Description of the Brodhead Watershed

Physical Setting of the Brodhead Watershed

The plan area encompasses the Brodhead Creek watershed from the creek's confluence with the Delaware River to its headwater sources in northern Monroe County and Greene Township, Pike County, including its major tributaries: Marshall's Creek, Paradise Creek, Pocono Creek, and McMichael Creek. The Brodhead watershed covers about 285 square miles, extending from Barrett Township and Mount Pocono in the north to Brodheadsville in the west to the Delaware River. The watershed is nearly as wide from east to west as it is long from north to south. The highest elevations (approx. 2,000 feet above mean sea level) are found in the northern and northwestern part of the watershed. Streams flow generally southeastward from the plateau to the relatively low-lying southeastern portion of the watershed. The Brodhead Creek feeds directly into the Delaware River at approximately 300 feet above sea level about two miles north of the Delaware Water Gap.

The watershed consists mostly of forested and recreation land in its headwater areas and around most of its tributaries, with urbanization increasing downstream. The Boroughs of Stroudsburg and East Stroudsburg, with a combined population of 60,000, are located at the base of the main stem, approximately three miles upstream of the Brodhead's confluence with the Delaware River. The Brodhead Creek provides potable drinking water to over 20,000 people in the Stroudsburg area.

Political Boundaries

The Brodhead watershed is located almost entirely within Monroe County, northeastern Pennsylvania, with a small portion of its northern reaches spilling over into Pike County. In the watershed there are eighteen (18) municipal political subdivisions. The Brodhead watershed touches on all or part of the townships and boroughs listed below:

Monroe County
Townships: Coolbaugh, Barrett, Paradise, Price, Middle Smithfield, Tobyhanna, Pocono, Stroud, Smithfield, Tunkhannock, Jackson, Hamilton, Chestnuthill, and Ross.
Boroughs: Stroudsburg, East Stroudsburg, and Mount Pocono.

Pike County
Townships: Greene.
Boroughs: none.

Topography / Geology

Topography. The Brodhead watershed lies within two of the major physiographic provinces of Pennsylvania. These physiographic provinces are characterized by their own unique landscape and a distinctive geologic character. The northern half of the watershed falls within the **Appalachian Plateaus Province,** a broad area of hilly to low mountainous terrain that extends north and east into New York State and west across the northern tier counties of Pennsylvania. Topography is characterized by high, flat plateaus with elevations between 900-1,800 feet. The southern portion of the watershed falls within the **Valley and Ridge Province**, characterized by long, parallel, sharp-crested mountain ridges separated by long, narrow valleys. Elevations range from 1,600 feet along ridgetops to 500 feet in the valley bottoms.

Each physiographic province is further divided into sections. The northwestern part of the watershed falls within the *Pocono Plateau Section* of the Appalachian Plateaus Province while the northeastern portion of the watershed lies within the *Glaciated Low Plateaus Section* of the same. The southern part of the watershed lies within the *Appalachian Mountain* S*ection* of the Valley and Ridge Province.

Pocono Plateau Section. The Pocono Plateau is located in the extreme southeastern corner of the Appalachian Plateaus Province and is known as the "Pocono Mountains." The plateau's scenic eastern rim towers about 1,000 feet above the surrounding countryside. Rocks of the plateau have a low dip to the east, resulting in a gently sloping rock structure in the plateau. Topographic relief is low, rarely exceeding 100 feet. The entire section has been glaciated, with swamps and peat bogs frequent.

Glaciated Low Plateaus Section. The northeastern part of the watershed lies within the Glaciated Low Plateaus Section, a glaciated plateau of moderate relief, characterized by smooth, rolling hills and a large number of glacial lakes and swamps.

Appalachian Mountain Section. The southernmost portion of the watershed falls within the Appalachian Mountain Section, characterized by long, parallel, sharp-crested ridges separated by long, narrow valleys. Rapidly-weathering rocks underlie the valleys, while more resistant quartzite and sandstone form the higher ridges. The differential weathering characteristics and upright folds have produced the long valleys and ridges unique to this section.

Geology. The plateau section of the basin is underlain by nearly flat-lying sandstone units containing subordinate amounts of siltstone and shale. The valley and ridge section of the basin is underlain by primarily shale, siltstone, and minor carbonate units. Fifteen thousand years ago, Wisconsian glaciers covered the entire basin. Nearly all areas, with the exception of hilltops, are now covered with unconsolidated sediments deposited or reshaped during deglaciation. Ground moraine till, up to several meters thick, covers most of the plateau section. The valley and ridge section is generally covered by thicker glacial deposits. They are typically meltwater-derived and include ice contact, outwash, and lacustrine deposits. Rock fragments in the glacial sediments are generally similar to the composition of the underlying bedrock and are thus assumed to be locally derived. Colluvium – soil and rocks deposited at the base of steep inclines – decreases the topographic slope at the base of most hills throughout the basin. Alluvium (sediment deposited by flowing water) consisting of sand, gravel, and cobbles from eroded till deposits is common to many of the streams. Several streams (Brodhead, Appenzell, and McMichael) have losing reaches immediately downstream of the point where they exit the bedrock uplands into thick permeable outwash deposits.

