplain - BFE's Determined
- 100-Year Floodplain - Average Depths Determined
- 500-Year Floodplain

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
"Q3 Digital Flood Data", Originator - FEMA, Source Data Scale 1:24,000.

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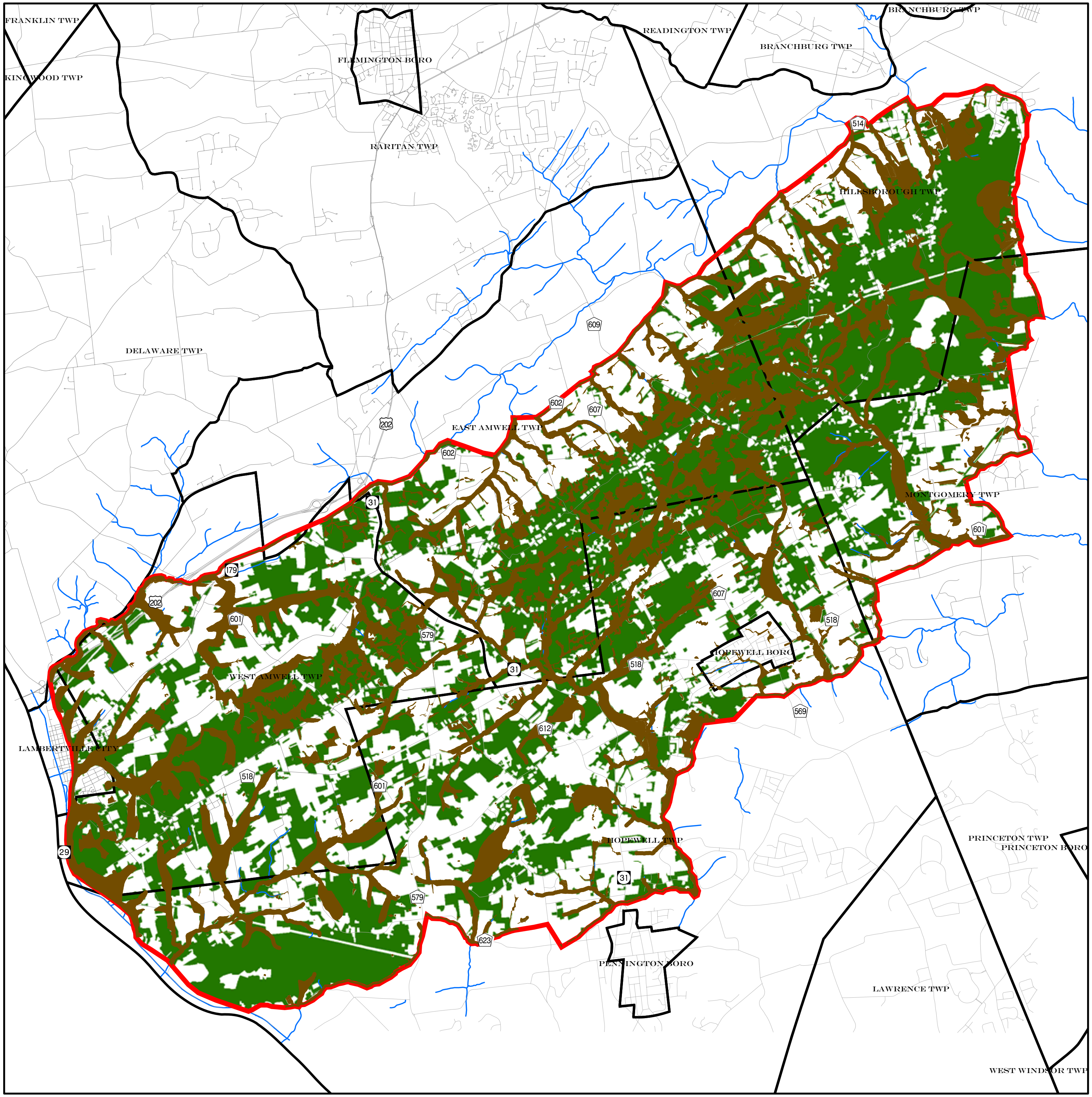
Figure 21

Riparian Areas and 1995 Forested Areas

The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 2
Miles



Legend

1995 Forested Areas

Riparian Areas

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
1995 Land Use/Land Cover Edition 1.3 - WMA 10 (Millstone Watershed Management Area), Originator - NJDEP, OIRM, BGIA, Source Scale 1:12,000.
"NJDEP Ambient Biomonitoring Network (AMNET) 2000", Originator - New Jersey Department of Environmental Protection (NJDEP), Bureau of Freshwater Biological Monitoring (BFBM), Source Data Scale - 1:24,000
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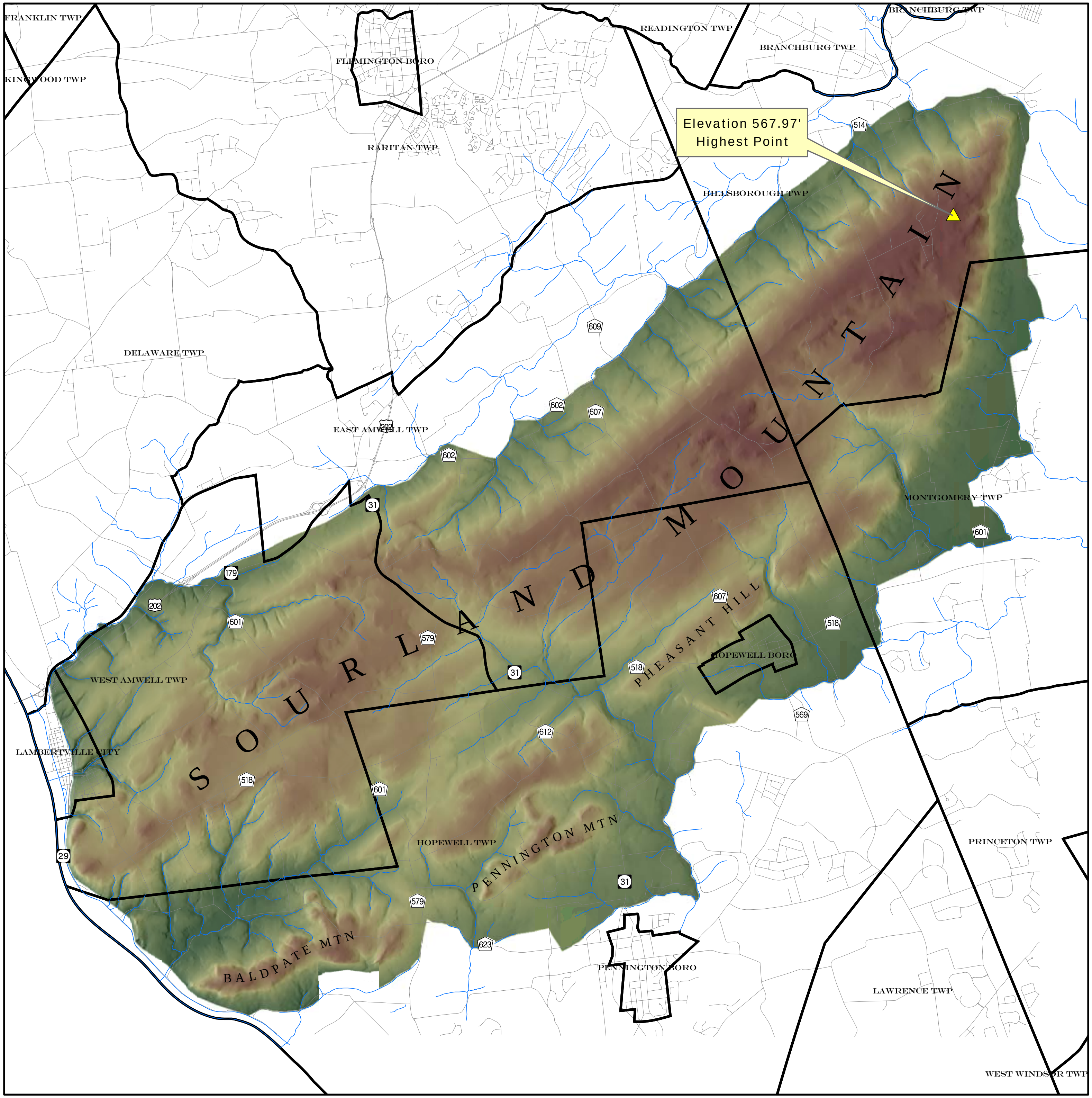
Figure 22

Topographic Features

The Sourland Mountain Region

A Portion of Central New Jersey



0 0.5 1 Miles

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
GIS DEM (10 Foot Grid), NAVD 88,
derived fromTIN interpolated from 2 foot DTM based on
1996 1"=100' groundscale orthophotography by ProMaps, Inc.

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Figure 23
Steep Slopes

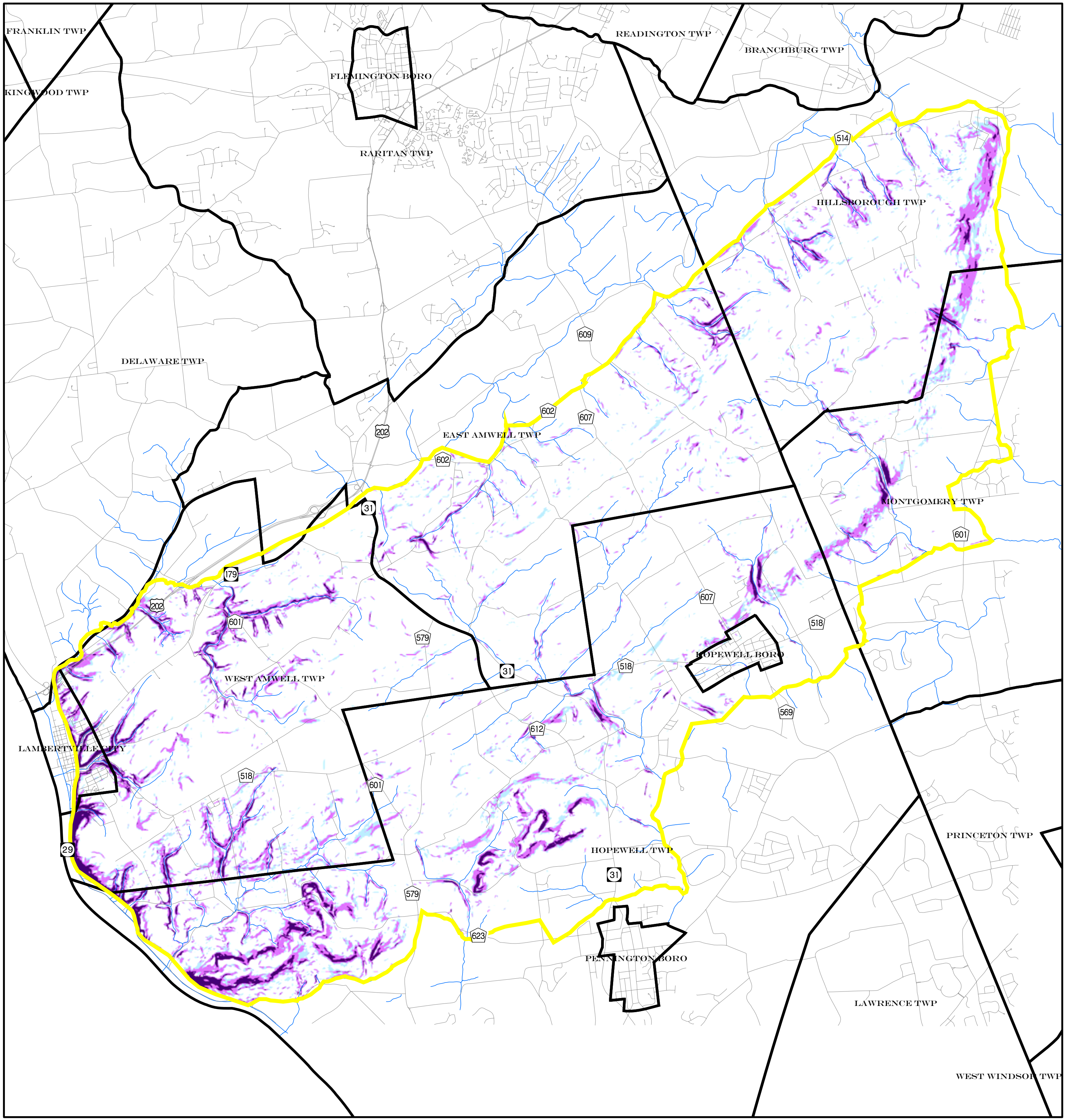
The Sourland Mountain Region

A Portion of Central New Jersey

0 0.5 1 2
Miles

Legend

- Slopes less than 12%
- Slopes 12% to 15%
- Slopes greater than 15% to 25%
- Slopes greater than 25%



This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Source:
GIS DEM (10 Foot Grid), NAVD 88,
derived fromTIN interpolated from 2 foot DTM based on
1996 1"=100' groundscale orthophotography by ProMaps, Inc.

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Figure 24
Ridgelines and Contours
The Sourland Mountain
A Portion of Central New Jersey

Æ

0 0.5 1 2
Miles

Legend

Ridgelines

20 Foot Contour

100 Foot Contour

This map was developed using New Jersey Department o
Environmental Protection Geographic Information Systen
digital data, but this secondary product has not been NJDEF
verified and is not State-authorized.

Data Sources:
GIS DEM (10 Foot Grid), NAVD 88,
derived fromTIN interpolated from 2 foot DTM based on
1996 1"=100' groundscale orthophotography by ProMaps, Inc.

Note:
Ridgelines were established manually using 3-dimensional DEM
and contour information.

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Figure 25

New Jersey Landscape Project Habitat Data

The Sourland Mountain Region

A Portion of Central New Jersey

Rank	Indication
1	Suitable habitat with no field survey conducted
2	Habitat patch with State special concern species 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

0 0.5 1 2 Miles

Legend

Wood Turtle Foraging

Forest
- Rank 1
- Rank 2
- Rank 3
- Rank 4

Emergent
- Rank 1
- Rank 2

Grassland
- Rank 1
- Rank 2
- Rank 3
- Rank 4

Forested Wetland
- Rank 1
- Rank 2
- Rank 3

This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Sources:
NJDEP Landscape Project Critical Habitat Data, Originator - NJDEP, Division of Fish and Wildlife, Endangered NonGame Species Program, Source Data Scale - 30 Meter Resolution. 2/04

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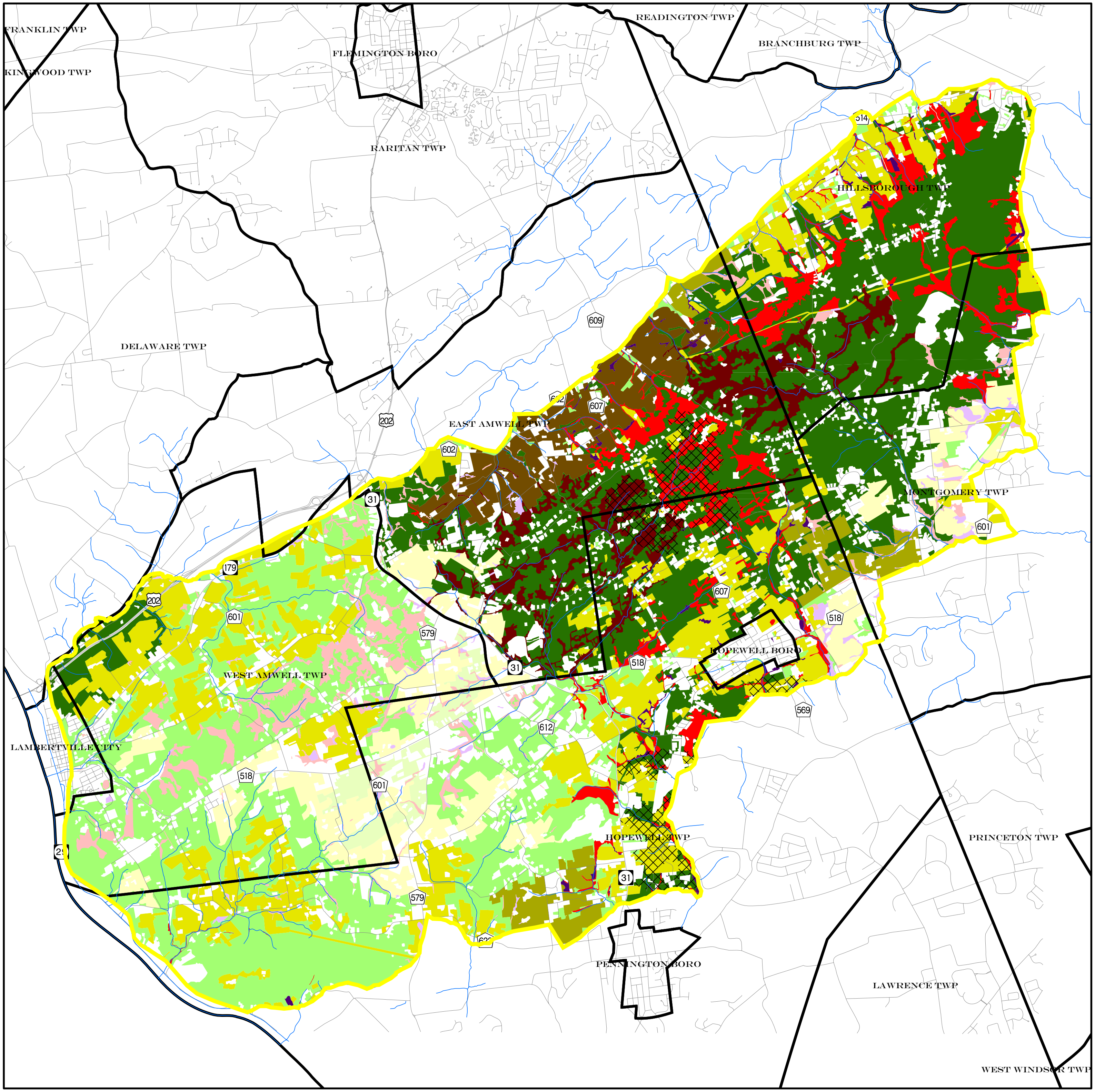
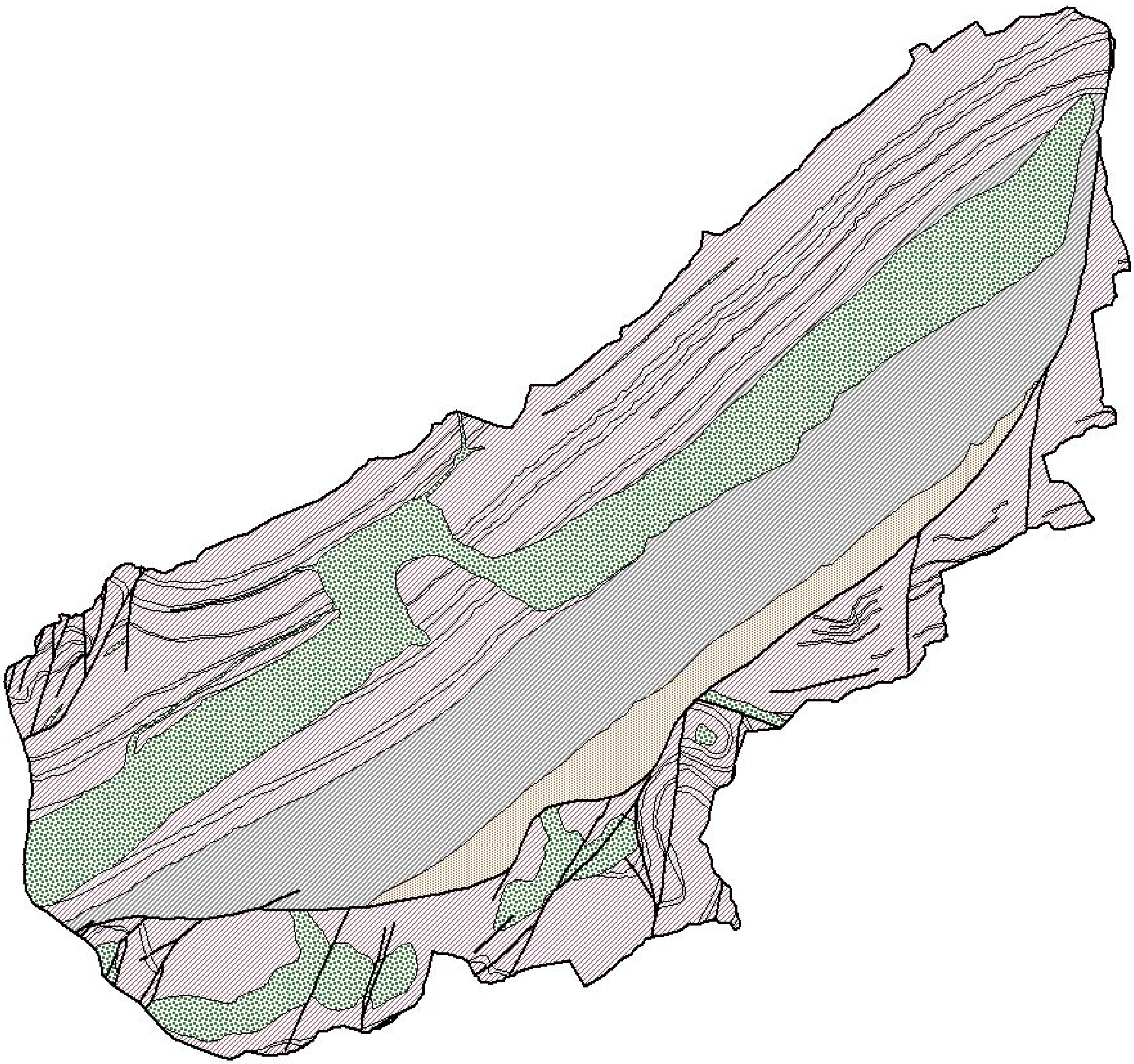


Evaluation of Groundwater Resources of Sourland Mountain Region of Central New Jersey



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151 Old Franklin School Rd
Pittstown, New Jersey 08867

Water: A Natural Renewable Resource

EVALUATION OF GROUNDWATER RESOURCES OF THE SOURLAND MOUNTAIN REGION OF CENTRAL NEW JERSEY

NOVEMBER 19, 2004

Prepared for:

Sourland Smart Growth Project

Prepared by:

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Water: A Natural Renewable Resource

EVALUATION OF GROUNDWATER RESOURCES OF THE SOURLAND MOUNTAIN REGION OF CENTRAL NEW JERSEY

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EVALUATION OF GROUNDWATER RESOURCES OF THE SOURLAND MOUNTAIN REGION OF CENTRAL NEW JERSEY

INTRODUCTION

SOURLAND SMART GROWTH

M^2 Associates, Inc. and Demicco & Associates, Inc. have been retained by the Sourland Smart Growth Project, which is comprised of representatives of Hunterdon, Mercer and Somerset Counties; West Amwell, East Amwell, Hopewell, Montgomery and Hillsborough Townships; the Sourland Planning Council; the Delaware & Raritan Greenway; and the Stony Brook-Millstone Watershed Association. M^2 Associates, Inc. and Demicco & Associates were retained to prepare an evaluation of the groundwater resources of the Sourland Mountain region. The report herein has been prepared for the Smart Growth Grant Agreement between the Township of East Amwell and the State of New Jersey Department of Community Affairs.

The Sourland Mountain forms a unique geologic and topographic feature in the Piedmont Physiographic Province of central New Jersey. The unique geology that creates the Sourland Mountain region also dictates the natural resources of the region. Groundwater is one of these resources directly related to the unique geology.

GROUNDWATER

Groundwater is subsurface water that fully saturates the geologic rock materials beneath the water table. Groundwater moves through the cracks and fractures in the rock materials from the water table to discharge in streams and wetlands under natural conditions. Groundwater and surface-water resources are interrelated. The surface-water streamflows during dry weather are dependent on the discharge of groundwater. Any impact that depletes groundwater depletes stream baseflow. In the Sourland Mountain region, during dry weather, baseflow in the streams is derived from groundwater systems.

HEADWATERS

The Sourland Mountain forms the headwaters of the stream in the region. There are no through-flowing streams bringing water into the region. Most of these headwaters are found within New Jersey's Regional Water Resource Planning Area (RWRPA) 10. The major streams draining the Sourland Mountain region in RWRPA 10 include tributaries to Back Brook and the Neshanic River, and Pike Run, Cruser Brook, Rock Brook, Beden Brook, and Stony Brook, which are all tributaries to the Millstone River. The southwesterly area of the Sourland Mountain region drains into RWRPA 9, the Trenton Delaware Tributaries. The major streams draining this area include Jacobs Creek, Moore Creek, Alexauken Creek and Swan Creek, which all drain to the Delaware River.

RWRPA 10 is the third most populated regional water resource planning area in the state. In 1996, the NJDEP projected this population would increase an additional 31 percent in the next fifty years. Currently, water resources within RWRPA 10 are diverted to other regions of New Jersey to meet demands that exceed the sustainable supplies within these other regions. The Sourland Mountain region contributes to these resources. Continued population growth is expected to further strain limited water-supply resources. In the document entitled "Water for the 21st Century: The Vital Resource, New Jersey Statewide Water Supply Plan", the NJDEP predicted that the water-supply demands within RWRPA 10 would exceed the sustainable resources of the combined Millstone and Raritan River watersheds by 2040. The New Jersey Water Supply Authority (NJWSA) indicates that these resources may be exceeded several years prior to 2040.

RWRPA 9 is relatively small drainage encompassing 181 square miles in parts of Hunterdon, Mercer and Warren Counties. RWRPA 9 is not anticipated to be in deficit during the 50 year planning period presented in the Statewide Water Supply Plan. The NJDEP projected this population would increase an additional 36 percent in the next fifty years. Sources of water include individual wells, the Delaware & Raritan Canal, and the Swan Creek Reservoir. Continued population growth could strain limited groundwater-supply resources.

GROUNDWATER RESOURCES

Groundwater resources serve a critical two fold function. Groundwater is the primary source of drinking water for residents of the Sourland Mountain region. Groundwater also maintains streamflow and wetlands ecosystems during periods of low rainfall. These juxtaposed uses of groundwater for environmental and human sustenance inevitability lead to competing demands for the resource. And in the Sourland Mountain region, the unique geology has left the area with scarce groundwater resources.

Withdrawals of groundwater from aquifer systems via wells can reduce groundwater discharge needed to sustain baseflow and wetland systems within the Sourland Mountain region. Increases in impervious coverage reduce the recharge to the groundwater. Land use coverage changes, specifically removal of the contiguous forest that characterizes the Sourland Mountain region, will also diminish replenishment of groundwater. Reductions in groundwater resources will ultimately result in reductions in the availability of surface-water resources and adverse impacts to interrelated wetland/ecosystems. Reduction in groundwater resources will result in well failures as described in the NJGS 1988 report entitled “Hydrogeologic Study of Water-Well Failures in Argillite Bedrock of Sourland Mountain, Somerset County, New Jersey, in 1982.”

Assessment of the impacts to water resources requires a conceptual understanding of the underlying geology and the mechanism that affect groundwater. This Report presents a conceptual model of the various hydrogeologic systems within the Sourland Mountain region. This conceptual model is used to identify areas of the watershed with differing hydrogeologic capabilities to receive recharge, and store and transmit water. The model is used to assess the interrelationship/interdependence between the aquifer and surface-water systems. From the model, potential dependable yields for the aquifer systems could be determined to assess water-supply availability and potential recharge rates could be calculated to assess dilution requirements for reducing concentrations of anthropogenic impacts primarily derived from septic-system discharges. Ultimately, the conceptual model could be used to understand the potential limits of these groundwater resources with respect to current and future populations.

HYDROGEOLOGIC FRAMEWORK

LOCATION

The Sourland Mountain region is located in central New Jersey in portions of Mercer, Somerset, and Hunterdon Counties. Hopewell, East Amwell, West Amwell, Montgomery, and Hillsborough Townships, and Hopewell Borough contain the majority of the land area. A small portion of the Sourland Mountain region is located within the City of Lambertville and Delaware Township. The Sourland Mountain region extends from the Delaware River in Hunterdon and Mercer Counties northeast into Hillsborough Township, Somerset County. The Sourland Mountain region with respect to the State and County boundaries for New Jersey is shown on Figure 1. The municipalities within the region are shown on Figure 2.

The Sourland Mountain region herein has been defined by critical “choke points” or places where water flowing from the mountain is concentrated before mixing with water from other areas of New Jersey. Many of the headwater streams draining the mountain have “choke points” where they meet other higher order streams such as the Back Brook and Beden Brook. The northern boundary was defined by choke points to Alexauken Creek, Back Brook and the Neshanic River where groundwater and surface-water flow from the northern portion of the mountain would ultimately discharge before draining into these streams and mixing with waters from other areas of New Jersey.

The eastern and southern boundaries were defined by points where flow from the mountain would meet water draining from other regions in Royce, Roaring, Cruser, Rock, Beden, and Stony Brooks, and Jacobs Creek. The western limits of the region were defined by the intersection of the cliffs above the City of Lambertville and the floodplain for the Delaware River. The Sourland Mountain region as depicted herein also includes critical groundwater recharge areas on the shoulders of the mountain, where surface-water runoff would likely infiltrate into highly fractured zones such as those represented by the Hopewell Fault.

POPULATION

U.S. Census data for 2000 indicate nearly 21,021 people live in 7,281 occupied-dwelling units within the Sourland Mountain region. The region as defined herein encompasses approximately 87 square miles.

PHYSIOGRAPHIC PROVINCE

The Sourland Mountain region is located within the Piedmont Physiographic Province in New Jersey. The Piedmont Province is primarily underlain by Triassic-Jurassic sedimentary, igneous, and metamorphic rocks formed as the Newark Basin opened 145 to 250 million years ago. The Piedmont Province is generally characterized by gently rolling hills to the west and broader, gently sloping landscapes to the east. The Sourland Mountain creates some of the highest elevations in the Piedmont Province ranging up to 568 feet above mean sea level. The Sourland Mountain region also maintains one of the largest continuous forest habitats left in the New Jersey Piedmont.

SURFACE WATER

Subwatersheds

Figure 3 shows the three watersheds as delineated by the USGS in the Sourland Mountain region. These watersheds are North and South Branch of the Raritan River (WMA08), Millstone River (WMA10), and Central Delaware (WMA11). The largest of these three watersheds is the Millstone River, which encompasses 43 square miles of the Sourland Mountain region. The Central Delaware Watershed drains 28 square miles and the North and South Branch of the Raritan River drains 15.3 square miles of Sourland Mountain region.

Figure 4 shows the subwatersheds within the Sourland Mountain region. These subwatersheds range in size from less than 0.1 to 10.2 square miles.

Figure 5 shows the major streams within the Sourland Mountain region. The two largest tributaries to the Millstone River are Stony Brook and Beden Brook, which have drainage areas prior to the confluences with the Millstone River of 55.4 and 49.7 square miles, respectively. Other tributaries to the Millstone River receiving water from the Sourland Mountain region include Rock Brook, Pike Run, Cruser Brook, Roaring Brook, and Royce Brook.

Back Brook and the Neshanic River drain the northern side of Sourland Mountain and ultimately flow into the South Branch of the Raritan River. Back Brook joins the Neshanic River after draining 11.7 square miles and the Neshanic River joins the South Branch of the Raritan River after draining 55.7 square miles.

The major tributaries to the Delaware River draining Sourland Mountain to the west are Alexauken Creek, Swan Creek, Moore Creek, Fiddlers Creek, and Jacobs Creek. These creeks have drainage areas within the Sourland Mountain region of 7.9, 5.2, 10.2, 1.8, and 2.9 square miles, respectively.

Studies summarized by Kaplan et al. (2000) indicate that adverse impacts to surface-water quality can occur when impervious surface coverage exceeds 10 percent of the contributing drainage area. Further impacts can result from surface or subsurface discharges within these drainage areas. At the point where a stream originates, the contributing drainage area is likely very small and there is little flow available. Impacts to water quality within the contributing drainage areas to these headwaters can extend significantly downstream until sufficient additional uncontaminated groundwater discharges are intercepted to reduce contaminant concentrations.

Within headwaters areas such as the Sourland Mountain region, water quality can be quickly impacted and degraded as a result of man-made discharges. Increasing percentages of impervious surface coverage will very likely result in increased stormwater and decreased groundwater discharges. Contaminant discharges from anthropogenic sources can significantly alter and degrade water quality and quantity in a stream and only through dilution can many of these impacts be mitigated or reduced. These impacts can affect the quality and quantity of water available to downstream consumers, and other natural resources and ecosystems.

Stream Classifications

Figure 5 also shows the surface-water quality standards as designated by the NJDEP in N.J.A.C 7:9B, for the streams in the Sourland Mountain region. In N.J.A.C 7:9B Surface Water Quality Standards, FW2 is the general classification for freshwaters within New Jersey. The NT designation indicates that trout populations cannot be maintained or produced. Trout are highly susceptible to changes in flow and water quality, especially changes in temperature. Therefore, trout are used as an indicator of stream water-quality conditions. Although, NT waters may not be capable of sustaining trout populations, they are likely capable of sustaining other species. Waters capable of sustaining trout populations are classified as TM for trout maintenance and waters capable of trout production are classified as TP. There are no trout production waters within the Sourland Mountain region.

The Category 1 (C1) classification indicates that these water have been designated for protection from measurable changes in water quality in N.J.A.C 7:9B because of "…clarity, color, scenic setting, other characteristics of aesthetic value, exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s)." Waters classified as C1 are protected from further degradation of water quality. Waters not designated as C1 are considered C2 waters and may not be afforded similar levels of protection against degradation of water quality.

With the exception of a small portion of Stony Brook in the Amwell Lake Wildlife Management Area, all of the Millstone River tributaries draining Sourland Mountain have been classified by the NJDEP as FW2-NT. Within the Amwell Lake Wildlife Management Area, Stony Brook is classified as FW2-NTC1. As shown on Figure 5, the NJDEP has designated in N.J.A.C 7:9B, Back Brook and the Neshanic River as non-trout waters. In the Delaware River basin, Alexauken Creek and Moore Creek are designated as trout maintenance waters indicating that these streams are high quality waters.

The NJDEP recently included the C1 designation for Alexauken Creek indicating that the waters in this stream should be protected from degradation. As the NJDEP further evaluates other streams within the Sourland Mountain region, they may assign the C1 designation. For example, Swan Creek may be assigned a C1 designation because it serves as water-supply resource to the Swan Creek reservoir east of the City of Lambertville.

SOILS

The U.S. Department of Agriculture (USDA) National Resource Conservation Service (NRCS) has mapped soils throughout New Jersey and these maps have been included in the New Jersey Geological Survey (NJGS) Geographic Information System (GIS) database. Based on the NRCS mapping, 127 soils have been delineated within the Sourland Mountain region. Some of these soils are differentiated based on slope gradient and composition. The 127 soils can be combined into 35 classifications based on the general characteristics of the soil. The general soils mapped within the Sourland Mountain region are shown on Figure 6.

Table 1 provides a summary of general soil types, approximate areas encompassed within the Sourland Mountain region, potential septic system limitations as described in N.J.A.C 7:9A, the hydrologic soil group codes, and whether the soil is considered hydric. The NRCS determines hydrologic soil groups based on minimum infiltration rates with soils ranked A having the highest infiltration rates and soils ranked D with the lowest. Soils with high infiltration rates will permit more incident precipitation to migrate vertically and potentially recharge groundwater systems and/or dilute septic-system contaminants. Soils with low infiltration rates are usually comprised primarily of clays and silts and underlying groundwater systems are poorly recharged. The NRCS defines hydric soils as "Soils that are sufficiently wet in the upper part to develop anaerobic conditions during the growing season". Hydric soils are associated with wetlands.

Based on the soils data, approximately 3.1 percent of the soils within the Sourland Mountain region would have slight to few operational limitations for septic systems. Approximately 32.5 percent of the soils would have moderate limitations for septic systems and 18.1 percent would likely have severe limitations for septic system operations. These moderate and/or severe limitations are typically associated with shallow depths to seasonal or perennial groundwater; shallow depths to bedrock or other hydraulically restrictive layer; or disturbed land. The NJDEP indicates in N.J.A.C 7:9A that the remaining 46.3 percent of the soils beneath the Sourland Mountain region are unsuitable for septic systems because of a shallow regional zone of saturation or hydraulically restrictive substratum. Within the Sourland Mountain region, the NRCS has mapped approximately 0.3 percent of the area as covered with water.

Based on the NRCS mapping, 0.1 percent of Sourland Mountain region is underlain by soils that will likely have low surface-water runoff rates and high infiltration rates and therefore, these soils have been given a hydrologic soil group code of A by the NRCS. These soils are associated with sand and gravel pits and are not residual soils derived from weathering of the underlying bedrock beneath Sourland Mountain region.

Soils beneath approximately 16.9 percent of Sourland Mountain region have moderate infiltration and surface-water runoff rates and therefore, have a hydrologic soil group code of B. These soils are Birdsboro, Bucks, Hazleton, Lansdale, Legore, Neshaminy, Pope, Riverhead, Tioga, and disturbed soils referenced as “Cut and fill land”.

Soils beneath approximately 83 percent of the Sourland Mountain region have low to very low infiltration rates and very likely, high to very high surface-water runoff rates and therefore, have hydrologic soil group codes of C and/or D. The NRCS has classified 4.5 percent of the soils within the Sourland Mountain region as hydric soils capable of supporting wetlands. Recent mapping completed by the NJDEP as part of its Landscape Project indicates that nearly 4.4 percent of the Sourland Mountain region is covered with wetlands forests.

GEOLOGY

Mapping

The geology of the Sourland Mountain region is shown on Figure 7. The geologic map has been primarily developed from extensive mapping efforts of the USGS and NJGS as shown on the "Bedrock Geologic Map of Central and Southern New Jersey" (Owens et al. 1998).

Bedrock

The majority of the Sourland Mountain region is underlain at shallow depths by consolidated bedrock. The bedrock units were deposited in a series of basins in the Triassic (245 to 208 million years ago) and Jurassic (145 to 208 million years ago). The basins were formed as result of continental separation or rifting as the North American, European and African continental plates moved in opposing directions forming the Atlantic Ocean. Three major geologic units and one subunit are mapped beneath the Sourland Mountain region. These units are the Stockton Formation, Lockatong Formation, Passaic Formation (and it subunit Passaic Formation gray bed), and diabase. The area of each formation and the percentage of the Region underlain by these units is summarized in Table 2.

STOCKTON FORMATION

The oldest of the Triassic-Jurassic rocks within the Sourland Mountain region were deposits of sand, gravel, and silt-sized sediments that were later indurated forming light-gray and yellow arkosic sandstones of the Stockton Formation. Conglomerates formed of rounded cobble-, boulder-, and pebble-sized fragments are often encountered near the base of the Stockton Formation.

The Stockton Formation has been mapped as a northeast-southwest trending band within the Sourland Mountain region. The Stockton formation is mapped within Hopewell and Montgomery Townships immediately north of the Hopewell Fault. Within the Sourland Mountain region, the Stockton Formation is encountered beneath approximately 4.2 square miles or nearly 5 percent of the mountain region and may range in thickness to as much as 3500 feet.

LOCKATONG FORMATION

Very-fine to fine-grained silts, clays, and sands were deposited in lake-type environments over the coarse-grained sediments of the Stockton Formation. These lacustrine deposits are known as the Lockatong Formation and are primarily comprised of gray-red, dark brown, and grayish-purple mudstones, argillaceous sandstones, and siltstones. The older beds of this formation are associated with transgressive, fluvial, or lake-margin sediments. The middle portion of the formation is primarily comprised of lake-bottom materials, and the youngest portion is associated with regressive waters, mudflats, and lake-margin materials (Owens et al. 1998).

The Lockatong Formation has been mapped as a band across the Sourland Mountain region. This band is encountered north of the Hopewell Fault in Hopewell, West

Amwell, East Amwell, Montgomery, and Hillsborough Townships. The Lockatong Formation may reach thicknesses of 3000 feet within the Sourland Mountain region. The Lockatong Formation is encountered beneath approximately 19.7 square miles or 23 percent of the mountain region.

PASSAIC FORMATION

Fine-grained sands, silts, and some clay were the sediments deposited in the fluvial, lake, and mudflat environments of the late Triassic-early Jurassic. These deposits were later cemented into the red-brown, brownish-purple, and grayish red shales, siltstones, silty mudstones, and argillaceous very-fine grained sandstones of the Passaic Formation.

In some areas, gray lake deposits are distinct from other portions of the Passaic Formation and therefore, are mapped as a subunit of this formation. These gray lake deposits are comprised of gray to black silty mudstones, gray and greenish to purplish-gray argillaceous siltstones, black shale, and gray argillaceous fine- grained sandstones.

Beneath the Sourland Mountain region, the Passaic Formation may reach thicknesses of up to 6500 feet (Owens et al. 1998). Combined the Passaic Formation and the subunit of gray lake beds are encountered beneath approximately 44.5 square miles or nearly 52 percent of the Sourland Mountain region making this the most common rock-type and prevalent groundwater resource within the region.

DIABASE

The youngest rocks within the Sourland Mountain region were intruded as sheets of medium to find-grained diabase and are primarily found in one large band and several smaller dikes. Since these rocks are hard, dense, and poorly weathered, they are found beneath the highest topographic features within the Sourland Mountain region. The band forms the core of Sourland Mountain region in Hopewell, West Amwell, East Amwell, Montgomery, and Hillsborough Townships. Smaller diabase intrusions underlie other topographic high points in the region including Belle, Baldpate, and Pennington Mountains. A diabase sill extends from the Hopewell Fault to the southeast along Crusher Road in Hopewell Township. Several diabase dikes are mapped throughout the region.

Diabase is comprised of dense, hard, and poorly fractured crystalline-rocks that were injected as molten magmas into fractures and other openings formed as the Newark Basin separated. As these hot magmas were injected, they thermally metamorphosed adjacent rocks of the Passaic and Lockatong Formations. Based on USGS data (Lewis-Brown 1995), the metamorphic effects generally extend 1000 feet radially from the diabase intrusions. The red-brown shales appear as bluish-gray hornfels and the gray argillites appear as brittle-black very-fine-grained hornfels after metamorphism.

STRUCTURE

Rocks such as those encountered beneath the Sourland Mountain region generally have no intergranular openings and therefore, no primary porosity for transmitting water. In these types of rocks, groundwater storage and transmittal are dependent on the secondary porosity or the openings between blocks of impermeable rock. In shales, sandstones, argillites, siltstones, mudstones, and diabase sills, these openings are typically associated with fractures from faults, joints, or changes in bedding planes.

As the Newark Basin opened, faults or fracture zones were formed in weaker rocks. Within the Sourland Mountain region, the most extensive faulting occurred along the Hopewell Fault in Hopewell Township, Hopewell Borough, and Montgomery and Hillsborough Townships. The Hopewell Fault separates older Stockton Formation rocks from the younger Passaic Formation. Based on USGS and NJGS mapping, the movement along the Hopewell Fault may have been as much as 11,700 feet. The younger Triassic-Jurassic formations on the upper block (northern) have been eroded exposing the older Stockton and Lockatong Formations.

Possibly in response to some of the movement along the regional Hopewell Fault, several other faults have formed to the south and east primarily in Hopewell Township and to a lesser degree in Montgomery Township. Several small faults that diverge from the regional Flemington Fault have been mapped in the northwest corner of the Sourland Mountain region in West Amwell and Delaware Townships. As shown on Figure 7, most of these faults have been mapped within areas underlain by the more brittle Passaic Formation shales, mudstones and sandstones. Some of the faults extend into diabase intrusions beneath Baldpate and Pennington Mountains.

The regional Hopewell Fault and the smaller local faults systems are normal faults and formed as the Newark Basin opened. Some horst and graben structures are apparent within the region, especially in the northwestern corner in West Amwell and Delaware Townships. These structures are commonly associated with rift valleys.

In addition to the fractures formed as result of the local and regional faulting, two other major sets of fractures may be encountered in the bedrock geologic formations beneath the Sourland Mountain region. The first set is associated with bedding planes and result from changes in the characteristics of the sediments at the time of deposition. These bedding planes fractures strike to the northeast and gently dip to the northwest.

In addition to the bedding plane fractures, small-scale fractures may be found in weaker layers which were pulled apart as a continents separated. Often, these fractures will have vertical to near vertical orientation and will extend a few inches to a few feet across weaker layers but will quickly dissipate or terminate within more competent rocks. These types of fractures are often referred to as joints. Depending on the proximity to regional or local faults systems and the brittle nature of the rocks, the spacing between these vertical to near vertical joints will range from fractions of an inch to several tens or hundreds of feet. In some areas, the joints serve to interconnect bedding plane fractures and in others, the bedding plane fractures interconnect joints, thereby forming aquifers.

GROUNDWATER SYSTEMS

Sole Source Aquifers

Two sole source aquifers, as designated by the USEPA, extend across the Sourland Mountain region. The "Northwest New Jersey Sole Source Aquifer" boundaries were defined by the NJDEP and designated by the USEPA in the Federal Register on May 23, 1988. The Northwest New Jersey Sole Source Aquifer extends across the north portion of the Sourland Mountain region.

The "Coastal Plain Sole Source Aquifer boundaries were also defined by the NJDEP and were designated by the USEPA in the June 24, 1988 Federal Register. The Coastal Plain Sole Source Aquifer boundaries extend from Trenton upstream along the Delaware River past Stockton, New Jersey. The southwest portion of the Sourland Mountain region is part of the Coastal Plain Sole Source Aquifer. Figure 8 shows the sole source aquifers system within the Sourland Mountain area.

The USEPA defines a sole source aquifer as the following: "Sole-source aquifers (SSAs) are those aquifers that contribute more than 50% of the drinking water to a specific area and the water would be impossible to replace if the aquifer were contaminated". The NJDEP and USEPA consider groundwater to be the primary source of drinking water within the designated sole source aquifers and indicate that measures should be taken to protect these critical resources from potential health hazards.

Within the Sourland Mountain region, groundwater provides well more than 50 percent of the water used for drinking water. Groundwater provides essentially all of the drinking water throughout the region and not just within the two designated sole source aquifers. A large band encompassing 16.7 square miles of the Sourland Mountain region has not been designated by the NJDEP and/or USEPA as a sole source aquifer although all persons residing within these areas of Hopewell and West Amwell Townships rely entirely on groundwater for drinking water. Groundwater beneath the 16.7 square miles of the region that has not been designated as a sole source aquifer should be afforded the same protections provided to the groundwater resources beneath the Northwest New Jersey and Coastal Plain Sole Source Aquifers. Since groundwater is the source of drinking water for essentially all residents of the Sourland Mountain region, the entire area should be afforded the protections of a designated Sole Source Aquifer.

