# SPRINGING FOR SAFE WATER: DRINKING WATER SOURCE SELECTION IN CENTRAL APPALACHIAN COMMUNITIES

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Biological Systems Engineering

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September 25th, 2019
Blacksburg, VA

Keywords: Appalachia, drinking water quality, point-of-use, roadside springs, total coliform, *E. coli*, heavy metals, maximum contaminant level, secondary maximum contaminant level

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## ABSTRACT

There are rural residents of Central Appalachia that collect their drinking water from roadside springs despite having access to in-home piped point-of-use (POU) water. Residents have cited perceptions about water availability/quality as primary motivators for collecting drinking water from roadside springs. Water from roadside springs has been found to contain total coliform and *E. coli*, suggesting that consumers may be at an increased risk of contracting gastrointestinal illnesses. This research effort seeks to better understand roadside spring usage in Central Appalachia, by exploring motivations influencing potable water source selection and comparing household and spring water quality to Safe Drinking Water Act recommendations. Households were recruited from communities surrounding springs in three states (Kentucky, Virginia, and West Virginia). 24 tap water samples were collected from participating households and paired with samples from six roadside springs. Samples were analyzed for fecal indicator bacteria and inorganic ions. Study participants also completed short surveys to inventory their perceptions of their household drinking water. The majority of participants did not trust their home tap water, indicating water aesthetics as primary motivators for distrust of their homer water source. Statistical comparisons indicated that 10 water quality constituents (Cd, F, $NO_3$-, Cu, Pb, Ag, Mn, Zn, Na, and Sr) were significantly higher in tap water samples and four constituents (total coliform, U, Al, and $SO^{2-}{}_4$) were significantly higher in spring samples. These results suggest that residents might be exposed to different risks based on their drinking water source and that water quality solutions must be devised case-by-case.

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## GENERAL AUDIENCE ABSTRACT

Some rural residents of Central Appalachia collect their drinking water from roadside springs, despite having access to piped drinking water at their homes. Water collected from roadside springs can contain harmful bacteria, suggesting that people may risk exposure to illness when consuming spring water. Through a household water quality study, this research effort aims to compare roadside spring and in-home tap water quality in order to determine what contaminants are present at each source, and why residents are choosing spring water over tap water. Households were recruited from communities surrounding roadside springs in three states (Kentucky, Virginia, and West Virginia). A total of 24 tap water samples were collected from participating households, and compared with samples from six nearby roadside springs. Samples were analyzed for bacteria, metals, and nutrients. Study participants were also asked to complete short surveys to better understand their perceptions of their drinking water sources. The majority of participants did not trust their home tap water, citing aesthetic concerns as the primary reason behind their distrust. When comparing roadside spring and home samples, 10 contaminants (Cd, F, $NO_3$-, Cu, Pb, Ag, Mn, Zn, Na, and Sr) had greater concentrations in home tap water samples and four (total coliform, U, Al, and $SO^{2-}{}_4$) had greater concentrations in spring samples. While home water samples had higher levels of metals, roadside spring samples had higher levels of bacteria, suggesting that residents might be exposed to different risks based on water source and that water quality solutions must be developed case-by-case.

## Acknowledgements

Endless thanks to my two glorious advisors, Dr. Leigh-Anne Krometis and Dr. Emily Sarver. You have both shown me what it means to be a strong, intelligent, thoughtful, caring professionals and I hope to carry on these traits in both my career, and my personal life. Thank you to Dr. Cully Hession for not only serving on my committee, but for caring about my well-being as both a graduate student and a human being. Thank you to Dr. Marc Edwards for not only being instrumental in funding my research, but for being a strong sounding board and for cheering me on at every opportunity. Thank you very to the soon to be Drs. Lauren Wind and Cristina Marcillo, and to Dr. Katherine Phetxumphou for helping me with sampling, offering research advice, reading my work, and assuring me that I am where I am supposed to be. Thank you to Ethan Smith, Casey Schrading, and Austin Wozniak for working so hard on this project in the field and lab, both before I even came to Virginia Tech and after the project became my own.

I want to extend a special thank you to my parents for showing me the power of education, being my strongest support system, pushing me to do my best, loving me unconditionally, and convincing me that graduate school would be not only life changing, but fun! Thank you to my family, boyfriend, friends, and most importantly, the best Shmoop in the whole wide world, Olive the Wonder Dog. Without the love, support, and humor of these individuals, I would not have been successful in pursuing my Master’s degree. Also, thank you to these folks for listening to me drone on about my research and the state of drinking water infrastructure in the United States.

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# 1. Introduction: Understanding Drinking Water Quality and Access in Appalachia

Despite near 100% reported access to drinking water in the United States, issues of piped and potable water access relating to water quality, distribution, and equity persist (Vanderslice, 2011; Stillo & Gibson, 2017; Switzer & Teodoro, 2017; Krometis et al., 2019). Indicators of inequity can include differences in safe drinking water access between urban and rural areas or regions (spatial inequality), different population groups within the same region (social inequality), or different age groups (generational inequality; Yang et al., 2013). Rural areas of the country, in particular, see disparities in drinking water quality and availability with 29% of Rural Alaskans, 30% of the Navajo Nation (Vanderslice, 2011), and over 10% of homes in several Central Appalachian counties (Krometis et al., 2017) living without access to in-home potable water. Gasteyer & Vaswani (2004) determined that in the United States in 2000, rural localities with populations of less than 1,000 and rural farm populations were particularly vulnerable to issues of potable water access, with the highest percentage of homes lacking services at 1.27% and 1.19% respectively, well above the national average of 0.64%.

This discrepancy between potable water availability in rural and urban areas of the United States is even more intense at the global scale as an estimated 96% of the global urban population has access to improved drinking water sources, while 19% of the global rural population is reliant on unimproved sources (Bain et al., 2014; Francis et al., 2015). Examining developed countries beyond the United States, 97% of urban populations have piped drinking water available in their homes but only 79% of the rural population have in-home access to drinking water (Bain et al., 2014). A primary challenge in addressing this potential inequity is urban access to drinking water infrastructure that is unavailable and perhaps impractical for rural communities, including connections to larger, better funded and more technologically advanced municipal treatment plants and distribution systems. An estimated 15% of the United States population is served by individual private wells or very small drinking water systems beyond the purview of the Safe Drinking Water Act (SDWA; CDC, 2019).

Drinking water quality has been a historic concern for rural inhabitants of Appalachia (Krometis et al., 2017), a region of the United States where essential infrastructure for water systems and utilities is limited by social, geographic, and economic challenges (Cook et al., 2015; Arcipowski et al., 2017). Despite focused efforts to increase community water system (CWS) coverage in Appalachian communities, coverage still lags behind the national level of 85% at 75% (ARC, 2016). Access to a CWS and municipally treated water is not necessarily a panacea however, as small, rural systems often struggle to support growing centralized service systems due to low public investment, few funding opportunities, updated water standards requiring new treatment technology, outdated and aging treatment systems or distribution lines, and/or lack of manpower (Allaire et al., 2018; Marcillo & Krometis, 2019). Persistent socioeconomic issues in Appalachia, accompanied by the challenging topography of the region, have resulted in aging and failing water infrastructure with a need for updated, modern water treatment and distribution systems (Arcipowski et al., 2017; The Appalachia Initiative, 2017).

Infrastructure challenges in the Appalachian region can result in limited access to adequate clean drinking water for community members and/or degradation of public trust in the safety of available drinking water. For example, Blakeney & Marshall (2009) determined that residents of Letcher County, Kentucky, despite in home access to municipal water, relied upon alternative water sources for potable uses including drinking, cooking, and cleaning because they viewed their tap water as aesthetically displeasing and therefore potentially associated with health risks. Additional studies have reported that individuals with inadequate access to water of sufficient quality or quantity in their home generally turn to alternative sources which can include the use of bottled water, natural springs, or a neighbor/family member’s water (McSpirit & Reid, 2011; Arcipowski et al., 2017; Page et al., 2017; Krometis et al., 2017, Krometis et al., 2019); however, these alternative sources are not without their own challenges. Private wells, springs, and cisterns are unregulated by the Environmental Protection Agency’s SDWA, with treatment and monitoring considered to be the responsibility of the homeowner (USEPA, 1991). Purchased (bottled) water can be both expensive and burdensome to obtain (McSpirit & Reid, 2011; Javidi & Pierce, 2018).

Emerging research by Krometis et al. (2019) and Swistock et al. (2015) reports that some residents of Central Appalachia “water scavenge” in order to obtain drinking water, collecting a portion or all of their household drinking water from roadside “spout” springs, despite having access to in-home piped point-of-use (POU) water. This choice presents a potential health risk, as both studies frequently detected *E. coli* in spring samples at the point of collection. Krometis et al. (2019) determined that 63% of spring users from Central Appalachia who participated in a related survey indicated that they collect spring water for drinking at least weekly, citing positive perception of spring water quality, home water quality concerns, and/or intermittent or no in-home water availability as primary motivators for visiting springs. Swistock et al. (2015) reported that 30% of Pennsylvania residents attending local extension programming had consumed water from a roadside spring and that 12% consume spring water every year, citing “taste” and the perceived “natural” state of the springs as motivators. Neither of the previously mentioned studies directly compared the quality of roadside spring water to that of in-home piped drinking water to determine whether “water scavenging” presents exposure to additional or different types of contaminants.

## 2. Literature Review

### 2.1 Drinking Water Quality Monitoring

### 2.1.1 *Safe Drinking Water Act*

The Safe Drinking Water Act, passed by Congress in 1974, is a primary piece of legislation aimed at protecting public health. It regulates all public drinking water supplies in the United States (USEPA, 2004; Weinmeyer et al., 2017). The law seeks to protect both finished drinking water that is distributed to communities by public water systems, and drinking water sources, including ground and surface waters (USEPA, 2004; Weinmeyer et al., 2017). SDWA authorizes the United States Environmental Protection Agency (USEPA) to set national health-based standards that protect against naturally-occurring and anthropogenic pollutants that have the potential to contaminate drinking water (USEPA, 2004). The responsibility for ensuring adherence to these standards is distributed among the USEPA, individual states, tribes, water systems, and the general public (USEPA, 2004; Weinmeyer et al., 2017). The national standards, known as the National Primary Drinking Water Regulations, set maximum contaminant levels (MCLs) for contaminants in drinking water that are considered a threat to public health, such as As, as well as specific treatment techniques (TT) for removing harmful contaminants from drinking water (USEPA, 2004). Public water systems are required to monitor contaminant concentrations to ensure they meet the MCLs (USEPA, 2004). The standards also define secondary maximum contaminant levels (SMCLs), i.e. appropriate levels for contaminants that cause aesthetic issues of color, odor, or taste in drinking water, such as Fe and Mn; although SMCLs are not generally enforceable.

### 2.1.2 *SDWA Compliance and Violations*

Approximately 157,00 public and private water systems are regulated by the SDWA in the United States, varying in both system size (large to very small) and type (municipal to campground systems; Tiemann, 2017). When a public water system fails to comply with SDWA stipulated regulations, violation(s) are issued. These are generally classified as either health-based or monitoring and reporting violations. Health-based violations occur when the drinking water distributed by a public water system contains contaminants at concentrations higher than the MCL, or when a public water system fails to treat for contaminants using methods dictated by the SDWA.

Monitoring and reporting violations encompass any non-health-based violations, including when a public water system fails to sample and test drinking water at required intervals, or when the system fails to report the results of these tests back to the EPA, the state, or its customers (Fedinick et al., 2017). It must be noted that while monitoring and reporting violations are not classified as health-based, violations of this nature can obfuscate core infrastructure or water quality issues at public water systems, e.g. critical health-based violations will not be detected if a monitoring regimen is faulty (Fedinick et al., 2017; Marcillo & Krometis, 2019). SDWA violations for every public water system in the United States are stored in the Safe Drinking Water Information System (SDWIS), hosted by the EPA, and are available to the general public.

## 2.2 Drinking Water Infrastructure in Appalachia

### 2.2.1 *Community Water Systems*

The EPA defines a community water system (CWS) as a public water system that provides year-round water to a non-transient group of people. This can include homes, apartments, condominiums, and mobile home parks located in cities and towns, but excludes campgrounds or seasonal communities. As of 2005, 47% of CWSs in Appalachia were privately owned and operated, serving 18.3% of the community in the region, with the remainder operated by municipalities (Hughes et al., 2005). Given that some areas of the region still comprise communities where up to 1 in 10 homes lack complete plumbing (Krometis et al. 2017), infrastructure investments to expand CWS coverage remains a key priority of the Appalachian Regional Commission (Hughes et al., 2005).

It is important to recognize that the existence of a CWS in a community does not necessarily guarantee water of sufficient quality and/or quantity at the user’s tap, particularly in rural regions. Small and rural CWSs in particular account for the majority of SDWA violations; in 2009, 64% of all reported violations were attributed to very small systems (serving less than 500 households) (USEPA, 2009). Moreover, several studies have found that water systems serving small and rural communities have a significantly higher rate of violations of health standards and a higher percentage of total SDWA violations when compared to large systems (Gasteyer & Vaswani, 2004; Fedinick et al., 2017). This is not necessarily surprising, given that smaller systems are often challenged by inadequate funding and aging facilities due to low income and/or declining populations (Anadu & Harding, 2000; Hu et al., 2011; Allaire et al., 2018; Marcillo & Krometis, 2019). Allaire et al. (2018) determined that small, rural CWSs reliant on surface water sources had the highest predicted probability of health-based SDWA violations across the United States. Work by Marcillo and Krometis (2019) that examined trends in SDWA violations across Virginia, a state that falls partially in Central Appalachia, reported that monitoring and reporting noncompliance was statistically greatest for very small systems in isolated rural areas. Gasteyer & Vaswani (2004) found that rural households, such as those present in Appalachia, are more likely to lack access to complete plumbing facilities. In particular, they determined that people living in poverty are more likely to lack access to complete plumbing facilities and are nearly four times more likely to have incomplete plumbing than individuals living above the poverty line.

In Central Appalachia, 55% of the population resides in rural and/or small-town communities (HAC, 2013). The prevalence of small, rural communities in Appalachia is reflected by the size profiles of CWSs in the region. In Appalachia in 2003, the proportions of "Small" and "Very Small" CWSs were much higher than those at the national scale, e.g. 50% of CWSs in Appalachia were classified as "Very Small", serving 500 or less people, and 30% of CWSs in Appalachia were classified as "Small", serving between 501 and 3,300 people. The proportion of individuals served by CWSs using surface water as a source is also higher than the national average, with 82% of the Appalachian population served by surface water CWSs in 2005, compared to 68% of the national population (Hughes et al., 2005). Operation and capital costs also tend to correlate with the size of a community water system, with smaller systems generally costing more than larger treatment systems (Hughes et al., 2005). CWSs that rely on surface water also tend to see higher operating and capital costs than groundwater CWSs or those that purchase water (Hughes et al., 2005). Given that system size and water source have been identified as potential risk factors for SDWA violations (Allaire et al., 2018; Marcillo & Krometis, 2019), it is perhaps not surprising that home water quality is a frequent environmental health concern identified by Appalachian communities, even when that water is sourced from centralized treatment system (Blakeney & Marshall, 2009; McSpirit & Reid, 2011; Levêque & Burns, 2017; Krometis et al., 2019).

### 2.2.1 *Infrastructure Challenges*

Small, rural, and/or economically disadvantaged communities often struggle to address challenges such as aging water supply infrastructure and sub-optimal existing system operation and maintenance (Wedgworth et al., 2014). Small system size and greater reliance on surface water sources also plays a role in higher capital and operation and maintenance costs for CWSs in the Appalachian region specifically, as compared to the rest of the nation (Hughes et al., 2005). The topography in the Appalachian region can render modern distribution and treatment systems expensive or less effective (Cook et al., 2015). Hard rock subsurface conditions make pipe installation and repair expensive, thin soil precludes reliance on on-site wastewater systems (i.e., which can ultimately affect drinking water sources), and steep and prevalent slopes can require more or larger pumps to distribute water. Additionally, communities are relatively dispersed in the Appalachian region, which requires more piping and pumps to distribute water to residents (Hughes et al., 2005).

To date, relatively little formal research has identified or quantified the impacts of various socioeconomic factors on drinking water quality in Appalachia (Krometis et al., 2017), though previous work has suggested that factors related to household income can influence water quality exposure at the tap in the United States more generally (Balazs et al., 2011; Switzer & Teodoro, 2017; Stillo & Gibson, 2017). In 1960, the average county poverty rate in Appalachian states was over 40%, leading to the "War on Poverty" and the formation of the Appalachian Regional Commission (ARC) in 1965 (Deaton et al., 2012; Partridge et al, 2013; Smith et al., 2014; Switzer & Teodoro, 2017). While the poverty gap between Appalachia and the nation has been significantly reduced since the 1960s (Partridge et al., 2013), poverty rates in the Appalachian subregion of Central Appalachia remain as high as 20% in some counties overall. Central Appalachian rural poverty rates in particular are at levels 50% higher than the national average (HAC, 2013). Factors influencing trends in poverty in the region include low educational attainment, low household mobility, remoteness from cities, and/or single industry economies, particularly those associated with extractive industries (Partridge et al., 2013). These economic factors can lead to a lack of revenue for those critical investments in local infrastructure required to improve drinking water quality at the tap (Hughes et al., 2005; Wedgworth et al., 2014).

### 2.2.2 *Private Well Water*

At present, nearly 75% of Appalachian homes are served by CWSs, with the remainder primarily reliant on private wells (Hughes et al., 2005). As mentioned earlier, private well water systems do not fall under the purview of the SDWA and water quality monitoring and well maintenance are the responsibility of each individual homeowner (USEPA, 2017). Private well systems normally do not include disinfection and other treatment processes common for CWSs, which can render households served by private wells more vulnerable to environmental contamination by bacteriological and heavy metals constituents (Hughes et al., 2005; Smith et al., 2014). Elevated concentrations of bacteria, Pb, Rn, As, and $NO_{3-}$ have been documented in well samples collected from homes in Appalachian states including Virginia, West Virginia, Pennsylvania, and New York (Gelberg et al., 1999; Shiber, 2005; Allevi et al., 2013; Pieper et al., 2015; Swistock et al. 2015). A study by Allevi et al. (2013) in Virginia determined that fecal indicator bacteria contamination, including coliform and *E. coli*, is quite common at the point-of-use of private well systems, with over 40% of homes testing positive for total coliform, and 10% positive for *E. coli*. Pieper et al. (2015) found Pb levels exceeding the SDWA action level of 15 ppb in 20% of first draw POU private well and spring water samples collected in Virginia. Although the connections between heavy metals and health impacts are still a topic of investigation, the connection between fecal indicator bacteria-positive private well water and an increase in the prevalence of acute and/or chronic gastroenteritis in well-users is fairly well documented (Denno et al., 2009; Charrois, 2010; Allevi et al., 2013; DeFelice et al., 2016).

## 2.3 Water Quality Perception in Appalachia

### 2.3.1 *Perception as a Driver of Water Source Selection*

Risk perception and associated reliance on alternative water sources to avoid perceived exposure to contamination can be the result of objective information and/or a multitude of social, cultural, psychological, and economic factors (Glicker, 1992; Hu et al., 2011). The decision to obtain drinking water from public or private water sources, such as municipal water, well water, or bottled water, is often influenced by factors including taste, smell, color, safety, cost, and convenience, which may not be directly associated with water quality data (Merkel et al., 2012;

Krometis et al., 2019). Unfortunately, decisions to avoid tap water in favor of alternatives are not without potential adverse consequences. Oftentimes the cost of bottled water represents a significant portion of total household income (Opel, 1999; McSpirit & Reid, 2011; Hu et al., 2011; Krometis et al., 2019). The price of bottled water is, on average, roughly 500 to 1,000 times greater than that of tap water, resulting in socioeconomic concerns for the affordability of access to drinking water (Ferrier, 2001; Hu et al., 2011). Household funds spent on alternate drinking water sources can also reduce public system support since revenues from water bills are traditionally used by communities and governments to make improvements to water infrastructure (Opel, 1999; Hu et al., 2011). Furthermore, mistrust of tap water is related to decreased water consumption and the increased intake of sugary beverages, contributing to health and welfare concerns in many communities (Hu et al., 2011; Onufrak et al., 2014; Pierce & Gonzalez, 2017).

### 2.3.2 *Examples of Alternative Water Sources*

#### 2.3.2.1 *Bottled Water*

Perceptions of drinking water safety, accompanied by beliefs surrounding the ground and surface water quality in a local area, might be factors contributing to an individual's decision to select bottled water over tap water (Hu et al., 2011). Several studies have documented consumer response to drinking water quality violations issued by the SDWA, particularly with respect to bottled water purchase. Zivin et al. (2011) determined that between 2001 and 2005, water bottle sales in 200 grocery stores across northern California and Nevada increased by 22% in response to public water system violations issued for microbial contaminants and 17% for metals and chemical contaminants. On a more national scale, Pape & Seo (2015) combined water quality violation data from annual reports with purchase data from the national Consumer Expenditure Survey and determined that households in the United States are 25% more likely to purchase bottled water, and increase their related household expenditures by 4 to 7%, after news of a water quality violation. They also determined that consumers are willing to pay an additional $300 million dollars every year, amounting to 4% of total annual household expenditures, on bottled water, in order to avoid the health risks associated with drinking water quality violations (Pape & Seo, 2015).

The purchase and use of bottled water during drinking water quality emergencies such as those in Flint, MI and Charleston, WV is also documented. Schade et al (2015) determined that during the crisis surrounding the Charleston, WV chemical spill in 2014, 92% of surveyed individuals used alternate sources of drinking water with 77% of these individuals purchasing water at large box stores or grocery stores and 57% obtaining drinking water from water distribution centers. After the Flint, MI water crisis in 2016, Heard-Garris et al (2017) found that 75% of their survey respondents reported that they were forced to spend extra money during the crisis, with 53% of respondents reporting that these additional expenditures were going towards buying bottled water.

Despite the perception of bottled water as a safe, better tasting alternative to tap water, several studies have reported that bottled water quality does not always exceed tap water quality (Lalumandier & Ayers, 2000; Raj, 2005). Lalumandier & Ayers (2000) tested bottled water purchased in Cleveland and determined, via heterotrophic plate count, that the samples contained increased levels of bacteria with concentrations as high as 4,900 CFUs/mL, and that the majority of bottled water samples also failed to fall within the Ohio EPA's recommended range for F of 0.80 to 1.30 mg/L. Additionally, Azoulay et al. (2001) determined that few bottled water brands examined in their study contained an "optimal mineral profile", i.e., high levels of $Ca^{2+}$ and $Mg^{2+}$ and a low level of $Na^{+}$, when compared to tap water in a range of North American cities.

#### 2.3.2.2 *Roadside Springs*

Springs are formed when the groundwater table intersects with the ground surface, due to geological, topographical, or man-made factors. Springs can occur at specific points or over a larger seepage area and are usually found along hillsides, low-lying areas, and at the base of slopes. While spring water is widely considered to be groundwater, given that its source is often relatively near-surface, this water is more readily exposed to contamination as compared to groundwater pumped from deep wells (Swistock et al., 2016). Private springs on residential properties are sometimes used as a primary household water supply and can be a reliable and inexpensive source of drinking water if developed and maintained properly. Springs are developed as drinking water supplies for homes by collecting the discharged spring water, often via tiles or pipe segments, and transferring the water into some sort of sanitary storage tank. During this process, the spring water must be protected from surface contamination between the spring, storage unit, and home, oftentimes via a spring box. Depending on the quality of water from the private spring, treatment methods may be included in the system to ensure safety of water (Swistock & Sharpe, 2017).

