West Virginia Watershed Assessment Pilot Project:

Monongahela River Watershed Assessment

Final Report

December 31, 2013

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Report Prepared by The Nature Conservancy for the West Virginia Department of Environmental Protection and the United States Environmental Protection Agency

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List of Abbreviations

AMD	Acid Mine Drainage
ARA	Active River Area
BMP	Best Management Practice
CRP	Conservation Reserve Program
CSRV	Cumberlands and Southern Ridge and Valley Ecoregion
DEM	Digital Elevation Model
ERO	Eastern Regional Office (TNC)
ESRI	Environmental Systems Research Institute, Inc.
FEMA	Federal Emergency Management Agency
FRA	Forest Reclamation Approach
GIS	Geographic Information Systems
GLIMPSS	Genus Level Index of Most Probable Stream Status
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NRAC	Natural Resource Analysis Center (WVU)
NRCS	Natural Resource Conservation Service
NWI	National Wetlands Inventory
PAFO	Pennsylvania Field Office (TNC)
PCS	Permit Compliance System
RBP	Rapid Bioassessment Protocol
SGNC	Species in Greatest Need of Conservation
SMCRA	Surface Mining Control and Reclamation Act
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USGS	United States Geological Survey
WAB	Watershed Assessment Branch (WVDEP)
WRP	Wetland Reserve Program
WVDA	West Virginia Department of Agriculture
WVDEP	West Virginia Department of Environmental Protection
WVDNR	West Virginia Division of Natural Resources
WVDOF	West Virginia Division of Forestry
WVFO	West Virginia Field Office (TNC)
WVGES	West Virginia Geological and Economic Survey
WVGISTC	West Virginia Geographic Information Systems Technical Center
WVSAMB	West Virginia Statewide Addressing and Mapping Board
WVU	West Virginia University

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Executive Summary

Accurate, current, and scientifically defensible watershed assessments are invaluable in a variety of decision-making processes, such as regulatory decisions concerning permitting impacts to aquatic and terrestrial resources, and the suitability and placement of mitigation and restoration projects to offset these impacts. The West Virginia Watershed Assessment Pilot Project was initiated to address the lack of comprehensive watershed assessments in the state, which has likely contributed to a loss in area and function of critical aquatic resources, particularly in watersheds where mining, oil and gas development, or other significant land use changes are occurring. Its purpose was to advance knowledge about aquatic and terrestrial resources within the state, inform regulatory decisions, and establish priorities for protection and restoration activities. It was also intended to facilitate communication and collaboration regarding watershed protection and restoration among regulatory personnel, decision-makers, and stakeholders; to identify data gaps/needs within West Virginia; and to suggest possible future projects to generate data that may inform future assessments. The intent of this pilot project was to develop an assessment process that may be applied to all watersheds within the state, given available funding. The initial watersheds chosen for the pilot project (Lower and Upper Monongahela, Elk, Upper Guyandotte, Little Kanawha, and Gauley) are experiencing significant impacts to headwaters and wetlands as a result of development and resource extraction.

We assessed the condition and function of the Monongahela River watershed at two different spatial scales—HUC12 watersheds and NHDPlus catchments—using a hierarchical approach that individually modeled three landscapes that characterize a watershed: streams, wetlands, and uplands. For each landscape, we defined several indices that contributed to its condition and function, e.g., water quality, habitat connectivity, and biodiversity. Each index consisted of multiple metrics, e.g., impaired streams, number of wells, and percent natural cover. Metric values were normalized and assigned to one of four categories to assess each planning unit objectively in terms of its deviation from an ideal ecological condition. Metrics were weighted and aggregated to provide index scores, which were weighted and aggregated into overall scores for each landscape. To ensure scientific validity of the assessment process, a Technical Advisory Team and an Expert Panel were assembled to provide peer review of the assessment methodology and review preliminary results throughout the project process. The two groups consisted of agency personnel, academic researchers, and individuals from the non-profit and private sectors with relevant expertise.

Results of the assessment indicated that all three landscapes in the Monongahela River watershed exhibited higher quality in the less developed areas in the southeastern and far western portion of the watershed. Development/impervious cover, surface mining, and underground mining were the most influential metrics determining stream quality.

Two products were developed to disseminate the assessment results to interested parties and potential users: individual watershed reports and an interactive web tool that displays the results of the analysis and selected spatial data with attribute information. The ranking of planning units generated in the assessment may be used to identify and prioritize areas within the watershed for conservation, restoration, or mitigation activities, depending upon stakeholders' goals and resources.

Section 1: Introduction

1.1 Project Description

The West Virginia Department of Environmental Protection (WVDEP) was awarded a US Environmental Protection Agency (USEPA) Region III Wetland Program Development Grant to complete a Watershed Assessment Pilot Project for five HUC8 watersheds in West Virginia. This was matched with funding from WVDEP and sub-awarded to The Nature Conservancy of West Virginia (TNC). The West Virginia Watershed Assessment Pilot Project (WVWAPP) was initiated to develop a watershed assessment process to inform conservation and management actions within the state. The project defined the methodology and data necessary to generate a peer-reviewed watershed assessment procedure and a decision support tool that can potentially be implemented for all watersheds throughout West Virginia. The information presented in these assessment reports will provide guidance to regulatory agencies, non-governmental organizations (NGOs), and other partners and decision-makers on potential strategies and locations for protection and restoration of critical aquatic and terrestrial resources within each watershed. Examples of intended uses include: identifying areas of high conservation value for protection by state and federal government agencies or NGOs, identifying high priority sites for conducting restoration activities, and assessing cumulative watershed effects contributing to the degradation of aquatic resources.

1.2 Project Goals

1. Provide a rigorous assessment process that leads to the advancement of the science and protection of aquatic headwater resources within watersheds in West Virginia.
2. Achieve a net increase in the quantity and quality of wetlands and other aquatic resources, and their resource function, within the watershed by providing support and information to state and federal agencies, private organizations, and stakeholders.
3. Protect, sustain, and restore the health of people, communities, and ecosystems by supporting integrated and comprehensive approaches and partnerships.

1.3 Project Objectives

1. Design and test a watershed assessment process that includes analysis of cumulative watershed effects.
2. Suggest priorities for protection and restoration of aquatic and terrestrial resources and evaluate/rank areas within watersheds accordingly.
3. Provide relevant information, strategies/actions, and a decision support tool to assist partners, stakeholders, and regulatory staff with decisions affecting watershed resources.
4. Increase communication and collaboration regarding watershed protection and restoration among decision-makers and stakeholders.
5. Identify data gaps/needs within West Virginia.

1.4 Project Process

1. Define the watershed **assessment methodology**.
2. Complete a **Baseline analysis** that describes watershed resources, impacts, and condition.
3. Conduct **expert workshop 1** to review the assessment process, evaluate the data collected, obtain local information on watershed specific resources, issues, and other relevant information, and define appropriate metrics for parameters used to evaluate the importance or value/contribution of potential actions.
4. Conduct **expert workshop 2** to review the data collected, evaluate the conclusions of the prioritization process, and develop strategies designed to address issues within the watershed.
5. Complete a **future threats analysis** using results from the expert workshop to incorporate local data and apply prioritization metrics to rank potential actions and sites within the watershed; create an **opportunities layer** to indicate where protection or restoration projects might expand upon currently protected lands or priority interest areas.
6. Complete a draft watershed assessment. Conduct a **decision maker/end user workshop** for Monongahela watershed stakeholders**.**
7. Complete final assessment.

1.5 Monongahela Watershed Timeline

Table 1. Monongahela River Watershed Timeline

Date	Activity
April 1, 2011	Award date, project initiation
June 13, 2011	First Technical Advisory Team meeting
Oct 24-25, 2011	Expert Workshop 1
Jan 31, 2012	Expert Workshop 2
April 3, 2012	Final End User Workshop for Monongahela River Watershed stakeholders
Dec 31, 2013	Final Monongahela River watershed assessment report and interactive web tool complete

For a detailed timeline of the entire project, please see Appendix C: Detailed Full Project Timeline.

1.6 Project Study Area

1.6.1 Pilot HUC8 Watersheds

The Project Study Area includes five 8-digit HUC watersheds (referred to as HUC8 watersheds) within West Virginia (Figure 1), including: **Lower and Upper Monongahela** (05020005 and 05020003, respectively), **Elk** (05050007), **Upper Guyandotte** (05070101), **Little Kanawha** (05030203), and **Gauley** (05050005). Draft watershed assessments were completed in two of the five identified watersheds (the Lower/Upper Monongahela and the Elk) in the first year of the project. During the second project year, the remaining three watershed assessments were completed and the assessment methodology was refined by incorporating new data, suggestions from the technical advisory team and other experts and stakeholders, and lessons learned during the first project year. The assessment results from the five watersheds were incorporated into an interactive web tool to be accessible to a wide variety of stakeholders.

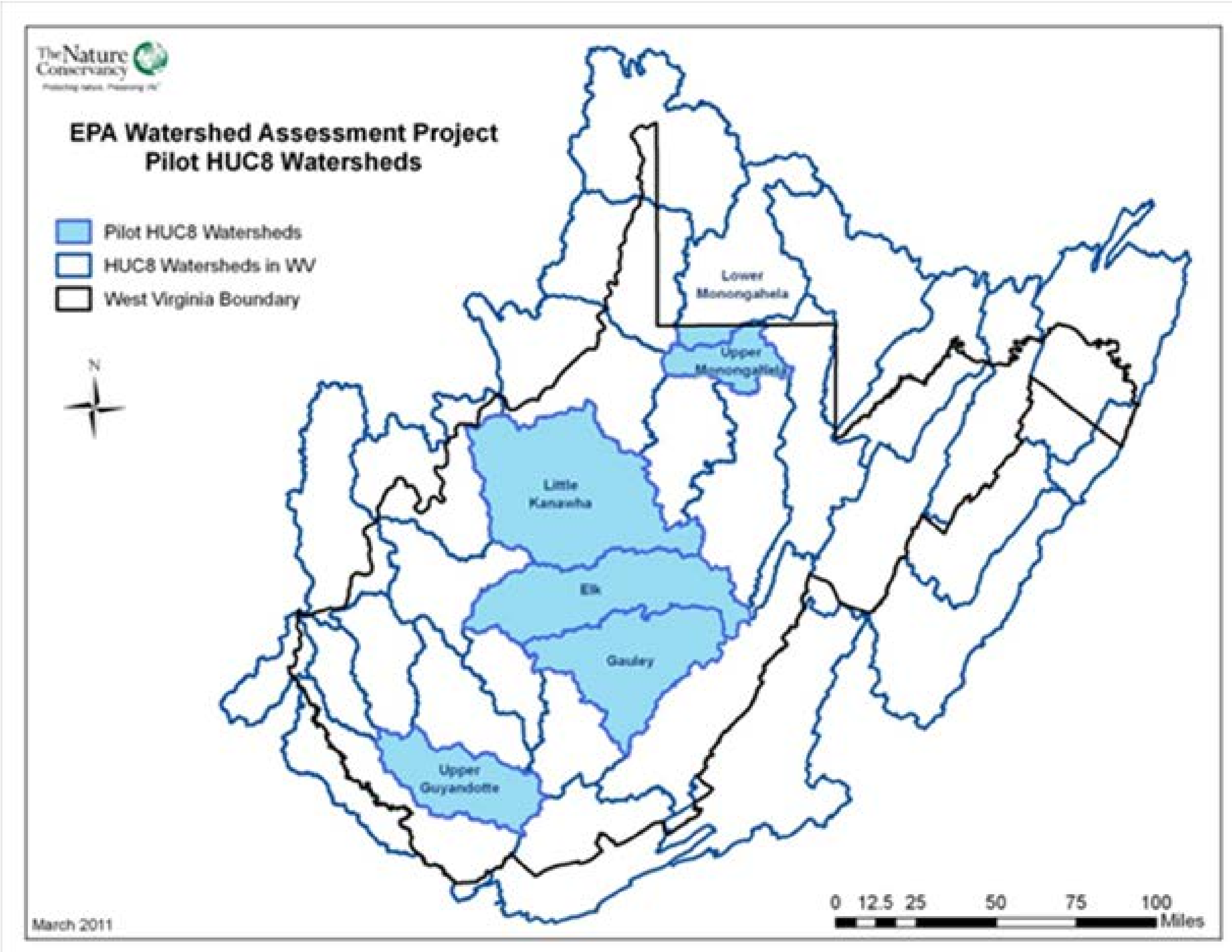

Figure 1. West Virginia Watershed Assessment Pilot Project HUC8 Watersheds (NRCS 2009)

1.6.2 Monongahela River Watershed Study Area

The study area considered in this report is the portion of the Monongahela River watershed that lies within West Virginia (Figure 2). The Monongahela River watershed, or drainage area, covers approximately 564.5 square miles in north-central West Virginia. The Monongahela is divided into two HUC8 level watersheds: the Upper Monongahela (05020003), which is entirely within West Virginia except for a small portion that extends from the state line to the confluence of the Cheat River; and the West Virginia portion of the Lower Monongahela (05020005), whose drainage area lies within both West Virginia and Pennsylvania. The Monongahela River (the "Mon") flows northward for 128 miles from the confluence of the Tygart and West Fork Rivers in the mountains of north central West Virginia, into western Pennsylvania where it meets the Allegheny River to form the Ohio River. The West Virginia portion of the Monongahela River flows for about 37 miles through Marion and Monongalia Counties, passing through the cities of Fairmont and Morgantown.

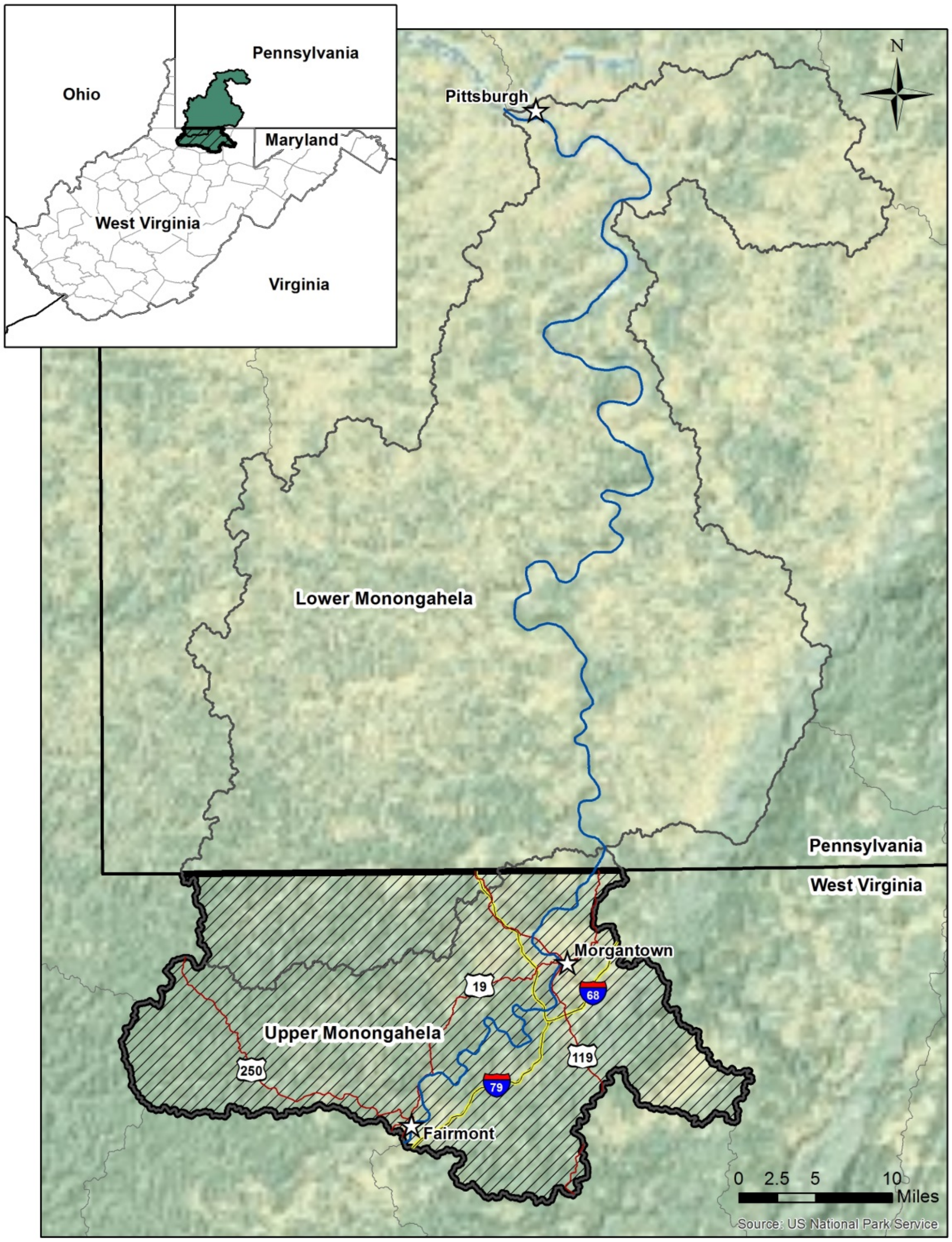

Figure 2. Monongahela River Watershed Study Area (USGS 2005)

Section 2: Monongahela Watershed Description

2.1 History/Economics

The name Monongahela is believed to be of Native American origin, meaning “crumbling or falling banks,” apparently related to the geologic instability and highly erodible nature of the river’s banks. The two major population centers within the watershed are Morgantown, situated in the north near the Pennsylvania state line, and Fairmont, just inside the southern boundary of the watershed. Both cities are located on the Monongahela River. Chartered in 1785 and incorporated in 1838, Morgantown had a population of 29,660 at the 2010 census and is home to West Virginia University, whose approximately 30,000 students double the size of the Morgantown area population for most of the year (WVU 2012). Fairmont, a contraction of “Fair Mountain,” is located at the confluence of the Tygart Valley River and West Fork River as they join to form the Monongahela. The city was chartered in 1843 and had a population of 18,704 at the 2010 census. Other communities throughout the watershed are quite small and rural, with populations less than 5,000.

Until the late 18th century, the history of the watershed was marked by repeated conflict between Native American tribes and early settlers. From very early on the Monongahela has been a working river. A lock and dam system has been in place since the early 19th century and through to the present, allowing navigation along the river’s full length for a variety of purposes that evolved over time, such as the transport of coal from West Virginian coal mines to the steel mills of Pittsburgh and eventually further, to power plants along the Ohio River and as far as New Orleans for international distribution. This navigation system altered the variability in flow that was a natural characteristic of the river, which was historically shallow and often ran dry during the late summer months. By 2006, the US Army Corps of Engineers (USACE) operated nine larger dam locks, with two planned to be converted into hydroelectric power plants in the future.

The history of the watershed is dominated by the coal industry, with extensive surface and underground mining activities beginning after the Civil War and only starting to decline after the 1970s (USEPA 2002). A major contributor to the increase in coal mining in the region was the development of rail lines and canals, with peaks in coal production occurring in the late 1800’s as demand for steel increased, and during World Wars I and II, due to industrial demand increasing alongside economic expansion (Ruppert and Rice 2001). Coal mining is still a significant part of the watershed’s economy today, with Marion and Monongalia counties contributing 22% of the underground mined coal and almost 15% of the total mined coal in West Virginia in 2010 (Table 2, WVOMHST 2012). Oil and gas production is a growing industry in the region, with the advancement of hydraulic fracturing techniques allowing greater access to the Marcellus Shale gas play that underlies the watershed. Forestry, agriculture, and recreation are also significant industries within the watershed.

Table 2. 2010 Coal Production by County, in tons (WVOMHST 2012)

County	Underground	Surface	Total
Marion	11,368,503	---	11,368,503
Monongalia	9,060,571	835,298	9,895,869
West Virginia	92,235,636	50,708,470	142,944,106

2.2 Climate

The Monongahela River watershed experiences a humid continental climate with variable weather patterns and a large seasonal temperature range. Temperatures are generally lowest in the mountainous areas in the southeast of the watershed, with the warmest temperatures within the central river valley. Outside of the higher elevations to the east, there is little overall variability in climate within the watershed. As shown in Figures 3 and 4, the average annual temperature in the eastern mountains ranges from 49-51 degrees Fahrenheit, with average annual precipitation from 47-51 inches. Temperature and precipitation average 53 degrees and 44 inches, respectively, in the central river valley and 51 degrees and 45 inches, respectively, in the west. Prevailing winds are from the west during most of the year, but in the summer low pressure cyclonic systems often bring southerly winds and heavy precipitation (USACE 2011).

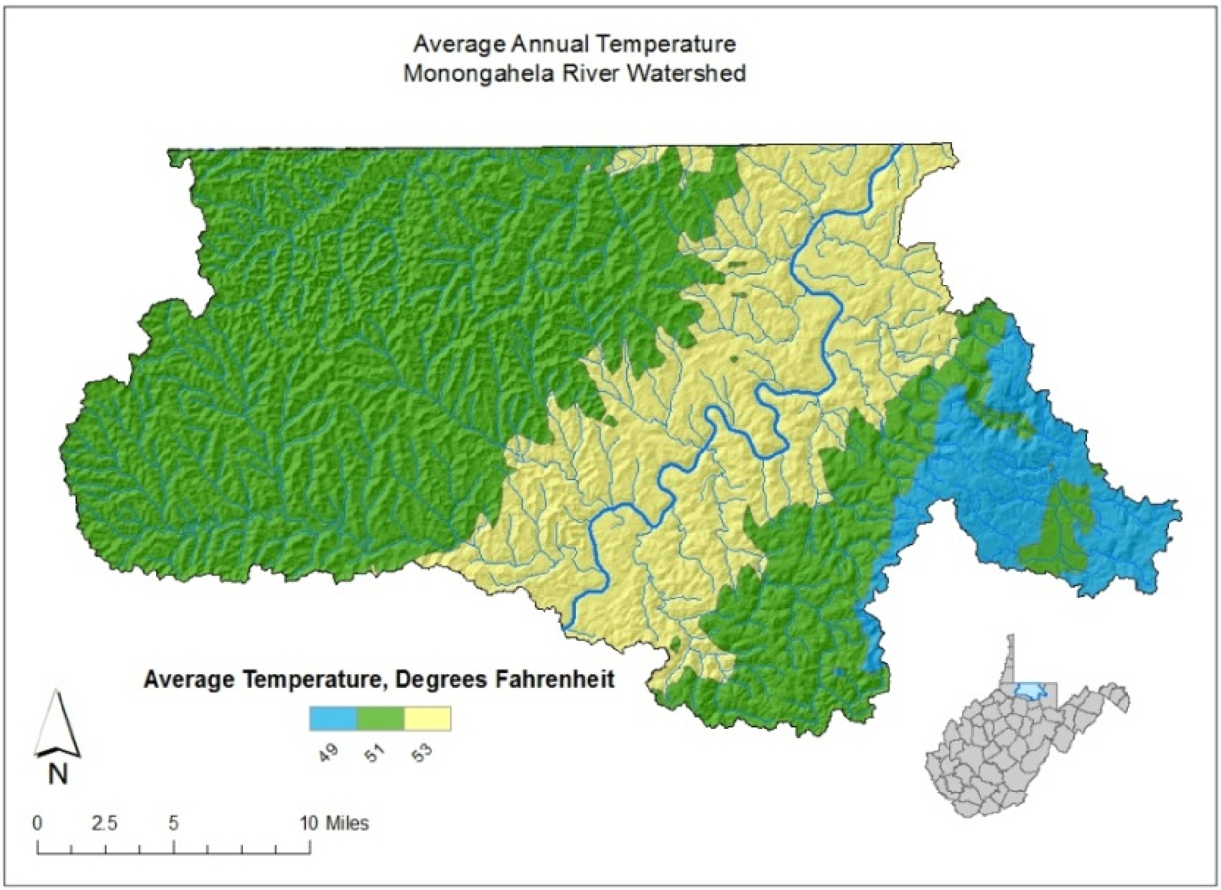

Figure 3. Average Annual Temperature in the Monongahela River Watershed (USDA/NRCS 2006a)

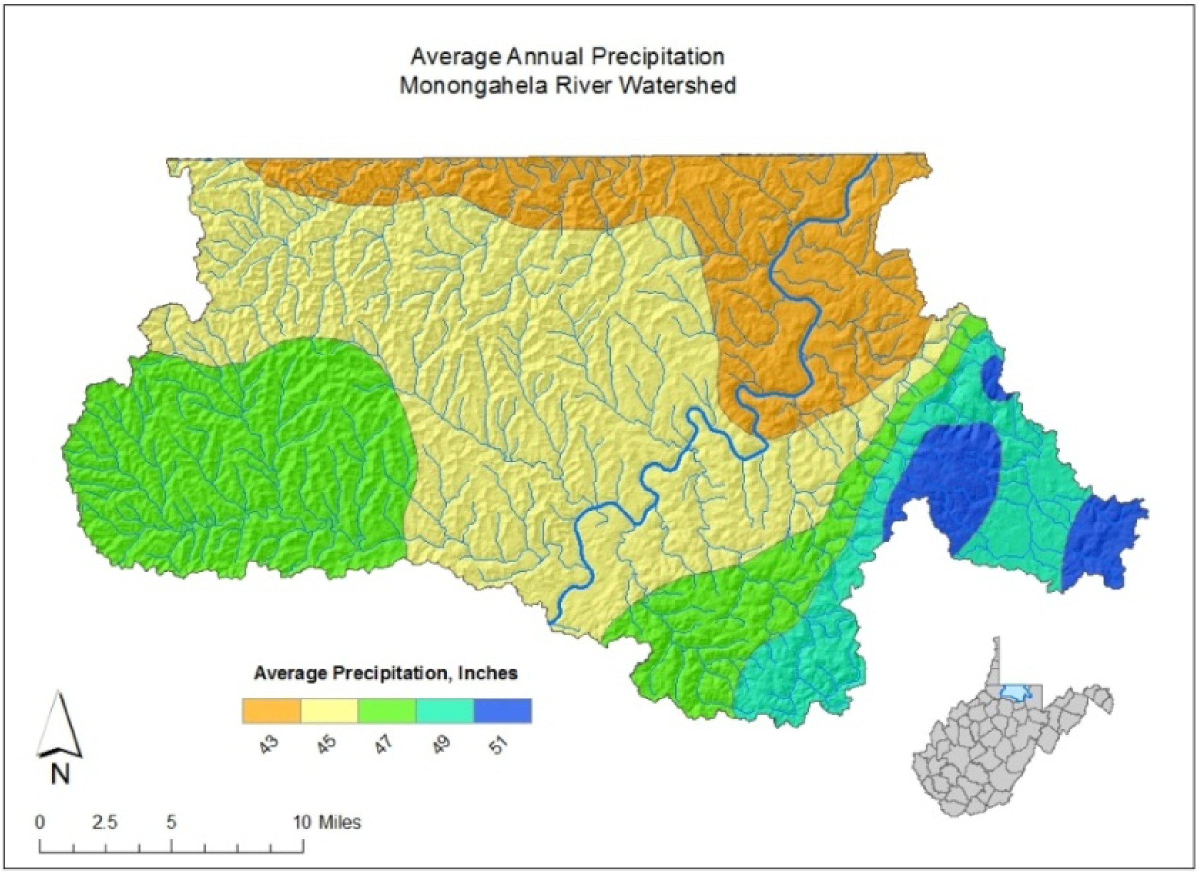

Figure 4. Average Annual Precipitation in the Monongahela River Watershed (USDA/NRCS 2006b)

2.3 Natural Resources

2.3.1 Ecoregions/Geology

The Monongahela River watershed is located within two ecoregions defined by The Nature Conservancy (modified from the ecoregions of Bailey 1995; Figure 5), which correspond to the USEPA Level III Ecoregions (Figure 6, Omernik et al. 1992). The majority of the watershed is part of the TNC Western Allegheny Plateau Ecoregion (USEPA Ecoregion 70), characterized as a mostly unglaciated, dissected plateau composed of horizontally embedded sedimentary rock (Woods et al. 1999). Ecoregion 70 soils support mixed mesophytic and oak (primarily white and red oak) forests, with forested cover remaining common, as the terrain is often too steep for farming or development. The easternmost portion of the watershed is in the TNC Central Appalachian Plateau ecoregion (USEPA Level III Ecoregion 69), which is characterized primarily by high, dissected and rugged terrain, with a cool climate and infertile soils, resulting in Ecoregion 69 being more densely forested and higher, cooler and steeper than the Western Allegheny Plateau (Woods et al. 1999). The watershed is underlain by sedimentary rocks (sandstone, shale, limestone, and coal), which are commonly fractured and folded, with more resistant

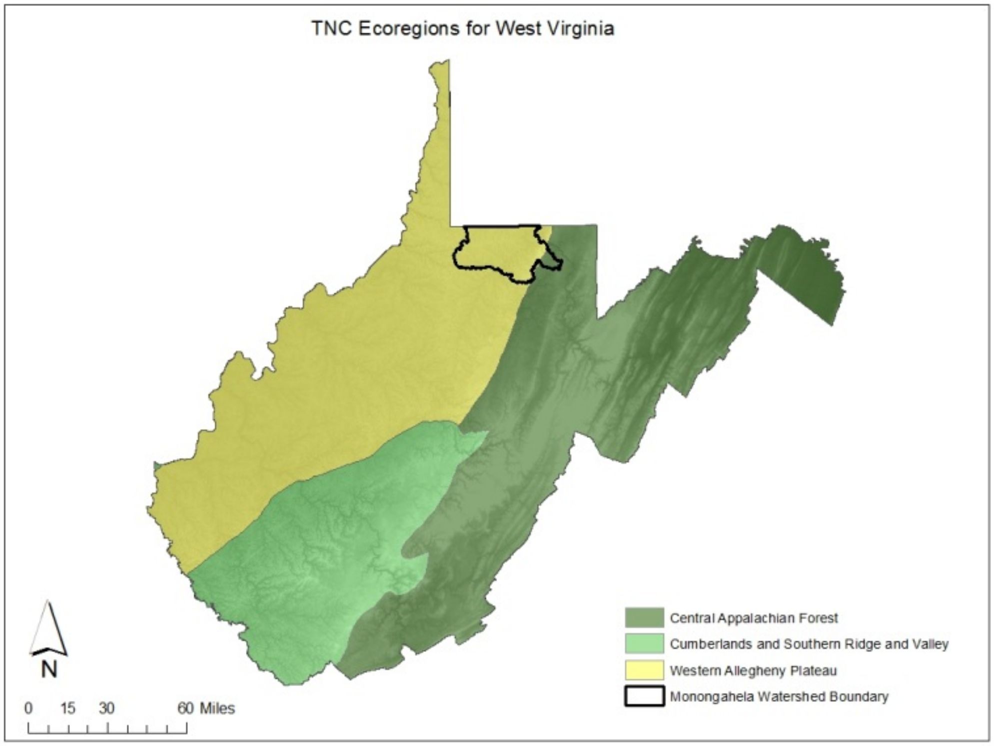

Figure 5. The Nature Conservancy Ecoregions – West Virginia (TNC 2009)

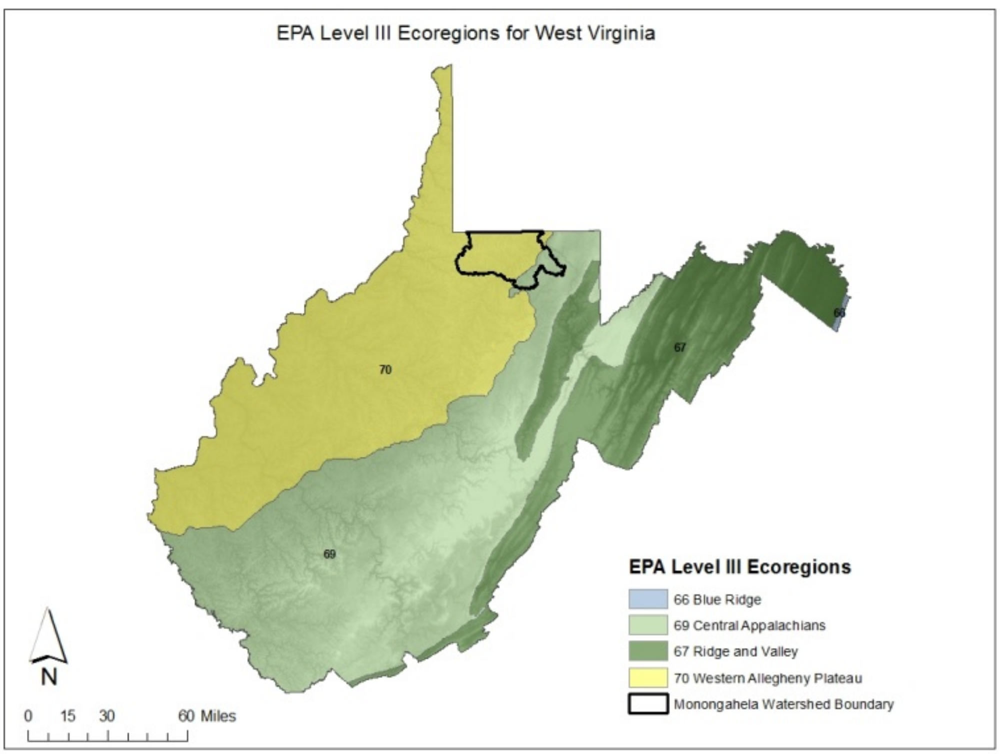

Figure 6. USEPA Level III Ecoregions – West Virginia (USEPA 2011)

rock underlying the Central Appalachian Plateau. The topography is generally rough, with deeply eroded stream valleys and terrain sloped at various degrees of steepness (USACE 2011).

The geologic features of the Monongahela watershed include Pennsylvanian and earliest Permian age coal-bearing strata, which are exposed at the surface across the entire Upper Monongahela watershed. In West Virginia, these strata are subdivided into the following groups (from oldest to youngest): Pottsville Group, Allegheny Formation, Conemaugh Group, Monongahela Formation and Dunkard Group. All of the northern coal fields are high volatile A and B bituminous in rank and generally have moderate to high ash yield and non-compliant sulfur content (Blake 2012). The majority of the economically mineable coal seams are found within the Allegheny and Monongahela Formations, most notably the Sewickley, Pittsburgh, Upper Freeport, and Lower, Middle and Upper Kittanning (PADEP 2012). The Pittsburgh coal seam is the thickest and most extensive coal bed in Appalachia and has been mined extensively for over 200 years, accounting for the highest production among all seams within West Virginia (Ruppert and Rice 2001). Eighty percent of coal from the Pittsburgh seam is used to generate electricity.

The Marcellus Shale formation, a large deposit of black sedimentary rock containing natural gas, underlies the entire watershed at a depth of 4,000-8,500 feet (USACE 2011). The thickness of the Marcellus shale increases from west-east across the watershed, ranging from 40-60 feet in the western portion to 100-120 feet within the higher eastern elevations (WVGES 2012b). Production from the Marcellus play has grown rapidly since 2008, due to advancements in hydraulic fracturing technology making extraction more economically feasible. The Monongahela River was listed as one of American Rivers' Most Endangered Rivers in 2010, resulting from the potential threat of "toxic pollution created by natural gas extraction activities in the Marcellus Shale", and due to the river being considered a valuable source of drinking water and recreation (American Rivers 2010).

2.3.2 Land Use/Land Cover

According to a 2009 land cover analysis (Maxwell et al. 2011, Figure 7), the Monongahela River watershed consists predominately of deciduous, evergreen, and mixed forest (Table 3), dominated by oak, beech, and hemlock trees. Development is largely concentrated around the urban centers of Morgantown and Fairmont. Grazing pasture is the predominant anthropogenic land use besides development, with other agricultural land use types at less than 1% of the watershed. There are very few wetlands, with most occurring in the riparian area and floodplains.

2.3.3 Biodiversity

The West Virginia Natural Heritage Program has recorded 38 Species in Greatest Need of Conservation (SGNCs) in the Monongahela watershed (WVDNR 2005). The USFWS listed the snuffbox (*Epioblasma triquetra*), a freshwater mussel, as a federally endangered species in February of 2012, due to declining populations and various threats including loss and degradation of stream habitat due to dams, pollution, mining, and sedimentation issues (USFWS 2012). In 2002 the Fisheries Technical Committee of the Pennsylvania Biological Survey filed a petition to list the Monongahela drainage population of the longnose sucker (*Catostomus catostomus*) as an endangered species, arguing that it was a distinct subpopulation; however, the petition was rejected by the US Fish and Wildlife Service (USFWS 2007). The Cheat minnow (*Pararhinichthys bowersi*), is designated by NatureServe as globally

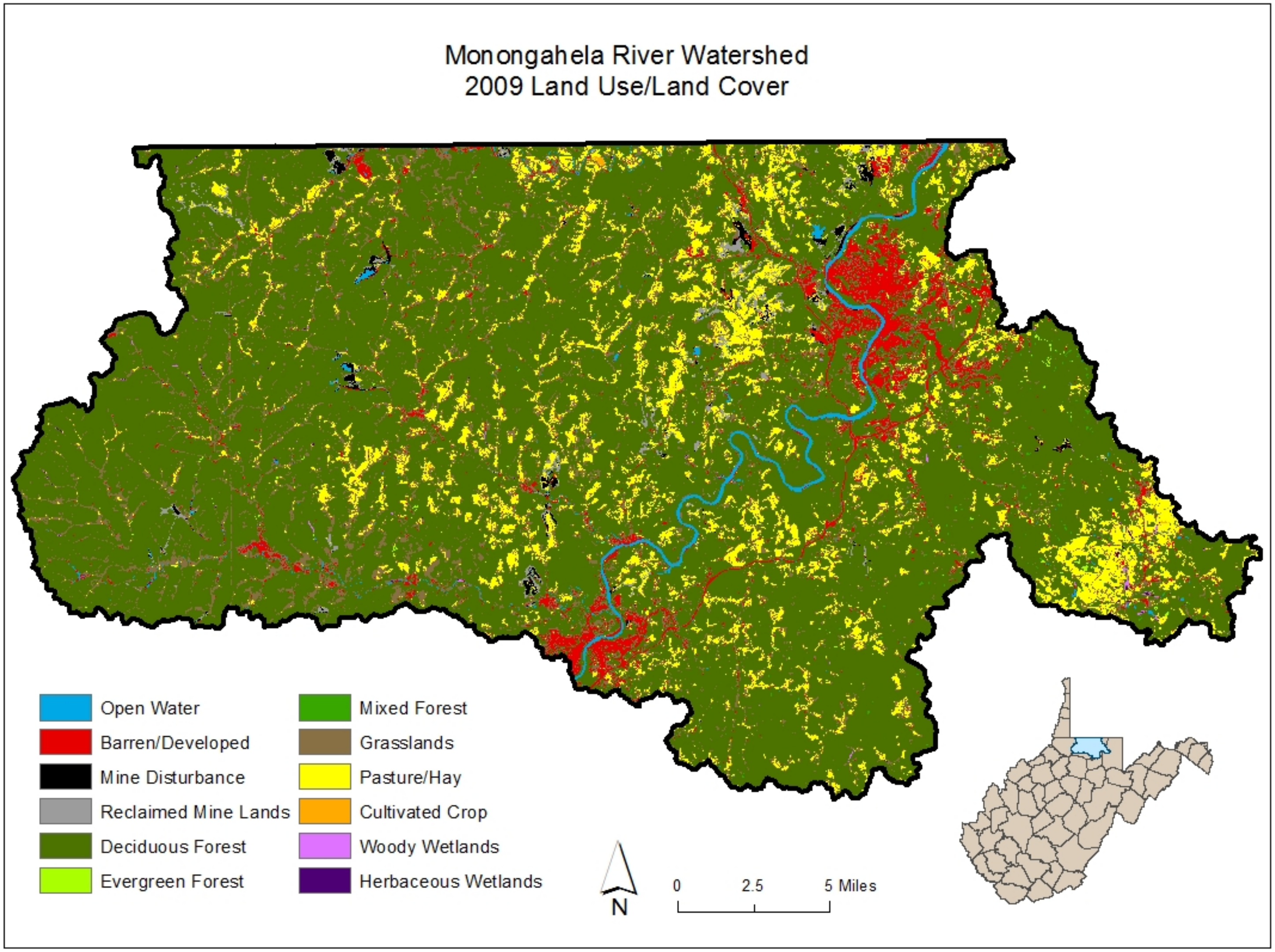

Figure 7. Monongahela River Watershed – Land Use/Land Cover 2009-2010 (Maxwell et al. 2011)

Table 3. Monongahela River Watershed - Land Use/Land Cover 2009-2010 (Maxwell et al. 2011)

Land Cover Type	Square Miles	Percent Area
Forest	421	75
Grassland	59	10
Pasture	50	9
Development	21	4
Mining Disturbance	8	1
Open Water	5	< 1
Agriculture	< 1	< 1
Wetlands	< 1	< 1

Imperiled/critically imperiled (rank G1G2, NatureServe 2012). The majority of the species are globally secure, although they are imperiled or vulnerable at the sub-national level (Table 4). An explanation of species rankings is provided in Table 5.

Thirty-four species of non-native invasive plants have been recorded in the Monongahela River watershed (Table 6), the five most common being multiflora rose (*Rosa multiflora*), Japanese knotweed (*Polygonum cuspidatum*), tree-of-heaven (*Ailanthus altissima*), common teasel (*Dipsacus fullonum*), and Japanese honeysuckle (*Lonicera japonica*). Invasive aquatic species such as Asian clam (*Corbicula fluminea*) and common carp (*Cyprinus carpio*) have been recorded in the Monongahela River, and zebra mussels have been found up to the Opekiska lock and dam.

Table 4. Rare Species in Monongahela River Watershed (WVDNR 2005)

Taxa	Scientific Name	Common Name	Global Rank	Sub-National Rank	Federal Rank
Amphibian	*Pseudotriton ruber*	Northern Red Salamander	G5		
Bird	*Tyto alba*	Barn Owl	G5		
Bird	*Carduelis pinus*	Pine Siskin	G5		
Crustacean	*Cambarus monongalensis*	A Crayfish	G5		
Crustacean	*Stygobromus franzi*	Franz's Cave Amphipod	G3G4		
Fish	*Pararhinichthys bowersi*	Cheat Minnow	G1G2Q		
Fish	*Lampetra aepyptera*	Least Brook Lamprey	G5		
Fish	*Ameiurus melas*	Black Bullhead	G5		
Fish	*Lepomis gulosus*	Warmouth	G5		
Fish	*Carpiodes carpio*	River Carpsucker	G5		
Fish	*Clinostomus elongatus*	Redside Dace	G4		
Fish	*Hiodon tergisus*	Mooneye	G5		
Insect	*Tachopteryx thoreyi*	Gray Petaltail	G4	S3	
Insect	*Enallagma vesperum*	Vesper Bluet	G5	S3	

Taxa	Scientific Name	Common Name	Global Rank	Sub-National Rank	Federal Rank
Insect	*Aeshna verticalis*	Green-striped Darner	G5	S23	
Insect	*Sympetrum semicinctum*	Band-winged Meadowhawk	G5	S34	
Insect	*Tramea carolina*	Carolina Saddlebags	G5	S3	
Insect	*Macromia taeniolata*	Royal River Cruiser	G5	S3	
Insect	*Stylogomphus albistylus*	Eastern Least Clubtail	G5	S3	
Insect	*Ladona deplanata*	Blue Corporal		S3	
Insect	*Anax longipes*	Comet Darner	G5	S3	
Insect	*Tramea onusta*	Red Saddlebags		S1	
Insect	*Celithemis fasciata*	Banded Pennant	G5	S3	
Insect	*Archilestes grandis*	Great Spreadwing	G5	S3	
Insect	*Macromia illinoiensis*	Swift River Cruiser	G5	S3	
Insect	*Chaetaglaea cerata*	A Noctuid Moth	G3G4		
Insect	*Hadena ectypa*	A Noctuid Moth	G3G4		
Insect	*Cicindela patruela*	Barrens Tiger Beetle	G3		
Insect	*Cicindela marginipennis*	Cobblestone Tiger Beetle	G2		
Insect	*Speyeria idalia*	Regal Fritillary	G3		
Mammal	*Neotoma magister*	Allegheny Woodrat	G3G4		
Mammal	*Zapus hudsonius*	Meadow Jumping Mouse	G5		
Bivalve	*Epioblasma triquetra*	Snuffbox	G3		LE
Bivalve	*Pleurobema sintoxia*	Round Pigtoe	G4		
Bivalve	*Simpsonaias ambigua*	Salamander Mussel	G3		
Plant	*Viola appalachiensis*	Appalachian Blue Violet	G3		
Plant	*Hasteola suaveolens*	Sweet-scented Indian-plantain	G3		
Plant	*Trifolium stoloniferum*	Running Buffalo Clover	G3		LE

Table 5. Species Rankings Definitions (NatureServe 2012)

G1	**Critically Imperiled**—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.
G2	**Imperiled**—At high risk of extinction or elimination due to very restricted range, very few populations steep declines, or other factors.
G3	**Vulnerable**—At moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors.
G4	**Apparently Secure**—Uncommon but not rare; some cause for long-term concern due to declines or other factors.
G5	**Secure**—Common; widespread and abundant.
LE	**Listed Endangered (Federal)** under the US Endangered Species Act of 1973
LT	**Listed Threatened (Federal)** under the US Endangered Species Act of 1973
S1	**Critically Imperiled**—Critically imperiled in the jurisdiction because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the jurisdiction.

S2	**Imperiled**—Imperiled in the jurisdiction because of rarity due to very restricted range, very few populations, steep declines, or other factors making it very vulnerable to extirpation from jurisdiction.
S3	**Vulnerable**—Vulnerable in the jurisdiction due to a restricted range, relatively few populations, recent and widespread declines, or other factors making it vulnerable to extirpation.
S4	**Apparently Secure**—Uncommon but not rare; some cause for long-term concern due to declines or other factors.
S5	**Secure**—Common, widespread, and abundant in the jurisdiction.

Table 6. Invasive Species in Monongahela River Watershed (WVDA 2011)

Taxa	Scientific Name	Common Name
Plant	*Ailanthus altissima*	Tree-of-heaven
Plant	*Albizia julibrissin*	Mimosa, Silk Tree
Plant	*Alliaria petiolata*	Garlic mustard
Plant	*Barbarea vulgaris*	Yellow rocket
Plant	*Berberis thunbergii*	Japanese barberry
Plant	*Buddleja davidii*	Butterfly Bush (Orange-eyed)
Plant	*Carduus acanthoides*	Plumeless thistle
Plant	*Celastrus orbiculatus*	Asiatic bittersweet
Plant	*Centaurea biebersteinii*	Spotted knapweed
Plant	*Centaurea nigra*	Black knapweed
Plant	*Cirsium arvense*	Canada thistle
Plant	*Cirsium vulgare*	Bull thistle
Plant	*Conium maculatum*	Poison hemlock
Plant	*Cuscuta sp.*	Dodders
Plant	*Daucus carrota*	Queen Anne's lace
Plant	*Dipsacus fullonum*	Common teasel
Plant	*Dipsacus laciniatus*	Cutleaf teasel
Plant	*Elaeagnus umbellate*	Autumn olive
Plant	*Glechoma hederacea*	Ground Ivy
Plant	*Hedera helix*	English ivy
Plant	*Holcus lanatus*	Common velvetgrass
Plant	*Iris pseudacorus*	Yellow iris
Plant	*Lespedeza cuneata*	Sericea
Plant	*Lonicera japonica*	Japanese honeysuckle
Plant	*Lonicera maackii*	Amur honeysuckle
Plant	*Lonicera morrowii*	Morrow’s honeysuckle
Plant	*Lythrum salicaria*	Purple loosestrife
Plant	*Microstegium vimineum*	Japanese stiltgrass
Plant	*Orobanche sp.*	Broomrapes
Plant	*Paulownia tomentosa*	Princess tree
Plant	*Polygonum cuspidatum*	Japanese knotweed
Plant	*Polygonum sachalinense*	Giant knotweed
Plant	*Pueraria Montana*	Kudzu vine
Plant	*Rosa multiflora*	Multiflora rose
Bivalve	*Dreissena polymorpha*	Zebra mussel
Bivalve	*Corbicula fluminea*	Golden clam/Asian clam
Fish	*Cyprinus sp.*	Asian carp

2.3.4 Impaired Streams

Currently, the quality of the Monongahela River and its tributaries are being negatively affected by acid mine drainage from underground mines abandoned before the West Virginia Surface Coal Mining and Reclamation Act (WVSCMRA) and Surface Mining Control and Reclamation Act (SMRCA) came into effect (USEPA 2002). However, while mine drainage laden with acid and/or minerals has long been acknowledged as one of the most serious and persistent water quality issues in the Monongahela basin, on-going remediation and restoration work has resulted in significant improvement in water quality over the past two decades, with increases in median pH, decreases in dissolved solids and an increase in the number and diversity of fish species (Anderson et al. 2001). In 2010, 135 stream miles in the Monongahela watershed, including the main stem of the river, were classified by WVDEP as 303(d) impaired streams, with impairments including bacteria, biology, pH, and metals. In 2002, metals and pH

Total Maximum Daily Loads (TMDLs) were generated for 39 waterbodies in the Monongahela Watershed. In Spring 2009, the WVDEP announced plans to develop TMDLs for all impaired tributaries in the Monongahela Watershed and expects to submit them to EPA by September 2013 (WVDEP 2010; Montali 2013). Sixteen miles of Whiteday Creek, in the southeastern section of the watershed, are designated as trout streams. Approximately eighty miles of streams in the Monongahela watershed have been judged by WVDNR to be high quality with potential for mussels or in which an endangered mussel species was identified.

A significant water quality issue occurred in the watershed when Dunkard Creek, a tributary of the Monongahela River that meanders along the West Virginia-Pennsylvania border in the western portion of the watershed, suffered a toxic event that resulted in significant mortality of the creek's fish, mussel, and mudpuppy salamander populations in September of 2009. The WVDEP determined that the cause of the devastation was a bloom of golden algae, which are usually found in brackish waters of the coastal states. Previous studies by the WVDNR indicated that Dunkard Creek supported one of the richest fish communities in the state in addition to the most diverse and abundant mussel population left in the Monongahela Basin before the golden algae bloom (Wellman et al. 2011). Some controversy still exists about whether the elevated stream conductivities and chloride levels in the creek that precipitated the golden algae bloom were caused by deep mine discharges from underground coal mining activities or by briny wastewater from Marcellus shale hydraulic fracturing activities (Soraghan 2011). In March of 2011, Consol Energy, Inc. agreed to pay a $5.5 million civil penalty for Clean Water Act violations and to install a reverse osmosis wastewater treatment plant near Mannington, WV, to treat mining wastewater. The WVDNR intends to use this money to restore the fish and mussel populations of Dunkard Creek to pre-kill levels. So far, monitoring conducted by WVDEP and Consol Energy indicate that Dunkard Creek has been free of golden algae since January 2010, and there is indication that the fish population is recovering well (WVDEP 2011c).

2.3.6 Vegetation Types

According to the Northeast Terrestrial Habitat Classification System (Gawler 2008), the upland habitat of the Monongahela River watershed is dominated by dry interior oak forest and mesophytic forest, with smaller pockets of specialized habitats such as Appalachian cove forest and hardwood forest (Table 7). For the purposes of this analysis, however, we used the more general concept of "forested cover" and combined the three forest landcover classifications (deciduous, evergreen, mixed) defined by the landcover dataset of Maxwell et al. (2011).

Table 7. Northeast Terrestrial Habitat Types – Monongahela River Watershed (TNC 2011b)

Ecological System Code	Habitat Type	Acres	Square Miles	Percent Area
202.592	Northeastern Interior Dry-Mesic Oak Forest	131,721	206	36
202.887	South-Central Interior Mesophytic Forest	99,884	156	28
20	Developed	41,680	65	12
80	Agriculture	40,540	63	11
202.359	Allegheny-Cumberland Dry Oak Forest and Woodland	36,438	57	10
11	Open Water	3,975	6	1
202.373	Southern and Central Appalachian Cove Forest	3,266	5	< 1
5271	Grassland/Shrubland/Herbaceous	2,391	4	< 1
202.593	Appalachian (Hemlock)-Northern Hardwood Forest	1,106	2	< 1
202.591	Central Appalachian Dry Oak-Pine Forest	172	< 1	< 1
201.594	Laurentian-Acadian Freshwater Marsh	166	< 1	< 1
201.582	Laurentian-Acadian Wet Meadow-Shrub Swamp	95	< 1	< 1
202.604	North-Central Appalachian Acidic Swamp	77	< 1	< 1
202.601	North-Central Appalachian Acidic Cliff and Talus	25	< 1	< 1
202.605	North-Central Interior and Appalachian Rich Swamp	14	< 1	< 1
202.690	Central Interior Calcareous Cliff and Talus	10	< 1	< 1

Section 3: Assessment Methodology

3.1 Assessment Design

3.1.1 Planning Units

The assessment analysis was conducted at two spatial scales, beginning with planning units at the coarser scale of 12-digit USGS Hydrologic Unit Code (HUC) watersheds (referred to as HUC12 watersheds) nested within the HUC8 watershed (Figure 8). A HUC12 is a drainage area delineated by a spatial modeling technique using 24K scale hydrographic and topographic maps and data, to represent a 10,000-40,000 acre area that contributes source water to a single outlet point on a river or stream. It is identified by a 12-digit code indicating its position in the larger landscape, as well as a name corresponding to a significant hydrographic, cultural, or political feature within its boundaries (USGS 2009, NRCS 2012). A HUC12 may be composed of headwater streams, in which case it is self-contained, or it may include streams that originate in an upstream HUC12, in which case its water quality may be influenced by attributes of the upstream watershed. Detailed information about the HUC12 watersheds within the Monongahela River basin is presented in Table 8.

A finer level of planning units consisted of NHDPlus catchments within the HUC8 watershed, a scale at which protection or restoration activities are more likely to take place. The NHDPlus catchments are elevation-derived drainage areas of individual stream segments produced by Horizon Systems Corporation, using a drainage enforcement technique that involved "burning-in" the 100K NHD flowlines and, when available, building "walls" using the national Watershed Boundary Dataset, primarily to achieve a compatible and hydrologically accurate catchment for each stream segment (USEPA and USGS 2005). Some NHDPlus catchments were modified to provide a more uniform planning unit size, by dividing very large catchments into smaller units or merging very small catchments with the larger adjacent catchment.

3.1.2 Landscape Classification

Watersheds were divided into three separate landscapes that were analyzed independently of each other, and for which separate sets of results at both levels of planning units (HUC12 watersheds and NHDPlus catchments) were calculated:

3.1.2.1 Streams/Riparian Areas

Streams considered in the assessment were defined using the USGS National Hydrography Dataset 24K (NHD24K) flowlines, plus an approximately 90-125 meter riparian buffer. The NHD24K dataset is known to be missing some headwater stream reaches, particularly intermittent streams, but several constraining factors, such as compatibility between datasets and amount of manual processing time required to generate auxiliary data for certain metrics, resulted in the NHD24K being the most detailed and reliable source of stream line data for the purposes of this project.

