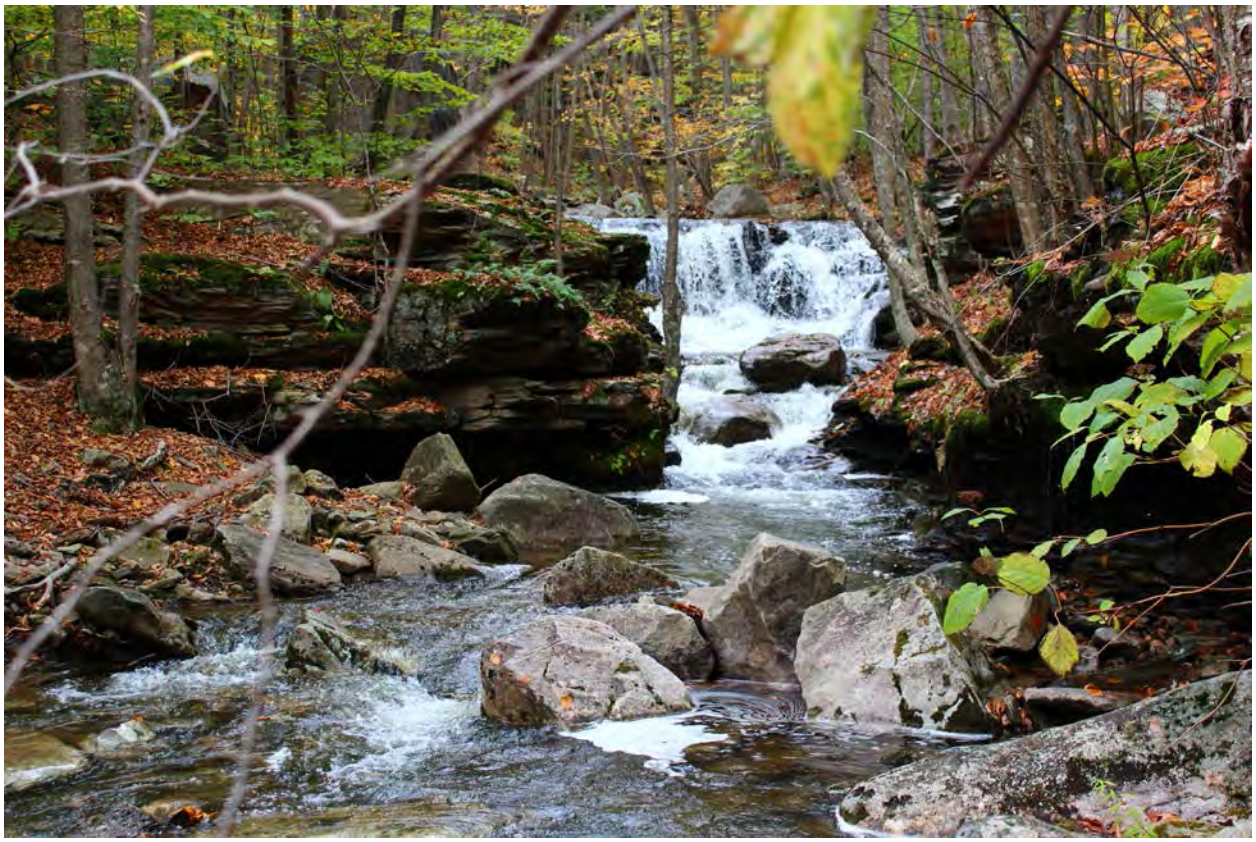
2017 Coldwater Heritage Plan for the Rock Run Watershed
Lycoming and Sullivan Counties, Pennsylvania



Susquehanna Chapter of Trout Unlimited
In cooperation with:
Trout Unlimited's Pennsylvania Coldwater Habitat Restoration Program

Final Report Prepared By:

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PROJECT OVERVIEW

The Susquehanna Chapter of Trout Unlimited was awarded a planning grant from the Pennsylvania Coldwater Heritage Partnership in 2015 to complete a coldwater heritage plan for the Rock Run Watershed, a tributary to Lycoming Creek. The main goals of this project were to; 1) gather, summarize and coordinate the analysis of existing water quality data for the Rock Run watershed, 2) evaluate the acidity issues in non-attaining tributaries and identify potential restoration projects, 3) assess aquatic organism passage issues, and 4) establish a volunteer-based, long-term monitoring program through Trout Unlimited's Coldwater Conservation Corps. Based on the results of this project and previous data collected within the watershed, several recommendations are highlighted to improve and protect the Rock Run watershed.

WATERSHED OVERVIEW

The Rock Run watershed is located primarily in Lycoming County, Pennsylvania with a small portion of the headwaters extending into Sullivan County. The mouth of Rock Run is located near the town of Ralston, PA (Figure 1). The Rock Run watershed drains an area of 28.3 square miles and contains a total of 54.89 miles of streams, yielding a stream density of 1.94 stream miles per square mile of the watershed. The watershed has a mean elevation of 1,945.4 feet above sea level and receives a mean of 38 inches of precipitation annually. The watershed is also very high gradient with a mean basin slope of 8.5 degrees.

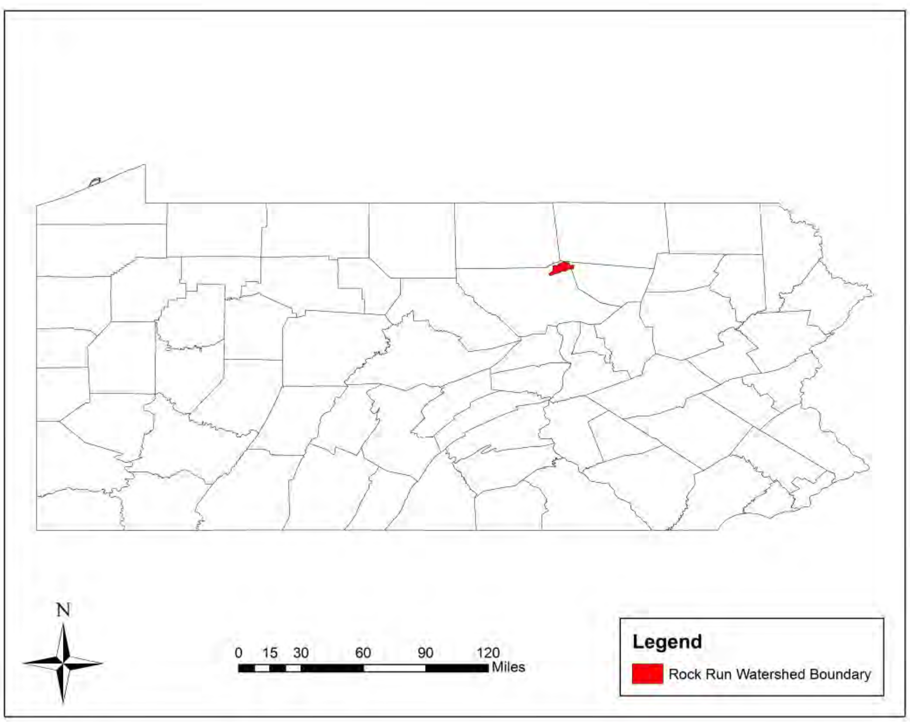

Figure 1. Rock Run watershed location within Pennsylvania. The watershed is located in the northeastern corner of Lycoming and part of Sullivan Counties.

The geology of the watershed is dominated entirely by sandstone (Berg et al. 1980; Miles et al. 2001) (Figure 2). The watershed is underlain by five primary geological formations, the 1) Allegheny and Pottsville, undivided, 2) Burgoon Sandstone, 3) Catskill, 4) Huntley Mountain, and 5) Pottsville formations. The Allegheny and Pottsville Formations, undivided are of Pennsylvanian geologic age with primary and secondary rock types of sandstone and shale, respectively. This formation also may include coal. This formation is present in the western edge of the watershed, primarily along Miner's Run (Figure 2).The Burgoon sandstone formation is of Mississippian geologic age with primary and secondary rock types of sandstone and conglomerate, respectively. Other rock types in this formation include shale and coal. The Catskill formation is of Devonian geologic age with primary and secondary rock types of sandstone and siltstone, respectively. Other rock types in this formation include shale, mudstone, and conglomerate. The Huntely Mountain formation is of Mississippian and Devonian geologic age with primary and secondary rock types of sandstone and siltstone, respectively. Shale may also be present in the formation. This formation forms the transition between the Catskill Formation and the Burgoon Sandstone formation. Finally, the Pottsville Formation is of Pennsylvanian geologic age with primary and secondary rock types of sandstone and conglomerate, respectively. There is no carbonate rock within the watershed (USGS Stream stats V. 4, Berg et al. 1980; Miles et al. 2001).

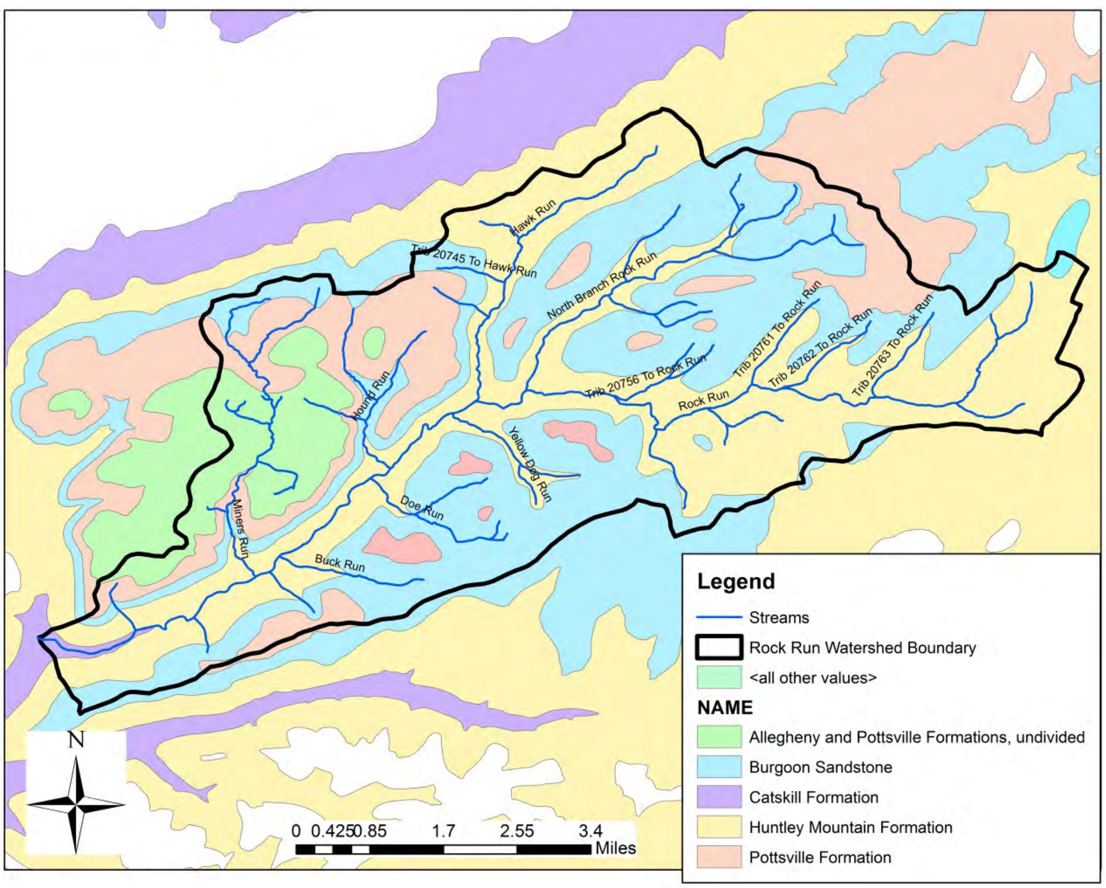

Figure 2. Geologic formations underlying the Rock Run watershed (Berg et al. 1980; Miles et al. 2001).

The Rock Run watershed is entirely within the glaciated area of Pennsylvania. The average depth of soil to bedrock is 3.6 feet and the soils are moderately drained. The Rock Run watershed contains two major soil series, Oquaga and Morris (Soil Survey Staff, NRCS, USDA) (Figure 3). Below are the official soil series descriptions for both series from the United States Department of Agriculture. Further information is available for the Morris series at https://soilseries.sc.egov.usda.gov/OSD_Docs/M/MORRIS.html and the Oquaga series at https://soilseries.sc.egov.usda.gov/OSD_Docs/O/OQUAGA.html.

"The Morris soil series consists of very deep, somewhat poorly drained soils formed in till from red sandstone, siltstone, and shale. They have a dense fragipan layer from 25-56 cm (10 to 22in) that restricts root penetration and water movement. Slopes range from 0 to 25 percent. Saturated hydraulic conductivity is moderately high or high above the fragipan and is low or moderately low in the fragipan and substratum."

"The Oquaga series consists of moderately deep, somewhat excessively drained soils formed in a thin mantle of till over sandstone, siltstone, and shale bedrock on nearly level to very steep uplands. Slope ranges from 0 to 70 percent. Permeability is moderate."

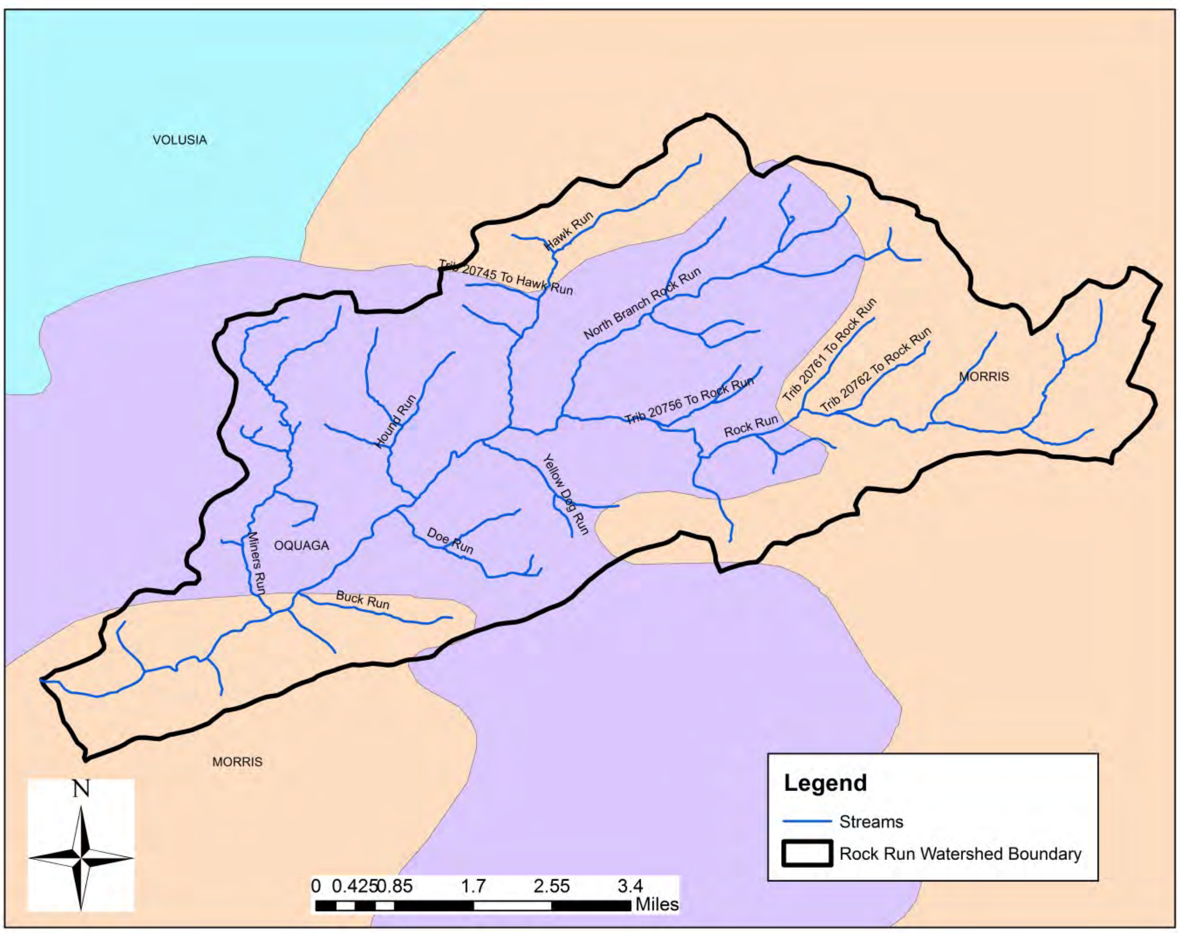

Figure 3. Soil series within the Rock Run watershed; Oquaga (purple), Morris (tan), and Volusia (light blue).

According to the National Land Cover Database (Homer et al., 2011), the Rock Run watershed is predominately covered (97%) by forest, with no urban development or impervious surfaces. The watershed also contains 1.42% developed land (NLCD 2011 classes 21-24). Figure 4 depicts high resolution land cover within the watershed based on 2013 data from the University of Vermont Spatial Analysis Laboratory. This dataset shows the presence of ecologically important emergent wetlands in the headwater areas of Rock Run.

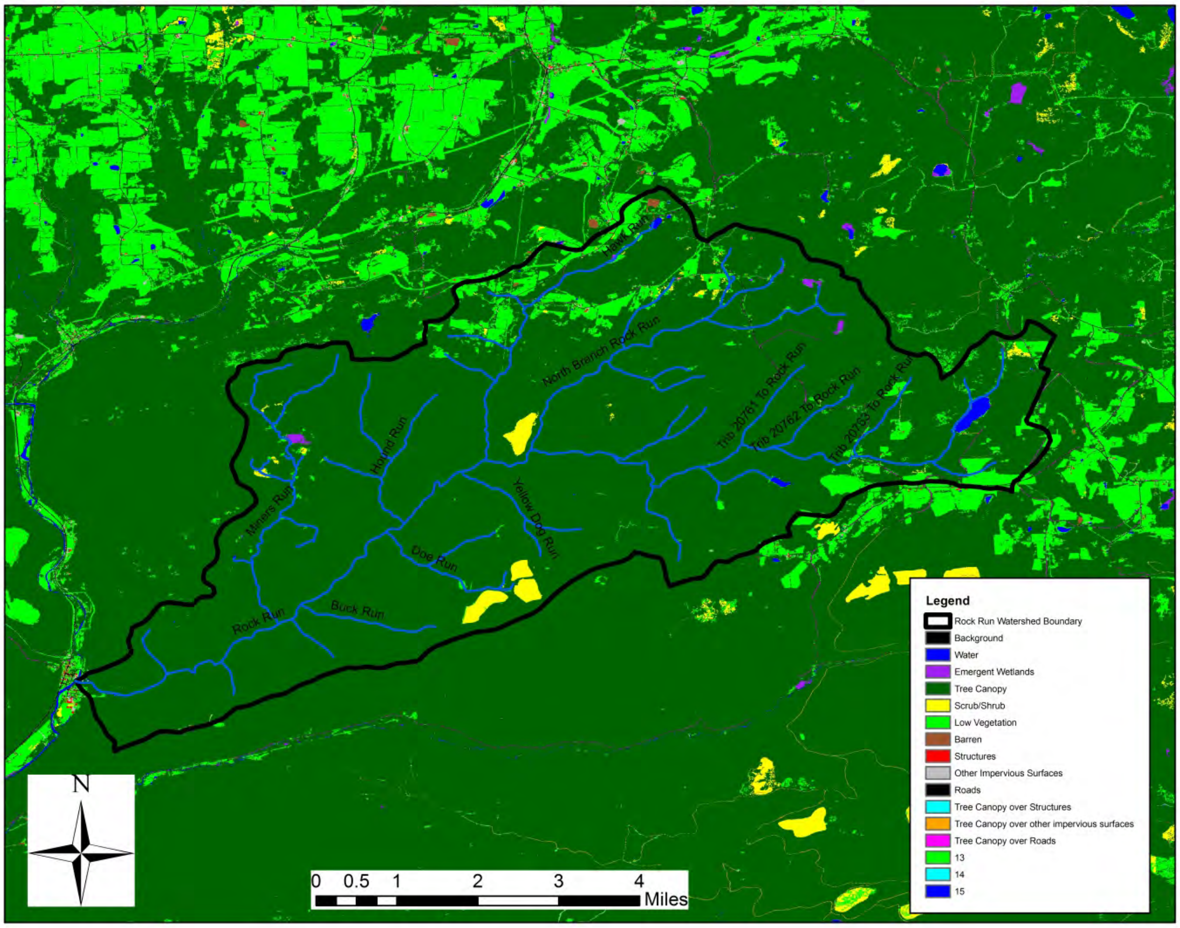

Figure 4. High resolution land cover data for the Rock Run watershed and surrounding area. Data source: University of Vermont Spatial Analysis Laboratory, 2016 (http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=3193).

The majority of the Rock Run watershed is owned by the PA Department of Conservation and Natural Resources (DCNR). Approximately 60% of the watershed is located within the Loyalsock State Forest (Figure 5). This area includes the McIntyre Wild Area and the Devil's Elbow Natural Area, making this watershed extremely valuable for recreational use. Recreational use in the watershed includes fishing, hiking, swimming, paddling, cross country skiing, hunting, and other similar outdoor recreational activities.

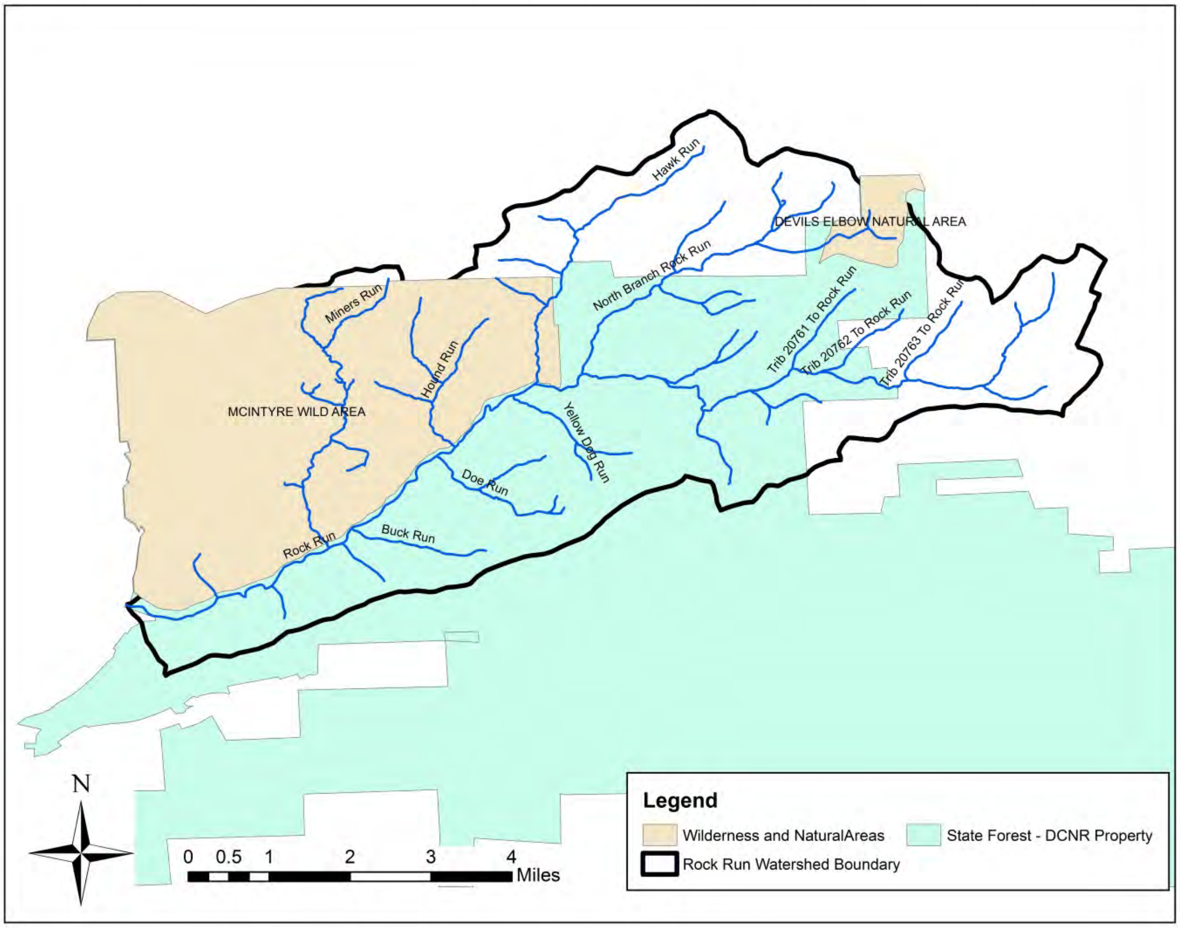

Figure 5. Loyalsock State Forest boundaries within the Rock Run watershed. The McIntyre Wild Area and Devil's Elbow Natural Areas are shown in tan colors. Unshaded areas within the watershed represent privately owned land.

POTENTIAL THREATS TO BROOK TROUT

Brook trout are a primary species of conservation concern across much of their native range in the eastern United States. They are also a good indicator species to anthropogenic disturbance due their requirements of clean, cold water with intact habitat (Lyons et al. 1996). Due to high levels of anthropogenic disturbance throughout their native range, only 31% of watersheds within the historical distribution are expected to support intact populations (Hudy et al. 2008). Rock Run supports a brook trout fishery in areas of the watershed (discussed in later sections) and therefore, an examination of the potential threats to these populations within the watershed is critical to determine possible measures to conserve brook trout resources within the watershed.

Natural Gas Development

The Rock Run watershed falls completely within the Marcellus Shale formation of the eastern United States. The development of the natural gas resources associated with the Marcellus Shale formation in Pennsylvania has significant potential for damage to the Commonwealth's coldwater resources (Weltman-Fahs and Taylor 2013). The damages may be a result of land disturbances, spills, water withdrawals and wastewater discharges associated with natural gas development. According to 2017 data from the PA Department of Environmental Protection, a total of 17 natural gas wells are active or proposed within the Rock Run watershed. Of these 17, seven are listed as active, seven were proposed but never materialized, two were reported as 'not drilled' by the operator, and one is a plugged well. Of the active wells, they are all unconventional wells. An unconventional gas well is defined by the PA DEP as:

"a bore hole drilled or being drilled for the purpose of or to be used for the production of natural gas from an unconventional formation. Unconventional formation is a geological shale formation existing below the base of the Elk Sandstone or its geologic equivalent stratigraphic interval where natural gas generally cannot be produced at economic flow rates or in economic volumes except by vertical or horizontal well bores stimulated by hydraulic fracture treatment by using multilateral well bores or other techniques to expose more of the formation to the well bore."