Roadside springs occur naturally in areas where road cuts have exposed shallow groundwater aquifers, often located along local and state roads (Swistock et al., 2015). While some roadside springs are merely a pull-off where the spring can be accessed, others have been upgraded with parking lots, plumbing systems, walls, or signs as a means of publicizing and improving access for the collection of water. Despite their use as a drinking water source in Appalachia and across the United States, roadside springs are generally unregulated and unmonitored by public authorities, and thus little is known about their water quality and extent of use as a drinking water source.

Untreated drinking water is a widely documented risk factor for infectious disease (Ritter et al., 2014). While the general public's perception of roadside springs is that they are a clean source of drinking water (Swistock et al., 2015; Arcipowski et al., 2017), Krometis et al. (2019) determined that roadside springs in the Central Appalachian region are often contaminated with fecal indicator bacteria including total coliform and *E. coli*. Swistock et al. (2015) also identified fecal indicator bacteria in roadside springs in Pennsylvania with 91% and 32% of water samples collected from 37 roadside springs testing positive for total coliform and *E. coli*, respectively. Additionally, on two occasions, Swistock et al. (2015) sampled eight of the springs for protozoan cyst analysis and determined that seven contained *Giardia* cysts or *Cryptosporidium* oocysts during one or both sampling events. The presence of fecal indicator bacteria and protozoan cysts in roadside spring water suggests that individuals collecting and consuming this water could be at risk of contracting an infectious disease. Swistock et al. (2015) generally observed low levels of aesthetic pollutants, such as Fe and Mn, in the Pennsylvania springs sampled. Krometis et al. (2019) also found low levels of Fe and Mn in spring water samples with only two of 21 springs exceeding SDWA SMCLs for these contaminants. Low levels of water quality constituents associated with unpalatable taste, odor, or appearance may contribute to a public perception that these water sources are "safe" and/or "natural" (Krometis et al., 2019; Swistock et al., 2015).

## 2.4 Goal and Research Questions

Anecdotal evidence and previous research efforts suggest that there are residents of Central Appalachian communities that obtain drinking water from roadside springs, despite having access to in-home piped drinking water. Given previous reports of spring water quality, individuals that collect their drinking water from such sources, which are untreated and unregulated, might risk exposure to bacteriological and/or heavy metal contaminants. However, little is known about the quality of water available at their home tap, which might also pose risks, given previous reports of struggling municipal infrastructure and high incidence of contaminants in private well water. The goal of this study is to better understand both the perceptions driving drinking source selection, and the real differences in water quality between roadside spring and POU drinking water sources in Central Appalachia. Accordingly, this research effort seeks to answer these questions:

1) What are the motivations influencing potable water source selection in Central Appalachia?
2) How does the water quality of roadside spout springs in Central Appalachia compare to SDWA regulations?
3) How does the water quality of household POUs in Central Appalachia compare to SDWA regulations?
4) How does the household POU water quality of individuals living in Central Appalachia compare to the water quality of local roadside spout springs?

# 3. Methods

This study sampled roadside springs and in-home POU tap water in the Central Appalachian region. Spring and tap water samples were paired based on location and sampling date in order to compare water quality between sources and determine what contaminants consumers may be exposed to on a given day. Additionally, study participants were given surveys to better understand their perception of their home tap and spring water.

## 3.1 Study Area

This study targeted households at least partially dependent on one of six roadside springs located in four counties in Central Appalachia (Figure 3.1). The land use in this region is primarily forested with areas featuring an agricultural presence as well. Spring sample sites were selected based on previous work by Krometis et al. (2019) that identified these springs as regularly used by members of the surrounding community as a potable water source. It is important to note that some springs are located in counties outside of those where home samples were collected, as some residents travel outside of their county, or state, to obtain drinking water from roadside springs. A total of 24 suites of household samples were collected from homes in four counties in three states: Martin County, Kentucky; McDowell County, West Virginia; and Craig and Floyd counties in Virginia, and compared with samples from one of six springs (Figure 3.2).

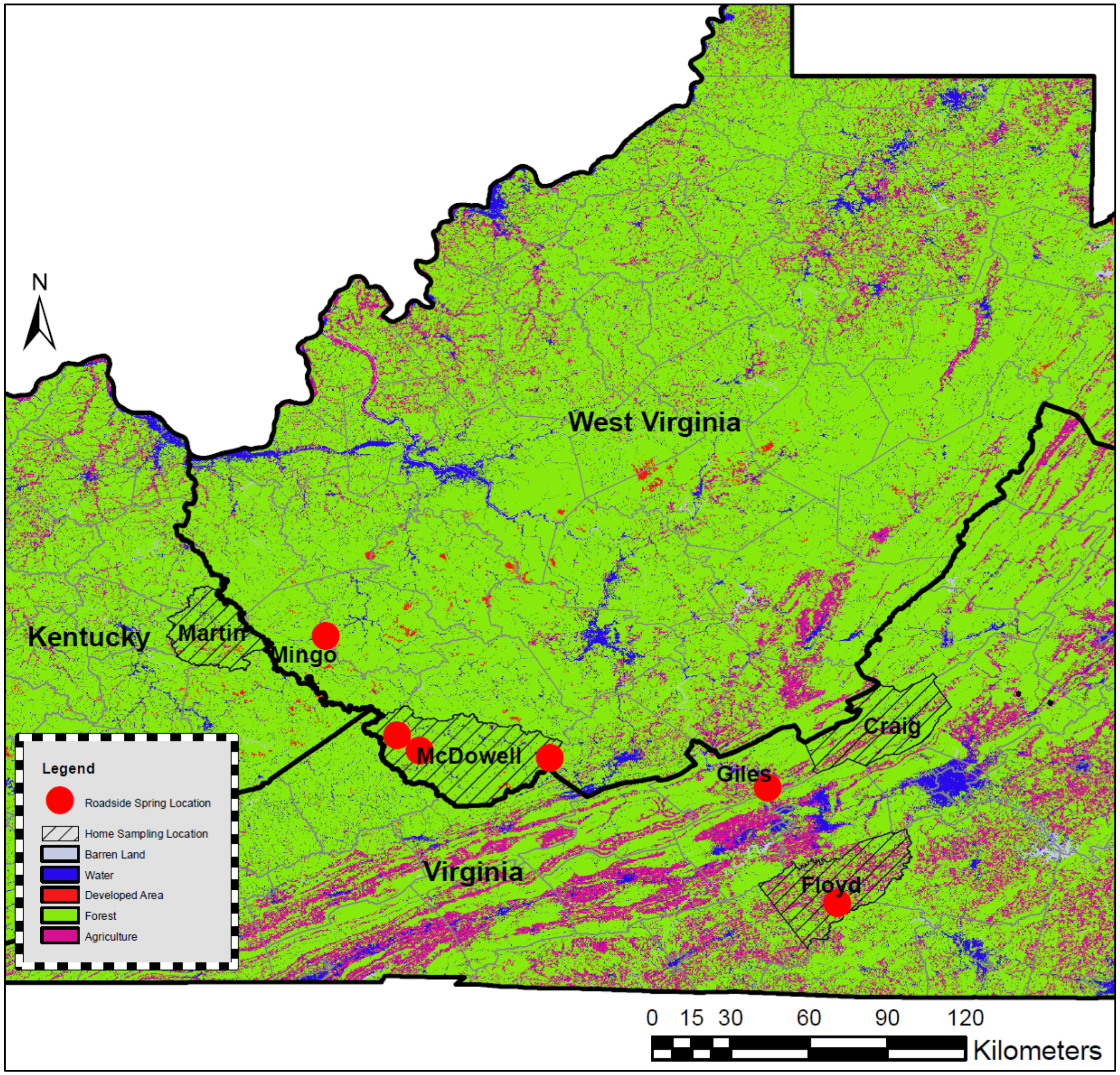


Figure 3.1: Map featuring Central Appalachian roadside spring locations and the counties in which home POU water samples were collected.

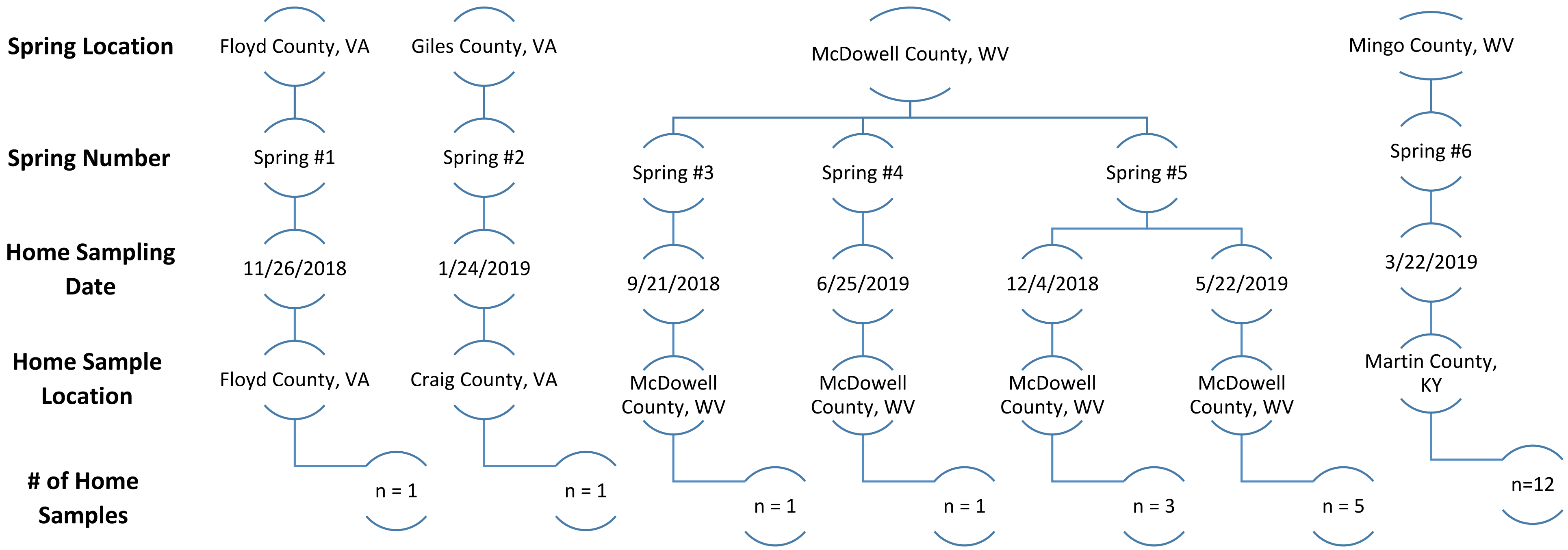


Figure 3.2: Diagram depicting home sample quantity and location matched to specific spring samples.

## 3.2 Site Sampling

### 3.2.1 *Home Tap Sampling and Participant Survey*

Laminated signs were attached to or near each spring advertising free and confidential POU water quality testing and providing a contact email and phone number. Participants either responded directly to this advertisement, or after discussion with a neighbor or community liaison. All project recruitment and procedures were approved by the Virginia Tech Institutional Review Board (IRB #18-269).

One day prior to sampling, each resident was given a home sampling kit including four bottles for sample collection and sampling instructions (Figure 3.3). Residents were instructed to collect their water samples from their most frequently used POU in their house (e.g. the kitchen tap) and asked if they had any questions regarding the instructions. Per EPA home sampling guidelines (EPA 815-F-18-022; USEPA, 2018), residents were instructed to leave their water stagnant in their pipes overnight and to obtain a first-draw sample, flush the pipes for 30 s, and then collect the additional three samples.

First- and second-draw samples were collected in prepared acid-washed 250 mL bottles for subsequent metal cation analysis. A third acid-washed 250 mL bottle was used to collect a sample for anion analysis. A 100 mL sterile bottle was then used to collect a fourth sample for bacteriological analysis. After the four samples were collected, residents were instructed to tightly cap the sample bottles, return them to the sample kit, and return to researchers for same-day pickup (generally either by leaving on the front porch or meeting at a central location). Researchers placed the samples in iced coolers for transport back to the Virginia Tech campus.

Residents were also provided with a household survey to complete and return along with their water samples (Front page, Figure 3.4; Full survey, Appendix D). The surveys consisted of 18 simple multiple-choice and short answer questions designed to target perceived water quality, water use, household plumbing characteristics, and alternate drinking water sources (Figure 3.4). Responses were coded in Microsoft Access and matched to home water quality results.

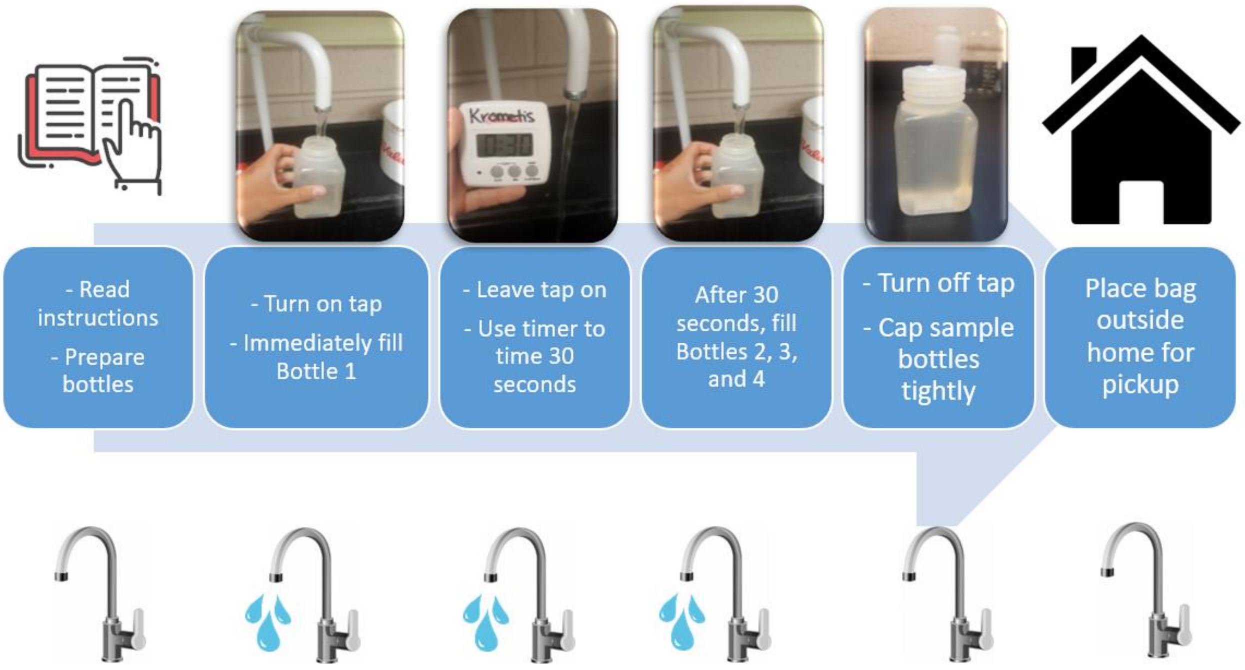
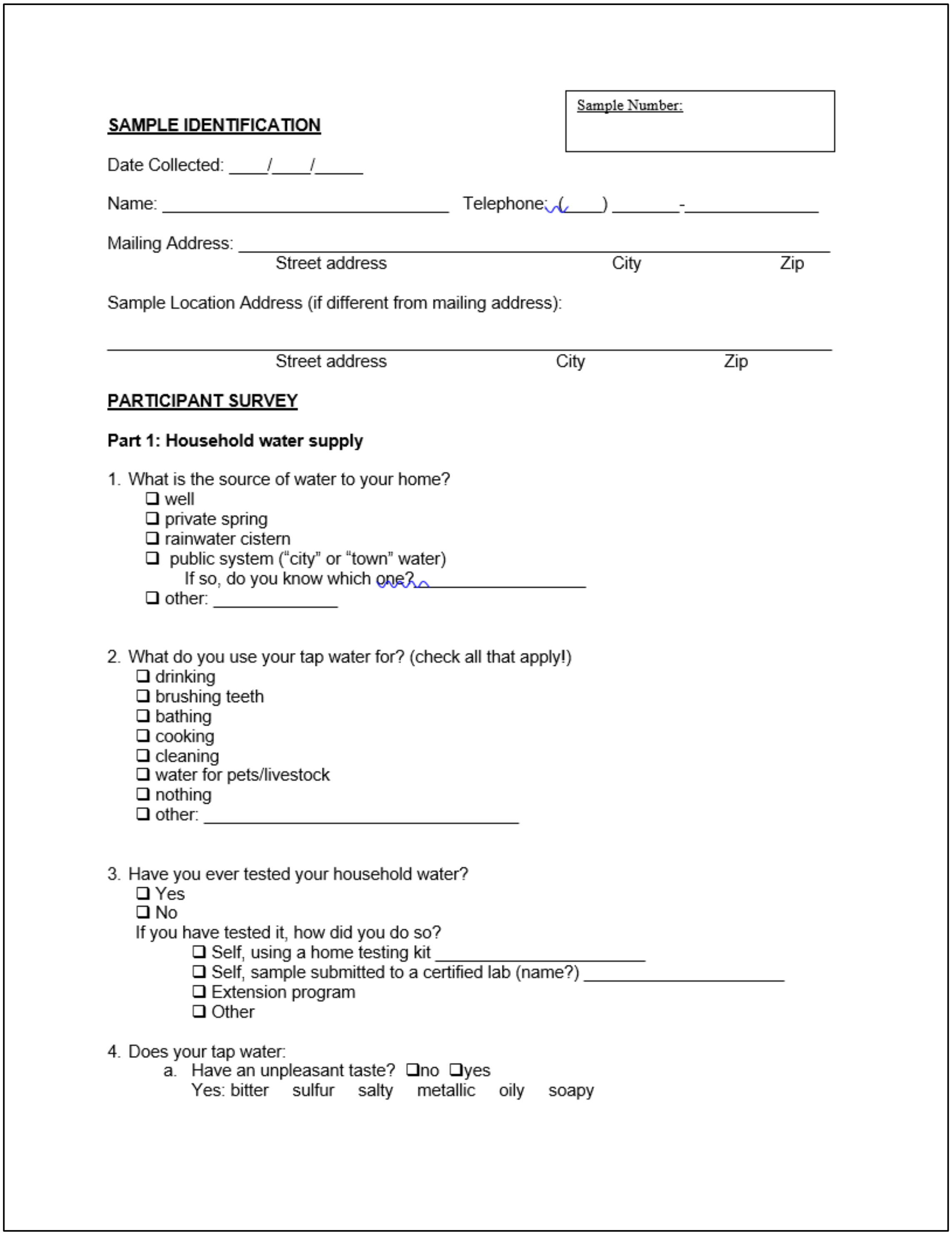


Figure 3.3: Home sampling instructions provided to each resident in the sampling kit.



Sample Number:

**SAMPLE IDENTIFICATION**

Date Collected: ____/____/_____

Name: ______________________________ Telephone: (____) _______-_____________

Mailing Address: ____________________________________________________________

Street address City Zip

Sample Location Address (if different from mailing address):

____________________________________________________________

Street address City Zip

**PARTICIPANT SURVEY**

**Part 1: Household water supply**

1. What is the source of water to your home?
   - ☐ well
   - ☐ private spring
   - ☐ rainwater cistern
   - ☐ public system (“city” or “town” water)
     - If so, do you know which one? _________________
   - ☐ other: _____________

2. What do you use your tap water for? (check all that apply!)
   - ☐ drinking
   - ☐ brushing teeth
   - ☐ bathing
   - ☐ cooking
   - ☐ cleaning
   - ☐ water for pets/livestock
   - ☐ nothing
   - ☐ other: _________________________________

3. Have you ever tested your household water?
   - ☐ Yes
   - ☐ No

   If you have tested it, how did you do so?
   - ☐ Self, using a home testing kit ______________________
   - ☐ Self, sample submitted to a certified lab (name?) _____________________
   - ☐ Extension program
   - ☐ Other

4. Does your tap water:
   - a. Have an unpleasant taste? ☐no ☐yes
     - Yes: bitter sulfur salty metallic oily soapy

Figure 3.4: Front page of written survey administered to home residents during home sample collection.

### 3.2.2 *Roadside Spring Sampling*

Roadside spring samples were collected immediately following collection of the household sampling kits to provide a comparison of water quality on the actual sampling day. In total seven spring samples (Figure 3.1) were collected from six springs during seven separate sampling events. Water samples were obtained from the spring using one autoclaved 2 L polypropylene sampling bottle for bacteriological testing, and two 250 mL sampling bottles for metals and nutrients analysis. Additionally, water quality parameters including pH, specific conductivity, dissolved oxygen, and water temperature were obtained using a YSI Quattro Pro on-site (YSI Inc., Yellow Springs, OH).

### 3.2.3 *Water Sample Analysis*

#### 3.2.3.1 *Bacteriological Analysis*

Bacteriological analysis of water samples collected from homes and springs were analyzed for total coliform and *E. coli*. Samples were analyzed immediately after being returned to campus via the Colilert defined substrate method (www.idexx.com, Westbrook, MN).

#### 3.2.3.2 *Metals and Nutrient Analysis*

Metals analysis (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Fe, Mn, Co, Ni, Cu, Zn, As, Se, Sr, Mo, Ag, Cd, Sn, Ba, Pb, U) of water samples collected from both homes and springs were analyzed using the ICP-IMS process as stated in Standard Methods 3030D and 3125B (APHA/AWWA/WED, 1998). Standard Methods 4500-NH was used to assess $NO_{3-}$ concentrations in the water samples and Standard Methods 300.0 was used to assess F concentrations (APHA/AWWA/WEF, 1998).

#### 3.2.3.3 *Statistical Analysis*

Statistical analysis of the difference between home and spring water quality data was conducted via the Wilcoxon Rank Sum Test for non-parametric data. All tests were conducted in RStudio version 3.5.1 (RStudio, Boston, MA). First, normality was checked visually using the "ggdensity" command in the "ggplot" data package. Then, the Wilcoxon Rank Sum Test was run on each individual constituent, with significance defined at an alpha of 0.05.

# 4. Results

## 4.1 Home Survey Responses

### 4.1.1 *Responses Regarding Home Tap Water*

A total of 23 survey responses were collected. The home tap water sources represented in the sampling group included private well water, private springs, and public drinking water systems. The majority of homes (60.9%) sampled obtained water from CWSs. An additional 34.8% of household samples collected were sourced from private well water, and one home obtained home tap water from a private spring (4.3%). For the purposes of qualitative data analysis, survey responses were analyzed both collectively (23 respondents), and when split into groups based on drinking water source, i.e. those served by CWSs (14 respondents), and those served by private well/springs (9 respondents). It should be noted that while a total of 23 individuals returned completed surveys, some individuals chose not to answer certain survey questions.

The majority of participants use their tap water for bathing and cleaning (96%), brushing their teeth (74%), cooking (61%), and water for pets/livestock (52%). Less than half drink their tap water (40%). There was little difference in response between individuals on private wells/springs and CWSs. Overall, the majority of respondents (82.6%) indicated that they do not trust their tap water, which is not necessarily surprising given that this population was selected for its preference for spring water and desire for formal water quality testing.