A riparian buffer was delineated using the northeast regional Active River Area (ARA) dataset generated by TNC’s Eastern Regional Office (Smith et al. 2008). The ARA is based on the concept that river health depends on a dynamic interaction between the water and the land through which it flows, thus incorporating both aquatic and riparian habitats. The ARA explicitly considers processes such as

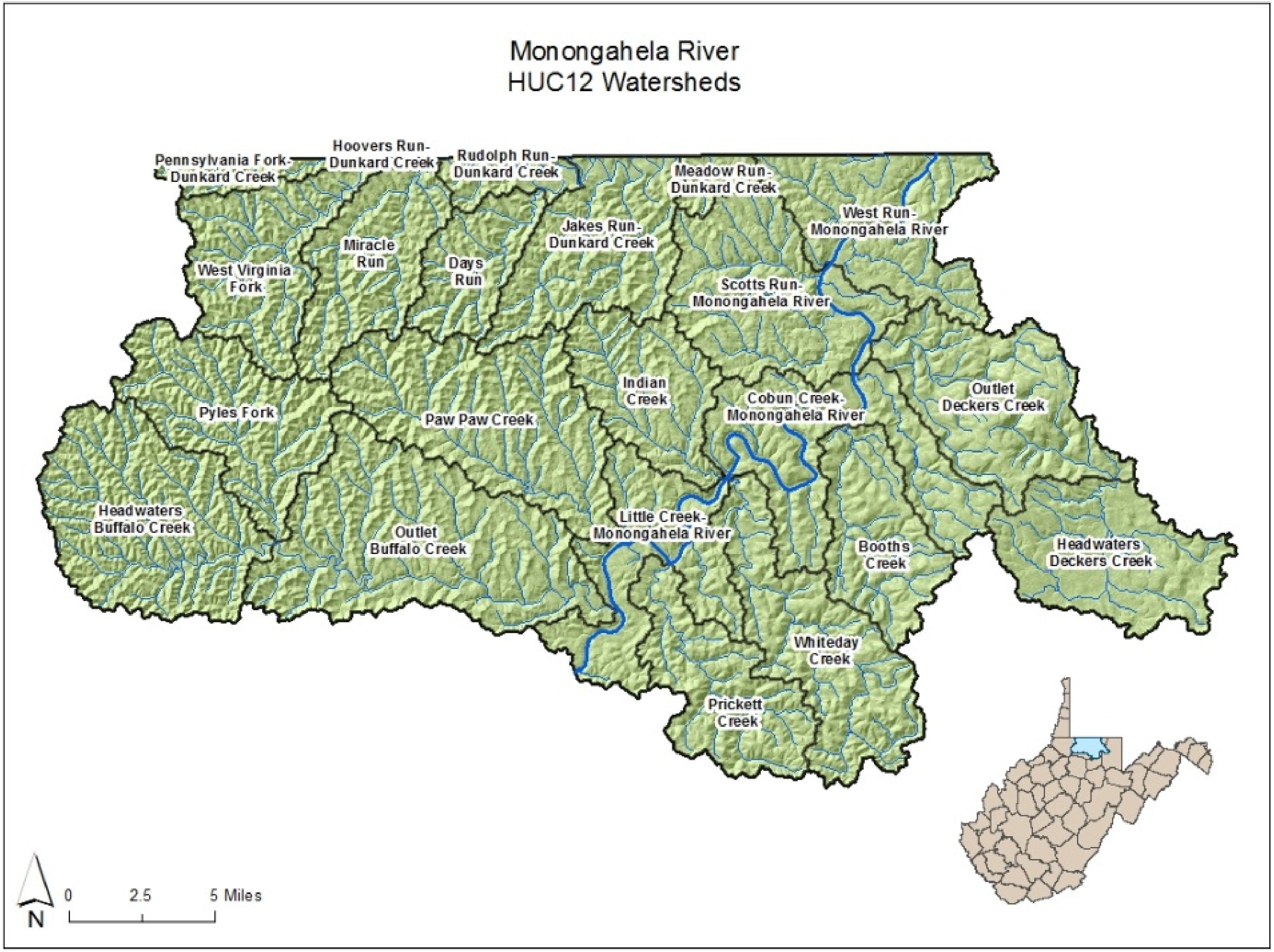

Figure 8. Monongahela River HUC12 Watersheds (NRCS 2009)

Table 8. Monongahela River Watershed – HUC12 Watershed Information (NRCS 2009, USGS 2011)

HUC12	HUC12 Name	Acres	Square Miles	Stream Miles (100K)	Stream Miles (24K)
050200030101	Pyles Fork	19175	30	41	64
050200030102	Headwaters Buffalo Creek	26446	41	64	94
050200030103	Outlet Buffalo Creek	34528	54	70	98
050200030201	Headwaters Deckers Creek	19211	30	37	54
050200030202	Outlet Deckers Creek	21316	33	52	62
050200030301	Paw Paw Creek	27144	42	54	81
050200030302	Prickett Creek	15635	24	32	41
050200030303	Indian Creek	13706	21	28	45
050200030304	Whiteday Creek	21050	33	46	63
050200030305	Little Creek-Monongahela River	17233	27	27	49
050200030306	Booths Creek	13795	22	32	41
050200030307	Cobun Creek-Monongahela River	21705	34	46	64
050200030308	Scotts Run-Monongahela River	22464	35	47	62
050200030309	West Run-Monongahela River	18393	29	39	47
050200050102	West Virginia Fork	16918	26	43	63
050200050103	Pennsylvania Fork-Dunkard Creek	3273	5	8	10
050200050104	Miracle Run	14854	23	28	56
050200050105	Hoovers Run-Dunkard Creek	222	0.35	0.85	1
050200050106	Days Run	9355	15	22	34
050200050107	Rudolph Run-Dunkard Creek	4045	6	12	17
050200050108	Jakes Run-Dunkard Creek	18186	28	40	58
050200050109	Meadow Run-Dunkard Creek	2607	4	2	7

system hydrologic connectivity, floodplain hydrology, and sediment movement along the river corridor and delineates areas along a stream where such processes are likely to occur (Smith et al 2008). However, the ARA for this region was generated based on the NHD 100K flowlines dataset, a coarser-level dataset than the NHD24K dataset. Since a primary goal of the project was to analyze headwater streams within each HUC8, the greater detail of the NHD24K dataset was needed. Therefore, a 120-meter buffer was generated for any headwater streams that occurred within the 24K dataset, but were not covered within the Active River Area.

3.1.2.2 Wetlands

Wetlands considered in this assessment were defined using the US Fish and Wildlife Service's NWI dataset. The West Virginia NWI contains data collected over a large time period, from February 1971 to December 1992, and the statewide coverage was published in 1996. Therefore, the quality and accuracy of the wetland locations within the watershed are questionable, as the dataset is both old and largely based on interpretation of aerial photography and a variety of field survey techniques. The general NWI palustrine wetland types are listed in Table 9. To include the immediately surrounding wetland habitat into the analysis, a 50-meter wetland buffer was generated. A width of 50 meters was chosen based on a literature review and discussions with experts during workshops. Additionally, some metrics were calculated based on the catchment area for each wetland. These catchments were delineated by NHDPlus catchments, using flow direction grids to determine which NHDPlus catchments drained to a particular wetland, and manually selecting those catchments to create a wetland catchment layer that approximated the total drainage area for all mapped wetlands within a watershed.

Table 9. National Wetland Inventory (NWI) Wetland Types – Monongahela River Watershed (USFWS 2010)

NWI Code Prefix	NWI Wetland Type	Total Acres
PEM	Palustrine Emergent Wetland	244
PFO	Palustrine Forested Wetland	74
PSS	Palustrine Shrub-Scrub Wetland	119

3.1.2.3 Uplands

The purpose of including uplands as a separate landscape was two-fold: to characterize areas that are important for terrestrial species, and to quantify the potential impacts of upland habitat disturbance on water quality. We defined uplands as any areas not included in the riparian or wetland buffers; however, the material contribution zone of the Active River Area extended into the uplands. For the majority of metrics, we used the spatial datasets for the entire watershed instead of limiting the analysis to the riparian or wetland buffer as with the analysis of the previous two landscapes.

3.2 Priority Models

Three Priority Models were defined based on the three landscapes defined in the assessment:

- Streams/Riparian Areas
- Wetlands
- Uplands

Priority models were further divided into several indices to assess both the condition and function of the watershed (Table 10). Each index was defined by numerous metrics, derived from various datasets that were processed and analyzed for each planning unit (HUC12 and NHDPlus catchment). Condition and function include both *quality indicators* of the inherent physical features of the landscape (e.g., total miles of headwater streams), as well as any *stressors*, or anthropogenic/natural factors that may have a negative impact on the landscape (e.g., active surface mining). In many instances, a direct measurement or data source for a particular metric was unavailable or unreliable. In such cases, surrogate data were identified and used to estimate quality or stress (e.g., dam drainage area used to approximate the impacts of flow alteration from impoundments).

The objective was to identify and utilize datasets that characterize the following aspects of the watershed:

a. Riparian, wetland, and upland natural resources in the watershed
b. Functional values and ecological services provided by the natural resources in the watershed (surface water use, flood storage/abatement, groundwater use, sediment retention, pollutant assimilation, recreational benefits, etc.)
c. Freshwater connectivity within the watershed, and hydrologic connections upstream and downstream of the watershed (where appropriate), to determine how these affect watershed condition
d. Water quality impairments (including 303(d) stream listings, acid mine drainage (AMD) impaired, and TMDL streams) within the watershed, and issues affecting hydrology and environmental flows
e. The contribution of consumptive water use on aquatic resource quantity and function
f. Rare, unique and/or sensitive species (and their habitat requirements) and vegetative communities within the watershed

Table 10. Watershed Characterization Priority Models and Indices

Priority Model	**Index**
Streams	Water Quality
	Water Quantity
	Hydrologic Connectivity
	Biodiversity
	Riparian Habitat
Wetlands	Water Quality
	Hydrology
	Biodiversity
	Wetland Habitat
Uplands	Habitat Connectivity
	Habitat Quality
	Biodiversity

g. Existing conservation investments on the ground (local, state, federal, and private conservation lands; conservation easements; mitigation sites)
h. Identified government and private conservation priorities within the watershed (protection and/or restoration priorities identified by conservation organizations and government agencies)
i. Natural physical vulnerability of the watershed as indicated by factors such as slope, highly erodible soils, etc.
j. Land use practices in the watershed with the potential to negatively impact natural resource value and function (resource extraction activities such as mining, oil and gas well drilling, mineral operations; development, road construction, etc.)
k. Land use practices in the watershed with the potential to cause pollution of aquatic resources (point sources such as facilities that discharge to water, non-point sources such as impervious cover runoff, agriculture, landfills, etc.)
l. Sources of natural resource and/or function loss due to fragmentation (dams, transportation infrastructure, energy transmission, etc.)

3.2.1 Streams/Riparian Areas Model

The *Streams Water Quality* (SWQ) index attempted to evaluate the overall water quality of all streams within the watershed. Metrics for impaired streams included those that have been 303(d) listed, covered by a Total Maximum Daily Load (TMDL) requirement, or are known to be impacted by acid mine drainage (AMD). Many streams were monitored and sampled by the WVDEP Watershed Assessment Branch (WAB) for a variety of standard water quality parameters (e.g., pH, sulfates, heavy metals, specific conductivity), as well as biological and habitat indices, such as GLIMPSS (Genus Level Index of Most Probable Stream Status, a measure of macroinvertebrates) and RBP (Rapid Bioassessment Protocol, a measure of habitat quality) scores. However, as other factors may affect the water quality in a stream, and many stream segments lack a WAB sampling station, several surrogate metrics were added to this index. These included percent imperviousness and various anthropogenic land uses and potential stressors (e.g., surface and underground mining, roads and railroads, well locations, etc.).

The *Streams Water Quantity* (SWN) index attempted to evaluate the overall degree of flow alteration within a given planning unit. However, very little data were available as direct measurements of stream flow or of stream withdrawals or discharges, with the few known points of such activities (such as public water supply intakes or sewer treatment plants) having incomplete or possibly inaccurate attribute data regarding water volume. The USGS stream-gauging network, a principal source of streamflow data in West Virginia, is concentrated on large streams. Since flow characteristics of large and small streams are different, flow data from the main stem of the Monongahela River could not be used to distinguish among the various HUC12s in the watershed (Messinger 2012). Therefore, surrogate metrics were developed to approximate the impact of water use within a planning unit and its potential alteration of flow, such as area of mining activities (surface and underground), percent of impervious surface, and dam drainage area (the total catchment area above a dam).

The *Streams Hydrologic Connectivity* (SHC) index attempted to evaluate the aquatic connectivity of the watershed in terms of network complexity and overall system integrity, with accompanying metrics such as miles of headwater streams, the mean local integrity of the planning unit, and total wetland area. The SHC index also addressed the more functional elements of hydrologic connectivity, focusing primarily on unimpeded flow and the ability of a stream segment to allow passage for aquatic species. Metrics generated for this purpose included the number of any potential structural impediments such as dams, roads/railroads in the riparian area (a surrogate for culverts and bridges), and conditions that may cause temperature changes that would affect passage of organisms (such as power plants whose discharges may raise overall stream temperatures or forested riparian area where the canopy may help maintain cooler temperatures).

The *Streams Biodiversity* (SBD) index attempted to capture the species diversity within the stream and riparian area, including metrics for the presence of rare or endangered species, the maximum number of invertebrate taxa found in stream samples, and known locations of non-native invasive species. Since species data for West Virginia do not distinguish between areas sampled with no species found and areas not sampled, additional metrics were included as an estimate of potential species presence (such as calcareous bedrock and number of terrestrial habitat types in the riparian area). Because of the lack of robust biodiversity data, this index received a weight of half compared to the other indices, and results should be used with caution.

The *Streams Riparian Habitat* (SRH) index attempted to characterize the habitat within the approximately 90-125 meter riparian buffer (the Active River Area), assuming that intact natural cover within this buffer will be most effective at stabilizing stream banks, moderating stream temperature, and providing habitat (such as native aquatic vegetation, rocks, and logs) for aquatic species. Corresponding metrics included various land uses and land cover within the riparian buffer (natural cover, mining, agriculture, grazing), percent impervious cover within the riparian area, RBP scores, and fragmenting features such as roads and wells.

3.2.2 Wetlands Model

The *Wetlands Water Quality* (WWQ) index attempted to identify the current water quality condition of existing wetlands, as well as approximate the functional value of each wetland in terms of pollutant filtration and sediment retention, two major functions related to wetland water quality. Thus, wetlands were evaluated based on their inherent ability to serve a designated function, as well as their potential for serving such function based on surrounding land uses and potential pollutants. WWQ metrics included type of wetland (e.g., forested headwater wetland) and stressors located within the wetland catchment (i.e., the drainage area of the wetland; with metrics including the amount of agriculture, grazing, or development; percent imperviousness; active surface mining; and wells). Since the WWQ metrics are dependent on the existence of a wetland, those planning units without an existing NWI wetland were excluded from this index.

The *Wetlands Hydrology* (WHY) index attempted to quantify the wetland extent within an area as well as assess the functional aspect of potential flood storage. Wetland extent was represented by total wetland area, while potential flood storage capacity metrics included the area of forested floodplain wetlands, total floodplain area, and hydric soils. These metrics also identified areas in the watershed with a greater potential for wetlands to develop under wet conditions, and which may have been areas of wetland loss in the past. It is due to these “potential wetlands” metrics (hydric soils and floodplain area) that the WHY index was calculated for all planning units (at both the HUC12 and NHDPlus catchment level), and not just those containing existing NWI wetlands. Any planning units with the potential wetlands metrics but no mapped NWI wetlands may be considered potential sites for wetland restoration.

The *Wetlands Biodiversity* (WBD) index attempted to capture the species diversity within the wetland buffer area, including metrics for the presence of rare or endangered species and known locations of non-native invasive species. Since species data for West Virginia do not distinguish between areas sampled with no species found and areas not sampled, additional metrics were included as an estimate of potential species presence (such as calcareous bedrock and number of terrestrial habitat types within the wetland buffer). Because of the lack of robust biodiversity data, this index received a weight of half compared to the other indices, and results should be used with caution.

The *Wetlands Wetland Habitat* (WWH) index attempted to quantify the habitat condition within the wetland buffer area. Habitat quality metrics included percent of natural cover and the mean size of unfragmented forest patches that intersected a given wetland buffer (connection with a larger forest patch is likely to create more desirable habitat within a wetland area). Habitat stressors included metrics that may indicate the amount of fragmentation within the wetland buffer, such as surface mining, wells, and road/railroad density.

3.2.3 Uplands Model

The *Uplands Habitat Connectivity* (UHC) index attempted to assess the ability of terrestrial organisms to reside and move within the landscape. It is generally agreed that blocks or corridors of native vegetation are most conducive to hosting native animal species. In West Virginia the natural cover is primarily forest. The amount of habitat required varies by taxon and species, but large forest blocks and blocks that are connected provide the optimal habitat for a variety of species to disperse, establish breeding territories, and migrate (Anderson et al. 2004). Habitat connectivity is positively affected by forest block size and local integrity, a metric developed by Compton et al. (2007) that quantifies the structural connections between ecosystems in a landscape. Fragmenting features (e.g., roads, energy transmission lines, and resource extraction) negatively affect habitat connectivity.

The *Uplands Habitat Quality* (UHQ) index attempted to quantify the degree to which a landscape has been altered from its original condition. Metrics included heterogeneity (a measure of landform variety) and the percent of the planning unit in natural cover (forest, grassland, wetlands). Conversion of forest to agriculture or pastureland is an example of degraded habitat quality. Some metrics that impact habitat connectivity also impact habitat quality, such as development and resource extraction.

The *Uplands Biodiversity* (UBD) index attempted to capture the species diversity within the uplands area, including metrics for the presence of rare or endangered species and known locations of non-native invasive species. Since species data for West Virginia do not distinguish between areas sampled with no species found and areas not sampled, additional metrics were included as an estimate of potential species presence (such as calcareous bedrock and number of terrestrial habitat types). Additional datasets were available from the US Forest Service (USFS) that provided information about predicted tree basal area loss to pests and pathogens within upland forests. Because of the lack of robust biodiversity data, this index received a weight of half compared to the other indices, and results should be used with caution.

3.3 Ranking Procedure

3.3.1 Objective Classification

The goal of the project was to prioritize the planning units for protection and restoration opportunities. To achieve this, it was necessary to develop a method of ranking planning units based on their current ecological condition and inherent overall quality. Therefore, individual metrics were evaluated using thresholds that assigned metric results to one of four quality categories, indicating the degree of deviation from a desirable ecological condition: Very Good, Good, Fair, and Poor (Table 11). These objective, or “categorized,” rankings were determined at both the HUC12 and NHDPlus catchment scales of planning units.

The Good/Fair threshold is also referred to as the “restoration threshold,” with any planning units in the Fair category requiring restoration to bring the planning unit into an acceptable ecological condition. Planning units in the Good category may require some restoration to increase the quality to ideal conditions and move the score into the Very Good category, and any planning units in the Very Good category should be considered as potential candidates for protection activities. Planning units in the Poor category may also be potential candidates for restoration, depending on the goals of the individual organization or restoration project.

Thresholds were used to define quantitatively, for each metric, the divisions among the four quality categories. Initially, research focused on identifying sources for threshold values from literature and previous studies (e.g., the percentage of surface mining that places the corresponding metric into a Poor category, or a specific conductivity level that places the metric into a Fair category). However, beyond a few land use classifications and impervious cover percentages, very few thresholds have been established in the scientific literature for landscapes comparable to those in West Virginia. Additional threshold values were solicited from experts, but there was still a notable lack of reliable, defensible threshold values for most metrics. Therefore, an alternative approach was developed using WVDEP’s reference and stressed streams to define the thresholds. The WVDEP has defined three levels (I, II, III) of reference (i.e., high quality) streams, which categorize a stream based on both water quality sampling data and field survey/visual inspections, such as Rapid Bioassessment Protocol (RBP) scores (Table 12).

Table 11. Definition of Objective Method Categories (Foundations of Success 2009)

Category	Definition
Very Good	Planning unit is in ecologically desirable status; requires little intervention or maintenance.
Good	Planning unit is within acceptable range of variation; some intervention is required for maintenance.
Fair	Planning unit is outside of an acceptable range of variation; requires human intervention.
Poor	Restoration of the planning unit is increasingly difficult; may result in extirpation of target.

Table 12. WVDEP Reference Stream Criteria (Pond et al. 2012)

Parameter	Value
Dissolved Oxygen	≥ 6.0 mg/l
pH	≥ 6.0 and ≤ 9.0
Conductivity	<500 µmhos/cm
Fecal coliform	<800 colonies/100 ml
RBP Epifaunal Substrate score	≥11
RBP Channel Alteration score	≥11
RBP Sediment Deposition score	≥11
RBP Bank Disruptive score	≥11
RBP Riparian Vegetation Zone Width score	≥6
RBP Total Habitat score	65% of maximum 200
No obvious sources of non-point source pollution	
Evaluation of anthropogenic activities and disturbances	
No known point discharges upstream of assessment site	

Level I reference streams are the highest quality, while Level II indicates slightly lower quality streams that still meet most criteria for reference stream designation, and Level III are considered the best representatives in geographic areas lacking true reference streams (WVDEP 2013). To ensure that only the highest quality streams were included in the analysis, the project used only Level I and II reference streams to determine threshold values.

The WVDEP has also identified criteria for water quality sampling and field survey data that indicate whether or not a particular stream reach is significantly impaired (Table 13). While the WVDEP defines stressed sites as meeting at least one of these criteria, this project used at least two criteria to minimize the potential for false positives.

To establish thresholds, the contributing NHDPlus catchments for both reference and stressed streams were identified, resulting in 501 reference catchments and 583 stressed catchments statewide, with a relatively broad and inclusive geographic distribution (Figure 9). Applicable metrics were calculated for the 1,084 reference/stressed catchments for all three landscapes (Streams/Riparian, Wetlands, Uplands) and threshold values were derived from these calculated results.

Table 13. WVDEP Stressed Stream Criteria (Pond et al. 2012)

Parameter	Value
Dissolved Oxygen	<4.0 mg/l
pH	< 4.0 or > 9.0
Conductivity	>1,000 µmhos/cm
Fecal coliform	>4,000 colonies/100 ml
RBP Epifaunal Substrate score	<7
RBP Channel Alteration score	<7
RBP Sediment Deposition score	<7
RBP Bank Disruptive score	<7
RBP Riparian Vegetation Zone Width score	<4
RBP Total Habitat score	<120

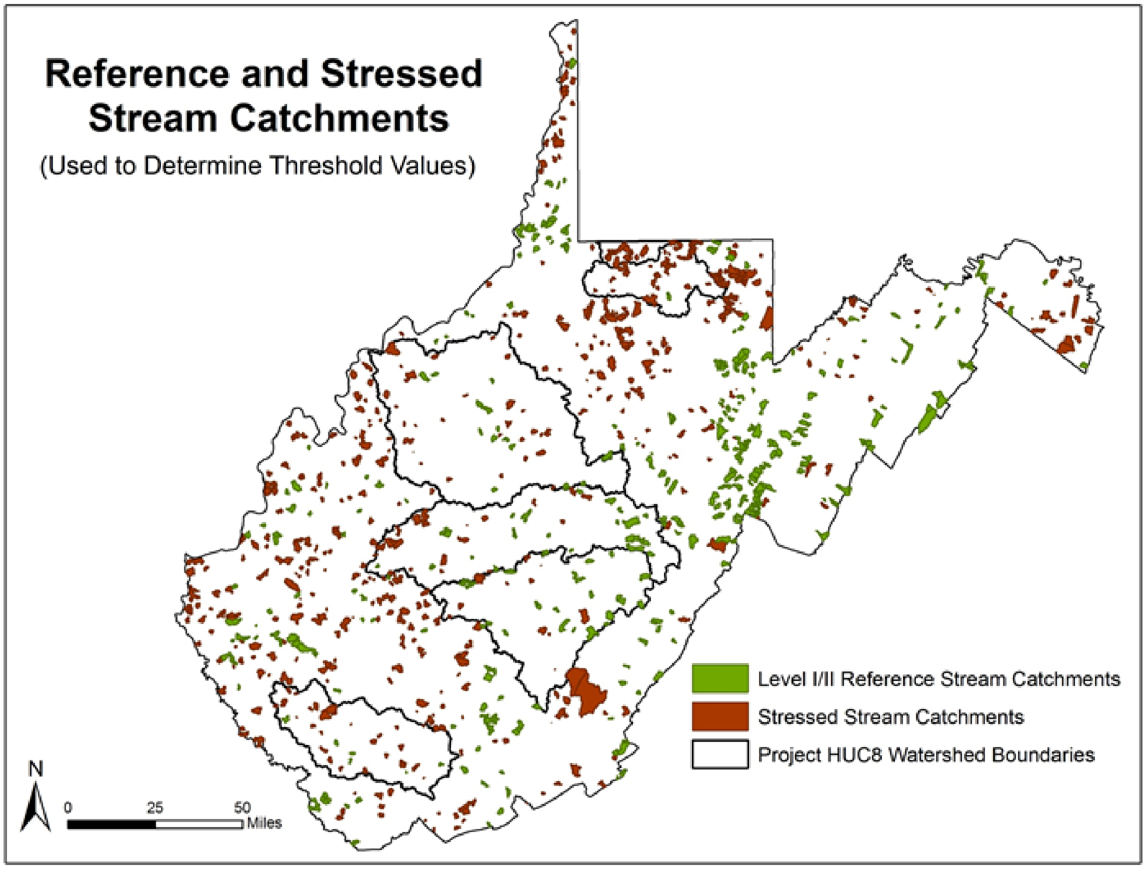

Figure 9. Reference and Stressed Stream Catchments

3.3.2 Objective Thresholds

To determine threshold values for each category, the distributions of the reference and stressed metric values were examined individually, and final analysis results were evaluated through an iterative process, using different percentiles as potential threshold values for all metrics. Different scenarios were run using different percentiles of the individual metrics as thresholds for all five pilot watersheds. Results were examined for consistency and validated by comparing the results of the various scenarios with known high-quality and impacted areas and by presenting the results to experts familiar with the condition of these areas at the expert workshops. For example, planning units in wilderness areas were expected to be in the Very Good category across most indices for all three models (Streams/Riparian Areas, Wetlands, and Uplands). Similarly, planning units with significant mining or development were expected to score predominantly in the Poor to Fair categories across most indices. It was determined during the expert workshops and project team discussions that the most consistent and reliable results were achieved when using the following percentiles: the Very Good/Good threshold was set as the 35% highest quality of reference catchment values, the Good/Fair threshold was set as the 75% highest quality of reference catchment values, and the Fair/Poor threshold was set as the 35% lowest quality of stressed catchment values (Figure 10). This methodology did not work well for some metrics with extremely skewed distributions, for example where both the 35th percentile and the median and 75th percentile were zero. Table 14 lists the percentiles for three different types of metrics: roads and railroads in the riparian area (a negative metric, with higher values indicating lower quality); percent forested riparian area (a positive metric, with higher values indicating higher quality); and percent surface mining (a metric for which this method of threshold selection did not work) in 5% increments for both stressed and reference catchments. Metrics for which the reference/stressed threshold determination were not suitable were either set as presence/absence metrics, resulting in a Good score if the metric was present for positive metrics or absent for negative metrics, or a Fair score if the metric was absent for positive metrics or present for negative metrics. A small subset of metrics (e.g., impervious cover and percent mining) had reliable threshold values in the literature, in which cases the values from the literature were used after consultation with and validation from experts at expert workshops. As water quality parameters were used by the WVDEP to define reference and stressed catchments, thresholds for water quality parameters were defined using the WVDEP's water quality standards.

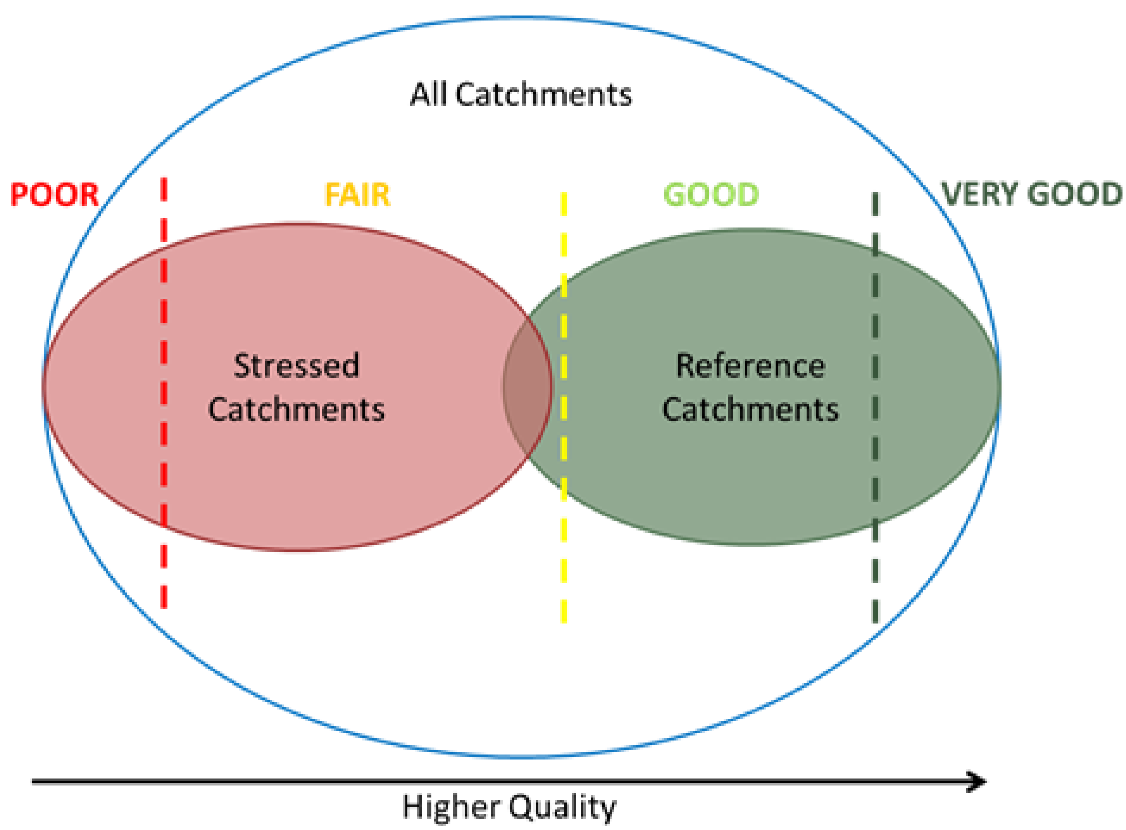

Figure 10. Threshold Definition Model

Table 14. Reference and Stressed Distribution Examples for Three Types of Metrics

Percentile[a]	Reference Catchments			Stressed Catchments		
	Negative Metric: Roads and Railroads in the Riparian Area (mi roads/sq mi planning unit)	Positive Metric: Percent Forested Riparian Area	Alternate Method[b]: Percent of Planning Unit with Surface Mines	Negative Metric: Roads and Railroads in the Riparian Area (mi roads/sq mi planning unit)	Positive Metric: Percent Forested Riparian Area	Alternate Method: Percent of Planning Unit with Surface Mines
Min/Max	0.00	102.7[c]	0.00	0.0	99.8	0.00
5th/95th	0.00	100.6	0.00	0.20	94.7	0.00
10th/90th	0.00	100.2	0.00	1.22	91.5	0.00
15th/85th	0.00	100.0	0.00	1.98	87.8	0.00
20th/80th	0.00	99.7	0.00	2.46	84.5	0.00
25th/75th	0.00	99.5	0.00	2.86	82.2	0.00
30th/70th	0.00	99.2	0.00	3.25	80.7	0.00
35th/65th	0.00	98.7[d]	0.00	3.62	78.0	0.00
40th/60th	0.00	98.5	0.00	3.93	75.2	0.00
45th/55th	0.13	98.0	0.00	4.29	63.8	0.00
Median	0.29	97.6	0.00	4.63	67.1	0.00
55th/45th	0.51	96.7	0.00	5.10	63.8	0.00
60th/40th	0.87	95.8	0.00	5.47	61.0	0.00
65th/35th	1.14	94.5	0.00	5.97	57.0[f]	0.24
70th/30th	1.69	93.2	0.00	6.34	53.4	0.80
75th/25th	2.46	91.6[e]	0.00	7.02	49.9	1.51
80th/20th	3.10	90.1	0.00	7.93	44.9	2.99
85th/15th	3.72	88.0	0.00	9.07	40.3	5.47
90th/10th	4.57	83.5	0.00	10.97	33.3	9.78
95th/5th	5.83	75.9	0.06	14.43	20.6	20.11
96th/4th	6.26	74.6	0.21	15.94	17.0	24.84
97th/3rd	6.49	72.3	0.54	16.87	14.5	27.72
98th/2nd	6.81	69.8	1.59	18.29	10.7	38.96
99th/1st	9.74	59.1	7.68	23.93	6.4	51.02
Max/Min	34.6	1.28	29.28	35.27	2.9	84.93

[a] Negative metrics used the first percentile (i.e., Minimum value if row is “Min/Max”), positive metrics used the second percentile (i.e., Maximum value if row is “Min/Max)
[b] Alternate method used for threshold selection
[c] Values are higher than 100% because of differences in the spatial properties of the geographic information system (GIS) datasets between the landcover dataset used for this metric and the planning units
[d] Selected as percentile for Very Good/Good threshold
[e] Selected as percentile for Good/Fair threshold
[f] Selected as percentile for Fair/Poor threshold

3.3.3 Critical Metrics

Discussions held during expert workshops suggested that some metrics, subsequently referred to as “critical metrics,” indicated an impairment or land use alteration of enough significance that these metrics should limit the final index category value, regardless of other metric values in that index. For instance, if a planning unit had a high enough percentage of impervious cover that placed the metric into the Fair category, the final index score for that planning unit could not be higher than Fair, regardless if other metrics ranked Good or Very Good. Since the Water Quality index in the Streams model had more critical metrics than the other indices, two of the critical metrics had to be Fair or Poor to cap the index at that category. Only a handful of metrics were considered critical (Table 15).

Table 15. Critical Metrics for Priority Model Analysis

Model	Index	Critical Metrics
Streams	Water Quality	Percent imperviousness
		Surface mining (active & legacy)
		Median pH values
		Median specific conductivity values
	Water Quantity	Percent imperviousness
	Hydrologic Connectivity	None
	Biodiversity	None
	Riparian Habitat	Percent imperviousness in riparian area
		Active surface mining in riparian area
Wetlands	Water Quality	None
	Hydrology	None
	Biodiversity	None
	Wetland Habitat	Development in wetland buffer
		Active surface mining in wetland buffer
Uplands	Habitat Connectivity	Development
		Active surface mining
	Habitat Quality	Development
		Active surface mining
	Biodiversity	None

3.3.4 Metrics Final Selection

Initially, the project team identified 214 metrics to characterize the three landscapes (listed in Appendix B: Metrics Description and GIS Process). The values for these metrics at the HUC12 level for all five HUC8 watersheds were subjected to a Pearson's Correlation analysis separately for each model, and if two metrics were highly correlated (R > 0.90), one of the metrics was eliminated. For metric pairs with correlation coefficients between 0.75-0.90, one of the metrics was eliminated if they were judged to be truly redundant. The full set of HUC12 metric values for the Streams priority model (which had the greatest number of metrics) was subjected to a Principal Components Analysis (PCA) to identify the most important metrics to retain in the assessment, i.e., those metrics that accounted for the greatest variation among the HUC12s. Three principal components together accounted for 45% of the variation among HUC12s (Table 16). The most influential component (eigenvalue 18.29, 25% of variation explained) described a gradient of anthropogenic disturbance, from high negative loadings on metrics such as forested riparian area and natural cover in headwater catchments, to high positive loadings on development metrics such as roads/railroads in riparian area. The second component (eigenvalue 9.34, 13% of variation explained) consisted of different mining and coal metrics, while the 3rd component consisted of oil and gas wells (eigenvalue 5.18, 7% of variation explained). Some of the metrics that were identified as important in the PCA were dropped from the assessment due to high correlation with other metrics, lack of data across watersheds, or other reasons. After the correlation and Principal Components Analyses, and discussions with experts at the expert workshops, the final current condition analysis dataset was reduced to 94 metrics.

Table 14 lists all metrics that were used in the final analysis with details on grouping of metrics into individual indices, thresholds, method of determining the thresholds, weight of the metrics in the final analysis, critical metrics, and if a metric was considered a positive or negative metric in the final analysis.

3.3.5 Metric Weights

Metrics were weighted to ensure that each metric contributed a value in its corresponding index relative to its significance in terms of affecting watershed condition. The weights were assigned to each metric based on literature where available, but more often on a synthesis of current knowledge provided by experts from TNC, state and federal agencies, universities, non-profit organizations, and local experts. Recommendations were provided and subsequently refined at several expert workshops and/or by follow-up correspondence with experts. Metric and index weights ranged from 0 to 3, with a weight of 0 assigned to those metrics initially considered but later removed from the analysis (see Appendix B for a full list of metrics originally considered in the analysis). Metrics with weights greater than 0 and considered in the final analysis are listed in Table 17.

Table 16. Principal Components Analysis of Streams Condition Metrics

Metric	Factor Loading*
Component 1	
Forested riparian area	-0.8252
Natural cover in headwater catchments	-0.6871
Median GLIMPSS scores	-0.6836
Local integrity in headwater catchments	-0.6786
Median taxa richness	-0.6210
Large quantity users	0.5107
Wastewater treatment plants	0.5166
Biologically impaired streams	0.5272
Septic systems in riparian area	0.5464
Power plants	0.5780
Energy transmission lines in riparian area	0.6117
Bridges	0.6600
Septic systems	0.6730
Roads and railroad density in riparian area	0.7385
Percent imperviousness	0.7659
Buildings in riparian area	0.7799
NPDES permits	0.7866
Development in riparian area	0.8049
Road and railroad density	0.8056
Component 2	
Total coal production	0.6804
Legacy surface mining in riparian area	0.7279
Active surface mining in riparian area	0.7395
Active surface mining	0.7514
Legacy surface mining	0.7641
Coal NPDES permits	0.7889
Component 3	
Oil and gas wells in riparian area	-0.6943

*Only factors with loadings > |0.5| and loading on only one component are presented here.

Table 17. Metrics Included in the Current Condition Analysis

Model	Index	Metric Description (* "Critical Metric")	Weight	Units	Positive/ Negative Metric[a]	Threshold Method	Threshold: Very Good – Good	Threshold: Good – Fair	Threshold: Fair – Poor
STREAMS	*Water Quality* *(Weight: 1)*	AMD, TMDL, 303(d) impaired streams	2	% of total stream miles in planning unit	N	Reference/stressed	0	11.32	78.09
		Median pH values*[c]	2	Index[b]	P	Literature	350[b]	250	150
		Median sulfate values[d]	1	Index	P	Literature	350	250	150
		Median specific conductivity values*[e]	1.5	Index	P	Literature	350	250	150
		Median GLIMPSS scores[f]	2	Index	P	Literature	350	250	150
		Median sedimentation & embeddedness[g]	1	Index	P	Literature	350	250	150
		Percent imperviousness*	2	mean % imperviousness per planning unit	N	Literature	0	2	8
		All wells	1.5	#/sq mi planning unit	N	Reference/stressed	0	2.28	5.47
		Surface mining (active & legacy)*	2	% of planning unit	N	Literature/Expert opinion	2	10	20
		Underground mining	2	% of planning unit	N	Reference/ stressed	0	3.82	18.30
		Agriculture in riparian area	1	% of riparian area	N	Reference/ stressed	0	0.07	0.12
		Grazing/pasture in riparian area	1	% of planning unit	N	Reference/ stressed	0	1.67	10.31
		Development in riparian area	1	% of planning unit	N	Reference/ stressed	0	0.02	2.44
		Natural cover in riparian area	2	% of planning unit	P	Reference/ stressed	99.88	97.01	75.48
		All roads & rail	1.5	miles/sq mi planning unit	N	Reference/ stressed	0.13	1.66	2.79
	Water Quantity *(Weight: 1)*	Public water supply intakes	0.5	#/stream mi	N	Presence/ absence	-	0	-
		Large quantity users	2	#/stream mi	N	Presence/ absence	-	0	-
		Wastewater treatment plants	0.5	# customers served/sq mi planning unit	N	Presence/ absence	-	0	-
		Dam drainage area	1	% of planning unit	N	Presence/absence	-	0	-
		Percent imperviousness*	1.5	mean % imperviousness per planning unit	N	Literature	0	2	8
		Surface mining (active & legacy)	1	% of planning unit	N	Literature/Expert opinion	2	10	20
		Underground mining	1.5	% of planning unit	N	Reference/ stressed	0	3.82	18.30
	Hydrologic Connectivity	Headwater streams (size class 1a)	1.5	% of total stream miles in planning unit	P	Presence/ absence	-	0	-
		Local integrity score	1	mean score/planning unit	P	Reference/ stressed	44.43	30.35	20.72

Model	Index	Metric Description (* "Critical Metric")	Weight	Units	Positive/ Negative Metric[a]	Threshold Method	Threshold: Very Good – Good	Threshold: Good – Fair	Threshold: Fair – Poor
STREAMS	*Hydrologic Connectivity (Weight: 1)*	Total wetland area	1	% of planning unit	P	Presence/ absence	-	0	-
		Power plants	0.5	# / stream mi	N	Presence/ absence	-	0	-
		Forested riparian area	1.5	% of riparian area	P	Reference/ stressed	98.73	91.60	57.00
		Dams	1.5	#/ stream mi	N	Presence/absence	-	0	-
		All roads & rail in riparian area	2	mi/sq mi planning unit	N	Reference/ stressed	0	2.46	5.97
	Biodiversity (Weight: 0.5)	Rare species in riparian area	1.5	# species/riparian area	P	Presence/ absence	-	0	-
		Maximum taxa	1	maximum # taxa	P	Reference/ stressed	27	21	13
		Mussel streams	1	% of total stream miles in planning unit	P	Presence/ absence	-	0	-
		Northeast habitat types in riparian area	1	#/riparian area	P	Reference/ stressed	6	5	-
		Calcareous bedrock in riparian area	1	% of riparian area	P	Presence/ absence	-	0	-
		Non-native invasive species in riparian area	1.5	# species/riparian area	N	Presence/ absence	-	0	-
	Riparian Habitat (Weight: 1)	Median Rapid Bioassessment Protocol score[h]	1	Index	P	Literature	350	250	150
		Natural cover in riparian area	2	% of riparian area	P	Reference/ stressed	99.88	97.01	75.48
		Agriculture in riparian area	1	% of riparian area	N	Reference/ stressed	0	0.07	0.12
		Grazing/pasture in riparian area	1	% of riparian area	N	Reference/ stressed	0	1.67	10.31
		Percent imperviousness in riparian area*	2	% of riparian area	N	Reference/stressed	0	2	8
		Active surface mining in riparian area*	2	% of riparian area	N	Literature/Expert opinion	2	10	20
		Legacy surface mining in riparian area	1	% of riparian area	N	Literature/Expert opinion	2	10	20
		All wells in riparian area	1	#/sq mi riparian area	N	Reference/stressed	0	3.22	5.00
		All roads & rail in riparian area	1.5	miles/sq mi riparian area	N	Reference/stressed	0	2.46	5.97
WETLANDS	*Water Quality*	Forested headwater wetlands	2	% of planning unit	P	Presence/absence	-	0	-
		Agriculture in wetland catchment	1	% wetland catchment	N	Reference/stressed	0	0.01	0.37
		Grazing/pasture in wetland catchment	1	% wetland catchment	N	Presence/absence	-	0	-
		Development in wetland catchment	1	% wetland catchment	N	Reference/stressed	0	0.04	2.17

Model	Index	Metric Description (* "Critical Metric")	Weight	Units	Positive/ Negative Metric[a]	Threshold Method	Threshold: Very Good – Good	Threshold: Good – Fair	Threshold: Fair – Poor
WETLANDS	*Water Quality (Weight: 1)*	Natural cover in wetland catchment	3	% wetland catchment	P	Reference/stressed	98.78	92.97	72.82
		Percent imperviousness in wetland catchment	1	mean % imperviousness wetland catchment	N	Literature	0	2	8
		All roads & rail in wetland catchment	1	# miles/sq mi wetland catchment	N	Presence/absence	-	0	-
		Active surface mining in wetland catchment	2	% wetland catchment	N	Literature/Expert opinion	2	10	20
		All wells in wetland catchment	1	#/sq mi wetland catchment	N	Reference/stressed	0	0.60	3.90
	Hydrology (Weight: 1)	Total wetland area	2	% of planning unit	P	Presence/absence	-	0	-
		Forested headwater wetlands	1	% of planning unit	P	Presence/absence	-	0	-
		Floodplain, forested wetlands	1	sq mi/wetland buffer	P	Reference/stressed	-	0	-
		Floodplain area	1	% of planning unit	P	Presence/absence	-	0	-
		Hydric soils	1.5	% of planning unit with hydric soils	P	Presence/absence	-	0	-
	Biodiversity (Weight: 0.5)	Rare species in wetland buffer	1.5	# species/sq mi wetland buffer	P	Presence/absence	-	0	-
		Calcareous bedrock in wetland buffer	1	% of wetland buffer	P	Presence/absence	-	0	-
		Northeast habitat types in wetland buffer	1	# types in wet buffer/planning unit	P	Reference/stressed	5	3	-
		Non-native invasive species in wetland buffer	1.5	# species/sq mi wetland buffer	N	Presence/absence	-	0	-
	Wetland Habitat (Weight:1)	Natural cover in wetland buffer	2	% of wetland buffer	P	Reference/stressed	92.76	82.63	58.95
		Agriculture in wetland buffer	1	% of wetland buffer	N	Presence/absence	-	0	-
		Grazing/pasture in wetland buffer	1	% of wetland buffer	N	Reference/stressed	0	1.16	26.55
		Development in wetland buffer*	2	% of wetland buffer	N	Presence/absence	-	0	-
		Mean forest patch size within wetland buffer	1	mean sq mi forest block size in wetland buffer/planning unit	P	Reference/stressed	14.37	3.23	-
		All wells in wetland buffer	1.5	#/wetland buffer	N	Presence/absence	-	0	-
		Active surface mining in wetland buffer*	2	% of wetland buffer	N	Reference/stressed	2	10	20
		Legacy surface mining in wetland buffer	1	% of wetland buffer	N	Reference/stressed	2	10	20
		All roads & rail in wetland buffer	1	miles/sq mi in wetland buffer	N	Reference/stressed	0	0.93	5.99

Model	Index	Metric Description (* "Critical Metric")	Weight	Units	Positive/ Negative Metric[a]	Threshold Method	Threshold: Very Good – Good	Threshold: Good – Fair	Threshold: Fair – Poor
UPLANDS	*Habitat Connectivity (Weight: 1)*	Mean forest patch size	2	mean forest block size/planning unit	P	Reference/stressed	10.43	2.40	0.77
		Local integrity score	1.5	avg score/planning unit	P	Reference/stressed	44.43	30.35	20.72
		Development*	1.5	% of planning unit	N	Reference/stressed	0	0.11	1.55
		All roads & rail	1	miles/sq mi planning unit	N	Reference/stressed	0.13	1.66	2.79
		Energy transmission lines	0.5	miles/sq mi planning unit	N	Presence/absence	-	0	-
		Gas pipelines	0.5	miles/sq mi planning unit	N	Presence/absence	-	0	-
		Wind turbines	0.5	#/sq mi planning unit	N	Presence/absence	-	0	-
		All wells	1	#/sq mi planning unit	N	Reference/stressed	0	2.28	5.47
		Active surface mining*	1.5	% of planning unit	N	Literature/Expert opinion	2	10	20
		Timber harvesting operations	0.5	sq mi/planning unit	N	Presence/absence	-	0	-
	Habitat Quality (Weight:1)	Heterogeneity score	2	avg score/planning unit	P	Reference/stressed	38	36	33
		Natural cover (forest, grassland, wetland)	2	% of planning unit	P	Reference/stressed	98.59	94.00	79.96
		Active surface mining*	1.5	% of planning unit	N	Literature/Expert opinion	2	10	20
		Legacy surface mining	1	% of planning unit	N	Literature/Expert opinion	2	10	20
		Timber harvesting operations	1	sq mi/sq mi planning unit	N	Presence/absence	-	0	-
		Agriculture	1	% of planning unit	N	Reference/stressed	0	0.01	0.1
		Grazing/pasture	1	% of planning unit	N	Reference/stressed	0.06	4.14	9.76
		Development*	1.5	% of planning unit	N	Reference/ stressed	0	0.11	1.55
	Biodiversity (Weight: 0.5)	Rare species	1.5	#/sq mi planning unit	P	Presence/ absence	-	0	-
		Northeast habitat types	1	#/planning unit	P	Reference/ stressed	7	5	-
		Calcareous bedrock	1	% of planning unit	P	Presence/ absence	-	0	-
		Non-native invasive species	1.5	#/sq mi planning unit	N	Presence/ absence	-	0	-
		Percent tree basal area loss	2	% of planning unit	N	Reference/ stressed	3	15	30

[a] Positive metrics are characterized by higher values indicating higher quality, negative metrics are characterized by lower values indicating higher quality
[b] To enable comparison among different water quality parameters and among planning units, an index was calculated based on the WVDEP's water quality standards. Highest quality values were assigned the value 400, values higher than impairment level but not in the highest category were assigned the value 300, values considered impaired were assigned the value 200, and values considered severely impaired were assigned the value 100. The values 400, 300, 200, and 100 are analogous to the categories Very Good, Good, Fair, and Poor, respectively.
[c] Index values for pH values were assigned as follows: >10 or <5: 100, >9 or <6: 200, >8 or <6.5: 300, between 6.5 and 8 (inclusive): 400.
[d] Index values for sulfate values were assigned as follows: >250 mg/l: 100, >50 mg/l and <=250 mg/l: 200, >25 mg/l and <=50: 300, <=25 mg/l: 400.
[e] Index values for specific conductivity values were assigned as follows: >835 µmhos/cm: 100, >500 µmhos/cm and <=835 µmhos/cm : 200, >200 and <=500 µmhos/cm: 300, <=200 µmhos/cm: 400.
[f] Index values for GLIMPSS values were assigned as follows: <50: 100, <100 and >=50: 200, <125 and >=100: 300, >=125: 400. Based on percent threshold values of the modified GLIMPSS (CF), which excludes genus-level Chironimidae.
[g] Index values for an added Sedimentation/Embededdness score, two components of the RBP, assigned as follows: <11: 100, <21 and >=11: 200, <31 and >=21: 300, >=31: 400.
[h] Index values for the Total RBP score, assigned as follows: <60: 100, <110 and >=60: 200, <160 and >=110: 300, >=160: 400.

3.3.6 Metric Scores

Each metric received an objective score according to the thresholds developed in the objective classification, placing the metric into one of the four quality categories: Very Good, Good, Fair, or Poor. To be able to aggregate the metric scores to index scores and ultimately to model scores, objective categories were translated to a numerical rating for each metric, where the categories Very Good, Good, Fair, and Poor were assigned the values 4, 3, 2, and 1, respectively.

To compare planning units relative to each other, a relative score for each planning unit was calculated in addition to the objective score. Relative scores were defined by scaling the results for each metric on a scale from 0 to 1 (0 being defined as the lowest quality value and 1 being defined as the highest quality value for a particular metric over all planning units in the watershed). For example, to rank according to the amount of forested riparian area, a positive metric where a high value indicated a higher quality, the highest scoring planning unit's metric was set to a value of 1 and the lowest scoring planning unit was set to a value of 0, with all remaining scores distributed between 0 and 1. Conversely, to score for the amount of mining in a planning unit, a negative metric where a higher value indicated lower quality, the highest scoring planning unit's metric was set to a value of 0 and the lowest scoring planning unit was set to a value of 1. These scores were determined for both HUC12 and NHDPlus catchments.

Table 18 illustrates the value, relative score, objective category, and objective score for several catchments for three metrics: percent forested riparian area, percent of planning unit with surface mines, and roads and railroads in the riparian area.

3.3.7 Index Scores

Metric scores were aggregated, according to their assigned weights, to produce index scores. To compute the individual index scores (for example, Streams Water Quality) the following formula was used for each index:

Index objective score:

$$IOS = \frac{MOS_1 * MW_1 + MOS_2 * MW_2 + \cdots + MOS_n * MW_n}{MW_1 + MW_2 + \cdots + MW_n}$$

Where: IOS = index objective score
MOS_i = metric i objective score, where Very Good = 4, Good = 3, Fair = 2, Poor = 1
MW_i = metric i weight

These results were standardized by assigning them to the four objective categories according to the following definitions:

$$IOS > 3.5 \rightarrow 4\ (Very\ Good)$$
$$2.5 < IOS \leq 3.5 \rightarrow 3\ (Good)$$
$$1.5 < IOS \leq 2.5 \rightarrow 2\ (Fair)$$
$$IOS \leq 1.5 \rightarrow 1\ (Poor)$$

Table 18. Example Values, Relative Scores, Objective Categories, and Objective Scores for Selected Catchments and Metrics

Metric	Catchment ID	Value	Relative Score	Objective Category	Objective Score
Percent Forested Riparian Area	C1167	100	1	Very Good	4
	C1277	98.79	0.9872	Very Good	4
	C932	98.50	0.9843	Good	3
	C622	91.88	0.9178	Good	3
	C995	82.71	0.8259	Fair	2
	C1336	61.43	0.6124	Fair	2
	C592	44.35	0.4409	Poor	1
	C662	10.17	0.0981	Poor	1
Percent of Planning Unit with Surface Mines	C998	0	1	Very Good	4
	C1018	1.71	0.9828	Very Good	4
	C874	3.12	0.9686	Good	3
	C359	6.93	0.9303	Good	3
	C999	10.51	0.8942	Fair	2
	C184	16.77	0.8313	Fair	2
	C210	23.61	0.7625	Poor	1
	C873	92.65	0.0680	Poor	1
Roads and Railroads in Riparian Area (mi roads/sq mi planning unit)	C998	0	1	Very Good	4
	C647	0	1	Very Good	4
	C1065	1.05	0.9514	Good	3
	C582	2.03	0.9061	Good	3
	C1055	2.56	0.8820	Fair	2
	C815	4.47	0.7936	Fair	2
	C387	6.41	0.7042	Poor	1
	C62	21.67	0.2422	Poor	1

Index relative score:

$$IRS = \frac{MRS_1 * MW_1 + MRS_2 * MW_2 + \cdots + MRS_n * MW_n}{MW_1 + MW_2 + \cdots + MW_n}$$

Where: IRS = index relative score
MRS_i = metric i relative score (between 0 and 1)
MW_i = metric i weight

A combined score was then calculated for every index for each planning unit, consisting of the objective category score added to the relative score, resulting in the possible values for each index ranging from the lowest possible score of 1 (a Poor catchment that also has the lowest possible value relative to the other catchments) to the highest possible score of 5 (a Very Good catchment that is also the highest relative quality compared to the other catchments). Table 19 gives examples of the Streams/Riparian Areas model indices and their corresponding objective, relative, and combined scores.