In addition to individual residential wells, Hopewell Borough Water Department operates four wells within the Sourland Mountain region. The locations of the Hopewell Borough wells are shown on Figure 9. In addition, the Mercer County Correctional Center and Pennington Water Department have 3 and 2 water-supply wells, respectively located adjacent to the boundary of the region.

The Swan Creek Reservoir is a major, but local, surface-water resource for the City of Lambertville. The system is operated by United Water Company. The Delaware and Raritan Canal (D & R) is a major regional surface-water resource that collects water draining from portions of Sourland Mountain and transmits this water through the canal to Bound Brook for the New Jersey Water Supply Authority (NJWSA).

In addition to groundwater extracted from wells, during dry weather, the percentage of groundwater used for drinking water increases because water extracted from Swan Creek for drinking water is almost entirely derived from groundwater discharges to the creek. Under drought conditions, United Water Company has to supplement the low flow of groundwater into the Swan Creek Reservoir through diversion from the D & R Canal.

Aquifer Rankings

The NJGS has compiled yield data for high-capacity wells throughout New Jersey. The NJGS used these yield data to determine potential ranges of yields for large-capacity water-supply wells and then assigned ranks to the aquifers based on their ability to sustain these types of wells. The public community water-supply wells depicted on Figure 9 could be considered high-capacity wells used for major water-supply systems. Figure 9 also shows the NJGS rankings of the aquifer systems within the Sourland Mountain region. The rankings are not necessarily reflective of random conditions associated with domestic wells nor are they reflective of actual conditions with the Sourland Mountain region since the data were derived throughout the State.

Wells with yields in excess of 500 gallons per minute have been installed in aquifers ranked by the NJGS as A. Wells with yields ranging from 251 to 500 gallons per minute have been installed in aquifers ranked B. Wells with yields ranging from 101 to 250 gallons per minute have been installed in aquifers ranked C. Wells with yields ranging from 25 to 100 gallons per minute have been installed in aquifers ranked D. Aquifer systems that can only support wells with demands of less than 25 gallons per minute have been ranked by the NJGS has E. The NJGS did not include the letter F in their ranking system.

The NJGS ranking system for aquifers does not indicate that all wells installed within these aquifer systems are capable of sustaining the yields suggested by their ranking. High-capacity wells are often located after conducting extensive geologic and hydrogeologic investigations to identify areas with the greatest potential to provide water. In many cases these high-capacity wells are not only sustained by groundwater resources but are also sustained by leakage or drainage from nearby surface-water resources. In many cases, high-capacity wells are installed near rivers or streams to maximize contributing drainage area and to take advantage of these surface-water resources. Three of the four Hopewell Borough wells are located within the Hopewell Fault.

Within the Sourland Mountain region, groundwater is primarily stored and transmitted in fractures and openings created after the rock formed. The exception is in the sandstones found primarily in the Stockton Formation. Within the Stockton Formation groundwater is stored and transmitted through openings or voids between sediment particles that formed as a result of weathering, in addition to the fractures created after the rock formed.

Bedrock

STORAGE AND TRANSMISSION

The Sourland Mountain region is underlain by entirely by bedrock aquifer systems. The Lockatong Formation, the diabase, and surrounding metamorphic rock account for nearly 44 percent of the area of the Sourland Mountain region. These rock units are poorly fractured compared to the Stockton and Passaic Formations. Within the study area, the Stockton Formation forms only a small percentage (4.8 percent) of the bedrock aquifer.

It is also important to note that the Sourland Mountain region bedrock aquifers do not have any glacial drift deposits at the surface. Glacial drift is unconsolidated material with a high potential groundwater storage capacity. In other bedrock regions of New Jersey, these glacial drift deposits create an important recharge and groundwater storage mechanisms that supply recharge to bedrock year round. The thin soils in the Sourland Mountain region can not act as a reservoir for recharging bedrock aquifers.

In bedrock aquifer systems, groundwater is stored and transmitted along fractures, joints, and bedding planes, and therefore, the availability of water is dependent on the separation distance between fractures, the degree to which these fractures are interconnected, and the degree of weathering between fracture planes. In some rocks, fractures are separated by a few inches of competent, unweathered, and impermeable bedrock. In other rocks, the distance between fracture openings may be several feet. In some areas such as near major regional faults, fractures form highly connected networks and therefore, more water can be stored and transmitted. In areas where single or few fractures are available, the rocks have little storage or transmission capability.

In some rock types, silt and clays are the predominant residual soil developed from weathering. In other rocks, sands, gravels, cobbles, and boulder-sized particles are the result of the weathering process. USGS studies indicate that the weathering of fractured rock is greatest within 75 feet of ground surface and is negligible at depths greater than 500 feet below ground surface. Since weathering increases fracture size and may result in increased fracture interconnection, much of the yield is likely derived from shallow bedrock. Yield is the measure of the volume of water that can be pumped from a well. In some bedrock formations such as the Passaic and Stockton Formations, high yielding fractures are often intersected at depths exceeding 75 feet. In the Lockatong Formation and diabase, high yielding fractures are much less likely to be encountered, especially at depths in excess of 150 feet.

In the Passaic, and Stockton Formations, wells are usually drilled to deeper depths because of the potential to encounter additional water-bearing fractures and therefore, to increase the yield. Wells are usually drilled to greater depths to store water for meeting short-term peak demands in the Lockatong Formation and diabase because increased yields are unlikely. The well borehole serves as a subsurface reservoir or storage tank. Most 6-inch diameter residential wells can stored nearly 1.5 gallons per foot of depth. The additional volume may be necessary to meet the needs of the residence or business relying on the well.

STOCKTON FORMATION

Studies conducted in Hunterdon and Mercer Counties indicate that the sandstones of the Stockton Formation are the primary water-bearing layers and these layers are often confined by less permeable siltstones (Lewis-Brown 1995). Within these two counties, the studies indicate that some of the highest yields for bedrock aquifers are for wells completed within the Stockton Formation. Within Hunterdon County, well yields for the Stockton Formation range from 1.5 to 70 gallons per minute with a median yield of 18 gallons per minute (Kasabach 1966). Within Mercer County, data compiled for the Stockton Formation by Widmer (1965) indicate that domestic well yields generally range from 1 to 50 gallons per minute within a median yield of 12 gallons per minute.

The Sourland Mountain Ground Water Management Report (Middlesex, Somerset Mercer Regional Study Council, Inc, 1984) (MSM Study) also compiled well data yield for the Sourland Mountain area. The data compiled in this study included Hillsborough and Montgomery Townships in Somerset County. The median well yield determined from data for 105 wells as reported by the MSM Study for the Stockton Formation, is 20 gpm. The MSM Study data indicate the Stockton Formation is the highest yielding unit in the Sourland Mountain region.

Data for 271 domestic wells studied by the USGS also indicate that the Stockton Formation is one of higher yielding bedrock aquifer systems within the Sourland Mountain region. The USGS studies of the Stony Brook, Beden Brook, and Jacobs Creek drainage basins indicate median yields of 15 gallons per minute for Stockton Formation wells (Lewis-Brown 1995).

Data compiled by the USGS indicate that the Stockton Formation has a median specific capacity of approximately 0.488 gallons per minute per foot of drawdown (Lewis-Brown 1995). The MSM Study (1984) had a similar result with a specific capacity of 0.343 gallons per minute per foot of drawdown. The USGS also divided the specific capacity measures for available well data by the length of the open interval in which water can enter the well. These measures of specific capacity per foot of open hole interval indicate an order of magnitude decrease with depth suggesting that much of the water entering a well within the Stockton Formation enters from shallow depths.

However, the yield and specific capacity measures for wells completed to depths exceeding 300 feet were higher than for wells completed to depths of less than 100 feet in the Stockton Formation. Furthermore, there is little change in the USGS data in median specific capacity per foot of open hole interval after a depth of 100 feet. Therefore, it is probably beneficial to drill wells in the Stockton Formation to depths exceeding 100 feet because additional water-bearing fractures may be encountered and these fractures are likely to increase the ultimate yield of the well.

In summary, well data compiled for Mercer and Hunterdon Counties indicate that the Stockton Formation has a median yield ranging from 12 to 20 gallons per minute. The data also indicate the Stockton Formation has a higher capacity to transmit water than other bedrock formations within the Sourland Mountain region. The data indicate that additional water-bearing fractures may be intersected at depths exceeding 100 feet in the Stockton Formation and therefore, the ultimate yield of the well could be significantly increased by drilling to greater depths. The well data indicate that the Stockton Formation is a good aquifer capable of readily meeting most domestic and small-commercial water-supply needs. The NJGS has ranked the Stockton Formation aquifer-system as C, which indicates that these rocks may be considered good groundwater resources.

LOCKATONG FORMATION

Kasabach (1966) indicated that the Lockatong Formation is one of the poorest yielding aquifer systems in Hunterdon County. Widmer (1965) indicates the 33 percent of the wells completed in the Lockatong Formation beneath Mercer County had yields of less than four gallons per minute and he considered this yield "inadequate" for more than domestic wells. The Mercer County study indicated that yields for domestic wells completed in the Lockatong Formation generally range from 0.75 to 35 gallons per minute with a median yield of 5 gallons per minute. The Hunterdon County study indicated that yields for wells completed in the Lockatong Formation range from 0.5 to 78 gallons per minute with a median yield of 6 gallons per minute. Data compiled for the MSM Study for 950 mostly domestic wells indicated a median yield of 7 gallons per minute. In summary, these data indicate the median yield of the Lockatong Formation is roughly one-third to one-half the median yield for the Stockton Formation.

Data compiled by the USGS for 348 domestic wells within the Stony Brook, Beden Brook, and Jacobs Creek drainage basins indicate that the Lockatong Formation is poor yielding (Lewis-Brown 1995). These data indicate a median yield of 7.0 gallons per minute, which is less than half the median yield calculated by the USGS for the Stockton Formation beneath these three stream basins.

The data compiled by the USGS indicate that the Lockatong Formation within the Stony Brook, Beden Brook, and Jacobs Creek basins has a median specific capacity of 0.115 gallons per minute per foot and a median specific capacity per foot of open hole interval of 0.00115 gallons per minute per foot per foot (gpm/ft/ft) (Lewis-Brown 1995). This value is less than one-fourth the median specific capacity measure determined for the Stockton Formation and indicates that regionally, the Lockatong Formation has a significantly lower potential to transmit water then the Stockton Formation.

The data compiled by the USGS of median specific capacity per foot of open hole indicate that this measure of aquifer transmission potential declines two orders of magnitude with depth. The data for shallow wells, less than 75 feet deep, have a median value of 0.0124 gpm/ft/ft. At depths greater than 300 feet, the median specific capacity per foot of open hole interval declined to 0.00011 gpm/ft/ft. These results indicate that water entering a well completed in the Lockatong Formation is primarily derived from more-weathered shallow zones and little additional water comes from deeper fractures. The USGS data indicate that drilling a well deeper within the Lockatong Formation will most likely not result in greater yields and will only serve to increase the storage capacity of the well reservoir.

In summary, the well data for Somerset, Mercer and Hunterdon Counties indicate that the Lockatong Formation is a poor yielding aquifer with a median yield ranging from 5 to 7 gallons per minute or less than half the median yield for the Stockton Formation. The data also indicate that the Lockatong Formation has a significantly lower capacity to transmit water than the Stockton Formation. The data from the wells compiled by the USGS indicate that a well completed in the Lockatong Formation to 300 feet below ground surface will most likely not have a higher yield than a well completed to a depth of 100 feet below ground surface. The data from the studies of Hunterdon and Mercer

Counties indicate that the Lockatong Formation probably has sufficient transmission capacity to meet most domestic water supply needs but most likely could not meet slightly higher demands. The NJGS has ranked the Lockatong Formation rocks as a D aquifer indicating that the Lockatong Formation rocks are poor water resources.

PASSAIC FORMATION

The fine-grained sandstones, shales, and thin-bedded siltstones of the Passaic Formation serve as the primary water-bearing layers. These layers are often confined by massive siltstones beds. In the Passaic Formation, vertical to near vertical joints may interconnect water-bearing layers.

Widmer (1965) indicates that the Passaic Formation is only slightly less yielding than the Stockton Formation in Mercer County. His results indicated that domestic well yields generally range from 0.5 to 60 gallons per minute with a median yield of 10 gallons per minute. Kasabach's (1966) study of Hunterdon County indicated a median yield of 15 gallons per minute for the Passaic Formation, which is only slightly less than the median yield calculated for the Stockton Formation beneath Hunterdon County.

The MSM Study (1984) indicated similar results for the Passaic Formation with a median well yield of 12 gallons per minute for 323 wells in the Sourland Mountain region.

The USGS study of the Stony Brook, Beden Brook, and Jacobs Creek drainage basins resulted in a compilation of data for 709 domestic wells and these data indicate that the Passaic Formation has yields similar to the Stockton Formation. The data from the 709 wells indicate a median yield of 15 gallons per minute for both formations.

The USGS domestic well data indicate a median specific capacity for non-metamorphosed Passaic Formation rocks of 0.462 gallons per minute per foot, which is very similar to the value determined for the Stockton Formation (Lewis-Brown 1995). The well data compiled by the USGS indicate that the Passaic Formation has a median specific capacity per foot of open hole of 0.00393 gpm/ft/ft, which is only slightly less than the value determined for the Stockton Formation (Lewis-Brown 1995). And similar to the Stockton Formation, the median specific capacity per foot of open hole for the Passaic Formation declined only one order of magnitude with depth. Unlike the Stockton Formation, the median yields and median specific capacities for the Passaic Formation are not significantly changed with depth. The results of the USGS assessment of median specific capacity per foot of open hole for the Passaic Formation indicate that drilling to depths greater than 200 feet most likely will not provide significant additional yield.

In summary, the well data compiled for Hunterdon and Mercer Counties indicate that the Passaic Formation has a median yield ranging from 10 to 15 gallons per minute. These data further indicate that the Passaic Formation has only slightly lower capacity to transmit water when compared to the Stockton Formation but significantly greater capacity to transmit water than the Lockatong Formation. The USGS results indicate that a well completed in the Passaic Formation to a depth of 300 feet below ground surface will not have significantly greater yield than a well completed to depth of 100 feet below ground surface in this same formation. The NJGS ranks the Passaic Formation as a C aquifer indicating that these rocks have moderate capacity to support major water-supply wells.

DIABASE/HORNFELS

Diabase intrusions are highly resistant to erosion and as a result, are found at the highest elevations in the Sourland Mountain region including beneath the core of Sourland Mountain as well as beneath Belle, Baldpate, and Pennington Mountains. In addition to the diabase, hornfels produced from the metamorphism of Passaic Formation or Lockatong Formation host rock are often found within 1000 feet of diabase intrusions. The diabase and the surrounding hornfels combined to form very poor aquifer systems. Except where transected by a local fault, these units have few fractures, which are often separated by distances of more than one-foot and in outcrop, these fractures are often not vertically extensive.

Kasabach (1966) indicated that the diabase is the "...poorest source of water..." in Hunterdon County with yields ranging from 0 to 55 gallons per minute and a median yield of five gallons per minute. Widmer (1965) indicated that wells in the diabase of Mercer County had poor yields generally ranging from 0.5 to 27 gallons per minute with a median yield of 6 gallons per minute.

The MSM Study (1984) indicated a median yield of 5 gallons per minute for 213 wells completed in the Sourland Mountain area.

The data for 97 domestic wells within the Stony Brook, Beden Brook, and Jacobs Creek drainage basins evaluated by the USGS indicated that the diabase has a median yield of 5 gallons per minute. The USGS study for wells completed in the hornfels indicated a median yield of 6 gallons per minute. Kasabach's (1966) study of Hunterdon County indicated yields for wells completed in metamorphosed shales ranging from 0.5 to 35 gallons per minute with a median yield of 6 gallons per minute.

Many of these low yielding wells were located in West Amwell Township, where the extent of metamorphism has significantly reduced the ability of Passaic Formation rocks to store and transmit water. Data from the Kasabach (1966) report indicate that yields of wells completed in the Passaic Formation rocks beneath West Amwell Township are only 40 percent of the yields measured in Passaic Formation rocks elsewhere in Hunterdon County.

The data compiled by the USGS indicate median specific capacities for wells completed in the diabase of 0.109 gallons per minute per foot and in the hornfels of 0.105 gallons per minute per foot. The median specific capacity values for the diabase and metamorphosed shales are similar but slightly less than those calculated by the USGS for the Lockatong Formation beneath the Stony Brook, Beden Brook, and Jacobs Creek basins. The specific capacity data for the diabase and metamorphosed shales indicate that these two rock types have significantly lower capacity to transmit water when compared to the Stockton and Passaic Formations.

Data compiled by the USGS indicate the diabase has a median specific capacity per foot of open hole of 0.00143 gpm/ft/ft (Lewis-Brown 1995). This value is equivalent to approximately 26 percent of the median specific capacity per foot of open hole determined for the Stockton Formation and indicates that the diabase has a transmission capacity similar to Lockatong Formation. The median specific capacity per foot of open hole for 49 wells completed in hornfels was 0.00097 gpm/ft/ft (Lewis-Brown 1995). These measures of median specific capacity per foot of open hole might be significantly lower if data from wells with little or no usable yield that were drilled but not placed in service within the Stony Brook, Beden Brook, and Jacobs Creek basins were included in the USGS database. The USGS database is limited to wells placed in service. Discussions with local well drillers and local Health Board representatives indicate that wells have been drilled in the diabase and/or metamorphosed shales with little or no usable yield and therefore, were not used or placed in service.

The results of USGS evaluation of median specific capacity per foot of open hole indicate that this measure of aquifer transmission potential declines nearly two orders of magnitude with depth (Lewis-Brown 1995). The data for shallow wells, less than 75 feet deep, have a median value of 0.00906 gpm/ft/ft. At depths greater than 126 feet below ground surface, the median specific capacity per foot of open hole declined in the USGS data to 0.00023 gpm/ft/ft. These results indicate that nearly all water from a diabase well is derived from shallow bedrock where weathering has enhanced openings between blocks of impervious rock. Furthermore these data indicate that unless a well is completed in a weathered portion of a diabase sill, there may be insufficient water available to meet many water-supply needs. Based on the results of the USGS analysis of specific capacity per foot of open hole, drilling wells in the diabase or hornfels to depths exceeding 125 feet is unlikely to provide additional yield.

In summary, the studies of well data from the regional studies indicate that diabase and associated metamorphosed shales are very poor yielding aquifer systems with median yields of 5 and 6 gallons per minute, respectively. These median yields are one-half to one-third the median yields determined for the Stockton and Passaic Formations. The median yields for the diabase and associated metamorphosed shales are very similar to those of the Lockatong Formation. Well data also indicate diabase and metamorphosed shales have significantly lower capacity to transmit water at depths. The results of the

USGS study of median specific capacity per foot of open hole indicate that wells completed to depths exceeding 125 feet are unlikely to intersect additional water-bearing fractures. These data indicate that wells drilled to depths greater the 125 feet in the diabase and/or associated hornfels will provide additional storage capacity but will most likely, not provide additional yield. The NJGS ranking for diabase aquifer is E indicating that these rocks have very little capacity to support major water-supply wells.

GROUNDWATER RESOURCES

HYDROLOGIC CYCLE

Water Balance

The hydrologic cycle is a balance of the Earth's water. Precipitation falls to the Earth's surface where it ultimately flows through streams to the ocean and evaporates to the atmosphere, or is transpired through living organisms and ultimately returned to the atmosphere. Locally, this balance is comprised of the following three general components:

1. Evapotranspiration is the component where water is returned to the atmosphere by plants and/or evaporated from puddles or other small surface-water features.

2. Surface-water runoff is the component where precipitation runs off the ground surface or immediately below the ground surface and quickly flows to streams during and/or shortly after precipitation.

3. Groundwater runoff is the component where precipitation enters a subsurface perennial or seasonally saturated zone through which, it slowly migrates to a stream. This component is most obvious during dry periods where maintains the baseflow in streams.

Each of these general components: evapotranspiration, surface-water runoff, and groundwater runoff, can be further subdivided. Groundwater runoff includes the portion of precipitation that sufficiently infiltrates soils into the underlying bedrock to enter an aquifer system where it can be used as a water-supply resource. The portion of groundwater runoff that enters an aquifer system is referenced as groundwater or aquifer recharge.

Groundwater runoff also includes water in shallow wet and sometimes saturated zones such as wetlands, floodplains, and stream banks that slowly migrates to a stream but does not enter an aquifer where it could be used as groundwater supply. Subsurface-water velocities are very slow and its can take months, years, and potentially decades for water to travel from the point of infiltration into one of these shallow systems, to the point of discharge to a stream. Within an aquifer system, it will take years, decades, and potentially centuries to travel from the point of infiltration to the point of discharge. Where a water balance can be used to assess percentages of annual precipitation that evaporate or transpire, run off the ground surface, or runoff through the subsurface, more detailed analyses are necessary to ascertain the amount of precipitation that actually infiltrates to an aquifer recharging groundwater supplies.

Similar to the capacities to transmit and yield water, the recharge capability of bedrock aquifers is dependent on the frequency and intensity of fractures, the size of the fracture openings, the interconnection of these openings to each other and to the ground surface or other saturated media, and the depth of weathering. Bedrock units with the greatest frequency/intensity of fracture openings, interconnected to each other, the ground surface, and/or other saturated media will have low surface-water runoff rates and high aquifer recharge rates. Weakly fractured bedrock will have high surface-water runoff rates and low aquifer recharge rates. The extensive occurrence of wetlands on the Sourland Mountain ridge is directly related to the poorly fractured diabase bedrock beneath.

Precipitation

A water balance can be used to evaluate inflow and outflow parameters associated with the hydrologic cycle. The inflow parameter to the equation, precipitation, can be directly determined from historical information. The outflow parameters, evapotranspiration, groundwater runoff, and surface-water runoff are determined by indirect methods such as measuring streamflow. The water balance can be used to evaluate the assumptions made in estimating these indirect parameters and provides a general range of possible values for these parameters. Since the equation is a balance, the inflows must equal the outflows and the assumptions can be tested as parameter values are refined.

Aquifers are replenished by incident precipitation that infiltrates through soils into fractures and other openings in bedrock aquifers or voids between particles in unconsolidated aquifers. Historical precipitation measurements collected by the National Climatic Data Center for the past 116 years at the Lambertville climatic-recording stations were used to evaluate average precipitation within the Sourland Mountain region during a year of normal precipitation.

The data collected at the National Climatic Data Center station indicate that during a year of normal precipitation, the Sourland Mountain region will receive approximately 45.4 inches of precipitation. Precipitation in the Sourland Mountain region of New Jersey is generally evenly divided throughout the year with January, February, March, June, October, and December receiving slightly less than average rainfall and April, May, July, August, September, and November receiving slightly more precipitation.

Table 3 provides monthly estimates of normal monthly precipitation for the watershed based on the historical data from the Lambertville climatic data recording station.

Using the water balance of the hydrologic cycle, precipitation equals the sum of groundwater runoff, evapotranspiration, and surface-water runoff. If an area has one or more large water bodies with respect to the total surface area, direct precipitation to this body and resulting evaporation from this body would also be included in the water balance. The total area covered with surface water within the Sourland Mountain region is less than 0.3 percent of the total land area within the mountain region boundaries. Therefore, precipitation to and evaporation from these surface-water bodies are not considered significant with respect to the watersheds overall water resources.

The water balance is often described by the following equation:

$$P = ET + SW + GW \qquad \text{(Equation 1)}$$

Where:

P = Precipitation
ET = Evapotranspiration
SW = Surface-Water Runoff
GW = Groundwater Runoff

Evapotranspiration

As part of the hydrologic cycle, water is returned to the atmosphere by evaporation from open water bodies and surface soils, and transpiration from vegetation. The return of water to the atmosphere by the processes of evaporation and transpiration is referred to as evapotranspiration.

Evapotranspiration is greatest during summer months because of higher temperatures and active growth of plants and trees. During the winter months, evapotranspiration in central New Jersey is usually very little to negligible. Evapotranspiration is the largest component of the water balance and returns 50 percent or more of annual precipitation to the atmosphere in New Jersey.

The Thornthwaite Method was developed for calculating potential evapotranspiration in New Jersey and other Mid-Atlantic States. Studies have shown that the Thornthwaite Method provides reasonable estimates of monthly and annual potential evapotranspiration for New Jersey.

Mean temperature data for the past 116 years for the Lambertville station were compiled from the National Climatic Data Center to calculate the expected mean monthly and annual temperature in Sourland Mountain region. The temperature data for

Lambertville indicate that the mean annual temperature in Sourland Mountain region is 53.3 degrees Fahrenheit.

Inclusion of the temperature and precipitation data in the Thornthwaite Method, results in an estimate that approximately 28.5 inches of precipitation or nearly 63 percent of annual precipitation will be returned to the atmosphere in the Sourland Mountain region. Potential evapotranspiration depends on water always being available within the root zone to be used by vegetation and transpired/returned to the atmosphere. Water is not always available within the root zone and therefore, actual evapotranspiration will be slightly less than 28.5 inches per year.

As part of its studies of the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, the USGS developed an estimate of evapotranspiration of 27.28 inches per year based on an annual precipitation rate of 45 inches per year. Lewis-Brown (1995) deemed this estimate of 27.28 inches per year high, since the analysis did not take into account land use, topography, and soil type which, as their report indicates affects the ratio of runoff to precipitation. Within their study area, Lewis-Brown (1995) determined that the ratio of runoff to precipitation was high and therefore, less water was available for evapotranspiration than estimated. Lewis-Brown (1995) did not provide any other estimates for evapotranspiration within the Stony Brook, Beden Brook, and Jacobs Creek basins.

In summary, local weather data indicates that potential evapotranspiration within the Sourland Mountain region may average approximately 28.5 inches per year. Studies conducted by the USGS within the Sourland Mountain region suggest that actual evapotranspiration will be slightly lower then this estimate of 28.5 inches. Based on studies conducted by the USGS elsewhere in New Jersey and in eastern Pennsylvania, actual evapotranspiration will likely range from 23.1 to 27.3 inches per year or 50 to 60 percent of annual precipitation to the Sourland Mountain region.

Surface-Water Runoff

Surface-water runoff is dependent on the infiltration capacity and rate of soils, types and density of vegetation, surface area of impervious materials, gradient or steepness of slopes, and the intensity and duration of rainfall. Surface-water runoff is comprised of two components. One of these components is overland flow, which occurs when the infiltration capacity of the soils is exceeded and the water flows over the land surface to a stream channel. In areas that are underlain by poorly drained soils, along steep slopes, and/or highly developed with impervious surfaces and compacted soils, overland flow can account for much if not all of the precipitation to an area.

The second component of surface-water runoff is referred to as interflow or throughflow and includes water that infiltrates soils to a shallow depth and then flows along an impermeable or very low permeability surface such as a clay layer or fragipan to a discharge point. Also included in this interflow is water retained in unconsolidated sediments in stream valleys as stream level rises in response to rainfall. This stored water is referred to as bank storage. This interflow/throughflow is not groundwater recharge because this water quickly discharges to a stream channel without infiltrating to a perennial saturated zone or water-table aquifer.

Often in areas with poor infiltration into bedrock, steep slopes, and weakly fractured bedrock, streams as depicted on USGS 7.5-minute topographic quadrangles as blue lines, will start at high elevations. Water is incapable or at best, significantly limited in its ability to infiltrate into the underlying bedrock aquifers and therefore, quickly runs off the land surface or throughflows immediately below the ground surface often along the top of bedrock to the nearest stream system.

Approximately 83 percent of the soils beneath the Sourland Mountain region have poor to very poor infiltration rates based on hydrologic soil group code and nearly 40 percent are classified as poorly drained. In addition, more than 10.4 percent of the region has slopes in excess of 15 percent and another 32.6 percent has slopes ranging from 8 to 15 percent. In addition, bedrock is within 1 to 4 feet of ground surface beneath nearly 95 percent of the soils within the region and the bedrock beneath more than 27 percent of the region is classified as hard, requiring special equipment or blasting to fracture. Given the limited infiltration capacities and poor drainage characteristics of the soils, the shallow depth and hardness of bedrock, and the steep slopes in the mountain region, it can be expected that much of the incident precipitation to the mountain will runoff the land surface or throughflow immediately below the surface to the nearest stream.

As part of a detailed evaluation of groundwater conditions within the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, the USGS evaluated surface-water runoff. Based on this evaluation, surface-water runoff in areas underlain primarily by the Stockton and Passaic Formations accounts for approximately 11.8 inches or 26 percent of annual precipitation (Lewis-Brown 1995). In areas underlain by diabase, the USGS determined that surface-water runoff equals approximately 15.9 inches per year or 35 percent of annual precipitation (Lewis-Brown 1995).

In summary, within the Sourland Mountain region, surface-water runoff rates ranging from 11.8 to 15.9 inches per year or 26 to 35 percent of annual precipitation are likely experienced.

Groundwater Runoff

Streamflow data can be separated into two components, surface-water runoff and groundwater runoff. During and shortly after periods of precipitation, the surface-water runoff component is the primary source of water flowing into stream. During dry weather, the groundwater runoff component maintains baseflow in streams.

Groundwater runoff includes water that infiltrates to aquifer systems, but also other subsurface environments such as perched zones, floodplain materials, and wetlands that do not serve as water-supply resources at least with respect to human consumption through wells. These resources are vital to ecosystems as well as downstream consumers where water discharging from these shallow subsurface sources is a significant percentage of baseflow between storm events. Herein, groundwater recharge is water that infiltrates to a perennial saturated zone or aquifer where it can be utilized as a water-supply resource through a well. Groundwater runoff includes groundwater recharge but also includes water that is collected, stored, and transmitted in shallow sources such as wetlands, floodplain soils, stream banks, and seasonal perched zones.

In the Sourland Mountain region, water can enter three subsurface environments. The first environment is shallow, seasonal to perennial, fully to partially saturated zones. These perched zones are often found immediately above the bedrock surface in weakly weathered soil, fragipan, or in shallow highly weathered bedrock layers that are not interconnected via vertical to near vertical fractures to underlying aquifers. Because the underlying materials have low to very low permeability, the water cannot migrate vertically to the underlying aquifer. The water will either migrate laterally to the nearest stream channel or more-permeable deposit, is extracted through root systems of trees and other vegetation during summer months, or supports wetland areas throughout the summer months.

The second subsurface environment with respect to the Sourland Mountain region is the water-table or unconfined aquifers within the fractured bedrock. The fractured-rock aquifers are usually water-table systems at shallow depth and water entering these systems is either extracted with a well or will discharge to streams where it serves as a potential surface-water resource downstream.

The third subsurface environment is the deeper confined fracture zones. These zones occur more frequently in the Passaic and Stockton Formations where fractures at depth can transmit water.

Equation 1 can be rearranged to develop estimated ranges for groundwater runoff within the Sourland Mountain region. In Equation 1, P or precipitation averages 45.4 inches per year, ET or evapotranspiration likely ranges from 23.1 to 28.5 inches per year, and SW or surface water runoff probably averages between 11.8 and 15.9 inches per year. Within the Sourland Mountain region, GW or groundwater runoff likely ranges from 1 to 10.5 inches per year.

GROUNDWATER RECHARGE

Groundwater

The following is a quote from the textbook Groundwater (Freeze & Cherry 1979):

> "The term groundwater is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated".

Water must enter a fully and perennially saturated zone also known as an aquifer system to be available as a water resource exploitable with wells. In New Jersey, because steel casing must be installed to prevent shallow water from entering a well, water must be capable of infiltrating to a depth of at least 50 feet below ground surface to be captured by a residential well. Although water in stream banks, flood plains, snowpack, wetlands or seasonally wet perched zones in soils, shallow bedrock, or unconsolidated deposits may be considered part of groundwater runoff in maintaining baseflow in streams, water that does not enter a fully and perennially saturated aquifer that extends to a depth greater than 50 feet below ground surface is not available for groundwater-supply purposes.

Water temporarily pooled on a fragipan layer, bedrock surface, or confining layer would not be considered groundwater unless this zone extends to a depth of at least 50 feet below ground surface or is interconnected to fractures or coarser-grained deposits that extend to depths of at least 50 feet. Water that infiltrates through soils but not to a fully saturated zone is not groundwater because it would not be available to wells within the watershed. Water that does not migrate to an aquifer system is not available to wells and therefore, should not be included in groundwater recharge estimates with respect to the Sourland Mountain region because if the water does not enter a saturated aquifer system, it cannot be used for groundwater supply.

Streamflow from Groundwater

BASEFLOW

Water flowing in streams during periods of dry weather is referred to as baseflow. Figure 10 provides an example of baseflow derived from USGS streamflow data for Stony Brook at Princeton, New Jersey. In this example, surface-water runoff from a precipitation event decreases as does streamflow from February 13 to 15, 1985. From February 15 to 22, 1985, the flow in Stony Brook is nearly constant because there is little if any surface-water runoff and most, if not all of the flow has been derived from subsurface discharges. The flow from February 15 to 22, 1985 is baseflow because it is almost entirely, if not entirely, derived from subsurface discharges.

In the past, baseflow was often assumed equal to aquifer/groundwater discharge, which was in turn equal to aquifer/groundwater recharge because the hydrologic cycle is a balance. However, a better understanding of hydrologic systems including wetlands, streams, aquifers, seasonal wet zones, flood plains, and stream banks and the role these systems have in providing water to streams during periods of dry weather has shown that not all water flowing during dry weather is derived from aquifer/groundwater discharge.

The water flowing during most dry weather periods is very likely to include water from shallow sources such as but not limited to flood-plain soils, stream bank-storage, wetlands, and perched zones. Discharges from these shallow sources should not be assumed entirely associated with flow from an aquifer serving as a water resource. It may take extensive periods of dry weather or drought to sufficiently dry up or dewater these shallow sources to determine the contribution to baseflow from an underlying aquifer system.

DROUGHT FLOW

Figures 11 through 16 depict streamflow data compiled by the USGS from Stony Brook at Princeton and the Neshanic River near Reaville during the “Drought of Record” in the 1960s, the “Summer 1999” drought, and the 2001/2002 drought. The 1962 through 1966 drought has been classified as the “Drought of Record” by the NJDEP for water-supply planning purposes. The “Drought of Record” is the most severe multi-year drought in the past 50 years. Based on precipitation data available from the National Climatic Data Center, 1963 through 1965 was the driest three year period in New Jersey in the past 100 years with the lowest precipitation measured in 1965. The “Summer 1999” drought and the 2001/2002 droughts are more recent but shorter dry-weather events. Flow data from these events could be compared to the longer and more severe drought of the 1960s to assess potential changes in baseflow over time.

The data from Stony Brook at Princeton for the 1960s drought indicate progressively lower flows each summer. The low flows achieved in 1963 after two consecutive years of below normal precipitation were again achieved in 1999 after a few months of dry weather (see Figures 11 and 12). If the wastewater component were removed from the streamflow data for this river, it is highly probable that baseflow during the recent droughts would be significantly less than during the more severe 1960s drought. Decreased baseflow indicates decreased water in storage within subsurface systems including the aquifers.

Figures 14 through 16 show streamflows for the Neshanic River and as the streamflow data indicate, during the “Drought of Record”, baseflow rates exceeding or equal to 0.1 cubic foot per second (cfs) could be maintained throughout this multi-year drought. Even during 1965, which is the year New Jersey received the lowest rainfall within the last 100 years and four years into the drought, water continued to flow in the Neshanic River at the Reaville stream gauge indicating that the underlying aquifer-systems had sufficient water in storage from years preceding the drought to maintain flow in the river.

Figure 15 is a hydrograph depicting streamflow in the Neshanic River at Reaville during the Summer 1999 drought. For more than a month during this short-duration drought, there was no flow in the Neshanic River at the Reaville stream gauge. Again during the 2001/2002 drought for a period of 10 days in August 2002, there was no measurable flow in the Neshanic River at the Reaville gauge. The 1999 and 2001/2002 data in comparison to the “Drought of Record” data indicate that as a result of upstream changes to the Neshanic River system and increased groundwater demands within this basin, shallow subsurface sources are quickly dewatered and the deeper aquifer systems are no longer capable of providing baseflow to this stream.

FLOW DURATIONS

Streamflow data were used by the USGS to calculate streamflow statistics for the Stony Brook at Princeton, Baldwins Creek at Baldwins Lake, Honey Branch near Pennington, Pike Run at Belle Mead, and Royce Brook Tributaries at Belle Mead and Frankfort. Flow exceedence statistics are depicted graphically on Figure 17 and the stream gauging station locations are shown on Figure 18. The streamflow statistics used to prepare Figure 17 show the flow rates that are exceeded 10, 25, 50, 70, 75, 90, and 95 percent of time. Flows exceeding the 10 percent rates are very high flows whereas; very low flow rates are exceeded 95 percent of time. Flows exceeded 95 percent of time are typically measured during prolonged dry weather.

For comparison purposes, streamflow data for the Millstone River at Plainsboro, New Jersey have also been included in Figure 17. The drainage basin for the Millstone River upstream of Plainsboro is entirely underlain by Coastal Plain deposits, which can serve as large reservoirs for maintaining baseflows. The drainage area for the Millstone River at Plainsboro (65.8 square miles) is not much bigger than the drainage area for Stony Brook at Princeton (44.5 square miles). The most significant difference between these two basins is that the Millstone River to Plainsboro is entirely underlain by Coastal Plain deposits whereas; Stony Brook upgradient of Princeton is entirely underlain by Triassic-Jurassic bedrock. The flow duration curves for these two streams significantly diverge as lower flows are measured.

The flow duration curve for the Millstone River at Plainsboro indicates much less variation between high flows and low flows when compared to the curve for Stony Brook at Princeton. The statistics for the Millstone River at Plainsboro reflect a change of one order of magnitude between the 10 percent flow exceedence rate and the 95 percent flow exceedence rate indicating low surface-water runoff rates and relatively-constant high rates of discharges from subsurface systems. The flow duration curve for Stony

Brook at Princeton declines two orders of magnitude between the 10 and 95 percent flow exceedence values indicating a flashy stream with high surface-water runoff rates and low groundwater storage capacities.

The flow duration curves for the other streams underlain by bedrock aquifers also show a difference of two orders of magnitude between the 10 and 95 percent flow exceedence values indicating very flashy conditions and low groundwater storage capacities. The flow duration curves for Pike Run, Baldwins Creek, Honey Branch, and the two Royce Brook tributaries show very significant breaks in the slopes of the curves at the 70 to 90 percent flow exceedences. During dry weather when the flow in these streams is entirely derived from subsurface sources, there is little water in storage to maintain discharge.

All of the flow duration curves for the streams entirely underlain by bedrock at shallow depths, indicate very significant declines between the 70 and 95 percent flow exceedence values, which indicates that when shallow subsurface sources become dewatered and much if not all flow is derived from underlying groundwater/aquifer sources, little water is available to continue streamflows.

The data for Baldwins Creek, Honey Branch, and Royce Brook Tributary at Frankfort indicate that the aquifers cannot provide water to these streams in dry weather. The data indicate that either the aquifers beneath these streams have extremely low storage capacities and are quickly dewatered in dry weather, or that groundwater withdrawals exceed rates of dry weather replenishment resulting in water levels being lowered below the natural discharge points in the streams. In either circumstance, the flow duration curves for these streams indicate that the underlying bedrock aquifers have little storage capacity, receive very little recharge, and can become quickly dewatered.

HYDROGRAPH SEPARATION

The volume or rate of water infiltrating to an aquifer cannot be directly measured. However, the rate and/or volume of water discharging from an aquifer to a stream can be estimated from streamflow data. Since the hydrologic system is a balance equation, the volume of water exiting an aquifer system is assumed equal to the volume that entered the groundwater system.

Several graphical methods have been developed for evaluating streamflow data and are often referred to as “hydrograph separation”. These methods are used for separating surface runoff from groundwater runoff or baseflow. Because streamflow rates increase, peak, and then decline as a result of overland runoff from precipitation events, the hydrograph separation methods assume a time delay after a storm event to impose similar increased, peaked, and declining groundwater runoff/baseflow rate changes resulting from the precipitation event.

The surface-water runoff component may be referenced as quickflow because it arrives rapidly in the stream channel and causes readily identifiable increases in streamflow rates, whereas, the increased baseflow may take several hours or days to migrate through the subsurface or to be released by wetlands or other shallow subsurface sources to the stream. The increased baseflow rates are not readily identifiable in the stream data because they are obscured by declining quickflow components.

These hydrograph separation methods are highly dependent on how the observer/hydrologist differentiates streamflow into baseflow and if the baseflow component includes discharges from sources other than the underlying aquifer system. The USGS notes in the document entitled “HYSEP: A Computer Program For Streamflow Hydrograph Separation And Analysis” (Sloto et al. 1996) that even when the same hydrograph-separation method is followed by two different scientists, each scientist is likely to produce a different baseflow estimate. Different baseflow estimates will often result when the same observer uses two different methods. Hydrograph separation methods are highly dependent on observer and method bias.

In addition to observer and/or method bias, in the article entitled “Problems Associated with Estimating Ground Water Discharge and Recharge from Stream-Discharge Records”, the authors found that hydrograph-separation techniques are “poor tools” for estimating groundwater discharge or recharge (Halford 2000). These authors found that the groundwater component in streamflow records could not be clearly defined because of complications associated with discharges from bank-storage, floodplain soils, wetlands, surface-water bodies, and seasonal sources such as snowpack and perched zones in soils and bedrock. These authors concluded that because of the difficulty separating groundwater discharges from shallow non-aquifer sources that significant overestimates of groundwater recharge resulted.

Discharges from sources other than an aquifer system should not be included in groundwater recharge because the water did not infiltrate to the underlying aquifer system. Inclusion of discharges from shallow sources would result in overestimates of groundwater recharge. If the water did not infiltrate to the groundwater/aquifer system used to supply water to wells, the water should not be included in estimates of groundwater/aquifer recharge.

POSTEN (1984) METHOD

Although hydrograph separation methods are highly dependent on observer and method bias, they are an available tool for estimating baseflow and from there, groundwater recharge. When these tools are used, it should be understood that the results are overestimates of groundwater recharge because of the difficulties separating aquifer/groundwater discharges from discharges associated with shallow sources such as wetlands, ponds, bank-storage, floodplain materials, and seasonal perched zones.

One method has been developed in New Jersey (Posten 1984) for areas underlain at shallow depths by bedrock. The Posten (1984) Method determines “delayed flow” from hydrograph separation and then ranks these “delayed flow” rates to determine exceedence probability values. The exceedence probability values and the “delayed flow” rates are depicted on arithmetic probability graphs to estimate potential groundwater recharge rates and aquifer yields that could be safely or dependably removed without causing adverse impacts. The author took the extra step of plotting the annual baseflow flow rates and exceedence probability values to define a line along which, baseflow rates under dry weather conditions could be determined. The author also recommended that the method should be used for streams underlain by a single-type of bedrock but in New Jersey, few streams with sufficient daily streamflow measurements qualify for this assumption.

In Posten’s (1984) Method, streamflow data are separated into “quick flow” or water draining an area shortly after a precipitation event from “delayed flow” or water draining the area on a more-regular basis. Although the rate of delayed flow is significantly dependent on the rate of quickflow in this method, the author assumed that “delayed flow” is equal to baseflow. As discussed above, baseflow is not necessarily equal to groundwater recharge.

Posten (1984) developed his method to reduce the number of “personal judgments” and therefore, reduce potential overestimates of groundwater recharge and the “safe yield’ that could be withdrawn based on his opinion without causing adverse impacts. A study of groundwater recharge rates in New Jersey conducted by Canace et al. (1992) indicates that the Posten (1984) Method does result in lower recharge rates than another hydrograph separation method. However, the Posten (1984) Method continues to result in overestimates of groundwater recharge and the “safe yield” because the fundamental hydrograph separation technique employed by Posten (1984) for separating streamflow records into delayed flow rates includes discharges from shallow sources in the delayed flow estimates. As a result, the Posten (1984) Method will result in overestimates of groundwater recharge rates to aquifer systems. However, these overestimates are possibly smaller than estimates made with other hydrograph separation approaches.

Although the Stony Brook basin upgradient of Princeton is not underlain by a single rock type, Posten’s (1984) Method was used to separate streamflow data from delayed flow for water years 1954 through 2002. Figure 19 shows the separations between streamflow and delayed flow for 1999 and 2000 made with the Posten (1984) Method. The second lowest delayed flow measurements were obtained from the 1999 data and the 2000 data indicated the eleventh highest flow rates for the 49 year period. The separations show a very strong correlation between streamflow and delayed flow with significant peaks in delayed flow suggesting underlying subsurface environments are quickly recharged. As indicated by Halford et al. (2000), these baseflow peaks, if real, in most probability are associated with shallow, near stream sources and not reflective of groundwater recharge. The Summer 1999 baseflow data may be more reflective of actual groundwater-surface water interactions with baseflow nearly coincident with streamflow and both declining as shallow sources are dewatered and flow becomes increasingly dependent on discharges from aquifer systems.

Depicting the data on arithmetic-probability graph in accordance with the Posten (1984) Method indicates that recharge to the bedrock aquifers beneath the Stony Brook basin upgradient of Princeton should be less than 1.6 inches per year. Some of the bedrock types are likely to have slightly higher recharge rates and others, lower rates. In the study of groundwater recharge rates in New Jersey conducted by Canace et al. (1992), they did not plot the data on an arithmetic-probability graph but instead selected the average baseflow rates for the period 1954 through 1989 to determine recharge to the Stony Brook basin upgradient of Princeton was 5.12 inches per year. The measures Posten (1984) included in his method to reduce overestimates of groundwater recharge and ultimately the “safe yield” of an aquifer system, by utilizing the arithmetic-probability graphs, would not be included in an averaging of baseflow values derived from a simplified hydrograph separation analysis.

Based on the data for the Stony Brook basin up stream of the Princeton station, the bedrock aquifers have a “safe yield” of 1.6 inches per year. Although the Posten (1984) Method in and of itself will result in an overestimate of groundwater recharge and the “safe yield”, the rate calculated for Stony Brook at Princeton is likely biased even higher because of continuous discharges from wastewater treatment plants, which will artificially inflate streamflow rates especially during dry weather.

The daily flow rate equivalent to 1.6 inches per year (1950 cubic feet per second divided by 365 days) equals 5.43 cubic feet per second. Streamflow in Stony Brook as measured at Princeton is less than 5.43 cubic feet per second approximately 23 percent of the time during the period from October 1, 1953 to September 30, 2002. The “safe yield” calculated for Stony Brook at Princeton with the Posten (1984) Method indicates a 1 in 4 year dry weather recurrence interval. The streamflow data indicate that if a yield of 1.6 inches per year were withdrawn from the bedrock aquifers beneath Stony Brook, then the stream would be dry 23 percent of the time except for flows derived from wastewater treatment plants. The “safe yield” of the aquifers as calculated with the Posten (1984) Method would very likely result in adverse impacts to Stony Brook, especially if there is no flow 23 percent of the time.

