E. coli Contamination of Stony Creek, Mill Creek, and the Northern Fork of the Shenandoah

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Abstract

Water is amongst the most vital natural resources, so the growing rate of antimicrobial Escherichia coli (E. coli) contamination of water sources around the world is quite unsettling, as the contaminated water can be a vehicle for the E. coli to enter the body and make people sick. Contamination typically originates from fecal sources, agricultural runoff, stormwater runoff, and various other agricultural sources (Odonkor and Addo, 2018). Stony Creek, Mill Creek, and the Northern Fork of the Shenandoah are listed as impaired for E. coli contamination, which poses issues for the population that uses them recreationally for activities such as swimming or kayaking (Brannan et al, 2006). As such, mitigating contamination in these water systems is of great importance. We want to develop and implement a strategy to help return these water systems to their communities, where we determine their uses in the community, trace the points of contamination, and analyze previous mitigation strategies to develop a plan for these particular systems. We expect to find that agricultural runoff is the largest source of contamination for Stony Creek, Mill Creek, and the North Fork of the Shenandoah. If all goes to plan and we get E. coli levels below the 126 units/100ml average E. coli level, the communities will be able to safely use these water sources, improving the health of the area and the ecosystem (Virginia Administrative Code, 2019).

Research Question

Our study stands out from previous research as we ask, “What is the most dominant factor in E. coli contamination, and how can it be mitigated in the rural bodies of water, Stony Creek, Mill Creek, and the Northern Fork of the Shenandoah?”

We hypothesize that if areas of the Stony Creek, Mill Creek and Northern Fork of the Shenandoah are tested for E.coli, then areas closest to agricultural operations will have the highest concentrations, due to improper manure storage and fertilization techniques

Literature Review

Global Patterns of E. coli Contamination

While reviewing the existing literature about E. coli contamination, we came to a number of conclusions in the field. One is that an extremely large amount of the recent studies are in countries without reliably clean drinking water, which we can still learn a lot from, even if the situations don't match perfectly, or in rural areas. We also found that when water in rural areas is contaminated, it is often contaminated by agricultural sources and stormwater runoff (Amato et al, 2020; DuPont, 2023; Liu et al, 2025). The E. coli that is contaminating water is proving to have increased antibiotic resistance, which is a growing and concerning problem, especially for those who use the water system (Coleman et al, 2013; Odonkor & Addo, 2018; Yoneda et al, 2024). We also see that many mitigation strategies are done separately from the previous work, without talking to the local people about the potential impacts the decontamination process may have on them (King & Lau, 2024).

Antibiotic Resistant E. coli in Water Systems

Coleman and her team’s study “Contamination of Canadian Private Drinking Water Sources With Antimicrobial Resistant Escherichia Coli” looked at samples provided from private drinking water sources to find risk factors for antimicrobial resistant Escherichia Coli (E. coli) contamination and to conduct this, researchers tested E. coli water samples to find those containing a resistant strain of the bacteria and surveyed households at random about risk factors (2013). The study found that the factors that increased the risk of E. coli contamination were having a shore well, keeping livestock on the property, or having your water source located in clay soil or gravel (Coleman et al, 2013). Their approach was more about looking at shared contaminants rather than tracing which would be important to our study. Coleman et al’s study shows the detrimental effects antibiotic-resistant strains of E. coli can have on the key water sources people rely on and why it is vital to detect and treat E. coli (all types, but especially the resistant kind) early (2013). The text is well-written by authors who have a vast library of published pieces in their respective fields, with the necessary background and study information provided, along with charts illustrating the types of water sources and households, and good background information as they consult the previous work of other experts in their field. My major grievance is that this study only included English speaking households with an operational phone number, excluding potential diverse perspectives from the study. Another large weakness is that this study was limited to samples that were submitted for bacteriological testing, not to mention that bacterial contamination can be sporadic. This particular piece is relevant to our project as it shows how water sources can be contaminated by a contaminant of interest to us, along with a brief piece about steps that can be taken to avoid Escherichia coli contamination.