Figure 6 shows the location of conventional and unconventional gas wells within the Rock Run watershed. It should be noted that more than one unconventional gas well may be located at a site.

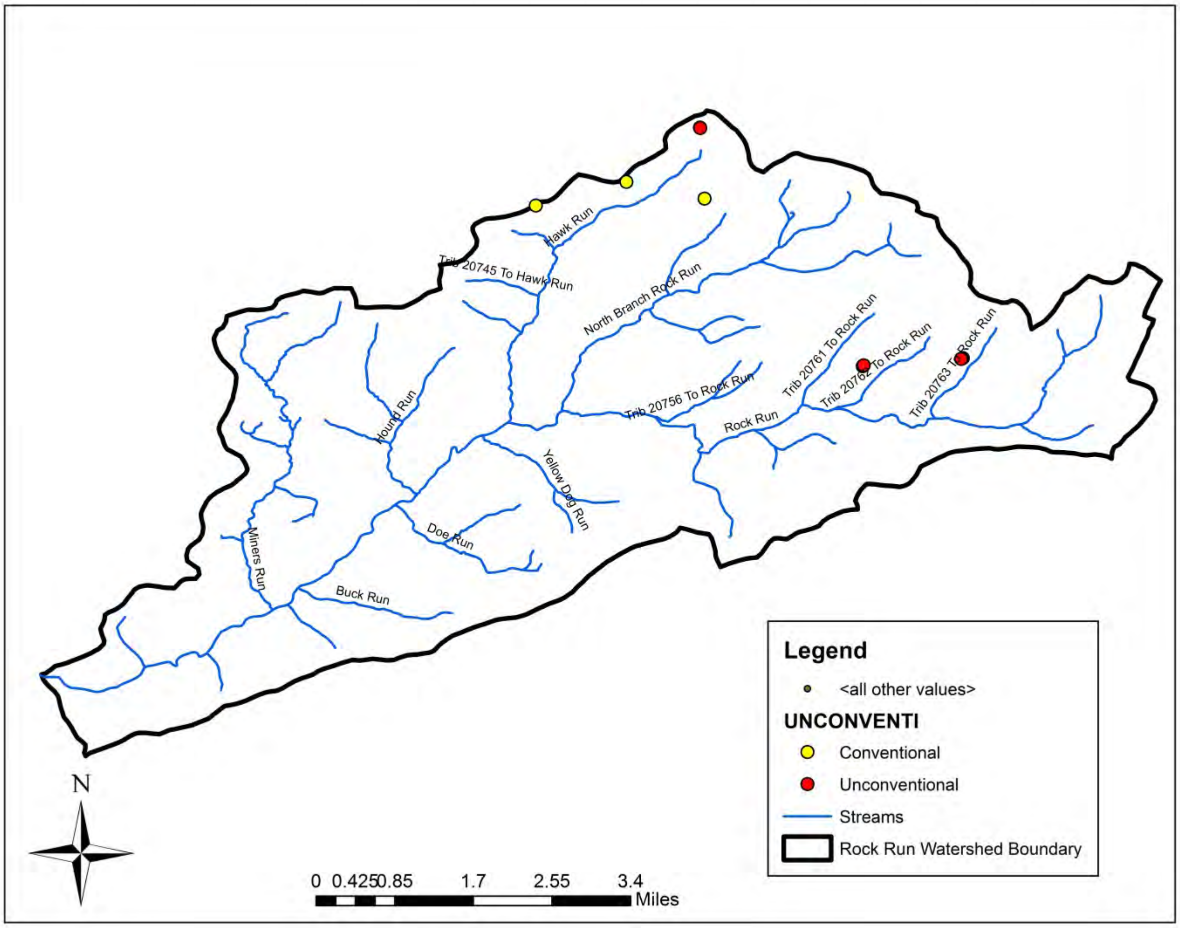

Figure 6. Conventional and unconventional gas well locations within the Rock Run watershed.

Weltman-Fahs and Taylor (2013) identified three primary pathways through which brook trout may be potentially affected by unconventional natural gas development: 1) changes in hydrology associated with water withdrawals; 2) elevated sediment inputs and loss of connectivity associated with supporting infrastructure; and 3) water contamination from introduced chemicals or wastewater (Kargbo et al. 2010, Entrekin et al. 2011, Rahm and Riha 2012). Figure 7 depicts a conceptual model derived from Fisher and Weltman-Fahs (2013) and Entrekin et al. (2011) demonstrating the possible relationships between hydraulic fracturing activities and the life cycle of brook trout.

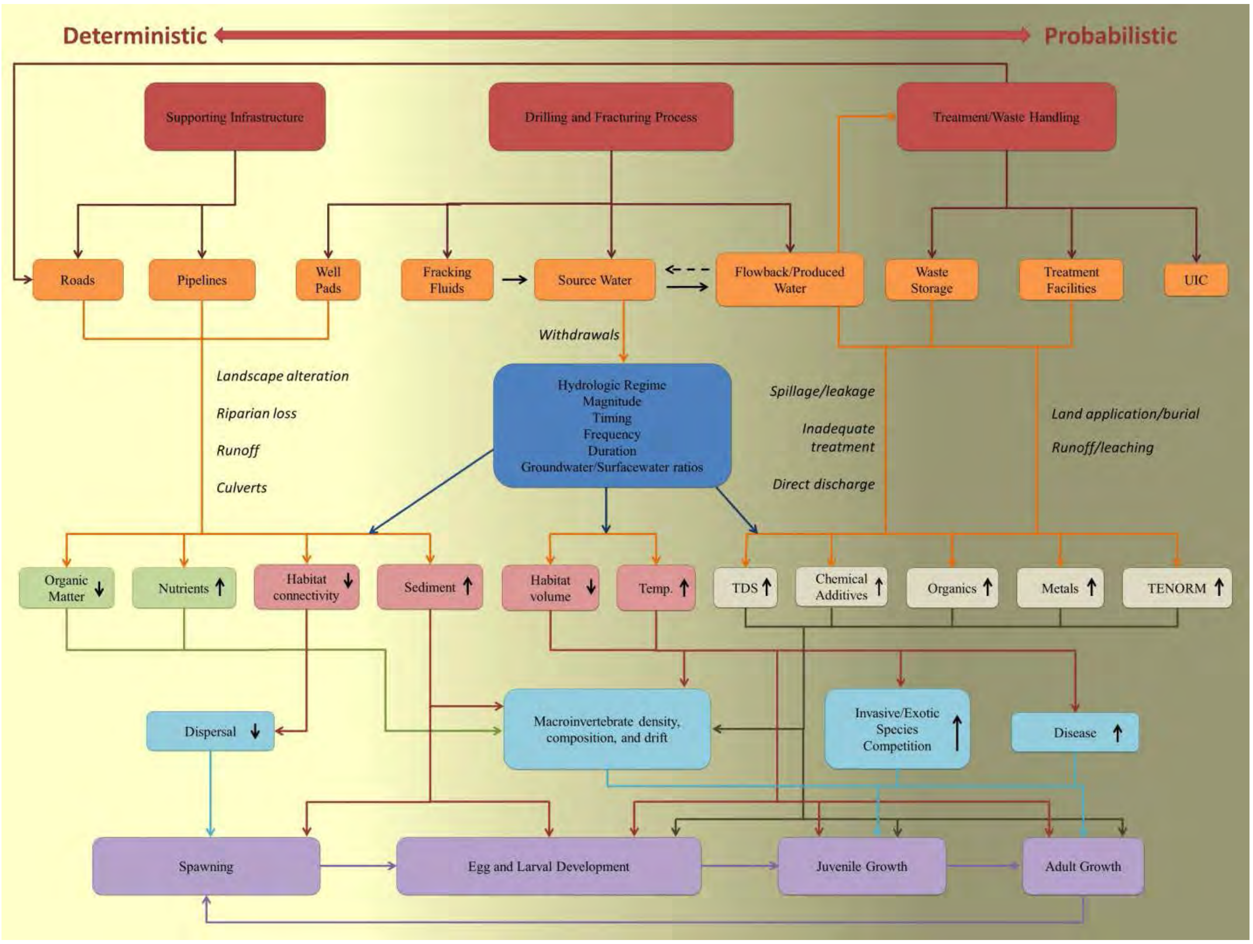

Figure 7. Conceptual model of relationships between hydraulic fracturing drilling activities and the life cycle of brook trout (from Fisher and Weltman-Fahs 2013 and Entrekin et al. 2011).

Non-native salmonids

The Pennsylvania Fish and Boat Commission annually released hatchery-reared trout into Rock Run for recreational fishing opportunities. Rock Run is stocked from its confluence with Hawk Run (41.5444; -76.8793) to the mouth (41.5049; -76.9528). According to PFBC 2017 trout stocking schedules, Rock Run is stocked with trout on three occasions in the spring. The preseason stocking is rainbow trout only and the two in-season stockings are a mixture of brook and brown trout.

The dispersal of hatchery-reared trout from the locations that they were intended to occupy may have a range of ecological effects. The ecological consequences of dispersal include interactions with wild trout and other native fishes, the possible spread of disease, and genetic effects on wild trout populations.

The stocking of hatchery-reared salmonids may have undesirable consequences on native salmonids through competition. Competition occurs between individuals when multiple organisms exploit a common resource and the fitness of at least one of the organisms is reduced, either because the resource is in short supply or other organisms interfere with its use (Birch 1957). Competitive interactions have been reported between stocked trout and wild or native trout and also between stocked trout and other native fish species (Symons 1969; Fausch 1984; McGinnity et al. 1997; Weber and Fausch 2003 for review; Rummel 2010).

Aquatic Organism Passage (AOP)

Pennsylvania alone has over 100,000 road-stream crossings. These road-stream crossings often present a barrier to the movement of aquatic organisms, resulting in fragmented populations. The U.S. Forest Service has estimated that half to two –thirds of road-stream crossings present a barrier to fish passage at some life state (Coffman 2005; Heller 2007). These barriers have had a detrimental impact on salmonids and aquatic diversity (Rieman et al. 1997; Hudy et al. 2005). According to the North Atlantic Aquatic Connectivity Collaborative (NAACC), the potential impacts of these barriers include; habitat loss and degradation, reduced access to vital habitats, population fragmentation and isolation, and the disruption of metapopulation dymanics (see https://streamcontinuity.org/aquatic_connectivity/ecological_concerns/barrier_impacts/index.htm for more information).

In areas that contain brook trout populations that are isolated due to barriers, a strategic approach to identifying barriers and replacing or removing barriers is important. The removal of these barriers will provide access to headwater streams that provide coldwater refuge and access to spawning and nursery habitat and lead to genetic diversity within brook trout populations, enhancing their long-term viability in the face of future disturbances. In addition to the ecological benefits, fish passage friendly road-stream crossing designs also provide economic benefits by increasing flood resiliency (Gillespie et al. 2014).

Water Quality

All of the streams within the Rock Run watershed have a Chapter 93 Designated Use of High Quality Coldwater Fishery (HQ-CWF) by the Pennsylvania Department of Environmental Protection (Figure 8). However, Miners, Doe, Hounds, and Yellow Dog Runs are also listed as non-attaining streams by the DEP. The DEP lists the source of impairment as low pH due to atmospheric deposition for each of these tributaries. Analyses of other sample sites throughout the watershed also indicate that there are acidity issues throughout the watershed. The acidity issues in Rock Run may be exacerbated from atmospheric deposition or abandoned mine drainage, or may originate naturally from headwater wetlands and poorly buffered, sandstone derived soils.

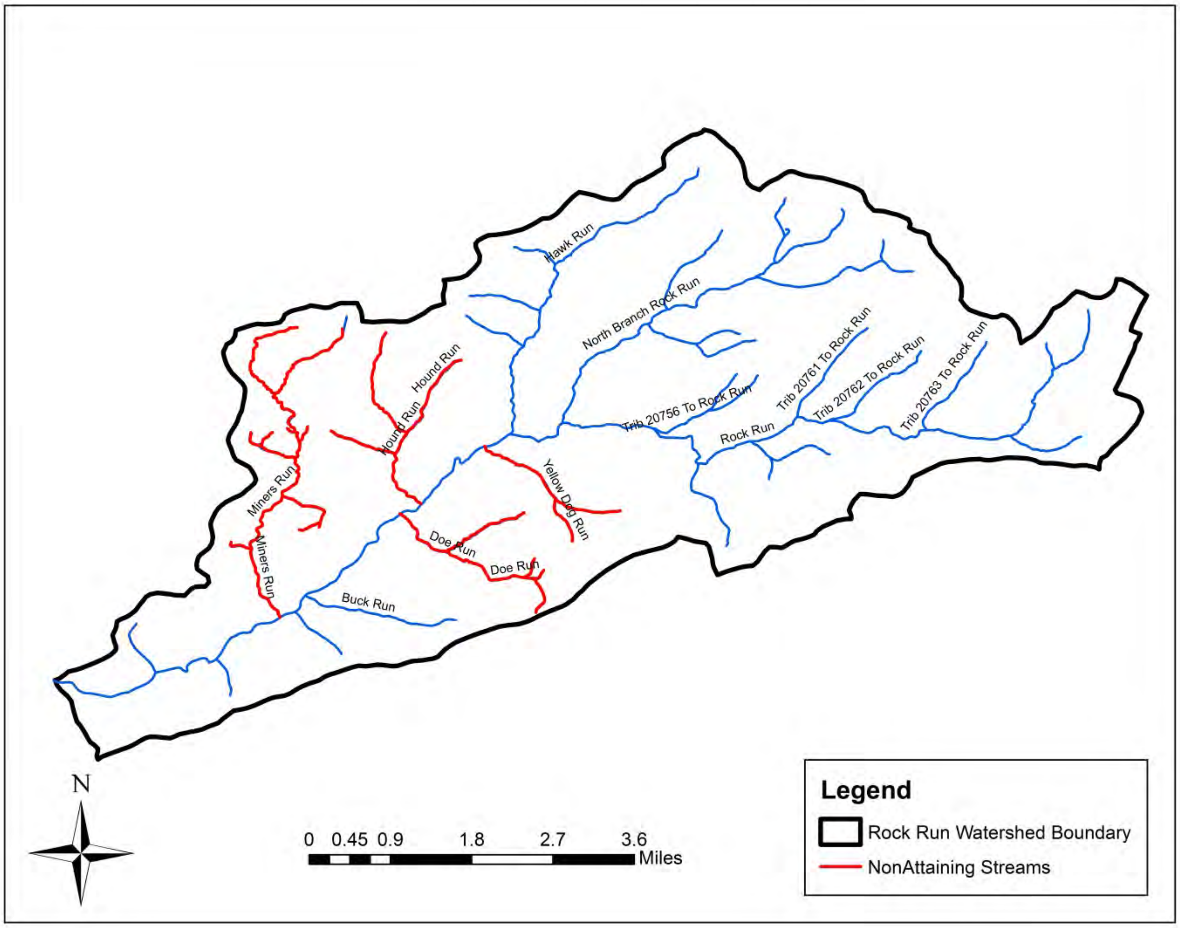

Figure 8. Non-attaining streams within the Rock Run watershed. The source of impairment for each of the streams in red is listed as low pH due to atmospheric deposition.

Most of Pennsylvania has received high deposition rates of hydrogen ions and sulfate from locations upwind, which has resulted in a high rate of atmospheric deposition in the state. In areas that contain geology and soils with low buffering capacity (i.e. sandstones, shales and their derived soils) and are at higher elevation, the effects of atmospheric deposition have been detrimental to aquatic life. Atmospheric deposition has resulted in both chronically acidic (always in an acidic condition) and episodically acidic (acidic conditions arise during periods of higher stream flow) streams. The effects of these acidic conditions on fish have been thoroughly documented in the scientific literature (Schofield 1976, Muniz and Leivestad 1980, Harvey and Lee 1982, Watt et al. 1983, Mills et al 1987, Sharpe et al. 1987, Gunn 1989, Baker et al. 1990, 1993, 1996, Matuszek et al. 1992, Bulger et al. 1993). Sharpe et al. (1987) showed that watershed with more than 30 percent Pottsville Group bedrock did not support trout and a combination of that with very stony land and high deposition rates may result in transient acidification and the absence of fish populations. Given the location of the Rock Run watershed and the underlying geology, it is highly likely that atmospheric deposition has increased acidification throughout the watershed and had a detrimental impact on the native brook trout populations.

A second possible cause of increased acidity in streams in Pennsylvania is abandoned mine drainage or AMD. As discussed in the geology section of this report, there is coal associated with the underlying geology around Miners Run. Some of this area was historically mined and has left the legacy of abandoned mine lands in the lower portion of the watershed (Figure 9). A typical relic of historical mining operations is the creation of Abandoned Mine Drainage formed when pyrite is exposed to oxygen and water during the mining operation, resulting in acidic water that is typically high in heavy metals such as aluminum and iron. These metals are highly toxic to fish and other aquatic organisms and often result in streams that are devoid of most aquatic life that is typically found in healthy streams.

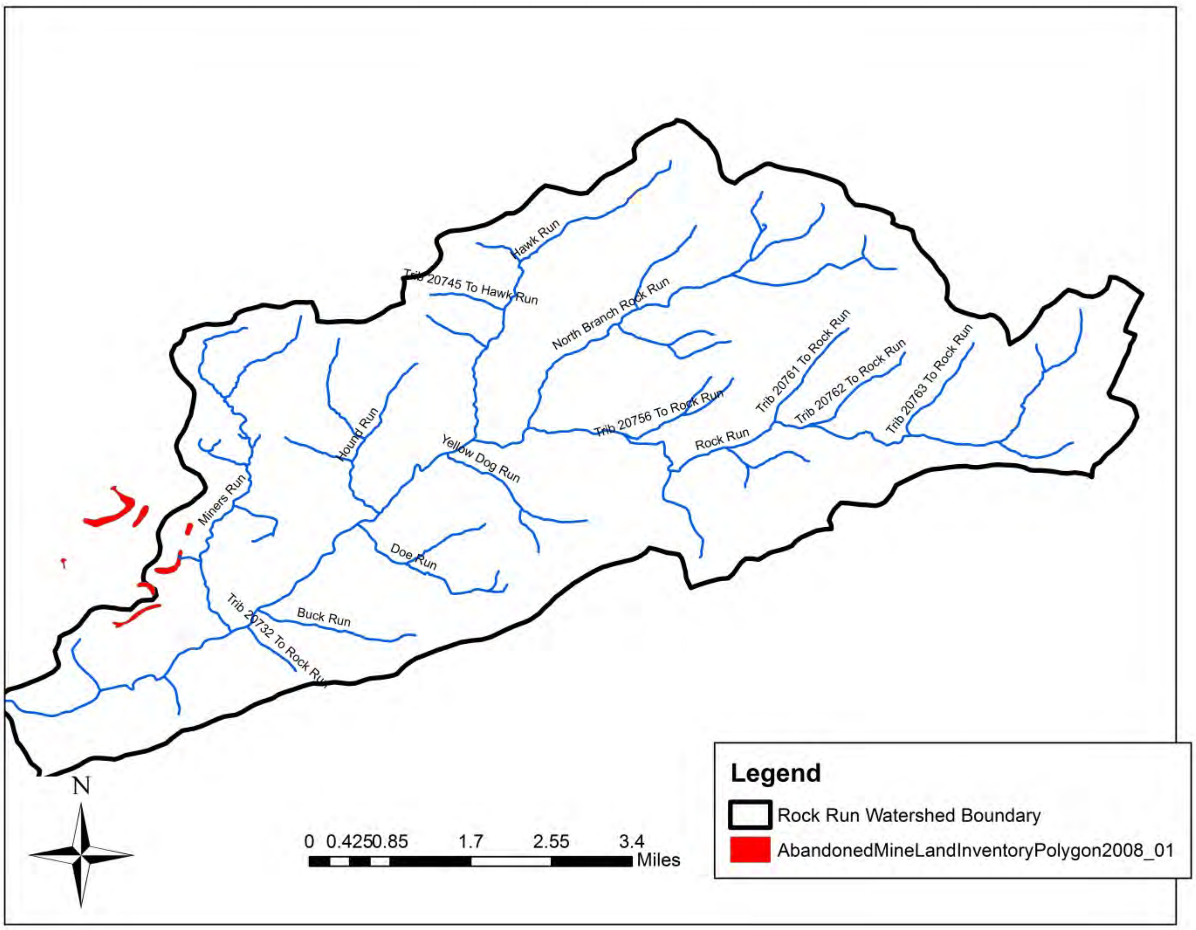

Figure 9. Abandoned mine lands identified by PA DEP within and near the Rock Run watershed.

Climate Change

The biological requirement of brook trout for cold water habitats is one of the major driving factors for their viability in a changing climate. A modest increase in water temperatures would be detrimental to many populations that are already in decline due to other disturbances as outlined above. In addition to direct increases in temperature, flow regimes are also likely to change substantially (Poff et al. 1996; Mulholland et al. 1997). Changes in water temperatures, streamflow regimes, and the associated habitat alterations are expected to result in widespread losses of brook trout populations throughout their native range (Meisner 1990; Clark et al. 2001; Flebb et al. 2006). In already fragmented habitats, these losses may be expected to be exacerbated.

Man-made Impoundments

There are at least two man-made impoundments within the Rock Run watershed. One is located in the headwaters region of the watershed (locally known as Baumonk's Pond) and the other is just west of Ellenton on UNT 20759. Impoundments generally increase sedimentation downstream of the dam and also may cause an increase in water temperatures. Both of these can negatively impact brook trout and other aquatic species that require cold, clean water.

HISTORICAL DATA/MONITORING

A large volume of work has been completed within the Rock Run watershed over the years, however much of that data has never been digitized or is housed in a variety of locations. One of the goals of this project was to compile some of the historical data so that it would be available in a single resource or at least direct interested individuals to the data.

Several sites throughout the Rock Run watershed have publically available data through the Water Quality Portal (WQP; https://www.waterqualitydata.us/) (Figure 10). The WQP is a cooperative service sponsored by the U.S. Geological Survey (USGS), the Environmental Protection Agency (EPA), and the National Water Quality Monitoring Council (NWQMC) that integrates publically available water quality data from the USGS National Water Information System (NWIS; https://waterdata.usgs.gov/nwis). For the Rock Run watershed, this includes sampling by the USGS, Susquehanna River Basin Commission, and the PA DEP. The data available have been provided to the Susquehanna Chapter of Trout Unlimited in Microsoft Excel format. Table 1 provides the station ID for the sites in the Rock Run watershed so that the available may be accessed via one of the websites provided above.

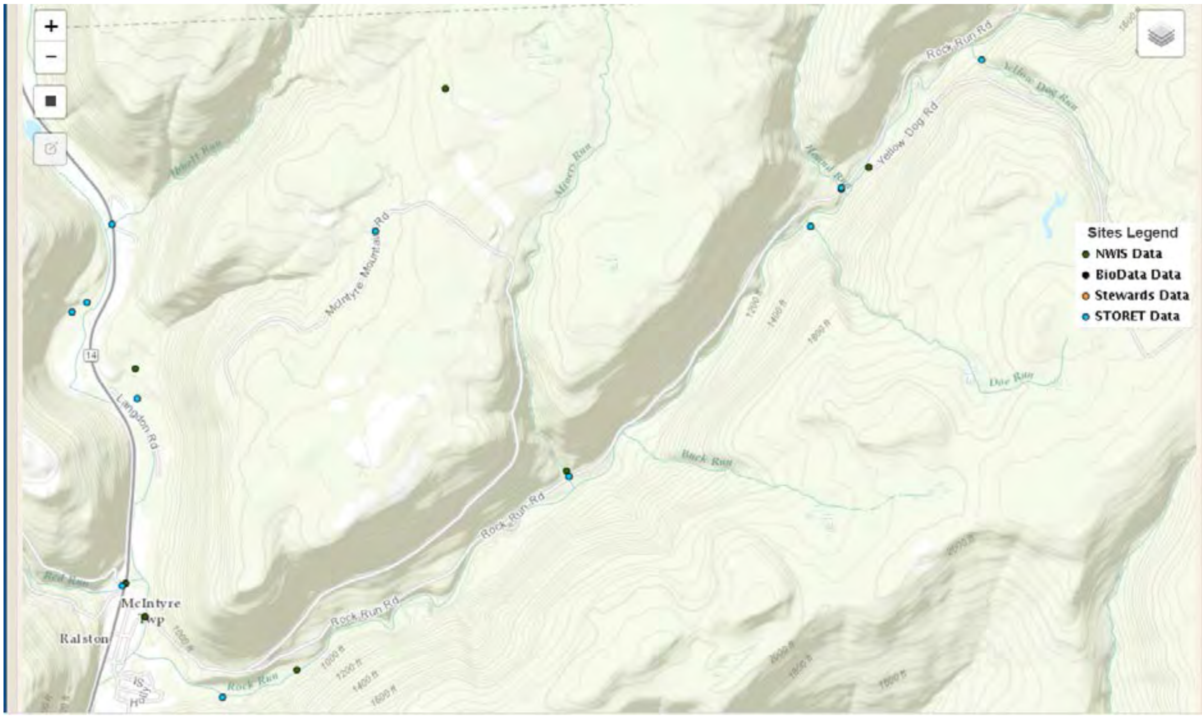

Figure 10. Sample site locations available on the Water Quality Data Portal for the Rock Run watershed.

Table 1. Site identification numbers for Rock Run sites shown in Figure 10. Individual site data may be accessed via the WQP site by using the Site ID number.

Site ID	Site Description (if provided)
USGS-01549904	Lycoming Creek at Ralston
USGS-015499068	Rock Run UPS Lycoming Creek
21PA_WQX-WQN0463	
42SRBCWQ_WQX-LYCO027.0-4176	
USGS-015499055	Rock Run
USGS-015499056	Hound Run
USGS-01549906	Miners Run
USGS-413223076553801	
42SRBCWQ_WQX-LYCO012.4-4176	Dutch Mine Discharge
42SRBCWZ_WQX-LYCO029.2-4176	
42SRBCWZ_WQX-LYCO030.7-4176	
42SRBCWZ_WQX-LYCO030.9-4176	
42SRBCWZ_WQX-LYCO032.0-4176	

The DCNR also has continuous monitoring equipment installed at several locations within the watershed to measure temperature, pH, and conductivity. These data were not available upon the completion of this project; however the locations are depicted in Figure 11 along with USGS sampling locations.

