



West Virginia Watershed Assessment Pilot Project: Tygart Valley River Watershed Assessment

Final Report
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Report Prepared by The Nature Conservancy for the West Virginia
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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.

We assessed the condition and function of the Tygart Valley 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 show that all landscapes in the Tygart Valley River watershed exhibited higher quality in the less developed areas with protected lands in the eastern and southern parts of the watershed. Development, impervious cover, mining and agriculture/grazing were the most influential metrics affecting stream quality in the northwestern, central, and southeastern river valley portions of the watershed.

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 Tygart Valley watershed stakeholders.
7. Complete final assessment.

1.5 Tygart Valley Watershed Timeline

Table 1. Tygart Valley River Watershed Timeline

Date	Activity
April 1, 2011	Award date, project initiation
June 13, 2011	First Technical Advisory Team meeting
November 13, 2013	Final End User Workshop and demonstration of prototype interactive web tool
December 31, 2013	Final Tygart Valley 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 seven 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), **Gauley** (05050005), **Tug Fork** (05070201), and **Tygart Valley** (05020001). Draft watershed assessments were completed in two of the seven watersheds (the Lower/Upper Monongahela and the Elk) in the first year of the project, and during the second year an additional three (Upper Guyandotte, Little Kanawha, and Gauley) were completed and the assessment methodology 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 final two watersheds (Tug Fork and Tygart Valley) were completed during an extension of the pilot project, using the methodology defined during the first two years. The assessment results from the seven watersheds were incorporated into an interactive web tool that is accessible to a wide variety of stakeholders.

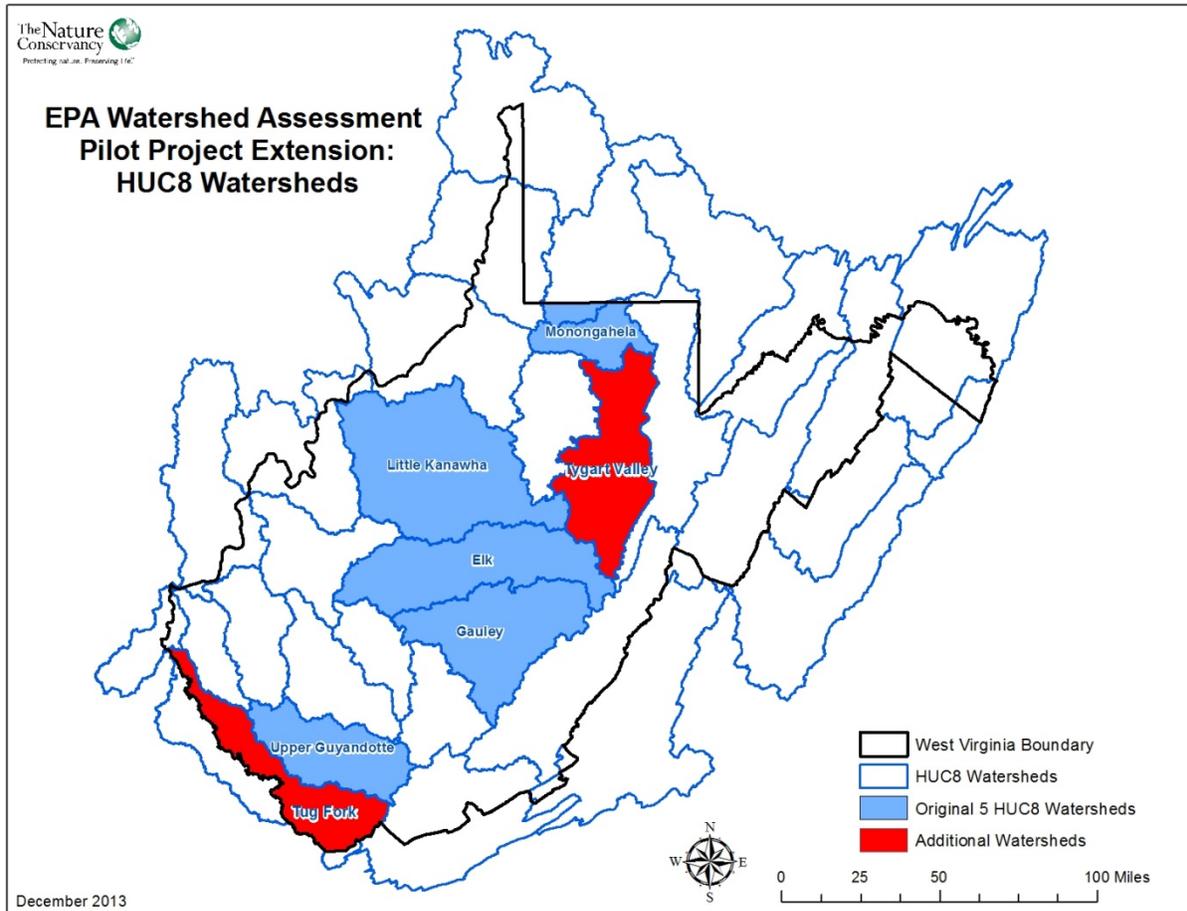


Figure 1. West Virginia Watershed Assessment Pilot Project HUC8 Watersheds (NRCS 2009)

1.6.2 Tygart Valley River Watershed Study Area

The study area considered in this report is the Tygart Valley River (Tygart River) watershed, or drainage area, which covers approximately 1,375 square miles in northeastern West Virginia (Figure 2). The Tygart Valley River flows north-northwest for about 135 miles from Cheat Mountain, at an elevation of about 4,400 feet, to the town of Fairmont, at an elevation of about 900 feet, where it joins the West Fork River to form the Monongahela River. Major tributaries to the Tygart include the Buckhannon River, the Middle Fork River, and Three Fork Creek. The Tygart Valley River flows through five West Virginia counties (Pocahontas, Randolph, Barbour, Taylor, and Marion) and the Tygart watershed drains portions of seven additional counties (Upshur, Monongalia, Preston, Tucker, and very small areas of Webster, Lewis, and Harrison). Several urban areas exist within the watershed, including the small city of Elkins (the largest town with a population of 7,094 at the 2010 census), Buckhannon, Grafton, and Philippi. Other small towns within the watershed include Belington, Beverly, Mill Creek, and Huttonsville.



Figure 2. Tygart Valley River Watershed Study Area (USGS 2005)

Section 2: Tygart Valley Watershed Description

2.1 History/Economics

While not densely settled by Native American tribes, the Tygart Valley River watershed has much evidence that the area was used extensively by some tribes (such as the Shawnee) as hunting grounds and temporary residences, including small clearings (“squaw patches”), Indian mounds, and burial grounds (Bosworth 1916). Several significant Native American hunting trails traversed the watershed.

Due to the rich farmland available in the extensive river valley, the Tygart watershed was settled early by immigrants and has remained steadily populated throughout modern history. The first European families (the Tygarts and Files) arrived in 1753, both settling in the area of current day Beverly. Very soon after, the families were attacked by traveling tribes of Native Americans, and this area of the watershed was abandoned until settlers returned in 1772, though skirmishes between Indian tribes and settlers continued throughout most of the late 18th century. However, the Tygart legacy remained with the naming of the valley, and subsequently the river, which was also frequently referred to as the East Fork of the Monongahela River. The Pringle brothers, deserters from the army at Fort Pitt, settled along the Buckhannon River in 1761 (as legend has it, living first within a sycamore tree on the west fork of the river), and acted as guides to the fertile river valley for newcomers to the area (Bosworth 1916). Agriculture and raising livestock have a long history in the economy of the watershed, being the first principal source of wealth in the region and continuing to contribute to the local economy today.

The upper river valley is a natural thoroughfare, and was occupied by the Staunton-Parkersburg Turnpike, which was started in 1840 and completed in 1847, and was a major east-west corridor that connected the Shenandoah Valley with the Ohio River. The turnpike also served as a strategic and well-used path for both northern and southern troops during the early days of the Civil War. One of the first major battles of the War took place here, at Rich Mountain, on July 11, 1861, providing a critical victory for the north as it granted control of much of the Appalachians of northwestern Virginia, and eventually led to the creation of the state of West Virginia (Rice 2010). Several minor skirmishes at the onset of the Civil War also occurred within the Tygart valley, including the Battle of Philippi, the Battle of Laurel Hill, and the Battle of Cheat Mountain.

Since the 19th century, resource extraction activities have been a significant part of the watershed’s economy, consisting mainly of coal mining (primarily underground) and logging. The entire Tygart Valley River watershed has been logged for timber at least once since the Civil War (WVDEP 2003).

The Tygart River Reservoir Dam, which created Tygart Lake in the northeast of the watershed, is a historic dam near Grafton. It was built between 1934 and 1938 as a flood control structure, and is managed by the Pittsburgh district of the U.S. Army Corps of Engineers. The benefits of the dam were demonstrated during the November 1985 floods in the region, when the reservoir was estimated to have lowered flood crests along the Monongahela River by almost 7 feet (USACE 2013). Tygart Lake is a popular destination for recreation and tourism, and is considered one of the best bass fishing waters in the area.

2.2 Climate

The Tygart Valley River watershed experiences a humid continental climate with variable weather patterns (warm to hot summers and cold winters) and a moderate seasonal and geographic temperature range (Figure 3). Temperatures are generally lowest (average 43-45 degrees Fahrenheit) in the mountainous areas in the southern part of the watershed, with the warmest temperatures in the far northwest (average 52-53 degrees Fahrenheit). This is expected with the increase in elevation of more than 3,500 feet from north to south. The mean annual precipitation shows a significantly larger contrast across the watershed with a range of 28 inches, from 45-51 inches annually throughout most of the watershed, to 63-73 inches annually in the southern mountain ranges (Figure 4). This area, the headwaters region of the Buckhannon River, receives the highest annual average amounts of precipitation in the state of West Virginia (WVDEP 2003).

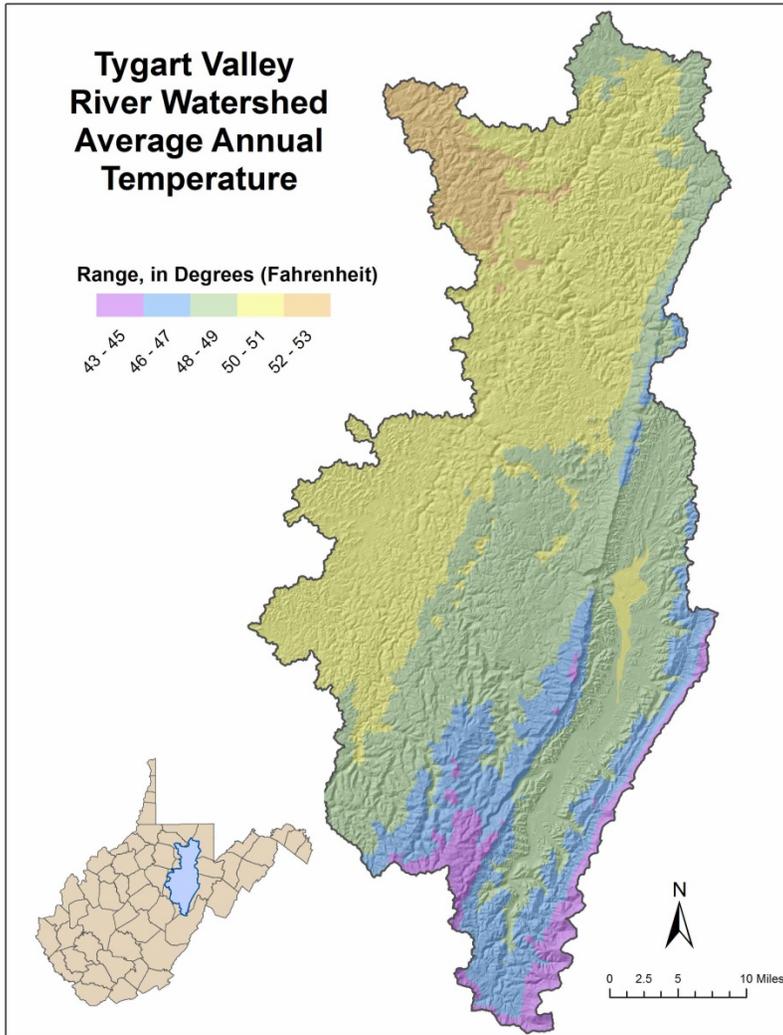


Figure 3. Average Annual Temperature Tygart Valley River Watershed (USDA/NRCS 2006a)

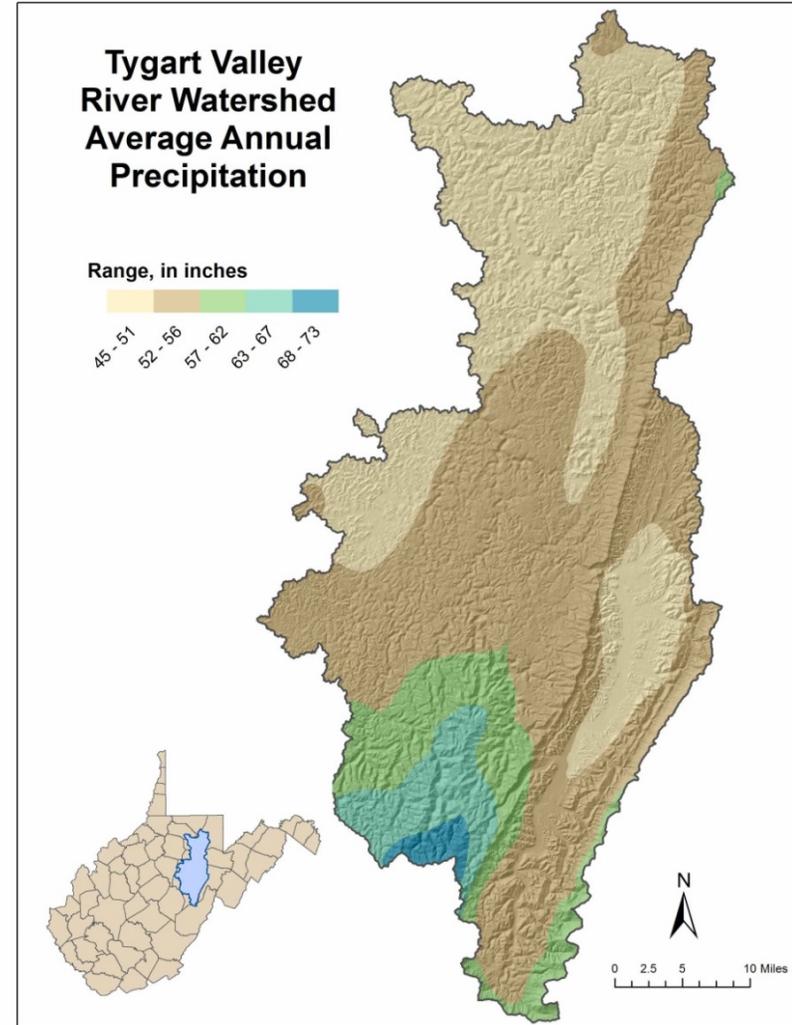


Figure 4. Average Annual Precipitation Tygart Valley River Watershed (USDA/NRCS 2006a)

2.3 Natural Resources

2.3.1 Ecoregions/Geology

The Tygart Valley River watershed lies within two TNC ecoregions (Figure 5). The majority of the watershed is within the TNC Central Appalachian Forest Ecoregion, which includes the dramatic ridges and valleys that characterize the Allegheny Mountains and contains high, dissected, and rugged terrain. The majority of the hills and mountains in this ecoregion are forested, unglaciated, and very ecologically diverse, with development (agriculture, urban, and suburban) concentrated in the valleys (TNC 2001). The far western areas of the watershed are within the TNC Western Allegheny Plateau Ecoregion, a maturely dissected plateau characterized by high hills, sharp ridges, and narrow valleys, with bedrock consisting of sandstone, siltstone, shale, some limestone, and coal (LandScape 2013).

The Tygart Valley River watershed covers three USEPA Level III Ecoregions (Figure 6). The western portion of the watershed is within the Western Allegheny Plateau ecoregion (70), characterized as a mostly unglaciated, dissected plateau composed of horizontally embedded sedimentary rock, making this region less forested and of lower elevation, warmer, and with less topographical range than the rest of the watershed (Woods et al. 1999). The central portion of the watershed is within the Central Appalachians Ecoregion (69), a “high, dissected and rugged plateau made up of sandstone, shale, conglomerate, and coal of Pennsylvanian and Mississippian age” (Woods et al. 1999). The elevation generally increases from west to east, and can be high enough in some areas to ensure a short growing season and a substantial amount of rainfall, resulting in extensive forest cover. The eastern part

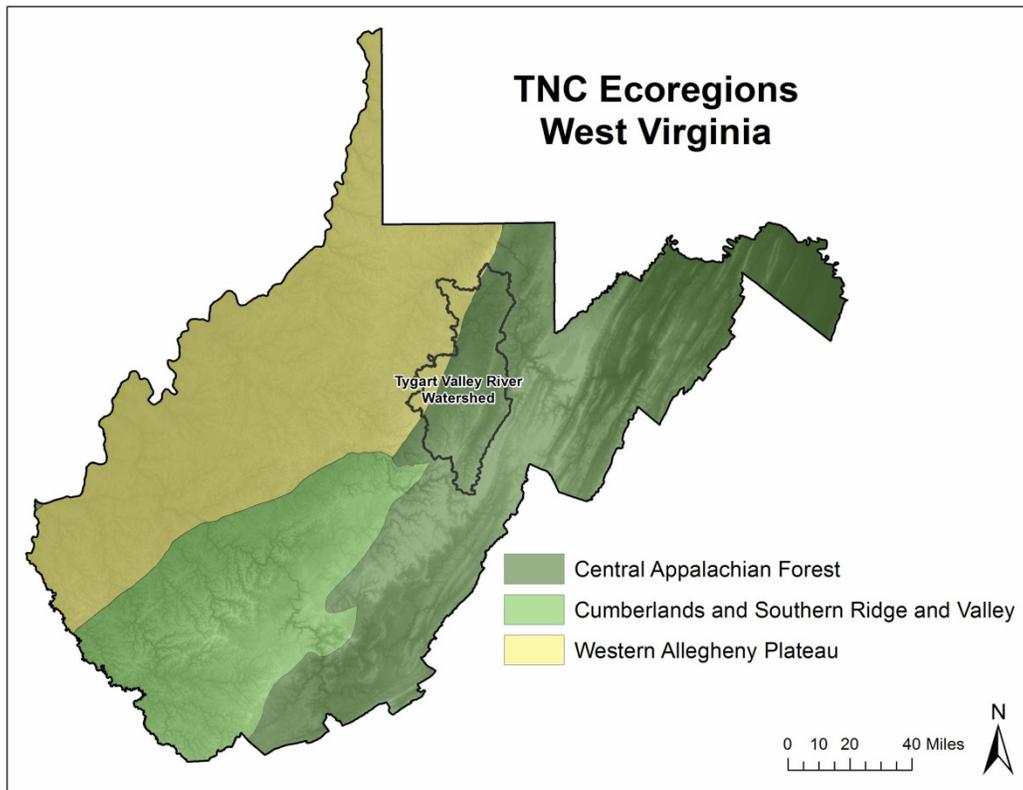


Figure 5. The Nature Conservancy Ecoregions – West Virginia (TNC 2009)

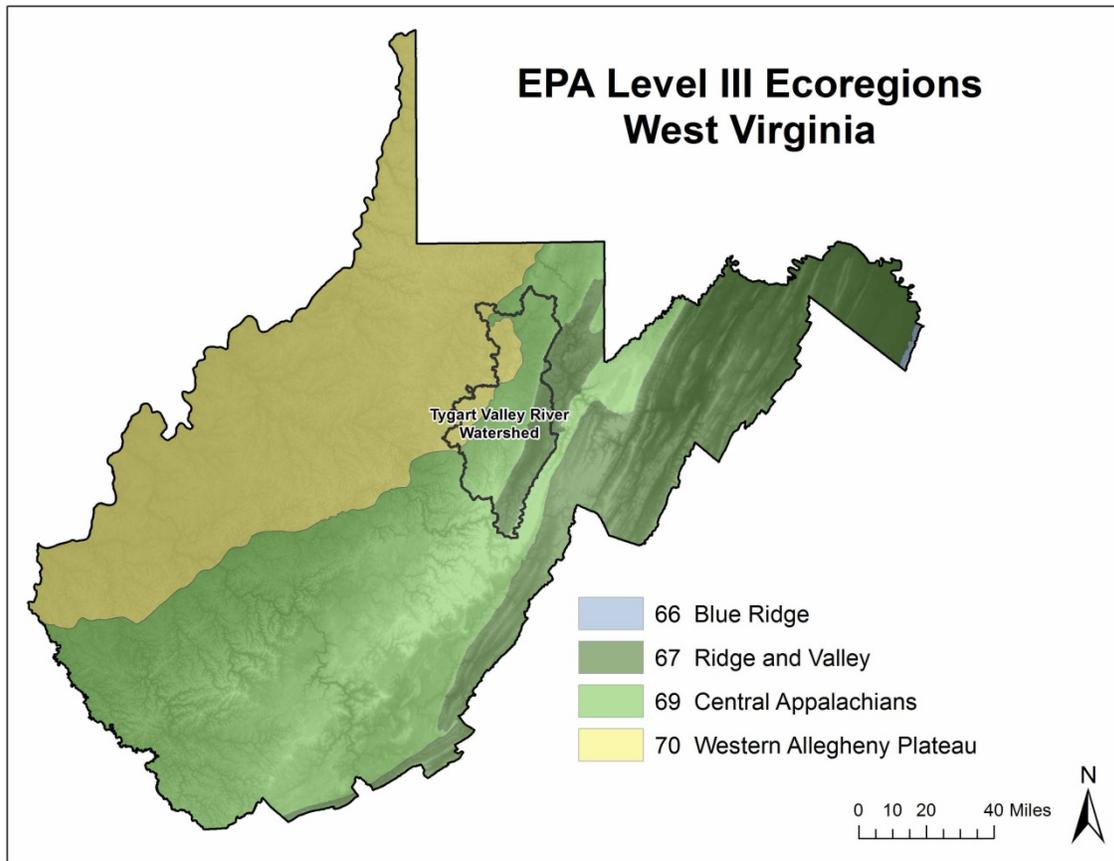


Figure 6. USEPA Level III Ecoregions – West Virginia (USEPA 2011)

of the watershed enters the Ridge and Valley (67) region, characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted, with large elevation ranges (Woods et al. 1999).

Most of the Tygart Valley River watershed lies in the Appalachian Plateau physiographic province, which covers about two-thirds of western West Virginia and has relatively flat lying rocks, except for folds and faulting to the east. The majority of the Plateau is comprised of Pennsylvanian and Permian-age strata, where the mineable coal and most of the natural gas is located. The Pennsylvania age surface bedrock generally has low acid buffering capacity (i.e., is low in calcium carbonate minerals), with acid-forming rock and acidic soils, which affects stream chemistry by severely lowering the pH and alkalinity of the water, thus affecting in-stream biology (USFS 2002). Brook and brown trout, popular fishing species, can survive at pH values as low as 5.5, but rainbow trout are much less tolerant (Hunter 1990). The Marcellus Shale formation, a large deposit of black sedimentary rock containing natural gas, underlies the entire watershed. The thickness of the Marcellus shale increases from west-east across the watershed, ranging from 60-120 feet (WVGES 2012b).

2.3.2 Land Use/Land Cover

According to a 2009-2010 land cover analysis (Maxwell et al. 2011, Table 2, Figure 7), the Tygart Valley River watershed consists predominately of deciduous, evergreen, and mixed forest. Grazing pasture is the predominant anthropogenic land use, with other agricultural land use types at less than 1% of the watershed. Development is limited to about 1% of the watershed, and is mostly concentrated around a few large towns. Surface mining is scattered throughout the watershed, but occupies less than 1% of the land. Wetlands also occupy less than 1% of the land, but exist in significant clusters, particularly in the southeastern river valley.

Table 2. Tygart Valley River Watershed - Land Use/Land Cover 2009-2010 (Maxwell et al. 2011)

Land Cover Type	Square Miles	Percent Area
Forest	1120	81
Pasture/Hay	148	11
Grassland	73	5
Development	14	1
Open Water	10	<1
Mining Disturbance	4	<1
Wetlands	3	<1
Agriculture	3	<1

2.3.3 Biodiversity

The West Virginia Natural Heritage Program has recorded 142 Species in Greatest Need of Conservation (SGNCs) in the Tygart Valley River watershed (WVDNR 2005), including several globally imperiled species like the Cheat minnow (*Pararhinichthys bowersi*), a cave springtail (*Arrhopalites pavo*), Virginia spiraea (*Spiraea virginiana*), Indiana bat (*Myotis sodalists*), Barbara's buttons (*Marshallia grandiflora*), small whorled pogonia (*Isotria medeoloides*), and organ cavesnail (*Fontigens tartarea*). A full list of rare species recorded in the Tygart Valley River watershed, and information about species ranking definitions, can be found in Appendix E.

Thirty-six species of non-native invasive plants have been recorded in the Tygart Valley River watershed (Table 3), with the most commonly recorded being multiflora rose (*Rosa multiflora*), common teasel (*Dipsacus fullonum*), Japanese knotweed (*Polygonum cuspidatum*), autumn olive (*Elaeagnus umbellata*), and ground ivy (*Glechoma hederacea*).

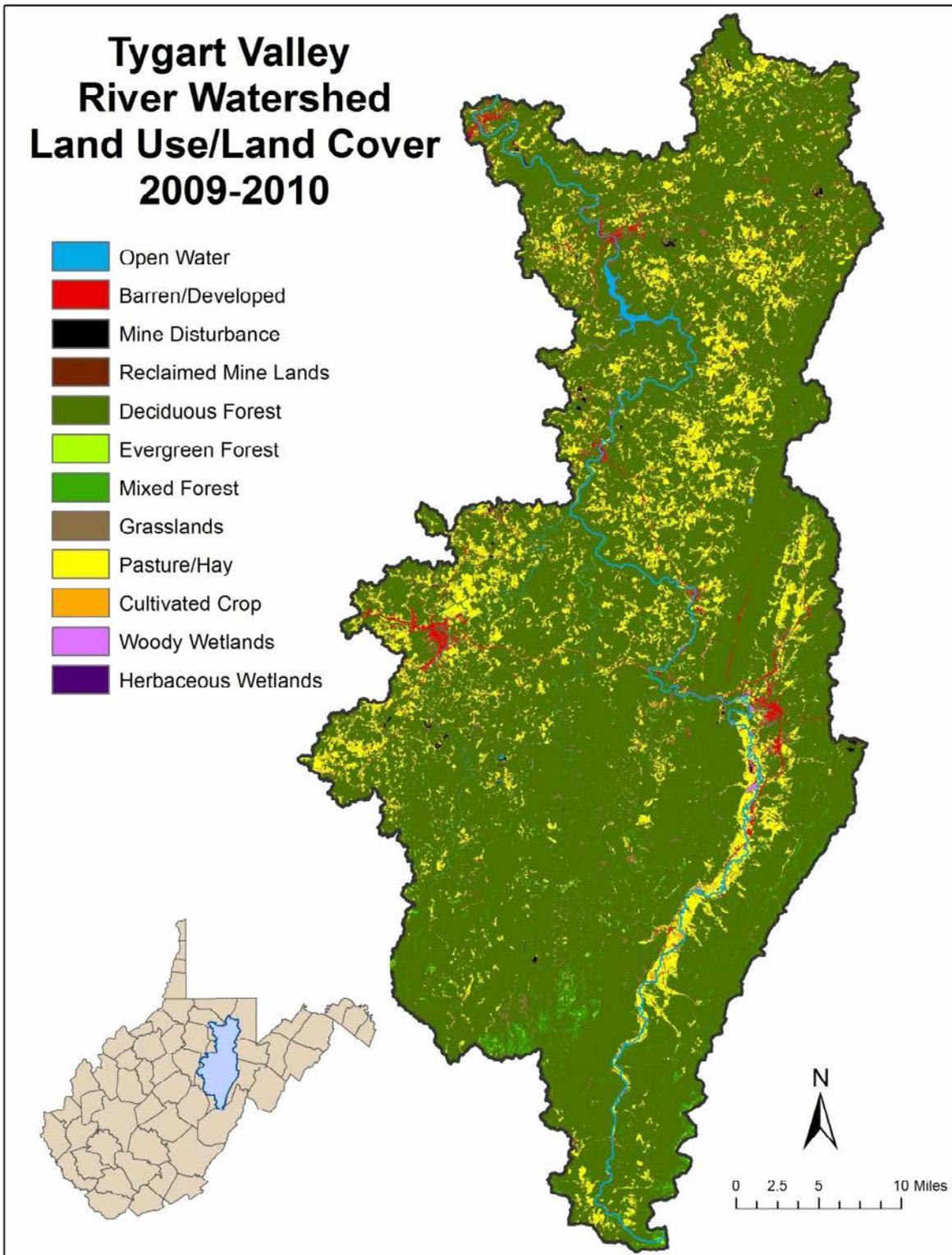


Figure 7. Tygart Valley River Watershed – Land Use/Land Cover 2009-2010 (Maxwell et al. 2011)

Table 3. Invasive Species in Tygart Valley River Watershed (WVDA 2011)

Taxa	Scientific Name	Common Name
Plant	<i>Ailanthus altissima</i>	Tree-of-heaven
Plant	<i>Alliaria petiolata</i>	Garlic mustard
Plant	<i>Arthraxon hispidus</i>	Jointhead arthraxon
Plant	<i>Berberis thunbergii</i>	Japanese barberry
Plant	<i>Carduus acanthoides</i>	Plumeless thistle
Plant	<i>Carduus nutans</i>	Nodding thistle
Plant	<i>Centaurea biebersteinii</i>	Spotted knapweed
Plant	<i>Celastrus orbiculatus</i>	Asiatic bittersweet
Plant	<i>Cirsium arvense</i>	Canada thistle
Plant	<i>Conium maculatum</i>	Poison hemlock
Plant	<i>Cuscuta campestris</i>	Prairie dodder
Plant	<i>Cuscuta sp.</i>	Dodders
Plant	<i>Daucus carota</i>	Queen Anne's lace
Plant	<i>Dipsacus fullonum</i>	Common teasel
Plant	<i>Dipsacus laciniatus</i>	Cutleaf teasel
Plant	<i>Echium vulgare</i>	Common viper's bugloss
Plant	<i>Elaeagnus umbellata</i>	Autumn olive
Plant	<i>Glechoma hederacea</i>	Ground Ivy
Plant	<i>Hedera helix</i>	English ivy
Plant	<i>Iris pseudacorus</i>	Yellow iris
Plant	<i>Lespedeza cuneata</i>	Sericea
Plant	<i>Lonicera japonica</i>	Japanese honeysuckle
Plant	<i>Lonicera morrowii</i>	Morrow's honeysuckle
Plant	<i>Lysimachia nummularia</i>	Moneywort/creeping jenny
Plant	<i>Lythrum salicaria</i>	Purple loosestrife
Plant	<i>Miscanthus sinensis</i>	Chinese silvergrass
Plant	<i>Microstegium vimineum</i>	Japanese stiltgrass
Plant	<i>Orobanche sp.</i>	Broomrapes
Plant	<i>Phragmites australis</i>	Common reed
Plant	<i>Polygonum cuspidatum</i>	Japanese knotweed
Plant	<i>Polygonum perfoliatum</i>	Mile-a-minute weed
Plant	<i>Polygonum sachalinense</i>	Giant knotweed
Plant	<i>Pueraria montana</i>	Kudzu vine
Plant	<i>Rosa multiflora</i>	Multiflora rose
Plant	<i>Rumex acetosella</i>	Sheep sorrel
Plant	<i>Sorghum halepense</i>	Johnson grass

2.3.4 Impaired Streams

Currently, the quality of the Tygart Valley River and its tributaries are being negatively affected by several types of impairment: mining-related water quality issues (metals and pH), PCBs, erosion and sedimentation, and bacteria. The WVDEP listed 90 streams in the Tygart Valley Watershed and the main stem of the river on their 2010 303(d) list, with impairments for aluminum, iron, manganese, pH, fecal coliform, PCBs, and biological (Figure 8). Historical mining has caused water quality issues in the form of acid mine drainage from underground mines abandoned before the Surface Mining Control and Reclamation Act (SMRCA) came into effect in 1977; abandoned mine lands (AMLs) are considered a critical nonpoint source of water quality pollution in the Tygart watershed (USEPA 2001). Total Maximum Daily Loads (TMDLs) were developed and approved in 2001 for 54 streams in the Tygart watershed, to address some of the known water quality issues (USEPA 2001). A TMDL for metals was approved by the EPA in 1998 for the Buckhannon River, also largely related to mining drainage impairments; it was recommended that the TMDL be achieved “through restoration or reining of abandoned areas and continued diversion and storage of runoff from reclaimed areas, identification of potential seeps, and eventual control through reforestation and passive treatment” (USEPA 1998). However, the upper reach of the Buckhannon River, which is a designated trout stream, was still listed as impaired for Iron in 2010.