Odonkor and Addos' study Prevalence of Multidrug-Resistant Escherichia coli Isolated from Drinking Water Sources examined the microbiological quality of drinking water resources in Ghana, with a focus on the prevalence and antibiotic resistance patterns of Escherichia coli (E. coli). Water samples were collected from six types of sources (dams, boreholes, rivers, streams, canals, and wells) across 27 communities. The bacteria were isolated and tested for susceptibility against fourteen antibiotics. Researchers found that 49.48% of the E. coli isolates were multidrug-resistant, with the highest levels of resistance observed against penicillin, cefuroxime, and tetracycline. However, it showed high susceptibility to nitrofurantoin, amikacin, cefotaxime, and gentamicin. The authors conclude that many drinking water sources in the study area are unsafe and act as reservoirs of multidrug-resistant bacteria. Some strengths of the study include its wide sampling across different water sources and the use of a broad antibiotic panel. Some limitations include the reliance on phenotypic testing without molecular characterization of resistance genes. The article is relevant to our research because it highlights the significant role that contaminated water plays in the spread of E. coli, a major public health concern. Its findings can support arguments about the risks of waterborne pathogens and emphasize the need for work to improve water safety.

Environmental and Land-USe Drivers of Contamination

The study investigated how different environmental factors in lake sediments influence the survival of E. coli and identified which variables are most important for inclusion in predictive models of fecal contamination. Laboratory experiments were conducted using sediments from three lakes while manipulating combinations of temperature, pH, total dissolved solids, and the presence or absence of coexisting microbes. The researchers found that low pH and the presence of other microbes accelerated E.coli death, while higher total dissolved solid levels promoted longer survival. Statistical testing showed that pH had the strongest independent effect on survival, followed by microbial interactions, sampling site, temperature, and total dissolved solid concentration. Several significant interactions were also identified, particularly between pH and microbial coexistence, indicating that survival depends on complex relationships among multiple factors. Some of the study’s strengths include its comprehensive experimental design that tested combinations of environmental variables and the use of sediments from multiple lakes. However, some limitations include that they used a laboratory strain of E.coli, which may not accurately represent natural strains found in bodies of water. However, despite the limitations, the article is relevant to research on water quality and microbial risk assessment because it highlights which environmental factors influence E. coli growth.

Within Dupont’s study, a hypothesis was tested to determine if water near to CAFO’s contained higher levels of E. coli as compared to water sources from further away. A CAFO is a concentrated animal feeding operation (Golda et al, 2023). A series of water sampling tests were done from an area in Missouri. Some samplings were taken from an area that was within a

1-mile radius from a CAFO, as others were taken from areas that were within a 5-mile radius from a CAFO. Results concluded that the water nearby to the CAFOs had up to ten times as much E. coli content present. The null hypothesis, stating how there was no difference in waters near or away from CAFOs, was rejected as it was seen that CAFO's did influence E. coli presence(Golda et al, 2023). While other factors, such as rainfall and a small sample size, may have skewed the data, this study employed descriptive and nonparametric statistics to conclude that CAFOs do cause an increase in E. coli content in waters, ultimately affecting water quality. This source is a newer piece of data that provides adequate background on the E. coli bacteria. It has faults in its areas of conclusion because the actual conclusion is not easily found. It also appears somewhat opinionated on the topic of CAFOs. It is relevant to our area of research because it directly highlights the impacts of E. coli on water quality and brings about one of the sources of contamination. In the end, this source provides an adequate piece of information that directly targets our research proposal on E. coli and water contamination. Although it lacks in areas of conclusion, it still provides factually relevant information.

In an effort to see the effects of large concentrated poultry operations on the Chesapeake Bay Watersheds, Amato and their team conducted a study to determine if nutrient overloads and antibiotic-resistant bacteria were present in the water surrounding poultry CAFOs. Several tests were performed involving water sampling, nutrient sampling and processing, isotope analysis, microbiological sampling and processing, E.coli identification testing, antibiotic susceptibility testing, manure tests, and finally a statistical analysis was conducted (Amato et al, 2020). Results concluded that increased nutrient amounts and resistant E.coli were found in streams of nearby poultry operations. These streams were direct extensions of the Chesapeake Bay Watersheds. This article overall provided a direct reason for the study and contained successful results. It provided adequate evidence and supported the main cause. It lacked, however, in its ability to conclude the study. It could've contained a longer conclusion of how the findings answered the research question at hand. The research question being do poultry CAFOs directly cause nutrient pollution and antibiotic-resistant E.coli in the water surrounding them (Amoto et al, 2020). While this may be a weakness, this paper directly links to the case of water quality concerns and E.coli contamination, which is the basis of the class research project.

