Beaver Run Reservoir

Water Quality Data Analysis Technical Report

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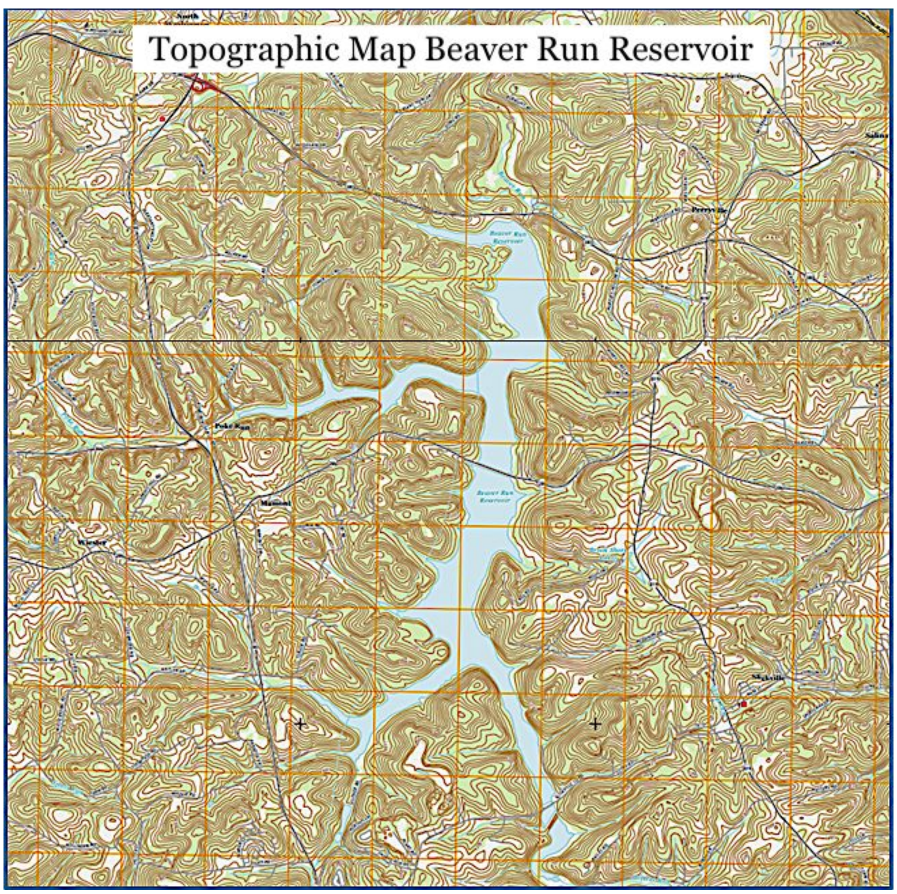

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Executive Summary

Objective

Westmoreland Marcellus Citizens Group and Protect PT associates collaborated for several months in 2019 to address the following regarding water quality at Beaver Run Reservoir (BRR): a) compile existing water quality data for BRR and adjacent private water wells; b) look for trends related to unconventional natural gas development (UNGD); c) compare the scope of regular testing protocol to the protocol recommended by TetraTech; and d) formulate recommendations for future actions at BRR by BRR management.

Approach

Water quality data was obtained from the Municipal Authority of Westmoreland County (MAWC) and the Pennsylvania Department of Environmental Protection (DEP) through Right-to-Know requests and formal and informal file reviews. Data collection occurred over numerous office visits and via email and telephone conversations with MAWC and DEP officials. The authors completed desktop reviews of water quality data collected by MAWC personnel and an Indiana University of Pennsylvania (IUP) research group; additional information was obtained from the Environmental Protection Agency's drinking water database and DEP's well inventory and well operator compliance reports. To gain additional insight into the testing recommendations, the author of the TetraTech report was interviewed.

Outcomes

The research group achieved the following results from this study: a) existing water quality data for BRR and adjacent private water wells was compiled; b) although few trends were able to be identified due to substantial gaps in the available data, one major trend was identified: disinfection byproducts have been steadily increasing since 2010; c) significant discrepancies between actual and recommended testing protocols were identified; and d) six requirements and recommendations for future action by MAWC were formulated.

Requirements and Recommendations for MAWC

1. Ensure compliance with updated Emergency Planning and Community Right-to-Know Act (EPCRA).
2. Take action to reduce disinfection byproducts in drinking water.
3. Bring standard water quality testing protocol in line with recommendations from TetraTech.
4. Engage a specialist on sediment hydrology to plan collection and regular testing of sediment in BRR and its tributaries.
5. Do not permit CNX or any future operators to store large quantities of diesel or fluid waste such as Produced Fluid on well pads in the vicinity of BRR or its tributaries.
6. MAWC Board should request no further UNGD on BRR property by contacting CNX and the PA DEP.

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Introduction

The oil and gas industry is rapidly expanding in southwestern Pennsylvania. The shale formations that make up much of the Allegheny Plateau are rich in natural gas, though this gas was previously inaccessible because it was so tightly packed in the rock formation. Advanced drilling methods such as hydraulic fracturing (“fracking”) allow for access to these gas reserves. Thanks to these new technologies, fracking wells are often located in places that previously had little or no oil or gas production and therefore are very close to residential areas. Between 2000 and 2015, the number of fracking wells in the United States increased more than tenfold, from 26,000 wells in 2000 to approximately 300,000 wells in 2015 [1]. The first fracked well in Pennsylvania was drilled in 2003, and by 2013 over 7,400 wells had been drilled; over that same period, the state Department of Environmental Protection (DEP) issued permits for over 15,000 wells [2]. This dramatic increase in the number of wells and the change in proximity to the general public has raised concern regarding the environmental impact of fracking activity.

Hydraulic fracturing is a drilling method in which a slurry of water, sand, and additive chemicals are injected at high pressure into a rock formation in order to create fractures in the rock, allowing for the extraction of natural gas from previously inaccessible reserves. When a well is designed to be used with hydraulic fracturing methods, the operator first drills a vertical bore down to the bottom of the aquifer. Then the drill is removed and the loose rock and sediment is brought to the surface and discarded. The operator then inserts a steel pipe (referred to as an isolation casing) into the well in an effort to protect the water supply; once the pipe is inserted, cement is injected into the annular space of the well and forced up between the steel casing and the rock walls of the well in order to seal the casing in place. With the casing in place, drilling continues vertically until the target depth is reached - in the Marcellus and Utica shales surrounding the Beaver Run Reservoir, this is typically over one mile deep. At this point, the well turns horizontal and drilling continues for up to 10,000 feet or more. Once the well has been drilled, hydraulic fracturing begins in order to create cracks in the surrounding rock so that the trapped natural gas can be released. Once released, the natural gas flows back to the surface of the well, along with “flowback fluid” - the remnants of the injected fracking fluid mixed with other liquids released from the shale formation during the fracking process [3].

Fracking operations intentionally impact local water supplies in two ways: first, large amounts of water are used in the drilling process, and second, substantial quantities of wastewater are produced as a result of the drilling process. In addition, fracking activities may inadvertently impact local water quality in the event of a spill of either the fracking chemicals or wastewater or if the well itself experiences a failure. The not-uncommon occurrence of spills and well failures instigate this report and necessitate regular analysis of water quality surrounding fracking operations.

According to the USGS, water quality concerns surrounding fracking include the possibility of chemical spills at the well surface, groundwater quality degradation, and surface water degradation due to improper wastewater disposal [4]. The industry asserts that the risk of groundwater contamination directly due to fracking operations is slim when wells are constructed properly and regulations are followed [5,6], however, these conditions are often not met. Even if best practices related to UNGD activities could prevent groundwater contamination from occurring, these are not always followed and accidents can and do occur [5,6,7].

Leaks of gas and toxic fluids, called well-head failures, are noted during inspections by agencies such as the DEP and also industry operators. Thousands of PA DEP records for inspections of UNGD wells ranging from 1-10 years old show substantial initial rates of leaks and increasing rates of well-head failures [8]. Specifically, DEP records and industry reports confirm the likelihood of well-head failure is 7% within the first year after drilling. Inspections show well-head failure risk rises steadily to 40% as wells age up to 10 years. The 55 UNGD wells at BRR range from 1-9 years of age. Well-head failures can occur as readily observable surface leaks of gases and fluids, some of which can be controlled, but other leaks can persist undetected underground.

The purpose of this report is to discuss the impact of fracking activity in the vicinity of the Beaver Run Reservoir and assess whether current analytical testing is sufficient to detect changes in water quality due to UNGD activities and if management policies regarding UNGD operations should be updated.

Beaver Run Reservoir as a Water Source

The Beaver Run Reservoir is a public water supply located in Westmoreland County, Pennsylvania and operated by the Municipal Authority of Westmoreland County (MAWC). The reservoir is one of two primary water sources for MAWC; the other is the Youghiogheny River. Beaver Run Reservoir was originally constructed in 1952 before being expanded ten years later in 1962 [9]. Currently, it holds roughly eleven billion gallons of water and serves approximately 130,000 people [9]. Under Pennsylvania Code Chapter 93, the Beaver Run Reservoir is a protected water use classified as a High-Quality Cold Water Fishes (HQ-CWF) [10]. Since construction of the reservoir, hiking, fishing, and hunting have been prohibited at BRR for the protection of public health. The George R. Sweeney Water Treatment Plant, which is operated by MAWC, began providing drinking water treatment services using water from the reservoir in July 1997 [9]. While it is designed to filter up to 24 million gallons of water daily, the current average is 22 million gallons of water daily [11]. MAWC has an allocation permit capacity for the Sweeney facility of 35 million gallons per day of water (MGD) [11].

