TECHNICAL REPORT 1

Plan for clean water

Monroe County, Pa.

Land preservation for water resource protection

Plan for clean water

INTRODUCTION

Land protects water quality and quantity. The Plan for Clean Water (P4CW) team aimed to highlight land which is best suited to protecting water. To do this, the team identified four measurable characteristics of land that contribute to keeping water safe, pure, and plentiful. This report explains those characteristics, or "factors." It also discusses the data sources and methods used to create the GIS maps.

This study considers two types of water resources: surface waters, including creeks, streams, lakes, ponds and wetlands; and land areas with the greatest potential for aquifer recharge. Aquifers are the underground bedrock areas where water is stored that supplies wells and keeps streams flowing in times of drought.

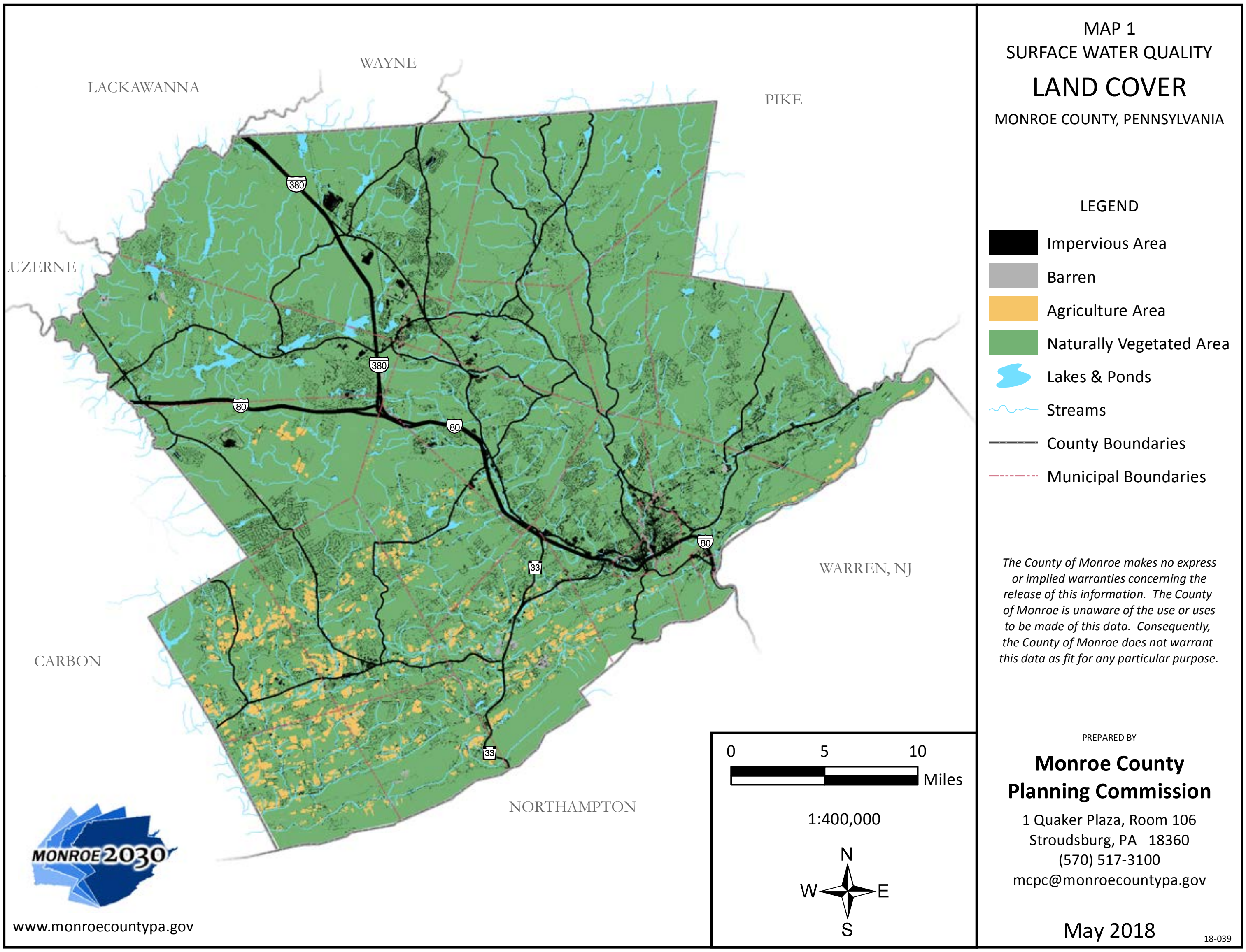
Evaluation of factors important to PROTECTION OF SURFACE WATER

Monroe County Planning Commission has been an invaluable partner on the Plan for Clean Water through developing the datasets and maps to categorize the four factors explained in this section. For more detail on the data sources and methods used, please see Appendix 1 at the end of this report.

The Plan For Clean Water identifies four characteristics, or factors, of the land that have a significant influence on surface water quality:

- **Land Cover**
- **Wetland Indicators**
- **Surface Water Buffers**
- **Soil Erodibility**

All factors are considered equal, with individual parameters within the factor ranked as described in the text that follows. A composite map, showing all four factors that affect surface water quality, is on page 4 of the summary.



MAP 1 *(see Appendix, page 15)*

SURFACE WATER QUALITY: LAND COVER

Monroe County Planning Commission staff used University of Vermont Land cover data and further enhanced that data by digitizing areas that show active farming 2015 (see GIS Appendix) as an additional category of land cover.