An ecological assessment of the Tygart Valley River watershed was conducted by WVDEP in 2003, which identified known and suspected associations between impaired benthic macroinvertebrate communities and contributing upstream land use activities. The assessment found that streams in the watershed suffered from negative impacts of acid mine drainage, acidic deposition from acid rain, nutrient enrichment, and poor stream and riparian habitats due to mining and logging practices, road construction and inappropriate land use management by some land owners (WVDEP 2003). Nutrient enrichment is believed to be mostly due to increased agricultural and grazing activities in those areas, but may also be linked to outdated central sewage collection systems downstream of served populations that may provide inadequate treatment during precipitation events. The assessment also found many healthy streams in the watershed, and noted that several of the WVDEP’s statewide reference stream sites are within the Tygart Valley watershed.

2.3.5 Wetlands

The Tygart Valley River watershed has approximately 2,240 acres of mapped NWI wetlands, less than one percent of the area of the entire watershed (Table 4, Figure 9). However, due to the clustering of wetland complexes within the watershed, particularly in the southeastern river valley, the Tygart has significant opportunities for wetland restoration and protection activities. The topography of the river basin allows many wetlands to occur within the river’s floodplain, fulfilling critical functional values such as flood control and storage, in addition to other ecological services like water filtration, sediment retention, wildlife habitat, etc.

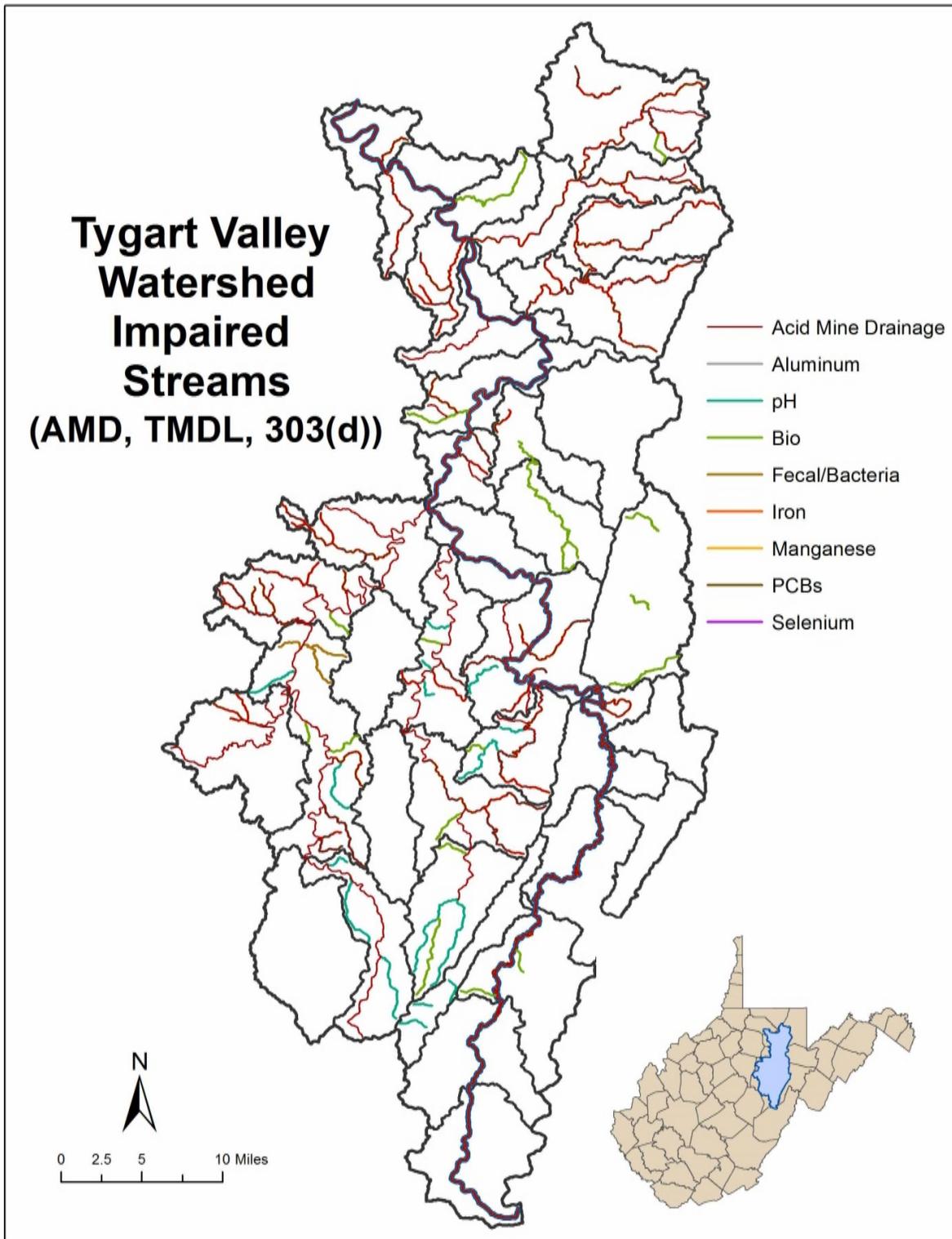


Figure 8. Tygart Valley River Watershed – Impaired Streams

Table 4. National Wetland Inventory (NWI) Wetland Types – Tygart Valley Watershed (USFWS 2010)

NWI Code Prefix	NWI Wetland Type	Total Acres
PEM	Palustrine Emergent Wetland	688
PFO	Palustrine Forested Wetland	1,117
PSS	Palustrine Shrub-Scrub	434

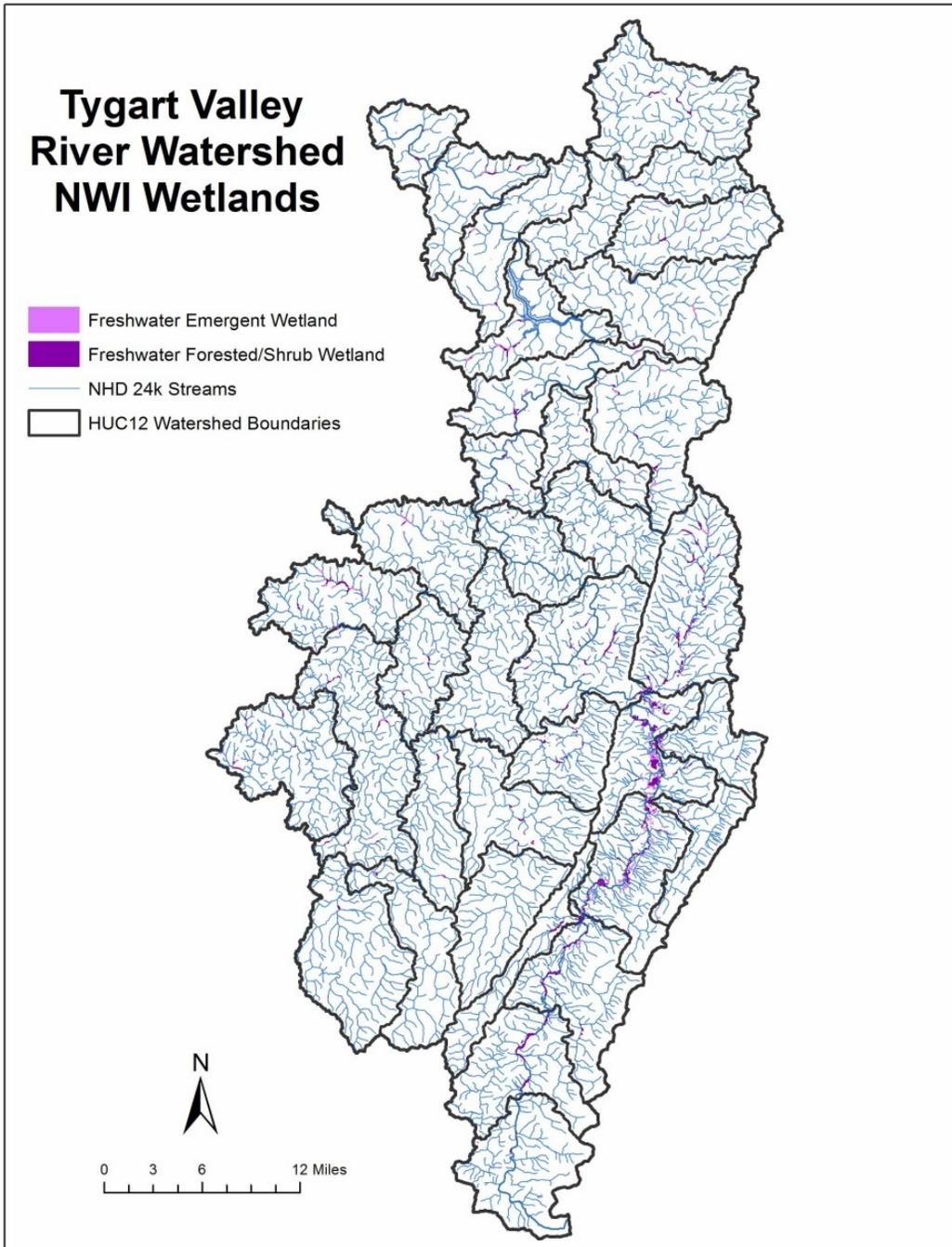


Figure 9. Tygart Valley River Watershed – NWI Wetlands (USFWS 2010)

2.3.6 Vegetation Types

According to the Northeast Terrestrial Habitat Classification System (Gawler 2008), the upland habitat of the Tygart Valley River watershed is dominated by northeastern interior dry-mesic oak forests, with significant south-central interior mesophytic and Appalachian hemlock-northern hardwood forests (Table 5). For the purposes of this analysis, however, we used a 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 5. Northeast Terrestrial Habitat Types – Tygart Valley River Watershed (TNC 2011c)

Ecological System Code	Habitat Type	Acres	Square Miles	Percent Area
202.592	Northeastern Interior Dry-Mesic Oak Forest	252,789	395	29
202.887	South-Central Interior Mesophytic Forest	147,733	231	17
202.593	Appalachian (Hemlock)-Northern Hardwood Forest	142,629	223	16
80	Agriculture	97,523	152	11
202.359	Allegheny-Cumberland Dry Oak Forest and Woodland	80,586	126	9
202.373	Southern and Central Appalachian Cove Forest	65,776	103	7
20	Developed	64,899	101	7
202.591	Central Appalachian Dry Oak-Pine Forest	16,490	26	2
11	Open Water	7,175	11	<1
202.601	North-Central Appalachian Acidic Cliff and Talus	1,433	2	<1
202.604	North-Central Appalachian Acidic Swamp	1,208	2	<1
201.594	Laurentian-Acadian Freshwater Marsh	908	1	<1
202.028	Central and Southern Appalachian Spruce-Fir Forest	561	<1	<1
201.582	Laurentian-Acadian Wet Meadow-Shrub Swamp	408	<1	<1
202.605	North-Central Interior and Appalachian Rich Swamp	3	<1	<1
202.603	North-Central Appalachian Circumneutral Cliff and Talus	89	<1	<1
202.690	Central Interior Calcareous Cliff and Talus	1	<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 10). 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 Tygart Valley River basin is presented in Table 6.

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.

The Tygart Valley River watershed has 3,226 miles of NHD24K streams, of which approximately 2,916 miles, or 90%, are headwater streams. 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

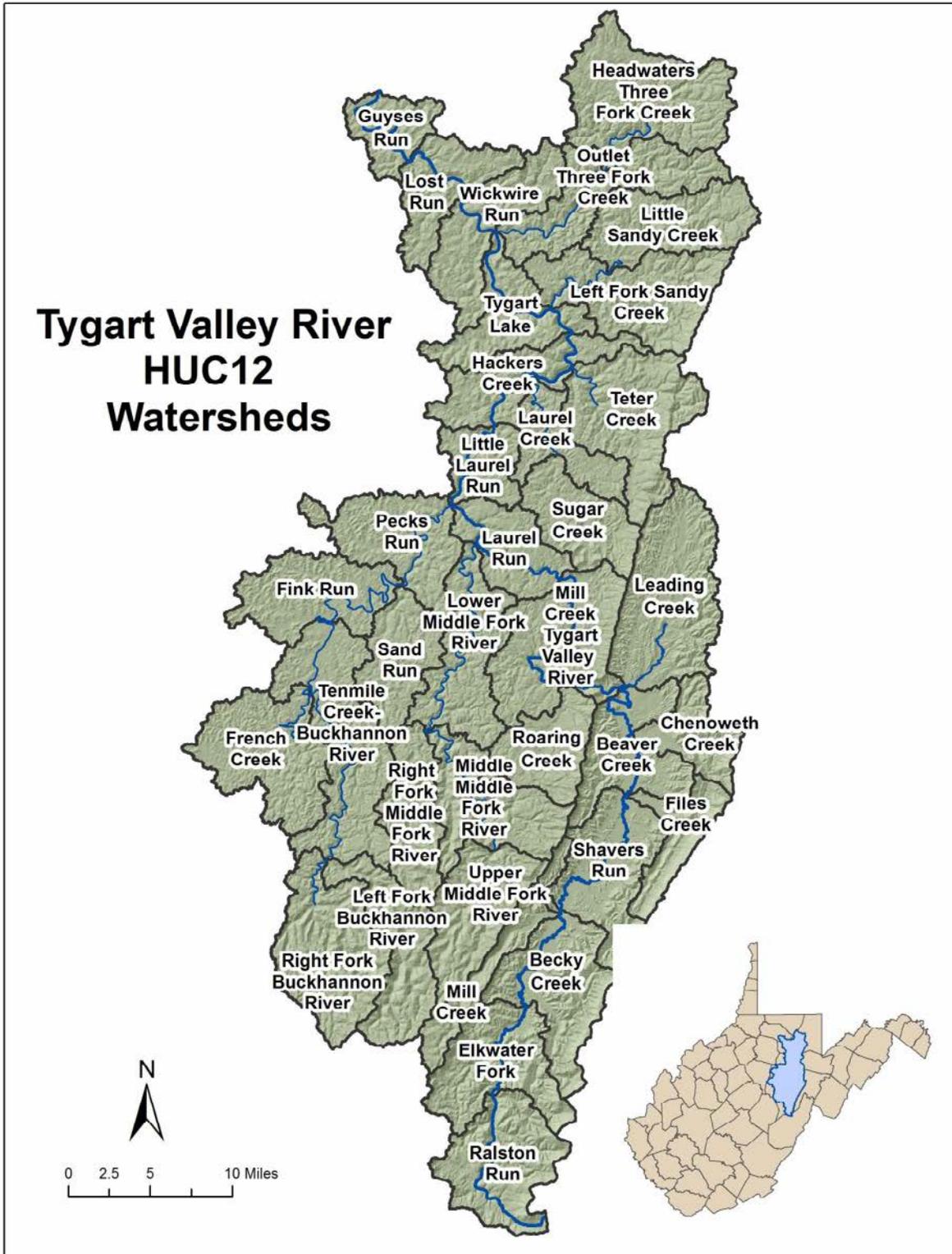


Figure 10. Tygart Valley River HUC12 Watersheds (NRCS 2009)

Table 6. Tygart Valley River Watershed – HUC12 Watershed Information (NRCS 2009, USGS 2011)

HUC12	HUC12 Name	Acres	Square Miles	Stream Miles (100K)	Stream Miles (24K)
050200010101	Ralston Run-Tygart Valley River	28343	44	57	94
050200010102	Elkwater Fork-Tygart Valley River	27237	43	60	102
050200010103	Mill Creek	14420	23	32	50
050200010104	Becky Creek-Tygart Valley River	28867	45	63	120
050200010201	Upper Middle Fork River	24554	38	60	81
050200010202	Right Fork Middle Fork River	19409	30	54	74
050200010203	Middle Middle Fork River	26434	41	60	89
050200010204	Lower Middle Fork River	26493	41	62	100
050200010301	Left Fork Buckhannon River	23766	37	50	74
050200010302	Right Fork Buckhannon River	33683	53	90	120
050200010303	French Creek	31282	49	80	133
050200010304	Tenmile Creek-Buckhannon River	39265	61	100	170
050200010305	Sand Run	18887	30	50	76
050200010306	Fink Run-Buckhannon River	24971	39	61	96
050200010307	Pecks Run-Buckhannon River	25858	40	56	93
050200010401	Files Creek	13281	21	24	50
050200010402	Shavers Run-Tygart Valley River	27474	43	62	137
050200010403	Chenoweth Creek	13688	21	30	62
050200010404	Leading Creek	38549	60	103	175
050200010405	Beaver Creek-Tygart Valley River	22085	35	49	102
050200010406	Roaring Creek	18414	29	46	77
050200010407	Mill Creek-Tygart Valley River	34960	55	83	139
050200010408	Laurel Run-Tygart Valley River	17633	28	43	76
050200010501	Little Sandy Creek	24713	39	53	82
050200010502	Left Fork-Sandy Creek	32306	50	56	99
050200010601	Headwaters Three Fork Creek	37697	59	89	131
050200010602	Outlet Three Fork Creek	27057	42	67	86
050200010701	Sugar Creek	19560	31	50	84
050200010702	Little Laurel Run-Tygart Valley River	12779	20	24	41
050200010703	Laurel Creek	14867	23	34	48
050200010704	Teter Creek	33904	53	74	102
050200010705	Hackers Creek-Tygart Valley River	21059	33	42	53
050200010706	Tygart Lake-Tygart Valley River	20919	33	39	59
050200010707	Wickwire Run-Tygart Valley River	23854	37	48	64
050200010708	Lost Run-Tygart Valley River	19022	30	39	55
050200010709	Guyses Run-Tygart Valley River	12455	19	25	32

and the land through which it flows, thus incorporating both aquatic and riparian habitats. The ARA explicitly considers processes such as 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 4. 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.

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 7). 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

Table 7. 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

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
- 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.

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- 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 Tygart Valley 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 8). 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 9). 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

Table 8. 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 9. 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	

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 10). 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 11). 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 10. 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

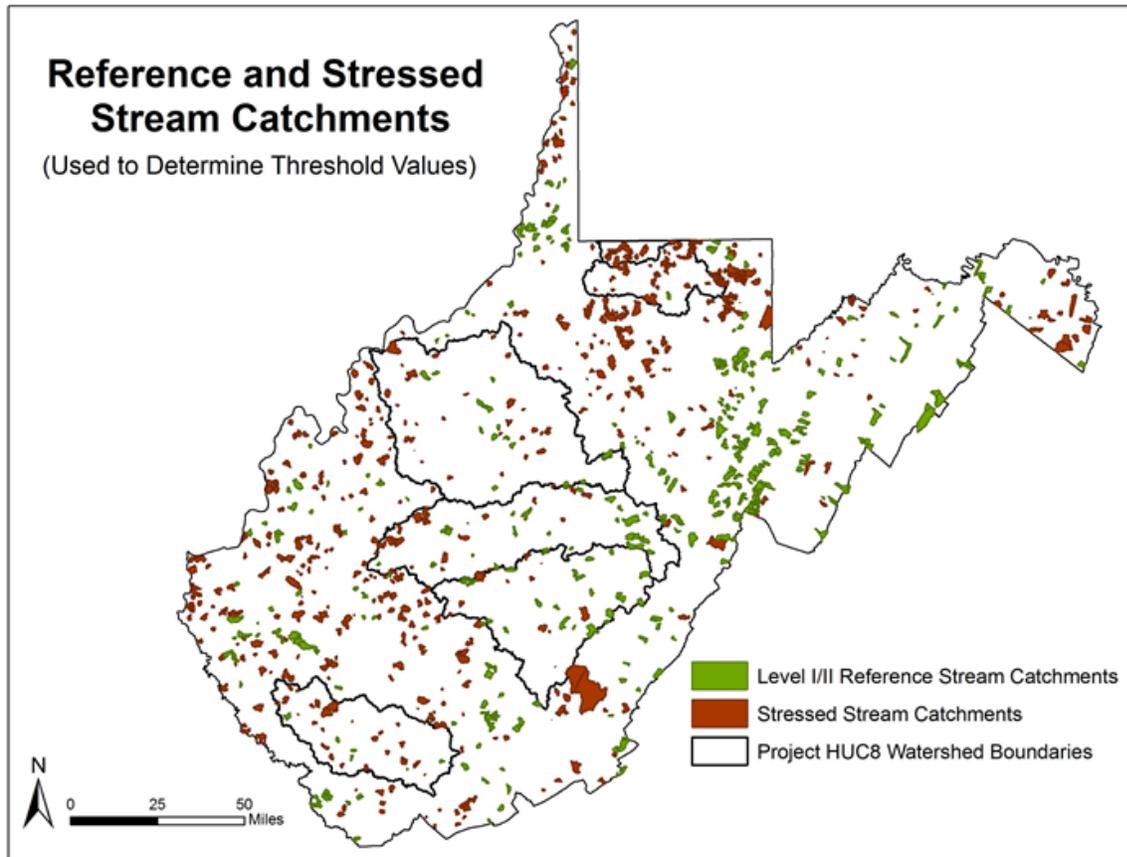


Figure 11. Reference and Stressed Stream Catchments

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 12). 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 11 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.

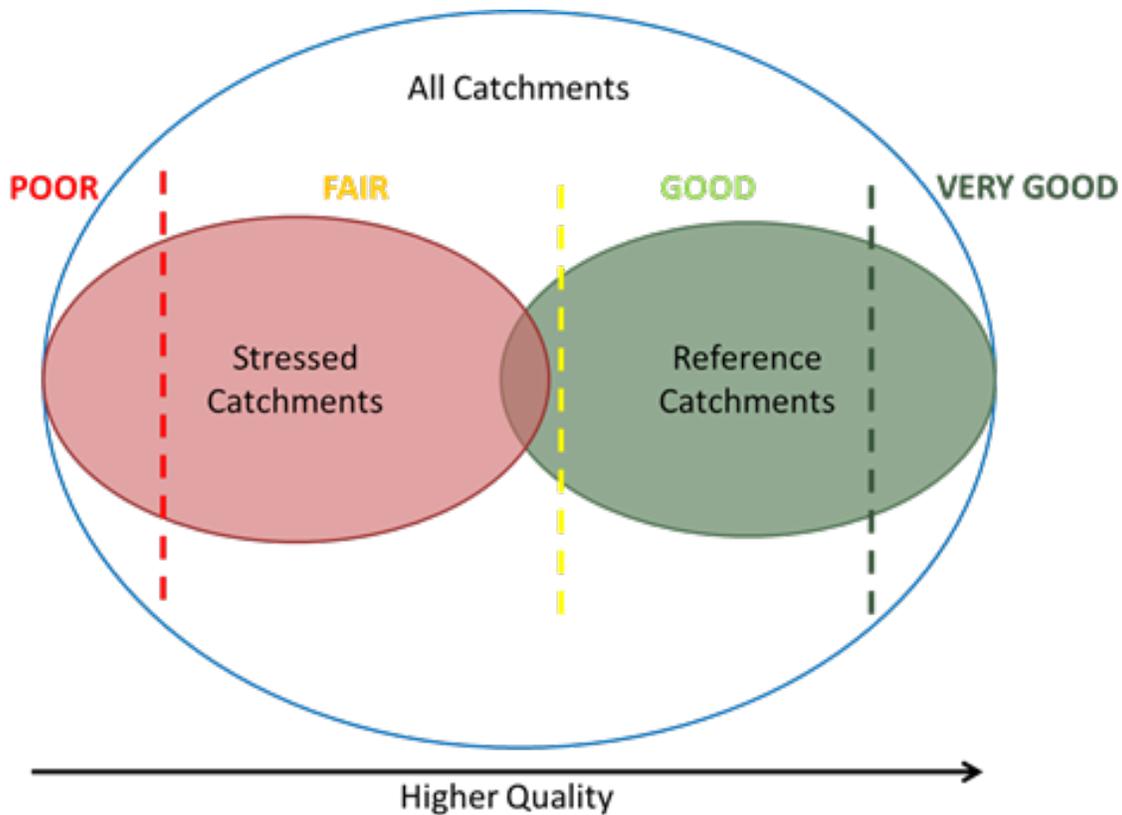


Figure 12. Threshold Definition Model

Table 11. 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 12).

Table 12. 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 13). 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 14.

Table 13. 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.

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Table 14. 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 Quality (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
	Hydrologic Connectivity	Underground mining	1.5	% of planning unit	N	Reference/ stressed	0	3.82	18.30
		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	

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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	<i>Hydrologic</i>	Total wetland area	1	% of planning unit	P	Presence/ absence	-	0	-
		<i>Connectivity</i> (Weight: 1)	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
	<i>Biodiversity</i> (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	-
	<i>Riparian Habitat</i> (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	
WETLANDS	<i>Water Quality</i>	All roads & rail in riparian area	1.5	miles/sq mi riparian area	N	Reference/stressed	0	2.46	5.97
		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

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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	<i>Water Quality</i> (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
	<i>Hydrology</i> (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	-
	<i>Biodiversity</i> (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	-
	<i>Wetland Habitat</i> (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	

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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
	Biodiversity (Weight: 0.5)	Development*	1.5	% of planning unit	N	Reference/ stressed	0	0.11	1.55
		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		

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^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 μ mhos/cm: 100, >500 μ mhos/cm and <=835 μ mhos/cm : 200, >200 and <=500 μ mhos/cm: 300, <=200 μ mhos/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/Embeddedness 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 15 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:

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

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

Metric	Catchment ID	Value	Relative Score	Objective Category	Objective Score
<i>Percent Forested Riparian Area</i>	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
<i>Percent of Planning Unit with Surface Mines</i>	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
<i>Roads and Railroads in Riparian Area (mi roads/sq mi planning unit)</i>	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:

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

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 16 gives examples of the Streams/Riparian Areas model indices and their corresponding objective, relative, and combined scores.

Table 16. 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:

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

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:

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

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:

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

Model relative score:

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

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 17 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:

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

Table 17. 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 13 - 15): 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 18 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 16. No water quality data were available for this planning unit and are therefore excluded from the analysis.

Similarly, the SWQ index relative score is:

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

which corresponds to the index relative score in Table 16.

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 16, and is considered to be in the Very Good category.

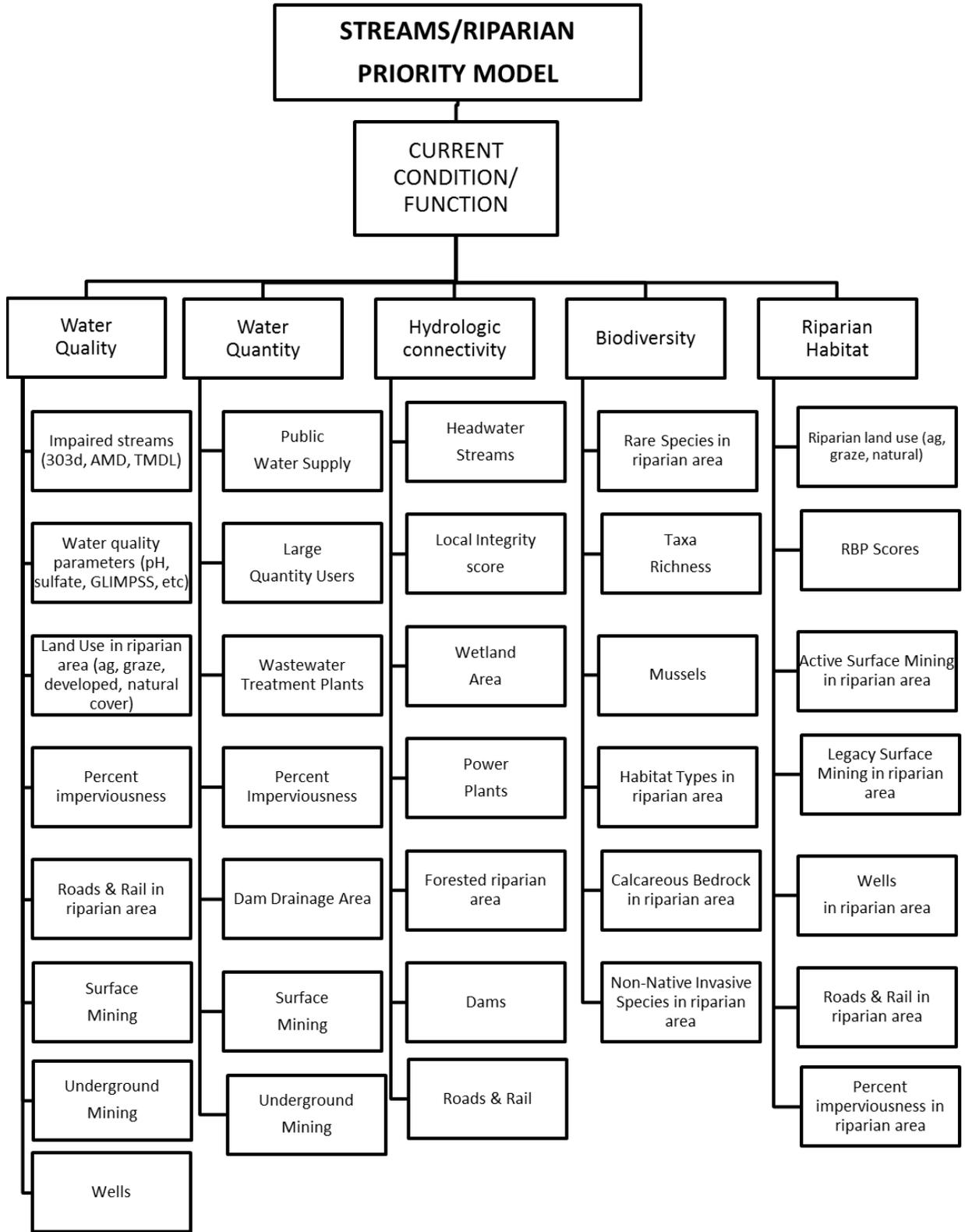


Figure 13. Streams/Riparian Areas Priority Model Flowchart

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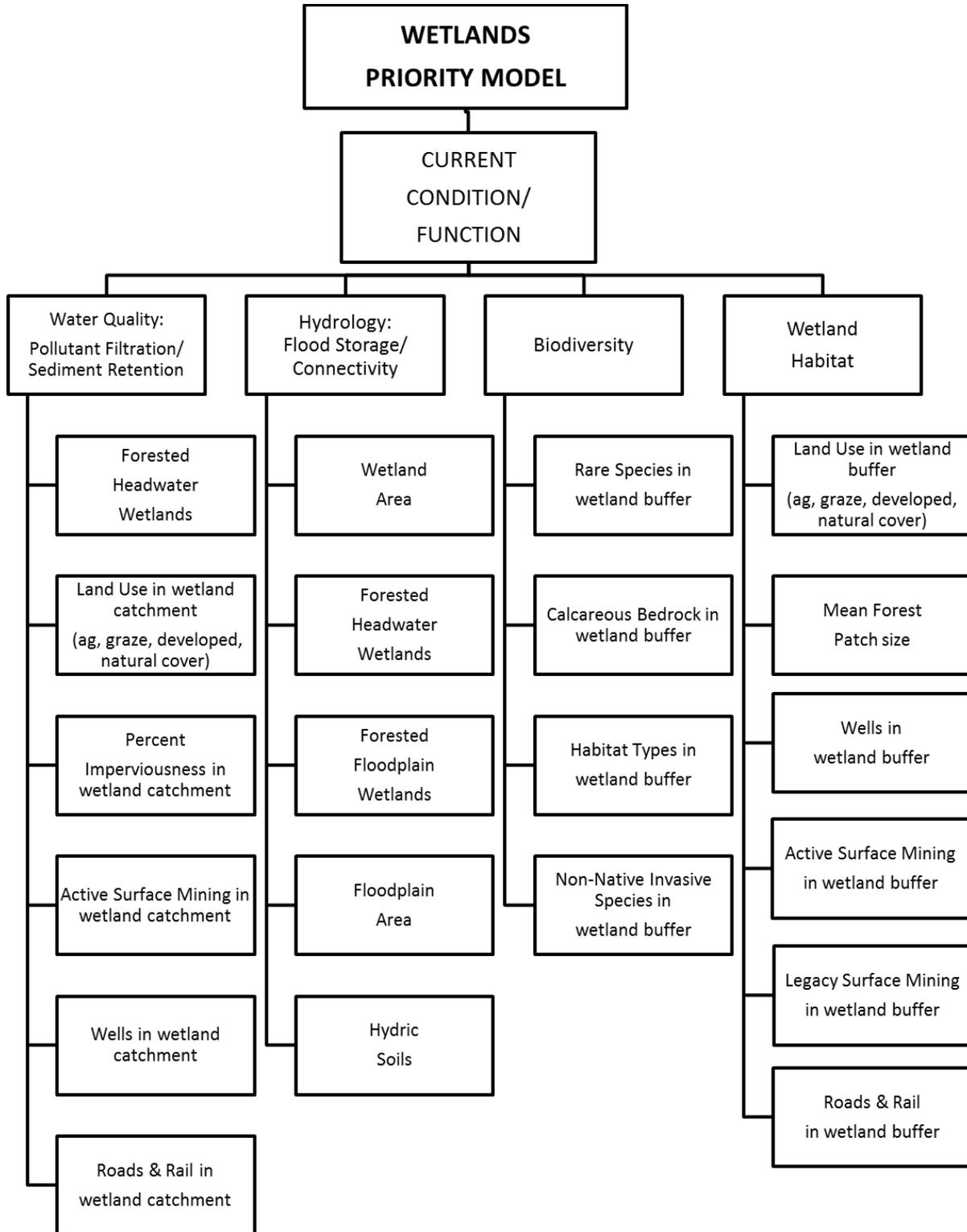


Figure 14. Wetlands Priority Model Flowchart

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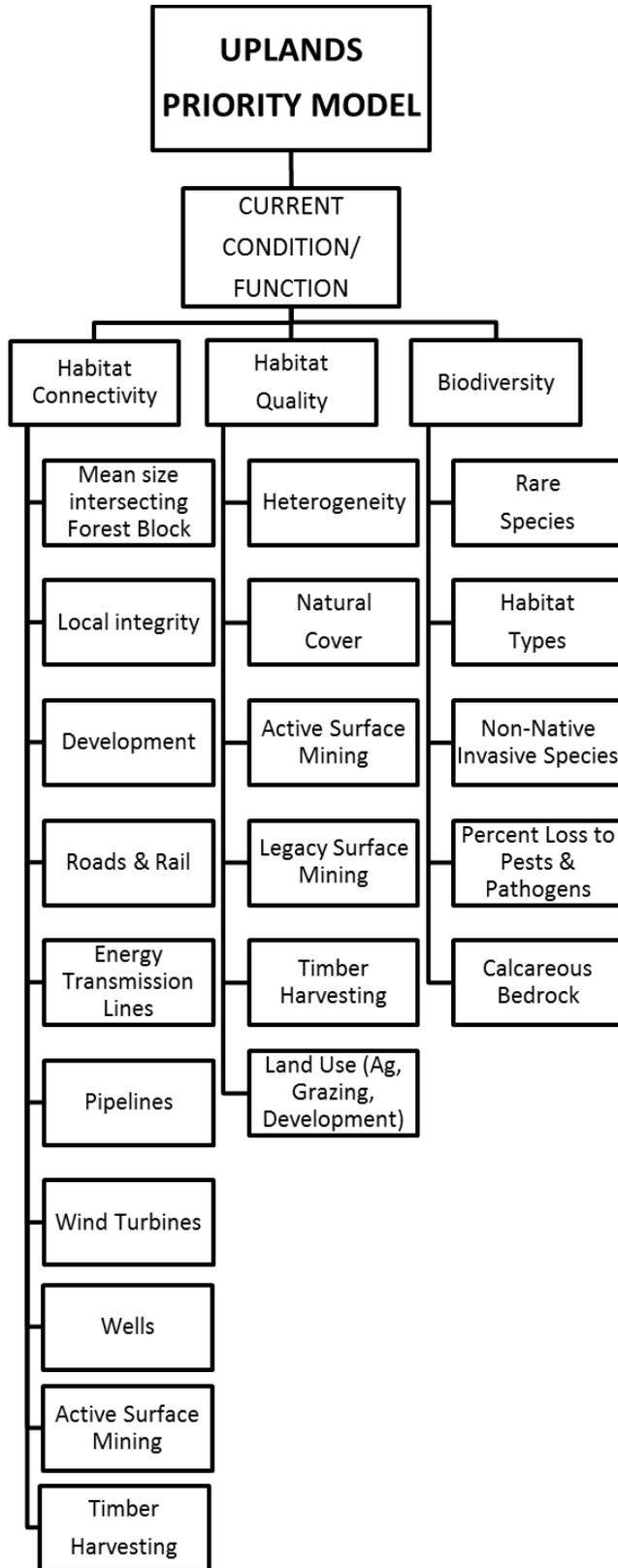


Figure 15. Uplands Priority Model Flowchart

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To calculate the Streams/Riparian Areas Model objective and relative scores, all index scores in Table 16 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 17.