Dr Liu and their team studied how rainfall impacts the E. coli concentration in water bodies across Texas, and their study showed that rainfall and runoff can cause a large amount of E. coli to fester in various waterbodies around Texas (2025). They did this by examining preexisting data sets and comparing watershed characteristics, climate conditions, and E. coli concentrations (Liu et al, 2025). One major strength of their study is that they were able to account for a substantial number of waterbodies with a large variety of characteristics because they were able to use said data sets. One large weakness is that they are relying on data collected by others, so they can not easily account for potential mistakes made over the 21 years of data they are using. A strength for us is that the study and data are pretty up to date. The authors have a wealth of other studies to their names from a variety of perspectives that they apply to this research. This study is important to our proposal because it shows how large an impact climate can have on E. coli concentrations in water systems.

Watershed Management and Regulatory Context

TMDL is a Total Maximum Daily Load. It combines the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources, and a margin of safety (MOS) (Brannan et al, 2006). In simpler terms, it states how much bacteria a body of water can possess and still meet water quality standards. In this report, the Virginia Tech Department of Biological Systems Engineering, conducted a study on the development of a TMDL for the Mill Creek, Stony Creek, and Northern Fork of the Shenandoah. The Mill Creek, Stony Creek, and Northern Fork of the Shenandoah are all tributaries flowing into one another (Brannan et al, 2006). These three bodies of water were being assessed for a TMDL due to their failure to regulate fecal coliform concentration levels below 400 cfu. High fecal coliform concentration levels are a direct effect of E.coli. Due to this, it is the main bacteria studied in this report. In an attempt to create a TMDL for these bodies of water, the report focuses on finding point and non point sources and addressing by how much contamination needs to be reduced from these sources. This text provides lots of key information with relevant graphics and high scale tables. While it gets repetitive at times, showing multiple tables for the same thing, all information is necessary for their study. This source directly relates to our study because we have chosen these three tributaries as the basis for our project. It also uses E.coli as it is the main source of contamination just like ours. While this source is older than 15 years, recent literature such as the, “E.coli Testing Results for July 02, 2025”, represents one of these tributaries still being impaired from E.coli. In all, while it is an older source, it still develops an informative baseline for our project.

Monitoring, Indicators, and Testing Approaches

Korajkic, McMinn, and Harwood (2018) present a comprehensive review of the relationships between commonly used microbial indicators (such as fecal indicator bacteria, general coliforms, *Escherichia coli*, enterococci), alternative indicators (e.g., *Clostridium perfringens* and bacteriophages), and actual pathogens in recreational water settings (Korajkic, McMinn, & Harwood, 2018). The authors surveyed 73 studies published over four decades from a variety of freshwater, marine, and brackish environments, synthesizing data on statistical associations (or lack thereof) between indicator organisms and bacterial, protozoan, and viral pathogens (Korajkic et al., 2018). They found that in many cases, fecal indicator bacteria (FIB) do correlate significantly with bacterial or protozoan pathogens, especially in freshwater following wet-weather events or at sites with known fecal inputs, but correlations with viral pathogens (such as adenoviruses) were much weaker (Korajkic et al., 2018). They also highlight that indicators are far more frequently detected and at higher concentrations than actual pathogens, which may bias perceptions of risk; moreover, methodological limitations (e.g., low pathogen recovery, infrequent sampling) and site-specific factors (e.g., multiple fecal sources, varying pathogen shedding) greatly restrict the predictive value of indicators for pathogen presence (Korajkic et al., 2018). One strength of the review is its broad scope and rigorous synthesis of decades of data, which helps clarify when and why indicators–pathogen relationships succeed or fail. A weakness, however, is that differences in study design, sampling frequency, and detection methods make it difficult to draw strong, universal conclusions. Nevertheless, the article is highly relevant to our project on *E. coli* contamination in the Shenandoah watershed because it warns against overreliance on indicator bacteria alone to infer pathogen risk. In our proposal, this work supports the justification for incorporating more direct or complementary pathogen testing (or molecular MST markers) into our monitoring plan, particularly after rainfall or high-flow events, and underscores the need to interpret *E. coli* counts in the context of environmental dynamics and methodological constraints.

