An Assessment of Natural Assets in the Appalachian Region: Water Resources

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<td>willingness-to-pay</td>
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Executive Summary and Key Findings

The Appalachian Regional Commission is dedicated to enhancing and promoting the economic viability of Appalachia, shown in Figure 1, a region that is 42% rural and where 18% of people live in poverty (ARC, 2009a). There is a trend that points towards recovery; over 223 counties were rated distressed in 1965, whereas now that number is 96 (ARC 2009a; 2011). These fluctuations in economic status can be associated with many factors, including historic and present levels of economic dependence on natural resources. Typically, economies in rural Appalachia use natural resources for extractive purposes: goods (coal, timber, natural gas, minerals) are harvested and usually shipped out of the region. Water, in contrast, is an “in-place” resource. This study quantifies the water assets of Appalachia, both in terms of economic development and quality of life. Water is essential to all life, and its quality and quantity have implications for the health of people, ecosystems, and economies.

Appalachia has a strategic significance related to water resources: parts of six major basins and many of their tributaries have headwaters in the region. Many cities and rural communities within and around the region are dependent upon the wise use, control, and development of Appalachian water. Thus, it is important to understand water resources in the region in terms of four aspects: quality, quantity, access, and value, which were examined by the research team using data and information collected from a variety of sources around several relevant categories of data (Table 1). A system was developed to calculate index values and map these values at the county level for each aspect of water resources as well as for the four aspects combined. An interactive Web-based geographic information system (GIS) was developed in an end-user–friendly manner that allows for the visualization of information on water quality, quantity, access, and value in the region at the county level. In addition, a decision-support system was created with which the user can determine the relative importance of one water asset over
another. In summary, this study provides useful information and tools for decision makers with regard to the importance and sustainable use of water resources in the region. The main body of this report contains an overview of each index. More detailed methods and technical aspects are presented in appendices.

Table 1: Data categories for the four water indices

<table>
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<th>Quality</th>
<th>Quantity</th>
<th>Access</th>
<th>Value</th>
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<tbody>
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<td>Land use</td>
<td>Water usage</td>
<td>Recreational access points</td>
<td>Market value</td>
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<td>Forest and wetlands</td>
<td>Water consumption</td>
<td>Boating access</td>
<td>Agricultural consumption</td>
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<td>Agriculture</td>
<td>Precipitation</td>
<td>Fishing access</td>
<td>Domestic consumption</td>
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<td>Facilities</td>
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<td>Flooding frequency</td>
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<td>Non-market value</td>
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<td>CSO communities</td>
<td>Surface water prevalence</td>
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<td>Willingness-to-pay</td>
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<td>Abandoned mine lands</td>
<td>Stream miles</td>
<td></td>
<td>Meta-analysis coefficients</td>
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<tr>
<td>Coal production</td>
<td>Lake acres</td>
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Note: NPDES=National Pollutant Discharge Elimination System; CSO=combined sewer overflow.

This study was developed so that each category could be combined to understand the overall water asset for each county. The **Water Quality Index** is based on impacts to water resources from a variety of stressors. Clean water can be an asset for recreational use, drinking water supply, and industrial growth, all of which can be significant economic drivers. The **Water Quantity Index** examines the amount of water available for withdrawal and use as well as the county’s propensity to flood. The **Water Access Index** summarizes the water resource recreation opportunities for each county. These three indices were scored and aggregated to create the **Water Asset Index**: Quality + Quantity + Access = Water asset index

As with any aggregation, some degree of resolution is lost. However, this method provides a means of comparing water-related assets. Basically, the higher the index, shown in Figure 2, the more the water resource should be considered an asset to the county and region. Counties with cleaner water, more sustainable quantity, and greater recreation access have higher index values.
The **Water Value Index** is excluded from the asset index because the value is based on many of the components of the other indices. The value is an economic representation of the three key water asset indices. These relationships are examined later in the report.
1.1 Key Findings

The following key findings are organized by research theme. Each theme and subsequent findings are developed in detail throughout the report. As described above, this study divided water resources into four distinct categories—quality, quantity, access, and value—and developed indices that represent a relative value for each asset category for each of the 420 Appalachian Regional Commission counties. The methods and data for developing these index values were based on a review of available scientific and economic literature and studies that have been completed across the United States. Each index is broken down into a range of six classes, from a low to a high index score. These scores are shown in Figure 3 through Figure 7.

1.1.1 Water quality

- Land use and facilities indicators were found to be closely related to documented water impairments.
- The water quality index has the highest correlation with both economic status and water value. Additionally, among quality, quantity, and access, quality is the only one that has a statistically significant correlation with both economic status and water value.
- The prevalence of forests and wetlands is directly related to water quality, whereas agricultural land and impervious surfaces are inversely related to water quality. In fact, most of the blue counties on the map correspond to areas of dense forest canopy cover.
- Facilities that discharge pollution directly to rivers and streams can impact water quality in ways not captured by land-use. The counties scoring the poorest on the facilities score are concentrated in two areas: the Kentucky-Virginia-West Virginia tri-state area and western Pennsylvania/northern West Virginia (The facilities score is one component of the water quality index and is not shown in Figure 3).
1.1.2 Water quantity

- Water demand is similar across most of Appalachia. Exceptions include several counties in Ohio and along the banks of the upper Ohio River; the eastern panhandle of West Virginia; and a few counties in Pennsylvania, Virginia, and North Carolina.

- The distribution for floods is more even than that for water demand. The highest concentration of flooding per land area is in central Appalachia—primarily Kentucky. The northern panhandle of West Virginia and isolated counties in Pennsylvania and Alabama also stand out as being slightly more flood-prone than the remainder of Appalachia.

- Generally speaking, there are higher water-to-land ratios in southern Appalachia (Tennessee, North Carolina, Mississippi, Alabama, Georgia, and South Carolina) as compared to northern Appalachia.

- Available precipitation (precipitation minus evapotranspiration) is highest in southern Appalachia and along a southwest-northeast–trending swath through central West Virginia; surface water volumes, however, are highest in large river valleys—especially the Ohio, the Tennessee, and the Susquehanna.

- While surface water use is far more prevalent in counties with high demand relative to county area, groundwater is the dominant water source reported in over one quarter of Appalachian counties. Concentrations of counties that use more groundwater than surface water are in Mississippi, Ohio, and the New York-Pennsylvania border.
1.1.3 Water access

- A total of 58,136 recreational water access points for swimming, fishing, and boating were collected through a variety of sources, with 87% of these points being associated with rivers or streams and 13% with lakes or reservoirs.
- Many counties in Kentucky and West Virginia have higher ratios of stream access points to lake access points, suggesting a high level of recreational water opportunities related to streams and rivers.
- Many counties in Kentucky and West Virginia were ranked high to highest in terms of recreational water access per capita.
- Other areas with high levels of recreational water access include eastern Pennsylvania, portions of eastern Tennessee, and the tri-state area of Georgia and the Carolinas.

Figure 5: Water access index

Map Title: County Water Access Index in Appalachia
Map Note: The counties were sorted by final water asset score and grouped into six categories, with 10 counties in each category.
Data Sources: WVUSDownstream Strategies, "Assessing Appalachian Natural Assets: Water" prepared under contract #O-16303-09
1.1.5 Water value

Water has tremendous aesthetic and recreational value that is not accounted for in the costs incurred by individuals and businesses for their water use. For this reason, water value was divided into market and non-market value.

Market value

- Market value is based on withdrawals in various sectors: public supply, domestic (home use), industrial, irrigation, and thermoelectric power generation.
- Total market value of water withdrawals in Appalachia is estimated to be $1.7 billion.
- The top ten counties have annual estimated per capita water valuations of $726 to $2,250, and include four counties in West Virginia, two in Ohio, and one each in Alabama, New York, South Carolina, and Virginia. These counties’ valuations are driven by thermoelectric and other industrial water use and small populations.
Non-market value

- Data on household income, surface water quality (relative to the average of Appalachian counties), and fish stocking were used to compute index scores.
- The average non-market value (as expressed by willingness-to-pay for existing water quality) is $8 per household.
- The average household income for the top ten non-market value counties is higher than that for the bottom ten. While income helps explain willingness-to-pay, fully 50% of the bottom ten counties for non-market value have income greater than the regional average.

Figure 7: Water non-market value index
1 Introduction

1.1 About this study and report

This study and report were initiated as part of the long-term research objective developed by the Appalachian Regional Commission (ARC) to understand Appalachia’s natural assets. In addition to water, ARC plans to undertake similar evaluations of forests; land and minerals; and social, cultural, historical, and recreational assets. Even though these studies are independent, one of the overarching goals of this project is to develop a framework and methodology that can be applied to all four research areas so that readers and practitioners can utilize the data and information in an efficient manner. The primary goal is to provide information that will encourage the development and sustainable management of natural assets across the Appalachian Region, which requires developing and updating an inventory of natural assets, analyzing their value and usage, assessing their potential contribution to economic development of the region, and creating a framework to assist with planning their best use.

The project team was comprised of several organizations representing the Appalachian Region. West Virginia is the only state that is entirely within the ARC service area, hence the large research team from West Virginia University (WVU). In addition to WVU staff and professors, Downstream Strategies—an environmental consulting company from Morgantown, West Virginia—and Pennsylvania State University’s Northeast Regional Center for Rural Development (NERCRD) participated as major contributors to the research. Many experts in water resources and economics were involved throughout this project, providing a well-rounded and representative team.

Merging science and policy can be a tremendous hurdle. This study attempts to summarize water resource data in a way that is understandable and relevant to policy makers. To enhance the study and its utility, a geodatabase—geographic information system (GIS) data—was created that contains all of the underlying layers and analysis results. These data can be used as a supplement to other research or in customized analysis or mapping projects. In addition to the geodatabase, a Web-based mapping tool and a decision support system (DSS) were created to help understand the results, both spatially and statistically (See preceding Section 1.3). The Web-based mapping tool provides an interactive point-and-click functionality that enables the user to drill down into the data, county by county. The DSS is a customized ArcMap GIS software tool that analyzes spatial

“[The present and future economic value of water resources is] perhaps the most important consideration in development of water projects (drinking water, industrial and agricultural, etc.).”

Earl Smith, Chief, Water Management Division, Interstate Council on Water Policy

“There is a need for more quantitative information on the economic value of water for different beneficial uses, [as well as] improved GIS capabilities to access water resource data...and associated analytical tools to summarize and document data.”

ARC water asset stakeholder

“The organization I represent established an interest in understanding our regional water resources several years ago. To date, we have coordinated a working group of water resource–knowledgeable individuals and have established a working relationship with State offices in Maryland and West Virginia as well as major universities in the area to create a knowledge-based group. Involvement by your firm would enhance our ability to understand our water resources.”

Colleen Peterson, Executive Director, Greater Cumberland Committee
patterns and creates an environment where users can weigh various decisions that could support or inhibit economic development. The functionality of this tool and technical details are presented in Appendix A.

One goal of this report is to assist the reader in understanding the complex process of developing the indices and to provide a level of transparency with regard to how the indices were developed. The main body of the report is meant to be less technical and more “readable.” Appendices cover the more technical processes that were utilized to create the indices. These appendices include statistical analysis results and summary tables and are original works from the contributors.

In addition to the technical appendices, many datasets and maps are provided with the report. These datasets consist of a master spreadsheet with all the indices and their components, an annotated bibliography, and a series of over 60 maps covering all the components of the study.

1.2 Implications for policy

This study has attempted to understand water assets in the Appalachian region in order to facilitate water management and planning strategies. This report is not an all-encompassing analysis, but does begin a conversation about water resource management. Due to the ever-expanding pressure on water resources, steps should be taken to understand the human influence on water resources, both positive and negative. There are many positive relationships between water resources and economic development, including non-transactional or quality-of-life benefits.

Appalachia’s economy is based on its natural and human resources. Some of its natural resources—for example, its timber, coal, and natural gas—are commodities sold in international markets. Its water resources, in contrast, flow freely and play a more subtle role in Appalachia’s economic development.

Understanding the relationship between the region’s water resources and its economic development can play many important roles. By clarifying the services that clean and plentiful water provides, local and state policymakers can make informed decisions; local leaders and state governments are frequently faced with difficult questions related to clean water standards, water withdrawals, water-intensive industries, and flood control.

It is also important for private sector leaders to fully appreciate Appalachia’s water resources. When making decisions about siting new businesses, for example, leaders consider several water-related factors; the availability of sufficient water for industrial processes is crucial for water-intensive industries and the proximity of an office to accessible lakes, trout streams, and other recreational assets can provide a high quality-of-life to employees.

This report, and the data that accompany it, can therefore be used by local and state leaders to inform their decisions on new policies related to water quality, quantity, and access. It can be used by economic development officials to attract new businesses. And it can be used by the private sector to inform business-siting decisions.

1.3 How to use the indices

This report presents an overview of the methods and data used and of the general trends in the final indices. Sprinkled throughout the document are boxes called “Putting the tool to work.” These are designed to inspire the reader to identify relevant opportunities, challenges, and actions that are illuminated by our indices.
Putting the tool to work

Drill down into the data using the Web-based mapping tool

View the final scores for your county via a Web-based mapping platform. This point-and-click system allows the user to explore all the variables that comprise the water asset indices for a given county. Visit www.map.wv.gov/arc

Create your own scenarios using the GIS decision support system

An interactive, GIS-based DSS was developed that allows users to prioritize areas for economic development opportunities. The DSS integrates spatial data, user input, and a ranking algorithm. This tool can be obtained from ARC.

Explore the distribution and compare scores

Histograms are provided with each index and help to visually represent the distribution of values. These charts can help the reader understand where their county falls in the context of the Appalachian region.

Examine the underlying data through maps and a downloadable geodatabase

Printable maps display all of the underlying datasets that comprise the water assets indices. These maps are part of this report and located in Appendix.
Different people, agencies, and organizations may place differing value on various indicators. The DSS allows users with access to ArcMap GIS software to apply their own priorities, thus re-scoring the counties according to locally important variables.

Histograms are displayed for each indicator throughout the report. Histograms are useful because they provide a visual representation of the distribution of values and they allow the reader to understand where her county falls in the context of the Appalachian region. For example, a score of 90 out of 100 is generally a good score. Any county that receives this score is generally far ahead of the lowest-scoring counties in the region. For an indicator such as water quantity, the histogram shows that a score of 90 is not only “better than the worst,” but in fact is in the top 20 counties across Appalachia. In contrast, a score of 90 for the facilities indicator suggests that while the county may be far ahead of the worst county for this indicator, it is not alone in this distinction, with over 80% of counties achieving this score or higher.

1.4 Data caveats

This study and report were developed to enable practitioners across the ARC region to understand their water resources and to better plan for the future. This report examines many different datasets that vary spatially, temporally, and in their intended application. The data and findings in this report are an attempt to understand water resources and their relationships. Despite the inherent difficulties, this study is the most comprehensive attempt to date to catalog and summarize water resource data across Appalachia.

Many types of water datasets exist across the United States (US); however, very few are consistent from region to region or state to state. Datasets of dirty streams exist for all states, but are classified according to varying water quality criteria. Some states have comprehensive boating access datasets, while others do not. Water resources do not follow political boundaries or adhere to easily manageable units. Based on available datasets, we devised a systematic method to index regionally consistent and representative characteristics in order to understand Appalachia’s water resource and begin to manage it for a more sustainable future. For each index, this study lists the specific datasets utilized, rationale for the methods, and overall results.

1.5 Background

The Appalachian Region consists of approximately 205,000 square miles (131 million acres), covering 420 counties in 13 states. It extends more than 1,000 miles, from southwestern New York to northeastern Mississippi, and is home to 24.8 million people (ARC, 2009a). Figure 8 shows the region’s 420 counties, color-coded by economic status. Similar to the development of the Water Asset Index, ARC creates indices to understand and monitor the economic status of the Appalachian counties. The same approach of indexing the status of counties based on available data and empirical research was directly applied in this study.

Many cities and rural communities within and around the region are dependent upon the wise use, control, and development of Appalachian water. This dependence on water resources for economic growth has become increasingly evident in recent decades. Human demand for freshwater has tripled since 1950 due to population growth, irrigation, and increasing material consumption (Postel and Carpenter, 1997). A downsizing of critical Appalachian industries has led to a decline in traditional agricultural, forestry, and mining jobs in many rural areas, leading to a large population migration to urban areas over the past 50 years. According to Freudenberg (1992), employment in traditional farming has dropped about 70% from the early 1900s and employment in other natural resource–dependent industries, such as mining and forestry, has been cut in half.
However, these macro-level economic and social trends are not uniform across all rural areas; the major factors affecting migration patterns across the rural landscape have changed substantially over the last few decades (Nord and Cromartie, 1997). Those areas and places rich in natural assets are more likely to experience substantial population growth than are areas with fewer natural assets. For instance, Johnson and Beale (2002), in a national study of rural counties, report a significant population rebound during the 1990s, with “recreation counties”—those with high tourism receipts and business activity—leading the way with a 20.2% population increase compared to a 10.4% increase for all rural counties. The economic and population growth patterns in Appalachia also reflect this reality (ARC, 2009a).

Natural assets are not only linked to population growth, but also to economic restructuring and economic well-being (Johnson and Beale, 2002; Shumway and Otterstrom, 2001). For example, Shumway and Otterstrom (2001) report that counties rich in natural amenities experienced dramatic increases in employment in service sectors such as health care, personal services, recreation and entertainment, and professional services.

Local or regional economic growth is dependent upon many factors—natural, social, economic, and political. Each factor’s contribution to economic growth may vary by county or region in terms of significance and magnitude. This poses a challenge to researchers: to determine the relative importance of each factor at the county or regional level. Water resources have multiple uses, ranging from commodity-type use in agriculture, industry, and households to social and environmental values, including biodiversity, aesthetics, and recreation (Young, 2005). These types of water use and corresponding values may have changed over time across counties in the region. While recognizing the positive contribution of water resources for economic growth, water may also be a threat to the quality of life and community development in the cases of widespread pollution or flooding.
1.6 Literature review

This study’s methodologies, framework, data, and approach are based on a literature review. This section highlights regional studies on water as well as methods used in the literature for index development.