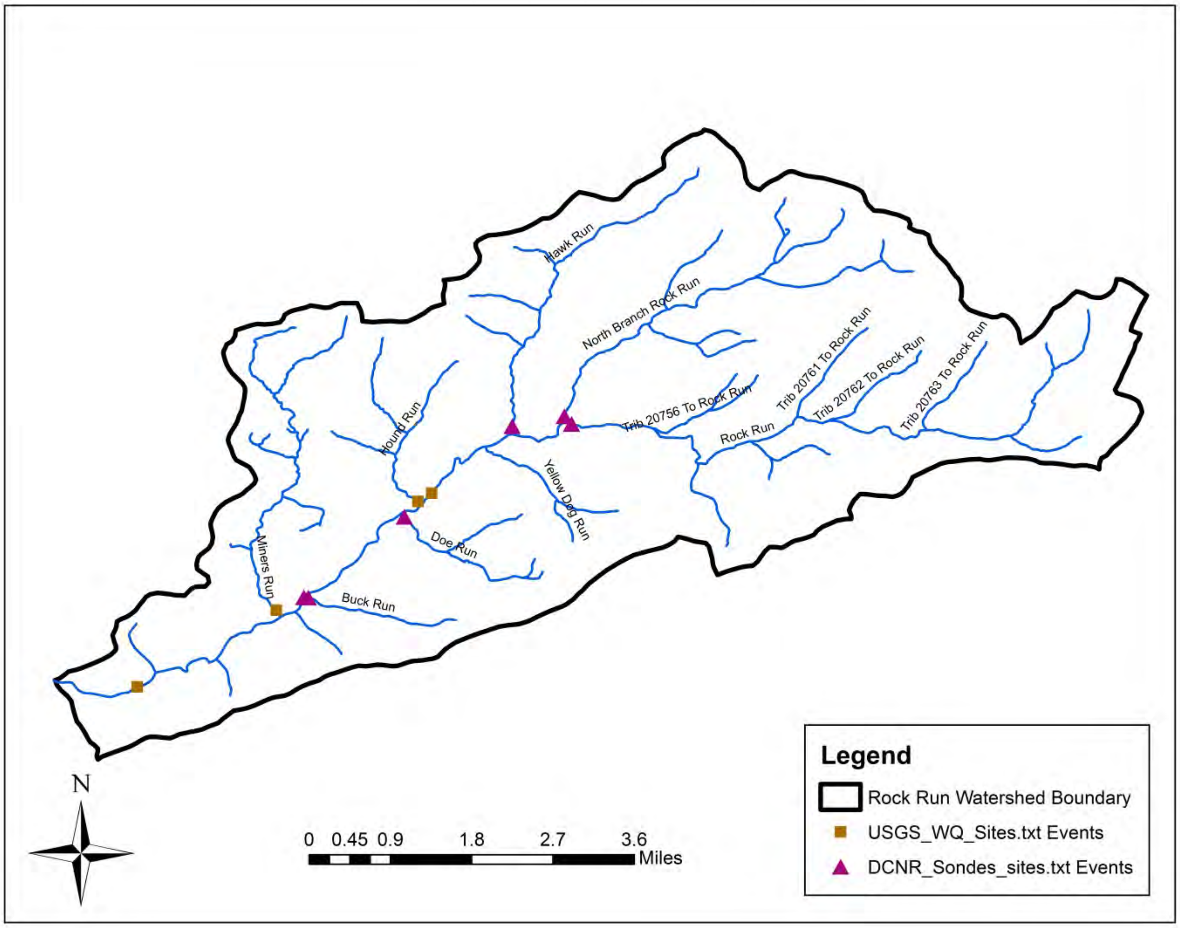

Figure 11. DCNR and USGS water quality sampling locations within the Rock Run watershed.

The PFBC has also historically sampled sections of the Rock Run watershed (Figure 12). Based on these historical surveys, several sections of Rock Run and its tributaries are managed under different designations by the PFBC (Figure 13). Additional fishery surveys were completed by Susquehanna University at several locations on tributaries on the lower end of the watershed as part of PFBC's Unassessed Waters Initiative (Figure 14). However, no trout were found at these locations.

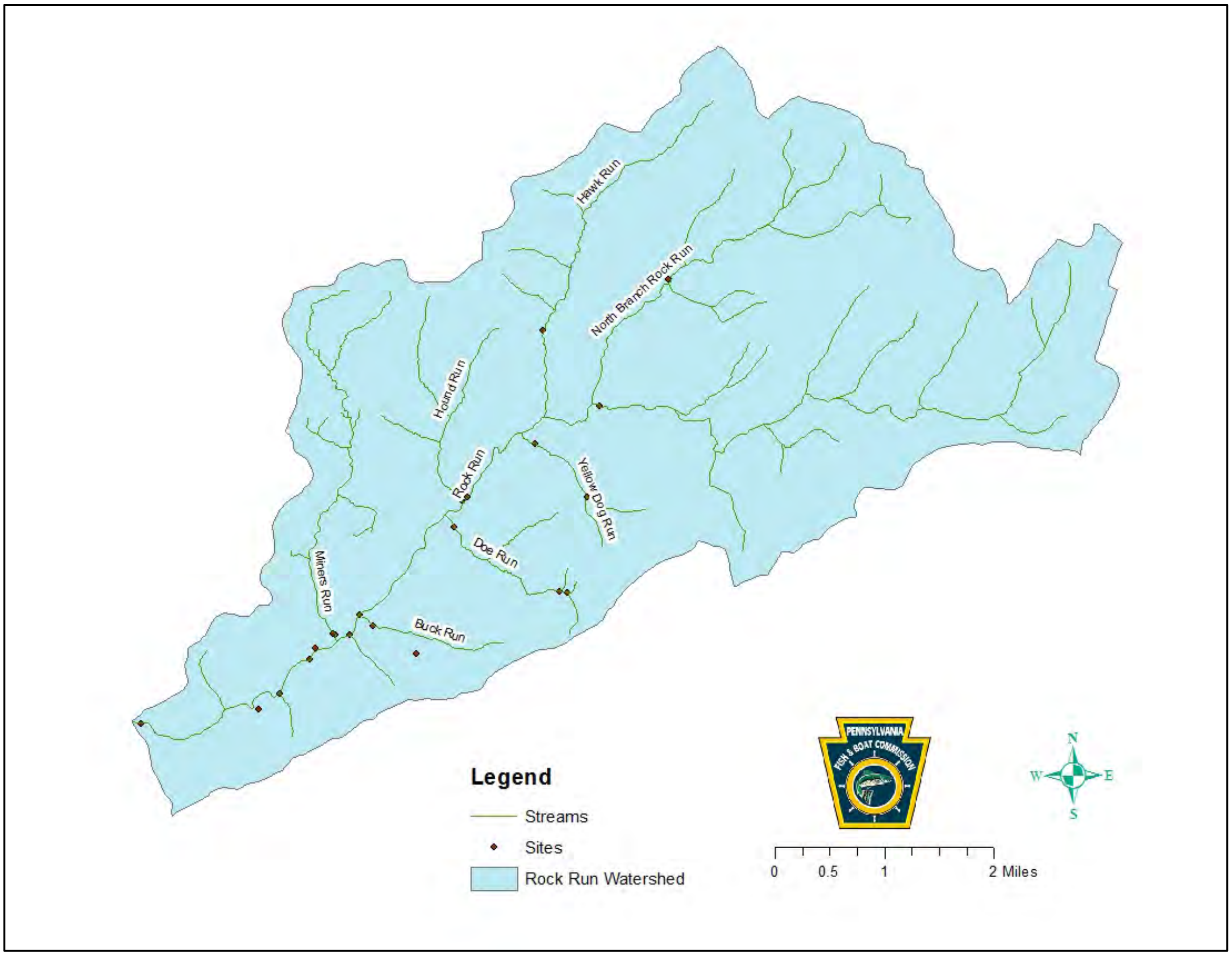

Figure 12. Historic fish survey locations by the PFBC.

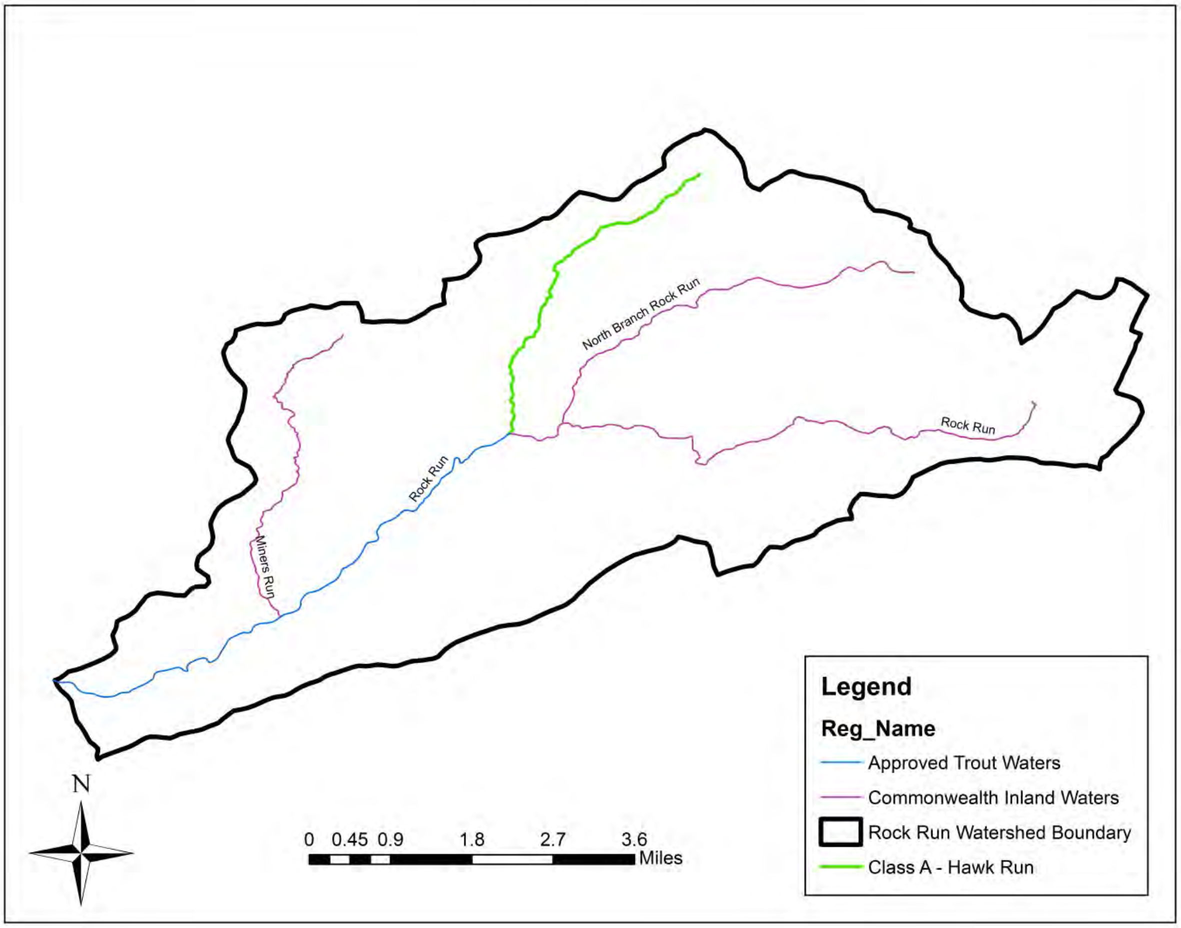

Figure 13. Current PFBC management designations of waters within the Rock Run watershed.

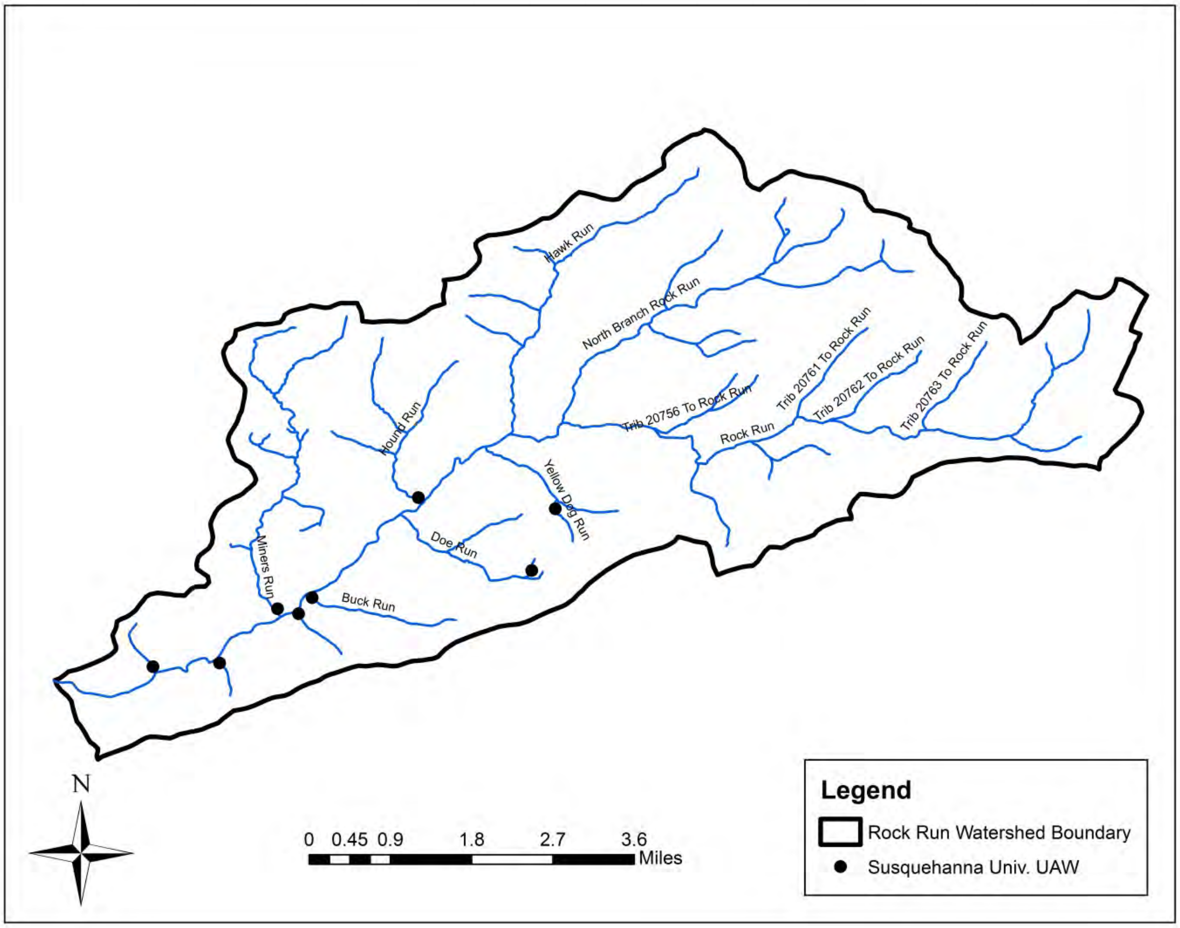

Figure 14. Fishery survey locations completed by Susquehanna University as part of the Unassessed Waters Initiative.

In addition to the publically available data, other resources that contain data on Rock Run and its tributaries also exist. These include:

- Lycoming Creek Watershed Strategic Restoration Plan, April 2006, Water's Edge Hydrology, Inc. – See Appendix 1
- Lycoming Creek Watershed – Rapid Watershed AMD Assessment – 2007 – Trout Unlimited TAG Program; available at http://www.wbsrc.org/uploads/2/5/6/0/25607137/lycoming_ck_interim_report.pdf
- Lycoming Creek Tributary Study; Lycoming College; available at https://www.lycoming.edu/cwi/pdfs/lycomingCreek/lycomingCreekTributaryStudy.pdf
- Appendix 2 contains additional historical data obtained during this project.

METHODS

Water Quality

Preliminary water quality data were collected on Miners Run, Doe Run, Yellow Dog Run, and Hound Run to identify potential inputs of acidity. Each of these streams were walked beginning at the mouth of the stream and proceeding upstream. Field chemistry was measured periodically for the length of the stream. Field chemistry measurements included pH (standard units), water temperature (^{o}C), and specific conductance (umhos) using an Oakton multiple parameter probe. The probe was calibrated daily to the manufacturer's specifications to ensure accuracy.

A detailed water quality analysis was also completed at 13 sites throughout the watershed during high and low flow conditions in the summer and fall of 2016 (Table 2 and Figure 15). Flow measurements were made at each sample site perpendicular to the direction of mid-channel flow and in areas where backwater and as many obstacles as possible could be avoided. Cross-sectional measurements of depth, velocity at $6/10^{th}$ of the stream depth, and distance from the bank were taken at approximately 20 locations or at intervals that comprised no more than 10% of the entire flow of the site. Where flows were too large to measure using conventional wading techniques, the existing USGS stream gage network was used.

Table 2: Water quality sample sites within the Rock Run watershed. Sites were sampled during low and high flow conditions in 2016.

Site ID	Site Description	Latitude	Longitude
RR_01	Rock Run Mouth	41.50551	-76.95149
RR_02	Rock Run DWS Miners Run	41.51461	-76.91674
RR_03	Miner's Run Mouth	41.51511	-76.91614
RR_04	Rock Run UPS Miners Run	41.51503	-76.916
RR_05	Rock Run DWS Doe Run	41.53178	-76.8968
RR_06	Rock Run UPS Doe Run/ DWS Hound Run	41.53232	-76.89429
RR_07	Doe Run Mouth	41.531469	-76.897162
RR_08	Hound Run Mouth	41.53325	-76.89375
RR_09	Rock Run UPS Hound Run/DWS Yellow Dog Run	41.53328	-76.89328
RR_10	Yellow Dog Run Mouth	41.54229	-76.88332
RR_11	Rock Run YPS Yellow Dog Run	41.54251	-76.88292
RR_12	North Branch Rock Run Mouth	41.54662	-76.87108
RR_13	Rock Run UPS North Branch Rock Run	41.54619	-76.87042

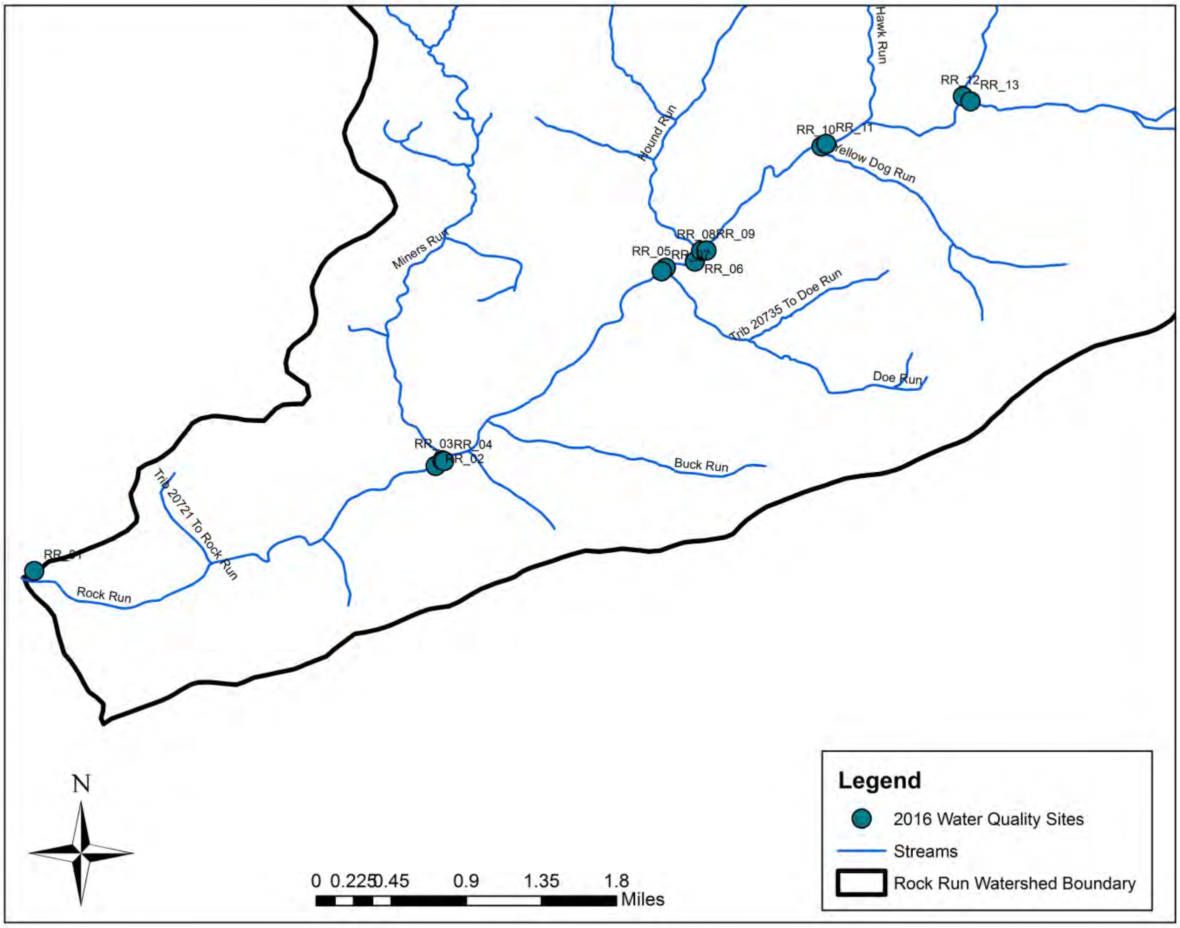

Figure 15: Map of water quality sampling locations within the Rock Run watershed. See Table 2 for description of sites.

Water quality samples were taken from the vertical profile of the main current usually in the center of the stream (except in cases of high flow when the center of the channel could not be waded). Samples consisted of a 500 mL raw sample and a 250 mL sample fixed with HNO_3. Samples were placed on ice and transferred to a DEP-accredited laboratory for analysis. Laboratory analysis included 10 parameters: pH (standard units), total alkalinity (mg/L), total acidity (mg/L), specific conductance (umhos), total sulfate (mg/L), total suspended solids (mg/L), total dissolved solids (mg/L), total aluminum (mg/L), total iron (mg/L), and total manganese (mg/L).

Fishery Surveys

Fishery surveys were completed on each tributary that was identified as an "Unassessed Water" by the Pennsylvania Fish and Boat Commission. A total of 11 tributaries were identified as unassessed for fish communities within the Rock Run watershed (Figure 16; Table 3). Sampling involved the collection of physical, chemical, and fisheries data at each sample site. Physical data collection includes taking extensive field notes and determining site length and width. Field notes included a written description of the downstream starting point of the sample site to allow future investigators to repeat the sample sites. Latitude and longitude of the beginning of the sample reach were also recorded using a hand-held GPS unit set to NAD 83. Site lengths were obtained using a hip chain and were a minimum of 100 meters unless a 100 meter sample reach was not available on the stream. Survey sites were established to end at a natural break point where fish movement out of the survey reach could be minimized. Wetted stream channel width measurements were taken with a tape at a minimum of five points within the survey reach. Mean wetted widths were then calculated from these measurements.

Table 3: Fishery survey locations for unassessed waters within the Rock Run watershed.

Tributary Name	Latitude	Longitude
UNT 20749	41.561648	-76.856972
UNT 20751	41.564789	-76.854307
UNT 20752	41.569643	-76.839935
UNT 20753	41.572594	-76.836889
UNT 20756	41.545563	-76.85602
UNT 20758	41.539471	-76.849548
UNT 20759	41.543088	-76.840696
UNT 20761	41.547371	-76.833368
UNT 20762	41.546991	-76.827657
UNT 20763	41.545468	-76.813095
UNT 20764	41.543754	-76.798223

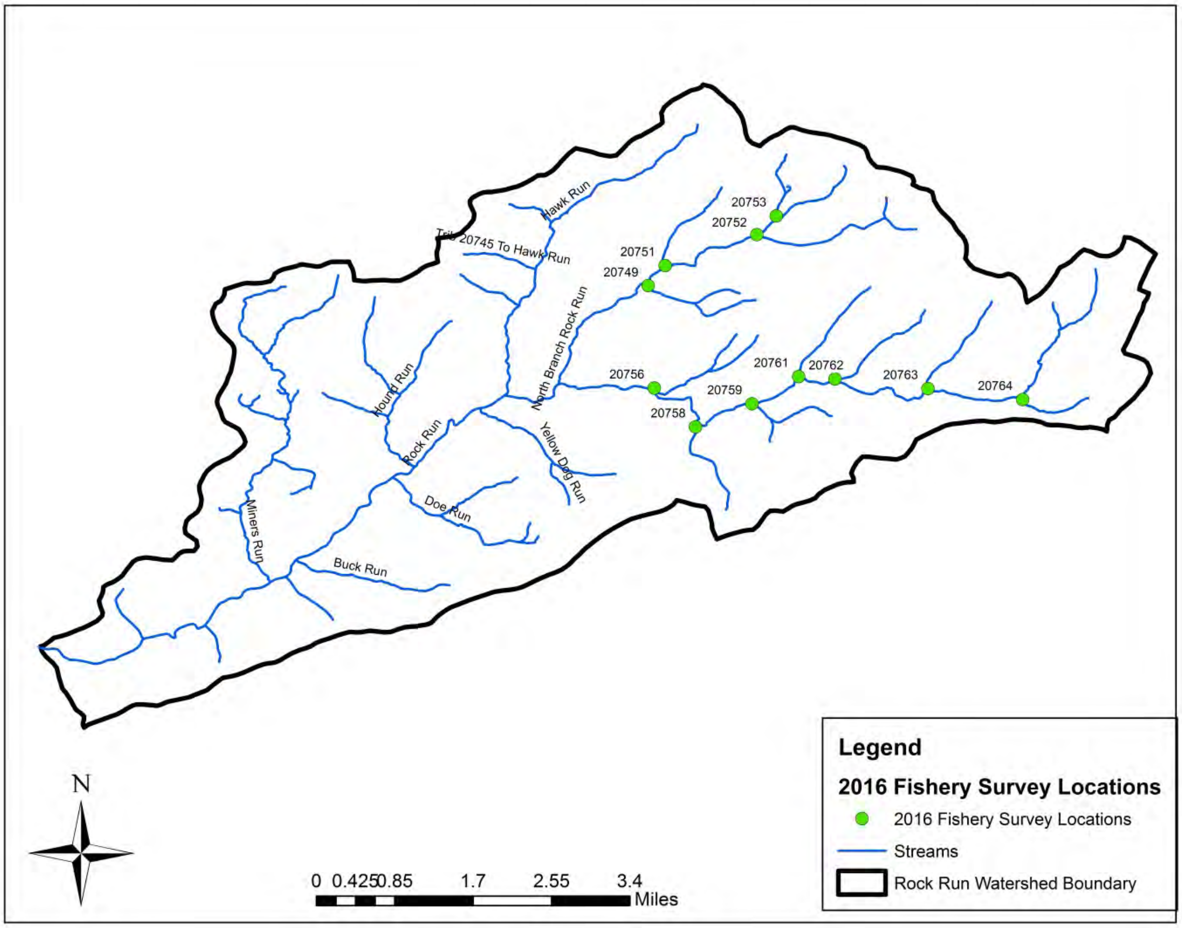

Figure 16: Map of 2016 fishery survey site locations. Numbers indicate UNT number (see Table 3).