Incidents Regarding Well Sites Surrounding the Reservoir

All seven of the well pads surrounding the Beaver Run Reservoir are operated by CNX Resources, the natural gas company born out of coal giant CONSOL Energy. CNX has been using unconventional drilling methods at the Reservoir since 2010. Since breaking ground (also known as “spudding”) on the first fracked well in July 2010, CNX has had 20 incidents which were reported to DEP; 17 of these were spills of fluids used in or produced by fracking operations or of mechanical fluids from drilling equipment, and one incident was a fire. In 7 of these instances, DEP issued violations to CNX for “Failure to properly control or dispose of industrial or residual waste to prevent pollution of the waters of the Commonwealth,” or for “Discharge of pollutional material to waters of the Commonwealth.” In another instance, drilling of the Kuhns 3B well was halted due to communication with a nearby spring; in this case, CNX reported the event in compliance with DEP policy, and the subsequent DEP inspection concluded that no regulatory violations had occurred [12]. Some incidents may not be reported. For example, on three occasions in 2018 (i.e., March, May, and June), in the waste report, CNX logged over 1000 gallons of “Soil contaminated from oil and gas spills”, but no spills on BRR well pads were reported during those months. (See Table 1 in section Toxicity of Industry Fluids)

Most recently and most dramatically, CNX’s Shaw-1GHSU (Shaw well), a new well tapping the Utica shale which lies beneath the Marcellus around the Beaver Run Reservoir, experienced a sudden loss of pressure during fracking operations on January 25, 2019. This loss of pressure was due to a “catastrophic loss of containment”, as described by the DEP. (9) This failure of well casing occurred about one mile below the surface. Because of this casing failure, gas escaped the Shaw well at a depth of approximately 5,260 feet and traveled to nearby conventional wells (which are vertical and run only 3,700-3,900 feet deep). As a result, CNX had to flare these shallow wells (that is, burn off excess natural gas) to reduce pressure and prevent uncontrolled fires or explosions in the wells. The migration of natural gas to surrounding wells demonstrates that the breach allowed flowback water to communicate with the surrounding hydrogeology and allowed for the potential hydraulic communication with the Reservoir and nearby water supply wells. According to the permit documents submitted to DEP, there are four private drinking water wells within 3,000 feet of the Shaw well pad. To address the possibility of contamination of these water sources, CNX screened 77 water supplies in the vicinity for elevated methane levels. Samples from 5 of these wells were sent to a third-party laboratory for isotopic analysis - that is, testing to determine the source of the methane contamination. The results of the analyses indicate that the methane collected from the well samples matched that of the Upper Devonian (UD) shale formation rather than the Marcellus or Utica shales being drilled on the Shaw well pad. CNX’s Closure Report claims that this demonstrates that the methane found in the well was not caused by the Shaw incident [13]; however, the UD formation lies above the Marcellus which lies above the Utica, so CNX would have had to drill through the UD shale to reach the intended rock layer [14]. As a result, the differing methane signature is not conclusive evidence that activity at the Shaw well did not lead to methane migration in the region.

Public Health Consequences of Water Contamination Due to UNGD Activity

Although there have been no long-term studies assessing the comprehensive effect of hydraulic fracturing on public health at this time, there have been many studies examining health outcomes related to UNGD. In June 2019, Concerned Health Professionals of New York and Physicians for Social Responsibility published the sixth edition of their *Compendium of*

Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction). The compendium integrated nearly 1,800 peer-reviewed studies and concluded that there is “no evidence that fracking can be practiced in a manner that does not threaten human health” [15]. The 361-page report included summaries of literature concerning air pollution, water pollution, noise pollution, light pollution, releases of radioactivity, flood risks, and earthquakes or seismic activity stemming from UNGD activities.

UNGD activities could potentially contaminate local water supplies in four primary ways: migration of fracking fluid, migration of natural gas, disturbance of previous settled natural contaminants in aquifers, and spills of flowback fluid [16,17]. A 2017 study looking to understand the impact of UNGD on groundwater quality estimated that each unconventional well drilled within one kilometer (0.62 miles) of a public water system’s groundwater source intake point increased the UNGD-related contamination in the water supply by 1.5-2.7 percent [18]. An earlier report suggested that upwards of 5% of all UNGD-related wastewater may be accidentally or illegally released into the environment, where it can easily contaminate ground- or surface waters [19]. Contamination of drinking water sources with UNGD-related substances would have numerous public health consequences, including endocrine disruption, low birth weights, congenital heart defects, neural tube defects, or even cancers [17, 20, 21].

Toxicity of Industry Fluids at BRR Wells: Diesel Fuel, Fracking Fluid, and Produced Water

Several fluids are stored and used in large volumes at well pads at BRR. These fluids have been spilled on several occasions, and some can leak underground in wellhead failures. In addition, brine is collected from many of the conventional gas wells at the reservoir. Hundreds of peer-reviewed studies show most of the components in these fluids are well-established as toxic to wildlife and humans. Some substances impact organisms at very low doses. For example, endocrine disruptors at doses less than 1 mg/liter (1 ppm) alter hormones and development. Studies of fish show these chemicals cause male fish to develop female characteristics. Other substances impact DNA, triggering mutations and cancer. Other compounds impair cells and tissues, for example, damaging gills of fish or other organs in mammals. This report will focus on three classes of fluids that occur in large volumes at BRR: diesel fuel, fracking fluids and produced fluids. Scenarios of the impacts of spills on reservoir water and wildlife mortality and carcass decomposition can be modeled. This should become part of modified policies and emergency planning at BRR.

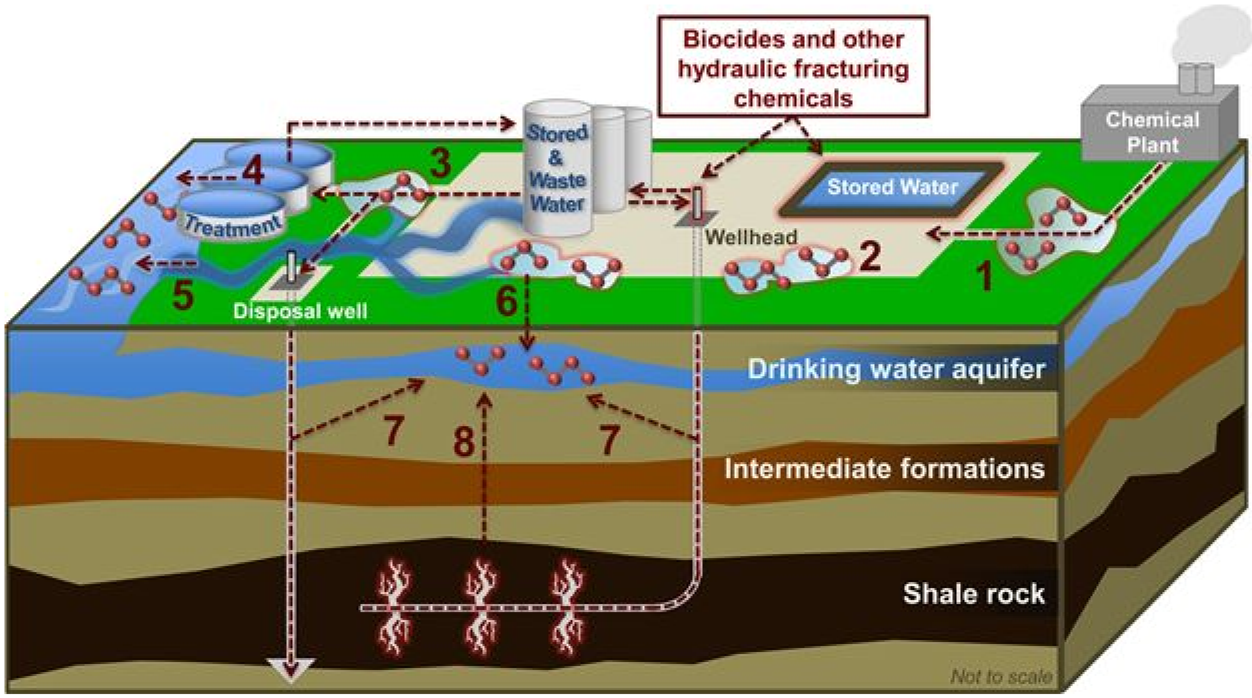


Fig. 1. Multiple routes of contamination occur for biocides, surfactants and other chemicals added to Fracking Fluids, substances in Produced Fluids after fracking and stored recycled Produced Fluids as well as diesel not shown in diagram. From *Environ. Sci. Technol.*201549116-32 [22].

Diesel Fuel Hazards

Diesel Fuel is stored in volumes up to 3,000 gallons on a pad to support engines used in drilling and fracking. Trucks carry 5,000 – 11,000 gallons. Diesel fuel certainly presents a hazard due to its flammability, as proven by a fire at a BRR well pad. Diesel spills into water present even more complex problems. Limits for hydrocarbons in drinking water are around 0.1 ppm. Concentrations above that limit will occur under a range of scenarios. The large volume of the reservoir is insufficient to dilute a large spill. One example is based on a tanker truck spill in 2017 that released 3,500 gallons of fuel near the reservoir, fortunately on a readily accessible road, Rt. 66 [23]. If the accident occurred on the Rt. 226 bridge over the reservoir, fuel concentrations in surface layers would be far above 0.1 ppm. If attempts were made to disperse the fuel throughout the entire 11 billion gallon reservoir, concentrations would be at 0.3 ppm at best. Another scenario is likely when a truck or well pad storage tank on the edge of the reservoir releases 1,000 gallons into a shallow section of the reservoir, also producing diesel concentrations in that section above the 0.1 ppm limit. Several spills of fluids including diesel have occurred on well pads at BRR. The volumes were reported by the operators and soils or other evidence was removed before inspectors such as the DEP could arrive. Thus far, spills occurred during normal weather conditions. Scenarios during extreme weather events should be considered for emergency planning.

Given the likelihood of diesel spills into reservoir water, the following sequence of events would then follow from a moderate diesel spill. First, water, birds and fish at the reservoir will die because diesel mats feathers and the fuel damages gills. For example, NOAA predicts that “small spills could result in serious impacts to birds under the “wrong” conditions, such as transport of sheens into a high bird concentration area” [24]. Scientists report that “diesel is considered to be one of the most acutely toxic oil types. Fish, invertebrates and seaweed that come in direct contact with a diesel spill may be killed. Fish kills have been reported for small spills in confined, shallow water.” Next, decomposition of dead birds and fish will further degrade water quality, a well-known process. Finally, diesel degradation is slow, taking approximately 1-2 months [25].

In summary, if a moderate or large diesel spill occurred at the reservoir, diesel concentrations and overall water quality would be at unacceptable values for an extended period of time. MAWC has the capacity to temporarily substitute the daily delivery of 24 million gallons of BRR water to consumers with extra amounts from the Indian Creek Treatment Plant, but this option has limitations. The Indian Creek plant currently withdraws 40 million gallons of river water per day from two rivers in the Laurel Mountains. This river system is regulated by considerations of adequate rainfall and the plant processing capacity.