Table 19. Example Index Objective, Relative, and Combined Results for Selected Catchments for the Streams/Riparian Areas Model

	Index Objective Scores					**Index Objective Scores, standardized**				
Index	**Water Quality**	**Water Quantity**	**Habitat Connectivity**	**Biodiversity**	**Riparian Habitat**	**Water Quality**	**Water Quantity**	**Habitat Connectivity**	**Biodiversity**	**Riparian Habitat**
Index Weight	**1**	**1**	**1**	**0.5**	**1**	**1**	**1**	**1**	**0.5**	**1**
C1235	3.81	3.75	3.59	3.50	3.74	4	4	4	3	4
C721	3.78	3.56	3.53	2.93	3.70	4	4	4	3	4
C191	3.36	3.56	3.53	2.76	3.48	3	4	4	3	3
C920	3.25	3.44	3.34	2.26	3.30	3	3	3	2	3
C519	2.00	3.31	3.59	2.67	3.65	2	3	4	3	4
C954	3.11	2.00	2.75	2.50	2.00	3	2	3	3	2
C765	2.53	2.53	2.88	1.51	2.00	3	3	3	2	2
C27	2.00	2.00	1.85	2.67	1.00	2	2	2	3	1
C872	1.00	1.00	2.97	1.51	1.00	1	1	3	2	1

	Index Relative Scores					**Index Combined Scores**				
Index	**Water Quality**	**Water Quantity**	**Habitat Connectivity**	**Biodiversity**	**Riparian Habitat**	**Water Quality**	**Water Quantity**	**Habitat Connectivity**	**Biodiversity**	**Riparian Habitat**
Index Weight	**1**	**1**	**1**	**0.5**	**1**	**1**	**1**	**1**	**0.5**	**1**
C1235	1.00	1.00	0.94	0.91	1.00	5.00	5.00	4.94	3.91	5.00
C721	0.99	0.99	0.82	0.17	0.99	4.99	4.99	4.82	3.17	4.99
C191	0.90	1.00	0.93	0.50	0.97	3.90	5.00	4.93	3.50	3.97
C920	0.98	1.00	0.89	0.06	0.97	3.98	4.00	3.89	2.06	3.97
C519	0.76	0.98	0.89	0.13	0.99	2.76	3.98	4.89	3.13	4.99
C954	0.88	0.98	0.63	0.37	0.93	3.88	2.98	3.63	3.37	2.93
C765	0.88	0.90	0.78	0.00	0.92	3.88	3.90	3.78	2.00	2.92
C27	0.65	0.95	0.31	0.38	0.67	2.65	2.95	2.31	3.38	1.67
C872	0.71	0.78	0.74	0.00	0.66	1.71	1.78	3.74	2.00	1.66

Index combined score:

$$ICS = IOS + IRS$$

Where: ICS = index combined score

These results were again standardized to the four objective categories according to the following definitions:

$$\begin{aligned} ICS \geq 4 &\quad \rightarrow 4\ (Very\ Good) \\ 3 \leq ICS < 4 &\quad \rightarrow 3\ (Good) \\ 2 \leq ICS < 3 &\quad \rightarrow 2\ (Fair) \\ ICS < 2 &\quad \rightarrow 1\ (Poor) \end{aligned}$$

The combined score indicates the planning unit's relative ranking within the respective category compared to all other planning units in that HUC8 watershed. The objective and relative ranking methods convey different information about the planning unit, and provide an additional level of analysis to help an end user make decisions about conservation projects. For example, in Table 16, while both C1235 and C721 catchments are in the Very Good category for Water Quality, C1235 is slightly higher quality than C721 and may be considered a slightly higher priority for conservation, all other factors being equal. However, both are considered to be in the ideal ecological condition for water quality.

3.3.8 Model Scores

Index scores were aggregated to produce a score for each model: Streams/Riparian Areas, Wetlands, and Uplands. The aggregated model scores are referred to as "overall scores" to differentiate them from the individual index scores.

Model objective score:

$$ModOS = \frac{IOS_1 * IW_1 + IOS_2 * IW_2 + \cdots + IOS_n * IW_n}{IW_1 + IW_2 + \cdots + IW_n}$$

Where: IOS_i = index i objective score
IW_i = index i weight
ModOS = model objective score

These results were once again grouped into the four categories according to the same standardization as the index objective scores:

$$\begin{aligned} ModOS > 3.5 &\quad \rightarrow 4\ (Very\ Good) \\ 2.5 < ModOS \leq 3.5 &\quad \rightarrow 3\ (Good) \\ 1.5 < ModOS \leq 2.5 &\quad \rightarrow 2\ (Fair) \\ ModOS \leq 1.5 &\quad \rightarrow 1\ (Poor) \end{aligned}$$

Model relative score:

$$ModRS = \frac{IRS_1 * IW_1 + IRS_2 * IW_2 + \cdots + IRS_n * IW_n}{IW_1 + IW_2 + \cdots + IW_n}$$

Where: IRS_i = index i relative score
IW_i = index i weight
ModRS = model relative score

A combined overall model score was then calculated using the same method as for individual indices above, to produce an overall combined score for each model (Streams/Riparian Areas, Wetlands, and Uplands). Table 20 lists examples of the Streams/Riparian Areas model objective, relative, and combined results aggregated from the results for all Streams indices (Water Quality, Water Quantity, Hydrologic Connectivity, Biodiversity, and Riparian Habitat indices) selected catchments. For example, both C1235 and C721 catchments are in the Very Good category and are therefore considered to be in an ideal ecological condition and priorities for conservation, though C1235 is slightly higher quality than C721, and may be considered a slightly higher priority, all other factors being equal.

Model combined score:

$$ModCS = ModOS + ModRS$$

Where: ModCS = model combined score

The combined results were standardized to the four quality categories as follows:

$$\begin{aligned} ModCS \geq 4 &\quad \rightarrow 4\ (Very\ Good) \\ 3 \leq ModCS < 4 &\quad \rightarrow 3\ (Good) \\ 2 \leq ModCS < 3 &\quad \rightarrow 2\ (Fair) \\ ModCS < 2 &\quad \rightarrow 1\ (Poor) \end{aligned}$$

Table 20. Example Model Objective, Relative, and Combined Results for Selected Catchments for the Streams/Riparian Areas Model

Catchment ID	Objective Score	Standardized Objective Score	Objective Category	Relative Score	Combined Score
C1235	3.70	4	Very Good	0.98	4.98
C721	3.56	4	Very Good	0.86	4.86
C191	3.40	3	Good	0.90	3.90
C920	3.21	3	Good	0.86	3.86
C519	3.09	3	Good	0.82	3.82
C954	2.47	2	Fair	0.80	2.80
C765	2.38	2	Fair	0.77	2.77
C27	1.82	2	Fair	0.62	2.62
C872	1.49	1	Poor	0.64	1.64

The calculation of scores occurred at both planning unit levels, generated independently of each other:

1. a ranking of HUC12 watersheds in terms of their overall model combined scores for each priority model (Streams/Riparian Areas, Wetlands, and Uplands) and each index combined score (e.g., Water Quality, Biodiversity, Habitat Connectivity, etc.), and
2. a ranking of NHDPlus catchments based on overall model and index combined scores.

Through this process, three Priority Models were generated (Figures 11 - 13): a Streams/Riparian Areas Priority Model, a Wetlands Priority Model, and an Uplands Priority Model. These models remain separate, as they each identify a key landscape that was independently ranked. The analysis presents the final combined scores for each planning unit (HUC12 and NHDPlus catchment), with a high score indicating a higher conservation priority within that Priority Model.

3.3.9 Example Index and Model Scores Calculation

To illustrate the methodology outlined above, an example is presented to clarify how the relative, objective, and combined scores were produced for the Streams Water Quality index and Streams/Riparian Area model for one particular catchment, C1235. Table 21 shows the metric results for this catchment for the Streams Water Quality index. Applying the formulas from Section 3.3.6 and the metric values from Table 18, the Streams Water Quality (SWQ) index objective score was calculated as:

$$IOS = \frac{4*2+4*2+4*1.5+4*2+4*2+4*1+3*1+4+1+3*2+4*1.5}{2+2+1.5+2+2+1+1+1+2+1.5} = \frac{61}{16} = 3.81$$

which corresponds to the index objective score in Table 19. No water quality data were available for this planning unit and are therefore excluded from the analysis.

Similarly, the SWQ index relative score is:

$$IRS = \frac{1*2+0.985*2+1*1.5+1*2+1*2+1*1+1*1+1*1+0.988*2+1*1.5}{2+2+1.5+2+2+1+1+1+2+1.5}$$
$$= \frac{15.946}{16} = 0.997\ (rounded\ to\ 1.00)$$

which corresponds to the index relative score in Table 19.

To calculate the ICS, the IOS is standardized to 4 (as it is greater than 3.5), and the IRS added to it:

$$ICS = 4 + 1.00 = 5.00$$

which corresponds to the index combined score in Table 19, and is considered to be in the Very Good category.

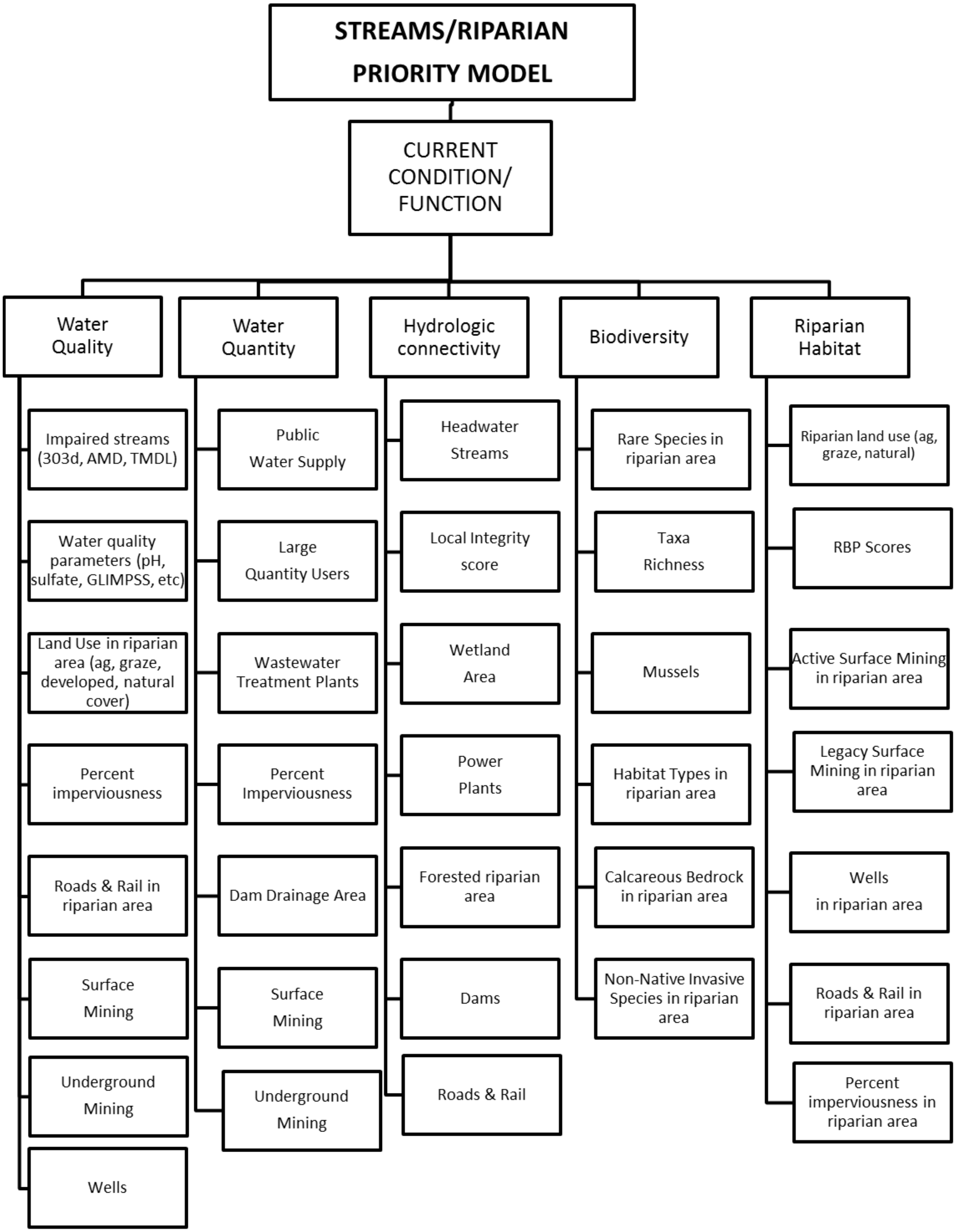

Figure 11. Streams/Riparian Areas Priority Model Flowchart

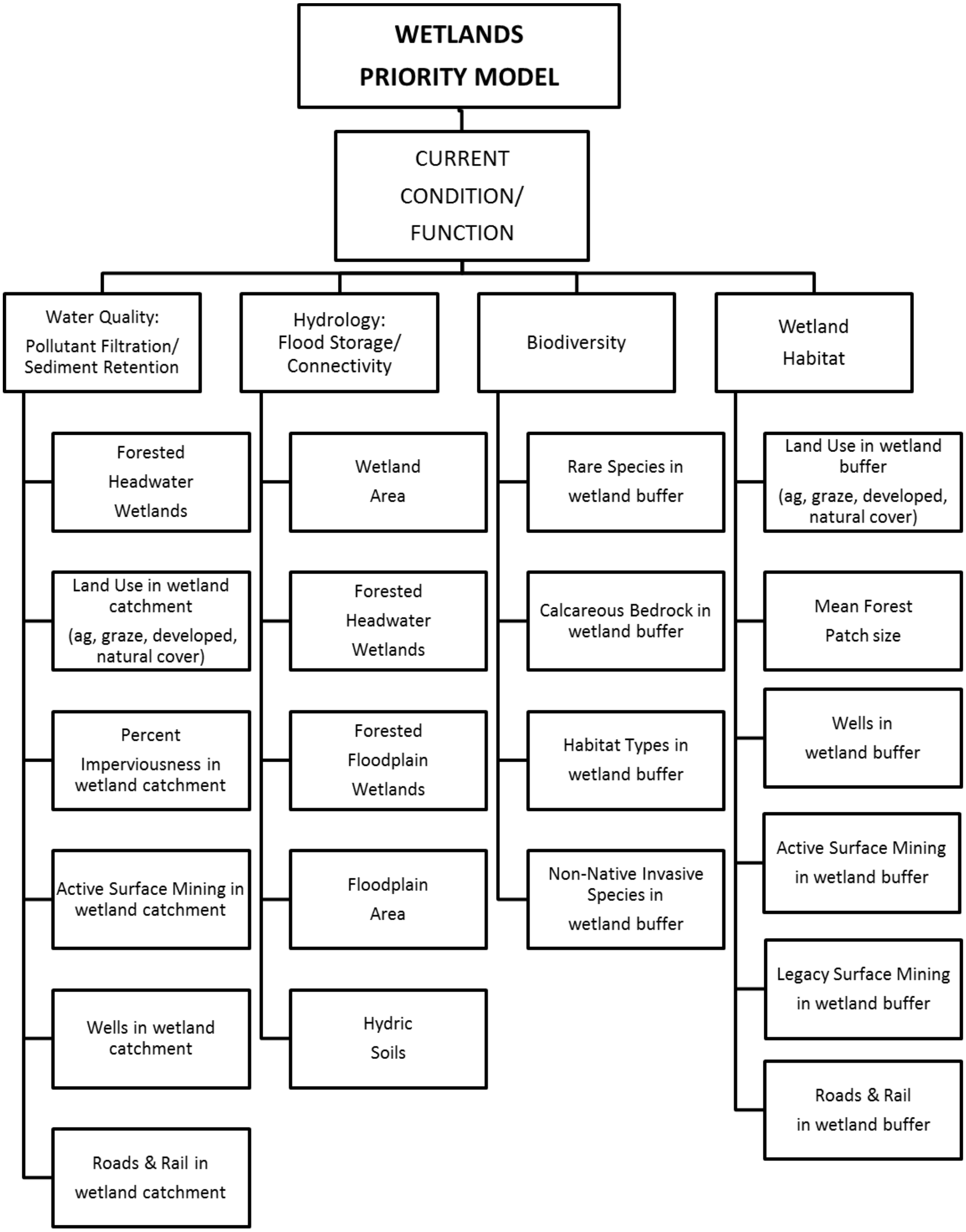

Figure 12. Wetlands Priority Model Flowchart

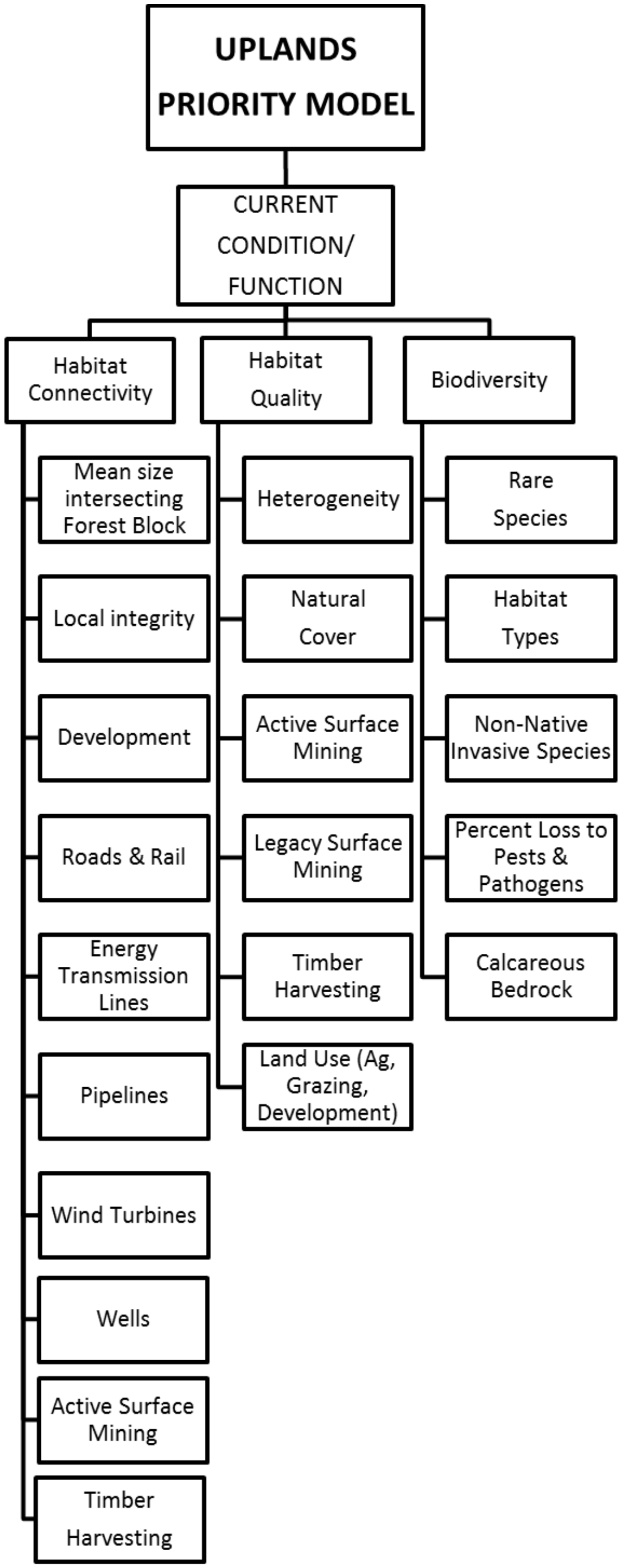

Figure 13. Uplands Priority Model Flowchart

To calculate the Streams/Riparian Areas Model objective and relative scores, all index scores in Table 19 are used:

$$ModOS = \frac{3.81 * 1 + 3.75 * 1 + 3.59 * 1 + 3.50 * 0.5 + 3.74 * 1}{1 + 1 + 1 + 0.5 + 1} = \frac{16.64}{4.5} = 3.70$$

which corresponds to the model objective score in Table 17, and places the index in the Very Good category.

$$ModRS = \frac{1.00 * 1 + 1.00 * 1 + 0.94 * 1 + 0.91 * 0.5 + 1.00 * 1}{1 + 1 + 1 + 0.5 + 1} = \frac{4.395}{4.5} = 0.98$$

which corresponds to the model relative score in Table 20.

The ModOS score is then standardized to 4 (as it is greater than 3.5), and the ModRS is added to it to produce the overall Streams/Riparian Area model combined score:

$$ModCS = 4 + 0.98 = 4.98$$

which corresponds to the model combined score in Table 20, and places the model into the Very Good category.

Table 21. Example Streams Water Quality Metrics for Catchment C1235 with Value, Objective Category, Objective Score, and Relative Score for Each Metric

Metric (* critical metrics)	**Weight**	**Value**	**Objective Category**	**Objective Score**	**Relative Score**
AMD, TMDL, 303(d) impaired streams	2	0 %	Very Good	4	1
Median pH*	2	[a]	[a]	[a]	[a]
Median sulfate	1	[a]	[a]	[a]	[a]
Median specific conductivity*	1.5	[a]	[a]	[a]	[a]
Median GLIMPSS	2	[a]	[a]	[a]	[a]
Median sedimentation & embeddedness	1	[a]	[a]	[a]	[a]
Percent imperviousness*	2	0 %	Very Good	4	0.985
All wells	1.5	0 %	Very Good	4	1
Surface mining (active & legacy)*	2	0 %	Very Good	4	1
Underground mining	2	0 %	Very Good	4	1
Agriculture in riparian area	1	0 %	Very Good	4	1
Grazing/pasture in riparian area	1	1.13 %	Good	3	1
Development in riparian area	1	0 %	Very Good	4	1
Natural cover in riparian area	2	98.80 %	Good	3	0.988
All roads & rail	1.5	0 %	Very Good	4	1

[a] null value due to the absence of a WVDEP WAB water quality station in this catchment

3.4 Consolidated Analysis

The Consolidated Analysis consists of two main parts, a Future Threats assessment and an Opportunities assessment (Figure 14). It was originally envisioned to evaluate cumulative watershed effects, to analyze historical and possible future conditions where applicable data were available, to assess the impacts of past changes on the watershed, and to project future trends that might significantly impact the planning units over time (such as climate change or population growth). The objective was to incorporate the following into the consolidated analysis:

a. Impacts and stresses to natural resources, functions, and sensitive species (and their habitats) and vegetative communities in the watershed
b. Current and past land use changes in the watershed, evaluating their cumulative watershed effects on natural resource condition and function
c. The extent and location of riparian, wetland, and upland loss compared to historic conditions, including the loss of any species or vegetative communities
d. Natural resources, functions, and/or services that have been lost or degraded, where they are, and how significantly they have been impacted
e. Future threats analysis
f. Projected land use change with the potential to negatively impact natural resource value and function (population growth and urban expansion, planned energy projects)
g. Potential for increased resource extraction activities due to the presence of undeveloped natural resources (unmined coal, high wind or geothermal energy potential, Marcellus shale gas play)
h. Potential effects of climate change
i. Priority interest areas identifying portions of the landscape that are known priorities for protection by various federal, state, or non-governmental organizations

However, much of the data necessary for a comprehensive and thorough Consolidated Analysis was not consistently available for the five pilot HUC8 watersheds, and these datasets are listed in Section 5.3 as data gaps/needs identified for the state. For example, potential Marcellus shale development projections are not yet available from partner agencies, so the Marcellus shale thickness was used as a surrogate to estimate the probability of Marcellus shale development. Urban development projections were surprisingly lacking in West Virginia, except for the Morgantown area in the Monongahela watershed, and population projections were only available on a county-wide level. In contrast, the modeled resiliency and regional flow data, indicating potential response to climate change, are at a relatively fine scale. The latter two datasets are part of a larger analysis of the Northeast and Mid-Atlantic region conducted by The Nature Conservancy's Eastern Conservation Science program to identify geographic areas that are resilient in terms of providing species on the landscape the opportunity to adapt to a changing climate (Anderson et al. 2012). The concept of "resiliency" in this sense indicates that some areas may be able to buffer the effects of climate change by "offering a connected array of microclimates that allow species to persist." The analysis is based on two factors:

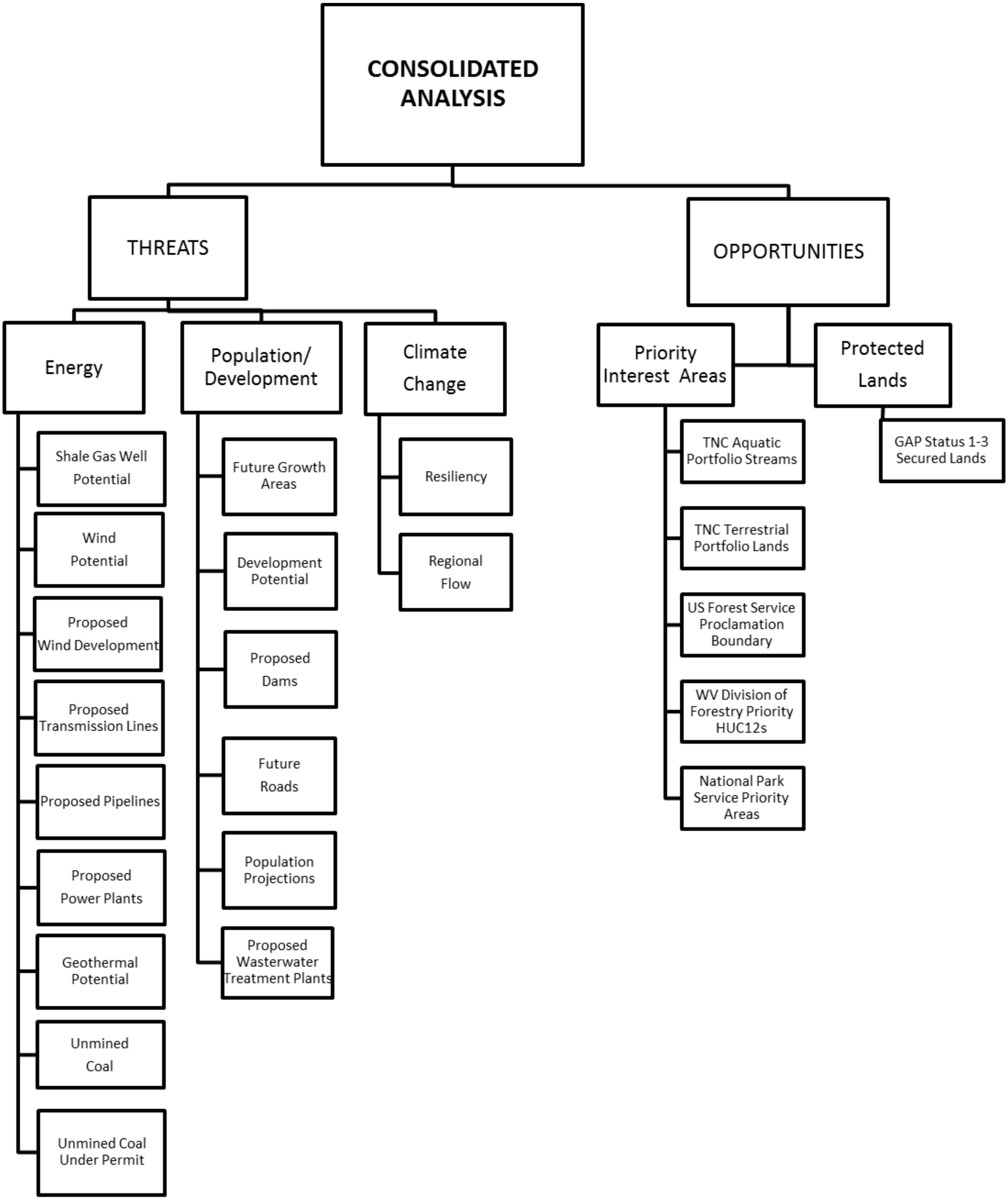

Figure 14. Consolidated Analysis Flowchart

landscape complexity (topography, elevation range, and wetland density) and landscape permeability (local connectedness and regional flow patterns, which are measures of landscape structure in terms of barriers, connected natural cover and land use patterns; Anderson et al. 2012). Detailed projections of temperature and precipitation changes are currently being developed for the Ohio River Basin by the USACE (Drum 2013) and may be incorporated into the Climate Change threats analysis when they become available.

Because of the inconsistent nature and variable scales of the different datasets, the Consolidated Analysis results were not calculated for the HUC12 or catchment-level planning units, but were instead calculated as gradients over the entire HUC8 watershed and are displayed as an informational layer rather than included in the model analysis results.

To display the cumulative known Future Threats to areas within the watershed, each metric was standardized from 0 to 100, with 100 indicating the lowest threat level for the metric in the HUC8 watershed, and 0 indicating the highest threat level. Metrics were weighted according to their significance in terms of affecting the overall future threat level of the watershed and summed to produce an overall index score. The indices were then combined using Esri's ArcGIS Spatial Analyst Raster Calculator tool to produce Threats Overall Results (a full list of metrics and assigned weights can be found in Table 22). This information was not included in the analysis results for each planning unit, but is meant to provide an additional set of information once the current condition of a planning unit has been determined.

The purpose of the second part of the Consolidated Analysis, the Opportunities assessment, was to provide information about currently protected areas, or areas that have been identified as priorities for protection by other organizations or regulatory agencies. This information may be helpful to entities planning protection or restoration activities in a given area by identifying potential partners or funding sources. Datasets included in the Opportunities assessment include permanently protected areas, The Nature Conservancy aquatic and terrestrial portfolios, West Virginia Division of Forestry priority areas, National Park Service priority areas, and National Forest proclamation boundaries.

Table 22. Metrics Included in the Consolidated Analysis

Model	Index	Metric Description	Weight	Units
FUTURE THREATS	Energy	Currently unmined area within permit boundary	2	% of planning unit
		Unmined area of mineable coal seams	2	% of planning unit
		Marcellus well potential, based on shale thickness	2	mean thickness/planning unit
		Modeled wind potential	2	% of planning unit
		Proposed wind turbine locations	1	#/sq mi planning unit
		Proposed energy transmission lines	1	mi/sq mi planning unit
		Proposed gas pipelines	1	mi/sq mi planning unit
		Proposed power plants	1	#/sq mi planning unit
		High geothermal potential (temp>150 degrees)	1	% of planning unit
	Population/ Development	Population projections	1	percent change, by county
		Areas designated for future development	1	% of planning unit
		Proposed dam locations	1	#/stream mile
		Proposed future roads	1	mi/sq mi planning unit
		Proposed wastewater treatment plants	1	#/planning unit
	Climate Change	Resiliency score	1	avg score/planning unit
		Current density score	1	avg score/planning unit
OPPORTUNITIES*	Priority Interest Areas	TNC aquatic portfolio streams	-	-
		TNC terrestrial portfolio lands	-	-
		US Forest Service proclamation boundary	-	-
		WV Division of Forestry priority areas	-	-
		National Park Service priority areas	-	-
	Protected Lands	GAP Status 1-3 secured lands	-	-

*The "Opportunities" metrics/datasets are considered informational and were not part of an analysis, but are presented to aid decision-making. Therefore, these datasets do not have assigned weights or normalized units of measurement.

3.5 Data

3.5.1 Data Sources

Spatial data acquired for this study included:

- Surface water quality monitoring data
- Impaired streams (303(d), TMDL, AMD)
- Land use and land cover (LULC) data
- Surface and subsurface geology
- Soils
- Elevation (DEM)
- Stream network and drainage areas
- Wetlands location and type
- Species and habitat data
- Protected lands
- Infrastructure (roads, railroads, dams, energy transmission lines, pipelines)
- Mining, mineral extraction, oil and gas wells data
- Regulated sites (permitted discharge, landfills, toxic waste disposal, etc.)
- Demographics/population data
- Climate change models
- Political boundaries

Data were obtained from many sources including, but not limited to:

Federal agencies

- US Environmental Protection Agency
- US Geological Survey
- US Forest Service
- US Fish and Wildlife Service
- US Department of Agriculture
- US Department of Transportation
- US Census Bureau

State agencies

- WV Department of Environmental Protection
- WV Division of Natural Resources
- WV Division of Forestry
- WV Geological and Economic Survey
- WV Statewide Addressing and Mapping Board

Local agencies

- City/county/regional governments
- River or Watershed Associations

Non-profit organizations

- The Nature Conservancy

Universities

- West Virginia University
- WV GIS Technical Center

For a thorough reference to all data sources and intended uses please see Appendix A: Detailed Data Source Information.

3.5.2 Data Quality

Data were selected or rejected based on their relevance, completeness, accuracy, quality, and age. The most current data available were used, except in cases where using historical data for comparison or trend prediction was desirable. For example, species occurrence data older than 20 years were not used since they are unlikely to reflect current conditions. Particular factors that caused data to be rejected included: lack of appropriate or complete metadata; data that do not accurately reflect the current status of the watershed; data that appear incomplete or significantly conflict with known quality-assured data (thus casting doubt on data quality); and data that were deemed irrelevant or redundant during the analysis.

4.1 Current Condition Results and Discussion

4.1.1 Streams/Riparian Areas

Figures 15a and 15b show the Overall results for the Streams/Riparian landscape at the HUC12 and NHDPlus catchment scales, respectively, incorporating the scores for all the Streams/Riparian Priority Model indices. The lowest scoring HUC12 is Scotts Run, with the catchment level analysis also showing several catchments in this area within the Poor category. This is most likely due to the level of urban development and accompanying anthropogenic stressors concentrated in this area, as the city of Morgantown and its associated sprawl is located along the river in the eastern section of the HUC12. The few Fair NHDPlus catchments in the western portion of the watershed may be due to a variety of factors, particularly mining and gas well activity. The highest scoring planning units are the Whiteday Creek HUC12 and its NHDPlus catchments. Whiteday Creek is generally acknowledged by regulatory staff and local experts as the highest quality watershed within the Monongahela basin, a pattern that emerges throughout the indices results. This is due to a variety of factors, such as good water quality, low development and resource extraction activities, and a high percent forested cover, particularly in the headwaters region. These same factors likely similarly influence other HUC12s scoring in the Good category, such as neighboring Prickett Creek. The remainder of the watershed had mostly Fair, or restoration-level quality, Streams Overall results at the HUC12 level. The NHDPlus catchments Overall results reveal a clear pattern of higher scoring planning units in the headwaters regions of the watershed, with many of the Fair-Poor catchments being in areas with more non-natural land use patterns, such as mining, development, or grazing.

Similar patterns emerge in the Streams Water Quality index results (Figures 16a and 16b), with the lower scoring planning units in the northeast of the watershed around Morgantown, and the higher scores in the southeast, around the Whiteday Creek and Prickett Creek HUC12s, though some Very Good catchments do emerge in other southeastern headwaters areas as well. The Headwaters Buffalo Creek HUC12 and catchments also have Good scores, particularly along the headwater reaches. This is likely caused by the lack of mining activity and development in this area compared to the rest of the watershed (Figure 17). Catchments in the Poor category, such as those found along the Monongahela River, along a northeast-south central corridor of the watershed, result from the increased presence of anthropogenic stressors such as mining activity and impervious surface/development, which correlate with poor water quality sampling results and an increase in stream impairments. Within planning units that may be good candidates for restoration activities (those that scored in the Fair category) the main issues that emerged in the SWQ results were: high levels of underground mining and some related water quality impacts, lack of natural cover, high density of roads and railroads, and some sedimentation issues. Catchments that scored within the Very Good category are relatively pristine compared to other areas in this watershed and are good candidates for protection activities, since they have minimal amounts of resource extraction activity, a high percentage of natural cover, and minimal water quality impairments.

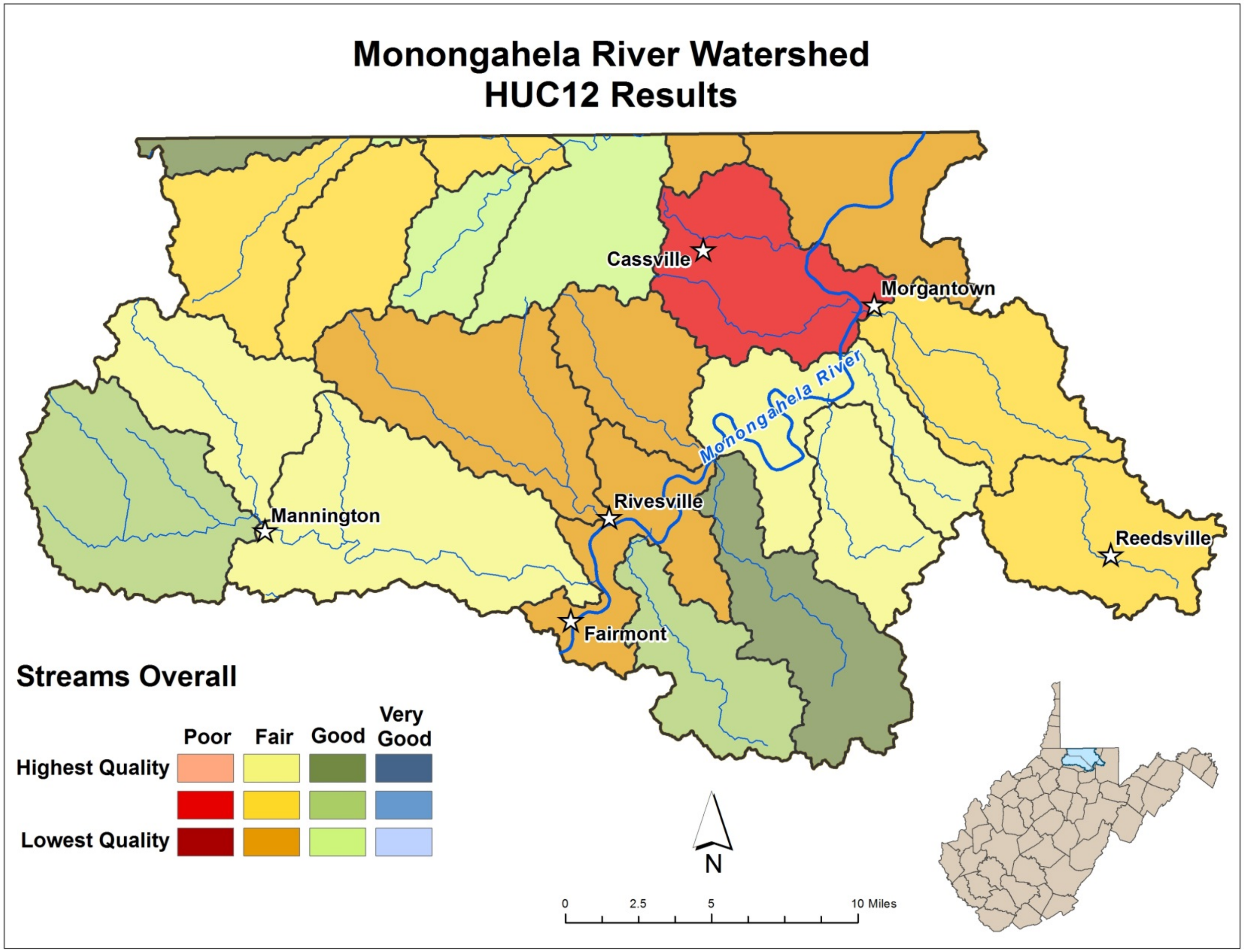

Figure 15a. Streams Overall Results – HUC12 Level

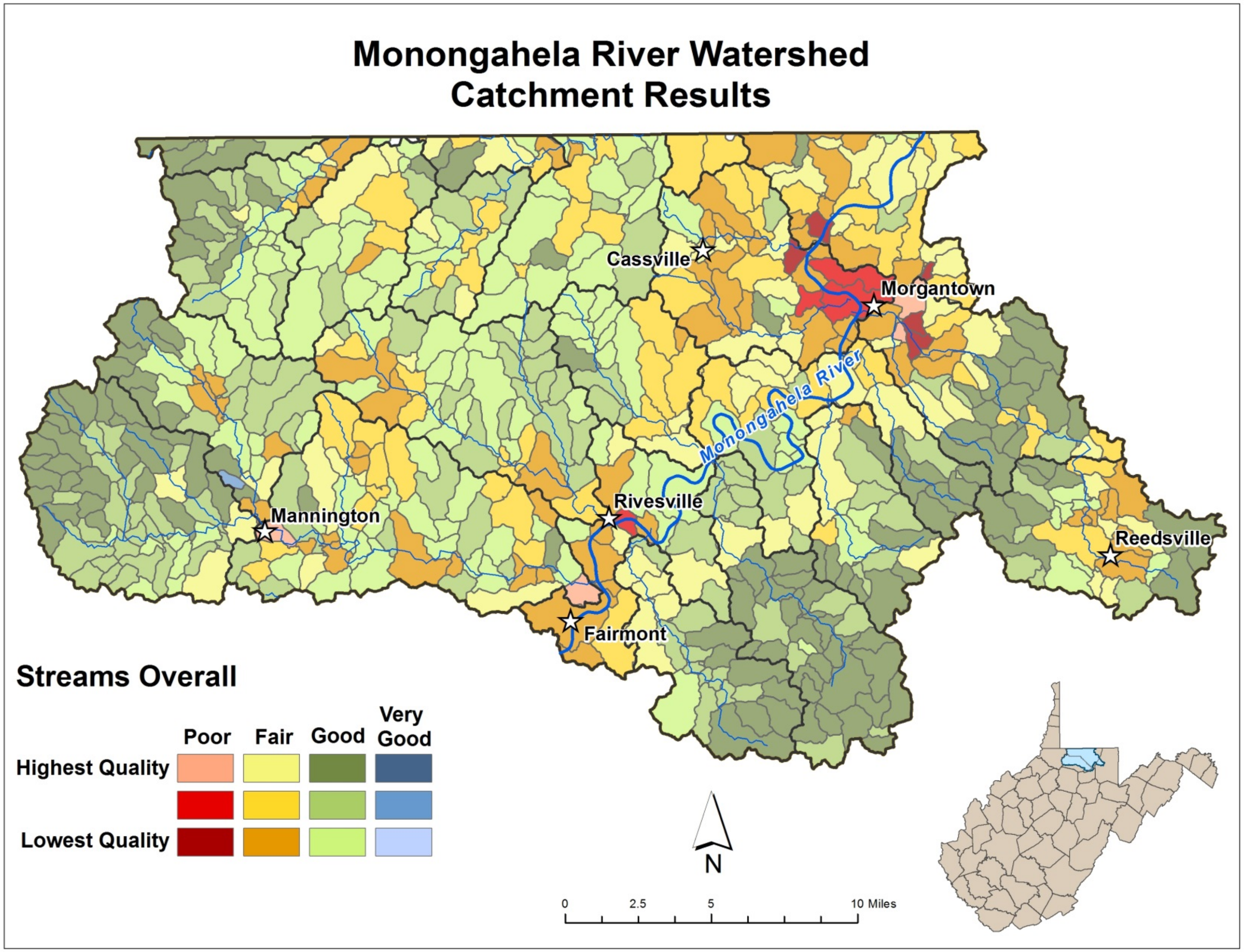

Figure 15b. Streams Overall Results – Catchment Level

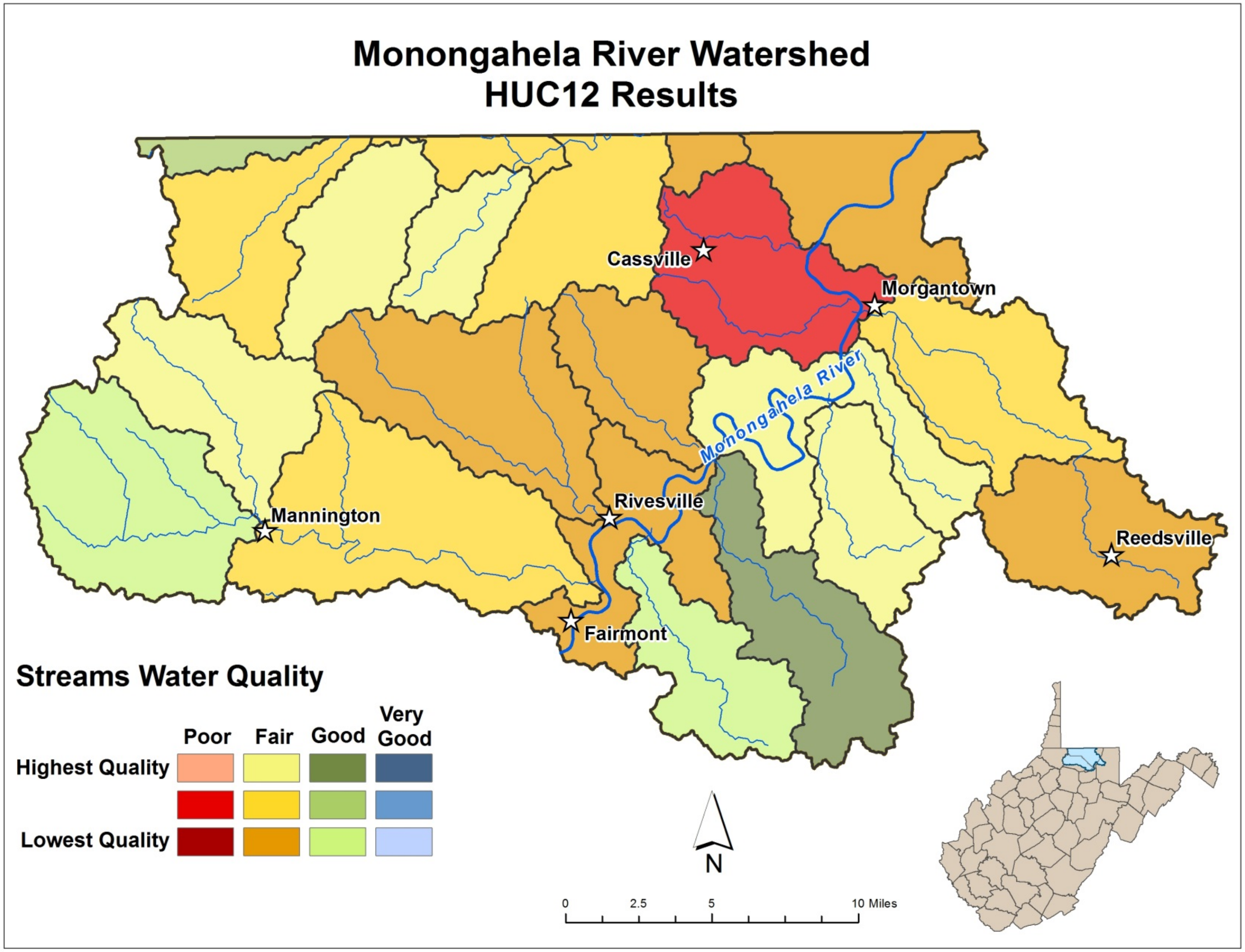

Figure 16a. Streams Water Quality Index Results – HUC12 Level

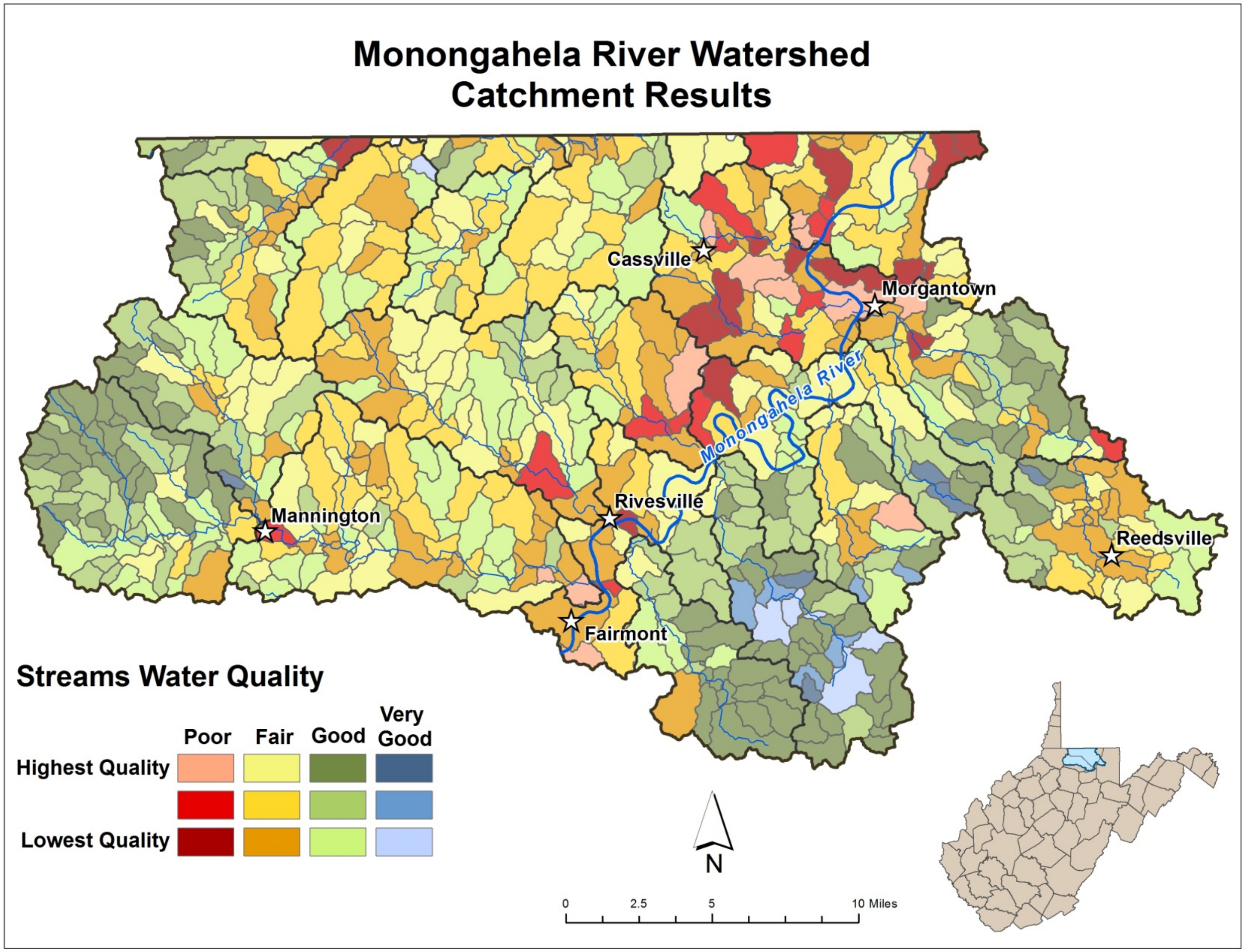

Figure 16b. Streams Water Quality Index Results – Catchment Level

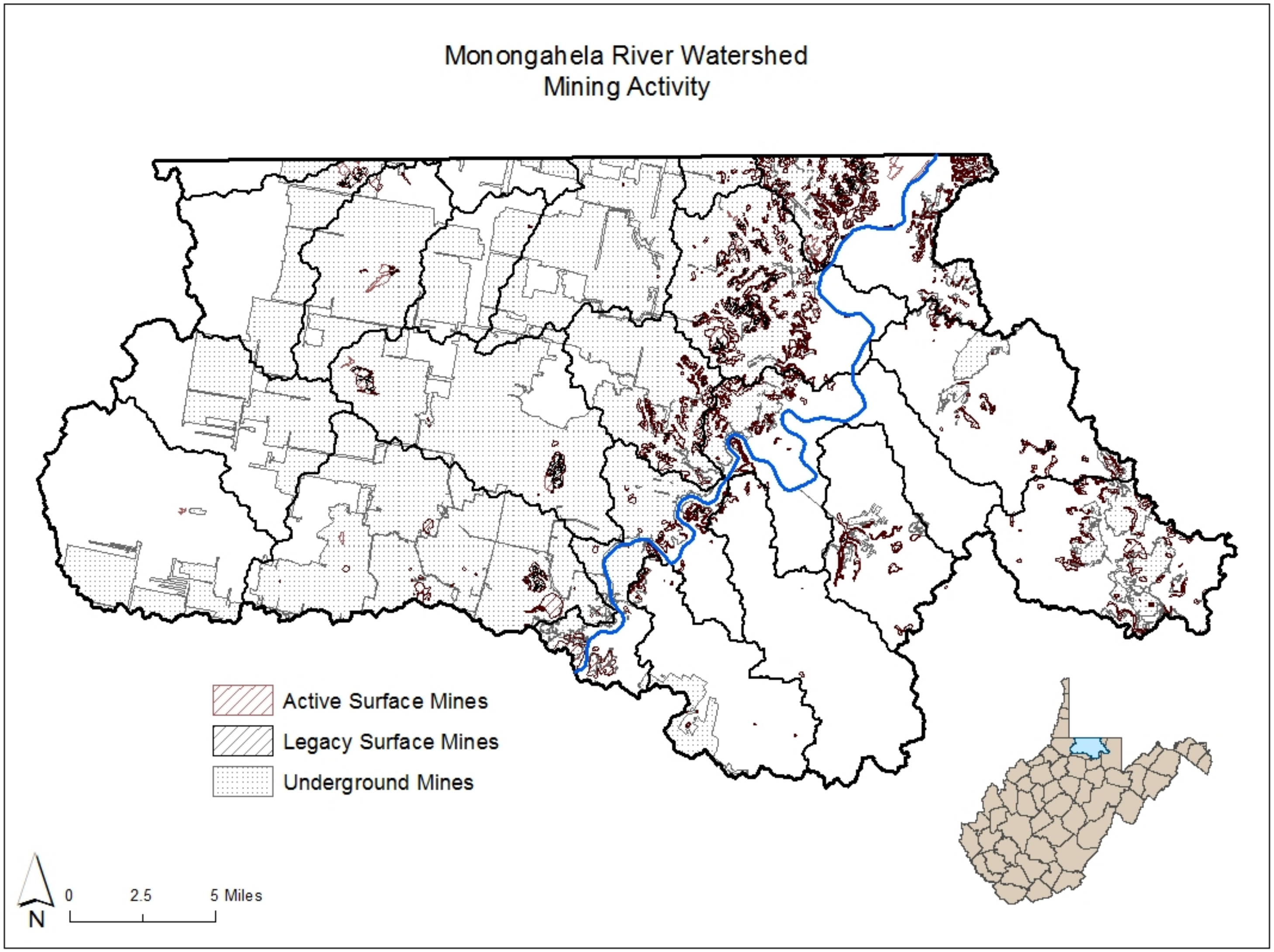

Figure 17. Monongahela River Watershed - Mining Activity (Maxwell et al. 2011, WVDEP 1996, WVDEP 2011b, WVGES 2010)

The same general pattern continues across the watershed in the Streams Water Quantity (SWN) HUC12 results (Figure 18a), though there are more HUC12s in the Good category and many more Very Good NHDPlus catchments (Figure 18b). The most highly weighted metrics in this index are large quantity users (Figure 19), percent impervious surface, and mining activity, so HUC12s with relatively low scores for this index often have a significant presence of one or more of these factors. The Poor rating for several catchments and the Poor HUC12 (Scotts Run) were primarily driven by percent impervious surface, which is a critical metric for this index. Within planning units that may be good candidates for restoration activities (those within the Fair category), the main issues that emerged in the SWN results were: greater mining activity (particularly underground mining), higher percent imperviousness, and the presence of large quantity users. The higher scoring planning units, particularly the Very Good catchments, all had low percentages of mining activity and Good scores in all other metrics and are ideal candidates when considering protection of water quantity in the watershed. Again, Whiteday Creek emerged as the best quality HUC12 for water quantity in the watershed.

The Streams Hydrologic Connectivity (SHC) index showed little variability across the watershed, with mostly Good-Fair scores. Those HUC12s and catchments surrounding cities remained the lowest ranked (including the Little Creek HUC12 in the vicinity of Fairmont and the West Run HUC12 around Morgantown; Figure 20a). This is likely due to impediments in connectivity from dams, culverts, and bridges, and due to the presence of few headwater streams in these HUC12s, as they are drainage areas contributing to the main stem of the river. Those HUC12s with the highest ranks generally have a much lower density of the metrics mentioned above, higher amounts of headwaters streams, and more wetland area. Catchment level results (Figure 20b) for the SHC index are consistent with these trends, with the I-79 corridor and adjacent interchange areas being among the lowest ranked, and the more undeveloped headwater reaches having the highest scores. Within planning units that may be good candidates for restoration activities, the main issues that emerged in the SHC results were: a lack of adequately forested riparian areas, the presence of many roads and railroads, which is highly correlated with numbers of culverts and bridges along the streams, and low local integrity scores. In a few areas, lack of wetland area was an additional issue.