The economic contribution of water has been recognized and estimated in many forms, including withdrawals (domestic, irrigation, industrial processing, and thermoelectric power generation) and instream use (hydropower, recreation, fish and wildlife habitat, navigation, and waste disposal). Ward and Michelsen (2002), in estimating the values of different uses in the US, found that the national average of water values per acre-foot were $3 for waste disposal, $48 for recreation/fish and wildlife habitat, $146 for navigation, $25 for hydropower, $75 for irrigation, $282 for industrial processing, $34 for thermoelectric power, and $194 for domestic.

Water-related economic activities play an essential role in promoting economic development and growth locally and regionally. For example, in the Texas Gulf Coast Region, the total economic impact (1993-1995 average annual) for commercial fishing activities was estimated at $265.5 million in economic output, $80.3 million in personal income, and 5,558 jobs (Robinson et al., 1996). In West Virginia, the economic impact of whitewater rafting activities is significant. Based on data collected in 1995 from commercial boaters on the Cheat, New, and Gauley Rivers, total direct expenditures associated with rafting these rivers were approximately $49.4 million, with nearly $43 million within West Virginia (Whisman et al., 1996).

Because of its importance, water has been extensively studied in the literature. An exhaustive literature review is beyond the scope of this study; however, selected studies on natural assets including water, as specified in the Request for Proposal for this project, are reviewed. In addition, studies on water quality, quantity, and value are reviewed in the corresponding sections.

1.6.1 US Army Corps of Engineers (1969)

One of the most comprehensive studies on water in the Appalachian region was conducted by the US Army Corps of Engineers (1969). This study divides Appalachia into four sub-regions: highlands, northern, central, and southern. It then examines the physical and developmental background, natural and human resources, economic situation, and overall needs related to social development, transportation, education, health, physical environment, and water resources. In addition, development plans for each sub-region were developed in the areas of flood control and prevention, water supply, upstream watershed investigation and development, soil and forest conservation and development, water quality control, fish and wildlife enhancement, general recreation, power, navigation, and economic expansion.

In this study, water’s role in regional economic development is clearly indicated. For instance, in 1964, there were 74 public or privately owned water companies in a defined region of seven counties in northeastern
Pennsylvania: Carbon, Lackawanna, Luzerne, Monroe, Pike, Schuylkill, and Wayne counties, with a land area of 4,427 square miles. On average, 98 million gallons per day (mgd) of water was sold in this region. For the whole Appalachian Region, it was estimated that municipal and industrial water use (exclusive of agricultural, mining, and thermal power operations) would be 7,700 mgd for the study year, and to meet the benchmark goals of economic development, these uses would be expected to require approximately 13,300 mgd by 1980, 23,400 mgd by 2000, and 42,200 mgd by 2020.

The Appalachian Region is rich in water bodies for recreational use, with 53,000 miles of rivers and streams, 117 man-made reservoirs and natural lakes of more than 500 acres, and hundreds of smaller lakes and ponds. Most of the reservoirs and lakes, particularly those located near urban centers, are used extensively for fishing, boating, swimming, and other water-dependent activities. Many rivers and lakes that, in the past, were suitable for outdoor recreation have since been severely polluted by a wide range of sources, chiefly industrial and municipal. In addition, many recreation areas in the region are beyond an hour’s driving time of much of the population and, therefore, cannot meet the day-use needs of many people residing inside as well as outside the region.

The 48,100 miles of fishing streams in Appalachia, when converted to acres at the assumed ratio of four acres per mile, represent approximately 14% of the region’s total surface water (or 192,000 acres). Reservoirs constitute about 67% (924,500 acres); natural lakes make up about 8% (115,900 acres), while farm ponds represent almost 11% (153,700 acres). In 1964, an estimated 52.8 million person-days of angling were expended on Appalachia’s 1.4 million surface acres of fishable habitat, which is equivalent to about 38 person-days per surface acre. Total fishing use in Appalachia during 1964 ranged from a low of 23.5 person-days per surface acre in Tennessee to a high of 102.2 person-days per surface acre in Pennsylvania.

There are approximately 89,200 surface acres of usable commercial fisheries habitat in the region, capable of providing 43.9 million pounds of commercial fish annually. This includes reservoirs and lakes 1,000 acres and larger within the region. The total commercial fish landings of both fish and shellfish in the region during 1966 were estimated at 10.4 million pounds, valued at $1,283,114.

A total of 40 units were used for comparing mean and median values for sport fishing opportunities and demand. These values were determined by using 1964 fishing license sales, 1960 population data, and the Appalachian water inventory, which includes natural waters and water development projects completed prior to 1965.

While the 1969 study recognized the positive aspects of water uses in the region, it also acknowledged that regional water quality was polluted to some extent, with the most serious issues being acid mine drainage (AMD) and municipal pollution. It was found that the AMD was generally coincidental with regions that have been or were presently being mined. The findings indicated that approximately 3% (5,700 miles) of Appalachia’s streams were polluted by AMD. The worst offending areas were in the old coal fields of West Virginia and Pennsylvania, and in a few areas of southeastern Ohio that had been strip-mined for several decades. Total estimated annual savings to water users resulting from a 90% reduction in AMD were $4.2 million. Another widespread problem for much of the region was flooding, which resulted, for example, in average annual damages of $27 million in Water Sub-Region B, which comprises part of New York, Pennsylvania, Maryland, and West Virginia.
1.6.3 More recent research

While the study reviewed above examines many aspects of water in the region, several studies have been conducted to look at more specific aspects of water, such as drinking water quality and supply. For instance, the University of North Carolina Environmental Financing Center (Hughes et al., 2005) analyzed the conditions of drinking water and wastewater services in the Appalachian Region in attempt to assess the financial requirements and strategies available to improve these services, particularly in areas that face chronic economic distress and clear deficiencies. The analyses were carried out at three levels: a regional level, a sub-regional and state level, and a community and system level (case studies).

Another study about drinking water supply in the Northeast and Midwest US, including northern Appalachia, developed a composite index of development pressure on forests important to drinking water supply (Barnes et al., 2009). This index is based on population, public water supply data, and various land-use metrics, including development pressure, private forest land, changes in housing density, agricultural land, riparian forest, road density, and soil erodability. Analyses were performed at the 8-digit hydrologic unit code (HUC) watershed scale. A detailed description of GIS analysis steps is provided as an appendix to the report. In three case studies, the report considers the specific characteristics of low-, moderate-, and high-scoring watersheds.

Several other studies, albeit not focused on water but more on land-use and economic growth, have also been conducted at the regional level in Appalachia. One comprehensive study—Southern Appalachian Man and the Biosphere Cooperative (1996)—examines the ecological conditions (i.e., atmospheric, aquatic, and terrestrial) and social, economic, and cultural status in the southern Appalachian region comprised of northern Virginia, eastern West Virginia, northwestern South Carolina, northern Georgia, and northern Alabama. The assessment was accomplished through the cooperation of federal and state natural resource agencies within the region. In terms of aquatic resources, the physical setting (i.e., stream density, impoundment acres, major drainages, etc.); effects of human activities on aquatic resources; water quality and associated nonpoint and point sources of pollution; aquatic species; laws, regulations, and programs affecting aquatic resources; and water usage are examined. In addition, the mining impacts by hydrological unit, percent of land area occupied by human activities, and percent of forest cover in riparian zones are mapped.

In terms of the social, economic, and cultural status in the region, this study examined four aspects: 1) communities and human influences, 2) the timber economy, 3) outdoor recreation supply and demand, and 4) roadless and designated wilderness areas. To address changes in population and housing in the region, census data from 1970, 1980, and 1990-91 were analyzed. Other data sources included the Census of Agriculture for the last three decades and US Department of Agriculture (USDA) Economic Research Service data. Maps displayed averages for the counties in the study area as compared to averages for the seven states in which the southern Appalachian counties reside. In addition, surveys were conducted among organizations and residents to understand their attitudes toward natural resources and the environment.

Another study examines land ownership patterns and their impacts on the Appalachian community based on a survey of 80 counties (Appalachian Land Ownership Task Force, 1981). The study found that only 1% of the local population, along with absentee land-holders, corporations, and government agencies, controlled at least 53% of the total land surface in the 80 counties; of the 13 million acres of surface sampled, 72% was owned by absentee owners. In addition, 7% of land was owned by out-of-state owners and 25% by owners residing out of the county of their holdings, but in the state. Four-fifths of the mineral rights in the survey were absentee-owned. Almost 40% of the land in the sample, and 70% of the mineral rights, were held by corporations. Indices were developed to illustrate the concentration of ownership of land and minerals.
Finally, the Economic Development Research Group, Inc., Regional Technology Strategies, Inc., and Massachusetts Institute of Technology Department of Urban Studies and Planning (2007) examined five regional growth paths in the Appalachian Region; these growth paths are outlined in Table 2.

Table 2: Appalachian regional growth paths

<table>
<thead>
<tr>
<th>Growth path</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade center</td>
<td>A growth pattern emanating from a small urban cluster that provides goods and services to the ex-urban communities and rural hinterlands</td>
</tr>
<tr>
<td>Agglomeration</td>
<td>Also known as cluster economy, resulting from geographic concentrations of interconnected businesses and institutions that enhance the productivity of the core industries</td>
</tr>
<tr>
<td>Supply-chain</td>
<td>Also known as dispersal economy, an economy structure wherein a remote location is chosen over the central metropolitan area to host a node of economic activity (distribution or assembly) that is part of a larger (geographic) production chain</td>
</tr>
<tr>
<td>Natural amenity or cultural assets</td>
<td>This path depends on either quality-of-place attracting new households or efforts to actively develop and promote cultural, recreation, and eco-tourism venues and their supporting visitor services</td>
</tr>
<tr>
<td>Knowledge assets</td>
<td>This path denotes the growth opportunities leveraged from the collective knowledge embodied in the region, including social capital, technical applications and commercialization, institutional assets (educational and financial), and entrepreneurial start-ups</td>
</tr>
</tbody>
</table>

Source: EDRG et al. (2007).

The study presents six case studies of local economic development in Appalachia that range from single counties to multi-county regions: Scioto County, Ohio; Chautauqua County, New York; Pike County, Kentucky; Marion and Monongalia Counties, West Virginia; southeast Tennessee/southwest North Carolina; and Alabama at the state level. The case studies document the local context and history of economic development in these areas in order to illuminate the processes of economic growth and change that have been and are occurring there. All of the case studies focus on non-metropolitan parts of Appalachia.

1.7 Index development

Several studies reviewed above involve the development of index systems (i.e., Appalachian Land Ownership Task Force, 1981). Generally, two index approaches have evolved in measuring natural assets: a summary index approach and an aggregate factor score approach (Kim et al., 2005). The summary index approach compiles natural assets into a single index that includes different natural attributes, while the aggregate factor score approach categorizes a wide array of natural attributes into multiple but similar groups (Kim et al., 2005).

McGranahan (1999) developed a summary index of each county's natural amenities that includes measures of mild sunny winters, moderate summers with low humidity, varied topography, mountains, and abundance of water area. This study found a strong association between population change and natural amenities scores in rural counties. The high-scoring counties almost doubled their population over 25 years, while over half of the low-scoring counties lost population. The study also found that employment change in rural counties was highly related to natural amenities over the same time period.

The well-known five-level ARC county distress status index system is also a type of summary index in which the three-year average unemployment rate, per capita income, and poverty rate of each county are compared with national averages. The resulting percent values are summed and averaged to create a composite index value for each county. Each county is then ranked, based on its composite index value, with higher values indicating higher levels of distress.

---

1 The measure of per capita income is inverted in the final calculations because low income is associated with high distress.
As Wang (2008) states, the summary index approach is not without problems. First, decisions about which attributes should be incorporated to develop a single summary index are quite subjective. Second, the relative importance of selected attributes is usually not considered. Third, variables used to create a summary index usually measure different things, and it may not make sense to add them together. (Kim et al., 2005)

In an alternate approach, several recent studies have evaluated the economic impacts of natural amenity attributes using the aggregate factor score approach (e.g., Deller et al., 2001; English et al., 2000; Marcouiller et al., 2004; Spotts, 1997). Principal component analysis or factor analysis was used in all of these studies to produce smaller sets of factors that can be used in subsequent modeling such as regression analysis (Kim et al., 2005). These studies differ from previous ones due to the calculation of the spatial dependence of natural amenities using a spatial error model.

In summary, there is no consensus on the best approach for developing indices. Because the summary index approach is simplest and most easily interpreted, it was adopted in this study.
1.8 Study framework and index methodology

A simple approach was used to summarize and understand each county’s water resources based on four categories: quality, quantity, access, and value. Each index contains specific data that summarize that county’s water assets. Figure 9 illustrates the nested framework for the index development and defines the indices, indicators, and metrics. For each index, several different indicators are used. These indicators are comprised of raw data points called metrics.

This index methodology is based on the ARC’s Research Report Guidelines and Distress Indicator Methodology (ARC, 2009b), wherein values of economic data are summed and averaged to create a composite index value representing varying degrees of economic distress.

Using this ARC methodology, our research team has designed the following methodology for creating a composite index representing the total asset score for each county’s water resources. Specialists in each of the four indices researched and chose several metrics to represent their assigned index. Each metric was scored for each ARC county.

Before combining metrics, we scale them so that the lowest county receives a score of 0 and the highest county receives a score of 100, using the following equation:

\[
\text{Metric}_{\text{scaled}} = \left[ \frac{\text{metric}_{\text{county}} \times x - \text{metric}_{\text{min}}}{\text{metric}_{\text{max}} - \text{metric}_{\text{min}}} \right] \times 100
\]
Through this equation, an abundance of a positive attribute results in a high score, and an absence of the attribute results in a low score. If the attribute has a negative impact, we reverse the equation so that the value appropriately reflects the relationship of the attribute to water resources, using the following equation:

\[
\text{Metric}_{\text{reverse-scaled}} = 100 - \left\{ \left( \frac{\text{metric}_{\text{county}} - \text{metric}_{\text{min}}}{\text{metric}_{\text{max}} - \text{metric}_{\text{min}}} \right) \times 100 \right\}
\]

For example, we have an indicator for abandoned mine lands (AMLs). A higher number of AMLs within a county should reflect a lower score. This is a case that requires the reverse equation above.

Once all metrics within an indicator have been scaled, they are combined for each county.

\[
\text{Indicator}_{\text{county}} = \text{metric}_a + \text{metric}_b + \text{metric}_c
\]

Indicators are then scaled, to create a score from 0 to 100:

\[
\text{Indicator}_{\text{scaled}} = \left\{ \left( \frac{\text{indicator}_{\text{county}} - \text{indicator}_{\text{min}}}{\text{indicator}_{\text{max}} - \text{indicator}_{\text{min}}} \right) \times 100 \right\}
\]

In a similar fashion, indicators are combined into indices:

\[
\text{Index}_{\text{county}} = \text{indicator}_x + \text{indicator}_y + \text{indicator}_z
\]

Indicators are then scaled in the final step, so that the county with the highest value receives a 100 and the county with the lowest value receives a 0:

\[
\text{Index}_{\text{scaled}} = \left\{ \left( \frac{\text{Index}_{\text{county}} - \text{Index}_{\text{min}}}{\text{Index}_{\text{max}} - \text{Index}_{\text{min}}} \right) \times 100 \right\}
\]
1.9 Stakeholder involvement

We solicited information and feedback from a variety of stakeholders in an effort to coordinate with outside institutions, as well as to ensure our project focus and efforts are aligned with regional objectives and goals.

We involved stakeholders who represent a wide variety of organizations, including federal and state agencies, interagency councils, universities, and non-profit institutions. An invitation to participate was distributed to over 70 stakeholders identified by the project team as having an important stake in the future of how water resources are used within the region. The invitation letter included project background, as well as a request to participate by answering seven open-ended questions.

Respondents included representatives from the following groups:

- City of Cumberland, Maryland;
- Greater Cumberland Committee (Cumberland, Maryland);
- Interstate Council on Water Policy;
- Maryland Department of the Environment;
- Mineral County, West Virginia;
- North Carolina State University;
- State of Arkansas;
- Susquehanna River Basin Commission;
- Tennessee State University;
- Tennessee Valley Authority;
- Trout Unlimited;
- West Virginia University Extension Office;
- United States Geological Survey; and
- University of Maryland Agriculture and Resource Economics.

Stakeholder respondents offered a variety of information concerning informational needs, desired data, and report format, as well as regional water assets and liabilities. In summary, ARC water asset stakeholder respondents’ informational needs included the following:

- water availability information for planning purposes,
- information to conserve water resources and special areas,
- monitoring for industrial and other contaminants, and
- evaluation of hydropower.

Data desired by stakeholders included information regarding existing conditions, threatened areas, as well as areas with potential for improvement or protection. In addition, stakeholders also wanted a report format with the following attributes:

- regional dataset housed in one location;
- improved GIS capabilities to access water resource data and associated analytical tools to summarize and document data;
- long-term projections;
- hard numbers or case studies of examples; and
- online access to water sources, quality, and availability.

Stakeholders were asked to identify what they perceived to be the region’s top water resource concerns; Table 3 summarizes these responses.
### Table 3: Top water resource concerns in Appalachia identified by stakeholders

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available data</td>
<td>Hydraulic fracturing concerns</td>
</tr>
<tr>
<td>Natural resources</td>
<td>Emerging contaminants</td>
</tr>
<tr>
<td>Natural resource use</td>
<td>Mine-related concerns</td>
</tr>
<tr>
<td>Natural resource potential</td>
<td>Agriculture concerns</td>
</tr>
<tr>
<td>Current research</td>
<td>Development concerns</td>
</tr>
<tr>
<td>Conservation</td>
<td>Political and institutional concerns</td>
</tr>
<tr>
<td>Partnerships</td>
<td>Availability concerns</td>
</tr>
<tr>
<td>Recent innovations</td>
<td>Aging structures</td>
</tr>
<tr>
<td></td>
<td>Future demands</td>
</tr>
</tbody>
</table>

Source: Data from e-mail solicitation to ARC water asset stakeholders in summer 2010.