Hundreds of millions of people have insufficient access to safe and clean water, the world over, and these inequities need to be addressed (Stauber et al, 2014). The first step is identifying that this is an affordable, accurate test. That is why researchers at UNC Chapel Hill developed the compartment bag test. The compartment bag test is an affordable and portable test to detect and quantify E coli in a water source without the need of a lab. Dr Stauber and her team set out to look at the efficacy of these tests in their area using naturally contaminated water sources in Metro-Atlanta. They found that the compartment bag test seemed to be as accurate as the standard membrane filtration mI agar test, meaning it can fulfill that need for better testing. The methods of the researchers' testing are sound, ensuring the samples are properly stored and tested within 24 hours, with multiple samples from each source, with the major limitations of their methods just being that it was limited to the Atlanta, Georgia area. This limitation is fine for their purposes, but for the purpose of our study, I wish there was more data on the bag tests efficacy on more strains of E. coli that occur in different areas. The researchers had done a fine job reviewing the previous literature in the field, with twenty listed sources that you can tell informed their study. This piece is relevant to our project because it is important for us to understand the various testing strategies and their benefits and drawbacks.

Upasana Bhumbla and their team’s study of isolation and identification of bacteria from lake water in and around Udaipur, Rajasthan, investigated the presence and identity of bacteria in lake water around Udaipur, Rajasthan, with a focus on potential microbial contamination and its public health implications (Bhumbla et. al., 2020). Researchers collected water samples from multiple lakes and employed standard microbiological techniques, including serial dilution, culturing on selective media, Gram staining, and biochemical tests, for bacterial identification. The key findings revealed the presence of Escherichia coli, Pseudomonas aeruginosa, and Staphylococcus aureus, among other organisms frequently linked to fecal contamination and pathogenicity. The study concluded that untreated lake water in this region poses potential health risks, particularly for communities utilizing it for domestic purposes. The study's strengths lie in its clear methodological approach, utilizing standard microbial techniques, and its direct relevance to public health. It offers valuable baseline data for environmental microbiology in a region where water quality monitoring may be limited. Weaknesses include a relatively small sample size and the absence of molecular methods (e.g., PCR) for more precise bacterial identification. The study also did not assess antibiotic resistance, a growing concern in environmental microbiology (Bhumbla, 2020). This research is highly relevant to studies concerning waterborne pathogens, microbial contamination, and environmental health risks, especially in developing regions. This paper directly supports our group's overarching research topic on microbial contamination in natural water sources and its impact on human health. By demonstrating the presence of pathogenic bacteria in lake water used by local communities, it highlights the critical need for water quality monitoring and underscores the importance of public health interventions or water treatment strategies. The findings align with our group’s focus on the importance of environmental microbiology and potential pathways of disease transmission through water.

Fewtrell and Kay review epidemiological studies and quantitative microbial risk assessments published between 2010 and 2014 to evaluate infection risks associated with recreational water use. They report that bathers generally show a higher incidence of gastrointestinal illness than non-bathers, but that this risk does not always correspond directly with fecal indicator bacteria levels, especially in waters affected by non-point source pollution. Their synthesis also reveals that human sewage poses greater infection risks than animal sources, particularly due to viral pathogens, and they stress the growing importance of microbial source tracking. The authors note several methodological challenges in the field, including inconsistent illness definitions, differences in exposure measurement, and disparities between culture-based and molecular detection methods. The article is strong in its integration of epidemiological and risk-assessment evidence, offering a broad and critical perspective on recreational water quality. Its critique of current monitoring and exposure-assessment practices provides useful direction for improving future research. One limitation is that, as a review, its conclusions depend on the quality and scope of available studies, and the literature covered ends in 2014. This source is relevant to our research because it highlights the complex relationship between water quality indicators and actual infection risk. Its emphasis on microbial source attribution and improved monitoring methods supports arguments for advancing beyond traditional indicator bacteria and adopting more precise tools to assess contamination and protect public health.