Chemical data collection was completed in the field at the time of the fishery survey. Chemical data included time of day, water temperature (^{o}C), pH, (standard units), total alkalinity (mg/L), and specific conductance (umhos). These measurements followed approved protocols (United States Environmental Protection Agency 1976; American Public Health Association et al. 1980). Water temperature, pH, and specific conductance were measured using an Oakton Multimeter probe and total alkalinity was measured using standard titration methodology.

Fisheries data were collected through electrofishing using a Smith-Root LR-24 battery powered backpack electrofishing unit using pulsed direct current (DC). Electrofishing surveys proceeded upstream from the starting point of the reach. All sampling utilized single pass electrofishing methods. During sampling, the electrofishing crew attempted to identify all fish species present at each site. Salmonids captured during electrofishing were held in five gallon buckets filled with stream water for processing once the survey was complete. All other fish species were identified to species and a subjective abundance rating was assigned to each species based on a count of all individuals observed at each sample site (PFBC 2007). The rating criteria were as follows:

< 2 = RARE
2-8 = PRESENT
9-33 = COMMON
>33 = ABUNDANT

Salmonids were identified to species and total lengths were recorded to the nearest millimeter and categorized into 25 mm size classes. Fish were then released unharmed back to the survey reach. No fishery surveys were completed if the stream was found to be dry at the time of sampling. These sites should be considered for further investigation when flows are adequate within the watershed. All fisheries data collected at these sites have been submitted to the PFBC's online database.

Aquatic Organism Passage Surveys

The methods for completing road/stream crossing assessments followed the North Atlantic Aquaitc Connectivity Collaborative's (NAACC) protocols. Details on this program are available at: https://streamcontinuity.org/.

The North Atlantic Aquatic Connectivity Collaborative (NAACC) is a network of individuals from universities, conservation organizations, and state and federal natural resource and transportation departments focused on improving aquatic connectivity across a thirteen-state region, from Maine to Virginia. The NAACC has developed common protocols for assessing road-stream crossings (culverts and bridges) and developed a regional database for these field data. The information collected will identify high priority bridges and culverts for upgrade and replacement.

Assessments were overseen or completed by Lead Observers, or more highly certified field staff, certified by NAACC. General information was collected at each site including; latitude and longitude, road name, township name, date, name of certified field staff, stream name, road type, crossing type, crossing material, and number of cells. Road stream crossing assessments consisted of physical measurements of crossing dimensions, photos of crossing as well as the stream channel upstream and downstream of the crossing, and observational notes of crossing and stream conditions. Assessments were completed using either paper field forms or digital PDF forms completed on electronic devices (the field form datasheet is available in Appendix 3). Measurements were taken using stadia rods and surveyors tape and were recorded in tenths of feet.

Measurements consisted of inlet/outlet dimensions, length of crossing, water depth at the inlet/outlet, and roadfill height, if roadfill is present. Additional observations included a visual assessment of the alignment of the structure relative to the stream channel, general crossing condition, type of inlet/outlet grade (ie. perched, inlet drop, outlet freefall, at stream grade, etc.), flow condition (ie. dry, typical low-flow, moderate flow, etc.), size of tail water scour pool, structure substrate type and % coverage, and comparison of water depth and velocity relative to natural stream conditions. Other information that can be collected but is not required in order calculate aquatic passability includes slope of structure using a inclinometer and bankfull measurements. Bankfull measurements were taken in undisturbed stream reaches out of the range of influence of the structure.

Assessments were saved on electronic devices or digitized from paper forms after surveys were completed. Assessment forms were uploaded to the NAACC database and GPS locations were matched to existing crossings identified by GIS analysis or assigned to a new crossing if one was not recognized by the GIS analysis. Once forms are uploaded they must be approved by L1 or higher certified staff to be finalized. Once assessments were uploaded and approved, passability scores were calculated and added to the online database. Appendix 4 details the aquatic passability scoring that is used by NAACC. Survey information and calculated passability scores can be viewed by the public at https://streamcontinuity.org/cbd2.

Habitat Surveys

Habitat was assessed visually by TU staff in areas of the watershed that were identified during other survey work. With the exception of the Rod and Gun Club property, no habitat assessments were made on privately owned land. The areas of potential habitat concern are described in more detail in the results section.

Volunteer-based Water Quality Monitoring

A volunteer-based water quality monitoring program was established in the Rock Run watershed during the course of this project. This was established through the Pennsylvania Trout Unlimited Coldwater Conservation Corps (PATU CCC) program. The Corps is a network of volunteer stream stewards who conduct stream monitoring and routine inspections of stream conditions and report problems to the appropriate agencies. Stewards also may be asked to assist in developing watershed inventories. This program promotes early detection and reporting of problems that develop during oil and gas drilling and production activities.

A PATU CCC training was hosted by the Susquehanna Chapter of Trout Unlimited in December 2015. The topics covered by the training and field protocols used in this program are detailed in the PATU Coldwater Conservation Corps Field Manual (available at

http://patrout.org/docs/default-source/default-document-library/patroutmanual6-12-15.pdf?sfvrsn=0).

During this meeting, volunteers established four sample sites to be sampled on a quarterly basis within the Rock Run watershed (Table 4; Figure 17). Key parameters measured by volunteers and/or the laboratory include air temperature, stream temperature, pH, conductivity, total dissolved solids, turbidity, barium, and strontium. Stream flows are also assessed using cross-sectional stream area as a surrogate. Observations on precipitation, water condition, and other general comments are also recorded. A quality assurance plan is also established with this program and is available in Appendix 5. Data collected by volunteers are uploaded to a centralized database.

Table 4. Volunteer- based water quality sampling locations established within the Rock Run watershed as part of the Pennsylvania Trout Unlimited Coldwater Conservation Corps monitoring program.

Stream Name	Sample Site ID	Latitude	Longitude
Hawk Run	HAWKRU002	41.5731	-76.86997
North Branch Rock Run	NBRORU001	41.56821	-76.83101
South Branch Rock Run	SBRORU001	41.5402	-76.81256
South Branch Rock Run	SBRORU003	41.54653	-76.8281

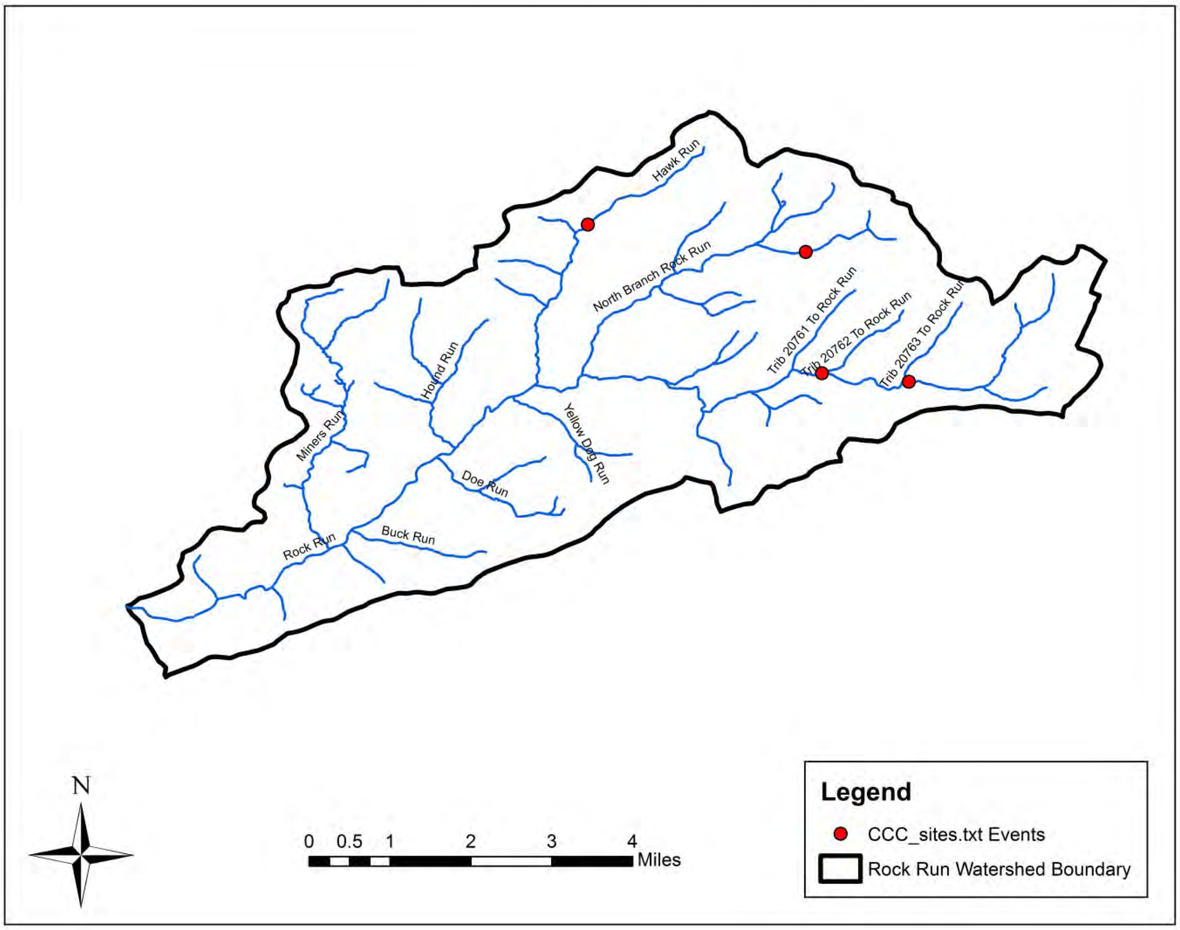

Figure 17. Map of volunteer- based water quality sampling locations established within the Rock Run watershed as part of the Pennsylvania Trout Unlimited Coldwater Conservation Corps monitoring program.

RESULTS

Water Chemistry

Figures 18 and 19 show the pH and specific conductivity (µS), respectively, field chemistry results from the preliminary water quality surveys within the Rock Run watersheds. These surveys specifically targeted the tributaries listed as impaired by the PA DEP and also included sites that were recommended by the Susquehanna Chapter of Trout Unlimited. The prelimary results show low pH is prevalent in Miner's and Doe Runs. Moderately low pH was found in Hound Run and Yellow Dog Run experienced low pH in the headwaters, but the pH was near neutral near the mouth of Yellow Dog Run. Conductivity ranges for all of the streams were low, suggesting that metal concentrations were also low in these waters.

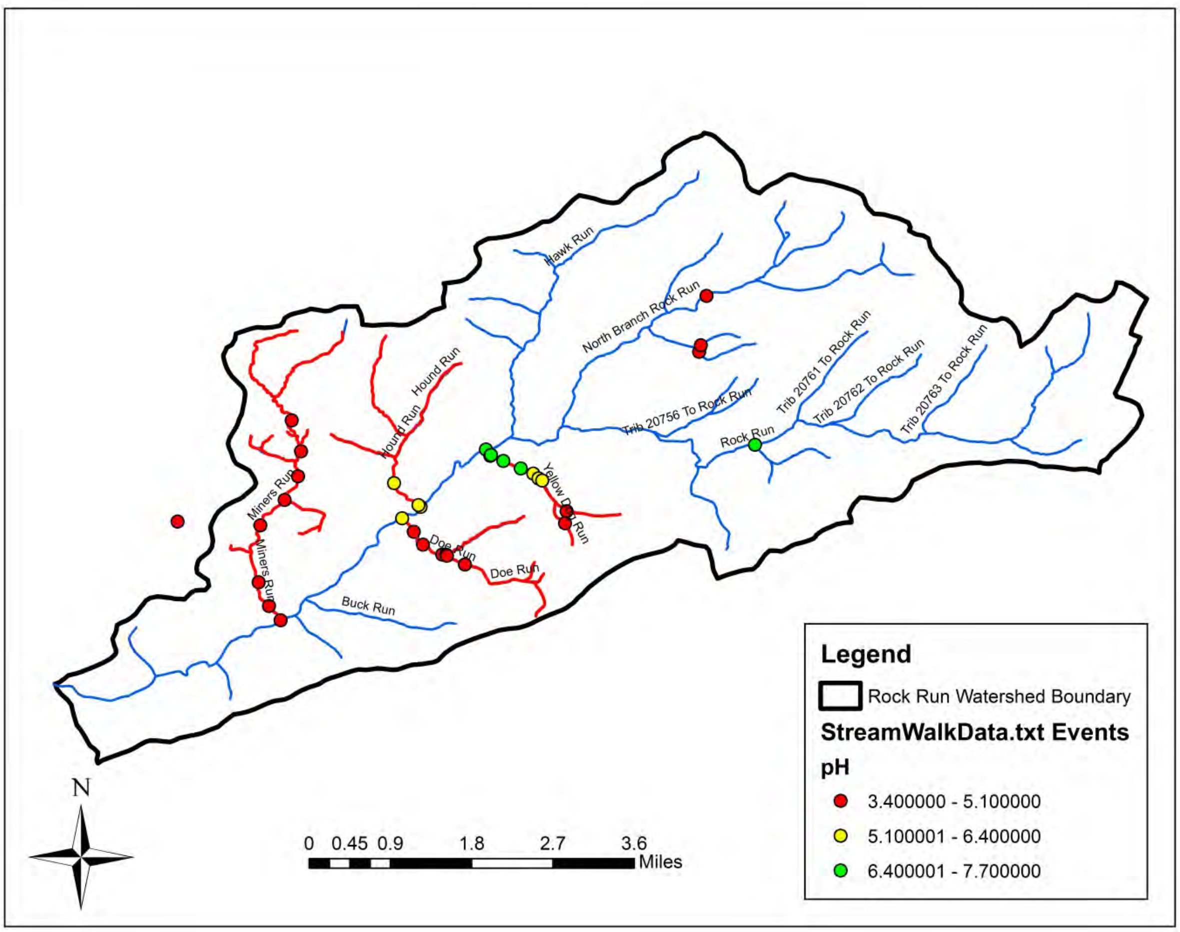

Figure 18. pH results from field chemistry surveys in the Rock Run watershed.

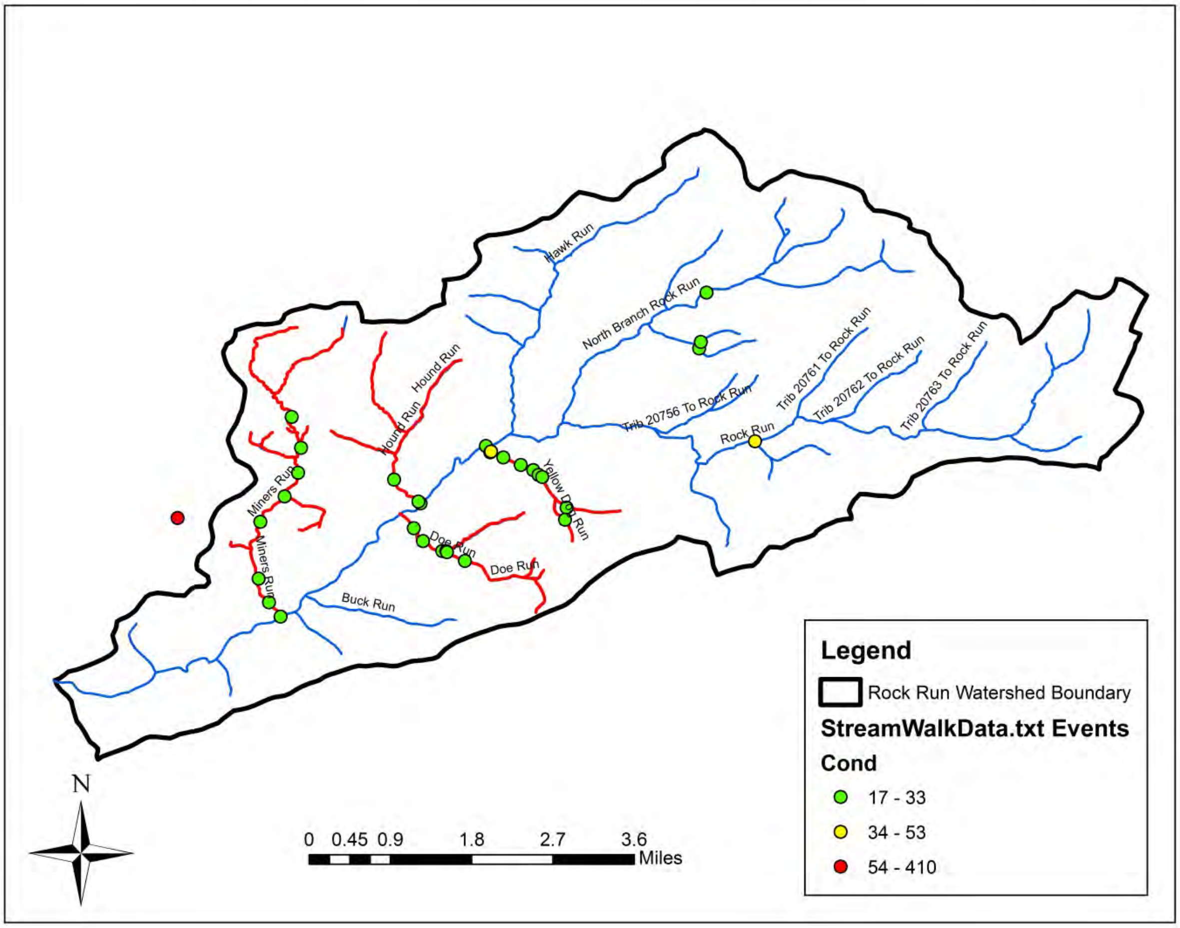

Figure 19. Specific conductivity (µS) results from field chemistry surveys in the Rock Run watershed.

In order to further evaluate the acidity that is present within the watershed, laboratory analysis of water quality samples at low and high flows were also completed throughout the watershed. Tables 5 and 6 contain the results of these analyses (see Table 2 and Figure 15 for site locations). Due to high flows, stream flow could not be measured in the mainstem of Rock Run at the time of water quality sampling. For comparison, stream flow at RR_03 during low and high flow samplings were 0.11 CFS^{-1} and 214.87 CFS^{-1}, respectively. Samples were not taken at RR_12 and RR_13 during the high flows because the sites were not accessible.

Table 5. Low flow water quality results.

ID	pH	Alk	Acid	Sulfate	TSS	Al	Fe	Mn
RR_01	7.1	14	-1	7	<5	<0.05	<0.05	<0.02
RR_02	7.0	15	-4	7	<5	<0.05	<0.05	0.02
RR_03	5.3	4	10	10	<5	0.15	0.07	0.11
RR_04	6.9	16	-6	7	<5	<0.05	<0.05	<0.02
RR_05	7.0	17	-3	7	<5	<0.05	<0.05	<0.02
RR_06	7.0	16	-2	7	<5	<0.05	<0.05	<0.02
RR_08	6.5	8	2	8	<5	<0.05	<0.05	<0.02
RR_09	7.0	17	-3	7	<5	<0.05	<0.05	<0.02
RR_10	6.7	12	-2	6	<5	<0.05	<0.05	<0.02
RR_11	7.0	19	-5	7	<5	<0.05	<0.05	<0.02
RR_12	6.8	13	1	6	<5	<0.05	<0.05	<0.02
RR_13	7.0	15	-5	7	<5	<0.05	<0.05	<0.02

Table 6. High flow water quality results

ID	pH	Alk	Acid	Sulfate	TSS	Al	Fe	Mn
RR_01	6.3	10	6	6	<5	0.15	0.13	0.03
RR_02	6.2	8	6	6	<5	0.23	0.29	0.05
RR_03	4.7	5	14	6	<5	0.32	0.12	0.21
RR_04	6.2	8	9	6	<5	0.17	0.15	0.02
RR_05	6.2	9	10	6	<5	0.17	0.15	0.02
RR_06	6.2	8	10	6	<5	0.18	0.18	<0.02
RR_07	5.0	5	13	6	<5	0.23	0.14	0.12
RR_08	5.5	6	10	6	<5	0.10	<0.05	0.04
RR_09	6.2	8	11	6	<5	0.20	0.18	0.02
RR_10	5.9	7	8	5	7	0.23	0.22	0.03
RR_11	6.2	8	5	6	<5	0.21	0.19	<0.02
RR_12	NA	NA	NA	NA	NA	NA	NA	NA
RR_13	NA	NA	NA	NA	NA	NA	NA	NA

A comparison of the water quality between low and high flow events shows a general depression of pH and an increase in metal concentrations under high flows. This pattern of water quality is generally indicative of acidity issues related to acidic deposition (Baker et al. 1996). Coupled with the geology and soils present in the watershed, it is likely that acidic deposition is the main driver of acidity within the watershed.

Based on the water chemistry results, it does appear that Miner's Run (site RR_03) is experiencing some acidification due to AMD, however the effect on the water chemistry in Rock Run downstream of Miner's Run (site RR_02) appears to be minor as pH is near neutral and the site is still generating alkalinity under low flow conditions when the effects of AMD would be more severe.

Volunteer Monitoring

Volunteer monitoring of water quality is continuing at the selected sites on a quarterly basis in an attempt to monitor for any changes in water quality in the headwater regions of the watershed. This area is of critical importance since it is the only areas of the watershed that contain native brook trout (see Results: Fishery Surveys). Preliminary water quality results from this monitoring effort are provided in Appendix 6. All data collected as part of this effort is being submitted to the Coldwater Conservation Corps database.

Fishery Surveys

Fishery surveys were completed at 11 sites throughout the watershed by Trout Unlimited staff and Lycoming College personnel during the summer of 2016. These streams each were previously categorized as “unassessed waters” by the PFBC. Following these surveys, all streams within the Rock Run watershed should have a fishery survey completed. Table 3 and Figure 16 show the location of the tributaries sampled in 2016. Table 7 includes the field chemistry and flow status of the each stream. Five streams were dry at the time of sampling and should be considered for resampling during adequate flow. Seven of the 11 streams surveyed were found to contain salmonids (Table 8). The streams that contained trout were primarily brook trout (*Salvelinus fontinalis*) with the exception of UNT 20761 where both brook trout and brown trout (*Salmo trutta*) were collected. Streams that were not dry were found to contain trout and were primarily brook trout (Figure 20). Based on the size class distribution of the salmonids in each stream (Tables 9a and 9b), four of the sites may qualify for addition to PFBC’s wild trout list (UNTs 20756, 20759, 20762, and 20764).

In addition to salmonids, blacknose dace (*Rhinichthys atratulus*) were collected in UNT 20763 and sculpin (*Cottus* spp.) and pumpkinseed (*Lepomis gibbosus*) were collected in UNT 20761, sculpin were collected in UNT 20756). All other sites were dry or were found to contain only salmonids. One juvenile largemouth bass (Micropterus salmoides) was found in UNT 20759.

Table 7. Field chemistry measurements for each of the streams surveyed during 2016.

Stream	Date	Flow	Temp (ºC)	pH	Alk. (mg/L)	Cond. (umhos)
20749		Dry	-	-	-	-
20751		Dry	-	-	-	-
20752		Dry	-	-	-	-
20753		Dry	-	-	-	-
20756	7/22/16	Low	15	6.9	20	35
20758	11/22/16	Low	4.5	6.2	n/a	24
20759	7/13/16	Low	16.3	6.7	10	34
20761	7/13/16	Low	16.1	7.3	10	57
20762	7/13/16	Low	14.9	7.6	29	60
20763	7/7/16	Low	16.4	6.6	45	119
20764	7/7/16	Low	16.4	6.2	18	71

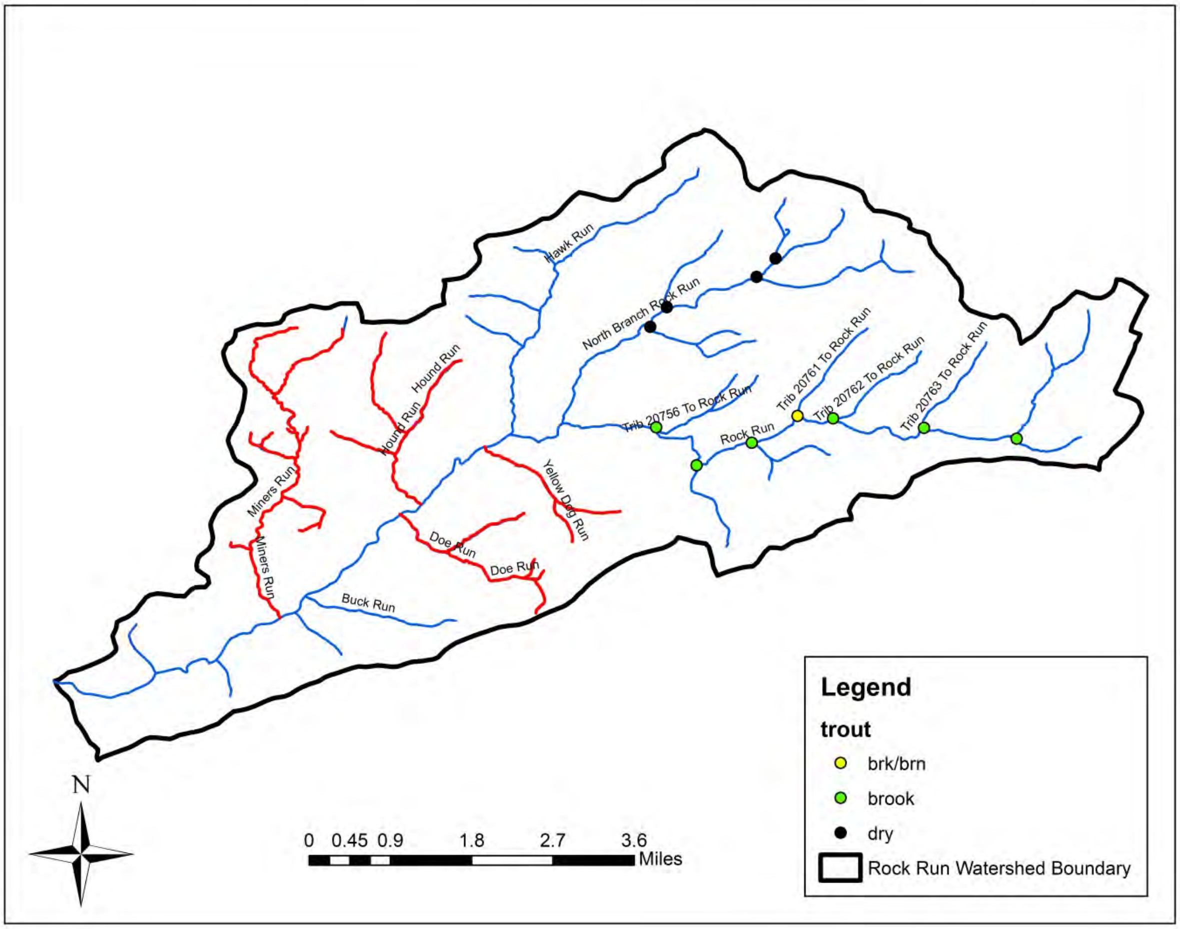

Figure 20. 2016 fishery survey results for the Rock Run watershed.