When grouping survey responses regarding tap water trust based on common themes, one key driver for this mistrust appeared to be aesthetic issues, with 42.1% of individuals citing issues of taste, smell, color, and/or odor as reasons that they did not trust their tap water. In addition, 21.1% of individuals cited a distrust of various facets of their CWS (e.g., concerns with distribution line location or treatment system age); these responses were grouped into a “Distrust of public system” category. Further, 15.8% of individuals cited health concerns (e.g., the death of a relative) and/or a general distrust of their tap water (e.g., water is “no good”) as reasons they did not trust their drinking water; these responses were grouped into “Concern about health effects” and “General distrust of water” categories.

There did appear to be somewhat of a distinction between respondents reliant on CWS versus well water in terms of their perception of trust: 100% of respondents reliant on CWS water did not trust the water from their tap, while nearly half (~45%) of respondents reliant on well water did trust their in-home water. It should be noted, however, that the majority of homes tested in this study that were reliant on CWS were from Martin County, KY, which had recently experienced a serious and well-publicized infrastructure crisis (Sizemore, 2018).

Table 4.1: Responses to home surveys regarding respondent's in-home POU tap water source and quality.

| | | |
|---|---|---|
| **What is the source of water to your home? (23 Responses)** | | |
| 60.9% Community Water System ("city" or "town" water) (14)<br>34.8% Well (8)<br>4.3% Private Spring (1)<br>0% Rainwater Cistern (0)<br>0% Other (0) | | |
| **What do you use your tap water for? (Can indicate more than one)** | | |
| Total (23 Responses) | Community Water System (14 Responses) | Private well/spring ( 9 Responses) |
| 95.7% Bathing (22)<br>95.7% Cleaning (22)<br>73.9% Brushing teeth (17)<br>60.7% Cooking (14)<br>52.2% Water for pets/livestock (12)<br>43.5% Drinking (10)<br>8.7% Other (Garden) (2)<br>4.3% Nothing (1) | 100% Bathing (14)<br>100% Cleaning (14)<br>85.7% Brushing teeth (12)<br>64.3% Cooking (9)<br>42.9% Drinking (6)<br>42.9% Water for pets/livestock (6)<br>7.1% Other (Garden) (1)<br>0% Nothing (0) | 88.9% Bathing (8)<br>88.9% Cleaning (8)<br>66.7% Water for pets/livestock (6)<br>55.6% Brushing teeth (5)<br>55.6% Cooking (5)<br>44.4% Drinking (4)<br>11.1% Nothing (1)<br>11.1% Other (Garden) (1) |
| **Have you ever tested your household water?** | | |
| Total (23 Responses) | Community Water System (14 Responses) | Private well/spring (9 Responses) |
| 91.3% No (21)<br>8.7% Yes (2)<br>**If yes, how did you do so?**<br>4.3% Self, sample submitted to certified lab (1)<br>4.3% Other (Nonprofit) (1)<br>0% Self, using home kit<br>0% Extension program | 100% No (14)<br>0% Yes (0)<br>**If yes, how did you do so?**<br>0% Self, sample submitted to certified lab (0)<br>0% Self, using home kit (0)<br>0% Other (0)<br>0% Extension program (0) | 77.8% No (7)<br>22.2% Yes (2)<br>**If yes, how did you do so?**<br>11.1% Self, sample submitted to certified lab (1)<br>11.1% Other (Nonprofit) (1)<br>0% Self, using home kit<br>0% Extension program |
| **Do you trust the water from your taps?** | | |
| Total (23 Responses) | Community Water System (14 Responses) | Private well/spring (9 Responses) |
| 82.6% No (19)<br>13.0% Yes (3)<br>4.3% Unsure (1)<br>**If no, why not? (19)**<br>42.1% Aesthetics (8)<br>21.1% Distrust of public system (4)<br>15.8% No specification (3)<br>15.8% General distrust of water (3)<br>15.8% Concern about health effects (3)<br>5.3% Distrust of home system (1) | 100% No (14)<br>0% Yes (0)<br>**If no, why not? (14)**<br>35.7% Aesthetics (5)<br>28.6% Distrust of public system (4)<br>21.4% No specification (3)<br>14.3% General distrust of water (2)<br>14.3% Concern about health effects (2)<br>7.1% Distrust of home system (1) | 55.6% No (5)<br>33.3% Yes (3)<br>11.1% Unsure (1)<br>**If no, why not? (5)**<br>60% Aesthetics (3)<br>20% General distrust of water (1)<br>20% Concern about health effects (1)<br>0% Distrust of public system (0)<br>0% Distrust of home system (0) |

When questioned regarding specific potential aesthetic issues, respondents reported issues of water taste, odor, color, staining, and particles (Table 4.2). “Metallic” was the most commonly cited taste descriptor by all respondents (45.5%), followed by “sulfur” (27.3%). With respect to unpleasant odor associated with their home drinking water, survey respondents collectively identified “chemical”, “sulfur”, and “musty” as the three most common scent descriptors. When broken down by drinking water source, over half of the CWS respondents found their water had a “chemical” odor, while the majority of private well/spring respondents found their water smelled like sulfur. The majority of survey respondents (73.9%) also reported that their tap water had an unnatural color with “milky” (43.5%), “muddy” (21.7%), and “yellow tint” (17.4%) as the most commonly cited visual descriptors. Some survey respondents also found their tap water to contain “floating and/or settled particles”. Respondents collectively found these particles to be “white flakes” and/or “black specks” primarily, followed by “red-orange slime” and “brown sediment.”

Table 4.2: Responses to survey questions regarding aesthetics of respondent's in-home POU tap water.

| **Does your tap water have an unpleasant taste? (Can indicate more than one)** | | |
|---|---|---|
| Total (22 Responses) | Community Water System (13 Responses) | Private well/spring (9 Responses) |
| 27.3% No (6) | 15.4% No (2) | 44.4% No (4) |
| 13.6% Yes, no specification (3) | 15.4% Yes, no specification (2) | 11.1% Yes, no specification (1) |
| 18.2% Bitter (4) | 23.1% Bitter (3) | 11.1% Bitter (1) |
| 27.3% Sulfur (6) | 15.4% Sulfur (2) | 44.4% Sulfur (4) |
| 4.5% Salty (1) | 0% Salty (0) | 11.1% Salty (1) |
| 45.5% Metallic (10) | 53.8% Metallic (7) | 33.3% Metallic (3) |
| 4.5% Oily (1) | 0% Oily (0) | 11.1% Oily (1) |
| 9.1% Soapy (2) | 7.7% Soapy (1) | 11.1% Soapy (1) |
| **Does your tap water have an unpleasant odor? (Can indicate more than one)** | | |
| Total (22 Responses) | Community Water System (14 Responses) | Private well/spring (8 Responses) |
| 18.2% No (4) | 14.3% No (2) | 25% No (2) |
| 13.6% Yes, no specification (3) | 14.3% Yes, no specification (2) | 12.5% Yes, no specification (1) |
| 31.8% Sulfur (7) | 14.3% Sulfur (2) | 62.5% Sulfur (5) |
| 0% Kerosene/Gas (0) | 0% Kerosene/Gas (0) | 0% Kerosene/Gas (0) |
| 18.2% Musty (4) | 21.4% Musty (3) | 12.5% Musty (1) |
| 40.9% Chemical (9) | 57.1% Chemical (8) | 12.5% Chemical (1) |
| **Does your tap water have an unnatural color? (Can indicate more than one)** | | |
| Total (23 Responses) | Community Water System (14 Responses) | Private well/spring (9 Responses) |
| 26.1% No (6) | 21.4% No (3) | 33.3% No (3) |
| 4.3% Yes, no specification (1) | 7.1% Yes, no specification (1) | 0% Yes, no specification (0) |
| 21.7% Muddy (5) | 21.4% Muddy (3) | 22.2% Muddy (2) |
| 43.5% Milky (10) | 64.3% Milky (9) | 11.1% Milky (1) |
| 8.7% Black/Gray tint (2) | 0% Black/Gray tint (0) | 22.2% Black/Gray tint (2) |
| 17.4% Yellow tint (4) | 7.1% Yellow tint (1) | 33.3% Yellow tint (3) |
| 4.3% Oily film (1) | 0% Oily film (0) | 11.1% Oily film (1) |
| **Does your tap water stain plumbing, cooking, appliances, utensils, or laundry? (Can indicate more than one)** | | |
| Total (23 Responses) | Community Water System (14 Responses) | Private well/spring (9 responses) |
| 26.1% No (6) | 21.4% No (3) | 33.3% No (3) |
| 13.0% Yes, no specification (3) | 21.4% Yes, no specification (3) | 0% Yes, no specification (0) |
| 4.3% Blue-Green (1) | 0% Blue-Green (0) | 11.1% Blue-Green (1) |
| 21.7% Rusty/Brown (5) | 0% Rusty/Brown (0) | 55.6% Rusty/Brown (5) |
| 21.7% Black/Gray (5) | 28.6% Black/Gray (4) | 11.1% Black/Gray (1) |
| 26.1% White/Chalk (6) | 42.9% White/Chalk (6) | 0% White/Chalk (0) |
| **Does your tap water have floating or settled particles? (Can indicate more thane one)** | | |
| Total (22 Responses) | Community Water System (13 Responses) | Private well/spring (9 Responses) |
| 31.8% No (7) | 38.5% No (5) | 22.2% No (2) |
| 4.5% Yes, no specification (1) | 7.7% Yes, no specification (1) | 0% Yes, no specification (0) |
| 27.3% White flakes (6) | 38.5% White flakes (5) | 11.1% White flakes (1) |
| 27.3% Black specks (6) | 23.2% Black specks (3) | 33.3% Black specks (3) |
| 13.6% Red-orange slime (3) | 0% Red-orange slime (0) | 33.3% Red-orange slime (3) |
| 13.6% Brown sediment (3) | 7.7% Brown sediment (1) | 22.2% Brown sediment (2) |

### 4.1.2 *Survey Responses Regarding Spring Use*

While 24 homes in total were sampled, and 23 individuals filled out surveys, only 9 survey respondents explicitly responded that they were visiting roadside springs to obtain drinking water (Table 4.3); this is largely attributed to the fact that the majority of participants were recruited by neighbors for water quality testing and/or did not want to explicitly discuss their spring use. Roadside spring users were split relatively evenly between CWS and private well/spring respondents. Out of the 9 respondents that noted visiting springs, the majority visited at least once per month, and over half visited once per week to collect drinking water. A total of 44.4% of spring users live between three and eight kilometers away from the spring they visit, 22.2% live between eight and 16 kilometers away, and only one respondent lives within two kilometers of the spring they visit. The majority of respondents use the spring water they collect for drinking, cooking, brushing teeth, and providing water to their livestock and pets. The most common responses addressing why these individuals collect water from roadside springs as opposed to using their tap water were characterized as falling into the category of “general distrust of home water”. With regards to spring water quality, 62.5% of respondents reported that they had no concerns relating to the spring water quality.

Table 4.3: Responses to home surveys regarding resident's specific spring use, if any is reported

| | | |
|---|---|---|
| **How often do you collect water at this spring?** | | |
| Total (9 Responses) | Community Water System (4 Responses) | Private well/spring (5 Responses) |
| 0% Once a day (0)<br>55.6% Once a week (5)<br>66.7% Once a month (6)<br>33.3% Other (3) | 0% Once a day (0)<br>50% Once a week (2)<br>25% Once a month (1)<br>25% Other ("When we have gas") (1) | 0% Once a day (0)<br>60% Once a week (3)<br>0% Once a month (0)<br>40% Other ("Twice a month") (2) |
| **How far is the spring from your home?** | | |
| Total (9 Responses) | Community Water System (4 Responses) | Private well/spring (5 Responses)) |
| 11.1% Within 1 mile (1)<br>44.4% 2-5 miles (4)<br>22.2% 5-10 miles (2)<br>11.1% 10+ miles (1)<br>11.1% Other ("1 hour") (1) | 0% Within 1 mile (0)<br>25% 2-5 miles (1)<br>25% 5-10 miles (1)<br>25% 10+ miles (1)<br>25% Other ("1 hour") (1) | 20% Within 1 mile (1)<br>60% 2-5 miles (3)<br>20% 5-10 miles (1)<br>0% 10+ miles (0)<br>0% Other (0) |
| **What do you use your spring water for?** | | |
| Total (9 Responses) | Community Water System (4 Responses) | Private well/spring (5 Responses) |
| 88.9% Drinking (8)<br>66.7% Brushing teeth (6)<br>11.1% Bathing (1)<br>88.9% Cooking (8)<br>11.1% Cleaning (1)<br>55.6% Water for pets/livestock (5)<br>0% Nothing (0)<br>0% Other (0) | 100% Drinking (4)<br>50% Brushing teeth (2)<br>25% Bathing (1)<br>100% Cooking (4)<br>25% Cleaning (1)<br>75% Water for pets/livestock (3)<br>0% Nothing (0)<br>0% Other (0) | 80% Drinking (4)<br>80% Brushing teeth (4)<br>0% Bathing (0)<br>80% Cooking (4)<br>0% Cleaning (0)<br>40% Water for pets/livestock (2)<br>0% Nothing (0)<br>0% Other (0) |
| **Why do you collect spring water?** | | |
| Total (9 Responses) | Community Water System (4 Responses) | Private well/spring (5 Responses) |
| 66.7% Distrust of home water (6)<br>11.1% Spring water quality is better (1)<br>22.2% Other (2) | 75% Distrust of home water (3)<br>25% Spring water quality is better (1)<br>0% Other (0) | 60% Distrust of home water (3)<br>0% Spring water quality is better (0)<br>40% Other ("Personal Use"/"Livestock") (2) |
| **How did you learn about the spring?** | | |
| Total (9 Responses) | Community Water System (4 Responses) | Private well/spring (5 Responses) |
| 44.4% Always known about it (4)<br>33.3% Heard from friends (3)<br>22.2% Saw it in passing (2) | 25% Always known about it (1)<br>50% Heard from friends (2)<br>25% Saw it in passing (1) | 60% Always known about it (3)<br>20% Heard from friends (1)<br>20% Saw it in passing (1) |
| **How many others in your community visit this spring (approximately)?** | | |
| Total (9 Responses) | Community Water System (4 Responses) | Private well/spring (5 Responses) |
| 22.2% Unsure (2)<br>11.1% A small amount of people (1)<br>11.1% An average amount of people (1)<br>55.6% A large group of people (5) | 50% Unsure (2)<br>0% A small amount of people (0)<br>25% An average amount of people (1)<br>25% A large group of people (1) | 0% Unsure (0)<br>20% A small amount of people (1)<br>0% An average amount of people (0)<br>80% A large group of people (4) |
| **Do you have any concerns regarding the quality of the spring water or things it would be useful for us to know?** | | |
| Total (8 Responses) | Community Water System (4 Responses) | Private well/spring (4 Responses) |
| 62.5% No (5)<br>12.5% Yes (1)<br>12.5% Unsure (1)<br>12.5% Other (1) | % No (2)<br>% Yes (0)<br>% Unsure (1)<br>% Other (Spring water storage) (1) | % No (3)<br>% Yes (1) |

## 4.2 Comparing Home and Roadside Spring Samples

### 4.2.1 *POU Source Distribution*

Home survey responses revealed that participants were reliant on a variety of in-home water sources. Of the 24 homes sampled, 33% were reliant on private wells, 10% maintained private spring boxes, and 57% were served by CWSs (Table 4.4). The type(s) of household water service varied by county. For example, while in McDowell County, WV the majority of homes sampled were on private wells/spring boxes, all of the homes sampled in Martin County, KY were reliant on the same CWS. The distribution of different tap water sources across sampled communities is in keeping with previous literature that identifies household water quality as a common regional concern (Blakeney & Marshall, 2009; McSpirit & Reid, 2011; Levêque & Burns, 2017).

Table 4.4: Distribution of homes on private wells and municipal drinking water treatment systems in each community.

| Community Location | # of Homes using Private Wells/Spring Box? | # of Homes using CWSs? |
|---|---|---|
| McDowell County, WV | 9 | 1 |
| Martin County, KY | 0 | 12 |
| Floyd County, VA | 0 | 1 |
| Craig County, VA | 1 | 0 |

### 4.2.2 *Bacteriological Contaminants*

A total of 7 spring samples and 21 of the 24 home samples collected were analyzed for bacteriological contaminants. All roadside spring samples tested positive for total coliform; the sample from spring #4 in McDowell County, WV exceeded the maximum detection limit of 2,420 MPN/100 mL. Over half of the spring samples also tested positive for *E. coli*, a more serious indicator of potential infectious disease risk, with spring #4 containing the highest concentration of 489 MPN/100 mL. Just over half of all home samples from all counties analyzed tested positive for total coliform. Bacteriological contamination was most prevalent in samples from homes in McDowell County, WV as 80% of samples were positive for total coliform, and 30% of samples were positive for *E. coli*, with concentrations observed as high as 461 MPN/100 mL. When analyzing the data based on water source, the private well/spring home tap water samples had substantially more total coliform and *E. coli* violations with 90% testing positive for total coliform and 30% testing positive *for E. coli*, compared to 18.2% and 0%, respectively, from CWS home samples. This is not surprising, given that previous surveys have reported that bacteriological contamination is fairly common in private water supplies, though the incidence of contamination observed in this study is notably higher than typically observed (Allevi et al., 2013).

Table 4.5: Maximum observed concentrations of bacteriological contaminants present in roadside spring and home tap water samples. Drinking water standards listed for each contaminant were obtained from the USEPA Safe Drinking Water Act. Bolded numbers are values that exceed the drinking water standard and a distribution of total samples in violation of the standard are provided below the value. It should be noted that while 12 home samples from Martin County, KY were obtained, only 9 were analyzed for bacteriological contaminants due to research error.

| **Bacteriological Contaminants** | | **Paired Springs (Max. Value)** | | | | | | **Home Samples (Max. Value & % in Violation)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **Location** | | | | **Water Source** | |
| | | ***#1*** | ***#2*** | ***#3*** | ***#4*** | ***#5*** | ***#6*** | ***Floyd County, VA*** | ***Craig County, VA*** | ***McDowell County, WV*** | ***Martin County, KY*** | ***Private Well/Spring*** | ***CWS*** |
| MCL | ***Total coliform (0 MPN/100 mL)*** | **194**<br>**(1/1)** | **816**<br>**(1/1)** | **4**<br>**(1/1)** | **>2,420**<br>**(1/1)** | **579**<br>**(2/2)** | **214**<br>**(1/1)** | **3**<br>**(1/1)** | **111**<br>**(1/1)** | **>2,420**<br>**(8/10)** | **1**<br>**(1/9)** | **>2,420**<br>**(9/10)** | **3**<br>**(2/11)** |
| | ***E. coli* *(0 MPN/100 mL)*** | 0 | **3**<br>**(1/1)** | 0 | **488**<br>**(1/1)** | **4**<br>**(2/2)** | 0 | 0 | 0 | **461**<br>**(3/10)** | 0 | **461**<br>**(3/10)** | 0 |

### 4.2.3 *Inorganic Ion Contaminants*

A total of 7 spring samples and 24 home samples were analyzed for USEPA regulated inorganic metal cations and anions. The majority of spring samples had levels of Al above the SDWA SMCL, and a total of 5 spring samples had concentrations above the SDWA SMCL. Aside from Al, no other elevated concentrations of SDWA-listed contaminants were observed in the spring samples. In the home samples, concentrations of Ba exceeded the SDWA MCL twice. Additionally, concentrations of the following contaminants exceeded SDWA SMCLs, Guidance Levels, or Health Reference levels, at least once: Al, Fe, Mn, Na, and Sr. The SMCL for pH was also exceeded once by the home sample from Craig County, VA. McDowell County, WV had the highest number of inorganic ion contaminants exceeding regulations/recommendations with a total of six (i.e., Ba, Al, Mn, Fe, Na, Sr), while the sample from Floyd County, VA exceeded just one inorganic ion contaminant recommendation (Mn). When analyzing samples based on water source, private well/spring home samples exceeded seven different contaminant regulations while CWS home samples exceeded only two.

Table 4.6: Maximum observed concentrations of inorganic ions present in roadside spring and home tap water samples. Drinking water standards listed for each contaminant were obtained from the USEPA Safe Drinking Water Act and drinking water guidelines. Bolded numbers are values that exceed the drinking water standard and a distribution of total samples in violation of the standard are provided below the value. ("BD" = below detection limit, TT = Treatment Technique, HRL = Health Reference Level, GL = Guidance Level).

| **Metal Cation Contaminants** | | **Paired Springs (Max. Value)** | | | | | | **Home Samples (Max. Value & # in Violation)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **Location** | | | | **Water Source** | |
| | | ***#1*** | ***#2*** | ***#3*** | ***#4*** | ***#5*** | ***#6*** | ***Floyd County, VA*** | ***Craig County, VA*** | ***McDowell County, WV*** | ***Martin County, KY*** | ***Private Well/Spring*** | ***CWS*** |
| MCL | ***As***<br>***> 10 ppb*** | BD | 0.19 | 0.05 | 0.23 | 0.07 | BD | 7.27 | 0.08 | 5.97 | 0.24 | 5.97 | 7.27 |
| | ***Ba***<br>***> 2,000 ppb*** | 34.0 | 14.7 | 49.9 | 25.5 | 64.6 | 31.8 | 44.7 | 42.3 | **12,399.0**<br>**(2/10)** | 19.9 | **12,399.0**<br>**(2/10)** | 44.7 |
| | ***Cd***<br>***> 5 ppb*** | 0.03 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | 0.02 | 0.03 | 0.42 | 0.03 | 0.42 | 0.03 |
| | ***Cr***<br>***> 100 ppb*** | 0.26 | 0.44 | 0.10 | 0.26 | 0.59 | 0.25 | 0.52 | 0.38 | 1.00 | 0.52 | 0.97 | 1.00 |
| | ***F***<br>***> 4 ppm*** | 0.08 | 0.03 | 0.06 | 0.04 | 0.10 | 0.06 | 0.08 | 0.02 | 0.64 | 0.82 | 0.12 | 0.83 |
| | $NO_{3^-}$<br>***> 10 ppm*** | 0.28 | 0.31 | 0.10 | 0.23 | 0.16 | 0.09 | 0.44 | 0.26 | 1.11 | 0.18 | 1.11 | 0.44 |
| | ***Se***<br>***> 50 ppb*** | 0.12 | 0.31 | 2.60 | 0.41 | BD | 0.21 | 0.47 | BD | 3.93 | 1.47 | 3.93 | 1.47 |
| | ***U***<br>***> 30 ppb*** | 0.00 | 0.06 | 0.13 | 0.02 | 0.03 | 0.02 | 6.28 | 0.04 | 0.05 | 0.05 | 0.05 | 6.28 |
| TT | ***Cu***<br>***> 1,300 ppb*** | 0.88 | 0.24 | 0.34 | 0.46 | 2.09 | 0.51 | 227.6 | 0.51 | 332.0 | 177.4 | 200.5 | 332.0 |
| | ***Pb***<br>***> 15 ppb*** | 0.02 | 0.21 | BD | 0.34 | 0.23 | 0.08 | 0.35 | 0.47 | 2.42 | 3.24 | 2.42 | 3.24 |
| SMCL | ***Ag***<br>***> 100 ppb*** | 0.00 | 0.11 | 0.00 | 0.01 | 0.02 | 0.01 | 6.04 | 0.05 | 0.03 | 0.29 | 0.05 | 6.04 |
| | ***Al***<br>***> 50 – 200 ppb*** | 22.9 | **211.3**<br>**(1/1)** | BD | **119.7**<br>**(1/1)** | **477.8**<br>**(2/2)** | **164.4**<br>**(1/1)** | 3.66 | **244.0**<br>**(1/1)** | **704.6**<br>**(3/10)** | **5,404.1**<br>**(8/12)** | **508.4**<br>**(4/10)** | **5,404.1**<br>**(8/14)** |
| | ***Fe***<br>***> 300 ppb*** | 27.0 | 127.5 | 1.70 | 223.0 | 221.5 | 72.2 | 111.2 | 48.9 | **34,776.0**<br>**(6/10)** | 96.7 | **34,776.0**<br>**(6/10)** | 111.2 |
| | ***Mn***<br>***> 50 ppb*** | 1.06 | 7.21 | 0.03 | 18.9 | 3.40 | 18.9 | **55.6**<br>**(1/1)** | 17.7 | **1,330.4**<br>**(6/10)** | 2.49 | **1,330.4**<br>**(6/10)** | **55.6**<br>**(1/13)** |
| | $SO_4^{2-}$<br>***> 250 ppm*** | 0.92 | 1.06 | 62.5 | 11.6 | 28.6 | 33.6 | 7.98 | 3.53 | 52.2 | 10.7 | 52.2 | 10.7 |
| | ***Zn***<br>***> 5,000 ppb*** | 9.04 | 14.3 | 12.2 | 8.38 | 15.0 | 8.26 | 1,048.4 | 15.9 | 1,848.6 | 266.9 | 1,848.6 | 1,048.4 |
| | ***pH***<br>***6.5 – 8.5*** | 6.59 | 7.55 | 6.17 | 7.60 | 7.73 - 8.41 | 6.85 | 6.90 | **6.15**<br>**(1/1)** | 6.67 - 7.33 | 7.11 - 7.43 | **6.15 - 7.7**<br>**(1/10)** | 6.67 – 7.29 |
| HRL/GL | ***Na***<br>***> 20,000 ppb*** | 5,629.7 | 725.0 | 8,224.2 | 3,382.4 | 10,185.5 | 4,467.07 | 7,179.8 | 313.2 | **604,434.9**<br>**(2/10)** | 6,286.6 | **604,434.9**<br>**(2/10)** | 14,369.0 |
| | ***Sr***<br>***> 1,500 ppb*** | 42.9 | 33.5 | 954.4 | 47.5 | 315.9 | 172.7 | 43.7 | 11.1 | **9,351.1 (2/10)** | 41.8 | **9,351.1**<br>**(2/10)** | 88.0 |

#### 4.2.4 *Statistical Analysis of Paired Home and Spring Samples*

A Wilcoxon Rank Sum Test was completed in R to compare paired home and spring samples based on each metal cation, anion, and bacteriological constituent that was analyzed, with significance defined at 0.05 (Table 4.7). The difference between spring and home samples was statistically significant when comparing total coliform, Cd, F, $NO_{3-}$, U, Cu, Pb, Ag, Al, Mn, $SO_4^2$, Zn, Na, and Sr. Spring values were significantly higher than home values for total coliform, U, Al, and $SO_4^2$. Home values were significantly higher than spring values when comparing Cd, F, $NO_{3-}$, Cu, Pb, Ag, Mn, Zn, Na, and Sr.