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 17, and places the model into the Very Good category.

Table 18. 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 16). 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:

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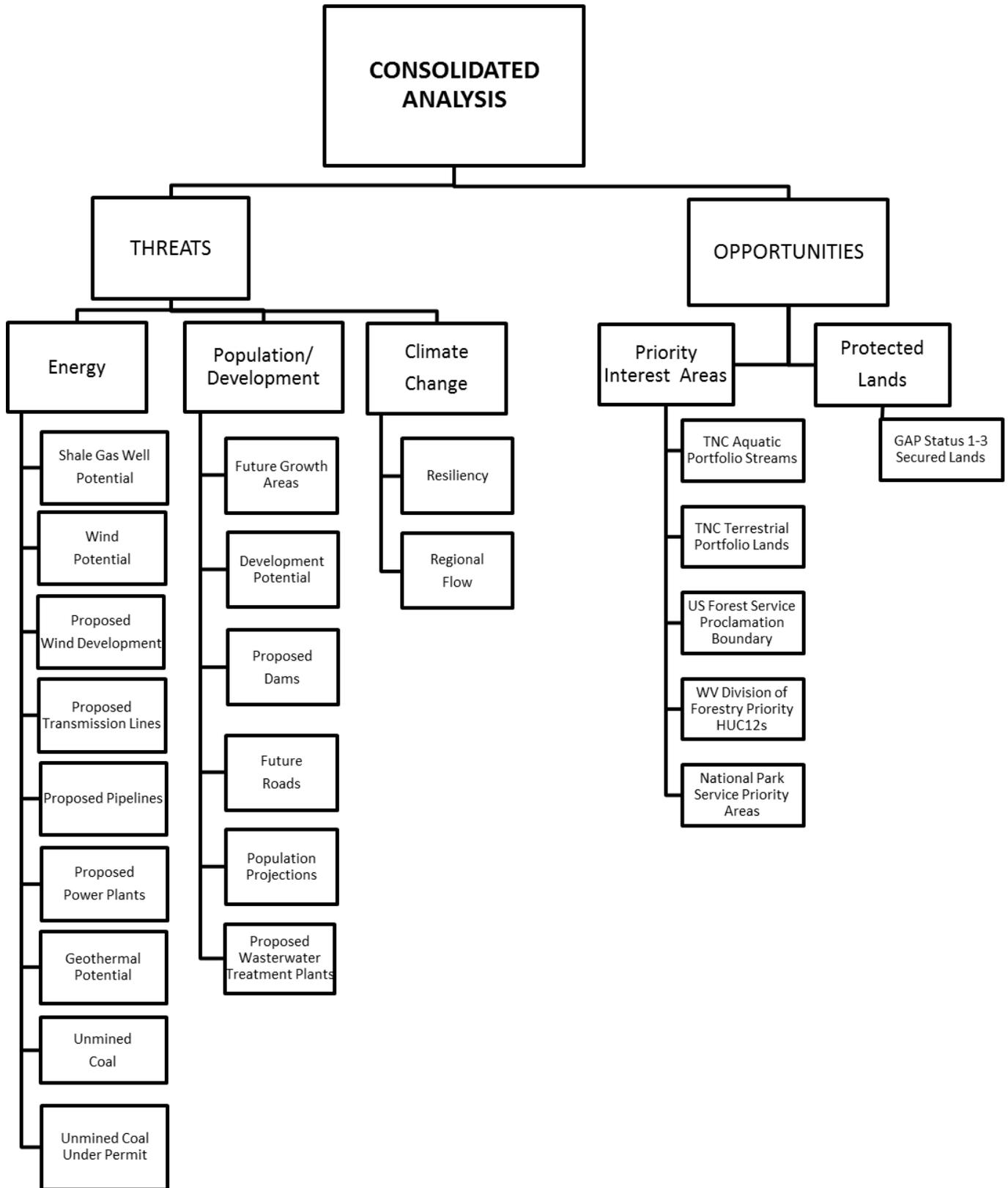


Figure 16. Consolidated Analysis Flowchart

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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 19). 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 19. 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.

Section 4: Results and Discussion

4.1 Current Condition Results and Discussion**4.1.1 Streams/Riparian Areas**

Figures 17a and 17b show the Overall results for the Streams/Riparian Areas landscape at the HUC12 and NHDPlus catchment scales, respectively, incorporating the scores for all the Streams/Riparian Areas Priority Model indices. The most notable trends, which are evident in all models and most indices, are the higher quality scores in the southern, headwaters, section of the watershed, due to the existence of currently protected lands and general forested cover in these areas. There is also a lack of surface and underground mining activity in the southern and eastern parts of the watershed (Figure 18), resulting in higher scores at the both the HUC12 and catchment level of results. The Tygart Valley has Good-Fair scores at the HUC12 level, with the Fair-scoring planning units in areas of increased mining activity and development. Greater variation is seen at the catchment level, with many of the eastern catchments along mountain ridges scoring Very Good (these are catchments that are almost completely forested, with few resource extraction activities or fragmenting features) and a few catchments scoring in the Poor category, due to more extensive active surface mining in these areas.

Similar patterns emerge, with slightly more variability, in the Streams Water Quality (SWQ) index results (Figures 19a and 19b). SWQ has four critical metrics: percent impervious cover, percent surface mining, median pH, and median specific conductivity. Four HUC12s score in the Very Good category (Sand Run, Teter Creek, Chenoweth Creek, and Files Creek); all HUC12s scored Very Good in all of the critical metrics besides impervious cover, where they scored in the Good category. These HUC12s have no impaired streams and score Very Good or Good in water quality parameters like sulfates and sedimentation and embeddedness; they also generally have minimal amounts of anthropogenic land use, and would be good candidates for protection activities. The Good-scoring HUC12s show similar trends, but with some impaired streams and higher percentages of non-natural land use activities in the riparian area, such as development, grazing, or agriculture. The Fair-scoring HUC12s have more impaired streams and a greater amount of one or more alternate land uses, plus greater density of roads and railroads or oil and gas wells; in general, HUC12 scores for SWQ were not largely determined by critical metrics, but rather by a combination of other metrics in this index. The same trends occur at the catchment level, with Very Good catchments being mostly forested cover in the headwaters area, often along mountain ridges or within protected lands, which minimizes resource extraction activities and development, both of which correlate with an improvement in water quality parameters. Fair-scoring catchments are clustered around areas of urban development in the watershed, or occasionally more intensive agriculture and grazing areas; depending upon the land use activity, these catchments may be good candidates for riparian restoration activities. The few Poor-scoring catchments are in areas of greater mining activity, and have Poor scores for both pH and specific conductivity metrics, which are likely mining-related water quality issues in these areas.

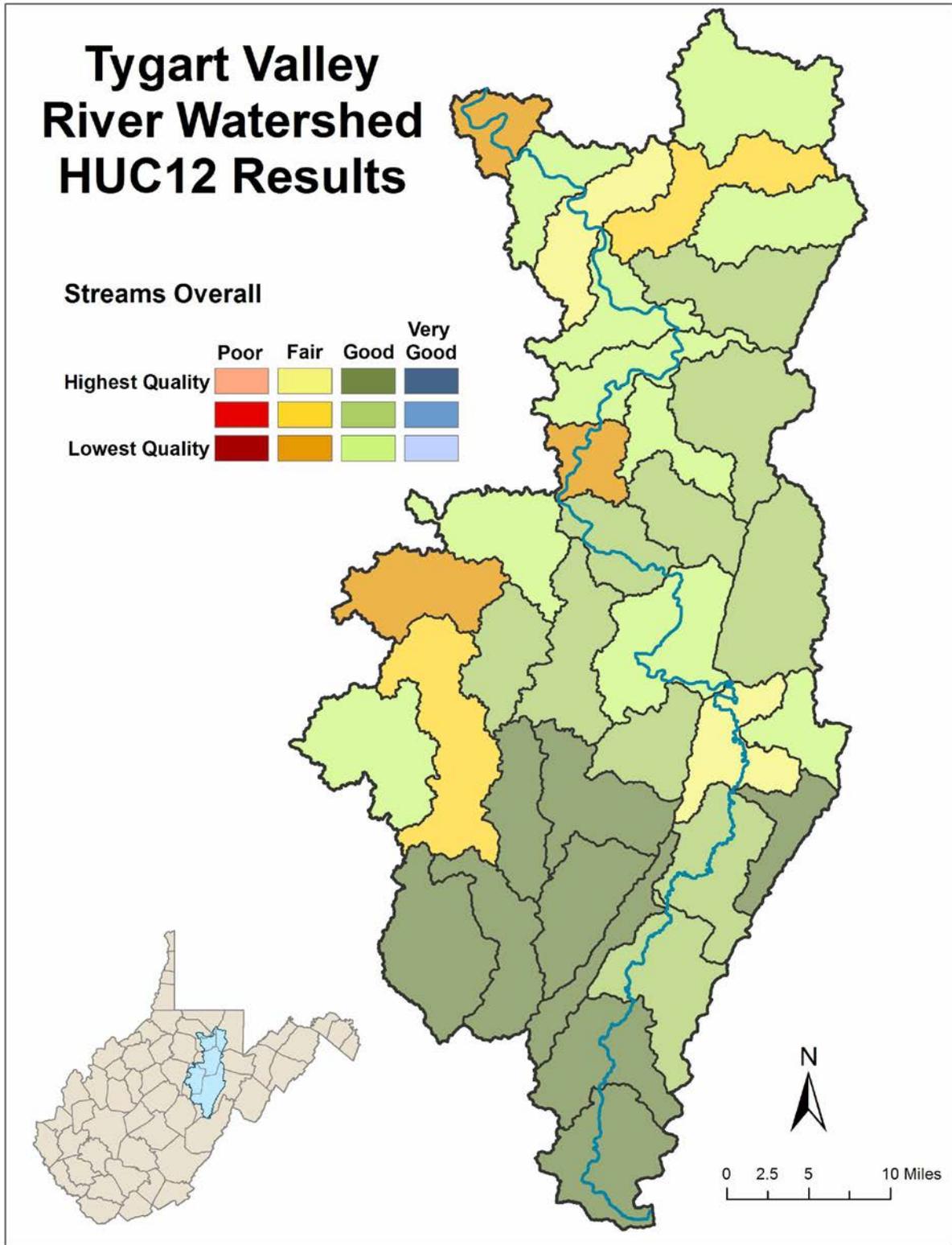


Figure 17a. Streams Overall Results – HUC12 Level

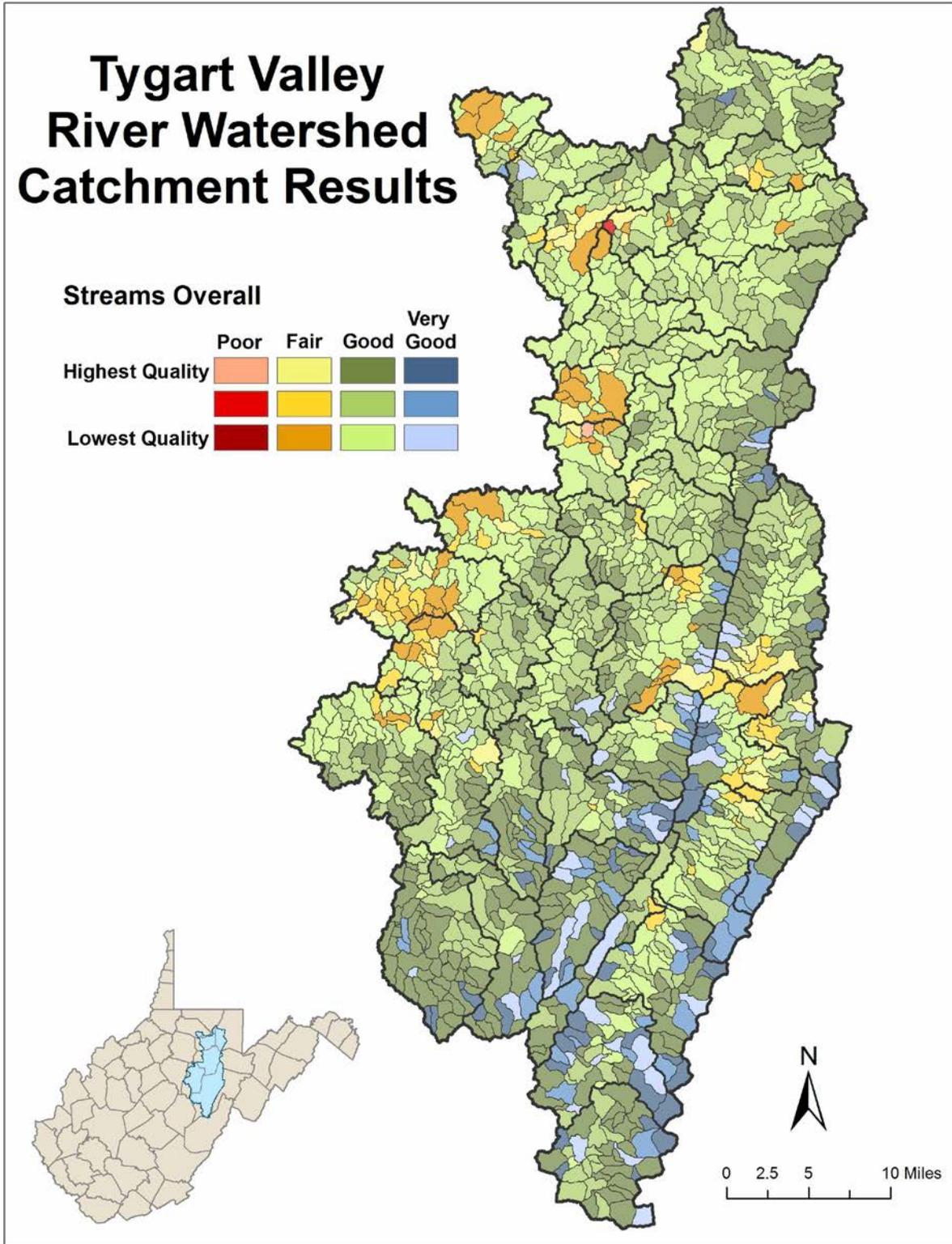


Figure 17b. Streams Overall Results – Catchment Level

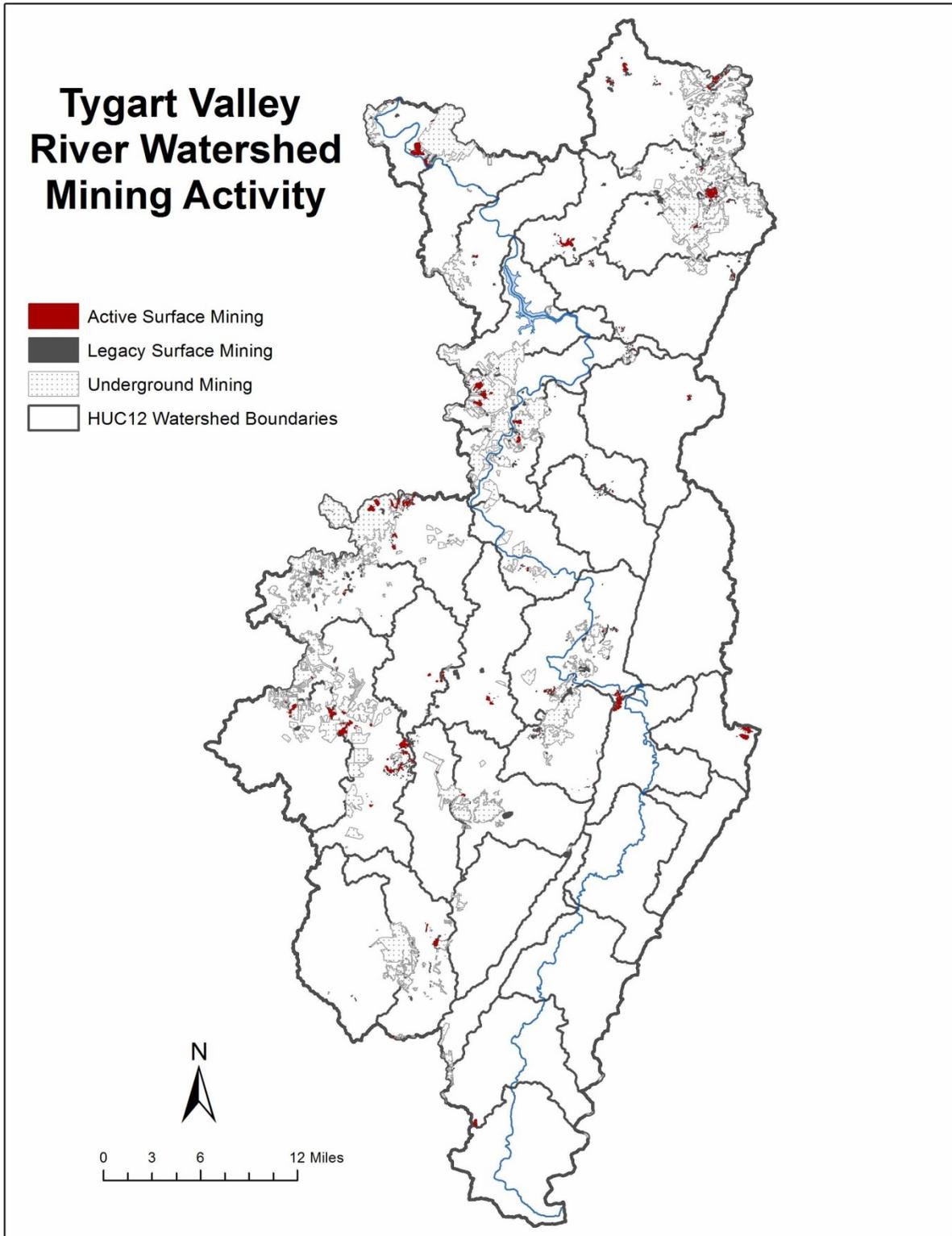


Figure 18. Tygart Valley River Watershed - Mining Activity
(Maxwell et al. 2011, WVDEP 1996, WVDEP 2011b, WVGES 2010)

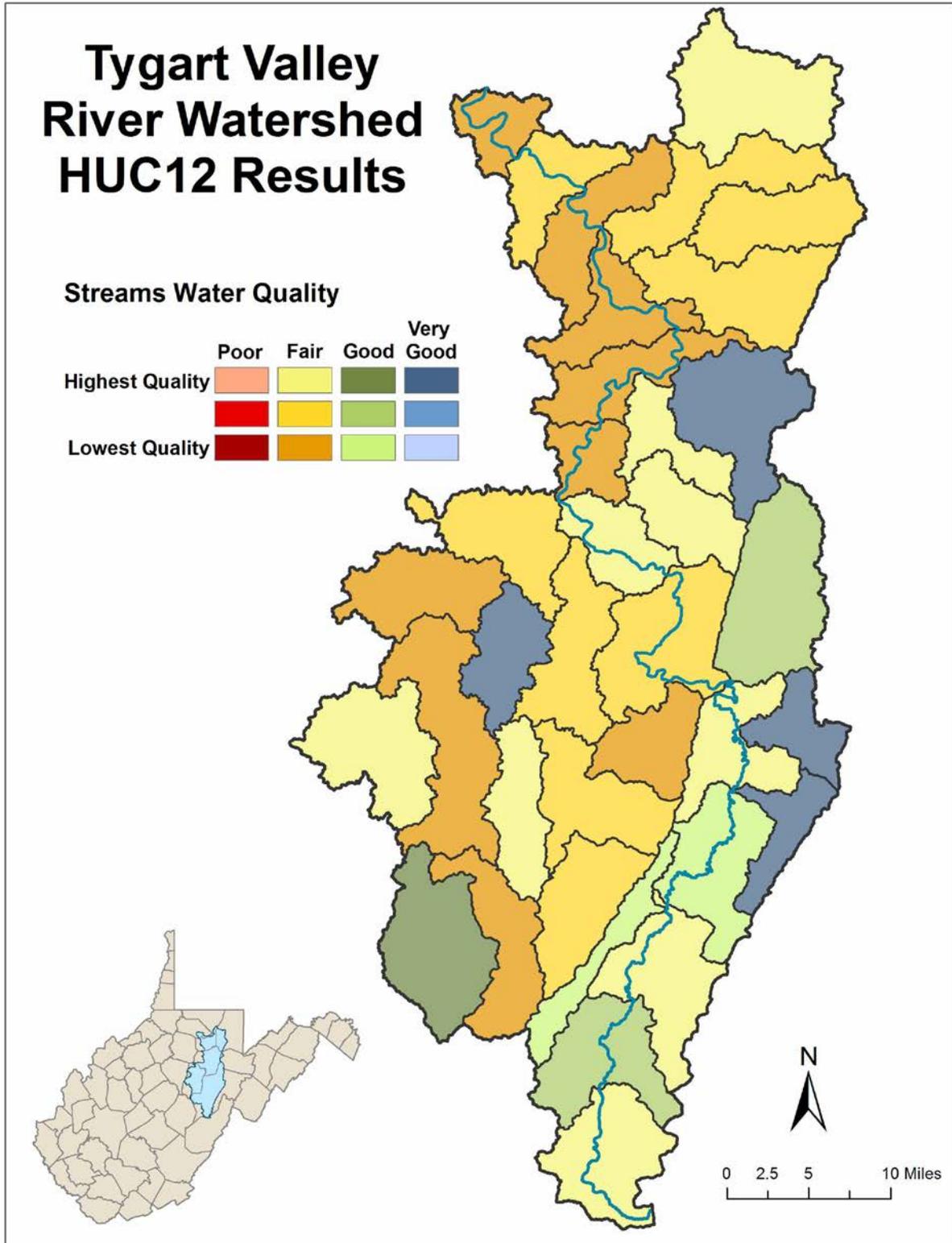


Figure 19a. Streams Water Quality Index Results – HUC12 Level

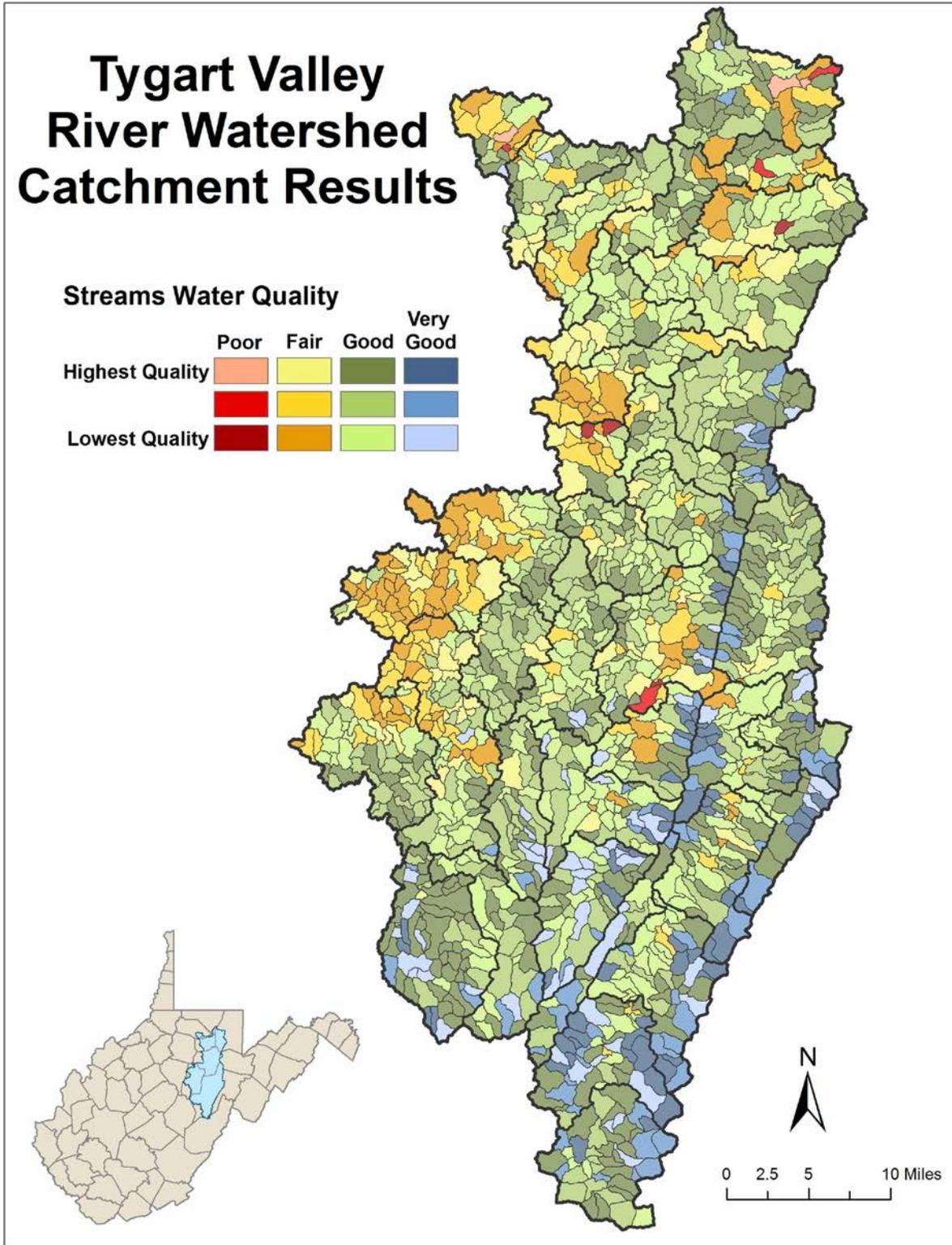


Figure 19b. Streams Water Quality Index Results – Catchment Level

The Streams Water Quantity (SWN) index results maintain the general pattern seen in all the watershed results at the HUC12 level, with Good-scoring planning units in the south and east, and Fair-scoring in the west and north of the watershed, where more resource extraction and development activities occur (Figure 20a). SWN has one critical metric, percent impervious cover. All of the Fair HUC12s scored a Fair in this metric except for one (Left Fork Buckhannon River, which scored a Good in this metric) - the critical metric is likely the main driver of these results, though some of the Fair HUC12s also have significant amounts of underground mining or public water supply facilities or wastewater treatment plants. Greater variation is evident in the SWN index at the catchment level (Figure 20b), with many more Very Good catchments. This is because many of the metrics in this index are based on discrete point features, such as the existence of large quantity users or dams, which lower the scores of planning units where they occur. As these features are generally clustered around the developed areas of the watershed, catchment-level results will reflect the lowered scores in a more localized manner than HUC12 results.

The Streams Hydrologic Connectivity (SHC) index maintains the same trends seen in other Streams indices, with the higher quality Good-Very Good planning units in the south and east along the mountain ridges in the headwater areas, and Fair-scoring planning units concentrated around areas of development or resource extraction (Figures 21a and 22b). Fair-scoring HUC12s had smaller percentages of forested riparian area, greater density of roads and railroads in the riparian area, and lower local integrity scores; these areas would be good candidates for riparian restoration or mitigation activities. The same principle applies to the Fair scores at the catchment level, with the inverse being true for the Very Good catchments (all of which have high percentages of forested riparian, very low density of roads and railroads in the riparian area, and very high local integrity scores). The Very Good catchments would be excellent areas for protection activities, particularly if these catchments also scored Very Good in other indices and are near or adjacent to existing protected lands.

The Streams Biodiversity (SBD) index results showed some variation at the HUC12 level, and slightly more variation at the NHDPlus catchment level, though continuing with the same geographic patterns (Figures 22a and 22b). While the coarser HUC12 scale may include many occurrences of rare or invasive species, at the catchment level often none, or only one or two, occurrences are recorded within each planning unit, thus decreasing the variation in scores among catchments across the watershed. In planning units without rare or invasive species the index results depend on the values of only two or three other metrics. The few Poor catchments were all due to Poor taxa richness scores and a lack of additional metrics recorded in those catchments; the Fair catchments often scored lower due to invasive species occurrences and lack of calcareous bedrock. Similarly, the Very Good catchments had Very Good terrestrial habitat scores and higher amounts of calcareous bedrock. The main difference between a catchment receiving a Good versus a Fair score was the presence of rare species. This metric, unfortunately, is not very robust, as it is not known where surveys did not occur compared where surveys occurred but no species were found. Biodiversity results are best viewed as informational, and should not be consulted as a primary or guiding index within the model without further evaluation of other index results and the individual Biodiversity metrics scores.

