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Acid Mine Drainage in the Shamokin Creek Watershed: A Spatial Analysis of Economic and Environmental Consequences of Coal Mining

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Executive Summary

The Shamokin Creek Watershed is located in the anthracite region of Pennsylvania and experiences significant consequences from the rise and fall of coal mining in the area. The economy and environment saw downturns in the region, with the latter specifically seen through acid mine drainage: a chemical reaction that occurs between water and mining waste that can leak into nearby waterways. This has negatively impacted the Shamokin Creek and its surrounding tributaries, and the mining history has residual consequences on the socioeconomic status of the area as well. Through the Katherine Mabis McKenna Foundation Summer Environmental Internship and Bucknell's Center for Sustainability & the Environment, a partnership with the Shamokin Creek Restoration Alliance (SCRA) was established to use GIS to visualize and analyze socioeconomic data, potential mining factors, and water chemistry data related to acid mine drainage and mining legacy in the Shamokin Creek watershed.

Data collection and visualization of socioeconomic data demonstrates the areas near AMD discharge points to have markedly higher rates of household poverty, vacancy, and disability while having lower median incomes and education rates compared to state averages and even nearby towns.

Mining factors that could influence acid mine drainage were mapped including the general mining region, mine slopes, drifts, and shafts, mine spoils, and boreholes. These were presented along with nearby streams and showed hundreds of locations where water could be entering mines to react with mine waste and be discharged as acid mine drainage into the Shamokin Creek watershed.

Mapped water chemistry data at discharge locations and stream locations identifies the chemical composition of each discharge and how it has impacted the creeks and streams that make up the watershed. AMD discharge chemistry can guide optimal treatment processes. Various stream samples in the maps are not compliant with PA's water quality standards for pH, iron concentration, and aluminum concentrations.

Introduction

Since the industrial revolution, fossil fuel mining has been a prominent force impacting the economy, quality of life, and environment of the communities attached to these industries. One of the most prominent mining regions in the United States is the cultural region of Appalachia, encompassing parts of Alabama, Georgia, Kentucky, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, and Virginia, as well as all of West Virginia (arc.gov). What was once a land formation that limited transportation before industrialization became a central hub for energy as technological advancements and evolving lifestyles required increasing amounts of fuel to power it. The Appalachian mountains were cherished for their rich mineral deposits, and thus began the extraction processes that would dictate the economy and environment of the region for the following centuries (Morrone et al 2011).

The value placed in resources underground arguably exceeded that of the lives and communities above the surface as mining endangered human lives, polluted ecosystems and atmospheres, and created unsustainable lifestyles driven by an industry founded on a limited supply of a valuable resource. Boomtowns were created by the growing industry in the 18th through 20th centuries, but after resource exhaustion, these previously lively towns seemingly vanished with environmental degradation and vacated buildings as the lasting traces of the prosperous coal towns that once existed (White 2013). These environmental consequences impact communities dealing with the loss of the mining industry and create an issue of environmental justice.

Studies have shown statistically significant relationships between one's residence in a coal-mining county and poor self-reported health, relationships that only grow more conclusive when specifying residence in an Appalachian coal-mining county. Subjects reported more days of poor physical/mental health and overall worse health-related quality of life according to a CDC standard questionnaire (Zullig 2010). In addition, these counties in Appalachia have historically had higher poverty rates, lower per capita incomes, and less education compared to national averages (arc.gov).

Standards of environmental justice portray the need for “equitable distribution of environments among peoples in terms of access to and use of specific natural resources in defined geographical areas, and the impacts of particular social practices and environmental hazards on specific populations” (White 2013). In the Appalachian region, these have clearly been sacrificed during extraction processes that have a broad benefit in energy production, but largely localized costs to the surrounding environments mostly consisting of poor, disadvantaged residents (White 2013). Acid mine drainage (AMD) is one of those environmental impacts that continues to impact human and environmental communities long after mining operations have ceased. The fluctuating economy, environmental degradation, and corresponding consequences to health and quality of life dictate the legacy that mining has had in Appalachia.

The City of Shamokin in particular is one such place in the region that has endured the highs and lows of coal mining. Once a prosperous mining town, Shamokin along with the adjacent Coal Township, experienced economic growth from the industries of coal mines and silk mills, however this did not last. The Great Depression, market shifts to oil and cheaper synthetic textiles, and the loss of Shamokin’s two railroads led to a decrease in area population from 50,000 at its peak to around 18,000 now (Shamokin website, n.d.). The City of Shamokin itself is home to only around 7,000 now, down from more than 20,000 residents a century ago. This decline has been a century long process, but an impassioned and resilient community has made inroads in revitalizing their economy and environment in wake of Shamokin’s troubled past.

The series of maps in this report supports the work of the Shamokin Creek Restoration Alliance (SCRA) in demonstrating the severe issue of AMD in the Shamokin Creek watershed by identifying where discharge sites are located, the characteristics of the discharge and impaired water, the demographics of the region, and other relevant data. These depict how an already disadvantaged community has to deal with the consequences of environmental injustice through acid mine drainage, while providing necessary information for reference when evaluating treatment options, their viability, and their priority in protecting the Shamokin Creek watershed.

Acid Mine Drainage

One consequence of mining that remains a severe issue in the Shamokin Creek watershed is that of acid mine drainage (AMD). AMD is a chemical process that occurs when water running through underground mine shafts, mine waste dumps, tailings, open pits, and/or ore stockpiles interacts with pyrite and oxygen to form ferrous oxide and sulfuric acid (Moeng 2017):

$$4FeS_2(s)+15O_2(aq)+14H_2O(aq) \rightarrow 8H_2SO_4(aq)+4Fe(OH)_3(s)$$

Ferrous oxide is commonly referred to as “yellow boy” for its distinguishable color. Sulfuric acid decreases the pH of the water, making it highly acidic. pH is measured on a logarithmic scale, so with 7 regarded to be neutral and the general estimation of water, a pH level of 6 would be 10 times more acidic, and a pH level of 5 would be 100 times more acidic than unimpaired water. When pH levels decrease to below 5.5, severe consequences for biotic communities ensue, effectively making the water uninhabitable for particular species such as trout. In addition, low pH levels can inhibit plants from receiving necessary nutrients by immobilizing nitrogen, phosphorus, and potassium while creating deficient levels of calcium and magnesium (Rodriguez-Galan 2019).

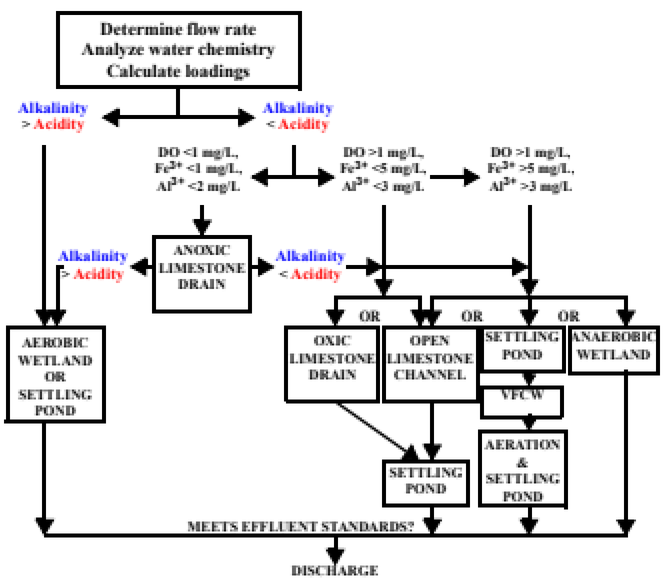
Instead, it increases the presence of dissolved heavy metals including iron, aluminum, manganese, and sulfate which can be severely detrimental to water quality (Moeng 2017, Rodriguez-Galan 2019). The iron in yellowboy settles on stream bottoms and smothers aquatic plant and animal life. Aluminum can be seen running white in the stream as a toxic compound referred to as gibbsite. This stunts root development in plants, prevents absorption of water and nutrients, and creates nutrient deficient aquatic plant life. Manganese also disturbs growth processes in the aerial parts of plants, stunting and discoloring the plant while inhibiting yields (AMRClearinghouse, n.d.).

In addition to disrupting aquatic life, AMD also disrupts human activity. It has clear detrimental effects on water’s use in agriculture, industry, recreation, and aesthetics (AMRClearinghouse, n.d.). Over two thirds of U.S. residents participate in water related activities each year, including swimming, fishing, and boating (The Social Cost of

Water Pollution, n.d.). These activities are impeded by acidic, orange-tinted streams that may not even be able to support fish. Infrastructure is a significant concern as well, with AMD proving to have corrosive characteristics especially for concrete and steel (Ekolu 2014). The added fact that this pollution occurs in economically depressed communities adds to a sense of hopelessness with such a visibly impaired environment (AMRClearinghouse).

The abandoned mines in consideration can produce this highly acidic discharge for more than 100 years after they are decommissioned, with the highest risk of water contamination from coal mining during the period after operation is halted (Moeng 2017). Treatment for these discharge locations and the AMD exuding from them must be a priority in restoring the environment, and revitalizing the communities that are subject to this pollution.

AMD treatments can be either active or passive systems, with various strategies to achieve desired water quality. Active treatment is a persistent process that can utilize injection of alkaline reagents, adsorption, ion exchange, or membrane systems (Rodriguez-Galan et al 2019). Passive treatment depends on a more natural process of neutralizing acidity and precipitating metals that require maintenance, but nonconstant work (Skousen et al 2017). In severe cases, active treatment is needed for optimal remediation of AMD; however, it requires continual expenses and often electrical power. Passive treatment systems include biological treatments such as vertical flow wetlands, aerobic and anaerobic wetlands, removal beds, and bioreactors, or they also include geochemical processes like anoxic limestone drains, limestone channels, limestone or steel slag leach beds, diversion wells, and more. Each system has advantages and disadvantages depending on topography, water flow rate, and discharge chemical composition, and other site characteristics (Skousen et al 2017).



Source: Cravotta and Kirby 2004

Methodology and Objectives

GIS (Geographic Information System) is a software used to spatially visualize location-based data. In this case, GIS was used to display data that orientates the viewer to the Shamokin Creek watershed, explain the overlapping socioeconomic and environmental issues, and provide information that could be useful in planning treatment for AMD. Water quality data was retrieved from a USGS report about the Shamokin Creek Watershed by Cravotta and Kirby (2004), socioeconomic data was provided by the U.S. Census, other watershed and mining related layers came from PASDA and Carl Kirby PhD, qualitative assessment indexes were taken from Kimball & Associates report (2004) on the watershed, and lastly landowner data was provided by Northumberland County's GIS Department.

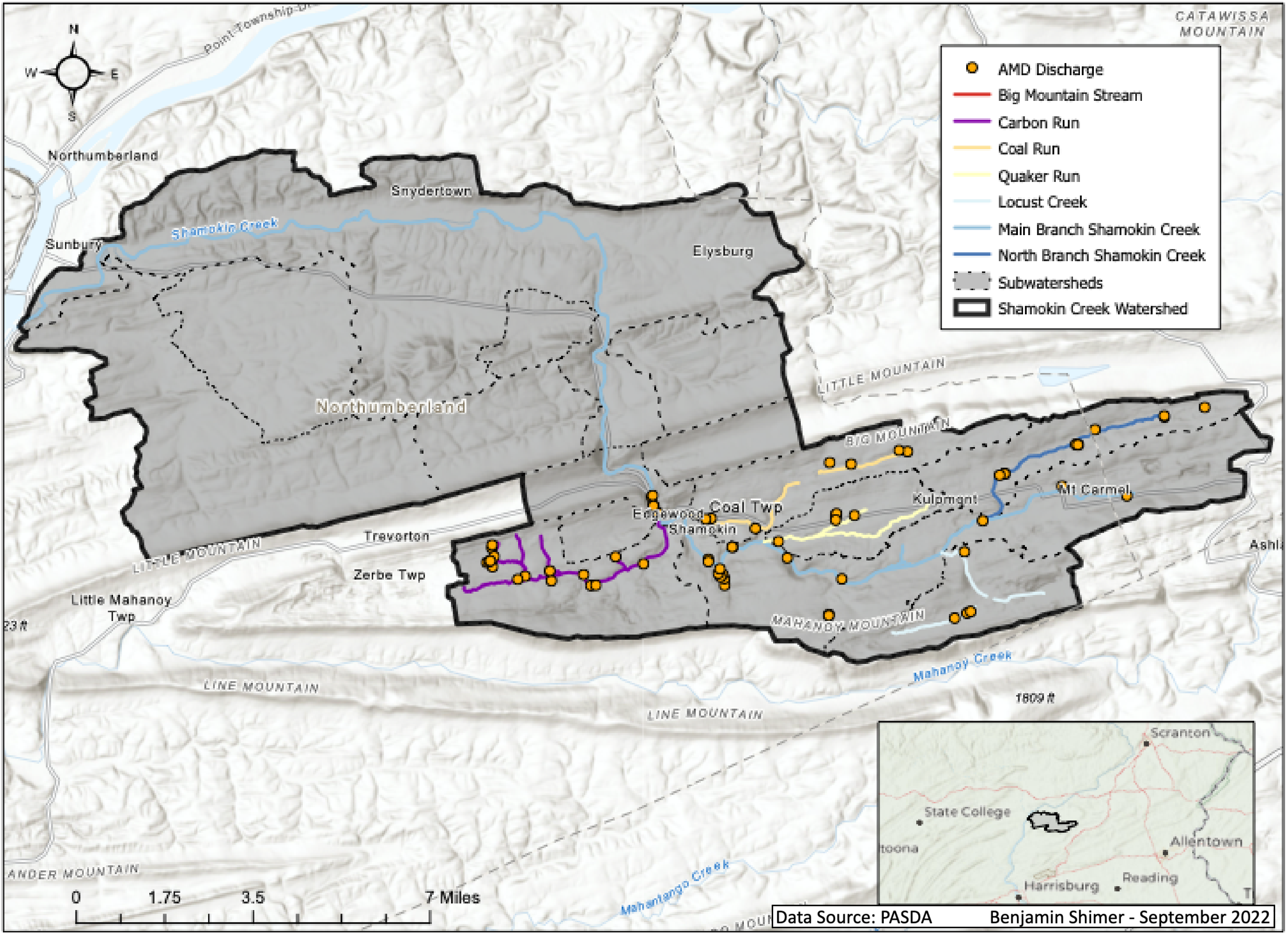
To visualize the demographics, census data at a block group level was spatially joined with shape files and stratified through natural breaks in the data. Each stratification was represented by a different color to highlight where and to what extent the socioeconomic stresses lie within the Shamokin Creek watershed. Stream and AMD discharge data was taken from prior reports and appended to existing layers with their coordinates and location identified. The size and colors of these symbols were adjusted to quickly display the intensity of metal loadings, acidity, or flow rate at each location. As a simpler watershed overview, the assessment indexes were also mapped to show the discharges that had greatest community interest, watershed impact, and treatment feasibility. Waterways were also mapped over details of the mining region which showed possible entries of water into mines, where the reaction creating acid mine drainage occurs. In addition, the underground mine pools were shown under a layer of the streams and runs in the watershed to signal the presence of mining underlying the entire lower section of the Shamokin Creek watershed.

These maps serve to demonstrate the environmental injustices endured by coal-mining communities who lose the economic benefits of the industry but maintain the environmental consequences. Visualizing this data and putting these maps together will support the Shamokin Creek Restoration Alliance's effort to mitigate the impacts of acid mine drainage in their community. The spatial analysis will potentially aid the group in grant funding applications and/or through their website to spread awareness of acid mine drainage in the area.

Watershed Overview

This map serves to orient one with the location of Shamokin Creek and its corresponding watershed while identifying the creeks and runs that contribute to it. The acid mine drainage discharge points are symbolized by orange dots and are included to give a broad view of the quantity and location of these problem areas. The locator map in the bottom right corner shows where this is in relation to other well-known areas in Pennsylvania.

Shamokin Creek Watershed and AMD Overview



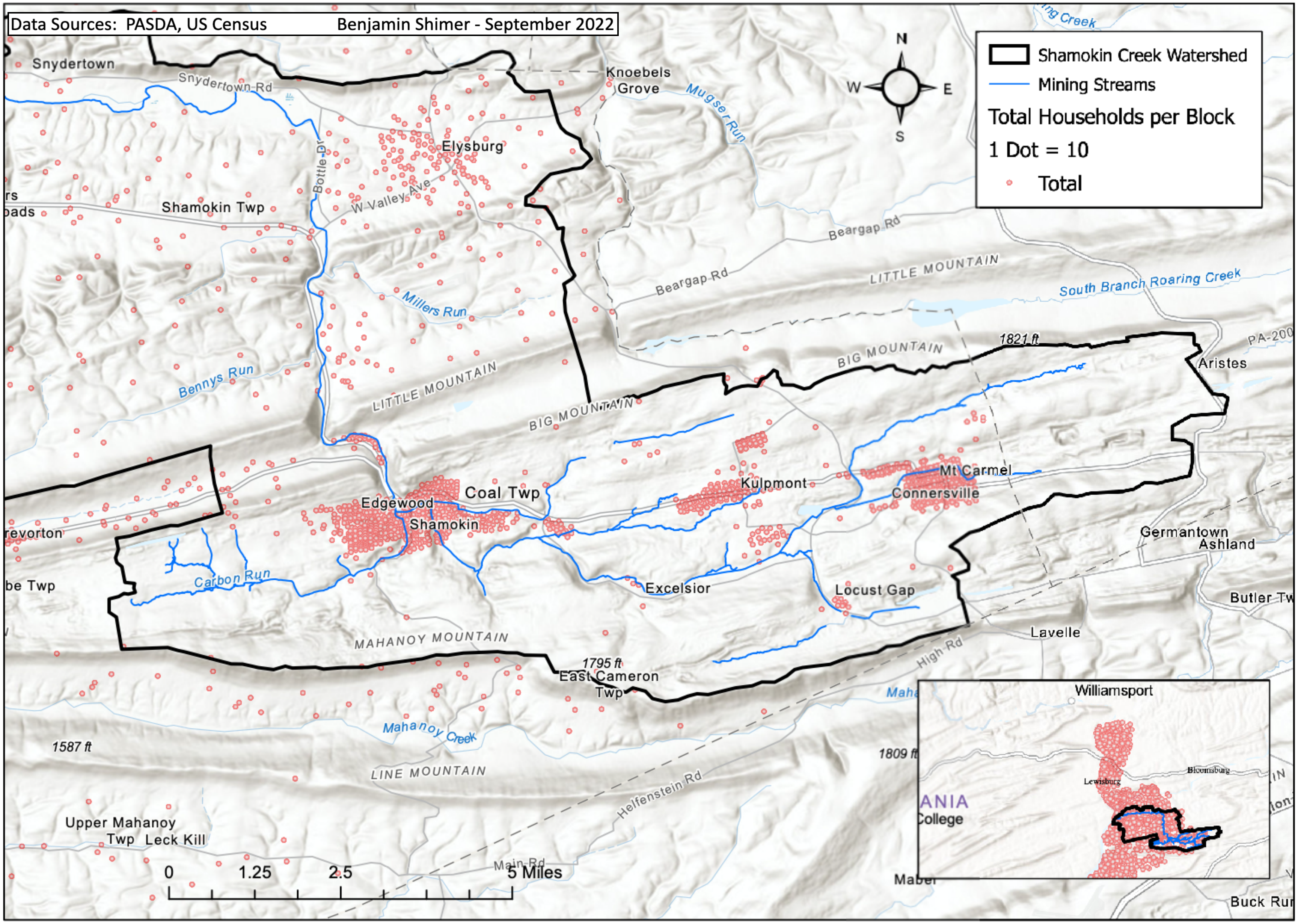
Socioeconomic Maps

Highlighting the socioeconomic data in the impacted mining region is important in understanding the link between the environmental and economic consequences from abandoned mining industries in the Shamokin Creek watershed. Measures of disability, income, poverty, education, and vacancies describe how the economy of a once prosperous mining town has fallen and impacted the individuals that call this region their home.
The AMD impaired area in the lower Shamokin Creek watershed has visible signs of a community enduring the economic consequences of coal mining boomtowns that have moved on due to market shifts and resource exhaustion. With few resources available, it is difficult for a community to remediate an issue as large as acid mine drainage is in this area, and the environmental degradation combines with economic downturn to create unjust difficulties for those not responsible for the industry that created them. In the following maps, socioeconomic data is represented at census block or block group samples. Blocks are identified by visible or invisible barriers and block groups represent all blocks sharing the same first digit in the four digit identification within a census tract.

Population Density

As a precursor for the rest of the maps due to their symbology, it is important to highlight the population density of the target area within the Shamokin Creek watershed to signify which areas will be of significance in the maps to come. Each red dot represents 10 households with this data collected by census block, showing the bulk of the population is in the towns of Shamokin, Kulpmont, and Mount Carmel. Few people live away from the more urbanized areas until you travel northwest in the watershed.