Fracking Fluid Hazards

Two types of fluid mixes are present in well pads at BRR and most fracking wells. First, fracking fluids (FF) are a mix of freshwater, acids, biocides, and surfactants designed to flow with sand down into wells. The components and mix ratios are trade secrets and not subject to Clean Water Act Laws due to the Halliburton Loop Hole arranged by Richard Cheney in 2005. About 5 million gallons of FF are sent down the well for one fracking event, but only about 1 million comes back up. That fluid is Produced Fluids (PF) or labeled by some operators as “produced water” and is discussed below. The environmental fate of fracking fluid that does not return to the well is unknown.

A biologically important component in FF is the biocide, and biocide compositions are usually held as trade secrets. Biocides in fracking are used to limit microbial growth that would clog gas flow return. These substances are described by the industry as being not highly toxic because some biocides show limited effects on a test animal in a short-term, acute toxicity test. UNGD biocides are largely unstudied, however, in real-world situations. University scientists in a 2015 review write, “Despite not being highly acutely toxic, certain biocides are suspected to possess developmental toxicity, carcinogenicity, mutagenicity, genotoxicity, and/or chronic toxicity. Only a few of the hydraulic fracturing biocides have thus far been evaluated by the International Agency for Research on Cancer (IARC) or the U.S. EPA. For the remaining biocides, the evidence that does exist is insufficient to draw any firm conclusions” [22].

Surfactants in FF can also be important to the environmental health of the reservoir and water quality. These are briefly discussed in the section on Recycling Produced Fluids.

Produced Fluid Hazards

Produced Fluids (PF) are a mix of FF and substances already present in the shale layer. PF from UNGD include many of the toxic components in brines from shallower, conventional gas wells and additional elements associated with UNGD. The substances in PF from deep shale layers can be divided into five groups: (1) radioactive elements such as Radium (Ra-226 and Ra228), Radon (R) and Uranium (U), (2) heavy metals such as Arsenic, Mercury and Manganese, (3) other elements such as Bromine, (4) inorganic compounds such as Sodium Chloride and (5) organic compounds such as benzene. Toxicity for each group is discussed below.

Radioactive elements are well established as carcinogenic, and exposure is also associated with more subtle health problems such as infertility and developmental disorders [26]. Exposures to different radioactive elements in drinking water are difficult to track because the simple Gamma radiation meters do not detect the Alpha and Beta emitting elements. For example, proper testing for Radium-226 and Radium- 228 requires sample incubation and specialty equipment [27].

Heavy metals have a wide range of health impacts, and they can accumulate in tissues over time. Exposure to heavy metals in water range from learning disabilities for children of mothers who consumed low concentrations of heavy metals during pregnancy to more obvious impairments such as cancer [28].

Elements such as bromine are not as directly toxic as heavy metals, but elevated bromide increases the formation of toxic disinfection byproducts in drinking water treated with chlorine. This is of special concern when the source water also has elevated organic compounds that react with the bromide [29].

Salts associated with ancient marine deposits are not classified as toxic in drinking water until concentrations exceed amounts that stress ion balance. Increasing salts in freshwater ecosystems, however, can impair the source water quality. Elevated salt concentration disrupts normal aquatic life and fosters the growth of undesirable or even toxic biota. For example, salty gas industry wastewater discharged into Dunkard Creek in Pennsylvania allowed toxin-producing marine algae to bloom and the toxin triggered a fish kill [30].

Organic compounds in produced water can be highly diverse and hard to predict. These compounds come from the compounds deliberately put into fracking fluids, substances present in the shale, interactions underground under anaerobic conditions, reactions when the produced water reaches oxygen at the surface and after microbes act on compounds. Some of these compounds in PF have been studied for toxicity. Many act as endocrine disruptors and others disrupt other body systems, such as the nervous system or kidneys [31].

Recycling Produced Fluids for Fracking

Fracking operators have chronic problems with disposal of PF and recently have been reusing the fluids as part of the fracking fluid mix for subsequent fracking events. This requires storage of PF for extended periods depending on PF fluid removal after one fracking event at one pad and the next fracking event at another pad. Storage and reuse of PF add to the hazards near drinking water in several ways. First, the PF produced by fracking with recycled PF contains additional toxins from the other shales where the other PF was generated. Substances such as radionuclides, heavy metals and organic compounds are not easily removed from large volumes of fluids and will accumulate. Second, the high salt content of PF inhibits the breakdown of some substances, such as polyethoxylated surfactants [32, 33]. Some surfactants are highly toxic to aquatic organisms and also toxic to mammals. During storage, other components in PF are converted to a new, toxic substance. For example, components in PF interact to produce diphenyl phosphate, a compound which is toxic itself [34]. Furthermore, Diphenyl Phosphate does not readily attach to soil particles and instead easily enters groundwater, water wells, springs and surface waters [32].

On well pads at BRR, large volumes (from tens of thousands to millions of gallons) of Fracking Fluids, Produced Fluids and other waste are present on one or more well pads at any given time, with PF as the most abundant fluid. For example, Table 1 illustrates industry records reported a monthly average of almost 1 million gallons of fluid waste was at Aikens 5 well pad each month throughout 2017 and similar amounts were at Kuhn. Both well pads are adjacent to the water’s edge and reservoir tributaries.

Table 1. Examples of Fluid Waste (in gallons) at Well Pads Adjacent to Beaver Run Reservoir 2013-2018

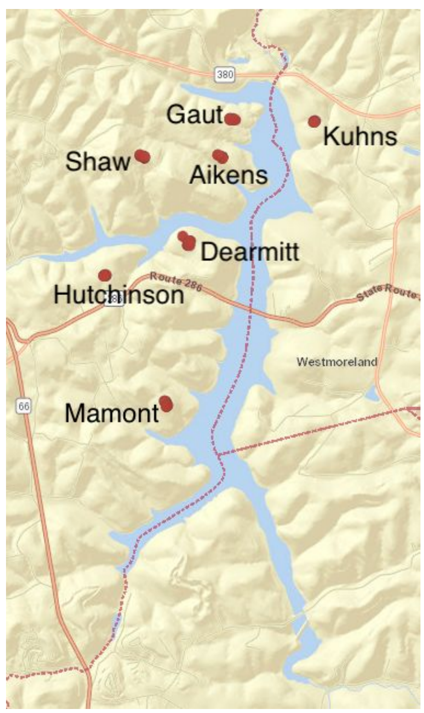
Well Pad	**Year**	**Time Frame**	**Produced Fluid**	**Drilling Fluid Waste**	**Fracking Fluid Waste**	**Other Oil & Gas Waste**
Aikens 5	2013	Jan-Jun	77,280			
		Jul-Dec	329,532	147,840	69,300	
	2014	Jan-Jun	3,360	291,581	298,885	
		Jul-Dec	684,413	4,620	296,519	
	2015	Jan-Jun	2,069,185	4,200	158,340	
		Jul-Dec	1,801,465	9,618	428,064	
	2016	Jan-Jun	7,283,524		26,460	1,200
		Jul-Dec	1,387,777	249,060	2,845,080	420
	2017	Jan-Jun	2,765,132	95,760		30,821
		Jul-Dec	3,358,878	40,320		113,946
		Per Month				
	2017	Jan	750,225	10,920		18,480
		Feb	386,890	2,100		12,341
		Mar	835,027	32,760		
		Apr	792,990	49,980		
		Jul	1,107,122	29,400		50,820
		Aug	778,921	10,920		2,100
		Sep	1,472,835			630
		Nov				60,396
	2018	Apr	5,040			
		May	4,705	1		
Kuhns	2017	May	1,852,200			
		Dec	51,244			
	2018	Jan	5,456			

Reservoir Water Quality Testing Information

Well Pad Sites Around Beaver Run Reservoir

Unconventional Well Sites

The Pennsylvania Department of Environmental Protection (DEP) defines an unconventional well site as any well drilled into an unconventional rock formation. An unconventional formation is defined by DEP as “a geologic shale formation...where natural gas generally cannot be produced except by horizontal or vertical wellbores stimulated by hydraulic fracturing” [35]. DEP reports indicate that there are 324 active unconventional wells in Westmoreland County; 55 of these wells are on seven well pads located within one half-mile of the Beaver Run Reservoir. The UNGD wells surrounding the Reservoir are operated by CNX Gas Company LLC. DEP inspectors have issued 13 violations to these wells and records show 11 additional incidents not resulting in violations have occurred since drilling activity began in this area in 2010 [12]. These incidents ranged from “minor” spills of less than one gallons of oil from a piece of equipment to “major” leaks of natural gas and chemicals as a result of operator error or well failure.



Map 1. *Unconventional gas wells surrounding the Beaver Run Reservoir [37].*

Future Proposed Unconventional Well Sites

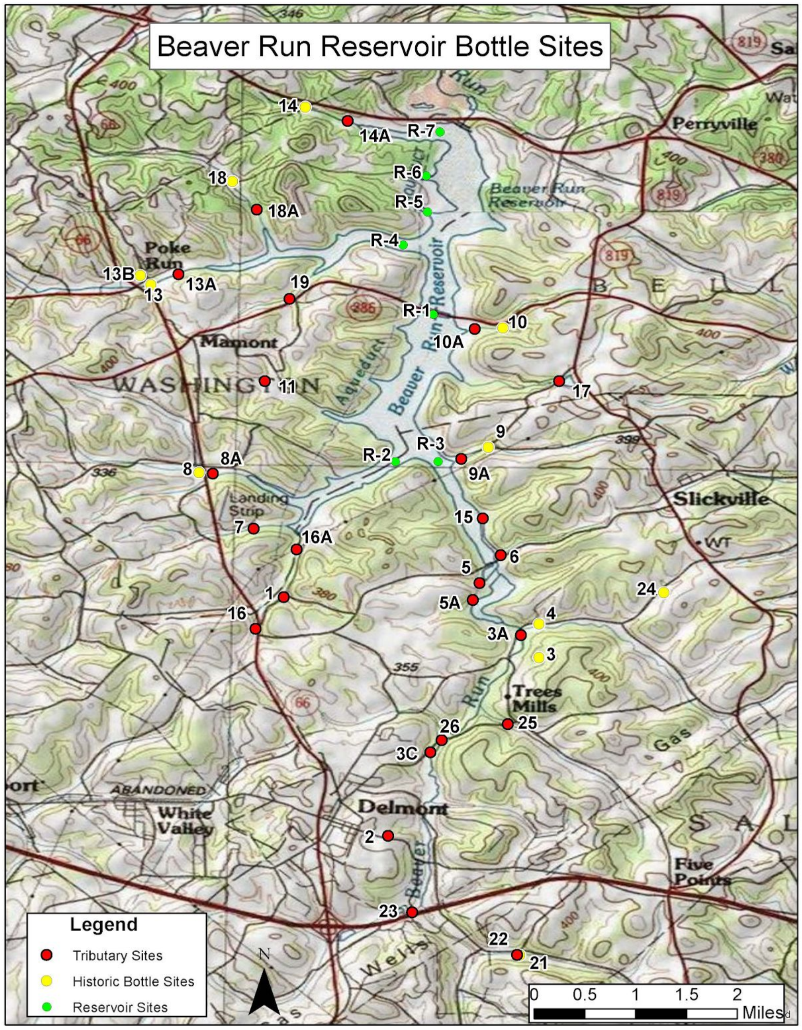
In January 2019, DEP issued drill and operate permits to CNX Gas Company LLC for four new unconventional wells to be drilled on the Mamont well pad.