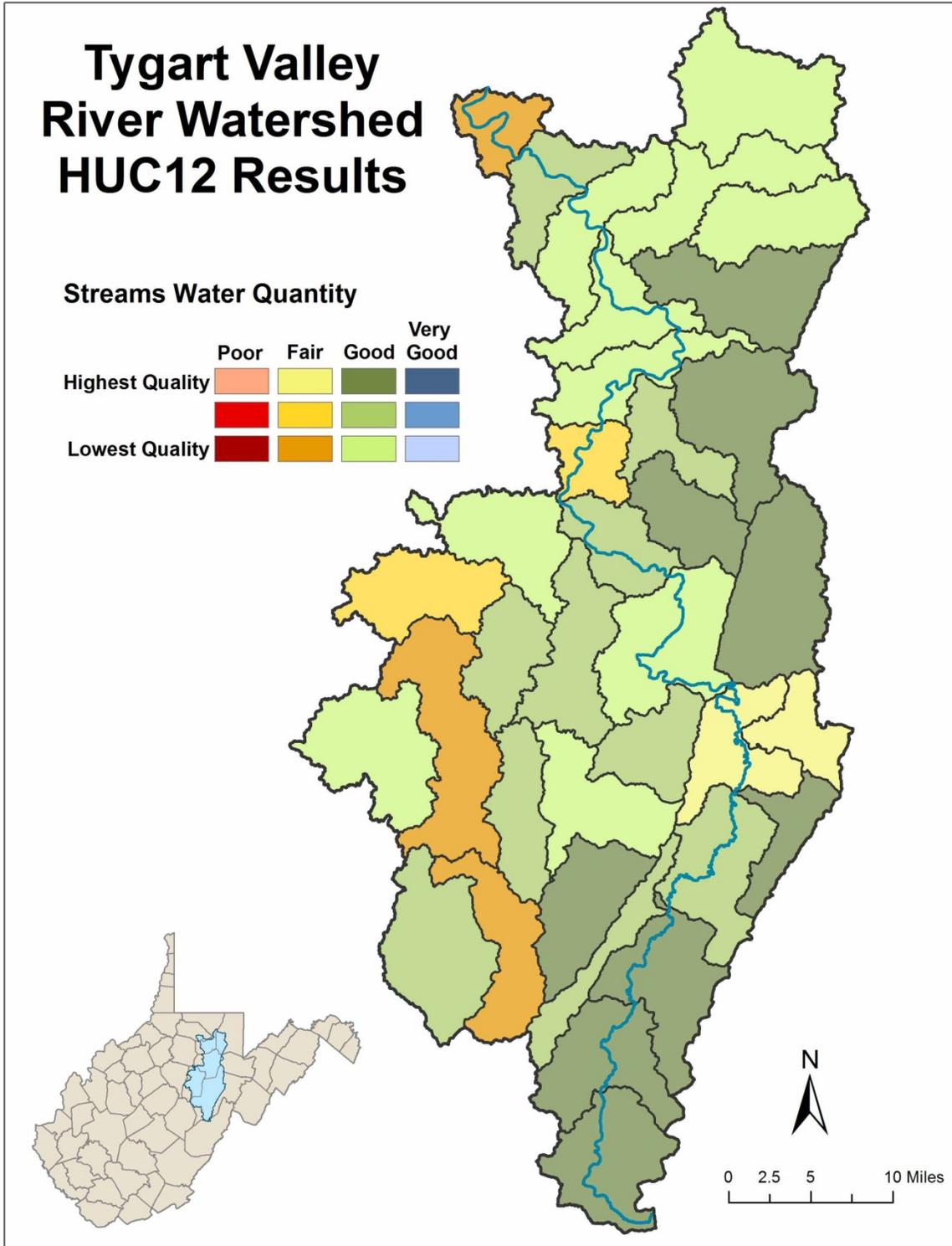


Figure 20a. Streams Water Quantity Index Results – HUC12 Level

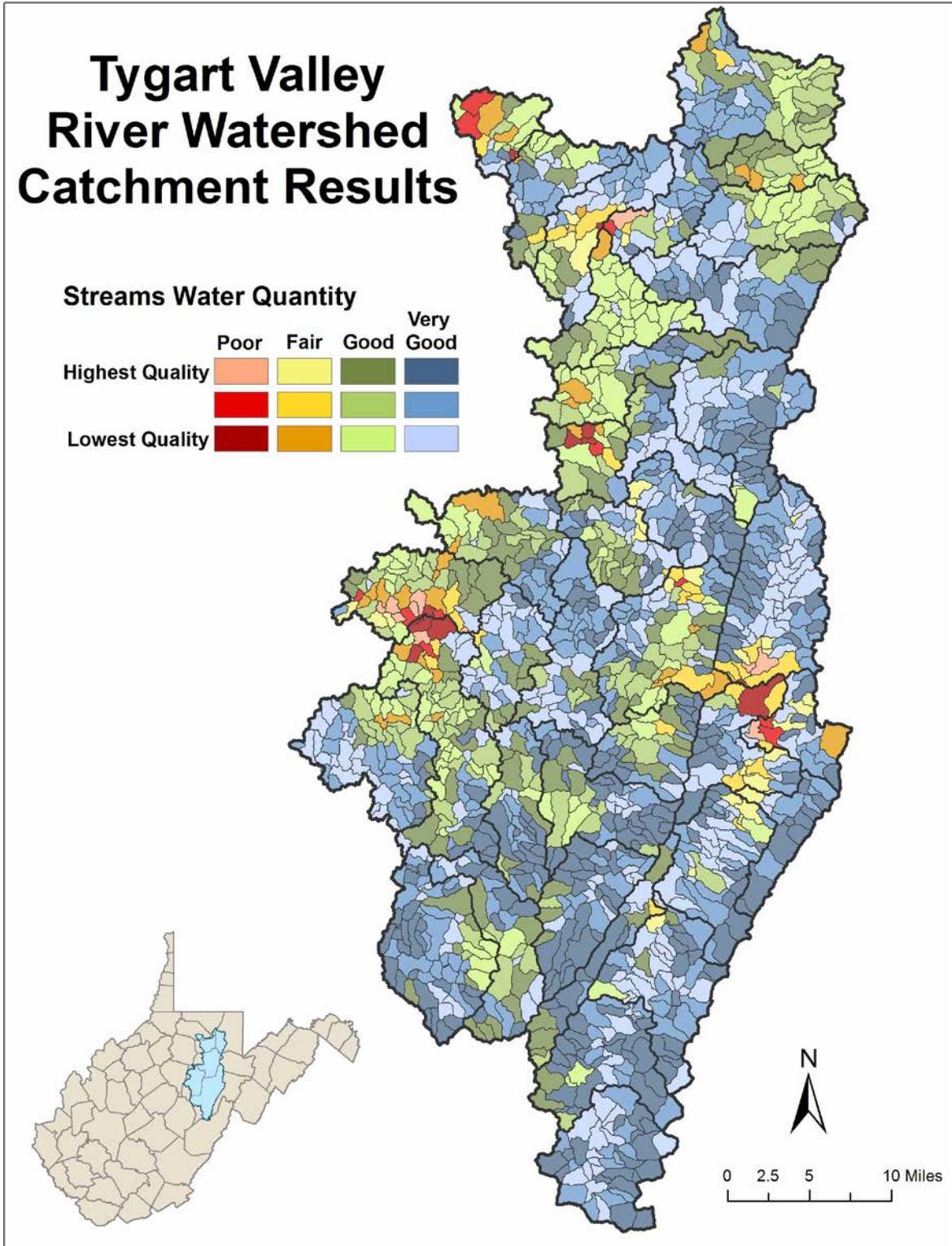


Figure 20b. Streams Water Quantity Index Results – Catchment Level

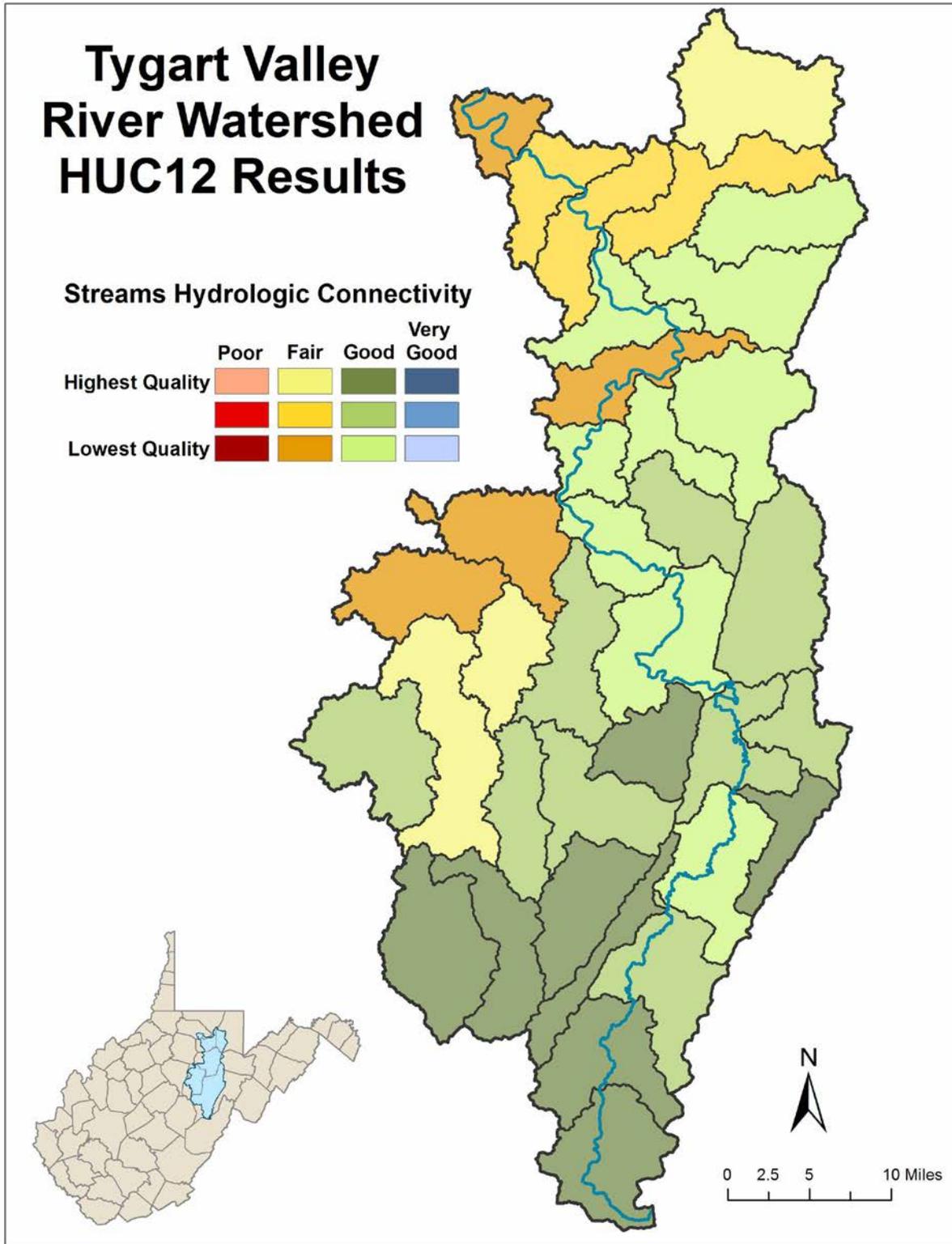


Figure 21a. Streams Hydrologic Connectivity Index Results – HUC12 Level

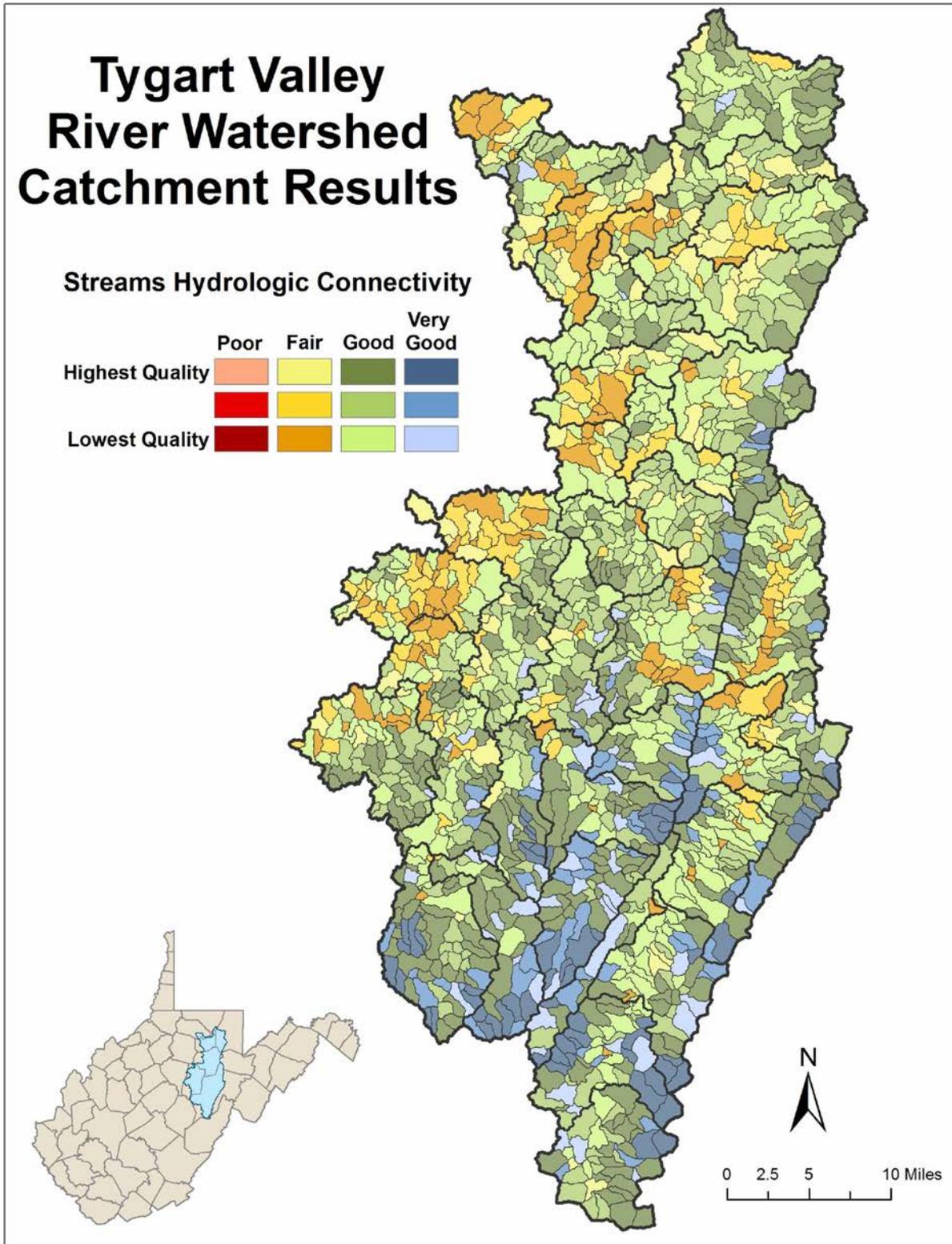


Figure 21b. Streams Hydrologic Connectivity Index Results – Catchment Level

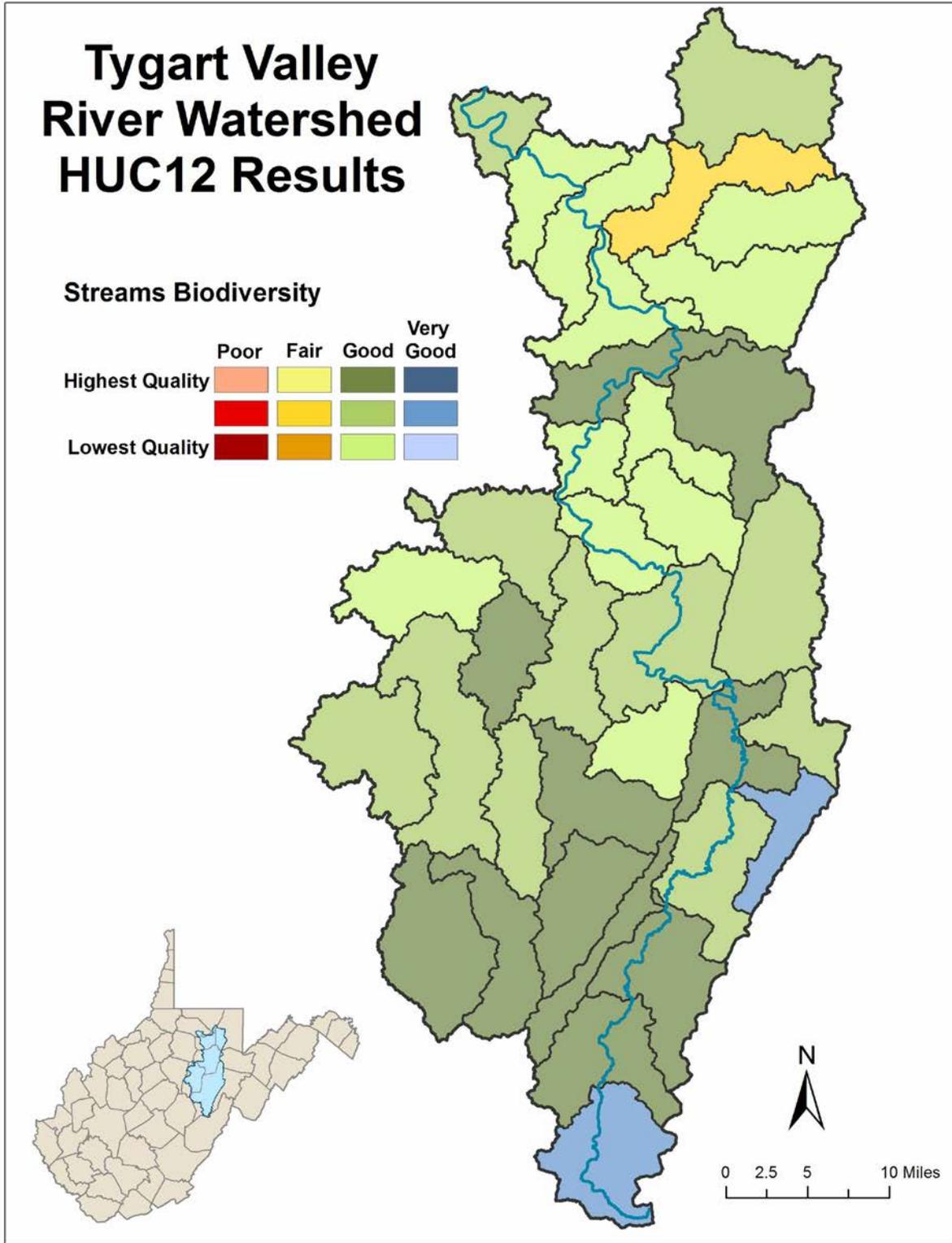


Figure 22a. Streams Biodiversity Index Results – HUC12 Level

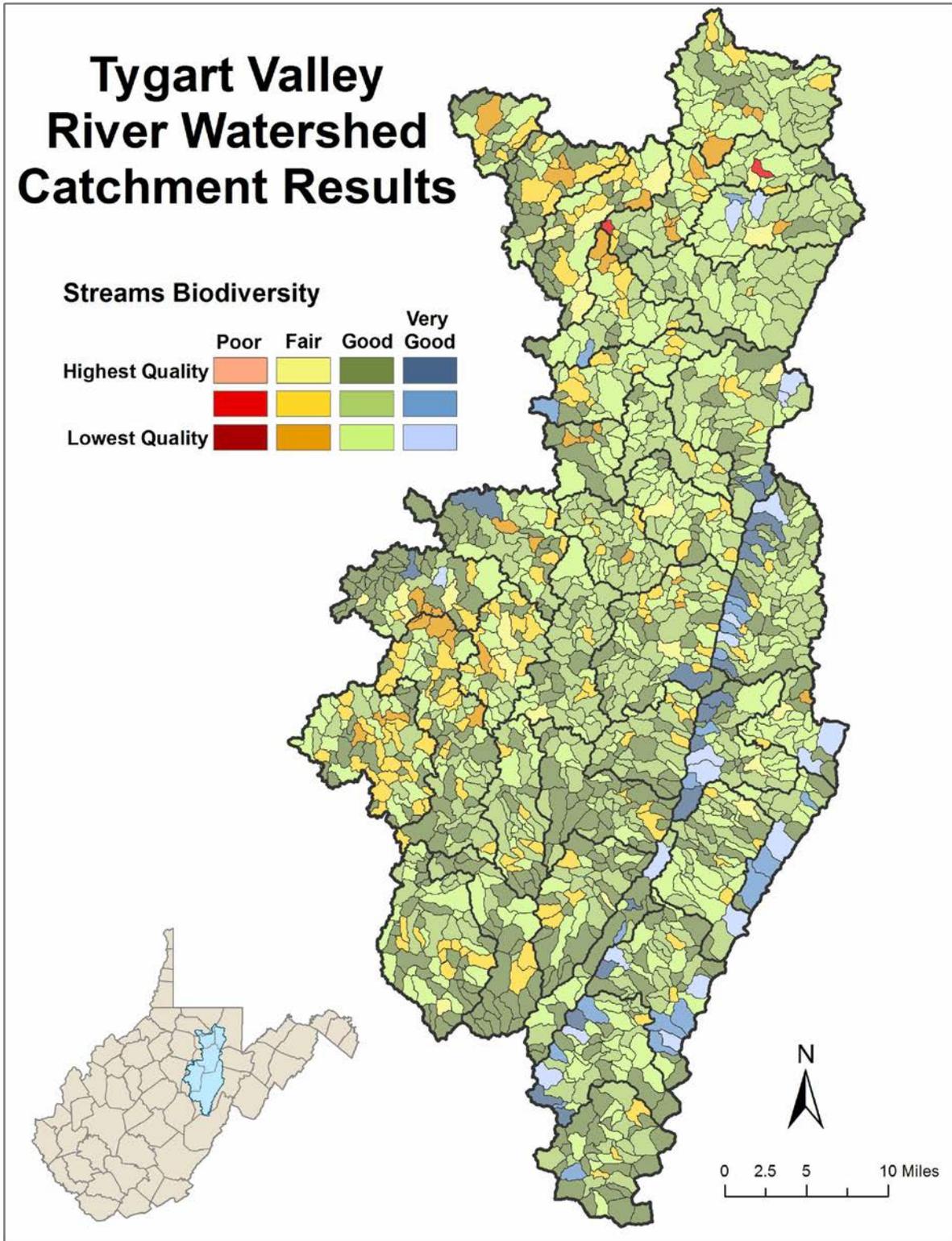


Figure 22b. Streams Biodiversity Index Results – Catchment Level

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The Streams Riparian Habitat (SRH) index results maintain the same trends as other Streams indices, with highest quality planning units in the south and east, lowest quality in the northwest, and the remainder of the watershed being mid-level quality (Figures 23a and 23b). The SRH index has two critical metrics, percent imperviousness and active surface mining in the riparian area. Imperviousness is the main driver of index results in many of the Fair HUC12s; none of the HUC12s had significant amounts of active surface mining in the riparian area. Other metrics that affected the Fair HUC12s were measures that reflect fragmentation in the riparian area, including roads and railroads and wells. The same pattern continues at the catchment level, with most of the Fair and Poor catchments having high levels of percent imperviousness (and a handful having high levels of riparian surface mining), and Very Good and Good catchments having minimal levels of any anthropogenic land use in the riparian area. Amount of natural cover in the riparian area and density of roads and railroads in the riparian area are highly weighted metrics in this index, and therefore affect the index score of the planning unit significantly. Another issue that emerges at the catchment level was grazing, agricultural activities, and roads and railroads in the riparian area, particularly around existing developed areas and in the southeastern river valley where these land use activities are more concentrated.

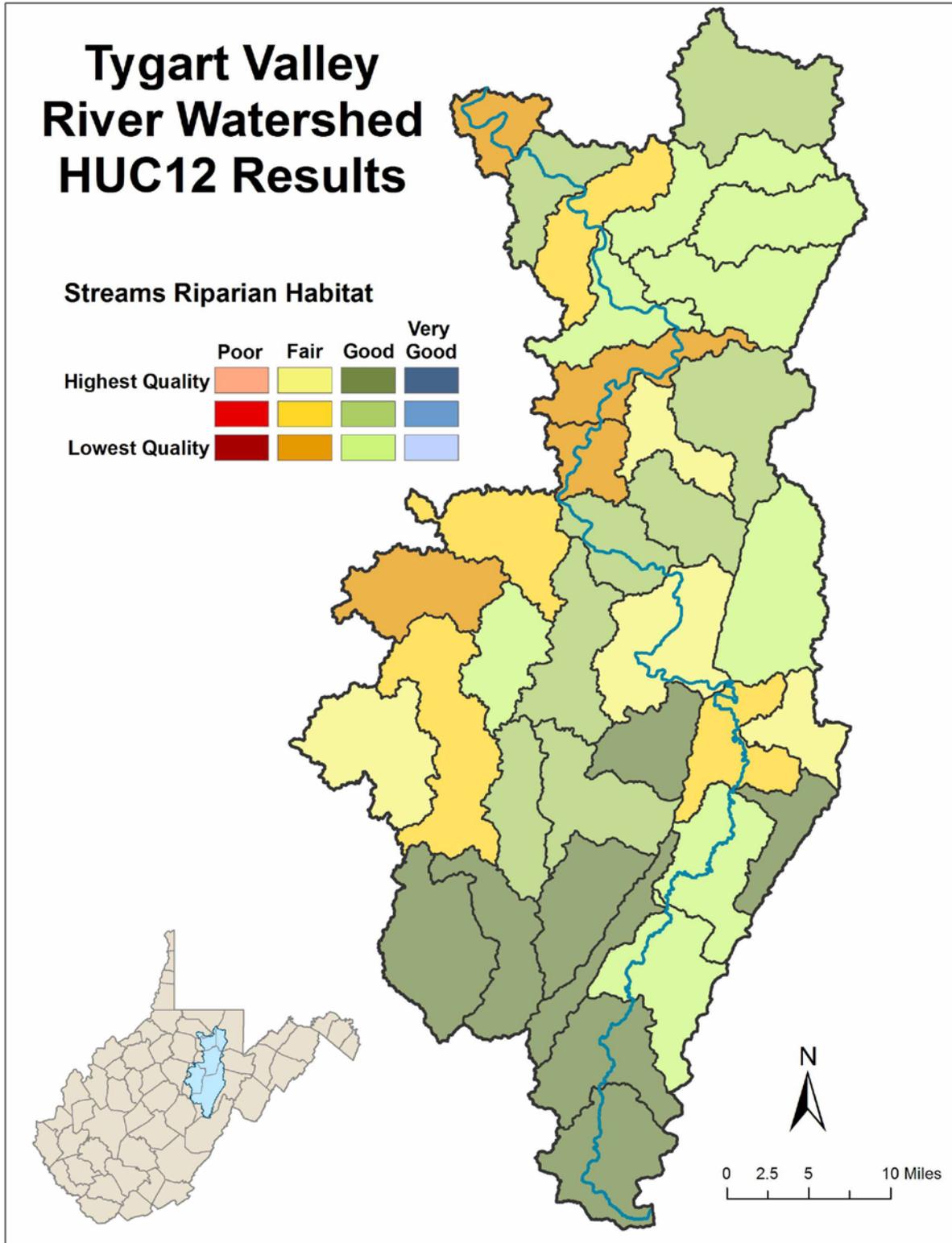


Figure 23a. Streams Riparian Habitat Index Results – HUC12 Level

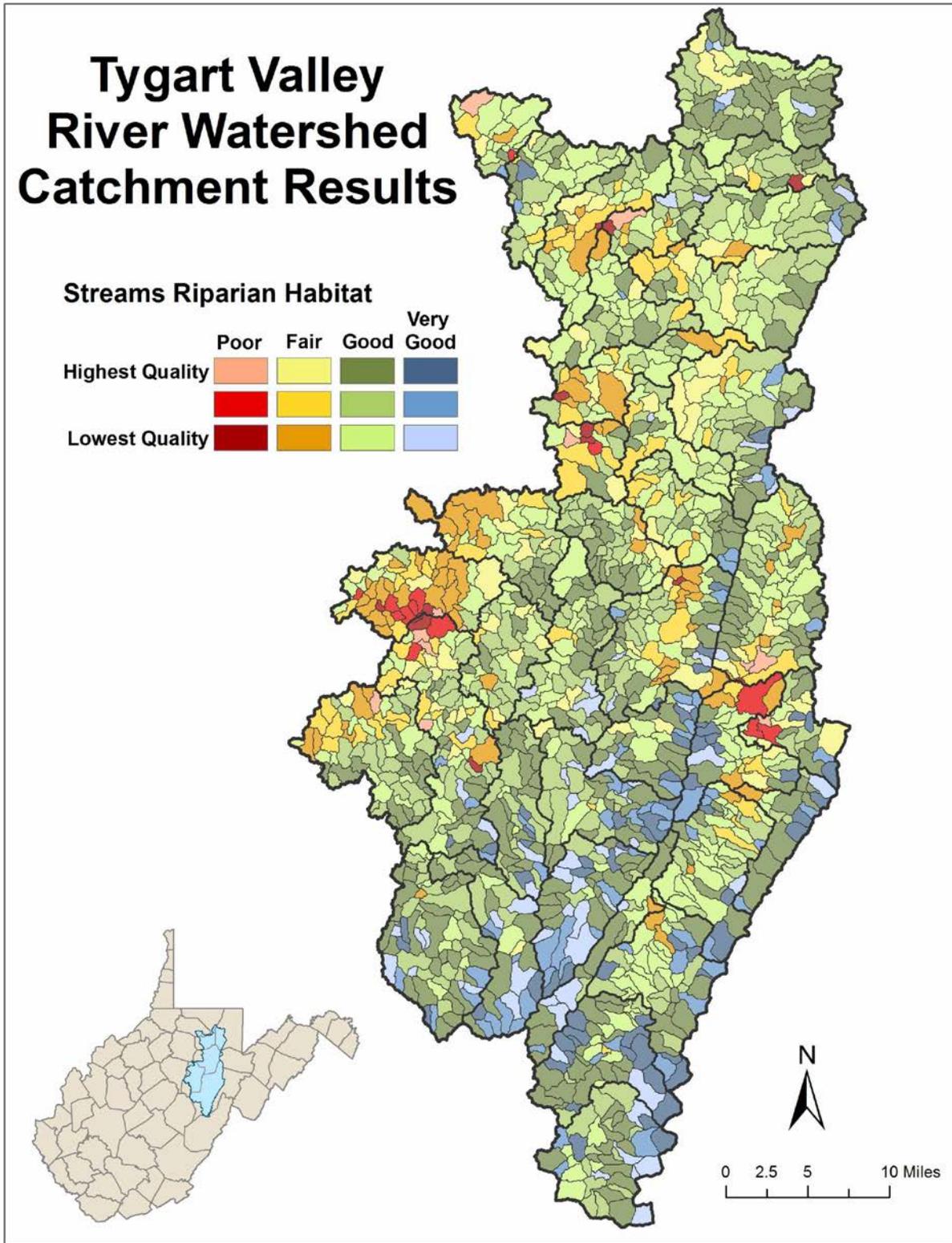


Figure 23b. Streams Riparian Habitat Index Results – Catchment Level

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 have 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.

The Tygart Valley River has a considerable amount of wetland area for a watershed in West Virginia, with particularly dense wetland complexes along the river valley in the southeastern section of the watershed. Wetlands Overall results for the Tygart are generally Good, with higher scoring planning units generally in areas with mapped wetlands, and lower scoring planning units in those portions of the watershed that have only hydric soils and floodplain area. At the HUC12 level (Figure 24a), all planning units scored Good overall, with the higher relative quality HUC12s in the southern half of the watershed, reflecting the density of mapped wetlands in this area. More variation is apparent at the catchment scale (Figure 24b), with those catchments that contain wetlands scoring Good, those with wetland potential scoring Fair, and those catchments with no wetlands or hydrologic potential for wetlands having null values. A general trend throughout the Wetlands indices results is the presence of higher quality wetland areas in the south along the main stem of the river and a smaller high quality wetland complex existing in the Tygart Lake HUC12.

The Wetlands Water Quality (WWQ) index results follow the same basic geographic pattern as the Overall results, with more variation in quality scores, including many Fair and even one Very Good HUC12, at Upper Middle Fork River (Figure 25a). The mapped wetland in this HUC12 drains a wetland catchment that is almost 100% forested cover, which is the highest weighted metric in this index. HUC12s that scored in the Good or Fair categories often had significant amounts of grazing, agriculture, roads and railroads, or oil and gas wells in their wetland catchments. At the catchment level, the planning units with Fair scores often had one or more metrics scoring in the Poor category, generally development, agriculture, or roads and railroads in the wetland catchment. Several areas in the southern portion of the watershed that would be top candidates for wetland protection activities, and many of the Fair catchments would be excellent opportunities for wetland restoration, as their lower scores are often the result of anthropogenic land uses in the wetland catchment that could be restored or mitigated.