Table 8. Total abundance of brook and brown trout captured at each site during electrofishing surveys.

Stream	Total Trout	Brook Trout	Brown Trout
20749	0	0	0
20751	0	0	0
20752	0	0	0
20753	0	0	0
20756	8	8	0
20758	1	0	1
20759	6	6	0
20761	3	1	2
20762	4	4	0
20763	1	1	0
20764	5	5	0

Table 9a. Abundance and 25 mm size class distribution of brook trout (*Salvelinus fontinalis*) for each stream surveyed in 2016.

Stream	*25-49*	*50-74*	*75-99*	*100-124*	*125-149*	*150-174*	*175-199*	*200-224*	*225-249*
20749									
20751									
20752									
20753									
20756		5		2	1				
20758									
20759		1	2	2	1				
20761					1				
20762	1	3							
20763		1							
20764	3	1	1						

Table 9b. Abundance and 25 mm size class distribution of brown trout (*Salmo trutta*) for each stream surveyed in 2016.

Stream	*25-49*	*50-74*	*75-99*	*100-124*	*125-149*	*150-174*	*175-199*	*200-224*	*225-249*
20749									
20751									
20752									
20753									
20756									
20758									
20759									
20761									2
20762									
20763									
20764									

AOP Surveys

A total of 17 road-stream crossings were assessed within the Rock Run watershed. Of the 17 sites, 11 scored as having no aquatic organism passage, five as reduced aquatic organism passage, and one as full aquatic organism passage. Detailed results are provided in Table 10 and Figure 23.

Hawk Run

The culvert on Hawk Run is located at the Yorktown Road (T-676) crossing (Survey 31153) (Figures 21 and 22). This culvert was calculated to have an AOP coarse screen score of "No AOP" by the NAACC protocol with an aquatic passage score of 0.32 (range = 0.0-1.0). If replaced with a full AOP structure, 1.6 miles of upstream habitat in Hawk Run would be reconnected. There are some ponds and water impoundments located upstream of the current culvert and access through or around those impoundments was not assessed for aquatic organism passage. The culvert is located on a single lane dirt road on privately-owned land. The reconnected stream miles would also be on private land. Since Hawk Run is the only stream designated as “Class A brook trout” by the PFBC, this should be a high priority reconnection project.

Figure 21. Culvert on Hawk Run (inlet)

Figure 22. Culvert on Hawk Run (outlet)

Rock Run upstream of North Branch Rock Run

The stream crossing on Ellenton Mountain Road (SR 1013) (Survey 31146) was calculated to be a barrier to fish movement with a coarse screen score of “no AOP” and a NAACC aquatic passage score of 0.11 (range = 0.0-1.0). The stream crossing on Old Ellenton Mountain Road (Survey 31149) was initially surveyed in June 2016 and was determined not to be a barrier to fish movement with and AOP coarse screen score of “Full AOP” and a NAACC passage score of 0.97 (range = 0.0-1.0) (Figure 24) Following the flooding event on 10/21/2016 this crossing collapsed into the stream and is now creating a backup of water upstream of where the crossing previously existed (Figure 25). The collapsed crossing is on private land and on a road that is no longer used. In order to prevent further barriers to fish movement or erosion/aggradation the material from the collapsed crossing should be removed from the stream channel.

Table 10. Aquatic organism passage results for the Rock Run watershed from North Atlantic Aquatic Connectivity Collaborative evaluation.

Survey	Type	AOP	Evaluation	Road	Stream	Lat	Lon
31147	Bridge	No AOP	Severe	Unnamed Club Road	Rock Run	41.54917	-76.794533
31152	Culvert	Reduced	Moderate	Bastian Rd	UNT to Hawk Run	41.572025	-76.87688
31154	Culvert	No AOP	Significant	SR 1013	UNT to Rock Run	41.559455	-76.8242833
41460	Bridge	No AOP	Severe	Rock Run Rd.	Miners Run	41.516304	-76.916757
41458	Bridge	Reduced	Insignificant	Rock Run Rd.	Hound Run	41.533537	-76.894144
41459	Bridge	Reduced	No Barrier	Yellowdog / Rock Run	Rock Run	41.535665	-76.892004
31161	Culvert	No AOP	Significant	Ellenton Rd	UNT to North Branch	41.57471	-76.8326933
31159	Culvert	Reduced	Insignificant	Ellenton Rd.	UNT to North Branch	41.579535	-76.836825
31158	Culvert	No AOP	Significant	Yorktown Rd.	UNT to North Branch	41.5779083	-76.8357716
31160	Culvert	No AOP	Significant	Bastian Rd.	UNT to Hawk Run	41.5738683	-76.8748983
31157	Culvert	Reduced	Minor	Yorktown Rd.	UNT to North Branch	41.5764316	-76.845715
31156	Culvert	No AOP	Moderate	SR 1013	UNT to Rock Run	41.5596833	-76.82445
31148	Culvert	No AOP	Significant	SR 1013	UNT to Rock Run	41.553866	-76.81872
31151	Culvert	No AOP	Severe	Ellenton Rd	North Branch	41.5681733	-76.831325
31153	Culvert	No AOP	Significant	Yorktown Rd.	Hawk Run	41.573025	-76.8700016
31146	Culvert	No AOP	Severe	Ellenton Rd.	Rock Run	41.5451366	-76.812615
31149	Culvert	Full	Insignificant	Camp Rd.	Rock Run	41.54493	-76.8134933

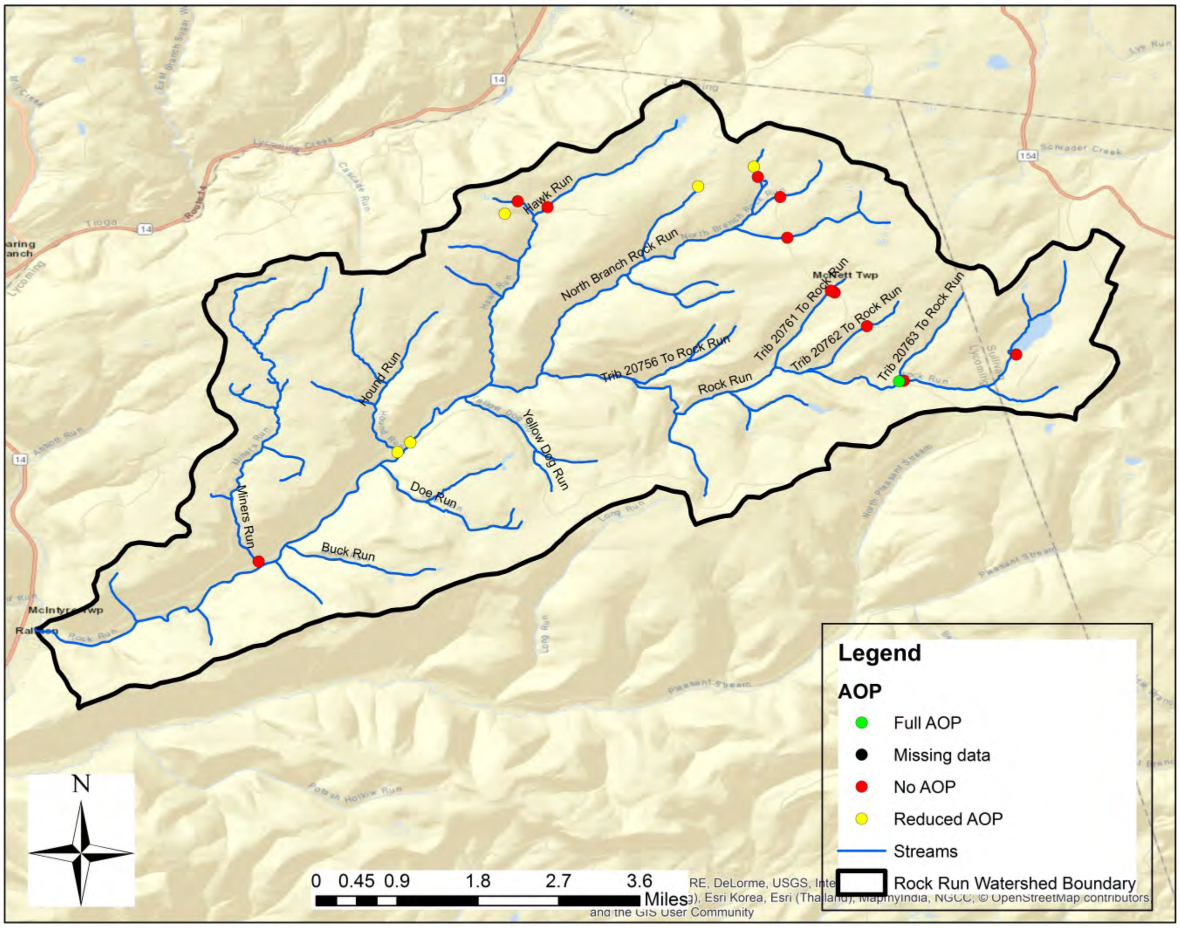

Figure 23. Map of aquatic organism passage results.

Figure 24. Road-stream crossing on Old Ellenton Mountain Road prior to flooding event.

Figure 25. Collapsed road-stream crossing on Old Ellenton Mountain Road following flooding event.

Habitat Surveys

South Branch Rock Run

Downstream of AOP Survey 31146 on Ellenton Mtn Rd. and collapsed AOP Survey 31149 is the Rock Run Rod and Gun Club property. Erosion of banks and sedimentation is evident as well as lack of riparian vegetation on the left bank for approx. 100 meters near the club building. There is potential for habitat improvements in this reach in the form of mudsills or other rock/wood structures to stabilize banks and planting of native vegetation (Figure 26) to better secure the left bank and provide instream cover in the existing pool.

TU staff walked downstream several hundred meters to assess habitat on state forest land downstream of the rod and gun club: A naturally braided channel as well as large riparian zones and hemlock vegetation was observed throughout the reach. Stable banks, complex instream habitat in the form of exposed roots, undercut banks, woody debris, variety of riffle and pool habitat, and presence of instream cover did not suggest habitat improvements were necessary in this reach.

Figure 26. Potential site for riparian planting.

Rock Run upstream of Yellow Dog Road crossing and downstream of Yellow Dog Run:

TU staff walked several hundred meters from the Yellow Dog Road crossing (AOP Survey 41459, 41.535074, -76.892156) upstream towards the confluence with Yellow Dog Run. Bedrock is the dominant substrate in much of this reach however gravel/cobble and potential spawning habitat was observed throughout. Natural barriers in the form of waterfalls and long sloped bedrock cascades are present throughout the entire lower Rock Run watershed and were present in this reach. There was adequate riffle and pool habitat as well as fully forested riparian zones on both banks. Steep rock slopes on both banks and lack of access make the feasibility of getting machinery into this section unlikely. A key component in trout habitat in the form of woody debris and instream cover were lacking and could potentially be limiting trout populations (Dolloff and Warren Jr 2003). Brook, brown and rainbow trout are annually stocked in lower Rock Run and the most upstream stocking point is just upstream of the bridge at Yellow Dog Rd. Due to the depth of the channel, presence of bedrock, and the known high flow events that frequent the watershed it would be difficult to anchor or secure woody debris/habitat structures in this section of stream. Figure 27 shows the size and amount of material moved during a flood event in Rock Run during an event in October 2016. No recommendations for habitat improvements were made for this reach due to feasibility/access as well as the presence of existing trout habitat.

Figure 27. Material transported during the October 2016 flooding event.

WATERSHED RESTORATION AND ENHANCEMENT RECOMMENDATIONS

Overall, due to the lower portions of Rock Run lacking suitable habitat, having very steep gradient with many natural barriers to fish movements, the presence of a stocked trout fishery, and the lack of native brook trout, it is recommended that future projects in Rock Run be concentrated, at least initially, in enhancing the existing native brook trout populations in the Hawk Run tributary and the headwater of Rock Run. The following are more specific recommendations based on the results of this project.

Support Pennsylvania Wild Trout Stream Listings

The results of this project have indicated that four previously unassessed streams may qualify for addition to the PFBC's Wild Trout Stream Listings. The presence of wild trout populations indicates that these are waters of exceptional quality. Trout streams are not just recreational resources for sportsmen; they also feed into Pennsylvania's drinking water supplies. These streams are given special protections during the DEP permitting process under Pennsylvania regulations (25 Pa. Code Chapter 93).

- Wild trout streams receive a Cold Water Fishes (CWF) designation, which requires their protection as trout habitat.
- Wetlands in or along the streams' floodplains are classified as Exceptional Value (EV).
- Some of the streams qualify for upgrades to Exceptional Value (EV) or High Quality (HQ) designations, which further protect against water-quality degradation. This is a first step.

The PFBC votes, on a quarterly basis, to add wild trout streams to the Commonwealth's Class A Wild Trout Waters and Wild Trout Streams lists. It is recommended that volunteers and concerned citizens help with ensuring that streams are added to these lists by filing public comments supporting the addition of wild trout waters with the PFBC at www.fishandboat/regcomments. It would be helpful if a TU chapter member could assist in spreading the word about when streams are listed for comment. This may be accomplished through email list serves or social media.

Address Aquatic Organism Passage Issues in Watershed

The areas in the Rock Run watershed that support native brook trout may benefit by enhancing aquatic organism passage through road-stream crossings. Based on the results of historic fishery surveys and the fishery results from this project, three road-stream crossings may have a benefit to brook trout populations in the watershed. These three culverts may be prioritized based on the brook trout population present and the amount of habitat opened up. In order of prioritization, it is recommended that the following culverts be further evaluated for their potential replacement or removal:

1) Hawk Run Culvert (survey 31153)
2) South Branch Rock Run (survey 31146)
3) South Branch Rock Run (survey 31147)

It is recommended that the feasibility of these projects be evaluated prior to the pursuit of a replacement project. Discussions should be initiated with the entities responsible for these road-stream crossings as well as the land-owners to communicate the importance of AOP and to ensure that a design will be used that will ensure fish passage. Given that Hawk Run is the lone

Class A brook trout fishery in the watershed, it is recommended that future projects be directed to this area first.

It is also recommended that groups interested in pursuing AOP projects in the watershed contact the entities responsible for road-stream crossings in the watershed to determine if any of the crossings are currently scheduled to be repaired or replaced. If this is the case, AOP designs should be used. These designs will also allow for greater flood resiliency and thus a longer life-span and less maintenance at these crossings.

Evaluate and Address Acidity Issues

Four of the tributaries listed as impaired by low pH by the PA DEP were evaluated as part of this project. Of those tributaries, Miner's Run had the lowest pH and highest metal concentrations. However, given the marginal effect this acidity has on the main stem of Rock Run (and thus Lycoming Creek) along with the lack of brook trout in Miner's Run (and all of the lower portion of Rock Run), addressing acidity issues in Miners Run may have an undetermined impact on the improvement of aquatic life within the Rock Run watershed.

The sandstone geology and acidic soils of the watershed have made it more susceptible to atmospheric deposition and portions of the watershed may be limited by episodic acidification. If acidity issues are to be addressed within the watershed, it is recommended that any mitigation project be targeted in areas that would benefit already existing brook trout populations (i.e. the headwaters region of the watershed). Determining the potential for adding alkalinity to this area was beyond the scope of this project. Therefore it is recommended that acidity issues be further evaluated in the headwaters areas (particularly the North and South Branches of Rock Run) to determine possible remediation techniques. This should include both high and low flow water chemistry analysis that includes metal concentrations. Soil acidity through various soil horizons may also be investigated to determine the feasibility of whole-watershed liming.

Once a more detailed evaluation of acid loadings is obtained, it is recommended that funding for the development of conceptual treatment designs and options be pursued, followed by project implementation, if remediation is deemed appropriate to enhance water quality and benefit aquatic life.

Several techniques are available and have been used to mitigate acidity due to atmospheric deposition, including whole watershed liming (Cho et al. 2009, Pabian et al. 2012), limestone addition (LeFevre and Sharpe 2002), and pumping alkaline groundwater (Gagen et al. 1989). Each of these have their own sets of pros and cons and the feasibility of these techniques should be thoroughly evaluated prior to an implementation project.

Continue and Expand Volunteer Water Quality Monitoring Program

It is recommended that the volunteer monitoring effort established through this project continue. In changing environment and political climates, baseline monitoring is crucial to detecting changes that may be detrimental to coldwater resources. The volunteer component of this project should continue the monitoring efforts currently established. In addition, this effort may be expanded to other sample sites within the watershed if further funding is obtained and/or more volunteers are interested in the program. Prior to any expansion, a sampling strategy should be developed to prioritize potential sampling sites.

It is also recommended that once the volunteer sampling program has collected sufficient data (this is subjective, but should include samples through the various flows that the site experiences during the course of a year) a summary of this data be compiled to provide baseline conditions for the established sample sites. These reports may be compiled on a regular basis as Susquehanna Chapter of TU sees fit.

Finally, a benthic macroinvertebrate survey protocol has also been established as part of the Coldwater Conservation Corp. It is recommended that this protocol be added to the water quality protocol currently being followed.

Implement Habitat Improvement Projects

The results of this project identified several possible habitat improvement projects that would potentially benefit native brook trout in the watershed. Although the majority of the main stem of Rock Run contains natural barriers, flows over bedrock, and is susceptible to extreme flow events, habitat improvement in the areas containing brook trout may have a positive effect on their populations.

Potential habitat improvements were identified near and within the Rock Run Rod and Gun Club property. The following are recommendations for habitat improvements in this area:

- Bank stabilization in the form of mudsills or other rock/wood structures near the Rock Run Rod and Gun club property.
- Approximately 100 meters of riparian plantings along left bank of Rock Run Rod and Gun Club property
- Remove material from collapsed culvert (Survey 31149) on Old Ellenton Mountain Road

Prior to the implementation of any habitat improvement project, these areas should be re-surveyed and formal plans for habitat structures should be made. Riparian plantings should utilize native plant species.

ACKNOWLEDGMENTS

We would like to thank the following agencies, organizations, and individuals for their contributions to the successful completion of this project:

Susquehanna Chapter of Trout Unlimited: Isaac Bragunier, Ben Patt, Steve and Linda Szoke, David Craig, Joe Radley, Kevin McJunkin, Walt Nicholson, and Jim Latini
Lycoming County Conservation District: Carey Entz
Lycoming College Clean Water Institute: Dr. Mel Zimmerman
Susquehanna University: Dr. Jonathan Niles
Lycoming Creek Watershed Association: Mike Ditchfield and Russ Cowles
DCNR Bureau of Forestry, Loyalsock District: Richard Glinski
USGS Pennsylvania Science Center: Dennis Risser and Jeff Chaplin
PADEP Northcentral Regional Office

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List of Appendices:

1 – Lycoming Creek Watershed Restoration Plan

2 – Historical data – not included in report due to file type and length. Available upon request.

3 – Field data sheet for stream crossing surveys.

4 – Aquatic Passability Scoring

5 – QAPP for TU's volunteer monitoring program.

6 – Preliminary water quality results from volunteer monitoring effort.

Lycoming Creek Watershed Strategic Restoration Plan

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REPORT SUMMARY

The Lycoming Creek Watershed presents many challenges for watershed protection and restoration. One of the first steps for the meeting these challenges is to develop a strategic plan to gain an understanding and address the stream conditions that are contributing to flooding, bank erosion and excessive sediment problems in the watershed. To begin this process, the Association initiated a Strategic Watershed Restoration Plan in 2004 funded by the Pennsylvania Growing Greener Grant Program. A stream survey covering approximately 130 miles of streams was completed in the summer of 2004. This survey identified 86 significant bank erosion hazard locations that are adding and estimated 12,000 tons of sediment annually to the stream along with numerous other hydrologic influences that are affecting the stability of stream channels in the watershed. In addition, through public meetings and interagency coordination efforts, more than a dozen potential projects have been brought to the attention of the Lycoming Creek Watershed Association as possible candidates for restoration. Fluvial geomorphic surveys were completed on representative stream reaches to establish a basis for future changes in stream channel morphology and to assess the applicability of recently published state-wide regional curves. For future planning purposes, a wide range of stream restoration methods and management plans were identified to address both localized and systemic channel instability problems and watershed-scale management approaches to eliminate or reduce the causes of channel instability. The plan also addresses the role of the Association in the watershed in light responsibilities and ongoing activities of local, county, state, and federal resource agencies. Specific planning considerations for objective prioritization of projects brought to the group for consideration. The conclusions and recommendations present a three year action plan for the Association's activities including implementation of a demonstration project for multiple cost-effective solutions to common stream erosion problems in the watershed. The plan is presented in two Volumes: Volume 1 – Findings and Volume 2 – Exhibits.

Lycoming Creek Watershed Strategic Restoration Plan Volume 2 - Exhibits

Lycoming Creek Watershed Assoc.

April 2006

[illegible]

Legend

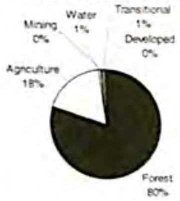
- • Bank Protection
- + Bridge / Culvert
- ■ Debris Jam
- ▲ Erosion Point
- —— Roads
- —— Highways
- —— Streams
- State Forest/Gamelands

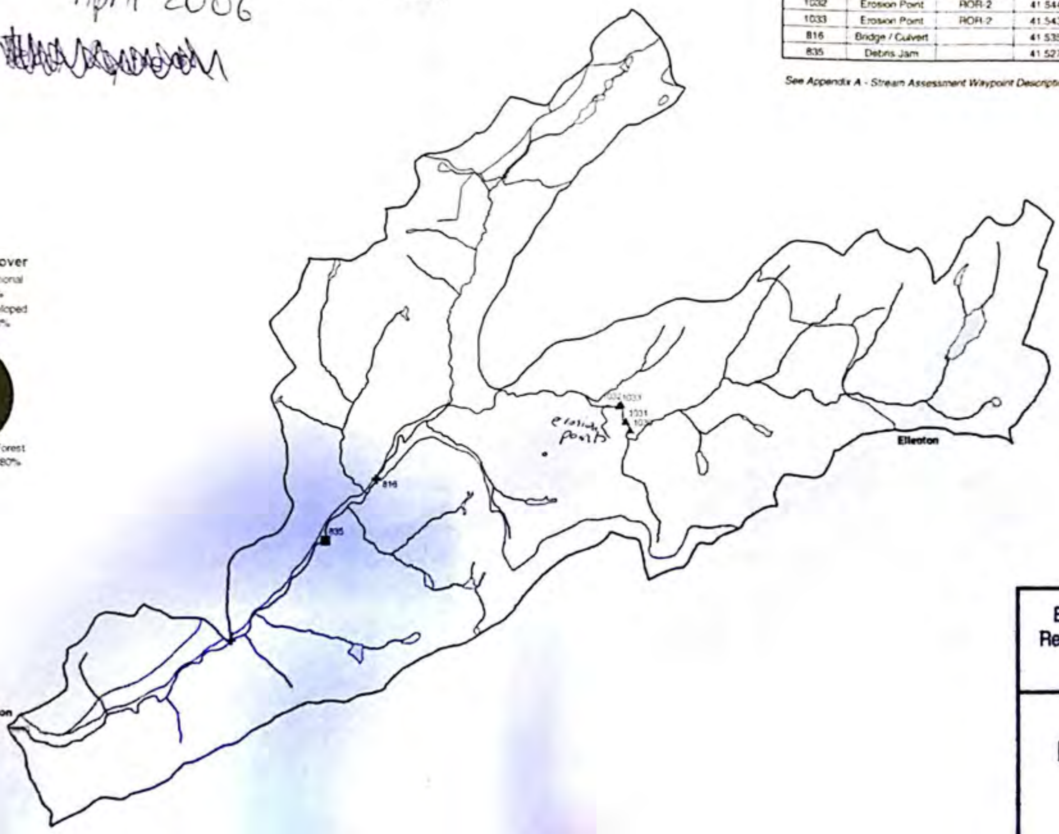
Rock Run

ID No	Description	BEHI ID	Latitude	Longitude
1010	Bridge / Culvert		41.50586	76.95175
1030	Erosion Point	ROR-1	41.54078	76.84896
1031	Erosion Point	ROR-1	41.54191	76.84969
1032	Erosion Point	ROR-2	41.54409	76.85047
1033	Erosion Point	ROR-2	41.54391	76.85080
816	Bridge / Culvert		41.53508	76.89208
835	Debris Jam		41.52742	76.90074