Responses were shared with the project team during various phases of the project to direct and ground the project.

Appendix B provides tables of themes and responses for each of the topics summarized here.
2 Water quality index

2.1 Introduction
The relationship between water quality and human health is well-documented (Shiber, 2005; Gaffield et al., 2003). However, links between the quality and quantity of water resources and the influence on the overall regional economic health and sustainability can be more confounding (Deller et al., 2008). The water quality index developed for this project provides a comprehensive regional assessment of aquatic assets and a portion of a data framework for analyzing how water quality factors into economic conditions.

There are numerous indicators of water quality: chemical, biological, and physical. It is beyond the scope of this project to compile and analyze water quality measurements or to make independent determinations as to whether specific waterbodies are clean or impaired. Instead, we must use existing determinations of water quality that are available across Appalachian states.

Based on the prevailing literature (Adamus et al., 1991; Forman and Alexander, 1998; Gergel et al., 2002; King et al., 2005; Morse et al., 2004; Ourso and Frenze, 2003) and best professional judgment, we generated a number of landscape-level water metrics using a variety of data sources.

2.2 Metrics and framework
Publicly available data were procured to examine water quality across Appalachia. Only regionally consistent databases were queried for this study. The water quality metrics were combined into two indicators, as shown in Figure 10.

Land use has a demonstrated effect on water quality (Gergel et al., 2002; King et al., 2005; Morse et al., 2004; Ourso and Frenze, 2003). This study began by examining all the land-use types that are classified in the 2001 US Geological Survey’s (USGS’s) National Land Cover Database (NLCD). Many of these land-use types are documented as predicting water quality.

Additionally, multiple industrial factors also have a relationship with water quality. The impaired stream dataset (mapped in Appendix) compiles individual states’ lists of streams that do not meet clean water standards. While these data are reported inconsistently across the region and cannot be used as part of the index, by using the impaired streams as a dependent variable, and controlling for state reporting inconsistencies, various predictor variables can be used to predict whether a stream would be classified as impaired. A statistical analysis was performed to determine whether the scores intended to quantify pollution sources were significantly related to the impairment dataset, after controlling for variations by state. Detailed results of this analysis can be found in the technical appendix of this report. Among the findings were that the prevalence of forests and wetlands is directly related to water quality, whereas agricultural land and impervious surfaces in a watershed are inversely related to water quality. Thus, the land-use metric considered these four land-uses; grouping forests and wetlands resulted in three independent variables with which to construct the land-use indicator (mapped in Appendix).

The second indicator in the quality index is facilities (mapped in Appendix). Facilities encompass many different types of operations such as factories, sewage treatment plants, and coal mines. These facilities, and in some cases the pollutants they release into waterways, are documented in the National Pollutant Discharge Elimination System (NPDES), the Toxics Release Inventory (TRI), the Abandoned Mine Lands Inventory System (AMLIS), and inventories of combined sewer overflows (CSOs) and county coal production. All of these facility types were determined to have a statistically significant impact on water quality.
Assessing Appalachian Natural Assets: Water

Figure 10: Water quality index framework

Metrics
- Percent forest
- Percent wetland
- Percent agriculture
- Percent impervious
- NPDES permits
- CSO communities
- Water-related AMLs
- Coal production
- Toxic releases

Indicators
- Land-use
- Facilities

Index
- Water Quality
  - Score 0 - 100
  - Index: Lowest to Highest categories

Note: NPDES=National Pollutant Discharge Elimination System; CSO=combined sewer overflow; AMLs=abandoned mine lands.
2.3 Indicators

A catchment-level watershed is the smallest commonly used watershed division, referring to the land area draining to a particular stream segment. All catchment-level watersheds were analyzed for percent of agricultural land, impervious land, wetlands, and forests. Analysis began at the catchment level, rather than at the county level, because this provides a more accurate assessment of the impact of land use on water quality.

Poorly managed agricultural land has the potential to negatively impact water quality by introducing harmful bacteria and excess nutrients and sediment to the waterways. Similarly, impervious land—paved surfaces, roofs, etc.—provide a fast-track for polluted stormwater to enter streams. Stormwater carries fertilizers and pet waste from yards, automotive fluids from roadways, and trash and other debris. While some areas do have storm sewers, these often transport stormwater, untreated, directly to waterways.

In contrast, wetlands and forests act as water filters, cooling water and cleaning it to some degree.

Percentages for each land-use variable were calculated and then scaled to achieve individual scores ranging from 0-100. The reverse equation was used for...
agricultural land and impervious surface scores to ensure all variables predict better water quality with increasing values. All catchments within a county were averaged to obtain county-level land-use scores. The results are shown in Figure 11.

Equation 1: Land-use formula

\[
\text{Land-use}_{\text{catchment}} = \text{impervious score}_x + \text{agriculture score}_x + \text{forest and wetland score}_x
\]

\[
\text{Land-use}_{\text{county}} = \text{average (catchment land-use scores)}
\]

\[
\text{Land-use}_{\text{scaled}} = \left( \frac{\text{land-use}_{\text{county}} - \text{land-use}_{\text{min}}}{\text{land-use}_{\text{max}} - \text{land-use}_{\text{min}}} \right) \times 100
\]

When mapped, the land-use scores predict higher water quality scores centered on West Virginia, the eastern mountainous region of Kentucky, north-central Pennsylvania, and western North Carolina. This is not surprising, as the land-use score is based on the cover of forests, wetlands, agriculture, and impervious surfaces. West Virginia and eastern Kentucky are heavily forested, in part due to steep and dendritic topography; the lack of wide valleys and floodplains makes for marginal agricultural land relative to lower elevation areas of Appalachia. In fact, most of the green counties on the map correspond to areas of dense forest canopy cover.

In contrast, counties on the periphery of the ARC region have lower land-use scores, reflecting the agricultural land use in most cases. The red patches in northern Alabama and the eastern panhandle of West Virginia represent growing urban centers—with more impervious surfaces and land being cleared for development—surrounded by agricultural lands. The swath of poor land-use scores in eastern Tennessee and extending into northern Alabama follows the flow of the Tennessee River, historically an agricultural region. There are relatively few large cities in the ARC region, and many of these are balanced by large tracts of forest in other parts of the county. A notable exception to this rule is Knox County, Tennessee, where development around the city of Knoxville has expanded to cover much of the county with impervious surfaces.

In addition to the land-use score that includes entire counties, we also investigated a score that focuses only on the area within 100 meters of each water body. These areas, known as riparian buffers, are extremely important in maintaining water quality; however, the effective width of the buffer can depend on slope and the type of water quality pollutant (Castelle et al., 1994; Wenger, 1999). We evaluated a 100-meter buffer because this is a conservative estimate of the width necessary to provide water quality protection against harmful excess nutrient and sediment inputs (Castelle et al., 1994; Wenger, 1999). However, this metric proved to be redundant with the land-use metrics summarized at the catchment level.

Also, the resolution of the NLCD data—30 meters by 30 meters—results in inconsistencies between the spatial locations of water resources in the NLCD data and the National Hydrography Dataset (NHD). In other words, the resolution of the NLCD data is so close to the buffer width that we were concerned that the GIS overlay would not necessarily provide a representation of the true riparian area. We conducted statistical analyses to determine whether one or the other land-use score was a better predictor of known impairments and found that the two were basically interchangeable in the model. We therefore chose a metric based on the land-use in entire counties.
2.3.2 Facilities

Facilities that discharge pollution directly to rivers and streams can impact water quality in ways not always captured by land-use. To capture the potential impacts from dischargers to Appalachian rivers and streams, we created the facilities score (Figure 12). This score combines information on the numbers of “major” NPDES permits,\(^2\) CSO communities, tons of coal produced from 1983-2009, pounds of chemicals discharged to water as documented in the TRI database, and water-related AML problem areas listed in the Abandoned Mine Lands Inventory System.

Each of these types of facilities was determined, through a mathematical process known as regression analysis, to have a significant negative impact on water quality.

NPDES permits are required for the discharge of pollutants to surface waters, but permittees sometimes violate their permits, and permits do not always control all pollutants. For example, many wastewater treatment plants still do not have enforceable limits for nutrients, despite the fact that excess nutrients harm fish by depleting oxygen from rivers and lakes. For the NPDES metric, each county was assigned a scaled value from 0-100 based on the number of

---

\(^2\) Major NPDES dischargers are those designed to discharge one million gallons per day or more.
Coal mining is a prevalent industry throughout much of Appalachia. The land and sub-surface disturbance associated with mining often results in mine drainage that acidifies streams and increases the amount of metals in the waters. While mining operations are required to have NPDES permits, most mines are not large enough to be considered major NPDES permits, and are therefore absent from the NPDES dataset.

In order to capture the potential effects of this industry on present water quality, two metrics were developed. The first captures impacts from recent activity and is based on total tons of coal mined per square mile, by county, since 1983. Values were then scaled between 0-100. Coal production has not historically occurred uniformly throughout the ARC region. Well over half of the ARC counties have no recent coal production, and therefore received a score of 100 for this metric.

The second coal-related metric captures continuing impacts from past activity because, across Appalachia, historic coal mining continues to significantly impact water quality. Thousands of mines abandoned prior to the 1977 federal Surface Mining Control and Reclamation Act still discharge polluted mine drainage, harming or even eliminating life in streams and rivers. While abandoned mine lands (AMLs) exist throughout the swath down the middle of Appalachia that continues to produce the region’s coal, many counties that no longer produce coal also have AMLs. To account for this important water quality impact, we included a score based on the count of water-related AMLs in each county. Operators that abandoned coal mines prior to 1977 are exempt from environmental liability under the Surface Mining Control and Reclamation Act, leaving the burden of any environmental remediation in the hands of local, state, or federal government. As such, the legacy of water quality impairments resulting from abandoned mine drainage is a costly and lasting reminder of the importance of environmental accountability and is reflected in the water quality scores. For the AML metric, each county was assigned a scaled value from 0-100 based on the number of water-related AMLs per square mile. Counties with no water-related AMLs received a score of 100.

Another significant sector not captured by the NPDES dataset is municipally-discharged, untreated sanitary waste. Prior to about 1950, it was a common practice in the eastern US to construct systems that direct stormwater runoff into combined sewer systems, mixing stormwater with sanitary sewage. Many of these combined systems are still in use. During long or intense rain events, the increased runoff overwheels the sewers, resulting in the release of the combined sewage and stormwater directly into streams through discharges known as CSOs. For this indicator, each county was assigned a scaled value from 0-100 based on the number of CSO communities per square mile.

Certain industries and federal facilities are required to report releases of toxic chemicals to the US Environmental Protection Agency (USEPA) on an annual basis. The selected chemicals are reported by weight released to air, water, and land. While we recognize that chemicals vary in their effects on water quality, it was not practical to weight specific chemicals based on their toxicity. Thus, for this indicator, each county was assigned a scaled value from 0-100 based on the pounds per square mile of TRI chemicals released to water.

To calculate the composite facilities score, each county’s NPDES, coal production, AML, CSO, and TRI scores were summed and scaled to range from 0-100.

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3 1983 was chosen as the start year because this is the first year for which county-level production is available in a consistent format across Appalachian counties.
Facilities scores display a pattern that overlays with much of the industry that has historically been part of Appalachia. The counties scoring the poorest on the facilities score are concentrated in two areas: the Kentucky-Virginia-West Virginia tri-state area and western Pennsylvania/northern West Virginia. In addition to being coal mining regions, these areas have many CSO communities. Other noteworthy concentrations of low facilities scores suggest concentrations of industry around Birmingham, Alabama.

Interestingly, only three counties in the top third of facilities scores contain cities greater than 20,000 in population according to the 2000 census; only sixteen contain cities greater than 10,000 in population. Conversely, 37 counties in the bottom third contain at least one city greater than 20,000 in population, and 66 contain at least one city with a population greater than 10,000.

NPDES, CSO, and TRI scores all displayed significant gaps between the worst county—assigned a score of 0—and the next worst county. This contributed to a clustering affect at the high end of the total facilities score as shown in the histogram in Figure 12. More than one-third of ARC counties score 100 for at least four facilities metrics, which also contributes to the skewed histogram.

### Equation 2: Facilities formula

\[
\text{Facilities}_{\text{county} i} = \text{NPDES score}_i + \text{coal production score}_i + \text{AML score}_i + \text{CSO score}_i + \text{TRI score}_i
\]

\[
\text{Facilities}_{\text{scaled}} = \left( \frac{\text{facilities}_{\text{county} i} - \text{facilities}_{\text{min}}}{\text{facilities}_{\text{max}} - \text{facilities}_{\text{min}}} \right) \times 100
\]
2.4 Discussion

Our water quality score (Figure 13) and water quality index (Figure 14) represent a general, county-by-county approximation of water quality. The data resolution and lack of on-the-ground measurements must be considered when evaluating the analysis. However, the water quality analysis is based on the best available data, and highlights many regional differences and trends.

The Web-based DSS can be used to weight the indicators and metrics differently. For our basic analysis, all were weighted equally.

This produced patterns that appear to follow the physical characteristics of the region, with exceptions that are indicative of current or historical industries that impact water quality. Throughout the region, higher elevation counties and those far from large cities and large rivers tend to have the best water quality score. The simple explanation is that the higher mountainous areas are not conducive to agriculture or transportation infrastructure, which often limits industry and development. These high-scoring counties also contain vast stretches of protected lands. These include the Allegheny National Forest in Pennsylvania, the Monongahela National...
Forest in West Virginia, the George Washington National Forest in Virginia, the Pisgah and Nantahala National Forests and Great Smoky Mountains National Park in North Carolina and Tennessee, the Chattahoochee National Forest in Georgia, and the Daniel Boone National Forest in Kentucky.

Equation 3: Water quality formula

\[
\text{Quality}_{\text{county}} = \text{land-use score} + \text{facilities score},
\]

\[
\text{Quality}_{\text{scaled}} = \left[ \left( \frac{\text{Quality}_{\text{county}} - \text{Quality}_{\text{min}}}{\text{Quality}_{\text{max}} - \text{Quality}_{\text{min}}} \right) \times 100 \right]
\]

There are certainly counties outside of federal lands that are also predicted to have high water quality, notably west-central West Virginia, the Pocono Mountains in eastern Pennsylvania, and parts of central Pennsylvania and northern Tennessee. Although many of these areas have low facilities or AML scores, their composite scores are raised by high land-use scores. Also, not all federally protected land receives high water quality scores. The Wayne National Forest in Ohio, Holly Springs National Forest in Mississippi, and the Bankhead National Forest in Alabama are among the exceptions. The Wayne National Forest and surrounding counties are currently and were historically mined, and Mississippi and Alabama National Forests tend to be situated within a matrix of agricultural lands.

As mentioned previously, agriculture is prevalent in the lower-elevation, less-mountainous, peripheral counties of the ARC region, especially in the southern region along the Tennessee River and its tributaries. In the north, agriculture is present in southwestern Pennsylvania, but the industrial boom that occurred along the major waterways of the Monongahela, Allegheny, and Ohio Rivers heavily influences the facilities score. This region is also subject to current and historical coal mining influences. Mining also influences water quality in the Cumberland Mountain region of southern West Virginia, eastern Kentucky, and southwestern Virginia. Despite being heavily forested, the impacts from this actively mined area are evident in our analysis. Also, throughout the Appalachian Region, a number of individual counties are affected by urban sprawl and development, notably around Greenville, South Carolina; Knox County, Tennessee; and the eastern panhandle of West Virginia.

Of all the counties at the far ends of the spectrum, only one region consistently has composite scores at the opposite side of the scale from its land-use scores: the red counties in Kentucky, Virginia, and West Virginia. Almost all other concentrations of dark red or dark blue counties are comparably colored on the land-use map. (The one exception is the red area centered around northern West Virginia and southwestern Pennsylvania.) These patterns suggest that land-use may be the most important single proxy for water quality in Appalachia.

We considered including in the water quality index an indicator that captures whether or not each stream is impaired. USEPA provides data on waters listed as impaired by state agencies. However, the data sources are not uniform across the entire study area, creating a measure of reporting bias. For example, Ohio does not list individual streams as being impaired; rather, impairment is described by watershed. Furthermore, the data source simply notes whether a stream segment is impaired or not; those not listed may be clean, but may also be unassessed. Because so many streams across Appalachia, and across the country, are unassessed, this data source provides an incomplete and misleading dataset regarding actual impairments.

In addition, we were concerned about mixing scores that represent pollution sources (land-use and facilities) with a score that directly represents the impacts from these pollution sources (impairment). We performed statistical analyses to determine whether the land-use and facilities scores were significantly related to
When controlling for the effects of differences among states, almost half of the variation in impairment scores is explained by differences in land-use and facilities scores. These results are statistically significant at $p < .01$. We therefore feel comfortable using the scores that represent pollution sources and leaving out the score that directly represents impacts.

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4 Two scores now included within the facilities score—coal and AMLs—were analyzed separately in the statistical analysis.
Figure 14: Water quality index

Water Quality Index in Appalachia

![Water quality index map of Appalachia showing various levels of water quality with a legend indicating categories (Lowest, Very Low, Low, Medium, High, Very High, Highest) and a formula for calculating the index.]

Formula:
Raw water quality score = final land use score + final facilities score

Final water Asset score = \[
\left(\frac{\text{raw quality score for County} \times \text{final water asset score}}{\text{maximum raw quality score} - \text{minimum raw quality score}}\right) \times 100
\]

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011

NOTE:
For mapping, the counties were sorted by final water asset score and grouped into six categories, with 70 counties in each category.
Putting the tool to work

Example 1: Water quality and recreational access

Fun and healthy water-based recreation experiences require high water quality. In this case study, surface water quality and recreation access indices were compared side by side to locate counties with unmet potential for water recreation. Water quality and access indices are mapped with the bottom 10% of each set of scores in red, and the top 10% in dark blue (Figure 15). These maps show that many regions with high water quality also have high water access. In fact, only two counties—Hamblen and Jefferson counties, Tennessee—are in the top 10% of water access scores, while falling in the bottom 10% for water quality.