Strain- Levels Differences and Treatment Implications

King and Lau (2024) investigate the effectiveness of conventional water-treatment and disinfection processes in removing bloom-forming strains of *Escherichia coli*, offering timely insight into an issue increasingly relevant to surface-water monitoring. Their study compares the behavior of environmental bloom-forming E. coli—strains capable of persisting and multiplying in aquatic habitats—to traditional fecal-derived strains during standard treatment steps, including coagulation, flocculation, sedimentation, filtration, and disinfection with chlorine, chloramine, and UV light (King & Lau, 2024). The authors report that both strain types responded similarly to treatment and disinfection, leading to the conclusion that current drinking-water treatment systems effectively remove bloom-forming E. coli even though these strains differ ecologically and are not associated with recent fecal inputs. A key strength of the study is its direct, controlled comparison between environmental and fecal strains, which challenges the assumption that all E. coli detections reflect fecal contamination. The methodological clarity and stepwise testing further enhance the study's reliability. Nonetheless, limitations exist, including the use of a small number of isolates, which may not represent the full diversity of bloom-forming E. coli, and the reliance on laboratory-scale treatment conditions that may not capture the complexity of full-scale systems (King & Lau, 2024). Despite these constraints, the study is highly relevant to our group's research on E. coli contamination in Stony Creek, Mill Creek, and the North Fork of the Shenandoah River. It suggests that elevated E. coli counts in these waterways may sometimes reflect environmental amplification rather than direct fecal pollution, an important nuance for interpreting monitoring results. Additionally, the confirmation that standard treatment methods effectively remove bloom-forming strains supports the feasibility of incorporating conventional treatment strategies into proposed mitigation efforts. Overall, the article strengthens the justification for examining strain-level differences in our study area and underscores the need to distinguish between fecal-origin E. coli and environmentally persistent strains when assessing water quality in the Shenandoah watershed.

Approach and Expected Outcomes

Our research question, “What is the most dominant factor in E. coli contamination, and how can it be mitigated in the rural bodies of water, Stony Creek, Mill Creek, and the Northern Fork of the Shenandoah?” can be broken down into five aims. Our first aim is to identify who the contaminated bodies of water are affecting and to what degree. In order to figure out who the contamination is affecting and to what degree, we are going to survey the people local to the area about their former use of the water systems and how it is of importance. The survey will first need to be approved by the IRB in order to use human test subjects. Once approved, we will pilot our survey with a healthy variety of questions including, age, are you located near the Stony Creek, Mill Creek, and Northern Fork of the Shenandoah if you are how close, approximate time living near the water system, do you use the tributaries currently, if so what do you use them for, has your use changed from previous uses to now, has contamination ever been a cause of concern for you, and do you know others who have been affected by water contamination. The outcome will likely be that the people living around the water are negatively impacted, and those closer to the water are impacted to the greatest degree. This is relevant because when water is contaminated by E. coli, it has negative impacts on the whole ecosystem, especially humans who utilize a specific body of water for recreation, so their perspective is at the center of why our research question is important.

The second aim is to determine the sections of the water bodies where E. coli contamination is the highest. These water bodies are not small, so tracing practices will help us pinpoint the source of contamination. For example, if there is a section of the Northern Fork of the Shenandoah that passes by a farm, it may contain higher levels of E coli downstream rather than upstream. We expect to determine this by conducting water testing techniques on different sites and mapping out levels. We will conduct these tests daily along different spots for a month. The outcome we expect to see is that water testing sites near farming areas with poor management strategies will contribute more to E. coli contamination. This is relevant to our research as it points us towards the sources we need to examine and consider in the mitigation strategy.

The next aim of the project is to identify the main contributors of E.coli contamination within the proposed area of the water sources. An approach to determining the prominent source of contamination includes testing for key identifiers such as genetic markers (genome sequencing) or microbial source testing (MST) to find evidence of treatment of manure. An expected outcome is that agricultural runoff from animal feeding operations will be the most dominant source of contamination, followed by sewage runoff from sewer plants, due to previous research. To answer the second part of the research question, “How can E.coli contamination be mitigated in the rural bodies of water?”, the source must be identified to figure out how to mitigate the bacterial growth.