See Appendix A - Stream Assessment Waypoint Descriptions for additional data

Rock Run Land Cover





Subwatershed Location

BEHI Sites and Related Hydrologic Influences

Rock Run

Lycoming Creek Watershed Strategic Restoration Plan -- April 2006

Sheet 1 of 1

Sub-watershed Land Uses

	Water				Developed				Agriculture						Forest				Mining				Other		
	Open Water		Emergent Wetlands		Low Density		High Density		Hay/Pasture		Row Crops		Probable Row Crops		Mixed Forest		Deciduous Forest		Quarry		Coal Mining		Land in Transition		
SUB-WATERSHED	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Total Acres
Beauty's Run	1	0.02	0	0.00	71	1	4	0	988	21	1,249	26	486	10	195	4	1,561	33	0	0	0	0	161	3.42	4,716
Big Sandy Run	1	0.03	0	0.00	0	0	0	0	69	3	5	0	269	11	23	1	2,167	85	0	0	0	0	9	0.35	2,542
Brion Creek	18	0.36	4	0.09	0	0	0	0	1,107	22	1,078	21	445	9	79	2	2,161	43	0	0	0	0	188	3.69	5,080
Fisher Hollow	0	0.02	0	0.02	0	0	0	0	310	11	440	16	224	8	87	3	1,607	59	0	0	0	0	57	2.11	2,727
French Lick Creek	5	0.27	0	0.00	0	0	0	0	353	21	515	31	123	7	11	1	614	37	0	0	0	0	60	3.57	1,682
Frozen Run	3	0.08	0	0.01	0	0	0	0	64	1	60	1	482	11	18	0	3,825	85	17	0	0	0	50	1.10	4,519
Gray's Run	5	0.04	0	0.00	0	0	0	0	186	1	114	1	1,615	13	53	0	10,407	83	0	0	0	0	102	0.82	12,483
Hoagland Run	5	0.07	1	0.02	12	0	0	0	593	8	535	8	944	13	253	4	4,592	65	5	0	5	0	80	1.15	7,027
Little Elk Run	1	0.05	0	0.01	0	0	0	0	445	26	703	40	104	6	42	2	369	21	0	0	0	0	72	4.17	1,737
Lycoming Creek Lower	132	0.87	37	0.24	1,670	11	676	4	1,784	12	2,267	15	1,672	11	807	5	5,853	39	0	0	0	0	231	1.53	15,129
Lycoming Creek Middle	47	0.29	41	0.25	62	0	0	0	566	3	801	5	2,376	15	334	2	12,032	74	0	0	0	0	111	0.68	16,369
Lycoming Creek Upper	33	0.27	7	0.06	107	1	25	0	1,201	10	1,290	10	1,102	9	192	2	8,102	65	79	1	0	0	269	2.17	12,408
Mill Creek	10	0.17	2	0.03	19	0	0	0	1,127	18	1,881	31	505	8	419	7	1,985	32	0	0	0	0	176	2.88	6,124
Miners Run	3	0.16	0	0.00	0	0	0	0	9	1	5	0	72	4	4	0	1,535	94	0	0	0	0	5	0.29	1,633
North Branch Rock Creek	0	0.01	0	0.01	0	0	0	0	103	4	56	2	425	15	20	1	2,276	78	0	0	0	0	51	1.74	2,932
Pleasant Stream	22	0.13	3	0.02	1	0	0	0	298	2	289	2	2,039	12	83	0	14,034	83	0	0	0	0	170	1.00	16,937
Red Run	82	2.28	4	0.12	2	0	0	0	84	2	111	3	332	9	23	1	2,767	77	131	4	0	0	56	1.56	3,592
Roaring Branch	1	0.02	1	0.01	1	0	0	0	867	15	841	14	613	10	102	2	3,279	56	0	0	0	0	165	2.81	5,870
Rock Run	97	0.74	20	0.15	2	0	0	0	262	2	302	2	1,795	14	37	0	10,487	80	0	0	0	0	128	0.98	13,130
Salt Spring Run	12	0.24	2	0.04	1	0	0	0	818	17	839	18	519	11	63	1	2,310	49	0	0	0	0	169	3.57	4,733
Slacks Run	1	0.02	0	0.01	1	0	0	0	121	3	104	2	422	10	56	1	3,475	83	0	0	0	0	23	0.55	4,204
Stony Gap Run	1	0.03	0	0.00	2	0	0	0	598	13	699	15	236	5	148	3	2,730	60	53	1	3	0	95	2.08	4,566
Sugar Works Run	5	0.11	1	0.01	4	0	0	0	1,042	21	1,348	27	167	3	50	1	2,150	43	0	0	0	0	275	5.46	5,040
Trout Run	2	0.02	1	0.01	119	1	0	0	238	3	367	4	1,488	16	92	1	6,789	74	0	0	0	0	63	0.69	9,159
West Mill Creek	8	0.11	1	0.02	9	0	0	0	1,097	16	1,119	16	575	8	89	1	3,921	56	0	0	0	0	184	2.63	7,002
Watershed Total	495	0	128	0	2,083	1	705	0	14,330	8	17,018	10	19,030	11	3,281	2	111,028	65	286	0	8	0	2,961	2	171,343

Lycoming Creek Watershed Association Stream Water Quality Data

2003

Stream	Parameter	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rock Run	pH	6.71	6.19	6.52	6.57	ND	6.4
Rock Run	Alkalinity	0	35	42	44	ND	ND
Rock Run	Nitrate	0.6	0.22	0	0	ND	0
Rock Run	Phosphate	<1	<1	0	<1	ND	0
Rock Run	DO	8.3	8.5	9	9.25	ND	11
Rock Run	Temp. °C	17.8	15.4	14.4	9.3	ND	2.4
Rock Run	Turbidity	0	0	0	0	ND	0
Pleasant Stream	pH	7.22	6.2	6.63	6	6.9	6.2
Pleasant Stream	Alkalinity	0	0	80	0	82	0
Pleasant Stream	Nitrate	0.1	4.4	4.4	4.4	0	4.4
Pleasant Stream	Phosphate	0	0	0	0	0	0
Pleasant Stream	DO	9.8	9	10	10	12	13
Pleasant Stream	Temp. °C	15.7	16	14.4	10.4	6.8	2.8
Pleasant Stream	Turbidity	0.01	0	0	0	0	0
Grays Run	pH	6.58	6.37	6.59	6.5	ND	6.75
Grays Run	Alkalinity	60	45	48	48	ND	ND
Grays Run	Nitrate	0.1	0.44	0	0	ND	0
Grays Run	Phosphate	<1	>1	0	>1	ND	0
Grays Run	DO	7.6	9	8.8	10	ND	11
Grays Run	Temp. °C	18.4	14.8	14.7	9.6	ND	0.01
Grays Run	Turbidity	0	0	0	0	ND	0
Trout Run	pH	7.4	6.95	7.11	7.11	ND	7.6
Trout Run	Alkalinity	82	60	65	68	ND	
Trout Run	Nitrate	0.1	0.44	0	0	ND	0
Trout Run	Phosphate	<1	>1	0	>1	ND	0
Trout Run	DO	9.4	11.4	9.2	10	ND	10
Trout Run	Temp. °C	20.5	15.1	15.3	10.1	ND	5.1
Trout Run	Turbidity	0	0	0	0	ND	0
Slacks Run	pH	6.11	6.99	ND	ND	ND	ND
Slacks Run	Alkalinity	0	32	ND	ND	ND	ND
Slacks Run	Nitrate	0.1	3	ND	ND	ND	ND
Slacks Run	Phosphate	<1	0	ND	ND	ND	ND
Slacks Run	DO	8.2	8.6	ND	ND	ND	ND
Slacks Run	Temp. °C	10.7	16	ND	ND	ND	ND
Slacks Run	Turbidity	ND	ND	ND	ND	ND	ND

2004

Stream	Parameter	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Rock Run	pH	6.21	ND	7.53	5.7	6.8	6.53	6.6	6.55	6.5	7.6	7.1	6.12
Rock Run	Alkalinity	ND	ND	ND	50	64	90	ND	75	70	66	58	ND
Rock Run	Nitrate	0	ND	0	0.1	0.88	0	0.44	0	0	0	0	ND
Rock Run	Phosphate	0	ND	0	0	0	0	0	0	0	0	0	ND
Rock Run	DO	12.6	ND	10	9.2	8.6	9.8	94	8.5	80	9.8	11.8	ND
Rock Run	Temp. °C	0	ND	2.8	7	10.3	14.2	15.8	16.5	16.4	ND	ND	0.9
Rock Run	Turbidity	0	ND	0	0	0	ND	ND	ND	ND	ND	ND	ND
Pleasant Stream	pH	ND	ND	6.47	6.94	6.89	ND	7.03	6.84	6.9	6.62	6.73	6.68
Pleasant Stream	Alkalinity	ND	ND	0	0	0	ND	0	0	20	20	30	30
Pleasant Stream	Nitrate	ND	ND	0	0	0	ND	0	0.44	0	0	0	0
Pleasant Stream	Phosphate	ND	ND	0	0	0	ND	0	0	0	0	0	0
Pleasant Stream	DO	ND	ND	5.5	7.5	7	ND	9	8	7.5	9	8.5	8
Pleasant Stream	Temp. °C	ND	ND	1.6	6.2	11.7	ND	14.9	14.4	15	11.1	4.1	5.6
Pleasant Stream	Turbidity	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Grays Run	pH	6.17	ND	6.14	6.63	6.23	6.2	ND	6.43	6.75	6.36	6.58	6.43
Grays Run	Alkalinity	ND	ND	32	24	22	30	ND	36	44	36	28	28
Grays Run	Nitrate	0	ND	0	0	0	0	ND	0	0	0	0	0
Grays Run	Phosphate	0	ND	0	0	0	0	ND	0	0	0	0	0
Grays Run	DO	13.2	ND	15.8	11.2	10	10	ND	10	9.8	10	11.4	11.4
Grays Run	Temp. °C	0	ND	3.1	10.1	11.3	11	ND	14.1	15.8		5.7	7.1
Grays Run	Turbidity	0	ND	0	0	ND	ND	ND	ND	ND	ND	ND	ND
Trout Run	pH	6.4		6.64	7.01	7.53	7.2	ND	7.7	7.3	7.35	7.33	6.94
Trout Run	Alkalinity		ND	38	28	24	40	ND	48	36	42	44	36
Trout Run	Nitrate	0	ND	0	0	0	0	ND	0	0	0	0	0
Trout Run	Phosphate	0	ND	ND	0	0	0	ND	0	0	0	0	0
Trout Run	DO	13.5	ND	13.6	10	13.2	10	ND	10	10	10	11.2	11.8
Trout Run	Temp. °C	0	ND	3.8	10.6	12.6	12.2		15.4	16.3	11.5	5.7	7.7
Trout Run	Turbidity	0	ND	0	0	0	ND				ND	ND	ND
Slacks Run	pH	6.8	ND	6.77	7.01	ND	6.85	6.73		6.7	ND	6.4	ND
Slacks Run	Alkalinity	20	ND	40.4	0	ND	ND	82	80	80	ND	332	60.5
Slacks Run	Nitrate	2.2	ND	0.88	0.44	ND	0.44	0	0.88	0	ND	0.1	0
Slacks Run	Phosphate	0	ND	<1	<1	ND	<1	<1	0	<1	ND	<1	<1
Slacks Run	DO	10	ND	4	11	ND	9.8	9.2	6	6	ND	11	11
Slacks Run	Temp. °C	11.1	ND	1.8	7.8	ND	12.6	15	17	17.5	ND	8	7
Slacks Run	Turbidity	0	ND	0	0	ND	ND		ND	ND	ND	ND	ND

2005

Stream	Parameter	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
Rock Run	pH	7.3	ND	6.3	6.51	6.85	7.08	ND	6.91	ND
Rock Run	Alkalinity	ND	ND	60	62	30	44	ND	100	ND
Rock Run	Nitrate	ND	ND	0	0	0	ND	ND	0	ND
Rock Run	Phosphate	ND	ND	0	0	0	ND	ND	0	ND
Rock Run	DO	ND	ND	10.5	10	8	7.5	ND	6	ND
Rock Run	Temp. °C	0	ND	3.2	9.5	22.8	21.4	ND	23.5	ND
Rock Run	Turbidity	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pleasant Stream	pH	6.45	6.43	6.51	6.45	ND	ND	ND	ND	ND
Pleasant Stream	Alkalinity	25	15	20	ND	ND	ND	ND	ND	ND
Pleasant Stream	Nitrate	0	0	0	0	ND	ND	ND	ND	ND
Pleasant Stream	Phosphate	0	0	0	0	ND	ND	ND	ND	ND
Pleasant Stream	DO	14	ND	10	7.25	ND	ND	ND	ND	ND
Pleasant Stream	Temp. °C	2.6	3.4	0	10.8	ND	ND	ND	ND	ND
Pleasant Stream	Turbidity	ND	ND	ND	ND	ND	ND	ND	ND	ND
Grays Run	pH	6.53	ND	ND	6.3	ND	6.69	ND	ND	ND
Grays Run	Alkalinity	40	ND	ND	20	ND	60	ND	ND	ND
Grays Run	Nitrate	0	ND	ND	0	ND	0	ND	ND	ND
Grays Run	Phosphate	0	ND	ND	0	ND	0	ND	ND	ND
Grays Run	DO	11.8	ND	ND	11.4	ND	9.2	ND	ND	ND
Grays Run	Temp. °C	3.4	ND	ND	7.7	ND	15.8	ND	ND	ND
Grays Run	Turbidity	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trout Run	pH	7.03	ND	ND	7.07	ND	7.19	ND	ND	ND
Trout Run	Alkalinity	30	ND	ND	30	ND	38	ND	ND	ND
Trout Run	Nitrate	0	ND	ND	0	ND	0	ND	ND	ND
Trout Run	Phosphate	0	ND	ND	0	ND	0	ND	ND	ND
Trout Run	DO	13.2	ND	ND	11.2	ND	9	ND	ND	ND
Trout Run	Temp. °C	3.8	ND	ND	8.7	ND	18	ND	ND	ND
Trout Run	Turbidity	ND	ND	ND	ND	ND	ND	ND	ND	ND
Slacks Run	pH	ND	ND	6.65	ND	ND	ND	ND	ND	ND
Slacks Run	Alkalinity	46	ND	70	ND	ND	ND	ND	ND	ND
Slacks Run	Nitrate	<1	ND	0	ND	ND	ND	ND	ND	ND
Slacks Run	Phosphate	1	ND	0	ND	ND	ND	ND	ND	ND
Slacks Run	DO	12.6	ND	8.5	ND	ND	ND	ND	ND	ND
Slacks Run	Temp. °C	ND	ND	3.5	ND	ND	ND	ND	ND	ND
Slacks Run	Turbidity	ND	ND	ND	ND	ND	ND	ND	ND	ND

☐ No Data

Stream Assessment Results

SUB-WATERSHED	Number of BEHI Erosion Evaluation Points	Total BEHI Bank Length (Ft)	Estimated Total Sediment Yield (Ton/Yr)
Pleasant Stream	31	13,710	3,459.67
Gray's Run	14	3,835	1,768.90
Lycoming Creek Upper	14	3,240	2,510.02
Lycoming Creek Middle	6	1,025	946.93
Trout Run	5	1,315	595.11
Salt Spring Run	4	795	90.90
Hoagland Run	3	2,240	1,515.34
Lycoming Creek Lower	2	275	48.13
Rock Run	2	360	176.92
Slacks Run	2	1,450	1,086.70
Beauty's Run	1	250	5.42
Frozen Run	1	3,000	647.11
Roaring Branch	1	60	10.83
Big Sandy Run	0	0	0.00
Brion Creek	0	0	0.00
Fisher Hollow	0	0	0.00
French Lick Creek	0	0	0.00
Little Elk Run	0	0	0.00
Mill Creek	0	0	0.00
Miners Run	0	0	0.00
North Branch Rock Creek	0	0	0.00
Red Run	0	0	0.00
Stony Gap Run	0	0	0.00
Sugar Works Run	0	0	0.00
West Mill Creek	0	0	0.00
Watershed Total	**86**	**31,555**	**12,861.98**

Watershed Stream Assessment

BEHI Erosion Points

Existing Conditions of Streambank Erosion Sites Based on 2004 (Pre-Ivan) Bank Erosion Hazard Index (BEHI) Assessments

BEHI ID	Waypoint Start/End	Coordinates		Bank Conditions		Erosion Rate		Near Bank Stress	Bed Materials	Flow Regime	Stream Type		Extent of Debris Blockages	Typical Meander Pattern	Major Depositional Features	Primary Causes of Instability	Dominant Riparian Vegetation	Land Use
		Latitude	Longitude	Length (Ft)	Height (Ft)	Ft/Yr	Tons/ Year				Current	Potential						
ROR-1	1030	41.54078	76.84896	300	4.60	0.38	25.25	High	Flat and Platey	Perennial	B3	B3	Infrequent	Regular Meanders	Numerous Mid-Channel Bars	Old Debris Jam	Bare	Woods
	1031	41.54191	76.84969														Grass and Brush	
ROR-2	1032	41.54409	76.85047	60	35.00	1.50	151.67	Extreme	Flat and Platey	Perennial	B3	B3	Infrequent	Truncated Meanders	Side Bars	Radius of Curvature too Tight	Bare	Woods
	1033	41.54391	76.85080														Evergreen Overstory	

ROR 1 – WP1030

ROR 2 – WP1032

ROR 2 – WP1033

Identified Bank Erosion Sites

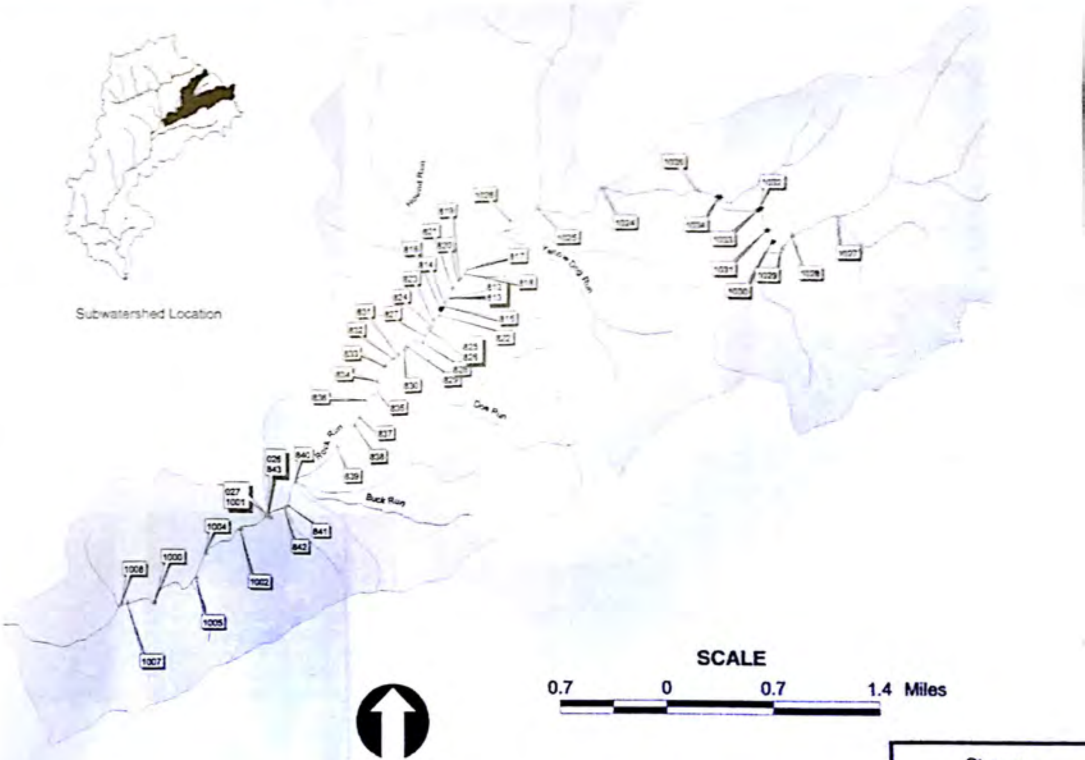
Rock Run

Sheet 1 of 1

Rock Run Waypoint Descriptions

Stream ID: ROR			Date:
Starting Waypoint	Ending Waypoint	Photo	Description
1027		X	Start
1028	1029		Mid channel bar
1029		X	Bed Rock
1030	1031	X	**ROR-1**
1032	1033	X	**ROR-2**
1034			Trib Right
1035		X	Nick Point A-1, 1
814	826		Bed Rock
815			Trib Left
816		X	Bridge
820			Trib Right
822			Trib Left
823			Trib Right
824		X	Trib Left
825			Trib Right
827	829		Bed Rock
828			Trib Left
829		X	Trib Left
830	831		Bed Rock
832	833		Bed Rock
834	835		Bed Rock
835			Debris Jam
836	837	X	Bed Rock
838	840		Bed Rock
839			Trib Left
840			Trib Left
841			Bed Rock
842		X	Trib Left
843			Trib Right
1001			Bed Rock
1002			Trib Right
1003			Trib Left
1004			Trib Left
1006	1007		Bed Rock
1008			Trib Right
1010			Confluence with Lycoming Creek

BEHI Location



Stream Assessment Waypoints

Rock Run

AQUATIC CONNECTIVITY

Stream Crossing Survey

DATA FORM

DATABASE ENTRY BY ____ ENTRY DATE ____

DATA ENTRY REVIEWED BY ____ REVIEW DATE ____

CROSSING DATA

Crossing Code____ **Local ID** (Optional)____

Date Observed (00/00/0000)____ **Lead Observer**____

Town/County____ **Stream**____

Road____ **Type** ☐ MULTILANE ☐ PAVED ☐ UNPAVED ☐ DRIVEWAY ☐ TRAIL ☐ RAILROAD

GPS Coordinates (Decimal degrees) ☐☐.☐☐☐☐☐ °N Latitude — ☐☐.☐☐☐☐☐ °W Longitude

Location Description

Crossing Type ☐ BRIDGE ☐ CULVERT ☐ MULTIPLE CULVERT ☐ FORD ☐ NO CROSSING ☐ REMOVED CROSSING ☐ BURIED STREAM ☐ INACCESSIBLE ☐ PARTIALLY INACCESSIBLE ☐ NO UPSTREAM CHANNEL ☐ BRIDGE ADEQUATE

Number of Culverts/ Bridge Cells ____

Photo IDs INLET____ OUTLET____ UPSTREAM____ DOWNSTREAM____ OTHER____

Flow Condition ☐ NO FLOW ☐ TYPICAL-LOW ☐ MODERATE ☐ HIGH

Crossing Condition ☐ OK ☐ POOR ☐ NEW ☐ UNKNOWN

Tidal Site ☐ YES ☐ NO ☐ UNKNOWN

Alignment ☐ FLOW-ALIGNED ☐ SKEWED (>45°)

Road Fill Height (Top of culvert to road surface; bridge = 0)____

Bankfull Width (Optional)____ **Confidence** ☐ HIGH ☐ LOW/ESTIMATED

Constriction ☐ SEVERE ☐ MODERATE ☐ SPANS FULL CHANNEL & BANKS ☐ SPANS ONLY BANKFULL/ACTIVE CHANNEL

Tailwater Scour Pool ☐ NONE ☐ SMALL ☐ LARGE

Crossing Comments

STRUCTURE 1

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Outlet Armoring ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**____.____ **B. Height**____.____ **C. Substrate/Water Width**____.____ **D. Water Depth**____.____

Outlet Drop to Water Surface____.____ **Outlet Drop to Stream Bottom**____.____ **E. Abutment Height** (Type 7 bridges only)____.____

L. Structure Length (Overall length from inlet to outlet)____.____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET GRADE ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**____.____ **B. Height**____.____ **C. Substrate/Water Width**____.____ **D. Water Depth**____.____

ADDITIONAL CONDITIONS

Slope % (Optional)____ **Slope Confidence** ☐ HIGH ☐ LOW

Internal Structures ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER____

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**____

Comments

STRUCTURE 2

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**________.____ **B. Height**________.____ **C. Substrate/Water Width**________.____ **D. Water Depth**________.____

Outlet Drop to Water Surface________.____ **Outlet Drop to Stream Bottom**________.____ **E. Abutment Height** (Type 7 bridges only)________.____

L. Structure Length (Overall length from inlet to outlet)________.____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET GRADE ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**________.____ **B. Height**________.____ **C. Substrate/Water Width**________.____ **D. Water Depth**________.____

ADDITIONAL CONDITIONS

Slope % (Optional)________ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**________

Comments

STRUCTURE 3

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**________.____ **B. Height**________.____ **C. Substrate/Water Width**________.____ **D. Water Depth**________.____

Outlet Drop to Water Surface________.____ **Outlet Drop to Stream Bottom**________.____ **E. Abutment Height** (Type 7 bridges only)________.____

L. Structure Length (Overall length from inlet to outlet)________.____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET GRADE ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**________.____ **B. Height**________.____ **C. Substrate/Water Width**________.____ **D. Water Depth**________.____

ADDITIONAL CONDITIONS

Slope % (Optional)________ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**________

Comments

STRUCTURE 4

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**________.___ **B. Height**________.___ **C. Substrate/Water Width**________.___ **D. Water Depth**________.___

Outlet Drop to Water Surface________.___ **Outlet Drop to Stream Bottom**________.___ **E. Abutment Height** (Type 7 bridges only)________.___

L. Structure Length (Overall length from inlet to outlet)________.___

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET GRADE ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**________.___ **B. Height**________.___ **C. Substrate/Water Width**________.___ **D. Water Depth**________.___

ADDITIONAL CONDITIONS

Slope % (Optional)________ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**________

Comments

STRUCTURE 5

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**________.___ **B. Height**________.___ **C. Substrate/Water Width**________.___ **D. Water Depth**________.___

Outlet Drop to Water Surface________.___ **Outlet Drop to Stream Bottom**________.___ **E. Abutment Height** (Type 7 bridges only)________.___

L. Structure Length (Overall length from inlet to outlet)________.___

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET GRADE ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**________.___ **B. Height**________.___ **C. Substrate/Water Width**________.___ **D. Water Depth**________.___

ADDITIONAL CONDITIONS

Slope % (Optional)________ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**________

Comments

STRUCTURE 6

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**________.____ **B. Height**________.____ **C. Substrate/Water Width**________.____ **D. Water Depth**________.____

Outlet Drop to Water Surface__________.____ **Outlet Drop to Stream Bottom**__________.____ **E. Abutment Height** (Type 7 bridges only)______________.____

L. Structure Length (Overall length from inlet to outlet)______________.____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET GRADE ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**________.____ **B. Height**________.____ **C. Substrate/Water Width**________.____ **D. Water Depth**________.____

ADDITIONAL CONDITIONS

Slope % (Optional)__________ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**____________

Comments

STRUCTURE 7

Structure Material ☐ METAL ☐ CONCRETE ☐ PLASTIC ☐ WOOD ☐ ROCK/STONE ☐ FIBERGLASS ☐ COMBINATION

OUTLET

Outlet Shape ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐ FORD ☐ UNKNOWN ☐ REMOVED **Outlet Armoring** ☐ NONE ☐ NOT EXTENSIVE ☐ EXTENSIVE

Outlet Grade (Pick one) ☐ AT STREAM GRADE ☐ FREE FALL ☐ CASCADE ☐ FREE FALL ONTO CASCADE ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Outlet Dimensions **A. Width**________.____ **B. Height**________.____ **C. Substrate/Water Width**________.____ **D. Water Depth**________.____

Outlet Drop to Water Surface__________.____ **Outlet Drop to Stream Bottom**__________.____ **E. Abutment Height** (Type 7 bridges only)______________.____

L. Structure Length (Overall length from inlet to outlet)______________.____

INLET

Inlet Shape ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ FORD ☐ UNKNOWN ☐ REMOVED

Inlet Type ☐ PROJECTING ☐ HEADWALL ☐ WINGWALLS ☐ HEADWALL & WINGWALLS ☐ MITERED TO SLOPE ☐ OTHER ☐ NONE

Inlet Grade (Pick one) ☐ AT STREAM GRADE ☐ INLET GRADE ☐ PERCHED ☐ CLOGGED/COLLAPSED/SUBMERGED ☐ UNKNOWN

Inlet Dimensions **A. Width**________.____ **B. Height**________.____ **C. Substrate/Water Width**________.____ **D. Water Depth**________.____

ADDITIONAL CONDITIONS

Slope % (Optional)__________ **Slope Confidence** ☐ HIGH ☐ LOW | **Internal Structures** ☐ NONE ☐ BAFFLES/WEIRS ☐ SUPPORTS ☐ OTHER________

Structure Substrate Matches Stream ☐ NONE ☐ COMPARABLE ☐ CONTRASTING ☐ NOT APPROPRIATE ☐ UNKNOWN

Structure Substrate Type (Pick one) ☐ NONE ☐ SILT ☐ SAND ☐ GRAVEL ☐ COBBLE ☐ BOULDER ☐ BEDROCK ☐ UNKNOWN

Structure Substrate Coverage ☐ NONE ☐ 25% ☐ 50% ☐ 75% ☐ 100% ☐ UNKNOWN

Physical Barriers (Pick all that apply) ☐ NONE ☐ DEBRIS/SEDIMENT/ROCK ☐ DEFORMATION ☐ FREE FALL ☐ FENCING ☐ DRY ☐ OTHER

Severity (Choose carefully based on barrier type(s) above) ☐ NONE ☐ MINOR ☐ MODERATE ☐ SEVERE

Water Depth Matches Stream ☐ YES ☐ NO-SHALLOWER ☐ NO-DEEPER ☐ UNKNOWN ☐ DRY

Water Velocity Matches Stream ☐ YES ☐ NO-FASTER ☐ NO-SLOWER ☐ UNKNOWN ☐ DRY

Dry Passage through Structure? ☐ YES ☐ NO ☐ UNKNOWN **Height above Dry Passage**____________

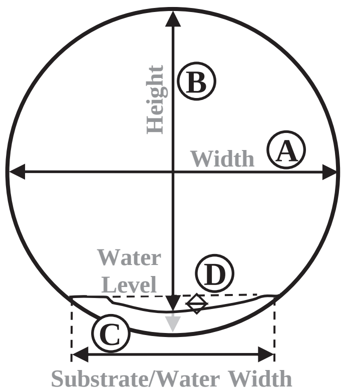
Comments

Structure Shape & Dimensions

1) Select the Structure Shape number from the diagrams below and record it on the form for Inlet and Outlet Shape.
2) Record on the form in the approriate blanks dimensions **A**, **B**, **C** and **D** as shown in the diagrams;
   C captures the width of water or substrate, whichever is wider; for dry culverts without substrate, C = 0.
   D is the depth of water -- be sure to measure inside the structure; for dry culverts, D = 0.
3) Record Structure Length (**L**). (Record abutment height (**E**) only for Type 7 Structures.)
4) For multiple culverts, also record the Inlet and Outlet shape and dimensions for each additional culvert.