This comparison draws out an area in the southernmost extent of the ARC region along the border of Mississippi and Alabama. Five counties in this region—Choctaw and Kemper counties, Mississippi and Fayette, Lamar, and Pickens counties, Alabama—all have water quality scores in the top 20%, but water access scores in the bottom 6% of ARC counties. Additionally, they all fall into either the At-risk or Distressed categories in the ARC economic index and all but Fayette County are among the top 20% for stream density. With their high water quality values, these rural counties should consider a study on the possibility of expanding water access to attract more visitors to the area.

Figure 15: Water quality (left) and access (right) indices mapped in 10% increments
3 Water quantity index

3.1 Introduction

Many cities and rural communities within and around the region are dependent upon the wise use, control, and development of Appalachian water resources. This dependence on water for economic growth has become increasingly evident in recent decades. Human demand for freshwater has tripled since 1950 due to population growth, irrigation, and increasing material consumption (Postel and Carpenter, 1997). The first quantity indicator—water budget—reviews supply and demand in each county, considering surface and groundwater regimes separately. These are combined into a total water budget index for each county, allowing the display of the spatial distribution of relative water quantity throughout the ARC region.

While recognizing the positive contribution of water resources for economic growth, water may also be a threat to quality of life and community development if flooding occurs. According to ARC (1964), “of the land that is suited for development, approximately 23% is located on or adjacent to the flood plain and therefore is subject to flooding” (as cited in Fuller, 1970). In order to capture both positive and negative aspects of water quantity, the project team chose flooding as a measure of water’s ability to cause a negative impact.

A third indicator quantifies stream length and lake area per total area of each county and provides a measure of water quantity independent of population and usage. It offers insight into each county’s water resources and allows comparison with some of the other indices and indicators in this study.

3.2 Metrics and framework

Publicly available data were procured to examine water quantity across the Appalachian Region. This study used datasets that are consistent across state boundaries; therefore, only regionally consistent databases were queried. Climatic and precipitation data were provided by the National Weather Service Climate Prediction Center’s Web site; flow and water consumptive use data were provided by USGS. Figure 16 illustrates the components of the water quantity index.
Surface water availability was derived from the flow rate of each county’s largest river. Because only surface supplies from rivers were considered, counties containing considerable water supply volumes from other sources (such as those bordering the Great Lakes) may receive inaccurately low indicator scores.

Groundwater availability is represented by precipitation minus evapotranspiration. This is a simplification because some precipitation enters streams as runoff, and because there is a constant exchange of water between the groundwater system and the surface water system.

To quantify water demand, consumptive use was summed separately for surface and groundwater utilizing USGS estimates of 2005 water withdrawals by county. Irrigation and thermoelectric cooling are the dominant withdrawal components nationwide.

Data for the second indicator, flooding, was provided by the National Climatic Data Center (NCDC) at the National Oceanic and Atmospheric Administration. NCDC compiles storm data provided by 124 regional offices of the National Weather Service (NWS). NCDC provided storm data for September 2000 through
August 2010. The database was queried for events reported in the “flood” and “flash flood” categories. The project team then summed the flood events by county and scaled them by county area to produce a score representing decennial flood events per square kilometer.

NWS compiles data based on forecast zones. For the most part, these zones correspond with county boundaries. However, a few counties with large topographic and geographic variability are split into two forecast zones. For consistency, storms occurring in these split-county forecast zones were reviewed to ensure that if a single flood event was documented in both of a split county’s forecast zones, it was only counted as one flood in that county.

A third obvious measure of water quantity is a simple ratio of water bodies to county area. Regardless of use or quality, a higher density of streams and lakes should contribute to a higher water quantity score. The research team used the NHDPlus dataset to determine ratios of total stream length and lake area to county area according to the following formulas.

For simplicity, this measure includes only lake area and stream length that fall within county boundaries and excludes the Great Lakes.

### 3.3 Indicators

#### 3.3.1 Water budget

Trends in water use and sustainability can be examined through historical records. For the water budget indicator, we estimated water surplus or deficit for each county in the ARC region for both surface and groundwater. The results provide an opportunity to examine spatial trends in historic water use as well as the likelihood of future water deficits of counties within the ARC region relative to each other. The methodology and much of the data for this study were taken directly from the work of Roy et al. (2005; 2010), whose published documents provide an in-depth and robust analysis on the national scale.

**Equation 4: Water budget formula**

\[
\text{Budget}_{county}^{x} = \text{surface water use score}_{x} + \text{groundwater use score}_{x}
\]

\[
\text{Budget}_{scaled} = \left( \frac{(\text{budget}_{county}^{x} - \text{budget}_{min})}{(\text{budget}_{max} - \text{budget}_{min})} \right) \times 100
\]

---

5 This analysis used the NHD 100k dataset. Streams in some areas are mapped inconsistently, so the accuracy of total stream length may vary regionally.
In order to quantify water resource trends throughout the ARC region, we began by comparing water available for human use to total water used at the county level for surface water and groundwater separately. Surface water consumptive uses were compared to stream flow; groundwater consumptive uses were compared to long-term annual averages of precipitation minus evapotranspiration.

The surface water usage ratio provides a generalized account of the ability of each county’s largest river to support its consumptive water withdrawal. The spatial variability of this index is driven by the distribution of the major rivers and the surface withdrawals. While the Ohio River appears capable of supporting current and future surface withdrawals, other rivers, such as the South Branch Potomac River, may prove less capable (Figure 17 maps the combined surface water and groundwater ratios and does not directly illustrate these patterns). Because this measure incorporates stream flow only, other sources such as major lakes and reservoirs are ignored. However, counties considered most “at-risk” relative to the rest of the region can be identified.

The groundwater usage ratio provides a relative measure of the ability of each county to sustain its groundwater withdrawals. The spatial distribution of this measure is primarily dominated by the variability of the groundwater
withdrawal data by county. Counties with the highest groundwater ratio values are more capable of supporting withdrawals, while those most at-risk to long-term depletion return low scores. Additional information such as aquifer storage and depletion could provide a more accurate measure of long-term groundwater sustainability.

Groundwater and surface water usage ratios were combined to obtain a single water budget indicator (Figure 17). High ratios of availability to consumption translate into high indicator scores; low ratios, low scores.

The results of this comparison of water availability and use can be analyzed to identify those counties most at risk for water shortages. In general, counties with higher values generally have greater water surpluses. Based on this analysis, none of the counties showed an actual water deficit. This index provides an overall estimate of water sustainability by county. It is interesting to note that the Ohio River valley counties have relatively lower indicator values while most counties in eastern Kentucky have high values.

3.3.2 Flood frequency

Raw flood numbers were collected by NWS and provided by NCDC. Using a 10-year data window, flood counts were divided by county area to avoid penalizing large counties for having more floods. The distribution of flood frequency scores is weighted heavily toward the higher end, with a mean of 83.
and a median of 87 (Figure 18). This suggests that much of Appalachia has a relatively similar number of floods per square mile. Eastern Kentucky is a notable exception to this general rule. Of the 37 counties in Kentucky that are entirely east of Lexington, the average score is 63; eastern Kentucky contains seven of the worst ten counties in the ARC in terms of flooding.

**Equation 5: Flood frequency formula**

\[
\text{Flood frequency}_{\text{county } x} = \frac{\text{flood event count}_{\text{county } x}}{\text{area}_{\text{county } x}}
\]

\[
\text{Flood frequency}_{\text{scale}} = 100 - \left[ \frac{\text{flood frequency}_{\text{county } x} - \text{flood frequency}_{\text{min}}}{\text{flood frequency}_{\text{max}} - \text{flood frequency}_{\text{min}}} \right] \times 100
\]

Other regions with greater than average flood frequency are northern Alabama, the northern and eastern panhandles of West Virginia, western Pennsylvania, and much of Appalachian Ohio. On the other hand, lower than average flood frequency occurs in counties that form a nearly contiguous northeast-southwest swath through central Appalachia.
Putting the tool to work

Example 2: Flooding and economic distress

Flash flooding is one of the most hazardous natural events and has environmental, social, and economic implications. The Buffalo Creek disaster is one of the best documented cases of the long-term impacts of flooding. In February 1972, 132 million gallons of debris-filled muddy water burst through an earthen mine dam, killing 125 people in the small community of Buffalo Creek, West Virginia. Approximately 4,000 of 5,000 residents lost their homes; 93% of residents suffered from emotional disturbance; nearly all had close experiences with death; and following the disaster, a once tightly knit community ended up with little individual concern for one another (Gruntfest, 1995). A study by Erickson (1998) concluded that the community of Buffalo Creek suffered two disasters: the gradual deterioration of mountain culture and the flood disaster itself. As such, policy makers, regulators, and managers need to recognize the long-term impacts of floods on communities.

Flooding has tremendous impact on society. Loss of human life, injury, and endangerment, as well as impacts on the environment, are often associated with larger floods. Every year, people are killed and displaced by flooding. Additional impacts of flooding include polluted water, food shortage, loss of homes, damage to personal property, exposure to elements, disruption of education and community cohesion, and loss of security, jobs, and enforcement programs. However, there is no consensus about the long-term social impacts of flooding. Studies generally indicate that socioeconomic trends in place prior to a flood are reinforced following flooding (Gruntfest, 1995). When a flood impacts a community already experiencing economic troubles, the flood can exacerbate or accelerate the rate of downturn. In recurrent flood-prone areas of Appalachia, communities can get caught in a continuing feedback cycle of disaster, relief, and repair, followed by another disaster (Gautam and van der Heok, 2003).

The economic impacts of flooding can be detected at local, regional, and national scales. Since 1978, more than $8 billion were paid in total loss payments in Appalachian counties (NFIP, 2011).
3.3.3 Stream and lake ratios

Stream and lake ratios were calculated as length of streams per unit area and area of lakes per unit area for each county.

Generally speaking, southern Appalachia—Tennessee and North Carolina and southward—receives higher stream and lake ratio scores than central and northern Appalachia. Fifty-eight of the 70 counties in the lowest category for stream and lake ratio are in central and northern Appalachia; 64 of the 70 in the highest category are in southern Appalachia.

Equation 6: Stream/lake ratio formula

\[
\text{Stream-lake ratio}_{\text{county} x} = \text{stream ratio score}_x + \text{lake ratio score}_x
\]

\[
\text{Stream-lake ratio}_{\text{scaled}} = \left( \frac{\text{stream-lake ratio}_{\text{county} x} - \text{stream-lake ratio}_{\text{min}}}{\text{stream-lake ratio}_{\text{max}} - \text{stream-lake ratio}_{\text{min}}} \right) \times 100
\]

Of 24 Mississippi counties in the ARC region, 16 are among the top 5% for stream ratio and none are in the bottom half. The average scaled score for stream ratio in Mississippi is 75. In contrast, the average stream ratio for the 66 New York and Pennsylvania counties is 38—about half the value in Mississippi. However, with the exception of these states at the geographic extremes of Appalachia, there is little correlation between latitude and stream ratio. And while the higher ratios are concentrated in Mississippi, the total variation is small, with the highest stream ratio...
just four times the lowest. This relatively tight distribution reflects the natural condition of stream formation in Appalachia.

On the other hand, lake-acres are strongly influenced by anthropogenic forces—namely, dams. At least 30% of Appalachian lakes larger than 1 km\(^2\) and a majority of those larger than 10 km\(^2\) are created by dams. These dams are especially prevalent along the Tennessee River, primarily in Tennessee and Alabama. In contrast to stream length, lake area varies significantly among counties in Appalachia. A handful of counties have no lakes at all, while Jefferson County, Tennessee is fully 12% water by area. Only two other counties—Meigs County, Tennessee and Russell County, Kentucky are more than 10% water by area. Nearly three quarters of Appalachian counties are less than 1% water. Counties with large lakes and reservoirs are often popular spots for real estate development and water recreation.

While stream length is effectively static and not subject to “improvement” by policy decisions, and lake acres only marginally more so, stream and lake ratios are a good place to start in evaluating water recreation and other water-related development potential.
3.4 Discussion

Counties with the highest consumptive water use are those containing populated and industrialized areas such as Pittsburgh, Pennsylvania; Weirton, West Virginia; Huntsville, Alabama; and the Ohio River Valley. After excluding the majority of thermoelectric use as non-consumptive, other categories emerge as major water consumers. The four counties with the highest use values for 2005 are: Allegheny, Pennsylvania (industry, public supply); Delaware, New York (public supply); Sullivan, Tennessee (industry); and Transylvania, North Carolina (aquaculture). The majority of water withdrawals in the ARC region are taken from surface water; in 2005, the total water withdrawn from the surface was nearly six times the amount taken from the ground.

Equation 7: Water quantity formula

\[
\text{Quantity}_{\text{county}} = \text{water budget score}_s + \text{flood frequency score}_s + \text{stream and lake ratio score}_s \\
\text{Quantity}_{\text{scaled}} = \left( \frac{\text{Quantity}_{\text{county}} - \text{Quantity}_{\text{min}}}{\text{Quantity}_{\text{max}} - \text{Quantity}_{\text{min}}} \right) \times 100
\]

The combination of the three water quantity indicators yields an index with geographic patterns similar to those of the stream and lake ratios scores (Figure 21 and Figure 22). Sixty-one of the bottom 70 counties are in northern and central Appalachia; 64 of the top 70 are in southern Appalachia. Interestingly, the counties with the highest stream and lake ratios are not necessarily those with the highest flooding frequency (corresponding to a low flooding score). Neither do large rivers seem to consistently predict floods.
Figure 22: Water quantity index

Water Quantity Index in Appalachia

Formula:
Raw water quantity score = final usage score + final flood score + final streams and lakes score

Final Water Quantity Score = \( \frac{\text{raw quantity score for County } x - \text{minimum raw quantity score}}{\text{maximum raw quantity score} - \text{minimum raw quantity score}} \) \times 100

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011

NOTE:
For mapping, the counties were sorted by final water asset score and grouped into six categories, with 10 counties in each category.
Putting the tool to work

Example 3: Marcellus Shale

The water quantity index and its indicators lend themselves to a number of applied policy uses. Increased drilling in deep shale formations (Figure 23) is occurring in several Appalachian states. Natural gas drilling and the concurrent water withdrawal from streams, as well as potential for water quality degradation, can then be evaluated for potential to impair water quality and stress quantity. Such an analysis could begin with a look at the water quantity index values of each county relative to the number of Marcellus Shale permit applications. If new wells are proposed in counties where water quantity is poor, there is a chance that the extraction could stress existing water resources. This index can therefore help identify counties within which extra precautions may be required in order to maintain water quantity.

Figure 23: Gas-bearing shale formations in Appalachia
4 Water access index

4.1 Introduction

While access to safe drinking water sources has been extensively examined in the literature, recreational water access has received little attention. Water for recreational purposes is usually considered a byproduct of a water project, accounting for a small percentage of total water use. However, in some cases, recreation is the major use of water. Recreational water use is mostly tied to reservoirs, lakes, rivers, and streams that can be used by anglers, waterfowl hunters, water skiers, swimmers, boaters/watercraft users, and nature enthusiasts. Such activities may vary from personal pursuits to commercial operations involving the use and provision of goods and services.

Studies have shown large economic impacts from water recreation. For example, English and Bowker (1996) studied five whitewater rivers, three of which are inside the ARC study region. The study reported total annual industrial output ranging from $4.35 million for the Chattooga River on the Georgia-South Carolina border to $14 million for the Nantahala River in North Carolina. Fishing and other water recreation activities are also an important part of the tourist economy in many Appalachian counties. A more recent study (Helvoigt et al., 2009) on the economic impacts of river-based recreation on the Wild and Scenic Rogue River found that in 2007, recreational activities—including hiking, fishing, and boating—accounted for 445 full- and part-time jobs and $30 million in total economic output, including $15.4 million in personal income.

In recognition of the increasing importance of the provision of water-based recreational opportunities to the general public, some organizations and agencies have developed and mapped recreational water data. For example, Water Access Alliance has been developing the Boating Access Surveillance and Indexing System (BASIS), which provides nationwide information on changes in available boating access. The system uses satellite photography and other resources to identify access points. With the establishment of the dataset on slips at marinas, dry storage capacity, private docks, launching ramps, and ramp parking, BASIS can determine exactly what has changed over time. The Minnesota Department of Natural Resources has also developed a recreational water access dataset with access points for boating and other water-related recreational activities. It also created an interactive map for each county, which shows the distribution of water access points, sites, and routes related to different recreational uses. While these two studies collected data mainly through the use of satellite photography or GPS, data collection for our study was primarily based on secondary sources: published datasets, Web sites, and stakeholders.

While the literature contains no single definition of water access for recreational purposes, recreational water access can be defined in terms of 1) the quantity of water access points/sites for recreational purposes per square mile; 2) the quantity of water access points/sites for recreational purposes per capita; and 3) the proportion of water used for recreational purposes. This project examines these three aspects of recreational water access by developing and mapping indices for recreational water access in the Appalachian region. The first definition—the quantity of water access points/sites for recreational purposes per square mile—is used in the water access index and incorporated into the final water asset index. The reason for using this ratio rather than the actual number of points per county is that the ratio allows for comparisons across counties, no matter the size of each county.
4.2 Metrics and framework

To develop an index system to reflect the distribution of the number of water access points/sites for recreational purposes, the project team developed an inventory of water access points for different uses. Access points were collected from various government agencies and non-profit organizations. Initially, the Web sites of these institutions were consulted for available, downloadable data. Readily available data were downloaded and request letters were sent to database management personnel in the agencies without downloadable data. Recreational water access points for three types of water-based activities were collected: swimming, boating, and fishing. These were combined into a single access index as shown in Figure 24.