The watershed is mainly underlain by sedimentary rocks of the Devonian (360 to 408 million years ago) and Silurian (408 to 436 million years ago) ages. The Devonian Period is sometimes called the "Age of Fishes" because fish became abundant and diverse during this time. The first amphibians also appeared during this time. The first jawed fishes and vascular plants appeared during the Silurian Period.

The rocks in the Appalachian Mountains Section (southern part) have been intensely deformed by folding and faulting, resulting in dramatic topography. Rocks in the northern part of the watershed are gently folded and not as deformed as those in the southern portion.

Summary of bedrock geologic units underlying the watershed.

Undifferentiated Silurian-Devonian aged rocks are found in a band across the southern part of the watershed. Devonian aged rocks are located through most of the watershed with the youngest rocks found in the northernmost part of the watershed:

- *Marcellus Formation* – Grayish-black, fine grained carbonaceous fissile shale and silty shale. Underlies valleys and is often overlain by thick, unconsolidated deposits.
- *Mahantago Formation* – Medium to dark grey fine-grained shale and siltstone.
- *Trimmers Rock Formation* – Gray to olive gray, fine to medium grained massive siltstone and minor shales characterized by graded bedding and marine fossils.
- *Catskill Formation* – A succession of grayish-red, fine to medium grained siltstone, shale and sandstone, usually encountered in fining upward cycles. The Catskill Formation is divided up into members: *Towamensing Member, Walcksville Member, Beaverdam Run Member, Long Run Member, and Packerton Member*.

Socio-Economic Setting

Population and Employment

The population of Monroe County, the county in which the predominant area of the watershed is located, has nearly doubled since 1980 and is projected to grow by 60 percent by 2020. Managing the impact of this growth in a way that conserves and protects natural and cultural resources while also encouraging the development of environmentally friendly businesses to provide close-to-home employment is at the root of the many recent planning efforts in the County. The following summaries the current population and employment situation:

Population
Monroe County's population boom began in the 1960s with the opening of Interstate 80. The trend continued during the '70s and '80s, and by the 1990 census, almost 96,000 people lived in the County. The 2000 census confirmed that the growth of the County continues – nearly 140,000 people live in the County today. The combination of further metropolitan in-migration and natural increase as county residents form new households and have children will result in continued growth over the next few decades and beyond. The projected population for the County in the year 2020 is 177,000 to 221,000.

Viewed together with average household size, this population estimate serves as a gauge for future housing demand. In 1990, average household size in Monroe County was 2.69 persons per house. Trends analyzed by the U.S Bureau of the Census show decreasing household size nationally and in Monroe County as well. Monroe County's demographic profile is approaching that of a typical suburban jurisdiction and its average household size is moving towards 2.5. The County is likely to see as many as 30,000 new dwelling units between 1998 and 2020 if the total population projected to 2020 lives in smaller household groupings as expected.

Employment
Many of Monroe County's jobs are held by people who commute in from other areas. For example, the Tobyhanna Army Depot is the County's largest employer, but fewer than 600 of its 3,600 employees live in the County. The majority of these commute from the Scranton/Wilkes-Barre area. Some workers also commute to Monroe County from Northampton and Carbon Counties to the south.

Likewise, many of Monroe County's residents commute to jobs outside of the county – many of these to the New York-New Jersey metropolitan areas, and some to the Allentown-Bethlehem-Easton area. The *Monroe County Comprehensive Plan* estimated that in 1998, an estimated 9,000 workers – or close to 18 percent of Monroe County's estimated 50,900 residents age 16 and older who are employed – commute out of Monroe County to work.

Not unusually, the County's labor force and its job base are not precisely aligned with each other. This trend is occurring in communities nationwide.

The *Monroe County Comprehensive Plan* projected the number of jobs in Monroe County in the year 2000 to be somewhere between 49,250 and 57,750, an average annual growth rate of about 1.6-1.9 percent. In the decade following the year 2000, Monroe County's rate of employment growth is expected to level off as at annual average of around 1.6 percent, consistent with rates expected in the nearby counties of New Jersey.

The following table illustrates Monroe County's population growth between 1990 and 2000.