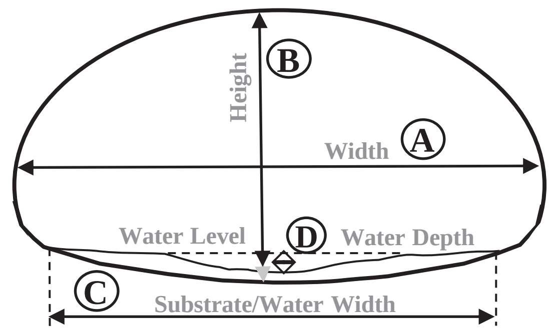
NOTE: Culverts 1, 2 & 4 may or may not have substrate in them, so height measurements (B) are taken from the level of the "stream bed", whether that bed is composed of substrate or just the inside bottom surface of a culvert (grey arrows below show measuring to bottom, black arrows show measuring to substrate).

1



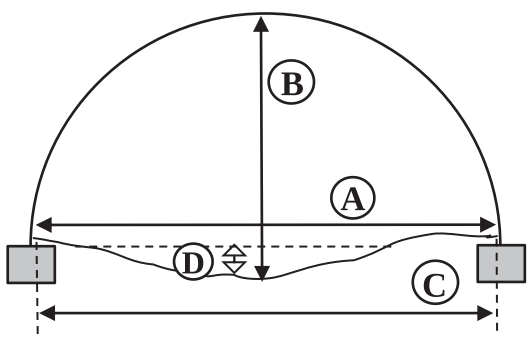
Round Culvert

2



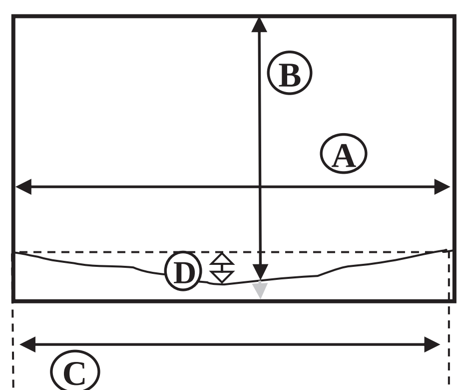
Pipe Arch/Elliptical Culvert

3



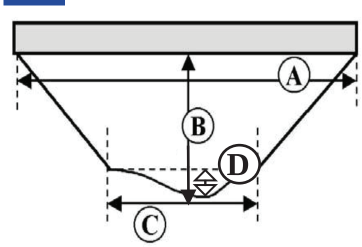
Open Bottom Arch Bridge/Culvert

4



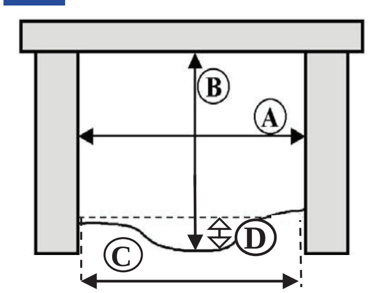
Box Culvert

5



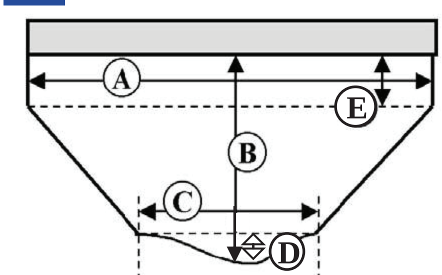
Bridge with Side Slopes

6



Box/Bridge with Abutments

7



Bridge with Abutments and Side Slopes

Scoring Road-Stream Crossings as Part of the North Atlantic Aquatic Connectivity Collaborative (NAACC)

Adopted by the NAACC Steering Committee
November 10, 2015

INTRODUCTION

The North Atlantic Aquatic Connectivity Collaborative (NAACC) was launched in 2015 with a rapid assessment protocol for evaluating aquatic passability at road-stream crossings and an online database (https://www.streamcontinuity.org/cdb2) for storing and scoring data collected using this protocol. Two scoring systems are proposed to evaluate aquatic passability at road-stream crossings. The first is a coarse screen for use in classifying crossings into one of three categories: "Full AOP" (Aquatic Organism Passage), "Partial AOP," and "No AOP." The second system is an algorithm for computing an aquatic passability score, ranging from 0 (low) to 1 (high), for each road-stream crossing. These two scoring systems are not particular to any taxonomic or functional group but instead seek to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams.

NAACC COARSE SCREEN

Table 1 below identifies characteristics and conditions that allow crossings to be classified as providing "Full AOP," "Reduced AOP," or "No AOP."

Table 1. NAACC Coarse Screen

Metric	Flow Condition	Crossing Classification		
		Full AOP	Reduced AOP	No AOP
		If all are true	*If any are true*	*If any are true*
Inlet Grade		At Stream Grade	Inlet Drop or Perched	
Outlet Grade		At Stream Grade		Cascade, Free Fall onto Cascade
Outlet Drop to Water Surface		= 0		≥ 1 ft
Outlet Drop to Water Surface/ Outlet Drop to Stream Bottom				> 0.5
Inlet or Outlet Water Depth	Typical-Low	> 0.3 ft		< 0.3 ft w/Outlet Drop to Water Surface > 0
	Moderate	> 0.4 ft		< 0.4 ft w/Outlet Drop to Water Surface > 0
Structure Substrate Matches Stream		Comparable or Contrasting		
Structure Substrate Coverage		100%	< 100%	
Physical Barrier Severity		None	Minor or Moderate	Severe

The primary objective of the coarse screen is to identify those crossings that are likely to be a barrier to most or all species and those that are likely to provide something close to full aquatic organism passage. If it is necessary to get a better feel for how bad those crossing are that are labeled as "reduced AOP" one can use the numeric scoring system.

NAACC Numeric Scoring System

The numeric scoring algorithm is based on the opinions of experts who decided both the relative importance of all the available predictors of passability as well as a way to score each predictor. Scoring involves three steps: (1) generating a component score for each predictor variable, (2) combining these predictions with a weighted average to generate a composite score for the crossing, and (3) assigning a final score based on the minimum of the composite score or the component score for the *outlet drop* variable.

Variables Used

Crossing assessments are generally done during "typical low-flow conditions." Some variables are important for assessing conditions at the time of the survey; others provide indirect evidence of likely conditions at higher flows.

<u>Inlet Grade</u>: The position of the structure invert relative to the stream bottom at the inlet.

<u>Outlet Drop</u>: Outlet drop is based on the variable *Outlet Drop to Water Surface* unless the value for *Water Depth Matches Stream* = "Dry" in which case outlet drop is based on the variable *Outlet Drop to Stream Bottom*.

<u>Physical Barriers</u>: This variable covers a wide variety of circumstances ranging from obstructions to dewatered culverts or bridge cells that represent physical barriers to aquatic organism passage.

<u>Constriction</u>: The relative width of the crossing compared to the width of the stream. "Severe" = <50%, "Moderate" = 50-100%; other options include "Spans Only Bankfull/Active Channel" and "Spans Full Channel & Banks." *Constriction* is an indirect indicator of potential velocity issues at higher flows.

<u>Water Depth</u>: Water depth in the structure relative to water depths found in the natural channel at the time of survey.

<u>Water Velocity</u>: Water velocity in the structure relative to water velocities found in the natural channel at the time of survey.

<u>Scour Pool</u>: Presence/absence of a scour pool at the crossing outlet and size relative to the natural stream channel. *Scour Pool* is an indirect indicator of potential velocity issues at higher flows. *Scour pool* is included solely as an indicator of velocities at higher flows. It is not based on the effects of the pool itself which can actually be positive for fish passage.

<u>Substrate Matches Stream</u>: An assessment of whether the substrate in the structure matches the substrate in the natural stream channel. *Substrate Matches Stream* is used to evaluate how a discontinuity in substrate might inhibit passage for species that either use substrate as the medium for travel (e.g., mussels) or require certain types of substrate for cover during movements (e.g., crayfish, salamanders, juvenile fish).

Substrate Coverage: Degree to which a crossing structure is covered by substrate. *Substrate Coverage* is directly related to passability for some aquatic species that require substrate or that tend to avoid areas that lack cover. It is also an important element of roughness that can create areas of low-velocity water (boundary layers) utilized by weak-swimming organisms. *Substrate Coverage* is also an indirect indicator of potential velocity issues at higher flows.

Openness: Cross-sectional area of the structure opening divided by the structure length (distance between inlet and outlet) measured in feet. *Openness* is calculated for both the inlet and outlet and the lower value is assigned to the structure. If there are multiple structures at a crossing the value for the structure with the highest *Openness* is assigned to the crossing as a whole. Turtles are believed to be affected by the *Openness* of a crossing structure; other species may be affected as well.

Height: Maximum height of the crossing structure. This variable is parameterized so that it only comes into play for very small structures.

Outlet Armoring: Presence/absence of streambed armoring (e.g., riprap, asphalt, concrete) at the outlet and the relative amount of armoring. Armoring is considered “extensive” if the length (upstream to downstream) of the streambed that is armored is greater or equal to half the bankfull width of the natural stream channel. *Outlet Armoring* is an indirect indicator of potential velocity issues at higher flows.

Internal Structures: Presence/absence of structures inside a culvert or bridge (e.g. weirs, baffles, supports). The *Internal Structures* variable is used in the scoring algorithm as it relates to the potential for creating turbulence within a crossing structure. To the extent that *Internal Structures* physically block the movement of aquatic organisms it is covered by the *Physical Barriers* variable.

Step 1: Component Scores

The component scores are not meant to equate to passability. In each case the component score is intended the cover the full range of problems (assessable by our protocol) associated with that variable: from 0 (worst case) to 1 (best case). For *inlet grade*, having an inlet drop or perched inlet is the worst case among the options, thus they score "0." This is not meant to say that all structures with inlet drops are impassible. The effect of *inlet grade* on passability scores is controlled by the weight it is given in computing the composite score (see Step 2 below).

Scoring categorical predictors is simply a matter of assigning a score for each possible category. Table 2 lists all of the categorical predictors and the scores associated with each category.

Scoring continuous predictors requires a function to convert the predictor to a score. There are three continuous predictors and three associated functions. The functional forms used were chosen because they have shapes desired by the expert team or because they fit the series of points specified by the expert team. Appendix A includes the r code defining each of these functions (“x” is the measured value for each variable).

The scoring equation for *Openness* is:

(1) $s_o = a(1 - e^{-kx(1-d)})^{1/(1-d)}$

Where S_o is the score for openness, a=1, k=15, and d = 0.62 when openness is recorded in feet.

The equation for Height is:

(2) $s_h = \min(\frac{ax^2}{b^2 + x^2}, 1)$

Where S_h is the component score for height, a = 1.1, and b=2.2 when height is recorded in feet.

The equation for Outlet Drop is:

(3) $s_{od} = 1 - \frac{ax^2}{b^2 + x^2}$

Where S_{od} is the Outlet Drop component score, a=1.029412, and b=0.51449575 when outlet drop is recorded in feet.

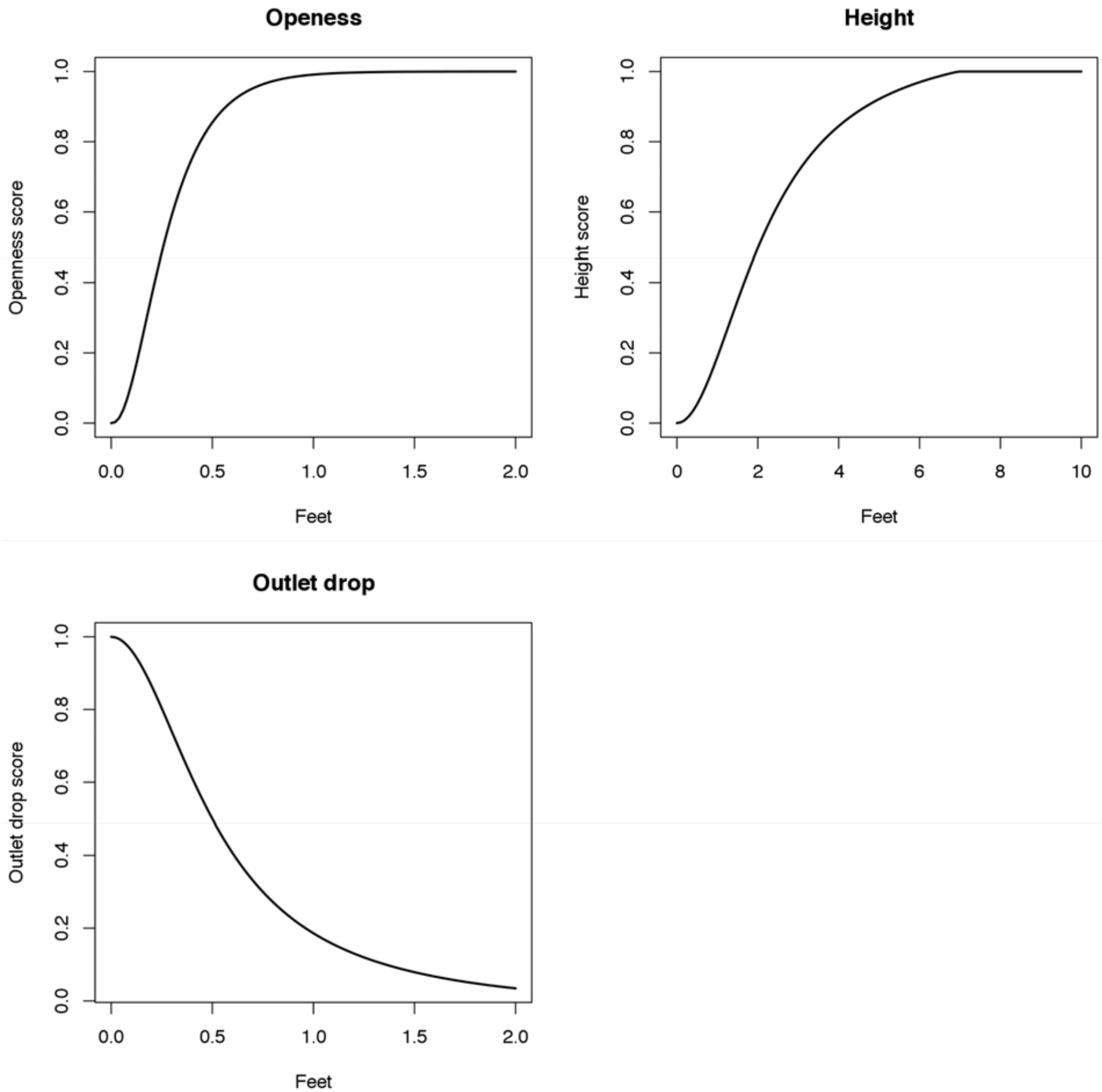


Figure 1. Continuous predictor variables

Table 2. Component scores for categorical variables used in calculating the crossing score

parameter	level	score
Constriction	severe	0
Constriction	moderate	0.5
Constriction	spans only bankfull/active channel	0.9
Constriction	spans full channel and banks	1
Inlet grade	at stream grade	1
Inlet grade	inlet drop	0
Inlet grade	perched	0
Inlet grade	clogged/collapsed/submerged	1
Inlet grade	unknown	1
Internal structures	none	1
Internal structures	baffles/weirs	0
Internal structures	supports	0.8
Internal structures	other	1
Outlet armoring	extensive	0
Outlet armoring	not extensive	0.5
Outlet armoring	none	1
Physical barriers	none	1
Physical barriers	minor	0.8
Physical barriers	moderate	0.5
Physical barriers	severe	0
Scour pool	large	0
Scour pool	small	0.8
Scour pool	none	1
Substrate coverage	none	0
Substrate coverage	25%	0.3
Substrate coverage	50%	0.5
Substrate coverage	75%	0.7
Substrate coverage	100%	1
Substrate matches stream	none	0
Substrate matches stream	not appropriate	0.25
Substrate matches stream	contrasting	0.75
Substrate matches stream	comparable	1
Water depth	no (significantly deeper)	0.5
Water depth	no (significantly shallower)	0
Water depth	yes (comparable)	1
Water depth	dry (stream also dry)	1
Water velocity	no (significantly faster)	0
Water velocity	no (significantly slower)	0.5
Water velocity	yes (comparable)	1
Water velocity	dry (stream also dry)	1

Some notes about the component scores

1. The option "clogged/collapsed/submerged" for *inlet grade* is an option surveyors use to indicate that it was not possible to measure the structure's dimensions. If the inlet is clogged or collapsed enough to affect passability it will be covered under *physical barriers*. This is why it receives a "1" instead of a "0", because problems associated with this option are covered by the *physical barriers* variable.

2. The rationale for giving a component score of "1" to "unknown" for *inlet grade* is similar to that for "clogged/collapsed/submerged." It is hard to know how to interpret "unknown." However, if conditions at the inlet are creating a physical barrier to passage it will be covered under *physical barriers*.

3. We included *inlet grade* as a variable in addition to *physical barriers* because inlet drops create both velocity and physical barrier (jump barrier) issues. The physical barrier issues are covered by the *physical barriers* variable. The *inlet grade* variable captures the velocity issues at the inlet. Perched inlets can create depth issues at low flows (if water can't get into the structure inlet). These may not be apparent at the time of the survey. Thus, the presence of a perched inlet is a concern even if it doesn't represent a physical barrier ("dry") at the time when the survey is conducted.

4. The variable *internal structures* is included to account for turbulence issues. There is likely to be turbulence associated with weirs and baffles when these are included inside crossing structures. If they also create physical barriers they will be covered by the *physical barriers* variable. They are often included in structures to help aquatic organism passage but they sometimes do more harm than good and may be good for some species while creating problems for others. The inclusion of well-designed weirs or baffles is likely to improve the component scores for water depth and water velocity. They get docked a little in our scoring system for introducing turbulence.

5. It is difficult to know how to score the "other" option under *internal structures* because it is difficult to know what, if any, impact these other structures will have on turbulence. If, however, they represent a physical barrier they will be covered under the *physical barriers* variable.

Step 2: Weighted Composite Scores

An expert team of nine people provided input on how the variables should be weighted based on best professional judgement. The weights used with the component scores are listed in table 3. The weights are simply the means of the nine weights for each variable provided by the experts. We display the weights out to three decimal places not to suggest that we know the weights to this level of precision but to reduce overall error in the model by not introducing an additional source of error (rounding error). The composite score is the sum of the products of each component score and its weight.

Table 3. Weights associated with each parameter in the scoring algorithm.

parameter	weight
Outlet drop	0.161
Physical barriers	0.135
Constriction	0.090
Inlet grade	0.088
Water depth	0.082
Water velocity	0.080
Scour pool	0.071
Substrate matches stream	0.070
Substrate coverage	0.057
Openness	0.052
Height	0.045
Outlet armoring	0.037
Internal structures	0.032

Step 3: Final Aquatic Passability Score

The final Aquatic Passability Score is the lower of either the composite score or the *Outlet Drop* component score. The rationale for this is that although many factors can affect aquatic organism passage, when an outlet drop is above a certain size it becomes the predominant factor that determines passability.

Aquatic Passability Score = Min[Composite Score, *Outlet Drop* score]

Mapping Aquatic Passability Scores

For mapping purposes, we assigned narrative descriptors for different ranges of aquatic passability as follows.

Descriptor	Aquatic Passability Score(s)
No barrier	1.0
Insignificant barrier	0.80 – 0.99
Minor barrier	0.60 – 0.79
Moderate barrier	0.40 – 0.59
Significant barrier	0.20 – 0.39
Severe barrier	0.00 – 0.19

People often ask about the relationship between these categories and actual passability for fish and other aquatic organisms. At this point the relationship is unknown and we regard it as a fruitful area for future research. The concept of aquatic passability is complicated and includes: variation in the swimming and leaping abilities of individuals within a species (what proportion of the population can pass), variability in passage requirements for a broad diversity of species that inhabit rivers and streams (what proportion of species can pass), and the timing of passability (for what proportion of the year is the structure passable).

For now, the best way to consider the aquatic passability scores is that they represent the degree to which crossings deviate from an ideal. We assume that those crossings that are very close to the ideal (scores > 0.6) will present only a minor or insignificant barrier to aquatic organisms. Those structures that are farthest from the ideal (scores < 0.4) are likely to be either significant or severe barriers. These are, however, arbitrary distinctions imposed on a continuous scoring system and should be used with that in mind.