Conventional Well Sites

A conventional well site is one which taps a conventional gas reserve, a pocket of gas found in a highly porous rock formation. Vertical wellbores can be used to reach this type of gas reserve, and then the gas can be extracted using natural pressure or pumps. There are 130 conventional well sites within half a mile of the Beaver Run Reservoir according to the DEP. Since 2000, these conventional well sites have collectively been issued a total of 18 violations and only 1 other incident has been recorded which did not result in a violation [12].

Testing Constituents and Frequency

Since 2011, the Municipal Authority of Westmoreland County (MAWC) has contracted with Indiana University of Pennsylvania (IUP) to have faculty and students monitor selected water quality criteria in tributaries and reservoir waters of Beaver Run Reservoir. Water collection occurs on a quarterly schedule and results are posted on a web site. IUP field tests for all water samples include pH, conductivity, and temperature. Raw reservoir water samples were analyzed by students for metals (calcium, magnesium, iron, manganese, aluminum, strontium, mercury, lead, cadmium, chromium, arsenic, and barium) and ions (fluoride, chloride, bromide, nitrate, phosphate, and sulfate). IUP also posted the results of fall 2017 radionuclide, volatile organic compounds, and BTEX (Benzene, Toluene, Ethylbenzene, and Xylene) tests as measured by Pace Analytical.



Map 2. IUP Sampling Sites Around Beaver Run Reservoir [38].

In April 2017, in response to requests from WMCG, MAWC contracted TetraTech to recommend water testing protocols, given the presence of UNGD and other activities such as farming in the watershed. This consultant sent MAWC a list of water quality parameters referred to as “constituents of concern” and also specified the frequency that MAWC should test the constituents of concern. The substances and current status of testing are summarized in Fig. 2. Details are described below and lists of chemicals are in separate tables located in the appendix.

TetraTech proposed that the inorganic parameters in Table 2A and organic parameters in Table 2B be tested at varying frequencies. In addition, they recommended that the inorganic parameters in Table 3 be tested on an annual basis in October at a minimum. Recommending testing in October, when parameters would typically have the highest level, is most likely due to turnover in the reservoir. Turnover occurs when the surface water layer begins to cool as sunlight hours decrease. Upper layers of water sink and lower water layers are pushed to the surface [39]. The movement of water causes sediments to be agitated, releasing different contaminants that had settled to the bottom of the reservoir. Additionally, TetraTech recommended that the organic parameters in Table 4 be tested on an annual basis in October at minimum. TetraTech advised the inorganic parameters in Table 5 be tested on a quarterly basis or more frequently. Furthermore, TetraTech suggested nitrate, nitrite, and phosphate levels be tested on a monthly basis if they are near farming activities. Multiple farming areas are located within 5 miles on every side of the reservoir with the closest being approximately 2,000 feet away from the west branch of the reservoir. It was not specified how close farming activities would have to be considered nearby. Total Coliform, E. Coli, and oil/grease are recommended to be measured on a quarterly basis. If there is to be additional well pad activity, TetraTech advised there be separate testing for all the mentioned parameters on a monthly basis from three months before the spud date until six months after the well pad activity concludes.

MAWC claimed in a March 2019 presentation to have been testing weekly for the month before any well pad activity started and continued testing until approximately one month after the well pad activity is completed. This schedule was not able to be proven as MAWC does not separate testing around active well pads from any typical monitoring. A weekly water sample from late-August to mid-November of 2017 was taken from around the Aikens well pad and tested for a large number of organic components as well as radionuclides. No other information for other testing or other locations has been provided through several informal and formal file reviews. From testing data acquired through Right-to-Know Requests, MAWC has been testing raw reservoir water for alkalinity, chloride, hardness, iron, manganese, pH, specific conductivity, and turbidity. All of these parameters were tested on a daily basis at a minimum, exceeding the recommended testing frequencies given by TetraTech. In a presentation given by MAWC in March 2019, MAWC claimed to be testing 179 parameters. Constituents that MAWC claimed to test were compared to the TetraTech recommendations and some of the parameters that were similar were not able to be proven to be tested as of the writing of this report. These include benzyl alcohol, chloroform, dichloromethane, ethane, fluoranthene, fluorene, methylene blue activated substances, methane, naphthalenes, propane, pyrene, pyridine, petroleum hydrocarbons, and phenol. Following a well pad incident in late January 2019, MAWC began testing daily for some parameters the first week after the incident. After February 4th, MAWC had increased testing frequency to about 3 times a week until an unspecified date.

General Parameters		Alkalinity	Hardness	Conductivity	pH	
		Total Dissolved Solids	Total Suspended Solids		Turbidity	
Inorganics		Bromide	Chloride	Fluoride	Sulfate	Sulfide
		Barium	Boron	Calcium	Lithium	Magnesium
		Potassium	Selenium	Sodium	Strontium	
	Heavy Metals	Aluminum	Arsenic	Cadmium	Chromium	
		Cobalt	Copper	Zinc	Iron	
		Lead	Manganese	Molybdenum	Nickel	
		Silver	Mercury	Uranium	Vanadium	
Organics		1,2 Propylene Glycol	1,4 Dioxane	Acetone	Acetophenone	Benzyl Alcohol*
		Benzene	Toluene	Ethylbenzene	Xylenes	Carbon Disulfide
		Chloroform*	Coliform (Total)	Cumene	Cyanide	Dichloromethane*
		Di-n-butyl phthalate	E. Coli	Ethane*	Ethylene Glycol	Fluoranthene*
		Fluorene*	Formic Acid	Isopropylbenzene	MBAS*	Methane*
		Methanol	Naphthalenes*	Nitrate	Nitrite	Oil and Grease
		VOC's	Propane*	Propargyl Alcohol	Pyrene*	
		Pyridine*	Surfactants	Petroleum Hydrocarbons*		Phenol*
Radionuclides		Gross Alpha	Gross Beta	Radium 226	Radium 228	

Legend

	MAWC is proven to test at or greater than the recommended frequency by TetraTech
	MAWC is testing but has not met the recommended frequency by TetraTech
	MAWC does not claim to test despite being recommended by TetraTech
*	MAWC claims to be testing these parameters but data was not obtained to confirm

Fig. 2 Overview of constituents of concern listed by MAWC consultant for regular testing. Boxes are color-coded to denoted compliance of testing frequency by MAWC and IUP.

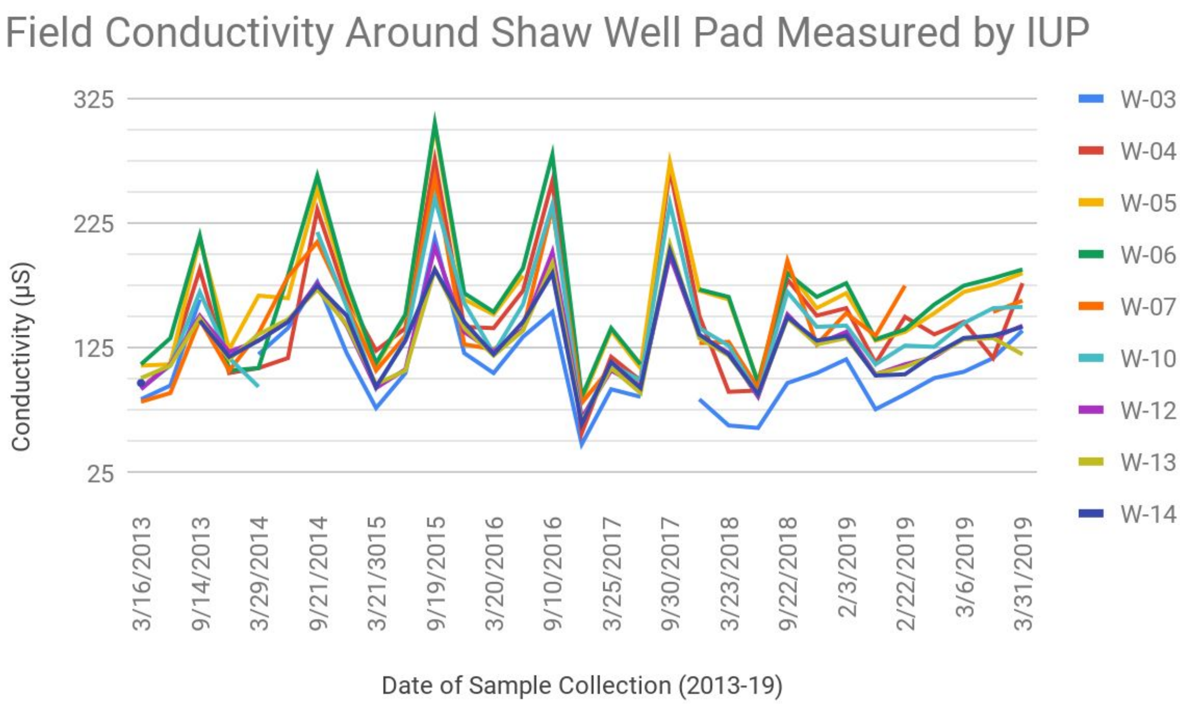
Results and Discussion

Data for Stream Water Near Well Pads

Nearby streams around the well pads were all monitored quarterly for pH, conductivity, total dissolved solids, and temperature by IUP. Since this was limited to field testing, the TDS value was found by plugging the conductivity value into an algorithm. Due to "dropped" sites, a number of IUP test sites have been excluded from some of the Figures. A dropped site refers to a site that is not being tested further for any reason [40]. For example, IUP mentions a site may be dropped due to redundancy with other sites or being no longer accessible due to land-use changes [40]. Any gaps that occur in the data are a result of "dry" sites where there was "little or no water present for field measurements" [40]. There are three well pads that are being selected to further compare stream water in this report. The Aikens well pad was chosen because it is one of the first well pads around the Beaver Run Reservoir, while the Shaw well pad was chosen due to its recent incident. The Kuhns well pad was also highlighted because of the history of having more than one accident since its spud date in 2012.