Table 4.7: Results of Wilcoxon Rank Sum Test to determine statistical significance in comparison of paired home and spring water sample constituents

| **Contaminants** | | **# of Homes Exceeding Violations** | **# of Springs Exceeding Violations** | **P-Value** | **Spring vs Home Values** |
|---|---|---|---|---|---|
| MCL | ***Total Coliform<br>0 MPN/100 mL*** | 11/21 | 7/7 | 0.02 | Spring > Home |
| | ***E. coli<br>0 MPN/100 mL*** | 3/21 | 4/7 | 0.15 | No significant difference |
| | ***As<br>> 10 ppb*** | 0 | 0 | 1.0 | No significant difference |
| | ***Ba<br>> 2,000 ppb*** | 2/24 | 0 | 0.70 | No significant difference |
| | ***Cd<br>> 5 ppb*** | 0 | 0 | 0.01 | Spring < Home |
| | ***Cr<br>> 100 ppb*** | 0 | 0 | 0.94 | No significant difference |
| | ***F<br>> 4 ppm*** | 0 | 0 | > 0.01 | Spring < Home |
| | $NO_3^-$<br>***> 10 ppm*** | 0 | 0 | 0.03 | Spring < Home |
| | ***Se<br>> 50 ppb*** | 0 | 0 | 0.68 | No significant difference |
| | ***U<br>> 30 ppb*** | 0 | 0 | 0.02 | Spring > Home |
| TT | ***Cu<br>> 1,300 ppb*** | 0 | 0 | > 0.01 | Spring < Home |
| | ***Pb<br>> 15 ppb*** | 0 | 0 | > 0.01 | Spring < Home |
| SMCL | ***Ag<br>> 100 ppb*** | 0 | 0 | > 0.01 | Spring < Home |
| | ***Al<br>> 50 – 200 ppb*** | 12/24 | 5/7 | 0.02 | Spring > Home |
| | ***Fe<br>> 300 ppb*** | 6/24 | 0 | 0.64 | No significant difference |
| | ***Mn<br>> 50 ppb*** | 7/24 | 0 | > 0.01 | Spring < Home |
| | $SO_4^{2-}$<br>***> 250 ppm*** | 0 | 0 | > 0.01 | Spring > Home |
| | ***Zn<br>> 5,000 ppb*** | 0 | 0 | > 0.01 | Spring < Home |
| HRL/GL | ***Na<br>> 20,000 ppb*** | 2/24 | 0 | > 0.01 | Spring < Home |
| | ***Sr<br>> 1,500 ppb*** | 2/24 | 0 | 0.03 | Spring < Home |

# 5. Discussion

## 5.1 Comparing Home and Spring Samples

### 5.1.1 *Common Spring Tap Water Contaminants*

The most common contaminants in spring samples exceeding SDWA S/MCLs were total coliform, *E. coli*, and Al (Tables 4.5 and 4.6). Total coliform and *E. coli*, though not generally pathogenic themselves, are regulated by the SDWA as surrogates of fecal contamination, potential pathogen presence, and infectious disease risk. While coliforms are present in the environment naturally (Leclerc et al., 2001), the presence of *E. coli* in the spring water samples indicates that the water is contaminated with human and/or animal fecal matter (Paruch & Maehlum, 2012). Pathogens associated with the fecal-oral route of transmission can cause gastrointestinal illness or distress to those who are exposed, including diarrhea, cramps, nausea, headaches, and other symptoms. Due to the associated symptoms, these pathogens may pose a heightened risk for infants, young children, the elderly, and anyone with compromised immune systems (USEPA, 2018). The presence of total coliform and *E. coli* found in spring water samples suggests that spring-users may be exposed to pathogens of fecal-oral origin that pose potential health risks such as gastrointestinal illness or distress. These results are consistent with results from Swistock et al. (2015) who sampled 37 springs in Pennsylvania and reported near universal total coliform contamination, with a third of spring samples also positive for *E. coli*. These results also align with those of Krometis et al. (2019), which reported total coliform and *E. coli* in 99% and 86% of 83 samples, respectively, from roadside spout springs in Central Appalachia. Krometis et al. (2019) reported on a set of 21 roadside springs in the Central Appalachian region, three of which were sampled in the present study. These three springs (#1, #2, and #6) tested positive for total coliform in both Krometis et al. (2019) and the present study, and spring #2 tested positive for *E. coli* in both studies as well.

Aluminum is currently included in the SDWA as an SMCL, as it can cause aesthetic issues in drinking water such as a change in color (USEPA, 2017). However, emerging epidemiological research has suggested that Al may promote the onset and progression of Alzheimer's disease and/or damage to cerebral function (McLachlan et al., 1996; Altmann et al., 1999; Flaten et al., 2001; Krewski et al., 2007; Bondy, 2014). In 1996, an early epidemiological study on Al exposure by McLachlan et al. (1996) found a correlation between the risk of developing Alzheimer's disease and individuals exposed to municipal drinking water with Al concentrations of 100 ug/L or greater. In a more recent study, Rondeau et al. (2009) established a similar relationship between elderly individuals exposed to Al in drinking water, and the prevalence of Alzheimer's disease. Though Al values in spring samples were observed as high as 477.8 ug/L, it is critical to note that both the USEPA and World Health Organization (WHO) have concerns regarding validity of reported correlations between waterborne Al and cognitive function given the wide range of environmental sources and bioavailability of aluminum, as well as poor characterization of Al exposure from drinking water and food (WHO, 2010). It is also critical to note that water quality in environmental samples (i.e., surface or groundwater) can be extremely variable, and the values presented here represent only a single day's observation.

### 5.1.2 *Common Home Tap Water Contaminants*

Common contaminants found in home tap water samples violating SDWA MCLs include total coliform**,** *E. coli*, and Ba (Table 4.5 and 4.6). Common contaminants violating SDWA SMCLs included Al, Fe, and Mn. Strontium was also found to be a common contaminant and its concentration exceeded an EPA health reference level in several instances. Total coliform and *E. coli* are regulated by a SDWA MCL and their presence in drinking water may indicate that harmful pathogens that can cause gastrointestinal illness may be present. Aluminum is listed in the SDWA as an SMCL and is considered to cause aesthetic issues, namely color change, in drinking water but is not currently considered to be a health risk. While Al in drinking water is not currently considered to be a health risk to consumers, the presence of the metal in home tap water can cause discoloration, dissuading residents from consuming the water for fear that it is unsafe. The majority of homes sampled in Martin County, KY tested above the SDWA SMCL for Al. The homes in Martin County are all on the same CWS, which may suggest that the water treatment technique used at the water treatment plant involves the use of Al salts for coagulation which can lead to elevated levels of aluminum in drinking water (WHO, 2010).

Two samples collected from homes in McDowell County, WV exceeded the SDWA MCL for Ba. Barium is regulated as an MCL in SDWA as it can increase blood pressure in exposed individuals, posing a health risk. Increased blood pressure is of particular concern in the Appalachian region where known health disparities, such as incidence of heart disease, exist due, in part, to lack of adequate health care (Behringer & Friedell, 2006; McGarvey et al., 2011;

Krometis et al., 2017). The two homes that exceeded the Ba MCL also exceeded the USEPA's guidance level for Na of 20,000 ppb with concentrations of 12.4 and 604,435 ppb, respectively. The USEPA's guidance level for Na was developed for individuals on low-sodium diets of 500 mg/day (USEPA, 2003). High concentrations of Na, coupled with high concentrations of Ba, is of concern for the residents of these homes that consume this drinking water as both excess Na and Ba can increase blood pressure, leading to larger health risks over time (USEPA, 2003; USEPA, 2018).

Just over half of household samples from McDowell County, WV exceeded SDWA SMCLs for both Fe and Mn. Iron and Mn are not considered to pose health risks to consumers, but are included in the SDWA as SMCLs because of aesthetic concerns. Iron can cause sedimentation, metallic taste, and a rusty color in drinking water and can also cause the water to stain pipes and plumbing fixtures. Manganese can cause black or brown colors and a bitter, metallic taste in drinking water, and can cause the water to stain plumbing and pipes black (USEPA, 2017). These aesthetic concerns may encourage household members to seek alternative sources for potable use (Swistock & Sharpe, 2016). The homes in McDowell County that had high levels of Mn and Fe obtained tap water from private wells. Iron and Mn often occur together in ground water and natural sources of Fe and Mn are common in deeper wells where the water has been in contact with rock for an extended period of time (Swistock & Sharpe, 2016).

Tap water samples from two homes in McDowell County, WV had Sr levels that exceeded USEPA guidelines. Though not yet included on the SDWA reference contaminant list, Sr has been assigned a health reference level (HRL) of 1.5 mg/L by the USEPA as high levels of Sr, especially when paired with poor nutrition, are thought to cause rickets (O'Donnell et al., 2016). Given that Appalachia is known to have a significant number of food deserts, i.e. low-income census tracts where a significant number of households have low access to vehicular transportation and/or are more than 20 miles from their nearest supermarket (ARC, 2013; Miller et al., 2016), high Sr intake could pose a health concern.

### 5.1.3 *Comparing Home and Spring Water*

Fourteen water quality constituents were significantly different in concentration between sources (Wilcoxon, $p<0.05$). Of these 14 constituents, four (total coliform, U, Al, and $SO^{2-}{}_4$) have significantly higher levels in spring water samples compared to homes. The remaining 10 constituents (Cd, F, $NO_3$-, Cu, Pb, Ag, Mn, Zn, Na, and Sr) have significantly higher levels in home water samples compared to springs. It is important to note that of these water quality constituents, only four (Al, Mn, Na, and Sr) had levels in homes and/or springs that exceeded SDWA SMCLs, guidance levels, or health reference levels, and only one (total coliform) exceed a SDWA MCL.

Aluminum, $SO_4^{2-}$, and total coliform, all with significantly higher concentrations in roadside springs, are common groundwater contaminants associated with local geology and/or soil (USGS, 2016). Aluminum occurs naturally in some rocks as well as in drainage from mines which can leach into groundwater sources. Sulfate concentrations in groundwater can result from saltwater intrusion, mineral dissolution, or domestic or industrial waste contamination. Coliform bacteria occur naturally in soils, plants, and the intestines of humans and other warm-blooded animals and can enter groundwater via exposure to the earth's surface and/or contact with these sources. (Leclerc et al., 2001)

Cadmium, F, Cu, Ag, and Pb are common constituents found in drinking water (USEPA, 2015) and, in this study, have levels that were significantly higher in-home tap water samples compared to roadside springs. A major source of Cd, Cu, and Pb in home tap water is the corrosion of lead service lines, galvanized or copper pipes with lead solder, household plumbing systems, and well pumps, particularly when source water has high acidity or a low mineral content (Pieper et al., 2016; Doré et al., 2019). Silver can be introduced into home tap water from carbon-containing water filters or other disinfection practices (WHO, 2018), however, it is also considered a groundwater contaminant, introduced into the environment by mining and processing. F is often added to drinking water to promote dental health, although, in increased levels it can cause bone disease (USEPA, 2015).

Manganese, Sr, Zn, Na, and $NO_{3-}$ were observed in home tap water samples and are more generally associated with groundwater sources (USGS, 2016). Strontium and Mn occur naturally in sediment and rocks while Zn is found naturally in water; all three contaminants are more common in areas where mining has occurred. Sodium present in groundwater can be geologically derived via the leaching of surface and underground salt deposits as well as the decomposition of other various minerals. While Na levels exceeded the guidance level in two homes using well water, it should be noted that no springs exceeded this recommendation. Nitrate can occur naturally in mineral deposits, soils and freshwater systems; however, it can also enter environmental waters through fertilizer, livestock waste, and sewage (USGS, 2016).

It is important to note that while the concentrations of 10 constituents were significantly higher in-home water samples when compared to springs, only five of these constituents (Cd, F, $NO_{3-}$, Cu, and Pb) are regulated by the SDWA as MCLs, posing a direct risk to human health. The remaining five remaining constituents that are significantly higher in-home samples (Ag, Mn, Zn, Na, and Sr), are considered SMCLs and HRLs in the SDWA. It should be noted that, though higher in home tap water, levels of Cd, F, $NO_{3-}$, Cu, Pb, Ag, and Zn never exceeded SDWA recommendations in any home samples. Concentrations of four constituents were significantly higher in spring water as compared to homes, however, only two constituents (total coliform and U) are regulated by the SDWA as MCLs, while the other two (Al and $SO_4^{2-}$) are considered to be SMCLs. It should be noted that, though higher in spring water, U and $SO_4^{2-}$ levels never exceeded SDWA recommendations in any spring samples.

Significantly more data, including rates of consumption, pathogenic profiles, and metals bioavailability, would be required to truly quantify the relative risks associated with the consumption of spring versus in-home water in any one of these households. However, in general, it appears that risks associated with the consumption of home tap water would largely be associated with concentrations of metals, whereas bacteriological exposures would be of greater concern following consumption of spring water. Based on the differing nature of harmful constituents found in sampled household and spring water, residents may be exposed to different health risks (heavy metals or bacteriological) depending on their drinking water source.

### 5.2 Comparing Water Quality and Survey Responses

The majority of survey respondents reported not trusting their home water, choosing not to use their in-home POU tap water for drinking, and instead using it predominantly for cleaning, brushing their teeth, and cooking (Table 4.1). Collectively, the home drinking water source (i.e., private or CWS) did not alter survey respondent’s perceptions of their home tap water or usage profile. Survey respondents cited issues relating to water aesthetics as a main reason that they did not trust their tap water. This is unsurprising given elevated concentrations of several metals (Fe, Mn, Al) associated with taste, odor, and appearance in tap water. The majority of survey respondents reported that their tap water had particles floating around in it, had an unnatural color, smell, and taste, and that they had issues with their tap water staining plumbing. The individual homes sampled in Floyd and Craig Counties, VA each had at least one SMCL violation, while the majority of homes sampled in Martin County, KY and McDowell County, WV violated at least one SMCL. Based on the number of household samples that exceeded SDWA SMCLs, it is unsurprising that so many survey respondents cited issues with the aesthetics of their drinking water as reasons that they did not trust their home tap water.

Those participants who answered questions specifically related to the roadside springs expressed few concerns regarding spring water quality, with several stating that they collect the spring water because their home tap water is of poor quality. The faith that these respondents have in the quality of water of roadside springs is reflected in the time they spend collecting drinking water from roadside springs, and the distance that they travel in order to do so. The majority of survey respondents collect water from roadside springs at least once a month with around half collecting water every single week. The majority of survey respondents live further than three kilometers away from their preferred roadside spring with one respondent living roughly 64 kilometers away. This is significant when considering that respondents have access to water right in their homes yet still choose to take time and money to visit roadside springs.

## 6. Conclusions

In general, study participants did not trust their home drinking water and less than half of participants used their in-home piped POU water for drinking. Participants primarily used home tap water for bathing, cleaning, and brushing teeth. Home drinking water source (CWS vs private well/spring) did not appear to influence positive or negative perceptions of in-home POU drinking water in the sample group. However, concerns relating to water aesthetics, general mistrust of tap water, mistrust of public system, and health effects were cited as primary drivers for why in-home POU tap water was not trusted. In particular, water aesthetic issues cited by residents were supported by water quality results in which several key contaminants of aesthetic concern (Al, Mn, Fe) were elevated above the SMCL. It should be noted that only a small number of homes were sampled in the Central Appalachian region, and, because participants were self-selected, it is likely that all were, at least in part, concerned about their water quality.

In contrast, study participants reported trusting spring water quality. However, bacteriological quality of the sampled springs was generally poor as all sampled springs tested positive for total coliform and three of the six springs tested positive for *E. coli*, violating the SDWA MCL for these contaminants. Another common contaminant found in roadside spring water samples was Al. The presence of these bacteriological and metals contaminants in spring water samples suggests that there may be a health risk associated with the consumption of spring water.

Common contaminants found in home tap samples included total coliform, *E. coli*, Al, Fe, Mn, Sr, and Ba. A total of 14 constituents had statistically significantly different concentrations when comparing home and spring samples. Of these, 10 constituents (Cd, F, $NO_{3-}$, Cu, Pb, Ag, Mn, Zn, Na, and Sr) had significantly higher levels in home samples, while four constituents (total coliform, U, Al, and $SO_4^{2-}$) had significantly higher levels in spring samples. It must be noted that each home and spring sample collected provides only a snapshot of water quality at that specific period in time, water quality can change over time.

While analysis of in-home POU drinking water samples suggest that tap water might pose a greater risk of metals exposure to consumers, roadside spring drinking water sample analysis suggest that these sources may pose a greater risk of bacteriological exposure to consumers. Due to the difference in risks associated with home and spring water sources, one water source cannot be generalized as being of better quality than the other. As a result, future solutions devised to help residents improve their drinking water quality must address risks and contaminants present at each specific home and paired spring. The same solution is not likely to remediate drinking water quality at all homes and springs in the study.

## 7. Future Work

Both the in-home and spring water sampled in this study contained elevated concentrations of contaminants that are associated with aesthetic concerns. In order to ensure proper sanitation and hygiene, these waters must be brought into compliance through household or community interventions. Given that the water quality often differs between each individual home and paired roadside spring, solutions must be devised on a case by case basis. A schematic for designing solutions based on how the water quality between a resident's home and the roadside spring they use might differ is presented in Figure 7.1. These solutions are oftentimes small-scale (POU filters to be used at the home tap or roadside spring) because large -scale solutions (re-digging wells, replacing water mains or home plumbing) are not always feasible for residents. Research on optimizing POU filters would be very valuable to the Central Appalachian region as filters can be used in any location (spring or tap) and are generally less expensive than other water treatment options.

Collection and analysis of additional paired in-home POU and roadside spring water samples in order to increase the sample size would allow for additional patterns in home or spring water quality to be highlighted, particularly if more samples are collected within one specific community. Any additional patterns relating to water quality that are determined can then be used more appropriately design large-scale solutions that address issues of water quality, at homes or roadside springs, on a community level. For example, if it is determined after a larger study that a community that is predominantly served by a CWS is struggling with a certain contaminant, arrangements can be made to meet with community leaders, the water provider, and the local government to devise a method of solving the problem. This method could involve amendments to the water treatment process and monitoring protocols, or creating a proposal that might fund an upgrade or expansion of the treatment plant, building a new treatment plant, or replacing service lines in homes and around the community.

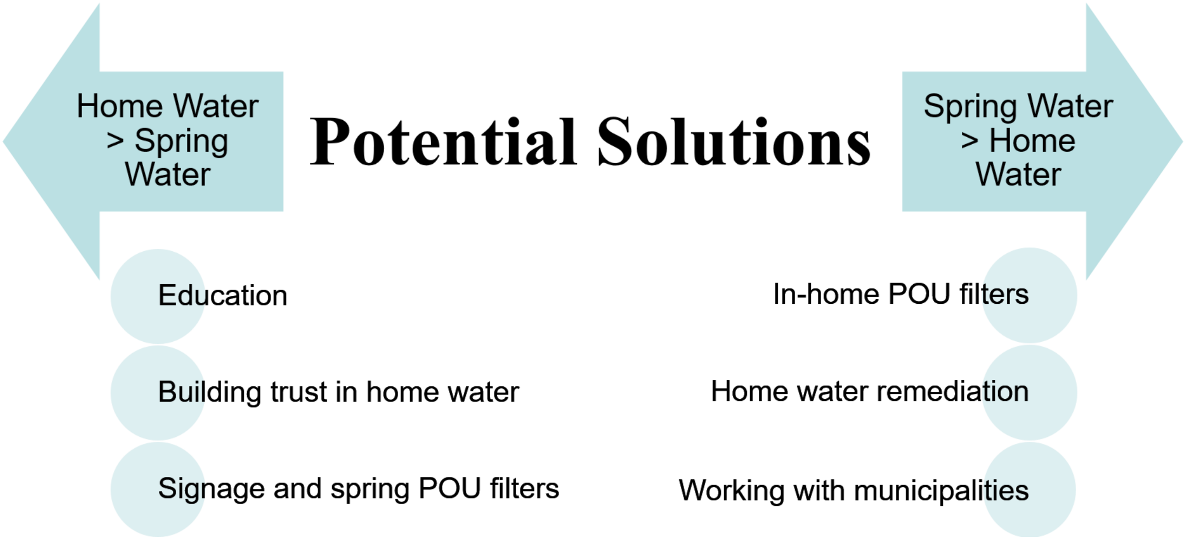


Figure 7.1: Schematic depicting potential solutions available to Central Appalachian spring-users based on their home and roadside spring water quality.