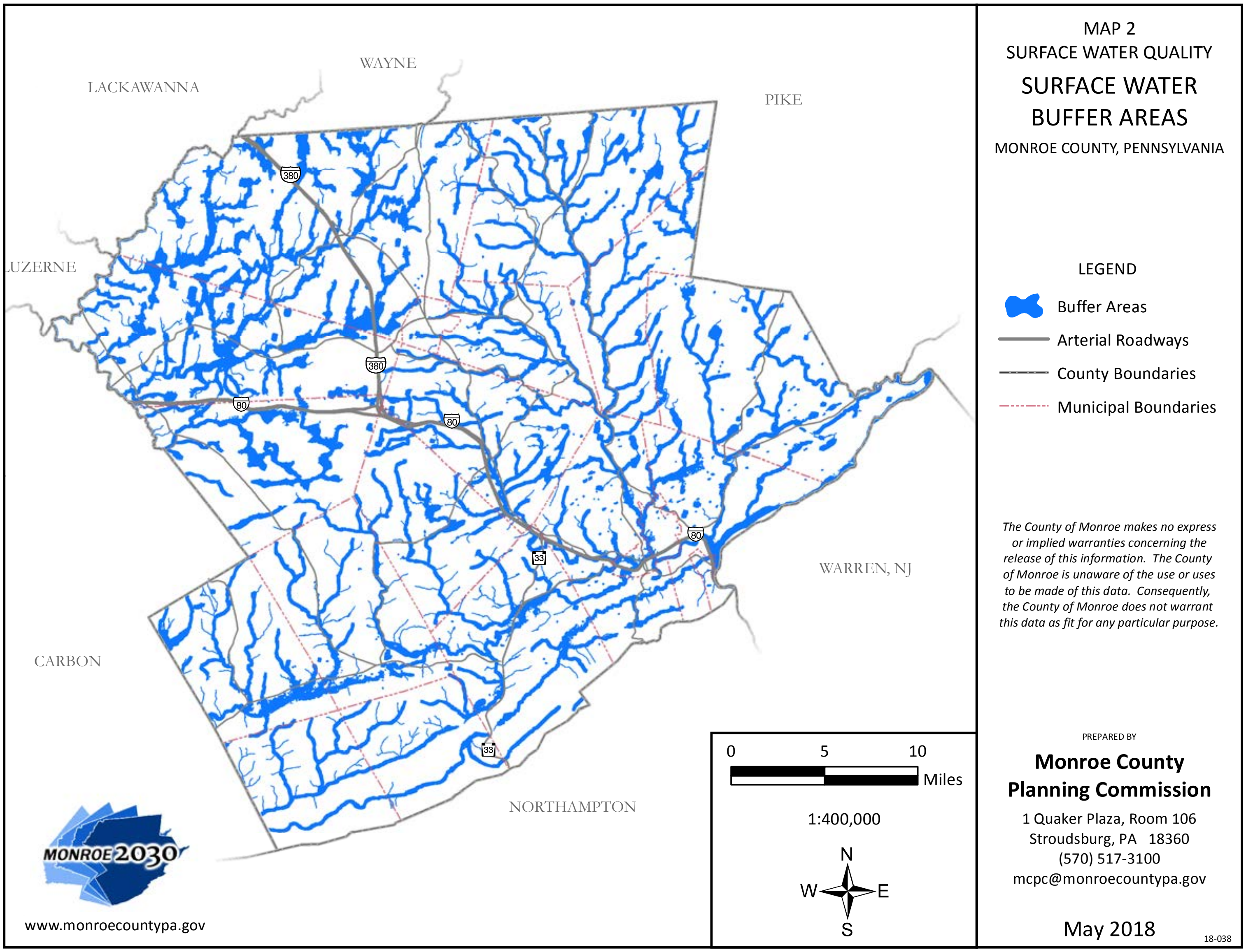
This evaluation uses four categories of land cover:

- Naturally vegetated — including forests, scrub/shrub and low vegetation
- Active farmland
- Barren (for example, rock quarries)
- Impervious – such as roads, buildings, parking lots

ABOUT THE UVM LAND COVER DATA

The University of Vermont, Rubenstein School's Spatial Analysis Laboratory (SAL), received funding from the William Penn Foundation to develop high-resolution land cover maps and land cover modeling tools for the Delaware River Basin. We used the GIS datasets developed by University of Vermont for this project because they are the most accurate and detailed land cover data available.

The William Penn Foundation awarded the $400,000 grant in 2015 as part of its Delaware River Watershed Initiative. The university completed the study in 2017.

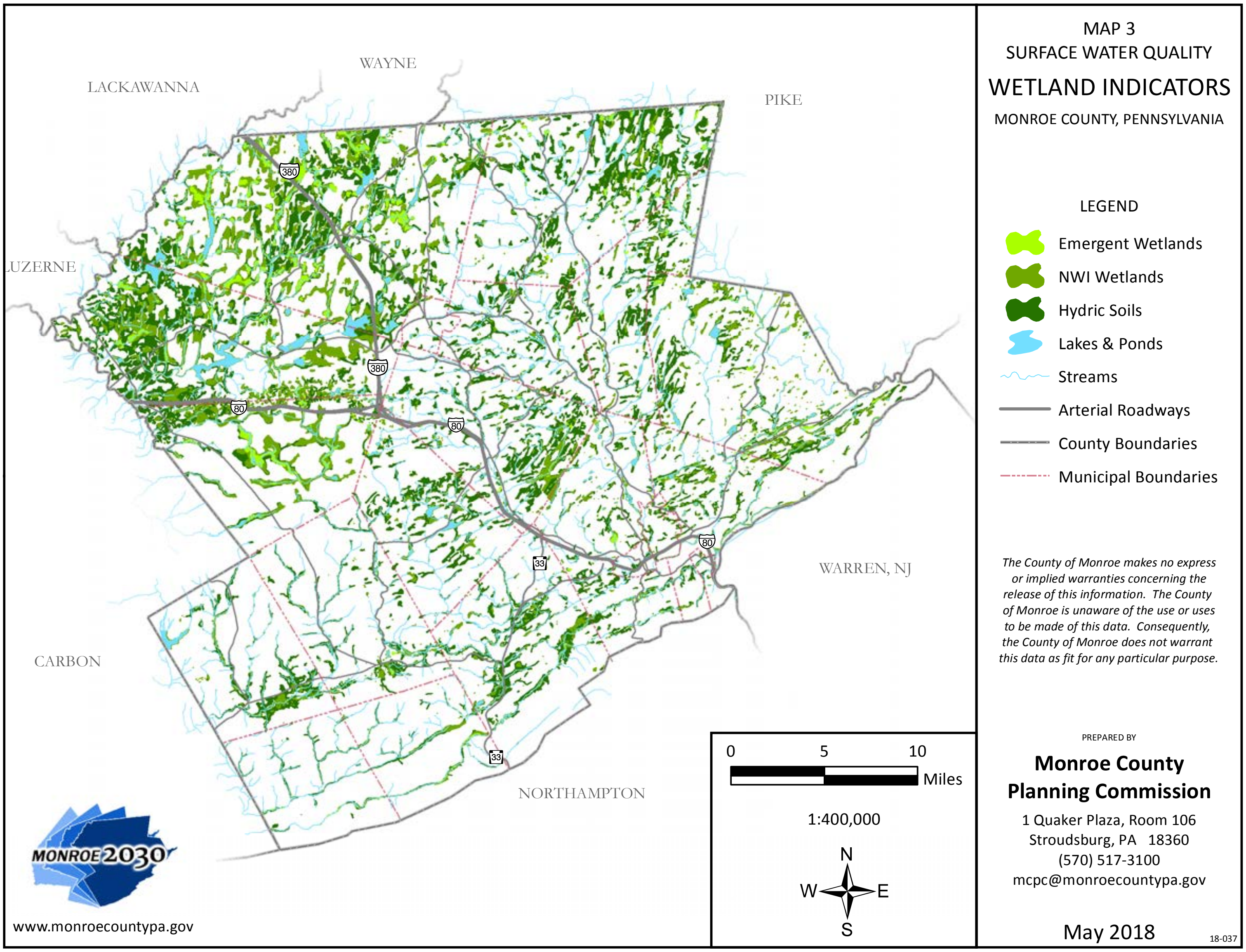


MAP 2 *(see Appendix, page 15)*

SURFACE WATER QUALITY: SURFACE WATER BUFFER AREAS

This map shows riparian areas, including Active River Areas (ARA) and 150-foot buffers from centerline of smaller streams where ARA is not defined. The Active River Area framework is a mapping tool developed by The Nature Conservancy to identify areas within which important physical and ecological processes of the river or stream occur. It is a more accurate description of stream processes than an arbitrary buffer width.