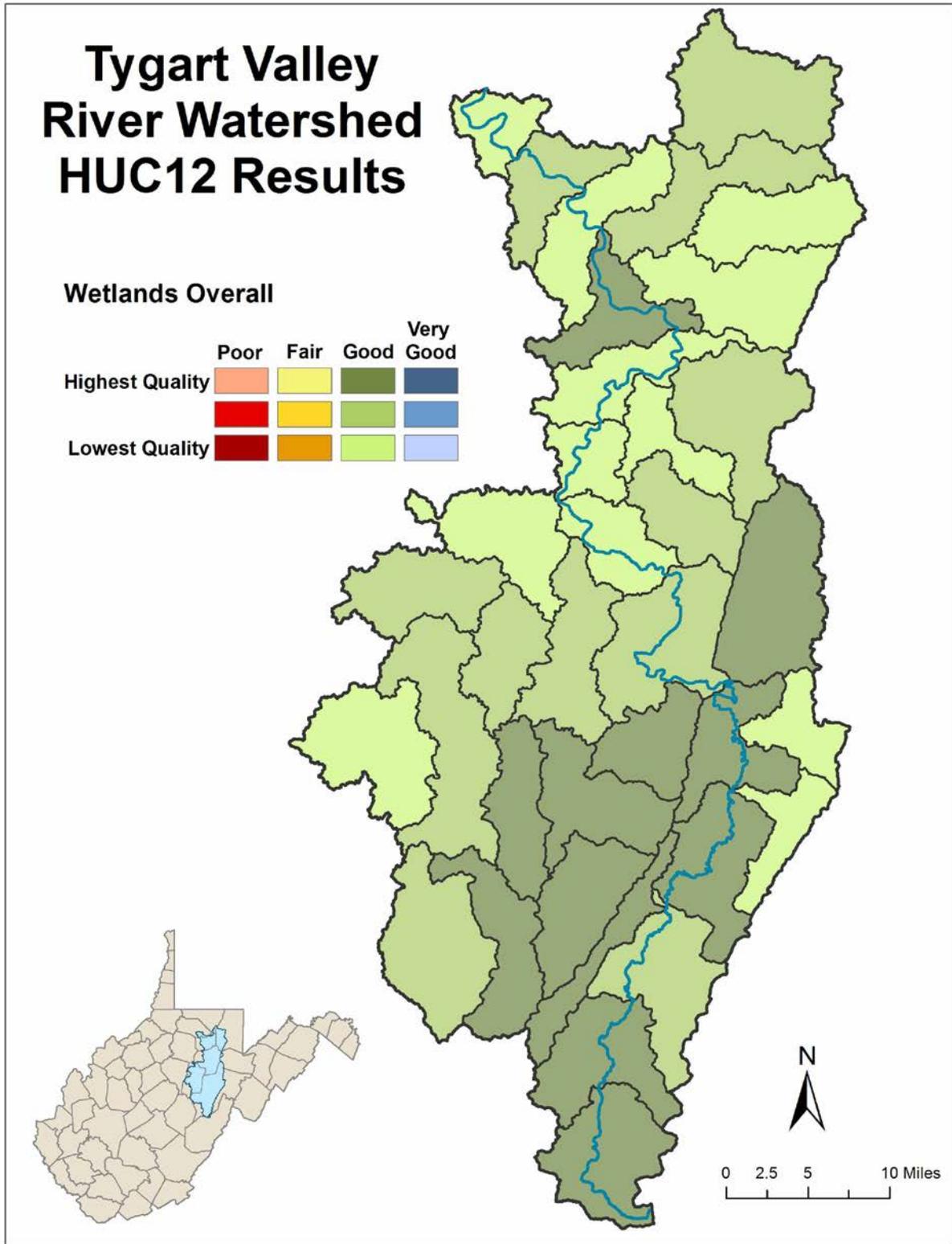


Figure 24a. Wetlands Overall Results – HUC12 Level

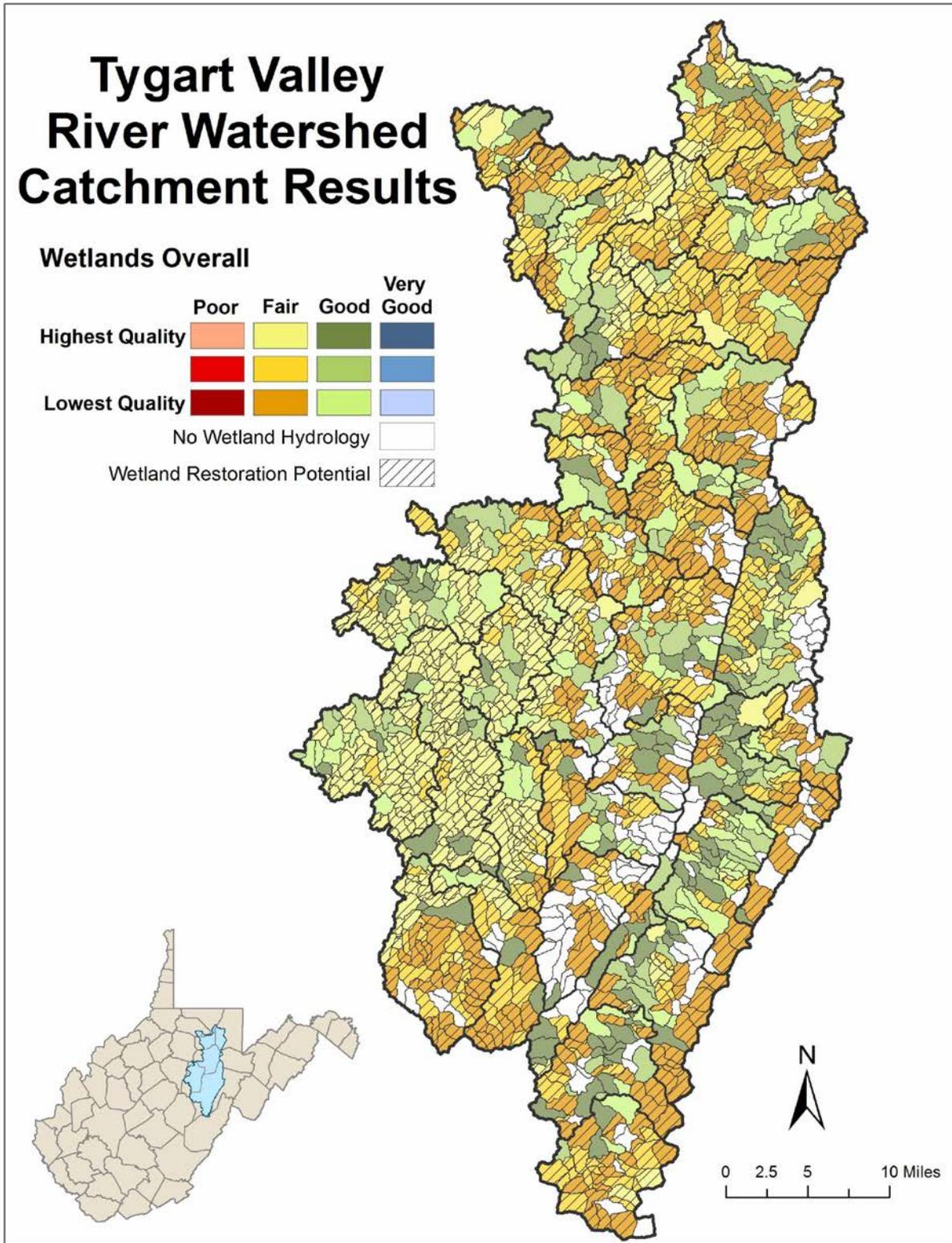


Figure 24b. Wetlands Overall Results – Catchment Level

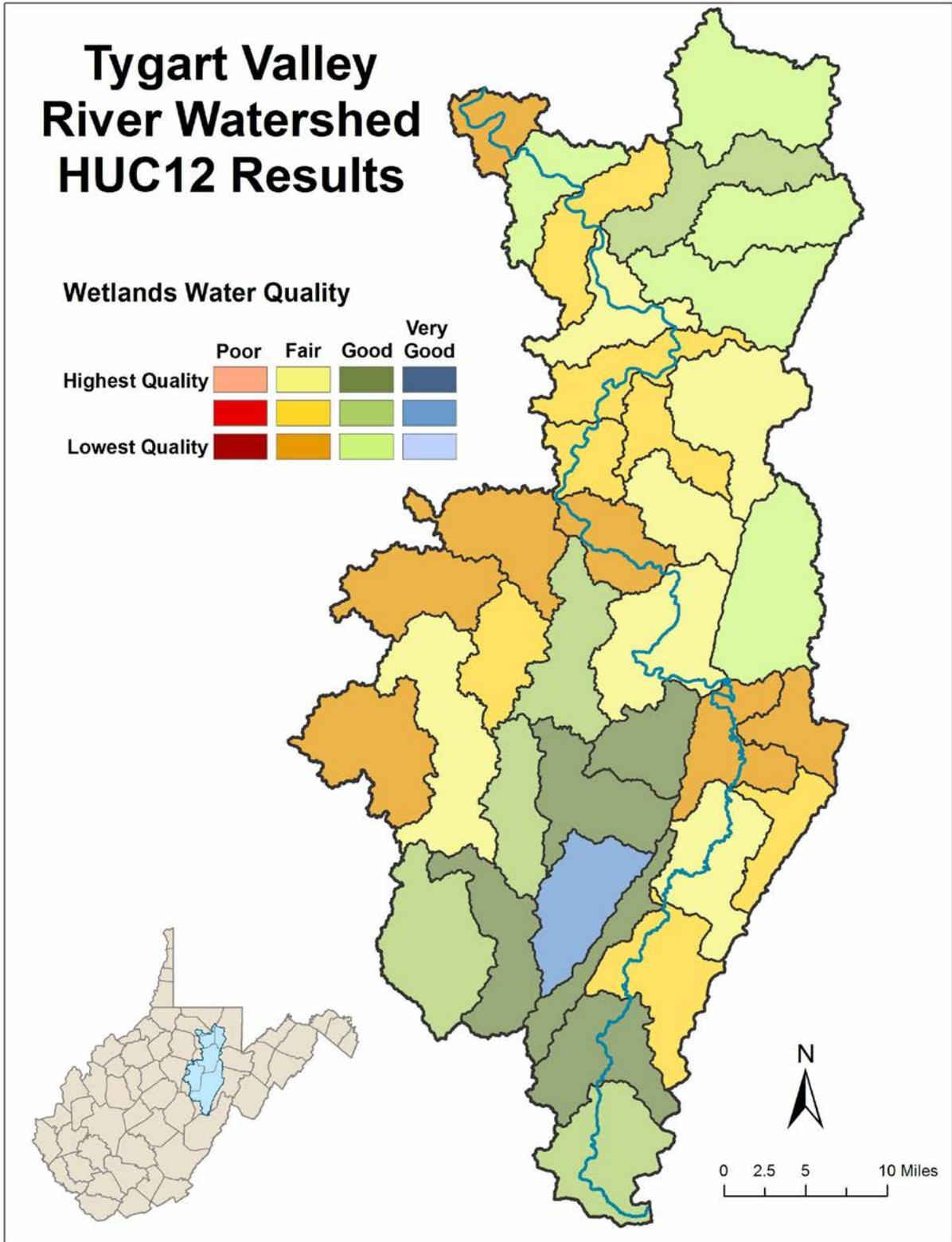


Figure 25a. Wetlands Water Quality Index Results – HUC12 Level

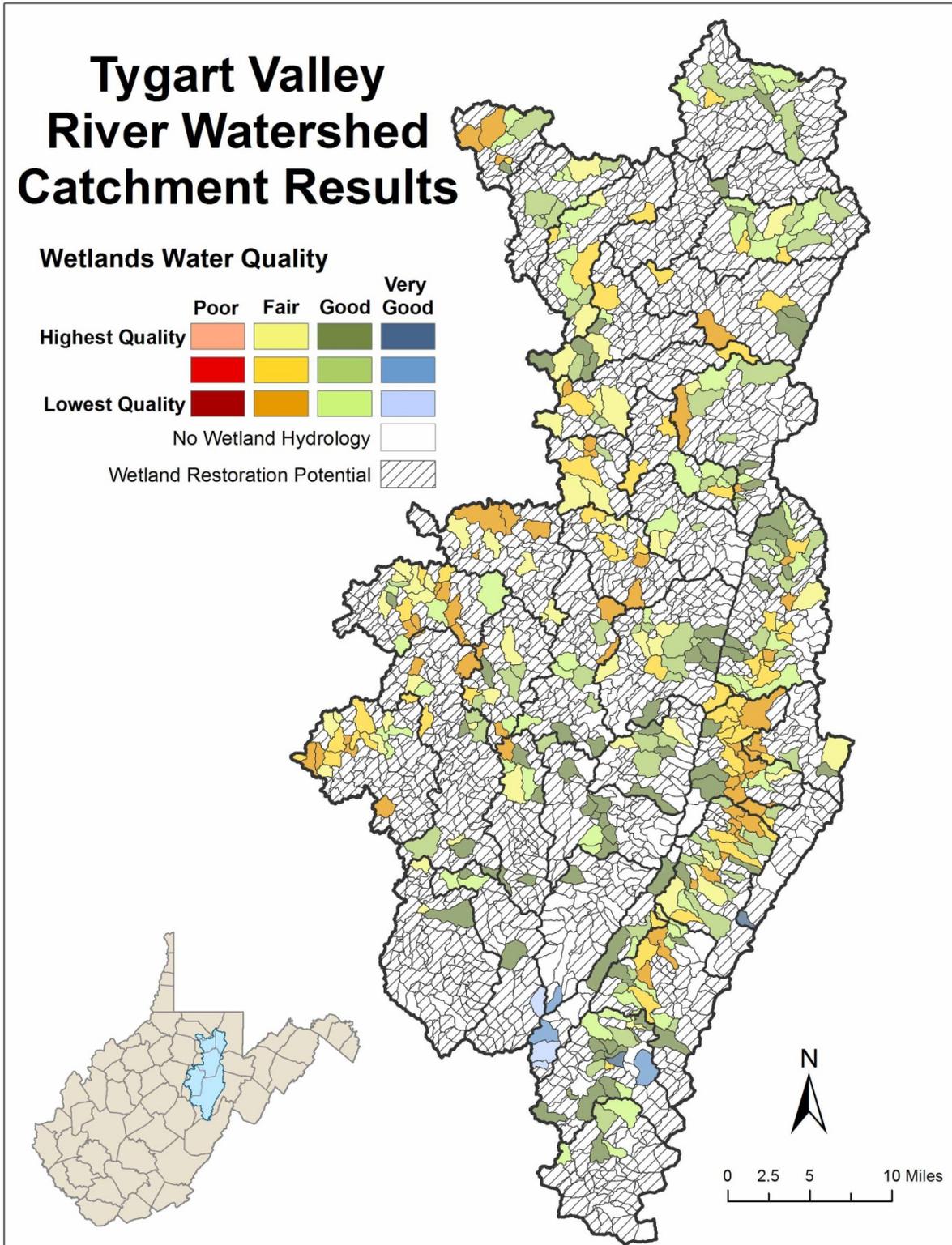


Figure 25b. Wetlands Water Quality Index Results – Catchment Level

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There is a general lack of variability in the Wetlands Hydrology (WHY) index results (Figures 26a and 26b). This index is designed primarily to identify areas with extensive and well-connected existing wetlands, or areas that have no mapped wetlands but have the potential for restoration of lost wetlands due to the presence of hydric soils and floodplain area. All of the WHY metrics are presence/absence, meaning the metric will receive a Good score if it has a value, and a Fair if it does not. The Tygart Valley watershed has mapped wetlands in every HUC12, as well as hydric soils and floodplain area, so all of the HUC12s received a Good WHY score. The greater variability at the catchment level is explained by the fact that some of the catchments do not have existing mapped NWI wetlands, therefore most of the Fair catchments have only hydric soils and floodplain area, indicating that they may be good candidates for restoration. Those catchments that have neither mapped NWI wetlands nor wetland hydrology are symbolized by white areas on the results map, and are not appropriate areas for wetland activities.

The Wetlands Biodiversity (WBD) index has only four metrics, three of which are presence/absence. Fair HUC12s therefore either have fewer terrestrial habitat types or more recorded non-native invasive species occurrences than higher-scoring HUC12s (Figure 27a). The Good HUC12s are generally the result of the presence of rare species, or occasionally the absence of invasive species. The four Very Good HUC12s all have many northeast habitat types (scoring a Very Good for that metric), contain at least some calcareous bedrock, and include no non-native invasive species. The same trends apply to the catchment level results (Figure 27b). As mentioned previously, it is recommended that individual metrics within the WBD index are evaluated closely to determine which metric(s) most influenced the index score.

The Wetlands Wetland Habitat (WWH) index results have more variability and lower scores than other Wetlands indices (Figures 28a and 28b), and generally lower scores overall, with most HUC12s scoring in the Fair category. Metrics in this index are based on the 50m wetland buffer and are only calculated for planning units with mapped NWI wetlands. At the HUC12 level, Very Good and Good planning units all had high percentages of natural cover within the wetland buffer, and minimal other land uses, with only some instances of grazing and a few roads and railroads. The WWH index includes two critical metrics, development and active surface mining – for HUC12-level planning units, development in the wetland buffer was the critical metric determining all of the Fair results. Similarly, catchment level results were often driven by the critical metrics, with all of the Fair catchments also scoring Fair in the development metric, and both of the Poor catchments scoring Poor in the active surface mining in the wetland buffer metric. However, many of the Very Good catchments have almost 100% natural cover, and may be good candidates for protection, particularly in conjunction with other high-scoring Wetlands index results.