The fourth aim of our project is to understand how the main contributors of E. coli contamination are contaminating the bodies of water, specifically the Stony Creek, Mill Creek, and the Northern Fork of the Shenandoah. The approach that we will take on this aim is to do tracking based on the land and organism activities that happen near those bodies of water that are involved in E. coli contamination. For example, if there is a notable amount of E. coli contamination in the bodies of water near a farm, we would be able to say that there is a correlation between the farm and E. coli contamination in the bodies of water. Once we are able to identify how the bodies of water are being contaminated by agricultural runoff, we will then be able to draw mitigation solutions or practices that such particular farms will take to decrease their E. coli contamination in the bodies of water. This is relevant to our project because we will be able to figure out what the source of E. coli contamination is in terms of agricultural runoff, and then we will be able to draw mitigation solutions for agricultural runoff.

The last aim approaches the mitigation strategies for E.coli contamination, and which strategy is most effective within a specific community. It focuses on past mitigation strategies in the area that were the most effective and analyzes data from nearby sources with successful mitigation strategies. For example, determining which manure treatment approaches they took, containment of contaminants, and how they controlled storm runoff. It is expected that by analyzing these successful strategies, developments for problematic areas can be approached, which can lead to farms or other industries putting these strategies into effect to provide cleaner water for their community. In turn, this will lead to aiding the problem of water contamination and enhancing the health and overall well-being of humans, animals, and the ecosystem.

Overall, these aims tie into the approach for mitigation of E.coli contamination in the Stony Creek, Mill Creek, and the Northern Fork of the Shenandoah. Individuals who are hurt by contamination, or in other words, the stakeholders of this project, are the basis for the mitigation. Understanding who is affected and how they are affected helps to find a solution that caters to the community's needs. It is important to determine where the contamination is coming from to determine what's not working and needs to be modified for a clean water system for the people who rely on it. In this process, we will determine what the contributors are and how much E. coli they contribute to the bodies of water, and this is what needs to happen first to determine how they are reaching the water in the first place. From this, we will look at previous strategies to mitigate E. coli contamination and their successes and failures, and can develop strategies tailored to the community to give them back their water for recreational activities. In the end, these aims allow us to face the community's needs and find a way to solve them. See Table 1 for a comprehensive table of these aims and outcomes.

Pitfalls and Alternatives

During this research project, problems may arise due to the vast nature of the testing strategies. In the event of a problem, the research team can either decide to approach a different route or talk about how conclusions would change without that bit of research. In this particular project, problems may occur with surveying, land access, or weather conditions.

For the surveys, problems may arise due to untruthful answers or limited applicants. The surveys in this study plan to ask community members how they use the Stony Creek, Mill Creek, and Northern Fork of the Shenandoah. Untruthful answers may occur if participants fail to remember when they used water bodies and for what they used them for. To avoid such bias, questions will be asked that are simple enough where the surveyor can easily answer truthfully. Such as have you used the Shenandoah River for recreational use? That would be a simple yes or no. If there is a lack in volunteers this would be harder to reroute, but it would not affect the conclusion it would just make it more broad.

Another testing strategy for this project involves testing different sites all alongside the three bodies of water. It is being tested like this in order to make the data as accurate as possible. This way it can be seen which sources are contributing the most amount of E.coli. For the problem of limited land access, this could arise if one of the testing sites is on private property and the land owner refuses access. This would directly affect this specific testing strategy. It would affect this testing strategy because there would be limited data for that specific site. To reroute from this problem, public sites could be tested in the same vicinity. While the data may be less detailed, data can be pooled from different sites close nearby in order to not disrupt the conclusions.

The last potential problem does not necessarily have to do with a direct testing strategy, but it affects them. The weather is a problem that may occur. Weather is hard to determine because it is impossible to control. In the event of a flood, data may be skewed. Increased water amounts can cause unusually high contamination levels in areas. In order to avoid this potential pitfall, weather will have to be carefully monitored. Or, on the contrary, the weather can be used as an advantage to mention how big of an effect rainfall has on contamination. Outliers due to rain are still useful data as it may lead to a need to suggest that the area needs better storm infrastructure, but may still be removed from the data set in order to point us towards typical sources of contamination in the area. Overall, these are potential pitfalls that may occur for this project. By addressing these alternatives to the problems, the team can reroute in the circumstance if it were to happen.