The map shows either presence or absence of buffers.



MAP 3 *(see Appendix, page 15)*

SURFACE WATER QUALITY: WETLAND INDICATORS

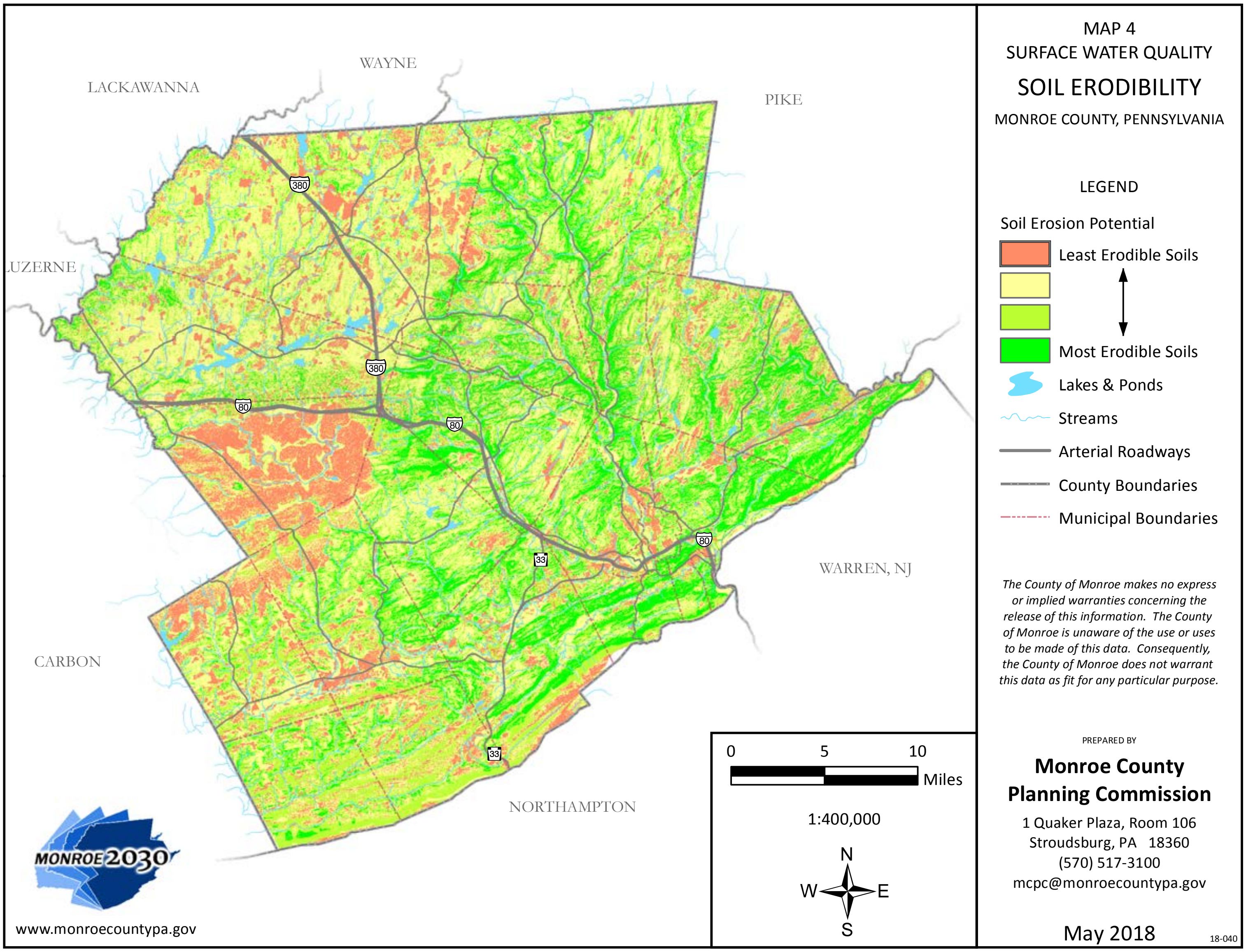
Wetlands absorb precipitation, slow it down and store it, reducing rapid run-off to surface water. Wetlands are both a factor in protection of surface waters and an element of the surface water system.

This map shows wetlands areas from three data sources: the National Wetlands Inventory from the U.S. Fish and Wildlife Service, emergent wetlands from the University of Vermont land cover data, and hydric soils from Natural Resources Conservation Service Soil Survey geographic database.

In many cases the three data sources coincide. However, all three datasets are derived from off-site/remote sensing and are only indicators of the possible presence of wetlands. This map is not a substitute for onsite verification of the presence or absence of wetlands.

(Note about "emergent wetlands": The term "emergent" in this case describes the type of vegetation in the wetland, i.e. emergent plants. These can be easily mapped using aerial photography.)

The map shows either presence or absence of wetland indicators.



MAP 4 *(see Appendix, page 16)*

SURFACE WATER QUALITY: SOIL ERODIBILITY

To develop the soil erodibility map, Monroe County Planning Commission staff used the National Resource Conservation Service (NRCS) Soil Survey geographic database. This map defines soil erosion potential of various soils, and combines that data with slope data.

Soils with high silt content have high erosion potential. Soils with high clay content are less erodible. Steep slopes are more likely to erode than shallow slopes. Wetlands soil and soils under lakes and ponds do not erode and are given a score of 0.

The four categories of soil erodibility shown are:

1. High potential for erosion – e.g. silty soils on steep slopes

2. Medium potential for erosion – e.g. soils containing more clay on shallower slopes

3. Low potential for erosion – e.g. clay soils on shallow slopes

4. Least potential for erosion – e.g. level land

Evaluation of factors important for AQUIFER RECHARGE POTENTIAL

(Note: A special thanks must go to Dr. Barry Evans, Penn State University, who advised us on the land characteristics/factors with the greatest potential for aquifer recharge, and developed the data used to illustrate those factors.)

WHY AQUIFER RECHARGE POTENTIAL MATTERS

An **aquifer** is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt). Aquifers provide flows to surface water and to wells, and so are essential for both drinking water and healthy streams. The flow present in streams when it has not rained for several days comes from water stored in the ground.