HORDON (1987) EVALUATION

The Posten (1984) Method was employed by Hordon (1984, 1987, 1995) in his evaluation of the groundwater resources of the Lockatong Formation and diabase rocks in sections of Hunterdon and Mercer Counties. Hordon (1984, 1987, 1995) concluded based on Posten's (1984) analysis of Walnut Brook at Flemington that the Lockatong Formation aquifer systems were recharged at a rate of 92,000 gallons per day per square mile (gpd/mi^2). This rate is equivalent to 144 gpd/acre or 1.9 inches per year. The Flemington Fault, a major regional fault crosses Walnut Brook and may result in higher recharge/discharge rates than would be measured in less fractured areas.

Hordon (1984, 1987, 1995) also evaluated data for Wickecheoke and Lockatong Creeks, which are Hunterdon County streams primarily underlain by the Lockatong Formation. Based on his evaluation of these two streams, he concluded that for areas underlain by Lockatong Formation and diabase rocks, groundwater is recharged at a rate of 80,000 gpd/mi^2, which is equivalent to 125 gpd/acre or 1.7 inches per year.

Hordon (1987) cited several references that indicated that groundwater recharge rates could be estimated from flow duration curves where streamflow is exceeded 90 or 95 percent of the time. However, he assumed based on the Posten (1984) analysis of Walnut Brook near Flemington, that groundwater recharge should be estimated at streamflows that are exceeded 70 to 80 percent of the time. The USGS indicates that flow rates of 2.0 cubic feet per second (cfs) and 1.1 cfs are exceeded 90 and 95 percent of the time in the Stony Brook at Princeton stream gauge. At this same station, the flow rates exceeded 70 and 75 percent of time are 8.4 and 6.2 cfs. The 90 and 95 percent flow exceedence rates indicate potential recharge rates on the order of 45 to 25 gpd/acre (0.6 to 0.3 inches per year) whereas, the 70 and 75 percent flow exceedence rates suggest potential recharge rates of 190 and 140 gpd/acre (2.5 to 1.9 inches per year) for the geologic units beneath Stony Brook upstream of Princeton.

Similar to the Posten (1984) Method and other hydrograph separation techniques, assuming from duration curves, a flow rate exceeded 70 to 80 percent of time to estimate groundwater recharge rates is very likely to result in overestimates of recharge to an aquifer and withdrawals that would adversely affect the surface-water resources of the region. These flow rates are very likely to include discharges from shallow sources in addition to the discharges from underlying aquifers. Based on the data from Stony Brook, the overestimates could be 4 to 7 times greater than recharge estimates made from flow rates during periods of prolonged dry weather when discharges from shallow sources are diminished if not eliminated.

USGS STUDIES

The USGS has conducted two extensive studies of the Stony Brook, Beden Brook, and Jacobs Creek drainage basins (Jacobsen 1993 and Lewis-Brown 1995). In addition, the USGS has recently updated its computer models of the Coastal Plain of New Jersey (Martin 1998). These studies provide information that can be utilized to assess rates of groundwater runoff within the Sourland Mountain region. The models do not further determine the percentage of groundwater runoff that ultimately infiltrates and therefore, recharges the underlying aquifer systems. Further measures would be required to adjust groundwater runoff rates to groundwater recharge.

Data from the Jacobsen (1993) study were used to prepare a computer models during the Lewis-Brown (1995) study. This computer model was calibrated to simulate hydrogeologic conditions within the Stony Brook, Beden Brook, and Jacobs Creek drainage basins. As part of the early study, baseflow rates were determined at several locations along the main branches and within some of the tributaries for these streams (Jacobsen 1993). As part of the second study, the USGS (Lewis-Brown 1995) used the baseflow rates to initiate calibration of a computer model simulating hydrogeologic conditions of the three basins. The baseflow data reported in the 1993 study indicate average aerial groundwater runoff rates of 8.06 inches per year for the Stony Brook basin, 10.2 inches per year for the Beden Brook basin, and 10.3 inches per year for the Jacobs Creek basin. These rates are much higher than normal-year conditions since they were determined during a year of above-normal precipitation and streamflow rates. Furthermore, they appeared to have been measured during the early portion of stream recessions and therefore, include interflow in addition to shallow subsurface discharges.

Further study with the USGS computer model (Lewis-Brown 1995) of the Stony Brook, Beden Brook, and Jacobs Creek watersheds indicates groundwater runoff rates to the individual basins of approximately 8.25, 9.11, and 8.11 inches per year, respectively. These rates are averages over the entire basins, which are underlain by varying percentages of the four Triassic-Jurassic rock types. However, the Passaic Formation is the predominant rock type in all three basins. All groundwater runoff rates determined with USGS model included discharges from shallow sources in addition to discharges from aquifer systems and therefore, should not be assumed equal to groundwater recharge.

The USGS model did not determine groundwater runoff rates specific to the Lockatong Formation, Passaic Formation, or Stockton Formation but determined a combined rate of 8.20 inches per year for these sedimentary formations. With respect to the diabase, the USGS (Lewis-Brown 1995) determined a groundwater runoff rate with the computer model of approximately 4.11 inches per year. However, this groundwater runoff rate is approximately 1 inch greater than the average groundwater runoff rate determined from the baseflow data summarized in the 1993 and 1995 USGS reports for streams underlain by diabase. The baseflow data indicate a groundwater runoff rate of approximately 3.15 inches per year and these baseflow measurements are high because they were made during a year of above-normal precipitation and streamflow.

Further evaluation indicates that the groundwater runoff rates determined with the computer model are not sensitive to the particular geologic units or reflective of basin-wide conditions. Given the widespread extent of the Passaic Formation within the three basins, the groundwater runoff rate of 8.2 inches per year determined with the computer model most likely is strongly influenced by this geologic formation.

SUMMARY

In summary, the USGS evaluations of the Stony Brook, Beden Brook, and Jacobs Creek basins indicate groundwater runoff rates averaging 8.2 inches per year for the Triassic-Jurassic sedimentary units and 3.15 inches per year for the diabase and associated metamorphic rocks. Further analyses or adjustment to these groundwater runoff rates would be required to eliminate or reduce the shallow subsurface discharges from the deeper aquifer/groundwater system discharges and ultimately determine groundwater recharge rates. As indicated above, the Posten (1984) Method analysis of Stony Brook indicates that the aquifer-systems in the Triassic-Jurassic rocks are recharged at a rate of approximately 1.6 inches per year. Fifty-six percent of the Stony Brook basin is underlain by Passaic Formation. The remaining 44 percent of the basin is underlain by the Lockatong Formation (25 percent), Stockton Formation (5 percent) and diabase (14 percent). The Hordon (1984, 1987, and 1995) analyses of the Lockatong and diabase beneath sections of Hunterdon and Mercer Counties indicate recharge rates to these two geologic formations of 1.7 to 1.9 inches per year.

NJGS Modified Method

AQUIFER VERSUS “GROUNDWATER” RECHARGE

The NJGS developed a method for estimating “groundwater” recharge based on soil types, land use, and municipal climate factors (Charles 1993). The NJGS method known as GSR-32, has been proposed for use statewide as a “planning tool” to identify areas of potential groundwater recharge. The GSR-32 method reportedly modifies the water balance equation by using factors for recharge, climate, and drainage basin that are based on general soil types, municipal location, and land use/land cover. The method does not consider slope gradients, depth to bedrock, presence of subsurface impervious or low permeability materials, topography, and/or geology beneath soils. As a result, the method does not measure rates of recharge to fractured bedrock aquifer systems such as those beneath the Sourland Mountain region.

The NJGS states that the GSR-32 method is for determining “groundwater” recharge as opposed to “aquifer” recharge. The NJGS makes the distinction by indicating that “groundwater” recharge is the volume of water that migrates through soils whereas, “aquifer” recharge is the volume of water that enters a geologic formation that is capable of economically yielding water to wells or springs. This distinction is significant because water may migrate through unsaturated soils but does not infiltrate to a perennial saturated zone. Unless the water infiltrates to a perennial saturated zone, it is not groundwater or aquifer recharge. If the water does not recharge an aquifer, residents of the Sourland Mountain region cannot use it for water supply nor is the water available to dilute contaminants in aquifers from septic systems or other anthropogenic sources.

Based on traditional hydrogeologic definitions, the results of the GSR-32 method should be referred to as soil recharge rates as opposed to groundwater or aquifer recharge rates. As indicated in the textbook Groundwater (Freeze & Cherry 1979) "(t)he term groundwater is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated." In the Sourland Mountain region, water-supply wells are completed in fractured bedrock aquifers that are under water-table conditions. Therefore, inclusion of water that does not infiltrate to the water-table aquifer in a recharge analysis will result in significant overestimates of water-supply availability and underestimates of the areas necessary to ensure adequate recharge is available to dilute contaminants in groundwater from septic systems.

Throughout this report and as typically referenced in USGS reports and hydrogeologic texts, the term groundwater recharge refers to water that infiltrates to the saturated zone, which for most of the Sourland Mountain region are water-supply aquifer systems. With the exception of few references to groundwater recharge within quotation marks in this section of the report, the terms aquifer recharge and groundwater recharge have the same definition and refer to water that infiltrates to an aquifer. The term soil recharge will be used in reference to rates determined with the NJGS Modified Method.

Soil Recharge Rates

Although the soil recharge rates calculated with the GSR-32 method are not appropriate for evaluating groundwater recharge or water-supply availability for the Sourland Mountain region, they are summarized in Table 4 for comparison purposes to other methods and because they are sometimes presented as supporting evidence that adequate groundwater is available to sustain water-supply demands and to dilute septic contaminants. The soil recharge rates summarized in Table 4 were calculated with GSR-32 method using a Microsoft Excel Workbook (Hoffman 2002) for the soils mapped in the Sourland Mountain region as shown on Figure 6. There may be slight variations in soils recharge rates between municipalities because of differences in municipal climatic parameters used in the calculations. In the calculations conducted to prepare Table 4, the municipal input parameter was adjusted for each soil type to a representative municipality where the soil had been mapped but the calculations were not completed for every municipality where the soil has been mapped.

Based on the soil types and climatic conditions of the Sourland Mountain region, soil recharge rates ranging from 10.5 to 15.2 inches per year were calculated with the GSR-32 method and there is very little variation in rates based on underlying geology. Some of the highest rates of recharge were calculated for areas underlain by shallow bedrock, thick confining layers, and steep sloping materials. These are areas where surface-water runoff rates should be the highest and groundwater recharge rates the lowest. The NJGS method cannot calculate soil recharge for several soils associated with wetlands, open water, hydric conditions or disturbed areas.

Although nearly 64.4 percent of the soils in the Sourland Mountain region have severe limitations for septic systems primarily because of shallow low permeability layers, seasonal high water, and/or steep slopes, all of which limit the infiltration capacity of the soils; the GSR-32 method indicates that these soils are recharged at high rates suggesting that septic systems should not be limited. The Neshaminy soils are primarily found in areas underlain by diabase and the Chalfont soils are in areas underlain by the Lockatong argillites. The GSR-32 method indicates that these soil types have soil recharge rates of 15.2 and 11.7 inches per year, respectively. Bucks soils are encountered primarily in areas underlain by the Stockton and Passaic Formations and have a soil recharge rate calculated with the GSR-32 method of 12.8 inches per year.

Based on Hordon's (1984) evaluation of Sourland Mountain, Posten's (1984) analysis of Walnut Brook, and the extensive USGS studies in the Stony Brook, Beden Brook, and Jacobs Creek basins, recharge to bedrock through the overlying soils at rates like those suggested by GSR-32 method is not evident. The USGS studies, which calculated groundwater runoff rates using streamflow and computer modeling methods, do not indicate rates that are the same for the Triassic-Jurassic sedimentary formations and the diabase. Furthermore, these studies indicate groundwater runoff rates that are nearly 36 percent lower than the soil recharge rates calculated with the GSR-32 method. The streamflow data and the Posten (1984) and Hordon (1984, 1987, 1995) evaluations indicate significantly lower recharge rates for the diabase and Lockatong Formation than the 15.2 and 11.7 inches per year suggested by the GSR-32 methodology.

Since the GSR-32 soil recharge rates for the Sourland Mountain region cannot be supported by empirical streamflow data, and since the NJGS made a clear distinction that their model does not determine "aquifer" recharge, this method should not be used to assess recharge rates to aquifer systems beneath the Sourland Mountain region. Based on geologic conditions, the results of the GSR-32 evaluation are not reliable for assessing groundwater recharge rates beneath the Sourland Mountain region nor are they reliable for evaluating groundwater resources.

WATER SUPPLY

DEMAND

Residential

As part of the recent statewide planning efforts, the NJDEP (1996) assumed a per capita water use rate of 75 gallons per day for residential self-supplied demand. The New Jersey Water Supply Authority (NJWSA 2000) indicates a guideline value of 140 gallons per day per capita. N.J.A.C. 7:10-3.32 and 7:10-12.6 both indicate that the average daily demand is 100 gallons per day per person. The per capita demand suggested by the New Jersey Administrative Code provides a reasonable mid-range estimate of per-capita water demands and may include a factor of safety if the NJDEP (1996) estimate is accurate.

Based on US Census data for 2000, the Sourland Mountain region is occupied by 21,021 people in 7,281 occupied housing units, which indicates a dwelling unit density of 2.9 persons per household. (Census data indicate that there are slightly more than 234 vacant homes within the Sourland Mountain region.) Based on the population of the region and the average daily demand indicated in N.J.A.C. 7:10, residents currently consume water at rates of approximately 2.1 million gallons per day (mgd), 65.1 million gallons per month (mgm), or 767 million gallons per year (mgy). These consumption rates do not include businesses, agricultural entities, or industries that utilize groundwater resources within the region.

NJDEP Permitted Withdrawals

Large-scale users of water for commercial, industrial, or agricultural purposes can have an impact on the available groundwater resources within the Sourland Mountain region. Records of the NJDEP-Bureau of Water Allocation were reviewed for known users of 100,000 gallons per day (gpd) or more. This includes records for both Water Allocation Permits and Agricultural Certifications for users over 100,000 gpd. In addition, Water Use and Agricultural Registrations for individuals capable of pumping over 100,000 gpd, but maintaining monthly use under 100,000 gpd, were also identified. The State Water Supply Management Act has set the regulatory threshold of 100,000 gpd for State permitting requirements.

NJDEP-Bureau of Water Allocation records were obtained for Hunterdon, Somerset and Mercer Counties. These records were then used to identify permits, registrations or certifications issued within or very near the Sourland Mountain region. The permits registrations or certifications were then reviewed at NJDEP-Bureau of Water Allocation to determine the potential volumes of water that could be withdrawn from the water resources of the region.

The NJDEP-Bureau of Water Allocation does not list any holders of agricultural certifications or registrations located within the Sourland Mountain region. Four water allocation permits and three water use registrations were identified within the Sourland Mountain region. These permit or registration holders can be divided into three categories, public community sources, industrial use, and golf course irrigation. The total maximum pumpage from each of these categories is 42.5, 10, and 10.8 mgm, respectively. Of the 42.5 mgm, the Hopewell Borough Water Department has an allocation of 9 mgm and that water is primarily used by the approximately 2,035 residents (2000 Census) of the Borough. These residents are included in the 21,021 persons living within the Sourland Mountain region and therefore, the 9 mgm is included within the 65.1 mgm consumption rate listed above for the region.

The largest public community water supply diversion within the Sourland Mountain region is United Water-Lambertville, which has a permit allowing a surface-water diversion of 30.4 mgm from Swan Creek Reservoir and D&R Canal. Both of these United Water-Lambertville diversions are surface-water withdrawals. The largest withdrawal from groundwater where the water is consumed outside the region is the Mercer County Correctional Institute, which has a water use registration permitting a diversion of 3.1 mgm.

The industrial water allocation permit within the Sourland Mountain region has been assigned to Minnesota Mining & Manufacturing (3M) in Hillsborough and Montgomery Townships. 3M is permitted to divert 10 mgm of groundwater from the bedrock aquifers beneath its site.

The golf course allocations are Hopewell Valley Golf Club, Stony Brook Golf & Tennis Club, and Amwell Valley Country Club. Hopewell Valley Golf Club has a water allocation permit that allows this club to pump 4.6 mgm from on-site surface-water resources. The Stony Brook Golf & Tennis Club and the Amwell Valley Country Club have water use registrations that permit diversions of up to 3.1 mgm.

Approximately 65.1 mgm could be withdrawn by the residents of the Sourland Mountain region from groundwater resources including the 9 mgm that Hopewell Borough Water Department is permitted to withdraw. An additional 19.3 mgm could be withdrawn from these same limited groundwater resources by the Mercer County Correctional Institute, 3M, Stony Brook Golf & Tennis Club, and the Amwell Valley Country Club.

Water: A Natural Renewable Resource

DEPENDABLE YIELD

Definition

The NJDEP (1996) Statewide Water Supply Plan defines the dependable yield as "…the water yield maintainable by a ground water system during projected future conditions, including both a repetition of the most severe drought of record and long-term withdrawal rates without creating undesirable effects." A similar definition is included in N.J.A.C. 7:19-6 and the New Jersey Water Supply Management Act 58:1A-3h. The "Drought of Record" as currently defined occurred in the mid-1960's with 1962 through 1966 recording below normal precipitation equal to approximately 82 percent of normal precipitation. In 1965, New Jersey received approximately 30 inches of precipitation, which is two-thirds of normal precipitation.

Drought Effects

STREAMFLOW

Drought conditions can alter the hydrologic water balance for an area depending on the time of year the precipitation shortfall occurs. During the winter months, a precipitation shortfall will adversely impact groundwater runoff and to a lesser degree, surface-water runoff. Evapotranspiration is negligible in winter months so this parameter is unaffected by precipitation shortfalls during cold weather. During summer months, precipitation shortages adversely impact evapotranspiration and surface-water runoff. Groundwater recharge is naturally reduced during the summer when most precipitation is rapidly consumed by vegetation and this parameter is not as significantly affected by a warm weather drought as are surface-water runoff and evapotranspiration. Droughts that occur over several years such as the "Drought of Record" adversely impact all water-balance parameters.

Based on stream discharge measurements compiled by the USGS in Stony Brook from October 1, 1953 to September 30, 2002, the median flow rate as measured in Princeton is 22 cubic feet per second. For the period October 1, 1961 to September 30, 1966, the median flow rate was 10 cubic feet per second or 45 percent of normal median flow for the entire period of record. For the Neshanic River from October 1, 1930 through September 30, 2002, the median flow rate is 12 cubic feet per second. For the period from October 1, 1961 through September 30, 1966, the median flow rate is 3.5 cubic feet per second. During the "Drought of Record", median flow in the Neshanic River was reduced 8.5 cubic feet per second or nearly 71 percent of normal conditions. These streamflow data indicate that during the "Drought of Record", discharges to the streams draining the Sourland Mountain region were reduced by 45 to more than 70 percent. These streamflow data indicate that prolonged drought conditions equally affect all water-balance parameters and groundwater recharge is very likely to be reduced by equivalent amounts.

BASEFLOW

The NJGS estimated baseflow using hydrograph separation methods for the periods 1954 to 1989 and 1960 to 1966 (Canace 1992). From 1954 to 1989, baseflow was 5.12 inches per year and for the period of 1960 to 1966 was 4.20 inches per year for Stony Brook at Princeton. Although the 1960 to 1966 baseflow rate indicates below normal-year groundwater runoff rates, it is an overestimate of drought conditions because data from 1960 and 1961 were included. Precipitation in 1960 and 1961 slightly exceeded normal-year precipitation and therefore, streamflows were higher than for the years 1962 through 1966 when precipitation was below normal. Based on the Posten (1984) Method analysis of the Stony Brook at Princeton streamflow data, baseflow in 1961 was the eighth highest rate for the period 1954 through 2002 and was more than twice the baseflow rates calculated for 1965 and 1966, when drought impacts were greatest.

If only the years 1962 through 1966 are evaluated, baseflow averaged 3.61 inches per year or 71 percent of the NJGS' average baseflow for the period 1954 to 1989. Given the precipitation data and using the NJGS baseflow estimates, it could be assumed that a drought similar to the "Drought of Record" would likely reduce baseflow to 71 percent of normal-year rates.

RECHARGE EFFECTS

Reasonable arguments could be made using the Stony Brook at Princeton and Neshanic River at Reaville streamflow data that groundwater recharge during a prolonged drought could be reduced to 45 to more than 70 percent of normal-year recharge. Drought recharge calculations based on the limits of this range could result in potentially conservative or non-existent margins of safety. Although groundwater in storage within an aquifer could be used to buffer brief precipitation shortfalls, this limited resource will be quickly consumed resulting in adverse long-term impacts to the aquifer system. Therefore, a reasonable margin of safety is necessary to ensure adequate water supplies are available during a repeat of the "Drought of Record".

In 1965, the lowest precipitation in the last 100 years was recorded. During this year, precipitation was equal to approximately 66 percent of precipitation during a normal year. Assuming groundwater recharge during a drought is equal to 66 percent of normal-year recharge should provide a moderate margin of safety and possibly, assurances that adequate water supplies are available during a prolonged drought.

To compensate for drought conditions and the very likely overestimates of groundwater recharge included in groundwater runoff estimates, the groundwater runoff rate of 8.2 inches per year for the Passaic and Stockton Formations as determined from the USGS

(Lewis-Brown 1995) computer model should be reduced by at least one-third when used for water-supply and septic system contaminant evaluations. Similarly, the groundwater runoff rate calculated from the USGS data for the diabase of 3.15 inches per year should also be reduced by at least one-third to account for precipitation and associated recharge reductions during drought. If the USGS (Lewis-Brown 1995) data are used to assess groundwater availability, at a minimum the groundwater runoff rates should be reduced to 5.5 and 2.1 inches per year for the Triassic-Jurassic sedimentary, and igneous and metamorphic rocks.

Based on hydrogeologic characteristics of the Lockatong Formation and on Hordon's (1984, 1987, and 1995) evaluations of recharge to the Lockatong Formation and diabase, the Lockatong Formation within the Sourland Mountain region very likely has a groundwater runoff rate of 2.1 inches per year similar to the diabase. The Lockatong Formation rocks are significantly less transmissive than the Stockton and Passaic Formations. Hordon's (1984, 1987, and 1995) studies of the Lockatong Formation and diabase indicated recharge rates ranging from 1.7 to 1.9 inches per year.

SUMMARY

In summary, the Water Supply Management Act (58:1A-3h) and N.J.A.C. 7:19-6 indicate that the effects of drought must be considered to ensure adequate water resources are available without resulting in adverse impacts. Therefore, normal-year groundwater runoff rates such as those calculated with the computer models used in the studies by Lewis-Brown (1995) require adjustment, especially if these rates are to be used as groundwater recharge rates. Based on precipitation data for the "Drought of Record", groundwater runoff within the Sourland Mountain region should range from 5.5 inches per year for the Stockton and Passaic Formations to 2.1 inches per year for the Lockatong Formation, and diabase and associated hornfels.

Planning Threshold

To ensure that water is available during all weather conditions without creating undesirable effects for human consumption as well as ecosystems dependent on water, the NJDEP established the "Planning Threshold". In the 1996 Statewide Water Supply Plan (NJDEP 1996), the NJDEP indicated that the dependable yield of most areas of the State have not been determined. Therefore, they established the "Planning Threshold" to reduce uncertainties associated with determining dependable yields for aquifer systems, and to limit human consumption within a basin.

The Posten (1984) Method was designed by the author to calculate "safe" yields that could be safely withdrawn for human consumption without causing adverse impacts in rock aquifers. However, the simplified hydrograph separation method very likely includes discharges from sources other than the underlying aquifers and therefore, the Posten (1984) Method is likely to result in overestimates of dependable yields.

The NJDEP determined that the Planning Threshold should equal 20 percent of aquifer recharge. Aquifer recharge rates are not available and were not determined with the USGS computer models. Therefore, the Planning Threshold is applied to the drought groundwater runoff rates, which are very likely overestimates of groundwater recharge since the baseflow data included non-aquifer discharges. For the Triassic-Jurassic Stockton and Passaic Formation rocks, application of the Planning Threshold to a drought groundwater runoff rate of 5.5 inches per year indicates a dependable yield of 1.1 inches per year. The Posten (1984) Method analysis indicated a "safe" yield of 1.6 inches per year for the Stony Brook basin. A dependable yield of 1.1 inches per year is equivalent to 82 gallons per day per acre (gpd/acre).

Hordon's (1984, 1987, 1995) studies indicate "safe" yield rates of 1.7 to 1.9 inches per year for the Lockatong Formation, and diabase and associated hornfels. If the Planning Threshold is applied to the drought groundwater runoff rate of 2.1 inches per year, then these rocks have a dependable yield of approximately 0.42 inches per year or 31 gpd/acre.

Water-Supply Yields

Table 5 summarizes the groundwater runoff rates, the adjustments to these rates for drought conditions, and the potential dependable yields for the fractured bedrock aquifer-systems within the Sourland Mountain region. Based strictly on the mapped areas of the bedrock geologic formations, these fractured rock aquifers likely have a total water-supply yield of approximately 3.3 million gallons per day. Table 6 summarizes areas of each bedrock formation within the Sourland Mountain region as well as the potential maximum yields from these bedrock units.

Current demands for residents within the Sourland Mountain region based on population are approximately 2.1 million gallons per day or approximately two-thirds of the dependable yields for the bedrock units beneath the region. The demands of the Mercer County Correctional Institute, 3M, and Stony Brook Golf & Tennis Club, and Amwell Valley Country Club would increase the daily consumption rates by approximately 0.63 million gallons per day. The total potential demands on the aquifer systems could be as much as 2.7 million gallons per day or nearly 83 percent of the long-term dependable yield of 3.3 million gallons per day.

During drought, groundwater resources are not only used by those with wells but also used by those downstream of the Sourland Mountain region that are withdrawing water from surface-water resources. During drought, these surface-water resources are maintained by discharges from aquifer systems. The United Water-Lambertville Swan

Creek Reservoir and the Hopewell Valley Golf Club withdrawals from surface-water resources could be adversely affected by decreased groundwater discharges.

The potential maximum dependable yield of 3.3 million gallons per day is based on the assumption that the entire land surface of each bedrock unit is available for receiving recharge. The potential maximum dependable yield has not been adjusted for developed areas, wetlands, open waters, or steep slopes, which would all effectively reduce groundwater recharge and ultimately the dependable yields of these aquifers. Construction of impervious surfaces, installation of storm sewers, and compaction of soils will result in increased surface-water runoff and decreased infiltration to underlying aquifer systems. These types of development activities will ultimately affect the dependable yields of the aquifer systems.

The entire land surface area of each aquifer system is not available for receiving recharge. In areas with steep slopes, wetlands, and open waters, there will be little if any groundwater recharge. Similarly in urban-commercial, industrial, and/or high to medium density residential areas, very little if any incident precipitation will infiltrate to the underlying aquifer systems. Overuse of groundwater resources either through withdrawals at rates in excess of recharge, or infiltration of wastewater effluent at rates exceeding dilution capacities will result in changes in water chemistry as well as impacts to associated ecosystems and downstream consumers.

Long-term protection of groundwater resources requires identification and minimizing disturbance of recharge areas. Recharge areas for bedrock aquifer systems are located within highly fractured zones such as along the Hopewell Fault where USGS computer modeling has shown very high groundwater runoff rates. Lesser amounts of water may infiltrate within local fault zones but these zones are no less vital to the long-term protection of groundwater resources within the Sourland Mountain region.

Dwelling Unit Densities

U.S. Census data for 2000 indicate each dwelling unit within the Sourland Mountain region is occupied by an average of 2.9 persons per unit. Based on the average number of people per home within the region and the per capita water demands indicated in N.J.A.C 7:10-12.6, each dwelling unit in the Sourland Mountain region consumes approximately 290 gallons per day. The total long-term sustainable yield of the bedrock aquifers is 3.3 million gallons per day. These aquifers may be capable of sustaining approximately 11,400 dwelling units or 33,000 persons. Table 6 summarizes the potential maximum water-supply yields, sustainable populations, sustainable number of dwelling units, and recharge area per dwelling unit for each aquifer system within Sourland Mountain region.

For each 100 gallons per day consumed by the Mercer County Correctional Institute, 3M, Stony Brook Golf & Tennis Club, and Amwell Valley Country Club, the potential population of the Sourland Mountain region as listed in Table 6 would be decreased by one person and for every 290 gallons consumed by these other users, the number of dwelling units would necessarily be decreased by one. If the correctional institute, 3M, and the golf courses withdrew the maximum amounts allowed by their permits or water use registrations, the potential maximum sustainable population would be reduced from 33,000 to 26,700 and the maximum number of dwelling units would be decreased from 11,400 to 9,200.

The Stockton and Passaic Formations encompass slightly more than 31,000 acres within the Sourland Mountain region. Based on a dependable yield of 82 gallons per day per acre, these formations may be capable of sustaining nearly 8,800 total dwelling units at a density of 1 unit for every 3.5 acres of available recharge area. However, the Mercer County Correctional Institute, 3M, Stony Brook Golf & Tennis Club, and Amwell Valley Country Club all obtain water from the Passaic Formation. The potential withdrawals of 19.3 mgm or approximately 0.63 mgd, would reduce the sustainable population by 6,345 persons or nearly 2,200 dwelling units. Therefore, the total number of dwelling units for the areas underlain by Stockton Formation and Passaic Formation rocks is approximately 6,600 or one unit for every 4.7 acres of the region underlain by these rocks.

The Lockatong Formation, diabase and hornfels underlie slightly more than 24,100 acres of the Sourland Mountain region and may be capable of sustaining slightly less than 2800 dwelling units. The dwelling unit density for areas underlain by the Lockatong Formation and the Jurassic igneous and metamorphic rocks is 1 unit for every 9.3 acres of available recharge area.

Recharge Areas

The recharge areas listed in Table 6 should not be assumed equal to lot sizes. In many areas of the Sourland Mountain region, dwelling units will have lots smaller than the recharge areas listed in Table 6. Sufficient water could be available to sustain the demands of these dwelling units provided that sufficient recharge areas are available, especially in an upgradient direction, to permit aquifer replenishment and the overall density is not exceeded.

Old agricultural villages with small village lots surrounded by farmlands would be an example of an area with lot sizes less than the recharge areas listed in Table 6 but where the overall density does not exceed the number of units per area available for recharge. In this example, the village's water-supply demands are sustained by recharge to upgradient farmlands beneath which, groundwater migrates to the village wells. Little precipitation would infiltrate to the aquifer beneath the village because of the high density of impervious surfaces, while sufficient precipitation could infiltrate through the adjoining open farm fields during late fall and winter months to sustain the local water-supply demands.

The areas available for recharge as listed in Table 6 for each aquifer system should permit precipitation to infiltrate to the aquifer and ensure the groundwater is available for both human consumption within the dwelling units associated with the recharge area, and also for downstream ecosystems and consumers. The recharge areas should be upgradient of the wells to maximize available storage and aquifer replenishment. These areas should be flat to gently sloping, vegetated, open to incident precipitation, and should not be covered with impervious materials or buildings. The recharge areas should be located within areas in which, bedrock is highly fractured with little to no impervious coverage along strike or trend of the fractures. The recharge areas do not have to be coincident with the dwelling unit but must be located with the same topographic drainage areas.

Seeps, wetlands, streams, bedrock outcrops, and/or steep slopes should not be included in recharge areas. All site improvements, especially those that include impervious surfaces should be in addition to the recharge area per lot.

In addition to ensuring adequate water supplies are available to the residents of the Sourland Mountain region during all weather conditions including a repetition of the "Drought of Record", groundwater quality must be maintained to provide safe drinking water. The recharge areas for the region permit water to infiltrate to an aquifer and dilute natural and man-made contaminants. In areas of the Sourland Mountain region where septic systems are utilized for disposal of wastewater, some portion if not all water used in a residence could be recycled to an aquifer system. The water from these wastewater disposal systems does not meet Federal or State Drinking Water Quality Standards and therefore, requires dilution within the aquifer to sufficiently reduce contaminant concentrations.

WATER QUALITY

NITRATE DILUTION

Nitrate

Nitrate is not naturally found in groundwater and its presence is a result of anthropogenic activities. Nitrate can be introduced to groundwater from sewage discharges, fertilizers, animal waste, and decomposing plants. In addition, some agricultural crops such as legumes and alfalfa can fix atmospheric nitrogen and transfer the nitrogen to soils where it can then enter groundwater. Nitrate is used as an indicator of anthropogenic impacts to groundwater, especially impacts associated with sewage disposal. Elevated nitrates can cause methemoglobinemia (Blue Baby Syndrome) in infants and can also be an indicator of pathogenic bacterial or viral contamination as well as contamination from other man-made chemical compounds.

Nitrate is a highly soluble, stable, and mobile compound in groundwater when sufficient dissolved oxygen is available. Fractured bedrock aquifer systems contain high concentrations of dissolved oxygen. Under these conditions, nitrate, much like the other contaminants for which nitrate serves as an indicator, can migrate large distances and result in extensive plumes of groundwater contamination. Since nitrate and other contaminants are not easily removed from groundwater, the source(s) of the contamination must be identified and removed, and contaminant concentrations diluted to meet Federal or State Drinking Water Quality Standards.

Background Concentrations

ANTIDEGRADATION LIMIT

On January 7, 1993, the NJDEP established groundwater classifications and quality criteria (N.J.A.C. 7:9-6). In accordance with these New Jersey Ground Water Quality Standards, groundwater within Sourland Mountain region is classified as Class II-A. The nitrate as nitrogen criteria for Class II-A water is 10 milligrams per liter (mg/l). This criterion is the same as the USEPA standard for nitrate as nitrogen in drinking water.

As part of New Jersey's groundwater quality standards, the NJDEP established an antidegradation policy to protect groundwater in which, the background concentration of a contaminant does not exceed the quality criteria. The policy limits the discharge of contaminants to groundwater to a percentage of the difference between the background concentration and the quality criteria. For Class II-A water, the limit is the background concentration plus 50 percent of the difference between the background concentration and the quality criteria. The NJDEP antidegradation policy is not a non-degradation policy. The antidegradation policy allows contaminant concentrations to increase.

As part of the 1993 study of the Stony Brook, Beden Brook, and Jacobs Creek basin, the USGS collected groundwater samples, some of which were analyzed for nitrite plus nitrate. These analytical results indicate background nitrate concentrations ranging from the detection limit of 0.1 milligram per liter (mg/l) to 4.7 mg/l with a median concentration of 0.82 mg/l. The NJGS summarized analytical data for samples throughout New Jersey and these data indicate that background concentrations of nitrate in groundwater within the Newark Basin range from 0.1 to 7.4 mg/l with a median concentrations of 1.6 mg/l. Based on the USGS and NJGS studies, within the Sourland Mountain region, the antidegradation limit for nitrate discharges should range from 5.4 to 5.8 mg/l.

Although the antidegradation limit would result in discharge concentrations of 5.4 to 5.8 mg/l, which is below the drinking water standard, this limit would permit background concentrations to increase more than 5 times above the current background limit and will likely result in adverse impairment of groundwater quality. Since all residents in the Sourland Mountain region rely on groundwater for drinking water and fractured bedrock aquifers provide minimal if any, contaminant removal, the aquifers beneath the region have similar needs for protection as those areas designated by the NJDEP as Class I-A and I-PL groundwater. In areas of New Jersey with Class I-A or I-PL groundwater, the NJDEP has a non-degradation policy and does not allow discharges to increase concentrations above background concentrations. Since groundwater is the source of drinking water, the Sourland Mountain region should be afforded the protections of Sole Source Aquifers, especially since the USEPA and NJDEP have long recognized the need for protecting water quality within much of this area.

Trela-Douglas Model

ACCEPTANCE

The Trela-Douglas nitrate-dilution model was developed in 1978 and presented at the First Annual Pine Barrens Research Conference. This model has been widely accepted and used by the NJDEP for more than 24 years when evaluating potential nitrate discharges from septic systems to groundwater and for determining the recharge area necessary to dilute nitrate concentrations. The model continues to be used by the NJDEP and is the nitrate dilution model used in their “Recharge Based Nitrate Dilution Model for New Jersey” (July 2001) and is used for evaluating septic system impacts from subdivisions of 50 lots or more.

The difference between the evaluation using the Trela-Douglas model discussed herein and an evaluation conducted using the July 2001 “Recharge Based Nitrate Dilution Model for New Jersey” is that the July 2001 analysis uses the soil recharge method outlined in GSR-32. As discussed above, since the soil recharge method does not calculate the volume of water infiltrating to groundwater, it would not be appropriate to use this model for assessing dilution needs in aquifer systems.

The Trela-Douglas model is considered conservative because it does not account for denitrification of nitrate in soils. However, this assumption is appropriate for fractured bedrock environments with a thin soil cover such as the systems beneath the Sourland Mountain region. Soils offer limited retention time before the septic-system effluent enters groundwater. In fractured bedrock environments, effluent can migrate quickly into underlying bedrock fractures. With limited retention times and oxidized conditions, little if any denitrification will occur in the bedrock fractures. Under these same conditions, many other man-made contaminants will not be reduced in concentration without adequate dilution.

Nitrates and other contaminants such as bacteria, viruses and man-made chemicals, can quickly migrate from a septic system into an aquifer system, especially a fractured bedrock system. Once the nitrate or other contaminant is in an aquifer system, there is little opportunity for removal or retardation. Since approximately 64 percent of the Sourland Mountain region is underlain by soils with severe limitations for septic systems, these soils are unlikely to prevent nitrates or other contaminants from impacting groundwater used for water supply. Therefore, adequate recharge is necessary to dilute the concentration of contaminants to conditions satisfying Federal and State Drinking Water Quality Standards.

ASSUMPTIONS

Similar to the water-supply evaluation discussed above, the Trela-Douglas model was applied to the Sourland Mountain region to evaluate existing needs based on current demographics. The Trela-Douglas nitrate dilution model is based on several assumptions, which for the region include the following:

1. The groundwater use rate is 100 gallons per day per person and 2.9 persons occupy each dwelling unit. These assumptions are the same assumptions used in determining recharge areas for water supply use. Therefore, groundwater use per dwelling unit is 290 gpd.

2. The groundwater runoff rate is 5.5 inches per year for areas underlain by the Stockton and Passaic Formations and 2.1 inches per year for areas underlain by the Lockatong Formation, diabase, and hornfels. The drought groundwater runoff rates were selected for this analysis to minimize potential adverse impacts to subsurface-water quality as well as to the health of residents and other water consumers during an extended drought similar to the "Drought of Record" in the 1960's.

3. The nitrate-nitrogen concentration in the septic system effluent is approximately 40 mg/l.

4. The nitrate concentration at the boundary of the recharge area, which is in accordance with the NJDEP antidegradation policy for Class II-A groundwater, is 5.6 mg/l. The 5.6 mg/l concentration is the mid-point between the anti-degradation limits determined from the USGS data for the Stony Brook, Beden Brook, and Jacobs Creek basins of 5.4 mg/l and the NJDEP findings of 5.8 mg/l for the larger Newark Basin.

5. No additional sources of nitrate such as fertilizers are added to the environment and migrate to groundwater.

6. Complete mixing of effluent and groundwater recharge beneath the property.

Water: A Natural Renewable Resource

EQUATION

The Trela-Douglas Model is defined by the following equation:

$$V_eC_e=(V_i+V_e)C_q \quad (2)$$

Where:

V_e = Volume of effluent.
C_e = Concentration of nitrate in effluent.
V_i = Volume of recharge.
C_q = Concentration of nitrate at downgradient property boundary.

The volume of effluent and volume of recharge parameters can be modified as follows:

$$V_e=HW_u \quad (3)$$
$$V_I=AR \quad (4)$$

Where:

H = Number of persons per home.
W_u = Per capita water use in gallons per day.
A = Recharge area in acres.
R = Recharge rate in inches per year.
And 74.39 is a factor to convert inches per year to gallons per day.

The Equation 2 can be modified with Equations 3 and 4 and rearranged to solve for recharge area as follows:

$$A=HW_u(C_e-C_q)/74.39(RC_q) \quad (5)$$

With the following values for these parameters:

H = 2.9 persons per home.
W_u = 100 gallons per day.
C_e = 40 mg/l.
C_q = 5.6 mg/l.
R = 5.5 inches per year for the Stockton and Passaic Formations and 2.1 inches per year for the Lockatong Formation, diabase, and hornfels.

Solving Equation 5 for the Stockton and Passaic Formations rocks beneath the Sourland Mountain region indicates a recharge area requirement of 4.4-acres to adequately dilute nitrates to the NJDEP anti-degradation policy. For the areas underlain by the Lockatong Formation, diabase, and hornfels, the solution of Equation 5 indicates recharge areas of 11.4-acres are necessary for adequate dilution of septic contaminants to the NJDEP anti-degradation policy. Table 7 summarizes the recharge areas per geologic unit for dilution of septic system contaminants beneath the Sourland Mountain region. The number of sustainable dwelling units calculated for septic-system dilution is less than the number of units calculated for water supply.

Similar to the recharge areas for water supply, the recharge areas necessary to dilute nitrate concentrations should be in areas with flat to gentle slopes and open to precipitation. The areas should not be covered with impervious surfaces or buildings that can prevent precipitation from infiltrating into bedrock fractures. Portions of properties that include seeps, wetlands, streams, bedrock outcrops, and/or steep slopes should not be included in the recharge areas. Recharge areas are not equivalent to lot sizes.

In areas of the Sourland Mountain region with existing recharge areas less than the densities required, additional areas or recharge enhancements may be needed for adequate septic-system contaminant dilution. It may be necessary to preserve or protect upstream open areas within the same subwatershed to ensure sufficient water infiltrates the aquifer to dilute septic-system contaminants from these existing dwellings. Even in areas where the existing recharge areas are capable of supporting existing dwelling units, it may be necessary to protect upstream open areas or enhance recharge to balance portions of the existing lots covered with impervious materials.

CONCLUSIONS

Based on the data, reports, and maps reviewed in preparation of the Sourland Mountain region water-resource evaluation, the following conclusions are made:

1. The source of drinking water for Sourland Mountain region residents is groundwater. Water is supplied to these residents from wells completed in fractured bedrock aquifers. Overuse of these aquifers could result in significant changes in water quality and availability detrimentally affecting the long-term viability of these resources as well as impacting downstream consumers, ecosystems, and other natural resources. Contamination of groundwater could also affect the long-term viability of this resource as well as require significant expenditures of public funds for remediation and/or improvement of water quality to meet appropriate State and Federal standards.

2. Residents of New Jersey downstream of the Sourland Mountain region that obtain their drinking water from public surface-water supply systems must rely on groundwater discharging to the Raritan River or its tributaries to meet their water-supply demands, especially during drought. The Raritan and Millstone Rivers are vital component of New Jersey's RWRPA 10, which is the third most populated regional water resource planning area in the state and expected to increase an additional 31 percent by 2046. The Sourland Mountain region is critical headwaters for these rivers and water flowing from the region is not only needed within the region, but also to sustain others downstream. U.S. Census data for 2000 indicate slightly more than 21,000 people live in nearly 7300 occupied-dwelling units within the Sourland Mountain region. An additional 234 housing units were vacant in the region according to the U.S. Census.

3. Currently, water resources within RWRPA 10 are diverted to other regions of New Jersey to meet demands that exceed the sustainable supplies within these other regions. Continued population growth is expected to further strain limited water-supply resources. The NJDEP predicted that the water-supply demands within RWRPA 10 would exceed the sustainable resources of the combined Millstone and Raritan River watersheds by 2040. The New Jersey Water Supply Authority (NJWSA) indicates that these resources may be exceeded several years prior to 2040.

4. Sourland Mountain is a critical headwater region for the Raritan and Millstone River systems. At headwaters, discharging groundwater provides the initial surface-water flow in the streams. Within headwaters areas, water quality can be quickly impacted and degraded as a result of man-made discharges. Increasing percentages of impervious surface coverage will result in increased stormwater and decreased groundwater discharges. Contaminant discharges from anthropogenic sources can significantly alter and degrade water quality and quantity in a stream and only through dilution can many of these impacts be mitigated or reduced. These impacts can affect the quality and quantity of water available to downstream consumers, and other natural resources and ecosystems.

5. Approximately 3.1 percent of the soils within the Sourland Mountain region are mapped as having slight to few operational limitations for septic systems. Approximately 32.5 percent of the soils are mapped as having moderate limitations and an additional 64.4 percent would likely have severe limitations for septic system operations. These moderate and/or severe limitations are typically associated with shallow depths to groundwater or low permeability layers such as bedrock or shallow seasonal or perennial saturated zones.

6. Approximately 0.1 percent of the region is underlain by soils with low surface-water runoff rates and high infiltration rates, and therefore, have an A hydrologic soil group code. Soils beneath approximately 16.9 percent of the region have moderate infiltration and surface-water runoff rates, and therefore, have a B hydrologic soil group code. Soils beneath approximately 83 percent of the region have low to very low infiltration rates and high to very high surface-water runoff rates, and therefore, have C and D hydrologic soil group codes.

7. The Sourland Mountain region is underlain by Triassic (245 to 208 million years ago) and Jurassic (145 to 208 million years ago) bedrock. The sediments later formed into the bedrock found today were deposited into basins formed as result of continental separation or rifting as the North American, European, and African continental plates moved in opposing directions forming the Atlantic Ocean.

8. The Passaic Formation is encountered beneath approximately 44.5 square miles or 51.5 percent of the Sourland Mountain region making this the most common rock-type within the region.

9. Two sole source aquifers have been designated by the USEPA beneath the Sourland Mountain region. The Northwest New Jersey Sole Source Aquifer extends across the northern portion and the Coastal Plain Sole Source Aquifer extends across the southwestern edge of the region. Although all the people rely on groundwater for drinking water, a section of the region between these sole source aquifers has not been designated by the USEPA or NJDEP. The USEPA defines a sole source aquifer as the following: “Sole-source aquifers (SSAs) are those aquifers that contribute more than 50% of the drinking water to a specific area and the water would be impossible to replace if the aquifer were contaminated”. The NJDEP and USEPA consider groundwater to be the primary source of drinking water within the designated sole source aquifers and indicate that measures should be taken to protect these critical resources from potential health hazards. Since all the residents of the Sourland Mountain region rely on groundwater for drinking water, the entire region should be designated a Sole Source Aquifer.

10. Within the Sourland Mountain region, groundwater provides essentially all of the water used for drinking water. In addition to individual residential wells, there are major water-supply wells within the region. In addition to the groundwater use within the region, downstream consumers rely on groundwater discharging to the Millstone or Raritan River systems for drinking water. During dry weather, the percentage of groundwater used for drinking water increases because water extracted from the Raritan and Millstone

Rivers for drinking water is almost entirely derived from groundwater discharges to the river and its tributaries. However, during dry weather, groundwater is not the only source of water flowing in the Raritan and Millstone Rivers. There are several facilities with permits to discharge wastewater to the river or groundwater. Water flowing from the Sourland Mountain region is needed to dilute the wastewater.