The Streams Biodiversity (SBD) index results should be interpreted with caution for a variety of reasons. The metrics with the highest weights include the presence of rare species and non-native invasive species, but often, particularly at the catchment level, there are no data available for these metrics. Final scores are therefore often influenced by the metrics where data are available, mostly terrestrial habitat types and the percentage of calcareous bedrock. For instance, the Very Good HUC12 and most of the Very Good catchments had Very Good northeast terrestrial habitat type scores. Therefore, it is important to note that the SBD index results require additional investigation into what metrics may be driving that result. Additionally, the rare species and non-native invasive species metrics in all models have presence data only, with no information on where the species did not occur versus where no surveys occurred. This means that the metric score is either Good (for rare species metrics with recorded occurrences) or Fair (for non-native invasive species metrics with recorded occurrences). Similarly, calcareous bedrock has only a presence/absence threshold, resulting in a Fair rating for areas without calcareous bedrock and a Good rating for areas with calcareous bedrock. At the HUC12 level, results are generally Good, as this large level of planning unit is likely to include at least one rare species

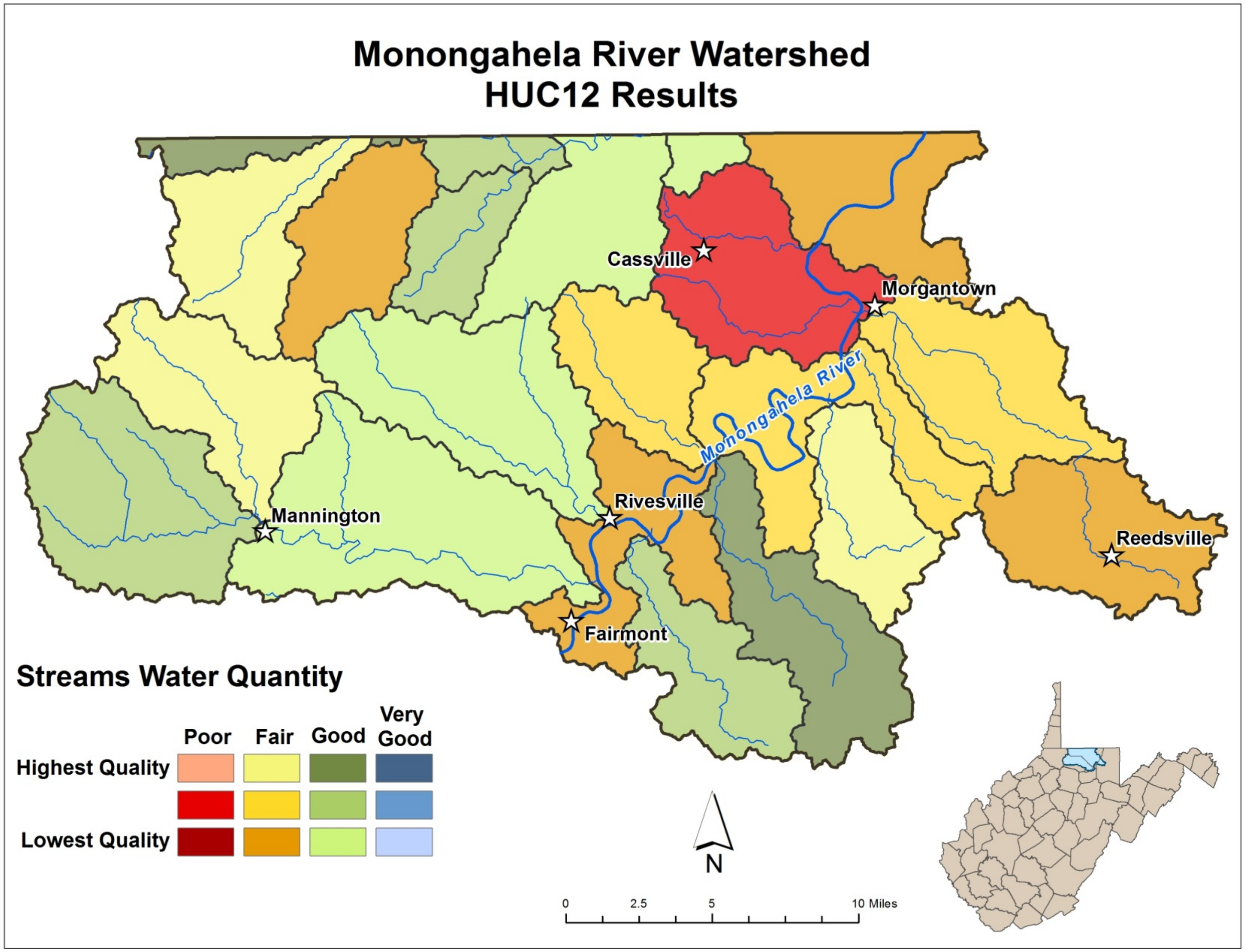

Figure 18a. Streams Water Quantity Index Results – HUC12 Level

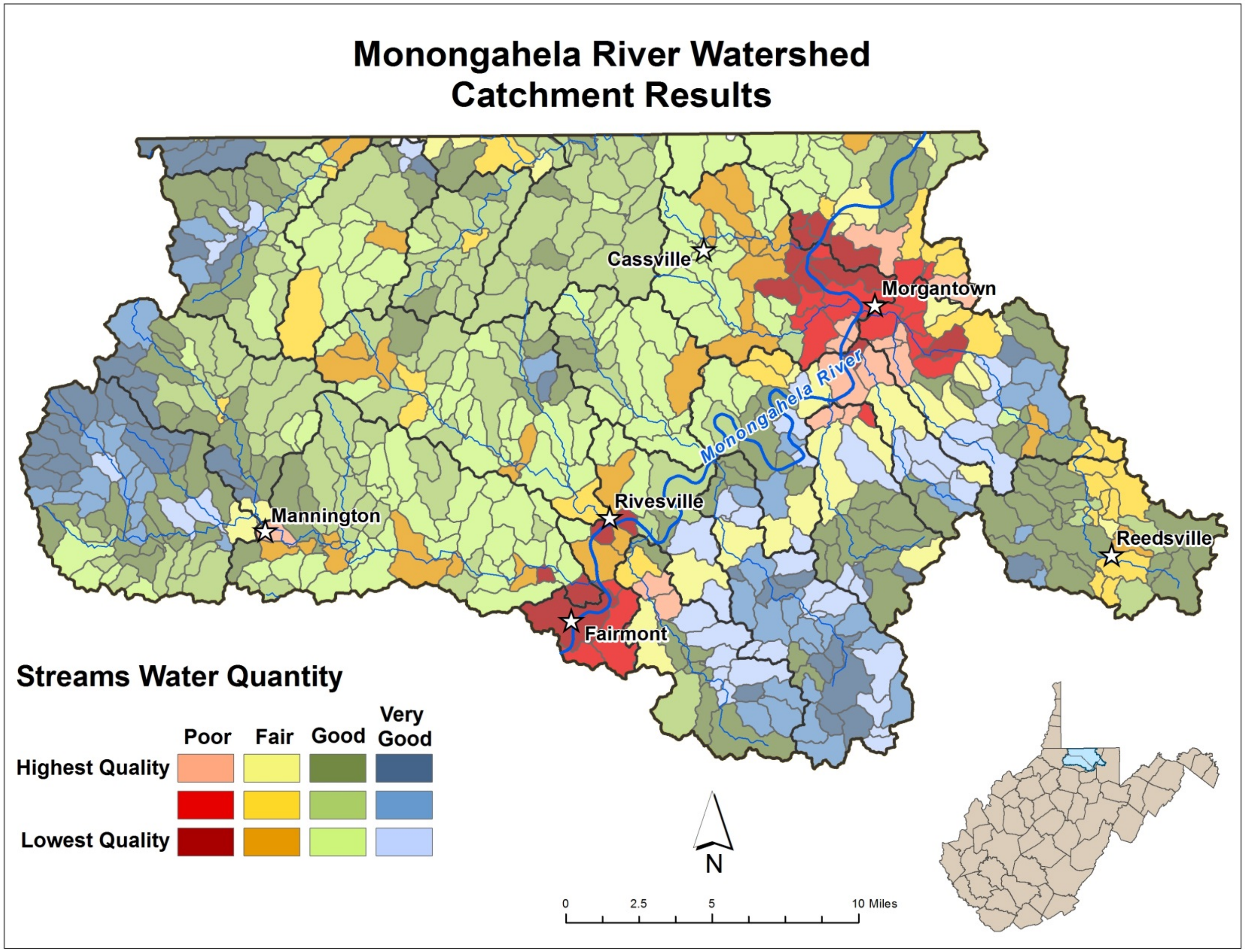

Figure 18b. Streams Water Quantity Index Results – Catchment Level

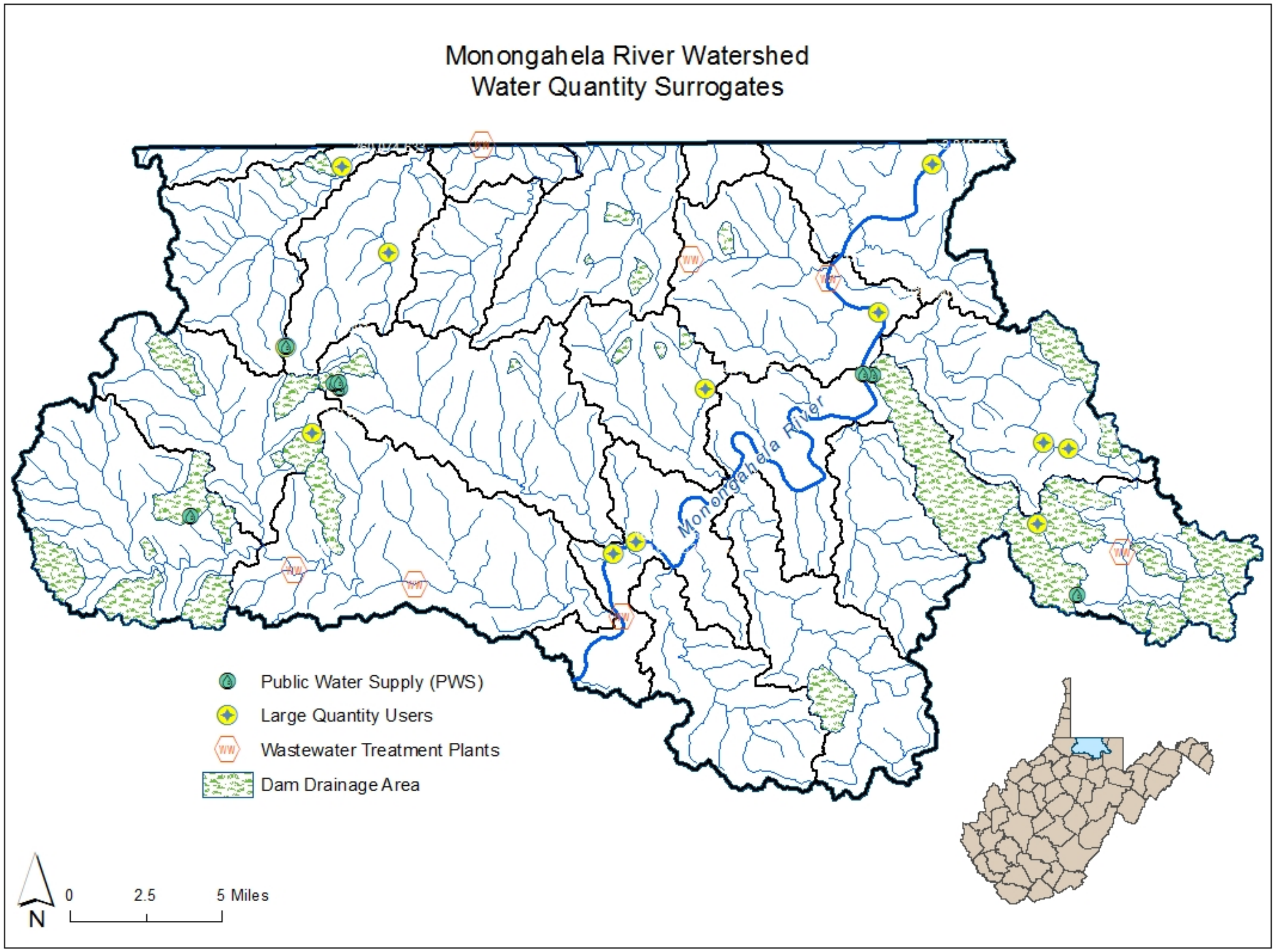

Figure 19. Monongahela River Watershed - Water Quantity Surrogates (WVDHHR 2011, WVDEP 2011a, WVDEP 2002)

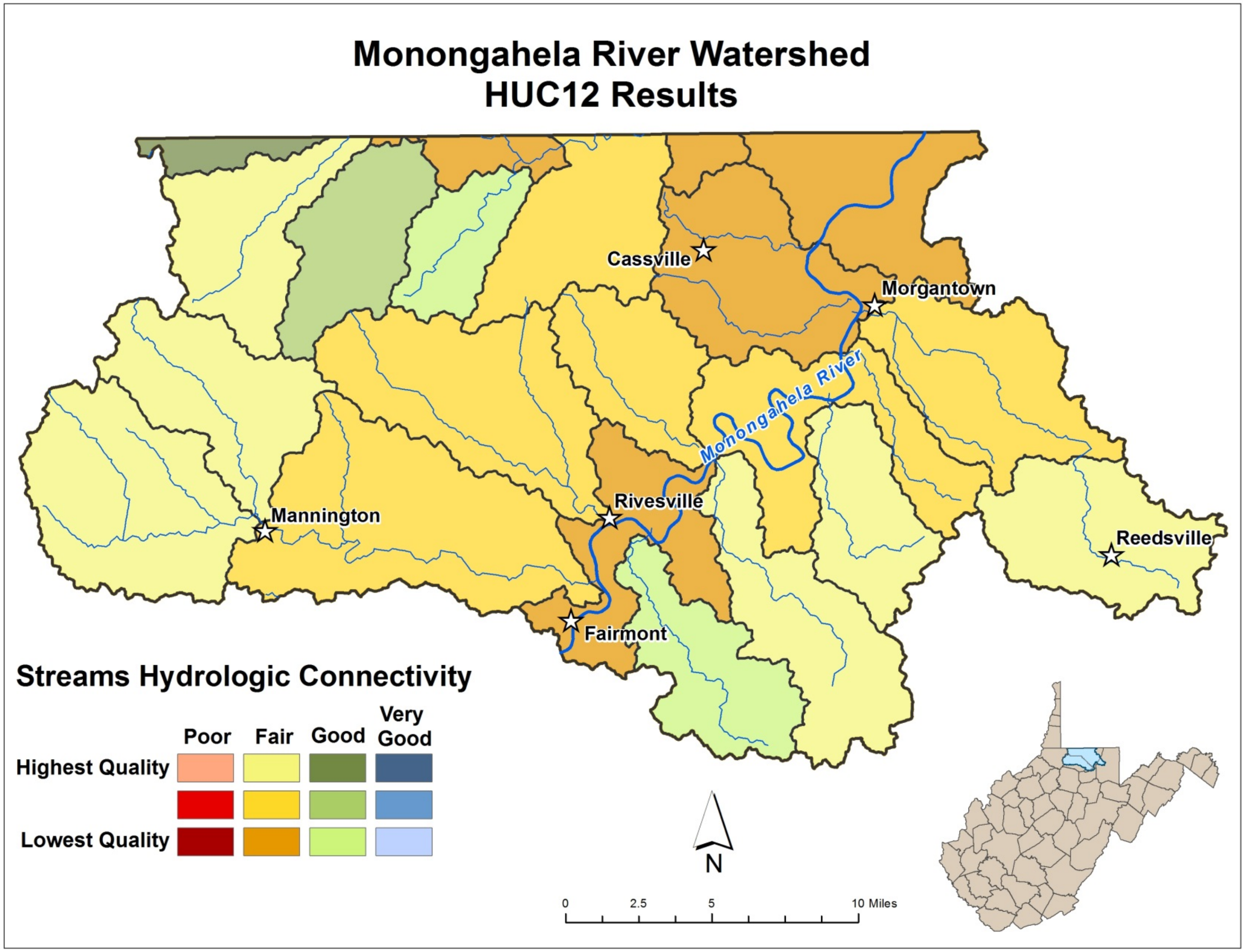

Figure 20a. Streams Hydrologic Connectivity Index Results – HUC12 Level

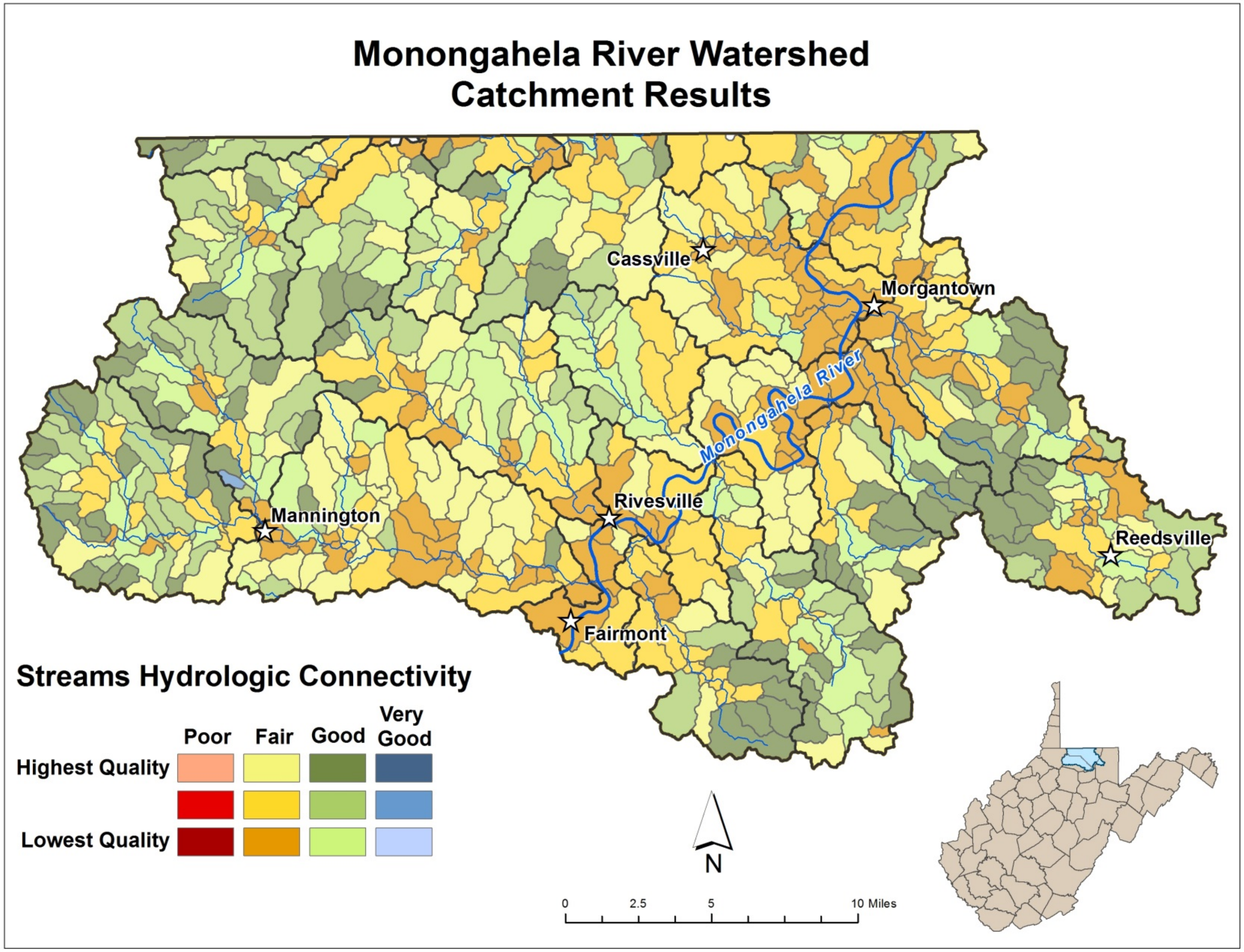

Figure 20b. Streams Hydrologic Connectivity Index Results – Catchment Level

and/or mussel stream occurrence, and higher taxa richness values than the smaller catchment-level planning units (Figure 21a). The catchment level analysis therefore shows more variability (Figure 21b). All of the Poor catchments have Poor taxa richness scores and Fair calcareous bedrock, with few other values for the remaining metrics, and the Very Good catchments have Very Good habitat types scores and Good calcareous bedrock, with few other values for the remaining metrics. The Biodiversity indices for all models are therefore limited by a lack of available or robust data and should be used with discretion. They are mostly intended as informational, to highlight areas that seem to support known high levels of biodiversity, and are included at half the weight of the other indices for the Overall model score.

The Streams Riparian Habitat (SRH) index results follow the same pattern as most of the other Streams indices results in the Monongahela watershed, with lower scoring planning units around the Morgantown area, and the Whiteday Creek area and many headwaters streams generally scoring as the highest quality areas. The SRH index has two critical metrics, percent imperviousness and active surface mining in the riparian area. The urban and very developed nature of the Scotts Run HUC12 results in its low rating, as there is very limited natural cover in the planning unit. Many of the Fair-scoring HUC12s were also brought down by alternative land use percentages and, consequently, low amounts of natural cover - often development but also due to agriculture, grazing, and the presence of oil and gas wells. Of the HUC12s scoring in the Good category (Figure 22a), the most noticeable trend is lack of mining activity; these planning units all had Good imperviousness scores, but only Fair natural cover scores, which suggests that while they may be the best available for protection, they are also reasonable candidates for restoration activities. Critical metrics, particularly percent imperviousness, also drive the catchment level Poor results, resulting in the spatial distribution of these catchments around the urban centers of Morgantown and Fairmont (Figure 22b). The Very Good catchments all have high percentages of natural cover and minimal riparian fragmentation from resource extraction activities, and would be excellent candidates for protection. The Fair-scoring catchments are caused by a variety of factors, mostly related to imperviousness, density of roads and railroads, and alternative land uses. These factors make these planning units good candidates for restoration activities, as these causes of riparian degradation can often be addressed through BMP implementation or efforts to restore natural cover.

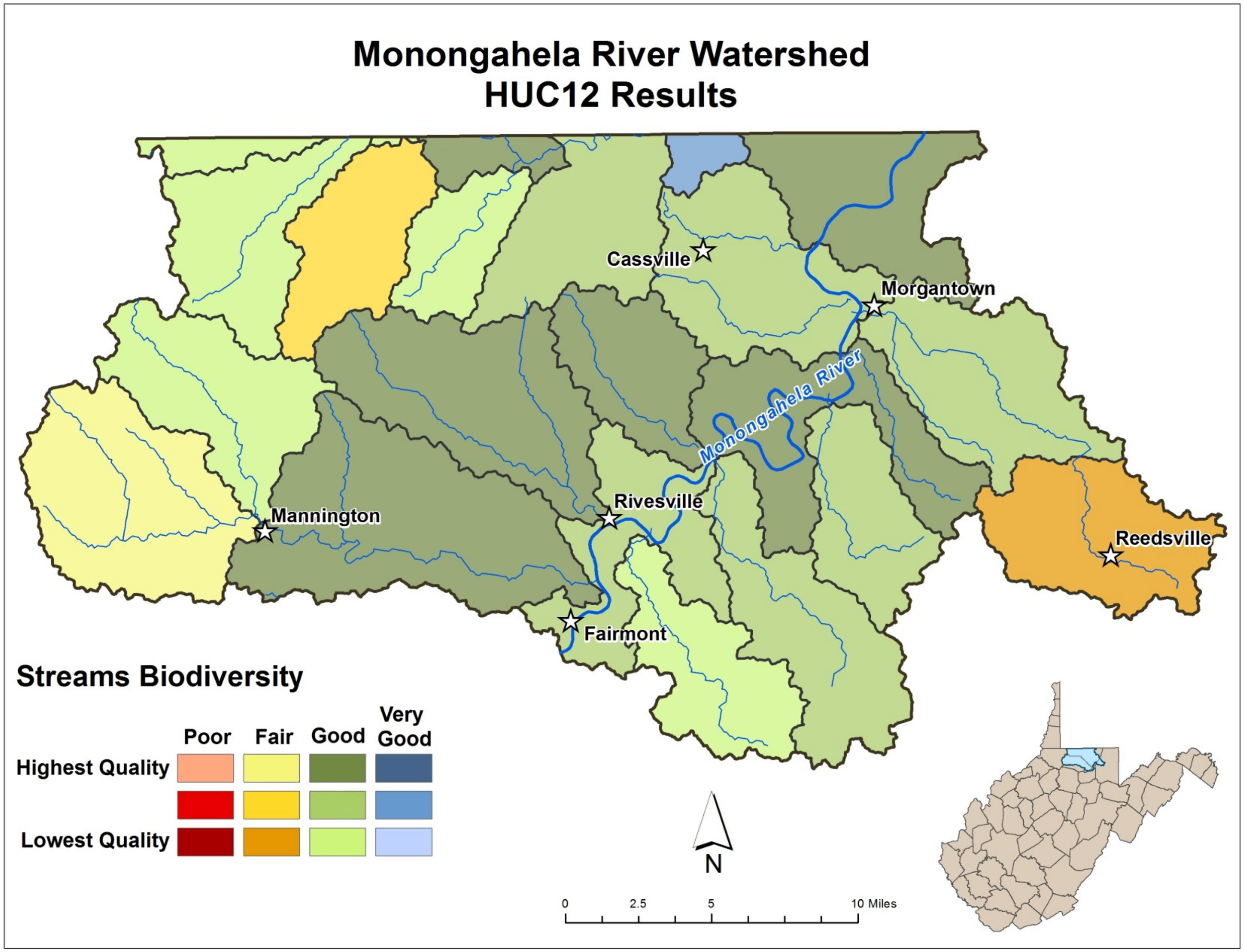

Figure 21a. Streams Biodiversity Index Results – HUC12 Level

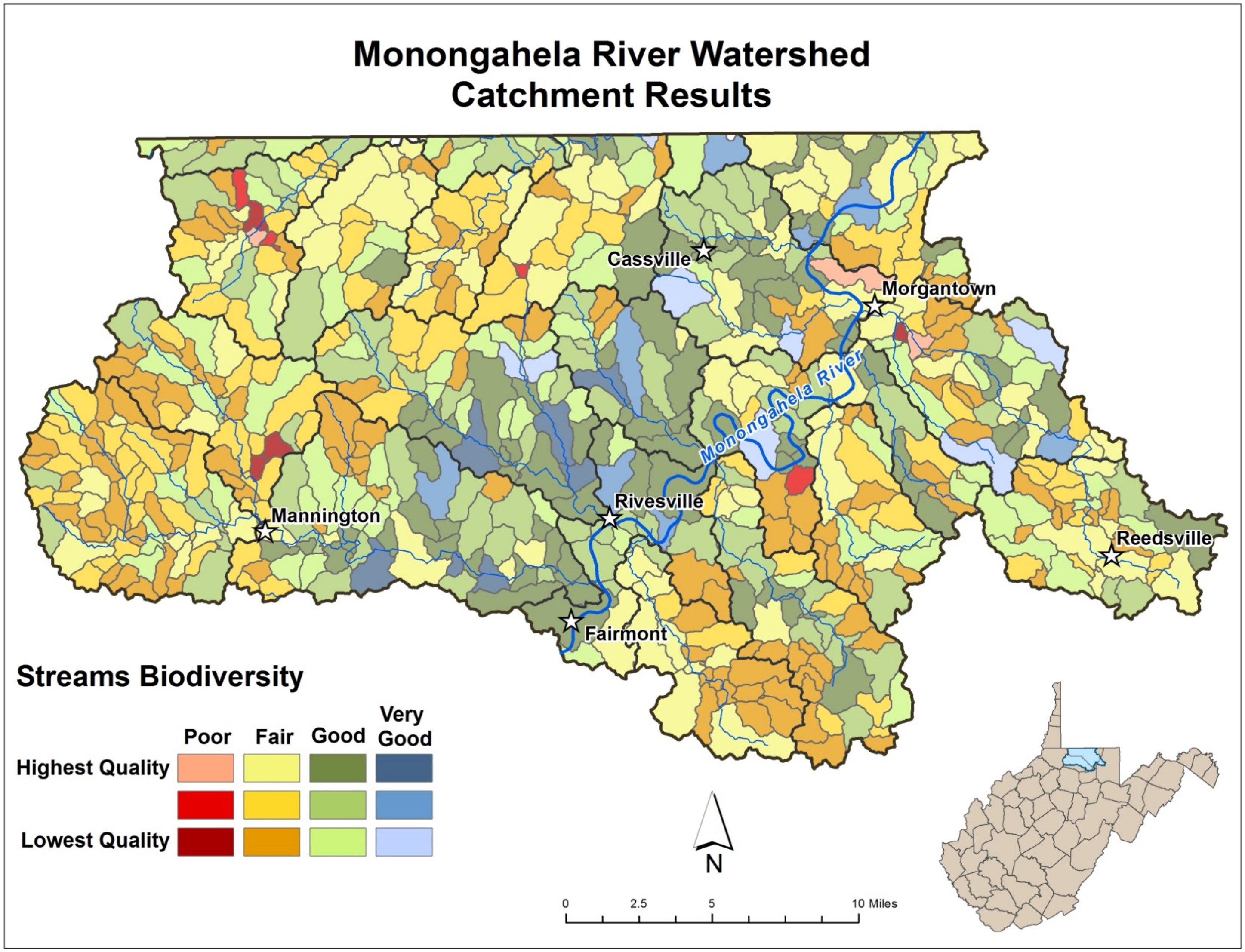

Figure 21b. Streams Biodiversity Index Results – Catchment Level

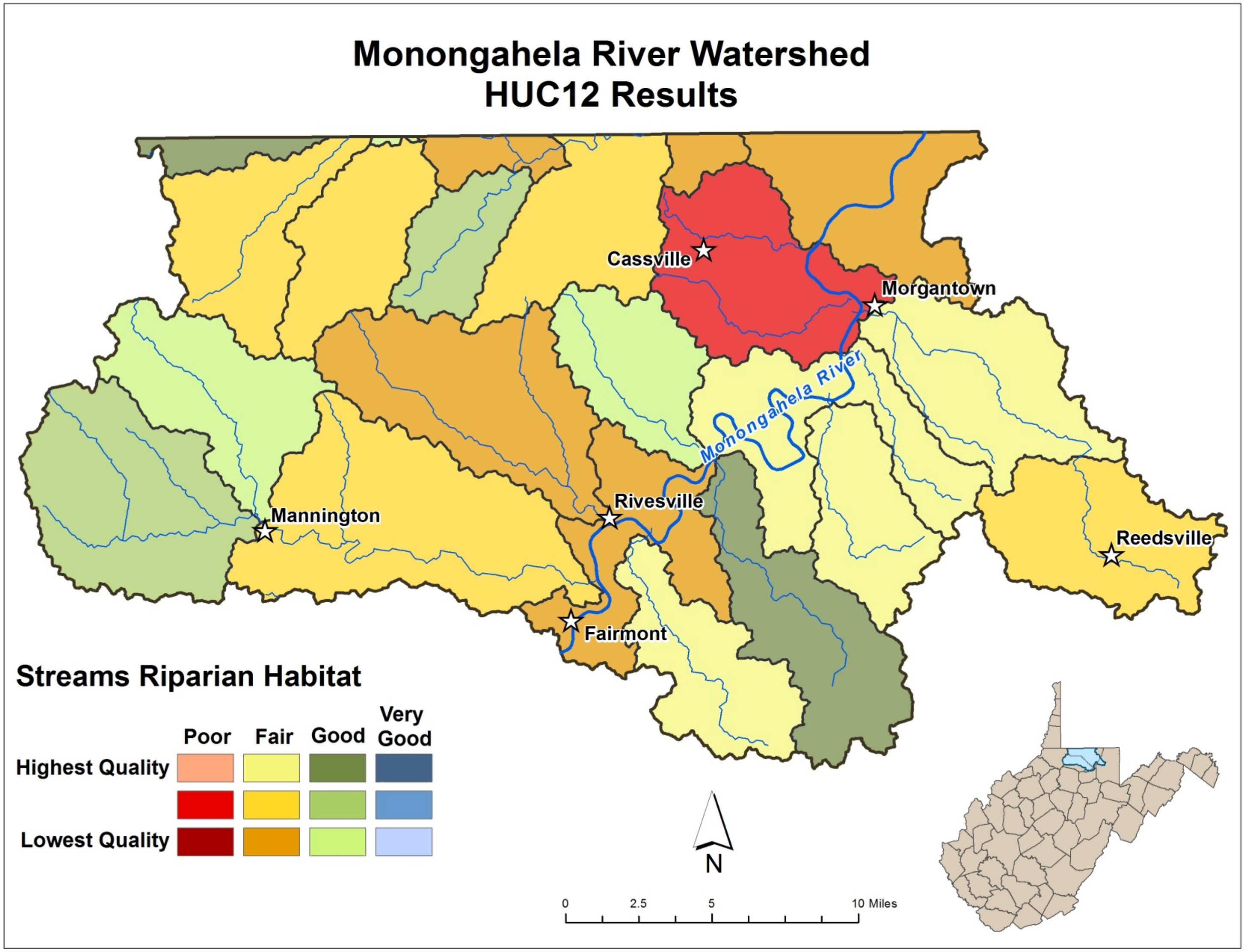

Figure 22a. Streams Riparian Habitat Index Results – HUC12 Level

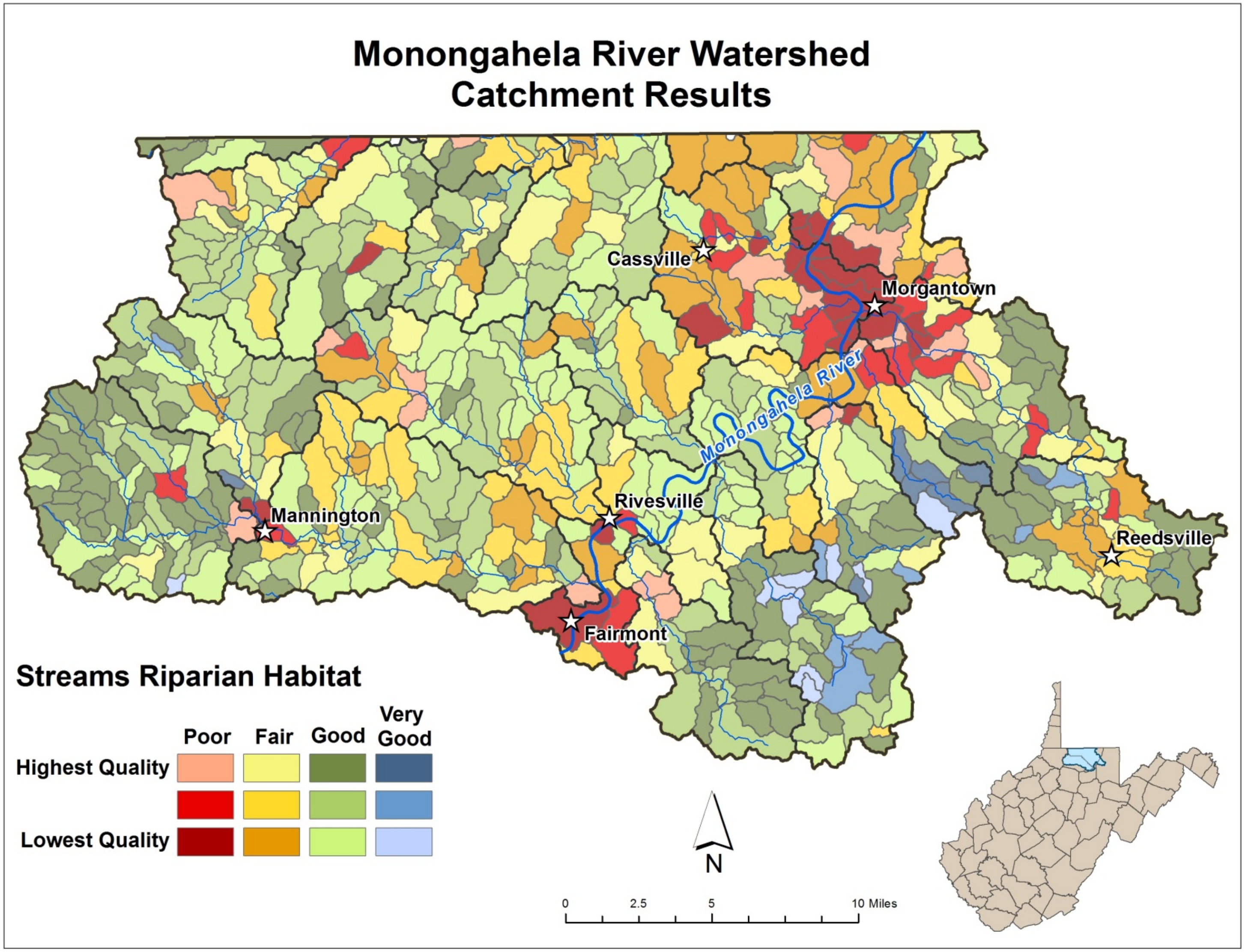

Figure 22b. Streams Riparian Habitat Index Results – Catchment Level

4.1.2 Wetlands

As previously stated, the wetlands NWI dataset was compiled over many years and published almost two decades ago, based on data from the 1970s and 1980s. Therefore, it is likely that wetlands locations and sizes have changed, some wetlands may no longer exist, or some wetlands may have been drained or converted to other land uses since they were mapped. New wetlands may also have been constructed or developed over time. Additionally, though most Wetlands metrics rely on data derived using existing wetland buffers or wetland catchments, the Wetlands Hydrology index (WHY) includes two metrics that do not depend on the current existence of wetlands: hydric soils and floodplain area. These metrics represent the potential for wetland hydrology and the possible historic presence of wetlands that have been drained, and therefore a potential for wetland restoration activities exists. All planning units have values for the WHY index, but planning units that contain no NWI wetlands include null values for the WWQ, WBD, and WWH indices. This can affect the Wetlands Overall results, as planning units without mapped wetlands but with hydric soils will automatically receive a Fair score due to the presence of wetlands hydrology, indicating that the potential for wetland restoration exists.

There is very little variability in the Wetlands Overall results (Figures 23a and 23b). The Booths Creek HUC12 has no mapped wetlands, which explains its Fair overall score, though it is still considered a good candidate HUC12 for wetland restoration activities. The remaining HUC12s fell into various levels of Good. More variability is evident in the Catchment level results, with the distinction between Good and Fair scores often being driven by the presence versus absence of existing wetlands. A few catchments scored in the Fair category even when wetlands were present, and this is largely due to alternative (non-natural) land uses within the wetland buffer or wetland catchment area.

Wetlands Water Quality (WWQ) results show the same trends as the Streams results, with the Morgantown area ranked the lowest and Whiteday Creek and Headwaters Buffalo Creek HUC12s ranked the highest (Figure 24a). Since many of the same datasets were used as water quality metrics (e.g., natural and forested land cover, mining, etc.), the parallel trends are expected. It is interesting and imperative to note the Fair results of some of the Headwaters Deckers Creek catchments (Figure 24b), since this HUC12 contains the largest wetland complex in the watershed. The relatively low ranking is likely due to low natural cover in the wetland catchments, caused by relatively high levels of grazing and development in the wetland catchments. These results suggest a high potential for wetland restoration in this area. Within other planning units that may be good candidates for restoration activities, the main issue that emerged in the WWQ results was a general lack of forested headwater wetlands.

Wetlands Hydrology (WHY) results are fairly uniform across the watershed, with all HUC12s and most catchments scoring in the Good category. Most Fair catchments have only wetland restoration potential, meaning they have values for the presence of hydric soils and floodplain area, but no existing wetlands. The Headwaters Deckers Creek HUC12 has a higher density of Good WHY scores because of the existence of a fairly large wetland complex in this area. These wetlands are not only large but also relatively well connected and potentially highly functional, considering landscape position and potential stressors. WHY results are consistent between the HUC12 and NHDPlus catchment levels of analysis (Figures 25a and 25b), with the high quality catchments generally containing the largest wetlands in the watershed.

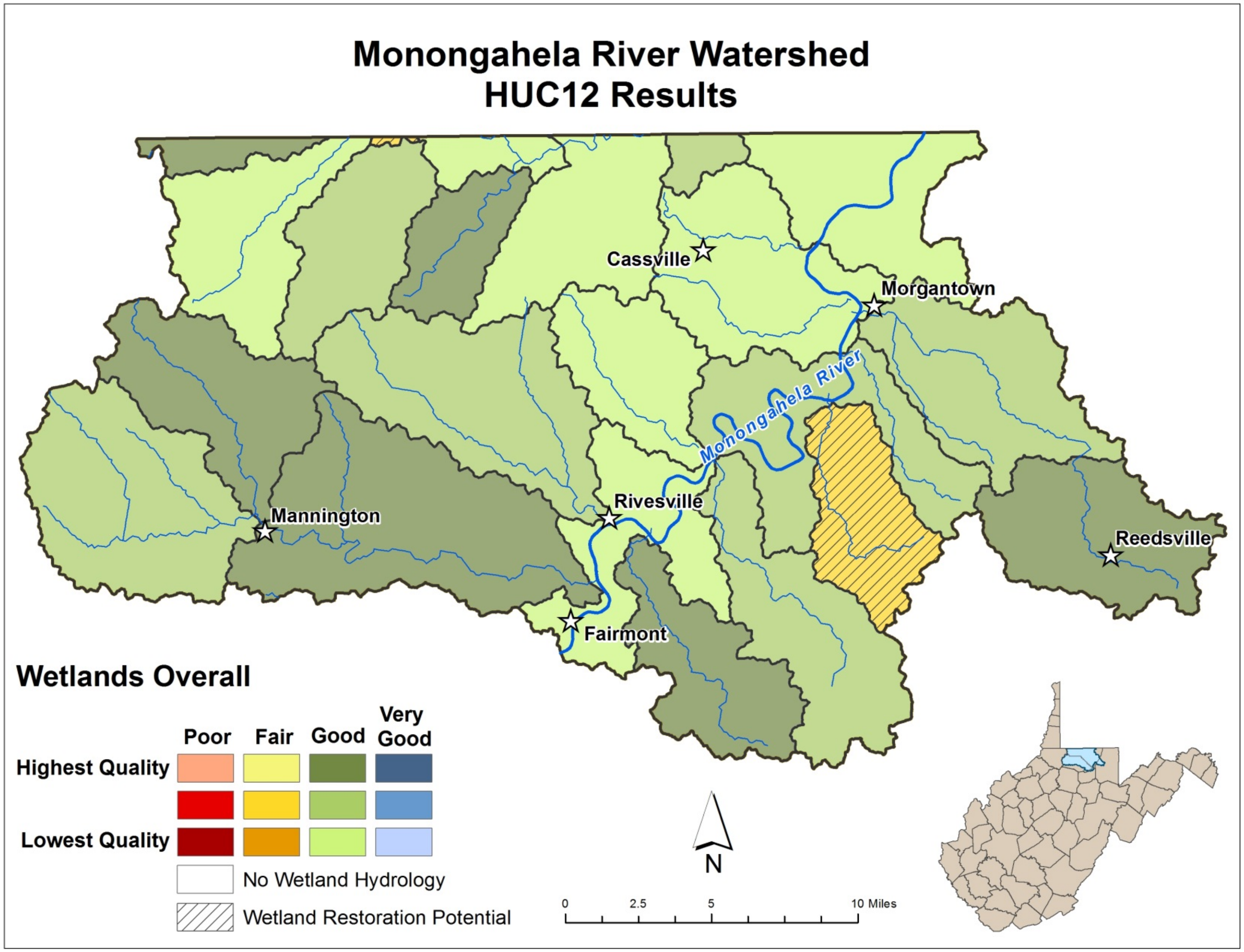

Figure 23a. Wetlands Overall Results – HUC12 Level

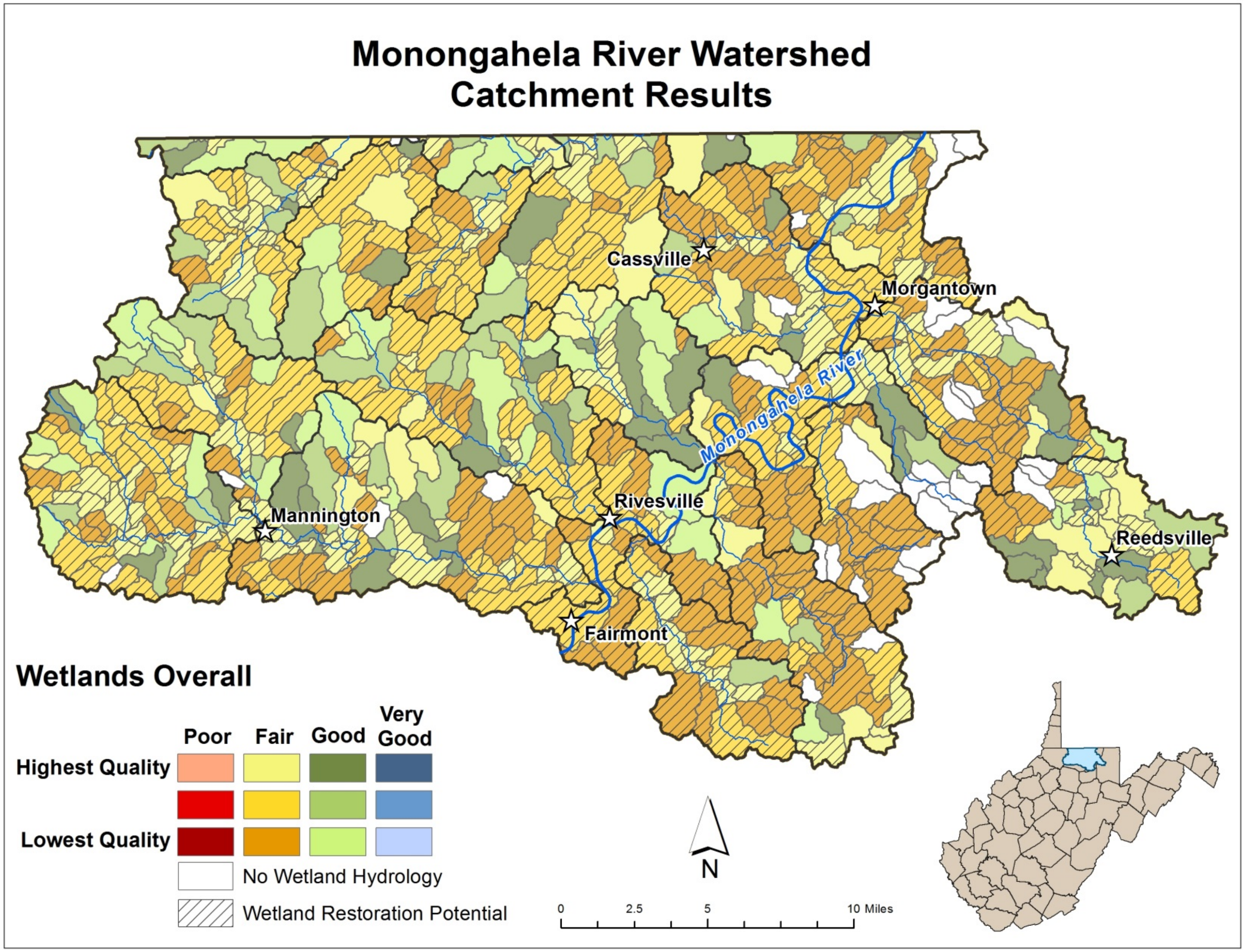

Figure 23b. Wetlands Overall Results – Catchment Level

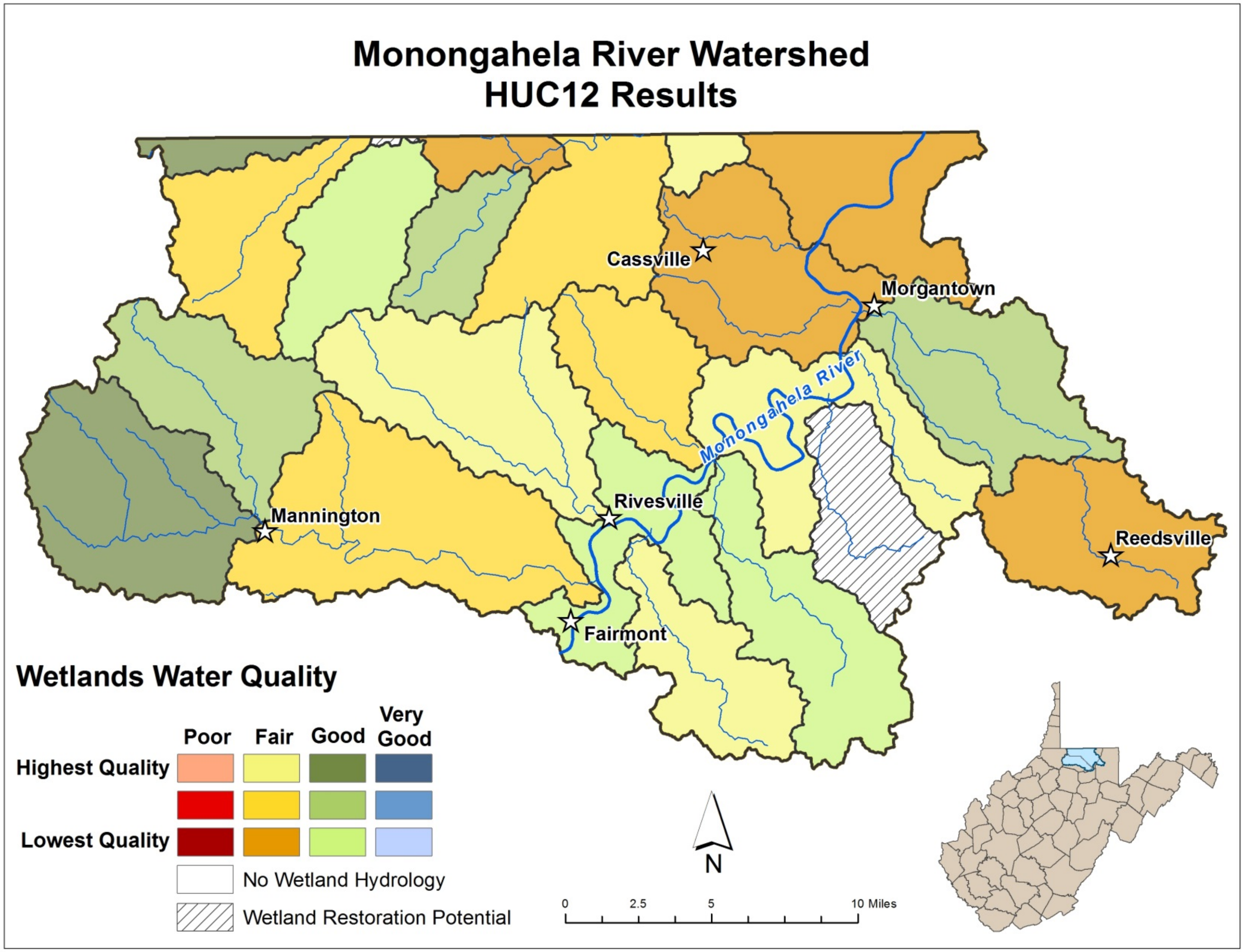

Figure 24a. Wetlands Water Quality Index Results – HUC12 Level

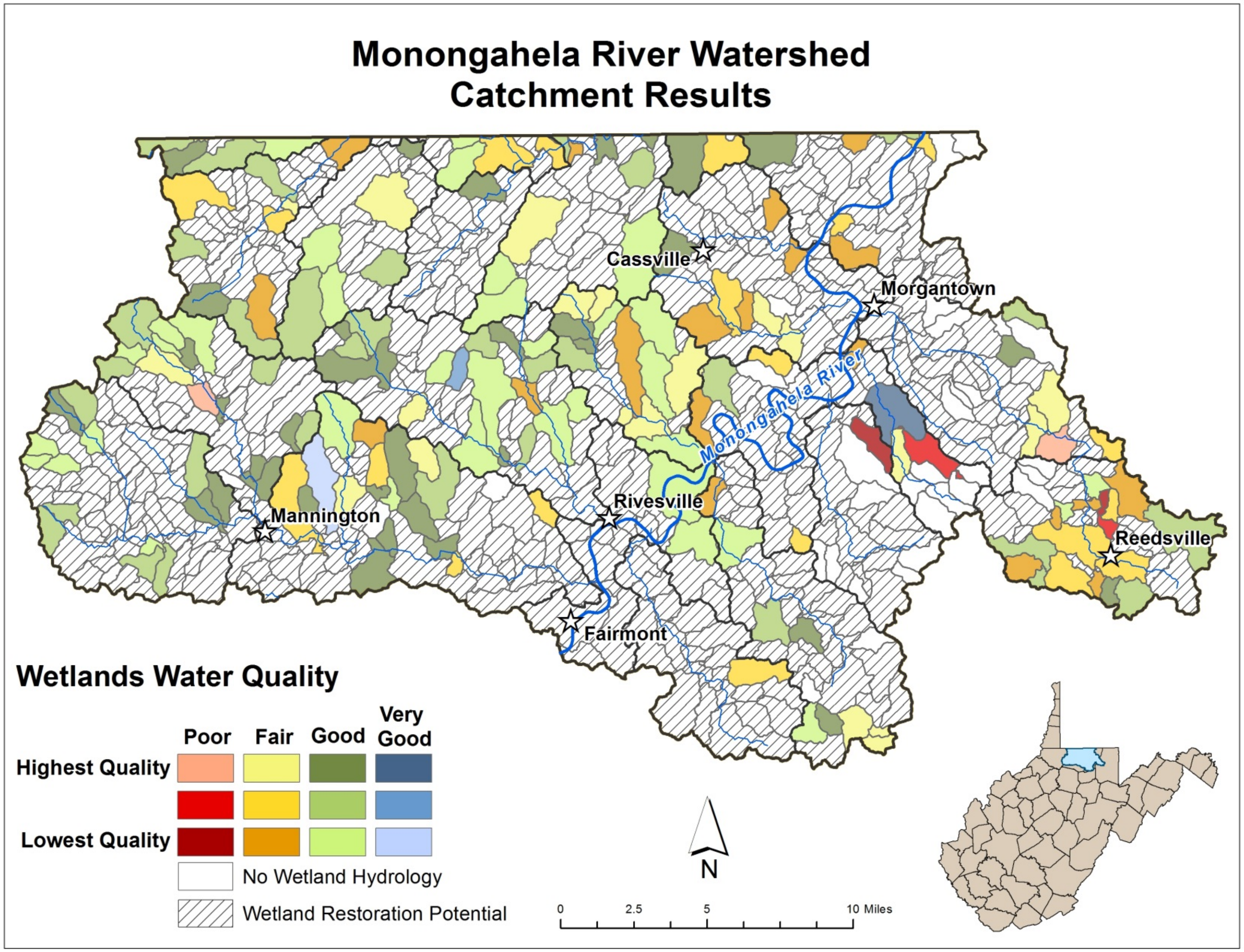

Figure 24b. Wetlands Water Quality Index Results – Catchment Level

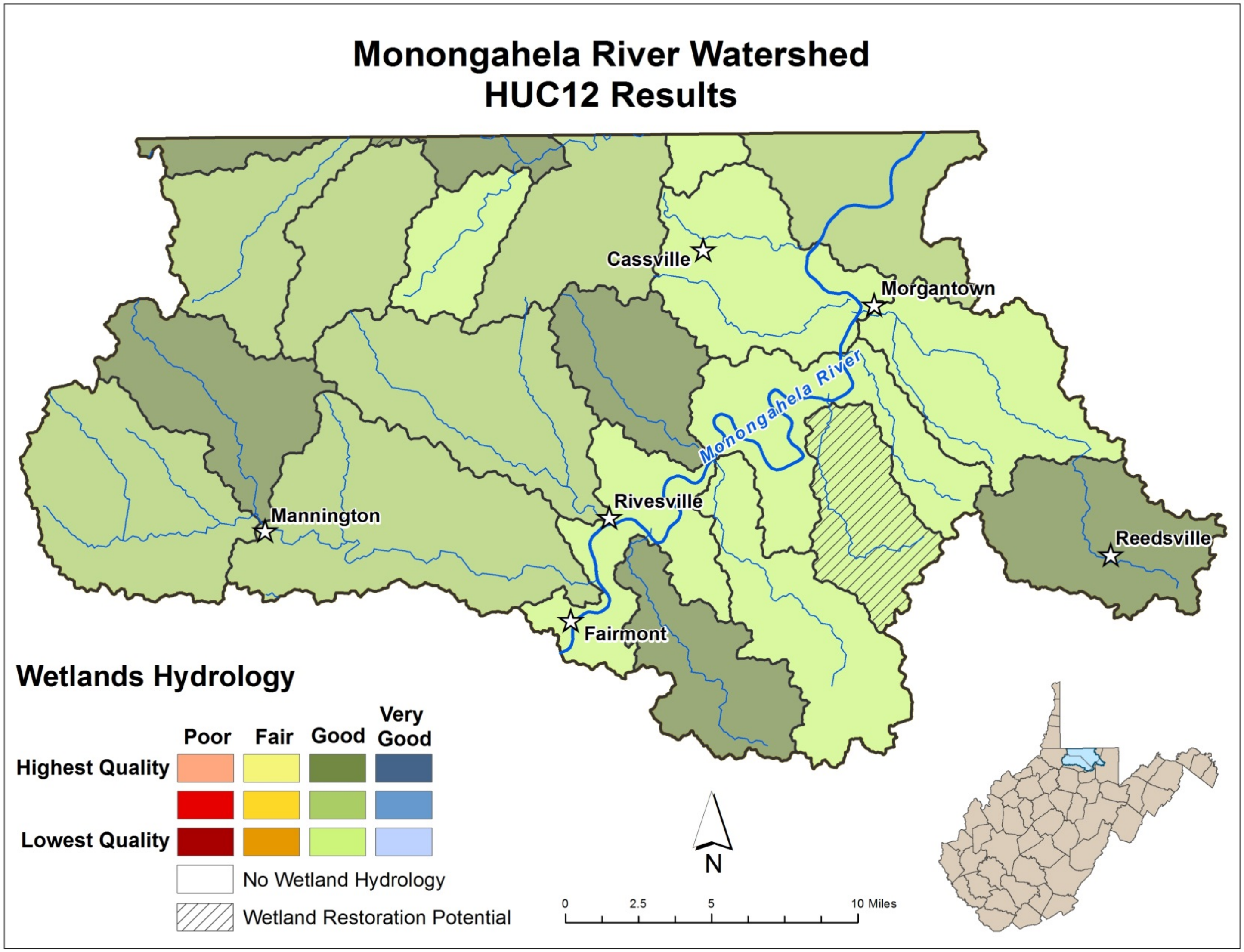

Figure 25a. Wetlands Hydrology Index Results – HUC12 Level

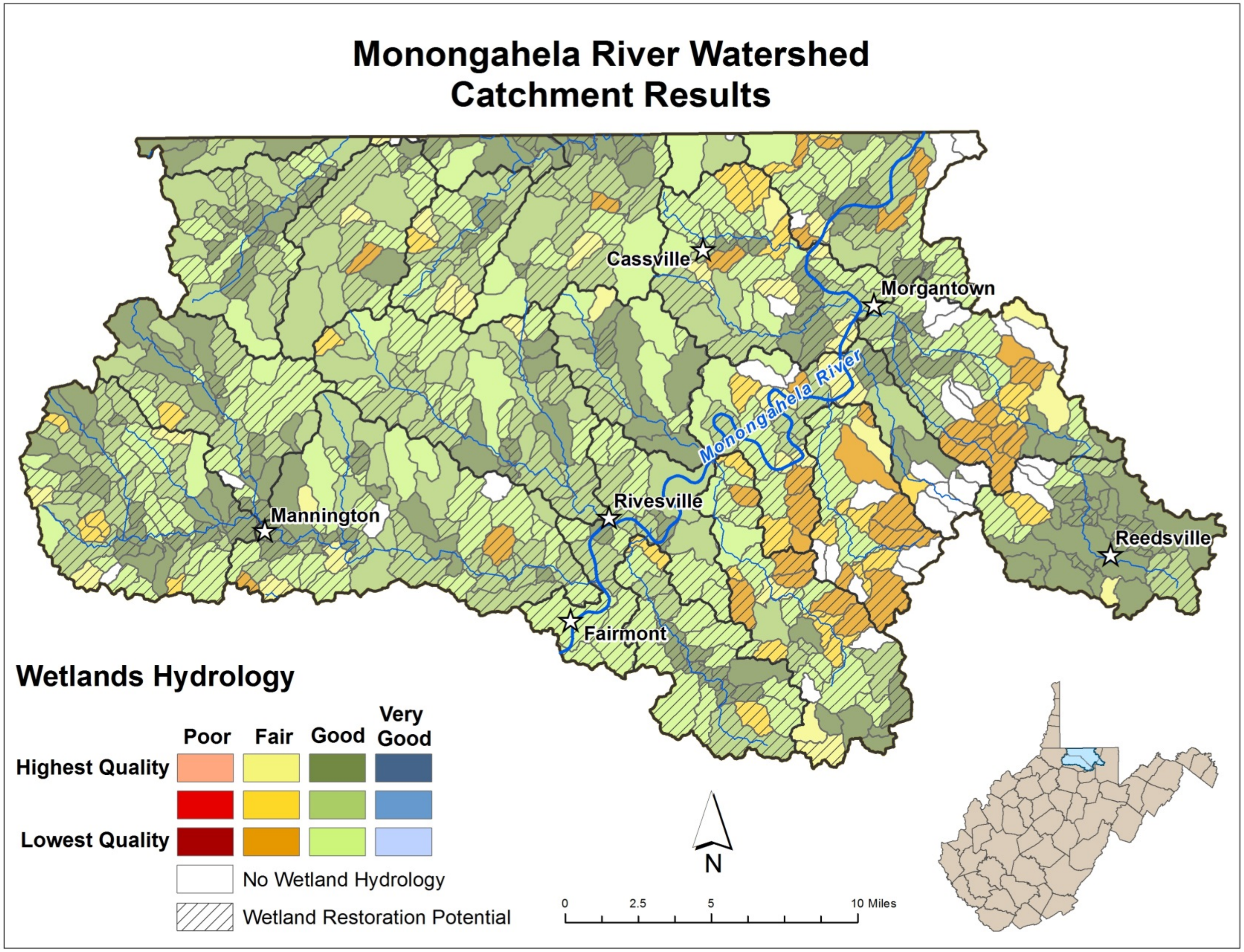

Figure 25b. Wetlands Hydrology Index Results – Catchment Level

The Wetland Biodiversity (WBD) index results range from Very Good to Fair (Figures 26a and 26b), for the same reasons that similar results were seen in the Streams Biodiversity index. However, the sparseness of the species data is even more apparent in this index, because rare species and non-native invasive species point locations would need to fall within the 50-meter wetland buffer. Any inaccuracies in the location of the points may cause them to erroneously fall outside of the wetland and its buffer and not be included in the index. Again, the WBD index results are mostly considered informational, and a thorough evaluation of the individual metrics scores would be necessary and appropriate.