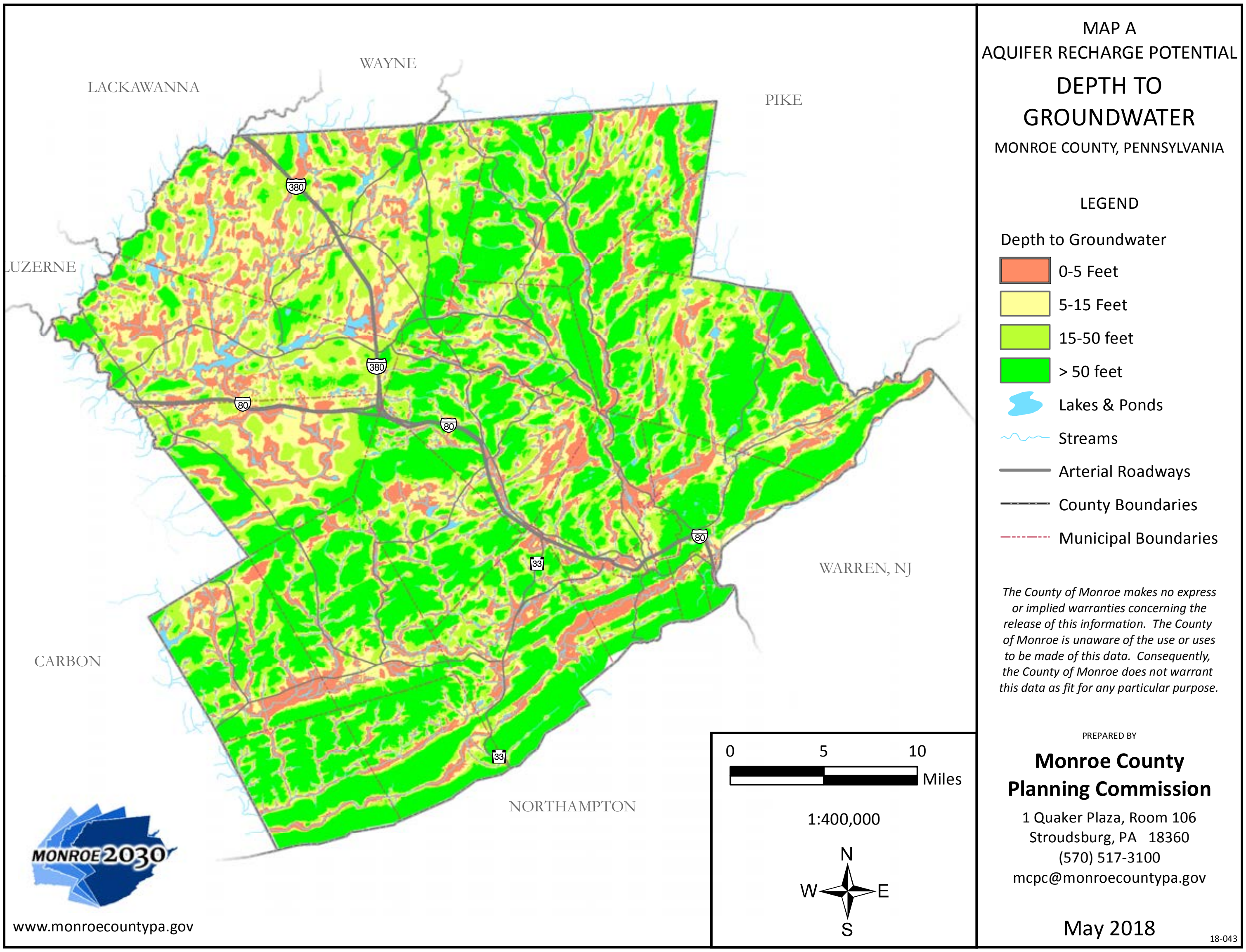
As groundwater flows out into streams and wells, groundwater **recharge** refills aquifers in a continuous cycle. This is a natural process where **snowmelt and rainwater** slowly filter through the earth, down into porous rock aquifers. These underground "reservoirs" store vast amounts of water we can tap. But when we alter recharge by paving over land, drinking water supplies and stream flow dwindle.

Most public water supply wells in Monroe County are drilled through the layer of soil, clay and gravel covering the underlying bedrock, and into bedrock, where the best water supply is located. Where wells are located close to streams, they are generally closely connected to water quality and flow in the stream.

The project team, with the assistance of Dr. Evans, determined four characteristics, or factors, that are most important in defining where aquifer recharge is most likely to occur. The factors are:

- **Depth to Groundwater**
- **Slope**
- **Glacial Deposit Thickness**
- **Hydrologic Soil Group**

All four factors as depicted on the following maps are equal to each other, with individual parameters within factors ranked as described in this report. A composite map, showing all four factors that affect aquifer recharge potential, is on page 5 of the summary.