Broad Impacts

E. coli contamination in waterways such as Stony Creek, Mill Creek, and the North Fork of the Shenandoah River carries broad environmental, public health, and socio-economic consequences. Elevated E. coli levels, introduced through agricultural runoff, failing septic systems, livestock access, wildlife waste, or stormwater surges, indicate fecal pollution and the potential presence of pathogenic microorganisms (U.S. Environmental Protection Agency, 2012). Aquatic ecosystems are especially vulnerable because fecal contamination is often accompanied by excess nutrients that can fuel algal blooms, lower dissolved oxygen, and stress or eliminate sensitive aquatic species (Dodds et al., 2009). These disruptions reduce biodiversity, destabilize food webs, and diminish long-term watershed resilience.

The public health implications are similarly significant. E. coli functions as a widely accepted indicator organism, signaling that harmful bacteria, viruses, and protozoa may also be present (World Health Organization, 2017). Streams affected by contamination pose risks for residents and visitors participating in recreation such as swimming, fishing, and wading. Because Stony Creek and Mill Creek flow into the North Fork of the Shenandoah, contamination can spread downstream and affect larger portions of the watershed. During floods or high-flow conditions, contaminated surface water can also infiltrate shallow private wells, increasing the risk of gastrointestinal illness among rural households (Virginia Department of Health, 2020).

Economically, persistent E. coli contamination can reduce the value of natural assets and disrupt local businesses that depend on clean water. Public health advisories or recreation closures lead to reduced visitation and lower revenue for tourism-dependent communities (National Park Service, 2018). Local governments may face increased monitoring and remediation costs, while farms may be pressured to implement best management practices such as expanded riparian buffers or improved manure management (Sharpley et al., 2015). Over time, chronic water-quality problems can affect property values and complicate regional planning efforts. Together, these impacts underscore the need for coordinated watershed management strategies that protect both ecological health and community well-being.

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Table 1. Project approach and outcomes table.

Project Aims	**Approach**	**Expected Outcomes**	**Relevance**
Who is the contamination of these water bodies affecting, and to what degree?	Surveying local individuals about the importance of the bodies of water and their former uses.	People living around the water are negatively impacted, and those closer to the water are impacted to the greatest degree. Example: open ended survey where they describe how the water was previously used and how it impacted their behaviors/hobbies/etc.	The people of the area are going to be impacted, and understanding how the community is impacted deepens our understanding of the importance of the system and informs our approach and the potential benefits and pitfalls
In what areas of the water bodies are E. coli contamination levels the highest?	Testing contamination levels in different areas, such as near farmland or away from farmland, and comparing the differences	The levels near concentrated farming operations with poor management strategies will have the highest levels of contamination	Helps to find out in what areas E.coli contamination is occurring and what occupies these areas.
What are the main contributors to contamination?	Test for key identifiers of certain sources of E. coli, such as genetic markers that match specific species or evidence of treatment to manure. (MST testing)	Agricultural runoff from animal feeding operations will be a major contributor as well as sewage runoff from sewer plants.	Identifying the major source of contamination is essential in taking the steps to mitigate the E.coli growth.
How are the major contributors contaminating the bodies of water?	Analyzing different containment methods across farms and testing the water from these farms. Analyzing if there is a correlation between waste management practices and nearby water quality.	Identifying the most dominant factor of E.coli within a specific body of water to find solutions to mitigate the bacterial growth. Example: liquid storage method for a farm High levels of E.coli in the water near the farm indicate a correlation	To understand the methods of contamination of the major contributors to E. coli contamination, to then draw plans for mitigation solutions.

What mitigation strategies are most effective for E.coli water contamination in this community structure?	Analyzing data from previous mitigation strategies and how successful they were. Using sample sites where water was not contaminated and seeing what the farm nearby implemented to stop the spread, then deeming this method as successful.	Farms or other industries using proper waste management will have cleaner waters near them. E. coli levels should be below the 235 colony forming units (cfu) per 100 ml of water, as designated by the Virginia Department of Health (2016)	Helps to identify which mitigation strategies are most successful and guides us on long-term and short-term approaches for contamination sources