The Wetlands Wetland Habitat (WWH) index results are largely driven by the critical metric of development in the wetland buffer, which keeps both HUC12 and catchment results at Fair (Figures 27a and 27b). Active surface mining in the wetland buffer is also a critical metric, but little surface mining is present within the wetland buffer in this watershed so this is generally not a factor (though this is the cause of the handful of Poor catchments in the northwest section of the watershed). The Very Good ranking catchments had very high percentages of natural cover within the wetland buffer, which also indicates that other land use metrics would have Very Good-Good scores. These catchments can be considered high priorities for protection when wetland habitat is a concern.

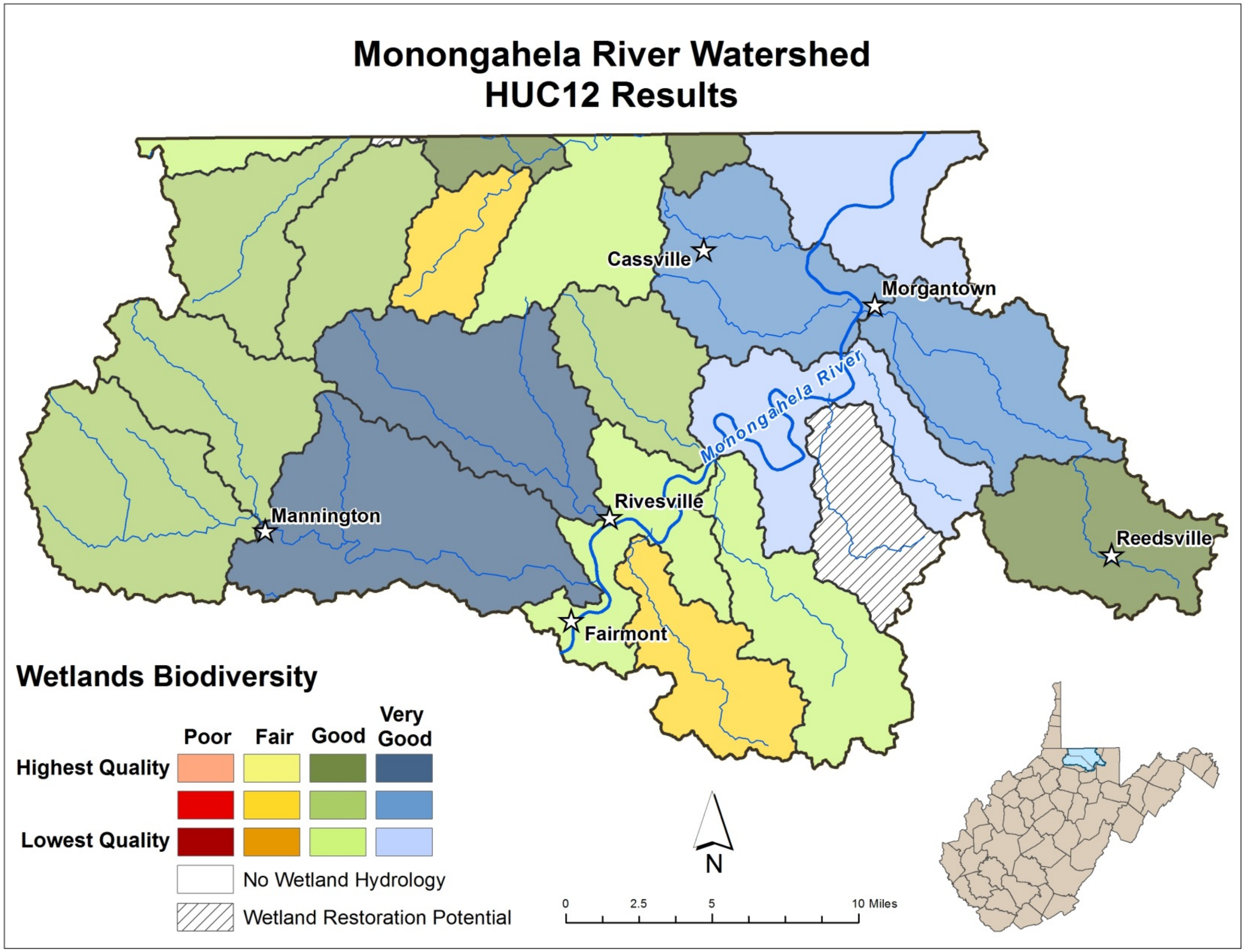

Figure 26a. Wetlands Biodiversity Index Results – HUC12 Level

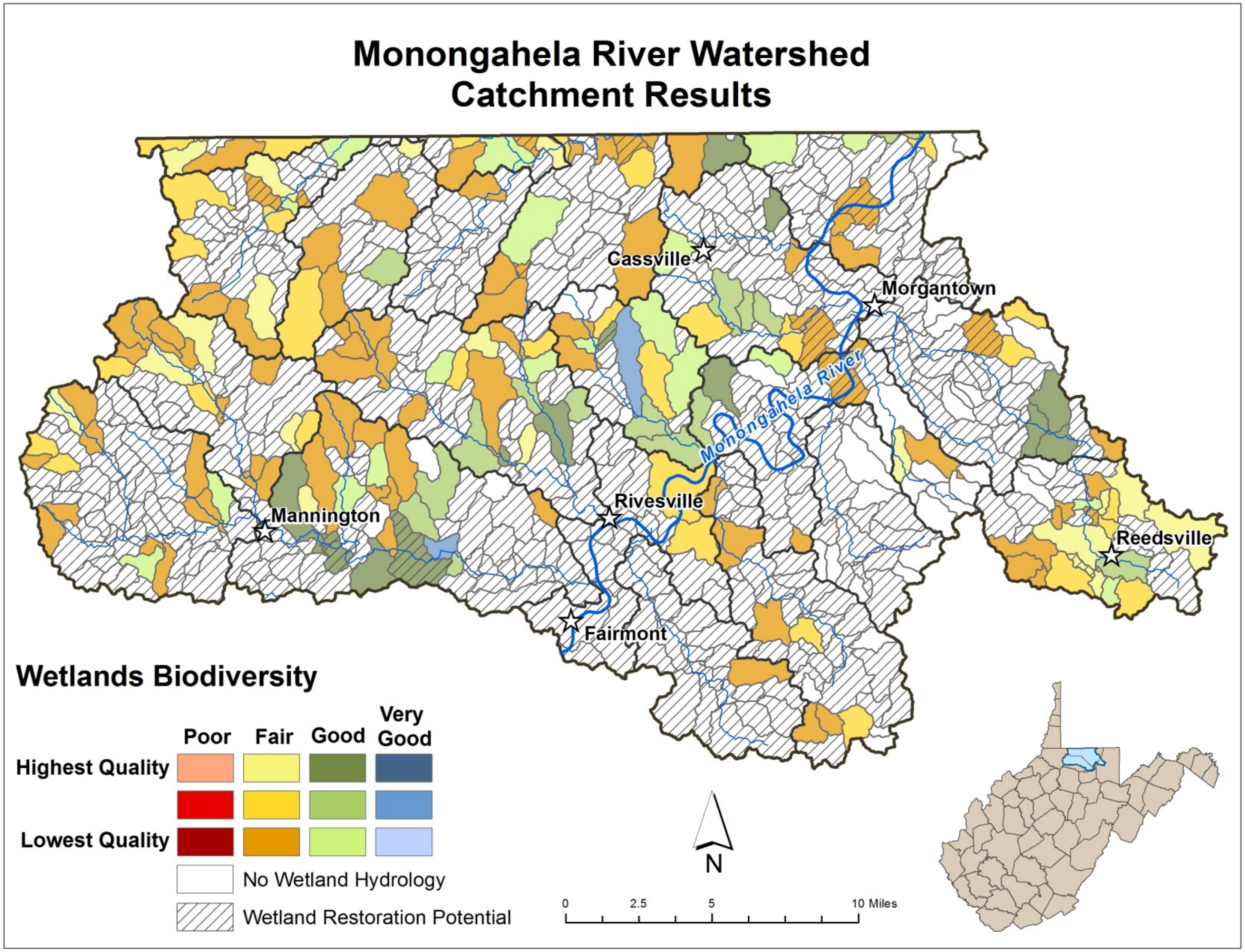

Figure 26b. Wetlands Biodiversity Index Results – Catchment Level

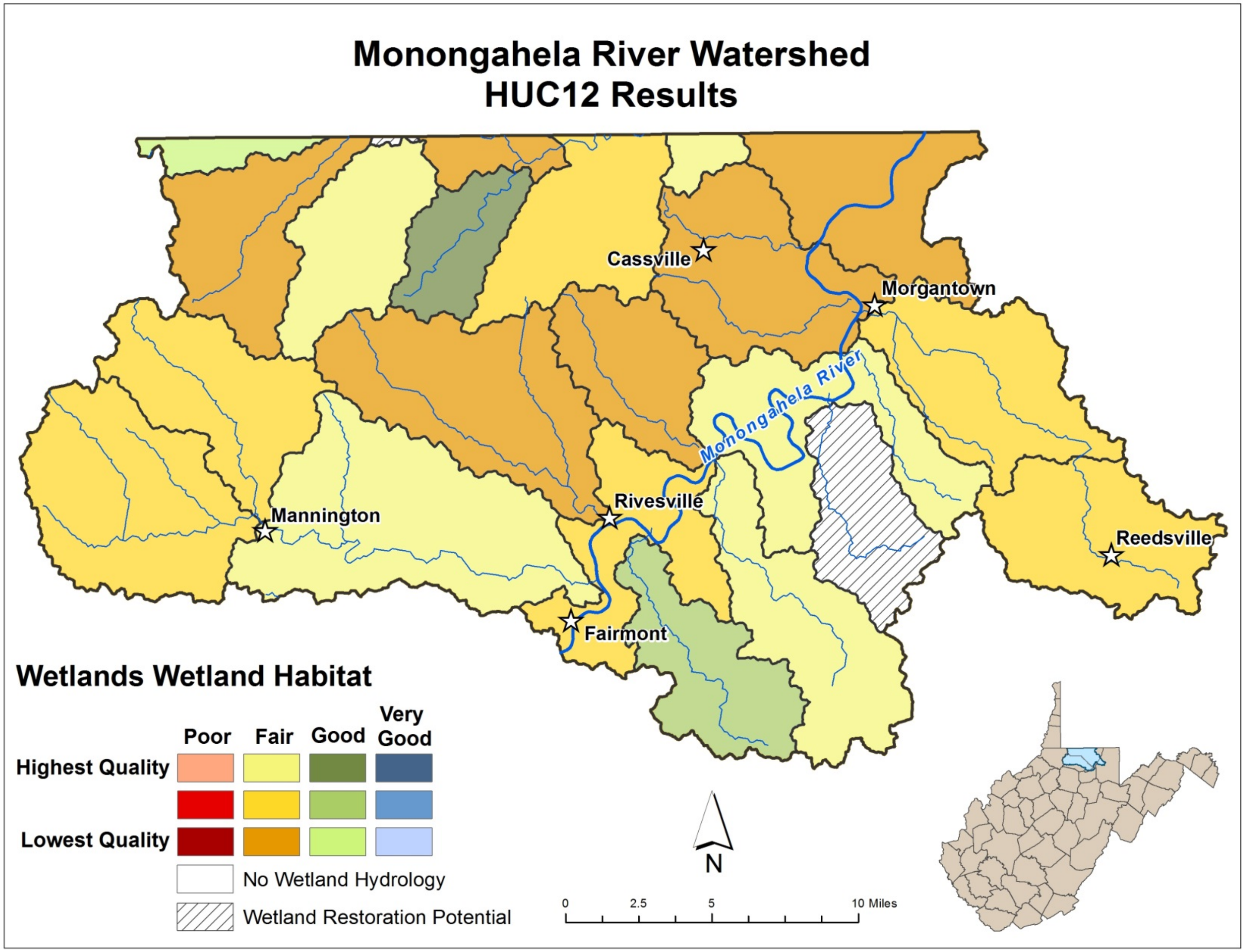

Figure 27a. Wetlands Wetland Habitat Index Results – HUC12 Level

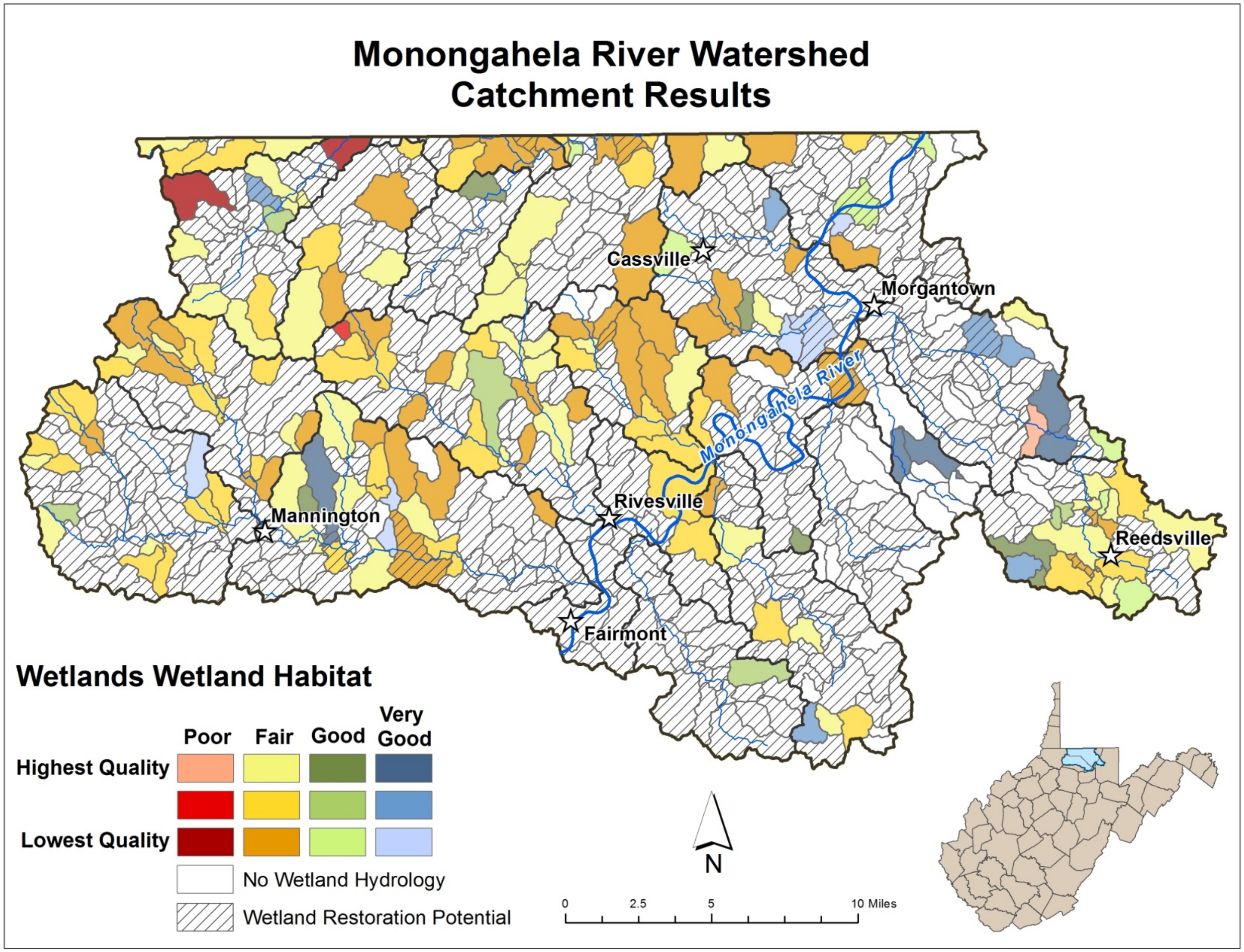

Figure 27b. Wetlands Wetland Habitat Index Results – Catchment Level

4.1.3 Uplands

The Uplands Priority Model Overall results exhibit a very different trend than the Streams and Wetlands Models, with many more planning units in the Fair-Poor categories (Figures 28a and 28b). This is largely due to the urbanization and level of development within certain parts of the watershed, a pattern that is evident from the lower scores tending to follow the I-79 corridor. The clusters of higher-scoring NHDPlus catchments are in the headwaters regions, so it may be assumed that this trend is largely due to the heavily forested cover and lack of surface disturbance in these higher portions of the planning units. The Headwaters Deckers Creek area includes a narrow corridor of development along State Highway 7, some surface mining, and the most extensive grazing and agriculture in the watershed. These factors explain the lower ranking for this HUC12 in some of the indices, reducing its overall rankings at the catchment level as well.

The Uplands Habitat Connectivity (UHC) index results are similar to the Overall model results, though the scores are generally lower in this index (Figures 29a and 29b). The UHC index has two critical metrics, the amount of development and active surface mining, and these metrics, in particular development, keep the final scores at Fair or Poor. Higher scoring planning units generally have no mining activity and minimal development, while also having few other fragmenting features (energy transmission lines and pipelines, wind turbines, timber harvesting, etc.). Again, the headwaters reaches of the watershed emerged as highest quality.

The Uplands Habitat Quality (UHQ) index results are also similar to the Uplands Overall model, with a notable lack of high-scoring HUC12s (Figure 30a). Again, development and active surface mining are critical metrics in this index and largely drive the results, particularly for those planning units in the Fair-Poor categories. The Headwaters Deckers Creek had lower scores for many of the same reasons as for the Overall model results discussed above, as there is less natural cover in the watershed and more grazing. The NHDPlus catchments maintain the recurring trends of lower relative scores in the developed or mined areas, and higher scores in the forested headwater reaches, with some Very Good catchments in the western headwaters area of the watershed (Figure 30b).

The Uplands Biodiversity (UBD) index results are fairly uniform at the HUC12 level (Figure 31a), with all HUC12s scoring Good, except for Pyles Fork, which scored Fair due to high predicted percent tree basal area loss and the presence of non-native invasive species. The UBD is a good illustration of how the addition of new metrics, particularly heavily weighted stressor metrics, can have a significant impact on the final scores; in this case, the influence of the percent loss metric. More variability is seen in the catchment level UBD results (Figure 31b), with the Very Good and Poor rankings being largely driven by the percent loss, terrestrial habitat types, and calcareous bedrock metrics (many of the catchments that fell into these two categories had data for these metrics only). Among the Good catchments either the rare species or non-native invasive species, or both, often either raised or lowered the final ranking.

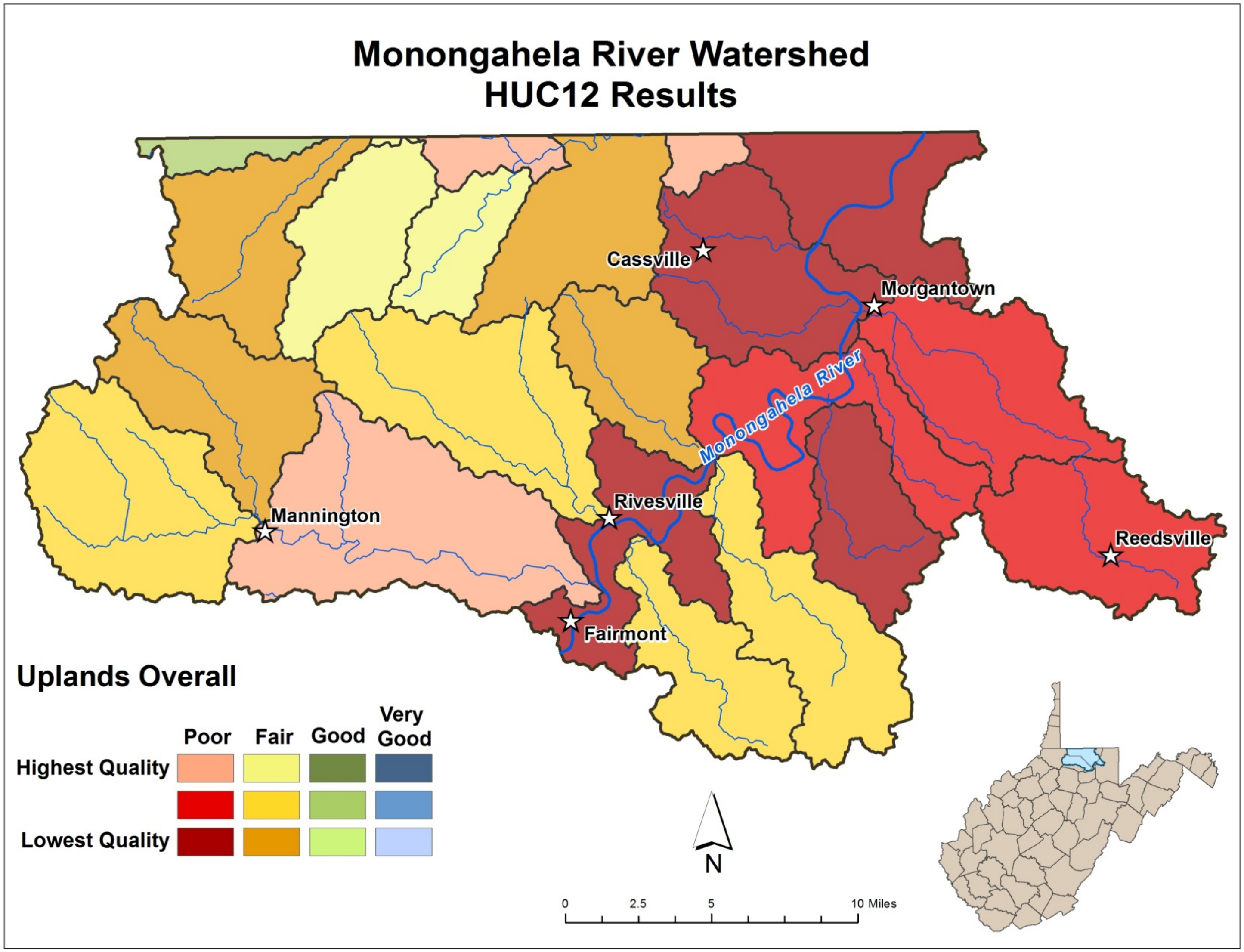

Figure 28a. Uplands Overall Results – HUC12 Level

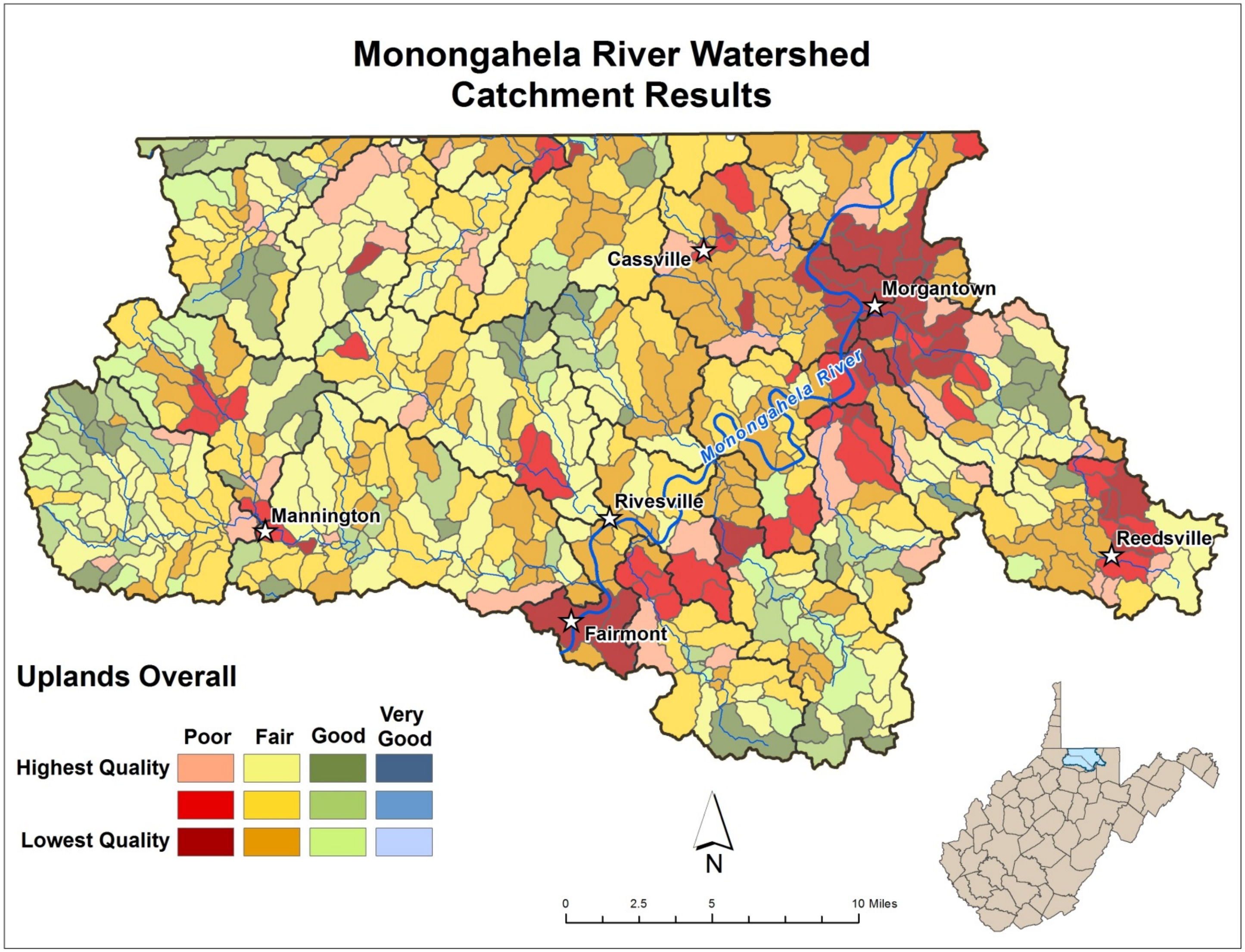

Figure 28b. Uplands Overall Results – Catchment Level

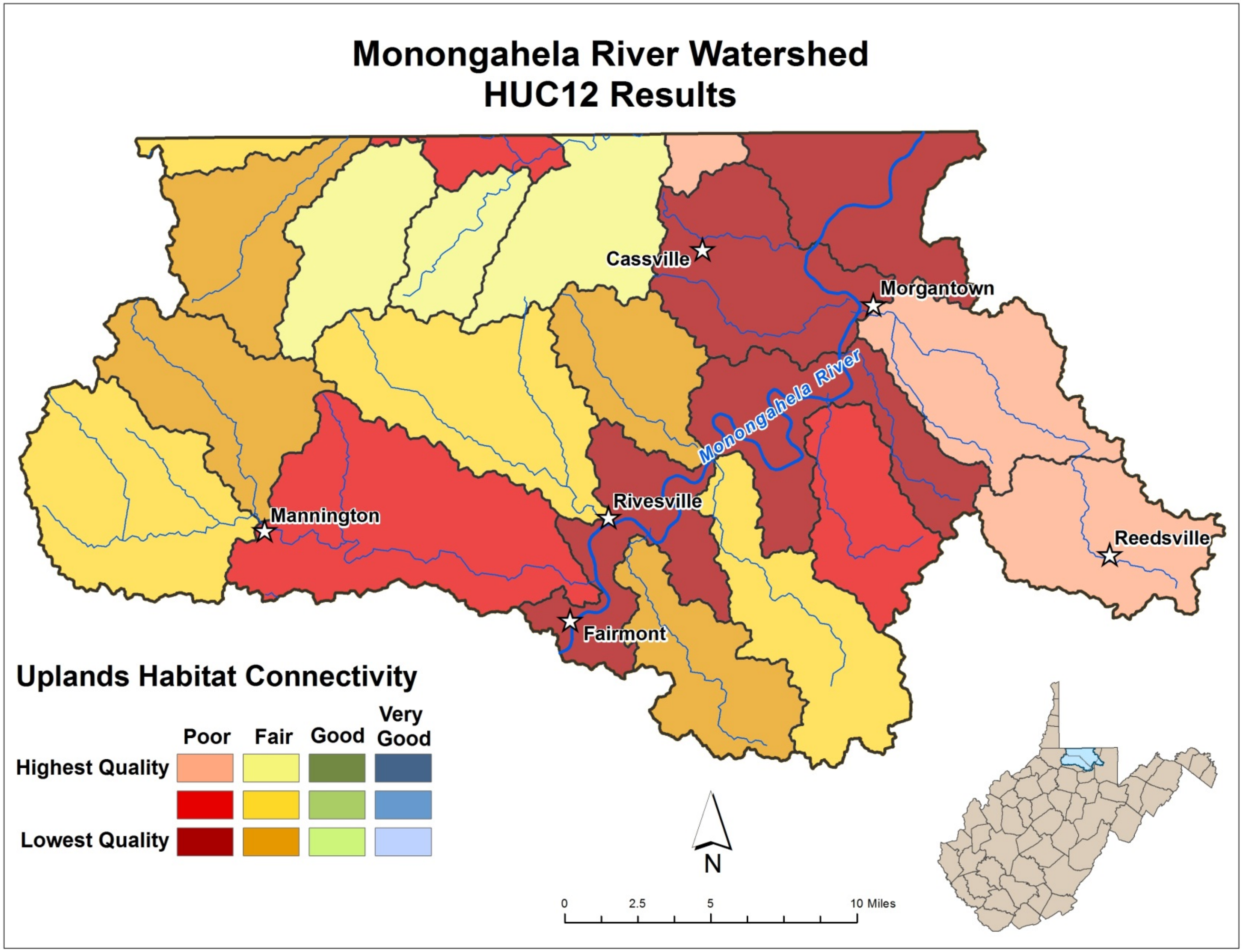

Figure 29a. Habitat Connectivity Index Results – HUC12 Level

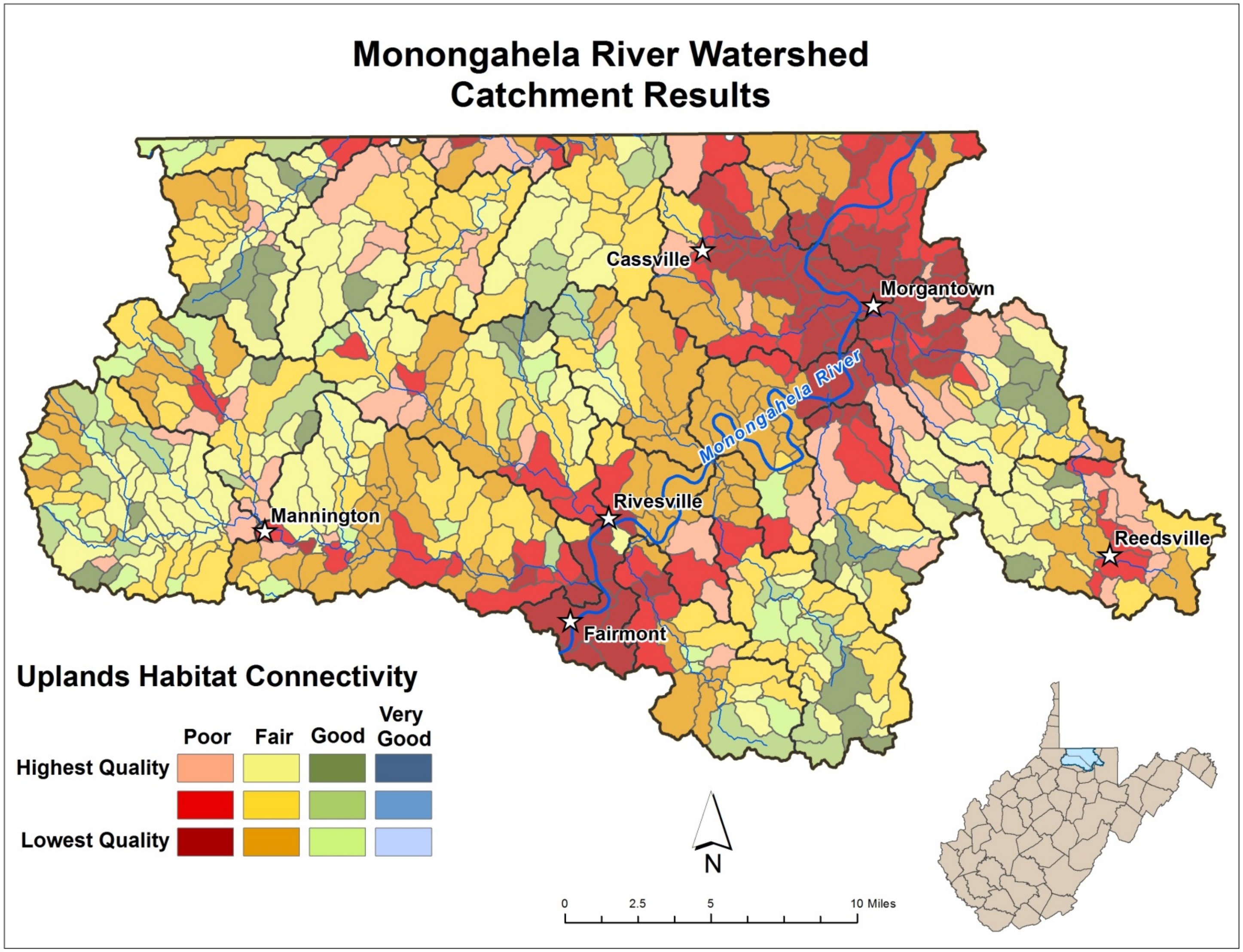

Figure 29b. Habitat Connectivity Index Results – Catchment Level

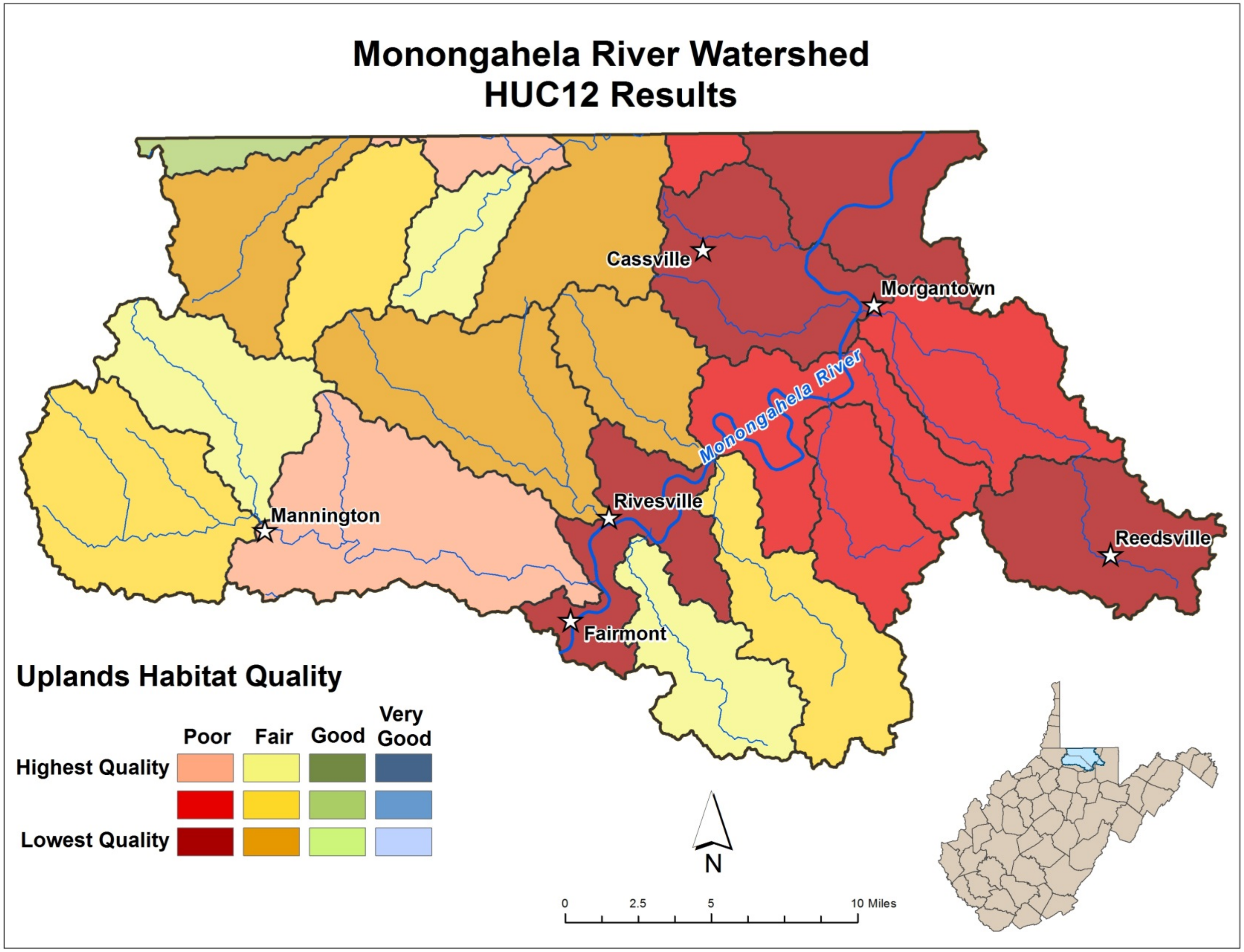

Figure 30a. Habitat Quality Index Results – HUC12 Level

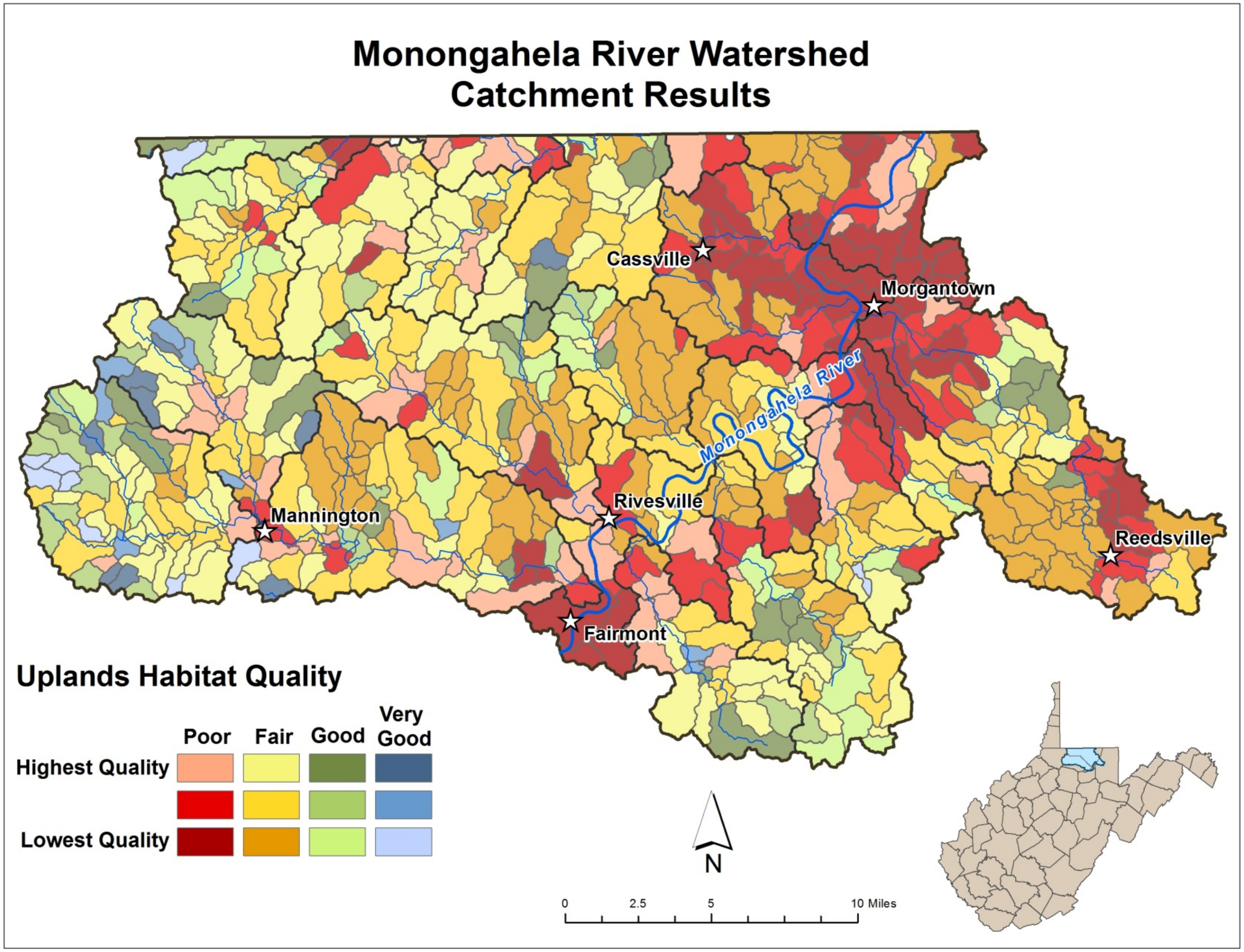

Figure 30b. Habitat Quality Index Results – Catchment Level

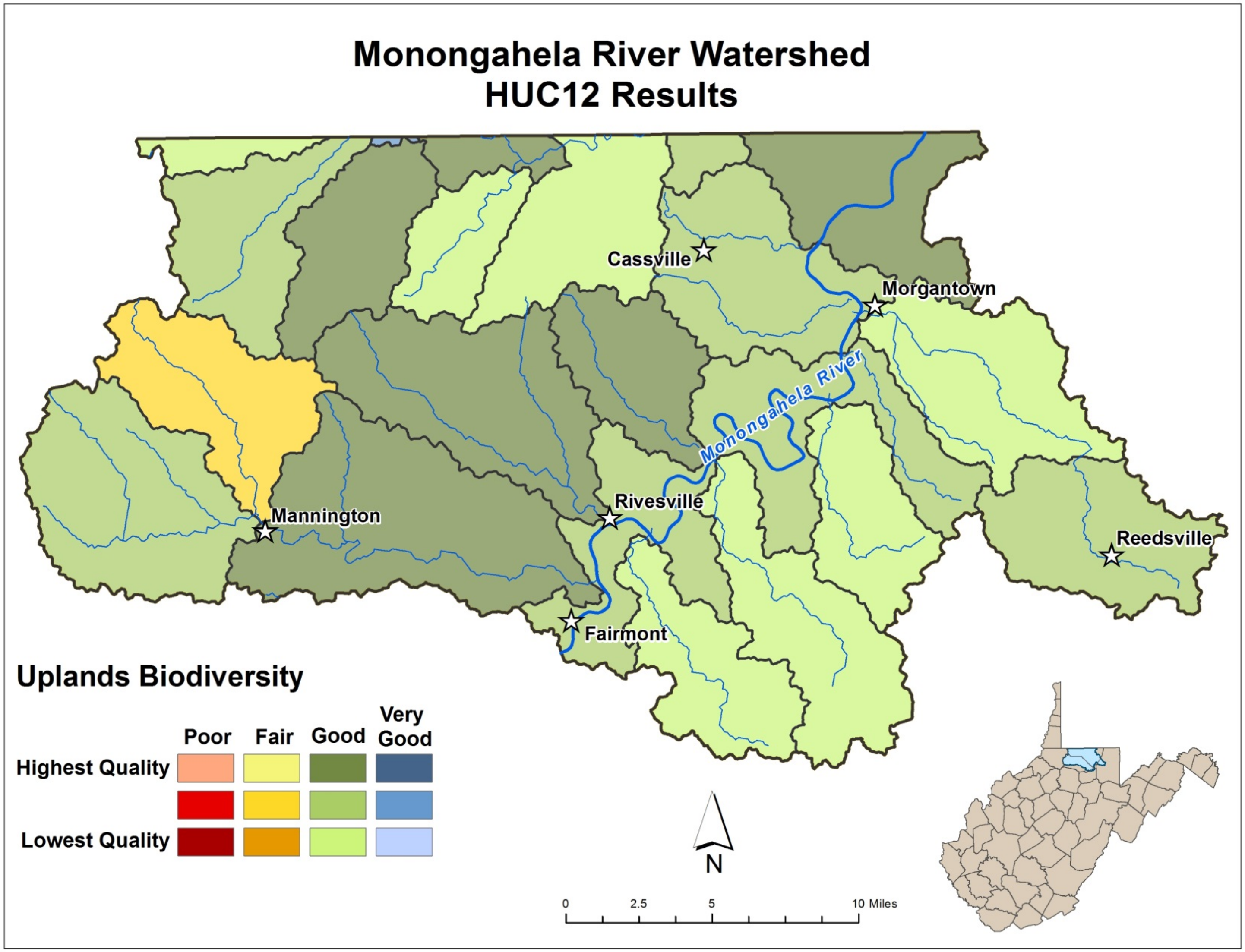

Figure 31a. Uplands Biodiversity Index Results – HUC12 Level

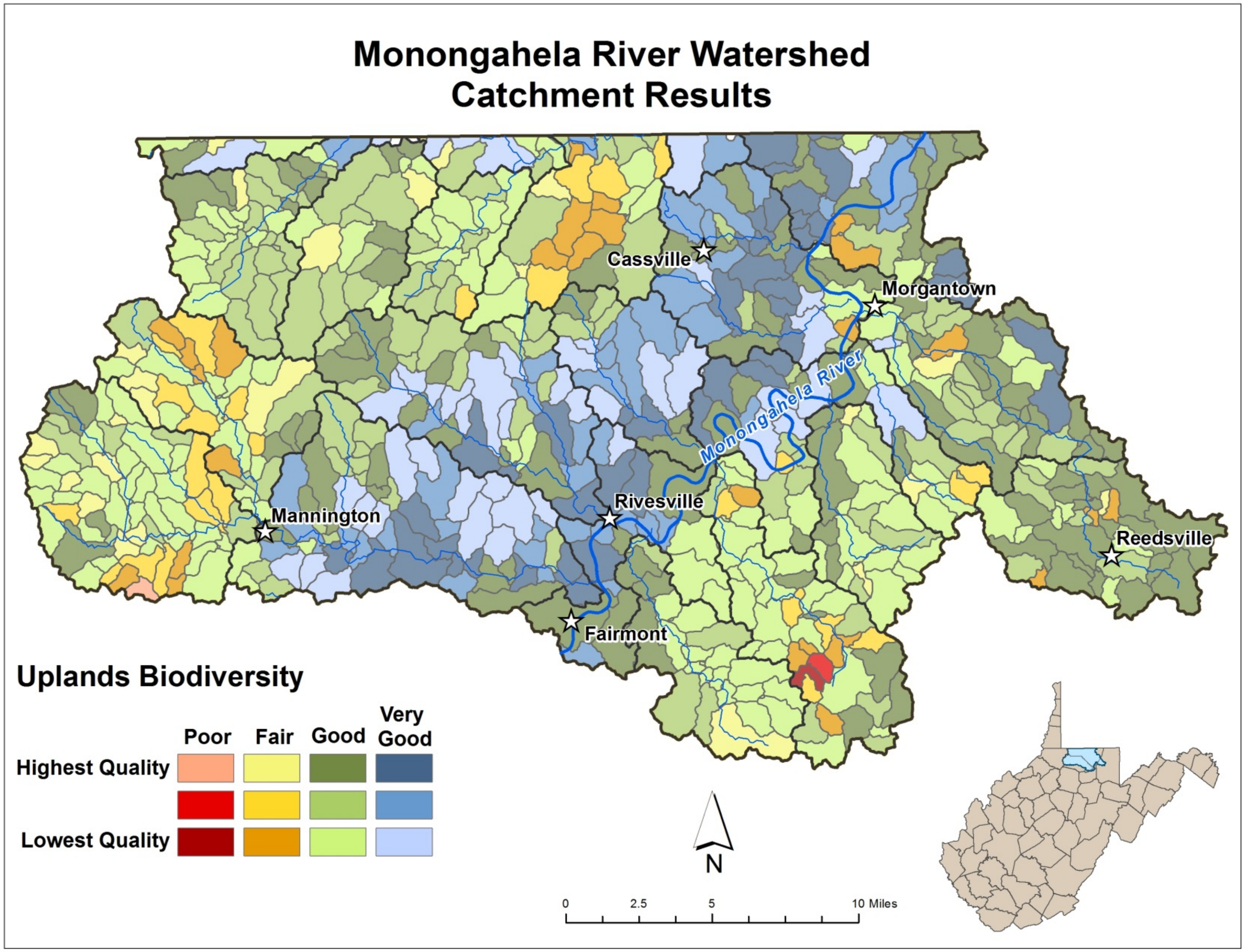

Figure 31b. Uplands Biodiversity Index Results – Catchment Level

4.2 Consolidated Analysis Results and Discussion

The Consolidated Analysis results were expected, with the greatest threats concentrated around the expanding urban area of Morgantown and along the I-79 and I-68 highway corridors (Figure 32). The western portion of the watershed shows relatively lower future threats primarily because of the lack of encroaching urban development. West-east trends are evident in several metrics, since the Marcellus Shale thickness and wind potential are greater in the high elevations to the east, and predicted climate change impacts are generally more severe to the east and the north. Hot spots of high future threats are mostly related to unmined coal within existing permit boundaries and potential future development patterns around the Morgantown area. Urban centers also generally have lower resiliency and regional flow scores, the datasets used as surrogates for the potential threat of climate change.