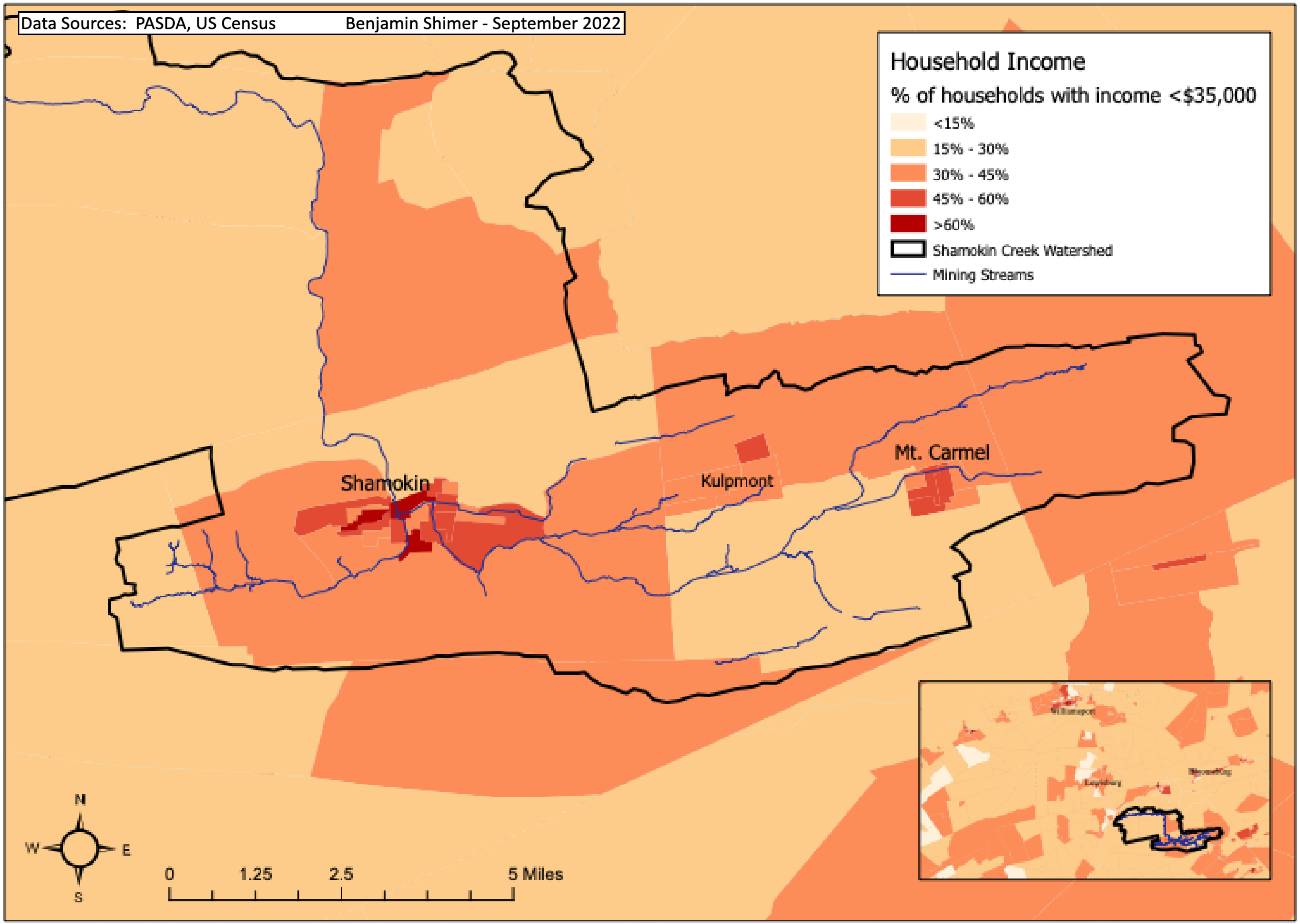
Household Density in the Lower Shamokin Creek Watershed by Block



Income

According to Statista's reports on median household income, nationally 26.2% of households earn less than $35,000 annually. The spatial analysis on median household income in the Shamokin Creek watershed shows much of the AMD impacted area to have low income. A lot of the populated region has income below that mark at rates greater than 30%. Shamokin specifically has multiple block groups where greater than 60% of households have income less than $35,000. The census also reports Shamokin to have a median income of $29,578 which is under half of the $63,627 estimated median listed for the entire state. Returning to the map, the towns in the northwestern section of the watershed absent of AMD discharge have a range of 15% - 30% of households under the $35,000 benchmark in comparison.

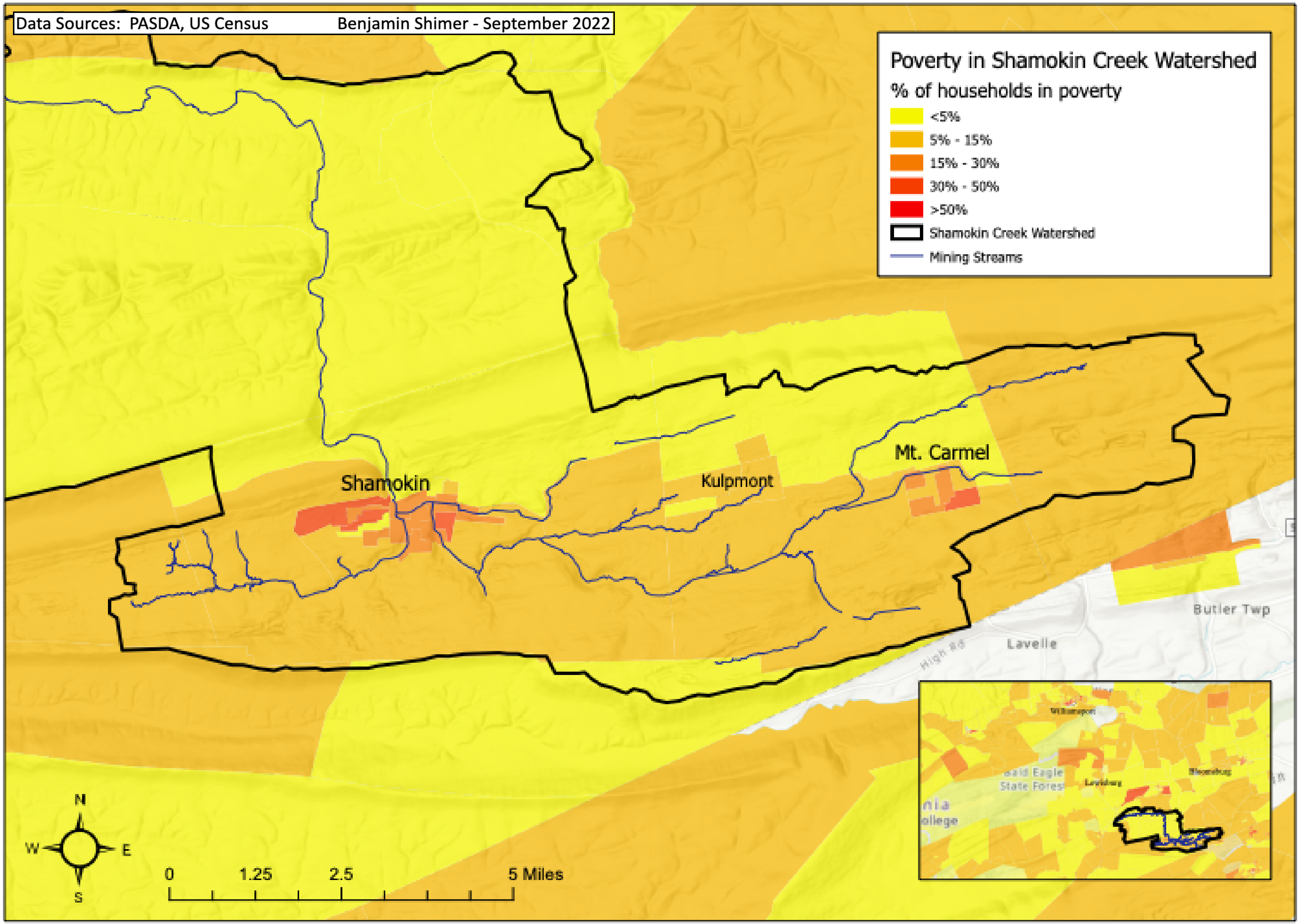
Household Income in the Lower Shamokin Creek Watershed by Block Group



Poverty

Poverty rates in Shamokin and Mount Carmel, both dealing with the unresolved consequences of abandoned mines, climb to the range of 30% - 50% in particular block groups. State estimates for poverty rates are about 10.9%. Census data on Shamokin calculates a 32.9% poverty rate, and for Mount Carmel this number is 19.8%. These high rates of poverty are a testament to the economic downturn that has occurred in the previous decades as coal mining began to leave the area while leaving environmental damage behind.

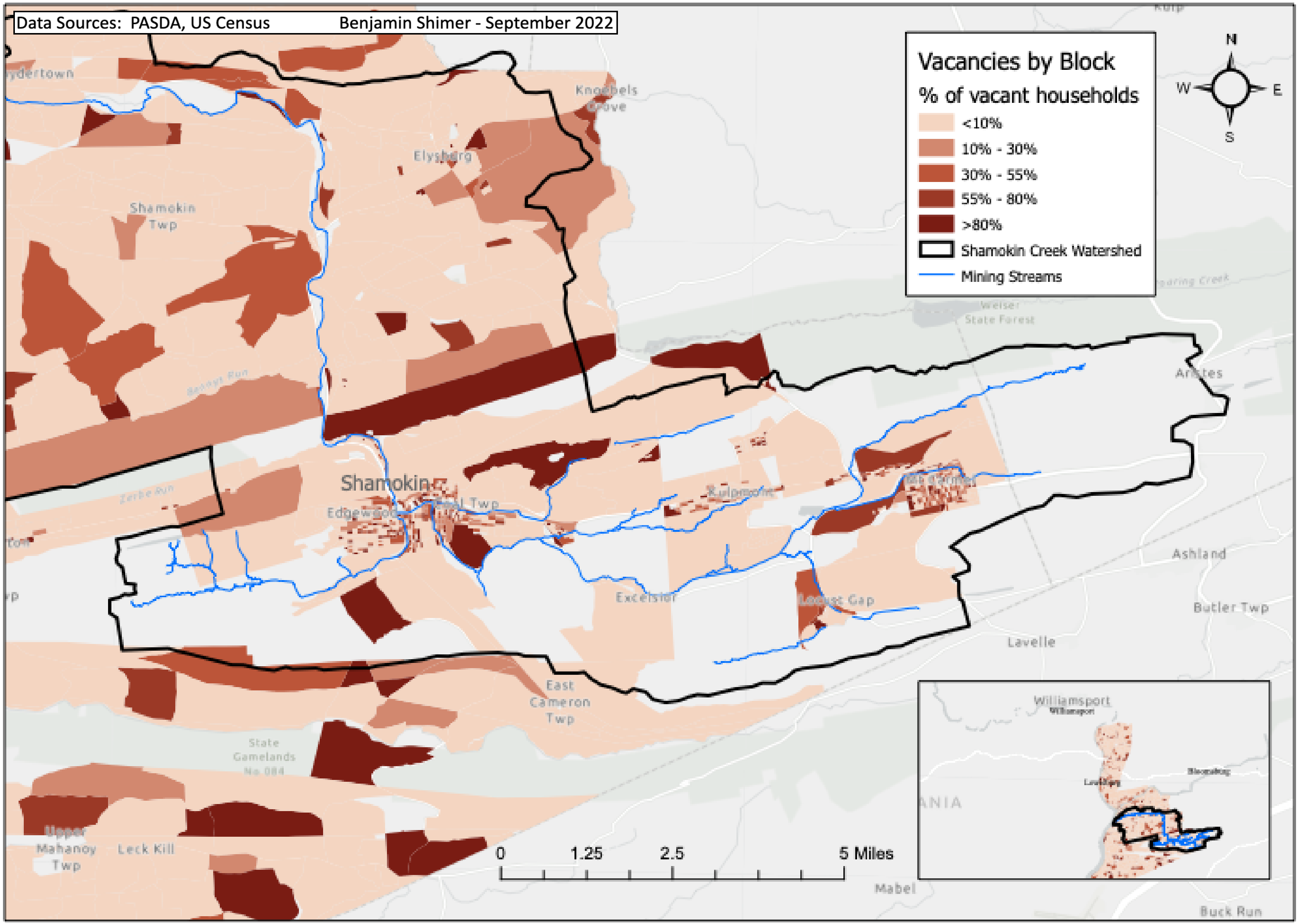
Poverty Rate in the Lower Shamokin Creek Watershed by Block Group



Vacancies

The data for vacancies was collected for Northumberland County by block level for greater specificity than the previous socioeconomic maps, due to its availability at this more refined level. Sections without color lack data due to an absence of households in the area. When looking at the blocks there are sporadic vacancy rates that include certain blocks with greater than 80% vacancy in the more urban areas of Shamokin, Kulpmont, and Mount Carmel. This signifies not only the lack of economic activity and opportunity nearby, but also unappealing living conditions that could be attributed to the imapired stream that flows brown and orange in the southeastern section of the Shamokin Creek watershed. Median value of owner-occupied housing units is between $40,000 and $45,000 in Shamokin and Mt. Carmel according to the US Census. This shows significant depreciation of housing value compared to the rest of the state in which the median property value is $187,500.

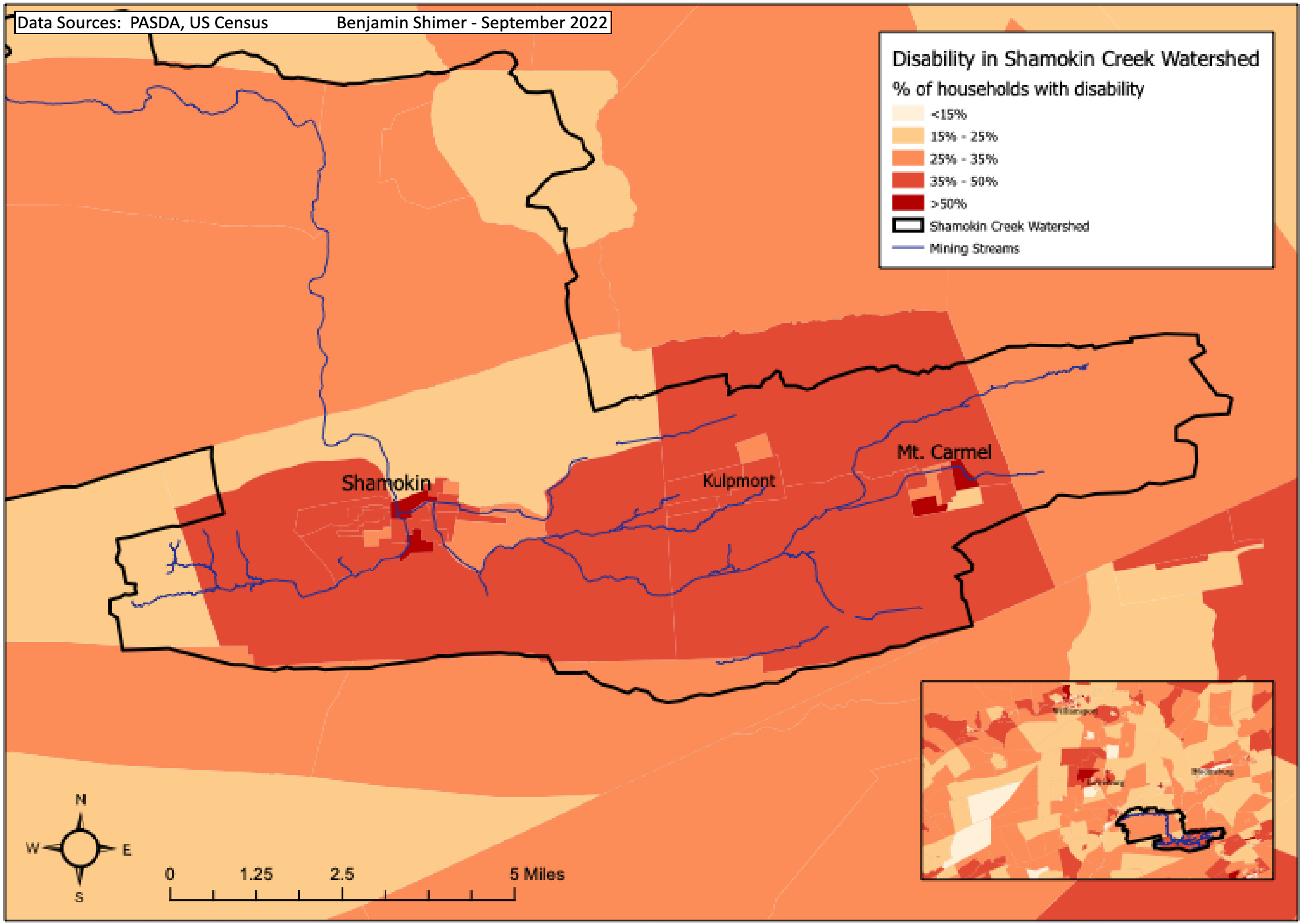
Vacancies in the Lower Shamokin Creek Watershed by Block



Disability

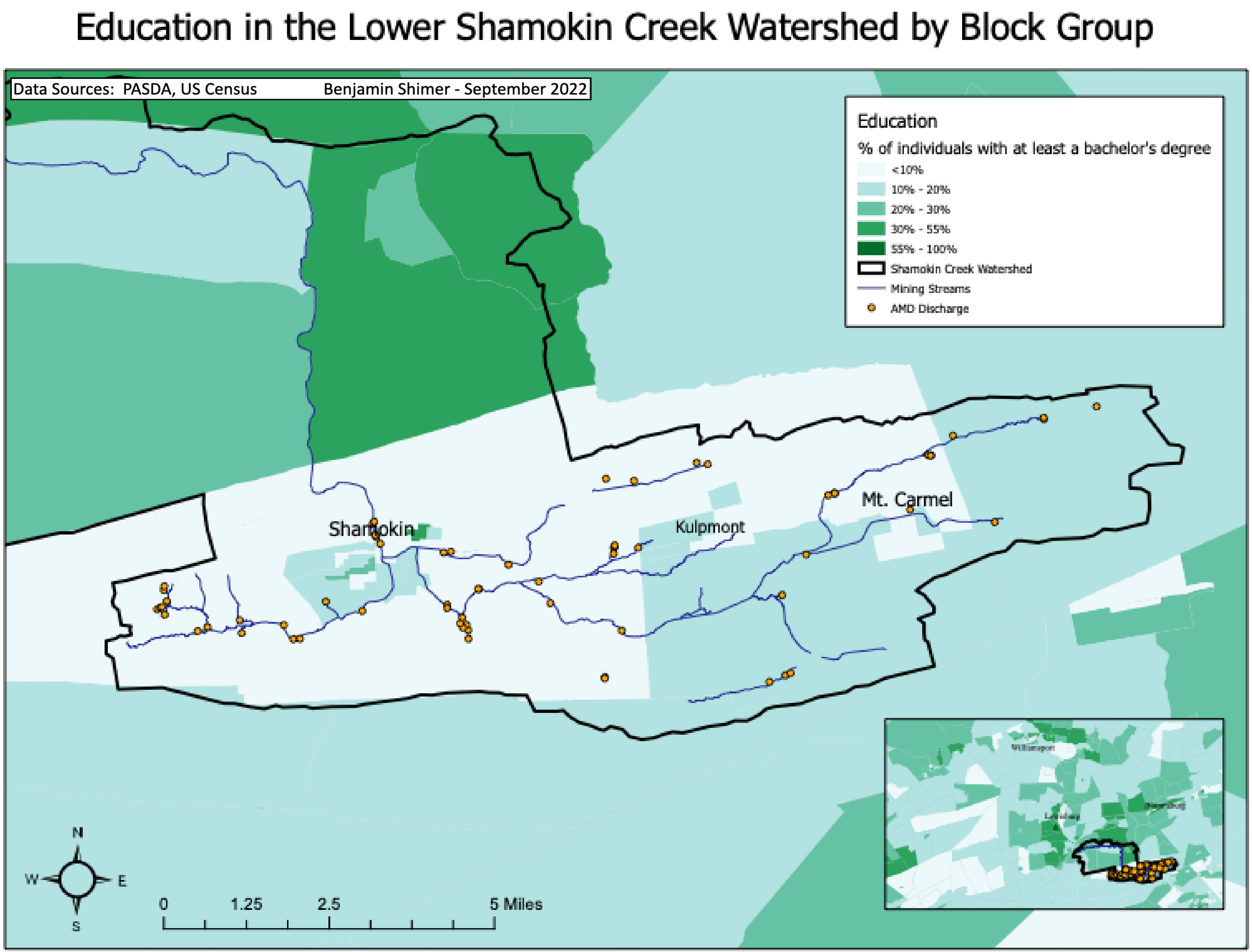
Much of the southeastern Shamokin Creek watershed have household disability rates between 35% and 50%, with some block groups in the stratification just above or below that. Per the U.S census, the City of Shamokin has disability rates that double the Pennsylvania average and are significantly higher in the AMD impacted southeastern region than the less-pollution impacted and wealthier northwestern region of the watershed which is predominantly between 25% and 35% for each block group.

Disability in the Lower Shamokin Creek Watershed by Block Group



Education

Looking at the map, levels of higher education outside of high school are reduced in the southeastern region of the Shamokin Creek watershed. Only two block groups signify an area where greater than 20% of residents have obtained a bachelor's degree or further education. Instead, this number is below 10% in a significant portion of the region. The statewide average according to the PA census is 32.3% showing the disparity between the Shamokin Creek Watershed and the entire state.