Table 4 summarizes the agencies and corresponding Web sites consulted in data collection. As shown, a total of 18 public agencies were approached either through Web searches, calls, or e-mails. In response to request letters, agencies sent their respective datasets as printed maps, atlases, or compact discs by mail or in the form of electronic Excel spreadsheets by e-mail. Furthermore, to supplement data collected from the government agencies, organized outdoor recreation groups were also contacted. The groups that maintain their own database forwarded their data to the research team, while others suggested alternative resources where data can be obtained (Table 5).
Table 4: Agencies providing water access data

<table>
<thead>
<tr>
<th>Agency</th>
<th>Web site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama Department of Conservation and Natural Resources</td>
<td><a href="http://www.outdooralabama.com/">http://www.outdooralabama.com/</a></td>
</tr>
<tr>
<td>Wildlife Resources Division, Georgia Department of Natural Resources</td>
<td><a href="http://www.georgiawildlife.com/">http://www.georgiawildlife.com/</a></td>
</tr>
<tr>
<td>Georgia GIS Clearinghouse</td>
<td><a href="http://www.gis.state.ga.us/">http://www.gis.state.ga.us/</a></td>
</tr>
<tr>
<td>Kentucky Department of Natural Resources</td>
<td><a href="http://www.kdfwr.state.ky.us/">http://www.kdfwr.state.ky.us/</a></td>
</tr>
<tr>
<td>Maryland Department of Natural Resources</td>
<td><a href="http://www.dnr.state.md.us/">http://www.dnr.state.md.us/</a></td>
</tr>
<tr>
<td>Mississippi Department of Wildlife, Fisheries and Parks</td>
<td><a href="http://home.mdwfp.com/">http://home.mdwfp.com/</a></td>
</tr>
<tr>
<td>New York Department of Environmental Conservation</td>
<td><a href="http://www.dec.ny.gov/">http://www.dec.ny.gov/</a></td>
</tr>
<tr>
<td>New York State Office of Parks, Recreation and Historic Preservation</td>
<td><a href="http://nysparks.state.ny.us/">http://nysparks.state.ny.us/</a></td>
</tr>
<tr>
<td>Ohio Department of Natural Resources</td>
<td><a href="http://www.dnr.state.oh.us/">http://www.dnr.state.oh.us/</a></td>
</tr>
<tr>
<td>Pennsylvania Spatial Data Access</td>
<td><a href="http://www.pasda.psu.edu/">http://www.pasda.psu.edu/</a></td>
</tr>
<tr>
<td>South Carolina Department of Natural Resources</td>
<td><a href="http://www.dnr.sc.gov/">http://www.dnr.sc.gov/</a></td>
</tr>
<tr>
<td>Tennessee Valley Authority</td>
<td><a href="http://www.tva.gov/">http://www.tva.gov/</a></td>
</tr>
<tr>
<td>Tennessee Wildlife Resources Agency</td>
<td><a href="http://www.tn.gov/twra/">http://www.tn.gov/twra/</a></td>
</tr>
<tr>
<td>US Fish and Wildlife Service</td>
<td><a href="http://www.fws.gov/">http://www.fws.gov/</a></td>
</tr>
<tr>
<td>Virginia Department of Game and Inland Fisheries</td>
<td><a href="http://www.dgif.virginia.gov/">http://www.dgif.virginia.gov/</a></td>
</tr>
<tr>
<td>West Virginia GIS Technical Center</td>
<td><a href="http://wvgis.wvu.edu/">http://wvgis.wvu.edu/</a></td>
</tr>
</tbody>
</table>

Table 5: Private outdoor recreation groups providing water access data

<table>
<thead>
<tr>
<th>Group</th>
<th>Web site</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Whitewater Association</td>
<td><a href="http://www.americanwhitewater.org/">http://www.americanwhitewater.org/</a></td>
</tr>
<tr>
<td>Kayak411</td>
<td><a href="http://www.kayak411.com/">http://www.kayak411.com/</a></td>
</tr>
<tr>
<td>MyFishMaps.com</td>
<td><a href="http://www.myfishmaps.com/">http://www.myfishmaps.com/</a></td>
</tr>
<tr>
<td>Recreation.gov</td>
<td><a href="http://www.recreation.gov/">http://www.recreation.gov/</a></td>
</tr>
<tr>
<td>SwimmingHoles.Info</td>
<td><a href="http://www.swimmingholes.info/">http://www.swimmingholes.info/</a></td>
</tr>
</tbody>
</table>

Based on the aforementioned data sources, a database was created that contained all relevant information received from the agencies and groups. The compiled database was then sent to the source agencies and groups for verification. After receiving responses from the source agencies and groups, the database was finalized. A total of 58,136 recreational water access points were identified, including 50,358 points associated with streams and rivers and 7,778 points for lakes and reservoirs.

Some access points were specific to swimming, boating, or fishing. Others were not specific to a single activity. Among the non-specific access points, fishing and boating access are reported in similar numbers, while swimming access is much less prevalent. However, since our goal was to classify water recreation access in the context of the ARC region regardless of an activity’s prevalence relative to other activities, fishing, boating, and swimming access were evaluated separately and weighted equally in the final access index.
4.3 Indicators

4.3.1 Fishing access

Fishing has long been a popular activity in Appalachia, both as a form of recreation and a means of catching dinner. Our analysis shows a high density of fishing access in central Appalachia.

Specifically, 20 of the top 25 counties in terms of fishing access are in eastern Kentucky or western North Carolina. West Virginia and Tennessee also have relatively high access, with several counties having more than one access point per two square miles. Counties at the extreme ends of Appalachia—especially those in Mississippi and New York—appear to have relatively lower fishing access.

Equation 8: Fishing access formula

\[
\text{FishAccess}_{\text{county}} = \frac{\text{count of fishing access points}}{\text{county area}}
\]

\[
\text{FishAccess}_{\text{scaled}} = \left[ \frac{(\text{FishAccess}_{\text{county}} - \text{FishAccess}_{\text{min}})}{\text{FishAccess}_{\text{max}} - \text{FishAccess}_{\text{min}}} \right] \times 100
\]
4.3.2 Boating access

Boating access covers a range of water recreation activities. The people of Appalachia have long launched fishing boats into small ponds and reservoirs, but in recent decades, whitewater boating has become increasingly popular. Opportunities for commercial whitewater rafting excursions and private kayak and canoe outings draw millions of visitors to the region each year, and rivers in many Appalachian states consistently make regional and national best-of lists for whitewater.

Equation 9: Boating access formula

\[
\text{BoatAccess}_{\text{county}} = \frac{\text{count of boating access points}}{\text{county area}}
\]

\[
\text{BoatAccess}_{\text{scaled}} = \left( \frac{\text{BoatAccess}_{\text{county}} - \text{BoatAccess}_{\text{min}}}{\text{BoatAccess}_{\text{max}} - \text{BoatAccess}_{\text{min}}} \right) \times 100
\]

As evidenced by the histogram, a small number of counties in Appalachia—two in North Carolina and one in northeastern Pennsylvania—have boating access in a much higher density than the rest of the region. In addition to these outliers, boating access is relatively high in the tri-state areas of North Carolina-South Carolina-Georgia and West Virginia-Pennsylvania-Maryland, as well as in northeastern Pennsylvania.

In contrast with reported fishing access, eastern Kentucky is among the lowest in terms of boating access.
4.3.3 Swimming access

Swimming access is also weighted heavily to the low side. While it may be that swimming is not as popular an activity as boating and fishing, it is also likely that swimming access locations are not as thoroughly documented as fishing and boating access points. This lack of documentation may result from the lack of commercialization of swimming recreation or absence of a need for formal swimming infrastructure.

Equation 10: Swimming access formula

\[
SwimAccess_{\text{county}} = \frac{\text{count of swimming access points}}{\text{county area}}
\]

\[
SwimAccess_{\text{scaled}} = \left( \frac{SwimAccess_{\text{county}} - SwimAccess_{\text{min}}}{SwimAccess_{\text{max}} - SwimAccess_{\text{min}}} \right) \times 100
\]

In any case, 233 Appalachian counties have no reported swimming access locations in the publicly available datasets gathered by the research team. Based on these datasets, regions with relatively high density of swimming access points include eastern Tennessee, western South Carolina, and Pennsylvania and Ohio—particularly the counties near Lake Erie and the eastern Pennsylvania counties near the Delaware River.
4.4 Discussion

Figure 28 and Figure 29 show water recreation access levels based on the total count per area of access points in the Appalachian region.

There is a relatively large amount of recreational water access in the Appalachian region and the majority of these points are devoted either to boating, fishing, or both recreational activities. More than 86% of these access points are located along streams or rivers while 14% are associated with lakes or reservoirs.

The central part of the region has the highest access levels. Notable concentrations of counties with high access levels are in Kentucky, West Virginia, Tennessee, the Carolinas, and eastern Pennsylvania. On the other hand, the counties along most of the region’s perimeter had very low access density levels, with notable clusters in Mississippi, Alabama, Virginia, Pennsylvania, and New York. It was also observed that Appalachian counties located on the border between Virginia and North Carolina have low water recreation access levels.
Figure 29: Water access index

Water Access Index in Appalachia

**Formula:**
Raw water access score = final boating score + final fishing score + final swimming score

**Final Water Access Score:** \[ \frac{\text{raw access score for County } x - \text{minimum raw access score}}{\text{maximum raw access score} - \text{minimum raw access score}} \times 100 \]

**NOTE:**
For mapping, the counties were sorted by final water asset score and grouped into six categories, with 70 counties in each category.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
The number of access points used for boating, fishing, or both was found to be well established. For access points associated with lakes and reservoirs, the central part of Appalachia including portions of the north and south-central regions have the most access points, including several neighboring counties in Georgia and Tennessee. For access points associated with streams and rivers, most are found along the entire middle portion of the region covering the majority of West Virginia, and the Appalachian counties in Kentucky, the Carolinas, and Tennessee. This pattern can be at least partially explained by the dearth of lakes in the mountainous central Appalachian region. However, this does not explain the low levels of access for lakes, reservoirs, streams, and rivers observed in the southern region of Appalachia.

Overall, more than half of all counties in the region have an above-average concentration of recreational water access points by recreational activity (i.e., boating or fishing), which means that there are available areas for the local population to enjoy water recreation activities. Consequently, these counties can also utilize these resources to entice visitors to the region who, in turn, can contribute to the region’s economy through their expenditures.

Appalachia has tremendous opportunities in water-based recreation as evidenced by the presence of access points across the region. The number of access points collected for the study may be treated as a rough estimate of what the whole region actually offers; this highlights the need for a more thorough and comprehensive initiative to gather more information on recreational water access points in the region.

Because the variety of water recreational activities available at each point is, at present, roughly documented, additional study would be helpful. Data availability was a major limitation that influenced the database compiled for this study. A systematic and geographically referenced database that can be shared by all counties in the region would be instrumental in drawing up future plans on the management of water resources for recreation in Appalachia.

---

**Equation 11: Water access formula**

\[
\text{Access}_{\text{county}x} = \text{fishing score}_x + \text{boating score}_x + \text{swimming score}_x
\]

\[
\text{Access}_{\text{scaled}} = \left[ \frac{(\text{Access}_{\text{county}x} - \text{Access}_{\text{min}})}{(\text{Access}_{\text{max}} - \text{Access}_{\text{min}})} \right] \times 100
\]
5 Water value indices

5.1 Introduction

There are a variety of different methods economists use to place monetary value on natural resources like water. These methods include information derived from markets (such as observed market prices) and information estimated from survey data or observed behaviors. This second approach is called non-market valuation and includes techniques such as contingent valuation, property value hedonics, and the travel cost method. Economists estimate monetary values to reflect what individuals in society are either: (1) willing to pay to acquire the resource if it is not owned by an individual or (2) willing to accept to give up this resource if it is owned by an individual.

In this section, the monetary values for surface water resources are based on market information for water withdrawal uses. For water quality, non-market information derived from contingent valuation studies was utilized. In both cases, the values reflect a willingness to pay for the water resource. These values were then utilized to derive indices in order to provide comparisons among counties in the Appalachian region.

5.2 Metrics and framework

The market valuation index utilized imputed values for water use and county-level data based on surface water withdrawals by sector to determine total and per capita valuations for water use per county. Imputed values were derived for four sectors of water users: agricultural, domestic, industrial processing, and thermoelectric. Figure 30 presents an overview of the valuation framework utilized in this section.

In order to impute reasonably accurate, relative values for water use by sector, data from Frederick et al. (1996) were utilized. In their summary of water valuation studies, national averages of water values were computed by sector. Issues arise trying to use these national averages, given the national variance in water supply. In order to adjust national averages per water use sector to reflect eastern water values, the average water value for the 17 studies applicable to water values in the eastern US was computed as a percentage of the national average water value. This percentage was 38.5% ($29 per acre foot in the eastern US/$75 per acre foot for a national average). National average water values reported were therefore multiplied by 0.385 to adjust national averages to eastern water values. A gross domestic product deflator of 1.37 was used to adjust the 1994 values to 2009 monetary values. Table 6 reports the water values used per sector to compute the index for this report.

<table>
<thead>
<tr>
<th>Use sector</th>
<th>2009 Water value (dollars per acre-foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural irrigation</td>
<td>40</td>
</tr>
<tr>
<td>Domestic self-supply and public supply</td>
<td>100</td>
</tr>
<tr>
<td>Industrial processing</td>
<td>150</td>
</tr>
<tr>
<td>Thermoelectric</td>
<td>20</td>
</tr>
</tbody>
</table>

Note: Water values rounded to the nearest $10. Values were derived from those originally reported by Frederick et al. (1996) in Tables 3.1 and 3.2.
Figure 30: Water value index framework

**Metrics**

- Agricultural water value (acre feet * value)
- Domestic water value (acre feet * value)
- Industrial water value (acre feet * value)
- Thermoelectric water value (acre feet * value)
- Household income (average per county)
- Surface water quality (compared to other ARC counties in the same state)
- Fish stocking (compared to average in state)

**Indicators**

- Consumption value
- Benefit transfer computation of willingness to pay (average $ per household)
- Meta-analysis coefficient estimates based on WTP studies

**Index**

- Market
- Non-Market

Score 0 – 100
Mapped Index
Score 0 – 100
Mapped Index
The caveats related to the values are very important to consider. First, and perhaps most important, a wide variety of valuation methods have been utilized in the individual studies summarized by Frederick et al. (1996). Thus, the value estimates from this report do not necessarily provide readily comparable estimates. Second, users must take care when comparing the values over time (or using them in the present period) because water values obtained from a particular study are a function of the demand and supply (e.g., technology) available at the time of the individual study. In other words, water use can vary considerably over time. Other important limitations specific to the value estimates include:

- quantity is the only dimension considered in the value estimates so that quality, which is important for both domestic and industrial water use values, is not directly reflected in the estimated water use values;
- timing of water use affects its value and the values from this report do not necessarily reflect the value of uses within different seasons of the year;
- water use values vary widely among locations so that even within the same basin, allowances need to be made for the costs of transporting water from the water source to the site of use;
- the values for domestic use may be understated relative to other uses due to the estimation methods used;
- the study does not adequately reflect the fact that few water uses are completely consumptive; and
- the methods used to convert use values to 1994 dollars are imperfect.

Because of these caveats, the water use values per sector were considered reflective of relative values between sectors rather than absolute measures of water value.

On the non-market side, a meta-analysis was conducted with data containing over 100 observations from 49 contingent valuation studies. The studies included journal articles and academic publications. Across the 420 counties of the Appalachian region, average projected annual mean willingness-to-pay (WTP) for surface water quality was about $8.50 per household. Projected mean WTP for each county was averaged and then converted into a percentage based on the maximum county average mean WTP in order to rank counties. Belmont County, Ohio had the highest average annual mean WTP per household ($12.30). Ohio, Virginia, and Georgia dominated the top ten counties within Appalachia, with three counties from each state. At the low end of the ranking, counties from Tennessee and West Virginia were the most prevalent in the bottom ten with five and four counties, respectively. Roane County, Tennessee had the lowest average mean WTP per household ($4.92).
5.3 Market value

To compute an index of water values per county, values presented in Table 6 were multiplied by freshwater withdrawal data by sector for each county. These data were estimated in million gallons per day by USGS for 2005 (Kenny et al., 2009). The weighted sum of water use value per county was computed as a total value and per 1,000 persons based on 2005 county populations. These values were indexed from 0-100, with the county with the highest value set to 100 (Figure 31).

From the computations described above, Table 7 shows the top ten counties in terms of total and per capita market values. The county with the highest total valuation of water use was Sullivan County, Tennessee. This county had substantial public water supply and the highest industrial processing withdrawals in Appalachia. The next two highest total valuations include Allegheny County, Pennsylvania (location of Pittsburgh) and Jefferson County, Ohio (with an average size population and power plants). After the top three counties, total valuation of water use is two-thirds or less than that of Sullivan County.
Table 7: The top ten counties for total value (a) and per capita (b) rankings

<table>
<thead>
<tr>
<th>County</th>
<th>State</th>
<th>Total valuation score</th>
<th>County</th>
<th>State</th>
<th>Per capita score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sullivan</td>
<td>Tennessee</td>
<td>100</td>
<td>Grant</td>
<td>West Virginia</td>
<td>100</td>
</tr>
<tr>
<td>Allegheny</td>
<td>Pennsylvania</td>
<td>81</td>
<td>Marshall</td>
<td>West Virginia</td>
<td>50</td>
</tr>
<tr>
<td>Jefferson</td>
<td>Ohio</td>
<td>79</td>
<td>Mason</td>
<td>West Virginia</td>
<td>47</td>
</tr>
<tr>
<td>Oconee</td>
<td>South Carolina</td>
<td>67</td>
<td>Delaware</td>
<td>New York</td>
<td>47</td>
</tr>
<tr>
<td>Delaware</td>
<td>New York</td>
<td>57</td>
<td>Jefferson</td>
<td>Ohio</td>
<td>44</td>
</tr>
<tr>
<td>Limestone</td>
<td>Alabama</td>
<td>52</td>
<td>Hancock</td>
<td>West Virginia</td>
<td>43</td>
</tr>
<tr>
<td>Beaver</td>
<td>Pennsylvania</td>
<td>49</td>
<td>Giles</td>
<td>Virginia</td>
<td>40</td>
</tr>
<tr>
<td>Hamilton</td>
<td>Tennessee</td>
<td>48</td>
<td>Oconee</td>
<td>South Carolina</td>
<td>38</td>
</tr>
<tr>
<td>Colbert</td>
<td>Alabama</td>
<td>45</td>
<td>Gallia</td>
<td>Ohio</td>
<td>38</td>
</tr>
<tr>
<td>Marshall</td>
<td>West Virginia</td>
<td>44</td>
<td>Colbert</td>
<td>Alabama</td>
<td>32</td>
</tr>
</tbody>
</table>

On a per capita basis, Grant County, West Virginia had by far the highest total, being 50% larger than the next highest county, Marshall. This value was primarily driven by two factors: (1) a small population, and (2) a thermoelectric plant that withdraws water. Grant County has a population of only 11,700, which is 40% of the median county population in the Appalachian region. In computing the value of water use, the thermoelectric withdrawal by the 1,600 megawatt Mt. Storm power plant makes up 99% of the use value. This plant makes Grant County the tenth largest among all thermoelectric withdrawals in the region.