The Energy results show a range of variability primarily because the various threats analyzed are unevenly distributed across the landscape (Figure 33). Certain potential future threats, such as shale gas development and wind potential, are higher in the east, but unmined coal is present both along the river valley and in the far eastern and western portions of the watershed. Geothermal potential is highest in the center of the watershed.

Two indices, Population and Development and Climate Change, had data available for only two metrics each and are therefore not very robust. General trends were growth within and around the urban area of Morgantown (based on county-level population projections and Morgantown growth projections), as well as decreased resiliency and regional flow in the developed parts of the watershed (Figures 34 and 35). The relatively pristine headwater reaches in the western part of the watershed, as well as those along the ridges in the eastern arm of the watershed, were the highest scoring for both resiliency and regional flow. These datasets are from a greater regional analysis conducted by The Nature Conservancy's Eastern Conservation Science division. Resiliency is a measure of landscape complexity and landscape permeability, while Regional Flow data more specifically identifies "larger-scale directional movements and…areas where they are likely to become concentrated, diffused, or rerouted, due to the structure of landscape" (Anderson et al. 2012). More details about the resiliency data can be found in Section 3.1.6 Consolidated Analysis.

The Monongahela watershed has only a handful of small protected lands, all of which are GAP Status 3 (Permanently Secured for Multiple Uses), including four Wildlife Management Areas and one State Park (Figure 36). The Monongahela River and Dunkard Creek are considered part of TNC's aquatic portfolio, and several of the HUC12s in the watershed are considered water quality priorities for the West Virginia Division of Forestry (Figure 37). These Opportunities datasets are included to encourage collaboration and partnership between agencies and organizations that may have overlapping goals and priorities within the watershed.

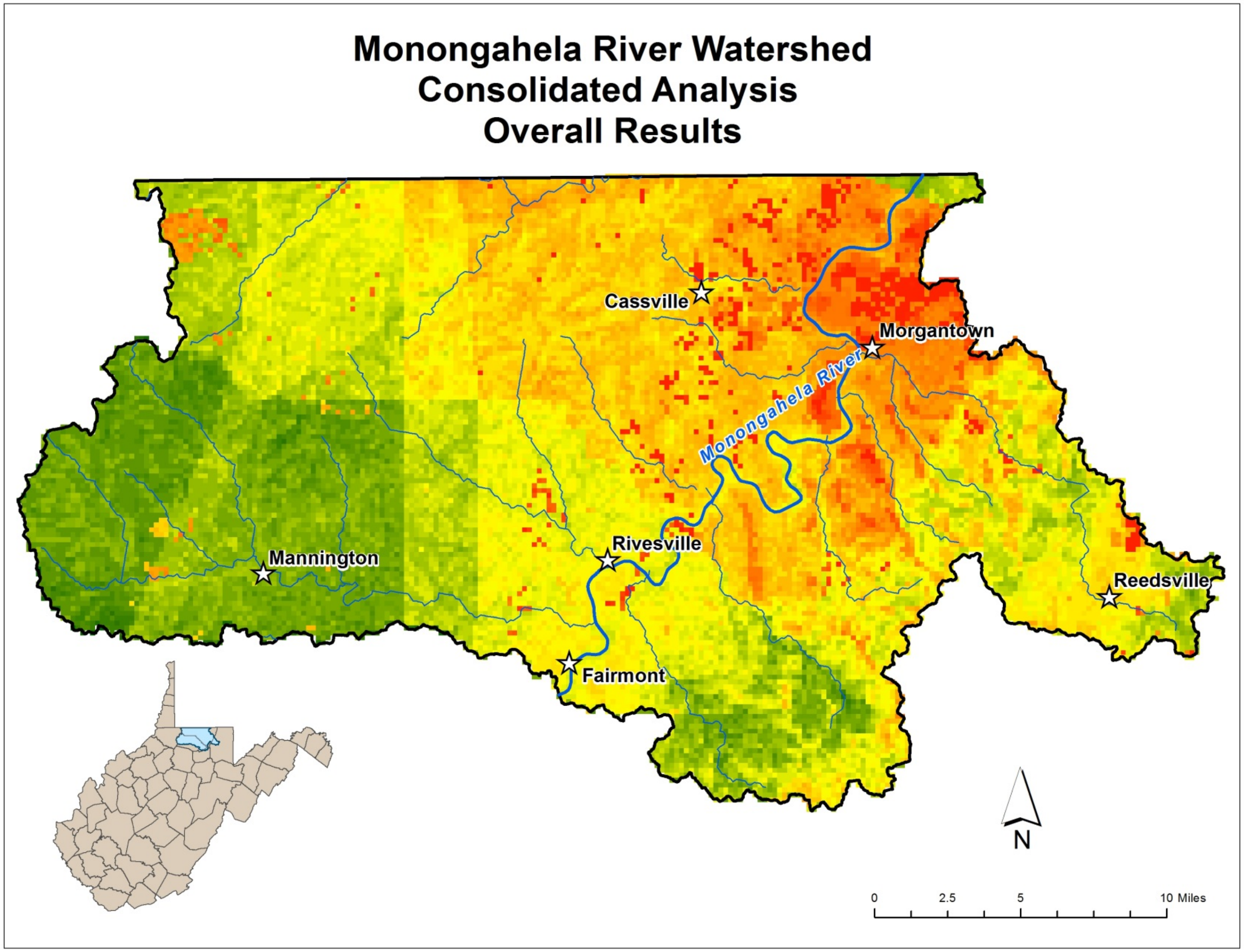

Figure 32. Consolidated Analysis Overall Results

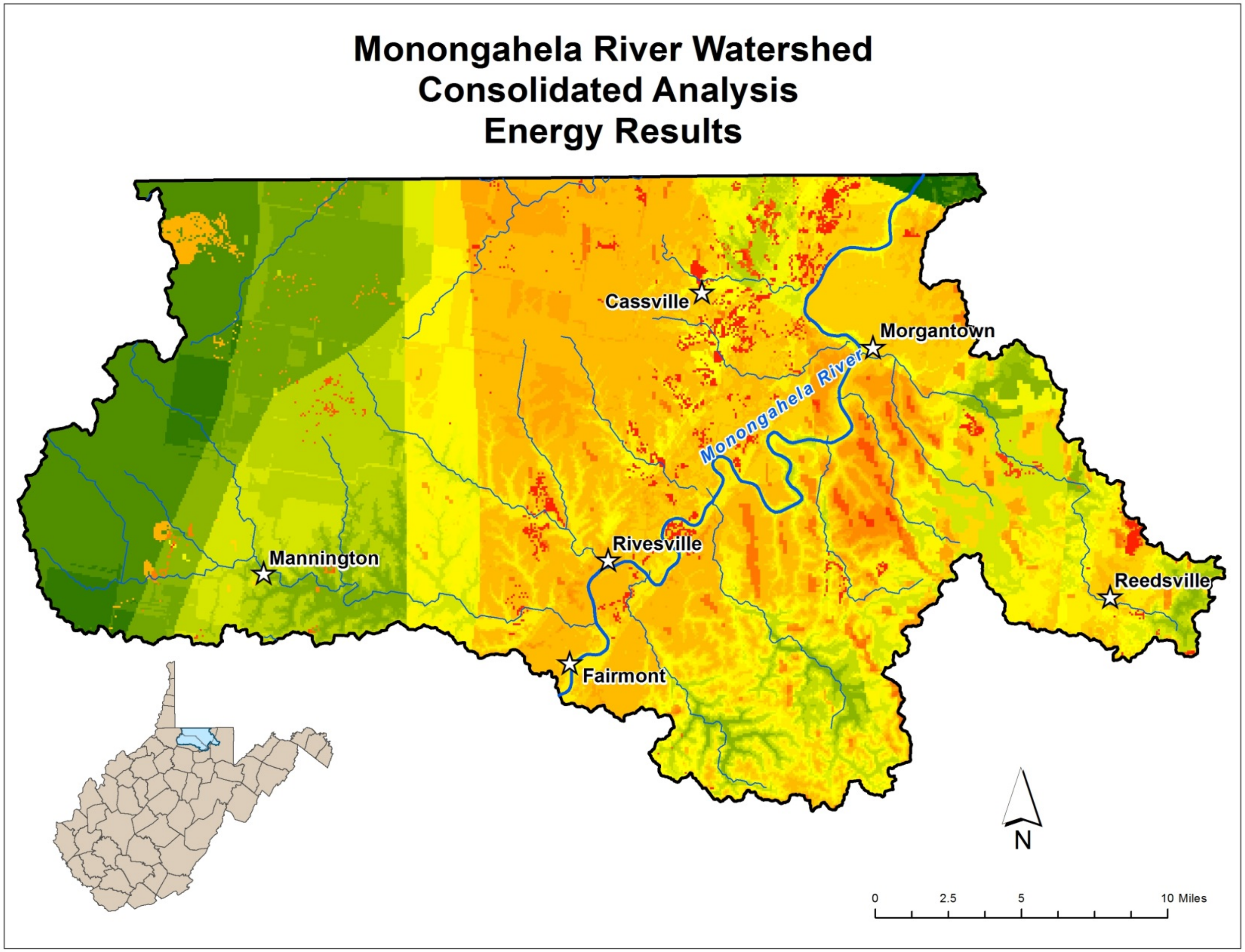

Figure 33. Consolidated Analysis Energy Results

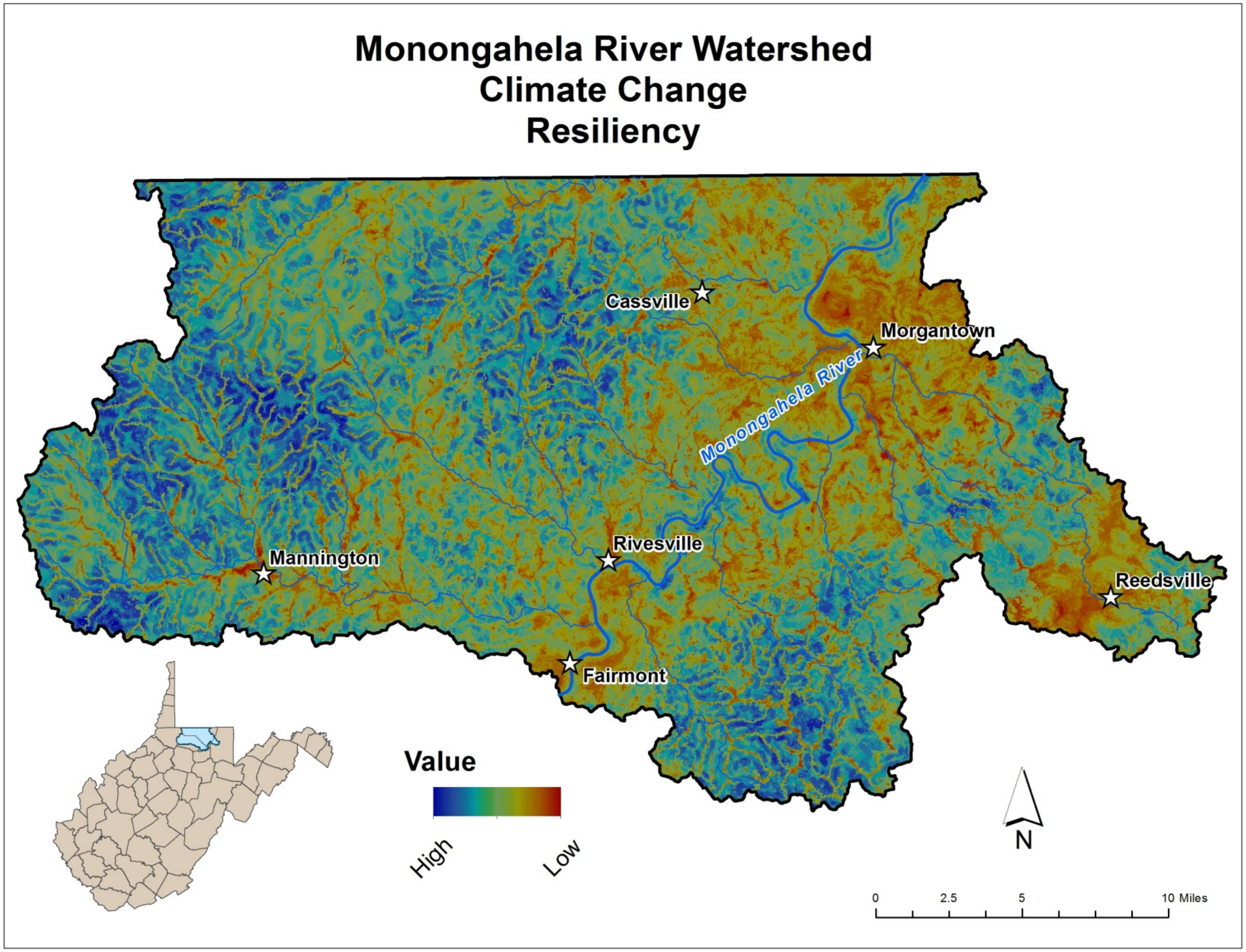

Figure 34. Monongahela River Watershed Climate Change - Resiliency (TNC 2012)

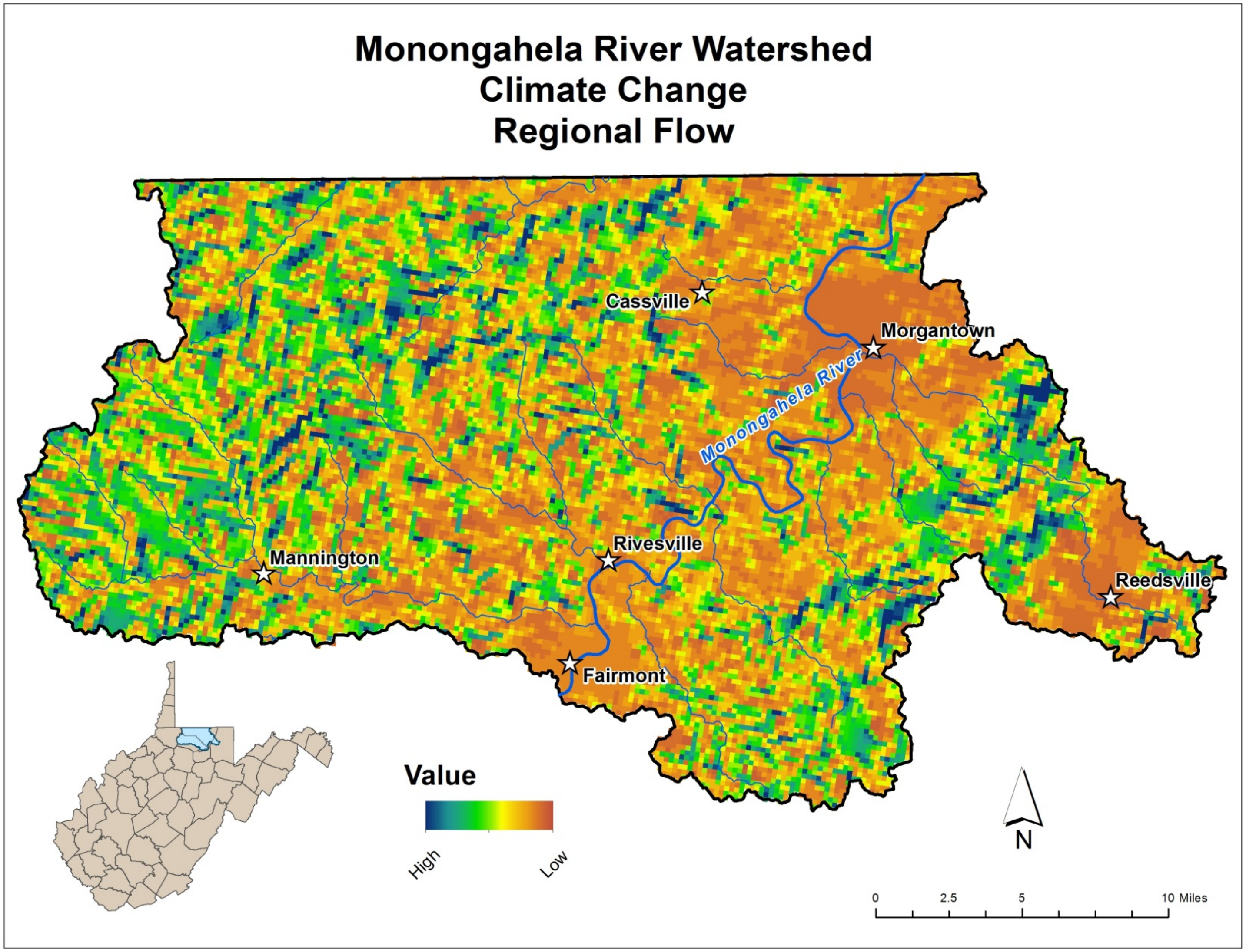

Figure 35. Monongahela River Watershed Climate Change - Regional Flow (TNC 2012)

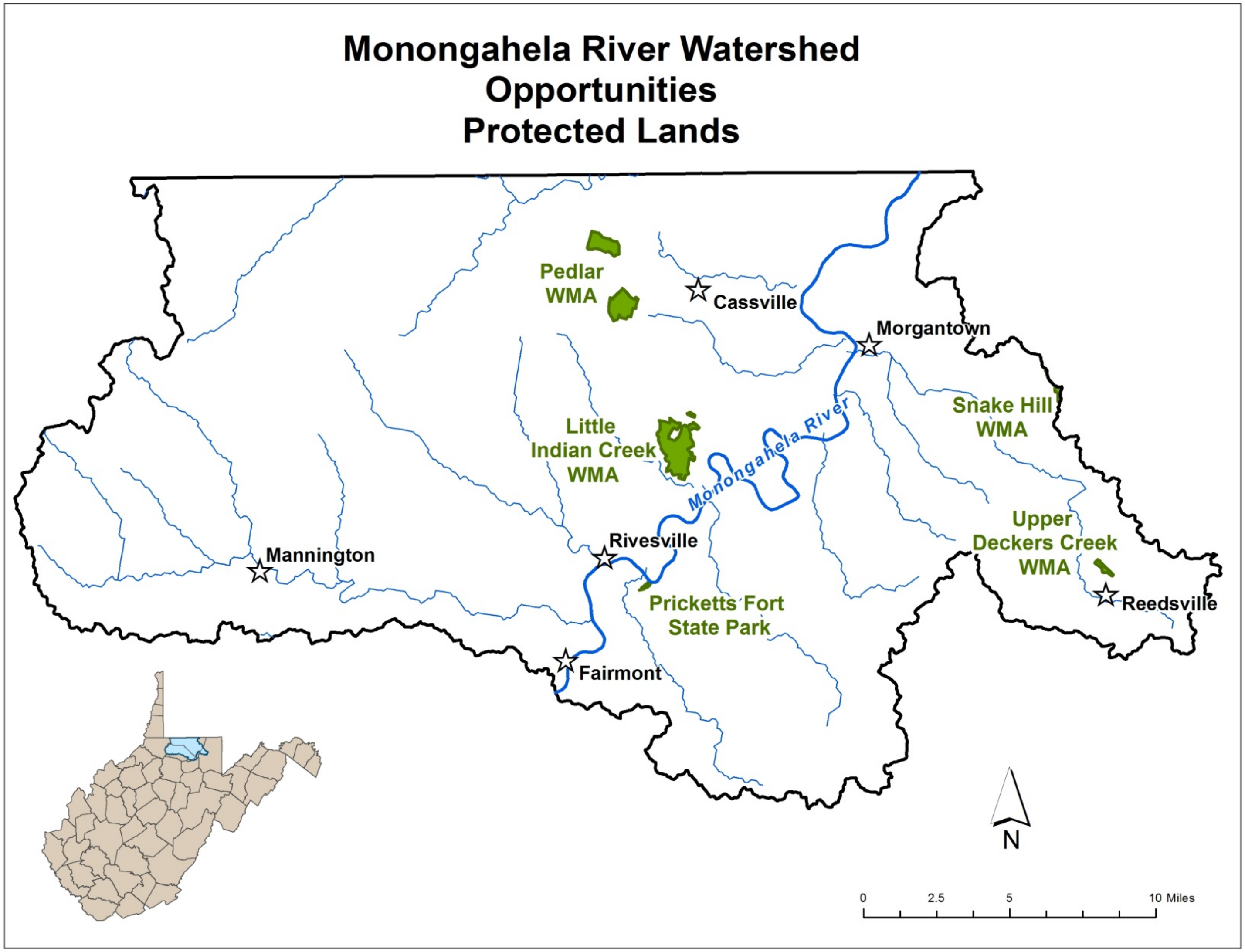

Figure 36. Monongahela River Watershed Opportunities - Protected Lands

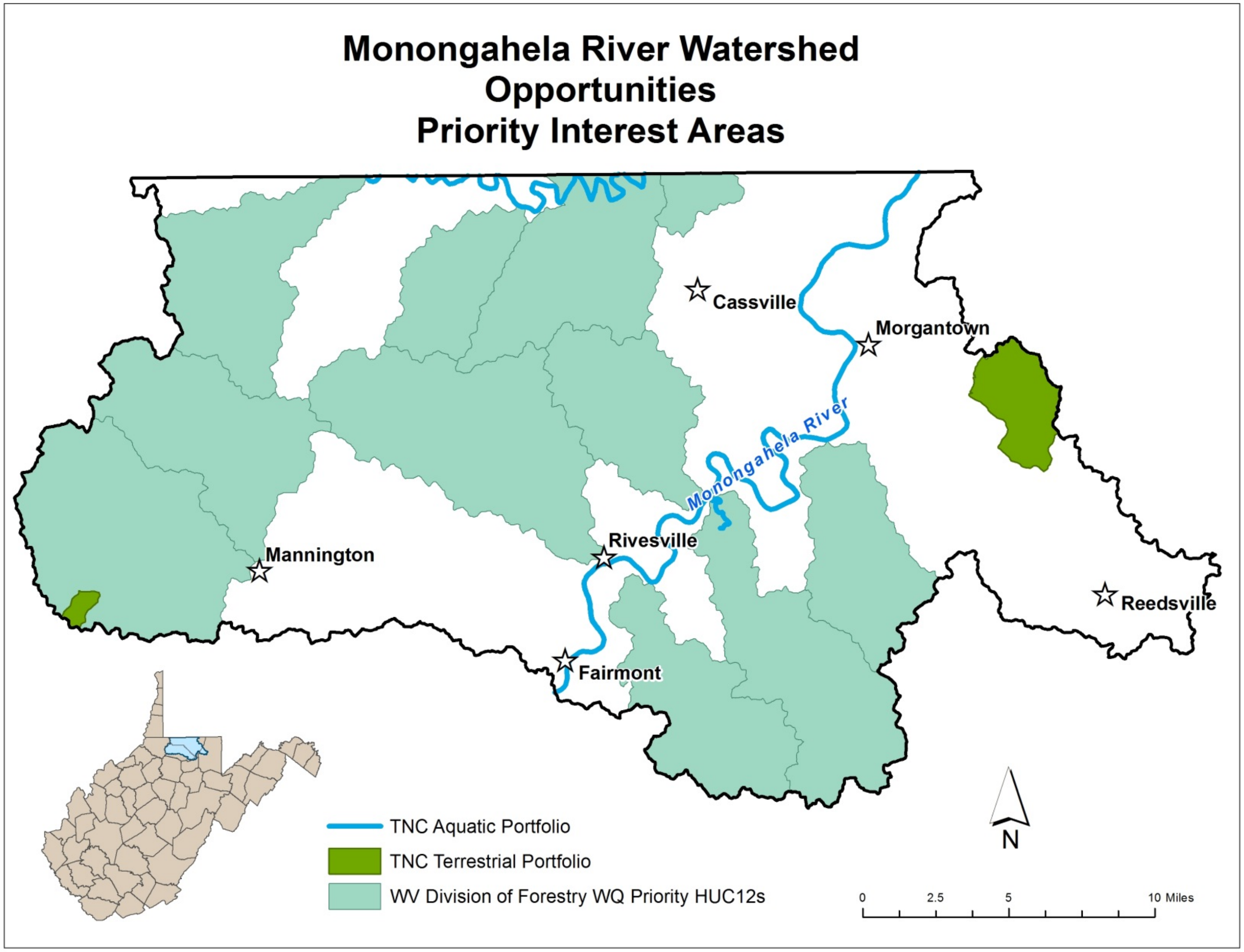

Figure 37. Monongahela River Watershed Opportunities - Priority Interest Areas

Section 5: Recommendations and Conclusions

5.1 Recommendations for Use

The goal of the watershed assessment pilot project was to be comprehensive and flexible enough to be applicable for a wide variety of potential end uses by regulatory staff, stakeholders, or any interested parties. We recognize that different users will likely have different goals, questions, and uses of the project results in mind. Regulatory staff may target a particular HUC12 watershed or stream reach, or have funds available for a particular strategy (e.g., to use funds targeted specifically for protection or restoration activities). Regulators may also use this information for cumulative impacts analyses to make permitting decisions. A watershed association may be interested in working only on streams, or may have a very specific issue they are interested in addressing within a watershed (e.g., treating acid mine drainage streams, or restoring wetland habitat to promote biodiversity). Alternately, an end user may not have any preconceived ideas of where they would like to work or what type of work they would like to pursue, and may just be interested in perusing the data collected and developing a comprehensive view of the watershed as a whole. And inevitably there will be additional uses and applications of the assessment results that the project team has not foreseen.

Considering the great variety of potential uses, it is necessary to not be too specific or prescriptive in suggesting different strategies on applying the assessment results on the ground or on using the interactive web tool. We have therefore developed two sample procedures for potential uses based on the strategies of protection and restoration. These examples are intended to walk users through a potential process for assessing the results, familiarizing themselves with underlying datasets, and choosing candidate sites for applying potential restoration or protection strategies on the ground.

As there are many decisions and factors involved in deciding where and how to work, the project team highly recommends as the initial step to determine the goals and objectives of a potential project, before approaching the assessment results and data (Figure 38). With the specifics and limitations of their own unique project(s) in mind, users can approach the results and web map in much the same way as the process described in the examples, by viewing and becoming familiar with overall and index results for each landscape model, and then viewing relevant data at whatever scale seems appropriate considering their unique goals.

The project makes some key assumptions: that protection priorities are most likely areas of Good or Very Good quality, possibly adjacent to or near existing public lands; and that restoration priorities are most likely areas with Fair scores, implying that they are in need of human intervention to repair function or restore quality, but are not so impacted by stressors that work in the area seems unfeasible or impractical. Within the results maps, blue areas indicate planning units with scores in the Very Good category, green areas indicate planning units in the Good category, yellow-orange planning units are in the Fair category, and red planning units have scores in the Poor category. Depending on the index, a Fair score may indicate an imbalance between quality metrics and anthropogenic stressors. A Fair planning unit may be of poor quality, but also have relatively few stressors, implying that restoration of the area may greatly benefit its overall quality and potentially changes its score from Fair to Good. Conversely, a Fair planning unit may have very high quality metrics, but also a high number of anthropogenic stressors, indicating that strategies designed to counteract the effects of the stressors may successfully increase the score from Fair to Good or even Very Good.

However, it is important to note that these are only a few of the possible uses for the project results. It is possible that the priorities and goals of different end users will suggest a different protection or restoration threshold to focus on.

Suggested process for using the results of the pilot project to determine project strategies:

Step 1: Define Project goals and objectives:

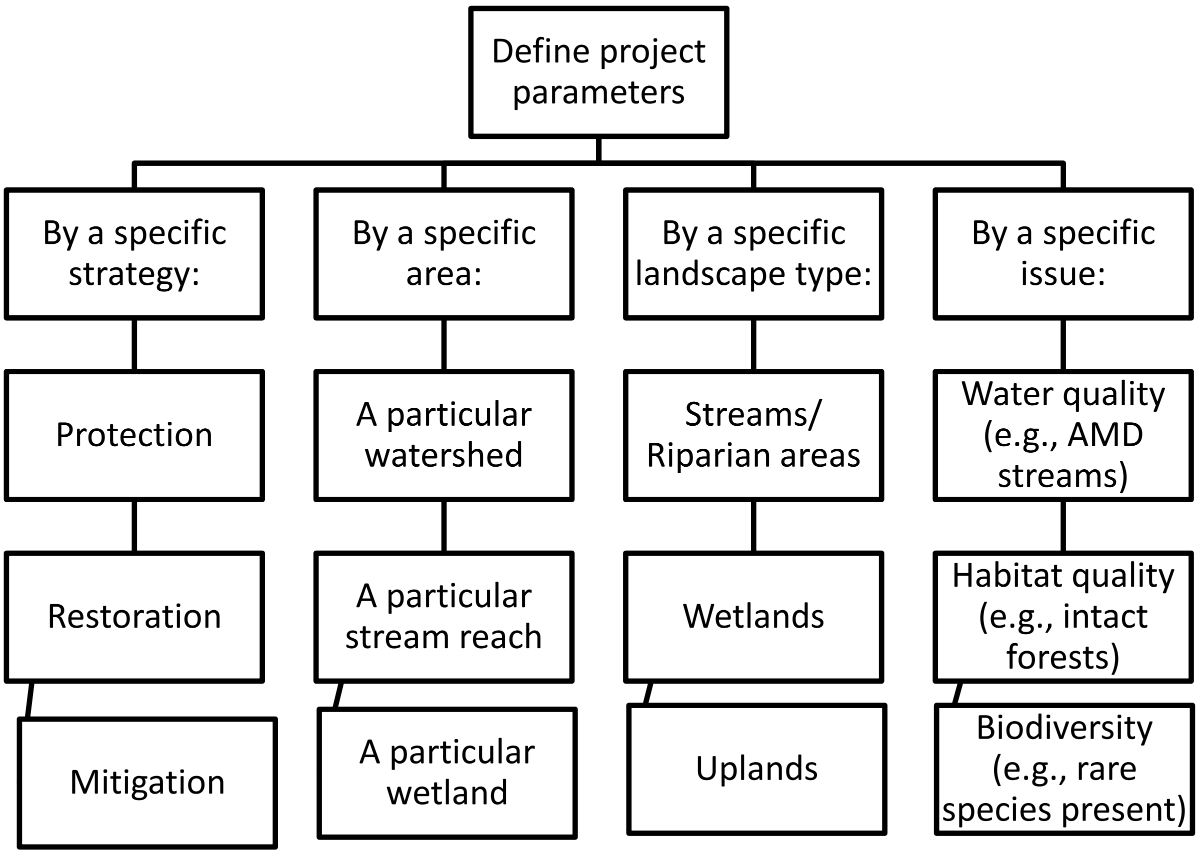

Figure 38. Possible End User Project Parameters

Step 2: Identify candidate areas for conservation action:

<u>a)</u> Protection Sample Process (Figure39)

1) Select a Priority Model (Streams, Wetlands, or Uplands) according to specific project goals, and examine model's overall condition results for highest scoring HUC12s (green - blue areas)
2) Choose several candidate HUC12s with high scores (green - blue) in index or indices of interest
    a. Example: A HUC12 with high Streams Water Quality and/or Riparian Habitat ranking
    b. Example: A HUC12 with a high Wetlands Hydrology ranking, indicating extensive wetlands
    c. Example: A HUC12 with a high Uplands Habitat Connectivity ranking, indicating a low level of fragmentation
3) If applicable, display the Opportunities layer and select HUC12s in proximity to protected lands or priority interest areas to evaluate the potential for collaboration with other agencies
4) If applicable, display the Future Threats layer to evaluate each candidate HUC12's potential for future energy development, population projections, and resiliency to climate change
5) Zoom to each candidate HUC12, display catchment level index results, select those with high scores (green-blue areas) in multiple indices
    a. Example: For Streams catchments, consult the Water Quality, Riparian Habitat, and/or Biodiversity indices
    b. Example: For Wetlands catchments, consult the Wetlands Hydrology and Wetland Habitat indices
    c. Example: For Uplands catchments, consult the Habitat Connectivity and Habitat Quality indices
6) Zoom to candidate catchment(s) and display relevant data layers (imagery, land use, roads, resource extraction, etc.) to evaluate individual factors and datasets that may have contributed to a particular index score
    a. Example: For a high-ranking Streams catchment, display impervious surface, roads, NPDES outlets, mining, and wells to indicate potential water quality threats in the area
    b. Example: For a high-ranking Wetlands catchment, display any nearby WAB station data to indicate water quality of contributing streams
    c. Example: For a high-ranking Uplands catchment, display the land use data layers and aerial imagery
7) Determine parcel ownership and conduct site visit(s) to evaluate on-the-ground conditions and formulate specific strategies and action steps

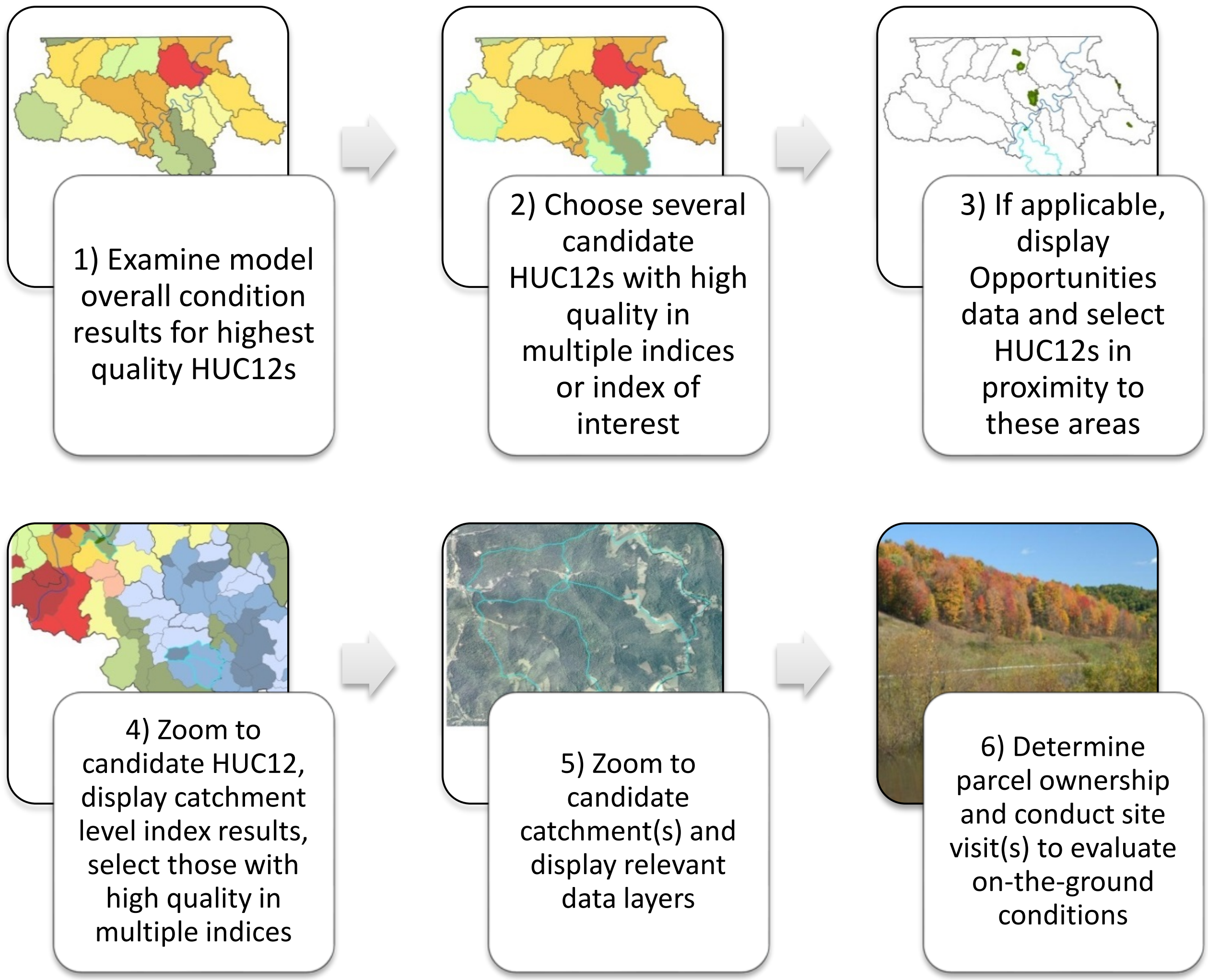

Figure 39. Protection Sample Process Flowchart

b) Restoration Sample Process (Figure 40)

1) Select a Priority Model (Streams, Wetlands, or Uplands) according to specific project goals, and examine model's overall condition results for Fair-scoring HUC12s (yellow-orange areas); or, if desired, select Poor-scoring HUC12s (red areas)
2) Choose several candidate HUC12s with Fair or Poor scores in index or indices of interest
    a. Example: A HUC12 with Fair or Poor Streams Water Quality
    b. Example: A HUC12 with Fair or Poor Wetlands Wetland Habitat
    c. Example: A HUC12 with Fair or Poor Uplands Habitat Connectivity
3) Compare to other index results. It may be advisable to select a candidate HUC12 with Good or Very Good scores (green-blue) in additional indices, depending on specific project goals
    a. Example: A HUC12 with Fair or Poor Streams Water Quality and Good or Very Good Riparian Habitat rankings, such as an AMD stream that could be chemically treated.
    b. Example: A HUC12 with Fair or Poor Wetlands Water Quality and Good or Very Good Wetlands Hydrology rankings, such as a wetland that could be expanded or revegetated
    c. Example: A HUC12 with Fair or Poor Uplands Habitat Connectivity and Good or Very Good Uplands Habitat Quality rankings, such as a grazed area that could be reforested
4) If applicable, display the Opportunities layer and select HUC12s in proximity to protected lands or priority interest areas to evaluate the potential for collaboration with other agencies
5) If applicable, display the Future Threats layer to evaluate each candidate HUC12's potential for future energy development, population projections, and resiliency to climate change
6) Zoom to each candidate HUC12, display catchment level index results, select those with Fair or Poor scores (yellow-red) in index of interest and Good or Very Good (green-blue) in additional applicable indices as in steps 2 and 3
7) Zoom to candidate catchment(s) and display relevant data layers (imagery, land use, roads, resource extraction, water quality impairments, wetlands, etc.) to evaluate individual factors and datasets that may have contributed to a particular index score
    a. Example: For Streams catchments, display nearby WAB station results to evaluate specific stream conditions, and land use/land cover and aerial imagery to visualize riparian habitat
    b. Example: For Wetlands catchments, display aerial imagery to determine if the wetland still exists, and hydric soils and floodplain layers to determine possible extent for wetland expansion/construction
    c. Example: For Uplands catchments, display roads, energy transmission lines and wells to locate permanent forest fragmenting features
8) Determine parcel ownership and conduct site visit(s) to evaluate on-the- ground conditions and formulate specific strategies and action steps
    a. Example: Restore natural vegetation along stream banks, improve streambed structure, restrict stream bank access, and/or treat chemical imbalances
    b. Example: Create/expand wetland basin structure, address quality issues of contributing streams, restrict access, and/or restore native vegetation
    c. Example: Restore native vegetation to upland forests and/or remove invasive species

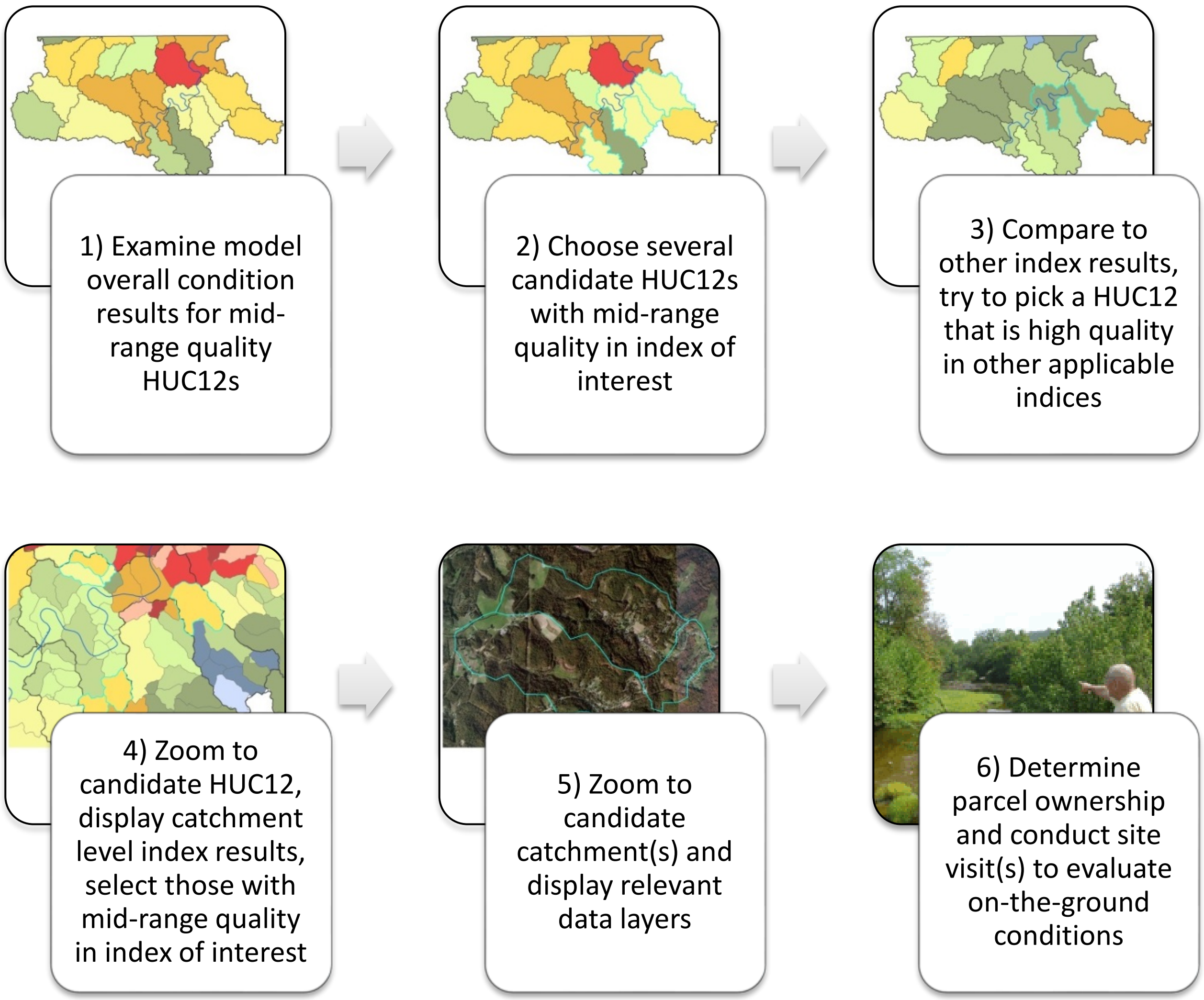

Figure 40. Restoration Sample Process Flowchart

5.2 Potential Strategies

As with the recommendations for use of the model results and selection of project sites, when suggesting potential strategies to address observed trends in selected project sites it is necessary to be aware of potential users' many different project goals and missions. The project team has therefore defined a set of broad potential strategies for various observed trends that are outlined in the results section. The user is encouraged to modify these strategies as appropriate for their particular project.

5.2.1 Streams/Riparian Areas

For Streams Water Quality results, observed trends that lowered index scores can be grouped into mining-related water quality impairments (AMD, pH, and heavy metals impairments, high specific conductivity values, low GLIMPSS scores), development (inadequate sewage treatment, high impervious surface, etc.), and riparian habitat stresses (grazing in riparian areas, high road/railroad densities, etc., which result in high fecal coliform and sedimentation issues). Potential strategies to address mining impacts may include treating and disposing of contaminated water appropriately before it leaves the mine site, controlling runoff and sedimentation from active mine sites, installing settling ponds to allow contaminants to settle out before reaching impacted streams, and installing lime treatment stations. Treatment for issues such as acid mine drainage requires a long-term investment of time, money, and equipment, and may be beyond some stakeholders' capabilities. Watershed associations may apply for funds through the Abandoned Mine Lands program for remediation of sites that were established before the Surface Mining Control and Reclamation Act (SMCRA) went into effect. In areas with inadequate septic systems, two potential strategies are to encourage installation/appropriate maintenance of functioning septic systems, and expansion of sewage treatment service areas. Urban areas also contribute to impaired water quality through runoff due to high imperviousness. A number of urban planning educational programs are available for interested parties to learn about how to minimize effects of impervious surfaces. Disturbance in riparian areas can be addressed by installing buffer areas along streams where activities such as grazing, timber harvesting, or road and railroad construction are limited, and adherence to Best Management Practices (BMPs) for any activities that do occur in riparian areas. Federal programs exist through the NRCS and Conservation Reserve Program (CRP) to assist private landowners with protecting watercourses from livestock.

Streams Water Quantity results indicated that index scores were often lowered by underground and active surface mining and high imperviousness. This index was dependent on surrogate measurements of flows altered from natural conditions, as no direct measurements were available to reliably rank individual planning units. Potential strategies include maintaining maximum natural cover in affected catchments to minimize imperviousness. High imperviousness in urban areas not only contributes to water quality impairments as noted above, but also alters natural flow conditions. Strategies designed to minimize effects of imperviousness on water quality will also help mitigate for any effects on water quantity. Mining effects on water quantity can be minimized by adhering to BMPs in actively mined areas, minimizing impervious surfaces in mined areas, controlling runoff and sedimentation from active mine sites, and controlling releases of mine pool water from underground surface mines.

Streams Hydrologic Connectivity issues included a lack of forested riparian area (which may impede the movement of organisms throughout the length of a stream due to temperature changes, potentially limiting their ability to complete their life cycles), and direct flow impediments such as bridges and culverts. Riparian areas that are lacking forested cover are prime candidates for forest restoration and installation of riparian buffers to minimize fragmenting activities along the stream. Culverts are often incorrectly installed and impede stream flow, and bridges can be impediments to organism movement and stream flow if not installed and maintained properly. Potential strategies would be to install and maintain appropriate culverts and bridges where they have been found to be negatively affecting stream flow and/or organism movement.

Streams Biodiversity index trends observed included invasive plants and lack of mussel streams identified in lower-scoring planning units. Strategies may include restoration of impacted areas by removing invasive species. Potential strategies to increase the mussel score of a planning unit may include direct relocation of mussels to an area, maintenance of an adequate flow regime where low flow conditions have impacted mussel populations, and improvement of water quality in potential mussel streams. Rare species data are hampered by the absence of information about where species were sampled but no rare species found versus where species were not sampled. Results in this index should therefore be regarded with caution and only used to design strategies in conjunction with other index results.

For the Streams Riparian Habitat index, results indicated that factors negatively affecting planning units' scores included a lack of natural cover in the riparian area and the presence of fragmenting features such as impervious surface, roads and railroads, oil and gas wells, and active surface mining. Trends also included low RBP scores (which may indicate problems with the stream bank itself). Potential strategies to address these issues include restoration of natural cover in riparian areas (including invasive species removal), and establishment of buffers in riparian areas designed to minimize fragmenting features by restricting incompatible activities. Any development that does occur in riparian areas should adhere to BMPs to minimize adverse effects from these activities. Areas with low overall RBP and bank stability scores may benefit from stream bank restoration, such as creating woody and vegetative riparian buffers and building bankfull benches, and other restoration activities depending on particular issues identified by the RBP assessment.

5.2.2 Wetlands

For the Wetlands Water Quality index, observed trends included a lack of forested headwater wetlands, presence of stressors in the wetland catchment area (including high impervious surface and low natural cover), and incompatible land uses in the wetland buffer (including fragmenting features and grazing). A lack of forested wetlands can be addressed by restoration of forested wetlands in headwater areas of the watershed. Restoration of natural cover in the wetland catchment area may mitigate for high impervious cover. In wetland catchments that include urban areas, urban planning programs mentioned above for Streams Water Quality are also potential strategies for this index. Construction of additional impervious surfaces in impacted wetland catchments should be avoided. Incompatible land uses in wetland buffers may be minimized by adhering to BMPs on any construction in buffer areas, fencing out livestock from wetland buffers, and assigning appropriate permitted discharges to NPDES outlets.

Observed trends for the Wetlands Hydrology index included small or no wetlands in planning units and a lack of floodplain area and hydric soils. A potential issue for this index is inconsistent soil mapping among different counties. Some counties did not map hydric soils to the same extent as neighboring counties did, resulting in a likely bias in the index results. One potential strategy to improve index results in the future is to implement a statewide project to consistently map hydric soils; work is currently in progress across the state updating soils maps in certain counties. Any planning units with hydric soils but no wetlands, or without existing floodplain areas, are potential candidates for wetland restoration.

Wetlands Wetland Habitat index results indicated that small forest patch sizes, low natural cover, and roads in wetland buffers are stressors in some areas. Potential strategies to address these issues include restoration of unfragmented forest areas that extend into wetland buffers, and restoration of natural cover in wetland buffers. Landowners may be able to take advantage of federal or state programs for wetland protection or conservation easements, such as the Wetland Reserve Program (WRP). Roads in wetland buffers should be minimized, and any road construction or maintenance projects should adhere to accepted BMPs to minimize any adverse impacts on wetlands.

For a discussion of Wetlands Biodiversity index, please see discussion of the corresponding index under Streams above.

5.2.3 Uplands

Uplands Habitat Connectivity results indicated that fragmentation was the main trend across planning units (small unfragmented forest blocks and presence of fragmenting features such as transmission lines, pipelines, roads, railroads, timber harvesting, oil and gas wells, active surface mining, and development). One key potential strategy would be to utilize this watershed assessment as a tool to identify less fragmented areas within the watersheds; then utilize direct corporate, regulatory, and/or stakeholder/public engagement to avoid, minimize, or mitigate fragmenting effects to these areas through appropriate siting of infrastructure, development and application of BMPs, retiring and restoring infrastructure no longer needed, and protection of irreplaceable sites.

Observed trends for Uplands Habitat Quality included low natural cover in upland areas, low heterogeneity, and incompatible land uses such as timber harvesting and grazing. Potential strategies include restoration of natural cover in affected areas and establishing compatible grazing regimes in areas affected by livestock grazing. Logging BMPs should be adhered to in all instances, and timber companies should be encouraged to utilize the Forest Reclamation Approach (FRA) of cultivating multi-species stands of hardwoods instead of managing for only one species.

For a discussion of Uplands Biodiversity index, please see discussion of the corresponding index under Streams above.

5.3 Data Needed and Next Steps

An objective of this pilot project was to identify data gaps and needs in West Virginia: datasets that would be useful to include in the analysis to improve the models developed, but that were not available to include in the assessment. These include:

- Updated NWI wetlands data such as NWIPlus. At this writing, the WVDNR is in the process of ground-truthing NWI wetlands. This dataset will be incorporated once available.
- Reference wetlands or wetlands analyzed for function.
- More information on rare species sampling; i.e., information on areas that were sampled and no rare species were found.
- More comprehensive rare species sampling, especially in upland areas.
- Common plant and animal species diversity data.
- Forest Inventory Analysis data that can be accessed for GIS analysis at planning unit scales, i.e., locations that are not blurred, along with type and extent of harvest.
- More randomly sampled water quality data, particularly reference index values.
- Additional long-term USGS stream gauge data.
- Current and projected Marcellus and Utica shale gas well development, including sources and quantity of water use.
- Data on underground mine discharge points, and mine pools locations, extent, and water quality.
- Updated status information on wells, e.g., inactive vs. plugged, Marcellus well status.
- Soils data that are consistently mapped and coded across county boundaries.

The consolidated analysis of future impacts for the five pilot HUC8 watersheds was hampered by lack of data on population and development projections (except for the Morgantown metropolitan area), incomplete coal mapping, and uncertainty in the direction and degree of Marcellus shale development, but projected declines in population in some counties and likely stagnation in development may slow any development-related declines in water and habitat quality. Since a consolidated analysis was one of the original goals of this project, the methods will continue to be refined as more data become available and more assessments inform our understanding of the influence of different metrics on index results. As more sophisticated climate projections become available, such as a predictive model for the Ohio River Basin currently being developed by the USACE (Drum 2013), they may be incorporated into the analysis to indicate areas that are especially vulnerable to temperature and precipitation changes and where landscape resilience is especially important.

This watershed assessment combines several features that make it unique:

- It addresses watershed condition not only in terms of species and habitat, but also in terms of functions, such as water purification, sediment retention, and flood storage.
- It allows for quantitative assessment at two spatial scales: the HUC12 scale, which is of interest to state agencies for regulatory purposes, and the NHDPlus catchment scale, which is more useful for site-specific conservation planning.

- It performs an in-depth analysis of three landscapes— streams, wetlands, and uplands—yet recognizes that they are not independent, but mutually influence condition and function; in particular it quantifies the contribution of upland habitat to stream and wetland function by incorporating both aquatic and terrestrial metrics in these models.
- It aggregates a wide variety of disparate spatial datasets from many sources, such as land use, water quality, and resource extraction, in one location.
- The assessment methods are transferable to all HUC8 watersheds across the state.

The West Virginia Watershed Assessment Pilot Project recognizes that conservation actions are not uniform: protection, restoration, and mitigation projects are undertaken by a variety of entities with a variety of goals and resources. It provides a tool and a framework for users to obtain information about a watershed and use the assessment analysis to inform their decisions or create their own strategies appropriate to their needs. The development and improvement of the interactive web map will be ongoing, with the goal of making the data as dynamic and the assessment procedure as automatic as possible. Potential users have expressed interest in predictive aspects of the tool and the desire for functionality that allows users to create “what-if” scenarios to evaluate the effects of conservation actions. When the web tool becomes available, continued involvement by users and experts throughout the development process may result in further efforts to develop this functionality.