Education in the Lower Shamokin Creek Watershed by Block Group
Data Sources: PASDA, US Census
Benjamin Shimer - September 2022
Education
% of individuals with at least a bachelor's degree
<10%
10% - 20%
20% - 30%
30% - 55%
55% - 100%
Shamokin Creek Watershed
Mining Streams
AMD Discharge
Shamokin
Kulpmont
Mt. Carmel
N
W
E
S
0
1.25
2.5
5 Miles

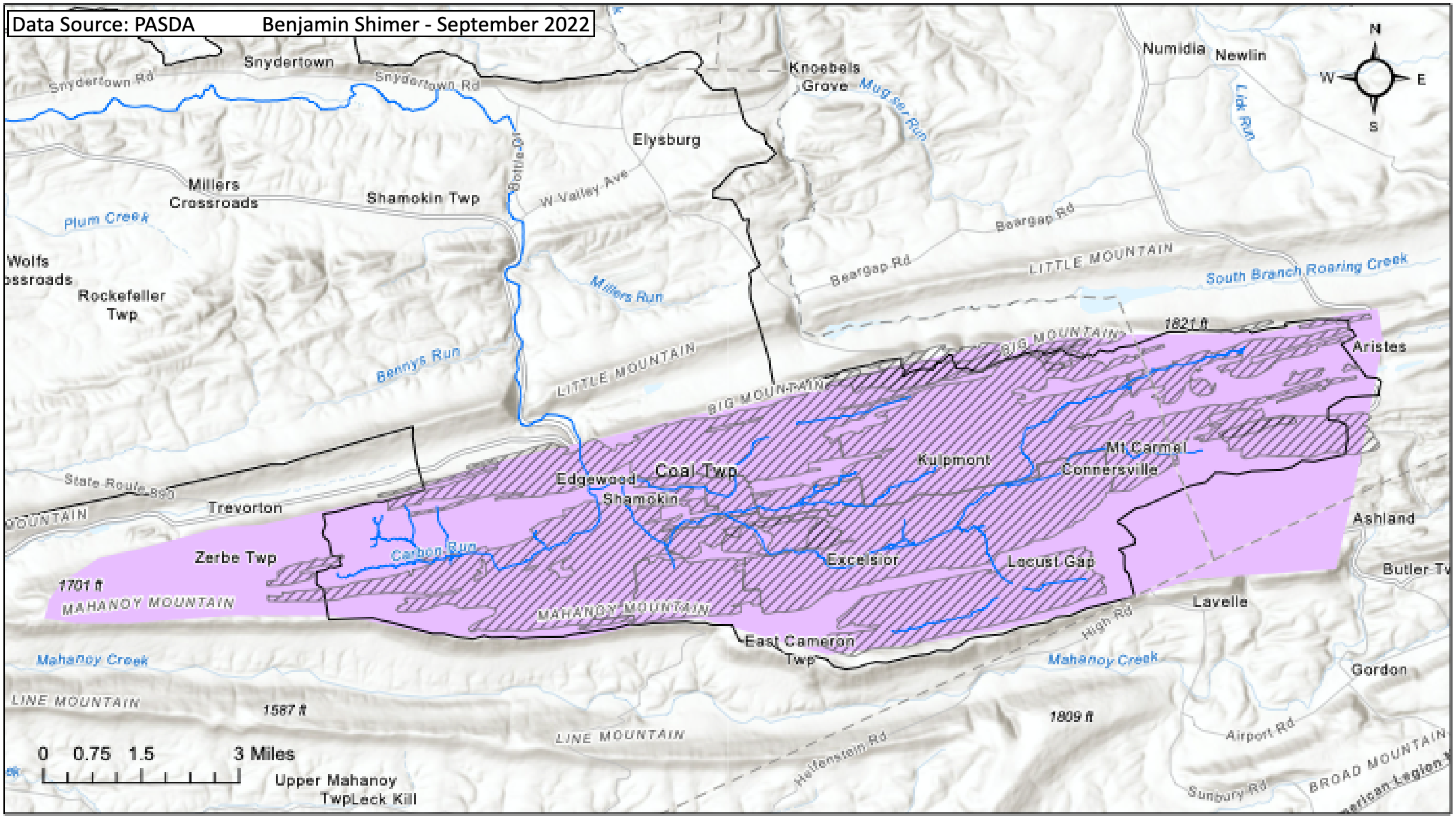
Mining Factors

Coal mining underlies the socioeconomic and environmental consequences experienced in the Shamokin Creek watershed. Data was retrieved from EPCAMR and Dr. Carl Kirby to visualize some of the significant mining factors that could contribute to the acid mine drainage impairing the waterways. Acid mine drainage can emanate from various sources including mine slopes, drifts, and shafts, underground mine spoils, and boreholes. These were plotted in relation to impacted waterways (labeled mining streams in the legend) to show potential sources of mine entry and where preventative measures may be able to take place to remediate acid mine drainage in the area.

A more general measure of the mining region serves as a pretense to the economic and environmental disparities that occur in the mined area of the watershed in comparison to the northwestern portion that has better indicators of socioeconomic opportunity and an absence of AMD discharges.

This first map acts to locate the extent of the mining region in relation to the Shamokin Creek watershed. It stretches across the area plagued by acid mine drainage as seen in the overview. The streams run over many mine pools as they underlie nearly the entire lower region of the Shamokin Creek watershed.

Mining Region and Mine Pools in Shamokin Creek Watershed



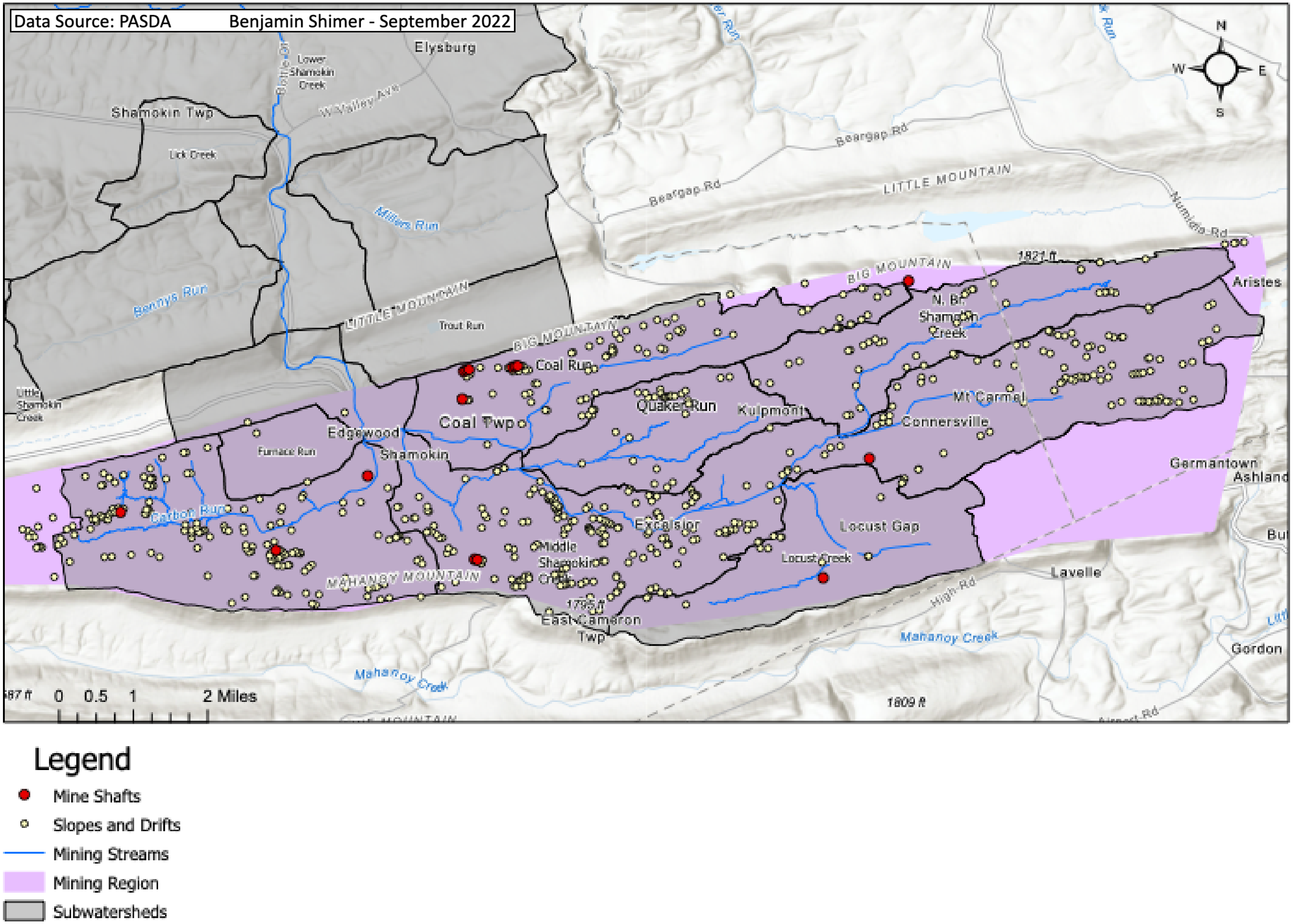
Legend

- Mining Streams
- Shamokin Creek Watershed
- Mining Region
- Mine Pools

Mine Slopes, Drifts, and Shafts

Mine slopes, drifts, and shafts are important features to map as they are locations where water may seep into mines creating the issues with acid mine drainage experienced in the watershed. These are all different types of mine entrances dependent on what kind of entry point was used. Drifts on this map represent horizontal entries into mines, but by definition do not have to intersect with ground level. Shafts are vertical entries into mines where one is sunk into the mining pits below, and slopes represent a diagonal and sloping entry into a mine (Thrush 2017). A total of 660 slopes and drifts alone were identified in the watershed through this map layer, with many mine shafts located in the region in addition.

Mine Shafts, Slopes, and Drifts in the Shamokin Creek Watershed

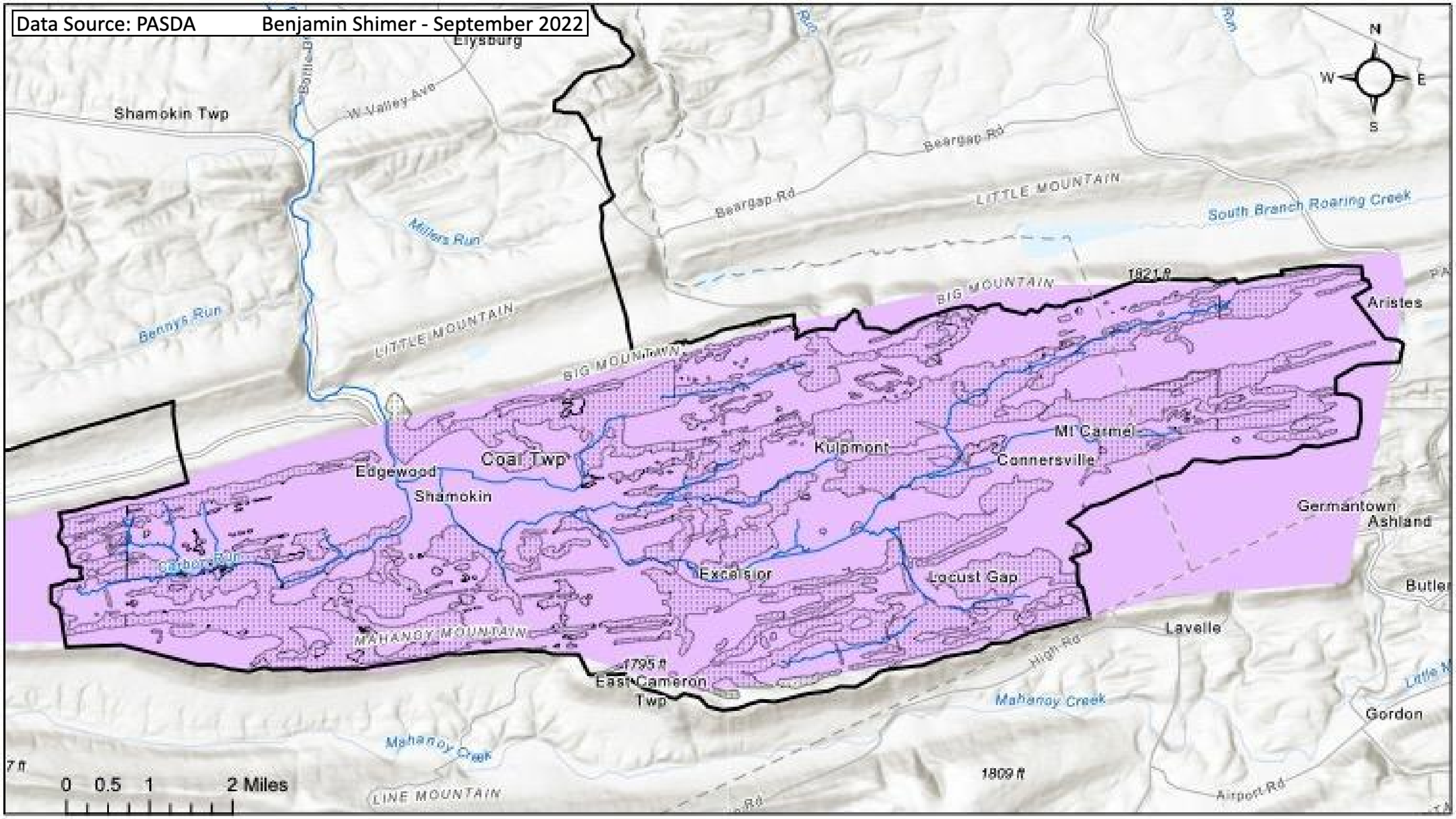


Mine Spoils

Mine spoils are another important layer as water interacting with these helps to create the acid mine drainage that gets discharged into the watershed. Spoils are the waste generated by removing the layers of earth that prevent easy access to the desired mineral, in this case coal. The interaction of water and these waste layers can be a source of AMD problems in the watershed.

Metadata from the original source in PASDA by Dr. Carl Kirby describes the mine spoils map layer as: "Polygon shapefile of mine spoils within the Shamokin Creek, PA watershed. Spoils piles are waste rock mixed with coal from surface or deep mining. Acidic discharges often emanate from these piles due to infiltration of water and weathering processes."

Mine Spoils in the Shamokin Creek Watershed



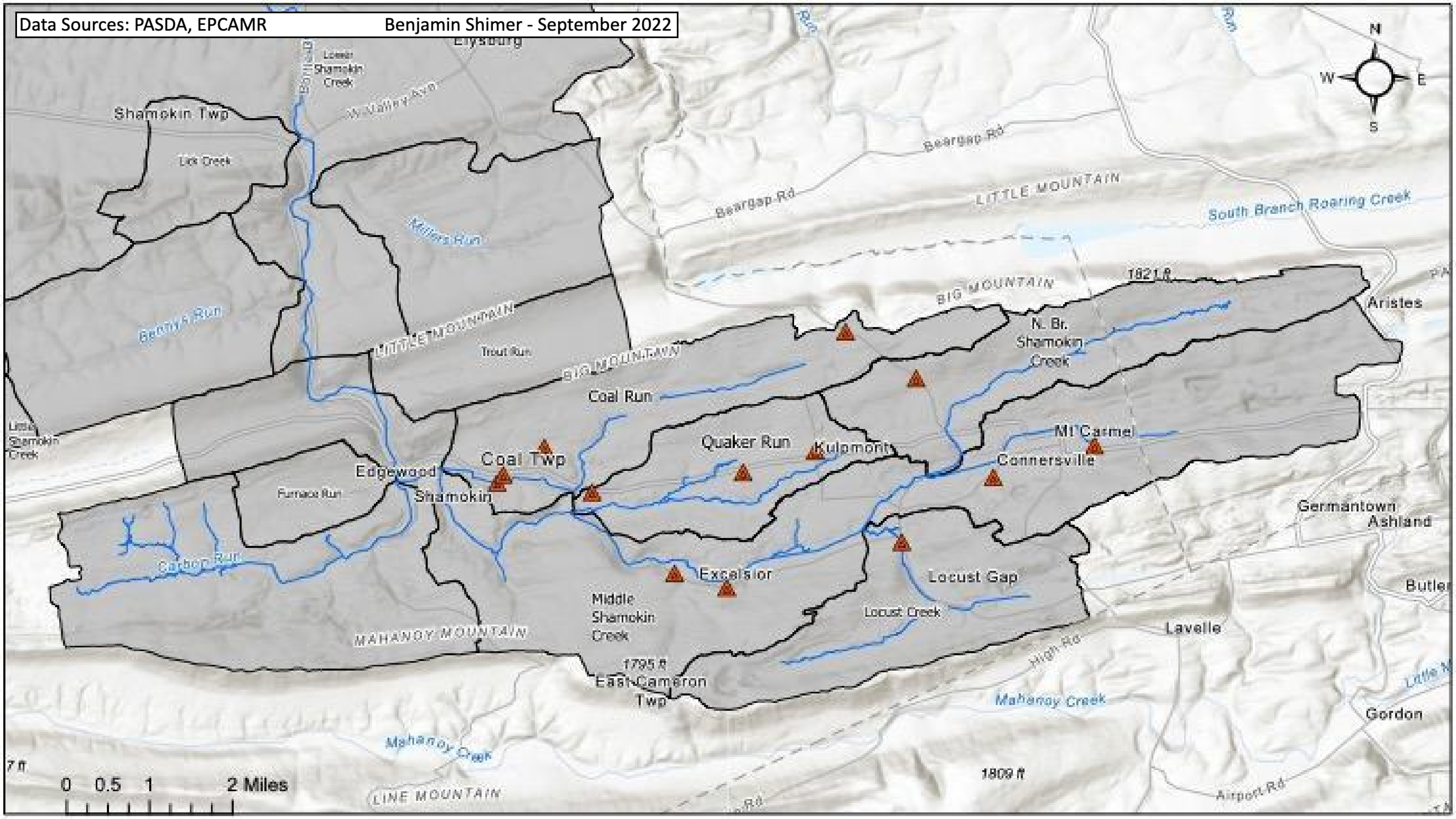
Legend

- Mining Streams
- Shamokin Creek Watershed
- Mining Region
- Mine Spoils

Boreholes

In addition to the previous hazards, boreholes were identified in the Shamokin Creek watershed and plotted on maps to be easily locatable. They can have various purposes, including mineral extraction and water monitoring. A total of 13 were identified and plotted in the following map of the Shamokin Creek watershed to identify further potential locations for emmanation of acid mine drainage. In addition, these can be used for significant treatment sites by discharging polluted water into treatment facilities.

Boreholes in the Shamokin Creek Watershed



Legend

- Mining Streams
- Subwatersheds
- Boreholes

Water Quality

Water quality data for the maps were provided through Cravotta and Kirby's 2004-05 USGS report on the Shamokin Creek watershed, 2019-2020 US Census Data from the American Community Survey and existing map layers from Dr. Carl Kirby, PASDA, and Northumberland County were also used in this work.

Details of the flow rate and water chemistry for each acid mine drainage discharge is important to identify which locations have the greatest impact on the watershed and which treatments are most applicable for each location.

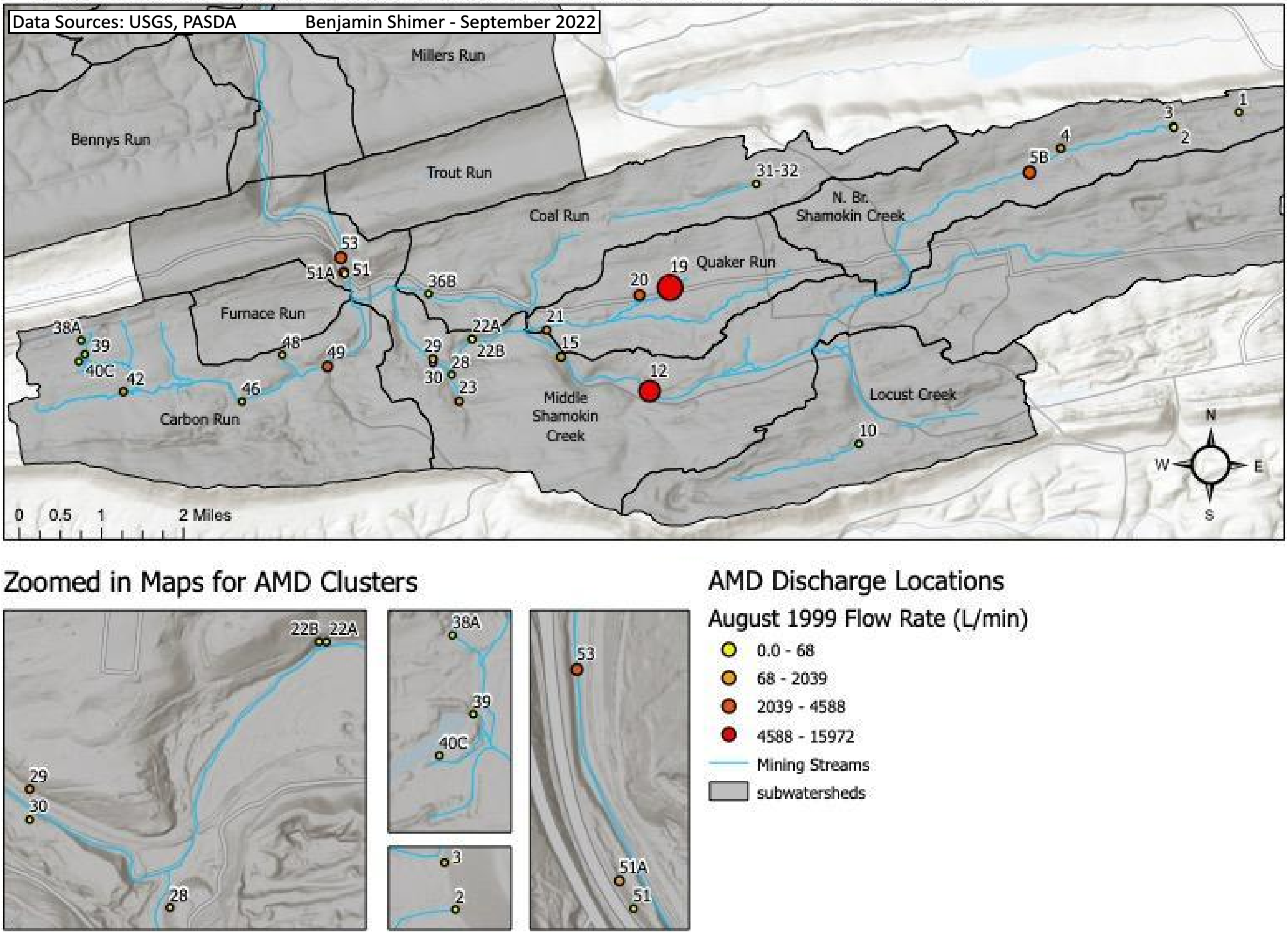
Maps were constructed from Cravotta and Kirby's assessment of the Shamokin Creek watershed based on a treatment flow chart provided in their publication for the following information: pH, iron concentration, aluminum concentration, and dissolved oxygen along with flow rate. This data was accumulated for high and low base flows to show the possible variety depending on external conditions. Despite 66 discharges being identified in the influential 1972 Scarlift report, not all were located in the USGS report and water quality data exists for 44 discharges during high baseflow, and 29 discharges during low baseflow. The same was done for stream locations sampled in the USGS report with 10 locations analyzed during low baseflow and 15 analyzed during high baseflow.