Population Change 1990-2000

County or Municipality	2000 Population	1990 Population	Population Change	Percent Change
Pennsylvania	**12 281 054**	**11 881 643**	**399 411**	**3.4**
Monroe County	**138 687**	**95 709**	**42 978**	**44.9**
Barrett Township	3 880	3 216	664	20.6
Chestnuthill Township	14 418	8 798	5 620	63.9
Coolbaugh Township	15 205	6 756	8 449	125.1
Delaware Water Gap Borough	744	733	11	1.5
East Stroudsburg Borough	9 888	8 781	1 107	12.6
Eldred Township	2 665	2 202	463	21.0
Hamilton Township	8 235	6 681	1 554	23.3
Jackson Township	5 979	3 757	2 222	59.1
Middle Smithfield Township	11 495	6 382	5 113	80.1
Mount Pocono Borough	2 742	1 795	947	52.8
Paradise Township	2 671	2 251	420	18.7
Pocono Township	9 607	7 529	2 078	27.6
Polk Township	6 533	4 517	2 016	44.6
Price Township	2 649	1 633	1 016	62.2
Ross Township	5 435	3 696	1 739	47.1
Smithfield Township	5 672	4 692	980	20.9
Stroud Township	13 978	10 600	3 378	31.9
Stroudsburg Borough	5 756	5 312	444	8.4
Tobyhanna Township	6 152	4 318	1 834	42.5
Tunkhannock Township	4 983	2 060	2 923	141.9

Source: U.S. Census Bureau Prepared by: Pennsylvania State Data Center

Land Cover

Dominant land covers in the watershed are forest (84%), pasture or hay (7%), and residential or commercial (5%). Eighty-four (84) percent of the watershed is covered by deciduous, mixed, and evergreen forests. Low intensity residential development covers approximately 3.5 percent of the land, while high intensity residential and commercial areas cover approximately 1 percent of the land in Stroudsburg, East Stroudsburg, and Mount Pocono. Examination of land cover within 100 meters on either side of the stream network shows that the area along streams is dominated by a transitional habitat, at 55.5 percent. Transitional habitat is defined as areas dynamically changing from one land cover to another, often because of land use activities. Examples of transitional habitat include forestlands cleared for timber. [8]

LAND COVER TYPE	AREA (HECTARES)	PERCENT
Deciduous Forest	49,528	66.84
Mixed Forest	7,682	10.37
Evergreen Forest	4,989	6.73
Pasture/Hay	4,703	6.35
Low Intensity Residential	2,555	3.45
Woody Wetlands	1,889	2.55
Open Water	1,122	1.51
High Intensity (Commercial/Industrial/Transportation)	562	0.76
Row Crops	548	0.74
Other Grasses (parks, lawns, golf courses)	199	0.27
High Intensity Residential	185	0.25
Transitional	83	0.11
Emergent Herbaceous Wetlands	42	0.06
Quarries, Strip Mines, Gravel Pits	10	0.01

Land Use / Zoning and Land Use Controls

Land use in the watershed is primarily residential, especially in Chestnuthill and Pocono Townships. Large undeveloped areas can be found throughout the watershed. Urbanized areas are found mostly in the southern part of the watershed, in Stroudsburg and East Stroudsburg Boroughs and Smithfield and Stroud Townships. Commercial land uses are

[8] 1988-1993 LANDSAT mapping, *Basin and Drainage System Characteristics, Brodhead Creek Watershed, Pennsylvania*, NIER, 1999.

mainly concentrated along major arterial and collector highways such as Routes 611, 209, 191, and 447.

Of the eighteen municipalities the watershed falls within, only two do not have zoning. These are Ross Township, in southwestern Monroe County, and Greene Township, Pike County, at the extreme northern end of the watershed.

Follow-up actions to Monroe 2020, the County's Comprehensive Plan, adopted in June of 1999, and the Monroe County Open Space Plan, adopted in June 2001, resulted in all twenty municipalities preparing joint municipal open space plans. Six joint municipal areas emerged for these follow-up planning efforts. All six joint municipal regions have some portion of their study area in the Brodhead watershed. To date, Pike County has no similar program that affects Greene Township.

Also as a result of these county plans, all twenty municipalities have "*Growing Greener*" audits either completed, in progress, or to be scheduled.[9] These audits provide recommendations for updating local plans and ordinances through the use of the *Growing Greener* techniques, including the model ordinance language for conservation subdivisions. Revisions to local ordinances based on these audits are required in order to implement the goals and recommendations of the County Comprehensive Plan, the County Open Space Plan, and the recommendations contained in this watershed conservation plan.

Another audit of municipal codes was conducted by the Monroe County Conservation District. This review focused on municipal floodplain regulations and points to weaknesses in the existing codes and makes recommendations for correcting the same.