APPENDIX A - R code for continuous scoring functions.

```
#------------------------------------------------------------------------------#
# define function for Openness score calculation
#------------------------------------------------------------------------------#
calc.openness.score <- function(x){
	# Using von Bertalanffy functional form (Bolker pg 97)
	a = 1
	k = 15
	d=0.62
	return(a * (1-exp(-k*(1-d)*x))^(1/(1-d)))
	# note exp is based on e not 10.
}

#------------------------------------------------------------------------------#
# Define Function for Calculating Height Scores
#------------------------------------------------------------------------------#
calc.height.score <- function(x){
	a <- 1.1
	b <- 2.2
	# Use Holling Type II function (Bolker pg 92):
	result <- a*x^2/(b^2 + x^2)
	result[result > 1] <- 1 # Truncate results to 1
	return(result)
}


#------------------------------------------------------------------------------#
# Define Function for Calculating Outlet Drop Scores
#------------------------------------------------------------------------------#
calc.outlet.drop.score <- function(x){
	a <- 1.029412
	b <- 0.51449575
	score <- 1 - a*x^2/(b^2 + x^2)
	score[x > 36] <- 0
	return(score)
}
```

QUALITY ASSURANCE PROJECT PLAN

Monitoring Water Quality Impacts in West Virginia's Coldwater Streams

Implemented by West Virginia Rivers Coalition and Trout Unlimited

July 2014

Prepared for:
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Table of Contents

Tables and Figures

Distribution List

Tim Craddock: West Virginia Department of Environmental Protection (DEP)
Angie Rosser: West Virginia Rivers Coalition (WVRC)
Katy Dunlap: Trout Unlimited (TU)

Project Task Organization

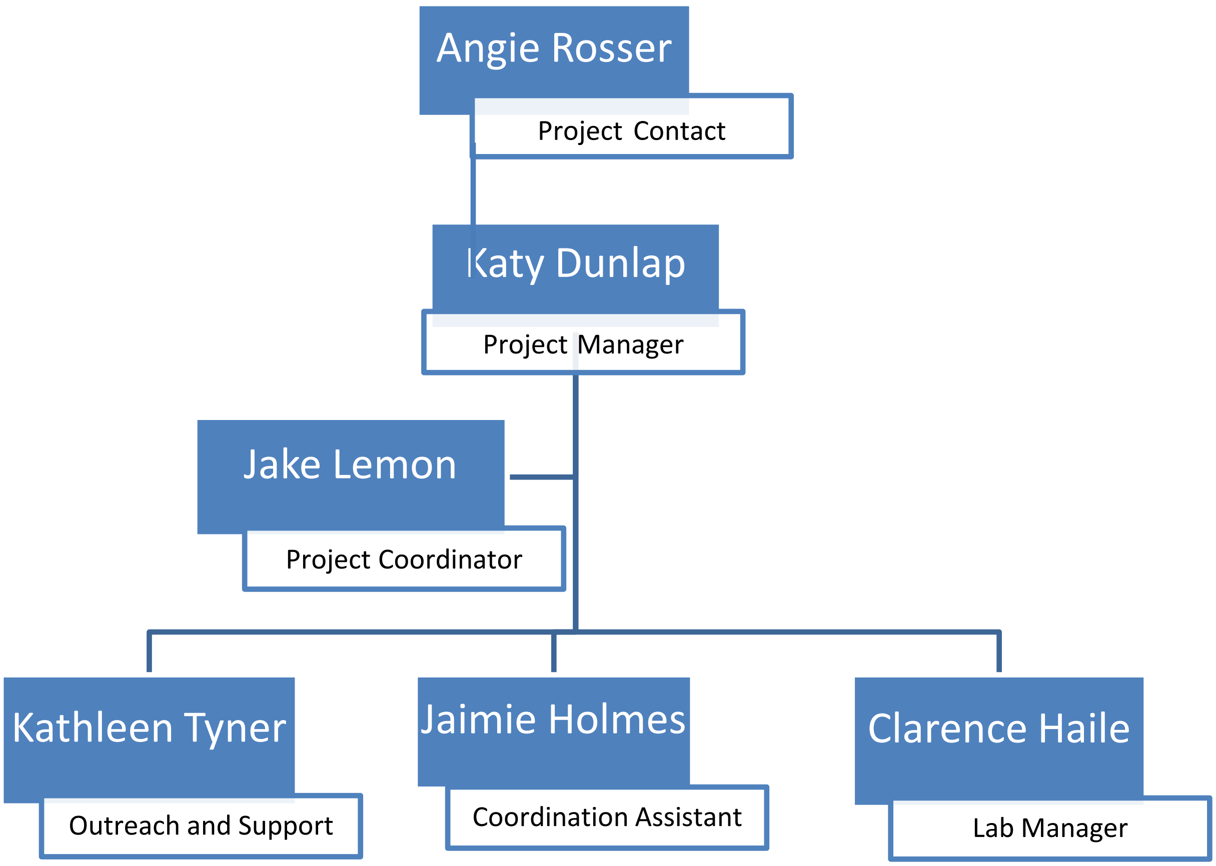

Figure 1

Problem Definition/Background

Our project focuses on engaging citizens to protect ecologically-sensitive water resources, and fish and wildlife habitat from a variety of non-point source pollution through a volunteer stream monitoring program. With the chemical leak into the Elk River in early January 2014, there is a new awareness of the importance of protecting water supplies and rivers and streams, and citizens are recognizing that they can play a key role in helping to watch over these valuable resources.

Our monitoring protocol includes measuring conductivity (a bulk parameter that measures the ability of water to pass an electrical current), pH, cross-sectional area, turbidity, and air and water temperature. Conductivity is affected by the presence of many different inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions, or sodium, magnesium, calcium, iron, and aluminum cations. Additionally, the geology of a given area can influence conductivity levels. Thus, with adequate baseline data to quantify the effect of local geology on conductivity measurements, volunteers can identify areas where land disturbance activities such as logging, construction, failing septic systems, agricultural lands (run-off) and practices (spreading fertilizers, pesticides) may be occurring. Additionally, by measuring pH, volunteers can help to identify sources of abandoned mine drainage pollution. By measuring turbidity, volunteers are measuring for sedimentation pollution from earth disturbance activities such as logging or construction. Measuring temperature and cross-sectional area are important for establishing a baseline relationship with conductivity for a specific stream.

Increased sedimentation can result in at least 15 different direct negative effects on trout, ranging from stress, altered behavior, reductions in growth and direct mortality. Loss of riparian forested areas from construction or logging activities can eliminate important shade cover for trout habitat and increase water temperatures. As a coldwater species, native and wild brook trout require cold clean water, and increased water temperatures (above 70 degrees) can stress trout populations, affect fish passage and food sources, and in some cases, can be deadly for trout. The optimal pH range for native and wild brook trout is 6.5-8.0, and sources such as abandoned mine drainage can lower pH levels, to lethal ranges for trout populations.

Project Task Description

TU's West Virginia Water Quality Monitoring Project is a program developed by TU that is being implemented in West Virginia by TU and WVRC. The goals of the project are threefold. First, to provide education for new WRVC and TU volunteers about the potential impacts to fish and wildlife resources in West Virginia and to train volunteers how to effectively monitor the water quality in these areas. Second, to provide ongoing technical support for those volunteers trained during winter/spring 2013-2014, to ensure continuous monitoring efforts and robust data sets. The third, and most important, goal is to work with all trained volunteers to conduct water quality monitoring in all priority watersheds that have been identified by TU's science team as critical for protecting ecologically significant lands and waters. WVRC and TU members are uniquely poised to monitor these critical areas—which are often out of sight of many due to their remote locations — because these are the very places where WRVC and TU members spend countless hours fishing and recreating.

Six water quality monitoring training sessions will be held from May 2014 through April 2015. Training sessions are typically held on Saturdays that do not fall on holidays or other important days for sportsmen and women (i.e., opening days of hunting seasons) in order to maximize participation and minimize potential conflicts. Project partners anticipate holding two training sessions in summer 2014, one training session in fall 2014 and two training sessions in winter 2014/2015 and one training session in spring 2015.

The DEP Save Our Streams program trains volunteers to collect benthic macroinvertebrates between April and October. TU will work with this program, to schedule training sessions for all currently trained volunteers, between April and October 2014, and in April 2015.

Planning for the regional watershed snapshot day began in May 2014, and the event will be held on August 2, 2014. During this event, monitoring volunteers will come together on one day to collect a large number of samples in the Monongahela National Forest with the goal of establishing baseline conditions. Volunteers will utilize our standard monitoring protocol and collect measurements for conductivity, pH, cross sectional area, turbidity and air and water temperature and conduct visual assessments for an estimated 50 sites (final number will depend upon the number of volunteers participating). A sub-set of samples will be sent to the Research Environmental Industries Consultant (REIC) lab for quality assurance/quality control (QA/QC) on conductivity measurements and for baseline barium and strontium measurements.

REIC will conduct QA/QC services for the collected water quality monitoring samples and analyze the samples for bromide throughout the project period, and report results to TU staff on a quarterly basis.

WRVC and TU water quality monitoring volunteers will conduct routine visual reconnaissance and collect water quality samples on a monthly basis. Conference calls for trained volunteers will be held monthly, in order to troubleshoot monitoring issues, discuss results, a

Table 1: Task Timeline

	2014-2015											
Major Task Categories	M	J	J	A	S	O	N	D	J	F	M	A
Volunteer Recruitment and Training	x	x	x	x	x	x	x	x	x	x	x	x
Monthly Water Chemistry Sampling	x	x	x	x	x	x	x	x	x	x	x	x
Seasonal Macroinvertebrate Assessments							x	x			x	x
QA/QC Samples	x	x	x	x	x	x	x	x	x	x	x	x
Barium and Strontium Analysis	x			x	x	x					x	x
Watershed Snapshot Event				x								
Lab Analysis	x	x	x	x	x	x	x	x	x	x	x	x
Technical/Coordination Support	x	x	x	x	x	x	x	x	x	x	x	x

Data Quality Objectives for Measurement Data

Table 2: Data Precision (Field)

Matrix	Parameter	Range	Accuracy	Precision
Water	Field Conductivity	0-19,990 µS	±2% FS	≤ 20%
Water	Temperature	32.0°-149.0° F	±1.8° F	≤ 20%
Water	pH	2.0-9.0	±0.5	≤ 20%
Water	Turbidity	0-240 NTU	n/a	≤ 20%
Air	Temperature	32.0°-149.0° F	±1.8° F	≤ 20%

Table 3: Data Precision (Lab)

Matrix	**Parameter**	**Method**	**Method Detection Limit**
Water	Lab Conductivity	SM 2510B	1.0 umho/cm
Water	Barium	EPA 200.7	0.002 mg/L
Water	Strontium	EPA 200.7	0.001 mg/L
Water	Bromide	EPA 300.0	0.06 mg/L

Table 4: Data Completeness

Parameter	No. of Valid Samples Anticipated Per Site (baseline)	No. of Valid Samples Anticipated Per Site (immediate)
Conductivity	4 to 12	24
Temperature	4 to 12	24
pH	4 to 12	24
Barium	2	2
Strontium	2	2
Bromide	2	2

Data Representativeness

Data representativeness is achieved through training volunteers in sampling protocols derived from guidance documents provided by the United States Environmental Protection Agency (USEPA) and the Pennsylvania Department of Environmental Protection (PADEP). The protocols have been specifically designed for small headwater streams. West Virginia sampling methods are based up those developed for Pennsylvania by Trout Unlimited with input from the PADEP, the Pennsylvania Fish and Boat Commission, and the Alliance for Aquatic Resource Monitoring at Dickinson College. Additionally, these methods have been reviewed by West Virginia DEP staff. For example, conductivity and water temperature are measured near the center of the stream in an area with moderate water flow. Macroinvertebrate sampling follows protocols used by West Virginia Save Our Streams program. Samples are collected from three different riffle areas exhibiting different characteristics (substrate, velocity etc.) when possible to achieve a representative sample.

Data Comparability

Data Comparability is achieved through the utilization of sampling protocols derived from widely used documents such as *Volunteer Monitoring: A Methods Manual* by the USEPA. West Virginia's Save Our Stream's program utilizes standardized taxonomic keys to identify macroinvertebrates at the order and familiar family levels.

Data Completeness

The amount of samples taken will be dictated by the monitoring strategy for the particular sampling location. See the table 4 for a breakdown on anticipated samples per site.

Training Requirements/Certification

Volunteer monitors participate in a one day field training course conducted by Trout Unlimited staff to be certified to collect water chemistry data and conduct visual reconnaissance. TU staff who will conduct the trainings are thoroughly- versed on the sampling program and have extensive experience collecting high quality water quality data. Volunteers are instructed how to strategically choose monitoring sites and conduct visual reconnaissance, calibrate their water quality meter, collect water quality samples, complete field measurement for temperature, conductivity, pH and turbidity and enter data into our online database. Volunteers have the opportunity to attend additional trainings in order to refresh their knowledge of sampling protocols. Additionally, bi-monthly phone calls are scheduled to provide additional training and address potential issues.

Volunteer performance is evaluated in a couple ways. First, the training concludes with a field exercise where volunteers simultaneously complete the entire sampling process. Results are compared amongst various groups to ensure the collection of quality data. Additionally, during the volunteer's first field data collection a QA/QC sample is collected and sent to a certified lab for water quality analysis. Lab measurements for conductivity are compared to the volunteer's field measurements to ensure volunteer and equipment reliability. After the initial field measurement, volunteers will collect QA/QC samples twice a year, during high flow and low flow, for each active monitoring location to ensure continued accuracy. Due to the inverse relationship between flow and conductivity, collecting samples at high flow and low flow allows us to determine accuracy of field measurements at the widest range of conductivity values. Also, it provides with a high quality measurement establishing baseline ranges in conductivity. Ten percent of volunteers will also send a split sample to REIC on an annual basis.

Documentation and Records

Each time field sampling occurs, a stream monitoring field data sheet is completed. On this sheet, the volunteer records their name, the date, stream being monitored, field qualitative observations and field chemistry data. Additionally, a checklist for visual observations is completed. When performing macroinvertebrate collections, field data is recorded using West Virginia Save Our Streams field data sheets. Volunteers will enter data into TU's online database hosted by CitSci.org. Additionally, each volunteer will keep an Excel spreadsheet of their own data as well as archive hard copies of their field data sheets.

When sending QA/QC samples to the lab, a chain of custody is completed and included with the sample. Additionally, a QA/QC data form including field measurements to be compared with lab analysis values is sent with the sample. The lab will summarize this information with their analysis and provide results to TU's Project Coordinator and the volunteer. Finally, in cases where sampling locations fall on private property, a landowner access authorization form will be completed.

Sampling Process Design

Sites are sampled for field parameters including conductivity, turbidity, pH, air and water temperature, and cross sectional area which is used as a surrogate for flow. Additional qualitative observations are made including weather, precipitation, stream flow (i.e. dry, low, normal, or high), water condition in addition to a visual reconnaissance checklist that identifies potential impacts of nonpoint source pollution. Monitoring locations are selected using TU's Central Appalachian Conservation Success Index (CSI). This tool takes into account the latest data available to determine the condition of native and wild trout watersheds and potential threats, including:

1. Population Integrity - population status and patch size.
2. Habitat Integrity
   - Land Use: miles of 303(d) streams listed as impaired, percent of watershed forested, percent of riparian zone forested, percent of watershed with agricultural land use, road density, and roads in riparian zone;
   - Existing Resource Development: active conventional oil and gas wells, active shale gas wells, mine county, and miles of 303(d) streams listed as impaired from abandoned-mine drainage; and
   - Flow Regime: dam count, water withdrawal count (total), water withdrawal count (no pass by flow), water withdrawal maximum volume, and road/stream intersections.
3. Future Security
   - Future Resource Development: maximum probable shale gas development, maximum probable shale gas development density, and watershed average of maximum development probability;
   - Climate: average August air temperature, base flows, and Karst-stream overlap (percent of stream); and

- Land Stewardship: percent of watershed protected (including all public and private designations)

Based upon this data, the CSI assigns one of three monitoring strategies to HUC-12 watersheds with wild and native trout in the region, including: "immediate" monitoring watersheds, where trout populations and habitat are most at risk from development-related impacts; ""long-term" watersheds, where future development poses a threat to trout populations and habitat; and "baseline" watersheds, where high quality trout populations and habitat exists and streams can be monitored for comparison purposes. The sampling frequency will depend upon which of these watersheds the location falls into. In Immediate watersheds, volunteers will sample twice a month. In baseline watersheds, volunteers may sample monthly or quarterly. The TU Project Coordinator works with volunteers to choose their monitoring locations at the conclusion of the training sessions. The CSI and detailed maps (which include streams, roads, bridge access and public lands) are the main tools used to determine monitoring stations.

Sites are chosen based upon TU's CSI, local knowledge of streams and potential impact concerns, interest of volunteers, and proximity to volunteer home, work or places of recreation. If volunteers do not reside near a priority watershed, a nearby stream may be chosen if it is trout water. If, after the training, the volunteer has not selected a site, then the TU Project Coordinator will hold a conference call/webinar with the volunteer to visually select sites on a map and/or go out with the volunteer to select specific sites. We expect to have 130 sites by the end of the grant period.

Macroinvertebrate sampling will take place in the springtime in accordance with WVDEP guidance. Additionally, volunteers will submit two samples per year, one during high flow and one during low flow, to be analyzed by a certified lab for barium, strontium and bromide.

Most site locations will be on public land but in the occasion that they fall on private property, a Landowner Permission Form is required. Streams may not be able to be accessed in the winter due to ice or other factors. In this case, volunteer will access and sample the streams as soon as they are deemed safe, a decision which is covered in volunteer training.

Sampling Method Requirements

Table 5: Sampling Methods

Matrix	Parameter	Sampling Equipment	Sample Holding Container	Sample Preservation	Holding Time
Water	Field Conductivity	LaMotte Pocket Tester	taken from stream	none	immediately
Water	Temperature	LaMotte Pocket Tester	taken from stream	none	immediately
Water	pH	Merck pH Indicator Strips	plastic sample tube	none	immediately
Water	Turbidity	120 cm Secchi Tube	taken from stream	none	immediately
Air	Temperature	LaMotte Pocket Tester	taken from air	none	immediately
Water	Lab Conductivity	n/a	Autoclaved sample bottle	none	28 days
Water	Barium	n/a	Autoclaved sample bottle	none	6 months
Water	Strontium	n/a	Autoclaved sample bottle	none	6 months
Water	Bromide	n/a	Autoclaved sample bottle	none	28 days
Substrate	Macroinvertebrates	Kick-net: 1m^2 (1/16-1/32 mesh size)	Identified in plastic trays	none	immediately

Sample Handling and Custody Requirements

Samples are taken twice a year at each site (during high and low flow) and analyzed for barium, strontium, and bromide as well as conductivity for QA/QC purposes. Bottles are labeled noting the location, sample number, the initials of the sampler, and date and time of collection. Bottles will be chilled and shipped within 24 hours to the REIC Lab where preserving acid will be added.. The date and time of arrival will be recorded by the lab technician. A chain of custody form is used to record all transport and storage information.

Analytical Method Requirements

All pH, conductivity, temperature and turbidity measurements are taken using protocols outline in the *Trout Unlimited West Virginia Water Quality Monitoring Program Handbook*. The protocols in this handbook were developed for Pennsylvania by Trout Unlimited with input from the PADEP, the Pennsylvania Fish and Boat Commission, and the Alliance for Aquatic Resource Monitoring at Dickinson College. Additionally, these methods have been reviewed by West Virginia DEP staff. Macroinvertebrate sampling follows protocols used by West Virginia Save Our Streams. Each of these protocols is included in the attached excerpts from the aforementioned handbook. Additionally, Barium and Strontium are analyzed in the lab using an inductively coupled plasma-atomic emission spectrometry following EPA Method 200.7. Conductivity is measured between spatially fixed chemically inert electrodes with an error not exceeding 1% or 1 umho/cm, whichever is greater following SM 2510b. Bromide is analyzed using ion chromatography following EPA Method 300.0.

Quality Control Requirements

All volunteer monitors will submit a QA/QC grab sample after their first monitoring event at each site. This sample will be analyzed for conductivity and compared against their field measurements to ensure proper usage and functionality of field meters. Additionally, all monitors will submit QA/QC samples for each of their sites twice a year, during high flow and low flow. Resulting data is sent to the volunteer as well as the project coordinator. If problems occur, the data will either be thrown out or qualified and arrangements will be made for monitor re-training. Continued technical support is provided to all monitors by the Project Coordinator. Also, training videos are available for those needing a refresher on sampling protocols.

Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Before usage, the field meter is checked to make sure it is clean and in good working order, including the batteries and electrodes. pH strips, meters and calibration solution are stored at room temperature in accordance with manufacturer suggestions. Turbidity tubes are rinsed with clean water between usages.

Instrument Calibration and Frequency

Calibration is completed before every other sampling event or at least once a month using 1413 calibration solution. After each sampling event, calibration and usage meters are rinsed with distilled water. Calibration solution is provided by the Project Coordinator and is used before the expiration date. Each volunteer maintains and calibration log for their meter. Calibration protocols are included in the attached sampling protocols.

Inspection and Acceptance Requirements for Supplies

All sampling supplies are purchased and distributed by the Project Coordinator. Field meters are ordered from Agricultural Solutions and pH strips are ordered from Fisher Scientific. Sample bottles are provided by REIC labs and remain sealed until the sample is taken. Kick nets are ordered from LaMotte. All supplies are inspected by the Project Coordinator before distribution. Gage staffs are created and calibrated by the Project Coordinator using wooden rods purchased at a hardware store. Measuring tapes are purchased from Lowe's.

Data Acquisition Requirements

TU's CSI tool, topographic maps and satellite photography are used to determine site locations. The most up-to-date Google Earth satellite photography is used but may not reflect recent changes in conditions. BMI values for macroinvertebrate assessments are calculated using SOS protocols adapted from DEP's WV Stream Condition Index (WVSCI).

Data Management

Data is collected using field data sheets provided in the volunteer manual. Once sampling is completed, monitors enter their data on CitSci.org, an online database developed by Colorado State University for citizen science projects. The database stores data, which can be view online, or downloaded as a CSV file. Monitors are trained on the usage of CitSci during their initial training and follow up refresher courses. Before usage, data downloaded from CitSci.org undergoes a QA/QC check by the Project Coordinator. Monitors also keep their own data on an Excel spreadsheet to track trends at their sites.

Assessment and Response Actions

Field conductivity measurements are audited twice yearly by completing a grab sample to be analyzed by REIC labs and comparing the field and lab measurements. If a significant difference (>20%) is detected, corrective action will take place. Corrective action may be a training refresher or equipment replacement. Field and lab activities may be reviewed by state quality assurance officers as requested.

Reports

Data will be reported to WVDEP, on at least a biannual basis, to enter or provide water quality monitoring data, for data collected in a waterbody pursuant to the implementation of a Section 319 project, into EPA's "storage and retrieval" (STORET) data system using either the Water Quality Exchange (WQX) or WQXweb.

Additionally, after three years of data has been collected (at least monthly) for at least 10 streams, the project coordinator will prepare a report, describing the baseline water quality and physical condition of each stream, changes in condition over time, and other watershed characterization information. The report will be prepared for general public understanding and will be distributed at public meetings and online.

Data Review, Validation and Verification Requirements

All field data is reviewed by the Project Coordinator to determine if it meets QAPP objectives. Lab data is reviewed by the REIC lab manager to determine if it meets their QA/QC objectives. Further review may occur as data is submitted to the West Virginia Department of Environmental Protection.

Validation and Verification Requirements

As part of the sampling protocol, any readings that are three times baseline conditions at a similar flow are reported to the Project Coordinator. Follow up sampling may occur to verify the readings. Additional QA/QC lab samples will be checked against field measurements. Before usage, data will be checked for outliers and nonsensical readings. These readings will be flagged or discarded.

Reconciliation with Data Quality Objectives

After each QA/QC sample is taken, it will be compared to field measurements to calculate the precision of field readings. Additionally, data submissions will be checked for completeness by the Project Coordinator on a rolling basis. If the cause is found to be equipment failure, calibration/maintenance techniques will be reassessed. If the problem is monitor error, refresher training will take place. Data limitations will be noted.

Appendix 6

VisitDate	Stream	Site Name	Recorder	Latitude	Longitude	Air Temperature (F)	Water Temperature (F)	Conductivity (us/cm)	Total Dissolved Solids (ppm)	Water pH	Stream cross sectional area (ft^2)	Subjective Precipitation	Precipitation Last 48 Hours	Stream Flow	Water Condition	Turbidity (NTU)	Turbidity (cm)	Comments
3/12/2016	Hawk Run	HAWKRU002	Isaac Bragunier	41.5731	-76.86997	58.6	42	55.85	35	5.5	1.485	No Rain	Light	Normal	Clear	<3	120	
4/10/2016	Hawk Run	HAWKRU002	Isaac Bragunier	41.5731	-76.86997	41.5	35.9	63.15	40	5	1.2	No Rain	Light	Normal	Clear	<3	120	2' of snow on the ground
10/2/2016	Hawk Run	HAWKRU002	Isaac Bragunier	41.5731	-76.86997	59.5	55.5	137.25	90	5.25	0.54	Mist	Moderate	Normal	Clear	<3	120	
11/13/2016	Hawk Run	HAWKRU002	Isaac Bragunier	41.5731	-76.86997	34	37	74.65	50	5	1.29	No Rain	None	Normal	Clear	<3	120	
1/1/2017	Hawk Run	HAWKRU002	Isaac Bragunier	41.5731	-76.86997	40	35	57.35	40	5	2.073	No Rain	Trace	Normal	Clear	<3	120	
3/12/2016	North Branch Rock Run	NBRORU001	Isaac Bragunier	41.56821	-76.83101	47.4	38.4	31	20	4	3.869	No Rain	Light	Normal	Clear	<3	120	
4/10/2016	North Branch Rock Run	NBRORU001	Isaac Bragunier	41.56821	-76.83101	35.4	33.2	31.4	20	4	3.588	No Rain	Light	Normal	Clear	<3	120	2' of snow on the ground
10/2/2016	North Branch Rock Run	NBRORU001	Isaac Bragunier	41.56821	-76.83101	58.8	55.7	42.05	20	4	3.16	Mist	Moderate	Normal	Clear	<3	120	
11/13/2016	North Branch Rock Run	NBRORU001	Isaac Bragunier	41.56821	-76.83101	35.4	37.7	31.9	20	4	2.46	No Rain	None	Normal	Clear	<3	120	
1/1/2017	North Branch Rock Run	NBRORU001	Isaac Bragunier	41.56821	-76.83101	33.2	33.2	33.5	20	4.25	3.015	No Rain	Trace	Normal	Clear	<3	120	
3/12/2016	South Branch Rock Run	SBRORU001	Isaac Bragunier	41.54502	-76.81256	52.3	43.3	40.7	20	4.5	3.792	No Rain	Light	Normal	Clear	<3	120	
4/10/2016	South Branch Rock Run	SBRORU001	Isaac Bragunier	41.54502	-76.81256	41.5	38.4	39.45	20	4.75	4.284	No Rain	Light	Normal	Clear	<3	120	2' of snow on the ground
10/2/2016	South Branch Rock Run	SBRORU001	Isaac Bragunier	41.54502	-76.81256	60.9	56.4	59.1	40	5.25	0.23	Mist	Moderate	Normal	Clear	<3	120	
11/13/2016	South Branch Rock Run	SBRORU001	Isaac Bragunier	41.54502	-76.81256	35.7	41.5	41.8	20	5	0.72	No Rain	None	Normal	Clear	<3	120	
1/1/2017	South Branch Rock Run	SBRORU001	Isaac Bragunier	41.54502	-76.81256	34.5	33.9	38.9	20	5	1.974	No Rain	Trace	Normal	Clear	<3	120	
3/12/2016	South Branch Rock Run	SBRORU003	Isaac Bragunier	41.54653	-76.8281	54.6	42.8	49.35	30	4.5	9.065	No Rain	Light	Normal	Clear	<3	120	
4/10/2016	South Branch Rock Run	SBRORU003	Isaac Bragunier	41.54653	-76.8281	35.7	35.7	42.55	25	4.5	8.507	No Rain	Light	Normal	Clear	<3	120	2' of snow on the ground
10/2/2016	South Branch Rock Run	SBRORU003	Isaac Bragunier	41.54653	-76.8281	59.1	55.9	62.55	40	5	4.08	Mist	Moderate	Normal	Clear	<3	120	
11/13/2016	South Branch Rock Run	SBRORU003	Isaac Bragunier	41.54653	-76.8281	39.7	38.6	54.15	30	5	14.41	No Rain	None	Normal	Clear	<3	120	Flood erosion changed stream bed
1/1/2017	South Branch Rock Run	SBRORU003	Isaac Bragunier	41.54653	-76.8281	32	33.4	50.3	30	5	18.425	No Rain	Trace	Normal	Clear	<3	120	