In order to justify and document the potential public health impacts of the interventions identified in Figure 7.1, a more detailed understanding of the exposures posed by these water sources must be defined. For example, both the present study and previously published work (Swistock et al., 2015; Krometis et al., 2019) have established that *E. coli* is present in roadside spring samples, however, this does not directly identify the types of pathogens present. Quantitative polymerase chain reaction (qPCR) can be used to determine whether roadside spring water samples contain *Cryptosporidium* oocysts or *Giardia* cysts, two fecal protozoan bacteria that can cause gastrointestinal illness and/or distress (Moulton-Hancock et al., 2000; Daniels et al., 2018). Linking the presence of actual pathogens with potential biomarkers or epidemiological evidence of disease in these households could be used to justify larger scale investments in water and wastewater infrastructure by local governments and/or industry.

The region of Appalachia is well-known for its rich history of natural resource extraction, but these are often accompanied by boom-bust economic cycles. The relationship of local economies and industries and water infrastructure is not well understood or quantified in literature. For example, an analysis of the relationship between coal production, coal severance tax, and SDWA violations would help foster a better understanding of the indirect effects of mining on potable water infrastructure in the region. Such insight could allow for more effective budgeting for water infrastructure or other uses of coal severance tax at the county or community level.

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# Appendix A. Master Data Sheet of All Home Water Quality Results

| Date | County Location | Water Source (P vs CWS) | Sample ID | Paired Spring | Sample Type | Na (ppb) | Mg (ppb) | Al (ppb) | Si (ppb) | P (ppb) | $SO_4^{2-}$ (ppm) | Cl (ppm) | K (ppb) | Ca (ppb) | Ti (ppb) | V (ppb) | Cr (ppb) | Fe (ppb) | Mn (ppb) | Co (ppb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21-Sep-18 | McDowell | CWS | McDAA | 3 | Max. values | 14,369.00 | 3,092.00 | 39.00 | 4,026.00 | 11.00 | 6.00 | 17.00 | 2,519.00 | 14,600.00 | 36.00 | 0.00 | 1.00 | 71.00 | 12.00 | 0.00 |
| 21-Sep-18 | McDowell | CWS | McDAA1 | 3 | First Draw | 13,722.00 | 2,929.00 | 31.00 | 3,874.00 | 11.00 | 6.00 | 16.00 | 2,409.00 | 14,008.00 | 35.00 | 0.00 | 0.00 | 22.00 | 9.00 | 0.00 |
| 21-Sep-18 | McDowell | CWS | McDAA2 | 3 | Second Draw | 14,369.00 | 3,092.00 | 39.00 | 4,026.00 | 10.00 | 6.00 | 17.00 | 2,519.00 | 14,600.00 | 36.00 | 0.00 | 1.00 | 71.00 | 12.00 | 0.00 |
| 08-Nov-18 | Floyd | CWS | FA | 1 | Max. values | 7,179.84 | 6,358.38 | 3.66 | 8,408.75 | 352.18 | 7.98 | 12.74 | 2,986.26 | 19,758.24 | 18.24 | 0.22 | 0.52 | 111.22 | 55.61 | 4.80 |
| 08-Nov-18 | Floyd | CWS | FA1 | 1 | First Draw | 7,156.34 | 6,308.39 | 3.66 | 8,305.86 | 348.73 | 7.98 | 12.74 | 2,974.10 | 19,758.24 | 18.24 | 0.21 | 0.48 | 111.22 | 55.61 | 0.05 |
| 08-Nov-18 | Floyd | CWS | FA2 | 1 | Second Draw | 7,179.84 | 6,358.38 | 3.26 | 8,408.75 | 352.18 | 7.90 | 12.43 | 2,986.26 | 19,709.73 | 17.85 | 0.22 | 0.52 | 92.73 | 43.59 | 0.03 |
| 24-Jan-19 | Craig | P | CrA | 2 | Only Sample | 313.18 | 704.70 | 243.96 | 2,197.22 | 1.96 | 3.53 | 0.52 | 484.24 | 790.66 | 2.90 | 0.25 | 0.38 | 48.85 | 17.70 | 1.52 |
| 22-Mar-19 | Martin | CWS | MaA | 6 | Max. values | 6,231.79 | 1,847.08 | 13.87 | 3,434.90 | -0.50 | 7.83 | 2.18 | 1,073.29 | 3,390.38 | 2.83 | -0.64 | 0.12 | 40.16 | 2.38 | 0.05 |
| 22-Mar-19 | Martin | CWS | MaA1 | 6 | First Draw | 6,020.07 | 1,810.34 | 13.87 | 3,279.15 | -0.52 | 6.94 | 2.18 | 1,045.05 | 3,390.38 | 2.83 | -0.64 | 0.12 | 40.16 | 2.38 | 0.05 |
| 22-Mar-19 | Martin | CWS | MaA2 | 6 | Second Draw | 6,231.79 | 1,847.08 | 12.99 | 3,434.90 | -0.50 | 7.83 | 1.88 | 1,073.29 | 3,267.04 | 2.73 | -0.69 | 0.09 | 8.08 | 0.35 | 0.04 |
| 22-Mar-19 | Martin | CWS | MaB | 6 | Max. values | 6,069.99 | 1,797.26 | 75.92 | 3,312.78 | 0.47 | 7.34 | 1.59 | 1,047.19 | 3,165.29 | 2.96 | -0.72 | 0.12 | 18.77 | 0.33 | 0.06 |
| 22-Mar-19 | Martin | CWS | MaB1 | 6 | First Draw | 6,069.99 | 1,797.26 | 75.92 | 3,312.78 | -0.50 | 7.34 | 1.59 | 1,047.19 | 3,165.29 | 2.96 | -0.72 | 0.11 | 18.14 | 0.33 | 0.06 |
| 22-Mar-19 | Martin | CWS | MaB2 | 6 | Second Draw | 6,038.49 | 1,775.18 | 27.12 | 3,311.37 | 0.47 | 7.27 | 1.34 | 1,044.88 | 3,098.23 | 2.75 | -0.77 | 0.12 | 18.77 | 0.25 | 0.04 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-Mar-19 | Martin | CWS | MaC | 6 | Max. values | 6,163.26 | 1,994.03 | 5,404.08 | 3,737.98 | 3.60 | 8.11 | 2.17 | 1,078.13 | 4,777.17 | 4.89 | -0.30 | 0.15 | 52.76 | 1.58 | 0.33 |
| 22-Mar-19 | Martin | CWS | MaC1 | 6 | First Draw | 6,163.26 | 1,994.03 | 5,404.08 | 3,737.98 | 3.60 | 8.11 | 2.17 | 1,078.13 | 4,777.17 | 4.89 | -0.30 | 0.15 | 52.76 | 1.58 | 0.33 |
| 22-Mar-19 | Martin | CWS | MaC2 | 6 | Second Draw | 6,069.65 | 1,889.24 | 2,719.52 | 3,170.97 | -0.04 | 7.80 | 1.88 | 1,053.10 | 4,108.23 | 3.81 | -0.64 | 0.09 | 24.69 | 1.07 | 0.21 |
| 22-Mar-19 | Martin | CWS | MaD | 6 | Max. values | 6,024.36 | 1,842.02 | 49.97 | 3,284.96 | -0.13 | 7.49 | 1.47 | 1,043.41 | 3,020.66 | 2.80 | -0.89 | 0.06 | 96.65 | 0.58 | 0.04 |
| 22-Mar-19 | Martin | CWS | MaD1 | 6 | First Draw | 6,021.10 | 1,842.02 | 49.97 | 3,176.10 | -0.13 | 7.49 | 1.47 | 1,043.41 | 3,020.66 | 2.80 | -0.89 | 0.06 | 96.65 | 0.58 | 0.04 |
| 22-Mar-19 | Martin | CWS | MaD2 | 6 | Second Draw | 6,024.36 | 1,818.15 | 11.62 | 3,284.96 | -1.15 | 7.49 | 0.86 | 1,039.10 | 2,873.72 | 2.43 | -0.92 | 0.07 | 79.09 | 0.20 | 0.03 |
| 22-Mar-19 | Martin | CWS | MaE | 6 | Max. values | 5,904.72 | 1,859.25 | 148.54 | 3,288.96 | 0.32 | 7.64 | 1.05 | 1,041.75 | 2,967.83 | 2.48 | -0.90 | 0.27 | 4.73 | 0.27 | 0.05 |
| 22-Mar-19 | Martin | CWS | MaE1 | 6 | First Draw | 5,808.35 | 1,777.61 | 148.54 | 3,111.19 | -0.19 | 7.31 | 1.05 | 1,012.19 | 2,944.77 | 2.47 | -0.90 | 0.18 | 3.38 | 0.27 | 0.05 |
| 22-Mar-19 | Martin | CWS | MaE2 | 6 | Second Draw | 5,904.72 | 1,859.25 | 20.22 | 3,288.96 | 0.32 | 7.64 | 0.92 | 1,041.75 | 2,967.83 | 2.48 | -0.95 | 0.27 | 4.73 | 0.20 | 0.03 |
| 22-Mar-19 | Martin | CWS | MaF | 6 | Max. values | 6,201.69 | 1,869.83 | 153.43 | 3,319.02 | -0.81 | 8.34 | 1.14 | 1,058.97 | 3,046.02 | 2.70 | -0.97 | 0.08 | 13.85 | 0.28 | 0.04 |
| 22-Mar-19 | Martin | CWS | MaF1 | 6 | First Draw | 6,201.69 | 1,869.83 | 153.43 | 3,319.02 | -1.23 | 8.34 | 1.14 | 1,058.97 | 3,046.02 | 2.70 | -0.97 | 0.09 | 3.23 | 0.28 | 0.04 |
| 22-Mar-19 | Martin | CWS | MaF2 | 6 | Second Draw | 6,075.79 | 1,823.22 | 57.55 | 3,311.72 | -0.81 | 7.83 | 0.88 | 1,047.32 | 2,916.43 | 2.49 | -0.99 | 0.08 | 13.85 | 0.26 | 0.03 |
| 22-Mar-19 | Martin | CWS | MaG | 6 | Max. values | 6,097.40 | 1,824.25 | 13.14 | 3,374.28 | 0.17 | 7.87 | 0.57 | 1,055.82 | 2,945.09 | 2.48 | -1.01 | 0.08 | 29.16 | 0.21 | 0.04 |
| 22-Mar-19 | Martin | CWS | MaG1 | 6 | First Draw | 6,097.40 | 1,824.25 | 10.09 | 3,374.28 | -1.22 | 7.87 | 0.57 | 1,055.82 | 2,945.09 | 2.48 | -1.01 | 0.08 | 5.40 | 0.21 | 0.03 |
| 22-Mar-19 | Martin | CWS | MaG2 | 6 | Second Draw | 6,023.31 | 1,801.24 | 13.14 | 3,333.56 | 0.17 | 7.64 | 0.53 | 1,043.64 | 2,904.44 | 2.47 | -1.03 | 0.07 | 29.16 | 0.20 | 0.04 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-Mar-19 | Martin | CWS | MaH | 6 | Max. values | 6,143.63 | 1,926.46 | 194.46 | 3,298.86 | 0.56 | 8.27 | 1.29 | 1,040.13 | 3,111.85 | 2.54 | -1.03 | 0.28 | 30.72 | 1.14 | 0.09 |
| 22-Mar-19 | Martin | CWS | MaH1 | 6 | First Draw | 6,143.63 | 1,926.46 | 194.46 | 3,117.42 | 0.08 | 7.68 | 1.29 | 1,027.73 | 3,111.85 | 2.54 | -1.03 | 0.28 | 30.72 | 1.14 | 0.09 |
| 22-Mar-19 | Martin | CWS | MaH2 | 6 | Second Draw | 6,018.32 | 1,789.35 | 15.24 | 3,298.86 | 0.56 | 8.27 | 0.48 | 1,040.13 | 2,868.67 | 2.38 | -1.06 | 0.12 | 6.44 | 0.51 | 0.03 |
| 22-Mar-19 | Martin | CWS | MaI | 6 | Max. values | 5,918.58 | 1,825.85 | 75.40 | 3,366.10 | 1.28 | 7.52 | 0.66 | 1,042.83 | 2,955.35 | 2.58 | -1.05 | 0.52 | 18.69 | 0.42 | 0.04 |
| 22-Mar-19 | Martin | CWS | MaI1 | 6 | First Draw | 5,918.58 | 1,825.85 | 75.40 | 3,366.10 | 1.28 | 7.42 | 0.66 | 1,042.83 | 2,955.35 | 2.58 | -1.05 | 0.13 | 12.25 | 0.32 | 0.04 |
| 22-Mar-19 | Martin | CWS | MaI2 | 6 | Second Draw | 5,913.26 | 1,796.53 | 13.35 | 3,301.09 | 1.01 | 7.52 | 0.38 | 1,038.35 | 2,794.36 | 2.35 | -1.08 | 0.52 | 18.69 | 0.42 | 0.03 |
| 22-Mar-19 | Martin | CWS | MaK | 6 | Max. values | 6,286.60 | 2,123.04 | 33.72 | 3,297.14 | 2.62 | 10.74 | 6.68 | 1,108.68 | 3,612.22 | 4.15 | 0.14 | 0.35 | 57.36 | 2.49 | 0.05 |
| 22-Mar-19 | Martin | CWS | MaK1 | 6 | First Draw | 5,987.70 | 2,123.04 | 33.72 | 3,297.14 | 2.62 | 10.70 | 6.68 | 1,108.68 | 3,612.22 | 4.15 | 0.14 | 0.35 | 57.36 | 2.49 | 0.05 |
| 22-Mar-19 | Martin | CWS | MaK2 | 6 | Second Draw | 6,286.60 | 1,989.80 | 14.11 | 3,285.71 | 2.23 | 10.74 | 6.34 | 1,074.36 | 3,101.90 | 3.52 | 0.11 | 0.32 | 21.22 | 0.18 | 0.03 |
| 22-Mar-19 | Martin | CWS | MaP | 6 | Max. values | 6,012.42 | 1,926.20 | 50.94 | 3,173.90 | 1.67 | 10.32 | 6.11 | 1,030.13 | 3,031.03 | 3.64 | 0.12 | 0.24 | 15.01 | 0.30 | 0.06 |
| 22-Mar-19 | Martin | CWS | MaP1 | 6 | First Draw | 5,638.42 | 1,926.20 | 50.94 | 3,168.19 | 1.67 | 10.08 | 6.11 | 1,030.13 | 3,031.03 | 3.64 | 0.12 | 0.24 | 15.01 | 0.30 | 0.06 |
| 22-Mar-19 | Martin | CWS | MaP2 | 6 | Second Draw | 6,012.42 | 1,908.72 | 9.32 | 3,173.90 | 0.86 | 10.32 | 5.79 | 1,024.91 | 2,987.98 | 3.33 | 0.08 | 0.16 | 11.02 | 0.18 | 0.04 |
| 22-Mar-19 | Martin | CWS | MaQ | 6 | Max. values | 5,986.77 | 1,881.48 | 34.41 | 3,089.19 | 0.87 | 9.83 | 5.71 | 1,011.02 | 2,923.62 | 3.66 | 0.10 | 0.19 | 36.67 | 0.50 | 0.05 |
| 22-Mar-19 | Martin | CWS | MaQ1 | 6 | First Draw | 5,850.92 | 1,840.44 | 34.41 | 3,059.74 | 0.87 | 9.31 | 5.71 | 981.21 | 2,857.13 | 3.66 | 0.10 | 0.19 | 36.67 | 0.50 | 0.05 |
| 22-Mar-19 | Martin | CWS | MaQ2 | 6 | Second Draw | 5,986.77 | 1,881.48 | 6.28 | 3,089.19 | 0.38 | 9.83 | 5.62 | 1,011.02 | 2,923.62 | 3.24 | 0.06 | 0.14 | 0.30 | 0.06 | 0.03 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-May-19 | McDowell | P | McDBC | 5 | Max. values | 1,833.79 | 7,325.39 | 43.66 | 4,783.70 | 1.49 | 52.22 | 0.59 | 1,985.53 | 9,450.38 | 11.52 | 0.08 | 0.14 | 20.75 | 4.92 | 0.07 |
| 22-May-19 | McDowell | P | McDBC1 | 5 | First Draw | 1,833.79 | 7,325.39 | 37.60 | 4,783.70 | 1.49 | 52.22 | 0.59 | 1,985.53 | 9,450.38 | 11.52 | 0.08 | 0.14 | 20.75 | 4.92 | 0.07 |
| 22-May-19 | McDowell | P | McDBC2 | 5 | Second Draw | 1,776.67 | 7,090.11 | 43.66 | 4,644.79 | 0.94 | 50.93 | 0.53 | 1,955.89 | 9,194.49 | 11.18 | 0.05 | 0.11 | 15.51 | 4.63 | 0.07 |
| 22-May-19 | McDowell | P | McDCC | 5 | Max. values | 1,651.25 | 1,804.59 | 108.16 | 4,730.28 | 4.95 | 8.21 | 0.68 | 1,067.63 | 3,290.00 | 4.80 | 0.16 | 0.35 | 89.16 | 5.73 | 0.06 |
| 22-May-19 | McDowell | P | McDCC1 | 5 | First Draw | 1,651.25 | 1,804.59 | 108.16 | 4,708.52 | 4.61 | 8.21 | 0.68 | 1,067.63 | 3,290.00 | 4.80 | 0.16 | 0.35 | 89.16 | 5.73 | 0.06 |
| 22-May-19 | McDowell | P | McDCC2 | 5 | Second Draw | 1,630.03 | 1,793.30 | 78.73 | 4,730.28 | 4.95 | 7.84 | 0.65 | 1,055.77 | 3,278.15 | 3.83 | 0.12 | 0.30 | 63.20 | 4.56 | 0.05 |
| 22-May-19 | McDowell | P | McDDC | 5 | Max. values | 7,808.75 | 3,381.14 | -0.48 | 5,846.80 | 39.51 | 9.73 | 6.01 | 1,033.11 | 9,455.89 | 9.44 | 0.16 | 0.11 | 3,648.67 | 1,330.44 | 0.24 |
| 22-May-19 | McDowell | P | McDDC1 | 5 | First Draw | 7,808.75 | 3,381.14 | -0.63 | 5,484.49 | 29.76 | 9.73 | 6.01 | 1,033.11 | 9,455.89 | 9.44 | 0.15 | 0.11 | 1,804.09 | 1,079.98 | 0.24 |
| 22-May-19 | McDowell | P | McDDC2 | 5 | Second Draw | 7,339.43 | 3,310.20 | -0.48 | 5,846.80 | 39.51 | 9.21 | 5.76 | 1,027.48 | 9,168.63 | 9.22 | 0.16 | 0.11 | 3,648.67 | 1,330.44 | 0.12 |
| 22-May-19 | McDowell | P | McDEC | 5 | Max. values | 244,315.55 | 22,887.86 | 704.56 | 6,496.63 | 102.02 | 0.14 | 589.45 | 3,074.37 | 90,695.53 | 71.78 | 4.11 | 0.19 | 34,775.95 | 1,093.37 | 0.30 |
| 22-May-19 | McDowell | P | McDEC1 | 5 | First Draw | 240,148.37 | 22,580.52 | 704.56 | 6,496.63 | 102.02 | 0.10 | 569.07 | 2,963.54 | 88,997.89 | 69.51 | 4.11 | 0.19 | 28,645.58 | 1,052.66 | 0.30 |
| 22-May-19 | McDowell | P | McDEC2 | 5 | Second Draw | 244,315.55 | 22,887.86 | 576.20 | 6,328.75 | 101.49 | 0.14 | 589.45 | 3,074.37 | 90,695.53 | 71.78 | 2.75 | 0.15 | 34,775.95 | 1,093.37 | 0.14 |
| 22-May-19 | McDowell | P | McDFC | 5 | Max. values | 604,434.89 | 28,189.99 | -9.36 | 5,475.26 | 49.54 | 0.85 | 1,218.81 | 3,669.55 | 131,412.14 | 101.64 | 5.56 | 0.28 | 5,673.34 | 260.40 | 0.40 |
| 22-May-19 | McDowell | P | McDFC1 | 5 | First Draw | 604,434.89 | 28,189.99 | -9.36 | 5,404.15 | 47.82 | 0.85 | 1,218.81 | 3,669.55 | 131,412.14 | 101.64 | 5.56 | 0.28 | 4,590.30 | 250.00 | 0.29 |
| 22-May-19 | McDowell | P | McDFC2 | 5 | Second Draw | 594,236.51 | 27,375.09 | -12.25 | 5,475.26 | 49.54 | 0.81 | 1,205.46 | 3,637.95 | 127,447.15 | 101.43 | 5.52 | 0.24 | 5,673.34 | 260.40 | 0.40 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24-Jun-19 | McDowell | P | McDAD | 4 | Max. values | 6,120.41 | 3,862.77 | 24.82 | 5,427.62 | 393.09 | 10.91 | 1.76 | 1,941.21 | 10,543.63 | 9.83 | 0.21 | 0.79 | 21,834.54 | 541.60 | 1.19 |
| 24-Jun-19 | McDowell | P | McDAD 1 | 4 | First Draw | 6,120.41 | 3,862.77 | 15.17 | 5,427.62 | 393.09 | 10.91 | 1.76 | 1,941.21 | 10,543.63 | 9.83 | 0.20 | 0.45 | 21,834.54 | 541.60 | 1.04 |
| 24-Jun-19 | McDowell | P | McDAD 2 | 4 | Second Draw | 6,042.65 | 3,803.45 | 24.82 | 5,318.92 | 334.70 | 10.86 | 1.75 | 1,917.81 | 10,480.94 | 9.76 | 0.21 | 0.79 | 19,515.64 | 532.74 | 1.19 |
| 04-Dec-19 | McDowell | P | McDAB | 5 | Max. values | 7,582.23 | 9,606.03 | 10.64 | 4,865.19 | 11.53 | 13.41 | 1.04 | 1,718.44 | 33,103.15 | 29.58 | -0.25 | 0.97 | 1,961.81 | 98.53 | 0.28 |
| 04-Dec-19 | McDowell | P | McDAB 1 | 5 | First Draw | 7,522.99 | 9,534.42 | 7.32 | 4,864.75 | 11.53 | 13.35 | 1.04 | 1,708.94 | 32,911.94 | 29.46 | -0.25 | 0.97 | 1,906.83 | 71.30 | 0.22 |
| 04-Dec-19 | McDowell | P | McDAB 2 | 5 | Second Draw | 7,582.23 | 9,606.03 | 10.64 | 4,865.19 | 10.18 | 13.41 | 0.96 | 1,718.44 | 33,103.15 | 29.58 | -0.29 | 0.96 | 1,961.81 | 98.53 | 0.28 |
| 04-Dec-19 | McDowell | P | McDBB | 5 | Max. values | 4,592.46 | 2,492.53 | 508.38 | 4,573.85 | 28.29 | 6.00 | 1.16 | 1,267.26 | 8,704.26 | 18.34 | 0.21 | 0.94 | 990.70 | 107.77 | 0.38 |
| 04-Dec-19 | McDowell | P | McDBB 1 | 5 | First Draw | 4,592.46 | 2,439.75 | 508.38 | 4,573.85 | 28.29 | 5.48 | 1.09 | 1,267.26 | 8,704.26 | 18.34 | 0.21 | 0.94 | 990.70 | 93.00 | 0.38 |
| 04-Dec-19 | McDowell | P | McDBB 2 | 5 | Second Draw | 4,508.42 | 2,492.53 | 304.04 | 4,111.46 | 20.00 | 6.00 | 1.16 | 1,132.80 | 8,447.57 | 10.68 | -0.01 | 0.71 | 965.48 | 107.77 | 0.37 |
| 04-Dec-19 | McDowell | P | McDCB | 5 | Max. values | 4,749.77 | 4,569.79 | 4.05 | 7,354.10 | -2.30 | 4.03 | 2.97 | 638.34 | 18,780.05 | 16.79 | -0.38 | 0.08 | 30.98 | 6.87 | 0.03 |
| 04-Dec-19 | McDowell | P | McDCB 1 | 5 | First Draw | 4,749.77 | 4,503.93 | 4.05 | 7,354.10 | -2.30 | 4.01 | 2.94 | 638.34 | 18,592.02 | 16.79 | -0.39 | 0.08 | 30.98 | 2.71 | 0.03 |
| 04-Dec-19 | McDowell | P | McDCB 2 | 5 | Second Draw | 4,745.37 | 4,569.79 | -0.79 | 7,292.01 | -3.04 | 4.03 | 2.97 | 618.04 | 18,780.05 | 16.68 | -0.38 | 0.07 | 17.84 | 6.87 | 0.02 |