MAP A *(see Appendix, page 16)*

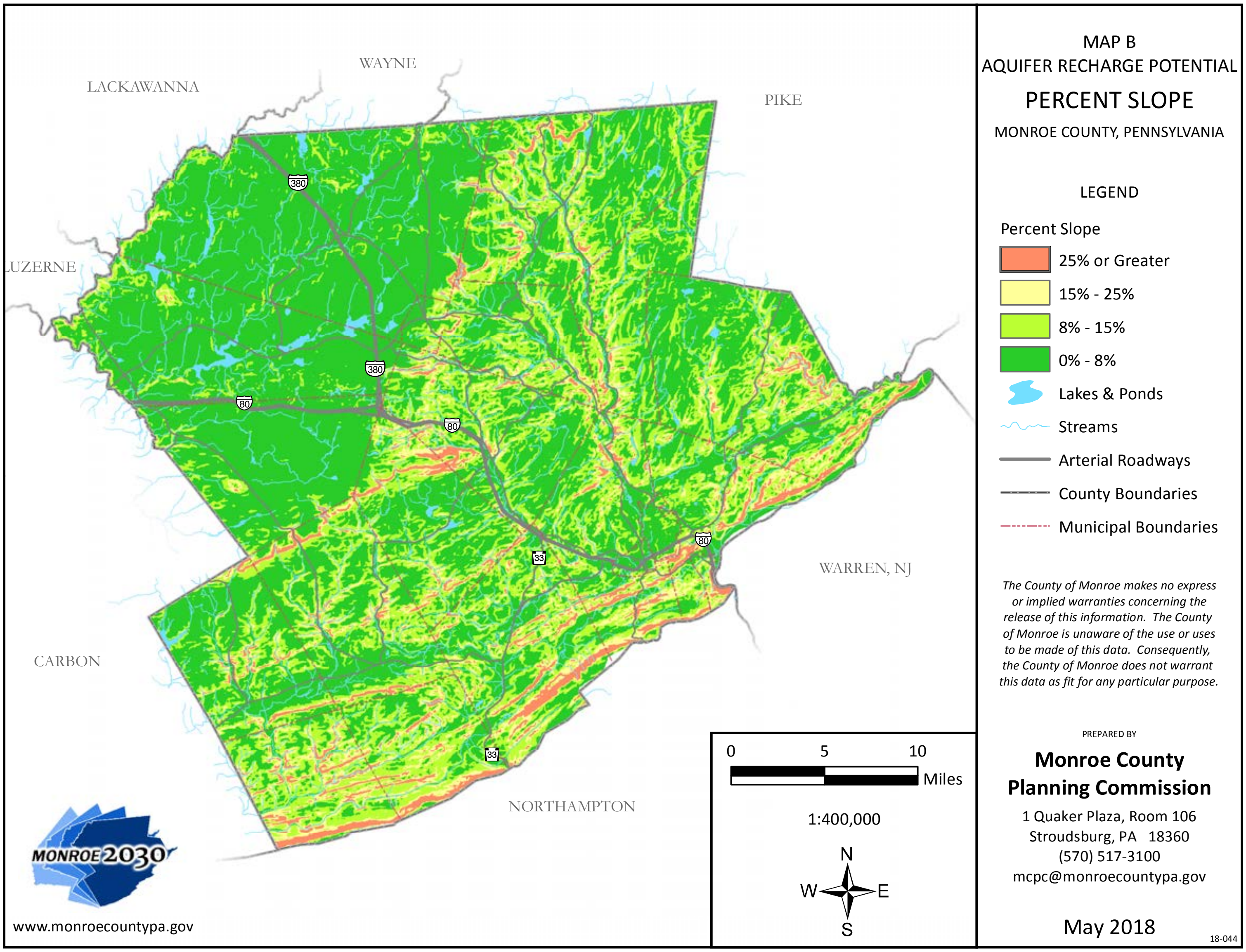
AQUIFER RECHARGE POTENTIAL: DEPTH TO GROUNDWATER

This is a measure of the distance from the land surface to the top of an underlying groundwater aquifer or water table. As the depth to groundwater increases, more "subsurface volume" becomes available for water storage. This translates to greater recharge potential.

Lands where the water table is high, such as along streams and in the bottom of valleys, provide little aquifer recharge. Rain that falls there travels rapidly to streams. Where several feet of unsaturated soils are present, precipitation can infiltrate through the soil and travel slowly to the water table (saturated zone) and recharge the bedrock aquifer below.

Depth is ranked as follows:

> 50 feet	3
15-50 feet	2
5-15 feet	1
0-5 feet	0



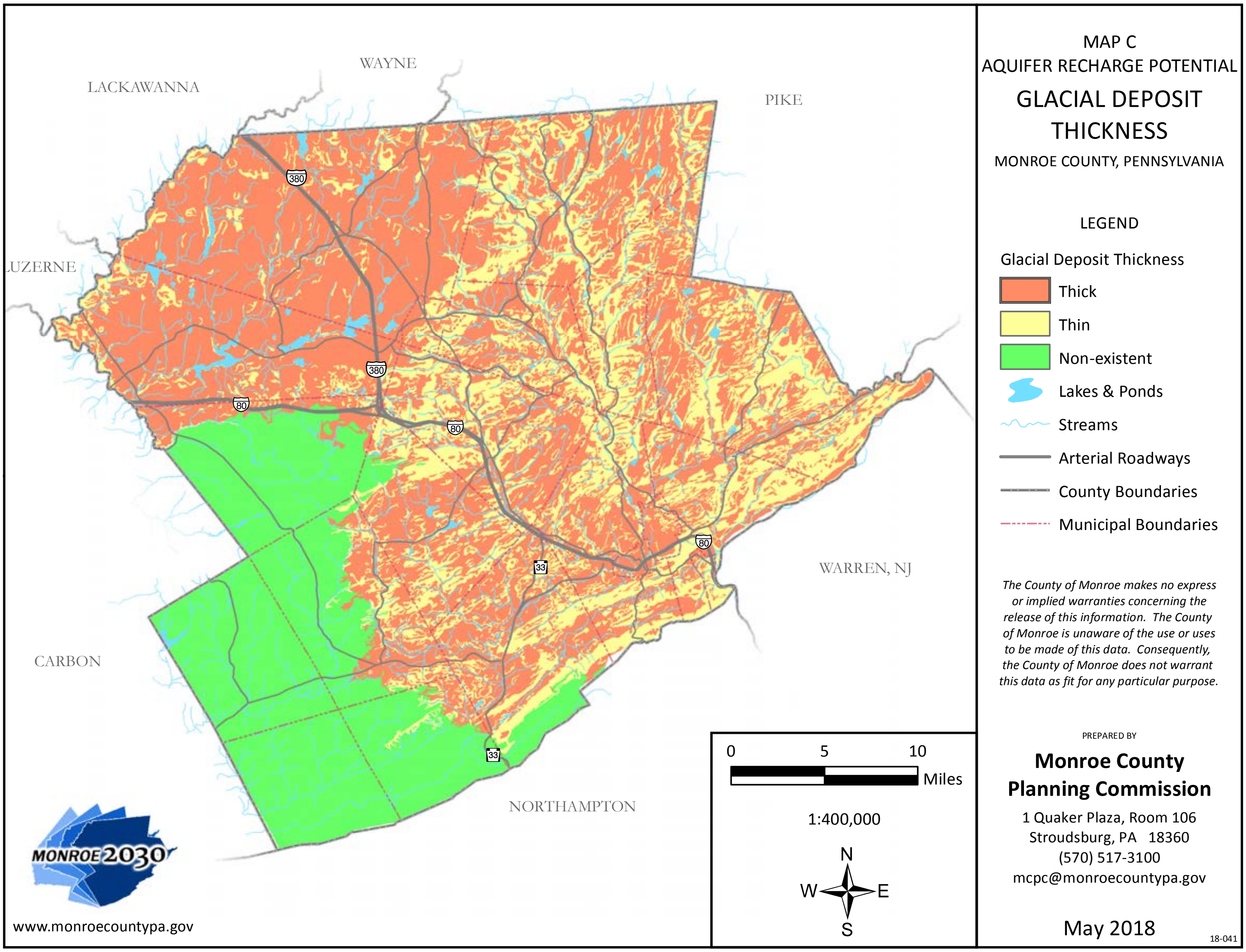
MAP B *(see Appendix, page 16)*

AQUIFER RECHARGE POTENTIAL: PERCENT SLOPE

Monroe County Planning Commission developed this map from PAMAP program's LIDAR-based Digital Elevation Model. The percent or steepness of a slope impacts the rate of water infiltration to the aquifer. That is, on steeper slopes water runs off more rapidly and is less likely to infiltrate. On flatter ground, water runs off more slowly and has the opportunity to infiltrate the soil.