Equation 12: Market value formula

\[
\text{Market value}_{\text{county}x} = \text{agricultural water value}_x + \text{domestic water value}_x + \text{industrial water value}_x + \text{thermoelectric value}_x
\]

\[
\text{Market value}_{\text{scaled}} = \left( \frac{\text{Market value}_{\text{county}x} - \text{Market value}_{\text{min}}}{\text{Market value}_{\text{max}} - \text{Market value}_{\text{min}}} \right) \times 100
\]

Even while the highest scoring county is a rural county with a small population, both total valuation and per capita valuation tend to be lower in counties with no major cities. However, the inverse is not necessarily true—Birmingham, Alabama; Greenville, South Carolina; and Pittsburgh and Scranton, Pennsylvania all have relatively low per capita valuation scores.

Per capita valuations are shown in the map and histogram in Figure 31. The histogram is highly skewed toward the low end, with Grant County being the main large outlier.
5.4 Non-market value

In order to understand non-monetary values for water on a county-by-county basis, a meta-analysis was conducted. This analysis combined the results of numerous studies in order to arrive at a value conclusion—in this case: what the current surface water quality is worth to county populations in the ARC region.

It is important to understand and attempt to quantify this value in order to account for the non-transactional economy, and place value on people’s perceptions of what clean water is worth to them. The meta-analysis of surface water valuation studies was initially utilized to estimate household WTP for surface water quality for each county in the region. These WTP values were then indexed on a scale 0-100 based on a ratio of the maximum county-level WTP (Figure 32).

The approach utilized monetary values based on the quality of surface water. A meta-analysis of contingent valuation (CV) studies was performed and then applied using a benefit transfer method. Basically, this method examines various studies across the country that quantify what people value, or how much they will pay for a certain item; in this study it is clean water.

Johnston et al. (2005) provided a template for how to conduct this meta-analysis in terms of what explanatory variables to include in the models and what functional forms to use to explain WTP for a surface water quality change. Using estimated coefficients and

![Figure 32: Non-market value score](image-url)

![Non-market value histogram](image-url)
projected values for the explanatory variables, a benefit transfer method was applied to estimate county mean WTP per household for existing surface water quality. These mean WTP values represent our estimate of what would have been found if county-level CV studies had been conducted throughout the entire Appalachian region to value surface water quality.

**Equation 13: Non-market value formula**

\[
\text{Non-market value}_{\text{county"x"}} = \text{semi-log unweighted willingness-to-pay}_x + \text{semi-log weighted willingness-to-pay}_x + \text{trans-log willingness-to-pay}_x \\
\text{Non-market value}_{\text{scaled}} = \left[ \frac{(\text{Non-market value}_{\text{county"x"}} - \text{Non-market value}_{\text{min}})}{(\text{Non-market value}_{\text{max}} - \text{Non-market value}_{\text{min}})} \right] \times 100
\]
Project Example:

An economic benefit analysis for abandoned mine drainage remediation in the West Branch Susquehanna River watershed, Pennsylvania

Streams across the West Branch Susquehanna River watershed, which encompasses about 7,000 square miles in central Pennsylvania, are still polluted from AMD from old coal mines. Cleaning up these impaired waters will cost millions of dollars, but these expenditures will provide a tremendous boost to the largely rural local economy. A 2008 study describes and quantifies the local and statewide economic benefits stemming from remediation of the WBSR watershed (Hansen et al., 2008).

Clearly, outdoor recreation is a popular and growing pastime, is diversifying, and is an important source of revenue for Pennsylvania. AMD can have a large, detrimental impact on outdoor recreation experiences, specifically angling opportunities.

The study estimated the WTP for a clean-up of AMD in streams within the watershed. Based on a mail survey of Pennsylvanians living both within and outside of the watershed, the best estimate of total WTP for AMD clean-up in the watershed was calculated to be $73.6 million. This was the value to users and non-users.

The study determined that sport fishing alone could be expected to generate $22.3 million in revenues per year with AMD remediation (Figure 33). To participate in outdoor activities, people spend money on food and lodging, transportation, and equipment. In Pennsylvania, almost $4 billion was spent on fishing, hunting, and wildlife viewing in 2006. Even more money was spent by people engaging in other outdoor activities. (Hansen et al., 2008)
5.5 Discussion

When ranked into the six ARC categories, total and per capita market valuation had essentially the same categorization of counties. As would be expected, most of the highest 10% of counties for water use valuation were concentrated along major rivers: the Ohio River in Ohio, Pennsylvania, and West Virginia; the Kanawha River in West Virginia; the Tennessee River in Alabama and Tennessee; and the Alabama River in Alabama. Looking at the per capita valuation scores, West Virginia had the largest number of counties (13) in the highest 10%. Tennessee was second at seven counties. Kentucky had the largest concentration of counties in the lowest 10%, with 13 counties. Pennsylvania was second with 11 counties.

These rankings reflect the high monetary value of surface water uses in many counties in West Virginia and Tennessee relative to counties in other Appalachian states. These high values mainly stem from large water withdrawals by power plants and other industrial facilities in both states. Both states are the originating sources of major rivers, which has historically made them attractive to industries, like electrical power generation, which are large water users.

For non-market surface water quality values, ranked average annual mean WTP counties were divided into six categories (Figure 36). A breakdown of counties in each category per state is presented in Table 6. Other than Maryland, which has few counties, the states of Pennsylvania, North Carolina, and Mississippi had the highest percentages of counties in the top category of WTP scores, while Pennsylvania was the only state with 50% of its counties in the top two categories. In contrast, the states of Mississippi, Kentucky, and South Carolina had 50% or more of counties falling into the bottom two categories. Of these, one-third of South Carolina counties were in the bottom category.

Table 6: Percentages of counties in sextile categories based on mean county-level WTP rankings for surface water quality

<table>
<thead>
<tr>
<th>State (# counties)</th>
<th>Highest</th>
<th>Lowest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama (37)</td>
<td>21.6%</td>
<td>16.2%</td>
</tr>
<tr>
<td>Georgia (37)</td>
<td>18.9%</td>
<td>18.9%</td>
</tr>
<tr>
<td>Kentucky (54)</td>
<td>5.6%</td>
<td>20.4%</td>
</tr>
<tr>
<td>Maryland (3)</td>
<td>66.7%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Mississippi (24)</td>
<td>25.0%</td>
<td>4.2%</td>
</tr>
<tr>
<td>New York (14)</td>
<td>21.4%</td>
<td>21.4%</td>
</tr>
<tr>
<td>North Carolina (29)</td>
<td>27.6%</td>
<td>17.2%</td>
</tr>
<tr>
<td>Ohio (32)</td>
<td>3.1%</td>
<td>6.3%</td>
</tr>
<tr>
<td>Pennsylvania (52)</td>
<td>28.8%</td>
<td>21.2%</td>
</tr>
<tr>
<td>South Carolina (6)</td>
<td>0.0%</td>
<td>16.7%</td>
</tr>
<tr>
<td>Tennessee (52)</td>
<td>15.4%</td>
<td>9.6%</td>
</tr>
<tr>
<td>Virginia (25)</td>
<td>12.0%</td>
<td>4.0%</td>
</tr>
<tr>
<td>West Virginia (55)</td>
<td>10.9%</td>
<td>29.1%</td>
</tr>
</tbody>
</table>
Putting the tool to work

Example 4: Potential conflicts between consumptive and non-market use

The potential for water conflicts may increase in the future in counties with low water budget scores, especially where non-market value and recreational use are high.

Here, counties were selected with both the highest non-market value scores (blue in Figure 34) and the lowest surface water budget scores (red). Counties that meet both these criteria are colored green and include Potter, Centre, and Carbon in Pennsylvania; Washington in Virginia; Transylvania in North Carolina; and Dekalb in Alabama.

These counties are susceptible to possible future conflicts between consumptive use—commercial, industrial, agricultural, and domestic withdrawals—due to the high non-market value they place on water.

Further analysis and research could be conducted to determine which of these counties have high rates of recreational water use. Communities that value their water resources for aesthetic and recreational purposes are more likely to oppose expanded consumptive use that may jeopardize their enjoyment of the waterways.
Figure 35: Water value index, market
Figure 36: Water value index, non-market

Formula:
Raw non-market value score = average of final scores for three willingness-to-pay models

Final non-market water value score = \left( \frac{\text{raw non-market score for County} \times \text{minimum raw non-market score}}{\text{maximum raw non-market score} - \text{minimum raw non-market score}} \right) \times 100

NOTE:
For mapping, the counties were sorted by final water asset score and grouped into six categories, with 10 counties in each category.
6 Conclusion

6.1 Water asset index

The water asset index combines the water quality, quantity, and access indices into a single index. Figure 37 illustrates this process. Water value, as stated earlier, is excluded from the asset index because it is based on components of the other indices. The asset index offers a broad understanding of the water resource assets in Appalachia.

Equation 14: Water asset formula

$$\text{Asset}_{\text{county}^x} = \text{Water Quality score}_x + \text{Water Quantity score}_x + \text{Water Access score}_x$$

$$\text{Asset}_{\text{scaled}} = \left(\frac{\text{Asset}_{\text{county}^x} - \text{Asset}_{\text{min}}}{\text{Asset}_{\text{max}} - \text{Asset}_{\text{min}}}\right) \times 100$$
Figure 37: Building the water asset index

Water Asset Components

Description:
Each of the individual water scores, scaled from 0-100, are combined and summed. This raw number, ranging from 0-300, is then rescaled to 0-100 to create the water asset score, shown on the following page.
Based on a literature review, this study quantified the level of water quality, quantity, and access across all Appalachian counties. These three components are all linked with economic development.

As mentioned previously, none of the metrics, indicators, or final indices are weighted or given preference in the construction of the final water asset index. This provides an objective observation of present water assets in Appalachian counties.

The DSS tool allows users to capture this dynamic and complicated resource in the context of their local understanding of water’s relationship to economic development or distress. The asset index is not meant to be a “one-stop” data point to understand water resources; instead, it demonstrates one way that water resources can be assessed and understood—one we hope will help guide conversation and future research, and begin to place an emphasis and priority on determining the true value of our natural resources, both economically and culturally.

The asset index was calculated by summing the quality, quantity, and access indices, then scaling the scores from 0-100, with 100 being the positive end of the asset spectrum. These scores are shown in Figure 38 and Figure 39. This final index displays a familiar bell shape with near-normal distribution.
Figure 39: Water asset index

![Water Asset Index in Appalachia](image)

**Formula:**

\[
\text{Final Water Asset Score} = \left( \frac{\text{raw water asset score for County } x - \text{minimum raw water asset score}}{\text{maximum raw water asset score} - \text{minimum raw water asset score}} \right) \times 100
\]

**NOTE:**

For mapping, the counties were sorted by final water asset score and grouped into six categories, with 10 counties in each category.
6.2 The relationship of water assets to economic development

As discussed in the literature review, water plays an essential role in the economy. In this chapter, we use correlation analyses to look at how water assets (i.e., water quality, quantity, and access) are related to economic status in Appalachia. Although much previous research involving natural resources and economic values has employed more advanced statistical analyses to examine the role of a natural asset in the economy at various levels (e.g., Deng et al., 2009; Deller et al., 2001; Marcouiller et al., 2004), these advanced methods were not used in this study because a county’s water asset is only one of many variables that can impact economic status. This is the first of a planned series of natural assets projects that will help quantify a variety of other natural assets that also may be related to economic status. Consequently, we examine the relationship of the economic status of the Appalachian region with water assets by using simple correlation analyses.

ARC uses a five-level ranked index system to reflect the economic status of the Appalachian counties, while we developed a six-level index system for a variety of variables. The index values for both methods are categorical and not used for correlation analysis. Instead, the correlation analysis is performed on the continuous values on which the index systems are based.

ARC measures economic status of all Appalachian counties. Values are developed based on three economic indicators in each county: three-year average unemployment rate, per capita market income, and poverty rate, all of which are compared with national averages. The resulting percent values are summed and averaged to create a composite index value for each county.

ARC compiles a single index of the economic status of all Appalachian counties. Values are developed based on three indicators in each county: three-year average unemployment rate, per capita market income, and poverty rate, all of which are compared with national averages. The resulting percent values are summed and averaged to create a composite economic status index value for each county.

In our correlation analysis, we use the economic status index as well as the three economic indicators separately. Because each indicator is a component of the economic status index, correlation coefficients among these indicators and between each indicator and the economic status index are not reported.

The indices created in this project are described in detail in previous chapters on water quality, quantity, access, and value. In addition, a composite index combines the quality, quantity, and access indices. The indices created in this project are described in detail in previous chapters on water quality, quantity, access, value, and assets. This water assets index combines the quality, quantity, and access indices. Therefore, correlation coefficients between each component indicator and the overall water assets index are not reported.

In general, counties with relatively better water quality, water quantity, and overall water assets tend to have better economic status. This finding is illustrated by Table 8. Specifically, economic status is significantly related to water quality (p < .01), water quantity (p < .05), and overall water assets (p < .01). Although economic status is also positively related to water access, the relationship is not significant.

While statistically significant, the relationships between economic status and each water index are not substantial or strong, given that the coefficients are relatively small. In addition, the three water asset variables—quality, quantity and access—positively interrelate with one another. Two of these relationships are significant: that between quality and quantity (p < .01) and that between water quality and water access (p < .01).
It should be noted while the economic status is significantly and positively related to water quality, quantity and overall water assets, the relationships between each component of the economic status index and each water index are not consistently significant. More specifically, unemployment rate is not significantly related to each water indicator, while income significantly correlates with water quality and overall water assets. Poverty rate is also found to be significantly related to water quality, but not to overall water assets.

Table 8: Correlations among economic and water-related variables

<table>
<thead>
<tr>
<th></th>
<th>Econ. status</th>
<th>Unempl. rate</th>
<th>Per capita income</th>
<th>Poverty rate</th>
<th>Water quality</th>
<th>Water quantity</th>
<th>Water access</th>
<th>Water assets</th>
<th>Water value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic status</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.194**</td>
<td>.099*</td>
<td>.073</td>
<td>.191**</td>
<td>-.114*</td>
</tr>
<tr>
<td>Unempl. rate</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>.016</td>
<td>.038</td>
<td>.041</td>
<td>.048</td>
<td>-.111*</td>
</tr>
<tr>
<td>Per capita income</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>.242*</td>
<td>.094</td>
<td>.052</td>
<td>.203**</td>
<td>-.070</td>
</tr>
<tr>
<td>Poverty rate</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>.115*</td>
<td>.055</td>
<td>.75</td>
<td>-</td>
<td>-.116*</td>
</tr>
<tr>
<td>Water quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>.191**</td>
<td></td>
<td></td>
<td>.228**</td>
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<tr>
<td>Water quantity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.046</td>
<td></td>
<td></td>
<td>.003</td>
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<tr>
<td>Water access</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>.052</td>
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<tr>
<td>Water assets</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>.154*</td>
</tr>
<tr>
<td>Water value</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Note: **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

Table 8 also shows that water value is positively related to quality, quantity, access, and the overall water asset index, with the relationships with water quality and overall water assets being significant at the .01 level.

Consistent with the literature, water assets as measured by quality, quantity, and access are all positively related to the economic status of Appalachian counties. In other words, a county in the Appalachian region with high levels of water quality, quantity, or access tends to have a better economic status than a county with lower levels of quality, quantity, or access. This is particularly true for water quality and water quantity. Likewise, water value, as measured by market and non-market values, is also positively related to the three water asset indicators, particularly water quality. This confirms previous findings that water plays an important role in the regional economy.

These correlation coefficients show that water quality has the highest correlation with the asset index. Thus, the water quality index is a better reflection of asset value than the other two indices. The water quality index has the highest correlation with both economic status and water value; among quality, quantity, and access, quality is the only one that has a statistically significant correlation with both economic status and value. In summary, this finding is further evidence that surface water quality protection is important and should be a part of any water planning process.
Countless challenges exist in assessing the economic value of water resources: “Placing an economic value on this precious resource is an art and science,” said one ARC water assets stakeholder respondent. Quantifying water quality, quantity, and access present other significant challenges. Yet multiple and growing human needs for water necessitate our valuing it as a foundation of Appalachia’s economy. This report documents and attempts to quantify and value the region’s water resources, while providing a foundation for future policy- and decision-making.

The dynamics of water resources are very complex, considering temporal variations, flow patterns, and competing uses. For example, examining a water resource and understanding its quality at a point in time at a certain location is certainly attainable; however, understanding a water resource’s true condition and value over time is more complicated.

Due to this complexity, this research project utilized existing measures and attempted to broadly assess water resources across region. The project team proposes several recommendations to further study the region’s water assets.

Data development and consistency

Regional data consistency and sharing of data among local, state, and federal agencies is the key to truly understanding the water assets of the region. For example, USEPA provides states with great flexibility in developing their impaired streams datasets. Many studies now devote large amounts of time and resources to develop methodologies to predict a stream’s quality, rather than using instream measurements or impaired stream lists. Standardization of the impaired streams dataset—as well as other datasets that apply across states—would enable more efficient and accurate regional comparisons of natural assets.