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APPENDICES

Appendix A: Detailed Data Source Information

Type	Description	Format	Source (Date Published)	Downloaded	Intended Use	Limitations	QA/QC*
BASE LAYERS							
NHDPlus (100K)	Catchments, flowline, flow direction grid	polygon, line, raster	USGS (2005)	5/2011	Planning unit delineation, base stream network, wetland distance to nearest surface water	100K (not consistent scale among various stream datasets)	Moderate
NHD24K with stream codes	Flowlines with additional attributes including DEP stream code	line shp	WVU Natural Resource Analysis Center (2010)	11/2010	Join with mussel stream survey data Excel file		None
Land Use/Land Cover 2009-2010	WV land use/land cover data; updated using Landsat 5 imagery	raster	WVU Natural Resource Analysis Center	11/14/2011	Recent land cover dataset, to determine percent forested, developed, mining, etc	Not all roads included as developed land	None
City boundaries	Outline of city boundaries	polygon	US Census (1990)	5/2010	Spatial reference		None
County boundaries	Outline of county boundaries	polygon	USGS/WVDEP (2002)	2/2010	Spatial reference		None
Ecoregions	TNC defined ecoregions	polygon	TNC - ERO (2008)	2/2010	Join with ecoregional targets Excel file		None
Ecological Land Units	TNC defined ecological land units	polygon	TNC-ERO(2008)	2/2010	Determine calcareous bedrock; predict rare species occurrence based on landscape and geology		None
Topographic maps	Relief maps of WV, by quad	image	USGS (varies)	Varies	Spatial reference, data verification, mining	Dated (mostly from 1970's)	None
Aerial imagery	Satellite imagery of WV	image	USDA (2007, 2009); ESRI online imagery (2009, 2010)	Online access; 6/2010	Spatial reference, data verification		None
WATER QUANTITY							
Public water supply (PWS)	Surface water intakes	points shp	WVDHHR (2011)	8/2011	Measure of water withdrawal along stream	Point locations required verification (not all outtakes along streams)	Limited

Type	Description	Format	Source (Date Published)	Downloaded	Intended Use	Limitations	QA/QC*
Large quantity users (LQU)	Withdrawal over 750,000 gal	points shp	WVDEP (2011)	8/2011	Measure of water withdrawal along stream	Self-reporting; table listed coordinates as "fuzzy", required verification	Limited
Wastewater treatment plants (WWTP)	Locations of municipal sewage treatment plants	points shp	WVDEP (2002)	5/18/2011	Identify points where streamflow may be altered due to plant discharges		None
USGS stream gages	Stream gage locations	points shp; Excel table	USGS (2003)	8/2011	Measure of flow variation along stream		None
WETLAND QUANTITY							
National Wetlands Inventory (NWI)	Locations of wetland features	polygon shp	FWS (2011)	4/2011	Identify locations of wetland features	Data derived from dated aerial imagery	Limited
Historical topo maps	Topo maps (from 1900-1930)	image	USGS/WVDEP (varies)	8/2011	Identify areas labeled as wetlands in the past		None
Floodplain area	FEMA 100-year floodplain area		WVGISTC (11/01/2010		Identify areas with potential wetland hydrology based on presence of floodplain		None
WATER QUALITY							
Impaired streams (303(d), TMDL)	2010 303(d) and TMDL listed streams	line shp	WVDEP (1/11/2011)	2/2011	Identify streams with known impairments	Combined with AMD impaired streams	Limited
Impaired streams (AMD)	Acid mine drainage streams	line shp	WVDEP (2/11/2009)	3/2010	Identify streams with known impairments	Combined with 303(d), TMDL impaired streams	Limited
WAB database samples	Water quality samples (includes water chemistry parameters, GLIMPSS, taxa richness, RBP scores, etc)	points shp	WVDEP (10/2011)	12/14/2011	Measure of water quality parameters, biotic index and riparian habitat, etc	Point locations required some verification due to NHD24k accuracy issues	Limited
NLCD impervious cover (2006)	Impervious surfaces	raster	USGS (2/16/2011)	2/2011	Measure of contributing area of impervious cover	Data based on 2006 aerial images, low resolution	None

Type	Description	Format	Source (Date Published)	Downloaded	Intended Use	Limitations	QA/QC*
BIODIVERSITY							
Element occurrences	Natural Heritage Program rare species	points shp	WVDNR (2/14/2011)	2/2011	Identify areas with known rare species	Some geographic coordinate errors (outside WV boundaries); some data prior to 1991	Moderate
SGNCs	Species in greatest need of conservation	Excel table	WVDNR (2005)	8/2011	Join with element occurrences		None
Odonates	Additional odonate occurrences	Excel table	WVDNR (8/2011)	8/2011	Join with element occurrences	Some element codes missing	Moderate
Hellbenders	Hellbender occurrences	Excel table	The Good Zoo, Wheeling, WV (11/2010)	11/2010	Join with element occurrences	Locations required verification.	Limited
Crayfish	Crayfish occurrences	Excel table	Researcher at West Liberty University (12/2010)	12/2010	Join with element occurrences	Locations required verification, some geographic coordinate errors (outside WV boundaries)	Limited
Fish	Fish occurrences	Excel table	WVDNR (10/2010)	10/2010	Join with element occurrences		None
Ecoregional targets	TNC target species for 3 ecoregions of WV	Excel table	TNC - ERO (2007)	8/2011	Join with element occurrences	Some data prior to 1991	Moderate
Mussel streams	Stream reaches containing endangered mussels	Excel table	WVDNR (09/2011)	9/2011	Join with NHD 24K streams shapefile; prioritize streams with endangered mussel species or high quality habitat	No specific information beyond presence/absence of unspecified endangered species in stream reach; some stream codes outdated	Moderate
Trout streams	Naturally reproducing trout streams	line shp	WVDEP (2010)	8/2011	Identify DEP priorities for trout streams		None
Northeast terrestrial habitat types	Terrestrial habitat types based on shared characteristics across region	raster	TNC – ERO (7/14/2011)	8/8/2011	Surrogate measure of potential species diversity based on variety of available habitats		None

Type	Description	Format	Source (Date Published)	Downloaded	Intended Use	Limitations	QA/QC*
PHYSICAL INTEGRITY							
Soils	Soils data by county	polygon shp	SSURGO (varies by county)	Varies	Determine hydric soils; highly erodible soils; high infiltration rate soils; soil buffering capacity	Varying resolution between county; generalized data; incomplete coding	None
Fire regime condition class (FRCC)	Degree of departure from reference condition vegetation	raster	USFS LANDFIRE (2007)	7/2011	Estimate of change in vegetation conditions	Low resolution	None
Heterogeneity	Landscape heterogeneity metric reflecting elevation change and landform variety	raster	TNC - ERO (03/2011)	3/2011	Indicate variation in landscape topography and landforms		None
HYDROLOGIC CONNECTIVITY							
Active River Area (ARA)	Riparian and material contribution zones along streams	raster	TNC - ERO (2009)	2/2011	Define riparian area		Moderate
Northeast Association of Fish and Wildlife Association (NEAFWA) streams	Stream classifications and stream order/size	line shp	TNC - ERO (2008)	8/2010	Determine headwaters streams		None
Power plants	Locations of power plants on small (size class 1a) streams	points shp	Ventyx	12/5/2011	Identify locations where plant discharge may change water temperature and disrupt aquatic connectivity for species		None
HABITAT CONNECTIVITY							
Forest blocks	Unfragmented forest blocks larger than 100 acres	polygon shp	TNC - PAFO (07/2011)	8/2011	Prioritize areas of unfragmented forest		None
Local integrity	Local integrity metric reflecting unfragmented natural habitat	raster	TNC - ERO (03/2011)	3/2011	Prioritize areas of unfragmented natural habitat (forest, grassland, wetland, stream)		None
PROTECTION PRIORITIES							
Aquatic portfolio	TNC priority streams	line shp	TNC - ERO (2/25/2011)	3/2011	Identify TNC priority streams		None
Terrestrial portfolio	TNC priority lands	polygon shp	TNC - ERO (07/2011)	8/2011	Identify TNC priority lands		None

Type	Description	Format	Source (Date Published)	Downloaded	Intended Use	Limitations	QA/QC*
Secured lands	Preserves and publicly owned lands	polygon shp	TNC – ERO/WVFO (6/27/2011)	NA	Identify lands already under protection or in public trust		None
National Forest proclamation boundary	USFS target area for land acquisition	polygon shp	USFS (2004)	2/2011	Identify USFS priority lands		None
Watershed assessment results	Division of Forestry analysis results for Water Quality and Forest Resource Areas	polygon shp	WVDOF (2010)	8/2011	Identify WVDOF priority lands	By HUC12	None
National Park Service priority areas	Priority interest areas identified by the NPS	polygon shp	NPS	2/152013	Identify NPS priority lands	No metadata for attributes	None
RESOURCE EXTRACTION							
Oil and gas wells	Locations of oil and gas wells	points shp	WVDEP (8/15/2011)	8/2011	Identify locations of active oil and gas wells	Point locations required verification	Limited
Marcellus Shale gas wells	Locations of Marcellus shale gas wells	points shp	WVGES (4/14/2011)	8/2011	Identify new and existing Marcellus wells	Point locations required verification	Limited
Surface mines (Appalachian Voices)	Digitized mining footprint for watersheds based on aerial imagery	polygon shp	Appalachian Voices (2007)	9/2011	Identify areas with active surface mines as of 2007		None
Abandoned mine lands	Outline of abandoned mine areas	polygon shp	WVDEP (1996)	2/2010	Identify areas with possible residual effects from mining activity	Accuracy issues	Limited
Mining footprint	Outline of current mining activity	polygon shp	WVGES (3/10/2011)	3/2011	Identify areas with current surface and underground mining activity	Some conflicts with aerial imagery (mining land possibly already overgrown/ reclaimed)	Extensive
Valley fills	Valley fill locations from SMCRA permit maps	polygon shp	WVDEP (8/23/2011)	8/2011	Identify areas with surface mining refuse	Some overlap with other mining datasets	Limited
Coal refuse structures	Coal refuse (disposal area) locations	polygon shp	WVDEP (8/23/2011)	8/2011	Identify areas with surface mining refuse	Some overlap with other mining datasets	Limited
Coal production data	Measure of coal production per facility, by year	Excel table	US EIA (2007, 2008)	7/2011		No MSHA ID in state data; production data distributed by county/mine site	None

Type	Description	Format	Source (Date Published)	Downloaded	Intended Use	Limitations	QA/QC*
Mineral operations	Quarries, mineral extraction facilities	points shp	USGS (2002)	3/2010	Identify surface mineral extraction activities	Some duplicate data; not polygon data so unable to calculate area	Limited
Timber harvesting	Locations of timber permits and acreage	points shp	WVDOF (2010)	6/2011	Identify timber extraction activities	Not polygon data so unable to determine exact spatial location	Limited
DEVELOPMENT & AGRICULTURE							
National Pollutant Discharge Elimination System (NPDES)	Locations of permitted discharges to surface water	points shp	WVDEP (2011)	8/2011	Identify possible point source pollution along streams	Point locations required verification	Limited
NLCD 2006	National Landcover dataset	raster	USGS (2/16/2011)	2/2011	ID development/agriculture/ pasture landcover types	Data based on 2006 aerial images, low resolution	None
Buildings	Locations of structures	points shp	WVSAMB (2003)	8/2011	Used to identify land disturbance and generate septic systems points for structures outside of city boundaries		None
Solid waste facilities	Locations of landfills	points shp	WVDEP (2002)	5/2010	Identify possible source of pollution		None
HABITAT FRAGMENTATION							
Roads	Interstate, US and state highways, county road networks	line shp	WVDOT (2011)	9/2011	Roads as potential source of runoff/sedimentation pollution and as forest habitat and stream fragmenting features (road/stream crossings)		None
Railroads	Railroad networks	line shp	WVDNR (2010)	5/2010	Railroads as potential source of runoff/sedimentation pollution and as forest and stream fragmenting features (RR/stream crossings)		None
Energy transmission lines	Locations of energy lines, by voltage class	line shp	Ventyx (08/2011)	9/2011	Lines as habitat fragmenting features		None
Natural gas pipelines	Locations of pipelines, by diameter	line shp	Ventyx (08/2011)	9/2011	Lines as habitat fragmenting features		None

Type	Description	Format	Source (Date Published)	Downloaded	Intended Use	Limitations	QA/QC*
Wind turbines	Locations of wind turbines and wind farms	points shp	TNC - PAFO (12/25/2010)	5/2011	Points as habitat fragmenting features, source of pollution (sedimentation)		None
Bridges	Locations of bridges and culverts	polygon shp	WVDOT (2008)	8/2011	Structures as habitat fragmenting features	Locations required verification	Limited
Dams	Locations of impoundments	points shp	TNC - ERO (2/10/2011)	2/2011	Points as habitat fragmenting features; surface water capture & storage capacity	Point locations required verification	Limited
ECOLOGICAL THREATS							
Non-native invasive species	Locations of invasive species sitings	Excel table	WVDA (8/2011)	8/2011	Estimate of invasive species location and coverage	Data table contains entries/formats not compatible with import into GIS; some geographic coordinate errors	Moderate
Basal area loss, by species	National Insect and Disease Risk Maps	rasters	USFS (2006)	8/2011	Estimate of timber pests and pathogens		None
Quarantined counties	Infested/infected/ quarantined counties	polygon shp	WVDA (2011)	8/2011	Used to estimate pests & pathogens threats	Resolution by county	Limited
FUTURE THREATS							
Mining permit boundary	Existing mining permit boundaries	polygon shp	WVDEP (8/23/2011)	8/24/2011	Used to estimate high potential threat of future mining activity		None
Unmined coal	Unmined coal formations	polygon shp	WVGES (6/30/2011)		Used to estimate potential threat of future mining activity	Some areas not mapped yet	None
Marcellus Shale thickness	Thickness of Marcellus shale geology	polygon shp	WVGES (11/16/2011)	11/22/2011	Used as surrogate for potential of gas well development		None
Wind development potential	Areas with high potential for wind energy development	polygon shp	National Renewable Energy Lab (2003)	5/10/2010	Used to estimate potential threat from wind development		None
Proposed wind turbines	Known locations of proposed wind turbines	points shp	TNC – PAFO (12/2010)		Used to estimate potential threat from wind development	Some locations are existing wind turbines	Limited
Proposed energy transmission lines	Known locations of proposed energy lines	line shp	Ventyx (01/2012)	01/2012	Used to estimate potential fragmentation threat from energy lines	Some large projects have been cancelled (e.g., PATH)	Limited
Proposed natural gas pipelines	Known locations of proposed gas lines	line shp	Ventyx (01/2012)	01/2012	Used to estimate potential fragmentation threat from energy lines	Some large projects may be missing from data	Limited

Type	Description	Format	Source (Date Published)	Downloaded	Intended Use	Limitations	QA/QC*
Proposed power plants	Known locations of proposed power plants	points shp	Ventyx (01/2012)	01/2012	Used to estimate potential threat from power plants	Some projects have been cancelled	Limited
Geothermal potential	Estimate of geothermal temperature ranges	kmz	SMU Geothermal Lab (2011)	10/27/2011	Used to estimate potential threat from geothermal energy		None
Population projections	Population projection to 2030, by county	PDF	WVU (08/2011)	2011	Used to estimate potential threat from development	County-level scale; only percentage estimates	None
Development potential	Potential for expansion of development, based on watershed	varies	varies		Used to estimate potential threat from development	Only data found was for Morgantown area in Monongahela	None
Future roads	Known locations of proposed new routes	line shp	WVDOT (2003)	9/28/2011	Used to estimate potential fragmentation threat from road construction	Some roads in dataset have already been constructed	Limited
Resiliency	From TNC resiliency dataset	raster	TNC – ERO/PAFO (3/06/2012)	3/14/2012	Used to estimate potential resiliency to climate change	Regional level analysis, not specific to WV	None
Regional flow (current density)	From TNC resiliency dataset	raster	TNC – ERO/PAFO (3/06/2012)	3/14/2012	Used to estimate potential resiliency to climate change	Regional level analysis, not specific to WV	None

* In the initial stages of data collection, datasets requiring varying degrees of Quality Assurance/Quality Control (QA/QC) were identified, the levels of which are explained below. All of the following descriptions refer to QA/QC activities conducted by the watershed assessment project team and do not refer to any QA/QC conducted by the generator of the data. (Many of the agencies that collected or generated the data adhere to more or less rigorous and extensive QA/QC protocols.)

- Little or no QA/QC required: National or state agency data such as the National Land Cover Dataset or WVDEP water quality data, and data generated by lead scientists at TNC Eastern Regional Office and published in the open literature, such as landscape connectivity and resiliency data. Generally these data need only to be clipped to the desired geographic extent or possibly converted between vector and raster data types.
- Limited amount of QA/QC required: Data that may have been received as "fuzzy" or with point locations requiring verification, such as large quantity water withdrawals, public water supply data and wells locations. Generally, verification involves comparing against 2010 aerial imagery or address information to ensure that points are accurately located. Limited QA/QC often results in data being filtered by attributes to only those features that are most reliable (e.g., taking only active well locations).
- Moderate amount of QA/QC required: Data generated by TNC partners and maintained in internal databases, such as locations of rare species ("element occurrences") collected by West Virginia Natural Heritage Program. Such data may include blank, duplicate, or erroneous records, or data earlier than the time frame during which it can be reasonably expected that a species or environmental condition persists. In these cases, removal, addition, or correction of records renders the data acceptable. Moderate QA/QC may also be conducted on datasets

to ensure compatibility with the formatting or resolution needs of the project, such as manual amendment of datasets generated from models.

- Extensive QA/QC required: Data that are found to be deficient for this analysis, irrespective of the data source, but that are necessary for a complete watershed assessment and for which no alternative exists. Such data may need extensive additions or deletions of geographic features or attributes, often based on manual verification from other data sources, such as the most recent aerial imagery (TNC 2011a). The only dataset that required extensive QA/QC for this project (mining footprint data from WVDEP) was later removed as a metric and replaced by more recent and complete datasets.

Appendix B: Metrics Description and GIS Process

Streams

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
WATER QUALITY					
Impaired	Impaired Streams	Impaired Streams: 303(d), TMDL, AMD (WVDEP)	Identify streams with known water quality impairment	Merge 303(d), TMDL , AMD impaired streams, Identity to planning unit and Dissolve to get miles per planning unit	2
Bio	Biologically impaired streams	Impaired Streams: 303(d), TMDL, AMD (WVDEP)	Not considered in final analysis	Select features where Cause: Bio, Identity to planning unit and calculate miles per planning unit	0[f]
DioxPCB	Dioxin/PCB impaired streams	Impaired Streams: 303(d), TMDL, AMD (WVDEP)	Not considered in final analysis	Select features where Cause: PCBs, Identity to planning unit and calculate miles per planning unit	0[f]
Fecal	Fecal coliform impaired streams	Impaired Streams: 303(d), TMDL, AMD (WVDEP)	Not considered in final analysis	Select features where Cause: Fecal/Bacteria, Identity to planning unit and calculate miles per planning unit	0[f]
pHImp	pH impaired streams	Impaired Streams: 303(d), TMDL, AMD (WVDEP)	Not considered in final analysis	Select features where Cause: pH, Identity to planning unit and calculate miles per planning unit	0[f]
MetalsImp	Metals impaired streams	Impaired Streams: 303(d), TMDL, AMD (WVDEP)	Not considered in final analysis	Select features where Cause: Aluminum, Iron, Lead, Manganese, Identity to planning unit and calculate miles per planning unit	0[f]
ChlorideImp	Chloride impaired streams	Impaired Streams: 303(d), TMDL, AMD (WVDEP)	Not considered in final analysis	Select features where Cause: Chloride, Identity to planning unit and calculate miles per planning unit	0[f]
MedpH*	Median pH sample values	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Represent pH values for sampled streams	pH index, calculated on median values among samples per station: 100: >10 or <5, 200: >9 or <6, 300: >8 or <6.5, 400: 6.5 - 8	2
MedRefIndex	Median reference index values	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Weighted Percentage of points that are DEP reference points (median among samples per station)	0[a]
MedSulfate	Median sulfates	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Represent sulfates values for sampled streams (possible indicator of impairment due to mining)	Sulfate index, calculated on median values among samples per station: 100: >250 mg/l, 200: >50, 300: >25, 400: <=25	1

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
MedNitro	Median nitrogen	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Total Kjeldahl Nitrogen index, calculated on median vallues among samples per station: 100: >=0.5 mg/l, 200: >0.4, 300: >0.25, 400: <=0.25	0[a]
MedStressed	Median stressed	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Median percent of stations fitting DEP's Stressed Category (GLIMPSS calculation)	0[a]
MedMetal	Median metals	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Median % of measured metals (Al, Fe, Mn, Se, Cu, Zn) not attaining DEP's water quality standards per station, calculated on median values among samples	0[f]
MedChloride	Median chloride	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Median chloride index: 100: >860mg/l, 200:>230, 300:>115, 400: <=115	0[f]
MedSpecCond*	Median specific conductivity	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Represent specific conductivity values for sampled streams (possible indicator of impairment due to mining)	Specific Conductance index, calculated on median values of samples per station: 100: >835 umhos/cm, 200: >500, 300: >200, 400: <=200	1.5
MedGLIMPSS	Median GLIMPSS scores	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Represent benthic macroinvertebrate communities in sampled streams	GLIMPSS_CF index of Percent Threshold, calculated on median values: 100: <50, 200: <100, 300: <125, 400: >=125	2
MedS&E	Median sedimentation & embeddedness	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Represent RBP habitat score of streambank condition	Median sum of individual indices for Embeddedness and Sedimentation scores: 100: <11, 200: <21, 300: <31, 400: >=31	1
MaxMinpH	Maximum/minimum pH	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	pH index calculated on extreme values among samples for each station (maximum or minimum): 100: >10 or <5, 200: >9 or <6, 300: >8 or <6.5, 400: 6.5 - 8	0[a]
MinRefIndex	Minimum reference index value	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Weighted Percentage of points that are DEP reference points (minimum among samples per station)	0[a]
MaxSulfate	Maximum sulfates	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Sulfate index, calculated on maximum values among samples per station: 100: >250 mg/l, 200: >50, 300: >25, 400: <=25	0[a]
MaxNitro	Maximum nitrogen	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Total Kjeldahl Nitrogen index, calculated on extreme values among samples per station: 100: >=0.5 mg/l, 200: >0.4, 300: >0.25, 400: <=0.25	0[a]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
MaxStressed	Maximum stressed	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Maximum percent of stations fitting DEP's Stressed Category (GLIMPSS calculation)	0[a]
MaxMetal	Maximum metals	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Median % of measured metals (Al, Fe, Mn, Se, Cu, Zn) not attaining DEP's water quality standards per station, calculated on extreme values	0[a]
MaxChloride	Maximum chloride	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Chloride index, calculated on extreme values among samples per station (maximum or minimum): 100: >860mg/l, 200:>230, 300:>115, 400: <=115	0[a]
MaxSpecCond	Maximum specific conductivity	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Specific Conductance index, calculated on extreme vallues among samples per station: 100: >835 umhos/cm, 200: >500, 300: >200, 400: <=200	0[a]
MinGLIMPSS	Minimum GLIMPSS score	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	GLIMPSS_CF index of Percent Threshold, calculated on extreme values among samples per station (maximum or minimum): 100: <50, 200: <100, 300: <125, 400: >=125	0[a]
MinRBP	Minimum Rapid Bioassessment Protocol score	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Total RBP Score index, calculated on extreme values among samples per station: 100: <60, 200: <110, 300: <160, 400: >=160	0[a]
MinBSS	Minimum Bank Stability Score	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Bank Stability Score index, calculated on extreme values among samples per station (maximum or minimum): 100: <6, 200: <16, 300: <17, 400: >=16	0[a]
MinS&E	Minimum sedimentation and embeddedness score	Water Assessment Branch (WAB) water quality sample data (WVDEP)	Not considered in final analysis	Sum of individual indices for Embeddedness and Sedimentation scores, calculated on extreme values among samples per station: 100: <11, 200: <21, 300: <31, 400: >=31	0[a]
VolRem	Voluntary remediation sites in riparian area	Voluntary Remediation Sites (WVDEP)	Not considered in final analysis	Spatial join to get number per planning unit	0[d]
KarstRip	Karst features in riparian area	Karst geology (WVDNR)	Not considered in final analysis	Identity to planning unit and calculate square miles per planning unit	0[f]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
HES	Highly erodible soils	Soils by county (SSURGO)	Not considered in final analysis	Generate erosion hazard dataset from Soil Data Viewer, select all values of EroHzdORT = severe, very severe, identity to planning unit, calculate square miles per planning unit	0[g]
Imperv1*	Percent imperviousness	NLCD Impervious surface (USGS)	Generates increased run off as potential non-point source of pollution to streams	Convert raster to polgyon, Identity to planning unit, Dissolve to get mean percent imperviousness per planning unit	2[b]
AllWells	Wells in riparian area	All Wells (WVDEP)	Source of sedimentation	Spatial join to get number per planning unit	1.5[b]
CBMTWellProd	Coal bed methane and Trenton well production	Coal bed methane and Trenton well production (WVGES)	Not considered in final analysis	Join Excel table by well ID, dissolve to get mean production per HUC12	0[d]
ActiveSurface1	Active surface mining	LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP)	Not considered in final analysis	Merge mining polygons, Identity to planning unit and calculate to get square miles per planning unit	0[a,c]
ActiveSurfaceRip1	Active surface mining in riparian area		Not considered in final analysis		0[f]
SurfaceMine1*	Surface mining (active and legacy)	LULC 2009 Mined and reclaimed mine lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP); Abandoned mine lands (WVDEP)	Source of pollutants and sedimentation	Merge all mining polygons, Identity to planning unit and calculate to get square miles per planning unit	2
UndrgrndMine1	Underground mining	Underground mining (WVGES)	Potential impacts to water quality from acid mine drainage	Identity to planning and calculate to get square miles per planning unit	2[b]
TotalCoalProd	Total coal production	Coal production: 2000-2010 (US EIA)	Not considered in final analysis	Calculate cumulative mine production totals in Excel, Join table, distribute by percent area active mining per county, calculate per planning unit	0[a]
MinOps	Mineral operations	Mineral operations (USGS)	Not considered in final analysis	Spatial join to get number per planning unit	0[d]
Timber	Timber harvesting	Timber operations (WVDOF)	Not considered in final analysis	Identity to planning unit and Dissolve to get total square miles per planning unit	0[f]
NPDES	National Pollutant Discharge Elimination System permit sites	NPDES permit sites (WVDEP)	Not considered in final analysis	Select features where perm_type: Industrial, Sewage; iut_code: OUTLT, CSO, Spatial Join to get number per planning unit, normalize by stream miles per planning unit	0[a]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
CoalNPDES	Coal-related NPDES permit sites	Coal NPDES (WVDEP)	Not considered in final analysis	Spatial Join to get number per planning unit	0[a]
Ag	Agriculture	LULC 2009 (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, Select features where Value: 82, Identity to planning unit and calculate square miles per planning unit	0[a,c]
Graze	Grazing	LULC 2009 (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, Select features where Value: 81, Identity to planning unit and calculate square miles per planning unit	0[a,c]
Developed	Development	LULC 2009 (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, Select features where Value: 20, Identity to planning unit and calculate square miles per planning unit	0[a,c]
AgRip1	Agriculture in riparian area	LULC 2009 (WVU NRAC)	Potential source of pollutants and sedimentation in stream	Convert raster to polygon, Select features where Value: 82, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit	1
GrazeRip1	Grazing in riparian area	LULC 2009 (WVU NRAC)	Potential source of sedimentation in stream	Convert raster to polygon, Select features where Value: 81, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit	1
DevelopedRip1	Development in riparian area	LULC 2009 (WVU NRAC)	Potential source of pollutants and sedimentation in stream (from run off and construction)	Convert raster to polygon, Select features where Value: 20, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit	1
NatCoverRip1	Natural cover in riparian area	LULC 2009 (WVU NRAC)	Can identify natural conditions of resiliency and riparian health in watershed	Convert raster to polygon, Clip to riparian area, Select features with values: 41, 42, 43, 71, 91, 92, Identity to planning unit and Dissolve to get square miles per planning unit	2
NatcoverHdwtr	Natural cover in headwater stream catchments	LULC 2009 (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, Select features with values: 41, 42, 43, 71, 91, 92, Select catchments containing headwater streams, Clip Natural Cover to headwater catchments, Identity to planning unit and Dissolve to get square miles per planning unit	0[a]
AllRdRail	Road/railroad density	Roads (WVDOT); Railroads (WVDNR)	Potential source of sedimentation in stream	Merge shapefiles, Identity to planning unit and calculate miles per planning unit	1.5

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
AllRdRailRip1	Road/railroad density in riparian area		Not considered in final analysis	Merge shapefiles, Clip to riparian area, Identity to planning unit and calculate miles per planning unit	0[a]
Superfund	Superfund sites	Superfund sites (USEPA Envirofacts)	Not considered in final analysis	Select values where CERC1_INT = superfund NPL, Spatial Join to get number per planning unit	0[d]
TSD	Toxic waste storage and disposal	Hazardous waste disposal sites (USEPA Envirofacts)	Not considered in final analysis	Select features where value RCRA1_INT, RCRA2_INT, or RCRA3_INT = TSD, Spatial Join to get number per planning unit	0[d]
BoatLaunch	Recreational boat launches	Boat launches (WVDNR)	Not considered in final analysis	Spatial Join to get number per planning unit	0[d]
Septic	Potential septic systems	Septic systems (WVFO generated)	Not considered in final analysis	Digitize sewer areas from WV IJDC GIS Data Portal, Erase structure points that fall within these areas, Clip to riparian area, Spatial Join to get number per planning unit	0[a,c]
SepticRip	Potential septic systems in riparian area		Not considered in final analysis		0[b]
Landfill	Landfills	Landfills (WVDEP)	Not considered in final analysis	Spatial Join to get number per planning unit	0[b,d]
WATER QUANTITY					
PWS	Public water supply intakes	Public water supply intakes (DHHR)	Points of water withdrawal from stream	Select any features except wells, Spatial Join to get number per planning unit, normalize by stream mile	0.5
LQU	Large quantity users	Large quantity users (WVDEP)	Potential flow alteration from large quantity water withdrawals	Select features where Size class 1(a,b) and 2, find LQU along those stream reaches	2
LQU3yr	Large quantity users 3 Year Average water use		Not considered in final analysis		0[f]
PWSTrib	Tributaries draining to a public water supply reservoir	Public water supply (DHHR) tributaries (NHD 24K)	Not considered in final analysis	stream segments draining to PWS reservoir; FAC_TYPE: IN, RS	0[d]
WWTP	Wastewater treatment plants	Sewer treatment plants (WVDEP)	Potential flow alteration from treated water discharges	Select features where sub_desc: Ind POTW, Spatial Join to get number per planning unit, normalize by stream miles	0.5[e]
DamDrainage	Dam drainage areas (catchment above dam sites)	Dam drainage area (WVFO generated)	Surrogate for potential flow alteration and dam storage capacity	Select NHDPlus catchments that drain to dam point along stream, Identity to planning unit and Dissolve to get square miles per planning unit	1[b]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
Imperv2*	Percent imperviousness	NLCD Impervious surface (USGS)	Surrogate for potential flow alteration from stormwater run off	Convert raster to polgyon, Identity to planning unit, Dissolve to get mean percent imperviousness per planning unit	1.5[b]
ActiveSurface2	Active surface mining	LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP)	Not considered in final analysis	Merge mining polygons, identity to planning unit and calculate square miles per planning unit	0[f]
LegacySurfaceRip1	Legacy surface mining in riparian area	LULC 2009 reclaimed mine lands (WVU NRAC); Abandoned mine lands (WVDEP)	Not considered in final analysis	Merge mining polygons, identity to planning unit and calculate square miles per planning unit	0[f]
SurfaceMine2	Surface mining (active and legacy)	LULC 2009 Mined and reclaimed mine lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP); Abandoned mine lands (WVDEP)	Source of pollutants and sedimentation	Merge all mining polygons, Identity to planning unit and calculate to get square miles per planning unit	1
UndrgrndMine2	Underground mining	Underground mining (WVGES)	Surrogate for potential flow alteration from mining discharge	Identity to planning and calculate to get square miles per planning unit	1.5[b]
LowFlow	Low flow impaired streams	Low flow impaired streams (WVDEP)	Not considered in final analysis	Select features where Cause: Low Flow, Identity to planning unit and calculate miles per planning unit	0[d]
Consum	Consumptive water use	Consumptive use data (USGS)	Not considered in final analysis	Sum of consumptive and non-comsumptive water usage by county	0[g]
NonConsum	Non-consumptive water use		Not considered in final analysis		0[g]
HYDROLOGIC CONNECTIVITY					
Unimpeded	Unimpeded streams	Functional river network (TNC - ERO)	Not considered in final analysis	Select features where value N_SZCL > = 4, Identity to planning and Dissolve to get miles per planning unit	0[e]
TempImp	Temperature impaired streams	303(d) Listed Impaired Streams - Temperature (WVDEP)	Not considered in final analysis	Select features where Cause: Temp Identity to planning unit and calculate miles per planning unit	0[d]
Hdwtrs	Headwater streams	Headwaters (NHD 24K)	Prioritize headwaters streams	Select features where Stream Order = 1,2, Identity to planning unit and Dissolve to get stream miles per planning unit	1.5[b]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
LocInt	Mean local integrity score	Local integrity (TNC - ERO/PAFO)	Measure of local connectedness of landscape	Convert raster to polygon; Identity to planning unit, dissolve to mean gridcode	1
LocIntHdwtr	Local integrity of headwater stream catchments	Local integrity/Headwater catchments (TNC - ERO/PAFO)	Not considered in final analysis	local integrity score (grid_code); Headwater catchments	0[a]
WetArea	Wetland area	NWI Wetlands (FWS)	Prioritize planning units with greater wetland areas	Type: Freshwater emergent wetland, Freshwater forested/shrub wetland	1
PowPlants	Power plants	Power plants (Ventyx)	Identify potential temperature increase from power plant discharges in entire stream segments as a potential fragmenting feature	Select streams features where size class = 1(a,b) and 2 streams, Select by location any power plant points along stream, Spatial join to get number per planning unit	0.5
Forestriparea	Forested riparian area	LULC 2009 (WVU NRAC)	Identify potential temperature maintenance from canopy cover of stream segments	Convert raster to polygon, Select features where Value: 41, 42, 43, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit	1.5[b]
Dams	Dams	Dams (TNC - ERO)	Fragmenting features that inhibit fish passage and natural flow levels within stream networks	Select features where Use = 1,2, spatial join to get number per planning unit	1.5[b]
Culverts	Potential culverts	Culverts (WVFO generated)	Not considered in final analysis	Headwater streams/roadRR crossings; Bridges over headwater streams	0[a]
Bridges	Bridges	Bridges (WVDOT)	Not considered in final analysis	Bridges over non-headwater streams	0[a]
AllRdRailRip2	Road/railroad density in riparian area	Roads (WVDOT); Railroads (WVDNR)	Potential source of sedimentation in stream	Merge shapefiles, Identity to planning unit and calculate miles per planning unit	2
BIODIVERSITY					
AllSGNCRip	Species in Greatest Need of Conservation in riparian area	SGCNs (WVDNR)	Identify and prioritize known locations of rare, endangered or threatened species	Select features that are G1-G3, S1-S3, Federally listed, Clip to riparian area, Spatial Join to get number per planning unit	1.5
Muss	Mussel streams	Mussel streams (WVFO generated)	Stream quality indicator	Identity to planning unit and Dissolve to get miles per planning unit	1
Trout	Trout streams	Trout streams (WVDEP)	Not considered in final analysis	Identity to planning unit and Dissolve to get miles per planning unit	0[d]
MedTaxa	Median taxa richness	Taxa richness (WVDEP)	Not considered in final analysis	GLIMPSS_CF taxa	0[f]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
MaxTaxa	Maximum taxa richness	Taxa richness (WVDEP)	Indicator of habitat quality	GLIMPSS_CF taxa	1[b]
NEHabRip	Northeast terrestrial habitat types	NE terrestrial habitat types (TNC - ERO)	Higher diversity of habitat types leads to greater species diversity	Convert raster to polygon, Clip to riparian area, Identity to planning unit and Dissolve to get count per planning unit	1
SpeciesPredict	Species diversity prediction index	Ecological Land Units (TNC - ERO)	Considers landform variability measures as possible indicators of resilient sites for presence of rare species, both currently and in the future	Export tables to Excel, calculate # geology classes/elevation range/hectares calcareous bedrock per planning unit, normalize data, roll up into index by planning unit	0[g]
CalcBedRip	Calcareous bedrock in riparian area	Ecological land units (TNC - ERO)	Contributes to soil structure and topography that support a variety of vegetative and animal species; partial predictor of rare species	Select features where GEOL_DESC = Calcareous sed/metased; Mod calcareous sed/metased, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit	1
NNISRip	Non-native invasive species in riparian area	Non-native invasive species (WVDA/WVDNR)	Non-native invasive species displace natives; alter food webs	Spatial Join to get number per planning unit	1.5
Corbicula	Corbicula	Corbicula mussels (WVDEP)	Not considered in final analysis	None: Access database by planning unit	0
Carp	Carp	Carp (WVDEP)	Not considered in final analysis	None: Access database by planning unit	0
Zebras	Zebra mussel streams	Zebra Mussels (WVDNR)	Not considered in final analysis	Identity to planning unit, Dissolve to get stream miles per planning unit	0
Infected	Quarantined/Infested/Infected counties	Quarantined/Infested/Infected counties (WVDA)	Not considered in final analysis	Sum number per county, Identity to planning unit and Dissolve to get mean per planning unit	0[a]
RIPARIAN HABITAT					
NatcoverRip2	Natural cover in riparian area	LULC 2009 (WVU NRAC)	Functional contribution in terms of water storage and filtration	Convert raster to polygon, Select Codes 41, 42, 43, 52, 71, 90, 95, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit	2[b]
AgRip2	Agriculture in riparian area	LULC 2009 (WVU NRAC)	Source of sediments and other pollutants	Convert raster to polygon, Select Code 82, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit	1
GrazeRip2	Grazing in riparian area	LULC 2009 (WVU NRAC)	Source of sedimentation	Convert raster to polygon, Select Code 81, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit	1

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
DevelopedRip2	Development in riparian area	LULC 2009 (WVU NRAC)	Source of sedimentation and other pollutants	Convert raster to polygon, Select Code 20, Clip to riparian area, Identity to planning unit, Dissolve to get square miles per planning unit	0[f]
ImpervRip*	Percent imperviousness in riparian area	NLCD Impervious surface (USGS)	Generates increased run off as potential non-point source of pollution to streams	Convert raster to polgyon, Clip to riparian area, Identity to planning unit, Dissolve to get mean percent imperviousness per planning unit	2
MedRBP	Median Rapid Bioassessment Protocol score	WAB database (WVDEP)	Indicator of stream physical habitat quality	Median total RBP index: 100: <60, 200: <110, 300: <160, 400: >=160	1
MedBSS	Median Bank Stability score		Not considered in final analysis	Median RBP Bank Stability Score index: 100: <6, 200: <16, 300: <17, 400: >=16	0
ActiveSurfaceRip2*	Active surface mining in riparian area	LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP)	Source of sediments and other pollutants	Merge mining polygons, Identity to planning unit and calculate square miles per planning unit	2
LegacySurfaceRip	Legacy surface mining in riparian area	LULC 2009 reclaimed mine lands (WVU NRAC); Abandoned mine lands (WVDEP)	Source of sediments and other pollutants	Merge mining polygons, Identity to planning unit and calculate square miles per planning unit	1
AllWellsRip	Wells in riparian area	Wells (WVDEP)	Source of sediments and other pollutants	Spatial Join to get number per planning unit	1
AllRdRailRip3	Roal/railroads in riparian area	Roads (WVDOT); Railroads (WVDNR)	Source of sediments and other pollutants	Merge shapefiles, Clip to riparian area, Identity to planning unit and calculate miles per planning unit	1.5
EnergyRip	Energy transmission lines in riparian area	Energy transmission lines (Ventyx)	Not considered in final analysis	Clip to riparian area, Identity to planning unit and calculate miles per planning unit	0[f]
PipeRip	Pipelines in riparian area	Pipelines (Ventyx)	Not considered in final analysis	Clip to riparian area, Identity to planning unit and calculate miles per planning unit	0
WindRip	Wind turbines in riparian area	Wind turbines (TNC - PAFO)	Not considered in final analysis	Spatial join to get number per planning unit	0[b,d]
BldgsRip	Buildings in riparian area	Structure points (WVSAMB)	Not considered in final analysis	Spatial join to get number per planning unit	0[a,b]
PROTECTED LANDS					
GAP1Rip	GAP Status 1 in riparian area	Secured lands (TNC)	Not considered in final analysis	Select features where value GAP_STATUS: 1, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit	0[f]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
GAP2Rip	GAP Status 2 in riparian area	Secured lands (TNC)	Not considered in final analysis	Select features where value GAP_STATUS: 2, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit	0[f]
GAP3Rip	GAP Status 3 in riparian area	Secured lands (TNC)	Not considered in final analysis	Select features where value GAP_STATUS: 3, Clip to riparian area, Identity to planning unit and calculate square miles per planning unit	0[f]

Wetlands

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
WATER QUALITY: POLLUTANT FILTRATION/SEDIMENT RETENTION					
ForestHdwtrWet1	Forested headwater wetlands	2009 LULC (WVU NRAC); Wetlands (NWI); Headwater streams (NHD 24K)	Functional contribution in terms of water storage and filtration	Select wetland buffers within 50 m of headwater stream, Clip forested landcover to wetland buffer, Identity to planning unit and Dissolve to get square miles per planning unit	2
AgWet1	Agriculture in wetland buffer	2009 LULC (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, Select features where Value: 82, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit	0[c]
GrazeWet1	Grazing in wetland buffer	2009 LULC (WVU NRAC)	Source of sedimentation	Convert raster to polygon, Select features where Value: 81, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit	0[f]
DevelopedWet1	Development in wetland buffer	2009 LULC (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, Select features where Value: 20, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit	0[c]
AgCatch	Agriculture in wetland catchment	2009 LULC (WVU NRAC)	Source of sediments and other pollutants	Convert raster to polygon, Select features where Value: 82, Clip to wetland catchment, Identity to planning unit and calculate square miles per planning unit	1

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
GrazeCatch	Grazing in wetland catchment	2009 LULC (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, Select features where Value: 81, Clip to wetland catchment, Identity to planning unit and calculate square miles per planning unit	1
DevelopedCatch	Developed in wetland catchment		Source of sediments and other pollutants	Convert raster to polygon, Select features where Value: 20, Clip to wetland catchment, Identity to planning unit and calculate square miles per planning unit	1
ForestCatch	Forest Cover in wetland catchment		Not considered in final analysis	Convert raster to polygon, Select features where Value: 41, 42, 43, Clip to wetland catchment, Identity to planning unit and calculate square miles per planning unit	0[a]
NatCoverCatch	Natural Cover in wetland catchment		Functional contribution in terms of water storage and filtration	Convert raster to polygon, Select Codes 41, 42, 43, 52, 71, 90, 95, Clip to wetland catchment, Identity to planning unit, Dissolve to get square miles per planning unit	3[b]
ImpervWet	Percent imperviousness of wetland buffer	NLCD 2006 Impervious surface (USGS)	Not considered in final analysis	Convert raster to polgyon, Identity to planning unit, Dissolve to get mean percent imperviousness per planning unit	0[c]
ImpervCatch	Percent imperviousness of wetland catchment		Source of sediments and other pollutants		1[b]
RoadsRRCatch	Roads/railroads in wetland catchment	Roads/rail	Not considered in final analysis	Merge shapefiles, Clip to wetland catchment, Identity to planning unit and calculate miles per planning unit	1
NPDESCatch	NPDES permits in wetland catchment	NPDES sites (WVDEP)	Not considered in final analysis	Spatial join to get number per planning unit	0
ActiveSurfaceWet1	Active surface mining in wetland buffer	LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP)	Not considered in final analysis	Merge mining polygons, Clip to wetland buffer, Identity to planning unit and calculate to get square miles per planning unit	0[c]
ActiveSurfaceCatch	Active surface mining in wetland catchment		Source of sediments and other pollutants	Merge mining polygons, Clip to wetland catchment, Identity to planning unit and calculate to get square miles per planning unit	2
SurfaceCoalProd	Surface coal production	Coal production 2000-2010 (US EIA)	Not considered in final analysis	Calculate cumulative mine production totals in Excel, Join table, distribute by percent area active mining per county, calculate per planning unit	0

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
DistAllWells	Distance to wells	Oil and gas wells (WVDEP)	Not considered in final analysis	Distance tool to get distance from wetland to well; Dissolve to get average distance	0[d]
AllWellsCatch	Wells within wetland catchment		Source of sediments and other pollutants	Clip shapefile to wetland catchment; Spatial join to get number per planning unit	1
SepticWet	Septic systems in wetland buffer	Septic systems as structure points which fall outside of sewer area boundaries (digitized from WV IJDC GIS Data Portal)	Not considered in final analysis	Spatial join to get number per planning unit	0[f]
SepticCatch	Septic systems in wetland catchment		Not considered in final analysis	Clip to wetland catchment; Spatial join to get number per planning unit	0[f]
LandfillCatch	Landfills in wetland catchment	Landfills (WVDEP)	Not considered in final analysis	Clip to wetland catchment; Spatial join to get number per planning unit	0[b,d]
MinOpsCatch	Mineral operations in wetland catchment	Mineral operations (USGS)	Not considered in final analysis	Clip to wetland catchment; Spatial join to get number per planning unit	0[d]
TimberCatch	Timber harvesting in wetland catchment	Timber operations (WVDOF)	Not considered in final analysis	Clip to wetland catchment; Spatial join to get number per planning unit	0[f]
HYDROLOGY: FLOOD STORAGE/CONNECTIVITY					
WetSize	Mean wetland size	Wetlands (NWI)	Not considered in final analysis	Select features where type: Freshwater emergent wetland, Freshwater forested/shrub wetland, Identity to planning unit, Dissolve to get mean size per planning unit	0[a]
WetArea	Total wetland area		Prioritize planning units with greater wetland areas	Select features where type: Freshwater emergent wetland, Freshwater forested/shrub wetland, Identity to planning unit, calculate square miles per planning unit	2[b]
ForestHdwtrWet2	Forested headwater wetlands	2009 LULC (WVU NRAC); Wetlands (NWI); Headwater streams (NHD 24K)	Functional contribution in terms of water storage and filtration	Select wetland buffers within 50 m of headwater stream, Clip forested landcover to wetland buffer, Identity to planning unit and Dissolve to get square miles per planning unit	1
RatioCatchWet	Ratio of wetland area to wetland catchment area	Wetlands (NWI); Wetland catchments (based on NHDPlus)	Not considered in final analysis	Export Excel tables of wetland area and wetland catchment values, sum per planning unit, divide area by catchment	0[c]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
DistNearWtr	Distance to nearest surface water feature	Surface water features (NWI Wetlands, NHD24K Hydrography)	Not considered in final analysis	Distance tool to get distance from wetland to streams layer; Dissolve to get average distance	0[d]
HdwtrWet	Headwater wetlands	Wetlands (NWI); Headwater streams (NHD 24K)	Not considered in final analysis	Select wetland buffers within 50 m of headwater stream, Identity to planning unit and Dissolve to get square miles per planning unit	0[a]
FldForestWet	Forested wetlands within the floodplain	Floodplain (FEMA); Wetlands (NWI)	Functional role for flood storage capacity, indicates areas of potential wetland development	Clip forest cover to wetland buffer; Clip to floodplain; Identity to planning unit and Dissolve to square miles per planning unit.	1[b]
FloodArea	Floodplain area			Identity to planning unit; Dissolve to get square miles per planning unit	1[b]
Hydricsoils	Hydric soils	Hydric soils (SSURGO)	Indicator of conditions suitable for potential wetland development	Use Soil Data Viewer to generate Hydric Rating by Map Unit, Select hydric, partially hydric soils, Identity to planning unit and calculate square miles per planning unit	1.5[b]
BIODIVERSITY					
AllSGNCWet	Species in Greatest Need of Conservation in wetland buffer	SGCNs (WVDNR)	Identify and prioritize known locations of rare, endangered or threatened species	Select features that are G1-G3, S1-S3, Federally listed, Clip to wetland buffer, Spatial Join to get number per planning unit	1.5
SpeciesPredict	Species diversity prediction index	Ecological Land Units (TNC - ERO)	Not considered in final analysis	Export tables to Excel, calculate # geology classes/elevation range/hectares calcareous bedrock per planning unit, normalize data, roll up into index by planning unit	0
CalcBedWet	Calcareous bedrock in wetland buffer	Ecological land units (TNC - ERO)	Contributes to soil structure and topography that support a variety of vegetative and animal species; partial predictor of rare species	Select polygons where GEOL_DESC = Calcareous sed/metased; Mod calcareous sed/metased, Clip to wetland buffer, Identity to planning unit and Dissolve to get square miles per planning unit	1
KarstWet	Karst in wetland buffer	Karst features (WVGES)	Not considered in final analysis	Clip to wetland buffer, Identity to planning unit and Dissolve to get square miles per planning unit	0[d]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
NEHabWet	NE terrestrial habitat types in wetland buffer	NE terrestrial habitat types (TNC - ERO)	Higher diversity of habitat types leads to greater species diversity	Convert raster to polygon, Clip to wetland buffer, Identity to planning unit and Dissolve to get count per planning unit	1
NNISWet	Non-native invasive species in wetland buffer	Non-native invasive species (WVDA/WVDNR)	Non-native invasive species displace natives; alter food webs	Clip to wetland buffer, Spatial Join to get number per planning unit	1.5
Infected	Pest/pathogen infected counties	Quarantined/Infested/ Infected counties (WVDA)	Not considered in final analysis	Sum number per county, Identity to planning unit and Dissolve to get mean per planning unit	0[d]
WETLAND HABITAT					
NatcoverWet	Natural Cover in wetland buffer	LULC 2009 (WVU NRAC)	Functional contribution in terms of water storage and filtration	Convert raster to polygon, Select Codes 41, 42, 43, 52, 71, 90, 95, Clip to wetland buffer, Identity to planning unit, Dissolve to get square miles per planning unit	2
AgWet2	Agriculture in wetland buffer	2009 LULC (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, Select features where Value: 82, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit	1
GrazeWet2	Grazing in wetland buffer	2009 LULC (WVU NRAC)	Source of sedimentation	Convert raster to polygon, Select features where Value: 81, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit	1
DevelopedWet2	Development in wetland buffer	2009 LULC (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, Select features where Value: 20, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit	1
WetForestPatchMax	Largest forest patch in wetland buffer	Forest Patches (TNC)	Not considered in final analysis	Select patches >100 acres, Clip to wetland buffer, Identity to planning unit and Dissolve to get maximum (in square miles) forest patch per planning unit	0[a]
WetForestPatchMean	Mean forest patch in wetland buffer	Forest Patches (TNC)	Larger forest patches provide more habitat for wetland organisms, greater sediment retention and pollutant filtration	Select patches >100 acres, Clip to wetland buffer, Identity to planning unit and Dissolve to get mean (in square miles) forest patch per planning unit	1
AllWellsWet	Wells within wetland buffer	Oil and gas wells (WVDEP)	Fragmenting features within the landscape	Spatial join to get number per planning unit	1.5

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
ActiveSurfaceWet2*	Active surface mining in wetland buffer	LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP)	Source of sediments and other pollutants	Merge mining polygons, identity to planning unit and calculate square miles per planning unit	2
LegacySurfaceWet	Legacy surface mining in wetland buffer	LULC 2009 reclaimed mine lands (WVU NRAC); Abandoned mine lands (WVDEP)	Source of sediments and other pollutants	Merge mining polygons, identity to planning unit and calculate square miles per planning unit	1
RoadsRRWet	Roads/railroads in wetland buffer	Roads (WVDOT); Railroads (WVDNR)	Fragmenting features within the landscape	Merge shapefiles, Clip to wetland buffer, Identity to planning unit and calculate miles per planning unit	1
CulvertsWet	Culverts in wetland buffer	Road/railroad crossings (WVFO generated)	Not considered in final analysis	Select streams size class 1a and 1b, generate points for intersection of streams and roads/railroads, spatial join to get number per planning unit	0
EnergyWet	Energy lines in wetland buffer	Energy transmission lines (Ventyx)	Not considered in final analysis	Identity to planning unit and calculate miles per planning unit	0
PipeWet	Pipelines in wetland buffer	Pipelines (Ventyx)	Not considered in final analysis	Identity to planning unit and calculate miles per planning unit	0
BldgsWet	Buildings in wetland buffer	Structure points (WVSAMB)	Not considered in final analysis	Spatial join to get number per planning unit	0[b]
PROTECTED LANDS					
UnsecnatcoverWet	Natural cover in wetland buffer within unsecured lands	LULC 2009 (WVU NRAC)	Not considered in final analysis	Convert raster to polygon, select codes 41, 42, 43, 52, 71, 90, 95, erase by secured lands, identity to planning unit and calculate square miles per planning unit	0
GAP1Wet	GAP Status 1 in wetland buffer	Secured lands (TNC)	Not considered in final analysis	Select features where value GAP_STATUS: 1, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit	0[f]
GAP2Wet	GAP Status 2 in wetland buffer	Secured lands (TNC)	Not considered in final analysis	Select features where value GAP_STATUS: 2, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit	0[f]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
GAP3Wet	GAP Status 3 in wetland buffer	Secured lands (TNC)	Not considered in final analysis	Select features where value GAP_STATUS: 3, Clip to wetland buffer, Identity to planning unit and calculate square miles per planning unit	0[f]

Uplands

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
HABITAT CONNECTIVITY					
LgstForest	Largest intersecting forest block	Forest patches (TNC)	Not considered in final analysis	Select forest patches >100 acres; Create shapefile from forest patches layer crossed by/within watershed outline; calculate geometry, identity to planning unit, dissolve to max forest patch size	0
ForestSize	Mean intersecting forest block	Forest patches (TNC)	Large forest blocks provide more habitat for greater species diversity	Select forest patches >100 acres; Create shapefile from forest patches layer crossed by/within watershed outline; calculate geometry, identity to planning unit, dissolve to mean forest patch size	2
LocInt	Mean local integrity score	Local integrity (TNC - ERO/PAFO)	Measure of local connectedness of landscape	Convert raster to polygon; Identity to planning unit, dissolve to mean gridcode	1.5
Developed1*	Development	LULC 2009 (WVU NRAC)	Structures and roads eliminate and fragment habitat	Identity to planning unit and Dissolve to get total square miles per planning unit	1.5
AllRdRail	Roads/railroads	Roads (WVDOT); Railroads (WVDNR)	Potential fragmenting feature	Identity to planning unit and Dissolve to get total miles per planning unit	1
Energy	Energy transmission lines	Energy transmission lines (Ventyx)	Potential fragmenting feature	Identity to planning unit and Dissolve to get total miles per planning unit	0.5

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
Pipe	Pipelines	Pipelines (Ventyx)	Potential fragmenting feature	Identity to planning unit and Dissolve to get total miles per planning unit	0.5
Wind	Wind turbines	Wind turbines (TNC - PAFO)	Potential fragmenting feature	Spatial Join to get number per planning unit	0.5
Bldgs	Buildings	Structure points (WVSAMB)	Not considered in final analysis	Spatial Join to get number per planning unit	0[a,b]
Towers	FCC Towers	Towers (WVGISTC)	Not considered in final analysis	Spatial Join to get number per planning unit	0[a]
AllWells	Wells	Oil and gas wells (WVDEP)	Potential fragmenting feature	Spatial Join to get number per planning unit	1
ActiveSurface1*	Active surface mining	LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP)	Eliminates and fragments habitat	Merge mining polygons, Identity to planning unit and calculate to get square miles per planning unit	1.5
SurfaceCoalProd	Coal production (2000-2010)	US EIA	Not considered in final analysis	Calculate cumulative mine production totals in Excel, Join table, distribute by percent area active mining per county, calculate per planning unit	0[a]
MinOps	Mineral operations	USGS	Not considered in final analysis	Spatial Join to get number per planning unit	0
Timber1	Timber harvesting	Timber operations (WVDOF)	Temporarily fragments and reduces quality of forest habitat	Identity to planning unit and Dissolve to get total square miles per planning unit	0.5
Landfill	Landfills	Landfills (WVDEP)	Not considered in final analysis	Spatial Join to get number per planning unit	0[b,d]
HABITAT QUALITY					
Hetero	Heterogeneity	ERO/PAFO	Heterogeneous landscapes have high potential for species diversity	Convert raster to polygon; Identity to planning unit, dissolve to mean grid code	2