Slope is ranked as follows:

0%-8%	3
9%-15%	2
15%-25%	1
26% or greater	0



MAP C *(see Appendix, page 16)*

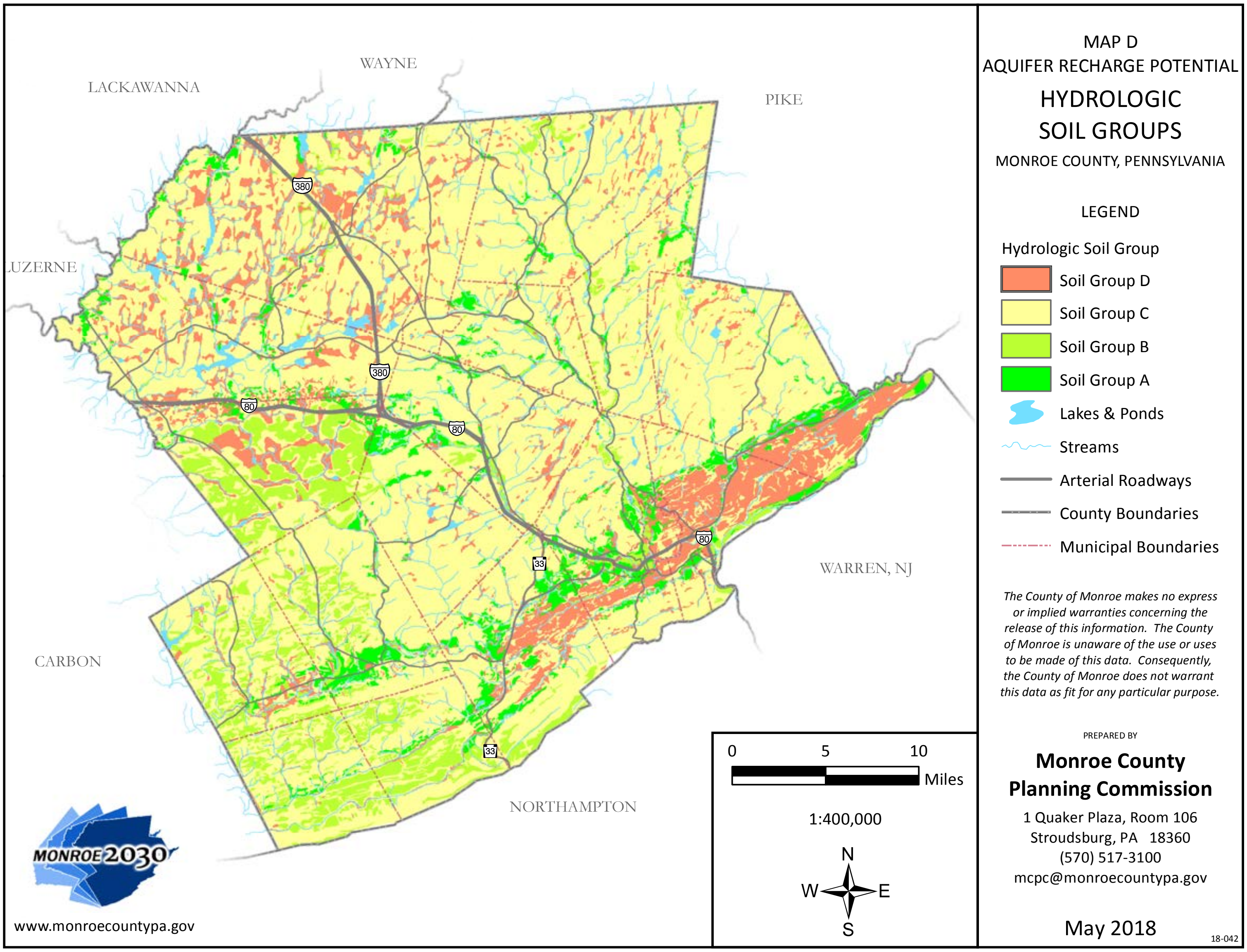
AQUIFER RECHARGE POTENTIAL: GLACIAL DEPOSIT THICKNESS

In the "glacial deposit" layer used in this analysis, the thicker deposits are more likely to include impervious layers which block precipitation from entering the saturated zone. Thinner deposits provide more opportunity for precipitation to reach the saturated zone and bedrock aquifer.

All other things being equal, aquifer recharge potential is greater where glacial deposits are thinner or non-existent.

The Plan for Clean Water team categorized the glacial deposit thickness as follows:

Non-existent	3
Thin	2
Thick	1



MAP D *(see Appendix, page 16)*

AQUIFER RECHARGE POTENTIAL: HYDROLOGIC SOIL GROUPS

This map shows location of soil types in Monroe County. Hydrologic soil types impact the rate of water infiltration to the aquifer. This soil classification system is based on the ability of soil to absorb water. Soils are classified A through D with A soils having the best infiltration rate and D the lowest.

Soil is ranked as follows:

Soil Group A	3
Soil Group B	2
Soil Group C	1
Soil Group D	0

THE NATURAL RESOURCE CONSERVATION SERVICE breaks soil types into four Hydrologic Soil Groups — based on the soil's runoff potential and infiltration rate. The four Hydrologic Soils Groups are A, B, C and D. A soils generally have the smallest runoff potential and D soils the greatest.

Group A is sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted.

Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted.

Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted.

Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This soil group has the highest runoff potential. These soils have very low infiltration rates when thoroughly wetted.

THE MAPPING PROCESS

The surface water factors maps have a scale of one meter, i.e. all information is detailed on a polygon that is one meter square (about 11 square feet).

The aquifer recharge maps have a 30 meter scale, so each polygon is 30 meters square (approximately 322 square feet). Data is provided for each polygon. This scale was necessary because some of the datasets used are available only at the 30-meter scale.

The user will be able to use the maps individually, or together – depending on the purpose. The scores are based on polygons and not on individual properties.

This chart summarizes priorities for preserving land to protect water in Monroe County

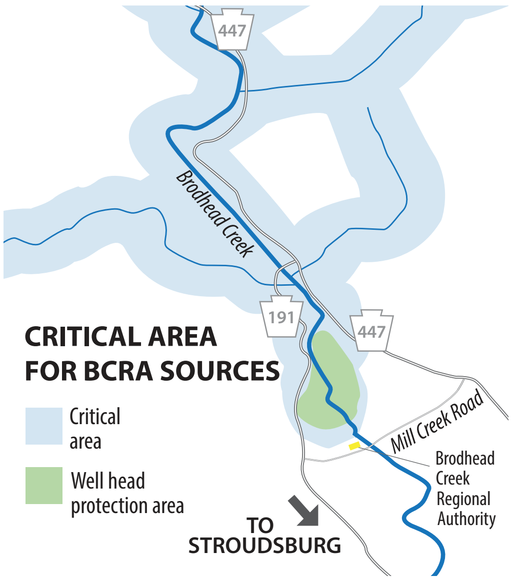
SCORE	FACTOR	PURPOSE	METRICS AND DATA	SCALE	MAP
SURFACE WATER QUALITY PROTECTION					
3 or 0	Land cover	Natural vegetation results in less runoff, more even stream flow, less stream bank erosion	Naturally vegetated – 3 Agriculture – 2 Barren – 1 Impervious – 0	1 meter	1
3 or 0	Wetlands and Hydric soils	Wetlands slow surface run-off,	Presence – 3 Absence – 0	1 meter	2
3 or 0	Riparian areas	Riparian areas intercept surface runoff, filter sediment, and shade streams (Important for trout production)	Presence – 3 Absence – 0	1 meter	3
0, 1,2, or 3	Soil erodibility	Highly erodible soils on steep slopes are more likely to send sediment loads to streams	High – 3 Medium – 2 Low – 1	1 meter	4
AQUIFER RECHARGE POTENTIAL					
0, 1,2, or 3	Depth to Groundwater	Deeper groundwater increases capacity of land to absorb water	>50 feet – 3 15-50 feet – 2 5 -15 feet – 1 0-5 feet – 0	30 meters	A
0, 1,2, or 3	Slope	Shallower slopes allow more precipitation to enter the soil	0 – 8% – 3 9-15% – 2 15-25% – 1 26% or greater – 0	30 meters	B
0, 1,2, or 3	Glacial deposit thickness	Thinner deposits allow more precipitation to enter the soil	Non-existent – 3 Thin – 2 Thick – 1	30 meters	C
0, 1,2, or 3	Hydrologic soil group	Sandy or loamy soils absorb more water	Soil Group A – 3 B – 2 C – 1 D – 0	30 meters	D