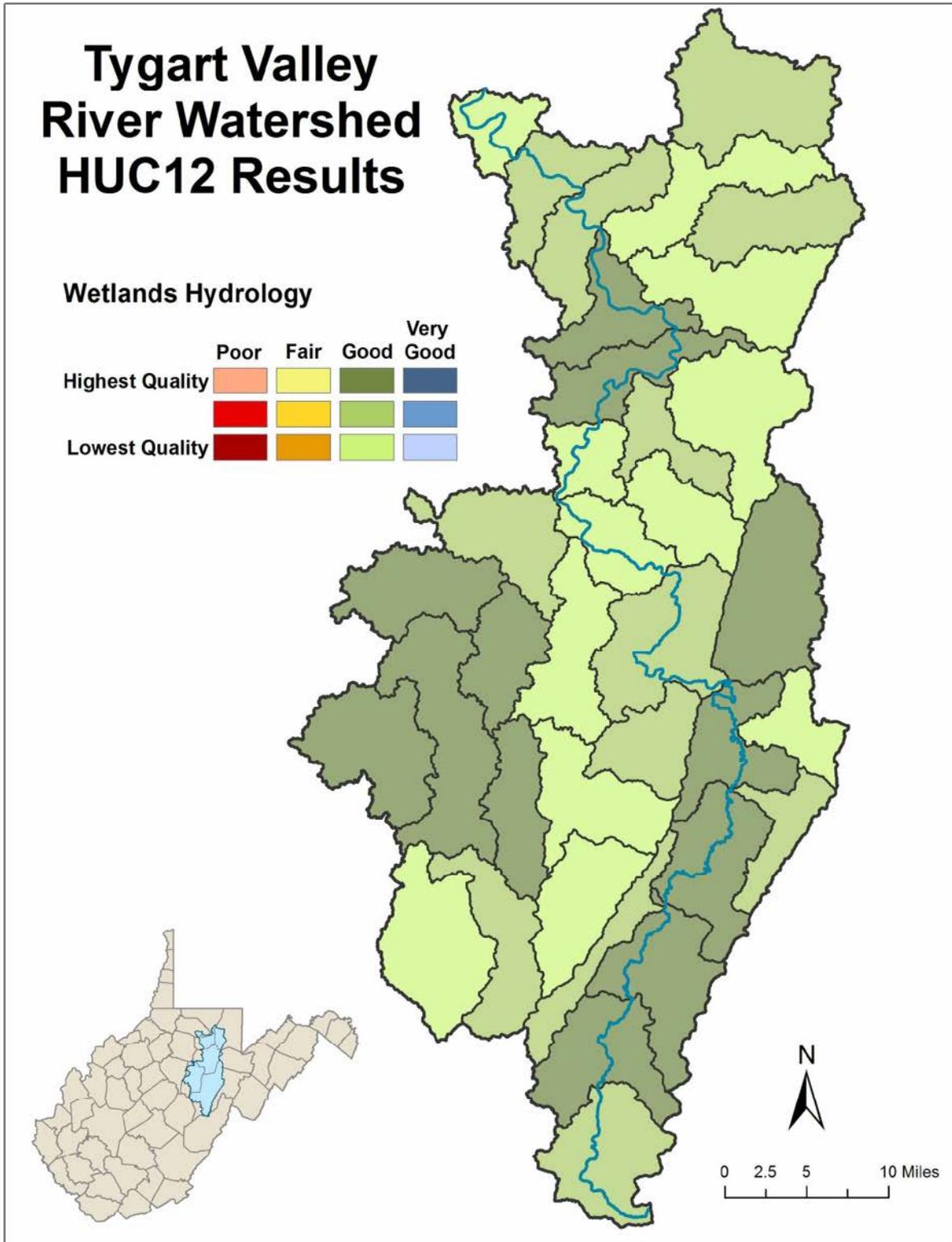


Figure 26a. Wetlands Hydrology Index Results – HUC12 Level

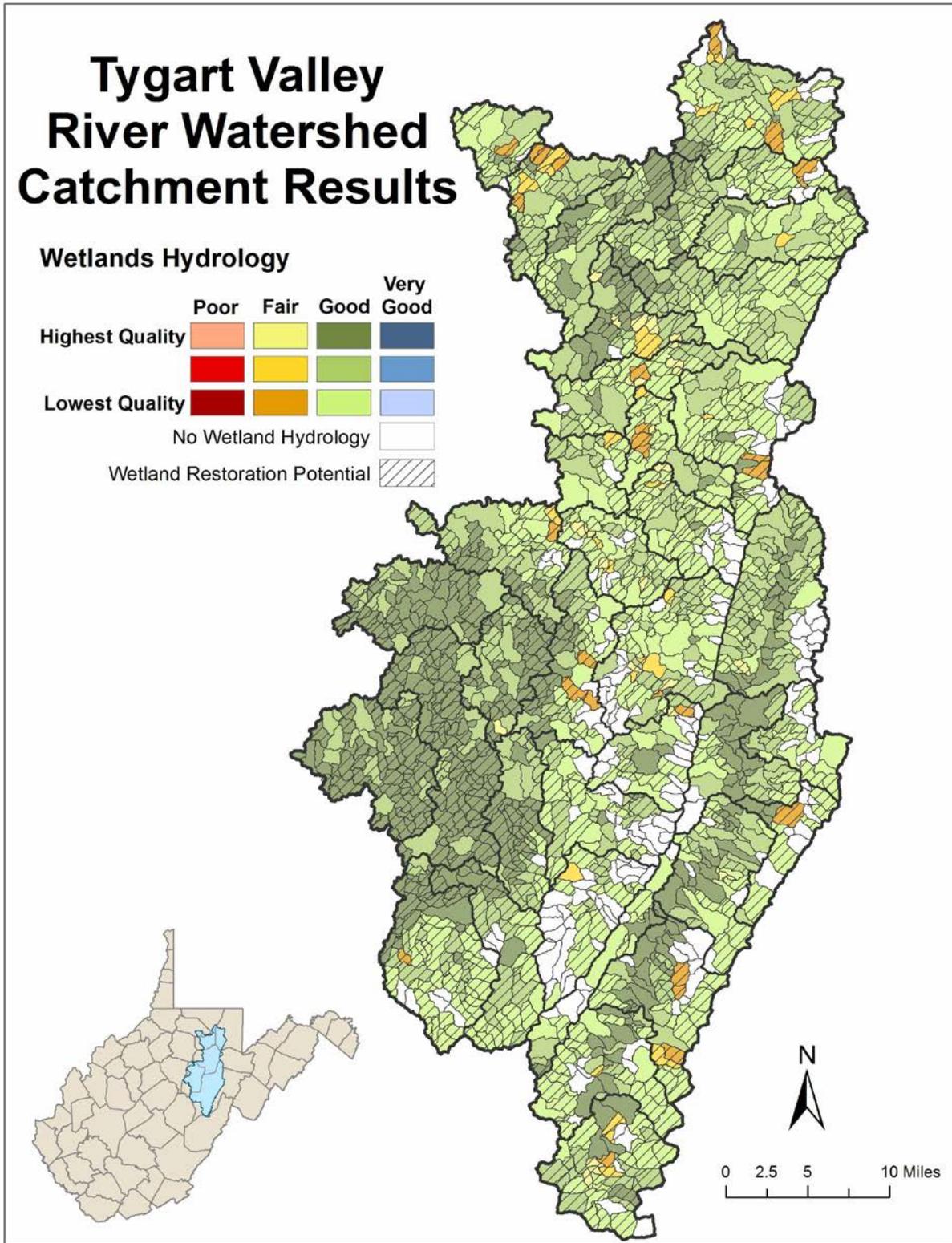


Figure 26b. Wetlands Hydrology Index Results – Catchment Level

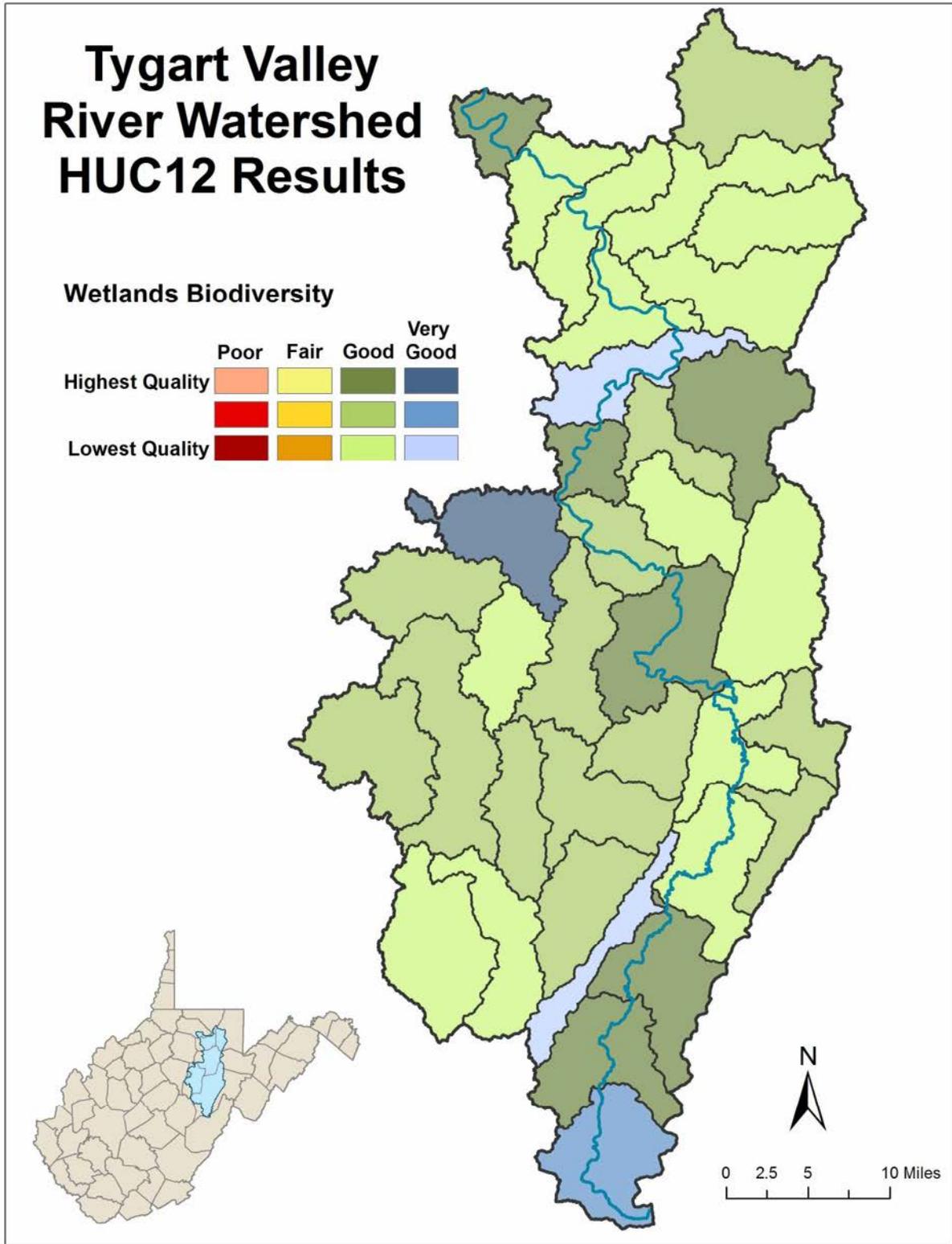


Figure 27a. Wetlands Biodiversity Index Results – HUC12 Level

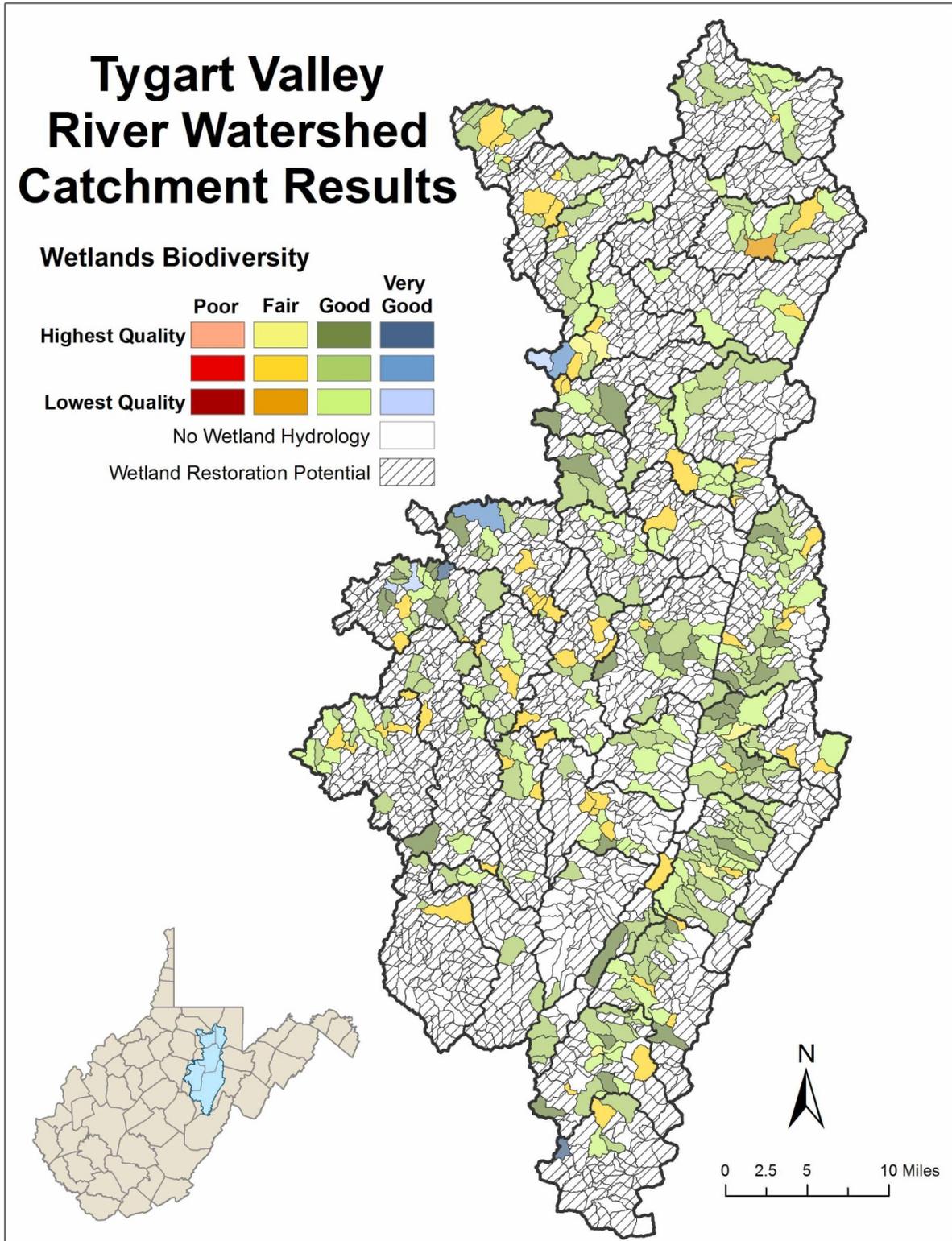


Figure 27b. Wetlands Biodiversity Index Results – Catchment Level

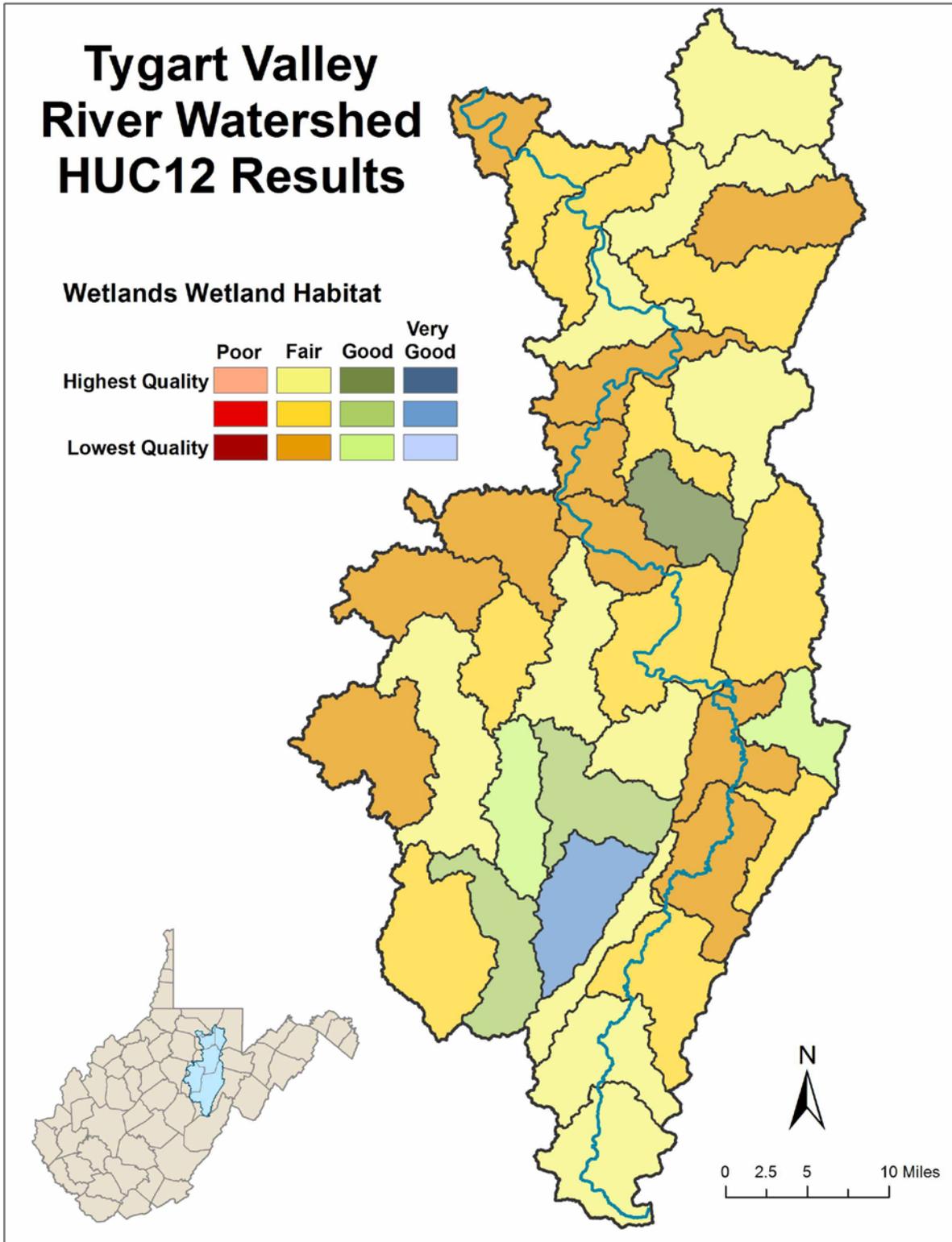


Figure 28a. Wetlands Wetland Habitat Index Results – HUC12 Level

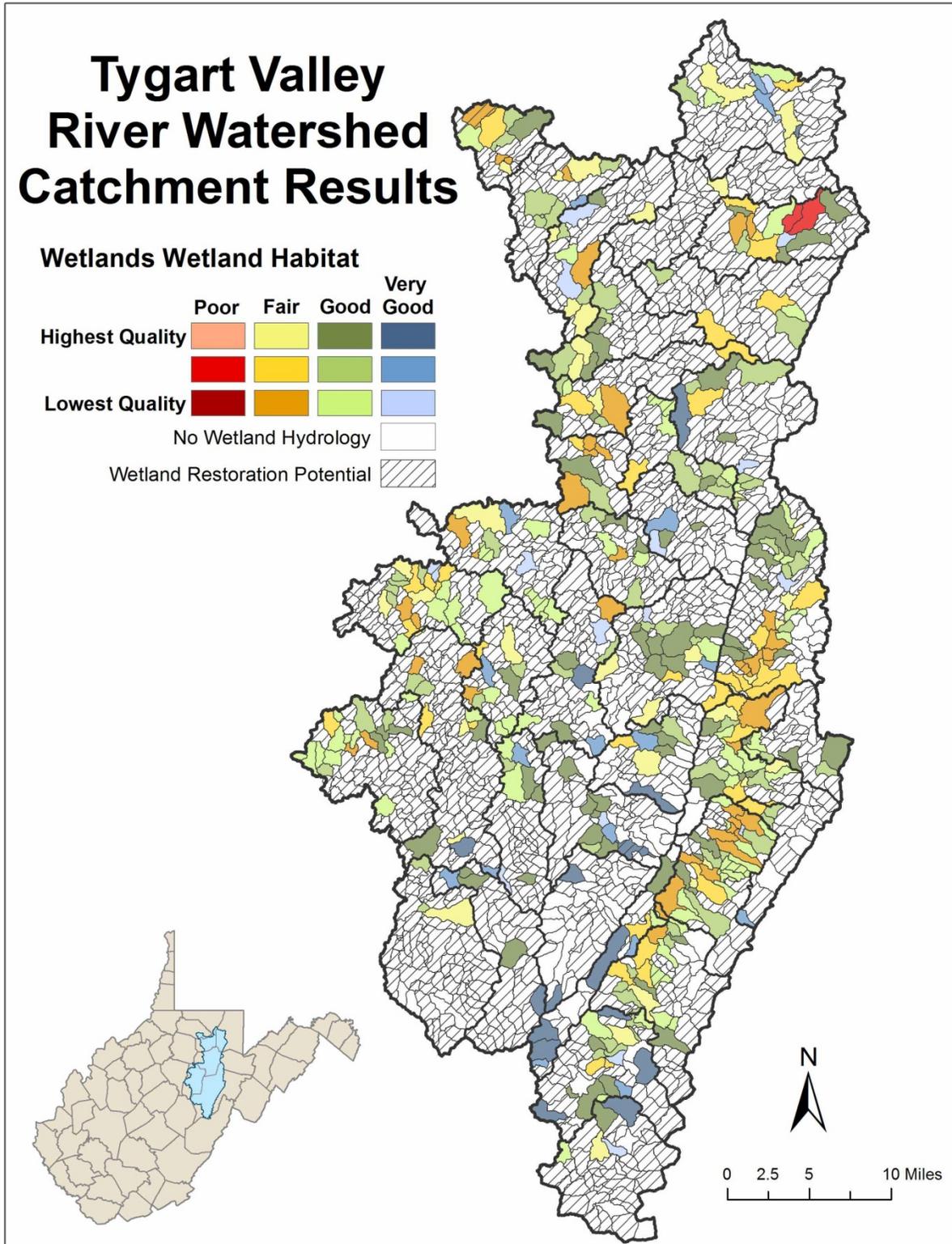


Figure 28b. Wetlands Wetland Habitat Index Results – Catchment Level

4.1.3 Uplands

The Uplands Priority Model Overall results exhibit the same general geographic trends as the Streams and Wetlands Models, though results tend to be lower for this model. At the overall level, HUC12s in the southern part of the watershed scored in the Good category, with Elkwater Fork and Ralston Run being the highest quality planning units (Figure 29a). Uplands metrics are based mostly on existing land use and land cover and the presence of fragmenting features. HUC12s in the Poor category are generally in the more developed areas of the watershed, and thus have higher impervious cover scores, lower scores for most land use metrics, and a greater density of features such as roads, railroads and wells. These geographic trends are even more apparent at the catchment level (Figure 29b), with Poor catchments clustered around the towns in the watershed, and Very Good and Good catchments in the southern headwaters areas of the watershed, characterized by significantly less development and more protected lands.

The Uplands Habitat Connectivity (UHC) index results are very similar to the Overall model results, with just minor variations in quality within a category. The UHC index is largely driven by the presence of intact forests and lack of anthropogenic stressors, therefore higher quality areas are generally in the higher elevation headwaters regions, which include protected lands with large forest patches and little development or industrial activity; Figure 30 shows the spatial distribution of the main fragmenting features found in this watershed. Two critical metrics drive the results in the UHC index, development and active surface mining. At the HUC12 level, development determined all of the Fair and Poor scores (Figure 31a). Several UHC metrics have presence/absence thresholds only (energy transmission lines, pipelines, wind turbines, and timber harvesting), which means that if that feature is absent the metric receives a Good score, and a Fair score if it is present. Therefore, many of the Very Good catchments include minimal amounts of fragmenting features and may be good candidates for protection activities; in the Tygart Valley watershed, these higher quality areas are generally within or adjacent to existing protected lands (Figure 31b).

The Uplands Habitat Quality (UHQ) index results are also similar to the Uplands overall model, with higher quality planning units in the south and in the headwaters areas (Figures 32a and 32b). The UHQ has two critical metrics, development and active surface mining, which are the driving metrics for many of the Fair to Poor planning units at both scales. The UHQ is almost completely based on the inherent quality of existing land cover in the watershed, so Very Good catchments have very high percentages of natural cover and high heterogeneity scores, both of which are heavily weighted. Besides the critical metrics, the most significant metrics that tend to lower scores are agriculture and grazing.

The Uplands Biodiversity (UBD) index results (Figures 33a and 33b) generally agree with the trends seen in the Streams and Wetlands Biodiversity indices, though the UBD results have slightly lower scores, with almost all Good HUC12s and just one Fair HUC12 (Lower Middle Fork River). This is due to an additional metric in the UBD index for uplands compared to streams or wetlands, the predicted percent tree basal area loss due to pests and pathogens. The one Fair HUC12 and isolated pockets of Fair catchments are in areas where the percent loss metric is the highest, indicating a greater threat to forest loss from pests and pathogens.