Valuation methodology

Water is a very complex resource to value. It is often easiest to value items based on their transactional value. But water has both consumptive and non-consumptive value. More resources should be utilized to develop consensus among stakeholders as to the most appropriate method for valuing resources. These types of valuations are far beyond any commodity value that is assigned, either in this study or on the open market. This report attempted to understand that value by looking at both market and non-market values. Our non-market valuation approach took into consideration people’s perceived value of water, based on what they would be willing to pay for clean, bountiful, and accessible water. More time and resources should be spent developing an approach to understand the true value of natural resources, not only as an exportable commodity, but as an integral part of life.

Greater support and continuity

Natural resources, such as water, are temporal in that their condition, status, and location change often and sometimes sporadically. This report offers a general snapshot in time of water resources in Appalachia. Time and energy should be put forth to create a body of resources that would continue to build upon the foundation of this regional assessment, developing new methods and building consensus to develop standard approaches for appraising water resources.

Overall, this report tackles a very difficult subject, with many viewpoints, datasets, and goals. It would be false to assume that it offers the only answers to the questions surrounding Appalachia’s water assets. However, it has begun the conversation and spurred insight into Appalachia’s water quality, quantity, access, and value.
References


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Helvoigt T, Neculate C, Josephson A, Charlton D. 2009. Regional economic impacts of recreation on the Wild and Scenic Rogue River. Commissioned by the Save the Wild Rogue Campaign, with funding support from the Giles & Elise Mead Foundation. ECONorthwest.


Appendix A: Web-based mapping and GIS Decision Support Tool

Integrated GIS Tool

One of the important aspects of any applied research project is the method of communicating results to decision makers. The output of our study includes an interactive GIS-based decision support system (Figure 40) that allows resource managers to evaluate inputs and results of this study, understanding the true spatial nature and relationships of these natural assets. This system integrates spatial data, user input, and a ranking algorithm within a multiple criteria analysis (MCA) framework. The goal of this framework is to provide a tool to integrate spatial data with a MCA-solving algorithm called compromise programming (CP), which allows users to quickly and interactively explore and analyze county-level data.

MCA is an alternative approach to traditional economic evaluation techniques. The basic idea behind MCA is to provide a framework for analyzing choices with multiple criteria and conflicting objectives (Malczewski, 1999). A spatial MCA approach aids in the identification of the most suitable management solution for a given purpose. The approach also allows users to examine the effects of alternative options and presents options in a variety of forms such as monetary units, physical units, and qualitative judgments. This makes it possible to analyze tradeoffs between different objectives and address potential conflicts at an early stage, thereby providing the ability to analyze the sensitivity and robustness of different choices.

The CP ranking algorithm was chosen since it allows a more theoretically significant ranking of alternatives as compared to a linear weighted model. It also allows the user to integrate sensitivity analysis by altering weights and parameter values to highlight the concern of the decision maker over the degree of separation or difference from the ideal criteria score. The highest ranked results are those that are closest to the ideal or furthest from the least preferred alternatives. CP algorithms have been used in many different MCA applications including preference ranking of irrigation technologies (Tecle and Yitayew, 1990), water resource system planning (Duckstein and Opricovic, 1980; Gershon and Duckstein, 1983), developing forest watershed management schemes (Tecle et al., 1988a), selecting wastewater management alternatives (Tecle et al., 1988b), defining hydropower operations (Duckstein et al., 1989), and river basin planning (Hobbs, 1983).
The tool compares each county’s score or index—related to the ARC water resource attributes—and allows the decision maker to assign a weight (or importance value) to each individual criterion and then combine all criteria together for a comprehensive overall result. End users can combine and map the various factors for ranking economic development and water resources in the ARC Region.

The final spatial model uses the GIS framework, as an extension to ESRI’s ArcGIS software. The extension consists of a graphical interface designed to guide a user through the process of interactively specifying risk factor criteria weights and viewing results Figure 41.

The main window of the ARC Ranking Toolbar consists of the ranking model, which provides the ability to display the top- and bottom-ranked counties and to map spatial clusters.

The CP ranking model requires that the user first highlight or make active a shapefile in the table of contents that contains attributes the user wishes to use for the ranking (Figure 42). It is assumed that the user already calculated or added the needed fields to the table in order to use the ranking model. Examples of attributes may be boating access locations, fishing access locations, or water quality indicators. All of the criteria are normalized by the program so the user does not have to worry about non-commensurate data. All that is required is the direction of value influence. For example, if a higher value for an attribute is desired, then nothing has to be altered in the compromise programming interface; this is the default. However, if the user feels that a lower value is preferred, the inverse button should be selected.

The parameter values of $P$ indicate the concern of the decision maker over the deviation from the ideal values. It may have values from zero to infinity and represents the concern of the decision maker.
over the maximum deviation (Tecle and Yitayew, 1990; Duckstein and Opricovic, 1980). The larger the value of \( P \), the greater the concern. For \( P = 1 \), all weighted deviations are assumed to compensate each other perfectly. For \( P = 2 \), each weighted deviation is accounted for in direct proportion to its size. As \( P \) approaches infinity, the alternative with the largest deviation receives more weight and importance (the largest of the deviations completely dominates the distance measure) (Zeleny, 1982). To solve the multi-criteria problem using the CP algorithm, the vectors of ideal point values and worst values are determined and then used to compute the \( L_p \) values’ distances from the ideal points. The preferred alternative has the minimum \( L_p \) distance value for each \( P \) and weight set that may be used. Thus, the alternative (county in our example) with the lowest value for the \( L_p \) metric will be the best compromise solution because it is the nearest solution with respect to the ideal point. The parameter \( P \) acts as a weight attached to the deviations according to their magnitudes. Similar weights for various deviations signify the relative importance of each criterion (Romero and Rehman, 1989).

The result of the model run is the addition of a new field to the shapefile—the \( L_p \) compromise programming metric. Lower values are preferred and a legend is produced automatically for the user. This legend can always be altered to show a different display of the ranked counties. The true utility of the tool is in the ability to quickly run different scenarios and test the spatial sensitivity of results.

**Other tools available**

Some of the other tools available for the user include the ability to find the top or bottom percentage of ranked features. This was designed to highlight the counties that may meet certain threshold requirements in regard to the rankings (Figure 43).

**Figure 43: Percentage queries for the highest and lowest percentages, as specified**
Spatial clusters

The Spatial Clusters Tool within the ARC Ranking Toolbar is based on a hot spot analysis. This is a spatial statistical calculation that takes into account the spatial position of features and their attributes. The purpose of using the tool is to find areas with high values surrounded by other high values (hot spot) or low values surrounded by other areas with low values (cold spot) that are statistically significant. Figure 44 shows a spatial clusters output for the boat access points attribute, which include hot and cold spots throughout the ARC counties.

Figure 44: Hot and cold spots for boating access

It is important to consider what will be the analysis field (Input Field). The Z-scores and P-values are measures of statistical significance, which tell you whether or not to reject the null hypothesis, feature by feature. In effect, they indicate whether the observed spatial clustering of high or low values is more pronounced than one would expect in a random distribution of those same values.
Web-based mapping

As part of the data and results dissemination process, a Web-based mapping application was developed and is being hosted by West Virginia University (www.mapwv.gov/arc). This tool allows the user to explore the results of this study, in an interactive and informative manner. Figure 45 displays two screenshots of the Web-based application, showing two different representations of the water quality results: the score and the index. These results are based on the maps presented throughout the report; this is a Web-based dissemination of those results. Each index, indicator, and metric is available by county and displays information in the content window, giving the user the ability to understand what is driving the county indices. This interface also offers several basemaps to choose from—aerial, topographical, and street map—in order to give a spatial frame of reference.
References


Appendix B: Stakeholder Responses

ARC water asset stakeholder respondents offered a variety of information, including informational needs (Table 9), desired data and reports (Table 10), and top water assets (Table 11) and liabilities (Table 12).

Table 9: Stakeholder informational needs

<table>
<thead>
<tr>
<th>Theme</th>
<th>Response</th>
</tr>
</thead>
</table>
| Water availability information for planning purposes | Availability, allocations, quality, protection options, planning  
Potential contribution of water to a region, ownership, usage patterns of water, framework for planning best possible uses  
Estimated sustainable groundwater potential for public water supply and domestic wells at any given location—for planning and permitting process  
Information on water inflows, outflows, and water supplies/demands by state and drainage basin  
More detailed and credible documentation on the quantity and quality of our water supplies and how much of it has already been secured by outside users  
Information and data relating to long term planning (i.e. are current methods of calculation of firm yield of reservoirs accurate when considering climate change?)  
More detailed documentation of water quantity and quality—groundwater sources, in particular |
| Information to conserve water resources and special areas | Guidance to limit development of sensitive areas along all watersheds—target local county/township leaders, flood plain managers, conservation groups, watershed associations and state regulators  
Guidance for karst and special areas most susceptible to development—target wastewater operators, along with system designers and regulators  
Information related to conservation of water resources  
Irrigation management; private well protection, landscape buffers |
| Monitoring for industrial and other contaminants | Monitoring of surface stream and river water quality of industrial, agricultural and emerging WWTP contaminants  
Monitoring of ground water extraction for industrial use such as poultry production in the region  
Better documentation of the potential threats to those resources and how they have increased DESPITE a lack of overall growth (through continued expansion of lower intensity land development practices) |
| Evaluation of hydropower | Evaluation of Federal Lock and Dam system to be adapted to generate hydro power and assist with removal of anthropogenic flotsam  
An economic valuation of small pond development for water storage, fish enterprises, emergency use and small hydro development |

Source: Data from e-mail solicitation to ARC water asset stakeholders in summer 2010

Table 10: Data and reports desired by stakeholders

<table>
<thead>
<tr>
<th>Theme</th>
<th>Response</th>
</tr>
</thead>
</table>
| Existing conditions | Quantity and quality of our water supplies and how much of it has already been secured by outside users  
Mapping well locations, depths, volumes and water quality with interpolation in between known data points to give a better understanding of what is available |
| Threatened areas | Areas at high risk for water withdrawals in the future  
Watersheds at high risk for Marcellus shale impacts  
Areas with low buffering capacity to attenuate effects of acid deposition  
Water resources damaged by flood recovery areas (dredged and channelized)  
Documentation of the potential threats to those resources  
Areas with depleted, impaired, or lack of riparian cover |
## Assessing Appalachian Natural Assets: Water

- Water resources with dissolved oxygen impairment
- Water resources exhibiting temperature regime impairment

<table>
<thead>
<tr>
<th>Areas with potential for improvement or protection</th>
<th>Water resources with potential for trout restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas of groundwater recharge</td>
<td>Spring resources</td>
</tr>
<tr>
<td>Spring resources</td>
<td>Water Resources with potential for trout restoration</td>
</tr>
<tr>
<td>Water Resources with potential for trout restoration</td>
<td>Eco-tourism potential</td>
</tr>
</tbody>
</table>

### Report format

- A report that could take advantage of a myriad of existing data sets
- A regional dataset housed in one location
- Watershed scale report pertaining pollution impairment
- Improved GIS capabilities to access water resource data (e.g., water supply demands, wastewater discharges, precipitation) and associated analytical tools to summarize and document data
- Long term projections
- Hard numbers or case studies of examples, not a modeling effort that runs what if scenarios
- Online access to water sources, quality, availability

Source: Data from e-mail solicitation to ARC water asset stakeholders in summer 2010

### Table 11: Top water assets in Appalachia identified by stakeholders

<table>
<thead>
<tr>
<th>Theme</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Available data</strong></td>
<td>Available water quality and quantity data for the Susquehanna River</td>
</tr>
<tr>
<td><strong>Natural resources</strong></td>
<td>Quality of water resources</td>
</tr>
<tr>
<td></td>
<td>Our groundwater quality and quantity</td>
</tr>
<tr>
<td></td>
<td>Water for aquatic habitat</td>
</tr>
<tr>
<td></td>
<td>Existing eastern brook trout populations</td>
</tr>
<tr>
<td></td>
<td>Reasonable annual rainfall rate near 40&quot; per year</td>
</tr>
<tr>
<td></td>
<td>Our headwaters streams that have very high quality, quantity, and temperature for multiple use</td>
</tr>
<tr>
<td></td>
<td>Rainfall and topography that allow for expanded use of small catchment impoundments</td>
</tr>
<tr>
<td><strong>Natural resource use</strong></td>
<td>Water for recreation</td>
</tr>
<tr>
<td></td>
<td>World class fisheries and white water recreation</td>
</tr>
<tr>
<td></td>
<td>Water for agriculture</td>
</tr>
<tr>
<td></td>
<td>Water for municipal use;</td>
</tr>
<tr>
<td></td>
<td>Clean drinking water</td>
</tr>
<tr>
<td></td>
<td>Relatively low cost of water supplies relative to surrounding growth areas</td>
</tr>
<tr>
<td></td>
<td>The overall benefits that the river system brings to stakeholders of Tennessee River Basin (e.g., substantial navigational capabilities, readily available water for municipal and industrial growth, low cost electricity, increased recreational opportunities).</td>
</tr>
<tr>
<td></td>
<td>Our river systems are navigable due the Corps lock and dam system that could be adapted to provide zero carbon power</td>
</tr>
<tr>
<td></td>
<td>Patterson Creek and New Creek watersheds have a total 40 flood control structures of which 29 are located within the County</td>
</tr>
<tr>
<td><strong>Natural resource potential</strong></td>
<td>North Branch water resource potential if withdraw were permitted</td>
</tr>
<tr>
<td></td>
<td>Capacity in available public water supplies</td>
</tr>
<tr>
<td></td>
<td>Recreational potential of Jennings Randolph Lake and over 50 miles of shoreline on the North Branch of the Potomac</td>
</tr>
<tr>
<td></td>
<td>Extensive untapped resource potential</td>
</tr>
<tr>
<td></td>
<td>Proximity to urban areas with high growth and limited supplies (not from perspective of selling or diverting our water resources, but from the perspective of tapping into a growth-constrained engine for our own growth and economic revitalization)</td>
</tr>
<tr>
<td></td>
<td>Current capacity, perceived water quality, unanticipated rapid growth (also a threat)</td>
</tr>
</tbody>
</table>
Assessing Appalachian Natural Assets: Water

**Research**
- WVU study underway of the limestone aquifer along the length of Knobley Mountain

**Conservation**
- Subwatersheds identified by Trout Unlimited’s CSI as protection priorities
- CSI directed restoration priorities

**Partnerships**
- Linkages to local decision makers
- Availability, cost, quality, ability to manage and state water law
- Recent media regarding water quality in the US

**Recent innovations**
- New and effective wastewater technologies
- Knowledge of innovations in water quality protection

Source: Data from e-mail solicitation to ARC water asset stakeholders in summer 2010

### Table 12: Top water liabilities in Appalachia identified by stakeholders

<table>
<thead>
<tr>
<th>Theme</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydraulic fracturing</strong></td>
<td>Marcellus Shale/hydraulic fracturing</td>
</tr>
<tr>
<td><strong>concerns</strong></td>
<td>Marcellus Shale is a major issue</td>
</tr>
<tr>
<td></td>
<td>Potential consumption and contamination of water capacity and untapped supplies by Marcellus Shale interests</td>
</tr>
<tr>
<td></td>
<td>Emerging interests in hydrofracking process related to natural gas extraction (need to know what we have to feed this interest)</td>
</tr>
<tr>
<td><strong>Emerging contaminants</strong></td>
<td>Emerging contaminants such as estrogen and other chemicals passed through wastewater treatment plants and dropped back into surface streams and river systems</td>
</tr>
<tr>
<td><strong>Mine-related concerns</strong></td>
<td>Mercury in the water column</td>
</tr>
<tr>
<td></td>
<td>Surface mining impacts on stream water quality</td>
</tr>
<tr>
<td></td>
<td>Oil and gas well development on ground water</td>
</tr>
<tr>
<td><strong>Agriculture concerns</strong></td>
<td>Non-point source runoff from farms and agriculture</td>
</tr>
<tr>
<td></td>
<td>Agriculture, nitrogen, phosphorous, and sediment losses to surface streams</td>
</tr>
<tr>
<td><strong>Development concerns</strong></td>
<td>Ill-advised and implemented mountain home development</td>
</tr>
<tr>
<td></td>
<td>Aquatic organism passage blockages on private lands and at public road crossings</td>
</tr>
<tr>
<td></td>
<td>Potential threat of exploitation and diversion of water resources by outside high growth urban areas with limited water capacity.</td>
</tr>
<tr>
<td></td>
<td>Potential impacts of continued low-intensity, consumptive land development practices despite the lack of growth (from a perspective of both contamination and inefficient use of land and water supplies)</td>
</tr>
<tr>
<td></td>
<td>Raw sewage direct deposited into surface streams from low income residents and failed/failing septic systems (800 pound gorilla, that never gets any attention)</td>
</tr>
<tr>
<td><strong>Political and institutional concerns</strong></td>
<td>Linkages to local decision makers</td>
</tr>
<tr>
<td></td>
<td>Knowledge of innovations in water quality protection</td>
</tr>
<tr>
<td></td>
<td>Minimal knowledge to existing ground water resources</td>
</tr>
<tr>
<td></td>
<td>Availability, cost, quality, ability to manage and state water law</td>
</tr>
<tr>
<td></td>
<td>Lack of local financial resources to properly care and manage water resources</td>
</tr>
<tr>
<td></td>
<td>Jennings Randolph and our surface supplies are vulnerable to terrorist activity</td>
</tr>
<tr>
<td><strong>Availability concerns</strong></td>
<td>Extended drought</td>
</tr>
<tr>
<td></td>
<td>Availability, impact of climate change, agricultural use, other consumptive uses, environmental impacts of low flows</td>
</tr>
<tr>
<td></td>
<td>Water shortages in high density areas that could appeal to use our water</td>
</tr>
<tr>
<td><strong>Aging structures</strong></td>
<td>29 aging flood control structures</td>
</tr>
<tr>
<td><strong>Future demands</strong></td>
<td>Reliance on surface water for much of the County’s public water supply</td>
</tr>
<tr>
<td></td>
<td>Potential cost of accessing and developing untapped water resources</td>
</tr>
<tr>
<td></td>
<td>Competing demands between water resources and economic development have the potential to hinder advances in both arenas</td>
</tr>
</tbody>
</table>