A special note about source water protection

"Source water" means the streams, rivers, lakes or aquifers that supply water for public drinking water and private water wells.

Protecting source water is one of the most important considerations in ranking land for preservation. Unfortunately, very few public water systems in Monroe County have defined what lands should be protected in order to keep their source water safe. Therefore, this study does not include a map that shows source water areas throughout the county. Those source water areas that are defined in the county are listed below.

More than 65 public water supply systems supply water to Monroe County residences and business, serving populations ranging from 30 to 30,000. Prioritizing source water areas for protection is an important next step for the Plan for Clean Water.

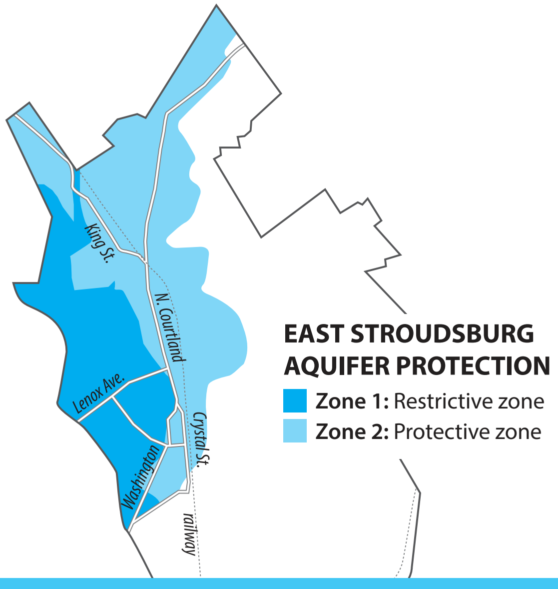


BRODHEAD CREEK REGIONAL AUTHORITY

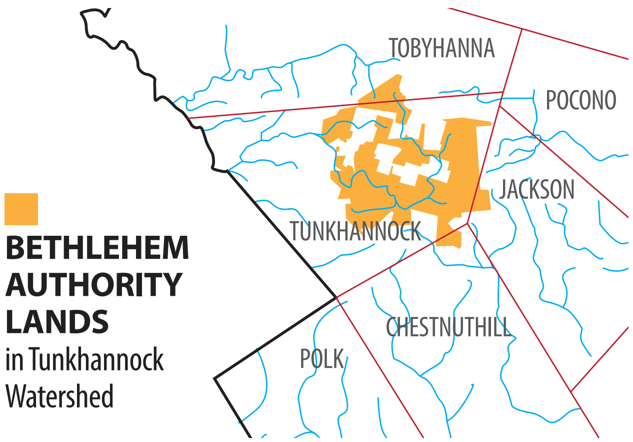
Brodhead Creek Regional Authority (BCRA) draws its water from Brodhead Creek and wells near the creek, at its treatment plant on Mill Creek Road in Stroud Township. BCRA is the largest public water supplier in Monroe County, serving Stroudsburg Borough, Stroud, Smithfield, Hamilton, Pocono, and Tobyhanna Townships. In 2010, BCRA did a source water protection study, and defined the lands necessary to protect their wells. The study also defined a critical area surrounding their intake on the Brodhead Creek. The BCRA Source Water Protection Plan also defines all land within one-quarter mile of streams in the upstream watershed (Brodhead and Paradise watersheds) as important to protecting water intake on the Brodhead Creek.

THE BOROUGH OF EAST STROUDSBURG

The Borough of East Stroudsburg operates its own water system, with supplies coming from reservoirs in the headwaters of Sambo Creek and wells along Brodhead Creek. East Stroudsburg has defined aquifer protection zones within the borough and limits activities that can be located in those zones. However, most of the land included in those zones is privately owned, and many prohibited uses existed before the zones were created.



The Borough of East Stroudsburg also owns much of the land surrounding its reservoirs on Sambo Creek, most of which is in Smithfield township. Some land that drains to the reservoirs, however, is privately owned, and none of the land is in any form of permanent protection.

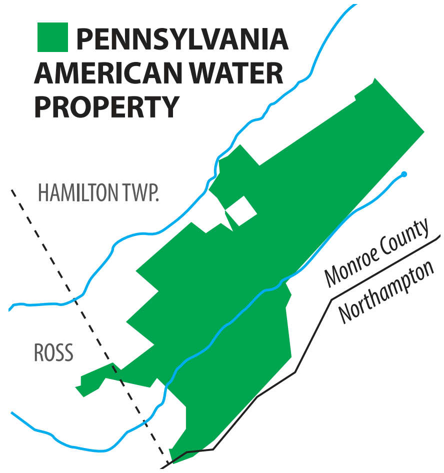


THE CITY OF BETHLEHEM

In an example of long-range planning, in the early and mid-1900s, the City of Bethlehem purchased 23,000 acres in the Poconos to protect their water supply — two reservoirs in Carbon County and an intake on Tunkhannock Creek in Monroe County. The city owns 8,500 acres in the Tunkhannock watershed and about 2,000 acres in Polk Township in the drainage to the reservoir system. The City of Bethlehem has worked with The Nature Conservancy to place a 60-year conservation easement on the watershed land to assure protection for that time-frame.

BLUE MOUNTAIN AND PENNSYLVANIA AMERICAN WATER CO.

Another out-of-the-county public water supply that looked to Monroe County for clean water is Blue Mountain Water Co., now a division of Pennsylvania American Water Co. (PAWC). The company supplies water to Nazareth Borough and surrounding area in Northampton County from Stony Garden Reservoir/Nazareth Reservoir and several springs in Hamilton and Ross townships in the Aquashicola watershed and in the headwaters of Cherry Creek.



PAWC owns much of the land that drains to the reservoirs and springs, but has not done a formal source water protection plan. However, PA DEP estimated the source water area at 4,865 acres in Monroe and Northampton counties. PAWC is a division of American Water, an investor-owned utility that operates water systems in 47 states and Canada.