[9] *Growing Greener* audits consist of a review of the municipality's local plans and ordinances relative to land conservation goals. The *Growing Greener* program was developed by the Natural Lands Trust and the Pennsylvania Department of Conservation and Natural Resources.

Transportation

The major traffic routes in the Brodhead watershed include:

- Interstate Routes 80 and 380;
- US Routes 209 and Business 209; and
- PA Routes 611, 715, 33,191, 390, and 447.

Interstate Route 80 runs east-west through the center of the watershed. There is also one active rail line, which snakes diagonally through the watershed from Mount Pocono Township to East Stroudsburg Borough. (See *Watershed Base Map*).

Scenic Geologic Features

Outstanding Scenic Geological Features of Pennsylvania are documented in a report by the same name authored by the State Geologist Arthur A. Socolow (Environmental Geology Report 7, Parts 1 & 2, 1979). In the preface, Mr. Socolow notes, *"Scenery has been recognized as a natural resource since 1864, when the first state park, Yosemite Valley, California, was established ... Today, society recognizes these geologic features as a valuable environmental resource ... Because of their outstanding geologic significance, the geologic features described here become outdoor classrooms, places where you can study the earth's surface in an almost natural condition, relatively undisturbed by human activities."* The following describes sites that occur in the Brodhead watershed:

Indian Ladder Falls. Privately owned by Skytop Lodges, Inc., permission to enter must be obtained to view these falls. Located 4.2 miles north of the village of Canadensis, these falls drop over gray and red sandstones, siltstones, and claystones at the escarpment of the Pocono Plateau.

Buck Hill Falls. Located one half mile north of Buck Hill Falls Village, these falls drop over sandstones and siltstones and are considered one of the most beautiful falls in the state.

Devils Hole. Located along Devils Hole Creek on State Game Lands No. 221, about two miles north of mount Pocono, the Devils Hole is a steep walled, shady ravine sculpted by glacial scour at the foot of the Pocono Plateau escarpment. The escarpment here rises a dramatic 500 - 600 feet above the surrounding land to the southeast.

Mount Pocono Overlook (Pocono Knob). Located along Knob Road in Mount Pocono, this overlook affords magnificent views of the rim of the Pocono Plateau, east into the Glaciated Low Plateaus section, and of the Delaware Water Gap in the distance.

Big Pocono Overlook. Located on top of Camelback Mountain within Big Pocono State Park, Big Pocono Overlook is the highest point in the Brodhead watershed at 2,133 feet.

On a clear day, the Catskill Mountains of New York can be seen. Camelback Mountain marks the edge of the Pocono Plateau in Monroe County.

Tannersville Cranberry Bog. Located parallel to Cherry Lane Road east of PA Route 611 near Tannersville, this is the best developed, southernmost low altitude boreal bog along the eastern seaboard.

Centerfield Coral Reef. Located on private property four miles north of Stroudsburg, this is one of the best sites in the state for collecting specimens of fossil horn corals. Fossils found here include coelenterates, bryozoans, brachiopods, and one genus of trilobite.

Marshalls Falls. These falls are found on Marshalls Creek, about one mile from the village of Marshalls Creek on private property. Remotely secluded in a hemlock grove, the falls plunge 35 feet into a deep pool. Siltstone cliff contains fossils.

Buttermilk Falls. Found several miles south of Marshalls Falls, these falls have a gradual drop of about 30 feet over limestone.

Twin Falls. Also found on Marshalls Creek, these falls are located upstream of Buttermilk Falls.

Clarke Falls. Located on the Brodhead Creek, just north of Analomink.

Indian Chair. Located northeast of the village of Minisink Hills, the dark-gray chert (flint) exposed here was used by the Lenni-Lenape tribe for making weapons and tools. Many important archaeological discoveries have been made here. Nearby is found the old tribal village of Minisink. Indian Chair is named for the rock outcrop near the crest of the hill which resembles a large chair.

Kellersville Esker. Located about 3.5 miles north of Saylorsburg, this is an outstanding example of an esker, delta, and lake plain. An esker is a long, narrow ridge of coarse gravel deposited by a stream flowing in or under a retreating glacial ice sheet. Very coarse gravel is exposed in the esker, while sand and gravel is quarried from the delta.

Some additional sites, identified through the public involvement process, include:

The Kettles. Located on an unnamed tributary to Kettle Creek, the Kettles are deep, circular depressions in bedrock created by the melting of large blocks of stagnant ice left behind by the glaciers.

Lake Mineola. Located just north of Route 209 in Brodheadsville, Lake Mineola marsh, in the McMichael watershed, contains the endangered northeastern bulrush. An adjacent property, including a pond which influences the water level in the marsh, has been purchased by the Nature Conservancy to protect the marsh habitat. Plans for the property include some recreational development and protection of the bulrush habitat.