| **Date** | **Sample ID** | **Sample Type** | **Ni (ppb)** | **Cu (ppb)** | **Zn (ppb)** | **As (ppb)** | **Se (ppb)** | **Sr (ppb)** | **Mo (ppb)** | **Ag (ppb)** | **Cd (ppb)** | **Sn (ppb)** | **Ba (ppb)** | **Pb (ppb)** | **U (ppb)** | **$NO_3^-$ (ppm)** | **F (ppm)** | **Total Coliform (MPN/100mL)** | ***E. coli* (MPN/100mL)** | **pH** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21-Sep-18 | McDAA | Max. values | 0.00 | 332.00 | 29.00 | 1.00 | 0.00 | 88.00 | 0.00 | 0.00 | 0.00 | 0.00 | 30.00 | 2.00 | 0.00 | 0.23 | 0.64 | 0 | 0 | 6.67 |
| 21-Sep-18 | McDAA1 | First Draw | 0.00 | 332.00 | 29.00 | 1.00 | 0.00 | 85.00 | 0.00 | 0.00 | 0.00 | 0.00 | 28.00 | 1.00 | 0.00 | - | - | - | - | |
| 21-Sep-18 | McDAA2 | Second Draw | 0.00 | 69.00 | 16.00 | 1.00 | 0.00 | 88.00 | 0.00 | 0.00 | 0.00 | 0.00 | 30.00 | 2.00 | 0.00 | - | - | - | - | |
| 08-Nov-18 | FA | Max. values | 6.95 | 227.55 | 1,048.40 | 7.27 | 0.47 | 43.72 | 5.09 | 6.04 | 0.02 | 0.05 | 44.66 | 0.35 | 6.28 | 0.44 | 0.08 | 3 | 0 | 6.9 |
| 08-Nov-18 | FA1 | First Draw | 6.95 | 207.97 | 1,048.40 | 0.01 | 0.32 | 43.56 | 0.05 | 0.01 | 0.02 | 0.05 | 43.14 | 1.58 | 0.06 | - | - | - | - | - |
| 08-Nov-18 | FA2 | Second Draw | 3.06 | 227.55 | 103.92 | 0.01 | 0.47 | 43.72 | 0.05 | 0.01 | 0.01 | 0.01 | 44.66 | 0.35 | 0.06 | - | - | - | - | - |
| 24-Jan-19 | CrA | Only Sample | 1.35 | 0.51 | 15.90 | 0.08 | -0.06 | 11.13 | 0.02 | 0.05 | 0.03 | 0.01 | 42.27 | 0.47 | 0.04 | 0.26 | 0.02 | 110.6 | 0 | 6.15 |
| 22-Mar-19 | MaA | Max. values | 1.15 | 3.38 | 60.83 | -0.21 | 0.34 | 27.23 | 0.03 | 0.29 | 0.01 | 0.02 | 15.03 | 0.19 | 0.01 | 0.17 | 0.81 | - | - | 7.14 |
| 22-Mar-19 | MaA1 | First Draw | 1.15 | 3.38 | 60.83 | -0.22 | 0.02 | 27.23 | 0.03 | 0.29 | 0.01 | 0.02 | 14.63 | 0.19 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaA2 | Second Draw | 0.45 | 1.94 | 14.84 | -0.21 | 0.34 | 25.30 | 0.03 | 0.22 | 0.01 | 0.02 | 15.03 | 0.06 | 0.01 | - | - | - | - | - |
| 22-Mar-19 | MaB | Max. values | 0.37 | 3.71 | 31.16 | -0.24 | 0.03 | 24.74 | 0.03 | 0.13 | 0.02 | 0.09 | 14.35 | 0.13 | 0.02 | 0.18 | 0.83 | - | - | 7.29 |
| 22-Mar-19 | MaB1 | First Draw | 0.37 | 3.71 | 31.16 | -0.24 | 0.03 | 24.74 | 0.03 | 0.13 | 0.02 | 0.09 | 14.34 | 0.13 | 0.02 | - | - | - | - | |
| 22-Mar-19 | MaB2 | Second Draw | 0.32 | 3.30 | 11.51 | -0.25 | 0.02 | 23.91 | 0.03 | 0.07 | 0.00 | 0.02 | 14.35 | 0.12 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaC | Max. values | 2.39 | 20.38 | 266.86 | -0.07 | -0.34 | 41.75 | 0.03 | 0.02 | 0.01 | 9.55 | 15.58 | 3.24 | 0.05 | 0.16 | 0.75 | - | - | 7.4 |
| 22-Mar-19 | MaC1 | First Draw | 2.39 | 20.38 | 266.86 | -0.07 | -0.69 | 41.75 | 0.03 | 0.02 | 0.01 | 9.55 | 15.58 | 3.24 | 0.05 | - | - | - | - | - |
| 22-Mar-19 | MaC2 | Second Draw | 0.46 | 6.80 | 43.79 | -0.22 | -0.34 | 34.93 | 0.03 | 0.01 | 0.00 | 2.83 | 13.59 | 1.88 | 0.01 | - | - | - | - | - |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-Mar-19 | MaD | Max. values | 0.79 | 19.38 | 140.28 | -0.26 | -0.03 | 24.43 | 0.04 | 0.06 | 0.00 | 0.11 | 15.37 | 0.18 | 0.00 | 0.17 | 0.8 | 0 | 0 | 7.43 |
| 22-Mar-19 | MaD1 | First Draw | 0.79 | 19.38 | 140.28 | -0.30 | -0.09 | 24.43 | 0.04 | 0.02 | 0.00 | 0.11 | 15.37 | 0.09 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaD2 | Second Draw | 0.31 | 7.47 | 13.38 | -0.26 | -0.03 | 22.67 | 0.03 | 0.06 | 0.00 | 0.02 | 15.36 | 0.18 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaE | Max. values | 1.24 | 3.35 | 113.75 | -0.33 | -0.04 | 24.89 | 0.03 | 0.04 | 0.03 | 0.15 | 16.49 | 0.04 | 0.00 | 0.17 | 0.78 | 0 | 0 | 7.3 |
| 22-Mar-19 | MaE1 | Not a true First Draw | 1.24 | 2.13 | 113.75 | -0.39 | -0.31 | 24.58 | 0.03 | 0.02 | 0.03 | 0.15 | 15.21 | 0.04 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaE2 | Not a true Second Draw | 0.68 | 3.35 | 44.02 | -0.33 | -0.04 | 24.89 | 0.03 | 0.04 | 0.01 | 0.02 | 16.49 | 0.02 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaF | Max. values | 8.13 | 177.37 | 39.20 | -0.36 | 0.01 | 24.76 | 0.03 | 0.03 | 0.01 | 0.11 | 15.64 | 1.62 | 0.01 | 0.17 | 0.79 | 0 | 0 | 7.18 |
| 22-Mar-19 | MaF1 | First Draw | 8.13 | 111.07 | 39.20 | -0.40 | 0.01 | 24.76 | 0.03 | 0.02 | 0.01 | 0.11 | 15.64 | 1.36 | 0.01 | - | - | - | - | - |
| 22-Mar-19 | MaF2 | Second Draw | 0.86 | 177.37 | 15.40 | -0.36 | 0.06 | 23.25 | 0.03 | 0.03 | 0.01 | 0.04 | 14.75 | 1.62 | 0.01 | - | - | - | - | - |
| 22-Mar-19 | MaG | Max. values | 0.43 | 4.85 | 34.22 | -0.28 | 0.26 | 23.25 | 0.04 | 0.05 | 0.02 | 0.02 | 15.12 | 0.06 | 0.00 | 0.17 | 0.78 | 0 | 0 | 7.16 |
| 22-Mar-19 | MaG1 | First Draw | 0.43 | 4.85 | 34.22 | -0.28 | 0.26 | 23.25 | 0.03 | 0.05 | 0.02 | 0.01 | 15.09 | 0.06 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaG2 | Second Draw | 0.33 | 2.36 | 14.20 | -0.29 | -0.12 | 23.07 | 0.04 | 0.04 | 0.00 | 0.02 | 15.12 | 0.05 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaH | Max. values | 1.92 | 15.72 | 226.10 | -0.30 | 0.22 | 24.34 | 0.03 | 0.04 | 0.03 | 0.15 | 14.75 | 0.06 | 0.00 | 0.17 | 0.82 | 0 | 0 | 7.19 |
| 22-Mar-19 | MaH1 | First Draw | 1.92 | 15.72 | 226.10 | -0.37 | 0.22 | 24.34 | 0.03 | 0.01 | 0.03 | 0.15 | 14.05 | 0.06 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaH2 | Second Draw | 0.36 | 2.83 | 13.69 | -0.30 | 0.08 | 22.65 | 0.03 | 0.04 | 0.00 | 0.02 | 14.75 | 0.02 | 0.00 | - | - | - | - | - |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-Mar-19 | MaI | Max. values | 0.46 | 3.50 | 114.39 | -0.29 | -0.15 | 22.91 | 0.03 | 0.03 | 0.00 | 0.08 | 15.58 | 0.02 | 0.00 | 0.17 | 0.81 | 0 | 0 | 7.17 |
| 22-Mar-19 | MaI1 | First Draw | 0.46 | 3.50 | 114.39 | -0.33 | -0.08 | 22.91 | 0.03 | 0.02 | 0.00 | 0.03 | 15.58 | 0.02 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaI2 | Second Draw | 0.38 | 1.78 | 11.64 | -0.29 | -0.15 | 22.09 | 0.03 | 0.03 | 0.00 | 0.08 | 15.08 | 0.02 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaK | Max. values | 4.20 | 29.54 | 159.10 | 0.22 | 1.47 | 31.97 | 0.08 | 0.01 | 0.00 | 0.02 | 19.86 | 0.54 | 0.00 | 0.18 | 0.78 | 0 | 0 | 7.11 |
| 22-Mar-19 | MaK1 | First Draw | 4.20 | 29.54 | 159.10 | 0.18 | 1.47 | 31.97 | 0.08 | 0.01 | 0.00 | 0.02 | 19.86 | 0.54 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaK2 | Second Draw | 0.54 | 9.57 | 21.91 | 0.22 | 1.40 | 24.40 | 0.08 | 0.01 | 0.00 | 0.01 | 17.05 | 0.03 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaP | Max. values | 1.12 | 5.53 | 110.36 | 0.18 | 0.95 | 24.27 | 0.04 | 0.02 | 0.02 | 0.07 | 18.04 | 0.13 | 0.00 | - | - | 0 | 0 | - |
| 22-Mar-19 | MaP1 | First Draw | 1.12 | 4.02 | 110.36 | 0.18 | 0.83 | 24.27 | 0.04 | 0.02 | 0.02 | 0.07 | 18.04 | 0.13 | 0.01 | - | - | - | - | - |
| 22-Mar-19 | MaP2 | Second Draw | 0.39 | 5.53 | 10.90 | 0.22 | 0.95 | 23.50 | 0.03 | 0.02 | 0.01 | 0.02 | 16.24 | 0.03 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaQ | Max. values | 0.41 | 12.12 | 10.68 | 0.24 | 0.84 | 22.82 | 0.03 | 0.01 | 0.00 | 0.02 | 15.24 | 0.85 | 0.00 | 0.17 | 0.8 | 1 | 0 | 7.14 |
| 22-Mar-19 | MaQ1 | First Draw | 0.41 | 12.12 | 10.68 | 0.23 | 0.60 | 22.39 | 0.03 | 0.01 | 0.00 | 0.02 | 15.08 | 0.85 | 0.00 | - | - | - | - | - |
| 22-Mar-19 | MaQ2 | Second Draw | 0.35 | 7.19 | 9.32 | 0.24 | 0.84 | 22.82 | 0.03 | 0.01 | 0.00 | 0.01 | 15.24 | 0.34 | 0.00 | - | - | - | - | - |
| 22-May-19 | McDBC | Max. values | 7.96 | 1.98 | 65.14 | 0.12 | -1.05 | 66.66 | 0.03 | 0.00 | 0.04 | 0.03 | 42.25 | 0.54 | 0.00 | 0.26 | 0.08 | 2419.6 | 7.4 | 7.7 |
| 22-May-19 | McDBC1 | First Draw | 7.96 | 1.98 | 65.14 | 0.12 | -1.11 | 66.66 | 0.03 | 0.00 | 0.03 | 0.03 | 42.25 | 0.54 | 0.00 | - | - | - | - | - |
| 22-May-19 | McDBC2 | Second Draw | 7.66 | 0.48 | 21.83 | 0.04 | -1.05 | 64.94 | 0.03 | 0.00 | 0.04 | 0.02 | 40.87 | 0.44 | 0.00 | - | - | - | - | - |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22-May-19 | McDCC | Max. values | 5.14 | 200.47 | 1,848.59 | 0.09 | -1.14 | 26.88 | 0.03 | 0.01 | 0.02 | 0.02 | 24.13 | 0.61 | 0.01 | 1.11 | 0.03 | 2419.6 | 461.1 | 7.17 |
| 22-May-19 | McDCC1 | First Draw | 5.14 | 200.47 | 1,848.59 | 0.09 | -1.14 | 26.88 | 0.03 | 0.01 | 0.02 | 0.02 | 24.13 | 0.61 | 0.01 | - | - | - | - | - |
| 22-May-19 | McDCC2 | Second Draw | 2.60 | 14.90 | 139.22 | 0.07 | -1.31 | 26.88 | 0.03 | 0.01 | 0.01 | 0.02 | 23.52 | 0.11 | 0.01 | - | - | - | - | - |
| 22-May-19 | McDDC | Max. values | 0.68 | 1.54 | 470.11 | 1.79 | -1.09 | 77.42 | 0.19 | 0.02 | 0.01 | 0.05 | 193.83 | 0.13 | 0.01 | 0.03 | 0.09 | 179.3 | 0 | 7.21 |
| 22-May-19 | McDDC1 | First Draw | 0.68 | 1.54 | 405.86 | 0.63 | -1.09 | 77.42 | 0.15 | 0.02 | 0.00 | 0.05 | 170.29 | 0.13 | 0.00 | - | - | - | - | - |
| 22-May-19 | McDDC2 | Second Draw | 0.45 | 1.42 | 470.11 | 1.79 | -1.38 | 75.61 | 0.19 | 0.02 | 0.01 | 0.04 | 193.83 | 0.07 | 0.01 | - | - | - | - | - |
| 22-May-19 | McDEC | Max. values | 1.46 | 20.69 | 158.10 | 1.09 | 2.13 | 3,676.94 | 0.17 | 0.03 | 0.00 | 0.92 | 5,743.07 | 0.72 | 0.00 | 0.03 | 0.08 | 0 | 0 | 7.28 |
| 22-May-19 | McDEC1 | First Draw | 1.46 | 20.69 | 158.10 | 1.09 | 0.75 | 3,676.94 | 0.17 | 0.03 | 0.00 | 0.92 | 5,724.56 | 0.72 | 0.00 | - | - | - | - | - |
| 22-May-19 | McDEC2 | Second Draw | 1.43 | 1.37 | 30.07 | 1.02 | 2.13 | 3,627.27 | 0.12 | 0.01 | 0.00 | 0.65 | 5,743.07 | 0.07 | 0.00 | - | - | - | - | - |
| 22-May-19 | McDFC | Max. values | 2.30 | 2.13 | 20.20 | 2.79 | 3.93 | 9,351.10 | 0.23 | 0.01 | 0.01 | 0.02 | 12,399.01 | 0.13 | 0.00 | 0.03 | 0.11 | 5.2 | 0 | 7.33 |
| 22-May-19 | McDFC1 | First Draw | 2.30 | 2.04 | 20.20 | 2.71 | 3.52 | 9,351.10 | 0.18 | 0.01 | 0.01 | 0.02 | 12,399.01 | 0.12 | 0.00 | - | - | - | - | - |
| 22-May-19 | McDFC2 | Second Draw | 1.38 | 2.13 | 15.19 | 2.79 | 3.93 | 9,090.82 | 0.23 | 0.01 | 0.01 | 0.02 | 12,326.69 | 0.13 | 0.00 | - | - | - | - | - |
| 24-Jun-19 | McDAD | Max. values | 1.12 | 2.13 | 143.18 | 5.97 | 0.31 | 105.85 | 0.12 | 0.01 | 0.09 | 0.03 | 158.11 | 2.42 | 0.01 | 0.03 | 0.04 | 2419.6 | 0 | 6.89 |
| 24-Jun-19 | McDAD1 | First Draw | 0.89 | 2.13 | 127.83 | 5.97 | 0.22 | 105.85 | 0.12 | 0.00 | 0.08 | 0.03 | 158.11 | 1.71 | 0.01 | - | - | – | - | - |
| 24-Jun-19 | McDAD2 | Second Draw | 1.12 | 2.12 | 143.18 | 5.69 | 0.31 | 104.68 | 0.11 | 0.01 | 0.09 | 0.02 | 152.43 | 2.42 | 0.01 | - | - | - | - | - |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 04-Dec-19 | McDAB | Max. values | 1.10 | 5.55 | 13.27 | 0.41 | 0.43 | 1,082.88 | 0.07 | 0.02 | 0.00 | 0.07 | 349.77 | 0.51 | 0.05 | 0.19 | 0.12 | 980.4 | 5.2 | - |
| 04-Dec-19 | McDAB1 | First Draw | 1.01 | 5.48 | 13.27 | 0.34 | 0.43 | 1,077.01 | 0.07 | -0.01 | 0.00 | 0.02 | 345.51 | 0.46 | 0.04 | - | - | - | - | - |
| 04-Dec-19 | McDAB2 | Second Draw | 1.10 | 5.55 | 9.15 | 0.41 | 0.31 | 1,082.88 | 0.06 | 0.02 | 0.00 | 0.07 | 349.77 | 0.51 | 0.05 | - | - | - | - | - |
| 04-Dec-19 | McDBB | Max. values | 0.97 | 8.31 | 986.27 | 0.19 | -0.41 | 138.15 | 0.08 | 0.01 | 0.42 | 0.41 | 110.60 | 1.03 | 0.02 | 0.13 | 0.12 | 5.2 | 0 | - |
| 04-Dec-19 | McDBB1 | First Draw | 0.97 | 6.24 | 986.27 | 0.19 | -0.46 | 138.15 | 0.08 | 0.01 | 0.42 | 0.41 | 110.60 | 1.03 | 0.02 | - | - | - | - | - |
| 04-Dec-19 | McDBB2 | Second Draw | 0.80 | 8.31 | 459.90 | 0.10 | -0.41 | 125.91 | 0.06 | 0.00 | 0.03 | 0.05 | 93.35 | 0.69 | 0.01 | - | - | - | - | - |
| 04-Dec-19 | McDCB | Max. values | 0.82 | 1.82 | 17.11 | 0.05 | 0.39 | 198.82 | 0.04 | -0.01 | 0.00 | 0.04 | 298.70 | 0.24 | 0.01 | 0.36 | 0.11 | 3.1 | 0 | - |
| 04-Dec-19 | McDCB1 | First Draw | 0.82 | 1.82 | 17.11 | 0.05 | 0.23 | 198.82 | 0.04 | -0.01 | 0.00 | 0.04 | 298.70 | 0.24 | 0.01 | - | - | - | - | - |
| 04-Dec-19 | McDCB2 | Second Draw | 0.69 | 1.21 | 7.85 | 0.02 | 0.39 | 192.71 | -0.01 | -0.01 | 0.00 | 0.02 | 274.76 | 0.05 | 0.01 | - | - | - | - | - |

# Appendix B. Master Data Sheet of All Spring Water Quality Results

| Paired Spring | Location | Date | Na (ppb) | Mg (ppb) | Al (ppb) | Si (ppb) | P (ppb) | SO$_4^{2-}$ (ppm) | Cl (ppm) | K (ppb) | Ca (ppb) | Ti (ppb) | V (ppb) | Cr (ppb) | Fe (ppb) | Mn (ppb) | Co (ppb) | Ni (ppb) | Cu (ppb) | Zn (ppb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Floyd | 11/8/18 | 5,629.68 | 1,845.72 | 22.86 | 5,539.28 | 13.23 | 0.92 | 13.13 | 1,073.48 | 6,271.44 | 5.80 | 0.01 | 0.26 | 27.04 | 1.06 | 0.02 | 0.51 | 0.88 | 9.04 |
| 2 | Giles | 1/24/19 | 725.01 | 5,238.62 | 211.32 | 3,647.39 | 20.40 | 1.06 | 1.60 | 791.15 | 20,977.85 | 20.82 | 0.57 | 0.44 | 127.54 | 7.21 | 0.12 | 0.66 | 0.24 | 14.28 |
| 3 | McDowell | 9/21/18 | 8,224.16 | 20,576.72 | -19.17 | 3,889.22 | -0.43 | 62.50 | -0.07 | 2,237.28 | 25,816.58 | 57.68 | 0.00 | 0.10 | 1.70 | 0.03 | 0.02 | 4.25 | 0.34 | 12.20 |
| 4 | McDowell | 6/25/19 | 3,382.36 | 3,124.10 | 119.70 | 3,891.09 | 8.65 | 11.57 | 2.43 | 1,608.83 | 7,128.35 | 7.27 | 0.29 | 0.26 | 223.04 | 18.88 | 0.20 | 0.57 | 0.46 | 8.38 |
| 5 | McDowell | 5/22/19 | 10,185.50 | 5,056.40 | 100.75 | 3,831.77 | 2.51 | 28.56 | 1.22 | 1,391.58 | 8,980.16 | 10.37 | 0.19 | 0.25 | 71.32 | 0.89 | 0.05 | 1.70 | 2.09 | 14.95 |
| 5 | McDowell | 12/4/18 | 3,814.49 | 2,241.33 | 477.76 | 4,382.03 | 3.48 | 13.57 | -0.17 | 1,134.19 | 3,827.17 | 10.62 | 0.07 | 0.59 | 221.46 | 3.40 | 0.09 | 1.04 | 1.37 | 11.99 |
| 6 | Mingo | 3/22/19 | 4,467.06 | 6,463.07 | 164.39 | 5,258.61 | 0.47 | 33.59 | -4.69 | 1,660.19 | 14,736.35 | 16.70 | -1.12 | 0.25 | 72.19 | 0.89 | 0.07 | 1.03 | 0.51 | 8.26 |

| Paired Spring | Location | Date | As (ppb) | Se (ppb) | Sr (ppb) | Mo (ppb) | Ag (ppb) | Cd (ppb) | Sn (ppb) | Ba (ppb) | Pb (ppb) | U (ppb) | NO$_{3-}$ (ppm) | F (ppm) | Total Coliform (MPN/100mL) | E. coli (MPN/100mL) | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Floyd | 11/8/18 | -0.02 | 0.12 | 42.94 | 0.03 | 0.00 | 0.03 | 0.02 | 33.95 | 0.02 | 0.00 | 0.28 | 0.08 | 193.5 | 0 | 6.59 |
| 2 | Giles | 1/24/19 | 0.19 | 0.21 | 33.54 | 0.07 | 0.11 | 0.01 | 0.03 | 14.74 | 0.21 | 0.06 | 0.31 | 0.03 | 816.4 | 3.1 | 7.55 |
| 3 | McDowell | 9/21/18 | 0.05 | 2.60 | 954.20 | 0.07 | 0.00 | 0.02 | -0.01 | 49.90 | -0.01 | 0.13 | 0.10 | 0.06 | 4.1 | 0 | 6.17 |
| 4 | McDowell | 6/25/19 | 0.23 | 0.41 | 47.54 | 0.07 | 0.01 | 0.01 | 0.02 | 25.45 | 0.34 | 0.02 | 0.23 | 0.04 | 2419.6 | 488.4 | 7.6 |
| 5 | McDowell | 5/22/19 | 0.07 | -0.83 | 315.88 | 0.04 | 0.00 | 0.00 | 0.01 | 64.58 | 0.10 | 0.01 | 0.13 | 0.06 | 517.2 | 4.1 | 8.41 |
| 5 | McDowell | 12/4/18 | 0.06 | -0.40 | 110.93 | 0.02 | 0.02 | 0.00 | 0.08 | 32.13 | 0.23 | 0.03 | 0.16 | 0.10 | 579.4 | 4.1 | 7.73 |
| 6 | Mingo | 3/22/19 | -0.50 | 0.21 | 172.70 | 0.05 | 0.01 | 0.01 | 0.01 | 31.84 | 0.08 | 0.02 | 0.09 | 0.06 | 214.2 | 0 | 6.85 |