11. Within the Sourland Mountain region, groundwater is stored and transmitted in fractures and openings created after the rock formed. The combined Stockton and Passaic Formations encompass more than 56 percent of the Sourland Mountain region and therefore, the aquifer-systems within these rocks are significant resources for the region as well as other areas of Central New Jersey.

12. Well data for Mercer and Hunterdon Counties indicate that the Stockton and Passaic Formations are good aquifers capable of readily meeting most domestic and small-commercial water-supply needs. Well data indicate that the Lockatong Formation, diabase, and associated hornfels are poor to very-poor yielding aquifers.

13. Flow duration curves for Stony Brook at Princeton and several other streams originating within the Sourland Mountain region decline two orders of magnitude between the 10 and 95 percent flow exceedence values indicating flashy conditions with high surface-water runoff rates and low groundwater storage capacities. Flow duration curves for these streams show very significant breaks in the slopes of the curves at the 70 to 90 percent flow exceedences. During dry weather when the flow in these streams is entirely derived from subsurface sources, there is little water in storage to maintain constant rates of discharge.

14. The data for Baldwins Creek, Honey Branch, and Royce Brook Tributary at Frankfort indicate that the aquifers cannot provide water to these streams in dry weather. The data indicate that either the aquifers beneath these streams have extremely low storage capacities and are quickly dewatered in dry weather, or that groundwater withdrawals exceed rates of replenishment resulting in water levels being lowered below the natural discharge points in the streams. In either circumstance, the flow duration curves for these streams indicate that the underlying bedrock aquifers have little storage capacity, receive very little recharge, and can become quickly dewatered.

15. The Posten (1984) Method indicates that recharge to the bedrock aquifers beneath the Stony Brook basin upgradient of Princeton should be less than 1.6 inches per year. Some of the bedrock types are likely to have slightly

higher recharge rates and others, lower rates. Fifty-six percent of the Stony Brook basin is underlain by Passaic Formation. The remaining 44 percent of the basin is underlain by the Lockatong Formation (25 percent), Stockton Formation (5 percent) and diabase (14 percent). Hordon (1984, 1987, 1995) determined that for areas underlain by Lockatong Formation and diabase rocks, groundwater is recharged at rates of 1.7 to 1.9 inches per year.

16. The USGS evaluations of the Stony Brook, Beden Brook, and Jacobs Creek basins indicate groundwater runoff rates averaging 8.2 inches per year for the Triassic-Jurassic sedimentary units and 3.15 inches per year for the diabase and associated metamorphic rocks. Further analyses or adjustment to these groundwater runoff rates would be required to eliminate or reduce the shallow subsurface discharges from the deeper aquifer/groundwater system discharges and ultimately determine groundwater recharge rates.

17. The Water Supply Management Act (58:1A-3h) and N.J.A.C. 7:19-6 indicate that the effects of drought must be considered to ensure adequate water resources are available without resulting in adverse impacts. Therefore, normal-year groundwater runoff rates such as those calculated with the computer models used in the studies by Lewis-Brown (1995) require adjustment, especially if these rates are to be used as groundwater recharge rates. Based on precipitation data for the “Drought of Record”, groundwater runoff within the Sourland Mountain region should range from 5.5 inches per year for the Stockton and Passaic Formations to 2.1 inches per year for the Lockatong Formation, and diabase and associated hornfels.

18. To ensure that water is available during all weather conditions without creating undesirable effects for human consumption as well as ecosystems dependent on water, the NJDEP established the “Planning Threshold”. The NJDEP indicated that the dependable yields of aquifers in most areas of the State have not been determined and therefore, established the “Planning Threshold” to reduce uncertainties associated with determining dependable yields for aquifer systems, and to limit human consumption within a basin.

19. Applying the Planning Threshold to the drought groundwater runoff rates indicates dependable yields as follows: 1.1 inches per year or 82 gpd/acre for the Triassic-Jurassic Stockton and Passaic Formations and 0.42 inches per year or 31 gpd/acre for the Lockatong Formation, diabase, and hornfels.

20. Based on the mapped areas of the bedrock geologic formations, the fractured rock aquifers likely have a total water-supply yield of approximately 3.3 million gallons per day. Current demands for residents within the Sourland Mountain region based on population are approximately 2.1 million gallons per day or

approximately two-thirds of the dependable yields for the bedrock units beneath the region. The Mercer County Correctional Institute, 3M, Stony Brook Golf & Tennis Club, and Amwell Valley Country Club are permitted to use an additional 0.63 million gallons per day. Therefore, the daily usage may be as much as 2.7 million gallons per day or 82 percent of the total water-supply yield of the aquifers beneath the region. During drought, groundwater resources are not only used by those with wells but also used by those downstream of the Sourland Mountain region that are withdrawing water from surface-water resources. During drought, these surface-water resources are maintained by discharges from aquifer systems.

21. The potential maximum dependable yield of 3.3 million gallons per day is based on the assumption that the entire land surface of each bedrock unit is available for receiving recharge. The potential maximum dependable yield has not been adjusted for developed areas, wetlands, open waters, or steep slopes, which would all effectively reduce groundwater recharge and ultimately the dependable yields of these aquifers. Construction of impervious surfaces, installation of storm sewers, and compaction of soils will result in increased surface-water runoff and decreased infiltration to underlying aquifer systems. These types of development activities will ultimately affect the dependable yields of the aquifer systems.

22. The entire land surface area of each aquifer system is not available for receiving recharge. In areas with steep slopes, wetlands, and open waters, there will be little if any groundwater recharge. Similarly in urban-commercial, industrial, and/or high to medium density residential areas, very little if any incident precipitation will infiltrate to the underlying aquifer systems. Overuse of groundwater resources either through withdrawals at rates in excess of recharge, or infiltration of wastewater effluent at rates exceeding dilution capacities will result in changes in water chemistry as well as impacts to associated ecosystems and downstream consumers.

23. Long-term protection of groundwater resources requires identification and minimizing disturbance of recharge areas. Recharge areas for bedrock aquifer systems are located within highly fractured zones.

24. U.S. Census data for 2000 indicates each dwelling unit with in the Sourland Mountain region is occupied by an average of 2.9 persons per unit and based on per capita water demands indicated in N.J.A.C 7:10-12.6, each dwelling unit in the region consumes approximately 290 gallons per day. The total long-term sustainable yield of the bedrock aquifers of 3.3 million gallons per day may be capable of sustaining approximately 11,400 dwelling units or 33,000 persons.

25. For each 100 gallons per day consumed by the Mercer County Correctional Institute, 3M, Stony Brook Golf & Tennis Club, and Amwell Valley Country Club, the potential population of the Sourland Mountain region would be decreased by one person and for every 290 gallons consumed by these other users, the number of dwelling units would necessarily be decreased by one. If the correctional institute, 3M, and the golf courses withdrew the maximum amounts allowed by their permits or water use registrations, the potential maximum sustainable population would be reduced from 33,000 to 26,700 and the maximum number of dwelling units would be decreased from 11,400 to 9,200.

26. To adequately dilute septic-system contaminants to the NJDEP anti-degradation policy beneath the Sourland Mountain region, recharge areas are required as follows: 4.4-acres for the Stockton and Passaic Formations rocks and 11.4-acres for the Lockatong Formation, diabase, and hornfels.

27. Recharge areas should be upgradient of wells to maximize available storage and aquifer replenishment and should be flat to gently sloping, vegetated, open to incident precipitation, and should not be covered with impervious materials or buildings. The aquifer recharge areas should be located within areas in which, bedrock is highly fractured with little to no impervious coverage along strike or trend of the fractures. For bedrock aquifers, the recharge areas do not have to be coincident with the dwelling unit but must be located with the same topographic drainage areas. Seeps, wetlands, streams, bedrock outcrops, and/or steep slopes should not be included in recharge areas. All site improvements, especially those that include impervious surfaces should be in addition to the recharge area per unit. Recharge areas are not equivalent to lot size.

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Table 1: Soils beneath the Sourland Mountain Region in New Jersey.

Soil Type	Area (acres)	Area (mi^2)	Hydrologic Group	Hydric	N.J.A.C 7:9A Septic System Soil Suitability Classification
Abbottstown	828.50	1.29	C	N	IIIHR, WP(IIISc); IISr, Wp(IIISc)
Birdsboro	242.20	0.38	B	N	I; IIWr; IISc; IIWrSc
Bowmansville	776.70	1.21	B/D	Y	IIIWr
Bucks	3706.40	5.79	B	N	IISc; IISr
Califon	25.20	0.04	C	N	IIIHRWP
Chalfont	12764.50	19.94	C	N	IIISrWp
Croton	386.30	0.60	D	Y	IIISrWp; IIISrWr
Cut and fill land	96.90	0.15	B	N	Disturbed ground
Doylestown	945.50	1.48	D	Y	IIISrWr
Hazleton	291.70	0.46	B	N	IISc
Klinesville	1707.20	2.67	C	N	IISc; IISr
Lansdale	263.70	0.41	B	N	IISc
Lansdowne	76.90	0.12	C	N	IIIHrWp(IISc); IIIHrWp(IISr)
Lawrenceville	2953.30	4.61	C	N	IIISrWp; IIIHrWp
Legore	1448.20	2.26	B	N	I; IISr
Lehigh	3743.60	5.85	C	N	IIISrWp; IIIHrWp(IISc)
Mount Lucas	7455.60	11.65	C	N	IIIWp(IISr)
Neshaminy	3250.70	5.08	B	N	IISr
Norton	79.70	0.12	C	N	IIIHr
Penn	4760.60	7.44	C	N	IISc; IIISr
Pits	59.00	0.09	A	N	Disturbed ground; excessively coarse substrata
Pope	3.80	0.01	B	N	I; IISc
Quakertown	3815.60	5.96	C	N	IISc; I
Quarries	27.10	0.04	D	N	Disturbed ground
Raritan	23.00	0.04	C	N	IIIHrWp; IIIHrWp(IISc); IIIHrWp(IISr)
Readington	354.50	0.55	C	N	IIIHrWp(IISc); IIWpSrSc; IIWrSc
Reaville	2326.00	3.63	C	N	IIISrWp(IIHc)
Reaville variant	169.40	0.26	D	Y	IIISrWp(IIHc)
Riverhead	2.70	0.00	B	N	I; IISc
Rough Broken Land	696.50	1.09	D	N	Excessively stony
Rowland	1429.90	2.23	C	N	IIIWr
Royce	129.20	0.20	C	N	IISc
Tioga	4.40	0.01	B	N	I; IIWr; IIWrSc; IISc
Urban land	51.70	0.08		N	Disturbed ground
Watchung	187.40	0.29	D	Y	IIIHrWpWr
Water	147.80	0.23		Y	Water

Table 2: Geologic Formations beneath the Sourland Mountain Region in New Jersey.

Formation	Area (acres)	Area (mi^2)	Percentage of Region
Jurassic Diabase	11,465.46	17.92	20.8%
Passaic Formation Gray bed	3,376.31	5.28	6.1%
Passaic Formation	25,079.03	39.19	45.4%
Lockatong Formation	12,631.83	19.74	22.9%
Stockton Formation	2,678.66	4.19	4.8%

Table 3: Normal Rainfall and Mean Temperature As Determined from Measurements Recorded by National Climatic Data Center for 115 Years at Climatic Station Lambertville, New Jersey.

Month	Precipitation (inches)	Mean Temperature (Farenheit)	Potential Evapotranspiration (inches)
January	3.44	29.6	0.00
February	2.93	32.2	0.00
March	3.75	41.7	0.63
April	3.94	51.3	1.73
May	4.37	62.0	3.51
June	3.72	70.9	5.02
July	4.73	75.4	5.92
August	4.06	74.0	5.26
September	3.96	66.8	3.60
October	3.05	55.5	1.95
November	3.85	45.3	0.78
December	3.63	34.5	0.08
Annual Total:	45.43	53.3	28.49

1 inch of rainfall equals 27152.4 gallons per acre.

Potential evapotranspiration calculated with Thornthwaite Method.

Table 4: Soil Recharge and Nitrate Dilution Calculations Made with NJDEP Model DGS02-06 for Soil Types in Sourland Mountain Region of New Jersey.

Soil Type	Soil Recharge Rate (inches per year)	Recharge Area per Septic System (acres)
Abbottstown	11.5	2.5
Birdsboro	12.9	2.2
Bowmansville	Hydric soil, method not applicable	
Bucks	12.8	2.3
Califon	12.4	2.2
Chalfont	11.7	2.4
Croton	Hydric soil, method not applicable	
Cut and fill land	Method not applicable	
Doylestown	Hydric soil, method not applicable	
Hazleton	14.9	1.8
Klinesville	14.4	2.0
Lansdale	12.9	2.2
Lansdowne	12.7	2.3
Lawrenceville	11.3	2.5
Legore	12.9	2.2
Lehigh	10.7	2.7
Mount Lucas	12.4	2.3
Neshaminy	15.2	1.9
Norton	12.8	2.2
Penn	12.6	2.3
Pits	Method not applicable	
Pope	14.5	1.9
Quakertown	10.5	2.7
Quarry	Method not applicable	
Raritan	12.3	2.3
Readington	11.0	2.6
Reaville	11.5	2.5
Reaville variant	Hydric soil, method not applicable	
Riverhead	14.8	1.9
Rough Broken Land	14.0	2.0
Rowland	12.0	2.4
Royce	12.3	2.3
Tioga	14.8	1.9
Urban land	Method not applicable	
Watchung	Hydric soil, method not applicable	

Table 5: Groundwater Runoff Rates and Potential Dependable Yields for Aquifers beneath the Sourland Mountain Region in New Jersey.

Aquifer System	Normal Precipitation Groundwater Runoff Rate		Drought Groundwater Runoff Rate		Planning Threshold Dependable Yield	
	(inches/year)	(gpd/acre)	(inches/year)	(gpd/acre)	(inches/year)	(gpd/acre)
Stockton/Passaic Formations	8.2	610	5.5	409	1.1	82
Lockatong Formation/diabase/hornfels	3.15	234	2.1	156	0.42	31

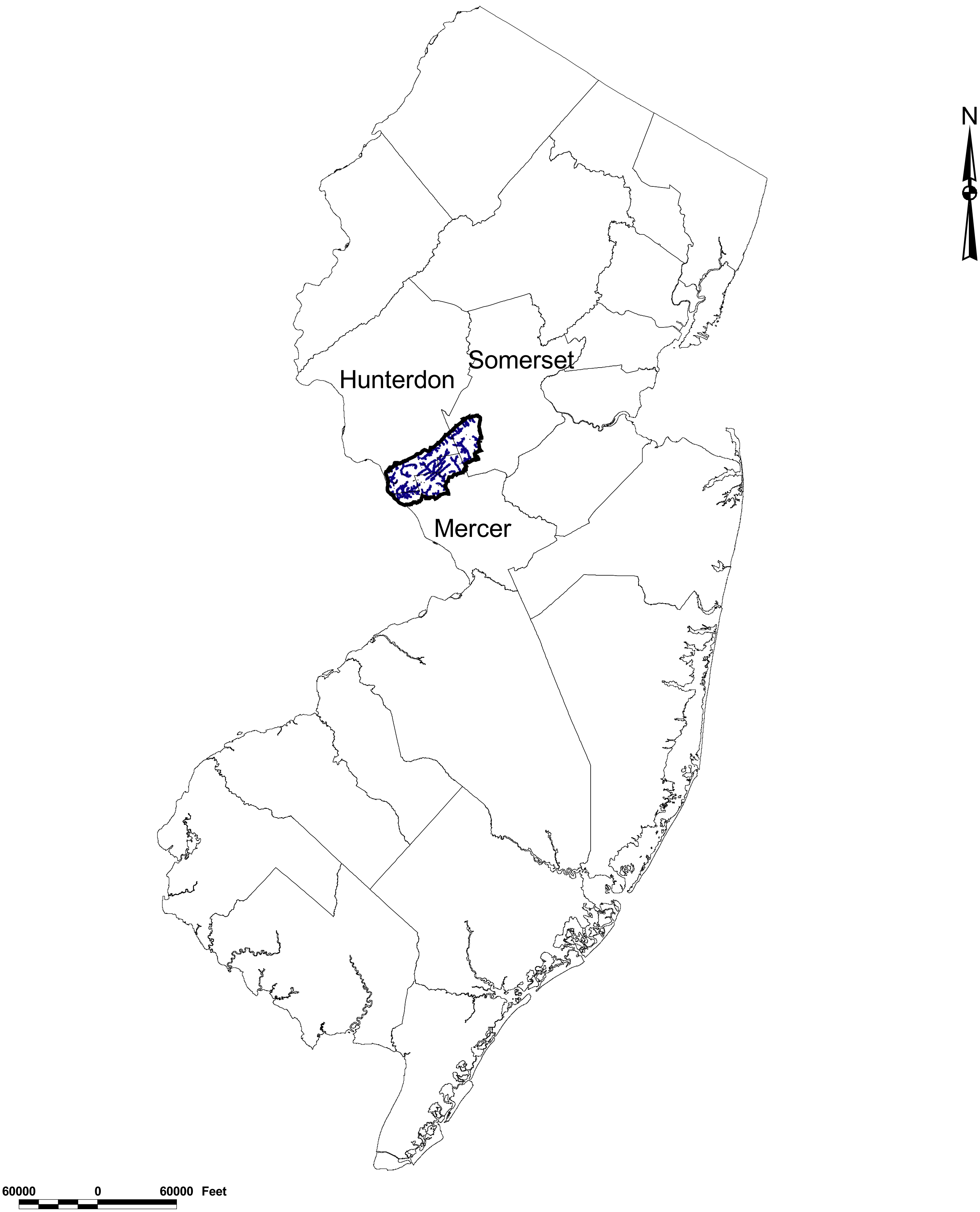
Table 6: Potential Available Groundwater-Supply Yields, Sustainable Populations, and Recharge Areas per Dwelling Units for Aquifers beneath the Sourland Mountain Region in New Jersey.

Aquifer System	Area of Watershed (acres)	Dependable Yield (gpd/acre)	Potential Maximum Water-Supply Yield (mgd)	Potential Maximum Sustainable Population	Potential Maximum Sustainable Number of Dwelling Units	Recharge Area per Dwelling Unit (acres per unit)
Stockton/Passaic Formations	31,134.0	82	2.55	25,477	8,785	3.5
Lockatong Formation/diabase/hornfels	24,097.3	31	0.75	7,529	2,596	9.3
Stockton/Passaic Formation after adjustment for correctional institute, 3M, and golf courses			1.91	19,132	6,597	4.7

Table 7: Recharge Areas per Dwelling Unit for Dilution of Septic-System Contaminants using Trela-Douglas Model for the Sourland Mountain Region in New Jersey.

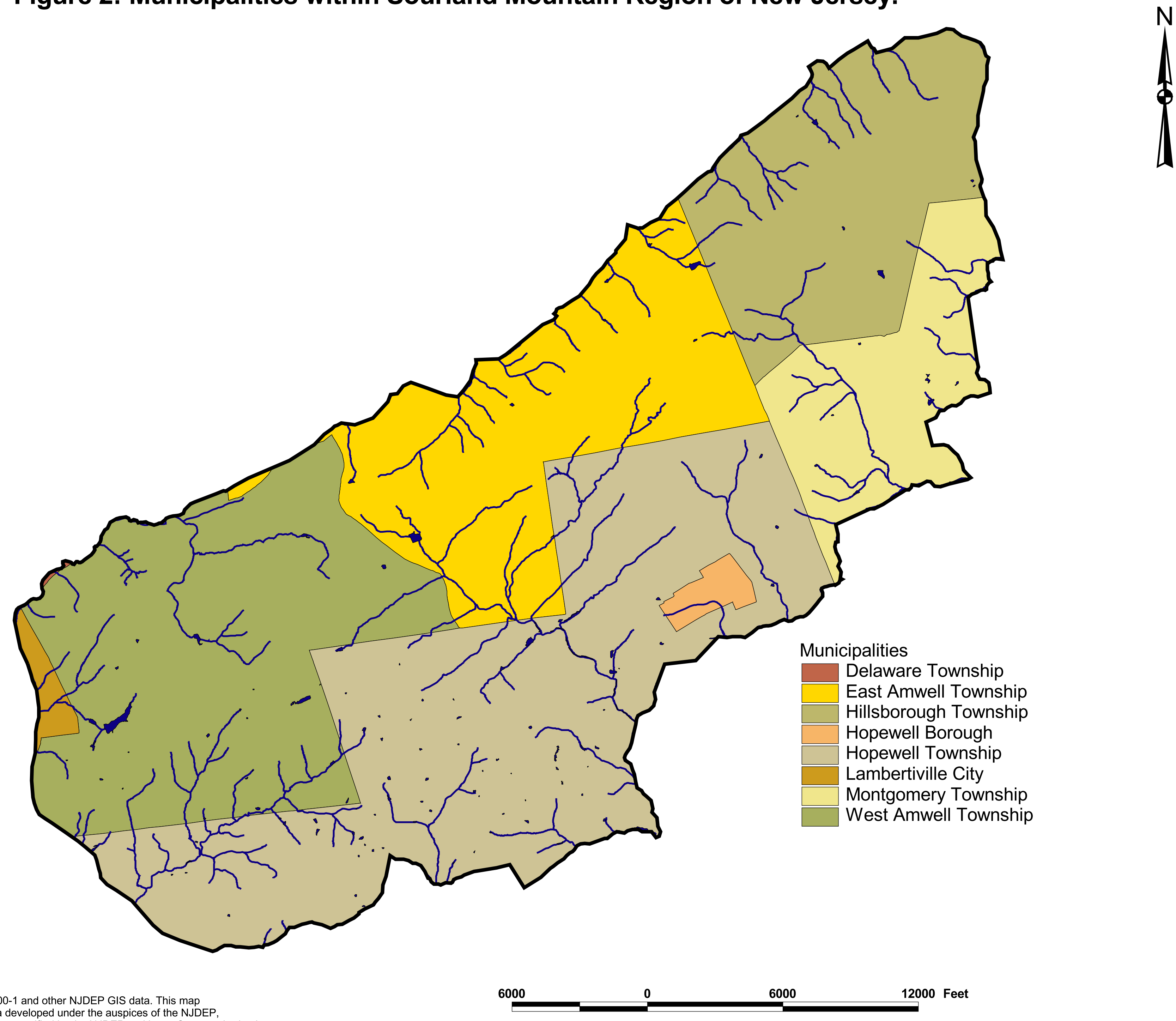
Aquifer System	Area of Watershed (acres)	Groundwater Runoff Rate (inpy)	Potential Antidegradation Limit (mg/l)	Recharge Area for Septic-System Dilution (acres)	Potential Maximum Sustainable Number of Dwelling Units
Stockton/Passaic Formations	31,134.0	5.5	5.6	4.4	7,151
Lockatong Formation/diabase/hornfels	24,097.3	2.10	5.6	11.4	2,113

Figure 1: Location of Sourland Mountain Region in New Jersey.



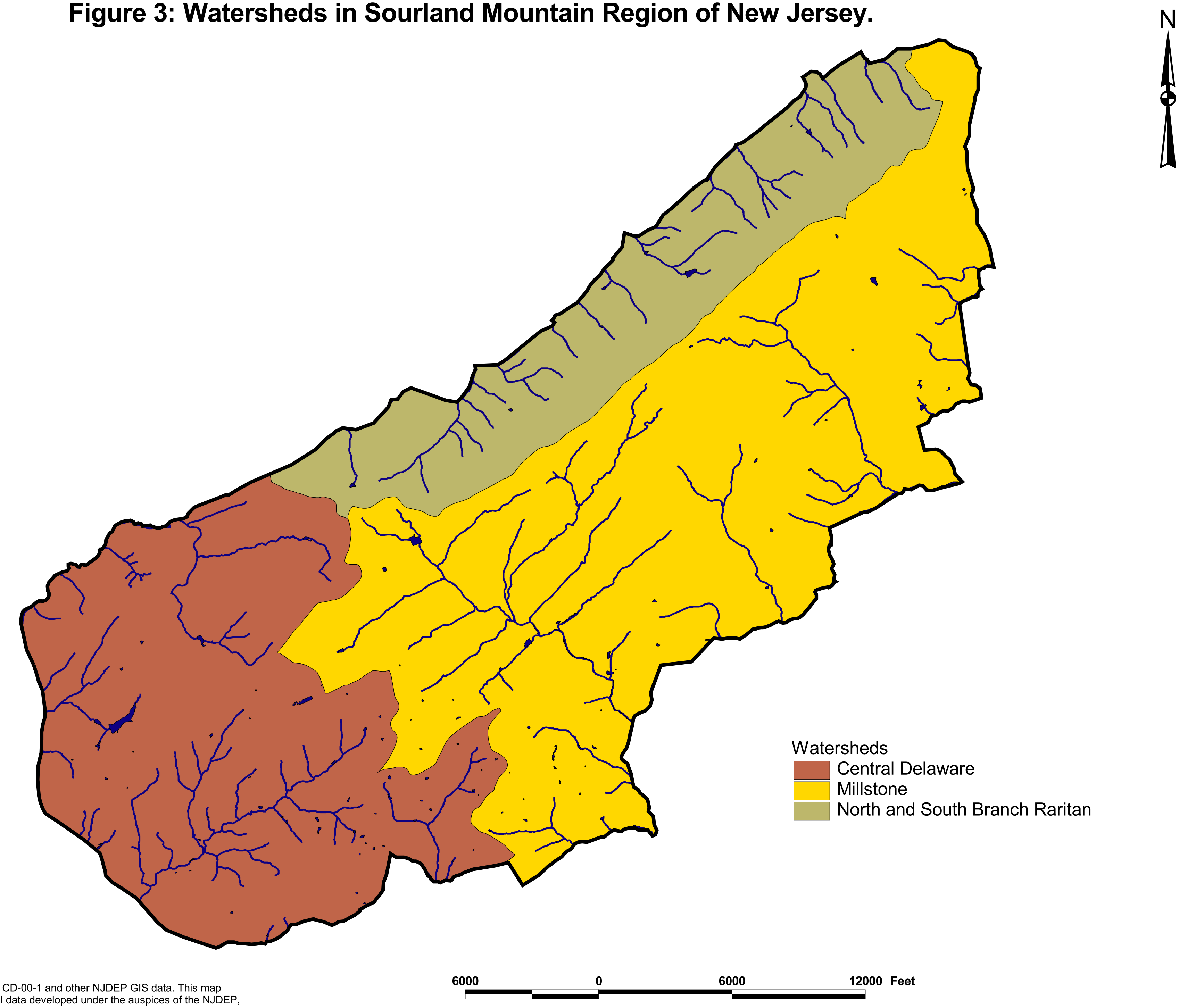
Modified from NJGS CD Series CD-00-1 and other NJDEP GIS data. This map was developed using GIS digital data developed under the auspices of the NJDEP, but this secondary product has not been verified by the NJDEP and is not State authorized.

Figure 2: Municipalities within Sourland Mountain Region of New Jersey.



Modified from NJGS CD Series CD-00-1 and other NJDEP GIS data. This map was developed using GIS digital data developed under the auspices of the NJDEP, but this secondary product has not been verified by the NJDEP and is not State authorized.

Figure 3: Watersheds in Sourland Mountain Region of New Jersey.



Modified from NJGS CD Series CD-00-1 and other NJDEP GIS data. This map
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but this secondary product has not been verified by the NJDEP and is not State authorized.

Figure 4: Subwatersheds of Sourland Mountain Region in New Jersey.

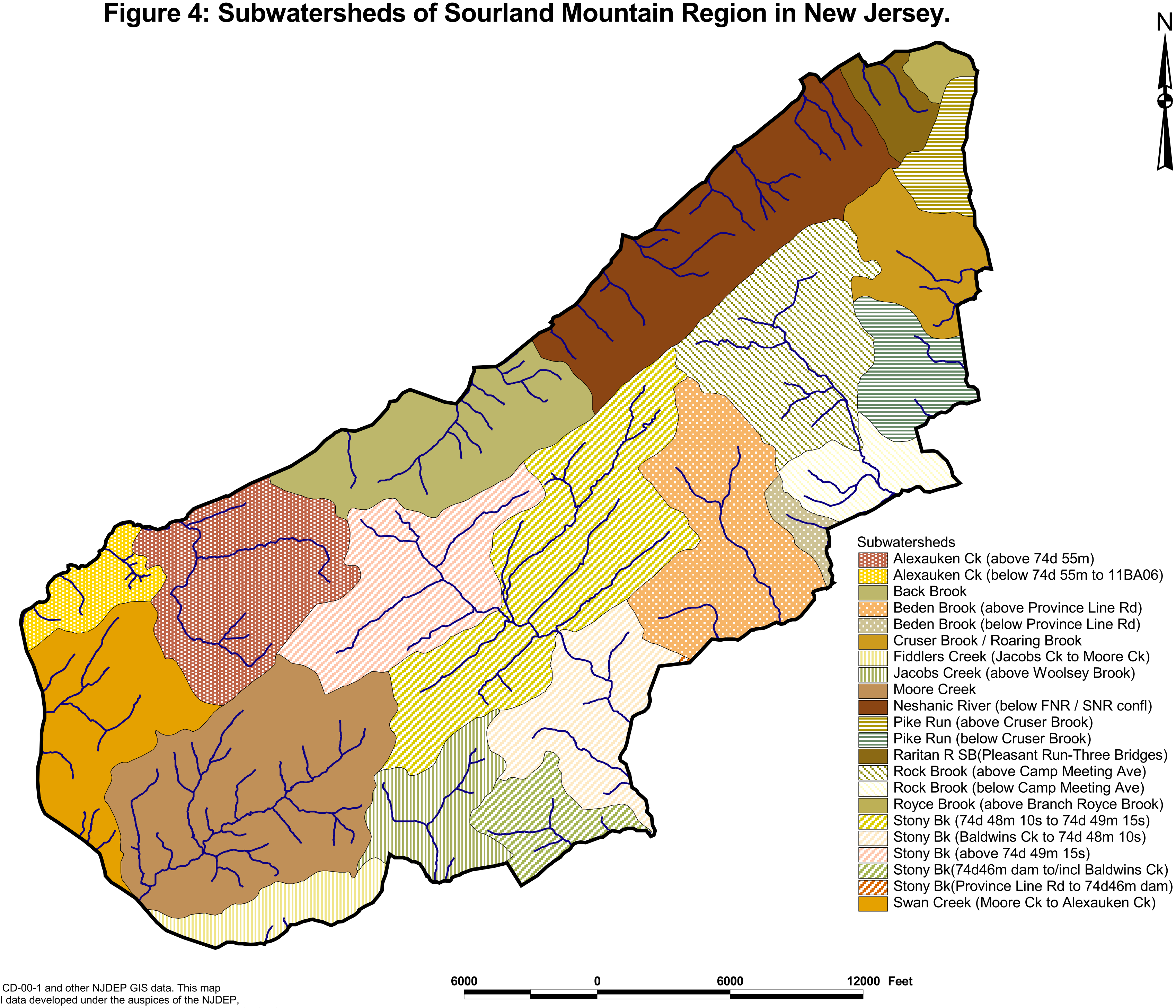

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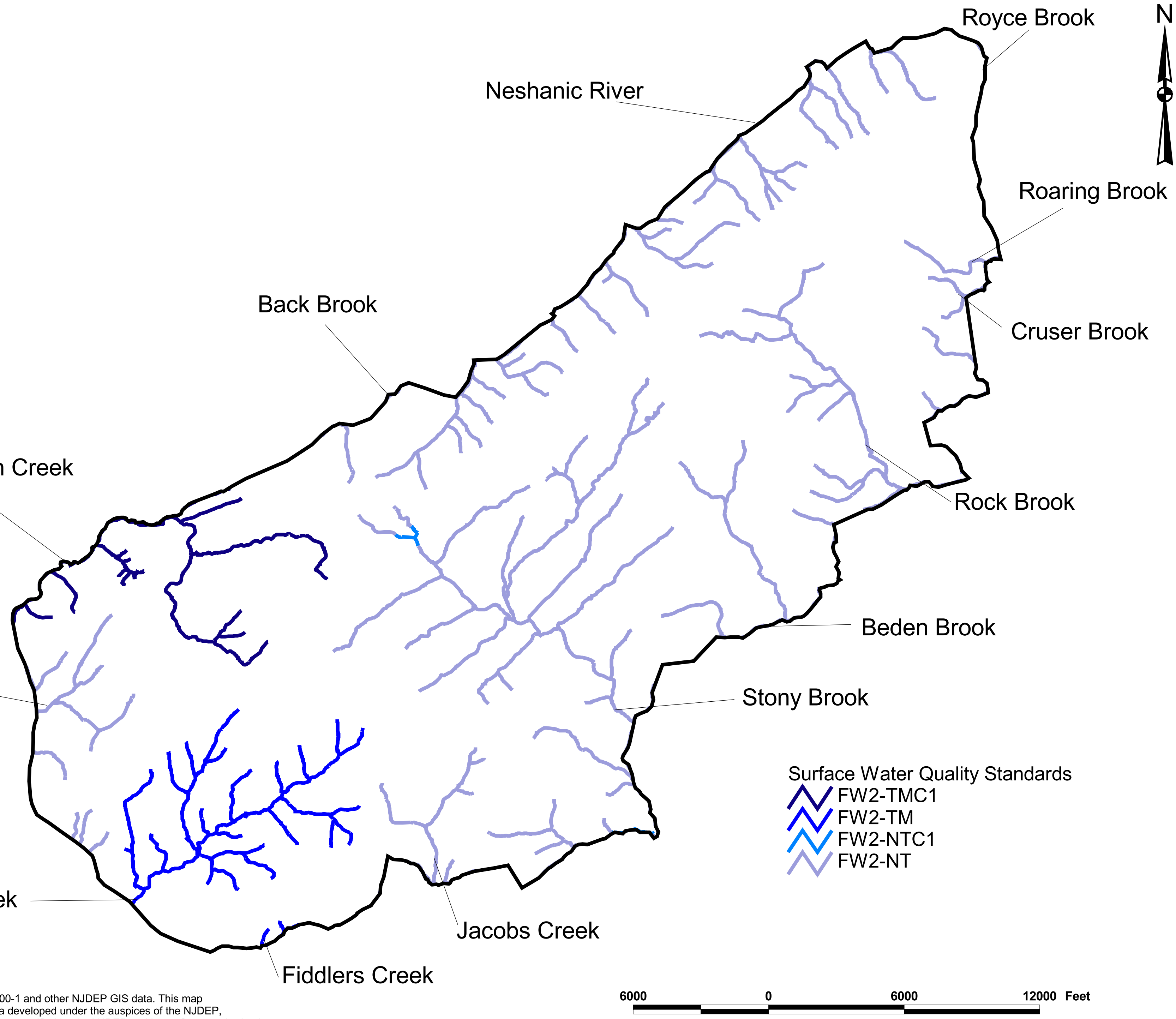
Figure 5: Streams and Surface-Water Quality Standards for Sourland Mountain Region of New Jersey.



Modified from NJGS CD Series CD-00-1 and other NJDEP GIS data. This map was developed using GIS digital data developed under the auspices of the NJDEP, but this secondary product has not been verified by the NJDEP and is not State authorized.

Figure 6: Soils of the Sourland Mountain Region in New Jersey.

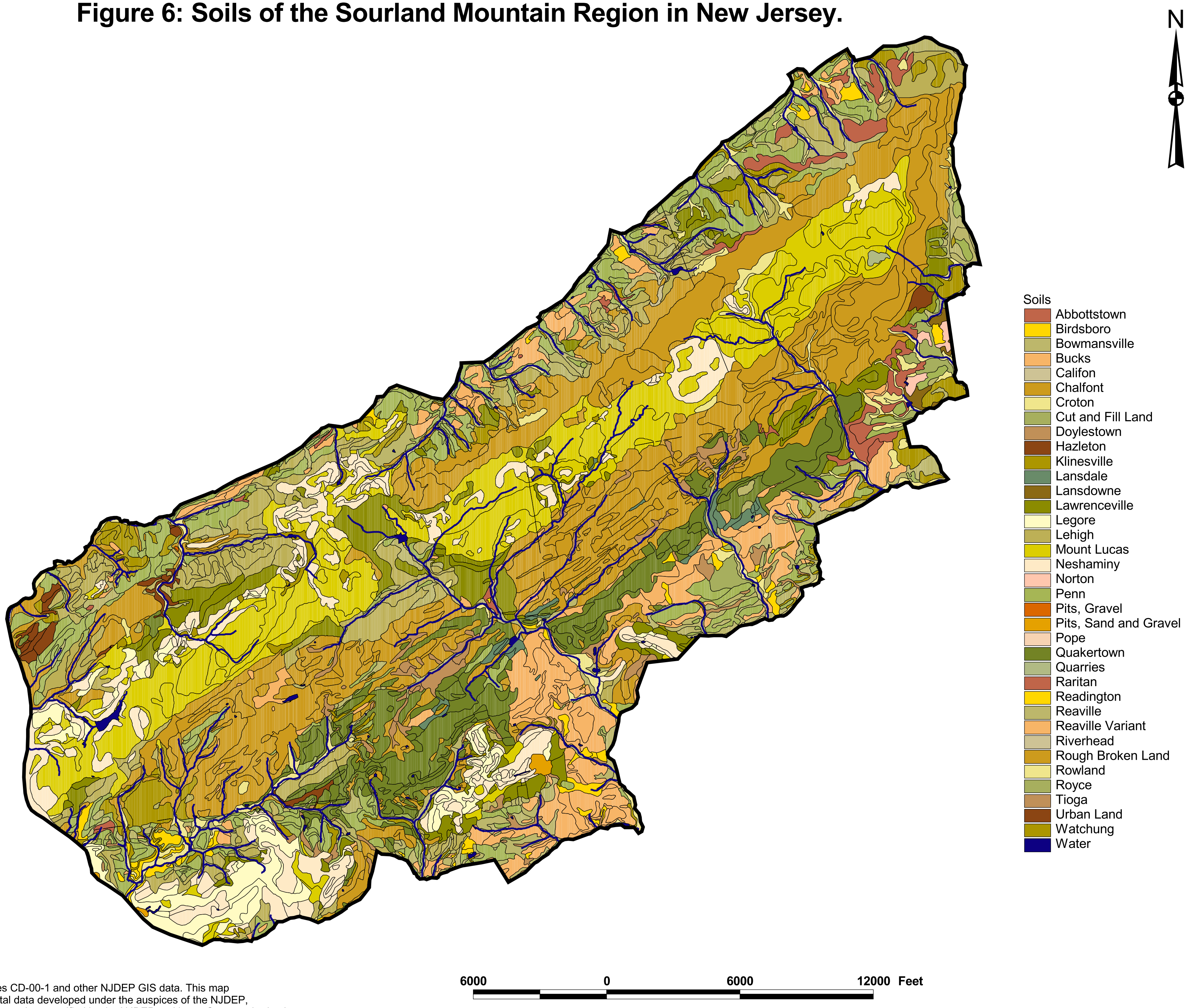


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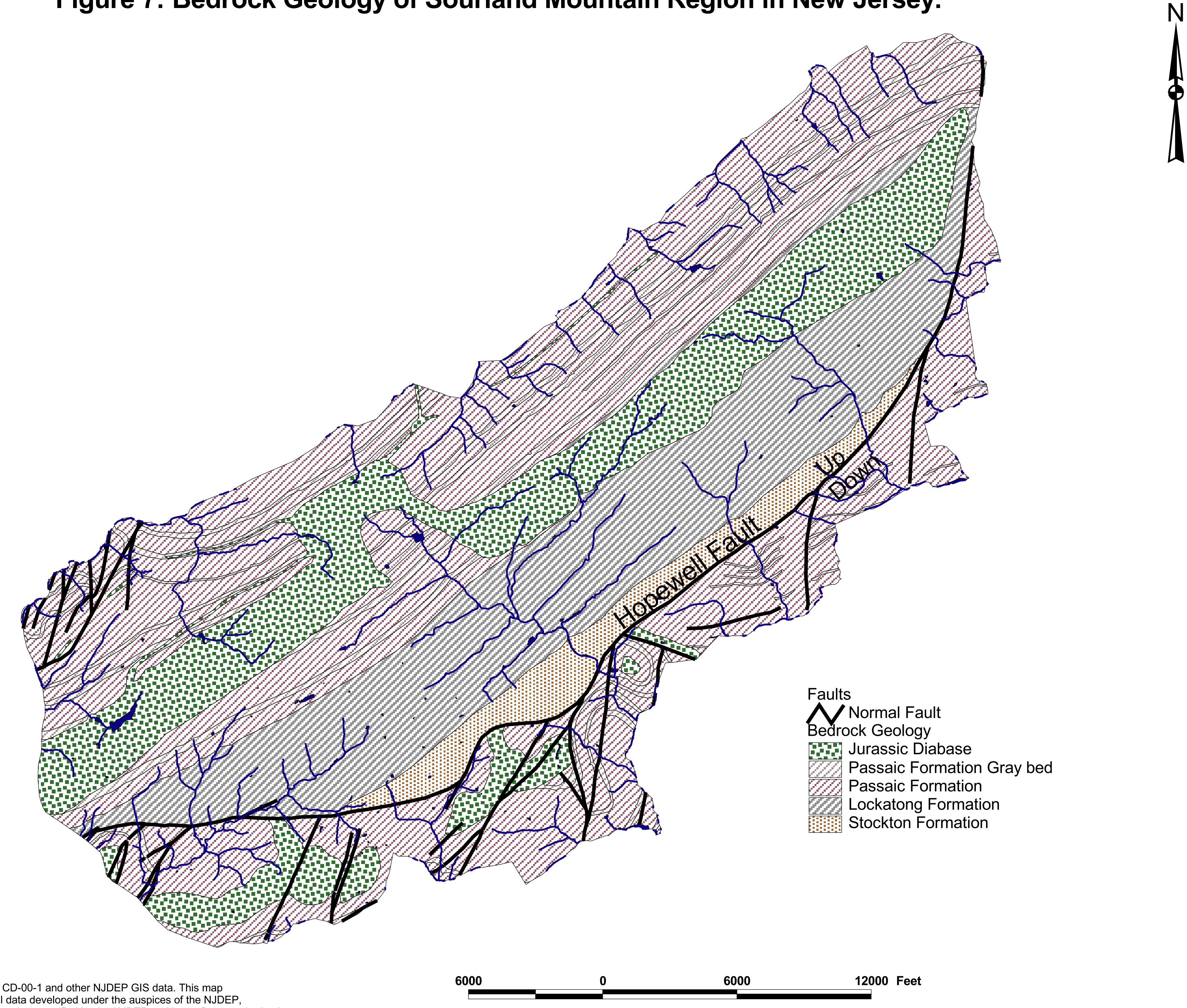
Figure 7: Bedrock Geology of Sourland Mountain Region in New Jersey.



Modified from NJGS CD Series CD-00-1 and other NJDEP GIS data. This map was developed using GIS digital data developed under the auspices of the NJDEP, but this secondary product has not been verified by the NJDEP and is not State authorized.

Figure 8: Sole Source Aquifers beneath the Sourland Mountain Region of New Jersey.

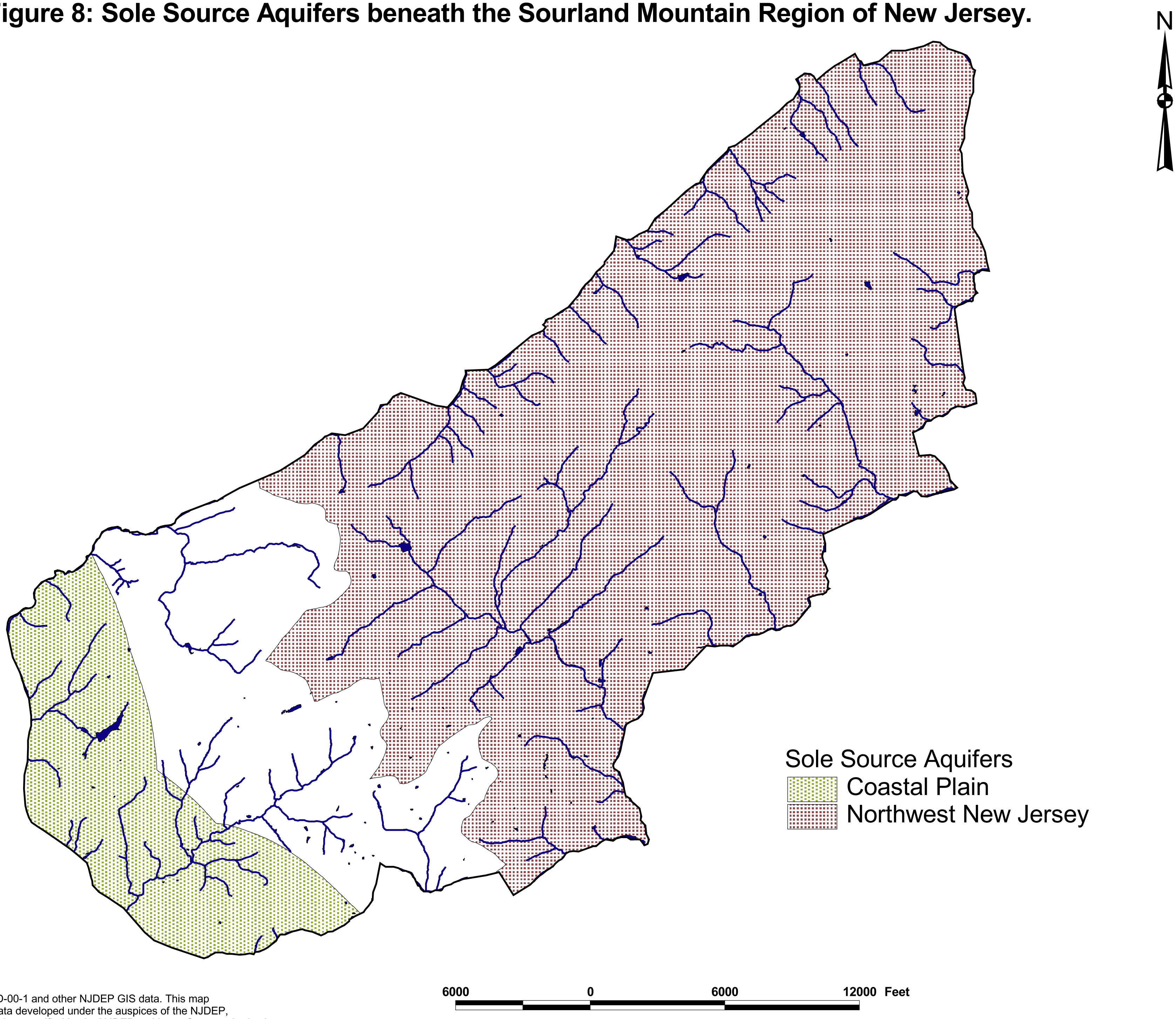


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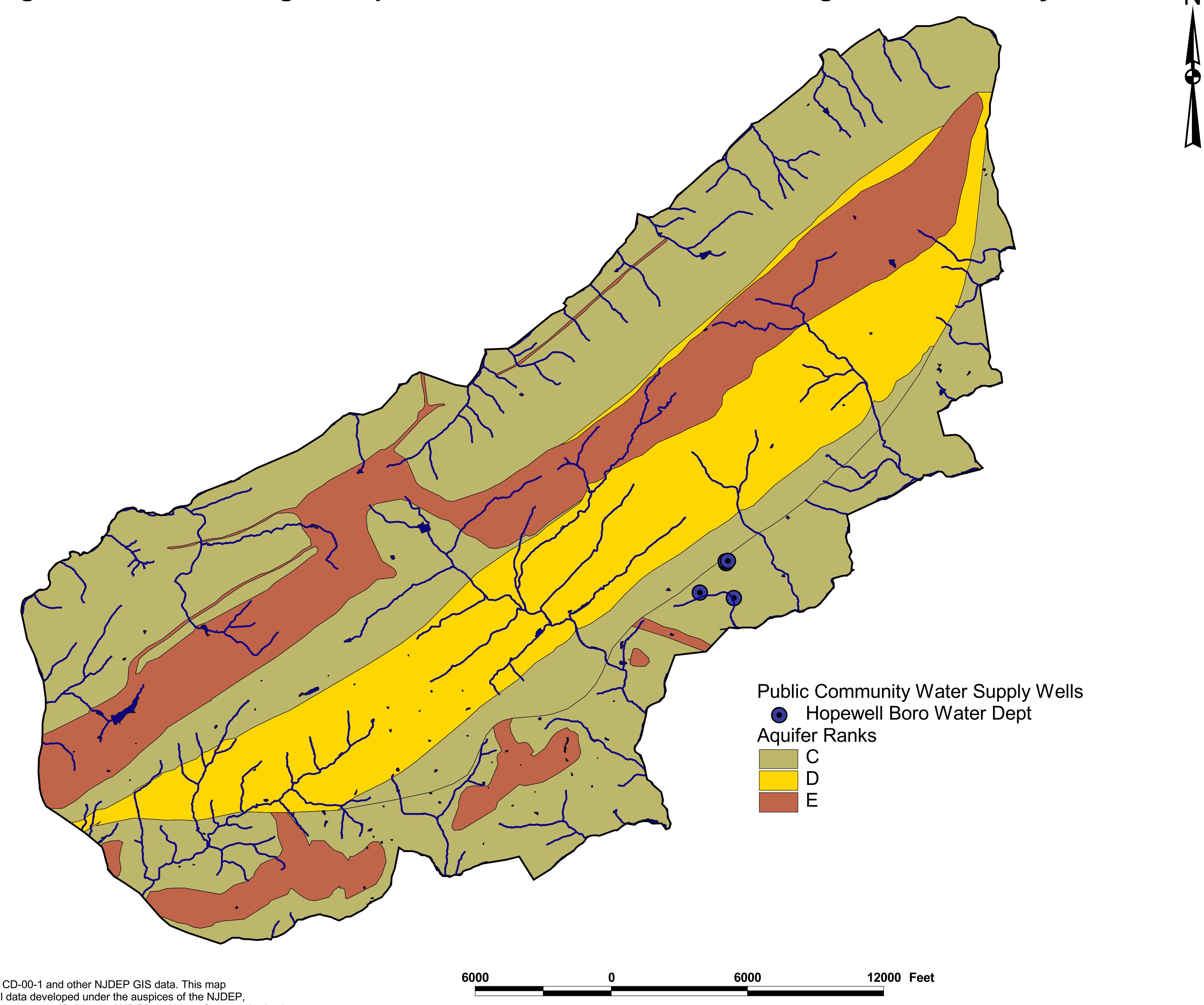
Figure 9: NJGS Rankings of Aquifers within Sourland Mountain Region in New Jersey.