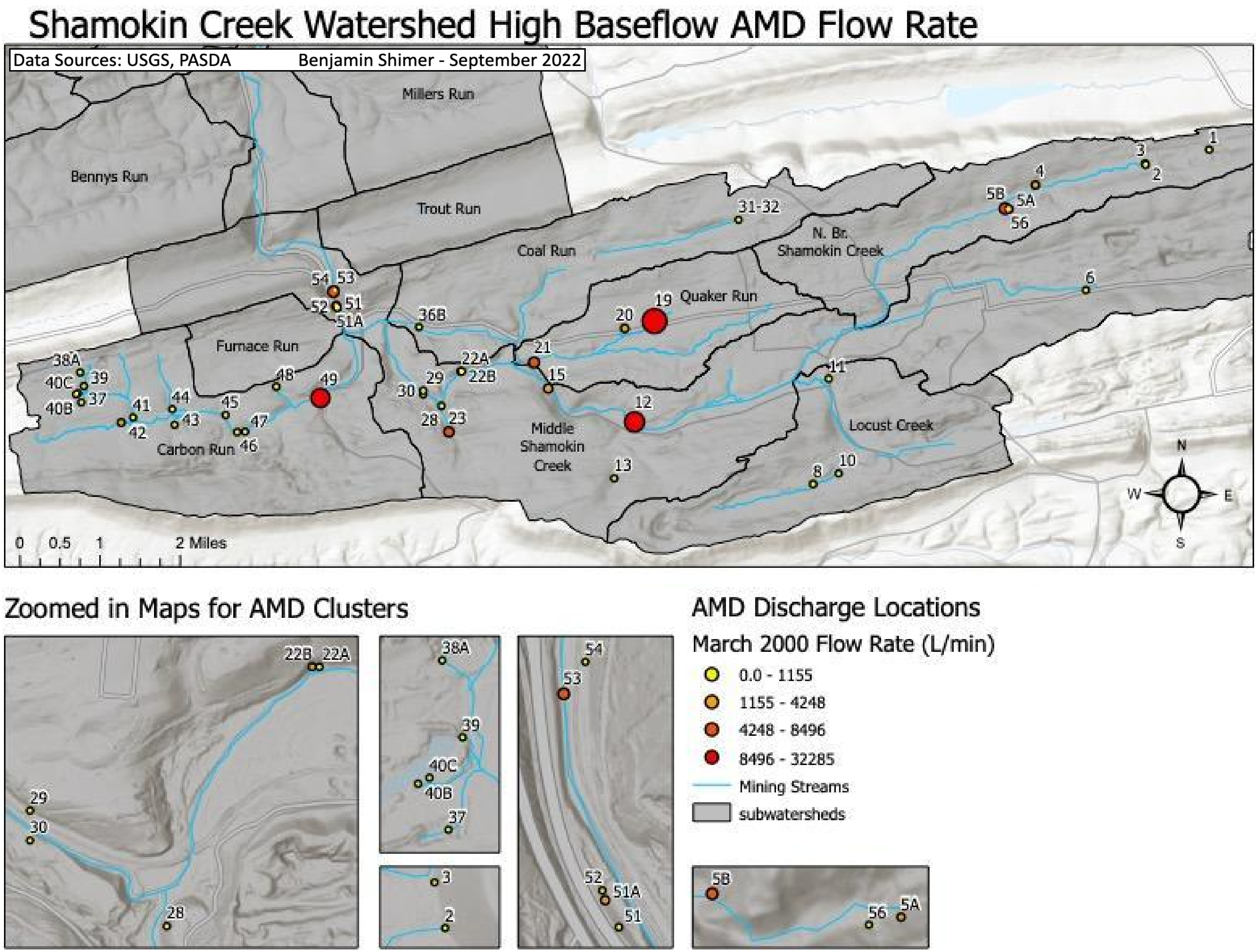
In addition, qualitative assessments provided through a study by Kimball & Associates (2004) were mapped for each discharge studied in their report. Their work ranked the community interest, impact, loading, and feasibility of treatment for each problem area, while providing a summative final rank for each location as well. Of the 66 discharge sites, a total of 57 were accounted for in this study and were mapped based on the criteria reported by the Kimball report.

Flow Rate

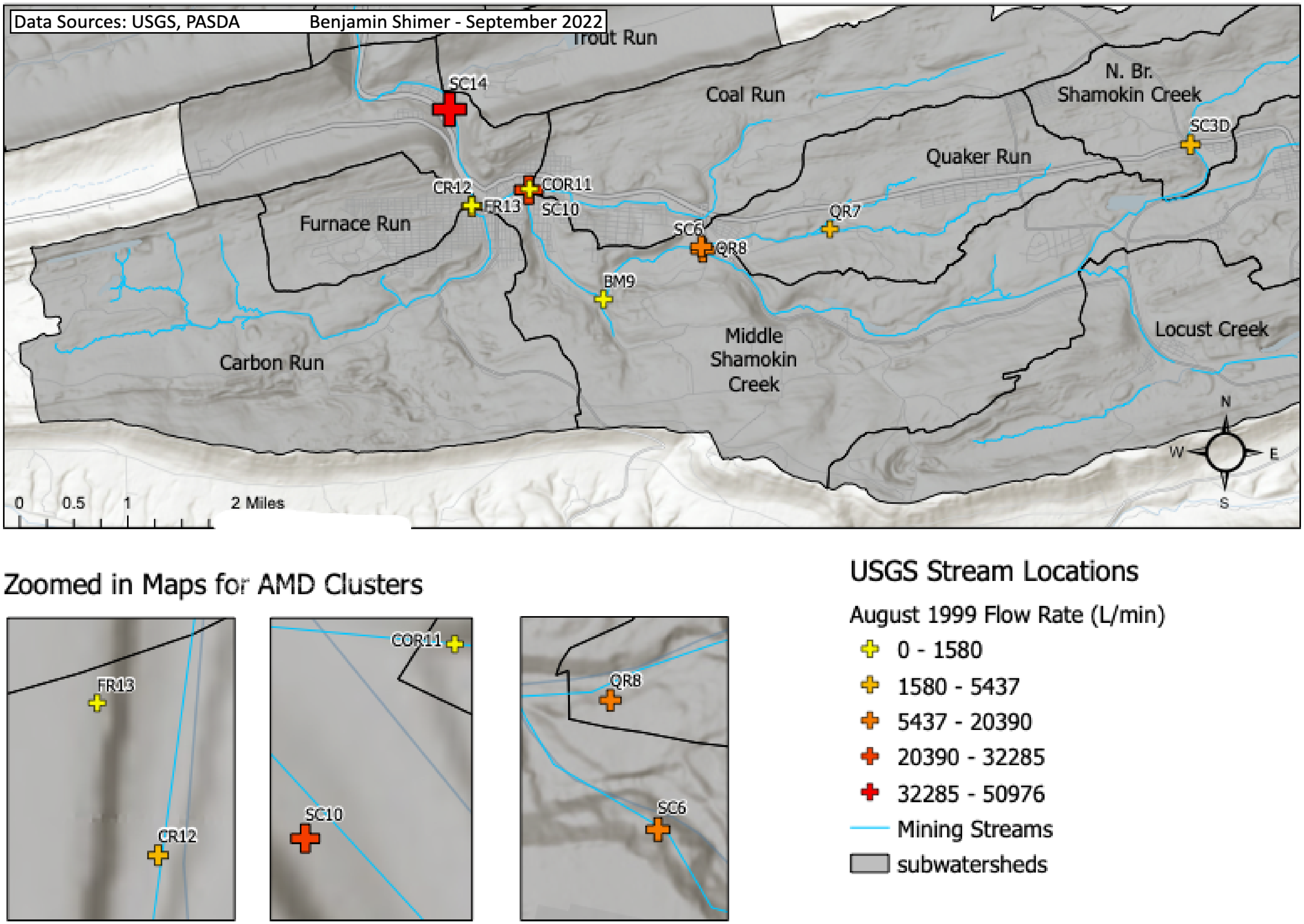
Flow rate for low and high baseflow at discharge locations as well as the stream locations sampled in Cravotta and Kirby's USGS report (2004) is symbolized by dots of varying color and size to orient the reader to the discharges of greatest volume. Sites 12 and 19 stand out for their particularly large flow rates which is important to consider as it implies greatest potential for harm in the watershed. The stream's flow rates are symbolized as well with crosses rather than dots, but are based on the same color and size stratification as the discharges. It's also worth noting the substantial difference in flow rate that exists between the low baseflow and high baseflow measures as site 19 discharged more than twice the volume when measured in March 2000 than August 1999.

Shamokin Creek Watershed Low Baseflow AMD Flow Rate

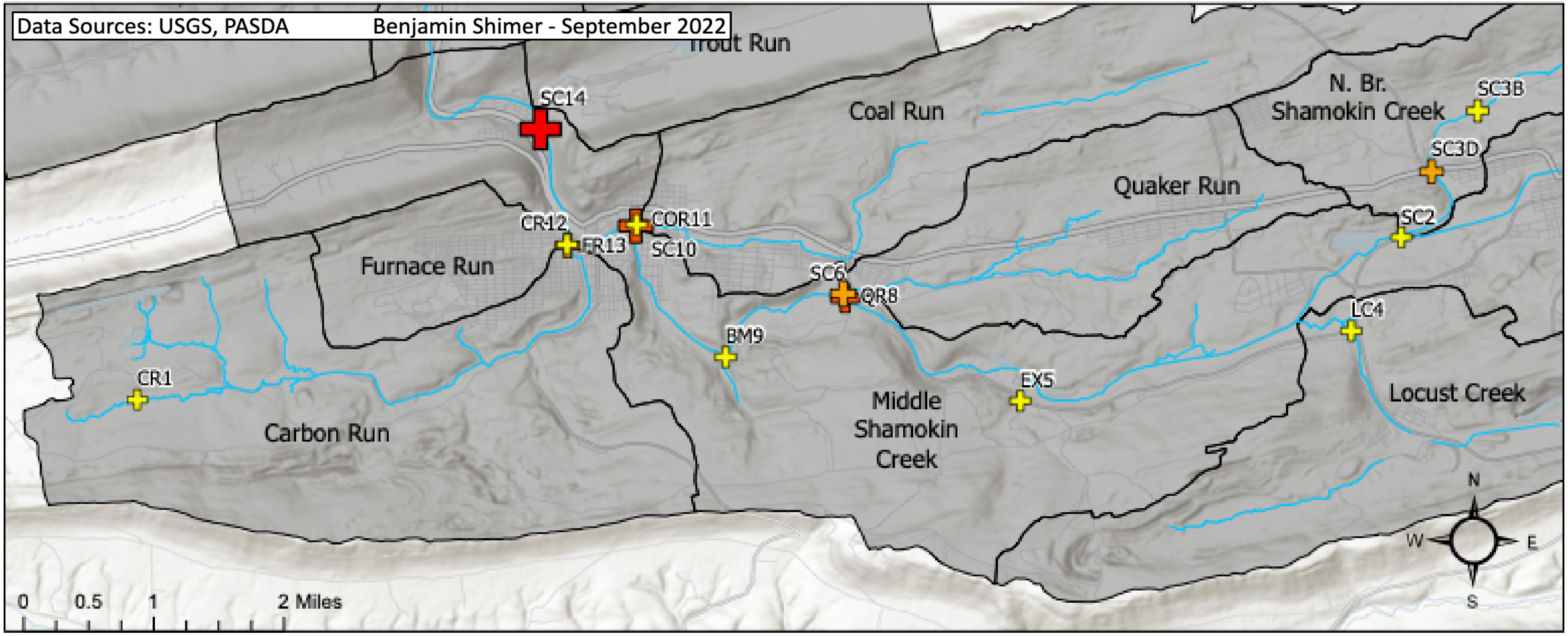



Shamokin Creek Watershed High Baseflow AMD Flow Rate
Data Sources: USGS, PASDA
Benjamin Shimer - September 2022
Millers Run
Bennys Run
Trout Run
Coal Run
N. Br. Shamokin Creek
Quaker Run
Furnace Run
Carbon Run
Middle Shamokin Creek
Locust Creek
0 0.5 1 2 Miles
N
W
E
S
Zoomed in Maps for AMD Clusters
AMD Discharge Locations
March 2000 Flow Rate (L/min)
0.0 - 1155
1155 - 4248
4248 - 8496
8496 - 32285
Mining Streams
subwatersheds

Shamokin Creek Watershed Low Baseflow Stream Flowrate



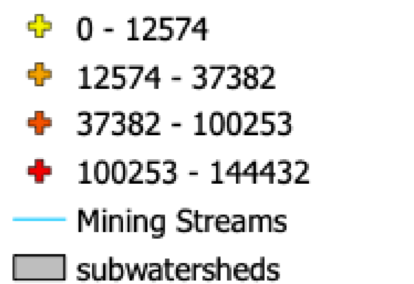
Shamokin Creek Watershed High Baseflow Stream Flowrate



Zoomed in Maps

USGS Stream Locations

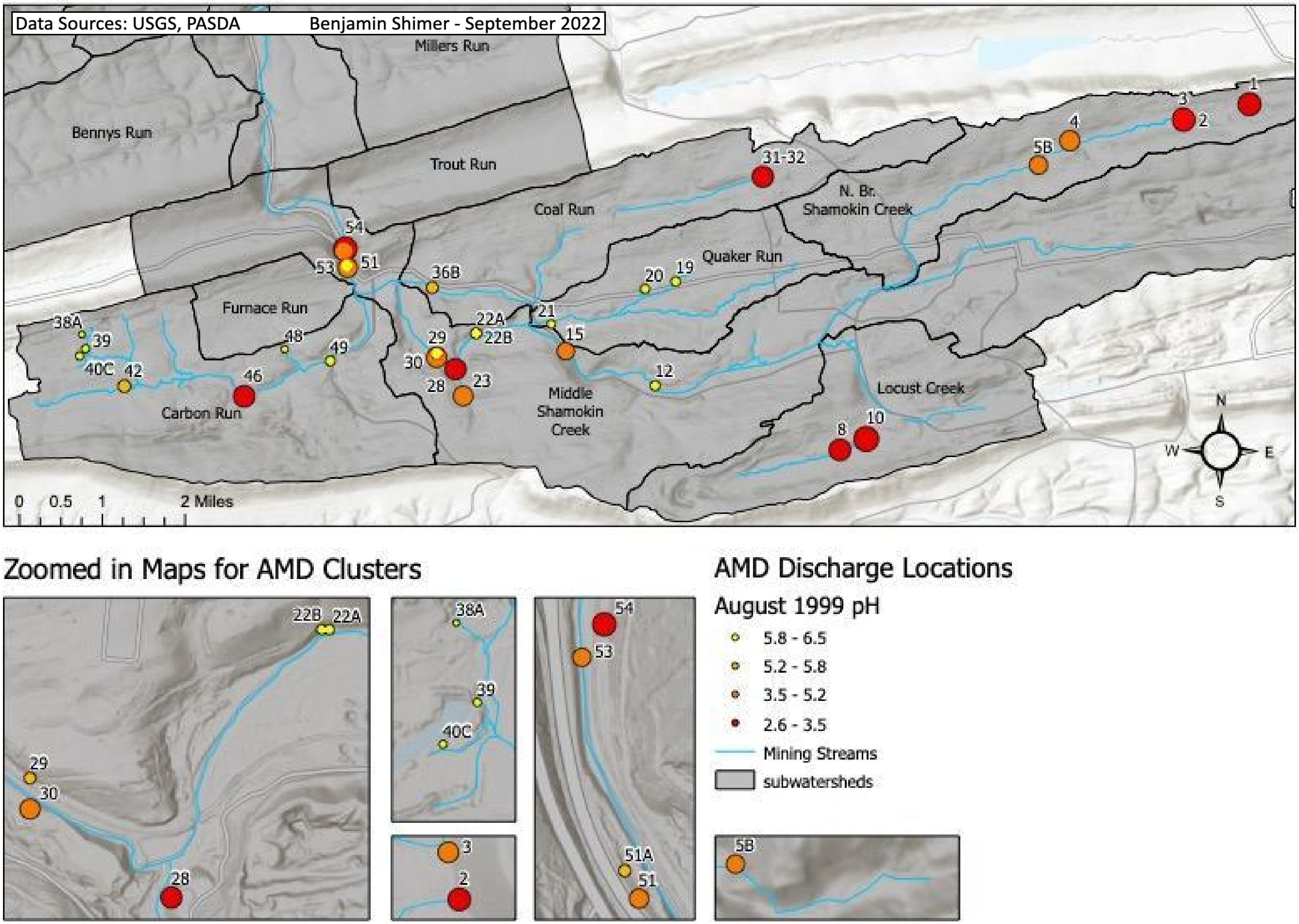
March 2000 Flow Rate (L/min)



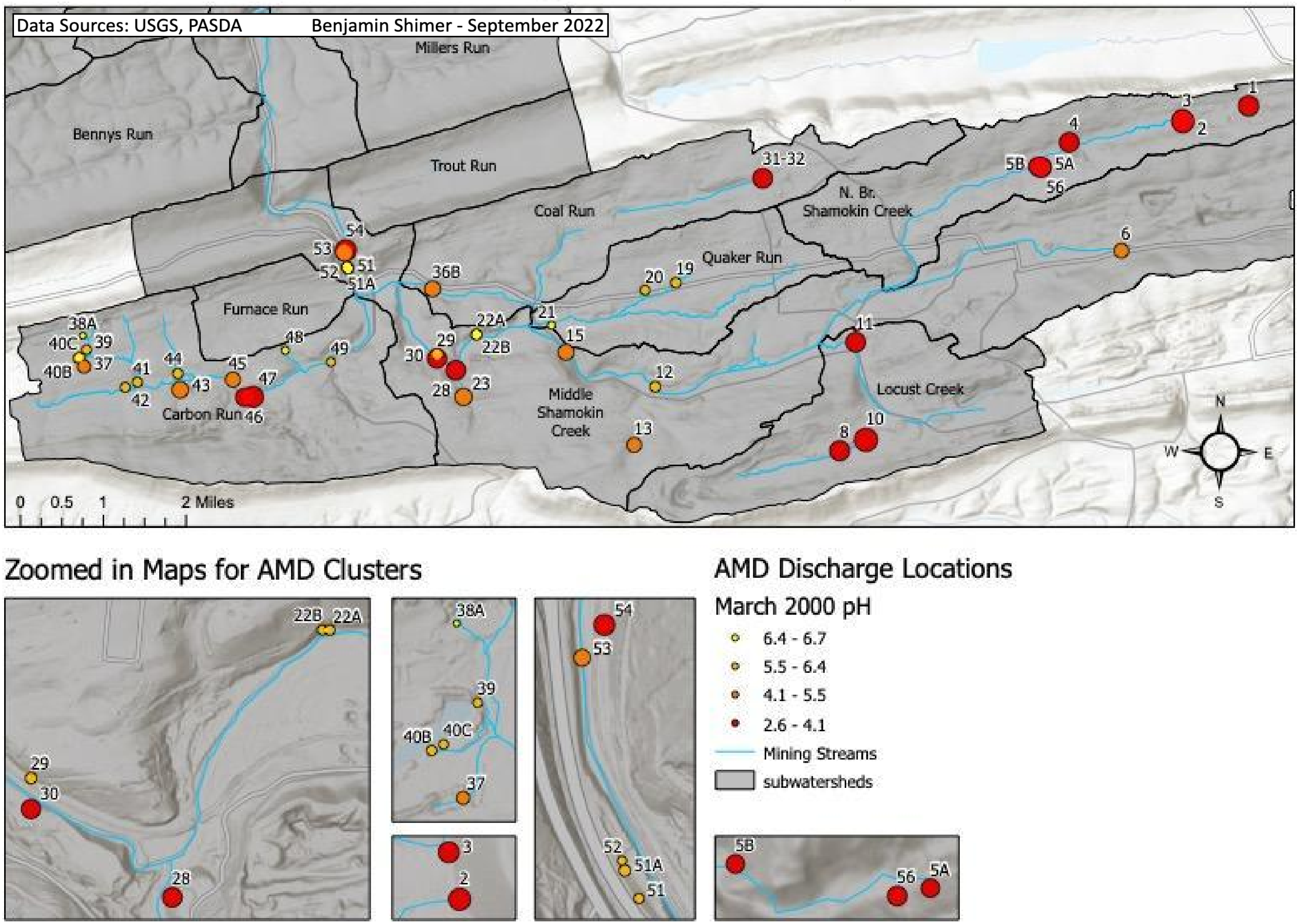
pH

Acid mine drainage can release highly acidic water into the streams which can have detrimental effects on aquatic ecosystems. This is measured through pH which is on a logarithmic scale from 0-14, with 7 being neutral and the general aim for pure water. As seen through the same symbology to flow rate, many AMD sites were discharging water with pH in the range of under 4 during low and high baseflow conditions. This has had varying effects on the pH of the stream itself as seen through the measurements visualized at each sampled location, with some stream locations being somewhat close to neutral and others still below 4, making them more than 1000 times more acidic than pure water. This is far below PA's water quality standards for natural water bodies which require pH levels between and including 6.0 and 9.0 (Water Quality 2022).