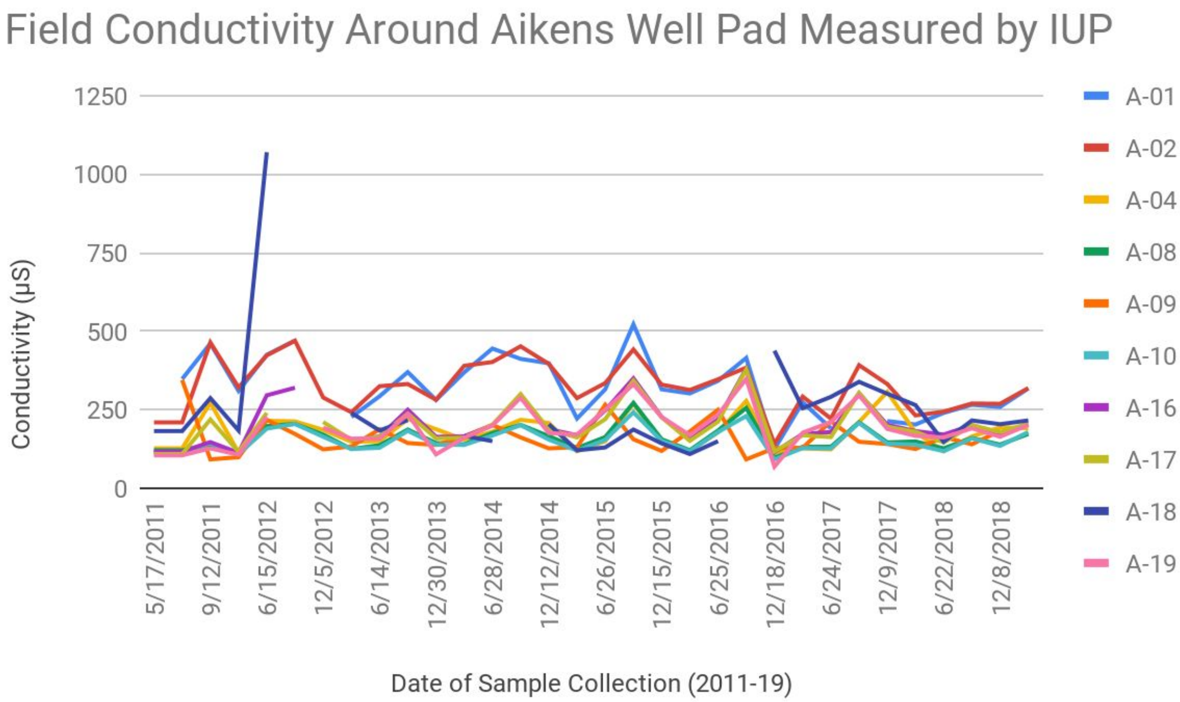
Conductivity is the measure of the ability of water to pass an electrical current. It is used as an indicator of changes in water quality as it can display changes in the amount of inorganic compounds in a source of water [41]. It was measured in micromhos per centimeter (μmho/cm) by MAWC using a Hach Model 1720E turbidimeter [11]. IUP used a pH combination meter to measure conductivity and used units of microSiemens (μS). Micromhos and microSiemens have a 1:1 ratio, as they are two names for the same unit. For practical purposes, all conductivity values that are discussed will be in units of microSiemens.

Shaw Well Pad



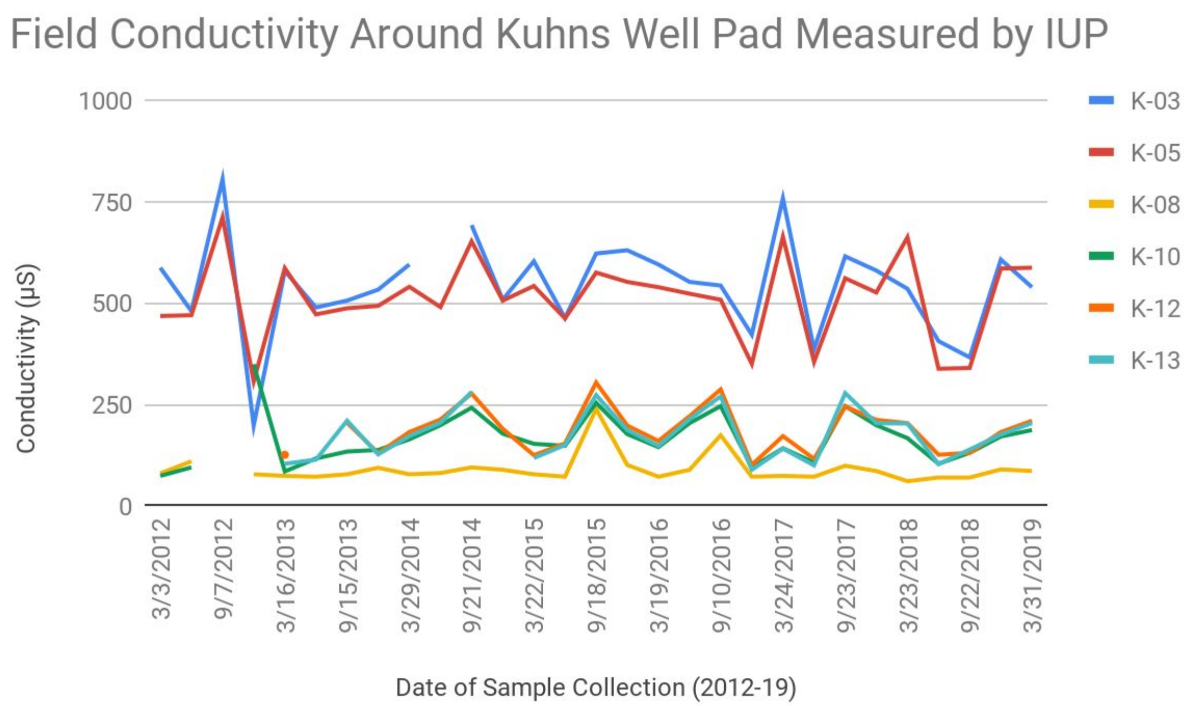
The Shaw well pad testing was initiated in 2013 and has continued up until the date of this report. IUP tested 14 sites around the well pad, but 5 sites were dropped sites, meaning 9 sites were kept throughout the entire monitoring period. Due to the pressure drop incident in January, the testing frequency was increased to once a week. The field conductivity of the sites follows mostly-defined patterns such as peaking in the fall sample. Additionally, the peaks and troughs are distinguished, except in 2018 where there is no significant difference between the highest and lowest conductivity values. The largest conductivity measured around the Shaw well pad was 305 µS in September 2015.

Aikens Well Pad



The Aikens well pad had 20 sampling sites, but 6 were dropped sites and have been omitted from the figure displaying the field conductivity. An additional 4 sites have been omitted due to an abundance of dry sampling quarters. The conductivity values of the Aikens well pad typically ranged from a value of 100 µS to 400 µS. The A-01 and A-02 sampling sites had higher conductivity values on average. These values fluctuated in a range of 225 µS to 500 µS. On June 15th, 2012, the A-18 sampling site was found to have a conductivity of 1070 µS. In general, the values peak annually each September quarterly testing period.

Kuhns Well Pad



IUP selected 14 sampling sites around the Kuhns well pad, of which only 6 had enough data and longevity to be displayed. Based on the conductivity values, the plotted sites can be split into two groups. Sites K-03 and K-05 fit into the higher conductivity group in which the values tend to oscillate between 350 µS and 700 µS. The remaining 4 sites all have lower conductivity values that vary between 75 µS and 275 µS. In September, the values of the sampling sites usually have annual highs. Additionally, the first group often has comparable peaks in March as well.

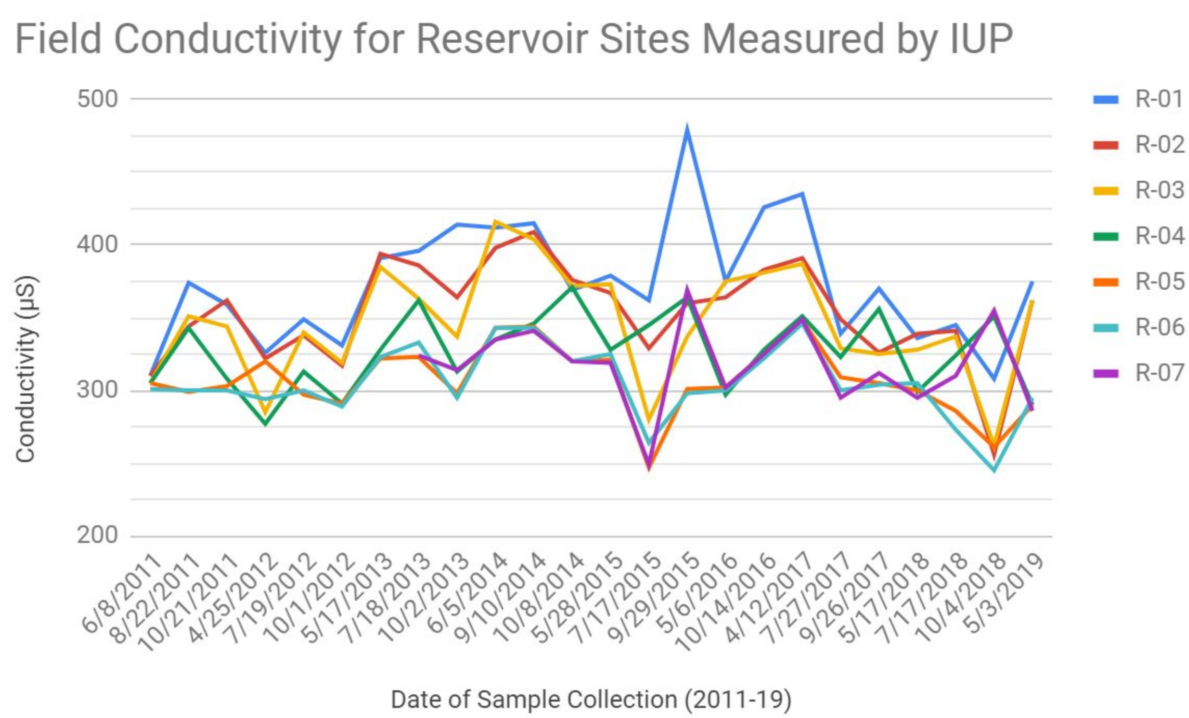
Well Pad Comparison

The locations of the well pads around Beaver Run Reservoir can be seen in Map 1. The Kuhns well pad is the northernmost well pad, and the Shaw well pad is the furthest away from the reservoir. The Shaw and Aikens well pads are along the Utica shale formation, as compared to the Kuhns well pad which is along the Marcellus shale formation. Of the three well pads examined, the Shaw well pad has the lowest typical conductivity. The conductivity peaked slightly above 300 ppm while the Aikens well pad had multiple samples above 400 ppm. The Kuhns well pad had sampling sites that were above 500 ppm and even one site, the K-05 site, that never dropped below 300 ppm. For reference, freshwater sources tend to have a conductivity between 100 µS/cm and 2000 µS/cm [41].