Modified from NJGS CD Series CD-00-1 and other NJDEP GIS data. This map was developed using GIS digital data developed under the auspices of the NJDEP, but this secondary product has not been verified by the NJDEP and is not State authorized.

Figure 10: Baseflow in Stony Brook at Princeton, New Jersey.

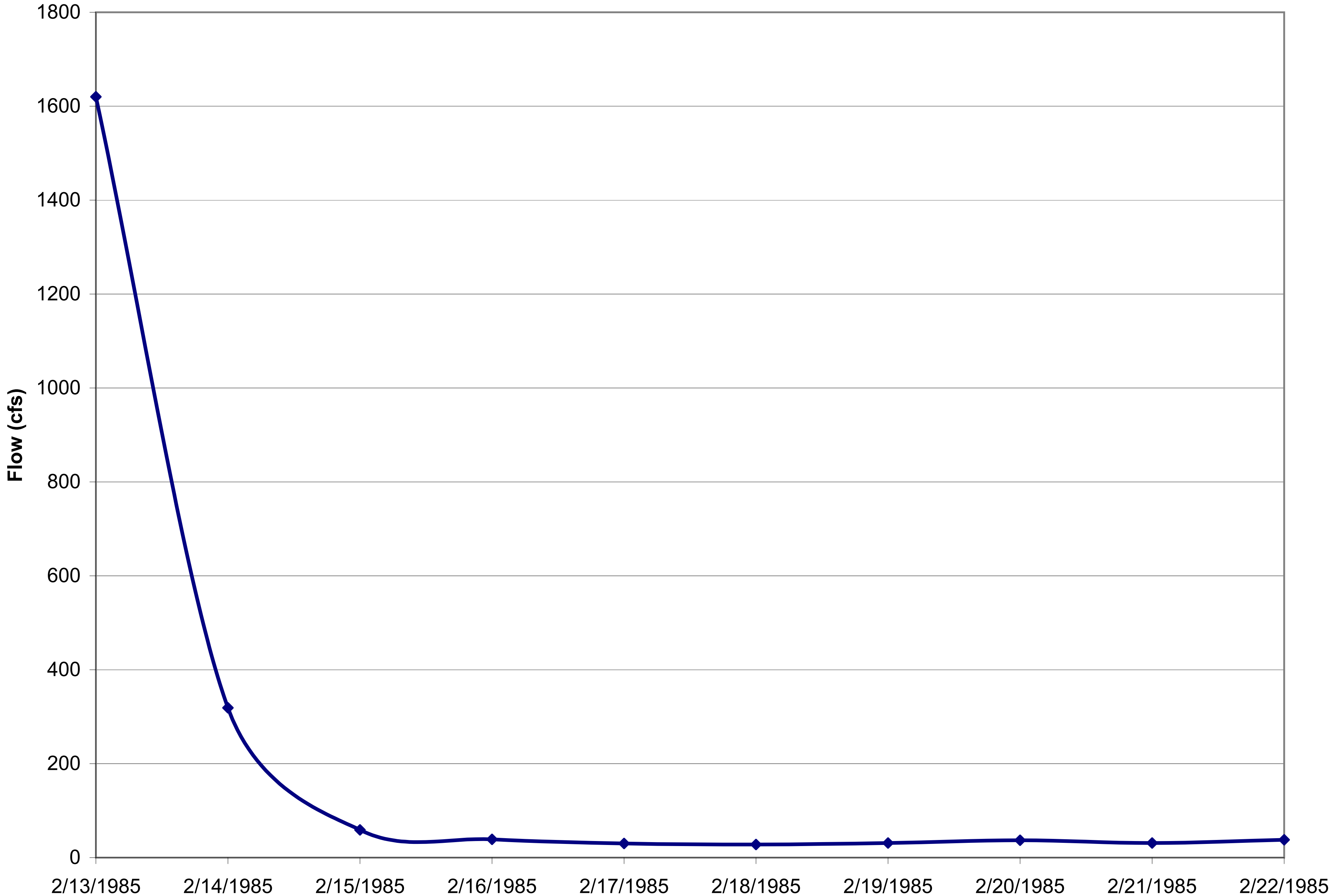


Figure 11: Streamflow in Stony Brook at Princeton During "Drought of Record"

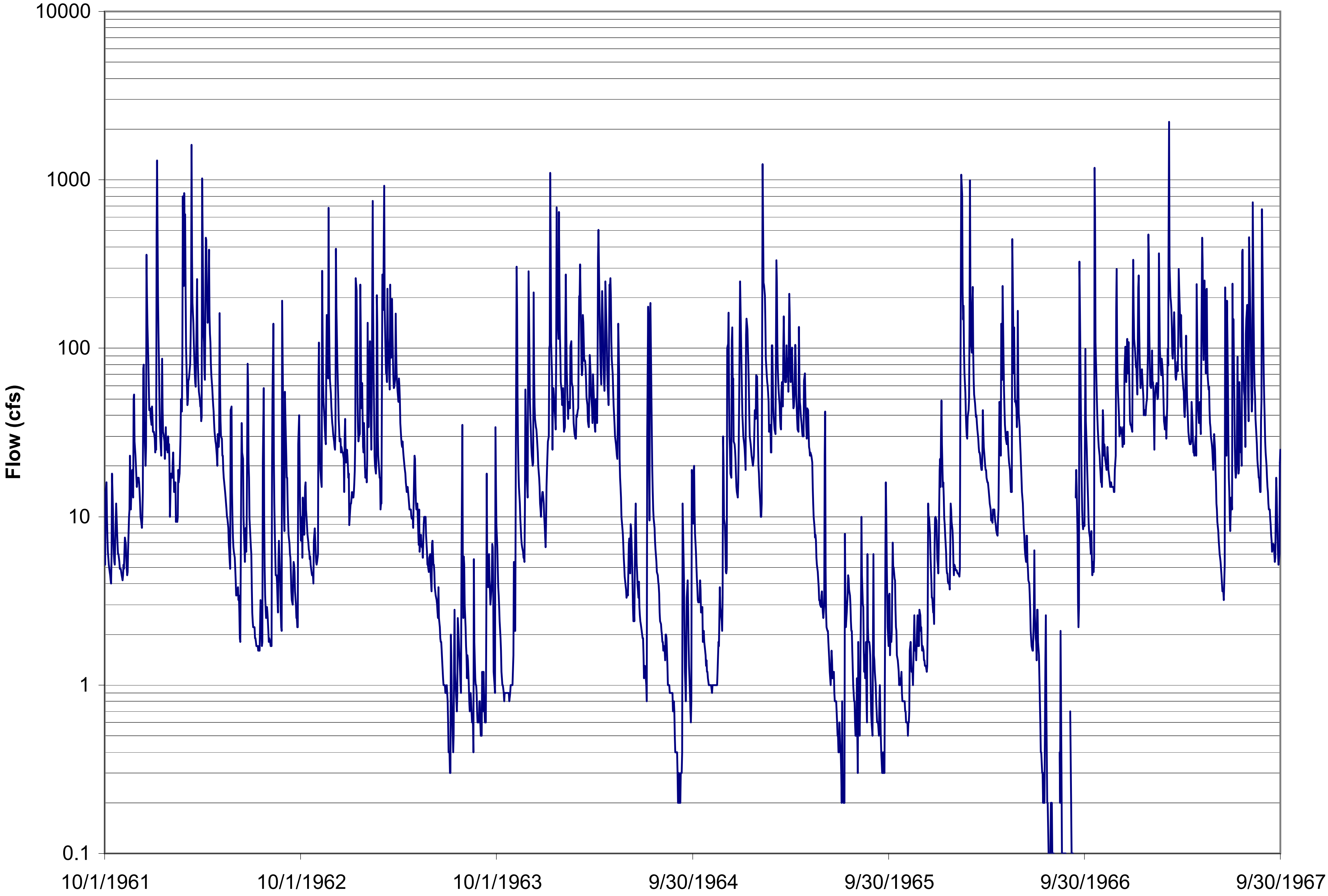


Figure 12: Streamflow in Stony Brook at Princeton During "Summer 1999 Drought"

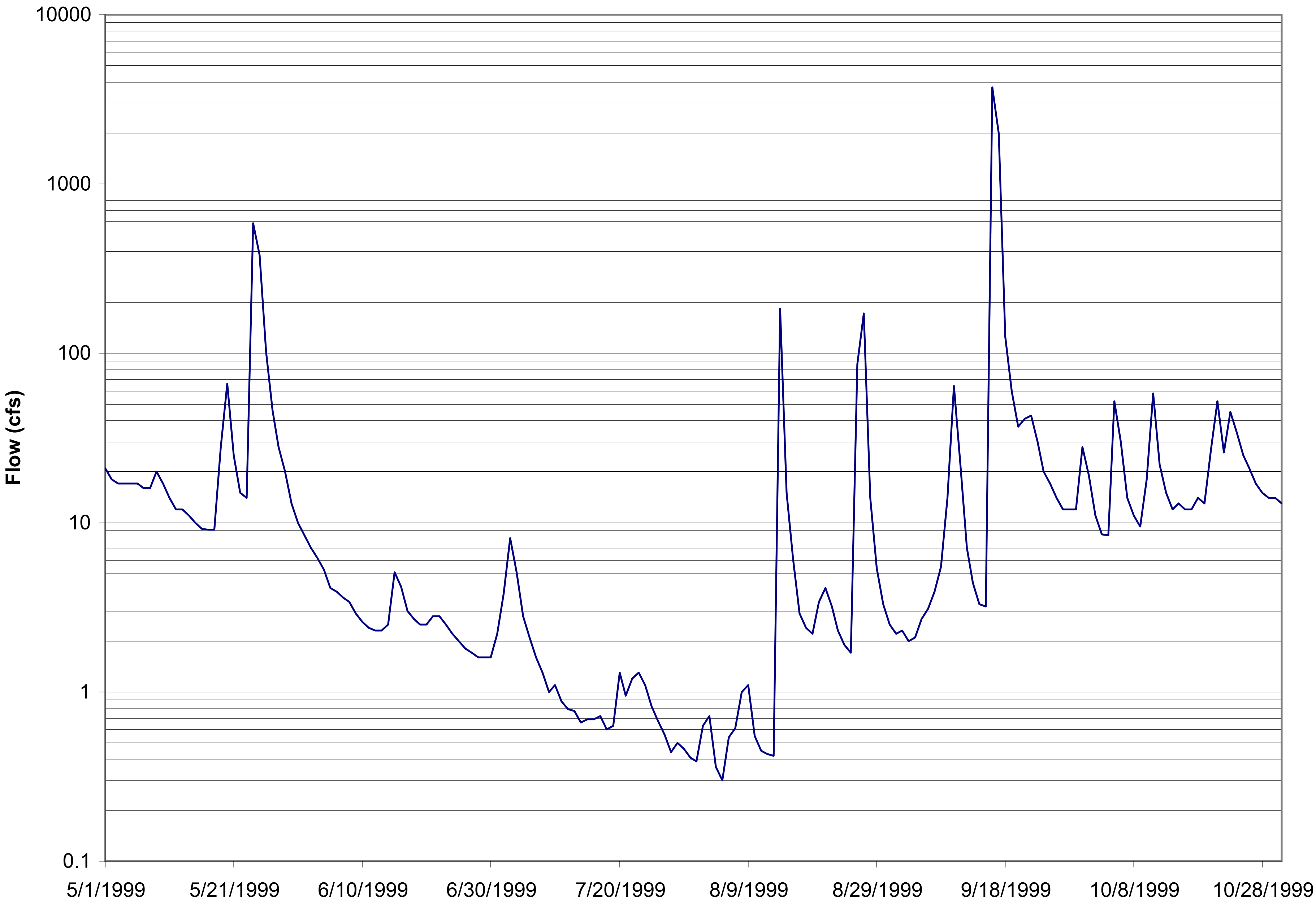


Figure 13: Streamflow in Stony Brook at Princeton During 2001/2002 Drought

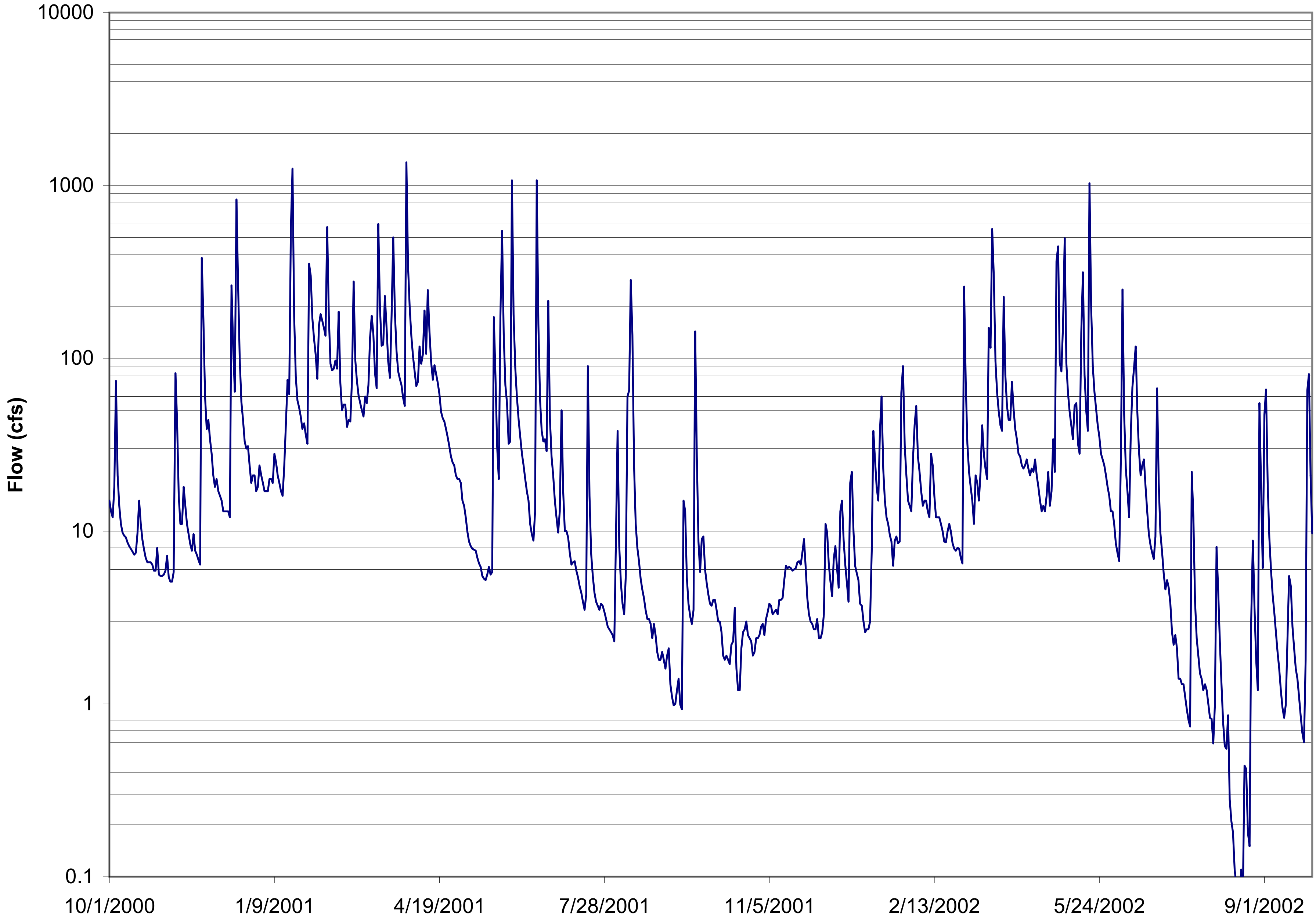


Figure 14: Streamflow in the Neshanic River near Reaville During "Drought of Record".

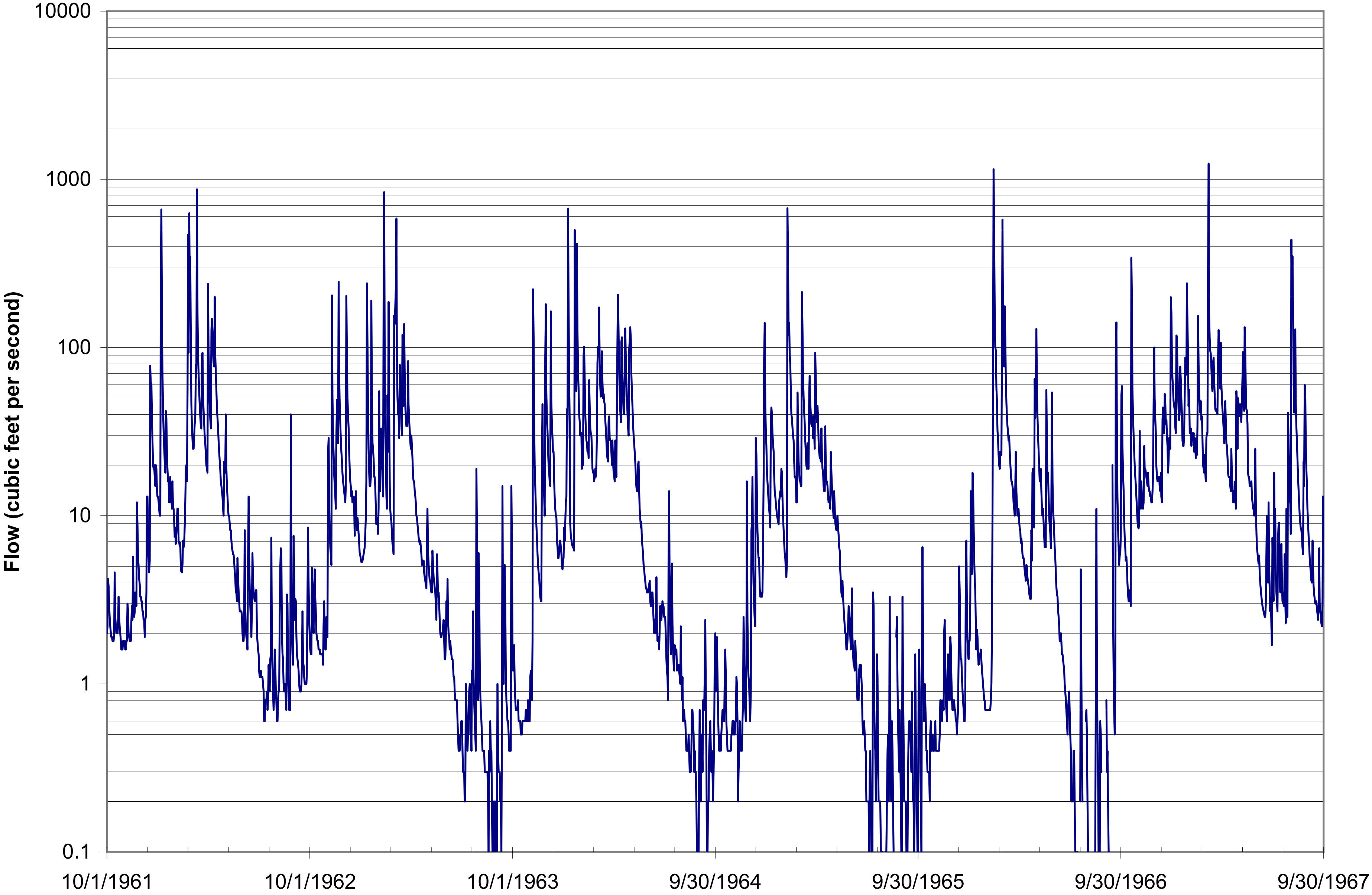


Figure 15: Streamflow in the Neshanic River near Reaville During Summer 1999 Drought.

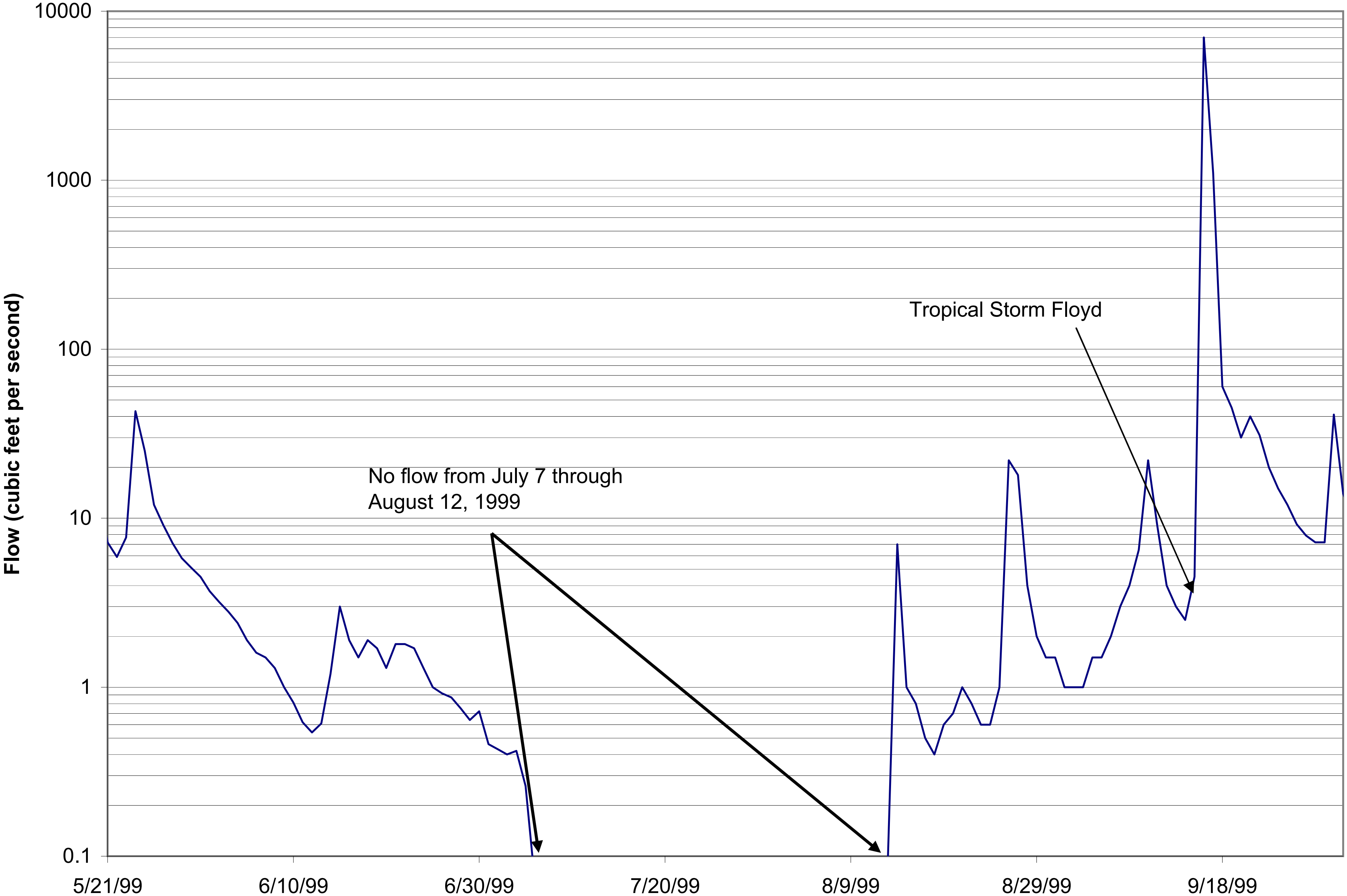


Figure 16: Streamflow in the Neshanic River near Reaville During 2001/2002 Drought.

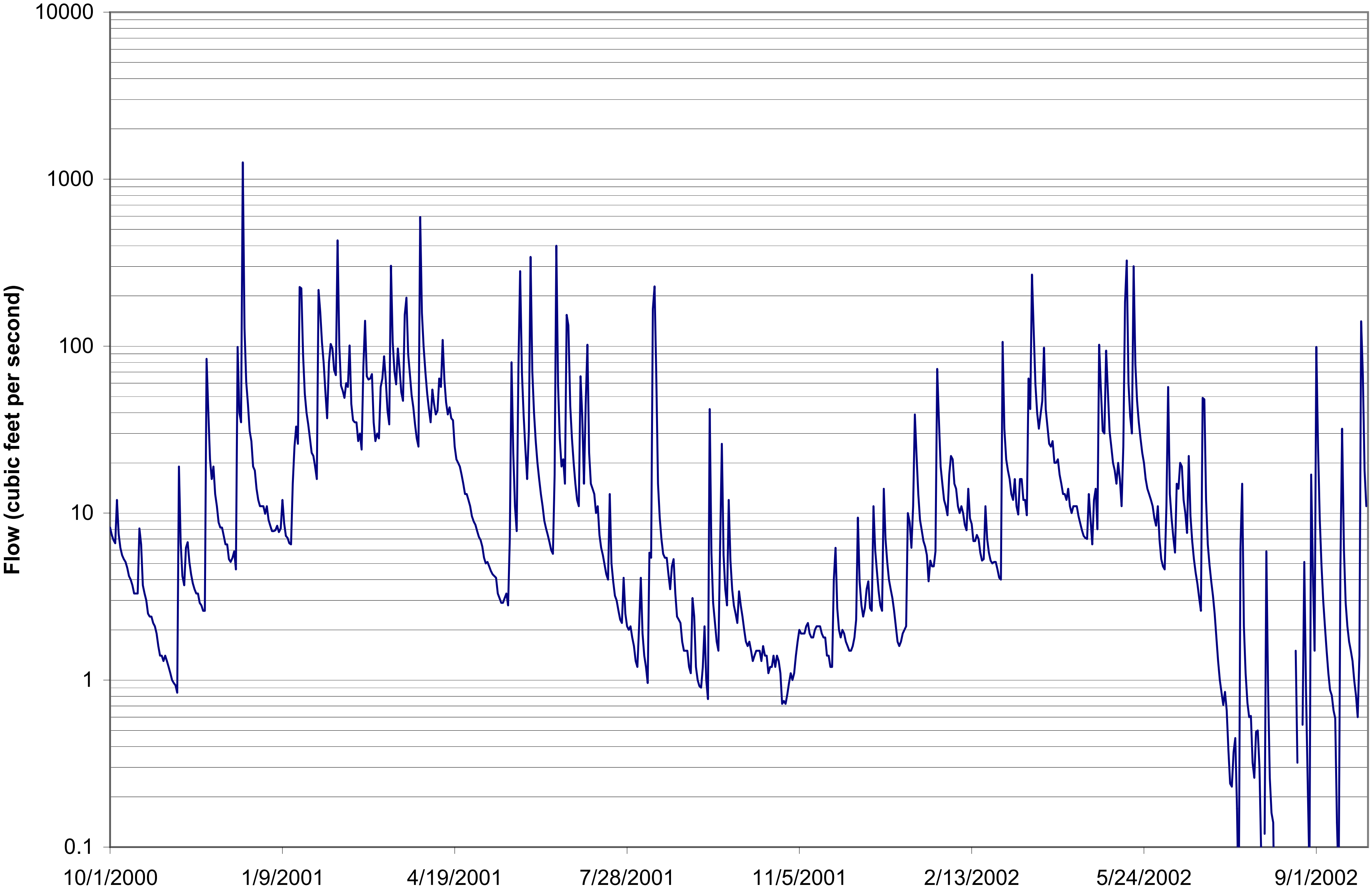


Figure 17: Flow Duration Curves for Streams Flowing From Sourland Mountain Region and Millstone River at Plainsboro, New Jersey.

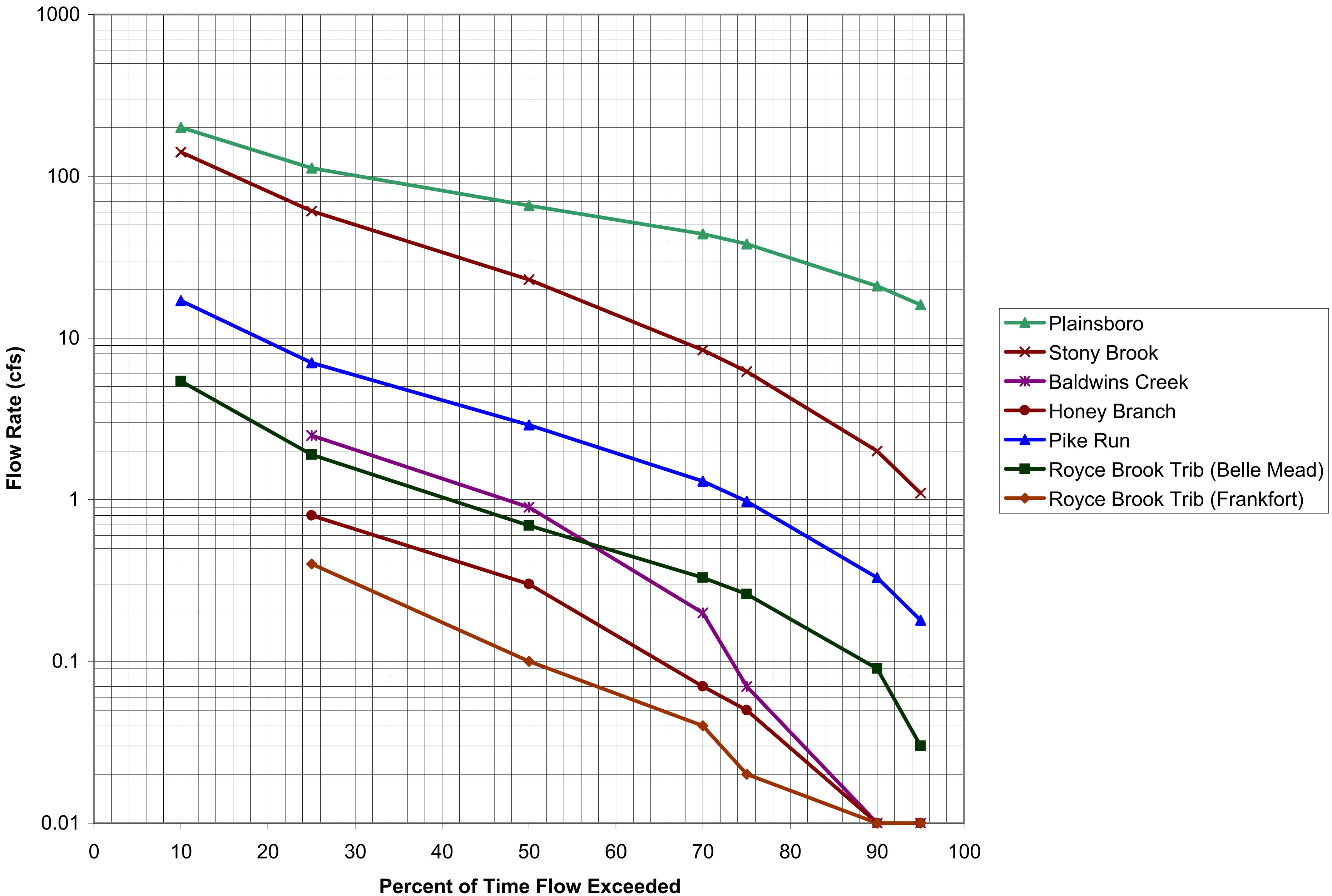
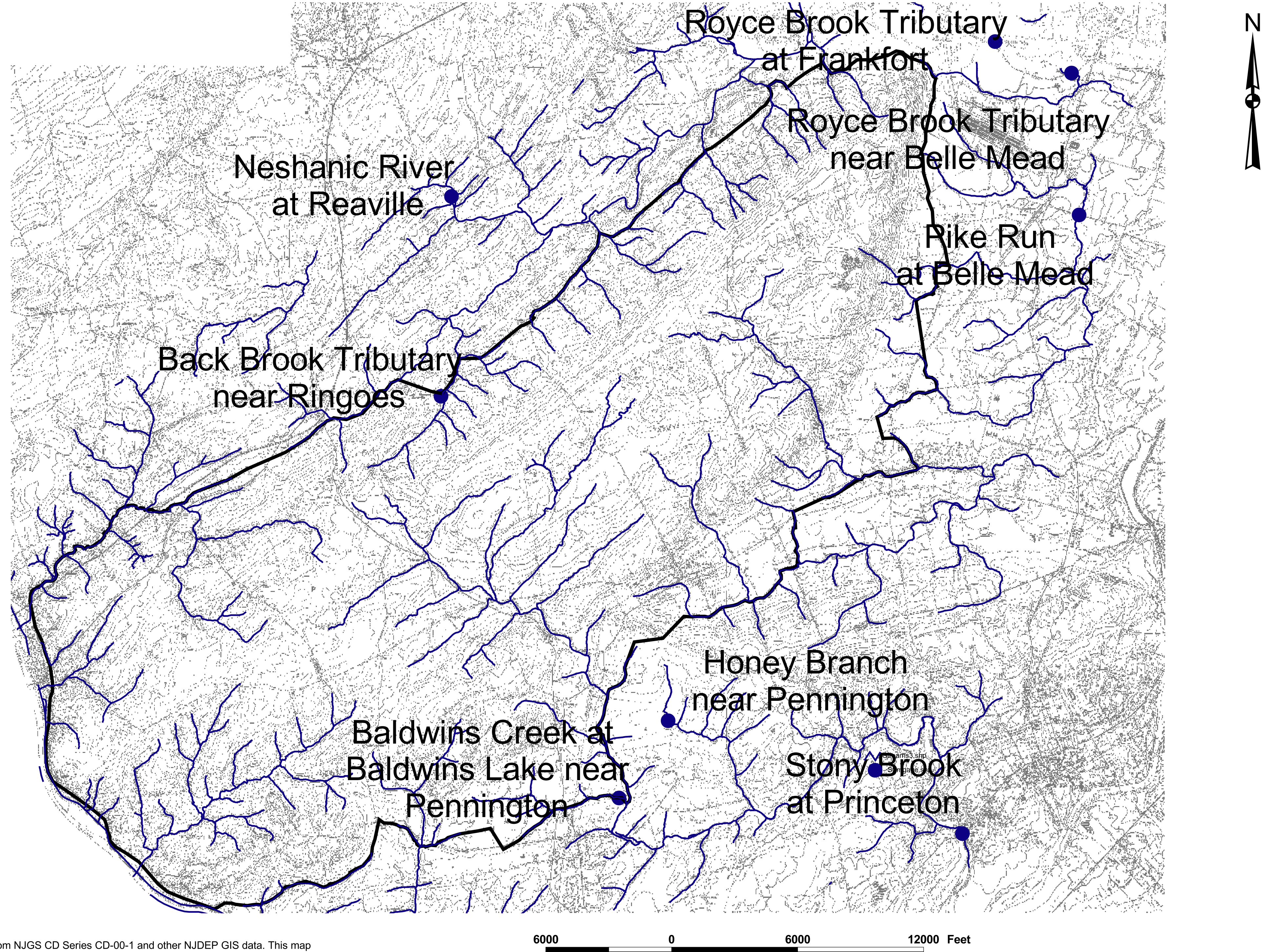
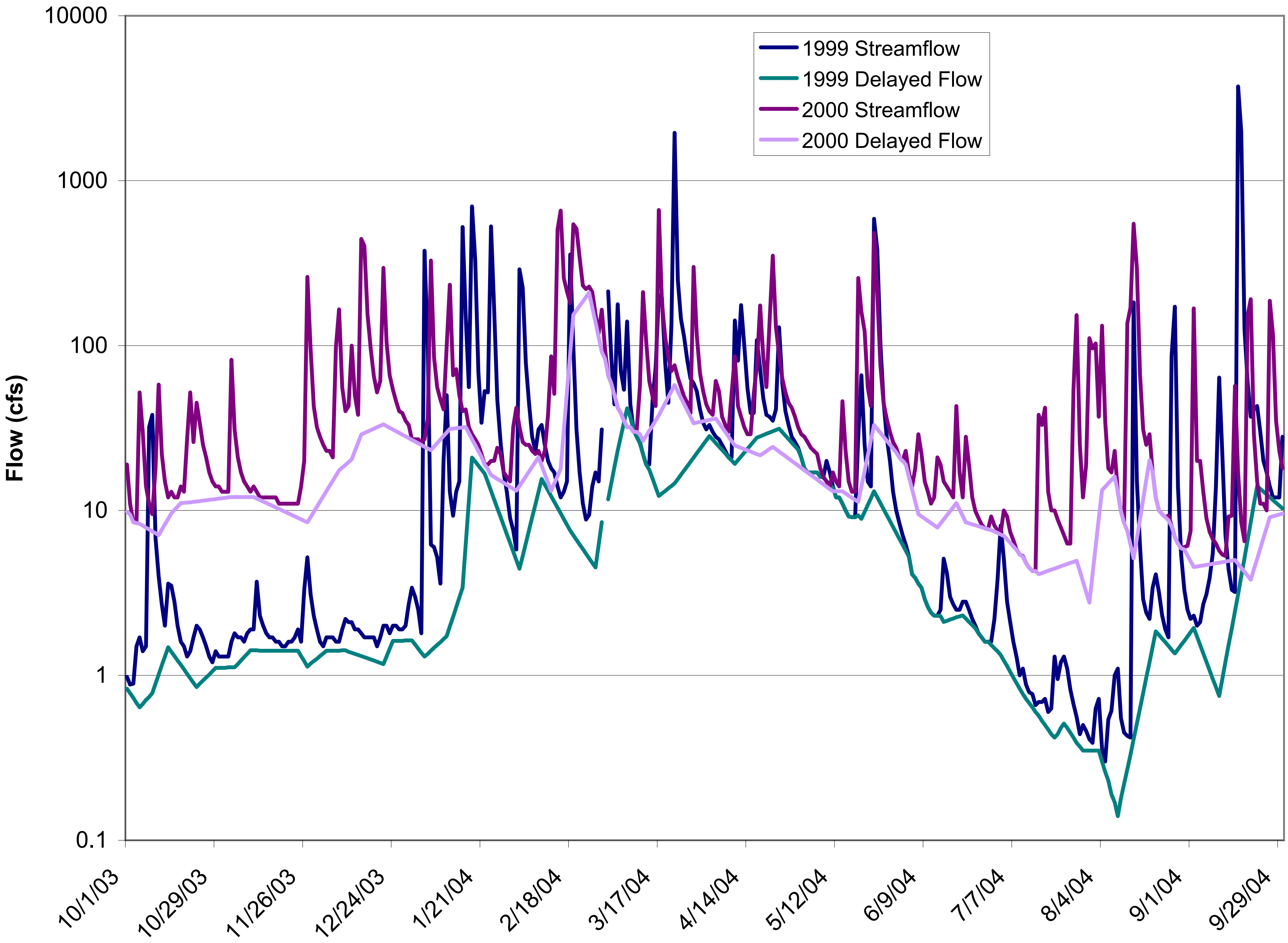


Figure 18: USGS Stream Gauges near Sourland Mountain in New Jersey.



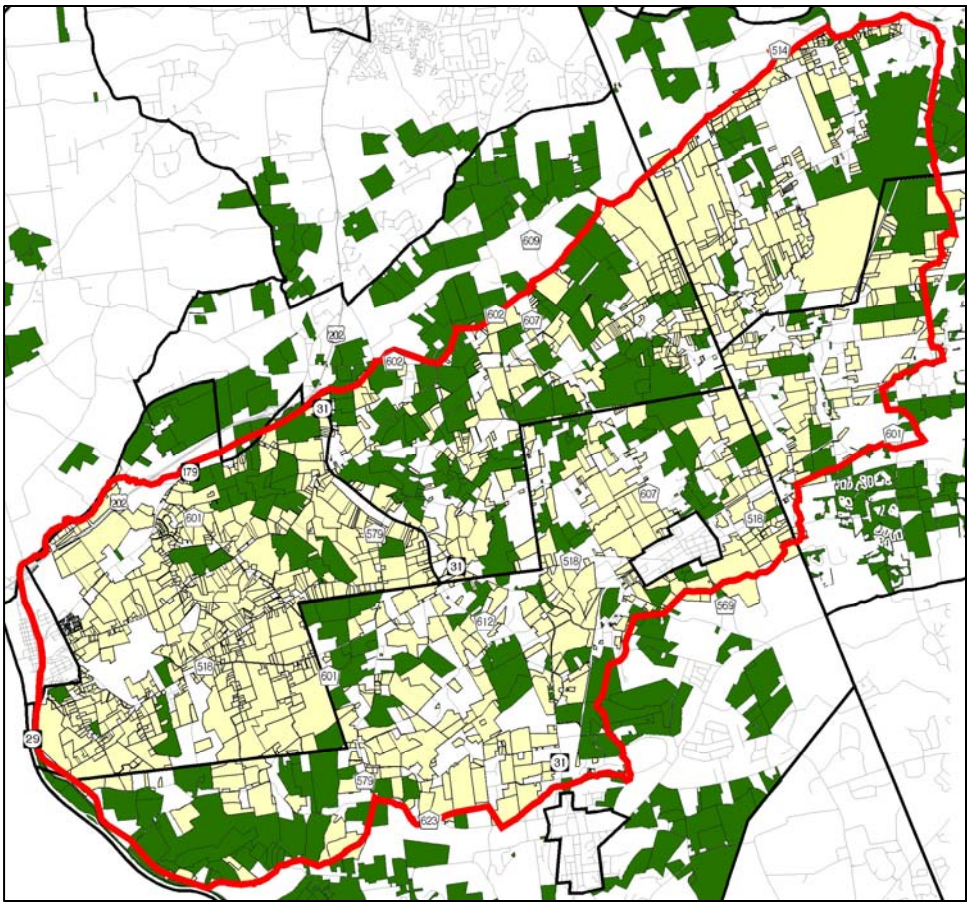
Modified from NJGS CD Series CD-00-1 and other NJDEP GIS data. This map was developed using GIS digital data developed under the auspices of the NJDEP, but this secondary product has not been verified by the NJDEP and is not State authorized.

Figure 19: Streamflow and Delayed Flow in Stony Brook at Princeton, New Jersey



Build-out Analysis for the

Sourland Mountain Region



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New Jersey Department of Community Affairs
The New Jersey Office of Smart Growth
Smart Growth Grant Program

Introduction

The Sourland Mountain Region spans three counties in central New Jersey and includes portions of East and West Amwell Townships, Hopewell Township, Montgomery Township, Hillsborough Township, Hopewell Borough and Lambertville City. In 2003, the New Jersey Department of Community Affairs awarded funding through the Smart Growth Grant Program for detailed study of this sensitive area, which includes headwaters to important streams, vast areas of wooded wetlands and important grassland and forest bird habitat.

Given the resource constraints of the Sourland Region, it is particularly important to relate the density of permitted development to the ecosystem's overall ability to support populations of both animals and humans. "The Natural Resource Inventory for the Sourland Mountain Region[1]" details factors that make the area suitable to an incredibly diverse group of birds, amphibians, reptiles and mammals. Matt Mulhall and Peter Demicco[2], both Professional Geologists, prepared an assessment of the groundwater resources which estimates the number of residential dwelling units that sustainable groundwater yield can support. This build-out analysis is prepared to provide a better picture of the land use patterns that will result from current municipal zoning policy. Analyzed and considered together, these three studies point to appropriate policies for the Conservation Plan and Open Space Plan, to be completed in the near future. The goal is to institute policies that provide overall measures of sustainability for the fragile Sourland Mountain ecosystem and guide land use in a manner that respects the needs of both humans and the ecosystem.

Methodology

Geographic Information System (GIS) digital data has greatly improved methods for quantifying residential development that could occur based on the intensity of development permitted in the zoning ordinance. Paper zoning maps can be translated into digital data and overlain on tax parcel information, allowing data to be combined for analysis (see Figure 1).