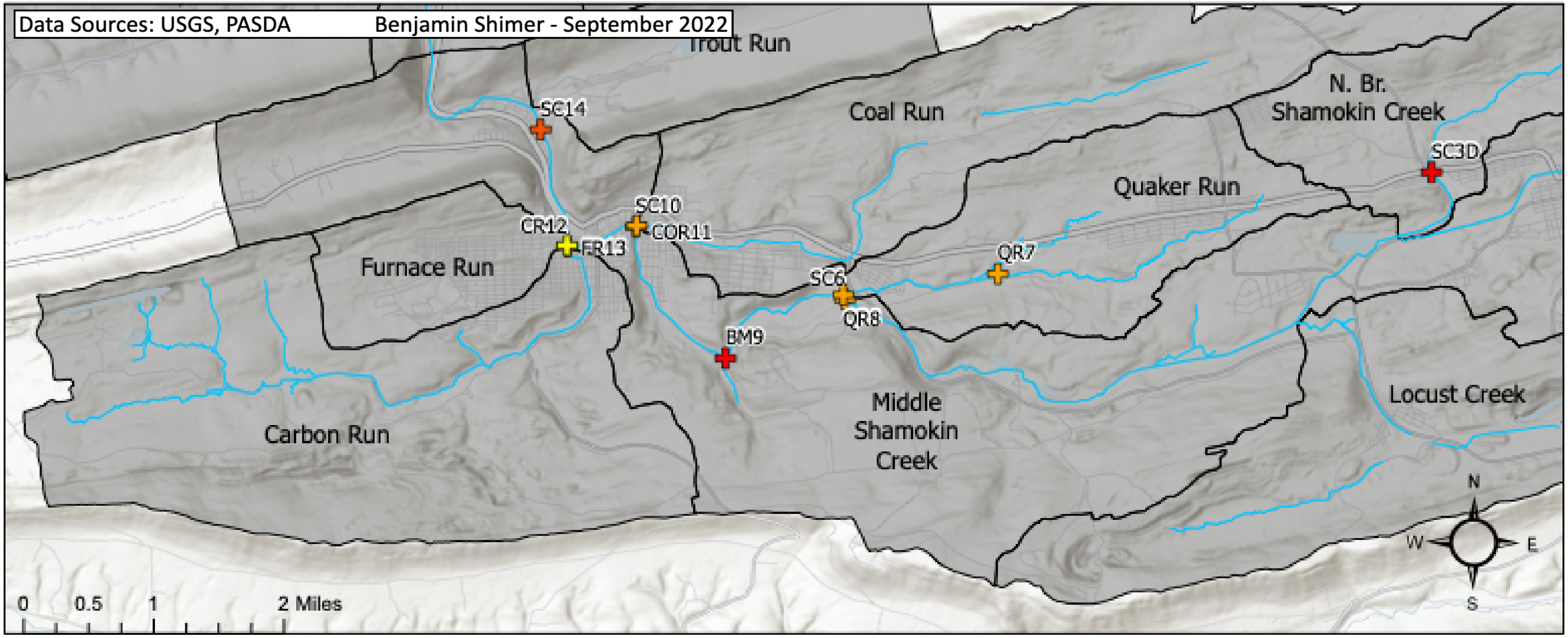
Shamokin Creek Watershed Low Baseflow AMD pH



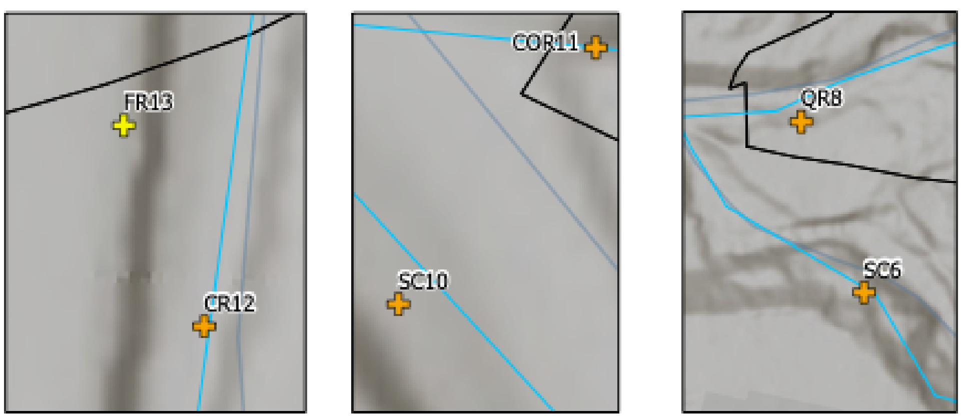
Shamokin Creek Watershed High Baseflow AMD pH



Shamokin Creek Watershed Low Baseflow Stream pH



Zoomed in Maps

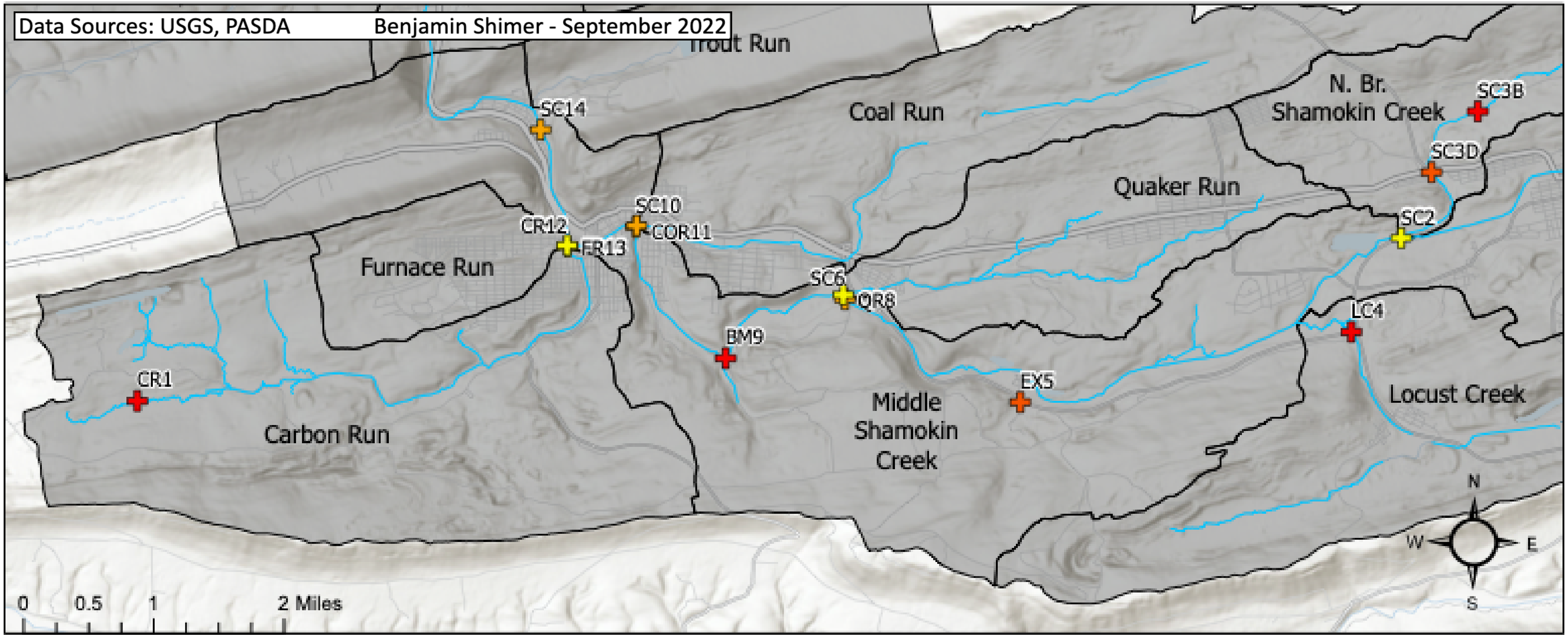


USGS Stream Locations

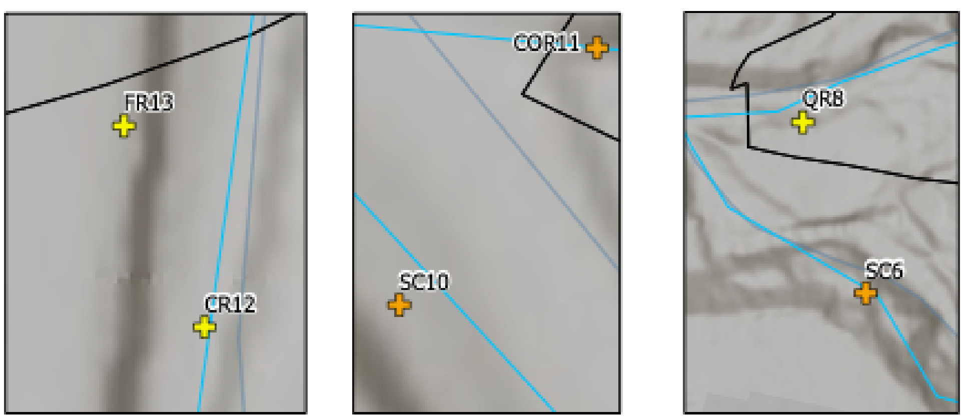
August 1999 pH

- 3.2 - 3.3
- 3.3 - 5.9
- 5.9 - 6.5
- 6.5 - 7.0
- Mining Streams
- subwatersheds

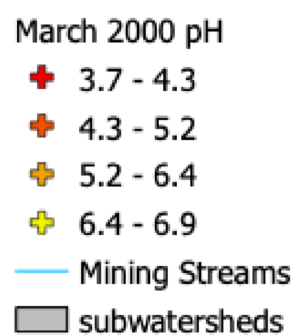
Shamokin Creek Watershed High Baseflow Stream pH



Zoomed in Maps



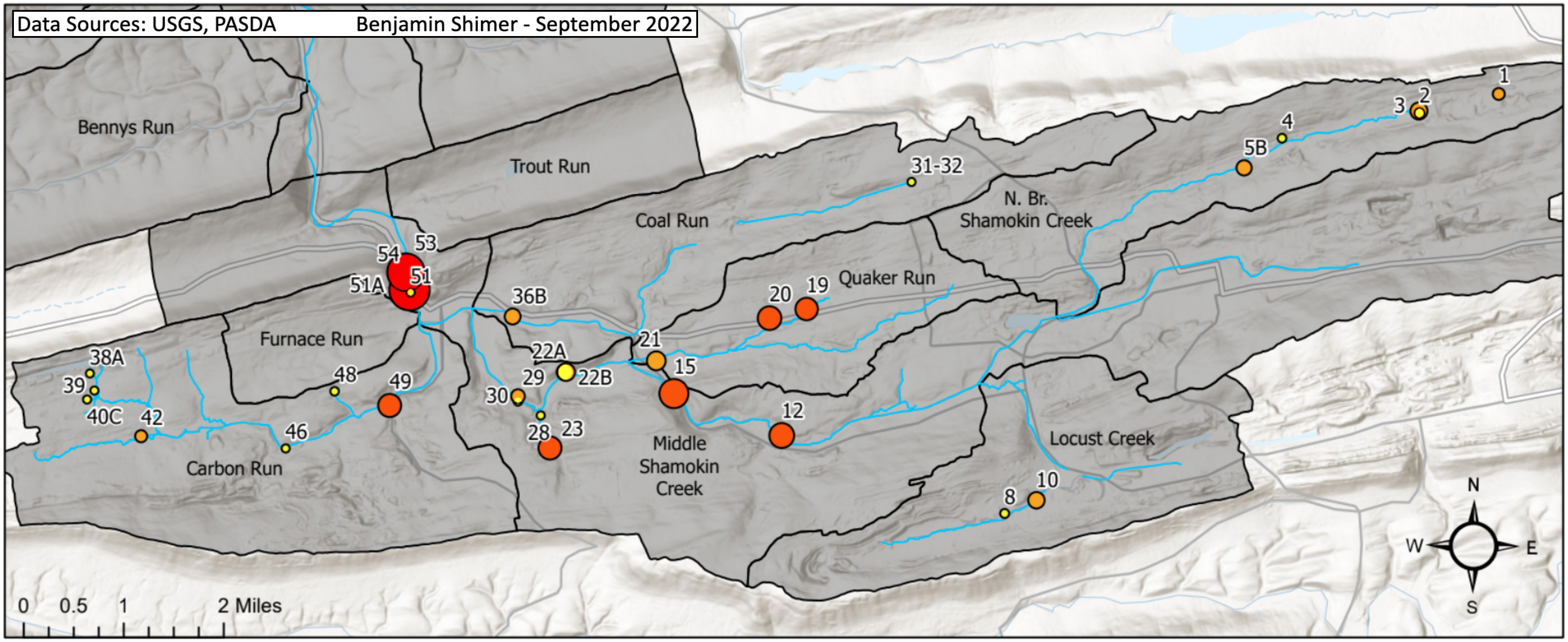
USGS Stream Locations



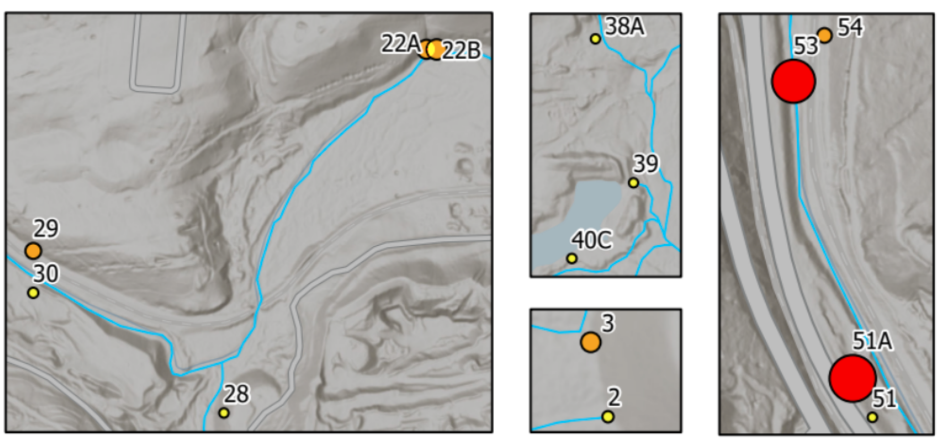
Iron Concentration

Iron is the primary metal that gives acid mine drainage its distinguishable color and also contributes to detrimental effects on a watershed with the ability to severely impair aquatic life and potentially alter the food chain of the ecosystem. As seen on the map, the greatest concentration of iron in the discharges comes from sites 51A and 53. However, high flow discharges such as at sites 12 and 19, as well as many other sites, still have high iron loadings that impact the health of the stream. Many of the stream samples from the center of the mining area of the watershed show the greatest concentrations of iron with measurements up to 22 mg/L. These greatly exceed the PA standards for iron which are set at 0.3mg/L (Water Quality 2022).

Shamokin Creek Watershed Low Baseflow Iron Concentration



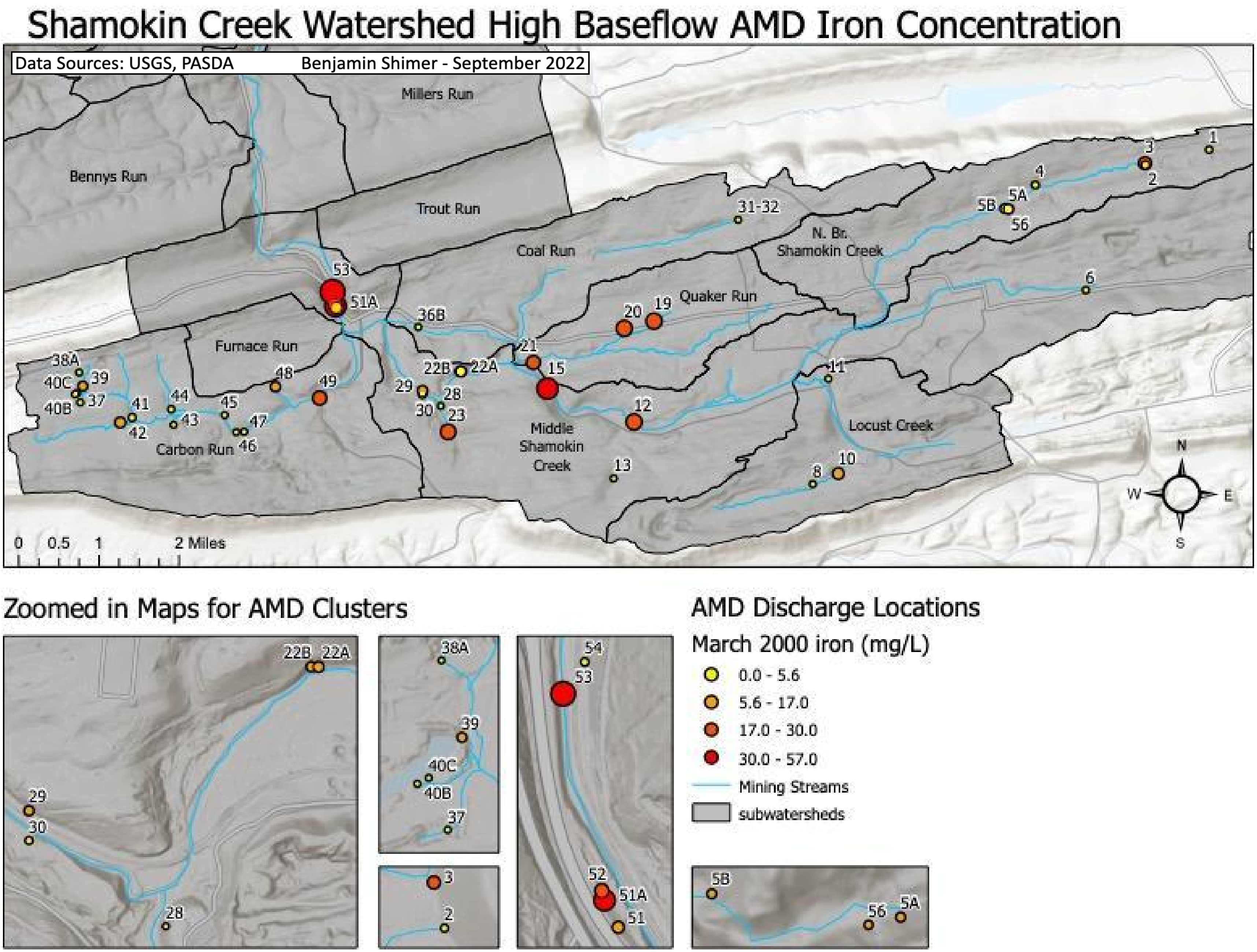
Zoomed in Maps for AMD Clusters



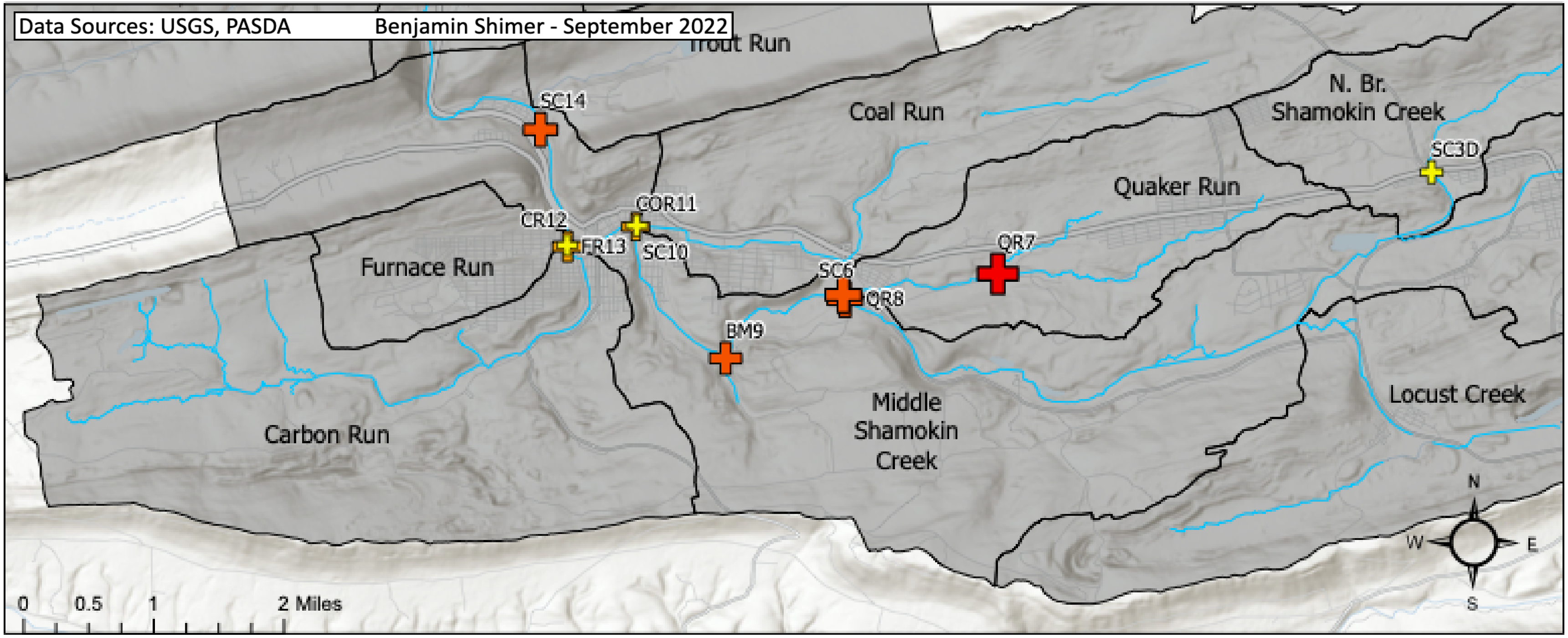
AMD Discharge Locations

August 1999 iron (mg/L)

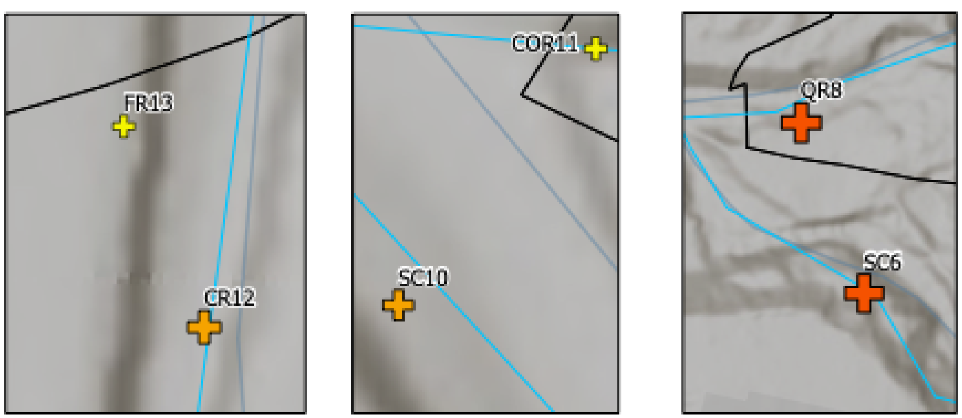
- 0.02 - 2.9
- 2.9 - 18.0
- 18.0 - 35.0
- 35.0 - 54.0
- Mining Streams
- subwatersheds