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
FRCC	Vegetation altered from reference condition	Fire Regime Condition Class (LANDFIRE)	Not considered in final analysis	Convert raster to polygon; Create new layer from gridcode =1; Identity to planning unit, dissolve to get total square miles per planning unit	0[g]
NatCover	Natural cover	LULC 2009 (WVU NRAC)	Natural cover indicates less disturbance, higher quality habitat for native species	Convert raster to polygon; Select features where Value: 41,42,43,71,92; Identity to planning unit and calculate sqare miles per planning unit	2
Karst	Karst features	Karst geology (WVDNR)	Not considered in final analysis	Identity to planning unit and Dissolve to get total square miles per planning unit	0[d]
ActiveSurface2*	Active Surface mining	LULC 2009 Mined lands (WVU NRAC); Valley Fills/Refuse Structures (WVDEP)	Eliminates and fragments habitat	Merge mining polygons, Identity to planning unit and calculate to get square miles per planning unit	1.5
LegacySurface	Legacy Surface mining	Appalachian Voices/TNC digitized shapefile	Mine sites represent poor to sub-optimal quality habitat due to altered topography, soil structure, and vegetation	Merge mining polygons: non-active WVFO generated mining from aerials/topo; abandoned mine lands	1
Timber2	Timber harvest	Timber operations (WVDOF)	Temporarily fragments and reduces quality of forest habitat	Identity to planning unit and Dissolve to get total square miles per planning unit	1
Ag	Agriculture	LULC 2009 (WVU NRAC)	Eliminates native species and original vegetation structure; alters soil structure and contributes to soil loss; not as destructive as development	Convert raster to polygon, Select features where Value: 82, Identity to planning unit and calculate square miles per planning unit	1
Graze	Grazing	LULC 2009 (WVU NRAC)	Eliminates native species and original vegetation structure/habitat; not as destructive as row-crop agriculture or development	Convert raster to polygon, Select features where Value: 81, Identity to planning unit and calculate square miles per planning unit	1

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
Developed2*	Development	LULC 2009 (WVU NRAC)	Structures and roads eliminate and fragment habitat	Convert raster to polygon, Select features where Value: 20, Identity to planning unit and calculate square miles per planning unit	1.5
BIODIVERSITY					
AllSGNCUp	Species in Greatest Need of Conservation	SGCNs (WVDNR)	Identify and prioritize known locations of rare, endangered or threatened species	Select features that are G1-G3, S1-S3, Federally listed, Spatial Join to get number per planning unit	1.5
NEHab	Northeast terrestrial habitat types	NE terrestrial habitat types (TNC - ERO)	Higher diversity of habitat types leads to greater species diversity	Convert raster to polygon, Identity to planning unit and Dissolve to get count per planning unit	1
SpeciesPredict	Species diversity prediction index	Ecological Land Units (TNC - ERO)	Not considered in final analysis	Export tables to Excel, calculate # geology classes/elevation range/hectares calcareous bedrock per planning unit, normalize data, roll up into index by planning unit	0
CalcBed	Calcareous bedrock	Ecological land units (TNC - ERO)	Contributes to soil structure and topography that support a variety of vegetative and animal species; partial predictor of rare species	Select features where GEOL_DESC = Calcareous sed/metased; Mod calcareous sed/metased, Identity to planning unit, Dissolve to get square miles per planning unit	1
NNIS	Non-native invasive species	Non-native invasive species (WVDA/WVDNR)	Non-native invasive species replace natives in the landscape; alter food webs for animals that depend upon native plants for food and habitat	Spatial Join to get number per planning unit	1.5
PctLoss	Pests and Pathogens	Percent basal area loss (USFS)	Reduces native plant populations and the animal species that depend on them	Convert raster to polygon, clip to watershed; Identity to planning unit, calculate geometry; Add field Pct_PU, calculate (area of fragment)/(area of planning unit); Add field Wtd_Value, calculate pct_PU*gridcode for weighted value per planning unit. Dissolve by planning unit to sum Wtd_Value	2

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
GypsyMoth	Pests and Pathogens	Percent basal area loss (USFS)	Not considered in final analysis	Convert raster to polygon, clip to watershed; Identity to planning unit, calculate geometry	0[a]
HrdDecline	Pests and Pathogens	Percent basal area loss (USFS)	Not considered in final analysis	Convert raster to polygon, clip to watershed; Identity to planning unit, calculate geometry; Add field Pct_PU, calculate (area of fragment)/(area of planning unit); Add field Wtd_Value, calculate pct_PU*gridcode for weighted value per planning unit. Dissolve by planning unit to sum Wtd_Value	0[a]
RdOakDecline	Pests and Pathogens	Percent basal area loss (USFS)	Not considered in final analysis	Convert raster to polygon, clip to watershed; Identity to planning unit, calculate geometry; Add field Pct_PU, calculate (area of fragment)/(area of planning unit); Add field Wtd_Value, calculate pct_PU*gridcode for weighted value per planning unit. Dissolve by planning unit to sum Wtd_Value	0[a]
Infected	Quarantined/Infested/Infected counties	Quarantined/Infested/Infected counties (WVDA)	Not considered in final analysis	Sum number per county, Identity to planning unit and Dissolve to get mean per planning unit	0[d]
EcoSubunits	Ecoregional subsections	Ecoregional subsections (TNC)	Not considered in final analysis	Identity to planning unit, dissolve to get count per planning unit	0[g]
PROTECTED LANDS					
GAP1	Secured lands	TNC	Not considered in final analysis	Select features where value GAP_STATUS: 1, Identity to planning unit and calculate square miles per planning unit	0[f]
GAP2	Secured lands	TNC	Not considered in final analysis	Select features where value GAP_STATUS: 2, Identity to planning unit and calculate square miles per planning unit	0[f]

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
GAP3	Secured lands	TNC	Not considered in final analysis	Select features where value GAP_STATUS: 3, Identity to planning unit and calculate square miles per planning unit	0[f]

Consolidated Analysis

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
ENERGY					
UnminedPerbd	Potential coal mining activity	Unmined coal beds (WVGES); Mining permit boundary (WVDEP)	Assumed that unmined coal within existing permits would have high potential to be mined in the future	Normalize raster 0-100, reclass based on data, sum with relevant data layers	2
UnminedCoal	Potential coal mining activity within active mine permit boundary	Unmined coal beds (WVGES)	Used to estimate potential for future coal mining activity, assuming all coal beds are mineable	Normalize raster 0-100, reclass based on data, sum with relevant data layers	2
MSWellPot	Potential Marcellus Shale gas well development	Marcellus Shale thickness (WVGES)	Used to estimate potential for future gas well development, assuming greater thickness indicates greater potential	Normalize raster 0-100, reclass based on data, sum with relevant data layers	2
WindPot	Potential wind energy development	Wind energy potential (NREL)	Used to estimate potential for wind development	Select polygons with values > 3, Normalize raster 0-100, reclass based on data, sum with relevant data layers	2
PropWind	Proposed wind turbines		Known locations of proposed future wind turbines	Spatial join to get number per HUC12	1
PropEnergy	Proposed energy transmission lines	Ventyx	Known locations of proposed future energy lines	Identity to HUC12, calculate length in miles per HUC12	1
PropPipe	Proposed gas pipelines	Ventyx	Known locations of proposed future energy lines	Identity to HUC12, calculate length in miles per HUC12	1
PropPower	Proposed power plants	Ventyx	Known locations of proposed power plants	Spatial join to get number per HUC12	1
Geothermal	Potential geothermal energy development	Geothermal energy potential (SMU Geothermal Lab/Google Earth)	Used to estimate potential for geothermal energy development	Select polygons with Temp (at depth 7.5 km) values > 150 degrees, Normalize raster 0-100, reclass based on data, sum with relevant data layers	1

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
POPULATION/ DEVELOPMENT					
PopProject	Projected future population	County population estimates to 2030 (Christiadi 2011)	Estimates of future population growth as indicator of possible future land use scenarios (surrogate for potential increase in developed lands and infrastructure)	Join Excel table of data by county name, Convert to raster based on percent change, Normalize raster 0-100, reclass based on data, sum with relevant data layers	1
FutureGrowthArea	Potential future growth scenarios	Socioeconomic Data Forecasts - 2030	Zoned areas of future development at various intensities	Digitize polygon of projected growth, Normalize raster 0-100, reclass based on data, sum with relevant data layers	1
DevelopPot	Potential development areas	Primary and Secondary Growth Areas (WVRPDC Region VI)	Projected economic development growth corridor	Digitize polygons of zoned future development, Normalize raster 0-100, reclass based on data, sum with relevant data layers	1
CLIMATE CHANGE					
Resiliency	Resiliency	Resiliency (TNC - ERO/PAFO)	Resilient landscapes have greater potential to preserve species diversity in the face of climate change due to landscape heterogeneity and permeability	Normalize raster 0-100, reclass based on data, sum with relevant data layers	1
CurrDens	Regional flow	Current density/Regional flow (TNC - ERO/PAFO)	Identify areas with high permeability and concentrated key linkages for species movement/adaptation to climate change	Normalize raster 0-100, reclass based on data, sum with relevant data layers	0
ClimateWizPrec	Potential future precipitation changes	Climate Wizard (TNC)	Estimates of future increases in precipitation, which will affect species and vegetation distribution	Generate map from Climate Wizard for: Medium Emissions, 2050s, precipitation change, annual, digitize, identity to HUC12 and dissolve for mean precipitation change	0[g]
ClimateWizTemp	Potential future temperature changes	Climate Wizard (TNC)	Estimates of future increases in temperature, which will affect species and vegetation distribution	Medium Emissions, 2050s, temperature change, annual	0[g]
PRIORITY INTEREST AREAS					
AquaPort	TNC aquatic portfolio streams	Aquatic portfolio (TNC)	Identify streams of known high value	Data intended as informational overlay, no analysis conducted	1

Metric Name	Metric Description	Data (Source)	Rationale	GIS Process	Weight
TerrPort	TNC terrestrial portfolio sites	Terrestrial portfolio (TNC)	Identify land of known high value	Data intended as informational overlay, no analysis conducted	1
USFSProBndy	USFS priority areas	National Forest proclamation boundary (USFS)	Identify land that the Forest Service has deemed a priority to acquire	Data intended as informational overlay, no analysis conducted	1
NPS	National Park Service priority areas	NPS priority areas (NPS)	Identify land that NPS has deemed a priority in future planning	Data intended as informational overlay, no analysis conducted	1
DOFPrior	WV Division of Forestry priority areas	WVDOF	Identify HUC12s that WV Division of Forestry has analyzed as high priority for water quality	Select poygons where layScr11 > 20. Data intended as informational overlay, no analysis conducted	1

*Metrics that are identified as "critical metrics" within an index (see Section 3.3.3 for detailed explanation)

[a] Highly correlated (r = 0.75- 1.00) with one or more other metrics
[b] Expert opinion/Literature
[c] Metric with different spatial extent considered more appropriate; e.g., grazing in riparian buffer instead of grazing in entire planning unit
[d] Metric insufficiently represented among planning units
[e] Project team decision
[f] Data effectively represented by or captured within other metric or index
[g] Data at insufficient resolution for scale of analysis (e.g. county or regional level data)

Appendix C: Detailed Full Project Timeline

Month	Activity
March 18, 2011	Grant award signed by DEP
April 1, 2011	Sub-award agreement between DEP and TNC, project timeline starts
April 15, 2011	Quarterly report (1) for January, February, March due
June 1, 2011	Draft assessment methodology completed, Baseline data set identification and compilation begins for 2 watersheds, QAP Plan developed and submitted for review
June 13, 2011	Technical Advisory Team 1st meeting
July 15, 2011	Quarterly report (2) for April, May, June due
Oct 1, 2011	QAP Plan completed, Baseline data collection completed
Oct 15, 2011	Quarterly Report (3) for July, August, September submitted
Oct 26, 2011	1st Expert Workshop on 2 watersheds completed, Consolidated analysis data development and revisions begin
Jan 15, 2012	Quarterly Report (4) for October, November, December submitted
Jan 31, 2012	Consolidated analysis data development and revisions completed, 2nd expert workshop held, strategy development completed in 2 watersheds
March 1, 2012	Draft assessments completed in 2 watersheds
April 5, 2012	Decision maker and end user workshops held. Final revisions made and sent out for peer review.
April 15, 2012	Quarterly Report (5) for January, February, March submitted
June 15, 2012	Quarterly Report (6) for April, May, June submitted
June 29, 2012	Peer review completed. Final assessment reports on 2 watersheds completed, assessment methodology report completed. Begin Baseline data collection on remaining 3 watersheds.
Sept 1, 2012	Baseline data collection completed on remaining 3 watersheds
Oct 11, 2012	1st expert workshops on remaining watersheds
Oct 15, 2012	Quarterly Report (7) for July, August, September submitted
Jan 1, 2013	Draft assessments completed in remaining 3 watersheds
Jan 8, 2013	Revisions completed in remaining 3 watersheds, draft web tool demonstrated, 2nd expert workshops held
Jan 15, 2013	Quarterly Report (8) for October, November, December submitted
April 15, 2013	Quarterly Report (9) for January, February, March submitted
May 8, 2013	Decision maker and end user workshops held. Final revisions made on 3 watersheds
Dec 31, 2013	Final assessment reports on all 5 watersheds completed, assessment methodology report revisions made. Final report and all completed deliverables, including interactive first version of web tool, submitted

Appendix D: Workshop Notes and Attendees

West Virginia Watershed Assessment Pilot Project
EXPERT WORKSHOP 1
October 25 & 26, 2011
Bridgeport Conference Center, Bridgeport, WV

In attendance:

Keith Fisher, TNC – WV
Ruth Thornton, TNC – WV
Amy Cimarolli, TNC – WV
Misty Downing, TNC-WV
Diane Packett, TNC-WV
Beth Wheatley, TNC-WV (10/25 only)
Braven Beaty, TNC-VA
Mike Strager, WVU (10/25 only)
Todd Petty, WVU (10/26 only)
Abby McQueen, Canaan Valley Institute (10/25 only)
Mitch Blake, WVGES
Ashley Petraglia, USACE (10/25 only)
Jennifer Skaggs, WV Conservation Agency
Terry Messinger, USGS (10/25 only)
Greg Gies, USEPA (Project manager) (10/25 only)
Greg Pond, USEPA (10/25 only)
Danny Bennett, WVDNR
Karri Rogers, Potesta & Associates
Rick Buckley, USDOI, OSM
Mike Whitman, WVDEP, WAB
Dennis Stottlemyer, WVDEP (DEP project manager)
John Wirts, WVDEP, WAB

Could not attend, but will provide written comments:

Stuart Welsh, USGS
Mike Owen, USFS
Michael Hatten, USACE
Tim Craddock, WVDEP
Michael Schwartz, The Conservation Fund
James Anderson, WVU
George Bell, Elk Headwaters Watershed Association
Evan Hansen, Downstream Strategies
Christine Mazzarella, USEPA
Tom Demoss, USEPA
Recommendation that Nathaniel ("Than") Hitt, Research Fish Biologist with USGS would be a good person to invite to participate

OVERVIEW PRESENTATION (Ruth Thornton, TNC)

CONDITION / FUNCTION

- Should Function be separate out from Condition? (Mike Strager)
- Need to define function (Greg Pond). This project defines function as ecological services.
- Metric - Impaired Streams – using both all impaired streams and individual impairments pulled out.
- Questions whether Thresholds should be consistent across state? (Abby) Since we are setting methodology for watershed assessments for the entire state are assuming that they are, however, for some metrics may need to adjust for different areas of the state.
- Metric – GLIMPSS index, very good condition (Braven), why 125% Ref Condition very good – wouldn't all of them be considered very good? Discussion with Greg Pond that 100% threshold is dividing line between Fair and Good categories (less than 100% is considered impaired, more than 100% not impaired). 125% of threshold approximates 25th percentile.
- Barriers to fish movement (Strager), yes using dams under threat: *Could it be used as measure of streamflow condition*?
- In WV, not sure would keep waterfalls as impeding stream
- Unimpeded stream= condition; Culvert=threat to system. Keep both?
- Mike Strager-culvert stream data layer available
- Wetland hydrologic connectivity (need WV thresholds, NC coastal plain paper may be a good source)-distance to nearest headwater streams & surface water, farther = poorer)
- Metric: Forest Block Size; largest intersecting, and mean- to get idea of how unfragmented upland habitat is
- Metric : Local Integrity-how fragmented is the area, ease of movement
- Lacking in Geology metrics (Mitch WVGS); could this inform our erosion metric better?
- Metric- change in vegetation Using Land fire now…other ideas?
- Metric-Rare species potential, need thresholds.
- Wetlands study, USEPA funded to WVU: biodiversity metric that isn't rare spp focused
- Bird IBI, amphibian IBI, hasn't seen it published – Anderson's students, 40-50 sites, Diane has seen (TNC has copies of thesis and publications in literature folder)
- Need to assess wetland functions, not there yet. May be difficult with current state of data in WV.
- Wetlands group discussed further (see below)

GENERAL COMMENTS, post-presentation

- Marcellus gas wells will likely be reused indefinitely to go deeper to other 'plays'. So will likely be refracked, roads and landings kept open, collection and transmission lines, indefinitely. Assume will continue to be used into future. (D Stottelmeyer). Our current metric as "new Marcellus wells" as estimator of water use will not work with this scenario, need to change.
- Can we know how many wells are permitted per pad? Yes, from permits. *This is the tip of the iceberg. Ruth 'good to know'; Amy 'actually, ignorance is bliss'*
- Company index. Joke! (impact will depend on company)
- WVDA models for loss to pests, so WVDA must have a baseline forest layer of dominant species

BREAK TO GROUPS
BREAKOUT SESSION NOTES: DISCUSSION OF METRICS AND THRESHOLDS
Streams Condition/Function

- Water quality metric: chloride is also an important metric to include, indicates fracking activity in watershed, consider putting under Threat – Resource extraction instead of condition
- Include Specific conductivity as its own metric, check lit for threshold values. Recent USEPA study found that 300 would be a good threshold instead of the 500 that is often cited. That is what EPA is going with and they're getting sued for it now.
- Check out chloride as 303(d) impairment and include as metric
- Sulfate as indicator for mining activity – remove from condition/function and put in threats – resource extraction
- "Stressed" category also in GLIMPSS paper. Instead of current if one of the metrics is not attaining, consider changing to 2+ need to be not attaining to make it into a stressed category to avoid false positives
- WQ – look back at both max values and most recent values for each station. Max values would give you a screening tool, where most recent is what you're dealing with currently. Depends on objective.
- Use medians instead of means for WQ metrics
- Caution with low flow impaired streams
- Imperviousness could be used as indicator for multiple indices, not just WQ – also water quantity (flash floods)
- Some modeling has been done in WV in some areas for flow
- 7Q10 flow is the lowest flow during 7 consecutive days in a 10-year period. Drought statistic
- WCMS – not publicly available, state agencies are using it, from DEP to the agencies directly
- IHA software better and easier to use than the USGS software (according to Terry Messinger) – consider using it to analyze flow. Either one can only be used for gauges with daily values over a long time period. USGS gauges are the only ones in WV that satisfy that. DEP take flow readings on some sites, but no daily values.
- Hydrologic connectivity – NHD24K
- RBP – use sedimentation & embeddedness as a summed metric (on a scale of 40). One gives values for sedimentation in riffle areas, the other for pool areas. Greg Pond sums them to analyze a site's characteristics. Also view Bank stability as a separate metric.
- Soil infiltration rate – check if SSURGO for WV includes a sanitation metric - could use that as a surrogate
- Biodiversity – Number of native aquatic species, including historical ones. Add original native spp (that are now extinct) as a metric – contact Dan Cincotta, he knows which fish were originally in which watershed
- Include forest block metric in streams as well
- extract Bank Stability Score or other possible measures of physical integrity from the RBP data
- weights/thresholds should vary based on type of stream impairment
- Tier III streams? (should they be included? –I believe I explained why they weren't and it was satisfactory)
- WARSSS (Watershed Assessment of River Stability & Sediment Supply)- sediment assessment technical procedure
- Consult with watershed groups such as Deckers Creek Watershed Organization (very active); Save Our Streams

- Priority on tribs that drain to a public water supply reservoir (such as Cobun Cr near Morgantown); could also emphasize the importance of wetlands in such catchments to reduce cost of water treatment
- High weight on riparian area with forested cover (most important metric); also, headwaters within forest blocks; 78% forested = good WQ?
- NPDES should be split by attributes (outlet type) and weighted differently (ie CSO weighted more heavily than industrial general SW permits

Streams Threats

- Coal vs non-coal discharges
- DEP only has non-coal NPDES permits
- Contact DEP's DMR for coal NPDES – Nick Schaer best person to approach for this. Put under mining.
- Brownfield/superfund sites, volunteer remediation cleanup status
- Septic systems: Where TMDLs are done James Summers with WAB (DEP) has done a lot of work on getting the # of septic systems. Current method we're doing not reliable, many areas outside of town boundaries are actually on public water systems. Contact him for his data. Currently done on Mon, in Elk from Sutton down
  Or: There's a field in census data, on a census block data - use that!!!
- Large feedlots – again, James Summers compiled this for TMDL. Upper Mon done 2009, Dunkard 2005/6, Elk (Sutton dam and down) 2007
- Population – may tell % urban
- Include # bridges again, many have a center pier that impedes flow. Use road crossings over small streams as one metric to estimate culverts, and over larger streams to estimate # bridges.
- Todd Petty & Mike Strager might be able to supply surface mining thresholds from their studies. (5-10% mining showing effects on WVSCI) Work in press: 26% watershed surface mined, stream conductivity increases to 500-600
- Check out Emily Bernhardt's study for thresholds of mining in watershed
- % of coal not mined from GES as way of assessing future threat
- Include plugged wells in addition to active – indicator for roads, sedimentation issues
- Future impacts – look at thickness of Marcellus shale, also Utica below it
- Include aquatic species under invasive spp – DEP data on Corbicula (invasive mussel), Zebra mussel (2 places in WAB db: Wildlife observations (more opportunistic), and under: Benthic – family – WVSCI – Corbiculidae (is the only one that occurs here in that family) – Benthic taxa – code)
  DNR invasives data – carp
  DNR – data on Didymo, golden algae occurrences
- Include voluntary remediation, Brownfield/superfund sites
- Acid rain
- Snowmaking (large quantity user)
- USEPA-funded study on developing IBI's for wetlands
- Number landfills: discussion if should consider distance to landfill, since its effect decreases over distance, but we decided for catchments simply to have a Good/Fair for absence/presence. Also active vs. inactive
- Add: # open dumps (from DEP) under dev & Ag. Also: # superfund sites
- Include a metric for miles road/RR in entire planning unit, not just riparian area. Roads farther from the stream still have a sedimentation effect
- Number dams/Max Storage – consider using median instead of mean to get rid of large effect of the Summersville impoundment on the Elk. Or look at log-transforming it.

- Separate out transmission lines from pipelines – pipelines should have heavier weighting. Capture effects of roads for Marcellus gas wells
- Move # buildings in riparian area from habitat frag to Dev & Ag
- Change name of "Ecological Threats" index to "Biological Threats"
- Be careful with the GES Marcellus well shapefile – many are actually conventional wells
- Marcellus wells have much larger footprint than conventional wells
- We need to change our "new Marcellus wells" as estimate of water quantity – many wells are refracked, we have no idea from attribute table. However, current legislation in the works that companies have to report water use from fracking, so this may be a metric we can realistically use soon to pinpoint large quantity users. With the intent that DEP will only permit taking water out of a stream if it will not stress the stream.
- From Rick Buckley: every acre of underground mine produces ½ gal water/day (check with him to make sure this statistic is correct, this is what he remembered off the top of his head)

Wetlands Condition/Function

- Wetlands are primarily a priority based on presence (particularly for restoration), quality not really a consideration (presence itself is a priority)
- Wetlands research by DNR (re-registering of NWI should be complete, not sure if we can get data, currently in the process of conducting functional analysis of wetlands, though seems to be at beginning stages?)- WRAP Wetland Rapid Assessment Procedure conducted by WVU (field samples to "quantify wetland condition in terms of functional capacity and biological integrity")
- Need hydrogeomorphic (HGM) classes of wetlands (ACE classification system)
- DNR wetland priorities value forested over shrub/scrub over emergent
- Should be considered by their functional values:
  Flood attenuation
  Pollutant filtration/assimilation
  Sediment retention
  Wildlife habitat
  Recreation
- Penn State wetlands center has possibly useful studies
- Possible Metrics:
  Width of floodplain; elevation of floodplain versus stream elevation (bank/height ratio)
  Geology composition (limestone base encourages biodiversity)
  Adjacency or proximity to existing public lands
- Highwall mining, old mine benches (strip bench data) as potential places for development of new wetlands of various water quality; created by gaps in undergrounding mining; "punch-out"
- Bad water quality in surrounding streams may increase the functional value of a wetland; water quality should not be a wetlands index since it varies by type of wetland and function of wetland; WQ in wetlands based on surrounding land use types
- Ratio of existing wetlands to potential wetlands
- Flow accumulation grid; wetland shape metrics (depth x width); depth to bedrock
- Existence of a natural corridor between wetlands or wetlands and streams
- Biodiversity should be weighted low for restoration priorities
- Wetland size may not be an issue as ALL wetlands are valuable in WV; wetland area very good would be even 10% or less

Wetlands Group Data Suggestions

- Lose current NWI data (useless); may be able to get updated NWI from the Google Earth application, or try to get DNR data
- LIDAR being processed for all WV south of 60/64; best contact Nick Schaer, DEP
- DNR priority areas (desired acquisition areas like Meadow River complex)
- CAFOs, chicken houses, # head cattle (or other livestock) by county then distributed through watershed, from Dept of Ag
- Farmland Protection Act data; information about tiled or any previously converted wetlands (would be very valuable because it is easiest to restore previously existing wetlands; also true for potential wetlands analysis results) – maybe NRCS drainage maps, by county
- Trend stations data
- Soils roughness coefficient; slope
- Paper maps of coal seams with their elevation data (time intensive to get to a digital format?)
- Below drainage deep mine areas
- Precipitation data

Wetlands Threats

- Threat should be called stress or stressor with "threat" referring only to future potential threats
- Use coal type as a metric, including whether seam is "hot or not hot" (related to acidity?)
- May be worthwhile to try and footprint Marcellus wells (or copy methodology for this?); wells may be re-fracked or drilled deeper into the Utica formation
- The idea that what is on the ground now should be considered a condition and potential future threats are the actual threats
- Impervious cover should be a threat metric
- We should weight the land use types differently (be good to know types of agricultural use, but is more significant than pasture lands)
- Landfills not a threat if managed properly (Landfill Closure Assistance Program), should have a low weight
- Consider also proximity of rail/roads to wetlands, which may affect its functional value; consider that wetlands may be created by abandoned roads or rail; also, in restoration projects some roads nearby is a good thing since it prevents them having to be constructed for project
- Buildings should have a low weight or be removed (redundant, not a threat); also, remove wind turbines? (should only be on ridges, where wetlands are unlikely)
- Wetlands should not be separated between conditions and threats for prioritization, especially for protection (there is potential for increased threat to make a wetland more valuable)
- Some mining outfalls are pumped to a different area
- Create an inverse metric of buffering capacity by identifying areas with poor capacity (sandstone); also get acid rain (deposition) data if possible
- Interbasin transfer data would be useful
- Snow-making activities
- Consider dam release rates to evaluate downstream threats
- Would be good to know type of timber harvesting

Uplands Condition/Function

- Common, or all, species diversity
- WVU land cover/forest type dataset: forested locations derived from NAIP photo 1:10000 dataset

- Number of soil types, support native vegetation types?
- Many areas not sampled for species. Use 2003 ELUs 1:48000 as surrogate for species diversity – Mike Strager's dataset
- Density of rare species vs number or presence/absence: measure of watershed condition
- Important to identify species that are restricted to patches (rare snail) vs matrix forest species?

Uplands Protected Lands and Priority Interest Areas

- Move from condition to prioritization indices
- What percent of a watershed is needed intact for it to be functional?
- How much protected land results in good condition? Mark Strager: studies show that good water quality results if 78% forest cover is maintained. Also depends on land use.
- Add farmland protection group interest areas, NPS proclamation boundaries
- Check GAP status of secured lands - & within protected lands GAP 1-3
- Challenge: Severed mineral rights can alter surface that is "protected"; check farmland protection program for lands that cannot be mined
- Need to consider lands that are adjacent or upstream, which could be across the watershed boundary
- Buffer watershed boundary to capture conditions in the neighboring watershed.

Uplands Habitat Connectivity

If any data could be added, what would it be?

- Large forest blocks > 15000 acres
- Integrity
- Connectors of forest blocks (corridors etc.): valuable, need info on how much they are really being used.

Uplands Physical Integrity

- Soil buffering capacity: Experts are Jeff Skousen at WVU, Lee Daniels at Virginia Tech
- Geology can influence the ability of soils to buffer acid deposition and AMD. Add % limestone per planning unit as metric under Physical Integrity
- Percent "native" or unaltered soils to support vegetation, as opposed to mined, farmed areas and drained wetlands, altered elevators, filled valleys

Uplands Resource Extraction

- Timber harvest – move to condition for those acres; leave for likely impact to streams from loggers (sometimes no or minimal best management practices, unmanaged forest jobs)
- Add Utica Shale wells to Marcellus wells
- Add coal footprint. The presence of any coal is a threat because new technologies allow it to be mined
- Oil wells are likely to remain. They have similar infrastructure to gas, but "spills are uglier"
- Oil and gas wells' greatest impact is at the surface: roads and pads. (Number of wells) X (avg area disturbed)
- Add "serviced areas": septic and water
- For quarries, use acres of disturbance

Uplands Ecological Threats

- Add WVU's "Suitability for Invasives" dataset, and prioritize areas with lower suitability. 30-m raster grid
- Add some measure of deer overpopulation, which results in poor forest health. Use DNR data (number of deer by county) and compare with forest ecologist recommendations for deer herd size. Elk also?

DAY 2 Prep for Exercise to prioritize indices for protection and restoration models

Todd Petty idea-objectives will determine how you weight indices to seek priorities, because objective will drive best places for those
Ruth conclusion: We need to have models be flexible enough so end user can manipulate for answer that will meet their objective

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Breakout Session: Priorities for Streams Restoration

- Weighting varies with objectives – weight index values
- We assign weights to metrics
- Idea: The end-use application could have menu of options for users with appropriate embedded mini-models according to their objectives
- Objectives likely for model users:
  Restoration of certain size streams for In Lieu Fee
  Restoration of 303(d) streams
  Restoration to increase aquatic diversity, increase species richness/population viability
  Restoration for recreational use (swimming/fishing/boating)
  Restoration to reduce sediment/nutrient input/soil erosion/downstream wq improvement
  Default option: find general stream/watershed condition

Stream Restoration Model Weighting Indices and Metrics

- Trout Conservation Success Index (Trout Unlimited): Web application similar to what we're doing, for trout streams. Users can see results and drill down to reasons for the index values. Available online.
- Weight each index based on how it affects objective; most significant = full weight
- Use regression analysis to inform which measures/factors to put in the tool, then use experts and resources to identify weights, which will depend on the factor
- Dennis: Could the tool also provide response predictions such as whether specific work would improve the score for the stream?
- Priorities: Improve stream condition and biodiversity
- First priority given to streams with some threats, otherwise wouldn't need protection
- Type of work will depend on budget
- Past threat data is actually a "condition", and future threat data is a "threat"

REVIEW OF ANALYSIS RESULTS FOR WATERSHEDS

- Consider keeping RED as always most high, now it's relative within a watershed. For objective measure could designate across the board and can get picture across wetlands.

Monongahela watershed comments on first assessment

- Todd Petty: Made a lot of maps, concerned about the Threat map, likes Condition map. It makes sense. White Day is still one of few high condition areas in watershed.

- Western part of watershed-rural, deep mining area; far East coal mining. Along I-79 a limestone/coal free zone. WAP-old plateau, ridges are leftover plain among incised rivers
- The lack of threat is contributing to its current condition (all trees, no mines). SE corner (White Day) is threatened by development not showing. Far E section shows as high threat but it's open wetlands and maybe not under such great development. (Future Trends - Threats are not yet included.)
- Call Threats=> Stressors (Todd, Danny)
- Todd-% impervious (Condition);
- Braven: Nutrient loading N P loading responses (want more or less)
- Consider extending Monongahela (and other borderland watershed asst's) across line into PA re: Dunkard and Robinson Creek
- Reach out to Dunkards' Creek Watershed Association-high profile
- Robinson Creek – another interstate creek that along with Dunkard could lead to collaboration with PA
- Head start on creek that are coming from PA and entering WV with PA's inputs
- As move to eastern panhandle these will become more complex.
- WMAs are not all Public lands—make sure ID those that are leased and remove them from the Public Lands layer
- Cannot assume removing water from any certain river for gas wells in a watershed…e.g., they are removing from Ohio River, piping to distribution center ponds, and then taking to well sites
- Basin exchange, water discharge into flood control ponds, pumping from three places.
- Underground mining has likely messed up flow of water/availability based on rainfall. Coalmine pumping also impacts flow in a stream , pump during wet seasons so it's diluted, not pumped during dry (solved problem) Water pumped is no longer in circulation, put in deep injection wells.
- White Day unmined, rivers in good condition (no 303(d) listed), but now gas is starting and this is likely to change.
- DEP has monitoring hourly records on streams to try to track Marcellus well changes
- Suggestion (Mitch) Run same model without coal and see if the same areas of good water quality still pop out
- At the thickest, Marcellus will continue to be threat. Where it is thin, rocks breaking up (e.g., Erbacon) poor production
- Use DEP map and ID places most likely to continue to operate
- Shale not gas producer where silty, Utica under entire state but not good producer in all places (Mitch)
- Mitch's opinion - potential for geothermal energy is slim in WV (WVGES can't reproduce the data/model, can't show any likelihood of the high potential). Researcher has graduated and WVGES can't find data, can't reproduce would think it'd be obvious if such high potential.) Heat flow not showing itself on surface.
- Describe what do with null points (insure users it wasn't set at 0)
- Mine pools—where there is mining there is water pooling underground

NEXT STEPS, FUTURE ANALYSES

- Data layers needed:
  DOH planned projects: bridges and roads. May have plans for expansion in their EIS
  Better info on value of forest connectors (current and potential); CVI may have something, and TNC CAP work

Energy development patterns: wind potential, power line corridors (PATH, TRAIL), coal & gas prioritization to estimate mining development.
USGS has data on location of "metcoal"
Dam purposing and operation
Power plants
Timber harvest activity – salvage work due to pests and pathogens

- Other datasets:
  From DEP: HPU – coal NPDES outlets (with emphasis on the outlet, not the permit)
  From DEP: Self-reported violations (of NPDES permits)
  From GES: oil & gas wells – contact Mary Behling with GES
  From USGS – coal reserves left and their estimates of desirability
  Powerplants – hydrologic connectivity issue (temperature)
- Any other major development projects that may be planned (like the Boy Scouts venue in New River Gorge)
- Unmined coal seams (existence of any coal is a potential future threat)
- Gas shale coverage (gas plays)
- Perhaps the Dam Safety department, for future dam removal projects or High Hazard dams as an indicator of possible future failing infrastructure as a potential threat
- Certain invasive species are often correlated with major roads projects; data on invasives spread and trends
- Division of Forestry should have some kind of trend analysis, or perhaps a private industry coalition like Society of American Foresters, may have some future projections data (good contact: Randy Dye, state forester)
- Air pollution data (considering things like power plants or waste incinerators that may deposit pollutants on land or water)
- West Virginia Watershed Network webpage (http://www.wvca.us/wvwn/) has information about Watershed Celebration Day event, as well as useful documents such as past meeting minutes, including information about 2009 Statewide Water Sampling Programs Forum, which gathered all entities involved in water quality sampling in the state together- good source of contacts and to find out what's happening in watersheds in the state; also has document describing Stream Disturbance Permitting Requirements (which describes permits for stream remediation projects)
- Population growth/development projections from census or city/county government- does WV have extraterritorial jurisdictions?
- Include information on funding sources; recreation
- Check with National Mining Reclamation Center
- Check with WV Water Research Institute (WRI) – Paul Ziemkiewicz – good contact who's been working on many of these issues (he was invited to this workshop, try engaging him again!)
- Include FAA cell phone towers as fragmenting feature
- Geothermal potential as something to be aware of
- Climate change concern- additions? We're capturing heterogeneity, elevation gradients already…can we add more? Will it change our decisions of where to work?
- Can we prioritize best & easiest to get of what's left in coal and gas reserves? That is where imminent threat is. See WVGES (steam coal vs. metallurgical coal) locations has 80% of coal mapped. Will be done in two years. New technologies make predictions difficult. Mitch can help us with this.
- Power plants-AEP said no new coal fired plants, but new gas plants. Changes water temperatures (hydro connectivity-temp and dams) new ones? New transmission lines, rivers-have projected in
- Hydro power on existing dams…hazards. All dams in now, do we need to separate them by use?

- Population change into future? USFS projections for development and impact on forest resources in East (value of these projections at HUC12 level?)
- Focus primarily on population growth/urban development and energy development/resource extraction
- Be able to weight some indices and metrics individually, possibly with certain data such as water quality sampling, remaining constant
- Cumulative impacts assessment makes more sense at the HUC12 or HUC8 level, not at NHD Plus catchments
- create scenarios of energy development (low-medium-high) similar to PA office

ARE WE ON TRACK? ARE WE MISSING ANYTHING?

- Growth estimates for state? (e.g., Development authority? demographic projections out 10-yrs, but they're not always correct)
- Will timber harvesting activities increase with invasion by new pests and pathogens-markets changing; longer travel to market

WHAT ARE THE MOST IMPORTANT QUESTIONS?

- Places to conserve.
- Places to fix.
- Make applicable to broad number of stakeholders (beyond TNC and DEP) with diverse priorities.
- Priorities
  Large forest blocks
  Water quality
  Unique land forms/communities/species
- Some data layers won't be used in our prioritization, but they may be useful for other users/decisionmakers-special features, cultural/historical resources (e.g., Blair Mountain, Indian burial grounds, campsites and trails, old growth stands, karst/caves-mapped by Nick Schear and George Dasher of DEP), Susan Pierce, Cultural and Historical office
- Include caves as biodiversity feature, as special habitat, in condition/function – biodiversity, as one of the communities. Caves/springs useful for mitigation work possibly, a mitigation bank? (Can't show rare cave species, location of caves published, can show.)
- Include springs as unique feature? Or simply include as additional layer in final web application, without including in any of the rankings
- Karst occurrence-boost the weight of it for conservation if it's on karst. Include karst as separate biodiversity feature? Not the same as % calcareous, which is currently included

IS METHODOLOGY SUFFICIENT?

- We have to start, build on it…this doesn't cover it all but this start will allow us to determine what is correlated, important.
- Where are cumulative impacts assessments most appropriate?

West Virginia Watershed Assessment Pilot Project
Second Expert Workshop Notes
January 31, 2012

Participant List:
TM Terry Messinger, USGS
TG Tom Galya, OSM
TC Tim Craddock, DEP (NPS program)
JB Jeff Bailey, DEP (WAB)
NM Nick Murray, DEP (WAB)
DS Dennis Stottlemyer, DEP
GP Greg Pond, USEPA
CM Christine Mazzarella, USEPA
JG Joy Gillespie, USEPA
GG Greg Gies, USEPA
JA Jim Anderson, WVU
DB Danny Bennett, DNR
JY Jessica Yeager, Potesta & Associates
KR Karri Rogers, Potesta & Associates

TNC participants:
AC Amy Cimarolli
MD Misty Downing
KF Keith Fisher
DP Diane Packett
RT Ruth Thornton

PROJECT REVIEW

- DB-protected lands include mineral rights ? No, no data.
- GP-riparian forests, "natural cover" can be shrub/scrub or forest, high conservation values could be ranked higher, are there different coverage to tell us natural/intact riparian areas vs e.g., old fields now reforested.
- CALL for more river gages-idea, contact WV Gaging Program about grants/needs

Wetlands

- DB-focused on rare species, is too limiting…DNR in final stages of wetlands (talk to Keith Krantz) on wetland functions (storage, habitat)
- JA-function, not animal data, some plant data
- RT could habitat types be used instead?
- TM Scales of wetlands? Vernal pools counted, small places? RT-used NWI
- DB a lot of small wetlands found to be missing now from recent field work
- RT hydric soils counted, potential for restoration noted, tried modeling but data incomplete
- JA 2.5x # wetlands on land vs in NWI
- CM Model as proxy? MD tried, soils data inaccurate/incomplete for Elk
- GP Atilla software from Las Vegas (landscape tool, in ArcView 3), models P & N. This would give outside validation by a model that wetlands are important.
- Atmospheric deposition N important here, "Possible validation of these wetlands in their position; this cluster of wetlands is important because less P even with development around it"

Forests

- DB Timber harvests by type?
- DNR Logging enforcement system data set potentially with location and methods—new tool from DOF
- GP coal production and water quality, yes But in upland terrestrial model, is surface disturbance more accurate indicator? Surface mining is more important than coal production in the uplands.
- TG Underground mining factor (discharges with sulfate, and volumetrically), importance of dewatering streams, long wall and second mining operations-*tough data to get, DEP is compiling*
- TG GES Mine pool data (underground water punching out, WVU can predict where); said they have reports of known issues in certain places, probably nothing geospatial though. Mine pools are correlated with water quantity of streams
- DS does it involve artesian points, Tom said it includes some
- DB/DS new rule to id where water will be withdrawn, but data not reported until up to 2 years later. Marcellus water used hard to quantify because sometimes only used for a short time, and sometimes is even trucked in from other areas.

RESULTS OVERVIEW

Thresholds

- GP General account of # quality vs # stress indices
  There are more stress indices b/c easier to find. Each counted on its own merits.

========================breakout groups==========================

- JA suggested use of AHP (Analytic Hierarchy Process) to decide weightings based on expert opinion (would make results more "publishable")
- DB would expect culverts to be weighted as much or more than dams (are just as impactful and there are many more of them than just a few dams)
- TM create placeholder metrics for those known issues but with incomplete/ less accurate/ pending data (such as underground mining issues, the Marcellus issue, etc.); also note which data will be updated soon
- DB would expect more correlation between WQ metrics (like conductivity/GLIMPSS, etc.); or the impaired streams/GLIMPSS (several people actually described these datasets as literally the same data, just in different formats…?)
- DB drainage ditches/tiled wetlands (NRCS or WVDA) – (MD explained that this data has been searched for but not found, esp. not in geospatial format)
- DB questioned having trout streams in Biodiversity, since trout streams are not diverse (at most 4 species)
- DB cumulative effects of metrics and weighting on results: maybe effects are watered down by using so many metrics?
- DB need a general diversity index, not just rare spp
- TM/JY use taxa richness from GLIMPSS; JB 200 organism subsample
- May be useful to maintain/distribute a list of those data/metrics that were considered but not used or dropped due to incompatibility or complete lack of data
- DB Mike or Jackie Strager water quality/water quantity study of HUC12s throughout the state (ARC)
- DB should differentiate between NRCS dams and Army Corps dams which are much larger
- Suggestion to compare known high quality or low quality (WQ) streams to "model" results, see what differs and why

- TM sewers, "others", augment some, but half as much as dams. Flow alteration vs flow reduction. Maybe "flow alteration" as another name for water quantity.
- JA Strager study on water quality and quantity
- ID? Additional metric/s for Protected Lands is level of interest/activity: existence of watershed group, watershed plans, TMDL plans
- GP use reference streams to help define thresholds, tie this to landscape (box and whiskers plots, etc.)
- GP define land use metrics based on WQ station catchment
- GP PCA: find the best and worst watersheds along the gradient, see if they are the same as what falls out of the rankings. Try PCA just on water quality metrics (not surrogates) and see what happens.
- GP try Discriminant Function Analysis: see what variables contribute the most towards e.g., GLIMPSS index.
- CM conducted study in southern WV on % mining impacts thresholds (Tug River?)
- Overall agreement that categorical analyses was very useful, CM especially meaningful to the "higher-ups". Maybe the categorical analysis looks the same for planning units on the HUC12 level, but would look different for smaller catchments
- TC TMDL stressors STEPL (Spreadsheet Tool for Estimating Pollutant Load) created by TetraTech USEPA, estimates contributions based on soil units, septic systems, agriculture (may have some threshold values)
- Mention again of TMDL data from the Mon for info on septic ranks by watershed (seemed to be confusion of what the study and data actually presented)
- TC NPDES should not be a big issue because it implies regulatory control over source; CM that assumes people are in compliance, the regulations are sufficient, etc.
- May need different thresholds for duplicate metrics in different indices
- Suggestion to "turn off" more questionable metrics and re-run (basically, play around with data to see what's happening)
- TC restoration funding is TMDL/303(d) driven (seemed to desire analysis that reflects this)
- The "bad stream, good neighborhood" idea, where a higher priority might be placed on a lower quality catchment surrounding by good quality, or vice versa, such as a mid-quality stream in a bad neighborhood creating refugia and thus being higher priority (this whole concept was debated back and forth)
- GP some issue with the word Fair (may not as strongly indicate the degraded or impaired status)
- CM categorization may look more meaningful and "accurate" (as expected) at the catchment scale
- CM suggested using air deposition data (apparently there is more detailed work from USEPA covering the whole state of WV?)
- Use Paw Paw Creek to dissect and see what's happening with the various metrics/methods
- TG – For Streams Water Quality modeling recommendation to weight Underground mining 2-3x heavier than surface mining.
- JB – consider using only random WQ sample points, other points target low-quality areas, potential for biasing results

CONSOLIDATED ANALYSIS/FUTURE THREATS OVERVIEW

- DS List of references available? Yes, source of data

=============================breakout groups==========================

- DB present future threats on a sliding scale, or scenario-based (ie Low, Medium, High) or reflecting market forces (Weak Economy/Strong Economy, etc.)
- TM refine Marcellus metric to reflect thickness (thicker is correlated with higher gas extraction potential)
- JY Pittsburgh coal seam W of the Monongahela River is almost entirely mined out (not as much E of the Mon), there should be more surface mining in the Mon in the future than underground; ash formation (?). 4-5 seams above Pittsburgh not mined out.
- Consult Pittsburgh ACE about proposed dams; Fish and Wildlife about private dam removals (DB mentioned plans to remove dams on West Fork)
- Check school boards for future growth information
- Display Phase II results as an overlay, not necessary to combine the two sets of results
- KR Chesapeake TMDL work may have datasets available, particularly CAFOs
- Under Priority Areas, include metrics such as # of Active Watershed Associations, Abandoned mine lands (as funding opportunity).
- Supportive information (not in rating, but as overlays): whether zoning is in place, stormwater regulation.
- Future water source – mine pools, differ greatly in water quality depending on geology

INTENDED RESULTS/FINAL PRODUCT

- Other data: DS Aerial photos, current and historic
- Other data: search tool so someone could find their own stream; Name/County/concatenate program by stream name and place that (GP); maybe HUC12, nearest town, quad name
- Other data: land use activity in the subwatershed so if looking for restoration site could see ag areas, for example; ID proposed activities, etc., so can find places that are to be developed; show secured land (e.g., CE GAP status xx, without landowner name)
- Current data at DEP could be called up, but TNC has done a lot of data QAQC and selection to improve data set for project. Raw data won't be able to just uploaded into this system for small watershed info and for heavily weighted factors. Would require a lot of time to create tool to adjust raw data. AND/OR feedback to data creators what datasets need improved/QAQC
- Rare spp data-individuals will go to DNR Heritage (data agreement)
- Can we show wind/pipelines on an interactive map (not sharing data)
- Water Quality information? Click on data point and see it? Yes it'd be valuable to DB when reviewing a permit if he could see information with a click; it is public information
- TC Not a ranking tool but if targeting a site, good to see loads of N, bacteria…? Annuals loads require time series of flows (TM) and this is beyond our scope
- GP idea: based on catchment area could you have a high/low ranking? Would have to calculate drainage area…Stream Stats in PA, is it coming to WV? it could with funding, Drainage Area Tool is included in it. It looks for gages, models 7Q10…a WV tool 'went away' (DB spoke of)
- If seeking potential wetland soils to restore; want soils…Mysti has included hydric & partially hydric soils—she has also reviewed old maps
- TC Providing tool, then might think about providing technical assistance. List of partners, contacts of watershed groups, current plans/TMDLs for watershed

- TM Biggest concern where have important threats / issues but no data to represent them in model (underground unmined, water removal from drilling, stream loss)
- -how to highlight data problems within the tool/Incorporate a measure of uncertainty?
- TC will have access to local input to use where necessary
- AC Working groups/expert local knowledge is important to incorporate
- For poor incomplete sets, could have water quality or some other data serve as an override of status if it is terrible, for example, but other things have made it look not too bad
- Explain use of 0 vs null

Keep weights same across state?

- TC-differences across state-energy extraction high in Western All Plat and Cumberlands, not so bad in GBR and eastern panhandle. Are all weighted same across state?
- KF keep consistent across state, makes process/modeling easier; non-presence of issue = 0 or null?
- DB watering down if use 0 instead use null;
- RT prefers Null but sees his point, if a lot of factors then individual important ones get watered down.

Rank high and low sulphur coals as different metrics?

- DS thinks other metrics e/g/ water quality will catch it…different impacts but still many.
- People comfortable with keeping streams/wetlands/uplands separate.
- When you did PCA did you to separate or all together? Did by streams, wetland and uplands, not separated by metrics. GP suggests PCA by index, thinks it may be smeared by doing it across. Want more sites than variables (keep in mind).

Do we want to let ‘power users’ to be able to have options for restoration /protection area ID?

- TC does not like idea of allowing this to protect TNC/team of creators’ work from being used/misused by others with different goals, messages – potential to manipulate results.
- DS Recommends keeping tool standard
- ID think about making ability to query; DB there is value in letting others tweak it for their use
- Need to be able to filter out some information by users (spruce uplands vs stream sites); see information about how make rankings but don’t let ratings change
- GP idea: play with data scenarios – mitigation tool – if raise GLIMPSS, certain issues, could see how rank/ score could change the color- target things weighted heavily to fix, could plug in post mitigation monitoring data to see if you’ve improved it

Is there anything we should get rid of?

- Test for a couple master variables – give some watersheds to DEP to get their expert judgment rankings; let statistics determine which variables make data fall within DEPs rankings—try to discover /test reality to see if any variables are highly significant to getting to those same rankings
- TM Under water quality, let hard data drive it, let surrogates be downweighted.

Should we get rid of roll ups of stressors/conditions being rolled up separately?

- GP combine just in Quality, get rid of Stressors (those working on stressors will look for bad water quality) End up with just overall which we have. Would eliminate the distraction of the colors that don’t match up in the quality/stressor maps.

FEEDBACK?

- DS, landfills? Delete? They are already part of impervious surfaces and they are (should be) represented as NPDES points.
- KF different categories?, have 10 categories to maintain across all results range

WRAPUP

- GP Freshwater meeting March 28, USEPA Region 3 freshwater biologists meeting; in Berkeley Springs, Talks on Thursday, 15-20 minutes; 125-145 people, place to ask for feedback, data requests possible, solicit feedback. Friday workshops-maybe one for next year could be planned.

West Virginia Watershed Assessment Pilot Project
Monongahela End User/Stakeholder Workshop
April 3, 2012

Participants:
Charlie Vannatta, Triad Energy
Paul Richter, Buckhannon River Watershed Association
Tom Bond, Guardians of the West Fork
Kathleen Tyner, West Virginia Rivers Coalition
Herbert Andrick, NRCS
Jessica Yeager, Potesta
Karri Rogers, Potesta
Holly Hildreth, Morgantown Utility Board
Amanda Pitzer, Friends of the Cheat
Duane Nichols, CLEAR
Robert Vagnetti, US DOE/FOC/TNC
Leslie Hopkinson, WVU Civil & Environmental Engineering
Greg Gies, USEPA
Mark Wozniak, USACE
Dennis Stottlemeyer, DEP
Ashley Petraglia, USACE
Kevin Ryan, Friends of the Cheat
Frank Jernejcic, DNR
Keith Fisher, TNC
Ruth Thornton, TNC
Mysti Downing, TNC
Diane Packett, TNC

Q: Question
C: Comment
A: Answer

Part I: Ruth Thornton
Project introduction

- Q (Bond?): DEP has some sort of stream quality ranking system; how does this fit in? Are you trying to improve upon their work with more info and more detail? A: We use their stream quality data, add other data to describe condition of watershed.
- Description of indices & metrics
- Q (Pitzer): Any differentiation between coal seams? Surface & underground, active sites & non-active? In Cheat, see a big difference between coal seams. A: Didn't look at different coal seams, underground & surface highly correlated.
- Q (Jernejcic): Consider contaminant levels in fish? DNR & DEP have this data.
- Consolidatated analysis
- Q (Bond?): Any reason we're only looking at Marcellus shale? Utica will require the same water use
- Presentation of results
- Q: Are catchments HUCs also or were they defined a different way?

Part II: Mysti Downing

- Q (Nichols): Where is Mon River on map?
- Potential use scenarios: Streams/Riparian.
- Q (Tyner): Will people be able to download data layer for their own use?
- Q (Tyner): Can users upload data? How often will data be refreshed? A: No, DEP will update data, but analysis may be done by TNC once every 5 years or so.
- Q: If uploading data is worthwhile, would we want QC information? A: Not the intent for users to upload.
- Q Vagnetti): Are analytical algorithms built into the product so that as the data is updated the results are automatically recalculated, or is analysis done offline? A: Depending on how people use it, DEP might make certain components automated.
- Q: Can user do what-if scenario, change index weight, see what attributes are most important for each catchment or watersheds? A: We would like to. . .
- C (Vagnetti): Need in the future more citizen science and ability to upload data so that save money and get community buy-in.
- C (Nichols): I can see an alternative color analysis based on poor-very good thresholds.
- Q (Ryan): Considered some kind of sensitivity analysis? Are all data available in all catchments, or are missing data leading to red colors? A: We have accounted for data absence with null values, but in wetland cases the numbers can be low
- Streams restoration, Wetlands, Uplands
- Q: What's an example of classified data? A: rare species occurrences from DNR, Public Water Supply Data (PWS)
  Q: Why is PWS classified? A: Because of homeland security issues
- Web mapping tool examples
- C: Importance in planning water use: projections for MS wells data from DEP database. Permit data. A: We have DEP & GES data for wells and permits, wells updated pretty quickly.
- C (Tyner): FrackTracker tool (University of Pittsburgh originally) updated quickly, users upload data.
- C: For projecting water use, need to know where water being pulled from
- C (Nichols): DEP has tool for water withdrawal.
- [discussion of availability & quality of water withdrawal data]
- C (Tyner & others): Good to have all the data together.
- Q (Nichols): What does "Overall" mean? Do the metrics and indices have weights? Is there a table of weights?
- Q (Ryan): Will people be able to print or publish the map they have created by adding various layers? PDF button, options to change format like font.
- Ruth: You would want ability to download public data? Nods all around.
- Ruth: Are you interested in seeing indices or metrics? (Ryan): would like to see stream condition indices.
- C: Would be good for user to know what metric is driving the overall quality of the watershed.
- Q: Would this be browser independent?
- C: I like words better than icons
- C: I like seeing the side menu with icons and explanation.
- Keith: One goal is to help people with dollars to spend on mitigation, protection, restoration, prioritize projects

- C (Jernejcic): This will be good so that information is out there. Often try to find information, and there are rumors someone knows but can't find it.
- C (Nichols): There are regions of Mon where legacy coal mining still impacts streams. Need to put that into the whole picture. Don't want to give impression that we're doing something for these streams. Don't need to do the model to know that area is bad. Running the model doesn't do anything for the streams. A: Keith: the intent of the model is only to give users information about the quality of the watershed, it is up to the users to decide on appropriate strategies and target sites for restoration and protection activities.
- C (Pitzer): Just because a subshed is red doesn't mean that isn't worth restoration. Each area and situation is specific. If USEPA gets my proposal, pulls up map and sees red, they will say it isn't worth it. A (Keith): We're not trying to infer what your question is, just a suite of information for you to use to ask and answer questions.
- C/Q (Kevin Ryan): Future funding for when the tool is available, re: troubleshooting, data updating. Demos are nice, but I don't know if a tool works until I try it and find things I want to change. I see the big issue as updating of data because often these things go online and then are out of date. The measure of success for this pilot project should be someone using the tool successfully to make changes to watershed, not to say you've published a web tool.