There are a number of factors that determine the intensity of permitted development including minimum lot size, required lot frontage, lot width, and lot depth, lot configuration, existing public streets, steep slopes, wetlands, wetland transition areas, floodplains and stream corridors, among others. These factors can only be applied on a parcel-by-parcel basis to determine their impact on the amount of development that could occur. Given the geographic extent of the Sourland Mountain region and the size of the study area defined for the overall project, not all of these factors could be applied on a parcel-by-parcel basis in analysis of likely future development. As such, the results of this study can be seen as the worst-case scenario and illustrates the maximum amount of development that could occur for the study area. Further, the Sourland Region is characterized by municipal zoning that requires relatively large lots which facilitates

[1] Banisch Asscoiates, Inc. "The Natural Resource Inventory for the Sourland Mountain Region". November 2004.

[2] Demicco, Peter and Matt Mulhall. "Evaluation of Groundwater Resources of the Sourland Mountain Region of Central New Jersey". November 2004.

development in especially constrained areas as critical resource factors such as wetlands and steep slopes can easily be avoided in the creation of larger lots. Most communities permit critical resource factors to be part of a newly created lot, although they must be given consideration in the siting of a dwelling unit; successful placement of a dwelling on a lot of 10 or even 15 acres can require as little as 30,000 square feet of unconstrained area.

The first step in quantifying residential development opportunities in the Sourland Mountain region was to identify properties that are "developable". Any parcels permanently preserved through farmland preservation or open space preservation were removed from consideration, as were any parcels that currently have a dwelling unit but were not twice the minimum lot size required for the zoning district in which they are situated.

Next, existing vacant lots not meeting the current minimum lot size were identified. Many communities have provisions in the municipal zoning ordinance with minimum standards for grandfathering (see Table 1), whereby a dwelling can be constructed without a variance from the Zoning Board of Adjustment. The figures presented in Table 2 represent the worst-case scenario and assume that all under-sized vacant lots will have the ability to construct a dwelling unit, whether under grandfather provisions or by variance.

Table 1 – Grandfathering Provisions

Township	Zoning District	Symbol	Minimum Lot Size for Grandfathering
East Amwell	Amwell Valley Agricultural District	AVAD	3 acres
	Sourland Mountain District	SMD	5 acres
West Amwell	9,375 Square Feet Residential	R-9	5,000 square feet
	2 Acre Residential	R-2	5,000 square feet
	3 Acre Residential	R-3	5,000 square feet
Montgomery	Single Family Residential	R-5	1 acre
	Mountain Residential	MR	3 acres
Hillsborough	Agricultural	AG	3 acres
	Mountain/Valley Preservation	MZ	Any legally existing at time of passage
Hopewell	Residential, Existing Single Family - 1/4 acre	R-75	n/a
	Residential, Existing Single Family - 1/2 acre	R-100	n/a
	Mountain Resource Conservation	MRC	3 acres
	Valley Resource Conservation	VRC	80,000 square feet

After determining the realm of “developable” parcels (see Figures 2 through 6), assessment of build-out was accomplished by dividing the total parcel acreage by the minimum lot size required for the zoning district in which the parcel is located. In all cases, fractional results were rounded down to the nearest whole number, as the fractional remainder would represent a lot not meeting the minimum lot size for the zoning district. As an example, if a parcel was 10.3 acres and the minimum lot size for the zoning district was 3 acres, the resulting number of permitted lots would be 3.43, which is rounded down to 3.

Once the number of potential units for each developable parcel was determined, the number of new units was summarized by zoning district within the study area boundary. The results are presented in Table 2, on the following page.

In 2004, the Sourland Mountain region contained approximately 3,660 residential units[3] covering 55,731 acres within the 5 townships (Hopewell, Hillsborough, East Amwell, Montgomery and West Amwell) studied in this Build-out analysis. This results in a gross density of roughly 1 unit per 15.2 acres. The Sourland Mountain region currently has approximately 3,660 residential units covering 55,731 acres, resulting in a density of roughly 1 unit per 15.2 acres. Under current zoning policy, at full build-out an additional 3,767 units can be expected for a total of 7,564 dwelling units, almost double what currently exists. The resulting density at full build-out is 1 unit per 7.4 acres. So while the majority of communities that comprise the region require minimum lot sizes of 10 and 15 acres in the study area, varying lot size requirements in other communities and an apparent wealth of remaining developable land will likely offset large minimum lot sizes.

[3] This total was derived from MOD-IV tax data for the 5 townships and does not coincide with the 2000 Census Block data used in the “Evaluation of Groundwater Resources of the Sourland Mountain Region of Central New Jersey” prepared by Peter Demicco and Matt Mulhall, which included portions of Lambertville and Hopewell Borough.

Table 2 - Build-out Summary for the Sourland Mountain Region

Township	District	Minimum Lot Size	Total District Acreage	Acreage of Preserved Land	Total Existing Lots	Existing Residential Units	Existing Non-conforming Vacant Lots	Additional New Units from Developable Parcels	Total New Units	Total Units At Full Build-out
East Amwell	AVAD	10 acres	3,164	1,240	258	195	16	102	118	313
	SMD	15 acres	6,702	2,680	619	384	101	133	234	618
			9,866	3,920	877	579	117	235	352	931
West Amwell	R-9	9,375 s.f.	41	0	120	47	39	80	119	166
	SRPD	8 acres	4,033	433	337	230	58	411	469	699
	RR-4	4 acres	744	0	42	25	13	159	172	197
	RR-5	5 acres	2,846	917	296	213	14	413	427	640
	RR-6	6 acres	4,114	144	340	264	73	753	826	1,090
			11,778	1,494	1,135	779	197	1,816	2,013	2,792
Montgomery	R-5	5 acres	1,538	88	270	191	2	141	143	334
	MR	10 acres	1,864	170	360	251	23	93	116	367
	PPE	N/A	993	993	N/A	N/A	N/A	N/A	N/A	N/A
			4,395	1,251	630	442	25	234	259	701
Hillsborough	AG	10 acres	731	34	113	90	11	36	47	137
	MZ	15 acres	7,577	2,785	701	521	111	148	259	780
			8,308	2,785	814	611	122	296	306	917
Hopewell	R-75	80,000 s.f.	30	0	34	32	1	0	1	33
	R-100	80,000 s.f.	115	0	112	103	6	5	11	114
	MRC	14 acres	11,808	4,161	946	710	116	189	305	1,015
	VRC	6 acres	5,949	1,327	686	541	61	459	520	1,061
			17,902	5,488	1,778	1,386	184	653	837	2,223
	Other Zones*		2,662						0	0
Region			54,911	14,938	5,234	3,797	645	3,234	3,767	7,564

* Denotes acreage of nonresidential zoning districts within the boundary of the study area as well as remaining acreage for Hopewell Borough and Lambertville City.

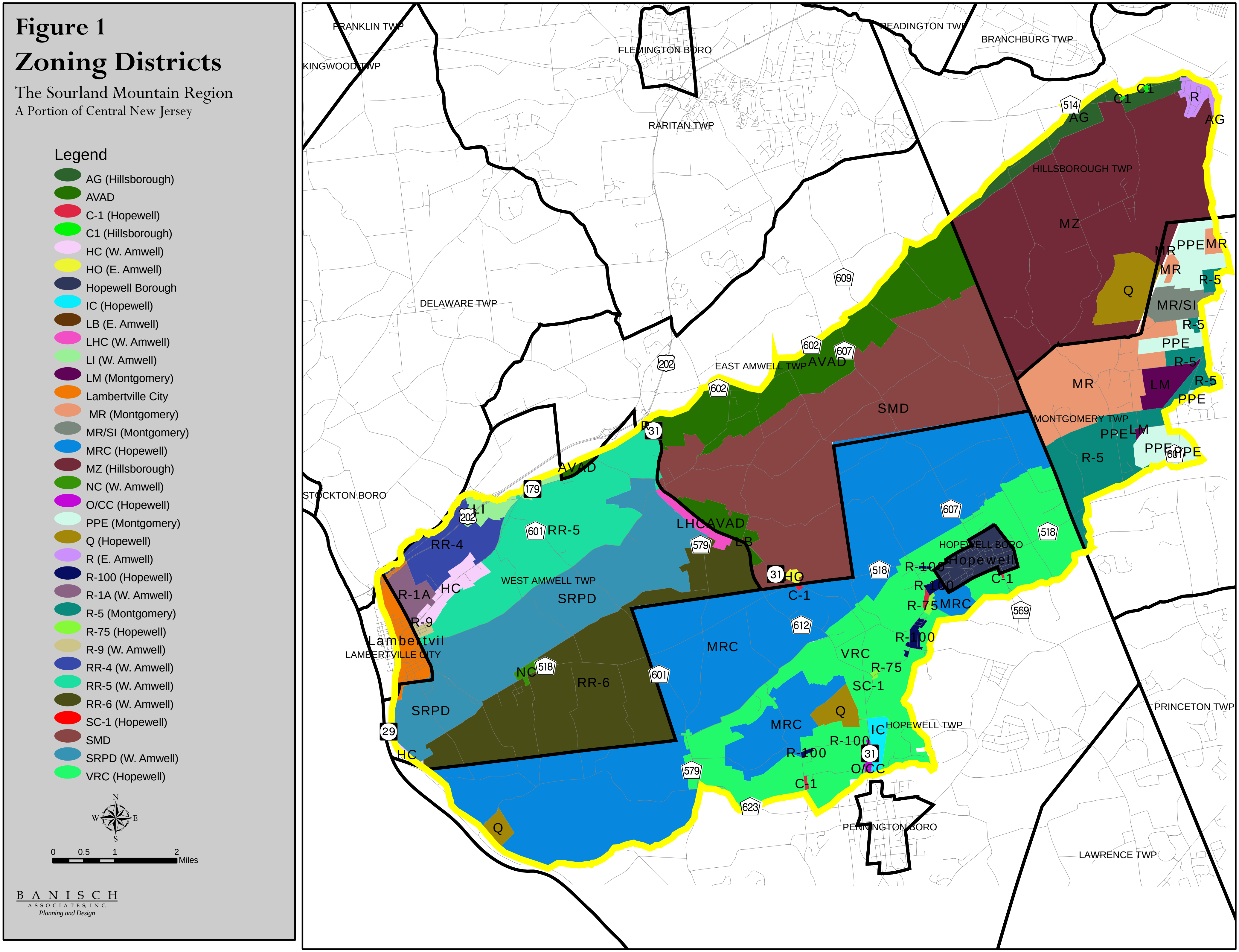


Figure 1
Zoning Districts
The Sourland Mountain Region
A Portion of Central New Jersey
Legend
AG (Hillsborough)
AVAD
C-1 (Hopewell)
C1 (Hillsborough)
HC (W. Amwell)
HO (E. Amwell)
Hopewell Borough
IC (Hopewell)
LB (E. Amwell)
LHC (W. Amwell)
LI (W. Amwell)
LM (Montgomery)
Lambertville City
MR (Montgomery)
MR/SI (Montgomery)
MRC (Hopewell)
MZ (Hillsborough)
NC (W. Amwell)
O/CC (Hopewell)
PPE (Montgomery)
Q (Hopewell)
R (E. Amwell)
R-100 (Hopewell)
R-1A (W. Amwell)
R-5 (Montgomery)
R-75 (Hopewell)
R-9 (W. Amwell)
RR-4 (W. Amwell)
RR-5 (W. Amwell)
RR-6 (W. Amwell)
SC-1 (Hopewell)
SMD
SRPD (W. Amwell)
VRC (Hopewell)
0 0.5 1 2 Miles
BANISCH ASSOCIATES, INC
Planning and Design
FRANKLIN TWP
KINGWOOD TWP
FLEMINGTON BORO
RARITAN TWP
READINGTON TWP
BRANCHBURG TWP
DELAWARE TWP
EAST AMWELL TWP
HILLSBOROUGH TWP
MONTGOMERY TWP
STOCKTON BORO
WEST AMWELL TWP
LAMBERTVILLE CITY
HOPEWELL BORO
HOPEWELL TWP
PRINCETON TWP
PENNINGTON BORO
LAWRENCE TWP

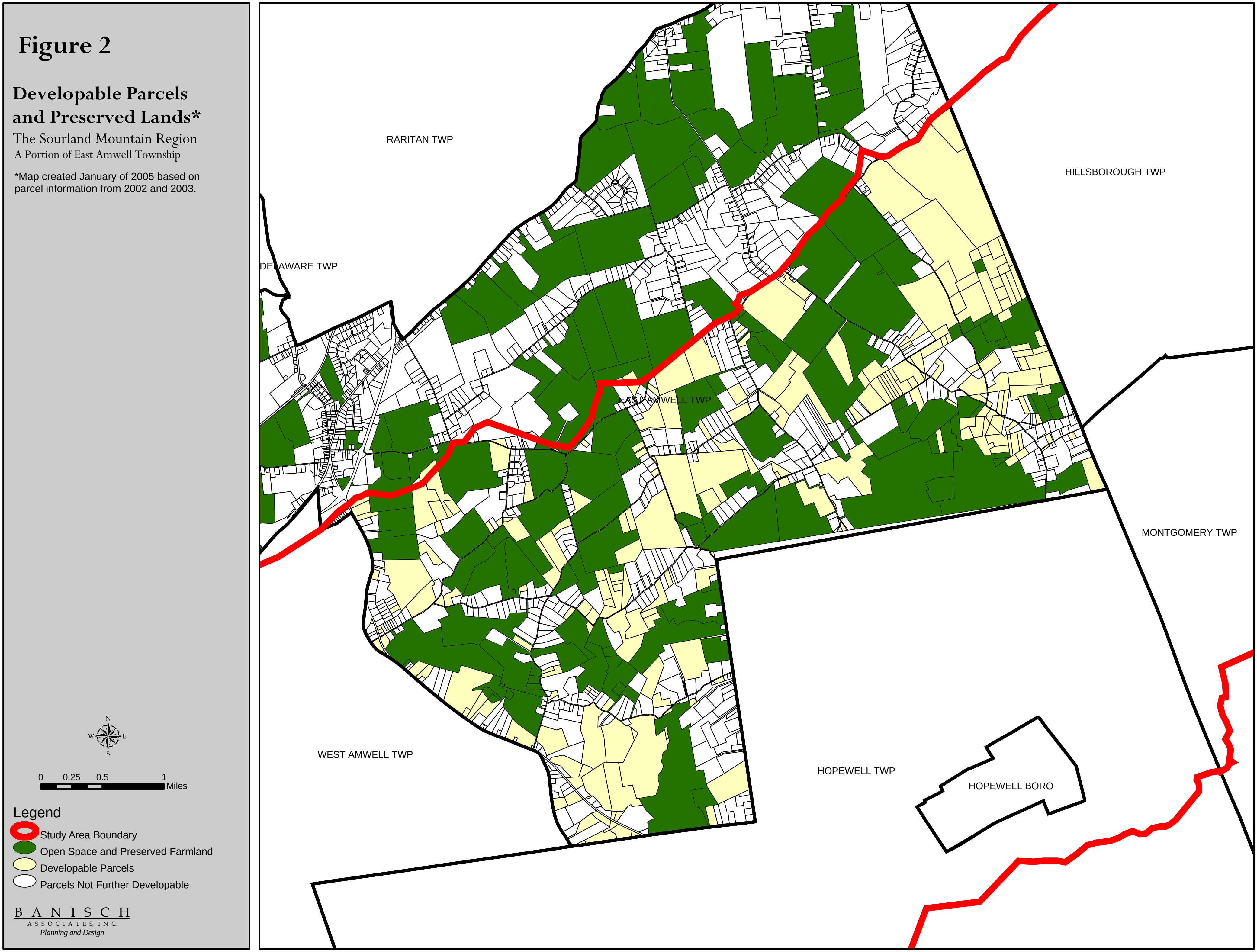
Figure 2

Developable Parcels and Preserved Lands*

The Sourland Mountain Region

A Portion of East Amwell Township

*Map created January of 2005 based on parcel information from 2002 and 2003.



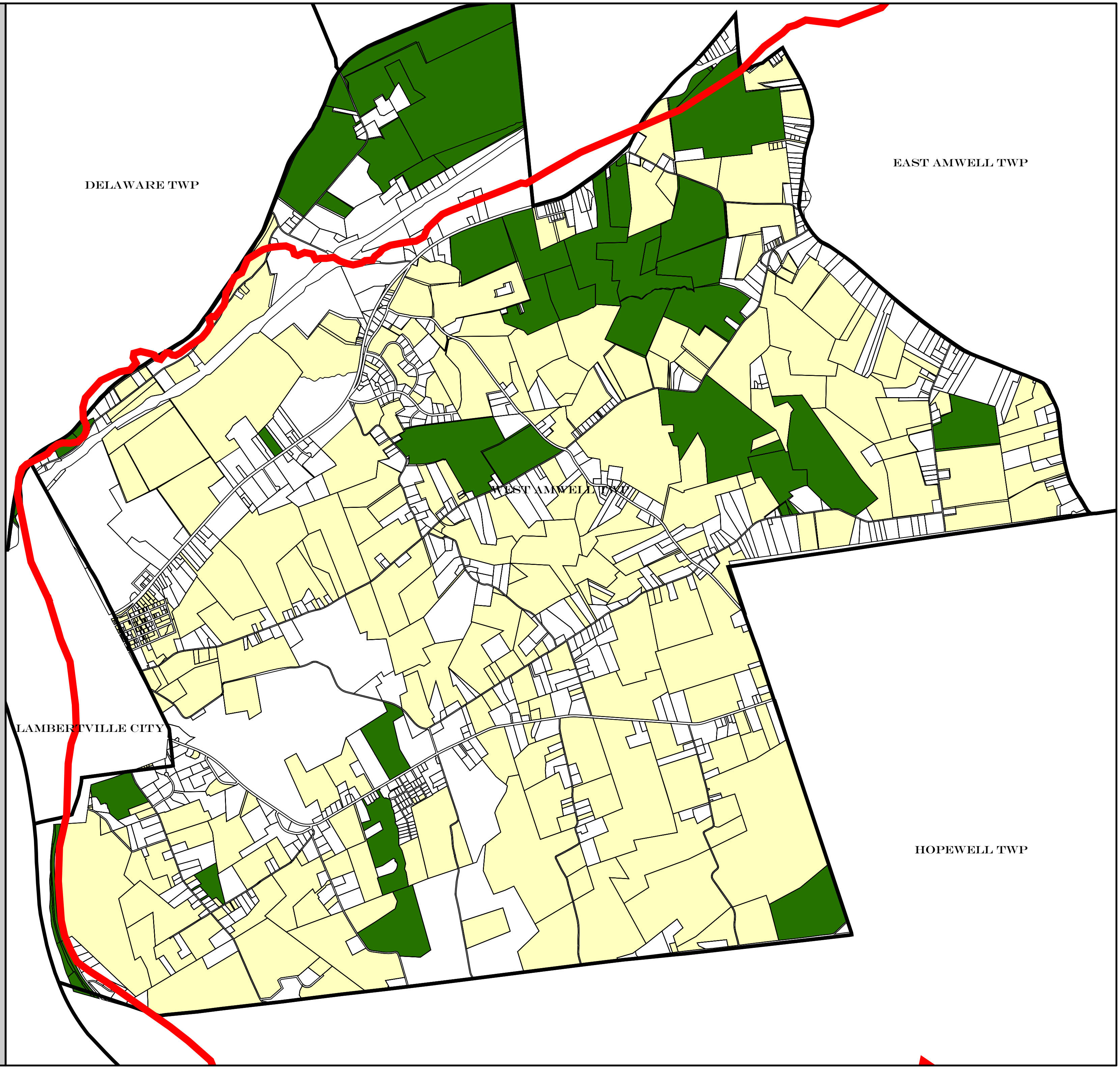
Legend

- Study Area Boundary
- Open Space and Preserved Farmland
- Developable Parcels
- Parcels Not Further Developable

B A N I S C H
A S S O C I A T E S, I N C.
Planning and Design

Figure 3
Developable Parcels and Preserved Lands*

The Sourland Mountain Region
A Portion of West Amwell Township
*Map created January of 2005 based on parcel information from 2002 and 2003.



N
W E
S

0 0.25 0.5
Miles

Legend

- Study Area Boundary
- Open Space and Preserved Farmland
- Developable Parcels
- Parcels Not Further Developable

B A N I S C H
A S S O C I A T E S, I N C.
Planning and Design

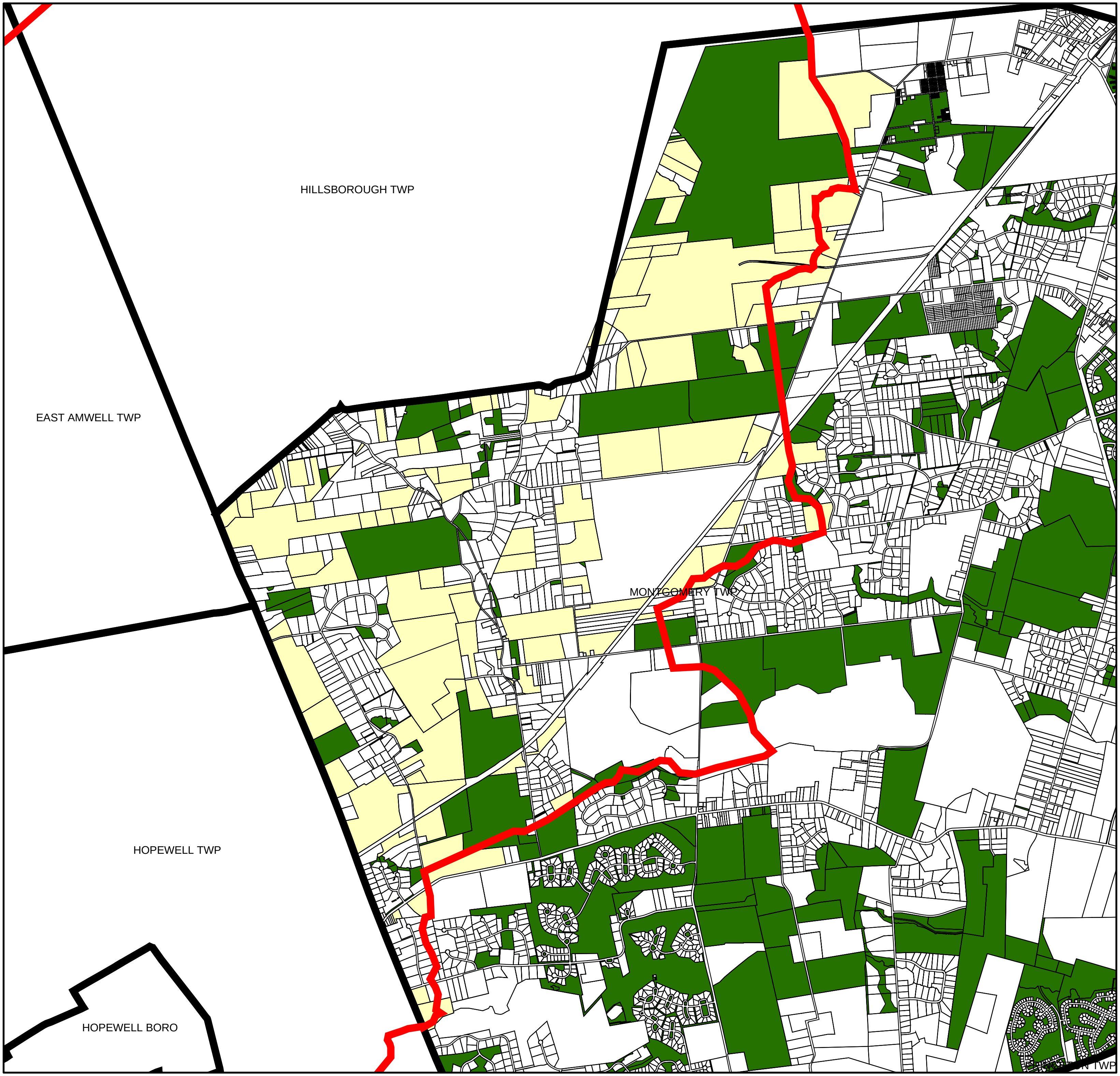
Figure 4

Developable Parcels and Preserved Lands*

The Sourland Mountain Region

A Portion of Montgomery Township

*Map created January of 2005 based on parcel information from 2002 and 2003.



N
W E
S

0 0.25 0.5 Miles

Legend

Study Area Boundary

Open Space and Preserved Farmland

Developable Parcels

Parcels Not Further Developable

B A N I S C H
A S S O C I A T E S, I N C.
Planning and Design

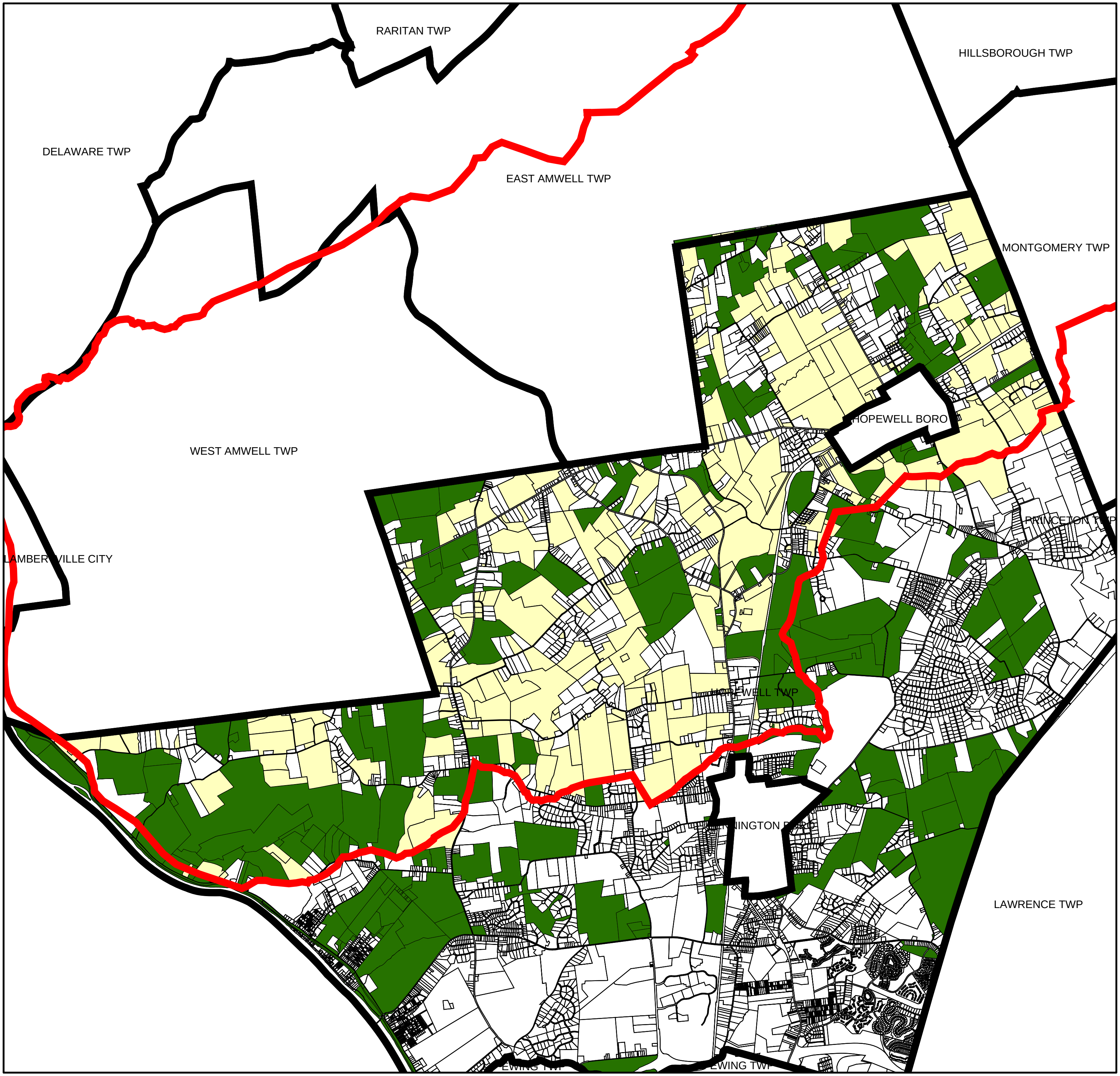
Figure 5

Developable Parcels and Preserved Lands*

The Sourland Mountain Region

A Portion of Hopewell Township

*Map created January of 2005 based on parcel information from 2002 and 2003.



N W E S

0 0.25 0.5 1 1.5 2 Miles

Legend

Study Area Boundary

Open Space and Preserved Farmland

Developable Parcels

Parcels Not Further Developable

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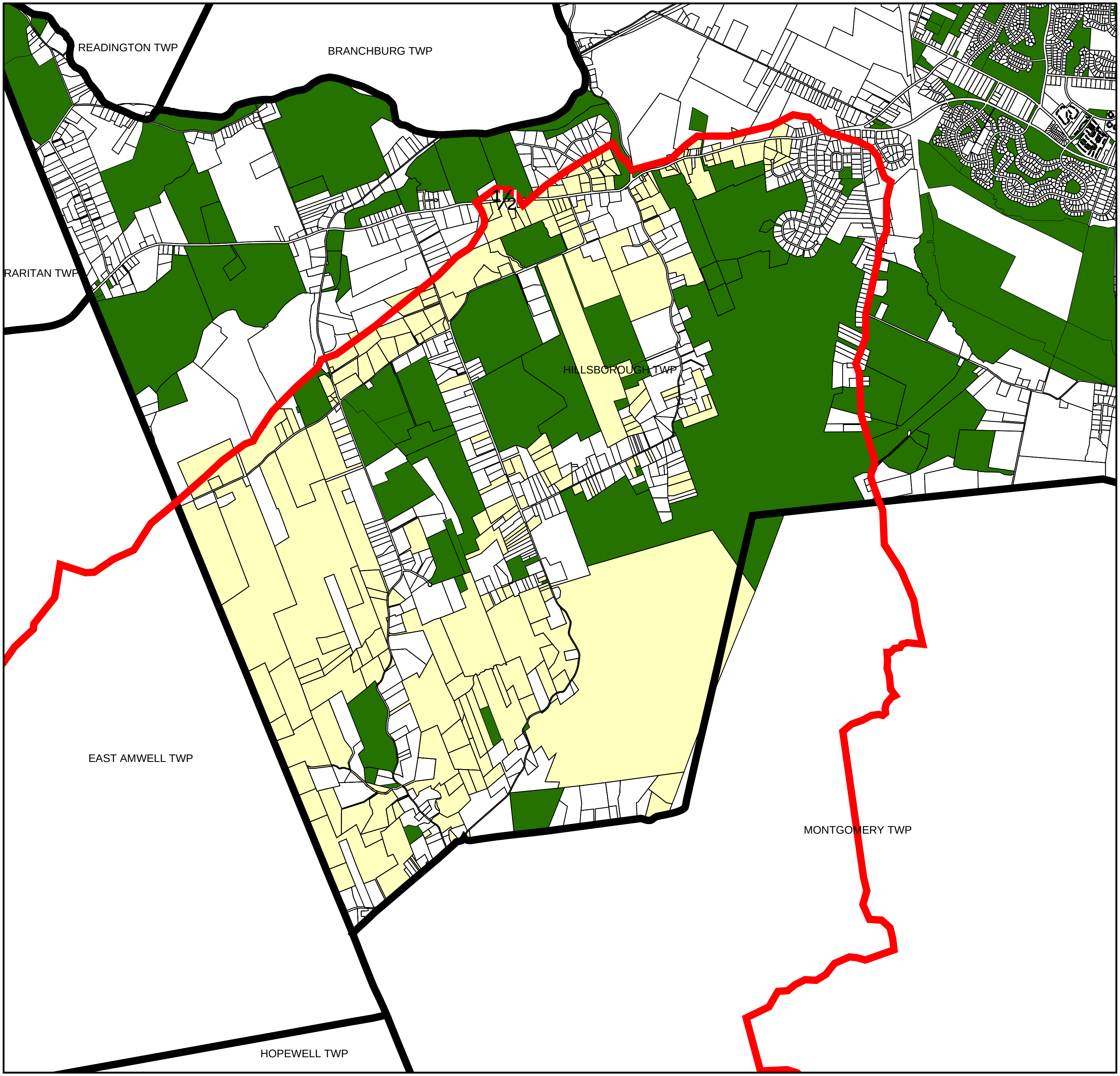
Figure 6

Developable Parcels and Preserved Lands*

The Sourland Mountain Region

A Portion of Hillsborough Township

*Map created January of 2005 based on parcel information from 2002 and 2003.



N W E S

0 0.25 0.5 1 Miles

Legend

Study Area Boundary
Open Space and Preserved Farmland
Developable Parcels
Parcels Not Further Developable

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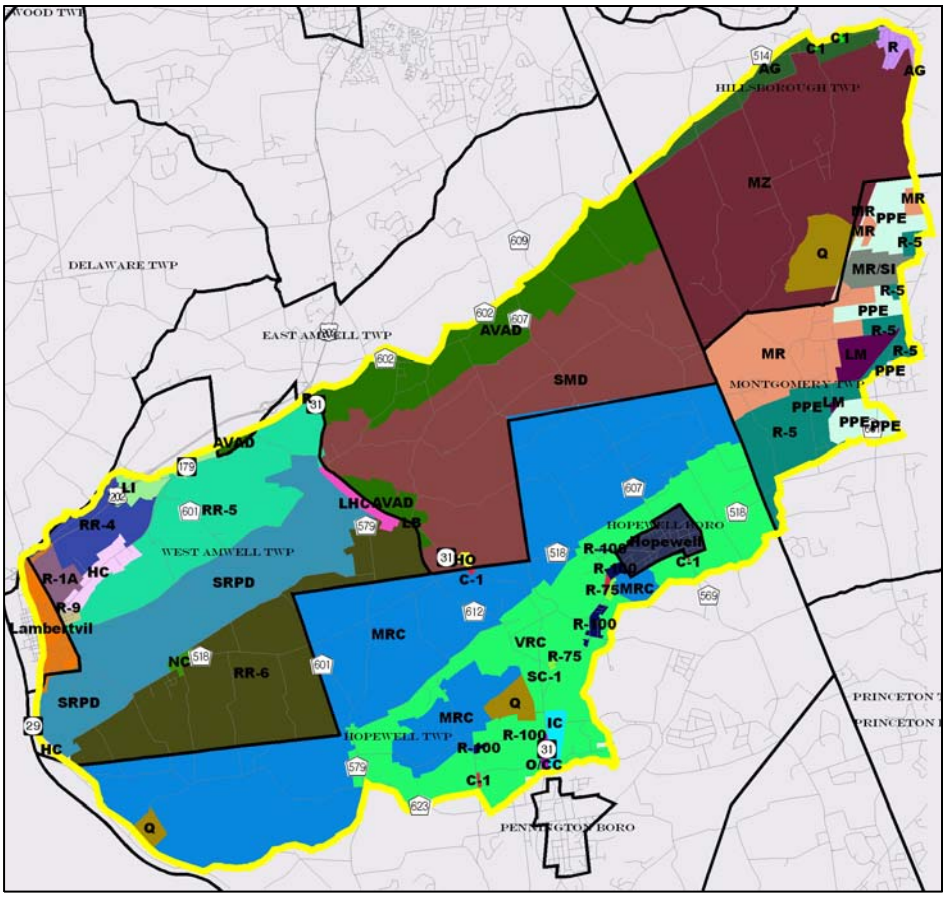
Comparison of State, County and Municipal Planning Documents, Ordinances and Board of Health Ordinances

Sourland Mountain Region



Prepared by:
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TABLE OF CONTENTS

Executive Summary

This comparison of municipal land use and board of health regulations has been prepared through the Smart Growth planning grant from the New Jersey Department of Community Affairs, Office of Smart Growth, with the Sourland Planning Council as a project partner, the five municipalities that share the core of the Sourland region (East Amwell Township, West Amwell Township, Hopewell Township, Montgomery Township and Hillsborough Township) are preparing a variety of studies to gain a better understanding of the region.

The first phase of the project involved preparation of a natural resources inventory and assessment of groundwater resources of the region. This Comparison Report compares and summarizes municipal land use and health regulations throughout the region, and together with the build-out analysis, assessing the extent of permitted development under current regulations, helps to provide background and context for the Conservation and Open Space Plan that will identify policies and actions that can promote sustainability for the Sourland Mountain region.

The five study area municipalities are reviewing regional planning and zoning policies and regulations in order to determine areas of strength and weakness in the ability to protect natural resources critical to the Sourland Mountain region (Figure 1). While each municipality has its own vision for the future, a compatible set of policies and regulations across jurisdictional boundaries can significantly impact the health of the Sourlands ecosystem.

Zoning Regulations

The adopted zoning regulations in each municipality reflect an understanding of the resource limitations affecting development in the Sourland Mountain region. Each municipality has adopted zoning districts specific to the Sourland (Figure 2), which comprises 56% of the Sourland Mountain study area. These “Mountain” districts generally call for a fairly large minimum lot size, ranging from 8 to 15 acres, and maximum lot coverage ranging from 1% to 15%. These ordinances reflect a vision for a future development pattern that respects the natural resource limitations of the region.

Critical Environmental Protection Regulations

Critical environmental features ordinances exhibit a similar pattern of compatibility areas across municipal boundaries, with standards for lot suitability, woodland protection, steep slopes, stream corridor buffers, groundwater protection and threatened and endangered species. However, the extent to which these ordinances protect specific environmental factors varies.

Lot suitability regulations, which require a minimum area of each lot that must be free of environmental constraints for development purposes, vary greatly from town to town. For example, Montgomery requires at least one contiguous acre of lot area free of environmental constraints, including a 205-foot inscribed circle unconstrained for development purposes. East Amwell and Hillsborough require that at least 22,000 square feet of a lot be unconstrained. Hopewell Township does not specify a set area of unconstrained land, but requires that areas of environmental constraint be deducted from development calculations. West Amwell currently has no ordinance in place for lot suitability.

Woodland protection ordinances exist in each municipality although they also vary. East Amwell and Montgomery limit maximum clearing to 30,000 square feet and 40,000 square feet respectively for “Mountain” zones. Hopewell Township requires protection for a 200-foot roadside buffer, as well as the Beech Grove climax forests. Hillsborough and West Amwell require identification of woodland protection and clearing as part of the development review process, but do not include specific regulations.

The protection of steep slopes is required in each municipality, although the threshold for slopes deemed critical varies from 12% to 25%, with varying regulations to match. For the most part, East Amwell, Hillsborough and Hopewell Township require that slopes be noted on site plans along with mitigation concepts. Montgomery and Hopewell Township go a step further to prohibit development on slopes over 15% and 25% respectively, and in Montgomery, no intrusion of vegetation on steep slopes is permitted.

Stream corridor protection is another universal concern. Montgomery Township identifies stream corridors as the area within a floodway, flood plain, flood hazard area, buffer strips one hundred (100) feet from the top of the channel banks of the stream, intermittent or State open water, adjacent slopes over 15% and the area that extends one hundred (100) feet from the 100-year flood hazard line on both sides of the stream and required that stream corridors remain in their natural state. East Amwell Township requires a minimum 200 foot separation distance of a septic system disposal field from a watercourse in the Sourland Mountain District and a minimum 100 foot separation distance in all other districts. Hillsborough recently amended and adopted a stream corridor ordinance in 2005 that limits activities on tracts that fall entirely or partially within stream corridors. Hopewell Township and West Amwell require that there be a 50-foot buffer on each side of the stream bank. Hopewell Township also requires a 100-foot buffer from any septic system.

Groundwater protection regulations are also in place in each participating municipality, where grading and drainage plans are identified and addressed during the development review process. East Amwell advances this goal by encouraging the use of dry wells, swales and rain gardens to promote infiltration. Montgomery has recently adopted an extensive ordinance requiring best management practices that increase infiltration rates and prevent non-point source pollution requiring that post construction non-point source pollution is less than or equal to pre-construction non-point source pollutant load.

Protection of threatened and endangered species habitat is highlighted in three of the five municipalities, with East Amwell, Hillsborough and Montgomery requiring threatened and endangered species habitat to be identified in each Environmental Impact Statement. Hopewell Township and West Amwell do not address this issue.

Board of Health Regulations

Board of Health regulations set standards for the placement of water and septic systems. The Natural Resource Inventory and groundwater assessment have identified the limiting factors for well and septics and the impact improperly placed systems can have on the ecosystem. The New Jersey Department of Environmental Protection has set forth statewide standards for Well (N.J.A.C. 7:10) and Septic System (N.J.A.C. 7:9A) placement and construction. However, provisions in the State regulations also allows for each municipality to offer additional standards given local environmental factors.

Ordinances regulating the placement and construction of private well water systems in each municipality adopt the State's standards, and require well permits to locate, construct or alter any well before approval of any development application. East Amwell, Hillsborough and Hopewell Township require a three-part pump test. Hydrogeology reports are required for major subdivisions in East Amwell and West Amwell prior to development approval. Hydrofracturing of wells is prohibited in Hillsborough and Hopewell Township with limited use permitted in East Amwell. Blasting of wells is prohibited in East Amwell and Montgomery Townships. Finally, East Amwell requires that wells constructed in the Sourland Mountain District must be certified before subdivision approval is granted, while Montgomery requires any wells located in the Lockatong Argillite or Diabase Regions to be certified prior to development approval.

Ordinances in each municipality regulating the placement, construction and alteration of septic systems enact the State regulations and require permits for any work on septic systems. While the regulations adopted by each municipality vary, East Amwell, Hopewell Township and Montgomery have recently adopted standards that require a minimum distance between water systems and critical environmental features such as fresh water wetlands. These three municipalities also permit holding tanks, but only if no other options are available. Hillsborough requires a textural analysis and a certified septic system in the Mountain Zone prior to issuance of a building permit, and West Amwell also requires a textural analysis in addition to the State regulations.

Summary

This Comparison Report provides a snapshot in time, reflecting current regulations and standards. While each municipality has taken steps to promote the ecological health of the Sourland Mountain region, the towns are exploring creative new ways to protect the fragile ecosystem, while also providing appropriate development and land use strategies. These efforts should be further advanced with the upcoming amendments to the New Jersey State Development and Redevelopment Plan (SDRP). Local consensus has been developed to designate a Special Resource Area designation for the Sourland Mountain, which will highlight and expand planning efforts to protect the Sourland Mountain region. This Comparison Report should not be seen as a static document, but rather should be viewed as a baseline in an ongoing effort to identify and promote new policies and standards that can be adjusted to reflect emerging knowledge and understanding of Sourland Mountain ecosystems.

Introduction

The Municipal Land Use Law requires that Municipal Master Plans indicate the relationship of municipal master plan policies to those of the State Development and Redevelopment Plan (SDRP), the county plan and the master plans of contiguous municipalities (NJSA 40:55D-28d). This provision seeks to provide an enhanced understanding of the plans of various levels of government and promote better regional planning. The following is a summary of relevant planning policies of the SDRP, the three counties that encompass the Sourland region and the five municipalities that make up the study area.

Review of County and State Plans

2001 New Jersey State Development and Redevelopment Plan

The New Jersey State Planning Act was signed into law on January 2, 1986, providing for the first State Plan ever formally adopted with input from New Jersey's counties, municipalities, and citizens. The State Planning Act of 1985 (NJSA 52:18A-196 et seq.) recognized the intent of the legislature to provide for sound and integrated statewide planning in order to "conserve its natural resources, revitalize its urban centers, protect the quality of its environment, and provide needed housing and adequate public services at a reasonable cost while promoting beneficial economic growth, development, and renewal....".

The State Planning Act established a process (Cross-acceptance) that invited the active participation of state agencies, county and local governments as well as concerned citizens and private interests**.** Among the guiding principles of the State Planning Act are "the provision of adequate and affordable housing in reasonable proximity to places of employment" and the recognition that "the preservation of natural resources and environmental quality is vital to the quality of life in New Jersey".

The State Planning Commission, created under the State Planning Act to effectuate its goals, was empowered to develop the State Development and Redevelopment Plan and promote coordination among state agencies and local government, provide technical assistance to local governments, develop recommendations for a more efficient and effective planning process and recommend to the Governor and Legislature such actions as would improve the efficiency or effectiveness of the planning process.

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, including the Sourland Mountain region.

The State Planning Commission (SPC) is required to prepare, revise, and readopt the State Development and Redevelopment Plan every three years to ensure that Statewide planning policies are coordinated and consistent with local plans. The New Jersey State Planning Commission is currently in the processed of Cross-Acceptance III and hopes to have the final SDRP ready sometime in 2006. As a result of the Cross-Acceptance process, the Sourland Mountain region has received additional attention and there are hopes that the Sourland Mountain region will be designated as a Special Resource Area. This will add additional policy and mapping area changes to the region to support the natural systems contained in the Sourlands. Additionally, Hunterdon County has recommended that Planning Area 4 be eliminated and designated all Planning Area 4 as Planning Area 4B.

The current State Plan Policy Map (Figure 1) includes the Sourland Mountain Region principally within three Planning Area designations, PA-5 - Environmentally Sensitive Planning Area (40%), PA-4B - Rural/Environmentally Sensitive Planning Area (29%) and PA-4 - Rural Planning Area (27%). A very small percentage of the Sourland Mountain region, on the northern fringe in Hillsborough Township, is designated as PA-2 – Suburban (1%) and a portion of Hopewell Township located along Route 31 is designated as PA-3 – Fringe (2%). The last remaining 1% of the Sourland region, located in West Amwell and Hopewell Townships, is designated as Park and Recreation Area. The following descriptions reflect the 2001 State Development and Redevelopment Plan's Policy Objectives for the 3 most prominent designations of PA-4, 4B and 5.

Policy Objectives for PA – 4B and PA – 5[1]:

Most of the Sourland Mountain region is situated within the environmentally sensitive Planning Areas (PA-4B and PA-5). The intent for PA-4B is the same as those identified in PA-4, as described in the following section. The intent for areas in PA-5 is as follows:

- Protect environmental resources through the protection of large contiguous areas of land;
- Accommodate growth in Centers;
- Protect the character of existing stable communities;
- Confine programmed sewers and public water services to Centers;
- Revitalize cities and towns

[1] New Jersey State Development and Redevelopment Plan, New Jersey State Planning Commission, March 2001, Pages 214-220.

The SDRP policy objectives for PA-4B and PA-5 with the most direct relevance in the Sourland Mountain region include the following[2]:

"1. **Land Use:** Protect natural systems and environmentally sensitive features by guiding development and redevelopment into Centers and establishing Center Boundaries and buffers and greenbelts around these boundaries. Maintain open space networks, critical habitat and large contiguous tracts of land in the Environs by a variety of land use techniques. Development and redevelopment should use creative land use and design techniques to ensure that it does not exceed the capacity of natural and infrastructure systems and protects areas where public investments in open space preservation have been made. Development and redevelopment in the Environs should maintain and enhance the natural resources and character of the area.