Source: Data from e-mail solicitation to ARC water asset stakeholders in summer 2010
### Appendix C: Project Maps

#### ARC-Water Asset Study - Map List and Order

<table>
<thead>
<tr>
<th>Figure Title</th>
<th>Index</th>
<th>Data Type</th>
<th>Map Order</th>
</tr>
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<tr>
<td>County Water Asset Index in Appalachia</td>
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<td>County Water Asset Score in Appalachia</td>
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<td>County Water Quality Indicator, Land-Use</td>
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<tr>
<td>County Water Quality Indicator, Facilities</td>
<td>Water Quality</td>
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<td>County Water Quality Metrics, Land-Use: Percent Agriculture by HUC-12</td>
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<td>Watershed Water Quality Metrics, Land-Use: Percent Wetland by HUC-12</td>
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<td>Watershed Water Quality Metrics, Land-Use: Percent Impervious by HUC-12</td>
<td>Water Quality</td>
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<tr>
<td>County Water Quality Metrics, Facilities: TRI, NPDES, CSOs per County</td>
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<td>County Water Quantity Index in Appalachia</td>
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<td>County Water Quantity Score in Appalachia</td>
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<td>County Water Quantity, Usage Indicator</td>
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<td>County Water Quantity, Impaired Streams</td>
<td>Water Quantity</td>
<td>Indicator</td>
<td>14</td>
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<td>County Water Quantity, Percent Impaired Streams</td>
<td>Water Quantity</td>
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<td>County Water Quantity Metrics, Facilities: TRI, NPDES, CSOs, and AMLs</td>
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<td>County Water Quantity, Usage Indicator</td>
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<td>County Water Quantity, Flooding Indicator</td>
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<td>County Water Quantity, Streams and Lakes Score</td>
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<tr>
<td>County Water Quantity, Total Groundwater Use, Year 2005 (million gallons/day)</td>
<td>Water Quantity</td>
<td>Metric</td>
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</tr>
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<td>County Water Quantity, Total Surface Water Use, Year 2005, Normalized to County Area (mm)</td>
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<tr>
<td>County Water Quantity, Total Surface Water Use, Year 2005, Normalized to County Area (mm)</td>
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<td>County Water Quantity, Mean Annual Evapotranspiration 1932-2009 (mm)</td>
<td>Water Quantity</td>
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<td>County Water Quantity, Mean Annual Precip Minus Mean Annual ET (mm)</td>
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<tr>
<td>County Water Quantity, Mean Annual Precipitation 1932-2009 (mm)</td>
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<td>County Water Quantity, Total Floods per County</td>
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<td>County Water Quantity, Total Floods per County, Normalized to County Area</td>
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<td>County Water Quantity, Miles of Streams</td>
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<td>County Water Quantity, Miles of Streams, Normalized to County Area</td>
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<td>County Water Quantity, Acres of Lakes</td>
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</tr>
<tr>
<td>County Water Quantity, Acres of Lakes, Normalized to County Area</td>
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<td>Metric</td>
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<tr>
<td>County Water Quantity, Maximum Flow Estimate in Each County</td>
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</tr>
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<td>County Water Access Index in Appalachia</td>
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<td>County Water Access, Boating Access Points Indicator</td>
<td>Water Access</td>
<td>Indicator</td>
<td>38</td>
</tr>
<tr>
<td>County Water Access, Fishing Access Points Indicator</td>
<td>Water Access</td>
<td>Indicator</td>
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<tr>
<td>County Water Access, Swimming Access Points Indicator</td>
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<td>Metric Description</td>
<td>Water Type</td>
<td>Metric Type</td>
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<td>-----------------------------------------------------------------------------------</td>
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<td>County Water Access, Boating Access Points per County</td>
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<tr>
<td>County Water Access, Fishing Access Points per County</td>
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<td>County Water Access, Recreation Access Points</td>
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<tr>
<td>County Water Access, Swimming Access Points per County</td>
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<td>Metric</td>
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<td>County Water Market Value Index in Appalachia</td>
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<tr>
<td>County Water Non-Market Value Index in Appalachia</td>
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<td>County Water Market Value Score in Appalachia</td>
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</tr>
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</tr>
<tr>
<td>County Water Value, Market - Total Water Market Value Indicator</td>
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<td>Indicator</td>
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</tr>
<tr>
<td>County Water Value, Market - Total Water Non-Market Value Indicator</td>
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</tr>
<tr>
<td>County Water Value, Market - Agricultural Water Withdrawals (acre-feet/year)</td>
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<td>Metric</td>
<td>51</td>
</tr>
<tr>
<td>County Water Value, Market - Domestic Water Withdrawals (acre-feet/year)</td>
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<td>Metric</td>
<td>52</td>
</tr>
<tr>
<td>County Water Value, Market - industrial Water Withdrawals (acre-feet/year)</td>
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</tr>
<tr>
<td>County Water Value, Market - Public Water Withdrawals (acre-feet/year)</td>
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<td>54</td>
</tr>
<tr>
<td>County Water Value, Market - Thermoelectric Withdrawals (acre-feet/year)</td>
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<td>Metric</td>
<td>55</td>
</tr>
<tr>
<td>County Water Value, Market - Total Water Withdrawals (acre-feet/year)</td>
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</tr>
<tr>
<td>County Water Value, Non-Market- Average Willingness to Pay by Household</td>
<td>Water Value</td>
<td>Metric</td>
<td>57</td>
</tr>
<tr>
<td>County Water Value, Non-Market- Fish Stocking Greater than the Average for All ARC Counties (in the Same State)</td>
<td>Water Value</td>
<td>Metric</td>
<td>58</td>
</tr>
<tr>
<td>County Water Value, Non-Market- Median Household income</td>
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<td>Metric</td>
<td>60</td>
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<td>County Water Value, Market - Agricultural Water Withdrawals (Acre-Feet/Year)</td>
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<td>County Water Value, Market - Public Water Withdrawals (Acre-Feet/Year)</td>
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<tr>
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</tr>
<tr>
<td>County Water Value, Non-Market- Median Household income</td>
<td>Water Value</td>
<td>Metric</td>
<td>60</td>
</tr>
</tbody>
</table>
Water Asset
County Water Asset Score in Appalachia

Formula:
water asset score = access score + quality score + quantity score

Final Water Asset Score = \left( \frac{\text{raw asset score for county}}{\text{maximum raw county score}} - \frac{\text{minimum raw county score}}{\text{minimum raw county score}} \right) \times 100

NOTE:
On the map, counties with the more desirable outcome—predictors of good water assets—are colored green; those with the less desirable outcome—predictors of poor water assets—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
Water Quality
County Water Quality Index in Appalachia

NOTE:
For mapping, the counties were sorted by final water asset score and grouped into six categories, with 73 counties in each category.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quality Score in Appalachia

Formula:
Raw water quality score = final land use score + final facilities score + final AML score

Final water quality score = \( \left( \frac{\text{raw quality score for County } x - \text{ minimum raw quality score}}{\text{maximum raw quality score} - \text{ minimum raw quality score}} \right) \times 100 \)

NOTE:
On the map, counties with the more desirable outcome—good water quality—are colored green; those with the less desirable outcome—poor water quality—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quality Indicator, Land-Use

Formula:
Raw land use score = average of all final catchment land use scores in county

Final Land Use Score = \left( \frac{\text{raw land use score for County } x - \text{minimum raw land use score}}{\text{maximum raw land use score} - \text{minimum raw land use score}} \right) \times 100

NOTE:
On the map, counties with the more desirable outcome—predictors of good water quality—are colored green; those with the less desirable outcome—predictors of poor water quality—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quality Indicator, Facilities

Formula:
Raw facilities score = final NPDES score + final CSO score +
final TRI score + final coal score + final AML score

Final Facilities Score = \( \frac{ \text{raw facilities score for County } x - \text{minimum raw facilities score} }{ \text{maximum raw facilities score} - \text{minimum raw facilities score} } \) \times 100

NOTE:
On the map, counties with the more desirable outcome—predictors of good water quality—are colored green; those with the less desirable outcome—predictors of poor water quality—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quality, Percent of Unimpaired Streams

Formula:
Percent unimpaired streams = 100 - percent impaired streams

NOTE:
These percentages include both streams that have been determined not to be impaired and streams that have not been assessed for impairment.

Map Created: June 2011
Data Sources: US Environmental Protection Agency (2010), Office of Water. EPA Office of Water (OW): 303(d) Listed Impaired Waters NHD Indexed Dataset.
County Water Quality, Impaired Streams

Map Created: June 2011
Data Sources: US Environmental Protection Agency (2010), Office of Water. EPA Office of Water (OW): 303(d) Listed Impaired Waters NHD Indexed Dataset.
County Water Quality, Percent Impaired Streams

Percent of Impaired Streams
- 51% - 59%
- 43% - 50%
- 35% - 42%
- 26% - 34%
- 18% - 25%
- 9% - 17%
- 0% - 8%

Formula:
Percent impaired streams = (Impaired stream miles)/(total stream miles)

Map Created: June 2011
Data Sources: US Environmental Protection Agency (2010), Office of Water. EPA Office of Water (OW): 303(d) Listed Impaired Waters NHD Indexed Dataset.
County Water Quality Metrics, Facilities: TRI, NPDES, CSOs, and AMLs

Facilities by Type
- CSOs Communities
- TRI Facilities
- Major NPDES Permits
- AML Problem Areas

NOTE:
Coordinates for AMLs were not available for Kentucky

Map Created: June 2011
Water Quantity
County Water Quantity Index in Appalachia

Formula:
Raw water quantity score = final usage score + final flood score + final streams and lakes score

Final Water Quantity Score = \left( \frac{\text{raw quantity score for County } x - \text{minimum raw quantity score}}{\text{maximum raw quantity score} - \text{minimum raw quantity score}} \right) \times 100

ARC Water Quantity Index
- Highest
- Very High
- High
- Low
- Very Low
- Lowest

NOTE: For mapping, the counties were sorted by final water quantity score and grouped into six categories, with 70 counties in each category.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity Score in Appalachia

Formula:
Raw water quantity score = final usage score + final flood score + final streams and lakes score

Final Water Quantity Score = \( \left( \frac{\text{raw quantity score for County} - \text{minimum raw quantity score}}{\text{maximum raw quantity score} - \text{minimum raw quantity score}} \right) \times 100 \)

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011

NOTE:
On the map, counties with the more desirable outcome—good water quantity—are colored green; those with the less desirable outcome—poor water quantity—are colored red.
County Water Quantity, Usage Indicator

Formula:
Final usage score = \frac{[(\text{raw usage score for County X} - \text{minimum raw usage score})]}{[\text{maximum raw usage score} - \text{minimum raw usage score}]} \times 100

Usage Score 0-100
- 100
- 95 - 99
- 97
- 95 - 96
- 92 - 94
- 84 - 91
- 0 - 83

NOTE:
On the map, counties with the more desirable outcome—predictors of a water surplus—are colored green; those with the less desirable outcome—predictors of a water deficit—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity, Flooding Indicator

Formula:
Final flood score = [(raw flood score for County X - minimum raw flood score) / (maximum raw flood score - minimum raw flood score)] x 100

NOTE:
On the map, counties with the more desirable outcome—predictors of good water quality—are colored green; those with the less desirable outcome—predictors of poor water quality—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity, Streams and Lakes Indicator

Formula:
Raw stream and lake score = final stream score + final lake score

Final Stream and Lake Score = (raw stream and lake score for County x minimum raw stream and lake score) / (maximum raw stream and lake score - minimum raw stream and lake score) x 100

NOTE:
On the map, counties with the more desirable outcome—more water—are colored green; those with the less desirable outcome—less water—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity, Total Groundwater Use, Year 2005 (Million Gallons/Day)

Formula:
Groundwater use = total consumptive groundwater withdrawals from all usage sectors

Map Created: June 2011
County Water Quantity, Total Groundwater Use, Year 2005, Normalized To County Area (mm)

Formula:
Normalized groundwater use = [groundwater use (converted to m^3/year)]/[county area (m^2)] x 1/1,000

Map Created: June 2011
County Water Quantity, Total Surface Water Use, Year 2005, Normalized To County Area (mm)

Formula:
Normalized surface water use = [surface water use (converted to m³/year)]/(county area (m²)) x 1/1,000

Map Created: June 2011
County Water Quantity,
Mean Annual Evapotranspiration 1932-2009 (mm)

Formula:
Mean annual evapotranspiration = average annual evapotranspiration for 1932-2009

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity, Mean Annual Precipitation Minus Mean Annual Evapotranspiration (mm)

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011

Formula:
Available annual precipitation = mean annual precipitation - mean annual evapotranspiration
County Water Quantity, Mean Annual Precipitation 1932-2009 (mm)

Formula:
Mean annual precipitation = average annual precipitation for 1932-2009

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity, Total Floods per County

Total Floods per County

<table>
<thead>
<tr>
<th>Total Floods per County</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 9</td>
</tr>
<tr>
<td>10 - 15</td>
</tr>
<tr>
<td>16 - 23</td>
</tr>
<tr>
<td>24 - 32</td>
</tr>
<tr>
<td>33 - 43</td>
</tr>
<tr>
<td>44 - 61</td>
</tr>
<tr>
<td>62 - 90</td>
</tr>
</tbody>
</table>

Formula:
Flood count = number of floods reported from September 2000-August 2010

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity, Total Floods Per County, Normalized To County Area

Formula:
Normalized flood count = (number of floods reported from September 2000-August 2010)/(county area)

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity, Square Kilometers of Lakes

Formula:
water asset score = access score + quality score + quantity score

Final water asset score = \left( \frac{\text{raw asset score for Count} \times (\text{minimum raw county score})}{\text{maximum raw county score} - \text{minimum raw county score}} \right) \times 100

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity, Square Kilometers of Lakes, Normalized to County Area

Formula:
Lake ratio = (total area of lakes)/(county area)

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Quantity, Maximum Flow Estimate in Each County

Baseline Flow (Cfs)
- 90 - 27301
- 27302 - 54511
- 54512 - 81722
- 81723 - 108932
- 108933 - 136143
- 136144 - 163353
- 163354 - 190563

Formula:
Maximum flow estimate = [(average annual flow for the largest stream in the county) (converted to m³/year)] / [county area (m²)] x 1/1,000

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
Water Access
County Water Access Index in Appalachia

Formula:
Raw water access score = final boating score + final fishing score + final swimming score

Final Water Access Score = \frac{(raw\ access\ score\ for\ County\ x - minimum\ raw\ access\ score)}{maximum\ raw\ access\ score\ - minimum\ raw\ access\ score} \times 100

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011

NOTE:
For mapping, the counties were sorted by final water asset score and grouped into six categories, with 70 counties in each category.
County Water Access Score in Appalachia

Water Access Score 0-100
- 37 - 100
- 28 - 36
- 23 - 27
- 18 - 22
- 14 - 17
- 11 - 13
- 0 - 10

Formula:
Raw water access score = final boating score + final fishing score + final swimming score

Final Water Access Score = \left( \frac{\text{raw access score for County } x - \text{minimum raw access score}}{\text{maximum raw access score} - \text{minimum raw access score}} \right) \times 100

NOTE:
On the map, counties with the more desirable outcome—good water access—are colored green; those with the less desirable outcome—poor water access—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
NOTE: On the map, counties with the more desirable outcome—more fishing access—are colored green; those with the less desirable outcome—less fishing access—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Access, Fishing Access Indicator

NOTE:
On the map, counties with the more desirable outcome—more fishing access—are colored green; those with the less desirable outcome—less fishing access—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
NOTE: On the map, counties with the more desirable outcome—more fishing access—are colored green; those with the less desirable outcome—less fishing access—are colored red.
Water Value
County Water Market Value Index in Appalachia

Formula:
Raw water value score = final non-market value score +
final market value score

Raw Water
Value Score = \left( \frac{\text{raw value score for County } x}{\text{maximum raw value score}} - \frac{\text{minimum raw value score}}{\text{minimum raw value score}} \right) \times 100

NOTE:
For mapping, the counties were sorted by final water asset score and grouped into six categories, with 70 counties in each category.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Non-Market Value Index in Appalachia

Formula:
Raw non-market value score = average of final scores for three willingness-to-pay models

Final non-market water value score = \( \frac{\text{raw non} - \text{market score for County} \times \left( \text{maximum raw non} - \text{market score} \right)}{\text{minimum raw non} - \text{market score}} \times 100 \)

NOTE:
For mapping, the counties were sorted by final water asset score and grouped into six categories, with 70 counties in each category.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Market Value Score in Appalachia

Formula:
Raw market value score = (public value + domestic value + industrial value + crop value + thermo-electric)

Final Market Water Value Score = \( \frac{\text{raw value score for County} - \text{minimum raw value score}}{\text{maximum raw value score} - \text{minimum raw value score}} \) \times 100

NOTE:
On the map, counties with the more desirable outcome—higher water market value—are colored green; those with the less desirable outcome—lower water market value—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
COUNTY WATER NON-MARKET VALUE SCORE IN APPALACHIA

FORMULA:
Raw non-market value score = average of final scores for three willingness-to-pay models

Final Non-market Water Value Score = \left( \frac{\text{raw nonmarket score for county} - \text{minimum raw nonmarket score}}{\text{maximum raw nonmarket score} - \text{minimum raw nonmarket score}} \right) \times 100

NOTE:
On the map, counties with the more desirable outcome—higher water non-market value—are colored green; those with the less desirable outcome—lower water non-market value—are colored red.

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Value, Market - Agricultural Water Withdrawals (Acre-Feet/Year)

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
Count Water Value, Market - Total Water Withdrawals (Acre-Feet/Year)

Formula:
Total water withdrawals = public supply withdrawals + domestic self-supplied withdrawals + industrial self-supplied withdrawals + crop irrigation withdrawals + thermo-electric withdrawals

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011
County Water Value, Non-Market- Fish Stocking Greater than the Average for All ARC Counties (in the Same State)

Map Created: June 2011
Data Sources: Appalachian Assessment of Natural Assets - Water Analysis by West Virginia University and Downstream Strategies for the Appalachian Regional Commission - May 2011