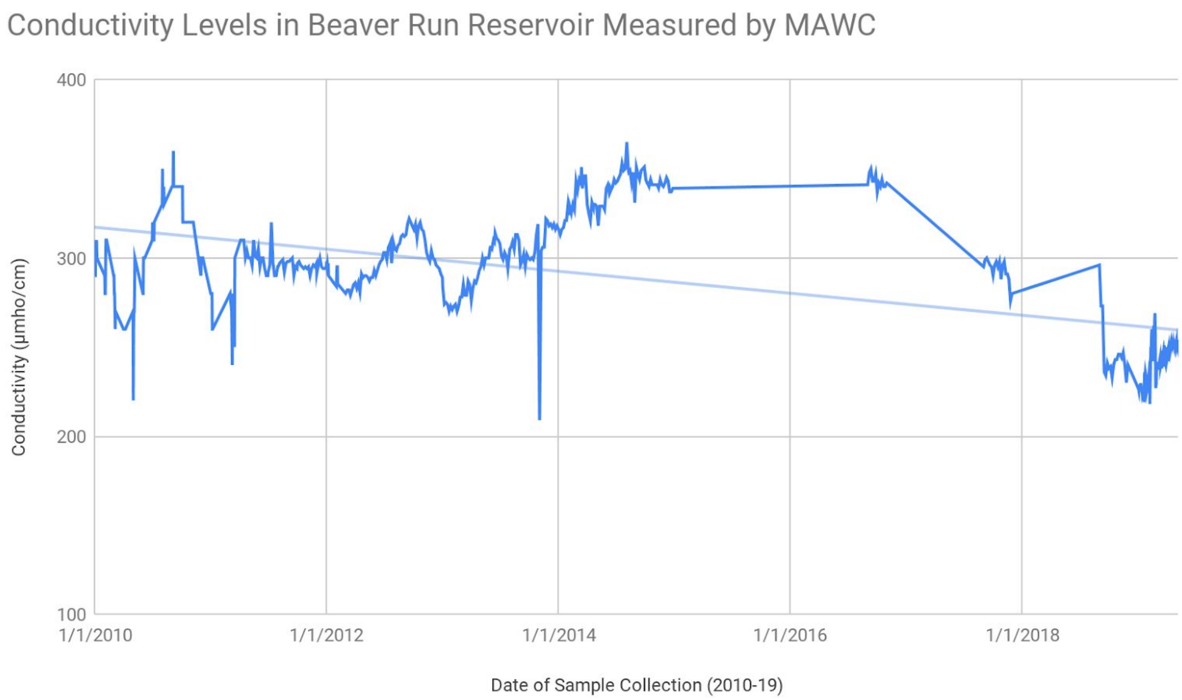
Reservoir Data

The Indiana University of Pennsylvania conducted sampling at 7 different sites within the Beaver Run Reservoir and are displayed in Map 2. They used a boat to navigate the reservoir and take samples from 5 feet above the bottom of the reservoir. Due to weather conditions, the boat was removed after the fall sampling set of each year, meaning that sampling was typically done three times a year instead of quarterly. There were only two sampling sets in 2016 due to a mechanical issue with the MAWC boat that was being used. Additionally, MAWC tests for turbidity, pH, manganese, conductivity, alkalinity, iron, and hardness on a daily basis. Collecting and plotting the daily data was infeasible due to time constraints, so data from every 5 days or every week per fall month basis were compiled. Fall months were prioritized specifically due to the anomaly of turnover when levels of each parameter tend to reach a peak.

Conductivity



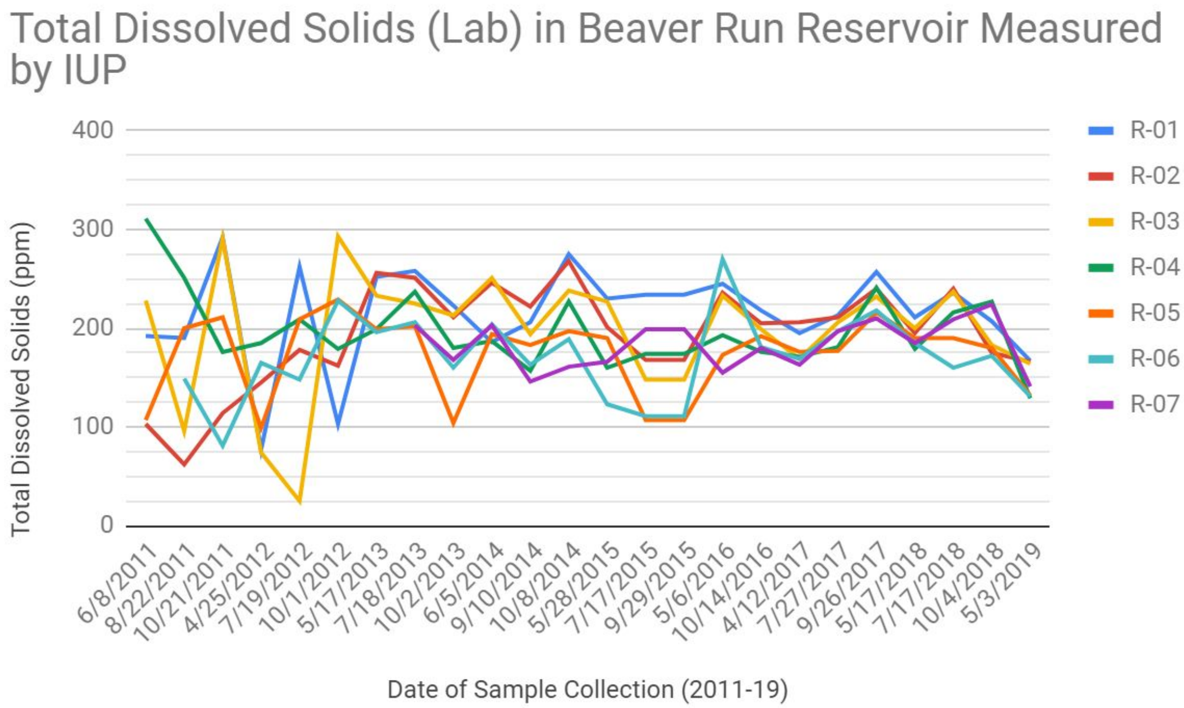
IUP measured field conductivity around the reservoir tends to stay within 275 µS to 400 µS. The three highest conductivities were measured at R-01 sampling site with values of 479 µS, 426 µS, and 435 µS. The first two values were measured in the fall 2015 and 2016 sampling periods, but the latter was from the spring of 2017.



The daily conductivity measured in the Beaver Run Reservoir by MAWC from 2010 to early 2019 has not been shown to exceed 375 µS. It is important to note that some data was excluded from this analysis due to the study's time constraints; specifically all of 2015, and winter, spring, and summer of 2016 to 2018. Conductivity was measured as 319 µS on October 28th, 2013 and dropped to 209 µS on November 2nd, the lowest of any conductivity value measured by MAWC.

Total Dissolved Solids

Total dissolved solids (TDS) are the sum of ion particles in a water source that is smaller than 2 microns (0.002 millimeters) [41]. IUP measured TDS in units of parts per million (ppm) using a gravimetric method for laboratory testing [42]. Dissolved solids balance cell density by dictating the amount of water entering an organism's cell, meaning different aquatic organisms require different TDS values for optimal survival [41].

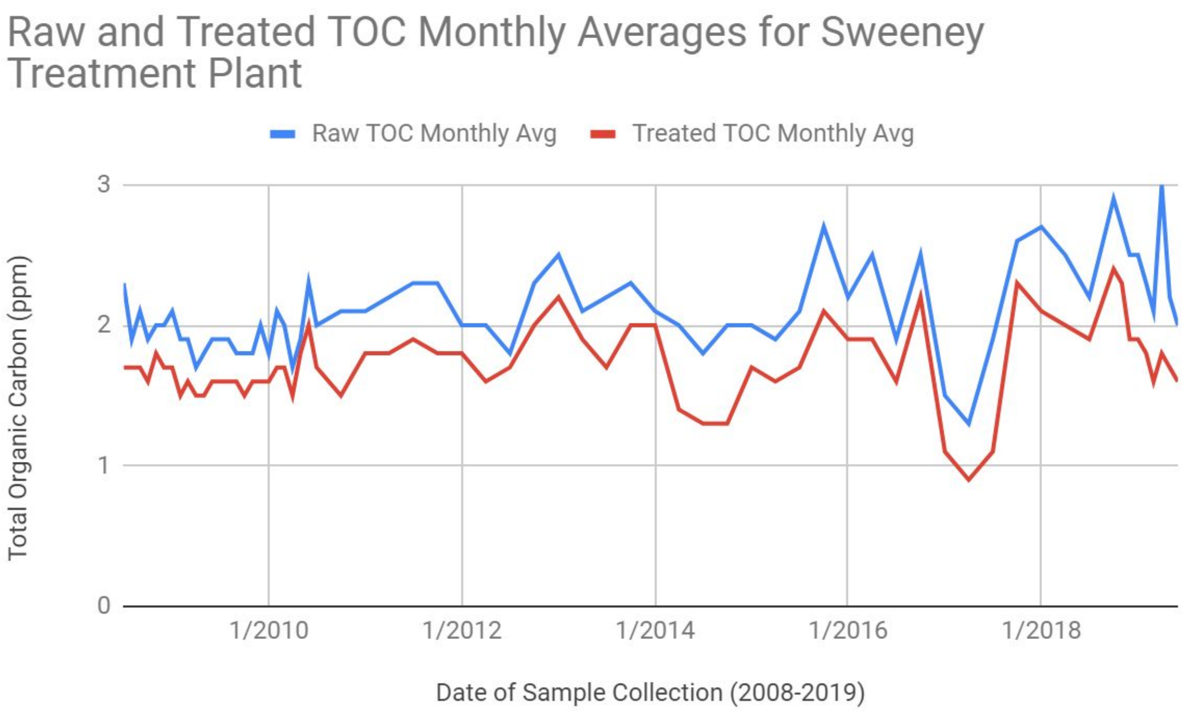


Total Dissolved Solids of the Beaver Run Reservoir were measured by IUP from June 2011 to the present. The TDS of the seven sites do not appear to follow any common trends, although the values at each site typically range from 100 ppm to 275 ppm. The lowest recorded TDS was 25 ppm in July 2012 and the highest recorded TDS was 311 ppm in June 2011.