5. **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.

7. **Recreation:** Provide maximum active and passive recreational and tourism opportunities at the neighborhood and local levels by targeting the acquisitions and development of neighborhood and municipal parkland within Centers. Provide regional recreation and tourism opportunities by targeting parkland acquisitions and improvements that enhance large contiguous open space systems. Ensure meaningful access to public lands.

9. **Historic Preservation:** Encourage the preservation and adaptive reuse of historic or significant buildings, Historic and Cultural Sites, neighborhoods and districts in ways that will not compromise either the historic resource or the ability for a Center to develop or redevelop. Outside Centers, coordinate historic preservation needs with open space preservation efforts. Coordinate historic preservation with tourism efforts.

11. **Intergovernmental Coordination:** Coordinate efforts of state agencies, county and municipal governments to ensure that state and local policies and programs support environmental protection by examining the effects of financial institution lending practices, government regulation, taxation and other governmental policies and programs."

Policy Objectives for PA – 4[3]:

[2] New Jersey State Development and Redevelopment Plan, New Jersey State Planning Commission, March 2001, Pages 218-219.

The following Policy Objectives and intent for PA-4 (Rural Planning Area) can be summarized as follows:

- Maintain the Environs as large contiguous areas of farmland and other lands;
- 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.

The SDRP policy objectives for PA-4 provide policy guidance for land use and management. The policies with the most direct relevance in the Sourland Mountain region include the following[4]:

"(1) **Land Use:** Enhance economic and agricultural viability and rural character by guiding development and redevelopment into Centers. In the Environs, maintain and enhance agricultural uses, and preserve agricultural and other lands to form large contiguous areas and greenbelts around Centers. Development and redevelopment should use creative land use and design techniques to ensure that it does not conflict with agricultural operations, does not exceed the capacity of natural and built systems and protects areas where public investments in farmland preservation have been made. Development and redevelopment in the Environs should maintain or enhance the character of the area.

(5) **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.

(6) **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.

(7) **Recreation:** Provide maximum active and passive recreational and tourism opportunities at the neighborhood and local levels by targeting the acquisition and

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[3] New Jersey State Development and Redevelopment Plan, New Jersey State Planning Commission, March 2001, Pages 205-214.

[4] New Jersey State Development and Redevelopment Plan, New Jersey State Planning Commission, March 2001, Pages 209-210.

development of neighborhood and municipal parkland within Centers. Provide regional recreation and tourism opportunities by targeting parkland acquisitions and improvements that enhance large contiguous open space systems and by facilitating alternative recreational and tourism uses of farmland.

(9) **Historic Preservation:** Encourage the preservation and adaptive reuse of historic or significant buildings, Historic and Cultural Sites, neighborhoods and districts in ways that will not compromise either the historic resource or the ability for a Center to develop or redevelop. Outside Centers, coordinate historic preservation needs with farmland preservation efforts. Coordinate historic preservation with tourism efforts.

(11) **Intergovernmental Coordination:** Coordinate efforts of various State agencies, county and municipal governments to ensure that State and local policies and programs support rural economic development, agriculture, and the rural character of the area by examining the effects of financial institution lending, government regulation, taxation and other governmental policies and programs."

Hunterdon County Growth Management Plan

Perhaps nowhere in Hunterdon County is the environment more unique than in the Sourlands. Hunterdon County's 1986 Growth Management Plan included the following goal related to the environment: "Maintain and protect the unique environmental quality of the County". Objectives directed at environmental protection in the County Plan included a focus on water resources, including:

- Coordinate local plans to insure an adequate supply of water for the diverse needs of the region
- Encourage groundwater recharge
- Encourage land use patterns and densities that protect water-related land features
- Encourage and coordinate protection of stream corridors to promote the biological integrity and water quality of our springs and streams

The Sourland Mountain District is mapped as part of the County's expansive Rural Conservation Area "intended to accommodate limited to moderate growth provided this development is sensitive to the rural nature and landscape….". In the Rural Conservation Area, the County plan notes that the "capacity of the land to accommodate development should be considered in determining what (these) densities should be. Important factors to consider are the suitability of the land for on-site sewage disposal, the availability of groundwater and sensitive natural features…" Policy recommendations for this area also included "a major effort" to site new development in ways which "minimizes impact on the rural landscape..."

More recent policy guidance is contained in the "Strategies for Managing Growth in Hunterdon County", published in the fall of 1998. This document represents a summary of recommendations from four task forces that were formed as part of the growth management planning process. This summary is provided from the Rural Character and Environment task force recommendations.

The Rural Character and Environment Task Force offered a number of recommendations related to open space, site design guidelines, farmland preservation and water quality. Goals related to rural character and the environment included, among others:

- Minimizing intrusion on aquifers, habitats, and natural vegetation,
- Preserving unique viewsheds, ridgelines and stream corridors,
- Preserving limited/non-renewable natural resources such as land, forests and wetlands.

The task force concluded that large lot zoning could contribute to the preservation of open space, under some circumstances, but found that lots of 2-3 acres were not useful for this purpose. Lots of 10 acres (or more) "…may give the visual appearance of open space…" according to the task force, although equity issues were cited as making such zoning unpopular. Large lot zoning was deemed appropriate in the following situations, (among others)[5]:

- In areas of poor soils – so there is no risk of losing prime farmland;
- In areas where groundwater is scarce so that the low density minimizes the usage of water.

The task force went on to further enumerate recommendations related to water resources, and acknowledged that continued development is a true threat to adequate water availability. They recommended the following[6]:

- Mitigate runoff impacts of new development by encouraging development practices that reduce impervious surfaces and facilitate groundwater recharge.
- Consider the availability of groundwater in determining the density of development.
- Municipalities should use the best scientific information available to evaluate groundwater supply and quality.
- Local land use planning projects/efforts should include information based upon geology, aquifers and contaminated site data.

Hunterdon County is currently in the process of preparing a new Growth Management Plan[7]. This plan will allow for further guidance and protection of the County's natural

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[5] "Strategies for Managing Growth", Hunterdon County Growth Management Task Forces, Fall 1998, page 7.
[6] "Strategies for Managing Growth", Hunterdon County Growth Management Task Forces, Fall 1998, page 13.
[7] Draft Hunterdon County Growth Management Plan, 1/15/2004.

resource base and lands that are important to residents. Hunterdon county has prepared a draft Vision Statement and Goals which will be incorporated into the final plan.

The Vision Statement for Hunterdon County focuses on the protection of natural resources and allowing for appropriate and meaningful development in areas that will least impact natural systems. The County recognizes the importance of critical environmental areas, limited groundwater supplies, large contiguous woodlands and other habitats, as well as providing residential neighborhoods to meet a variety of needs. The objective of the County is to identify potential conflicts between the need for appropriate services and opportunities for residents and the protection of the overall health of the environment and to resolve these conflicts through active involvement in the planning and design of their communities.

The goal statements to be adopted into the final Hunterdon County Growth Management Plan encompass a wide range of issues, including environmental sustainability, efficient development patterns, appropriate transportation systems, balanced economy, diverse housing opportunities, and supported community-based planning. The goal most relevant to the Sourland Mountain Region is that of promoting environmental sustainability. This goal seeks to maintain large contiguous areas of open space, woodlands, wetlands, grasslands and farmland in order to protect and support natural resources and healthy watersheds.

Hunterdon County Park and Recreation Master Plan 2000

The Hunterdon County Park and Recreation Plan identifies the need to protect and preserve natural resources based on bioregions, areas with similar physiographic and biological features. The protection of bioregions allows areas that encompass contiguous ecosystem and habitats to be preserved based on their natural resources and capacity of each distinctive bioregions. The county identified four main reasons why the County Park System should prioritize the acquisition of large contiguous areas that include; living museums, ecological integrity, viewscapes and soundscapes. The preservation of bioregions also includes discussion of six distinct bioregions located in the County that merit preservation. Included in this list is the Sourland Mountain Region. The goal of the County is to preserve large contiguous areas in the Sourlands and link greenways and open space with adjacent counties for more appropriate preservation beyond political boundaries.

Sourland Mountain Preserve Master Plan prepared by Somerset County Park Commission 1997

The Somerset County Park Commission undertook the preparation of a Master Plan for the Sourland Mountain region as it pertains to Hillsborough and Montgomery Townships. The Master plan divides the 2,300-acre preserve into two distinct regions, the Main Preserve and the East Preserve. The Main Preserve is approximately 1,800 acres and is characterized by its mature woodlands, steep slopes and boulder-strewn land. The Main Preserve is located west of East Mountain Road which runs along the east portion of the

Sourland Mountains. The East Preserve is located east of East Mountain Road and contains approximately 500 acres of land. This area has been programmed for more passive and limited active recreation development. The East Preserve also includes an additional 250 acres of farmland to the south of the preserve which is not contiguous but acts as a buffer to the larger preserve.

There are 3 overall goals of the Sourland Mountain Master Plan. First, to provide passive and limited active recreation pursuits which could include a variety of nature trails, a visitor center and other low impact recreational opportunities. Secondly, these facilities would require a development and maintenance policy. Third, to evaluate opportunities to expand the preserve to buffer against encroaching development and to offer new passive and active recreation pursuits.

Somerset County Smart Growth Strategic Plan

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 that 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 that are applicable to the Sourland Mountain region. Listed below the relevant guiding principles are specific planning objectives[8].

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.

[8] "Draft Guiding Principles for "Creating Quality Communities Together", Somerset County Planning Board, June, 2003, pgs 3-8.

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

<u>*The Somerset County Parks, Recreation and Open Space Master Plan Update*</u>

"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.

Somerset County has made significant parkland acquisitions within the Sourlands during the past several decades. The Somerset County Parks, Recreation and Open Space Master Plan Update refers to the Sourland Mountain Preserve Master Plan, which proposes passive and limited active recreation facilities with a focus on protecting and preserving the area's natural resources. It also notes significant environmental constraints make it imperative that park development is sensitive to the mature native forests, critical habitat and critical slopes that are characteristic of the region.

<u>*The Somerset County Agriculture Retention and Development Master Plan*</u>

"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, identifying three areas where agricultural retention is a priority (Hillsborough, Bedminster and Franklin). Although agriculture has continued to decline within the County, remaining opportunities for the retention of agriculture provide a range of open space and rural character benefits that are increasingly important to the quality of life in New Jersey's fastest growing County. Aside from quality of life benefits, preservation of farmland provides fresh produce close to wealthy markets and conserves important areas for aquifer recharge. It also protects the extensive prime and statewide important agricultural soils that form the basis of agriculture in the County.

Mercer County Growth Management Plan

The Mercer County Planning Board adopted the Growth Management Plan in 1986. The Executive Summary states:

> The Mercer County Growth Management Plan is the basis for a comprehensive program to ensure that land development occurs in appropriate areas, at appropriate intensities, and at an appropriate rate to preserve and enhance Mercer County's existing communities, economy, and quality of life. Demands for growth are to be balanced with the capacity of the region's infrastructure and natural resources and the ability of local, County, State, and regional agencies to adequately sustain additional growth and development.

Revisions and amendments to the Growth Management Plan have occurred continuously since that time. In 1992, the Mercer County Planning Board adopted the Open Space and Recreation Plan and amended it several times, most recently in 2003.

In 2003 Mercer County began a comprehensive examination of the 1986 Growth Management Plan to evaluate the Plan's relevance to present and future conditions. This examination expands the County's traditional role of linking state and local planning through infrastructure coordination alone. The Growth Management Plan update project uses a comprehensive, target-based planning process that expands the County's traditional focus on transportation and water resources to include planning for sustainable economic growth. A focus on the economy, transportation, and the environment—employment and housing targets, transit corridor choice, and watershed protection, respectively—all influence and are influenced by land use. The planning process involves building a consensus over future land use patterns, informed by regional economic, fiscal and social justice goals, environmental constraints, and transit opportunities. The goal of the process is to generate policy decisions across all levels of government based on how decision-makers want to maintain or change growth projections in order to move toward smart growth. The County anticipates that the final Growth Management Plan will serve as the basis for future regional flood control, water quality management, and stormwater management plans.

The County's approach toward environmental preservation continues with balancing growth. Consistent with this approach, the County Growth Management Plan will develop comprehensively. Policy decisions on the environment will simultaneously consider current trends that affect the jobs and housing balance, availability of affordable housing, and improvement of traffic congestion and patterns within the region. Environmental recommendations are intended to prevent further loss of open land, valuable water resources, and historic and cultural resources. The Plan's environmental recommendations are likely to include: 1) implement clustering and innovative development methods, 2) effective land acquisition to preserve environmentally-sensitive lands, 3) coordination of land use planning with storm and waste water planning, and 4) protection of historic and cultural resources through natural land protection.

Mercer County Open Space and Recreation Plan 2003

The Open Space and Recreation Plan preservation and development goals address the importance of preserving lands in a natural state that have county-wide significance. The objective is to protect ecologically sensitive areas through a process that involves regional cooperative preservation efforts with neighboring counties and municipalities. This includes preserving areas of scenic, agricultural, historic and cultural value while minimizing the impacts of recreational development through the use of recreational facility design attentive to environmentally sensitive areas, scenic vistas, and plant and animal habitats.

The Plan identifies open space acquisition and development criteria for protection of natural or undeveloped lands, historic and cultural lands, and farmland preservation. Consistent with the intent of the County’s Growth Management Plan with respect to the environment, the Open Space and Recreation Plan’s established criteria include protection of watersheds and potable water supply, including unique geologic features and formations, and ecosystem protection through the preservation of large, contiguous areas of quality natural lands. These criteria include the eventual connection of existing, large areas of preserved land with other open space areas. The Plan also recognizes the critical relationship of historic sites and farmland to preservation of the natural environment.

Baldpate Mountain Concept Plan 2002

The Baldpate Mountain Concept Plan was prepared for the Mercer County Park Commission June 2002. Mercer County purchased 1,100 acres on Baldpate Mountain in April 1998 from Trap Rock Industries, Inc. through a financial partnership with State Green Acres, the Township of Hopewell and the Friends of Hopewell Valley Open Space, Inc. Baldpate Mountain, in its entirety, is located within the Sourland Mountain region.

The overall goal of the Plan is based on the stipulation from the ownership agreement that “the property is to remain primarily in a natural state, and that only passive recreation opportunities may be provided to the public on the site.” The site includes existing structures that are currently undergoing restoration to reflect the historic presence of people on the mountain. The goal of the Plan regarding forest and wildlife management is to keep these systems in a “primarily natural state.”

The goals of the Plan are consistent and enhance the land use activities adjacent to Baldpate Mountain and within and adjacent to the Sourland Mountain region.

Howell Living History Farm Master Plan 2002-2012

The Howell Living History Farm Master Plan was prepared for the Mercer County Park Commission, Howell Living History Farm, and the Friends of Howell Living History Farm in 2002. The Farm, through its interactive educational programs, goals for preservation of historic structures and surrounding landscape, and ongoing practices to conserve natural resources within the Sourlands, provides a working historical example of life within the Sourland Mountain region.

The Plan's guiding principles to preserve and maintain the farm's natural landscape and resources, improve the quality of the surrounding environment, and enhance the rural character of Pleasant Valley, are tied to the farm's physical and historical relationship to adjacent Baldpate Mountain and to the Pleasant Valley Historic District.

The goals and objectives of the Plan reflect the importance of natural landscape and historic preservation within the Sourland Mountain region. The Plan identifies the importance of Baldpate Mountain for interactive programs related to woodlots, maple grove, archaeology, and historic landscape. It also identifies the need to conserve and enhance the cultural landscape through landscape design compatible with the historic setting of the farm and the present natural state of the mountain. Plan goals and objectives address the need to conserve natural resources through stream bank restoration and establishment of riparian buffers and cultural resource preservation through continuation of the oral history collections program.

Review of Municipal Plans and Ordinances

The following summarizes the local land use plans and local ordinances. Figure 2 provides a map of the Sourland Mountain and the various districts located within each township and Appendix A and B provides a chart-based comparison for each Municipality.

East Amwell, Hunterdon County

East Amwell has studied the Sourland Mountain District and adjusted local planning and zoning policies to reflect the limited water resources and fragile environmental infrastructure of the Sourlands. The Sourland Mountain District contains many critical features, including wetlands, large contiguous forests, limiting geology, low rates of recharge for bedrock aquifers and low yielding wells, and critical habitat for threatened and endangered species. These features point to the need for land use policies and regulations that promote sustainability and resource preservation. The intent of policies for this district is to protect critical natural resources, to balance ecological systems and beneficial growth, and to maintain large contiguous areas of undisturbed habitat to protect natural resources. The minimum lot size of the Sourland Mountain District is 15 acres/unit for residential and 30 acres/unit for farm uses. Farming is discouraged, and the ordinance specifies that no trees may be cleared for expanded or new farming use, fields, or pastures.. Clustering is not permitted in the Sourland Mountain District due to public health concerns related to limited water supplies and poor groundwater recharge, which limits dilution of septic effluent. Pre-existing five-acre lots, which conformed to the ordinance prior to the zoning change in 2003, are grandfathered for single-family homes.

A portion of the Amwell Valley Agricultural District (AVAD) is in the Sourland Mountain study area. The AVAD is primarily characterized by more rural agricultural land uses and contains a higher farmland base. The purpose of this zoning district is to promote and protect the rural character of the area, to encourage agricultural industry, and to preserve critical environmental features. Permitted uses in the Amwell Valley District include single-family detached units, agricultural uses and farms and public parks. The Amwell Valley Agricultural District has a low density of 10 acres/unit, but zoning options encourage land use patterns of clustering and lot size averaging, where lots of 1½ acres can be created and bonus density of 1 unit per 6.7 acres.

The Local Business District (LB) has primarily developed areas that serve the needs of local residents. The small pockets of the LB district permit local retail sales, business services and restaurants.

The Highway Office District (HO) allows for low-coverage, one-story structures near the Village of Ringoes and a small area near the intersection of routes 31 and 518. Specific design standards for this district require context sensitive design to better maintain the rural character of the surrounding areas while providing nonresidential uses. These uses include offices, medical and dental offices and cluster residential development. The minimum lot size is two acres for most uses but can be five acres or more.

Hillsborough Township, Somerset County (2002)

Hillsborough Township has also amended its Land Use Plan Element as it relates to the Sourland region, which encompasses rugged mountain lands as well as productive farmland.

Mountain District

With an increased focus on environmental constraints, and the abundance of environmentally critical land, the Mountain District is designed to respect the limitations of the fragile mountain ecology and protect the forest habitat and water resources. Fifteen acres/unit (0.06 units/acre) is the maximum permitted density within this residential district.

The Mountain District consists of approximately 20% of the land area of Hillsborough Township. The lack of public water and sewer infrastructure throughout the District limits future development potential. Respecting the carrying capacity limitations of the natural systems to provide potable water and treat septic effluent without degrading water quality is therefore of critical concern.

Capacity-based planning involves the measurement of a municipality’s ability to accommodate growth and development within limits defined by natural resource capabilities and existing infrastructure. A capacity analysis identifies and evaluates limiting factors as they related to an area’s ability to grow. With an absence of public water and sewer infrastructure, the limiting factor thus becomes water.

The Mountain District seeks to promote sustainable development policies to provide a land use framework that meets the needs of the present without compromising the ability of future generations to meet their own needs. It cites respecting capacity limits with a margin of safety as an objective and incorporates the goals of stewardship over land and water resources and the prolonged maintenance of a healthy and desirable physical environment.

Agricultural District

Part of the Sourland region in Hillsborough is situated within the Agricultural District. Here, an agricultural mosaic dotted with farmsteads, barns, stream corridors and small clusters of houses typify most of the district, and the critical mass of open land and cultivated fields imparts a prevailing rural character. Over 80% of the Agricultural District consists of highly productive farmland, including Prime farmland and Soils of Statewide or Local Importance (over 80%), although the Mountain area is a transitional area.

Hillsborough Township’s vision for the future of undeveloped lands in the Agricultural District embodies the smart growth principles of the State Plan intended to deter sprawl. The density for single-family detached development is one unit/10 acres.

Hopewell Township, Mercer County (2002)

The 2002 Master Plan outlined a series of key concepts and guiding principles to manage change and promote a sustainable future. Growth management, natural resource conservation, maintenance of rural character, respect for carrying capacity, sustainable development and stewardship provide the underpinnings of Hopewell's plan to provide a variety of opportunities.

The Sourland Mountain Region in Hopewell Township includes the Mountain Resource Conservation District (MRC), the Valley Resource Conservation Districts (VRC, the Neighborhood Retail Commercial District (C-1) and the R-100 Residential District.

The Valley Resource Conservation (VRC) and Mountain Resource Conservation (MRC) Districts include approximately 78% of the land area of Hopewell Township. The lack of public water and sewer infrastructure throughout these Districts limits future development potential, which should respect the carrying capacity limitations of the natural systems to provide potable water and treat septic effluent without degrading water quality below prescribed limits. In addition to the protection of groundwater and surface water resources, the VRC and MRC Districts respond to the goals of conserving significant elements of the rural and agricultural countryside. The rural character that pervades much of Hopewell Township, embodied in scenic vistas, wooded hillsides, agricultural fields and historic settlement patterns, is highly susceptible to degradation.

Open lands zoning permits property owners in the Valley Resource Conservation District a density of approximately one unit/6 acres, provided that a significant remainder (60 to 70 % of the parcel) is permanently deed restricted against future residential use and remains available for agricultural or other resource conservation uses. Minimum lot sizes should be large enough to assure an adequate site for a home, septic system and accessory uses, but small enough so that the open space ratios can be provided. In the Mountain Resource Conservation District, open lands zoning permits a density of approximately one unit/13 to 14 acres, provided that 75 to 80 percent of the parcel is permanently deed restricted against future residential use and remains available for agricultural or other resource conservation uses. In this District minimum lot sizes also should be large enough to assure an adequate site for a home, septic system and accessory uses, but small enough so that the open space requirements can be met.

The R-100 District largely encompasses pockets of existing development, many of which were historically developed as subdivisions under prior zoning or strip frontage lots along collector and arterial roads. The R-100 Districts allows for residential development to occur at 1 unit/2 acre density.

The Neighborhood Retail Commercial (C-1) District is intended to recognize patterns of existing, isolated retail uses consisting of single lots or two adjoining uses. The purpose of this district is not to perpetuate strip development, but merely to recognize existing uses. Permitted uses include retail sales and service establishments, offices, banks, restaurants and commercial recreational establishments.

Montgomery Township, Somerset County (2002)

The Montgomery Township Master Plan lists eleven objectives and goals in the Land Use Plan Element. The primary goal is to "maintain the continuity of the Township's planning process and build upon and refine the past planning decisions of the municipality, consistent with present local and regional needs, desires and obligations." The Plan seeks to preserve the integrity of individual neighborhoods, and limit development in response to the capabilities and limitations of the land.

The Mountain Residential (MR) District has been established in recognition of the inherent limitations imposed by the geologic formations and soil characteristics within the Sourland Mountain areas and the need to protect the potable water supply from septic effluent contamination. The major types of permitted land uses include low-density residential uses and passive recreational areas compatible with the prevailing rural atmosphere. The minimum lot size for residential construction is 10 acres in the MR District.

The R-5 Single Family Residential District, which includes parts of the prior R-2 and R-3 Districts, was created to better address the loss of the Township's rural character and natural resources. The major type of permitted land use includes low-density residential uses. The minimum lot size required for residential construction is 5 acres in the R-5 District. The previous 2- and 3-acre zoning was identified as allowing a development pattern that resulted in suburban sprawl.

The Public, Parks and Education (PPE) district, occupied largely by parkland and Montgomery High School, permits farms, public parks, conservation areas, open space, public purpose uses and schools, including public and private elementary and/or high school. Other uses include detached single-family dwelling units, however most of the current land use in the zone consists of school and parkland. These areas are primarily occupied by parks or are still in a vacant and natural state. The minimum lot area for the PPE district is 10 Acres for residential development and 5 acres for public developments.

The Mountain Residential/Special Industrial District, where 3M mines diabase and manufactures roofing shingles, is rural in nature and contains environmentally sensitive features found primarily in the Sourland Mountain region. While permitted uses for this district include single-family detached developments and special processing activities, the 3M Corporation owns almost the entire district. Given the critical environmental resources in this district and the need to develop according to the limitations of natural resources, development is permitted on 10 acre lots for residential and 50 acres for processing activities.

A small portion of the Sourland Mountain region is located in the Limited Manufacturing District (LM). The LM district's permitted uses include, farms, offices, existing single-family detached and limited manufacturing. The minimum lot area for the LM district is 2-5 acres. Johnson & Johnson Consumer Products Division owns this entire district, which is completely built out with no future ability to expand.

Grandfathering of vacant residential lots, previously permitted in the MR and R-5 Districts, is proposed for elimination in Montgomery. Undersized lots will require a variance, where reasonable conditions can be imposed, for construction of a new dwelling.

West Amwell Township, Hunterdon County (2003)

The 2003 West Amwell Township Master Plan Land Use Plan Element includes plans, policies and principles pertaining to agriculture, environmental and groundwater protection, residential densities, flexible development, industrial and office use, highway, commercial and growth management. The primary goals within the Master Plan are to retain rural character and natural habitats, and promote environmentally sensitive planning. Other goals focus on retaining a sense of community, protection of environmental resources, growth management and housing for all citizens.

The Sourland Regional Planning District (SRPD), which encompasses the contiguously forested portion of the Sourland Mountain region in West Amwell, is recognized for unique regional environmental qualities including important woodland habitat, limited groundwater recharge, steep slopes and other qualities. The SRPD permits single-family residential development at 1 unit per 8 acres.

The Rural Residential Northern District (RR-4) of the Township contains subsurface and geological features most conducive to groundwater recharge. Therefore this region can support a higher density of development. The minimum lot size for the RR-4 district is 4 acres.

The Rural Residential Central District (RR-5) lies on the northerly boundary of the Sourland Mountain Region and also contains the Mt. Airy Historic District. The RR-5 district has severely limited access to groundwater and limited recharge opportunities, and thus lower density development on lot sizes of 5 acres is permitted.

The Rural Residential Southern District (RR-6) lies south of the Sourland Mountain Zone and is also constrained by groundwater limitation. The zone contains larger tract parcels and a variety of agricultural lands. The minimum lot size for this zone is 6 acres.

The Village Residential Zone (R-9) permits single-family development on lots containing 31,250 square feet. The zone is located on the western boundary of the Township adjacent to the City of Lambertville.

The R-1A zone is designed to allow single-family development as a result of Mt. Laurel settlement. The goal of this zone is to allow for development in the context of the surrounding neighborhood context.

The Highway Commercial (HC) zone is designed to permit shopping and services by providing sites for highway-oriented business, warehousing and offices. Within this area West Amwell hopes to avoid a strip-commercial development appearance. The maximum floor area ratio for this zone is 15% and the maximum impervious coverage is 50%.

The Light Industrial District (LI) is intended to provide warehousing and distribution activities. This zone has a minimum lot size of 5 acres with a maximum floor area ration of 15% and a maximum impervious coverage of 40%.

The newly adopted 2003 Master Plan also includes discussion on the Sourlands Region in its Land Use Plan Element. The Township acknowledges the significance of the Sourlands Region and identifies proposed changes to the current zoning and planning criteria to address the natural resource limitations of the area. These include establishing a Sourlands Regional Planning District to encompass the portion of the Sourlands and creating a revised residential district south of the Sourlands to more adequately address capacity limitations.

Comparison of Resource Management Standards in the Sourland Region

The Following is a summary of relevant ordinances adopted by the Townships that share the Sourland Mountain Region as they pertain to natural resource protection and development standards. A comparison table of ordinances follows this section.

East Amwell

As a result of detailed study, East Amwell has adopted ordinances to address activities in the Mountain Zone. These include:

- Agricultural practices are a conditional use in the Sourland Mountain District, however new clearing in the Sourland Mountain Region for agricultural purposes is prohibited. (§92-89:D (4))
- Maximum lot coverage uses a sliding scale as follows: first, 5 acres are allowed 5% maximum lot coverage, lot area between 5 and 15 acres are permitted 3% maximum lot coverage and additional lot area over 15 acres are permitted 1% maximum lot coverage. (§92-89:F)
- Maximum Gross Floor Area is also on a sliding scale according to lot area. (§92-89:G)
- Design standards and forest preservation efforts require that clearing of trees and native vegetation not exceed 30,000 square feet for any lot, exclusive of driveways. (§92-89:I(1)(a))
- All clearing and development shall be limited to an area within 500 feet of the street line when the lot abuts a street (§92-89:I(1)(b)), and a 100 foot setback from the road is required. No trees or other vegetation may be removed in this 100 foot buffer area.
- Each new lot created must have a minimum of 22,500 square feet of unconstrained area within the required 500 foot diameter circle inscribed within its lot lines. Unconstrained areas include those free of wetlands and their transition, floodplains and slopes greater than 12%. (§92-89:I(4)(b))
- No new flag lots can be created.

Hillsborough Township

Hillsborough Township has passed many ordinance to that are meant to protect natural resources. These include:

- A stream corridor ordinance that applies to all residential zone that restricts activities on lot that are partially or completely within a stream corridor. Stream corridor areas are to remain in their natural state with limited to no clearing of trees and brush, expect for dead vegetation or pruning, there is to be no altering the watercourse, and no construction activities shall occur in the stream corridor area unless stated. (Ordinance 2005-02)

MZ Zone regulations in Hillsborough Township include:

- Agricultural practices are a conditional use however, maximum clearing is one acre or 10% of the lot, whichever is less (except for those farms in existence prior to the passage of the ordinance). (§188-99.4:D(3))
- Lot Suitability is defined for all residential development as: "In any development application, no residential building lot with a private well and individual septic system shall contain less than 22,500 contiguous square feet of unconstrained land area on which any building using such well and septic system shall be located. Soil boring or percolation/permeability tests shall show the ground conditions to be adequate for proper septic disposal, wherever the septic system is located on the lot, according to Board of Health regulations." (§188-3)
- Stream corridors, and their associated buffers, are defined as the area within a floodway, flood plain, flood hazard area, buffer strips 100 feet from the top of the channel banks of the stream, intermittent stream and/or State open water, and the area that extends 100 feet from the 100-year flood hazard line on both sides of the stream. If there is no 100-year flood hazard line delineated, the distance of 100 feet is measured from the top of the banks of the stream channel on both sides of the stream, intermittent stream and/or State open water. If slopes greater than 15% abut the outer boundary of the stream corridor, the area of such slopes shall also be included as the stream corridor. If the flood plain or flood hazard area extends for more than one hundred (100) feet from the top of the channel bank, said larger area shall be the stream corridor. (§16-6.4(c)(13))

<u>Hopewell Township</u>

Hopewell Township has adopted the following ordinances to protect natural resources in the Township:

- The lot area is contained within the lot lines, including wetland buffer areas, but not including any portion of a street nor any lands within the 100-year flood plain of any watercourse or lake site, wetlands, any areas reserved for future roadways, or areas encompassed within any easements, except that in areas with sewer service, lot areas need only deduct streets, future roadways, and 100-year flood plains.
- Hopewell Township contains an extensive Water Supply and Analysis Requirement Ordinance (§17-149). The purpose of this ordinance is to ensure that residential development of two or more new lots demonstrate that adequate water supply is available without adverse effect on neighboring wells and other resources.
    - The testing procedures for a subdivision of two or more new lots and all site plans shall be based on a hydrogeologic analysis and a minimum of one aquifer test. A geologic and hydrogeologic report containing appropriate maps, well logs, aquifer test data and observation well data

shall be prepared and submitted. Prior to conducting any aquifer test, a preliminary hydrogeologic evaluation and the design of the aquifer test(s) shall be submitted for review and approval by the Township Planning Board or Board of Adjustment herein after referred to as Board.

- Hopewell Township also provides Transfer of Development rights out of the Mountain Resource Conservation Zone to municipally designated Villages in the VRC District. The intent is to provide an opportunity to create an alternative development opportunity that furthers the goals of resource conservation in the Township, while also providing a development form that supports the goals and policies of the Master Plan. (§17-160)

Montgomery Township

Montgomery Township has passed a variety of ordinances to address natural resource protection in the Sourland Mountain Region. These include:

- A contiguous land area of at least 43,560 square feet (1 ac) within any existing or proposed lot proposed for the development of a residential unit. The 43,560 square feet must be contiguous acreage and not include any freshwater wetlands, wetlands transition areas, 100-year flood plains and/or topographic slopes fifteen (15%) percent or greater, any hydric soils, any detention or retention basin, and any land within a designated stream corridor. Additionally, the 43,560 square feet of land must be in the shape of a circle with a diameter of at least two hundred five (205) feet within its bounds. (§16-4.2d)
- Conservation Design Subdivisions are permitted as optional development alternatives within the R-5 and MR zoning districts only, with individual lots served either by public sewage treatment facilities or by individual septic systems, and with minimum sized tracts of land areas as follows:
    - Tracts of contiguous land twenty-five (25) acres in size and larger
    - Tracts of contiguous land less than twenty-five (25) acres in size, but in no case less than ten (10) acres in size, may be permitted to be developed in accordance with the optional single-family conservation design subdivision provisions of this subsection, provided that the Planning Board concludes the following based upon evidence provided by the applicant:
    - The lands to be conserved as open space are noted for preservation in the Conservation Plan Element portion of the Montgomery Township Master Plan; and/or
    - The lands to be conserved as open space are adjacent to existing lands already conserved, or expected to be conserved, as open space; and/or
    - The lands to be conserved as open space are heavily treed and/or provide a notable scenic vista; and/or
    - The resulting development pattern of the single-family homes to be constructed within the single-family conservation design subdivision will

safeguard the environmental attributes of the subject land significantly more than a conventional development. (§16-6.5g)

- An extensive drainage ordinance exists in the Township to provide for a variety of stormwater drainage and non-point pollution sources (§16-5.2o). The Township requires a non-point source pollutant loading analysis for all subdivision and site plans as we as for applicants seeking subdivision or site plan approval or approval for "d" variances pursuant to N.J.S.A. 40:55D-70d or for "c" variances for lot coverage. The applicant shall be required to address nonpoint source pollution as follows:
    - Each application must have a non-point source pollutant loading analysis. The analysis identifies the acreage of existing and proposed land uses for each drainage area. The pollutants to be analyzed are total phosphorus, total nitrogen, total suspended solids, and total petroleum hydrocarbons. Loadings per land use category are to be multiplied by the acreage of land use category for existing and proposed conditions. If increased nonpoint source pollutant loadings are associated with the proposed change in land use, Best Management Practices must be implemented so that the nonpoint source pollutant loadings are equal to or less than existing nonpoint source pollutant loadings. A minimum of eighty (80%) percent of the proposed land use total suspended solids loading shall be removed. Where a pollutant is not associated with an existing land use and the predevelopment load is zero, the proposed pollutant loading analysis of the land use shall be removed to the maximum extent practicable.
    - Nonstructural stormwater management measures are the preferred method to reduce nonpoint source pollutant loadings. The developer must protect areas that provide water quality benefits, such as riparian corridors and areas near watercourse vegetation, regulations promulgated under the Flood Hazard Area Control Area Act, and Critical Areas section of the Township code. Areas of impervious coverage are to be minimized. Where practicable, storm sewers shall discharge to vegetated swales. Stormwater management should decrease from pre-construction time to post-construction time to the extent reasonably practicable and environmentally beneficial. Landscaping with natural vegetation requiring minimal fertilization or pesticide treatment and minimization of land disturbances and new lawn areas are preferred. Adverse impacts of pollutants flows on habitat for Helonias bulbs (Swamp Pink) and/or Clemmys muhlenbergi (Bog Turtle) documented in the Natural Heritage Database as defined in N.J.A.C. 7:5C-1.4 shall be minimized or avoided.

<u>West Amwell Township</u>

West Amwell has the following ordinances addressing natural resource protection. Included is a brief summary of the newly adopted zoning in the Township.

- West Amwell Township has recently adopted Ordinance 15, 2004 amending chapter 109 of the Zoning and Land Use Regulations. This newly adopted ordinance provides for the creation of the several new residential zoning districts. In general, minimum lot sizes went from 2 and 3 acres to 4, 5, 6 and 8 acre zoning. While increasing the lot size, the new zones also offer two cluster development options to preserve open space and critical features.
- The minimum lot area standards include the following environmental constraint factors; slopes of 25% or greater, flood hazard areas, wetlands, wetland transition areas, open water (§4-A (3)(e)).
- The disturbance of sloped areas shall be limited to the following (§4-A (4)).
    - Slopes of 15 %, but less than 20 %; a maximum of 30 % of the total area in this slope category may be disturbed for development purposes
    - Slopes of 20 %, but less than 25 %; a maximum of 20 % of the total area in this slope category may be disturbed for development purposes
    - Slopes of 25 % or more; Disturbance of slopes in this category shall be prohibited, except where an applicant can demonstrate that such disturbance is essential in order to achieve access to a property or in order to establish any reasonable use of the property

Introduction to Board of Health Ordinance Comparison

The location, placement, construction and maintenance of water supply wells and septic systems play a vital role in water quality and quantity. Given the unique geologic conditions that exist in the Sourland Mountain Region, the location and construction of these systems becomes increasingly important. Systems that are not properly located, constructed or maintained can lead to significant groundwater deterioration and depleted water supply, not only for individual owners, but for well and septic systems of adjoining neighbors. This report seeks to provide an understanding of the State Regulations and municipal ordinances, how they relate in order to promote better regional planning. The following is a summary of relevant State, (elaborated in Appendix C and D) and Local regulations (Summarized in Appendix E) for Water Supply and Septic Systems.

Drinking Well and Water Quality Standards

State of New Jersey-Safe Drinking Water Act Regulations (N.J.A.C. 7:10) Summary

The State's "Safe Water Act Regulations" (NJAC 7:10), adopted in August 2000, set forth standards regulating construction and monitoring wells. The following is a brief summary of the general provisions set forth for the construction and monitoring of wells.

The regulations govern public non-community water systems or nonpublic water systems and require well drillers to possess a valid New Jersey well driller's license of the proper class or to be under the immediate on-site supervision of a person who possesses a valid New Jersey well driller's license. No well shall be installed unless a well permit from the Department of Environmental Protection has been issued.

Well pumps or well pumping equipment can only be installed by a licensed pump installer or well driller.

State regulations require that a well driller maintain sanitary conditions and proper containment of all materials and surface drainage away from the well and to prevent introduction of any material that will cause the delivered water to be toxic during installation.

The regulation also limits the lead content used in a public noncommunity water system or nonpublic water system to .2% of solder and flux, pipes, fittings, and any metallic components in contact with the drinking water (8 % maximum). The use of lead packers on potable water wells is prohibited

Water volume and pollutant requirements specify that the pumping capacity from regulated residential water supply shall be at least 2.0 gallons per minute per bedroom served for 30 minutes and water systems that supply other than residential consumers and use hydropneumatic storage. The total yield from all available water sources for a public non-community or nonpublic water system shall be at least 0.25 gallons per minute per bedroom served and other than residential consumers, the yield shall be at least 3 times the average daily demand, as seen on Table 1 in Appendix C.

Minimum distance require minimum distances of public non-community or nonpublic water systems from sanitary sewer and septic systems, fuel storage tanks and other structures are set forth in Table 2, located in Appendix C.

The administrative authority may require a greater separation distance in areas of gravel, limestone, or fractured, creviced or fissured rock formations and shall approve a reduction in the separation distance to a minimum of 50 feet, if the well is cased to a depth of 50 feet or more and is sealed into a confining layer separating the well's aquifer from the soil stratum of the disposal field.

The reference to cesspools contained in Table 2 (located in Appendix C) of this subsection is intended only to specify the minimum distance from an existing cesspool that water systems must be located. Cesspools are regulated by the Department pursuant to N.J.A.C. 7:9A, Standards for Individual Subsurface Sewage Disposal Systems.

Other regulations control the minimum distance and location requirements for distribution mains and permit a reduction in the distance from a well to a building sewer to a minimum of 15 feet if the building sewer is watertight and there are no other practicable alternatives. Additionally a well shall not be drilled within 20 feet of a wood frame building, (the Department recommends a minimum distance of 50) and a well shall be located at least 5 feet horizontally from a structure or any portion thereof, other than a pumphouse that serves the water system. The Department also can increase the minimum distance requirements for an individual well if the natural geologic conditions do not provide adequate protection of the water supply (e.g. cavernous limestone).

Municipal Board of Health Ordinances for Water Quality and Private Wells

East Amwell Water Supply Ordinance #03-03 BH

- Recognizes that water supply and well performance widely varies throughout East Amwell Township and that East Amwell's sole water source is groundwater

- The Township adopts the State N.J.A.C. 7:10-1 for water quality and safe drinking water with the following additions:

  - Well permits must be approved and well testing and certification is required in order to locate, construct or alter any well in the Township.

  - Well performance requirements consist of the following tests:
    - Residential drilling discharge test
    - Residential three part pump test
    - Or non residential three part aquifer test

  - Residential and/or non-residential three-part pump tests requiring interference testing with neighboring wells

  - Residential three-part pump well test can be waived if the applicant obtains test waivers from all owners of adjacent wells eligible for interference observation. Actual yield would then be determined by the Drilling Discharge test. Three-part pump test cannot be waived in the Sourland Mountain District or for non-residential wells in any district.

  - Existing residential water wells require re-certification to support alterations to wells that will increase demand by 20% or more over its certified capacity, or, if not certified, over 20% increase over its present use.

  - All major subdivisions require a hydrogeological report to be submitted prior to granting approval

  - Certified wells for each lot in a subdivision are required in Sourland Mountain District before approval for the lot is given. Each well must be available for observation.

  - For subdivisions in all other zones, certified wells are required prior to issuance of construction permits on each lot in that subdivision.

  - Non-residential development with a total project water use of 2,000 gallons per day or more in the Sourland Mountain and Stony Brook Districts and 4,000 gallons per day or more in all other areas require a hydrogeological analysis prior to approval.

- Non-residential developments with a total project water use under the 2,000 and 4,000 gallons per day as described above require a constant rate and recovery test to be conducted

- Agricultural wells must be certified according to the non-residential three-part aquifer test and the landowner or applicant must include the total number of acres owned or operated, the acreage planted in each crop, and the number of acres of each crop under irrigation. Also should include a letter of the type of irrigation and water use practices employed. For animal demands, see table in ordinance.

- Hydrogeological reports for either residential or non-residential should include all the elements set forth in the ordinance including following the requirements for number of test and observation wells according to number of lots in subdivision or non-residential uses per district.

- Blasting for development of any well is prohibited.

- Hydrofracturing for development of any well within 250' from an existing well is prohibited

Hillsborough Township Water Supply Ordinance Chapter 350

- Hillsborough Township adopts the State's Well Standards identified in N.J.A.C. 7:10-12.1.

- Information about each well shall be certified by the applicant's well driller, hydrogeologist, or engineer and furnished to the administrative authority

- A permit is required to locate, construct or alter any water well within Hillsborough Township

- All well applications must include the locations and technical specifications for all new wells, the location of all pre-existing wells and the location of all existing wastewater and other subsurface disposal areas

- Twenty-four-hour notification to administrative authority prior to drilling or pump tests

- All new wells must be pump tested

- For subdivisions in all zones, approved wells shall be required prior to issuance of construction permits on each lot proposed in that subdivision

- For nonresidential and multiple residence development proposals, a hydrogeological analysis may be required prior to granting of approval as to the suitability for subdivision by the administrative authority.

- The well casing must extend to a minimum of 20 feet into unweathered bedrock; however, the total length of the casing in all other cases is 60 feet and 80 feet in areas affected by any contamination.

- Artificial fracturing for construction, repair or development of any well is prohibited

- The capability of a well to meet the peak demand and the total daily demand of its user shall be evaluated through a three-part pump test.

- No constant head test or well recovery test is required when the peak demand test is passed

- A well may be excluded from the recovery portion of the three-part pump test if less than 1/2 of the water necessary to satisfy the peak demand test at the calculated peak demand rate and peak demand time is drawn from storage

- An interference test which is restricted to the MZ-Zone, or any zone in which the well driller's report indicates the presence of diabase or argillite rock formations, is an evaluation of the influence a new well will have on existing well(s) so as to determine if that influence would be sufficiently large as to interfere with operation of existing wells

<u>Hopewell Township Water Supply Ordinance</u>

- Hopewell Township adopts the State's Well Standards identified in N.J.A.C. 7:10-12.1

Ordinance BH 2003-1

The purpose of this ordinance is to protect and educate buyers, sellers or occupants of properties in the Township whenever there is a transfer of property, change in use or change in tenancy.

No transfer or change in use or tenancy of a property that utilizes an onsite public or private well system for potable water supply can be conducted until the administrative authority issues a Letter of Review stating that the water system complies or does not comply with water quality standards specific to NJDEP regulations. In the event of non-compliance all involved parties shall be notified.

Ordinance No. 03-1298

The purpose and intent of this Section is to ensure that residential development of two new lots or more and all site plan applications demonstrate that adequate water supply is available without adverse affect on neighboring wells and other resources including but not limited to wetlands and streams

- The provisions of this ordinance are applicable to all residential subdivision applications of two new lots or more and all site plan applications

- Based on the limited groundwater resources within Hopewell Township as outlined in M^2 Associates March 2, 2001 report entitled "Evaluation of Groundwater Resources of Hopewell Township, Mercer County, New Jersey", no wells shall be permitted to be connected to a permanent irrigation system except if that system is used entirely for commercial agricultural purposes. In addition, no wells can be used for the filling of swimming pools

- The testing procedures for a subdivision of two or more new lots and all site plans shall be based on a hydrogeologic analysis and a minimum of one aquifer test

- The aquifer test shall consist of at least one constant-rate pumping test conducted at a sufficient rate and duration to be able to determine aquifer characteristics such as transmissivity and storage coefficient. As part of the aquifer test, observation wells are to be monitored to determine and evaluate the cone of depression and aquifer parameters, and predict the effect of long term pumping on existing and future wells

    - The rate and duration of the aquifer test will depend upon the size of the proposed development and expected average and peak daily demands for water

    - The aquifer test shall be conducted at a location most representative of site geologic conditions

    - The number of observation wells required per aquifer test will depend on the number of dwelling units and/or commercial units

    - The observation wells and pumping well must have a geologic log describing the depth and types of soils and rocks encountered and the depth and yields of all water-bearing fracture zones. Furthermore, the logs must include static water-level measurements and total yield estimates for each well

Ordinance No. 03-1299

The purpose of this section is to assure that adequate water supply is available without adverse effect on others and to maintain the long-term natural equilibrium of the ground and surface waters of Hopewell Township

- The provisions of this ordinance are applicable to all new, altered and replacement supply wells, wells on existing lots, and wells installed or to be partially or totally used for non-essential use

- No person shall locate, construct, repair, deepen, abandon, decommission or alter any well, or utilize an existing well for any non-essential use, without first receiving a well permit from the Board of Health

- No construction permit for a new home or other structure shall be issued unless the well intended to serve the home(s) or structure(s) has been drilled, tested and certified by the applicant's engineer or well driller as complying with State standards for the construction of public non-community and nonpublic water systems.