## Appendix C. Water quality reports distributed to study participants by sampling date and location

### McDowell County, WV (6-25-19)

A –

| Home A Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 6.89 | **pH – 6.5 – 8.5** | 7.6 |
| 0.03 | **Nitrate - 10 ppm** | 0.23 |
| 21,835 | **Iron - 300 ppb** | 223.0 |
| 542 | **Manganese - 50 ppb** | 18.9 |
| 2.4 | **Lead - 15 ppb** | 0.3 |
| 6.0 | **Arsenic - 10 ppb** | 0.2 |
| 0.04 | **Fluoride – 4 ppm** | 0.04 |
| 6,120.4 | **Sodium – 20,000 ppb** | 3,382.4 |
| 2.1 | **Copper – 1,300 ppb** | 0.5 |
| 0.3 | **Selenium – 50 ppb** | 0.4 |
| 0.1 | **Cadmium – 5 ppb** | 0.0 |
| 0.0 | **Uranium – 30 ppb** | 0.0 |
| 0.02 | **Aluminum – 0.05 – 0.2 ppm** | 0.1 |
| 10.4 | **Sulfate – 250 ppm** | 0.05 |
| 0.1 | **Strontium – 1.5 ppm** | 0.03 |
| 0.2 | **Barium – 2 ppm** | 11.6 |
| 1.8 ppm | **Chloride – No Limit** | 2.4 ppm |
| 10.5 ppm | **Calcium – No Limit** | 7.1 ppm |
| 3.9 ppm | **Magnesium – No Limit** | 3.1 ppm |

McDowell County, WV (5-22-19)

B –

| **Home B Conc.** | **Contaminant – SDWA Standard** | **Local Spring Sample Conc.** |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| PRESENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.70 | **pH – 6.5 – 8.5** | 8.41 |
| 0.26 | **Nitrate - 10 ppm** | 0.13 |
| 20.7 | **Iron - 300 ppb** | 71.3 |
| 4.9 | **Manganese - 50 ppb** | 0.9 |
| 0.5 | **Lead - 15 ppb** | 0.1 |
| 0.1 | **Arsenic - 10 ppb** | 0.1 |
| 0.08 | **Fluoride – 4 ppm** | 0.06 |
| 1,834 | **Sodium – 20,000 ppb** | 10,186 |
| 2.0 | **Copper – 1,300 ppb** | 2.1 |
| BD | **Selenium – 50 ppb** | BD |
| 0.0 | **Cadmium – 5 ppb** | 0.0 |
| 0.0 | **Uranium – 30 ppb** | 0.0 |
| 0.04 | **Aluminum – 0.05 – 0.2 ppm** | 0.1 |
| 52.2 | **Sulfate – 250 ppm** | 28.6 |
| 0.07 | **Strontium – 1.5 ppm** | 0.3 |
| 0.04 | **Barium – 2 ppm** | 0.06 |
| 0.6 ppm | **Chloride – No Limit** | 1.2 ppm |
| 9.5 ppm | **Calcium – No Limit** | 9.0 ppm |
| 7.3 ppm | **Magnesium – No Limit** | 5.1 ppm |

| Home C Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| PRESENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.17 | **pH – 6.5 – 8.5** | 8.41 |
| 1.11 | **Nitrate - 10 ppm** | 0.13 |
| 89.2 | **Iron - 300 ppb** | 71.3 |
| 5.7 | **Manganese - 50 ppb** | 0.9 |
| 0.6 | **Lead - 15 ppb** | 0.1 |
| 0.1 | **Arsenic - 10 ppb** | 0.1 |
| 0.03 | **Fluoride – 4 ppm** | 0.06 |
| 1,651 | **Sodium – 20,000 ppb** | 10,186 |
| 200.5 | **Copper – 1,300 ppb** | 2.1 |
| BD | **Selenium – 50 ppb** | BD |
| 0.0 | **Cadmium – 5 ppb** | 0.0 |
| 0.0 | **Uranium – 30 ppb** | 0.0 |
| 0.1 | **Aluminum – 0.05 – 0.2 ppm** | 0.1 |
| 8.2 | **Sulfate – 250 ppm** | 28.6 |
| 0.03 | **Strontium – 1.5 ppm** | 0.3 |
| 0.02 | **Barium – 2 ppm** | 0.06 |
| 0.7 ppm | **Chloride – No Limit** | 1.2 ppm |
| 3.3 ppm | **Calcium – No Limit** | 9.0 ppm |
| 1.8 ppm | **Magnesium – No Limit** | 5.1 ppm |

| Home D Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.21 | **pH – 6.5 – 8.5** | 8.41 |
| 0.03 | **Nitrate - 10 ppm** | 0.13 |
| 3,649 | **Iron - 300 ppb** | 71.3 |
| 1,330 | **Manganese - 50 ppb** | 0.9 |
| 0.1 | **Lead - 15 ppb** | 0.1 |
| 1.8 | **Arsenic - 10 ppb** | 0.1 |
| 0.09 | **Fluoride – 4 ppm** | 0.06 |
| 7,809 | **Sodium – 20,000 ppb** | 10,186 |
| 1.5 | **Copper – 1,300 ppb** | 2.1 |
| BD | **Selenium – 50 ppb** | BD |
| 0.0 | **Cadmium – 5 ppb** | 0.0 |
| 0.0 | **Uranium – 30 ppb** | 0.0 |
| BD | **Aluminum – 0.05 – 0.2 ppm** | 0.1 |
| 9.7 | **Sulfate – 250 ppm** | 28.6 |
| 0.08 | **Strontium – 1.5 ppm** | 0.3 |
| 0.19 | **Barium – 2 ppm** | 0.06 |
| 6.0 ppm | **Chloride – No Limit** | 1.2 ppm |
| 9.5 ppm | **Calcium – No Limit** | 9.0 ppm |
| 3.4 ppm | **Magnesium – No Limit** | 5.1 ppm |

| **Home E Conc.** | **Contaminant – SDWA Standard** | **Local Spring Sample Conc.** |
|---|---|---|
| ABSENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.28 | **pH – 6.5 – 8.5** | 8.41 |
| 0.03 | **Nitrate - 10 ppm** | 0.13 |
| 34,776 | **Iron - 300 ppb** | 71.3 |
| 1,093 | **Manganese - 50 ppb** | 0.9 |
| 0.7 | **Lead - 15 ppb** | 0.1 |
| 1.1 | **Arsenic - 10 ppb** | 0.1 |
| 0.08 | **Fluoride – 4 ppm** | 0.06 |
| 244,316 | **Sodium – 20,000 ppb** | 10,186 |
| 20.7 | **Copper – 1,300 ppb** | 2.1 |
| 2.1 | **Selenium – 50 ppb** | BD |
| 0.0 | **Cadmium – 5 ppb** | 0.0 |
| 0.0 | **Uranium – 30 ppb** | 0.0 |
| 0.7 | **Aluminum – 0.05 – 0.2 ppm** | 0.1 |
| 0.1 | **Sulfate – 250 ppm** | 28.6 |
| 3.7 | **Strontium – 1.5 ppm** | 0.3 |
| 5.7 | **Barium – 2 ppm** | 0.06 |
| 0.59 ppm | **Chloride – No Limit** | 1.2 ppm |
| 90.7 ppm | **Calcium – No Limit** | 9.0 ppm |
| 22.9 ppm | **Magnesium – No Limit** | 5.1 ppm |

| Home F Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.33 | **pH – 6.5 – 8.5** | 8.41 |
| 0.03 | **Nitrate - 10 ppm** | 0.13 |
| 5,673 | **Iron - 300 ppb** | 71.3 |
| 260 | **Manganese - 50 ppb** | 0.9 |
| 0.1 | **Lead - 15 ppb** | 0.1 |
| 2.8 | **Arsenic - 10 ppb** | 0.1 |
| 0.11 | **Fluoride – 4 ppm** | 0.06 |
| 604,435 | **Sodium – 20,000 ppb** | 10,186 |
| 2.1 | **Copper – 1,300 ppb** | 2.1 |
| 3.9 | **Selenium – 50 ppb** | BD |
| 0.0 | **Cadmium – 5 ppb** | 0.0 |
| 0.0 | **Uranium – 30 ppb** | 0.0 |
| BD | **Aluminum – 0.05 – 0.2 ppm** | 0.1 |
| 0.8 | **Sulfate – 250 ppm** | 28.6 |
| 9.4 | **Strontium – 1.5 ppm** | 0.3 |
| 12.4 | **Barium – 2 ppm** | 0.06 |
| 1.2 ppm | **Chloride – No Limit** | 1.2 ppm |
| 131.4 ppm | **Calcium – No Limit** | 9.0 ppm |
| 28.2 ppm | **Magnesium – No Limit** | 5.1 ppm |

Martin County, KY (3-22-19)

| Home A Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| – | **Coliform bacteria – 0 MPN** | PRESENT |
| – | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.14 | **pH – 6.5 – 8.5** | 6.85 |
| 0.17 | **Nitrate - 10 ppm** | 0.09 |
| 40.2 | **Iron - 300 ppb** | 72.2 |
| 2.4 | **Manganese - 50 ppb** | 0.89 |
| 0.2 | **Lead - 15 ppb** | 0.08 |
| BD | **Arsenic - 10 ppb** | BD |
| 0.81 | **Fluoride – 4 ppm** | 0.06 |
| 6,231.8 | **Sodium – 20,000 ppb** | 4,467.1 |
| 3.4 | **Copper – 1,300 ppb** | 0.51 |
| 0.3 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.01 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 7.8 | **Sulfate – 250 ppm** | 33.6 |
| 0.03 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 2.2 ppm | **Chloride – No Limit** | BD |
| 3.39 ppm | **Calcium – No Limit** | 14.7 |
| 1.84 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home B Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| – | **Coliform bacteria – 0 MPN** | PRESENT |
| – | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.29 | **pH – 6.5 – 8.5** | 6.85 |
| 0.18 | **Nitrate - 10 ppm** | 0.09 |
| 18.8 | **Iron - 300 ppb** | 72.2 |
| 0.3 | **Manganese - 50 ppb** | 0.89 |
| 0.1 | **Lead - 15 ppb** | 0.08 |
| BD | **Arsenic - 10 ppb** | BD |
| 0.83 | **Fluoride – 4 ppm** | 0.06 |
| 6,070.0 | **Sodium – 20,000 ppb** | 4,467.1 |
| 3.7 | **Copper – 1,300 ppb** | 0.51 |
| 0.0 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.08 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 7.3 | **Sulfate – 250 ppm** | 33.6 |
| 0.02 | **Strontium – 1.5 ppm** | 0.17 |
| 0.01 | **Barium – 2 ppm** | 0.03 |
| 1.6 ppm | **Chloride – No Limit** | BD |
| 3.2 ppm | **Calcium – No Limit** | 14.7 |
| 1.8 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home C Conc. | **Contaminant – SDWA Standard** | **Local Spring Sample Conc.** |
|---|---|---|
| – | **Coliform bacteria – 0 MPN** | PRESENT |
| – | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.40 | **pH – 6.5 – 8.5** | 6.85 |
| 0.16 | **Nitrate - 10 ppm** | 0.09 |
| 52.8 | **Iron - 300 ppb** | 72.2 |
| 1.6 | **Manganese - 50 ppb** | 0.89 |
| 3.2 | **Lead - 15 ppb** | 0.08 |
| BD | **Arsenic - 10 ppb** | BD |
| 0.75 | **Fluoride – 4 ppm** | 0.06 |
| 6,163.3 | **Sodium – 20,000 ppb** | 4,467.1 |
| 20.4 | **Copper – 1,300 ppb** | 0.51 |
| BD | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 5.40 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 8.1 | **Sulfate – 250 ppm** | 33.6 |
| 0.04 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 2.2 ppm | **Chloride – No Limit** | BD |
| 4.78 ppm | **Calcium – No Limit** | 14.7 |
| 1.99 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home D Conc. | **Contaminant – SDWA Standard** | Local Spring Sample Conc. |
|---|---|---|
| ABSENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.43 | **pH – 6.5 – 8.5** | 6.85 |
| 0.17 | **Nitrate - 10 ppm** | 0.09 |
| 96.7 | **Iron - 300 ppb** | 72.2 |
| 0.6 | **Manganese - 50 ppb** | 0.89 |
| BD | **Lead - 15 ppb** | 0.08 |
| 0.2 | **Arsenic - 10 ppb** | BD |
| 0.80 | **Fluoride – 4 ppm** | 0.06 |
| 6,024.4 | **Sodium – 20,000 ppb** | 4,467.1 |
| 19.4 | **Copper – 1,300 ppb** | 0.51 |
| 0.0 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.05 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 7.5 | **Sulfate – 250 ppm** | 33.6 |
| 0.02 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 1.5 ppm | **Chloride – No Limit** | BD |
| 3.02 ppm | **Calcium – No Limit** | 14.7 |
| 1.84 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home E Conc. | **Contaminant – SDWA Standard** | Local Spring Sample Conc. |
|---|---|---|
| ABSENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.30 | **pH – 6.5 – 8.5** | 6.85 |
| 0.17 | **Nitrate - 10 ppm** | 0.09 |
| 4.7 | **Iron - 300 ppb** | 72.2 |
| 0.3 | **Manganese - 50 ppb** | 0.89 |
| BD | **Lead - 15 ppb** | 0.08 |
| 0.0 | **Arsenic - 10 ppb** | BD |
| 0.78 | **Fluoride – 4 ppm** | 0.06 |
| 5,904.7 | **Sodium – 20,000 ppb** | 4,467.1 |
| 3.4 | **Copper – 1,300 ppb** | 0.51 |
| 0.0 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.1 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 7.6 | **Sulfate – 250 ppm** | 33.6 |
| 0.02 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 1.1 ppm | **Chloride – No Limit** | BD |
| 2.97 ppm | **Calcium – No Limit** | 14.7 |
| 1.86 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home F Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| ABSENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.18 | **pH – 6.5 – 8.5** | 6.85 |
| 0.17 | **Nitrate - 10 ppm** | 0.09 |
| 13.9 | **Iron - 300 ppb** | 72.2 |
| 0.3 | **Manganese - 50 ppb** | 0.89 |
| BD | **Lead - 15 ppb** | 0.08 |
| 1.6 | **Arsenic - 10 ppb** | BD |
| 0.79 | **Fluoride – 4 ppm** | 0.06 |
| 6,201.7 | **Sodium – 20,000 ppb** | 4,467.1 |
| 177.4 | **Copper – 1,300 ppb** | 0.51 |
| 0.1 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.2 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 8.3 | **Sulfate – 250 ppm** | 33.6 |
| 0.02 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 1.1 ppm | **Chloride – No Limit** | BD |
| 3.05 ppm | **Calcium – No Limit** | 14.7 |
| 1.87 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home G Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| ABSENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.16 | **pH – 6.5 – 8.5** | 6.85 |
| 0.17 | **Nitrate - 10 ppm** | 0.09 |
| 29.2 | **Iron - 300 ppb** | 72.2 |
| 0.2 | **Manganese - 50 ppb** | 0.89 |
| BD | **Lead - 15 ppb** | 0.08 |
| 0.1 | **Arsenic - 10 ppb** | BD |
| 0.78 | **Fluoride – 4 ppm** | 0.06 |
| 6,097.4 | **Sodium – 20,000 ppb** | 4,467.1 |
| 4.8 | **Copper – 1,300 ppb** | 0.51 |
| 0.3 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.01 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 7.9 | **Sulfate – 250 ppm** | 33.6 |
| 0.02 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 0.6 ppm | **Chloride – No Limit** | BD |
| 2.95 ppm | **Calcium – No Limit** | 14.7 |
| 1.82 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home H Conc. | **Contaminant – SDWA Standard** | **Local Spring Sample Conc.** |
|---|---|---|
| ABSENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.19 | **pH – 6.5 – 8.5** | 6.85 |
| 0.17 | **Nitrate - 10 ppm** | 0.09 |
| 30.7 | **Iron - 300 ppb** | 72.2 |
| 1.1 | **Manganese - 50 ppb** | 0.89 |
| BD | **Lead - 15 ppb** | 0.08 |
| 0.1 | **Arsenic - 10 ppb** | BD |
| 0.82 | **Fluoride – 4 ppm** | 0.06 |
| 6,143.6 | **Sodium – 20,000 ppb** | 4,467.1 |
| 15.7 | **Copper – 1,300 ppb** | 0.51 |
| 0.2 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.2 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 8.3 | **Sulfate – 250 ppm** | 33.6 |
| 0.02 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 1.3 ppm | **Chloride – No Limit** | BD |
| 3.11 ppm | **Calcium – No Limit** | 14.7 |
| 1.93 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home I Conc. | **Contaminant – SDWA Standard** | **Local Spring Sample Conc.** |
|---|---|---|
| ABSENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli*** **bacteria – 0 MPN** | PRESENT |
| 7.17 | **pH – 6.5 – 8.5** | 6.85 |
| 0.17 | **Nitrate - 10 ppm** | 0.09 |
| 18.7 | **Iron - 300 ppb** | 72.2 |
| 0.4 | **Manganese - 50 ppb** | 0.89 |
| BD | **Lead - 15 ppb** | 0.08 |
| 0.0 | **Arsenic - 10 ppb** | BD |
| 0.81 | **Fluoride – 4 ppm** | 0.06 |
| 5,918.6 | **Sodium – 20,000 ppb** | 4,467.1 |
| 3.5 | **Copper – 1,300 ppb** | 0.51 |
| BD | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.08 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 7.5 | **Sulfate – 250 ppm** | 33.6 |
| 0.02 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 0.7 ppm | **Chloride – No Limit** | BD |
| 2.96 ppm | **Calcium – No Limit** | 14.7 |
| 1.83 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home K Conc. | **Contaminant – SDWA Standard** | **Local Spring Sample Conc.** |
|---|---|---|
| ABSENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.11 | **pH – 6.5 – 8.5** | 6.85 |
| 0.18 | **Nitrate - 10 ppm** | 0.09 |
| 57.4 | **Iron - 300 ppb** | 72.2 |
| 2.5 | **Manganese - 50 ppb** | 0.89 |
| 0.2 | **Lead - 15 ppb** | 0.08 |
| 0.5 | **Arsenic - 10 ppb** | BD |
| 0.78 | **Fluoride – 4 ppm** | 0.06 |
| 6,286.6 | **Sodium – 20,000 ppb** | 4,467.1 |
| 29.5 | **Copper – 1,300 ppb** | 0.51 |
| 1.5 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.03 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 10.7 | **Sulfate – 250 ppm** | 33.6 |
| 0.03 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 6.7 ppm | **Chloride – No Limit** | BD |
| 3.61 ppm | **Calcium – No Limit** | 14.7 |
| 2.12 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home P Conc. | **Contaminant – SDWA Standard** | **Local Spring Sample Conc.** |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli*** **bacteria – 0 MPN** | PRESENT |
| - | **pH – 6.5 – 8.5** | 6.85 |
| - | **Nitrate - 10 ppm** | 0.09 |
| 36.7 | **Iron - 300 ppb** | 72.2 |
| 0.5 | **Manganese - 50 ppb** | 0.89 |
| 0.2 | **Lead - 15 ppb** | 0.08 |
| 0.8 | **Arsenic - 10 ppb** | BD |
| - | **Fluoride – 4 ppm** | 0.06 |
| 5,986.8 | **Sodium – 20,000 ppb** | 4,467.1 |
| 12.1 | **Copper – 1,300 ppb** | 0.51 |
| 0.8 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.05 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 9.8 | **Sulfate – 250 ppm** | 33.6 |
| 0.02 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 5.7 ppm | **Chloride – No Limit** | BD |
| 2.92 ppm | **Calcium – No Limit** | 14.7 |
| 1.89 ppm | **Magnesium – No Limit** | 6,463.1 |

| Home Q Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 7.14 | **pH – 6.5 – 8.5** | 6.85 |
| 0.17 | **Nitrate - 10 ppm** | 0.09 |
| 36.7 | **Iron - 300 ppb** | 72.2 |
| 0.5 | **Manganese - 50 ppb** | 0.89 |
| 0.2 | **Lead - 15 ppb** | 0.08 |
| 0.8 | **Arsenic - 10 ppb** | BD |
| 0.8 | **Fluoride – 4 ppm** | 0.06 |
| 5,986.8 | **Sodium – 20,000 ppb** | 4,467.1 |
| 12.1 | **Copper – 1,300 ppb** | 0.51 |
| 0.8 | **Selenium – 50 ppb** | 0.21 |
| 0.0 | **Cadmium – 5 ppb** | 0.01 |
| 0.0 | **Uranium – 30 ppb** | 0.02 |
| 0.03 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 9.8 | **Sulfate – 250 ppm** | 33.6 |
| 0.02 | **Strontium – 1.5 ppm** | 0.17 |
| 0.02 | **Barium – 2 ppm** | 0.03 |
| 5.7 ppm | **Chloride – No Limit** | BD |
| 2.92 ppm | **Calcium – No Limit** | 14.7 |
| 1.89 ppm | **Magnesium – No Limit** | 6,463.1 |