Shamokin Creek Watershed High Baseflow AMD Iron Concentration
Data Sources: USGS, PASDA
Benjamin Shimer - September 2022
Millers Run
Bennys Run
Trout Run
Coal Run
N. Br. Shamokin Creek
Quaker Run
Furnace Run
Carbon Run
Middle Shamokin Creek
Locust Creek
0 0.5 1 2 Miles
N
S
W
E
Zoomed in Maps for AMD Clusters
AMD Discharge Locations
March 2000 iron (mg/L)
0.0 - 5.6
5.6 - 17.0
17.0 - 30.0
30.0 - 57.0
Mining Streams
subwatersheds

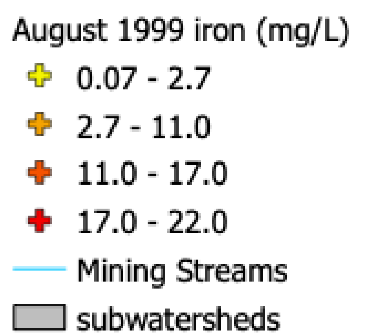
Shamokin Creek Watershed Low Baseflow Stream Iron Concentration

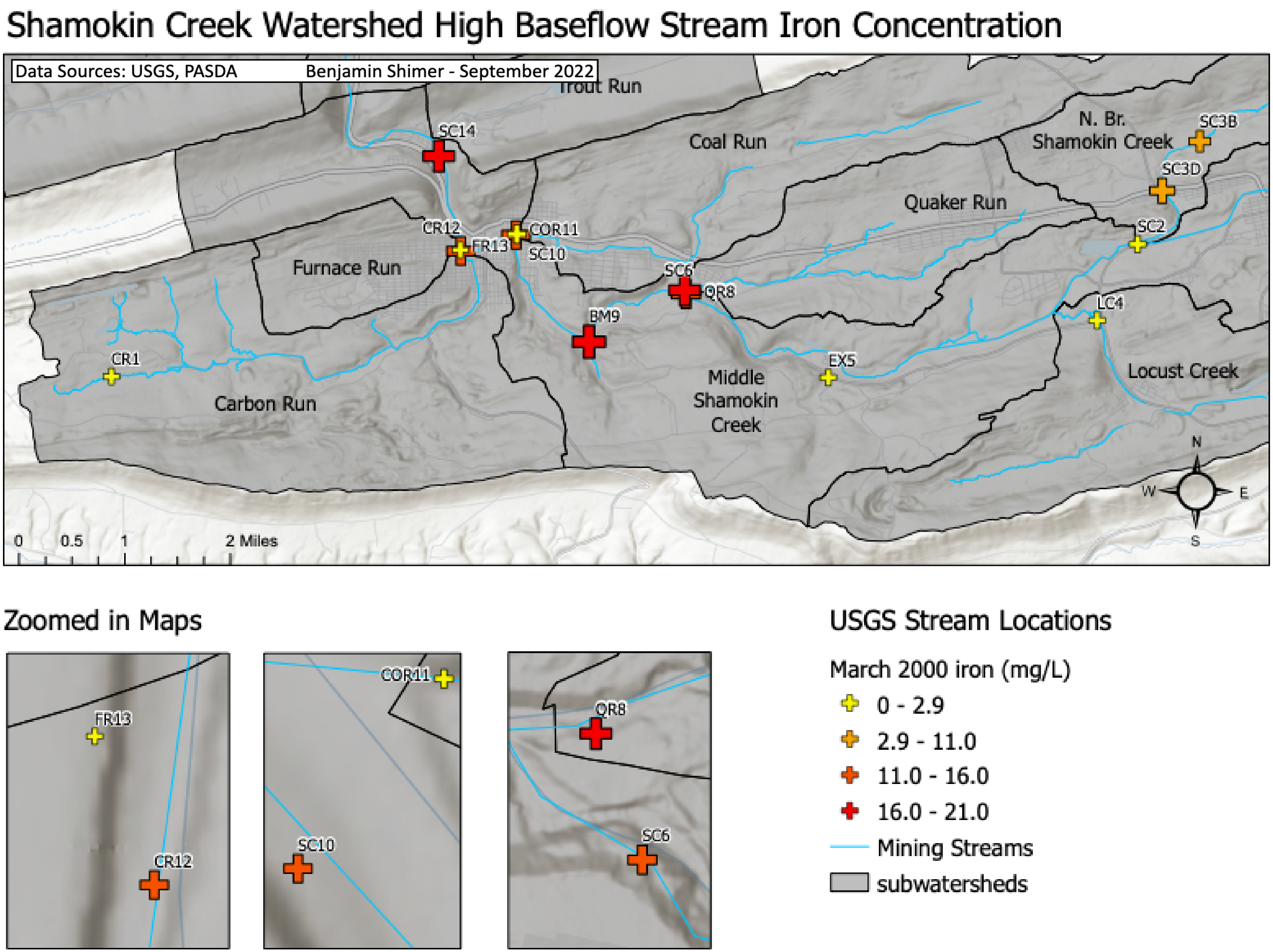


Zoomed in Maps



USGS Stream Locations

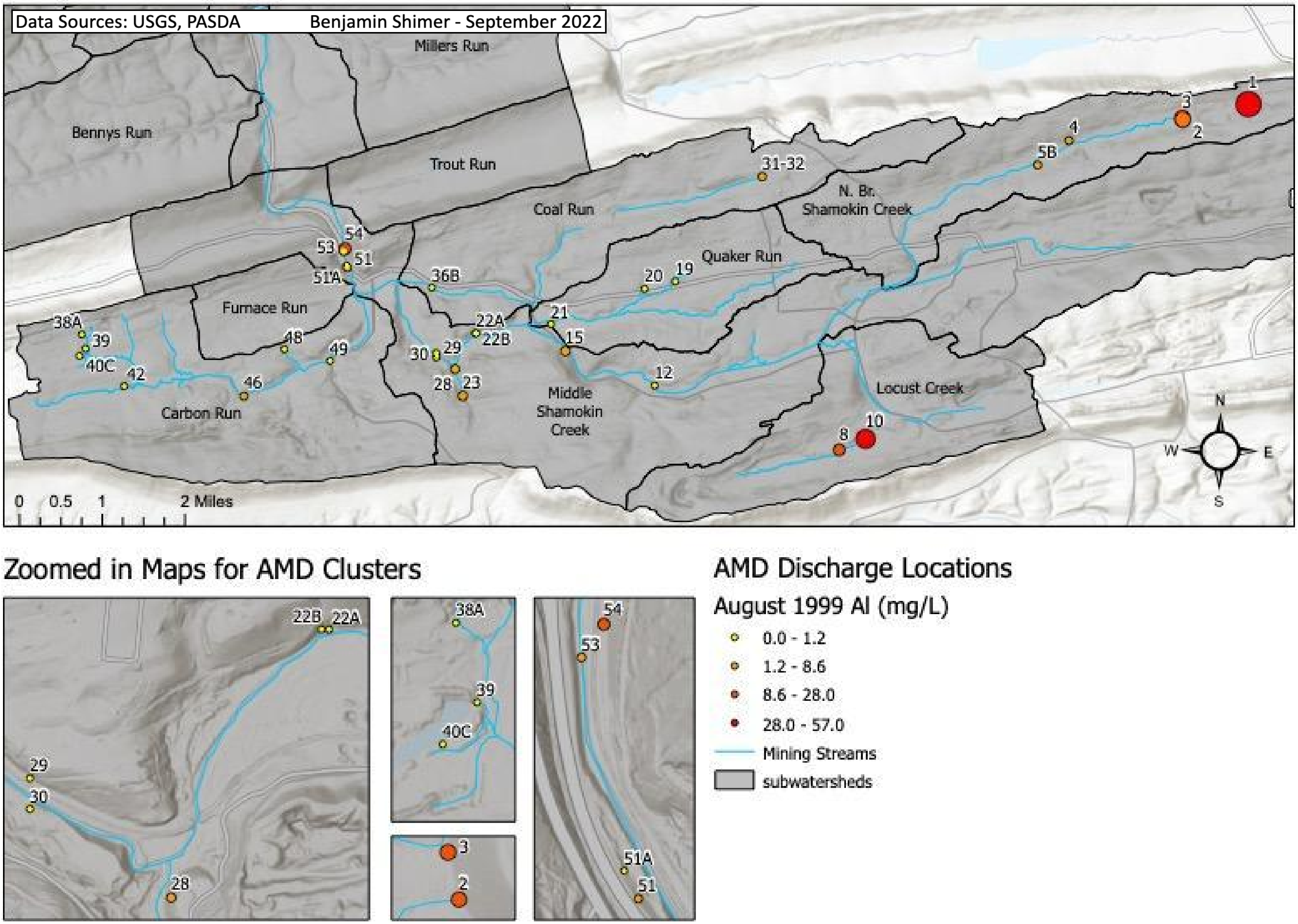



Shamokin Creek Watershed High Baseflow Stream Iron Concentration
Data Sources: USGS, PASDA
Benjamin Shimer - September 2022
Trout Run
SC14
Coal Run
N. Br. Shamokin Creek
SC3B
SC3D
Quaker Run
SC2
CR12
COR11
FR13
SC10
Furnace Run
SC6
QR8
LC4
BM9
CR1
EX5
Middle Shamokin Creek
Locust Creek
Carbon Run
N
W
E
S
0
0.5
1
2 Miles
Zoomed in Maps
FR13
CR12
COR11
SC10
QR8
SC6
USGS Stream Locations
March 2000 iron (mg/L)
0 - 2.9
2.9 - 11.0
11.0 - 16.0
16.0 - 21.0
Mining Streams
subwatersheds

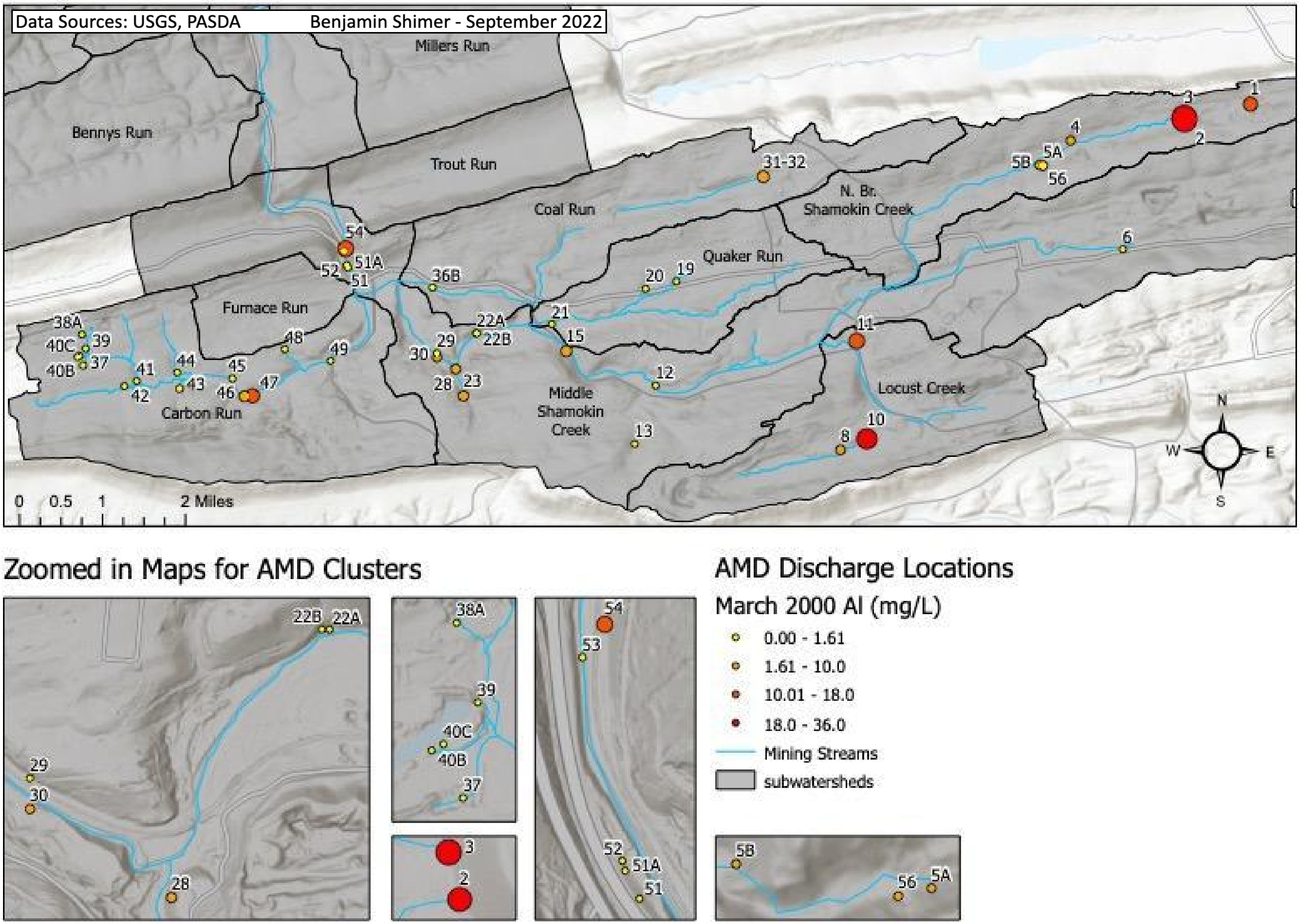
Aluminum Concentration

Aluminum is one of the more prevalent polluting metals due to its frequent use in the industrial sector and common natural occurrence. One of the products of acid mine drainage, aluminum has significant issues for aquatic species such as fish as elevated levels can impact species' regulation of ions and inhibit respiratory processes according to a fact sheet produced by the EPA for aluminum in freshwaters in 2019. High pH waters dissolve aluminum, increasing its concentration in waterways where it can deplete aquatic life if under chronic exposure to high levels of the metal (Hedge 2019). Specific stream locations exceed PA standards set at 0.75mg/L, further showing the dangerous chemistry of water in the Shamokin Creek watershed (Water Quality 2022).

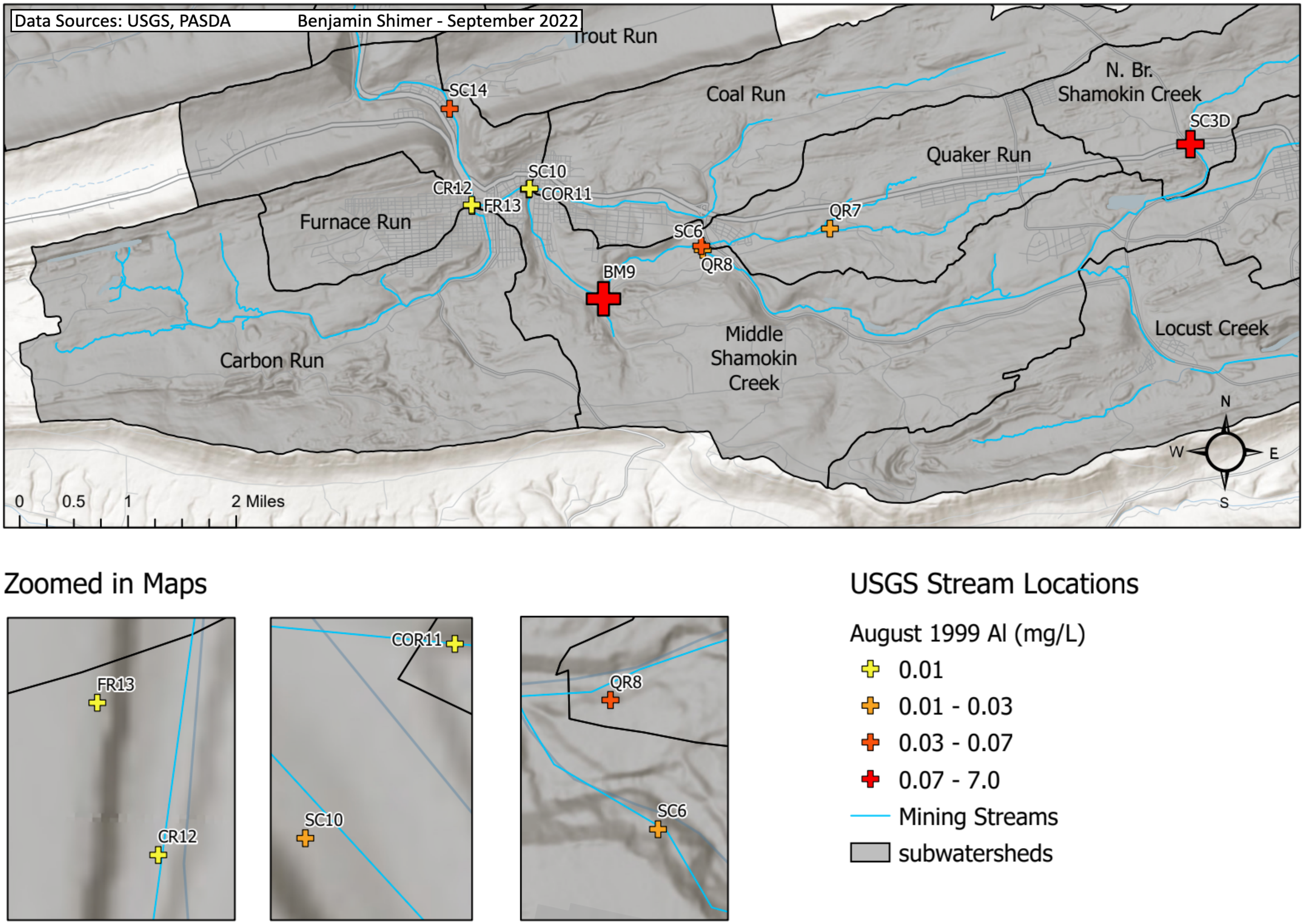
Shamokin Creek Watershed Low Baseflow AMD Aluminum Concentration



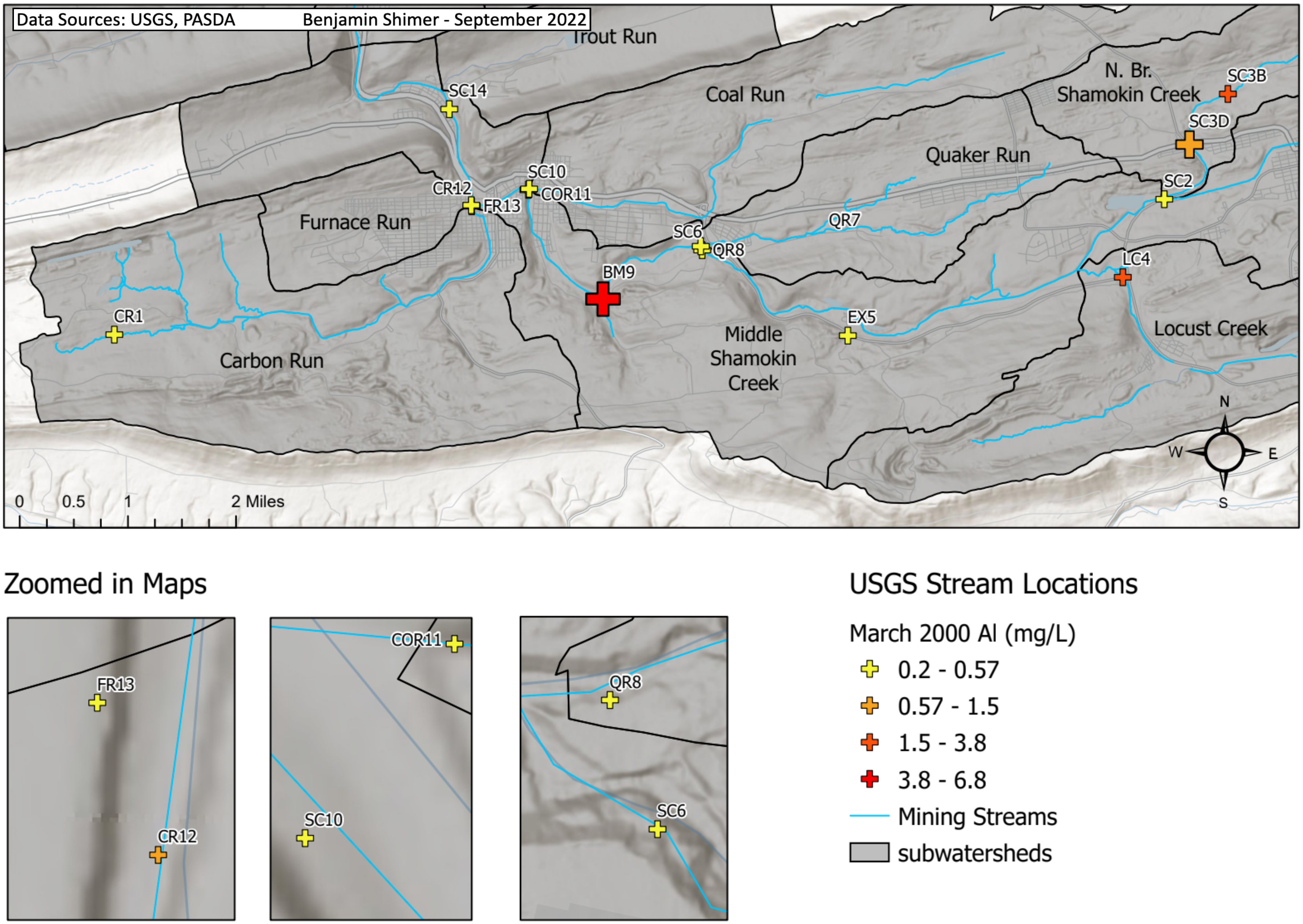
Shamokin Creek Watershed High Baseflow AMD Aluminum Concentration