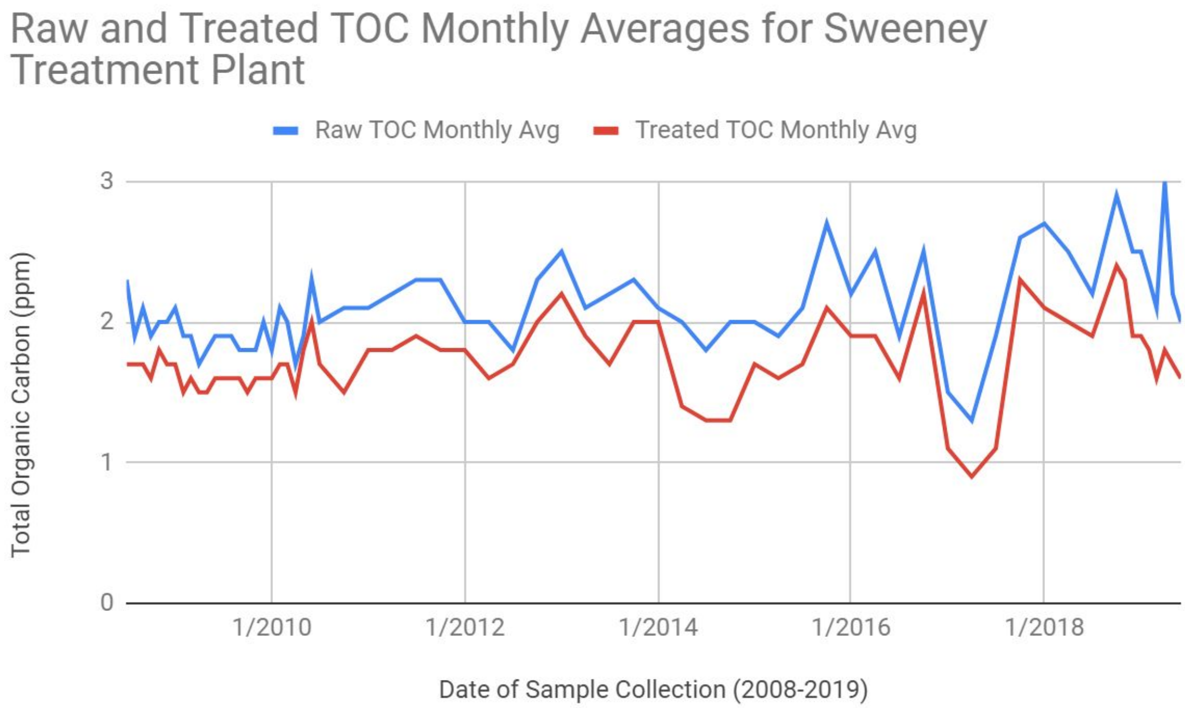
Freshwater sources, like the Beaver Run Reservoir, tend to have less than 1,000 ppm in terms of TDS [42]. The reservoir is within this value as the highest level measured was 311 ppm. At the beginning of the sampling period, there tends to be a larger oscillation between the measured values at all sites, which dampens as the sampling period continues. During the first sampling period, individual sites have a range of 103 ppm to 311 ppm. In the most recent tests, the range between sites is 131 ppm to 167 ppm. This means that there was originally a difference between sites of 208 ppm as compared to a difference of 36 ppm in the last sampling period.

Total Organic Carbon

Organic carbon (TOC) can occur in waterways due to many processes such as the use of agricultural chemicals or natural means [43]. Spills from industrial wastes can also lead to an increase in the number of organic contaminants in nearby water sources [43]. The amount of carbon in a body of water can be used as an indicator of how much aquatic life a system can support. If TOC gets too high in a body of water, micro-organisms that consume organic compounds may proliferate and produce undesirable substances. Also, excess bacteria can deplete the oxygen needed by fish and aquatic insects. This process can spiral into a fish kill that further degrades water quality. TOC is also important because these compounds contribute to the formation of disinfection by-products (DBP) that form when organic compounds react with chlorine added for water disinfection. The topic of DBP is addressed in a later section. Drinking water suppliers are required to keep TOC below certain limits and reduce TOC in raw water by specific proportions to reduce TOC in final water vs. intake water. MAWC uses granular activated carbon to reduce TOC in drinking water at the Sweeney plant.



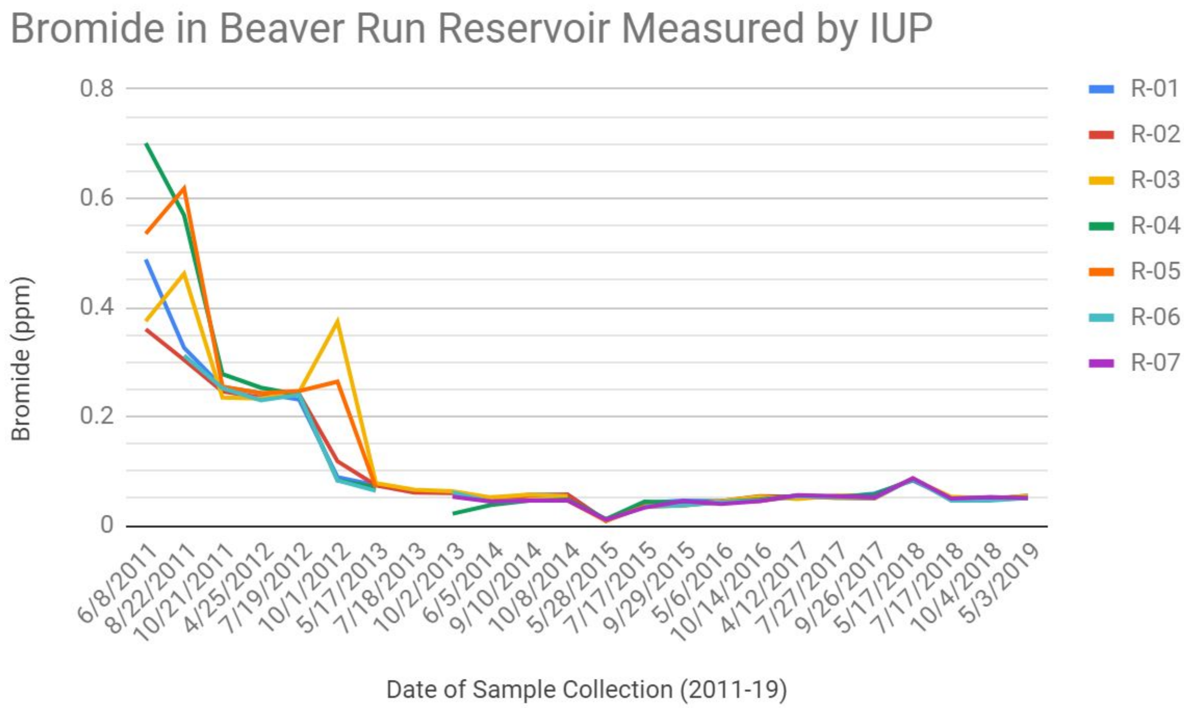
The average monthly TOC of raw water from the Beaver Run Reservoir is monitored by MAWC at the Sweeney Water Treatment Plant. The highest recorded raw water TOC monthly average value came in April 2019 at a value of 3 ppm. The lowest recorded monthly average was 1.3 ppm two years prior, in April of 2017. Since October 2017, the TOC of raw reservoir water did not drop below 2.0 ppm.



The TOC levels recorded by MAWC in 2018 do not meet the drinking water standards set forth by the EPA. In the 2018 Water Quality Report for Westmoreland County, MAWC claimed "significant rainfall" resulted in a TOC removal ratio of 0.55 while the standard is a TOC removal ratio of 1.0 [44]. Over the same time interval, the Indian Creek water treatment plant, also operated by MAWC and roughly 35 miles away, had a TOC removal ratio of 1.01. While there is no specific maximum amount TOC must meet for drinking water, there is a recommended removal ratio of 35%. Even though the Indian Creek treatment plant had higher maximum monthly average TOCs, it achieved a removal ratio greater than the required 1.0.

Bromide

Bromide (Br^-) is an anion that forms in nature and is found in some common foods such as fish, grains, and nuts [45]. Bromide concentration increases in source water may be attributed to nearby chemical spills. IUP measured bromide in units of parts per million using ion chromatography.