Craig County, VA (1/24/2019)

| **Home A Conc.** | **Contaminant – SDWA Standard** | **Local Spring Sample Conc.** |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| 6.15 | **pH – 6.5 – 8.5** | 7.55 |
| 0.26 | **Nitrate - 10 ppm** | 0.31 |
| 48.8 | **Iron - 300 ppb** | 127.5 |
| 17.7 | **Manganese - 50 ppb** | 7.2 |
| 0.1 | **Lead - 15 ppb** | 0.2 |
| 0.5 | **Arsenic - 10 ppb** | 0.2 |
| 0.02 | **Fluoride – 4 ppm** | 0.03 |
| 313.2 | **Sodium – 20,000 ppb** | 725.0 |
| 0.5 | **Copper – 1,300 ppb** | 0.2 |
| BD | **Selenium – 50 ppb** | 0.2 |
| 0.0 | **Cadmium – 5 ppb** | 0.0 |
| 0.0 | **Uranium – 30 ppb** | 0.1 |
| 0.2 | **Aluminum – 0.05 – 0.2 ppm** | 0.2 |
| 3.5 | **Sulfate – 250 ppm** | 3.5 |
| 0.01 | **Strontium – 1.5 ppm** | 0.03 |
| 0.01 | **Barium – 2 ppm** | 0.04 |
| 0.5 ppm | **Chloride – No Limit** | 1.6 ppm |
| 0.8 ppm | **Calcium – No Limit** | 21.0 ppm |
| 0.7 ppm | **Magnesium – No Limit** | 5.24 ppm |

McDowell County, WV (12/4/2018)

| Home A Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| PRESENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| – | **pH – 6.5 – 8.5** | 7.73 |
| 0.19 | **Nitrate - 10 ppm** | 0.16 |
| 1,961.8 | **Iron - 300 ppb** | 221.5 |
| 98.5 | **Manganese - 50 ppb** | 3.40 |
| 0.41 | **Lead - 15 ppb** | 0.06 |
| 0.51 | **Arsenic - 10 ppb** | 0.23 |
| 0.12 | **Fluoride – 4 ppm** | 0.10 |
| 7,582.2 | **Sodium – 20,000 ppb** | 3,814.5 |
| 5.55 | **Copper – 1,300 ppb** | 1.37 |
| 0.43 | **Selenium – 50 ppb** | BD |
| 0.00 | **Cadmium – 5 ppb** | 0.00 |
| 0.05 | **Uranium – 30 ppb** | 0.03 |
| 0.01 | **Aluminum – 0.05 – 0.2 ppm** | 0.5 |
| 13.4 | **Sulfate – 250 ppm** | 13.6 |
| 1.1 | **Strontium – 1.5 ppm** | 0.1 |
| 0.3 | **Barium – 2 ppm** | 0.03 |
| 1.04 ppm | **Chloride – No Limit** | BD |
| 33.1 ppm | **Calcium – No Limit** | 3.83 ppm |
| 9.61 ppm | **Magnesium – No Limit** | 2.24 ppm |

| Home B Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| – | **pH – 6.5 – 8.5** | 7.73 |
| 0.13 | **Nitrate - 10 ppm** | 0.16 |
| 990.7 | **Iron - 300 ppb** | 221.5 |
| 107.8 | **Manganese - 50 ppb** | 3.40 |
| 0.19 | **Lead - 15 ppb** | 0.06 |
| 1.03 | **Arsenic - 10 ppb** | 0.23 |
| 0.12 | **Fluoride – 4 ppm** | 0.10 |
| 4,592.5 | **Sodium – 20,000 ppb** | 3,814.5 |
| 8.31 | **Copper – 1,300 ppb** | 1.37 |
| BD | **Selenium – 50 ppb** | BD |
| 0.42 | **Cadmium – 5 ppb** | 0.00 |
| 0.02 | **Uranium – 30 ppb** | 0.03 |
| 0.5 | **Aluminum – 0.05 – 0.2 ppm** | 0.5 |
| 6.00 | **Sulfate – 250 ppm** | 13.6 |
| 0.1 | **Strontium – 1.5 ppm** | 0.1 |
| 0.1 | **Barium – 2 ppm** | 0.03 |
| 1.16 ppm | **Chloride – No Limit** | BD |
| 8.70 ppm | **Calcium – No Limit** | 3.83 ppm |
| 2.49 ppm | **Magnesium – No Limit** | 2.24 ppm |

| Home C Conc. | **Contaminant – SDWA Standard** | Local Spring Sample Conc. |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | PRESENT |
| – | **pH – 6.5 – 8.5** | 7.73 |
| 0.36 | **Nitrate - 10 ppm** | 0.16 |
| 31.0 | **Iron - 300 ppb** | 221.5 |
| 6.87 | **Manganese - 50 ppb** | 3.40 |
| 0.05 | **Lead - 15 ppb** | 0.06 |
| 0.24 | **Arsenic - 10 ppb** | 0.23 |
| 0.11 | **Fluoride – 4 ppm** | 0.10 |
| 4,749.8 | **Sodium – 20,000 ppb** | 3,814.5 |
| 1.82 | **Copper – 1,300 ppb** | 1.37 |
| 0.39 | **Selenium – 50 ppb** | BD |
| 0.00 | **Cadmium – 5 ppb** | 0.00 |
| 0.01 | **Uranium – 30 ppb** | 0.03 |
| 0.004 | **Aluminum – 0.05 – 0.2 ppm** | 0.5 |
| 4.03 | **Sulfate – 250 ppm** | 13.6 |
| 0.2 | **Strontium – 1.5 ppm** | 0.1 |
| 0.3 | **Barium – 2 ppm** | 0.03 |
| 2.97 ppm | **Chloride – No Limit** | BD |
| 18.8 ppm | **Calcium – No Limit** | 3.83 ppm |
| 4.57 ppm | **Magnesium – No Limit** | 2.24 ppm |

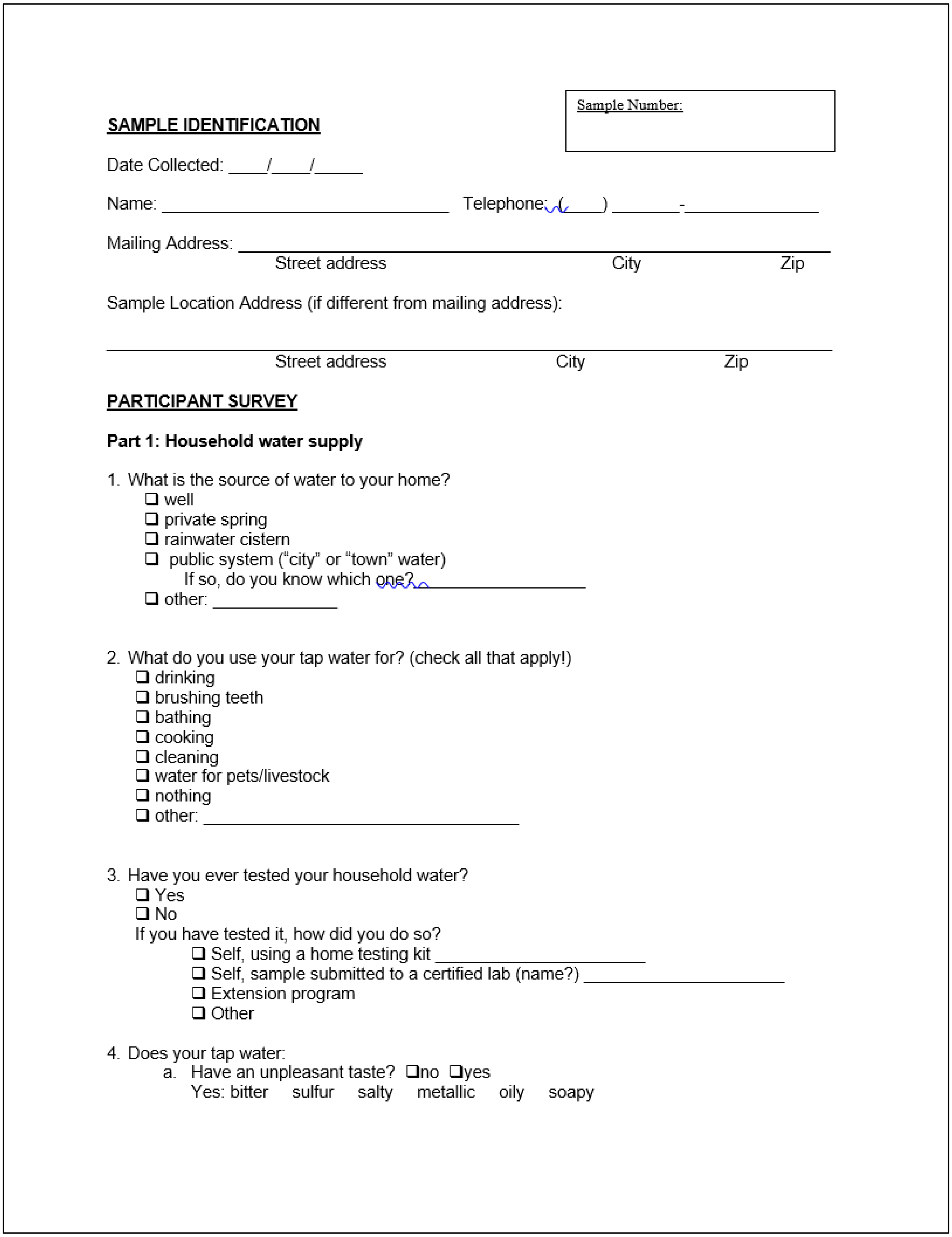
Floyd County, VA (11/8/18)

| **Home A Conc.** | **Contaminant – SDWA Standard** | **Local Spring Sample Conc.** |
|---|---|---|
| PRESENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | ABSENT |
| 6.90 | **pH – 6.5 – 8.5** | 6.59 |
| 0.44 | **Nitrate - 10 ppm** | 0.28 |
| 111 | **Iron - 300 ppb** | 27.0 |
| 55.6 | **Manganese - 50 ppb** | 1.06 |
| 0.01 | **Lead - 15 ppb** | BD |
| 1.58 | **Arsenic - 10 ppb** | 0.02 |
| 0.08 | **Fluoride – 4 ppm** | 0.08 |
| 7,179.8 | **Sodium – 20,000 ppb** | 5,629.7 |
| 227.6 | **Copper – 1,300 ppb** | 0.88 |
| 0.47 | **Selenium – 50 ppb** | 0.12 |
| 0.02 | **Cadmium – 5 ppb** | 0.03 |
| 0.06 | **Uranium – 30 ppb** | 0.00 |
| 0.04 | **Aluminum – 0.05 – 0.2 ppm** | 0.02 |
| 7.98 | **Sulfate – 250 ppm** | 0.92 |
| 0.04 | **Strontium – 1.5 ppm** | 0.04 |
| 0.04 | **Barium – 2 ppm** | 0.03 |
| 12.7 ppm | **Chloride – No Limit** | 13.1 ppm |
| 19.8 ppm | **Calcium – No Limit** | 6.27 ppm |
| 6.36 ppm | **Magnesium – No Limit** | 1.84 ppm |

McDowell County, WV (9/21/18)

| Home A Conc. | Contaminant – SDWA Standard | Local Spring Sample Conc. |
|---|---|---|
| ABSENT | **Coliform bacteria – 0 MPN** | PRESENT |
| ABSENT | ***E. coli* bacteria – 0 MPN** | ABSENT |
| 6.67 | **pH – 6.5 – 8.5** | 6.17 |
| 0.23 | **Nitrate - 10 ppm** | 0.10 |
| 71.3 | **Iron - 300 ppb** | 1.70 |
| 12.0 | **Manganese - 50 ppb** | 0.00 |
| 2.20 | **Lead - 15 ppb** | 0.00 |
| 0.70 | **Arsenic - 10 ppb** | 0.00 |
| 0.64 | **Fluoride – 4 ppm** | 0.06 |
| 14,369 | **Sodium – 20,000 ppb** | 8,224 |
| 332 | **Copper – 1,300 ppb** | 0.30 |
| 0.10 | **Selenium – 50 ppb** | 2.60 |
| 0.00 | **Cadmium – 5 ppb** | 0.00 |
| 0.00 | **Uranium – 30 ppb** | 0.10 |
| 0.04 | **Aluminum – 0.05 – 0.2 ppm** | BD |
| 6.50 | **Sulfate – 250 ppm** | 62.5 |
| 0.09 | **Strontium – 1.5 ppm** | 0.9 |
| 0.03 | **Barium – 2 ppm** | 0.05 |
| 16.8 ppm | **Chloride – No Limit** | BD |
| 14.6 ppm | **Calcium – No Limit** | 25.8 ppm |
| 3.10 ppm | **Magnesium – No Limit** | 20.6 ppm |

## Appendix D. Study Participant Survey Questions



Sample Number:

**SAMPLE IDENTIFICATION**

Date Collected: ____/____/_____

Name: ______________________________ Telephone: (____) _______-______________

Mailing Address: ______________________________________________________________
Street address City Zip

Sample Location Address (if different from mailing address):

______________________________________________________________
Street address City Zip

**PARTICIPANT SURVEY**

**Part 1: Household water supply**

1. What is the source of water to your home?
   - ☐ well
   - ☐ private spring
   - ☐ rainwater cistern
   - ☐ public system ("city" or "town" water)
     If so, do you know which one? _________________
   - ☐ other: _____________

2. What do you use your tap water for? (check all that apply!)
   - ☐ drinking
   - ☐ brushing teeth
   - ☐ bathing
   - ☐ cooking
   - ☐ cleaning
   - ☐ water for pets/livestock
   - ☐ nothing
   - ☐ other: _________________________________

3. Have you ever tested your household water?
   - ☐ Yes
   - ☐ No

   If you have tested it, how did you do so?
   - ☐ Self, using a home testing kit ______________________
   - ☐ Self, sample submitted to a certified lab (name?) _____________________
   - ☐ Extension program
   - ☐ Other

4. Does your tap water:
   a. Have an unpleasant taste? ☐no ☐yes
      Yes: bitter sulfur salty metallic oily soapy

b. Have an unpleasant odor? ☐no ☐yes
Yes: sulfur kerosene/gas musty chemical

c. Have an unnatural color? ☐no ☐yes
Yes: muddy milky black/gray tint yellow tint oily film

d. Stain plumbing, cooking appliances, utensils or laundry? ☐no ☐yes
Yes: blue-green, rusty/brown, black/gray, white/chalk

e. Have floating or settled particles? ☐no ☐yes
Yes: white flakes black specks red-orange slime brown sediment

5. Do you trust the water from your taps? ☐yes ☐no
If no, why not?

6. Would you like to receive your water quality results via email (please provide), mail, or both?

**Part 2: Your Local Spring**

7. Where (approximately) is the spring you visit? ____________________________

8. How often do you collect water at this spring?
   - ☐ Once a day
   - ☐ Once a week
   - ☐ Once a month
   - ☐ Other: ____________________________

9. How far is the spring from your home (approximately)? ____________________________

10. What do you use the spring water for? (Check all that apply)
   - ☐ drinking
   - ☐ brushing teeth
   - ☐ bathing
   - ☐ cooking
   - ☐ cleaning
   - ☐ water for pets/livestock
   - ☐ other: ____________________________

11. Why do you collect spring water?

12. How did you learn about this spring?

13. How many others in your community visit this spring (approximately)?

14. Do you have any concerns regarding the quality of the spring water or things it would be useful for us to know?

**Part 3: General Household Information**

15. Do you own your home?

☐ Yes
☐ No, owned by family member
☐ No, I rent
☐ Other

16. What age is the house (approximately)?

17. What type of wastewater system do you have?

☐ Sewer
☐ Septic field
☐ Community line/straight pipe
☐ Other

18. What ages are the members of your household?

## Appendix E. Study Participant Survey Short Answer Written Responses

Question #5: Do you trust water from your taps? If no, why not?

| |
|---|
| “I am afraid it cause my dad’s death due to kidney failure” |
| “Cause of smell, taste, color, and 1 person with kidney failure, and 1 senior” |
| “1. Public water main is 200’ from the house and the connection is unknown as to location, materials of construction etc.<br>2. Older home. Plumbing inside is copper from days of “leaded” solder (1950s)” |
| “It changes color sometimes it clear sometimes its milky looking sometimes its gray” |
| “Don’t know” |
| “It nasty water” |
| “I don’t cook with it or drink it because of the color and the stuff in it” |
| “Bad smell – like frog pond water with a commensurate taste” |
| “No good” |
| “Sometimes it smells strong of chlorine – bleach smell the water is milky looking – then somes it a brownish color” |
| “It’s unsafe” |
| “Bad smell, reports of carcinogens” |
| “The smell + taste for one. Its impossible to drink. The problems our county has had at the water plant and reservoir over the years since the coal slurry spill also is a main reason my family doesn’t drink it.” |
| “The system is outdated” |
| “Doesn’t taste right, has an odor, and is often discolored” |
| “Due to 75% water loss + ground water infiltration and coal slurry spill with arsenic + heavy metals into water supply” |
| “Smell, color” |

Question #11: Why do you collect spring water?

| |
|---|
| "Animals" |
| "Better than tap water" |
| "Concerns noted under (question) '5' with public water supply re:our connection to the main and interior plumbing" |
| "My well water tastes really bad" |
| "Personal use" |
| "Because I have bad water" |
| "Because I'm worried about drinking and cooking using my well water" |
| Drinking |
| "It doesn't have chemicals put in public water, natural source, better quality than comes from faucet" |
| - |
| "We get diarrhea everytime we drink the city water" |
| "My well water tastes really bad" |
| "Personal use" |
| "Because I have bad water" |
| "Because I'm worried about drinking and cooking using my well water" |
| Drinking |

Question #12: How did you learn about this spring?

| |
|---|
| "Saw it" |
| "Drove past and saw it" |
| "A friend." |
| "Its been there for over 25 years that I know" |
| "Know about it for years" |
| "Several people" |
| "I knowed about it all my life" |
| "We have been visiting my whole life I am 41" |
| "Neighbors" |
| "Its been there for over 25 years that I know" |
| "Know about it for years" |
| "Several people" |
| "I knowed about it all my life" |

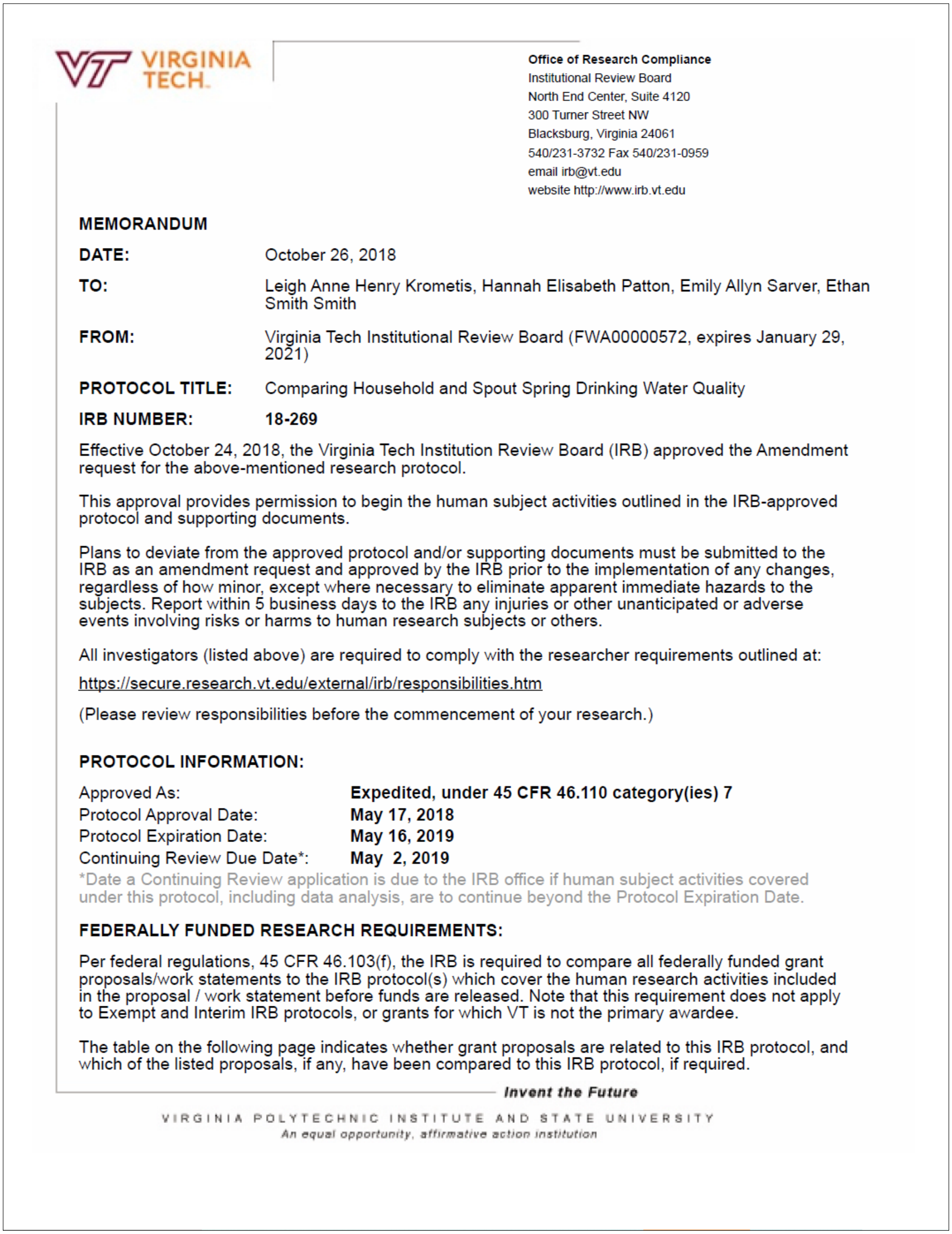
Question #13: How many others in your community visit this spring (approximately)?

| |
|---|
| "A couple" |
| "Don't know" |
| "Hard to say/ It is not unusual to encounter someone else on my weekly visit but I would say it happens less than half the time" |
| "A lot of people" |
| "Almost everyone" |
| "Not sure but a quite of few of them" |
| "A hundred or more" |
| "Unknown" |
| "Over half the people we know" |
| "A lot of people" |
| "Almost everyone" |
| "Not sure but a quite of few of them" |
| "A hundred or more" |

Question #14: Do you have any concerns regarding the quality of the spring water or things it would be useful for us to know?

| |
|---|
| "No" |
| “No” |
| "My concerns are probably not your concerns, but I'll tell you anyway. They are how I should handle and store the water I collect, which of course has no chlorine residual. "I use glass containers, disinfected with household bleach about once every month.. |
| "Yes" |
| "No" |
| "No" |
| "I know it comes out of an old mines" |
| "No it taste wonderful + is pure, clean, + odorless" |
| "??" |
| "Yes" |
| "No" |
| "No" |
| "I know it comes out of an old mines" |

## Appendix F. Copy of Internal Review Board (IRB) Approval Letter



VIRGINIA TECH.

**Office of Research Compliance**
Institutional Review Board
North End Center, Suite 4120
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

**MEMORANDUM**

| | |
|---|---|
| **DATE:** | October 26, 2018 |
| **TO:** | Leigh Anne Henry Krometis, Hannah Elisabeth Patton, Emily Allyn Sarver, Ethan Smith Smith |
| **FROM:** | Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021) |
| **PROTOCOL TITLE:** | Comparing Household and Spout Spring Drinking Water Quality |
| **IRB NUMBER:** | **18-269** |

Effective October 24, 2018, the Virginia Tech Institution Review Board (IRB) approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

**PROTOCOL INFORMATION:**

| | |
|---|---|
| Approved As: | **Expedited, under 45 CFR 46.110 category(ies) 7** |
| Protocol Approval Date: | **May 17, 2018** |
| Protocol Expiration Date: | **May 16, 2019** |
| Continuing Review Due Date*: | **May 2, 2019** |

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

**FEDERALLY FUNDED RESEARCH REQUIREMENTS:**

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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