Shamokin Creek Watershed Low Baseflow Stream Aluminum Concentration



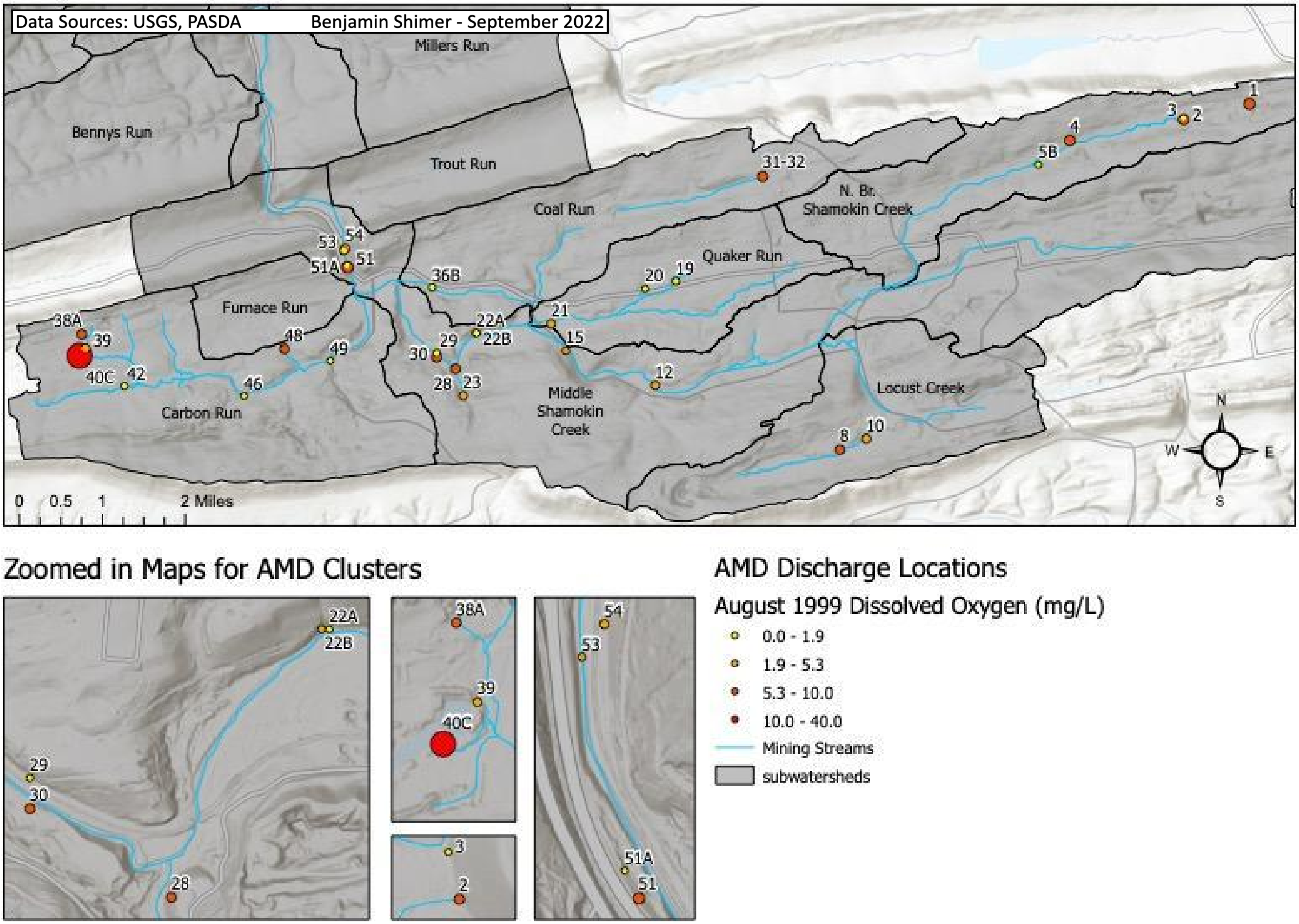
Shamokin Creek Watershed High Baseflow Stream Aluminum Concentration



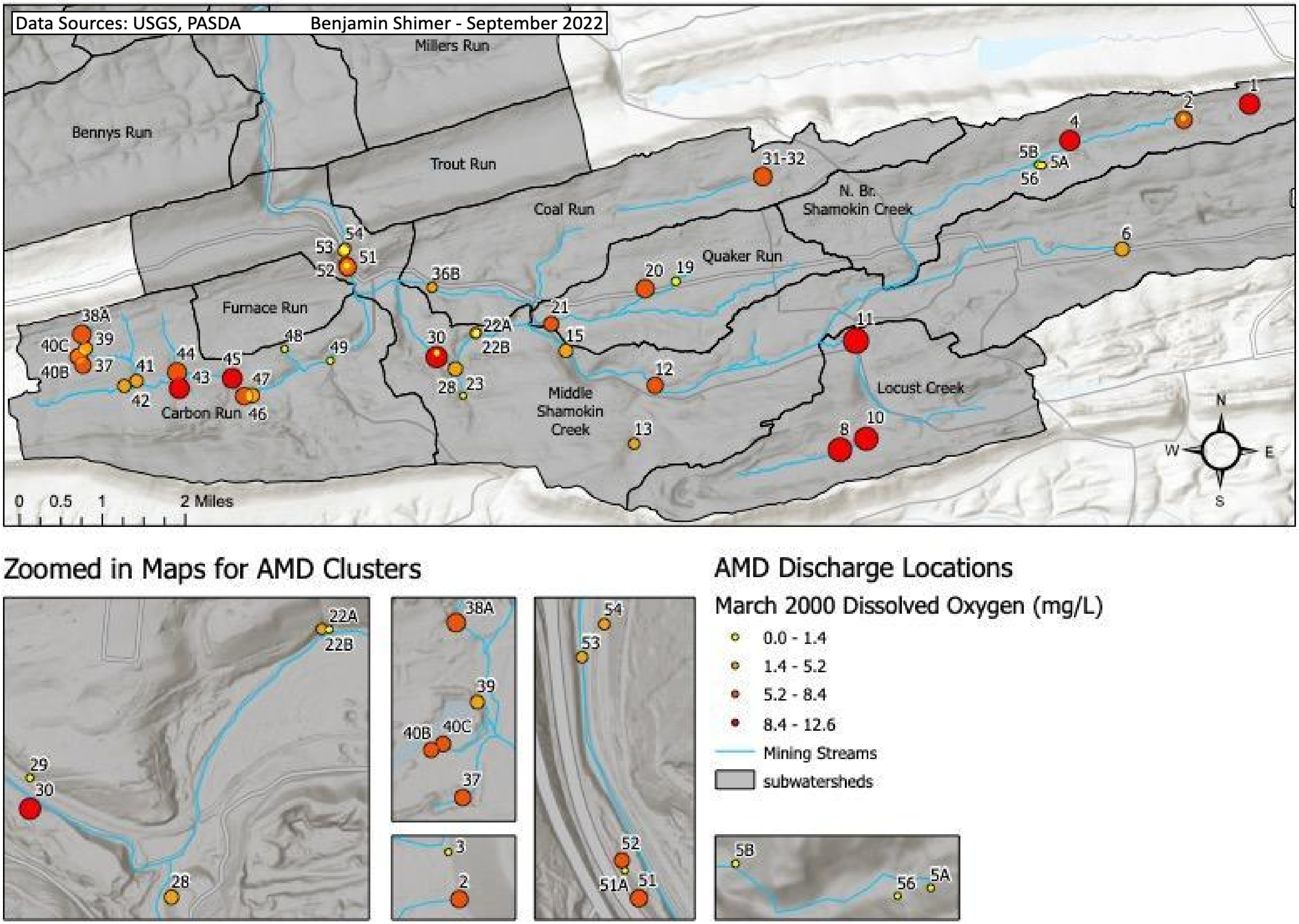
Dissolved Oxygen Concentration

Dissolved oxygen is a good indicator of a waterway's ability to sustain life as it is essential for respiratory processes. The concentration of dissolved oxygen is also important to know when considering treatment for a particular discharge if considering use of passive treatment systems for smaller projects. Locations of concern for these maps are represented by the plethora of smaller dots representing lower concentrations of dissolved oxygen which can inhibit aquatic life. The US EPA defines <3.0 mg/L as a concerning concentration and <1.0 mg/L as hypoxic and usually lifeless (2013). Data from the Cravotta and Kirby USGS report (2004) depict acceptable levels of dissolved oxygen in the stream samples with the lowest measurement at 5.8 mg/L.

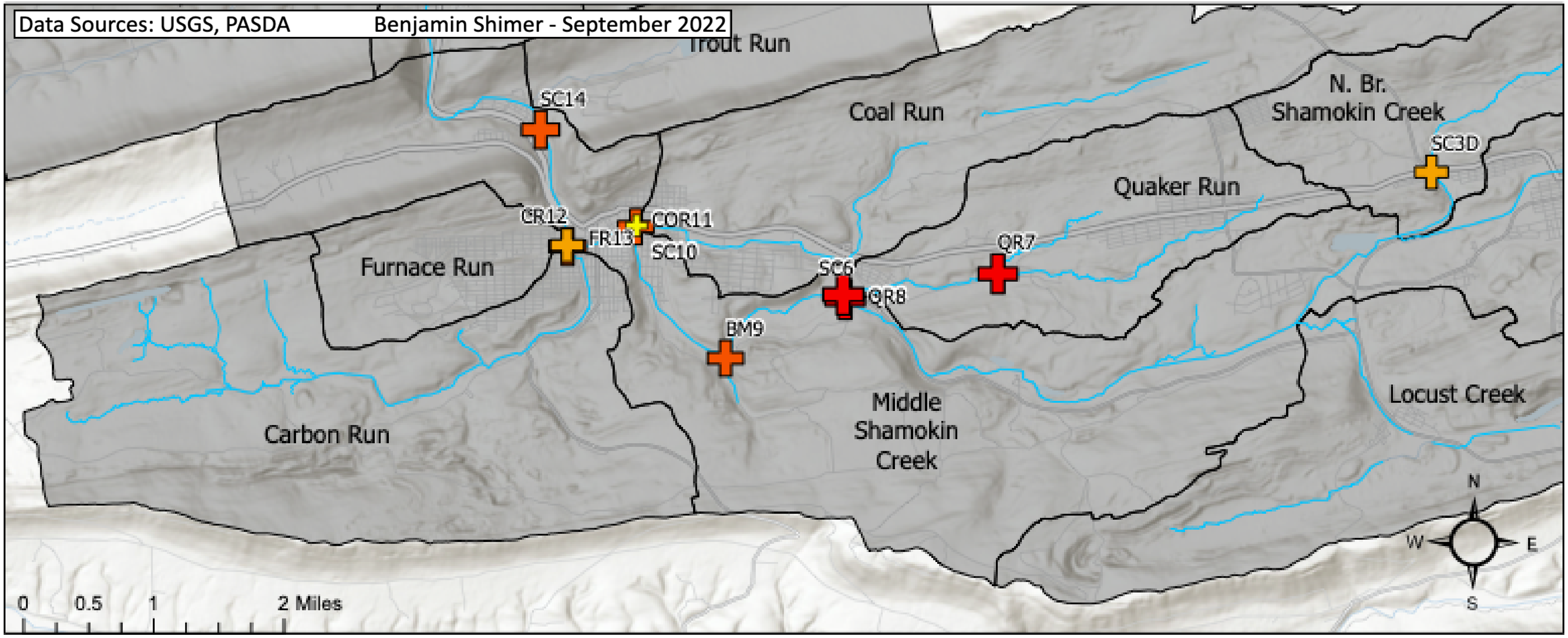
Shamokin Creek Watershed Low Baseflow AMD Dissolved Oxygen Concentration



Shamokin Creek Watershed High Baseflow AMD Dissolved Oxygen Concentration



Shamokin Creek Watershed Low Baseflow Stream Dissolved Oxygen Concentration



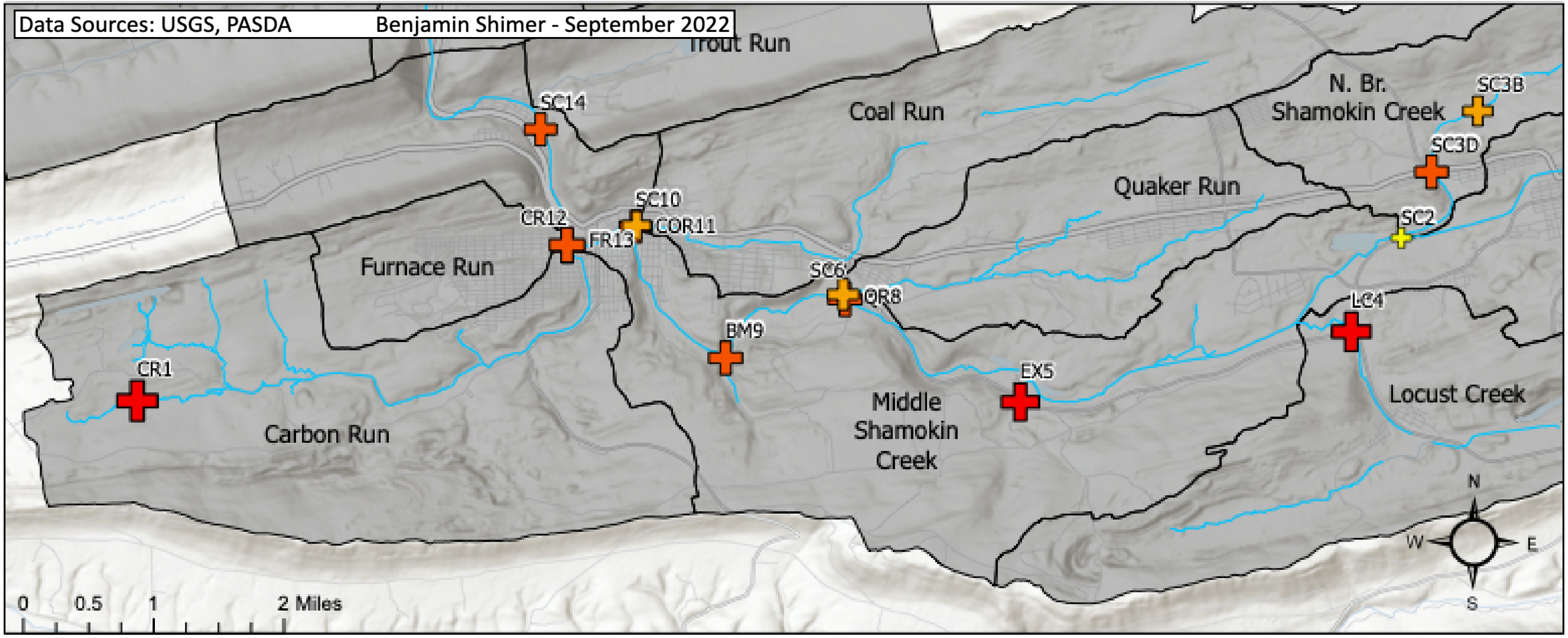
Zoomed in Maps for AMD Clusters

USGS Stream Locations

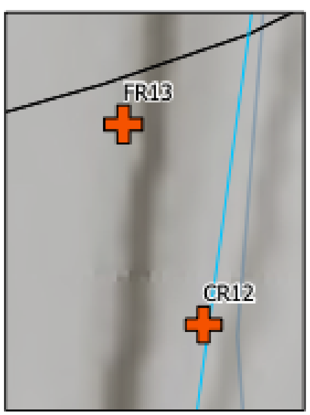
August 1999 Dissolved Oxygen (mg/L)

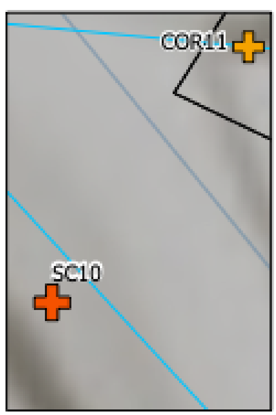
- 7.1
- 7.1 - 8.9
- 8.9 - 9.6
- 9.6 - 10.0
- Mining Streams
- subwatersheds

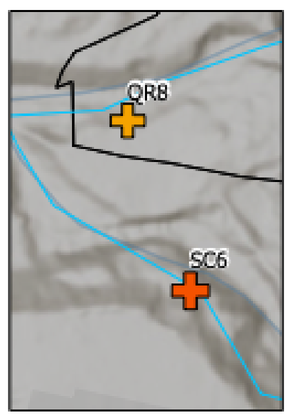
Shamokin Creek Watershed High Baseflow Stream Dissolved Oxygen Concentration



Zoomed in Maps







USGS Stream Locations

March 2000 Dissolved Oxygen (mg/L)

- 5.8
- 5.8 - 9.1
- 9.1 - 10.2
- 10.2 - 11.8
- Mining Streams
- subwatersheds

Assessment Indexes

Assessment indexes were provided by a Shamokin Creek watershed assessment report created by Robert Kimball & Associates, Architects, and Engineers (2004). These took a look at various different years of available water quality data, including the data mapped in this report here, and made more comprehensive qualitative rankings of each discharge in a variety of categories. These included community interest, metal loadings, watershed impact, feasibility of treatment, and final rankings. The rankings were stratified into groups based on color and plotted in their respective positions as a summative view of each discharge location.

Community interest rankings were developed based on what Shamokin Creek Watershed residents found to be the most important AMD discharges to treat. They are stratified from least to greatest interest on a yellow to red color scheme.

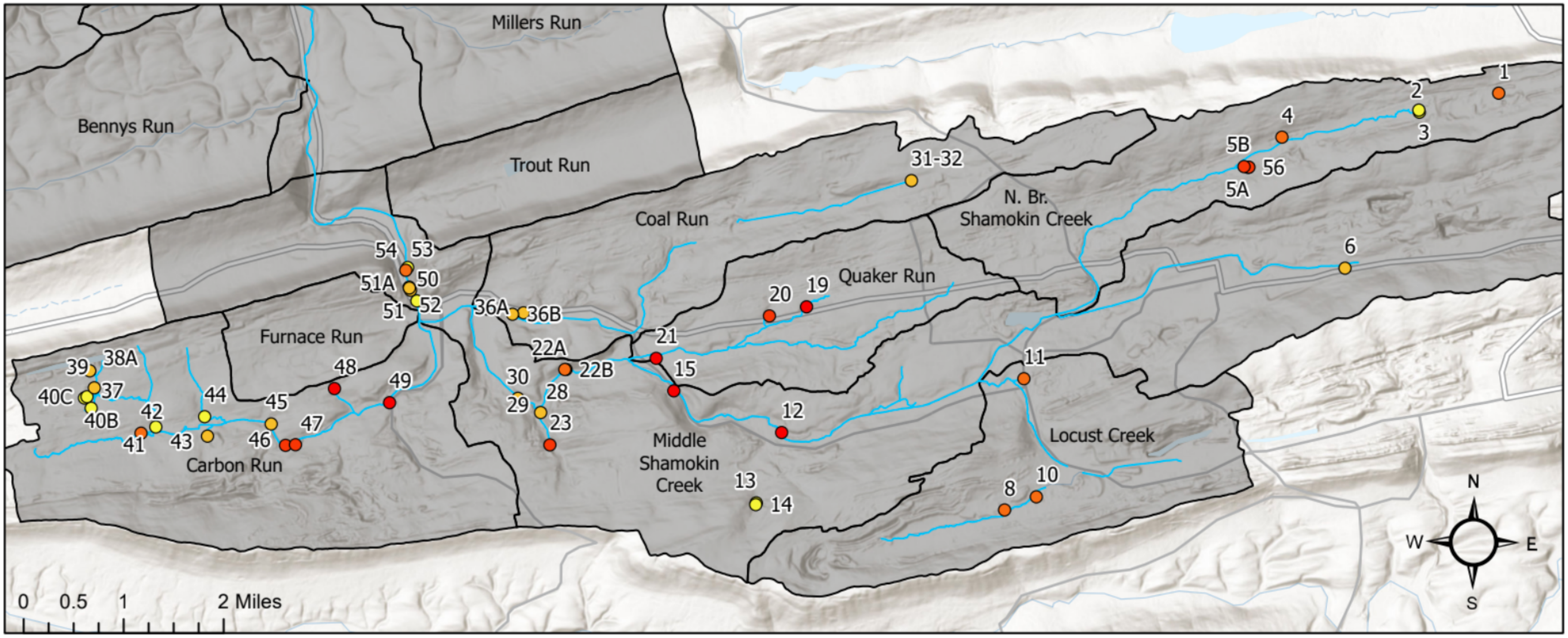
Metal loading rankings were determined based on the presence of harmful metals in the AMD discharge. Those with the greatest amounts of metals are marked with darker reds while those with less metal range in the yellows.

Impact rankings were developed to show which discharges have the greatest impact on the water quality, and therefore which treatments could have the greatest positive effect on the health of the watershed. These are marked on a scale from yellow to red with the latter representing the greatest impact on the watershed.

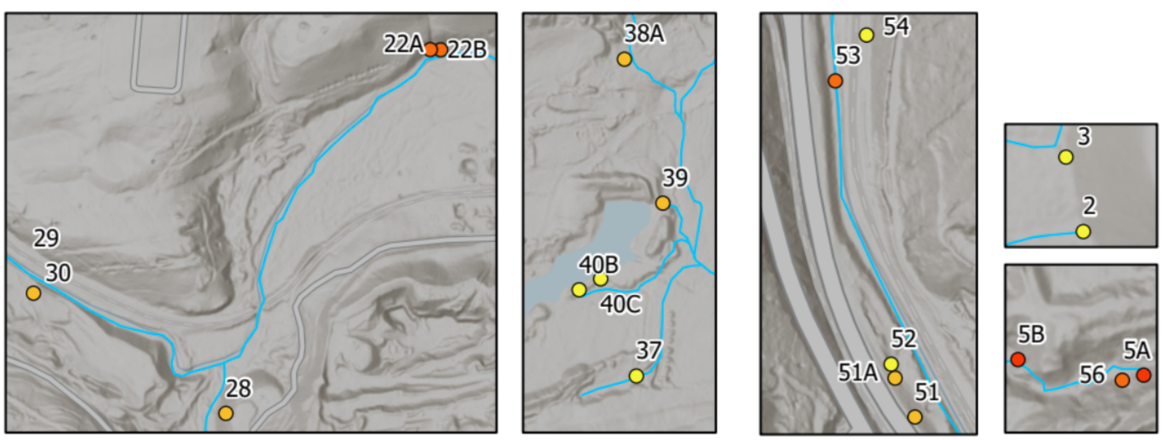
Feasibility rankings were created to assess the viability of treatment at each discharge. The most feasible discharges are marked in white-yellow, with more difficult discharges shown as orange-red dots depending on the difficulty.