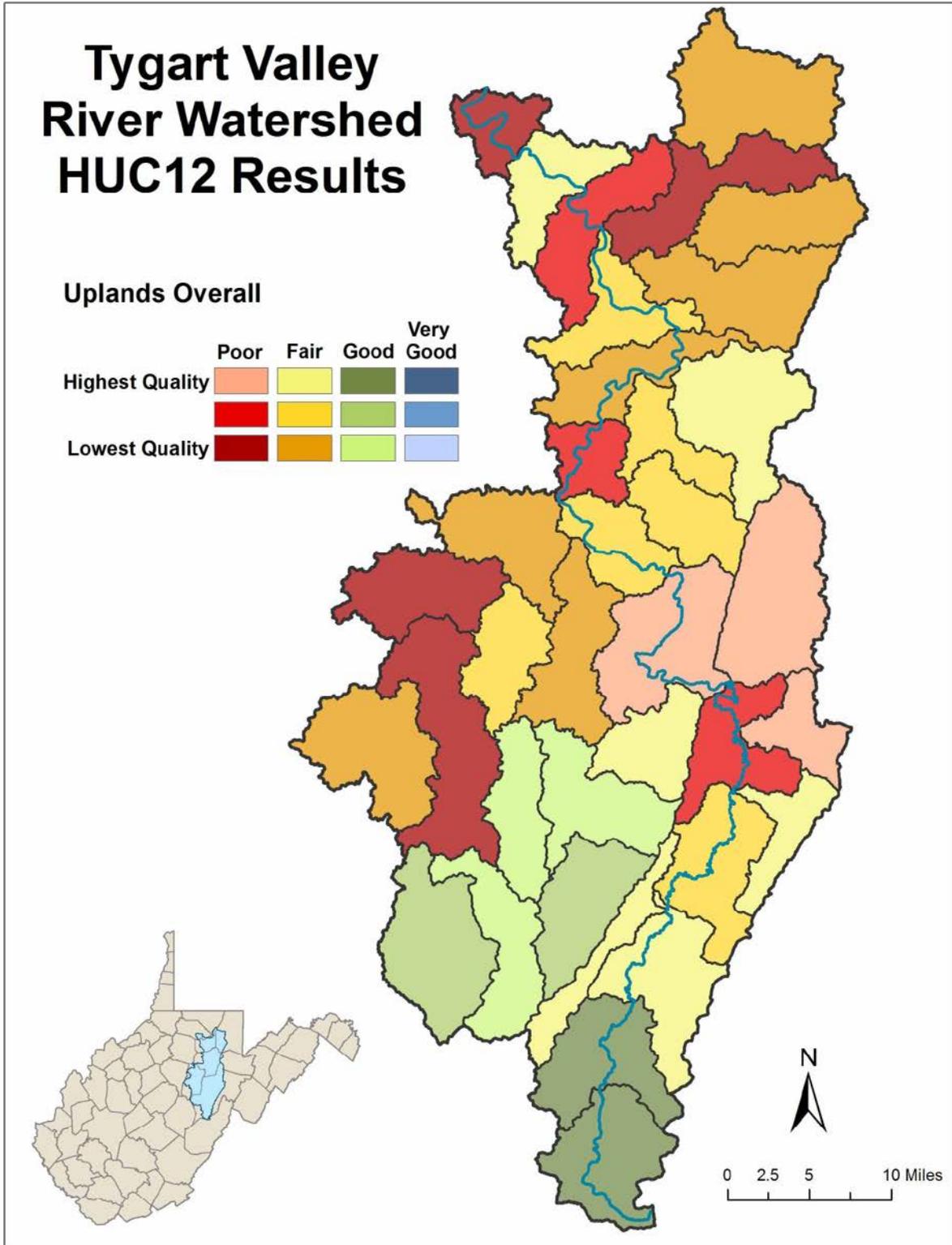


Figure 29a. Uplands Overall Results – HUC12 Level

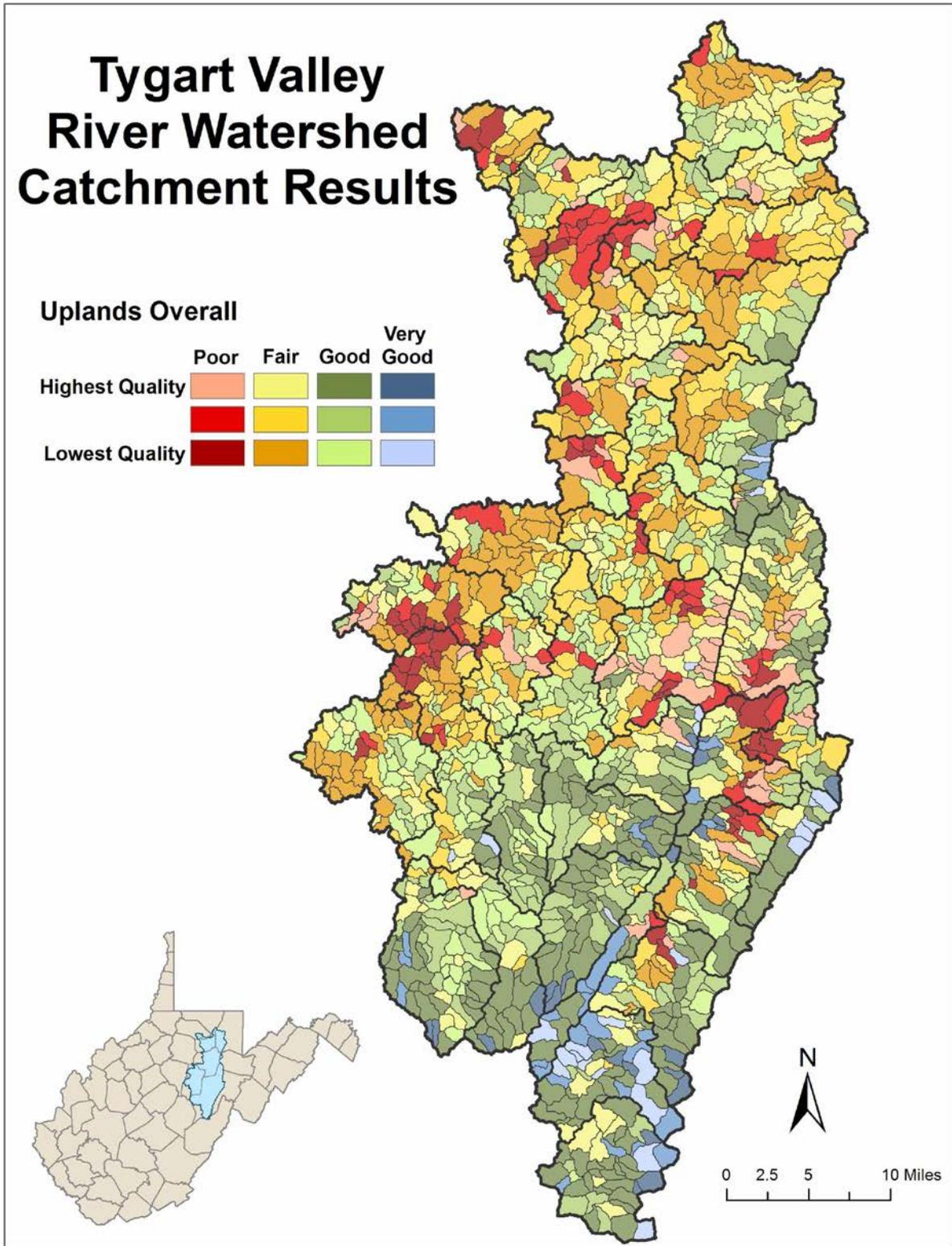


Figure 29b. Uplands Overall Results – Catchment Level

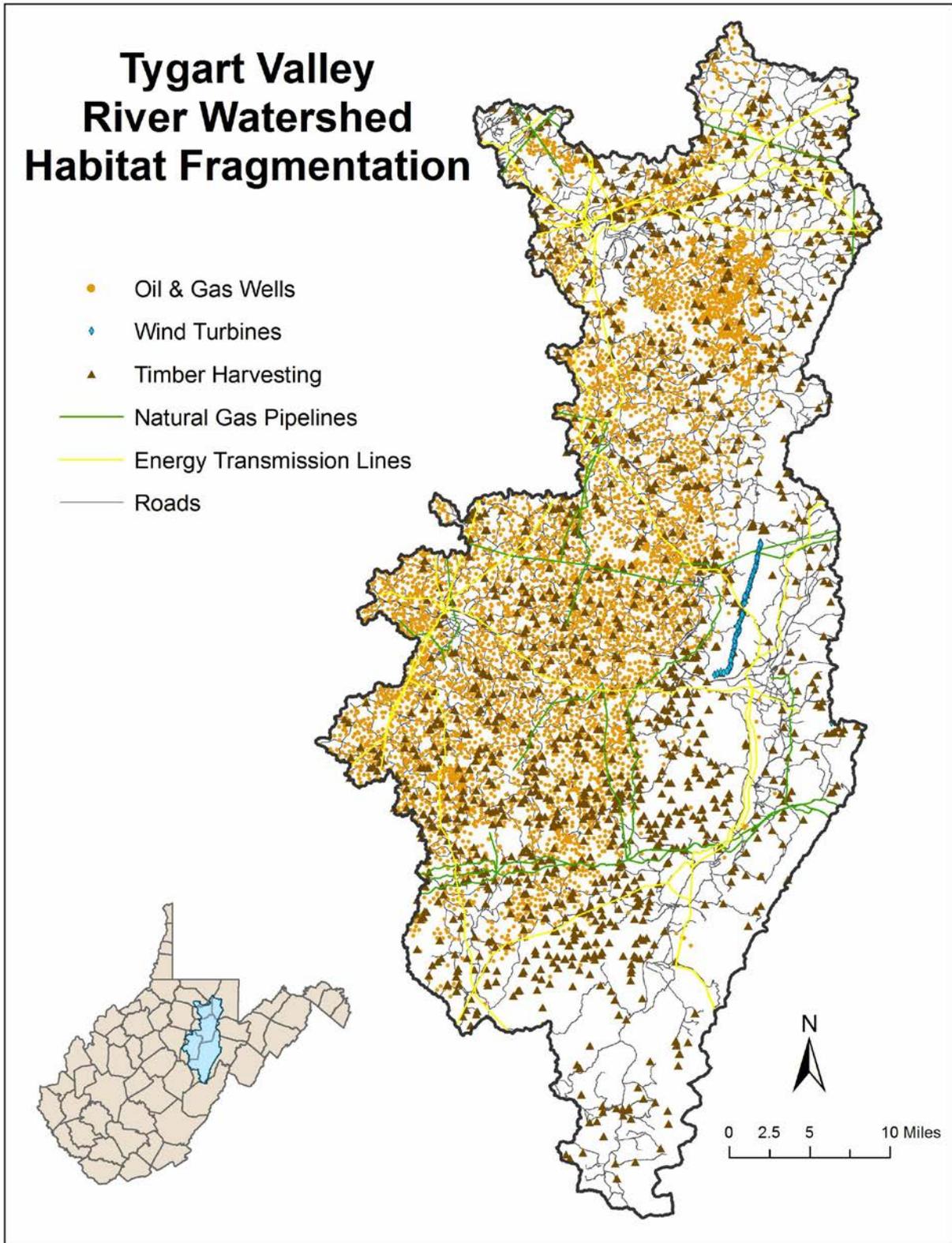


Figure 30. Tygart Valley River Watershed – Habitat Fragmentation

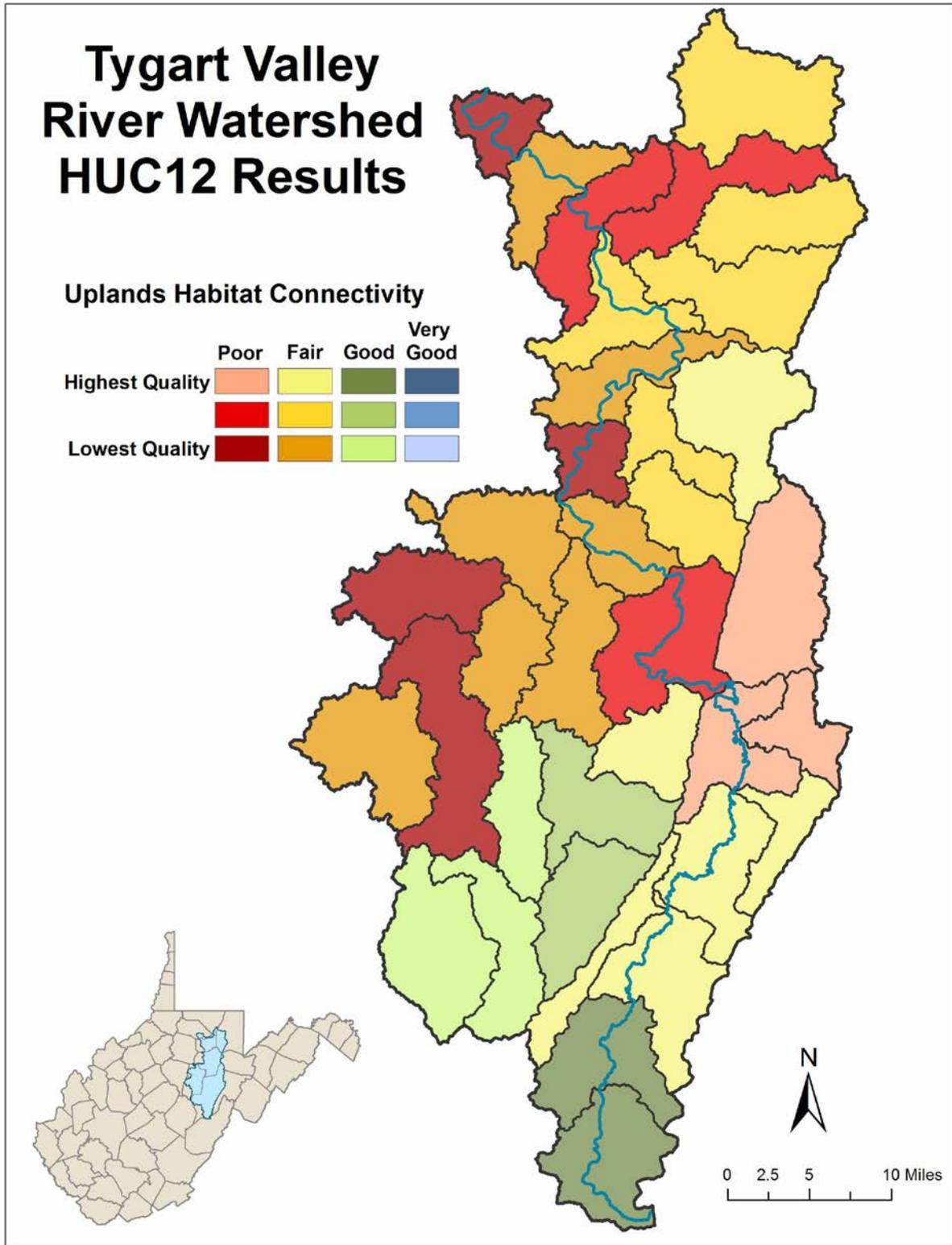


Figure 31a. Uplands Habitat Connectivity Index Results – HUC12 Level

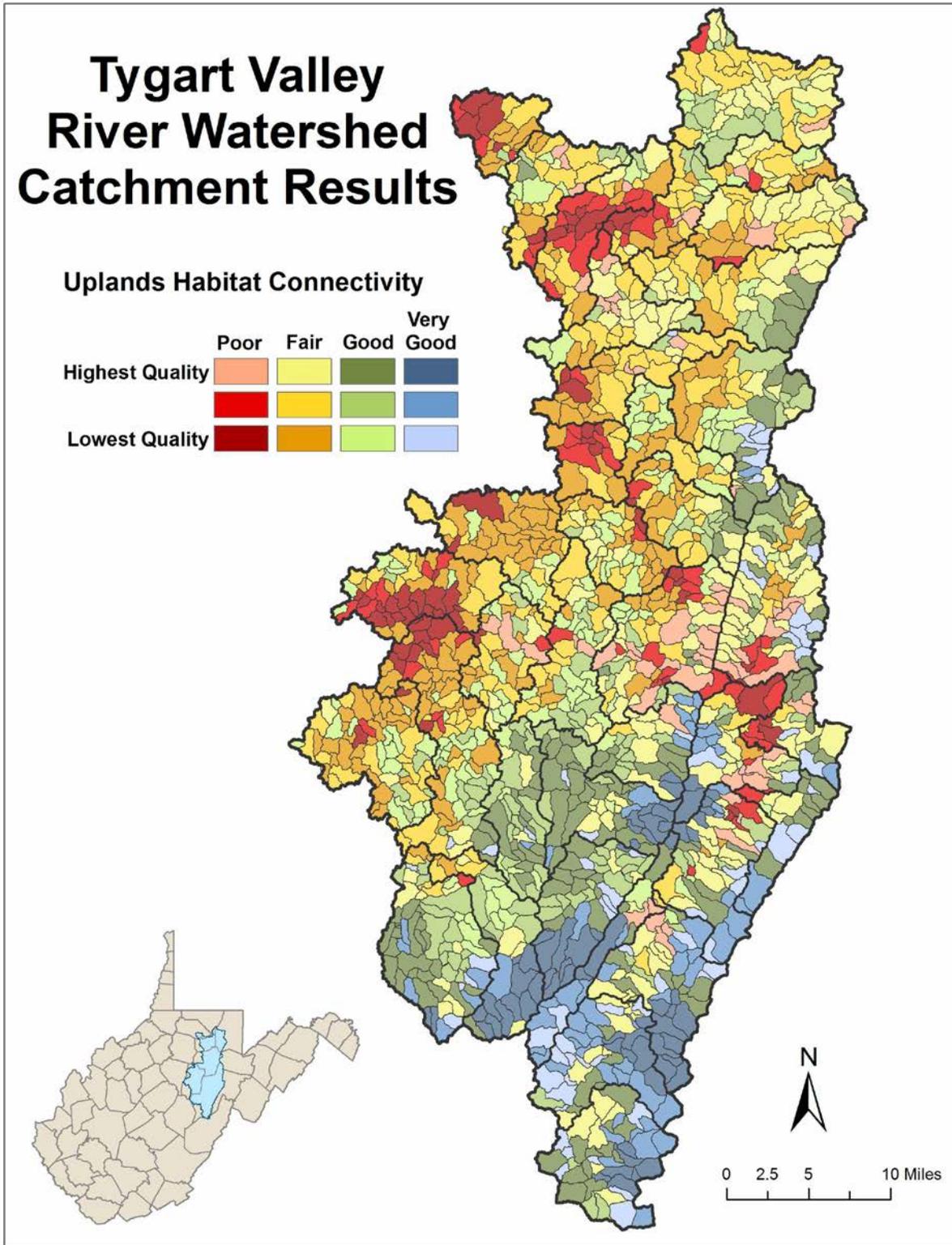


Figure 31b. Uplands Habitat Connectivity Index Results – Catchment Level

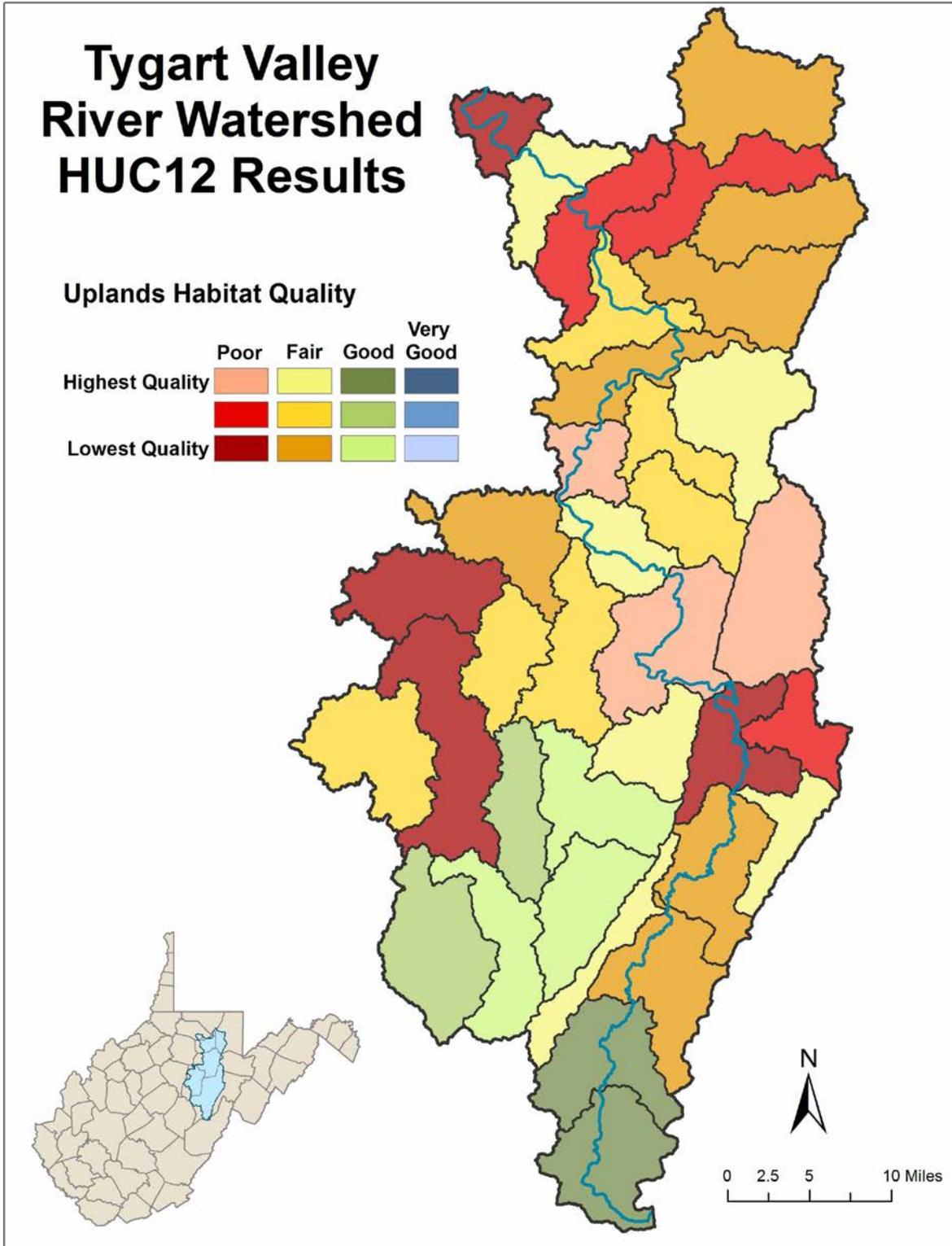


Figure 32a. Uplands Habitat Quality Index Results – HUC12 Level

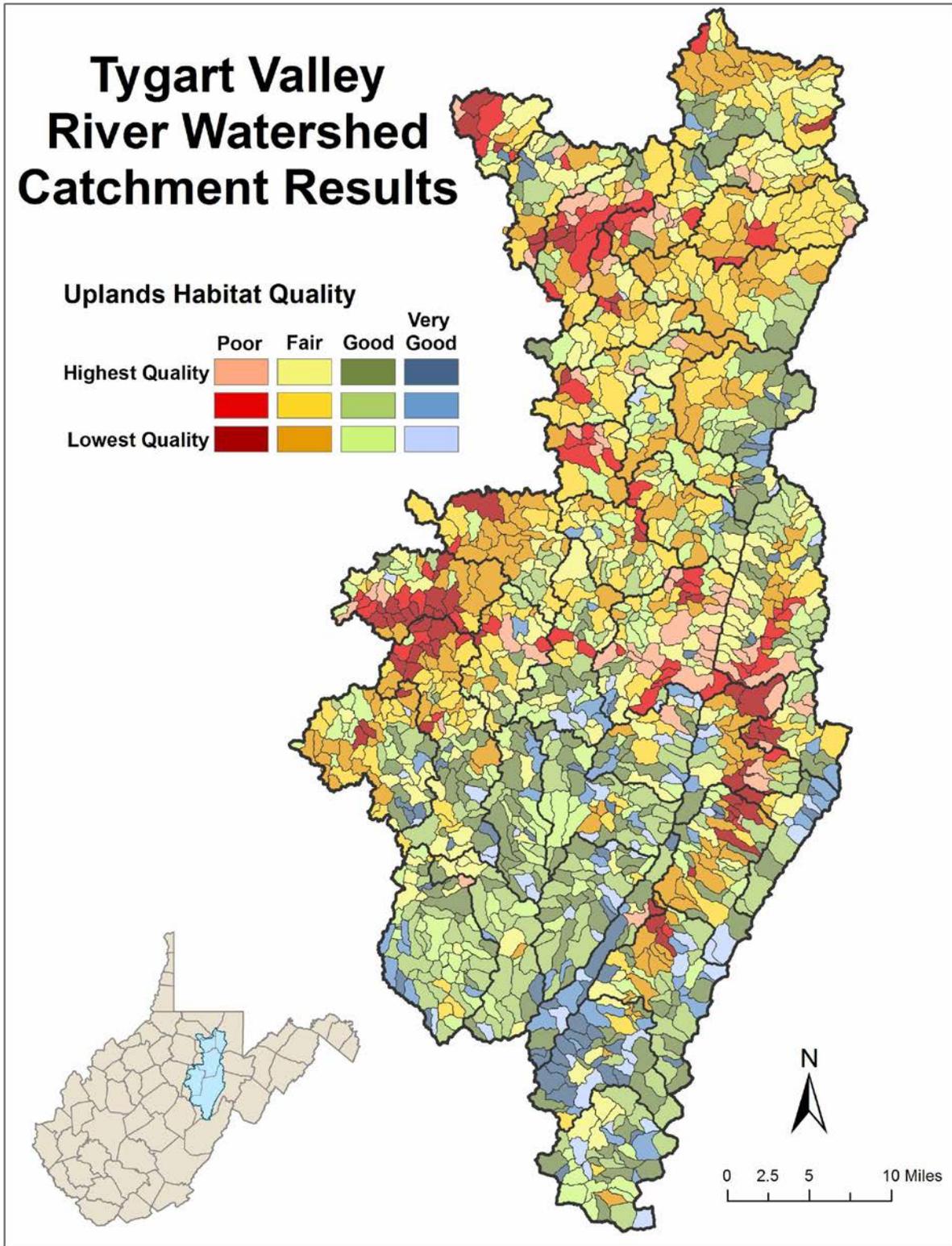


Figure 32b. Uplands Habitat Quality Index Results – Catchment Level

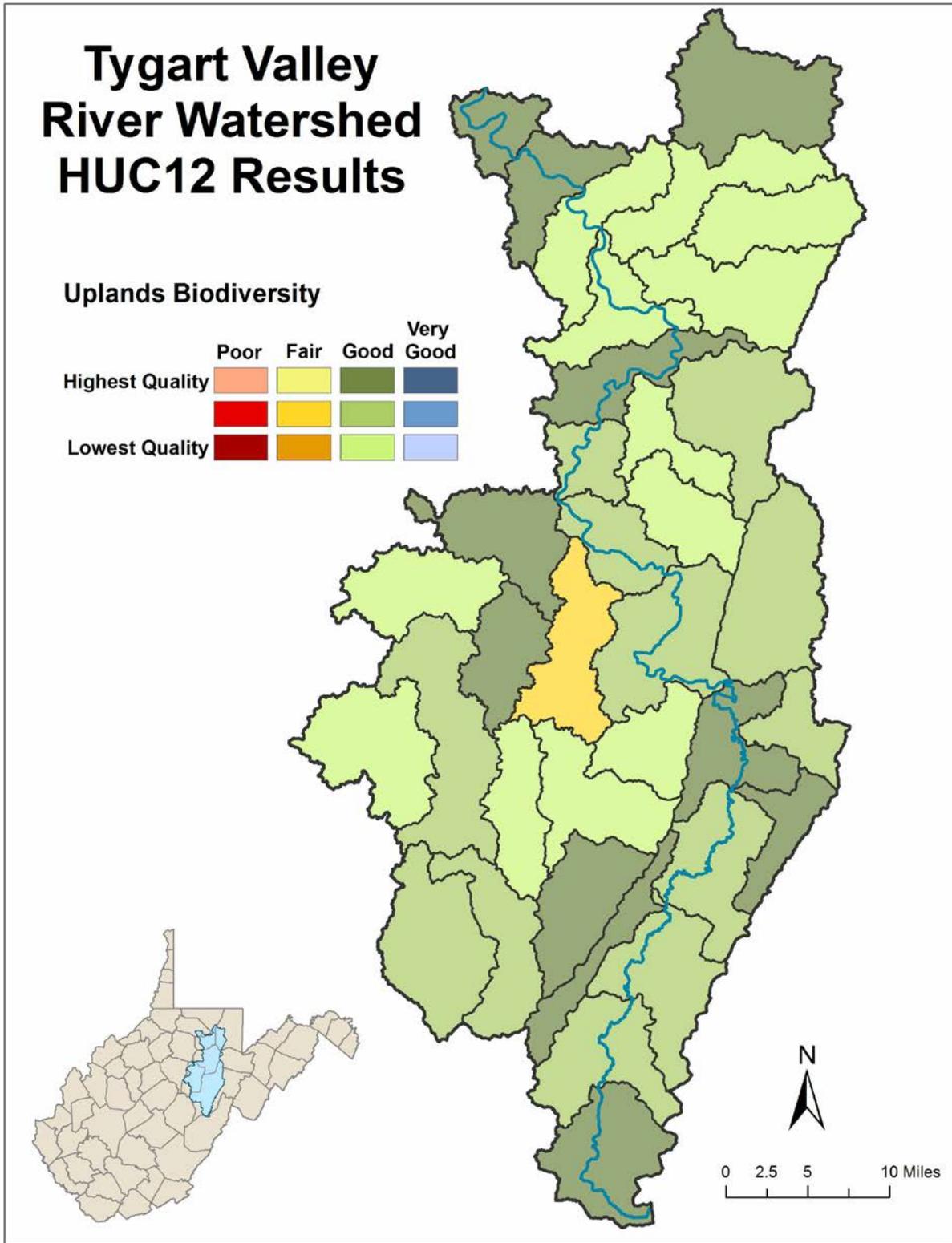


Figure 33a. Uplands Biodiversity Index Results – HUC12 Level

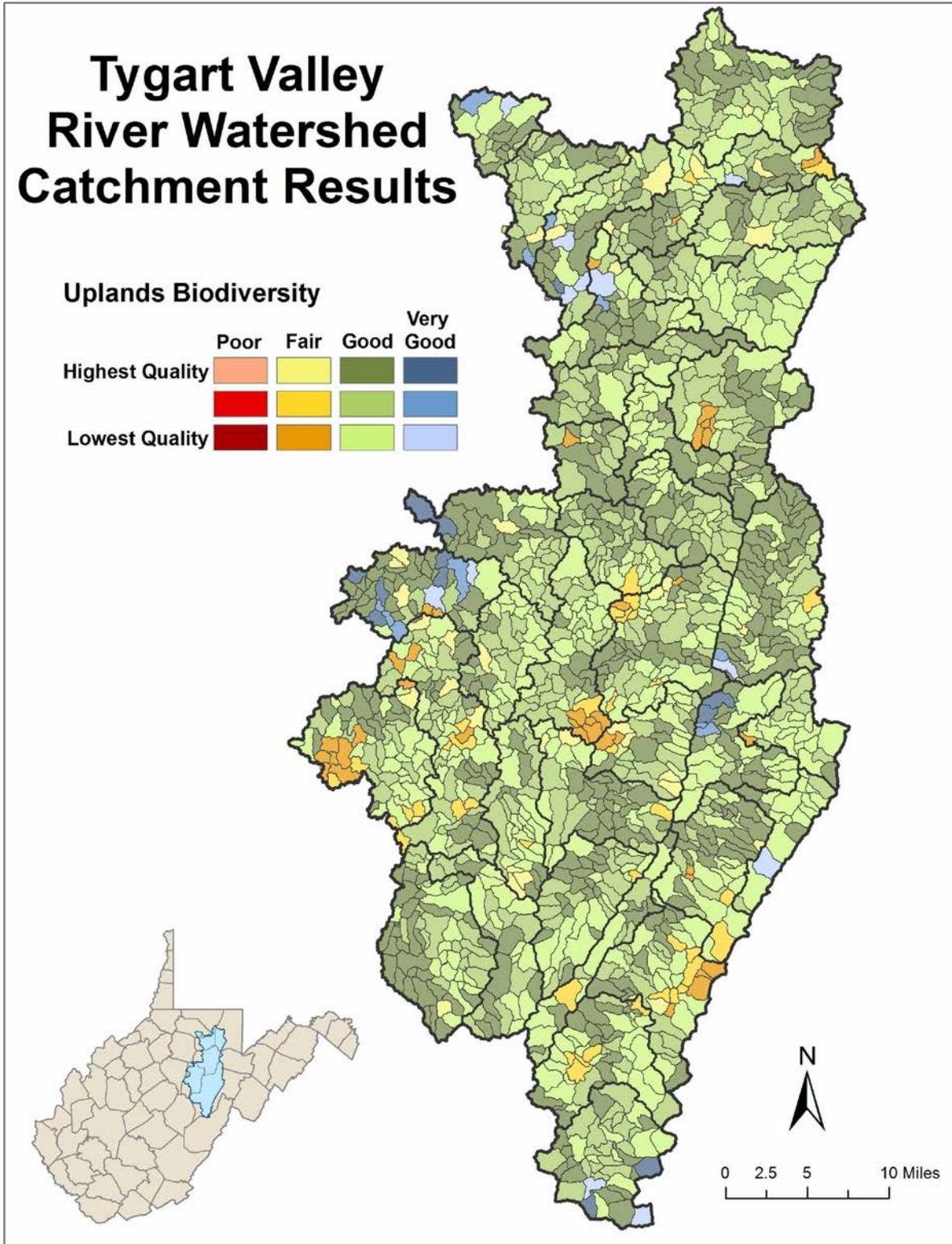


Figure 33b. Uplands Biodiversity Index Results – Catchment Level

4.2 Consolidated Analysis Results and Discussion

The Consolidated Analysis Overall results for the Tygart Valley watershed show varying levels of future threats dispersed across the watershed (Figure 34). The future threats results are primarily influenced by energy development, as data for other threats were scarce for this geographic area. High potential threat areas are concentrated in the northwest section of the watershed, also the geographic area of current mining activity. The southern portion of the watershed, particularly the very south, is largely free from significant future threats, except for small areas of mining and/or potential wind development.

The Consolidated Analysis Energy results show large amounts of variability as the different threat sources are unevenly distributed across the landscape (Figure 35). The southern half and eastern portions of the watershed are not targeted for resource extraction and have the lowest future threats from energy development. Marcellus shale thickness and geothermal potential increases across the watershed, with higher threat levels in the west and lower threat levels in the east. Marcellus well development is unlikely in the far eastern region due to the geology in this part of the watershed. Future threat from coal mining is concentrated mostly within the northwest in areas around existing active surface mining, though areas of unmined coal beds exist throughout most of the northern and central sections of the watershed. The potential for wind energy development follows ridgelines along the central diagonal and southeast edges of the watershed.

Two indices, Population and Development and Climate Change, had data available for only one or two metrics each and are therefore not very robust. It should be noted that county-level population projections for the Tygart Valley watershed show a decrease in population for about half of the counties in the watershed; however, the northern counties are projected to experience increases in population (with Monongalia County having a projected population increase of 26.5%), and contain the fastest growing urban areas in the state (Christiadi 2011). Increasing development is a threat within the northern part of the watershed, particularly around existing developed areas and road infrastructure. The Climate Change metrics Resiliency and Regional Flow indicate lower threat levels (more resilient to the impacts of climate change and with enough connectivity to allow species to adapt within the landscape) along the mountainous ridges of the watershed, particularly along the central diagonal of Laurel and Rich Mountains, and along Cheat Mountain in the southeast (Figures 36 and 37). 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 3.4 Consolidated Analysis.

The Opportunities analysis is not a quantitative analysis, but rather an overlay intended as an aid to conservation action planning, incorporating areas of potential conservation priorities for different agencies as well as lands currently under various degrees of protection by state, federal, and private agencies, which could be expanded on or connected in the future. Over 52,000 acres of protected lands occur in the Tygart Valley River watershed, covering about six percent of the watershed (Table 38). Over

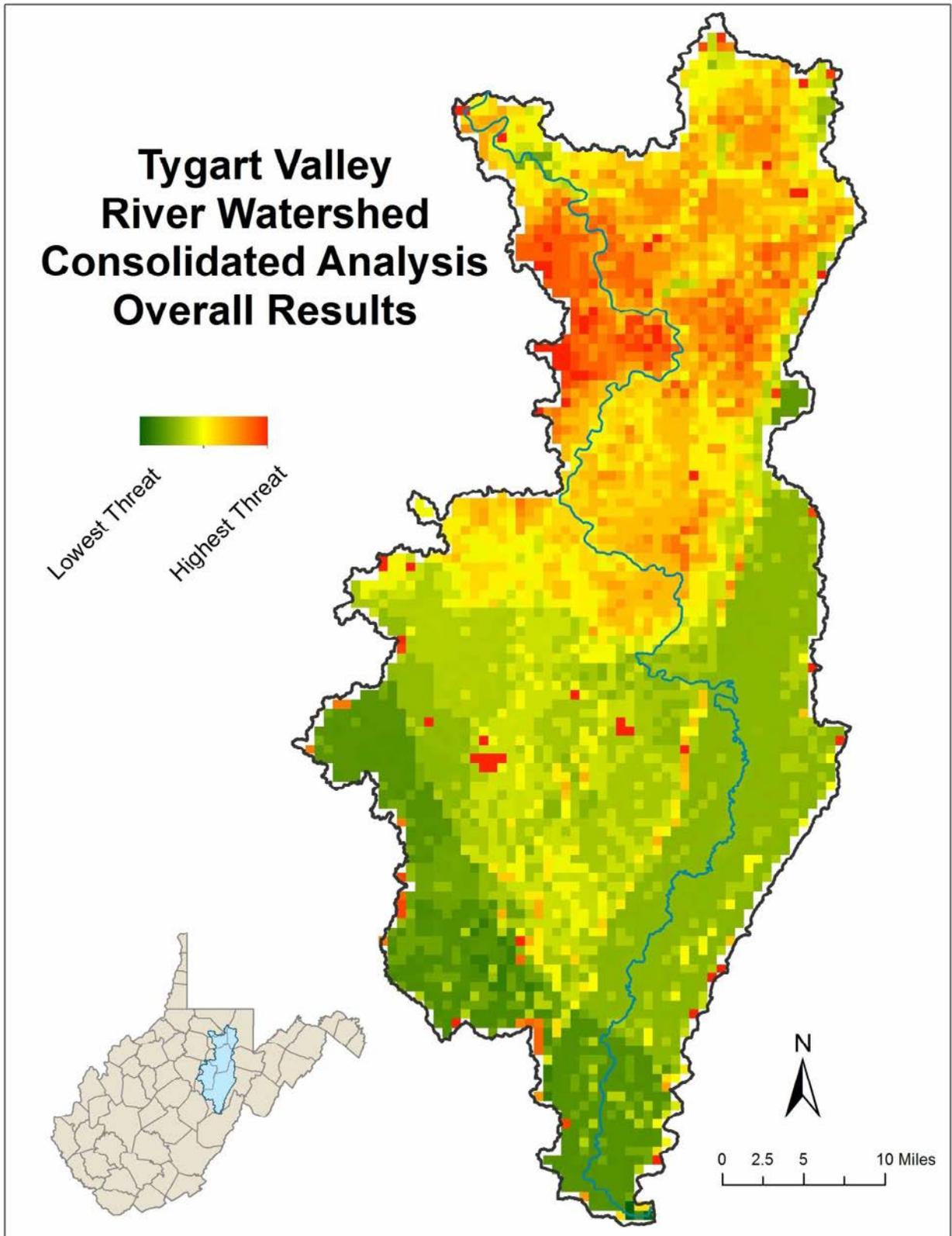


Figure 34. Consolidated Analysis Overall Results

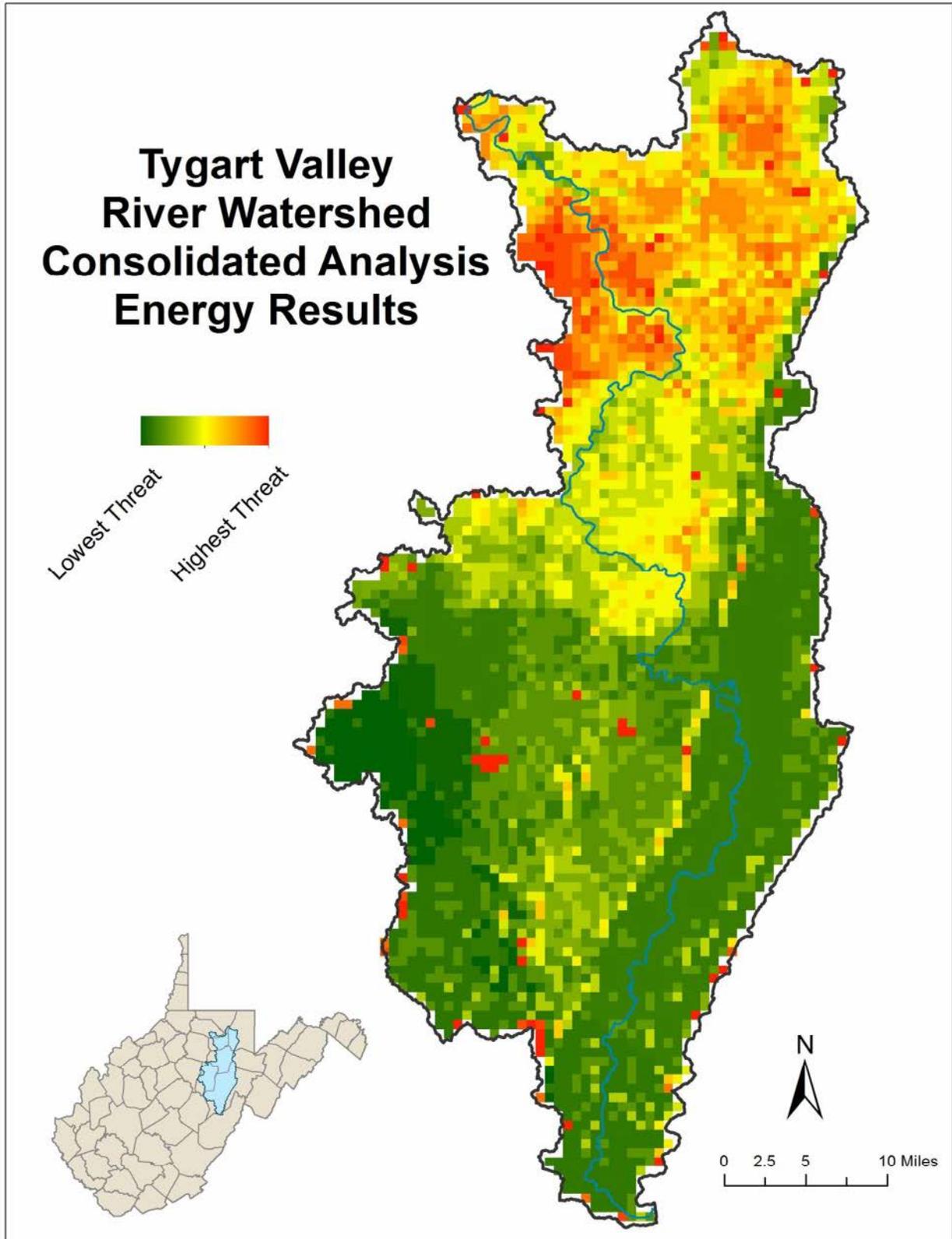


Figure 35. Consolidated Analysis Energy Results

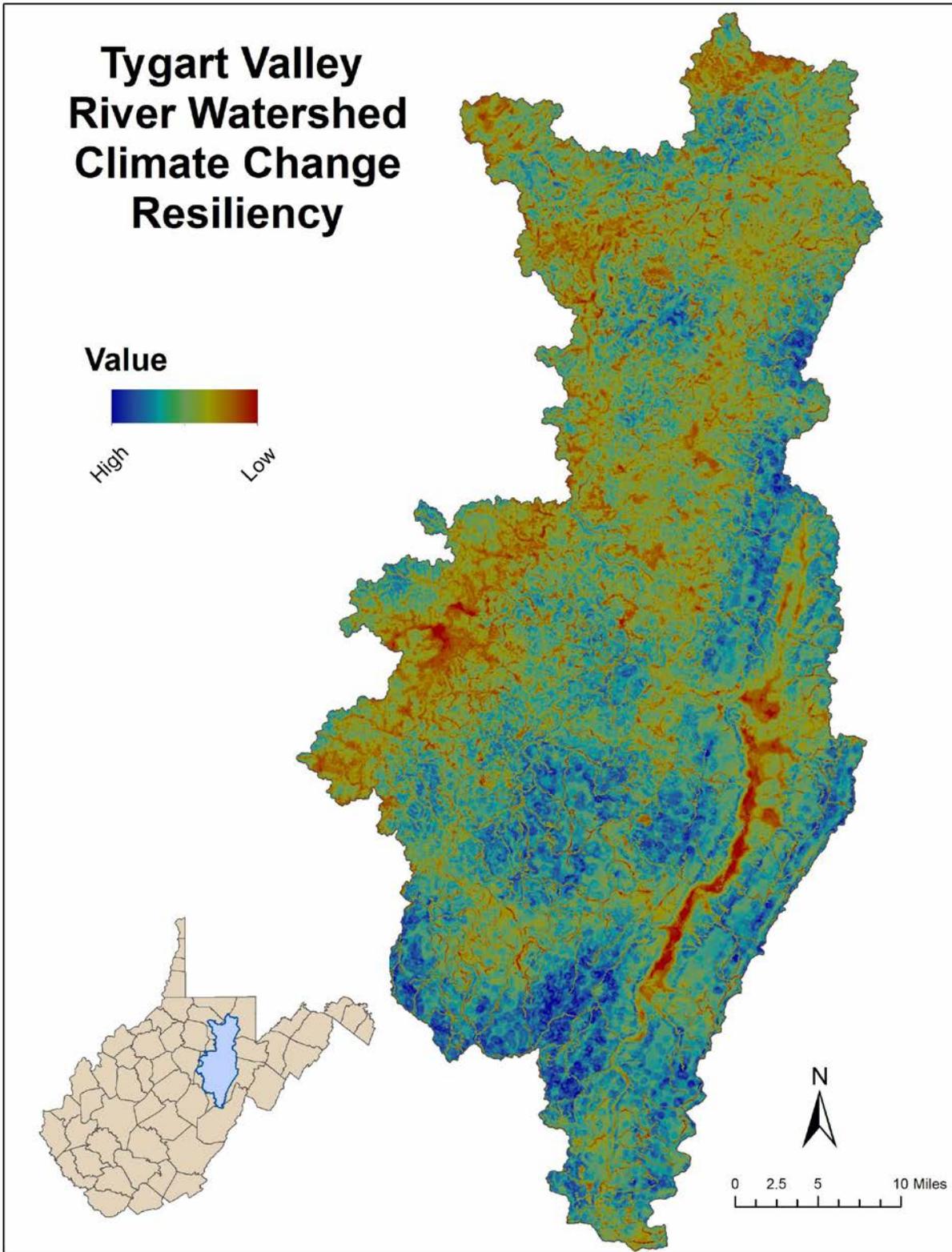


Figure 36. Consolidated Analysis Climate Change – Resiliency (TNC 2012)

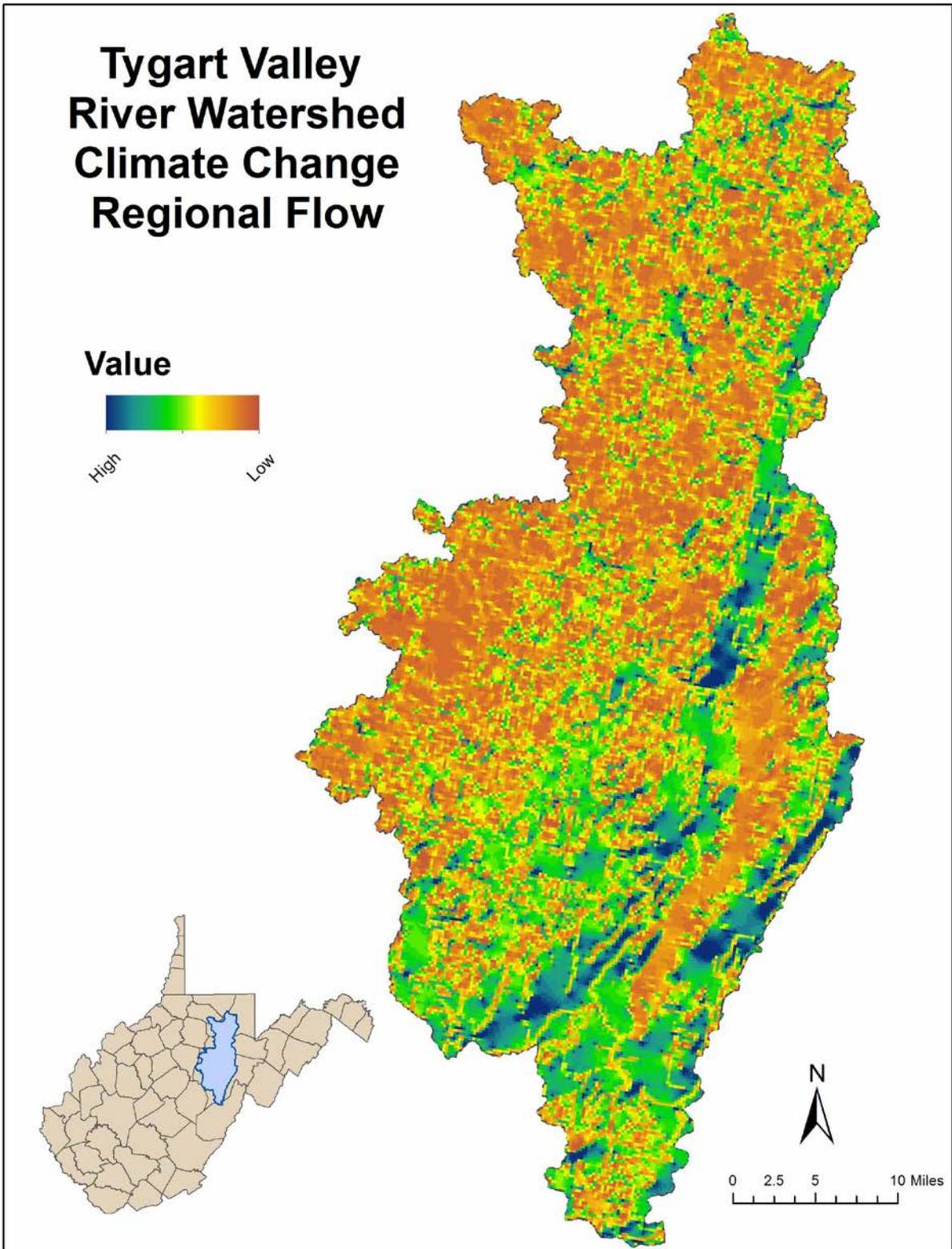


Figure 37. Consolidated Analysis Climate Change – Regional Flow (TNC 2012)

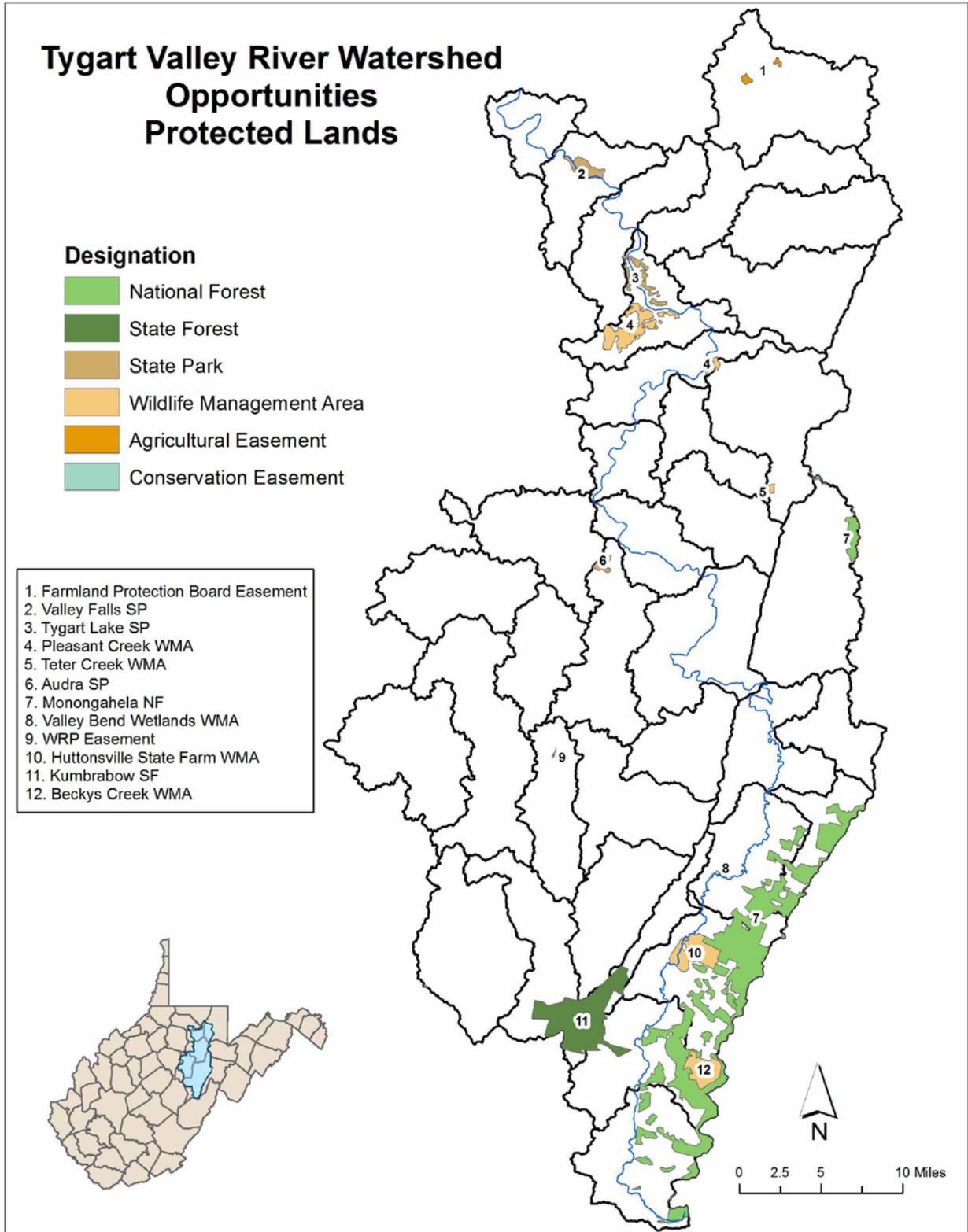


Figure 38. Tygart Valley River Watershed Opportunities – Protected Lands

half of the existing public lands are in the Monongahela National Forest, with about 28,500 acres along the southeastern edge of the watershed. Kumbrabow State Forest covers about 8,700 acres at the very southern tip of the watershed. There are also three popular state parks (Valley Falls, Tygart Lake, and Audra), five wildlife management areas (Pleasant Creek, Teter Creek, Valley Bend Wetlands, Huttonsville State Farm and Beckys Creek) and several easements within the river basin.

Many overlapping priority areas occur within the Tygart Valley River watershed (Figure 39). The Nature Conservancy included most of the upper reach of the Tygart Valley River main stem, the upper reaches of the Buckhannon River, French Creek, and Teter Creek, in their aquatic portfolio. The southern part of the watershed around the currently protected Kumbrabow State Forest and the Monongahela National Forest are also included in TNC's terrestrial portfolio. Over half of the HUC12s (20 out of 36) were identified as priorities by the West Virginia Division of Forestry water quality analysis report, including the Buckhannon River. The southeastern portion of the watershed is within the National Forest Proclamation Boundary of the US Forest Service, identifying lands prioritized for future inclusion within the Monongahela National Forest. These Opportunities datasets are included to encourage collaboration and partnership between agencies and organizations that may have overlapping goals and priorities within the watershed.