The Conservation Fund is purchasing much of the land owned by PAWC to assure permanent protection of the headwaters of the Aquashicola and Cherry creeks. The Conservation Fund will transfer the land purchased to the U.S. Fish and Wildlife Service to be managed as part of the Cherry Valley National Wildlife Refuge.

Pennsylvania American owns other water systems in Monroe County – including the Mount Pocono borough and A Pocono Country Place systems. The status of source water protection activities for those systems is unknown.

APPENDIX

GEOSPATIAL REFERENCE INFORMATION

Geographic Coordinate System	GCS North American 1983
Projected Coordinate System	NAD 1983 State Plane PA North FIPS
Linear Unit	Feet (US)

SURFACE WATER QUALITY FACTORS

Land Cover (Map 1, page 3)

The University of Vermont's Land Cover raster digital model was selected as the basis for Surface Water Quality Land Cover Factor. The model contained 12 land use classes:

1. Low Vegetation
2. Scrub-Shrub
3. Tree Canopy
4. Wetlands
5. Water
6. Barren
7. Structures
8. Tree Canopy over Structures
9. Roads-Railroads
10. Tree Canopy over Roads-Railroads
11. Other Paved Areas
12. Tree Canopy over Other Paved

First, the **Land Cover** raster digital model was converted to a vector digital model. Next, the structures and tree canopy over structures, roads-railroads and tree canopy over roads-railroads, and other paved areas and tree canopy over other paved areas land use classes were combined, respectively.

In order to incorporate geospatial information associated with actively farmed lands, an **Active Farmland** vector digital model was created by analyzing **ortho-rectified aerial photography flown in June 2015 (National Agriculture Imagery Program) and April2015 (MCPC).** Areas of land that showed visual evidence of farming activities and/or the concentration of farm animals were digitized into a vector digital polygon model. This data was then combined with the recently modified land cover vector digital model, replacing the previous land use designation information. As a result of the modifications, the newly modified land cover vector digital model contained 10 land uses classes; the final Land Cover vector digital model was converted to a raster digital model so that it could be included in the map algebra associated with the **Surface Water Quality Factors Composite Map.**

Surface Water Buffer Areas (Map 2, page 4)

Ortho-rectified aerial photography, flown in 2008 (PA-MAP) and 2015 (MCPC), was compared against the existing stream centerline data to discover areas of insufficient data accuracy; the existing stream centerline vector digital model was then manually edited in order to more accurately reflect the stream conditions visually confirmed on the aerial photography.

In addition, a **Flow Accumulation** raster digital model was derived from a **3.2-foot Digital Elevation Model (DEM)** of Monroe County by utilizing the Hydrology Toolset. Streams that were indicated within the **Flow Accumulation** raster digital model and observed on aerial photography were manually digitized to complete the new **Stream Centerline** vector digital model.

The buffer tool was utilized to create a vector digital model that represents a **150-foot buffer** from the newly created stream centerline data; the dissolve tool was then was utilized to create one (1) polygon feature.

The dissolve tool was utilized in order to reduce the multi-feature **Active River Area (ARA)** vector digital model to one (1) polygon feature. The newly created **ARA** and **150-foot buffer** vector digital models were combined and the dissolve tool was then was utilized to create the final **Surface Water Buffer Areas Factor** data set. The final **Surface Water Buffer Areas** vector digital model was converted to a raster digital model so that it could be included in the map algebra associated with the **Surface Water Quality Factors Composite Map.**

Wetland Indicators (Map 3, page 5)

Three (3) wetland indicator data sets were selected to be included as part of the Wetlands Indicators Factor data set. **Emergent Wetlands** data was selected and extracted from the University of Vermont's Land Cover raster digital model; this raster digital model was then converted to a vector digital model so that it could be combined with the **NWI** and **Hydric**

APPENDIX, continued

Soils data sets. Upon combining the data sets, the dissolve tool was utilized to create one (1) polygon feature. The final Wetland Indicators vector digital model was converted to a raster digital model so that it could be included in the map algebra associated with the **Surface Water Quality Factors Composite Map.**

Soil Erodibility (Map 4, page 6)

A **Slope** raster digital model was derived from a **3.2-foot Digital Elevation Model** (DEM) of Monroe County by utilizing a Slope Tool within the Spatial Analyst toolset. Next, the **Slope** raster digital model was combined with detailed soil erodibility (K-factor) data taken from the **Soil Survey Geographic Database (SSURGO).** The procedure used to create the Soil Erodibility Factor raster digital model was derived from the methodology utilized by the Open Space Institute (Evans, 2015). The final **Soil Erodibility** raster digital model was included in the map algebra associated with the **Surface Water Quality Factors Composite Map.**

Surface Water Quality Factors Composite (Summary, page 4)

As described in the Technical Report, the four surface water quality factors detailed above were combined using the **Raster Calculator** tool in Spatial Analyst. The impervious area, shown in the Land Cover dataset, was then used as a clip to recalculate any grid cell value within that extent down to 0.

AQUIFER RECHARGE FACTORS

Depth to Groundwater (Map A, page 8)

This layer was developed by Dr. Barry Evans of Penn State University and Stroud Water Research Center. In order to develop this data, a layer of stream elevation points was generated by extracting elevation values for points along a regional stream network using a GIS procedure that uses a stream network shapefile and a 30m elevation grid. These "elevation points" that represented the elevation of "contact points" where underlying groundwater intersects the ground surface were then processed via surface interpolation to generate a "groundwater elevation" layer. Then, the "groundwater elevation" layer (grid) was subtracted from the 30m elevation grid to produce a "depth to groundwater" grid.

Percent Slope (Map B, page 9)

A Slope raster digital model was derived from a 3.2 foot Digital Elevation Model (DEM) of Monroe County by utilizing Slope Tool within the Spatial Analyst toolset. In order to match the grid size of the other Aquifer Recharge factors, this grid dataset was resampled to a 30 meter grid cell size in order to match the grid cell size of the data provided to our office by Dr. Evans.

Glacial Deposit Thickness (Map C, page 10)

This layer was developed by Dr. Barry Evans of Penn State University and Stroud Water Research Center. In order to develop this data, a map of "glacial extent" was obtained from USGS's national geodata website. The above map was merged with a soil layer (SSURGO data from USDA) to differentiate glacial till areas from glacial outwash areas (i.e., different types of glacial deposits). Documentation from the New York Geological Survey was then used to assign typical thickness values to the different "glacial deposit" types.

Hydrologic Soil Groups (Map D, page 11)

This is the hydrologic soil group for each soil map unit shown on the Soil Survey Geographic (SSURGO) database for Monroe County, PA (USDA, NRCS). The original polygon GIS database was converted to a 30 meter cell size grid dataset in order to match the grid cell size of the data provided to our office by Dr. Evans.

Aquifer Recharge Factors Composite (Summary, page 5)

As described in the Technical Report, the four aquifer recharge factors detailed above were combined using the Raster Calculator tool in Spatial Analyst. The impervious area, shown in the Land Cover dataset, was then used as a clip to recalculate any grid cell value within that extent down to 0.