Final rankings were determined by combining data, including that previously listed, to determine the best options for treatment in the report. The highest rankings are represented in red with the lowest ranking marked in yellow.

Shamokin Creek Watershed Interest Ranking



Zoomed in Maps for AMD Clusters



AMD Discharge Locations

Interest Rank

Greatest Interest

Least Interest

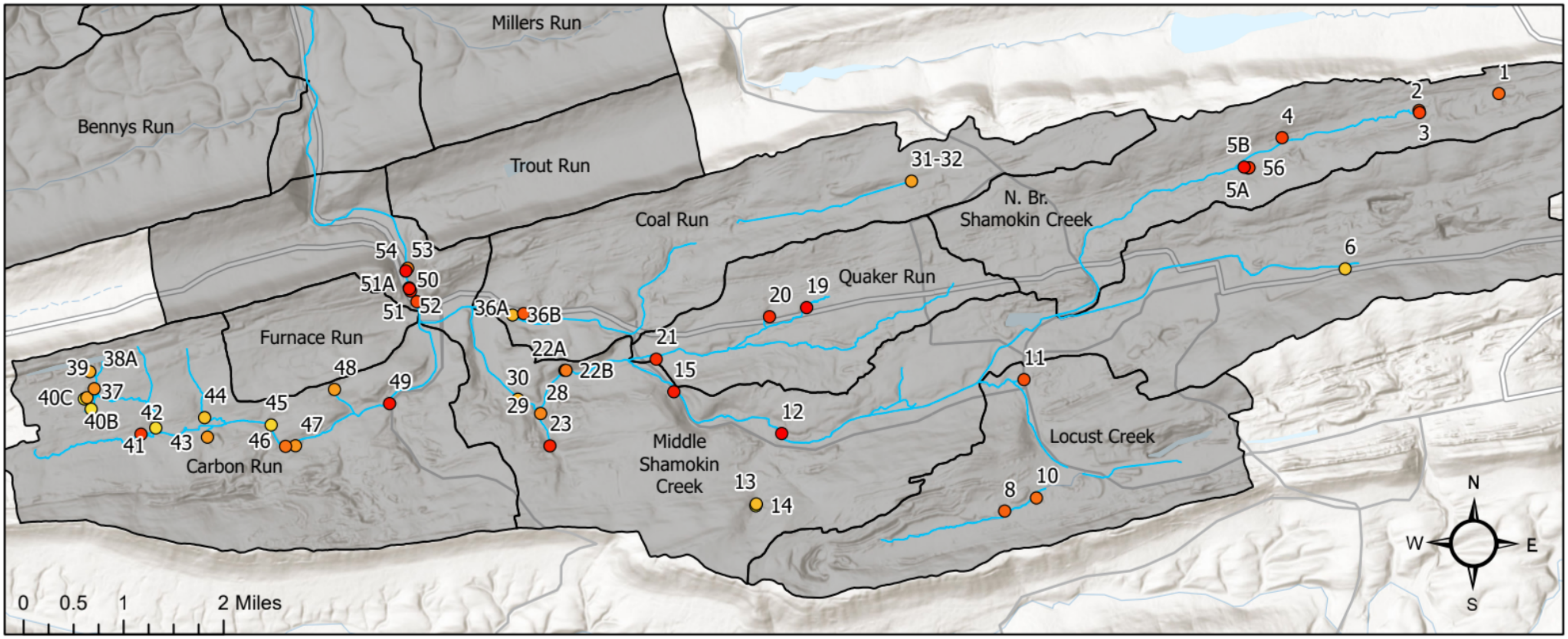
Mining Streams

subwatersheds

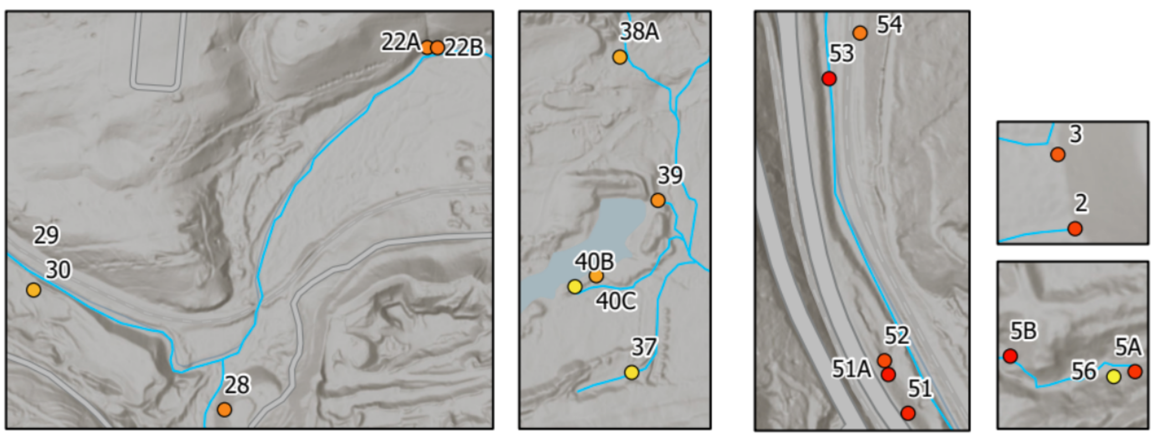
Data Sources: PASDA, Kimball Shamokin Creek Watershed Assessment

Benjamin Shimer September 2022

Shamokin Creek Watershed Metal Loading Rankings



Zoomed in Maps for AMD Clusters



AMD Discharge Locations

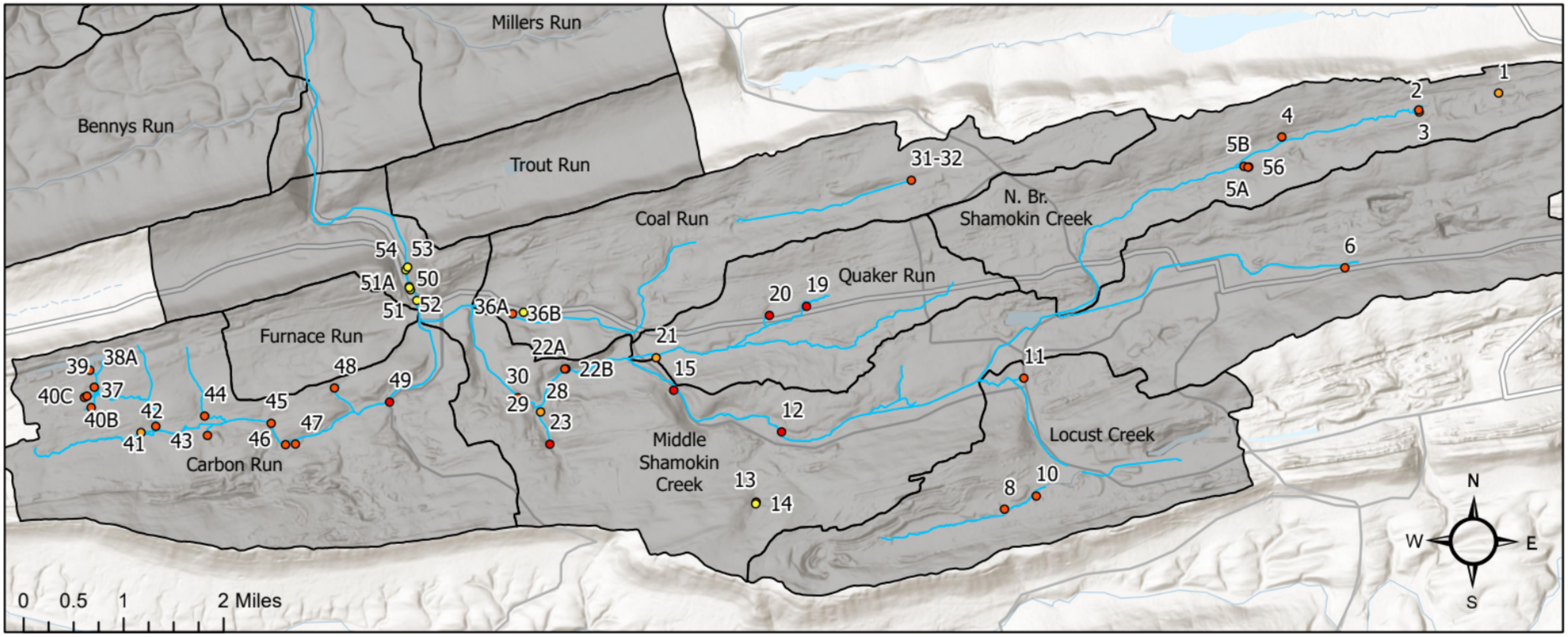
Loading Rank

- Greatest Metal Loading
- Least Metal Loading
- Mining Streams
- subwatersheds

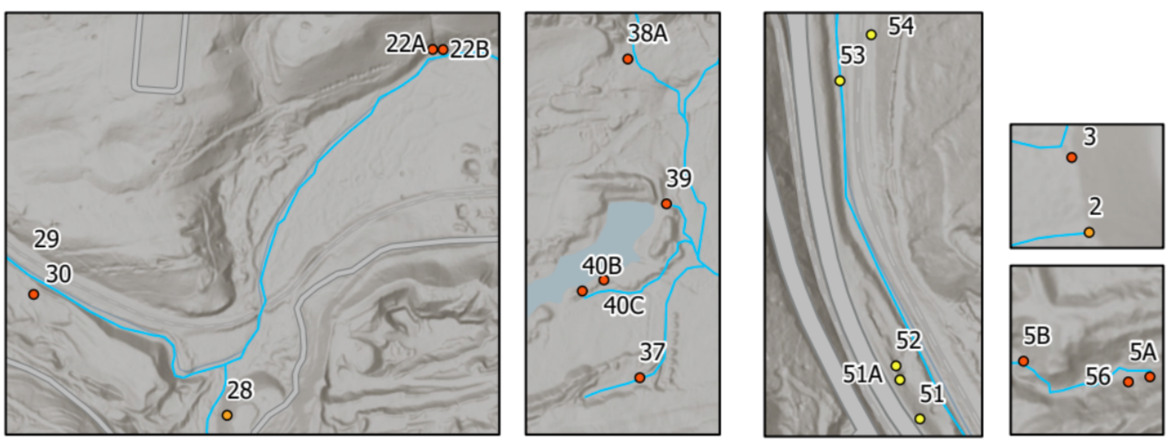
Data Sources: PASDA, Kimball Shamokin Creek Watershed Assessment

Benjamin Shimer September 2022

Shamokin Creek Watershed Impact Rankings



Zoomed in Maps for AMD Clusters



AMD Discharge Locations

Impact Rank

Greatest Impact

Least Impact

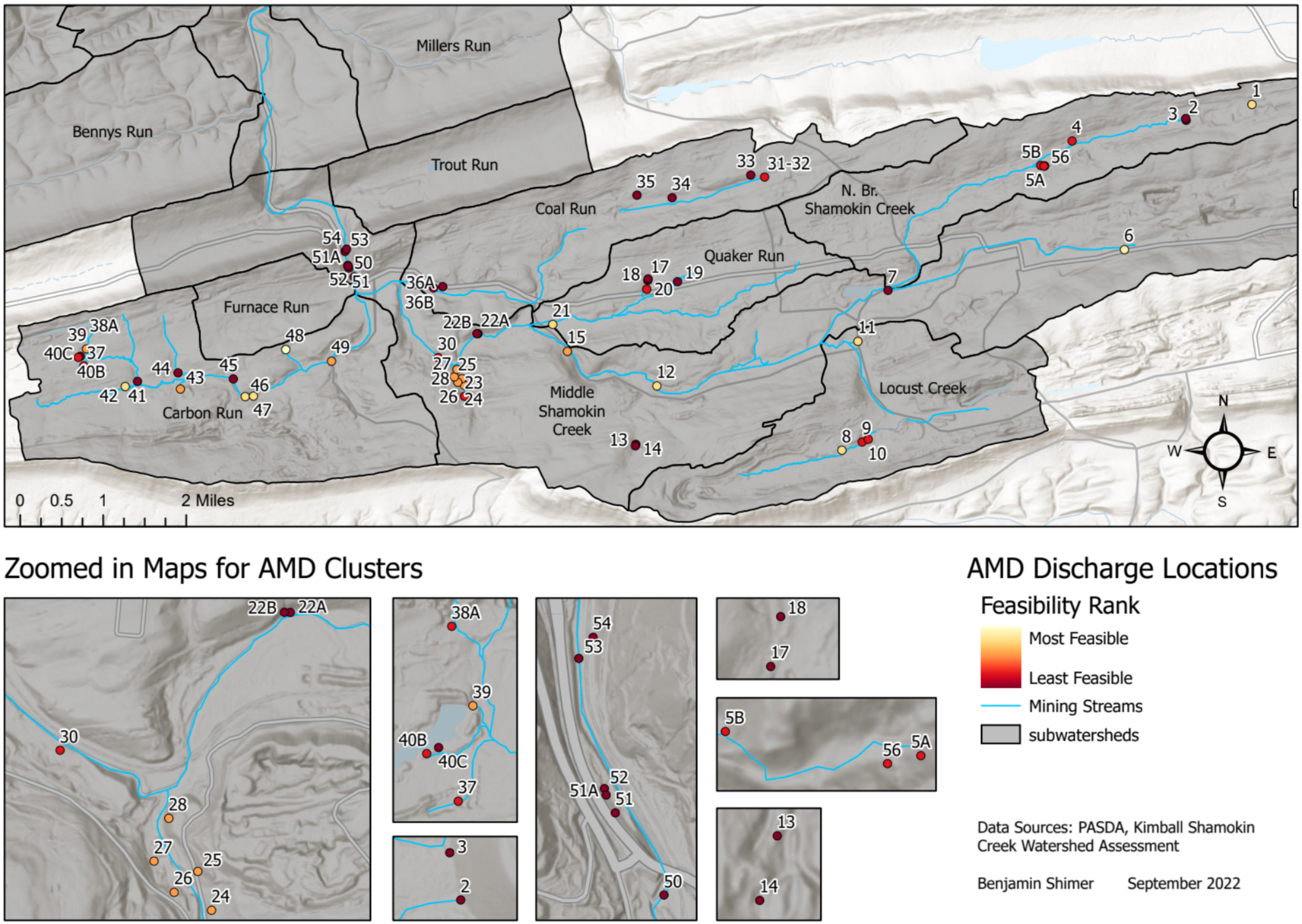
Mining Streams

subwatersheds

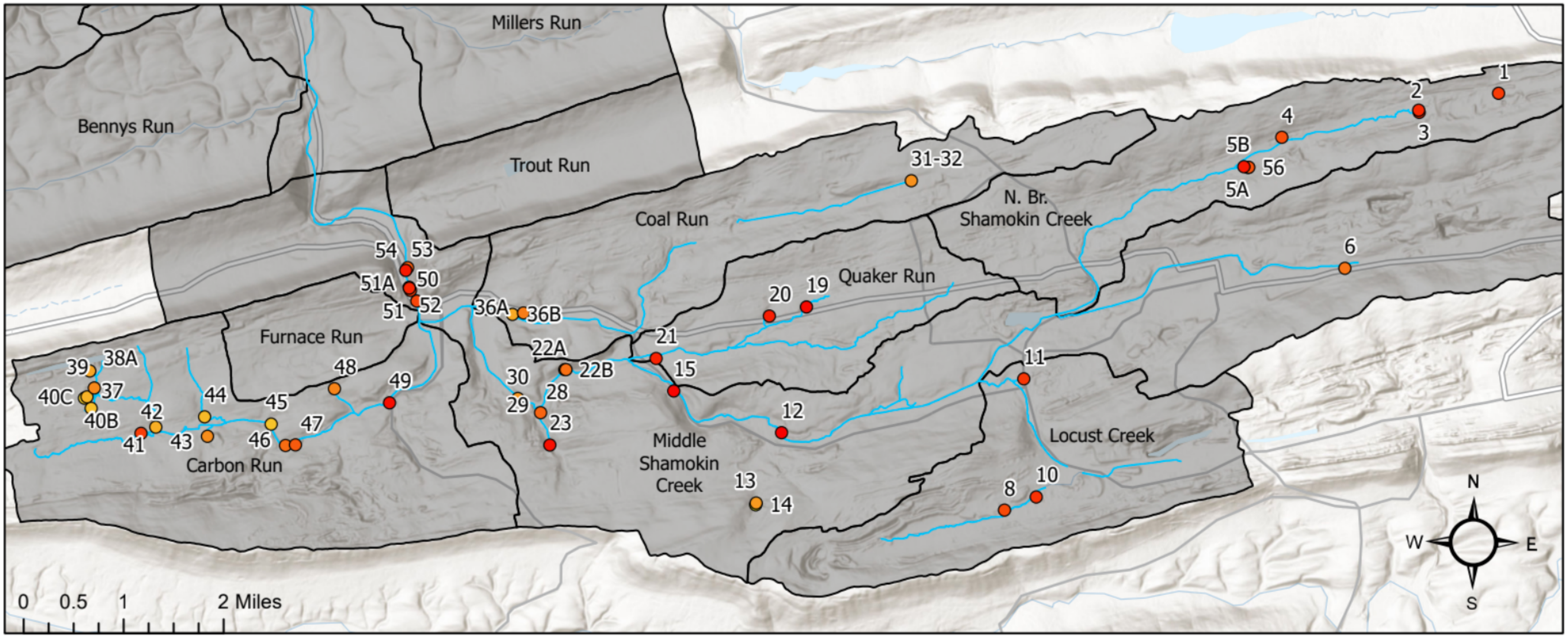
Data Sources: PASDA, Kimball Shamokin Creek Watershed Assessment

Benjamin Shimer September 2022

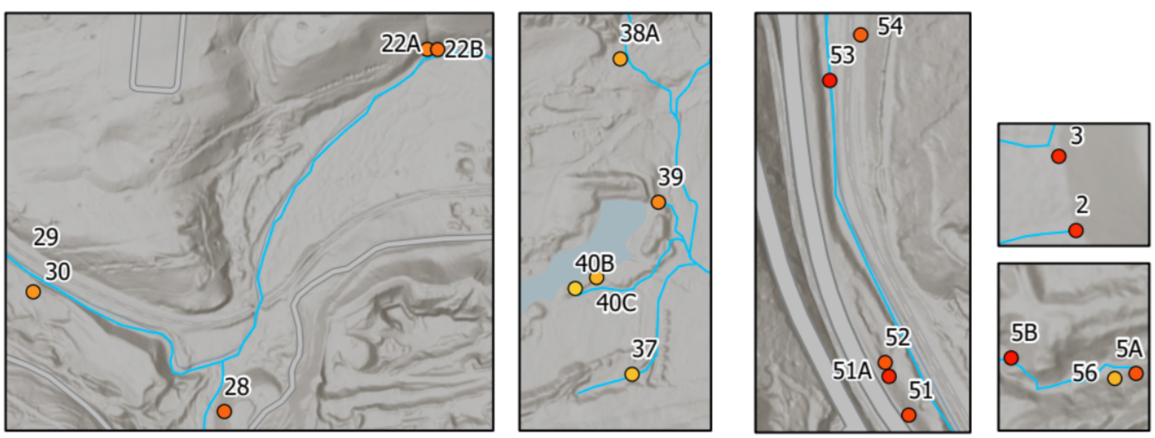
Shamokin Creek Watershed AMD Treatment Feasibility Rank



Shamokin Creek Watershed Final Rankings



Zoomed in Maps for AMD Clusters



AMD Discharge Locations

Final Rank

Highest

Lowest

Mining Streams

subwatersheds

Data Sources: PASDA, Kimball Shamokin Creek Watershed Assessment

Benjamin Shimer September 2022

Conclusion

The creation of these maps and this report hopes to visualize the environmental and socioeconomic consequences of abandoned coal mines and aid the Shamokin Creek Restoration Alliance in their efforts to clean up the Shamokin Creek watershed. Through the report, socioeconomic data demonstrates the difficulties the region faces with notably lower income and education levels, high disability and poverty rates, and large numbers of vacant households in what was once a mining and factory boomtown. Coupled with the economic consequences of the abandoned industry, the consequences of acid mine drainage has depleted aquatic life in the waterways while discoloring and polluting the main bodies of water that run through the mining region of the Shamokin Creek watershed. The details of these discharges are provided with maps detailing the metal loadings, dissolved oxygen, pH, and flow rates of certain discharges and stream locations. In addition, the mining factors that contributed to the economic and environmental burdens are mapped including possible entry points for water to turn into AMD discharge and the overall scale to which mining was exercised in the region.

These various maps all come together to tell the story of a region that has dealt with unjust consequences of abandoned mines in their economy and environment. GIS visualization of the mining problems existing in the Shamokin Creek watershed contributes data describing the environmental justice area while providing water chemistry and mining details that are essential to treatment plans and funding applications. However, with the most recent comprehensive water quality data for the watershed being collected in 1999-2000, it is difficult to fully assess the impacts of acid mine drainage in the watershed today. Collecting more recent and accurate water quality data is a necessary step towards understanding and treating acid mine drainage. The remediation of acid mine drainage in the Shamokin Creek represents an opportunity to revitalize a watershed and a community.

Acknowledgements

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