- No well pumps shall be replaced without first securing a well pump replacement permit

- Reports on the repair, replacement or abandonment of all wells and well pumps shall be submitted no later than thirty (30) days upon completion of permitted activity

- Hydrofracturing of the geologic formation to increase yields prior to aquifer testing is prohibited

- No wells shall be located within 100 feet of any other existing or proposed well or within 10 feet of an existing or proposed lot line

- A three-part aquifer test will be conducted with the first part evaluating the peak demand, the second part determining the constant head yield and the third part determining the rate of recovery

- The number of observation wells required per aquifer test will depend on the maximum daily demand. Observation wells must be located in such a manner that will yield the most accurate information concerning the aquifer
    - Observation wells must be located parallel and perpendicular to strike of the primary regional fractures and those intersected by the tested well

<u>Montgomery Township Water Systems Ordinance BH: 4-1</u>

- Montgomery Township adopts the State's Well Standards identified in N.J.A.C. 7:10-12.1.

- Testing requirements are set forth for new wells or single family dwellings or cottages that
    - Are located in a geological region designated in the Montgomery Township Natural Resources Inventory (1984) Geology and Groundwater Map as "Lockatong Argillite" or "Diabase" or
    - Are located in a geological region designated in the Montgomery Township Natural Resources Inventory (1984) Geology and Groundwater "Stockton Sandstone" or "Brunswick Shale" and have a yield less than 5 gallons per minute or in an area where it has been demonstrated by performance in existing wells in the vicinity.

- Testing will take place in two parts, a "peak demand test" and a "constant head test" and notification of test is to be given 72 hours prior to the test to the Administrative Authority.

- If the well tests prove unsatisfactory, the well should be either deepened or developed as to produce a larger aquifer contribution. If these steps still do not meet acceptable standards, then the well should either be modified to meet the needs or abandoned.

- All new wells for single-family dwellings in either the Lockatong Argillite or Diabase Regions must be approved before any approval of permits relating to the construction of individual or community subsurface sewage disposal systems.

- No blasting is allowed in the construction of wells.

<u>West Amwell Township Board of Health Ordinance BOH 96-01 for Water Supply Systems</u>

- West Amwell Township adopts the State's Well Standards identified in N.J.A.C. 7:10-12.1.

- All wells installed for domestic use are to be constructed in conjunction with the State's Standards (N.J.A.C. 7:10-12.1).

- Initial well tests must be performed by a New Jersey licensed well driller to drill and test any well for domestic use. The initial test should determine the yield of the well, which must produce 5 gallons per minute or more for a single-family home. If the yield proves less than 5 gallons per minutes than a constant rate drawdown test is to be performed and a study of surrounding wells in the vicinity is to be conducted to determine if the well is adequate for use.

- Adequate water supply is to be determined as follows:
    - Residential dwellings yields should be .25 gpm per bedroom and usable storage should be 80 gallons per bedroom
    - Non-residential water supply daily pumping capacity must be equal to the total planned wastewater discharge of the facility as determined during the design of the onsite wastewater disposal system.

- Water supply for “major” developments must prove that water supplies are adequate to meet the demands of the project without adversely impacting existing wells.
    - For multiple residence developments hydrogeological analysis and report must be required prior to granting approval for the subdivision
    - Where a single well is to be used to supply the entire development, the pump test is to be conducted to meet New Jersey Department of Environmental Protection’s GSR-29.
    - In either case the applicant must show all wells within 500 feet of the proposed well and all potentially affected owners must be notified that the well test will be performed and whom they should contact if their well is adversely affected.

Sewage Disposal Systems Standards

State of New Jersey – Standards for Individual Subsurface Sewage Disposal Systems (N.J.A.C. 7:9A) Summary

The New Jersey Standards for Individual Subsurface Sewage Disposal Systems (N.J.A.C. 7:9A), adopted in August 1999 (see Appendix D for full version), governs the installation and repair of individual subsurface sewage disposal systems, and limit the use of a subsurface sewage disposal to no more than one property unless a treatment works approval or a New Jersey pollutant Discharge Elimination System (NJPDES) permit has been issued by the Department.

The regulation prohibits the discharge of an effluent onto the surface of the ground or into any watercourse, and prohibits the construction or alteration of individual subsurface sewage disposal systems or other means of private sewage disposal where a sanitary sewer line is available within 100 feet of the property to be served.

The discharge of sanitary sewage into any well is prohibited, and the construction or installation of cesspools is prohibited. State standards also regulate the use of seepage pits except, as provided by N.J.A.C. 7:9A-7.6, and prohibit discharge of industrial wastes into an individual subsurface sewage disposal system unless authorized by a treatment works approval or a NJPDES permit, as well as prohibit the discharge of industrial wastes into any individual subsurface sewage disposal system.

Standards for site evaluation and system location require an evaluation of all site characteristics that may affect the functioning of the system, including minimum required separation distances as prescribed in N.J.A.C. 7:9A-4.3, slope, surface drainage and flood potential. A site plan is also required as part of each application as outlined in N.J.A.C. 7:9A-3.5(c)2.

Individual subsurface disposal systems shall be located and installed so that they will function in a satisfactory manner and will not create a nuisance or source of foulness, pose a threat to public health or safety or the environment, or otherwise adversely affect the quality of surface water or groundwater.

Location for individual subsurface sewage disposal systems shall avoid:

1. Bedrock outcrops or areas with excessive stones;
2. Sink-holes;
3. Steep slopes showing signs of unstable soil such as landslide scars, slump blocks, fence posts or lower trunks of trees bending downslope;
4. Bare eroded ground, denuded of vegetation, or with deep wheel ruts;
5. Highly disturbed ground indicated by such features as remnants of foundations or pavements, buried building debris or buried plant remains;
6. Sand dunes;
7. Mine spoils, borrow pits, dumps or landfills;

8. Low-lying coastal areas exhibiting signs of tidal inundation or tidal marsh vegetation
9. Low-lying inland areas showing signs of ponding or freshwater wetland vegetation and
10. Flat low-lying areas adjoining streams.

unless the design adequately addresses the special limitations associated with these features and complies with all applicable local, State and Federal laws, regulations and ordinances.

Municipal Board of Health Ordinances for Water Quality and Private Wells

East Amwell Board of Health Regulations Code of East Amwell Chapter 171: Sewage Disposal Systems, Individual

East Amwell adopted regulations in 1995 more stringent than NJAC 7:9A, and subsequently amended these regulations in November 2003.

- Requirement for conformance with currently valid state and local standards and regulations

- Engineer certification of various requirements

- Septic system to be constructed, installed and operating prior to issuance of certificate of occupancy by the building inspector; permit to construct septic system required prior to issuance of other building permits

- Test witnessing to be scheduled by the municipality's agent

- Well to be installed, tested and certified as per well ordinance prior to issuance of the permit for construction of the septic system

- Expiration of permit after 3 years; can be renewed for 2 years after that with approval by Board of Health

- Requirement for reserve expansion/replacement area that is equivalent to 100% of the approved disposal area for lots based on soils (only one lot in township has ever not had soils that required a reserve area); requirements for how reserve area is to be delineated and protected for future use

- Minimum separation distances are increased for: distance allowed between disposal field and property line (25 feet instead of 10 feet); Sourland Mountain: : minimum separation distance allowed for septic tank and septic field from a water course, well, reservoir, or water line, is 200 feet; Other districts: minimum separation distance of a septic field from a water course, well, reservoir or water line is 100 feet, up to 200 feet, at discretion of Board based on site limitations)

- Distance of disposal field from detention/retention or infiltration basin must be 100 feet and no closer than 50 feet to other recharge structure such as dry well; distance from flood hazard area must be a minimum of 50 feet (waiver provision for site limitations); no part of septic system can be located in transition area for freshwater wetlands;

- Slope of a mound not to exceed 1:5 (instead of 1:3)

- When basin flood test are used, a minimum of 3 profile pits are required for primary and reserve areas; when pit bail test are used, a minimum of 4 profile pits are required for primary and reserve areas; permeability tests of the horizon that will be the zone of disposal is required for the design of the septic system

- All soil test results and locations, passing and failing, must be shown on plat;

- Minimum of 2 1000-gallon septic tanks or at least 1 1500-gallon septic tank is required

- Clean-out ports required along the connecting pipe of the system; observation port required for the field; system components required to be visibly marked permanently

- Bed sizing cannot be reduced for pressure dosing systems (the State allows a reduction in size)

- Specifications for quality of fill material included

- No garbage disposals allowed

- No swimming pool backwash water allowed

- Lot grading plan to be submitted to Board of Health when it is required by other Township entities

- As-builts are required to be filed with the Board of Health upon completion

As per NJSA 26:3-31a and 58:11-23 et seq., the Board of Health must act in a responsible fashion to protect the water quality of its ground and surface waters for the benefit of present and future generations, the East Amwell Board of Health has adopted additional sewage regulations.

Portable Sanitation Unit/Portable Chemical Toilet Ordinance (03-01 BH—amended October 2004):

- Requires supplemental port-a-potties for all activities that generate human waste in excess of the design flow of the septic system (i.e. fairgrounds) or on a site where septic system is not available (i.e. seasonal farm stand)

- Requires a permit for use of port-a-potties for events that last longer than 5 days

- Does not apply to construction sites (governed by the construction official)

- Provides maintenance, placement, management specifications (i.e. number to be used per capita; pump out and disposal procedures by licensed provider; minimum separation distance of unit from waterway is 200 feet, from commercial food service, 100 feet, etc.)

- Use of a unit on the grounds of a permanent facility permitted only on a temporary basis to supplement existing sewage facilities that process the normal flow of sewage of the facility; otherwise, the use is considered a holding tank and subject to State and municipal holding tank regulations

Code of East Amwell Chapter 159: Holding Tanks

NJAC 7:9A strictly regulates the use of holding tanks for sewage management—a holding tank can only be used in certain circumstances and must be approved by both NJDEP and the municipal Board of Health. The Board of Health has a local ordinance that has additional requirements.

- Permission to use a holding tank can only be granted for existing premises where a sewage disposal system has failed and the Board is satisfied that the failure cannot be rectified

- Permission to use a holding tank can only be granted when the conditions above are satisfied and where soil tests and an engineer's report indicate that the septic system cannot function according to current design requirements and where no other method of sewage disposal is available

- Permission to use a holding tank can only be granted when the conditions above are satisfied and where use of a holding tank will not pose danger to the health and welfare of the residents of the Township

- Construction, maintenance, location, and circumstances of use are specified (i.e. sizing, alarm systems, monitoring and metering requirements, pumping contract requirements, continuing use permitting, etc.)

- Requires reporting of pumping on a specific form within 5 days of each pump event to the Board of Health

Hillsborough Township Individual Sewage Systems – Chapter 333

- Percolation test results, soil logs and determination of seasonally high water table made prior to January 1, 1990, may be used as a basis for design and location of an individual subsurface sewage disposal system for two years following January 1, 1990, following the submission to and approval by the administrative authority of a detailed and comprehensive by-lot analysis certified by a professional engineer of previously obtained validated site test data's applicability to compliance with system design requirements set forth in this chapter

- When fill material is utilized within the zone of treatment, the fill material shall meet the following requirements
  - Coarse fragment content less than 15% by volume or less than 25% by weight
  - Textural analysis (composition, by weight, of size fraction passing the two-millimeter sieve): from 85% to 95% fine to coarse sand, from 5% to 15% silt plus clay, minimum 2% clay, and
  - Permeability from two to 20 inches per hour; or percolation rate from three to 30 minutes per inch

- When the fill material is placed within the zone of disposal, the fill material shall meet the following requirements
  - Textural analysis (composition, by weight, of size fraction passing the two-millimeter sieve): 85% or more fine to coarse sand; and
  - Permeability greater than two inches per hour; or percolation rate faster than 30 minutes per inch

- All disposal field construction must be completed and backfilled within seven days of the initiation of the excavation of the disposal field area

- All new septic system construction permitted within Hillsborough Township's Mountain Zone (MZ) must be completed and approved by the administrative authority before a building permit is issued

Hopewell Township Individual Subsurface Disposal Systems

Ordinance BH 2003-1

The purpose of this ordinance is to protect and educate buyers, sellers or occupants of properties in the Township whenever there is a transfer of property, change in use or change in tenancy.

No transfer or change in use or tenancy of a property that utilizes an onsite septic system can occur until a report by an independent inspection company is conducted. If the inspection reveals an inadequate system a plan must be submitted to the Board of Health itemizing how the system will be brought up to compliance.

Ordinance # 2000-1

Hopewell acknowledges that onsite sewage disposal systems may constitute a potential source of pollution of ground and surface waters, resulting in contamination of potable water supplies, foul odors, nuisance problems and other hazards to public health and provides requirements for soil testing, specifying lot area, restricting system locations and providing additional design and installation requirements for onsite sewage disposal systems in Hopewell Township. These include:

- The Board of Health may only approve an individual subsurface disposal system design using an aerobic or aeration type waste treatment system as permitted in N.J.A.C. 7:9A, and only when the owner at all times keeps in force an annual service and inspection contract with an individual or company licensed by the board of health.

- The board of health allows holding tanks for use only in accordance with N.J.A.C. 7:9a-3.4c and 3.12 and only when other possible methods of disposal and are not acceptable. Holding tank systems designed to accommodate flows greater than 2,000 gallons per day must be reviewed and approved by NJDEP.

- In addition to meeting the requirements for minimum lot size set forth in the Land Use and Development Ordinance. The lot area required for onsite sewage disposal systems and water supply wells shall meet certain contiguous net square footage or acreage requirements located outside of any watercourses, wetlands, wetlands buffers, State open waters, areas of steep slopes, or any areas restricted against development by State, Federal or local approvals.

- Each lot to be approved for subdivision, site plan, or dwelling construction have two acceptable adjoining areas within 50 feet of each other for the construction of a primary and reserve area for onsite sewage systems. Primary and reserve soil tests and profile pits are required in both areas. All soil testing must be witnessed by a representative of the board of health.
    - Each proposed lot shall have a minimum of two acceptable soil profile pits, and series of soil permeability tests or basin flood tests performed in the proposed primary disposal area.

Ordinance BH 2004-1

- Waivers for Reduction of lot area for pre-existing lots
    - Approval of onsite disposal systems on existing lots with less than the minimum net lot area, will only be considered by the Board if the waiver being requested is for not less than 80% of the net area requirements from table One. The applicant must seek approval of the Zoning Board of Adjustment, only after receiving conditional approval for the design from the Board of Health. The Board of Health will review the design to assure it meets all other Township & NJDEP site and technical design conditions.
    - In areas within or close to an area of known microbiological or chemical contamination of ground water, the Board of Health may require an alternative water supply or public water if an onsite safe water supply can not be assured.

Montgomery Township Individual Subsurface Disposal Systems - BH: 6-1

Montgomery Township adopts the N.J.A.C. 7:9A and expands on the following:

- Must conform with all State, County and Local requirements for standards and regulations
- Engineer must be certified by the State
- Applicant must file all necessary site and plan design and include all relevant information outlined in the Township's checklist.
- All necessary permits have been secure prior to any testing or construction, which includes approval of both the primary and reserve septic
- Soil evaluation must be conducted and witnessed by an individual with experience in the matter.
- All site tests must be conducted within 12 months of the systems construction. If testing was completed prior to 12 months, approval to continue must be granted or a demonstration that no significant changes have occurred in the Code with respect to testing procedures or data in question.
- Sites where mounded disposal field or mounded soil replacement disposal must be utilized, the engineer must provide the Board with a design that utilizes the lowest profile and the best possible system in order to secure the public's health, safety and welfare.
- Percolation and tube tests must be performed according to State regulations
- Disposal systems must be located in areas free of encroachments by man-made and natural obstacles that could potential clog any part of the system.
- Textural Analysis is to be completed. The fill must be 85 to 95 percent sand, from 5 to 15 percent silt plus clay, a minimum of 2 % clay and no more than 25 % total of fine and very fine sand.
    - A composite sample from each truckload of suitable fill material delivered to and stockpiled at the installation site must be tested.

Closed Sewage Systems (BH: 6-2)

- Closed Sewage Systems are only allowable with special permission from the Board of Health.

- Permission to be granted only in cases where soil tests indicate septic system will not function properly within the State regulations and where no other method of handling sewage is available at the time of application.

- The applicant must show the following condition in order to gain approval:
  - The system will be used as a temporary means of sewage disposal where an adopted Sanitary Sewer Bond Ordinance for the lot in question and bids have been received and an award made to a successful bidder
  - Where prior existing methods of sewage disposal have failed and where the Board has certified that the failure cannot be rectified.

- Storage tank must meet size and holding requirements and monitored by owner and be accessible to officials for monitoring.

- Owner must sign a receipt statement acknowledging the cost and maintenance of the system and that the tank will be emptied regularly.

Non-individual Subsurface Sewage Disposal Systems (BH:6-3)

- Defined as any system servicing more than one property, dwelling, commercial unit or other realty improvement.

- Applicant must demonstrate that the regulations for individual disposal systems are impossible or impractical by reasons such as:
  - Soil and site limitations
  - Construction
  - Design
  - Location of each property
  - Dwelling
  - Commercial unit

- The legal owner of the site will be responsible for maintenance and operation of the system

- The system must meet a variety of regulations and take into account a variety of site conditions and conditions surrounding the area.

- The design of the system must take into account guidelines as outlined in various technical documents identified in the ordinance.

- No portion of the disposal field is to be located within 150 feet of the boundary line, a 50 foot buffer along the lot is to be landscaped, and cannot be located within 100 feet from another disposal field.

- At least four groundwater monitoring wells are to be provided.

West Amwell BOH Ordinance 01, 2003 – Sewage Disposal Systems

The West Amwell Township adopts the NJAC 7:9A "Standards for Individual Subsurface Sewage Disposal Systems", with the following additions:

- A textural analysis is to be completed and must contain 85 to 95 percent sand (fine and very fine sand to 25% or less by weight) from 5 to 15 percent silt plus clay, minimum 2 % clay.

- All permits must be obtained for location, construction, alteration or repairs of sewage disposal systems.

- Engineer must be State certified

- Soil logs and permeability tests must be performed and certified reports submitted.

Appendix A: SCHEDULE OF ZONING REQUIREMENTS

Township	Zone (% of total land in Sourland Mountain study area)	Primary Principal Use	Minimum Lot Area	Minimum Depth (feet)	Minimum Lot Width (feet)	Front Yard (feet)	Rear Yard (feet)	Side Yard (feet)	Height (feet)	Maximum lot Coverage (percent)	Floor Area Ratio
EAST AMWELL	SM (12%)	Single-Family Residential Farm	15 Acres 30 Acres	500 500	500 500	100 100	100 100	100 100	60 35	Sliding scale of 1, 3, and 5	
	AVAD (5.7%)	Single-Family Residential Farm	10 Acres 5 Acres	400 400	400 400	150 150	75 100	75 100	35 60	8	
	LB (.01%)	Local Business	12,000	50	75	30	25	10	35	50	.12
	HO (.05%)	Highway Office	2 Acres	250	250	100	100	75	20	25	
HILLSBOROUGH	AG (1.3%)	Farm Single Family Residential Single-Family Res. Lot Averaging	5 Acres 10 Acres 2 Acres	300 400 250	300 400 150	NA 150 75	NA 75 50	NA 75 50	60 35 35		
	MZ (12.2%)	Farm Single Family Residential	15 Acres 15 Acres	300 250	300 250	NA 150	NA 50	NA 50	60 35		
HOPEWELL	MRC (21%)	One-family dwellings Conventional lot Clustered lot or lot average lot	14 acres 80,000 sf	500 ft 200 ft	400 200	150 75	75 50	75 50	35 35	6 15	
	VRC (11%)	One-family dwellings Conventional lot Clustered lot or lot average lot	6 Acre 8,000 ft.	400 200	300 200	100 75	60 50	60 50	35 35	10 15	
	C-1 (.05%)	Neighborhood Retail Commercial	80,000	250	250	100	70	50	30	65	.20
	R-100 (.2%)	Single Family Residential	2 Acres	300	275	100	50	50	35	65	.20
	SCI (.06%)	Shopping Centers	5 Acres	300	300	100	75	75	35	60	.20

Appendix A: SCHEDULE OF ZONING REQUIREMENTS

Township	Zone (% of total Sourland Mountain Region)	Primary Principal Use	Minimum Lot Area	Minimum Depth (feet)	Minimum Lot Width (feet)	Front Yard (feet)	Rear Yard (feet)	Side Yard (feet)	Height (feet)	Maximum lot Coverage (percent)	Floor Area Ratio
MONTGOMERY	MR (3.4%)	Residential	10	750	350	100	100	100	35	10	N/A
	R-5 (2.8%)	Single-Family Residential	5	500	300	75	100	75	35	15	N/A
	LM (.5%)	Limited Manufacturing									
		Individual Lots	5	400	400	125	60	60	45	32.5-42.5	.08-.175+
		Lots w/in Develop. Park	2	250	250	75	40	40			.016-.035
	PPE (1.8%)	Public, Parks and Education									
		Schools	5	600	300	100	100	100	35	20	N/A
		Single-Family Detached	10	750	350	100	100	100	35	10	
	MR/SI (.5%)	Mt. Residential/Special Industrial									
		Residential	10	750	350	100	100	100	35	10	N/A
		Processing Activities	50	750	750	300	200	250	45/75	25	

Appendix A: SCHEDULE OF ZONING REQUIREMENTS

Township	Zone (% of total Sourland Mountain Region)	Primary Principal Use	Minimum Lot Area	Minimum Depth (feet)	Minimum Lot Width (feet)	Front Yard (feet)	Rear Yard (feet)	Side Yard (feet)	Height (feet)	Maximum lot Coverage (percent)	Floor Area Ratio
WEST AMWELL	SRPD (7.3%)	Single-Family Residential Cluster	8 Acres AVG 2 Acres			150 60	150 60	60 25	35	10 15	
	RR-6 (7.5%)	Rural Residential Southern District Cluster	6 Acres AVG 1.25 Acres			150 60	150 60	60 25	35	12 15	
	RR-5 (5.2%)	Rural Residential Central District Cluster	5 Acres AVG 1.25 Acres			100 50	100 50	50 20	35	15 20	
	RR-4 (1.3%)	Rural Residential Northern District Cluster	4 Acres AVG 1.25 Acres			100 50	100 50	50 20	35	15 20	
	R-9 (.07%)	Highway Density Residential Septic Sewer	31,250 sq. ft. 9,375 sq. ft.			25 25	50 25	25 10	35 35	20 35	
	R1-A (.5%)	Historic Residential Septic Sewer	40,000 20,000	175 160	170 135	50 40	50 40	25 10	35 35		
	LI (.5%)	Light Industrial	5 Acres			100	100	25	35	50	.15
	NC (.1%)	Neighborhood Commercial	1 Acre			25	25	15	35	60	.20
	LHC (.3%)	Limited Highway Commercial	1.5 Acres			75	75	20	35	50	.15
	HC (.5%)	Highway Commercial Zone	2 Acres			100	100	30	35	50	.15

Appendix B: Critical Environmental Ordinance Chart

Name	Lot Suitability	Woodland Protection	Steep Slopes	Stream Corridor/Buffers	Groundwater Protection	Threatened And Endangered Species
East Amwell	At least 22,000 square feet free of environmental constraints	Clearing max. 30,000 s.f. and located within 500' of the public road, tree conservation buffer 100' wide adjacent to any road (Sourland Mountain District only)	12%+classified as Steep slope; preservation to be noted on development design	Stream corridor preservation to be noted on development design	Major Development review requires groundwater depth analysis; dry wells, swales, rain gardens to increase infiltration	Developer to note threatened and endangered species in EIS and habitat areas to be avoided in development
Hillsborough	At least 22,000 square feet free of environmental constraints	Woodland protection in reference to water quality	>12%classified as critical areas	Residential zones restrictions on activity in stream corridors. Corridors to remain in natural state.	Review and approvals dependent on groundwater recharge and drainage plans	Developer to note threatened and endangered species in EIS
Hopewell	Critical Environmental Features deduction	200' roadside buffer in forest areas; Beech grove climax vegetation to be protected	18%+classified as critical areas	50' from each bank, 100' buffer of septics from streams, also includes wetlands and steep slope areas	Grading and drainage plans must be submitted in application process	
Montgomery	At least 1 acre of contiguous unconstrained area+ 205'circle of unconstrained area	No more than 50% of lot or 40,000 sq. ft. of trees cleared or removed on residential lots in the MR and R-5 zones	15%+classified as critical areas and development to occur outside of steep slope areas	100-year flood hazard and steep slopes classified as critical areas with 100' buffer limit disturbance.	Best Management Practices to prevent non-point source pollution, allow drainage and maximum groundwater recharge	EIS to identify habitats of endangered species
West Amwell		Woodlands along stream corridors are a critical environmental resource highlighted in development review process	25%+classified as critical areas and development to occur outside of steep slope areas with no intrusion on vegetation on steep slopes	50' buffer on both sides of stream where critical areas do not exist. Sufficient vegetation should be present to trap silt.	Maintain stream channel, quality of surface runoff	

Appendix C:

State of New Jersey - Safe Drinking Water Act Regulations (N.J.A.C. 7:10)

The State's "Safe Water Act Regulations" (NJAC 7:10) was adopted in August 2000 and set forth standards for regulating and monitoring wells. The following is a brief summary of the general provisions set forth for the construction and monitoring of wells.

7:10-12.4 General provisions and prohibitions

(a) No person shall construct, alter, or replace a public non-community water system or nonpublic water system except in accordance with the standards set forth in this subchapter and any regulations adopted pursuant to the State Act and with the approval of the administrative authority as required pursuant to this subchapter.

(b) When two or more adjacent water systems are owned by the same person and, in combination, serve 15 or more realty improvements, the water systems shall be constructed in accordance with the rules and standards applicable to public community water systems at N.J.A.C. 7:10-11.

(c) A person seeking to build a realty improvement or seeking to alter or replace an existing water system shall determine whether to construct a public non-community water system or a nonpublic water system based on the following considerations:

1. If an adequate public community water system is available if such public community water systems water lines are within 200 feet of the property line of the realty improvement or the existing water system, if connection can legally be made thereto, and if such connection is practical, then the realty improvement or the existing water system shall be supplied with water from that source except as provided in i. below. Such connection shall be considered practical unless the connection to the public community water system involves major construction such as the crossing of a highway, stream or body of water, or major utility easement; and/or distance from the water line or any other field condition renders such connection cost-prohibitive.

    i. An existing well in an existing system may be replaced in lieu of such connection to a public community water system with the approval of the administrative authority.

2. The feasibility of establishing a new public community water system;
3. The dependability of the source of water supply;
4. Geology;
5. Major or minor pollutant sources as defined at N.J.A.C. 7:10-11.4(a)4 & 5; and 97
6. The components necessary to construct a balanced system of supply, pumping, treatment, distribution and finished water storage facilities to meet the peak demand.

(d) A person shall not drill, construct, install, repair, replace, modify, stimulate or decommission any well or engage in such business unless such person possesses a valid New Jersey well driller's license of the proper class or unless such drilling is performed under the immediate on-site supervision of a person who possesses a valid New Jersey well driller's license of the proper class issued by the Department pursuant to N.J.S.A. 58:4A-4.1 et seq.
(e) A person shall not undertake or arrange for any well drilling activity that is not under the immediate on-site supervision of a person who possesses a valid New Jersey well driller's license of the proper class issued by the Department pursuant to N.J.S.A. 58:4A-4.1 et seq.
(f) A person shall not drill, construct, install or replace a well unless such person has obtained a well permit from the Department pursuant to N.J.S.A. 58:4A-4.1 et seq.
(g) A person shall not install, repair or replace a well pump or well pumping equipment or engage in such business unless such person possesses a valid New Jersey pump installer's license or a valid New Jersey well driller's license of the proper class.
(h) A person shall not undertake any operation involving the drilling, coring, boring, driving, jetting, digging or other construction or repair of any well unless such operation is performed under the immediate on-site supervision of a person who possesses a valid New Jersey well driller's license of the proper class. The name of the well drilling company shall be prominently displayed on the equipment used by such person.

1. Wells, pumps, and related appurtenances serving a single dwelling or other nonpublic water systems may be configured by a master or journeyman well driller.

(i) A well driller shall not perform any well drilling operation without maintaining the area surrounding the operation in a sanitary condition and providing proper containment of all materials and surface drainage away from the well.
(j) No material that will cause the delivered water to be toxic shall be used in the installation of a well.
(k) Any component and/or construction material containing lead alloys used in a public noncommunity water system or nonpublic water system shall meet the following:

1. The lead content of solder and flux shall not exceed 0.2 %.
2. The lead content of pipes, fittings, and any metallic components in contact with the drinking water shall not exceed 8 %.
3. The use of lead packers on potable water wells is prohibited

7:10-12.6 Water volume requirements

(a) The pumping capacity from all available water sources for a public non-community or nonpublic water system shall meet the following minimum requirements:

1. For water systems that supply residential consumers, the system shall deliver a minimum of 2.0 gallons per minute per bedroom served for 30 minutes.
2. For water systems that supply all persons other than residential consumers and use hydropneumatic storage, the pumping capacity shall be 10 times the average daily demand as determined using Table 1 below. If gravity storage is used, the minimum pumping capacity may be lowered, but not to less than the minimum required yield as set forth in (b) below.

(b) The total yield from all available water sources for a public non-community or nonpublic water system shall meet the following minimum requirements:

> 1. For water systems that supply residential realty improvements, the yield shall be at least 0.25 gallons per minute per bedroom served.
> 2. For water systems that supply all persons other than residential consumers, the yield shall be at least 3 times the average daily demand as determined using Table 1 below.

Table 1: Average Daily Water Demand

Type of Establishment	*Gallons per Person*
1. Cottage	100
2. Single family dwelling	100
3. Multiple family dwelling (apartment)	75
4. Rooming house	50
5. Boarding house**	75
a. *For each nonresident boarder*	15
6. Hotel**	50-75
7. Motel or tourist cabin	50-75
8. Mobile home park	100
9. Restaurant	
a. *Sanitary demand, per patron*	5
b. *Kitchen demand, per patron*	5
c. *Kitchen and sanitary demand*	10
10. Camp*	
a. *Barracks type*	50
b. *Cottage type*	40
c. *Day camp (no meals served)*	15
11. Day school	
a. *No cafeteria or showers*	10
b. *With cafeteria and no showers*	15
c. *With cafeteria and showers*	20
d. *With cafeteria, showers and laboratories*	25
12. Boarding school**	100
13. Health care institution other than hospital	75-125
14. Hospital (depending on type)	150-250
15. Industrial facility (8 hour shift)	25
16. Picnic grounds or comfort station	
a. *With toilet only*	10
b. *With toilet and showers*	15
17. Swimming pool or bathhouse	10
18. Club house**	
a. *For each resident member*	60
b. *For each nonresident member*	25
19. Nursing home	150
20. Campground	
a. *Without individual sewer hook-up*	75 per site
b. *With individual sewer hook-up*	100 per site
c. *With laundry facility, individual sewer hook-up*	150 per site
21. Store, office building	0.125 gal/sq. ft
22. Self-service laundry	50 gal/wash

* When the establishment will serve more than one use, the multiple use shall be considered in determining water demand.

** Includes kitchen demand at 10 gallons per person per day. If laundry demand is anticipated, the estimated water demand shall be increased by 50 per cent.

7:10-12.12 Minimum distance requirements

(a) The minimum distances at which certain components of a public non-community or nonpublic water system shall be located away from sanitary sewer and septic systems, fuel storage tanks and other structures are set forth in Table 2, below.

Table 2: Minimum Distance in Feet

Component	Building sewer	Septic tank	Distribution box	Disposal field	Seepage pit	Dry well	Cesspool	Fuel storage tank
Well	25	50	50	100	150/100 *	50	150	25
Suction line	25	50	50	100	100	50	150	-
Water service line	5	10	10	10	10	-	25	-

*The 150 foot minimum distance between a well and a seepage pit system shall apply only when a new well is being installed in conjunction with a new seepage pit system pursuant to N.J.A.C. 7:9A-4.3.

1. An administrative authority may require a greater distance than that listed in Table 2 between a well and a sewage system component where gravel, limestone, or fractured, creviced or fissured rock formations are expected to be encountered during drilling.
2. An administrative authority shall approve a reduction in the distance required between a well and a disposal field or a seepage pit to a minimum of 50 feet, if the well is provided with a casing to a depth of 50 feet or more and such casing extends to, and is sealed into, a confining layer separating the aquifer into which the well is drilled from the stratum of soil in which the disposal field is located.
3. The reference to cesspools contained in Table 2 of this subsection is intended only to specify the minimum distance from an existing cesspool that water systems must be located. Cesspools are regulated by the Department pursuant to N.J.A.C. 7:9A, Standards for Individual Subsurface Sewage Disposal Systems.
4. The minimum distance and location requirements for distribution mains are set forth at N.J.A.C. 7:10-12.36.
5. The administrative authority shall approve a reduction in the distance from a well to a building sewer to a minimum of 15 feet if it can be demonstrated that the building sewer is watertight and there are no other practicable alternatives.

(b) A well shall not be drilled within 20 feet of a wood frame building. The Department recommends a minimum distance of 50 feet between a well and a wood frame building.

(c) A well shall be located at least 5 feet horizontally from a structure or any portion thereof, other than a pumphouse that serves the water system.

(d) The Department shall increase the minimum distance requirements for an individual well if the natural geologic conditions do not provide adequate protection of the water supply (e.g. cavernous limestone).
(e) The Department shall reduce the minimum distance requirements for an individual well if the well driller demonstrates that such distances are not feasible and adequate protection is provided through alternative well construction methods pursuant to N.J.A.C. 7:10-12.5(d).

Appendix D:

State of New Jersey – Standards for Individual Subsurface Sewage Disposal Systems (N.J.A.C. 7:9A)

The State's Standards for Individual Subsurface Sewage Disposal Systems (N.J.A.C. 7:9A) was adopted in August 1999 and sets forth the standards of individual septic systems. The following is a summary of the standards:

7:9A-1.6 General prohibitions

(a) A person shall not install, construct, alter or repair an individual subsurface sewage disposal system without first obtaining the necessary permits, approvals or certifications as required by this chapter.

(b) An administrative authority shall not issue an approval, permit or certification for installation, construction, alteration, or repair of an individual subsurface sewage disposal system where such installation, construction, alteration or repair will violate or otherwise not be in compliance with the requirements of this chapter.

(c) The use of a subsurface sewage disposal system for more than one property is prohibited unless a treatment works approval or a NJPDES permit has been issued by the Department.

(d) Individual subsurface sewage disposal systems shall not be located, designed, constructed, installed, altered, repaired or operated in a manner that will allow the discharge of an effluent onto the surface of the ground or into any water course.

(e) The administrative authority shall not approve the construction or alteration of individual subsurface sewage disposal systems or other means of private sewage disposal where a sanitary sewer line is available within 100 feet of the property to be served. For the purpose of this subsection, an existing sanitary sewer line shall be considered to be available when the following conditions are met:

1. Connection of the facility to the sanitary sewer line may be accomplished without installing a pump station, blasting bedrock, acquiring an easement or right-of-way to cross an adjoining property, or crossing a watercourse, railway, major highway or other significant obstacle; and
2. The property to be served is located within the designated sewerage service area of the sewage treatment plant to which the sanitary sewer line is connected.

(f) The discharge of sanitary sewage or the effluent from any individual subsurface sewage disposal system into any abandoned well or any well constructed for the purpose of sanitary sewage disposal is prohibited. The administrative authority shall not approve the discharge of sanitary sewage or septic tank effluent into an existing well or the construction of a new well for the purpose of waste disposal.

(g) The construction or installation of cesspools is prohibited. Alterations, repairs, and/or corrections to cesspools shall, at a minimum, include placement of a septic tank sized in conformance with N.J.A.C. 7:9A-8.2 before the point of discharge into the cesspool.

(h) The administrative authority shall not approve the construction or installation of seepage pits except as provided by N.J.A.C. 7:9A-7.6.

(i) The discharge of industrial wastes into an individual subsurface sewage disposal system is prohibited unless such discharge has been authorized by a treatment works approval or a NJPDES permit issued by the Department.

(j) The administrative authority shall not approve the construction, installation or alteration of any individual subsurface sewage disposal system used for the discharge of industrial wastes.

7:9A-4.1 General provisions for site evaluation and system location

(a) Selection of a location for each individual subsurface sewage disposal system shall be based upon evaluation of all site characteristics which may affect the functioning of the system. Site characteristics to be evaluated shall include, but may not be limited to, minimum required separation distances as prescribed in N.J.A.C. 7:9A-4.3, slope, surface drainage and flood potential.

(b) A site plan shall be required as part of each application and shall, as a minimum, provide the information outlined in N.J.A.C. 7:9A-3.5(c)2.

7:9A-4.2 Location generally

(a) The location and installation of each individual subsurface sewage disposal system and every part thereof shall be such that with reasonable maintenance, as required by N.J.A.C. 7:9A-12, it will function in a satisfactory manner and will not create a nuisance or source of foulness, pose a threat to public health or safety or the environment, or otherwise adversely affect the quality of surface water or groundwater.

(b) Individual subsurface sewage disposal systems shall not be located in such a manner that their functioning may be adversely affected by the following features unless the design adequately addresses the special limitations associated with these features and complies with all applicable local, State and Federal laws, regulations and ordinances.

1. Bedrock outcrops or areas with excessive stones;
2. Sink-holes;
3. Steep slopes showing signs of unstable soil such as landslide scars, slump blocks, fence posts or lower trunks of trees bending downslope;
4. Bare eroded ground, denuded of vegetation, or with deep wheel ruts;
5. Highly disturbed ground indicated by such features as remnants of foundations or pavements, buried building debris or buried plant remains;
6. Sand dunes;
7. Mine spoils, borrow pits, dumps or landfills;
8. Low-lying coastal areas exhibiting signs of tidal inundation or tidal marsh vegetation such as cordgrass (Spartina alterniflora), salt-meadow grass (Spartina patens) or spike grass (Disticlis spicata);

9. Low-lying inland areas showing signs of ponding or freshwater wetland vegetation such as skunk cabbage (Symplocarpus foetidus), tussock sedge (Carex stricta), cat-tails (Typha spp.), alders (Alnus spp.), or white cedar (Chamaecyparis thyoides); and
10. Flat low-lying areas adjoining streams.

Appendix E: Board of Health Regulations Comparison

Township	Well	Septic
All Municipalities	-Adopts N.J.A.C 7:10 -Well Permits required to locate, construct or alter any well -Well Permits required prior to approval of application	-Adopts N.J.A.C 7:9A State Sanitary Code -All permits must be obtained for location, construction, alteration or repairs of sewage disposal systems
East Amwell	-Testing and certification of all new, expanded or altered wells required prior to any use -Three-part pump test required in SMD prior to subdivision; three-part pump test or drilling discharge test in all other zones prior to building permit -Major subdivisions require hydrogeologic report and individual well certification -Non-residential wells require three-part aquifer test -Blasting of wells prohibited -Hydrofracturing for new well prohibited within 250 feet of existing well	-Distance from flood hazard area must be a minimum of 50 feet -septic system cannot be located in transition area for freshwater wetlands -Holding tanks granted only if sewage disposal system has failed and cannot be rectified -Well to be installed, tested and certified prior to issuance of permit for the septic system; permit to construct septic system must be issued prior to building permit -Distance of disposal field from detention/retention or infiltration basin is 100 feet and 50 feet to other recharge structure such as dry well; minimum distance of disposal field from water course is 200 feet in SMD and 100 to 200' in all other districts -Distance of disposal field and tank from well is 200 feet in SMD and 100-200 feet in all other districts
Hillsborough	-3-part Pump test required -Hydrofracturing is prohibited -Interference test required for MZ-Zone or where report the presence of diabase or argillite rock formations	-Require Textural Analysis -All disposal field construction must be completed and backfilled within seven days of initiation -All new septic system construction permitted within -Those located in MZ must be completed and approved before a building permit is issued
Hopewell	-3 part aquifer test required prior to building permit -Hydrofracturing to increase yields prior to aquifer testing is prohibited -Inspection and certification required before sale of property	-Approval for aerobic or aeration waste treatment system must be approved upon conditions by the Board -Holding tanks granted only if sewage disposal system has failed and cannot be rectified -Minimum lot acreage must be contiguous acreage which does not contain any utility or conservation easements, and which is located outside of any watercourses, wetlands, wetlands buffers, State open waters, or areas of steep slopes -In areas with known microbiological or chemical contamination of ground water, the Board of Health may require an alternative water supply or public water if an onsite safe water supply can not be assured -Inspection and certification required before sale of property
Montgomery	-Pump test required prior to building permit -Peak demand test and constant head test required -All new wells for single-family dwellings in the Lockatong Argillite or Diabase Regions must be approved before any approval of permits relating to the construction of individual or community subsurface sewage disposal systems -No blasting is allowed in the construction of wells	-Textural Analysis is to be completed -Percolation and tube tests must be performed according to State regulations -Disposal systems must be located in areas free of encroachments by man-made and natural obstacles that could potential clog any part of the system -Holding tanks granted only if sewage disposal system has failed and cannot be rectified -At least four groundwater monitoring wells are to be provided for non-residential systems
West Amwell	-Pump test required prior to building permit -For major subdivision hydrogeological analysis and report required prior to granting approval	Require Textural Analysis

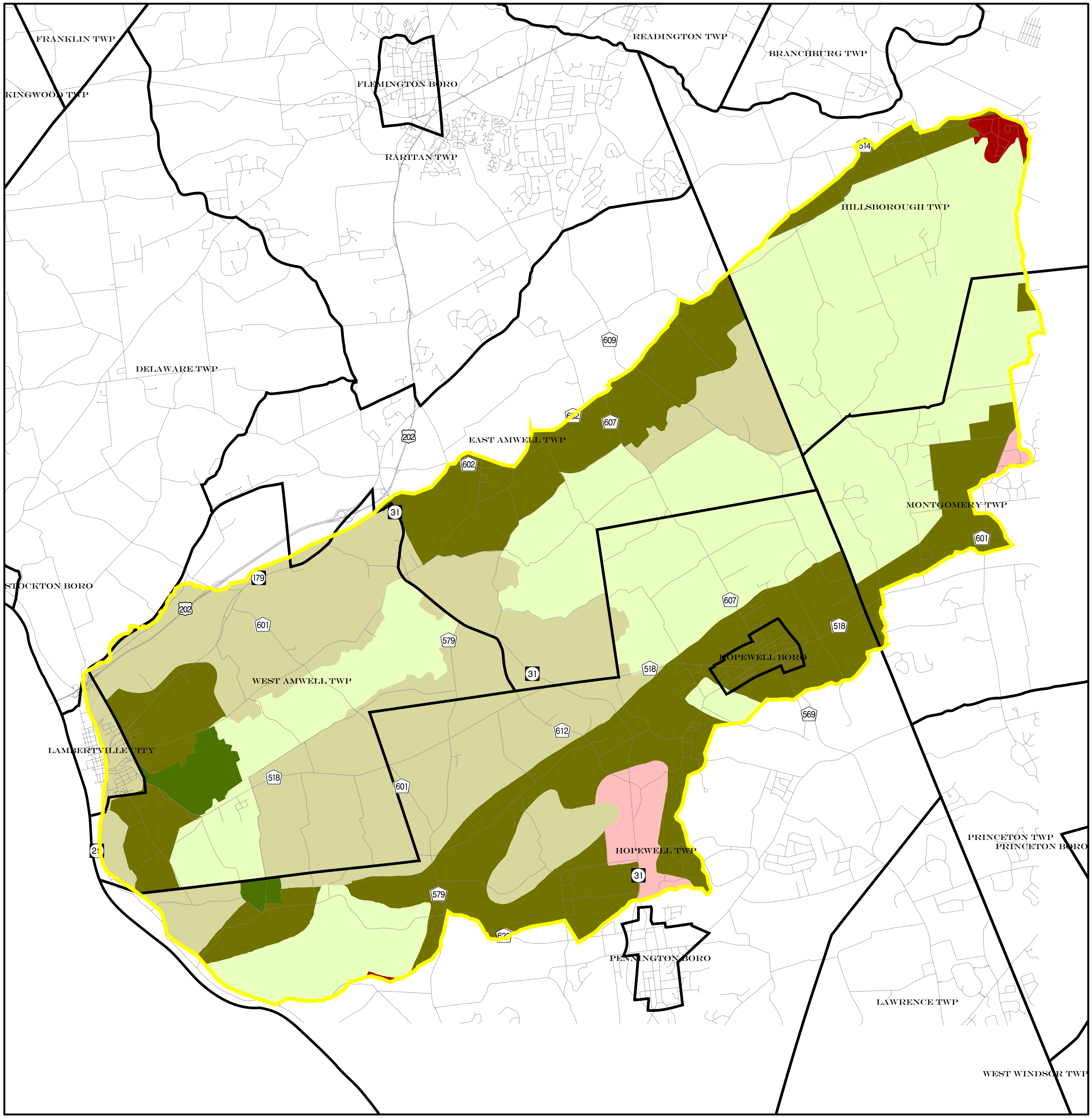
Figure 1
2001 State Plan
State Plan Policy Map

The Sourland Mountain

A Portion of Central New Jersey

Legend

- PA-2 Suburban Planning Area
- PA-3 Fringe Planning Area
- PA-4 Rural Planning Area
- PA-4B Rural/Environmentally Sensitive Planning
- PA-5 Environmentally Sensitive Planning Area
- Park and Recreation Area



This map was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been NJDEP verified and is not State-authorized.

Data Source:
NJDEP
New Jersey Office of Smart Growth

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Figure 2
Zoning Districts

The Sourland Mountain Region

A Portion of Central New Jersey

Legend

- AG (Hillsborough)
- AVAD
- C-1 (Hopewell)
- C1 (Hillsborough)
- HC (W. Amwell)
- HO (E. Amwell)
- Hopewell Borough
- IC (Hopewell)
- LB (E. Amwell)
- LHC (W. Amwell)
- LI (W. Amwell)
- LM (Montgomery)
- Lambertville City
- MR (Montgomery)
- MR/SI (Montgomery)
- MRC (Hopewell)
- MZ (Hillsborough)
- NC (W. Amwell)
- O/CC (Hopewell)
- PPE (Montgomery)
- Q (Hopewell)
- R (E. Amwell)
- R-100 (Hopewell)
- R-1A (W. Amwell)
- R-5 (Montgomery)
- R-75 (Hopewell)
- R-9 (W. Amwell)
- RR-4 (W. Amwell)
- RR-5 (W. Amwell)
- RR-6 (W. Amwell)
- SC-1 (Hopewell)
- SMD
- SRPD (W. Amwell)
- VRC (Hopewell)

N W E S

0 0.5 1 2 Miles

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