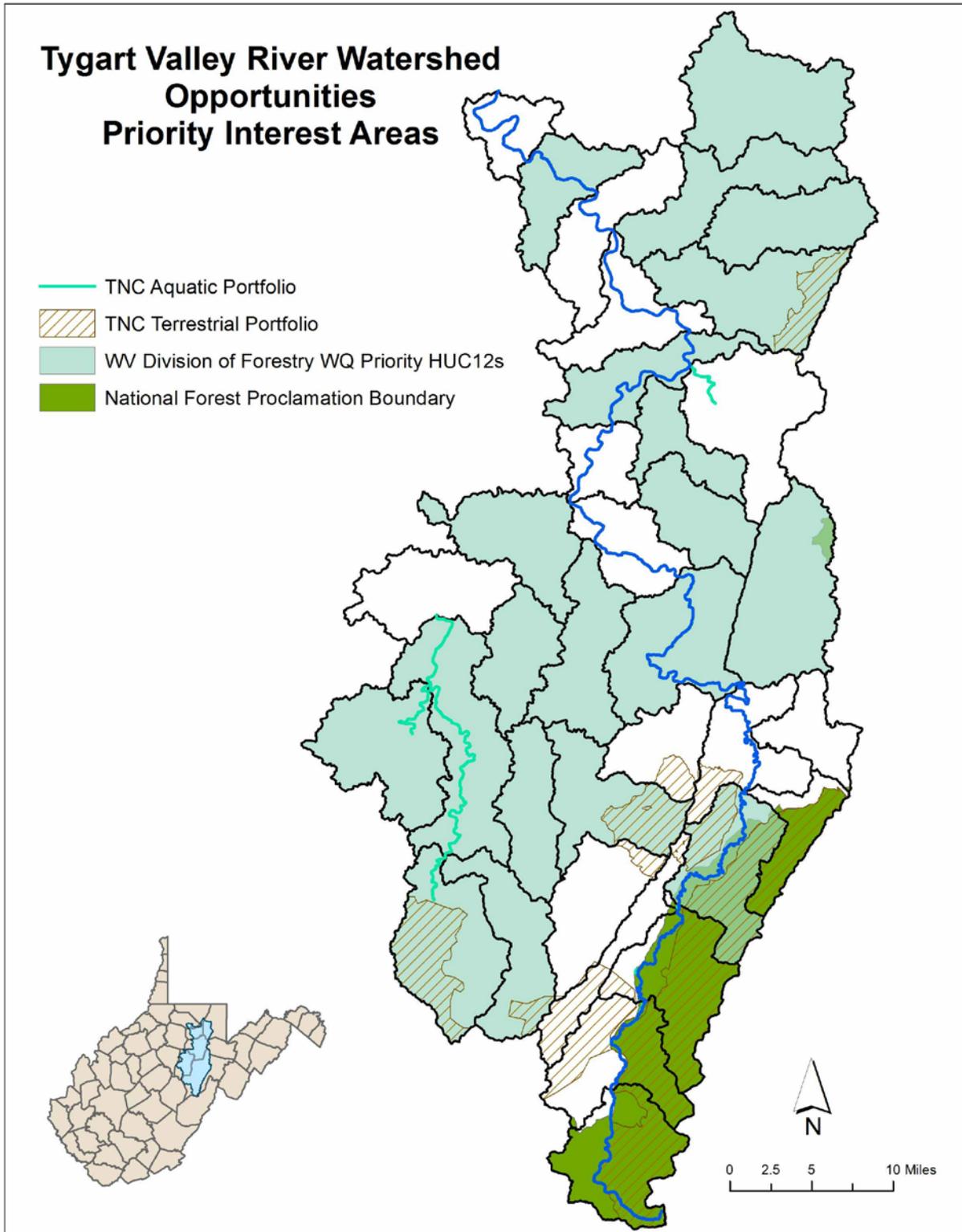


Figure 39. Tygart Valley River Watershed Opportunities – Priority Interest Areas (TNC 2012)

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 40). 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:

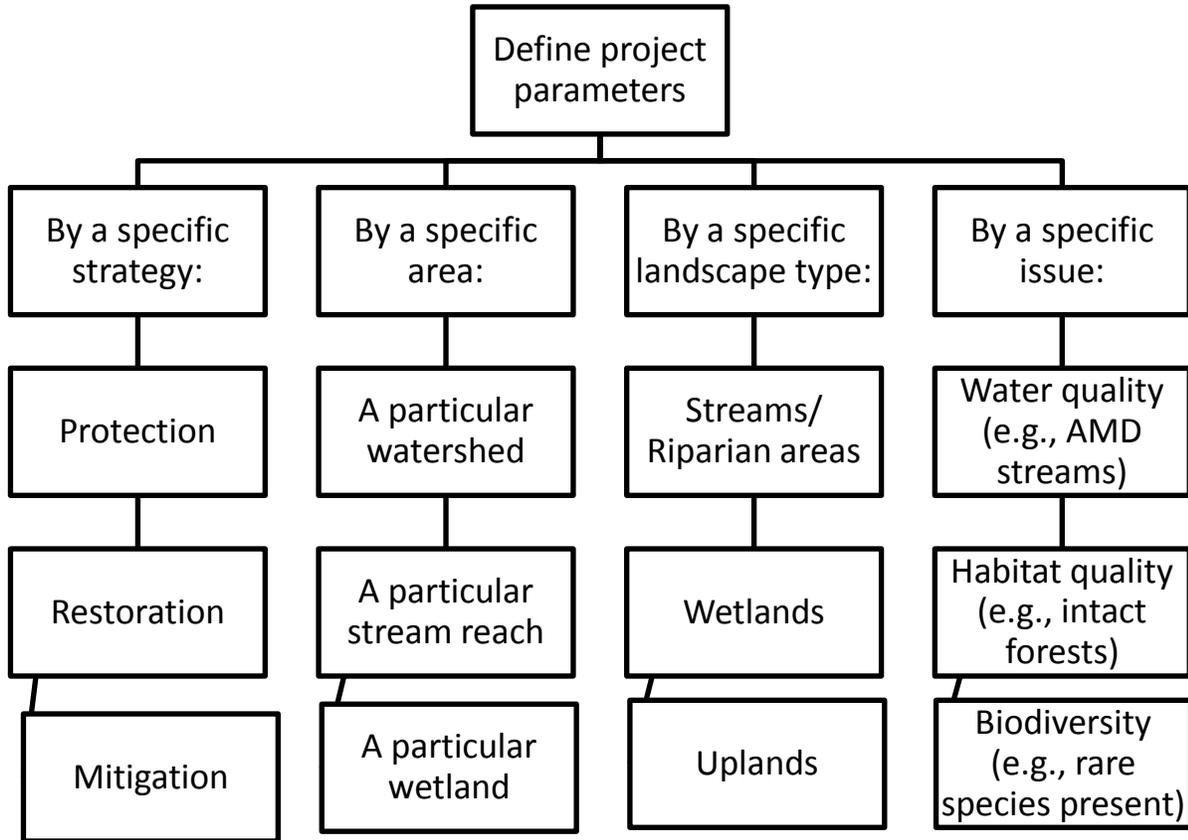


Figure 40. Possible End User Project Parameters

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Step 2: Identify candidate areas for conservation action:

a) Protection Sample Process (Figure 41)

- 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

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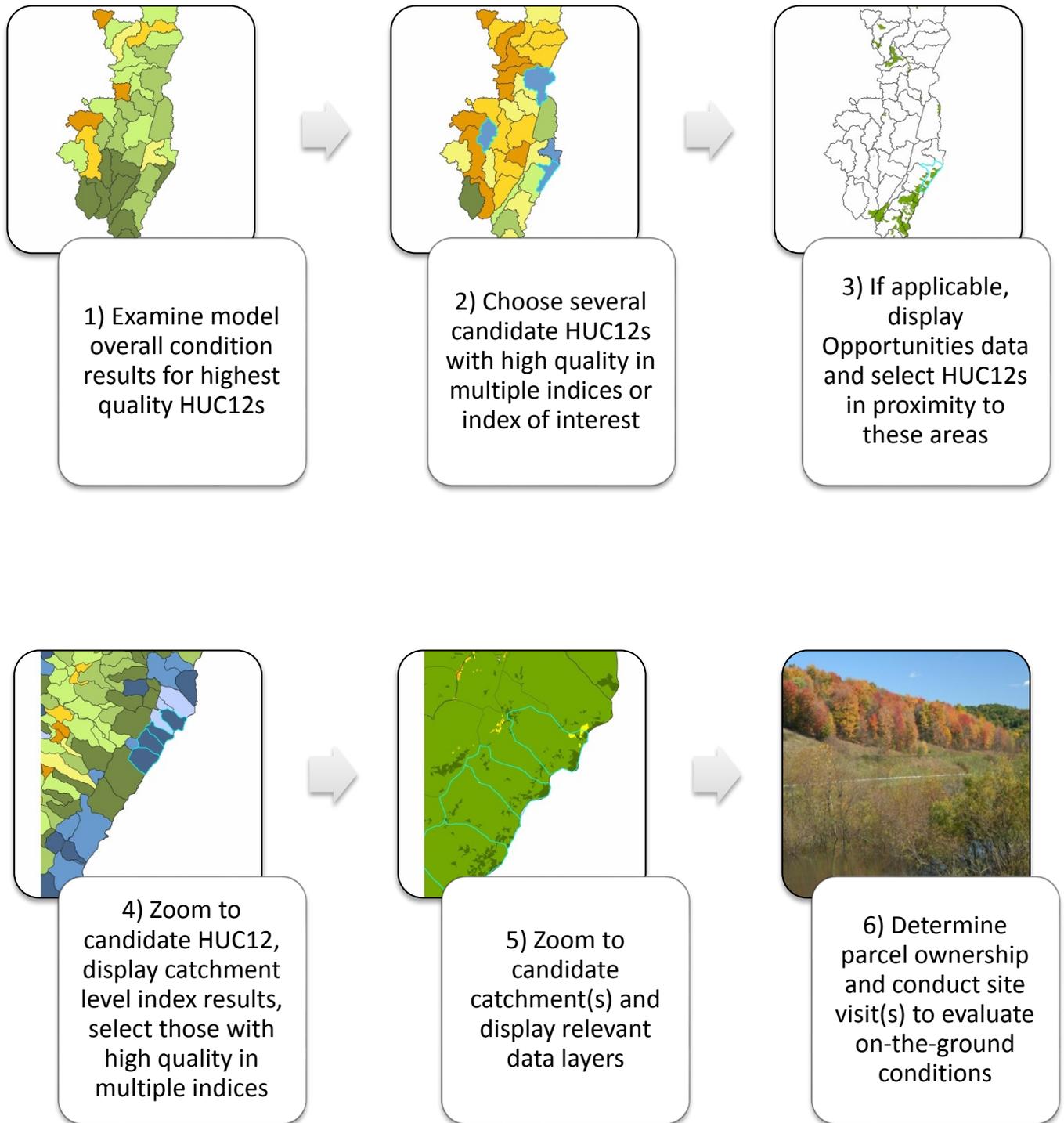


Figure 41. Protection Sample Process Flowchart

b) Restoration Sample Process (Figure 42)

- 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

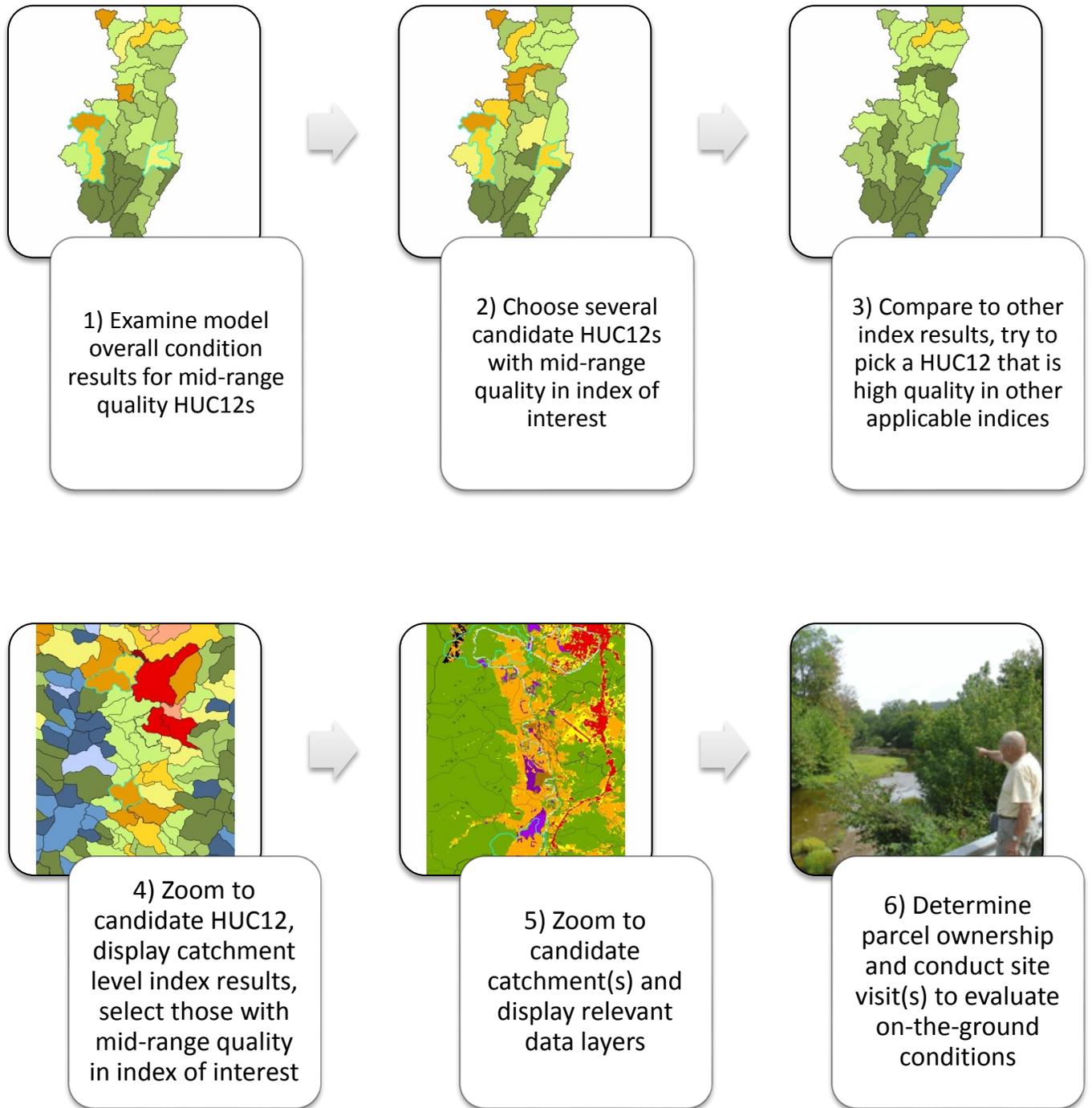


Figure 42. Restoration Sample Process Flowchart

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 Mine 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

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activities 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 were 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 the 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.

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- 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

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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

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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

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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

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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

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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

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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

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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	WV DOT (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

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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

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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 values 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

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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

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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 ^b
Imperv1*	Percent imperviousness	NLCD Impervious surface (USGS)	Generates increased run off as potential non-point source of pollution to streams	Convert raster to polygon, 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

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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

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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

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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 polygon, 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-consumptive 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

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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

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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 ^b
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

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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 polygon, 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	Road/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

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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

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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 polygon, 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

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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

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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

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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

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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

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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

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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

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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 square 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

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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

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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 ^e
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

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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

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

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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

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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 polygons 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 1 st 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	1 st 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, 2 nd 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	1 st 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, 2 nd 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
July 1, 2013	Extension of project to include 2 additional watersheds due to unspent funds
Nov 13, 2013	Decision maker and end user workshop held on final 2 watersheds. Final revisions made
Dec 31, 2013	Final assessment reports on all 7 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
Tug Fork and Tygart Valley Watersheds
Stakeholder Workshop Summary
November 13, 2013
Flatwoods, West Virginia**

Workshop Objectives

The goals of this workshop were to:

- 1) present the current condition and consolidated analysis results for the final two watersheds and obtain stakeholder feedback; and
- 2) demonstrate a preliminary version of the interactive web tool and present potential use scenarios. Get stakeholder input on desired web tool design, functionality, and possible uses/workflows.

Presentation Summary

The workshop began with a review of the project background, including project goals and timeline, and a brief review of the watershed assessment methodology: landscapes, indices, metrics, and objective thresholds and categorizations. This was followed by a presentation of the latest version of the current condition and consolidated analysis results for the Tug Fork and Tygart Valley watersheds. An open discussion followed each presentation, during which experts who had not attended previous workshops requested further information, and experts familiar with the project offered suggestions and additional questions. Overview and results maps for the two watersheds were displayed for reference. After the watershed presentations, the demo version of the web map tool was presented, and potential workflows for use of the tool were discussed. The Team reviewed trends emerging from the analysis results with stakeholders, and solicited feedback on desired functionality and possible user workflows for the interactive web tool.

Review of Project Background

Ruth Thornton, TNC

Ruth presented the project background and a review of the methodology, including a detailed review of analysis indices and metrics, and how the thresholds used for the analysis were determined from reference and stressed catchments. She also presented the concept of “critical” metrics, those metrics significant enough to cap their corresponding index score, regardless of other metrics within that index.

Following the review of the project, stakeholders were given the opportunity to ask questions about the assessment methodology and results. An initial question dealt with whether or not there would be a way for individuals to get ground-truthed data into the system to update the analysis results. The response from the project team was that this process would likely be too complex to incorporate into the web tool automatically, but that the project does plan to provide a list of data providers and links to relevant contacts so that users can get in touch with the right people to help update the data. Another question was whether there was a consideration of land costs in the final results and/or web tool. The

project team acknowledged that this was valuable information, but that there are many technical and proprietary issues around providing those data publicly and keeping them current, and suggested that users compare the watershed assessment results and data with tax map parcels to determine ownership and appraisal values.

Overview of Tug Fork Watershed Results

Misty Downing, TNC

A large amount of resource extraction activity occurs in this watershed, particularly surface and underground mining and oil and gas well development. There is very little urban development, but significant amount of roads and railroads. There are a few areas of protected lands, including several wildlife management areas and one state forest. Overall, streams suffered from a variety of mining-related water quality impairments in certain areas, and there are areas of degraded riparian habitat and fragmented hydrological features. The watershed has few wetlands, and most of the existing mapped wetlands were in decent condition, with generally minimal habitat fragmentation in the wetland buffer or anthropogenic land use in the wetland catchments. The watershed has a significant amount of fragmenting features and recorded invasive species (which are likely roadside based surveys, based on the spatial distribution of the data).

Comments: It was noted that water from underground mining pools in McDowell County is used as a public water supply and is generally very high quality water. Thus, underground mining should not be considered an impairment of water quality in that area. Underground mining water regulation has also reduced flashiness in streams. The project team acknowledged this reality, which has been discussed multiple times in various expert and stakeholder workshops; however, due to the fact that the assessment methodology is designed to be applicable across the state and in various geographies, it is difficult to modify results based on just one county or several HUC12s. Additionally, underground mining is a polygon dataset, and does not include point features where mining pool discharges exist. Therefore, the contribution of high quality underground mining water cannot be spatially identified; also, this water is stored in aquifers/subsurface waters, and groundwater is not a consideration in this analysis, also due to data limitations. WVDEP stakeholders shared that more information about underground mining water may be available in mining permit data or well sampling data, but this will only cover newer permits, and wouldn't apply to older mines (the mines discussed in the Tug Fork are older mines with existing permits). Stakeholders also noted that there is a water quality assessment report for the Pigeon Creek HUC12, conducted by the Natural Resource Conservation Service (NRCS).

Overview of Tygart Valley Watershed Results

Misty Downing, TNC

The Tygart Valley River watershed has distinct land use/land cover trends, and results for all models and indices tend to reflect these patterns, with higher quality areas in the south and east along headwater mountain ridges, and lower quality areas in the northwest and around developed areas of the watershed. There are significant amounts of oil and gas wells and some surface and underground mining in the western parts of the watershed. There are several large towns in the watershed, and this land use and associated fragmenting features are concentrated in these areas. The Tygart has some significant

wetlands complexes, particularly in the southeastern river valley; these areas also have higher concentrations of agriculture and grazing pasture land uses. Several protected lands occur in the watershed, particularly in the south and east, with Kumbrabow State Forest and a portion of the Monongahela National Forest in these areas of the watershed.

Comments: It was noted that within this watershed development of Marcellus shale in the eastern mountainous regions would be limited regardless of shale thickness values, due to tectonic shifting in this area which releases gas and makes drilling geologically and economically infeasible.

Interactive Web Mapping Tool

Ruth Thornton, TNC

The stakeholder group was presented with the demonstration/draft version of the future web mapping tool currently under development by Casey Schneebeck and Paul Angelino of TNC's Colorado office. Currently, the demonstration version is a basic map with data layers that can be turned off and on in a table of contents, with a prototype of the attribute table design. Current layers include hydrology and mining, various land use and land cover layers, and the assessment analysis results. To provide a clearer example of how the final web tool would function and what potential work flows would be, a potential use scenario was presented for each watershed and landscape. These scenarios were based on many of the project team's assumptions about how users would mainly use the web tool, for example that Very Good areas would be considered priorities primarily for protection and Fair areas mainly for restoration. Stakeholders were encouraged to provide their own examples of how they anticipated using the tool, their possible workflow(s), and what data and attribute information may be most useful in project planning.

Desired functionality/features of the web tool suggested by participants:

- Make a YouTube video as a how-to manual to guide users in using the web tool
- Link to other economic/social websites to get further data or information/contacts
- Be able to export data as a .kmz (Google Earth) file
- Search function, and identify function, print function, export as Excel function
- Label or the ability to identify USGS stream names
- Provide a link to WVDEP alerts
- Ability to bookmark certain areas or by a list of catchments
- Ability to download data from a user-specified AOI (area of interest) into GIS – primarily results from the analysis, since other datasets are already publicly available from various sources
- May be useful to open multiple attribute tables to compare different results between planning units (for example, if you were determining where best to work on water quality issues for the drainage area of a lake, you may want to be able to compare several of the contributing catchments to see where your work may be most effective)
- Find water quality sampling stations by latitude/longitude and/or stream name

The project team will work with the developers of the web tool to incorporate as many of these suggestions as is practically feasible within the project scope.

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Meeting Attendees

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Appendix E: Rare Species in Tygart Valley River Watershed and Species Rankings Definitions

Scientific Name	Common Name	Sub-national Rank	Global Rank	Federal Rank
<i>Accipiter gentilis</i>	Northern Goshawk	S1S1	G5	
<i>Acer rubrum / Osmunda cinnamomea var. cinnamomea / Sphagnum spp. Forest Seep</i>	Cinnamon Fern Seep	S3		
<i>Acer saccharum - fraxinus americana - tilia americana / acer spicatum / allium tricoccum - caulophyllum thalictroides forest</i>	High Elevation Rich Mesic Deciduous Forest	S2S3	G4	
<i>Aconitum reclinatum</i>	White Monkshood	S3	G3	
<i>Aegolius acadicus</i>	Northern Saw-whet Owl	S2S1	G5	
<i>Aeshna verticalis</i>	Green-striped Darner	S2S3	G5	
<i>Agrimonia microcarpa</i>	Small-fruited Agrimony	S1	G5	
<i>Alnus serrulata</i>	Saturated Southern Shrubland		G4	
<i>Ameiurus melas</i>	black bullhead	S3S4		
<i>Anax longipes</i>	Comet Darner	S3	G5	
<i>Aneides aeneus</i>	Green Salamander	S3	G3G4	
<i>Anemone canadensis</i>	Canada Anemone	S1	G5	
<i>Ardea herodias</i>	Great Blue Heron	S3S4	G5	
<i>Arrhopalites pavo</i>	A cave springtail	S1S2	G1G2	
<i>Botrychium matricariifolium</i>	Chamomile Grape-fern	S2	G5	
<i>Botrychium oneidense</i>	Blunt-lobe Grape-fern	S3	G4	
<i>Caecidotea holsingeri</i>	Greenbrier Valley Cave Isopod	S3	G5	
<i>Callophrys irus</i>	Frosted Elfin	S1	G3	
<i>Carex aestivalis</i>	Summer Sedge	S2	G4	
<i>Carex appalachica</i>	Appalachian Sedge	S2	G4	
<i>Carex bromoides ssp. bromoides</i>	Brome-like Sedge	S3	G5	
<i>Carex buxbaumii</i>	Brown Bog Sedge	S2	G5	
<i>Carex laxiculmis var. copulata</i>	Spreading Sedge	S1	G5	
<i>Carex manhartii</i>	Manhart Sedge	S1	G3G4	
<i>Carex normalis</i>	Larger Straw Sedge	S3	G5	

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Scientific Name	Common Name	Sub-national Rank	Global Rank	Federal Rank
<i>Carex roanensis</i>	Roan Mountain Sedge	S1	G2G3	
<i>Carex woodii</i>	Pretty Sedge	S2	G4	
<i>Chenopodium standleyanum</i>	Standley Goosefoot	S2	G5	
<i>Chlosyne harrisii</i>	Harris's Checkerspot	S2	G4	
<i>Chondestes grammacus</i>	Lark Sparrow	S1	G5	
<i>Cicindela ancocisconensis</i>	A Tiger Beetle	S3	G3	
<i>Cleistis bifaria</i>	Spreading Pogonia	S1	G4	
<i>Clinostomus elongatus</i>	reduceside dace	S1S2		
<i>Coeloglossum viride var. virescens</i>	Long-bract Green Orchis	S1	G5	
<i>Corallorhiza maculata var. occidentalis</i>	Spotted Coralroot	S1	G5	
<i>Corynorhinus townsendii virginianus</i>	Virginia Big-eared Bat	S2	G4	
<i>Crotalus horridus</i>	Timber Rattlesnake	S3	G4	
<i>Cryptobranchus alleganiensis</i>	Eastern Hellbender	S2	G3G4	
<i>Cuscuta indecora var. neuropetala</i>	Pretty Dodder	S1	G5	
<i>Cuscuta rostrata</i>	Beaked Dodder	S2	G4	
<i>Drosera rotundifolia var. rotundifolia</i>	Roundleaf Sundew	S3	G5	
<i>Eleocharis palustris</i>	Creeping Spike-rush	S3	G5	
<i>Eleocharis quadrangulata</i>	Squarestem Spike-rush	S2	G4	
<i>Elodea nuttallii</i>	Nuttall Waterweed	S3	G5	
<i>Eupatorium pilosum</i>	Vervain Thoroughwort	S2	G5	
<i>Euphorbia pubentissima</i>	Flowering Spurge	S1	G5	
<i>Fontigens tartarea</i>	Organ Cavesnail	S2	G2	
<i>Geum aleppicum</i>	Yellow Avens	S1	G5	
<i>Glaucomys sabrinus fuscus</i>	WV Northern Flying Squirrel	S2	G5	
<i>Glyceria acutiflora</i>	Sharp-scaled Manna-grass	S2	G5	
<i>Gomphus quadricolor</i>	Rapids Clubtail	S3	G3G4	
<i>Gomphus viridifrons</i>	Green-faced Clubtail	S3	G3G4	
<i>Haliaeetus leucocephalus</i>	Bald Eagle	S2S3	G5	

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Scientific Name	Common Name	Sub-national Rank	Global Rank	Federal Rank
<i>Heuchera alba</i>	White-flowered Alumroot	S2	G2	
<i>Hierochloa hirta ssp. arctica</i>	Holy Grass	S1	G5	
<i>Isotria medeoloides</i>	Small Whorled Pogonia	S1	G2	
<i>Juglans cinerea</i>	Butternut	S3	G4	
<i>Juncus dichotomus</i>	Forked Rush	S1	G5	
<i>Lasionycteris noctivagans</i>	Silver-haired Bat	S2	G5	
<i>Liparis loeselii</i>	Loesel's Twayblade	S3	G5	
<i>Listera cordata var. cordata</i>	Heartleaf Twayblade	S2	G5	
<i>Listera smallii</i>	Kidney-leaf Twayblade	S2	G4	
<i>Luxilus cornutus</i>	common shiner	S3		
<i>Lycaena hyllus</i>	Bronze Copper	S2	G5	
<i>Lygodium palmatum</i>	Climbing Fern	S3	G4	
<i>Lysimachia hybrida</i>	Lowland Loosestrife	S1	G5	
<i>Maianthemum stellatum</i>	Starflower False Solomon's-seal	S2	G5	
<i>Marshallia grandiflora</i>	Barbara's-buttons	S2	G2	
<i>Microtus chrotorrhinus carolinensis</i>	Southern Rock Vole	S2	G4	
<i>Monotropsis odorata</i>	Sweet Pinesap	S1	G3	
<i>Myotis leibii</i>	Eastern Small-footed Bat	S1	G3	
<i>Myotis sodalis</i>	Indiana Bat	S1	G2	
<i>Najas gracillima</i>	Slender Water Nymph	S2	G5	
<i>Neotoma magister</i>	Allegheny Woodrat	S3	G3G4	
<i>Notropis buchanani</i>	ghost shiner	S3S4		
<i>Oenothera argillicola</i>	Shale Barren Evening-primrose	S3	G3G4	
<i>Oenothera pilosella ssp. pilosella</i>	Evening-primrose	S2	G5	
<i>Packera paupercula</i>	Balsam Squaw-weed	S2	G5	
<i>Pandion haliaetus</i>	Osprey	S2	G5	
<i>Panicum verrucosum</i>	Warty Panic Grass	S1	G4	
<i>Pararhinichthys bowersi</i>	Cheat Minnow	S1S2	G1G2	
<i>Parnassia asarifolia</i>	Kidneyleaf Grass-of-parnassus	S2	G4	
<i>Pedicularis lanceolata</i>	Swamp Lousewort	S2	G5	

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Scientific Name	Common Name	Sub-national Rank	Global Rank	Federal Rank
<i>Phanetta subterranea</i>	A Spider	S3	G5	
<i>Picea rubens</i> - <i>Tsuga canadensis</i> - <i>Fagus grandifolia</i> / <i>Dryopteris intermedia</i> Forest	Red spruce - Northern hardwood forest		G3	
<i>Platanthera ciliaris</i>	Yellow-fringed Orchid	S3	G5	
<i>Platanthera peramoena</i>	Purple Fringeless Orchid	S4	G5	
<i>Plethodon nettingi</i>	Cheat Mountain Salamander	S2	G2G3	
<i>Poa saltuensis</i>	Drooping Bluegrass	S1	G5	
<i>Pogonia ophioglossoides</i>	Rose Pogonia	S2	G5	
<i>Polemonium vanbruntiae</i>	Jacob's Ladder	S2	G3G4	
<i>Polygala cruciata</i> var. <i>aquilonia</i>	Crossleaf Milkwort	S1	G5	
<i>Polygala curtissii</i>	Curtiss' Milkwort	S2	G5	
<i>Porrhomma cavernicola</i>	Appalachian Cave Spider	S2	G5	
<i>Potamogeton pusillus</i> var. <i>tenuissimus</i>	Slender Pondweed	S1	G5	
<i>Potamogeton zosteriformis</i>	Flatstem Pondweed		G5	
<i>Pseudanophthalmus hypertrichosis</i>	A Cave Beetle	S3	G5	
<i>Pseudosinella gisini gisini</i>	A cave springtail	S3	G3G4	
<i>Pseudotriton ruber</i>	Northern Red Salamander	S3	G5	
<i>Rhionaeschna mutata</i>	Spatterdock Darner	S1	G4	
<i>Rhododendron viscosum</i>	Swamp Azalea	S1	G5	
<i>Rhynchospora recognita</i>	Globe Beaked-rush	S2	G5?	
<i>Riparia riparia</i>	Bank Swallow	S2	G5	
<i>Rosa blanda</i> var. <i>blanda</i>	Smooth Rose	S2	G5	
<i>Saxifraga pensylvanica</i>	Swamp Saxifrage	S2	G5	
<i>Schoenoplectus purshianus</i>	Weakstalk Bulrush	S3	G4G5	
<i>Scirpus cyperinus</i> Wet Meadow	Woolgrass Wet Meadow	S3		
<i>Scleria triglomerata</i>	Whip Nutrush	S2	G5	
<i>Sericocarpus linifolius</i>	Narrowleaf Aster	S1	G5	
<i>Sinella agna</i>	A Springtail	S3	G3G4	
<i>Solidago rugosa</i> - <i>Euthamia graminifolia</i> var. <i>graminifolia</i>	Goldenrod Wet Meadow	S3		

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Scientific Name	Common Name	Sub-national Rank	Global Rank	Federal Rank
<i>Wet Meadow</i>				
<i>Solidago simplex ssp. randii var. racemosa</i>	Sticky Golden-rod	S2	G5	
<i>Solidago simplex ssp. randii var. randii</i>	Mountain Goldenrod	S1	G5	
<i>Sorex dispar</i>	Long-tailed Shrew	S2S3	G4	
<i>Sorex hoyi winnemana</i>	Southern Pygmy Shrew	S2S3	G5	
<i>Sorex palustris punctulatus</i>	Southern Water Shrew	S1	G5	
<i>Spiraea tomentosa / Sphagnum palustre Shrub Peatland</i>	Steeplebush Shrub Swamp	S2		
<i>Spiraea virginiana</i>	Virginia Spiraea	S1	G2	
<i>Spiranthes tuberosa</i>	Little Ladies'-tresses	S3	G5	
<i>Stenanthium gramineum var. robustum</i>	Stout Featherbells	S1S2	G4G5	
<i>Stygobromus emarginatus</i>	Greenbrier Cave Amphipod	S3	G3G4	
<i>Stygobromus parvus</i>	Minute Cave Amphipod	S1	G2G3	
<i>Sylvilagus obscurus</i>	Appalachian Cottontail	S2	G4	
<i>Symphyotrichum boreale</i>	Boreal Aster	S1	G5	
<i>Taxus canadensis</i>	Canadian Yew	S2S3	G5	
<i>Thalictrum clavatum</i>	Mountain Meadow-rue	S1	G4	
<i>Thamnophis sauritus</i>	Eastern Ribbonsnake	S2	G5	
<i>Toxicodendron vernix</i>	Poison Sumac	S2	G5	
<i>Trifolium stoloniferum</i>	Running Buffalo Clover	S2	G3	
<i>Trillium nivale</i>	Snow Trillium	S2	G4	
<i>Triphora trianthophora</i>	Nodding Pogonia	S2	G3G4	
<i>Utricularia gibba</i>	Humped Bladderwort	S2	G5	
<i>Utricularia macrorhiza</i>	Greater Bladderwort	S1	G5	
<i>Vaccinium macrocarpon</i>	Large Cranberry	S2	G4	
<i>Vaccinium oxycoccus</i>	Small Cranberry	S2	G5	
<i>Vermivora chrysoptera</i>	Golden-winged Warbler	S2	G4	
<i>Viola appalachiensis</i>	Appalachian Blue Violet	S2S3	G3	
<i>Viola septentrionalis</i>	Northern Blue Violet	S2	G5	
<i>Vittaria appalachiana</i>	Appalachian Gametophyte	S1	G4	

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Scientific Name	Common Name	Sub-national Rank	Global Rank	Federal Rank
<i>Woodwardia areolata</i>	Netted Chainfern	S2	G5	
<i>Xyris torta</i>	Yellow-eyed Grass	S2	G5	
<i>Zapus hudsonius</i>	Meadow Jumping Mouse	S3	G5	

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.