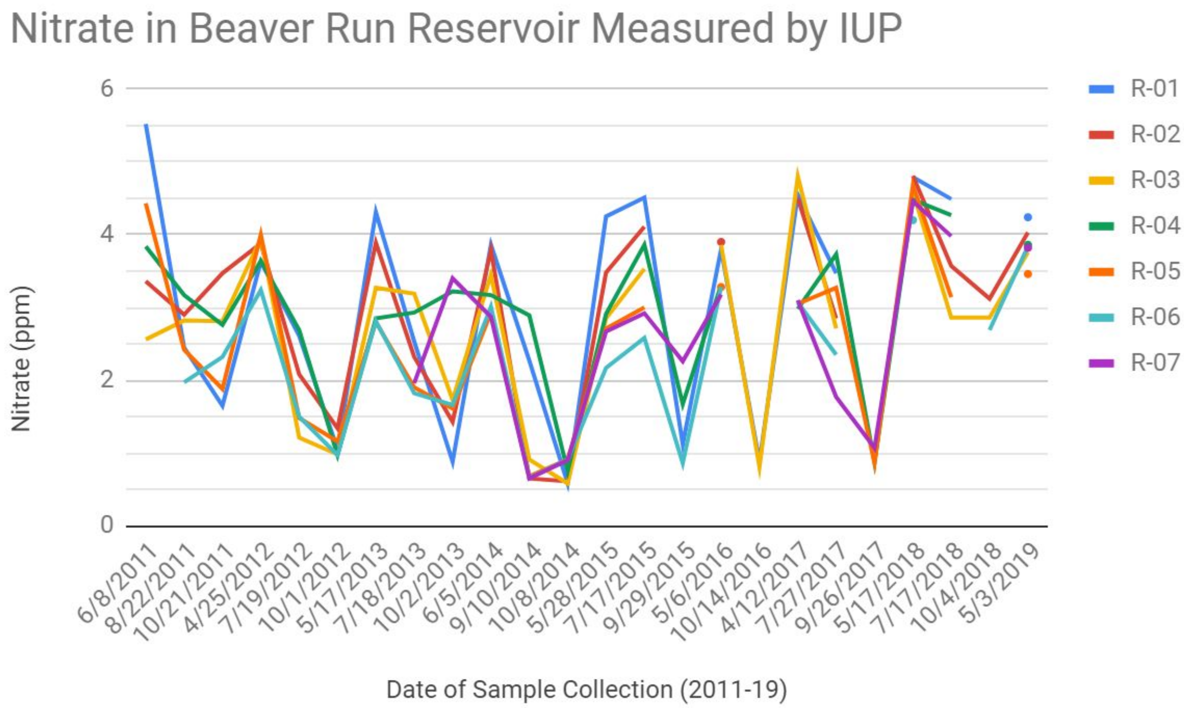


The bromide levels in the Beaver Run Reservoir have been decreasing since the first reservoir sampling set was conducted by IUP in June of 2011. The highest bromide level was recorded as 0.701 ppm at the R-04 sampling site in the first sampling set. The values began to become relatively uniform around July of 2013 and have stayed around 0.050 ppm since that time.

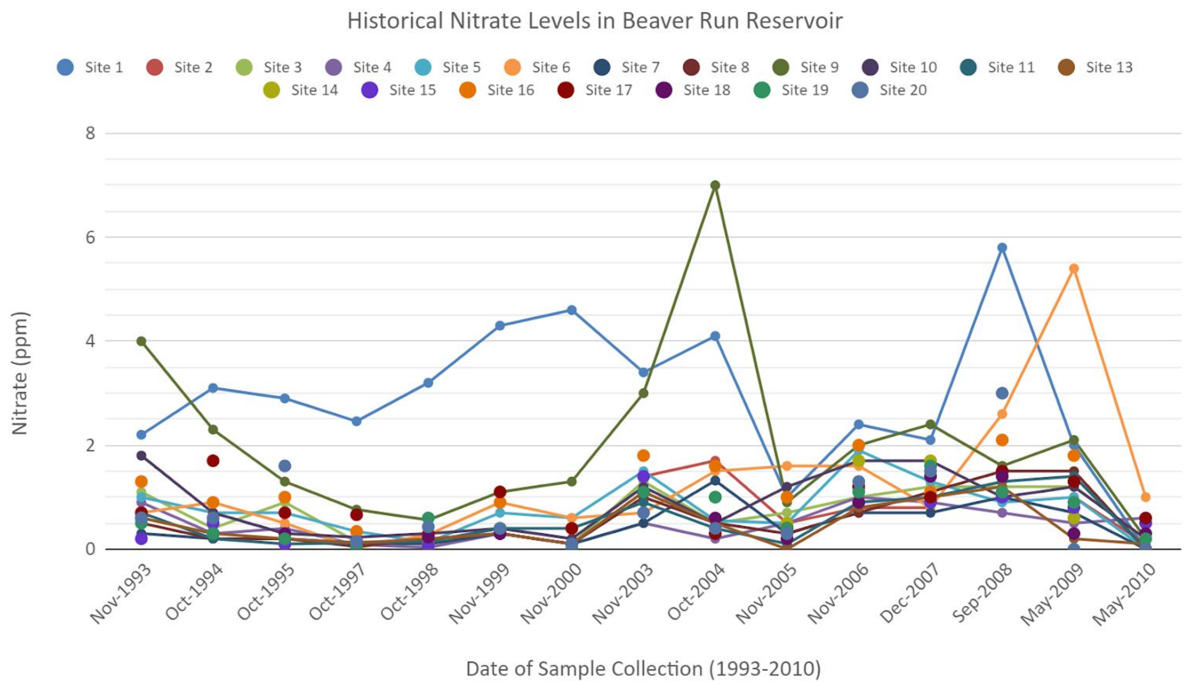
According to the World Health Organization, bromide in freshwater frequently ranges from trace amounts to 0.5 ppm [45]. At the beginning of the IUP monitoring period, bromide was above 0.5 ppm but has since dropped below that value. The maximum bromide concentration recorded was 0.701 ppm. Presently, bromide in the reservoir is down around 0.05 ppm and has been that way for close to 7 years. As the bromide levels had a decreasing trend, there were two sites, R-03 and R-05, in which the values saw small increases. These increases came in August 2011 and October 2012 and while these samples did not reach the overall maximum value, they did stand out against the remaining test values.

Nitrate

While nitrates (NO^{3-}) are naturally occurring, they are best known for being introduced to source water from fertilizer runoff or chemical spills. Excess nitrates in water can be harmful to the quality of aquatic life because nitrates use up oxygen in the water, depleting the oxygen supply used by flora and fauna, especially fish. Additionally, excess nitrate in water can cause a plethora of human health problems such as methemoglobinemia, also known as blue baby syndrome [46]. IUP measured nitrates using ion chromatography and reported units of parts per million.



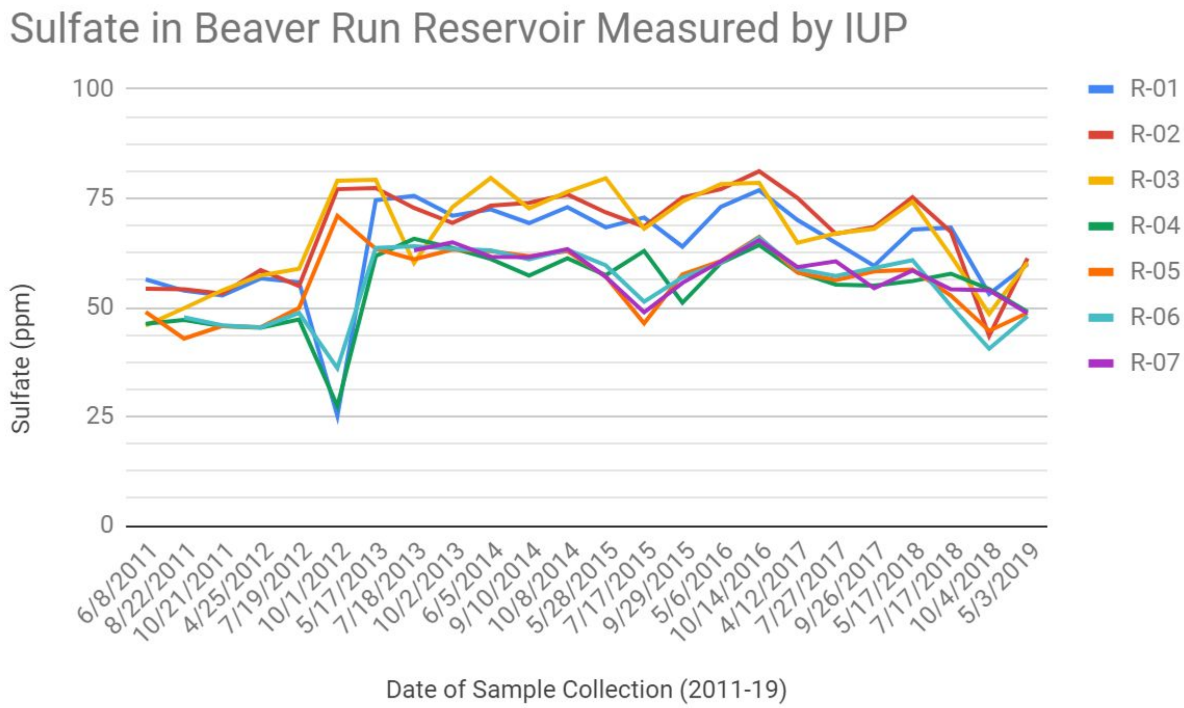
The nitrates in Beaver Run Reservoir consistently follow the same patterns across all sites for each quarterly sample. Unlike some of the other parameters that had peaked in the fall, the nitrates seem to be at their lowest in the fall samples. Instead, nitrate values continuously peak around the spring month samples. Most of the test values fall between 1.0 ppm and 4.5 ppm, although the highest concentration was measured at 5.52 ppm in June 2011.



Nitrates could be at increased levels due to the amount of farming located around the reservoir. Historically, the nitrates in the Beaver Run Reservoir have been below 2.0 ppm across a majority of the sites tested. Most of the data collected by IUP showed nitrates that typically ranged between 1.0 ppm to 4.5 ppm. Although three sites experienced nitrate levels higher than 5.0 ppm, only one of those sites was consistently above 2.0 ppm throughout the rest of the sampling period. That lone site was designated Site 1 and had a high value of 5.8 ppm. Meanwhile, the highest overall value was 7.0 ppm at Site 9 and came in October 2004. The EPA recommends all drinking water have nitrates below 10.0 ppm which all of the tested levels are below [46].

Sulfate

Sulfate (SO_4^{2-}) is a naturally occurring anion that can also enter waterways as a result of industrial discharges. Currently, there are no known long-term effects of drinking water with high amounts of sulfate, although it can lead to temporary laxative effects when exposed to 500 ppm to 750 ppm of sulfate [47]. IUP used ion chromatography to measure sulfates and reported units in parts per million.

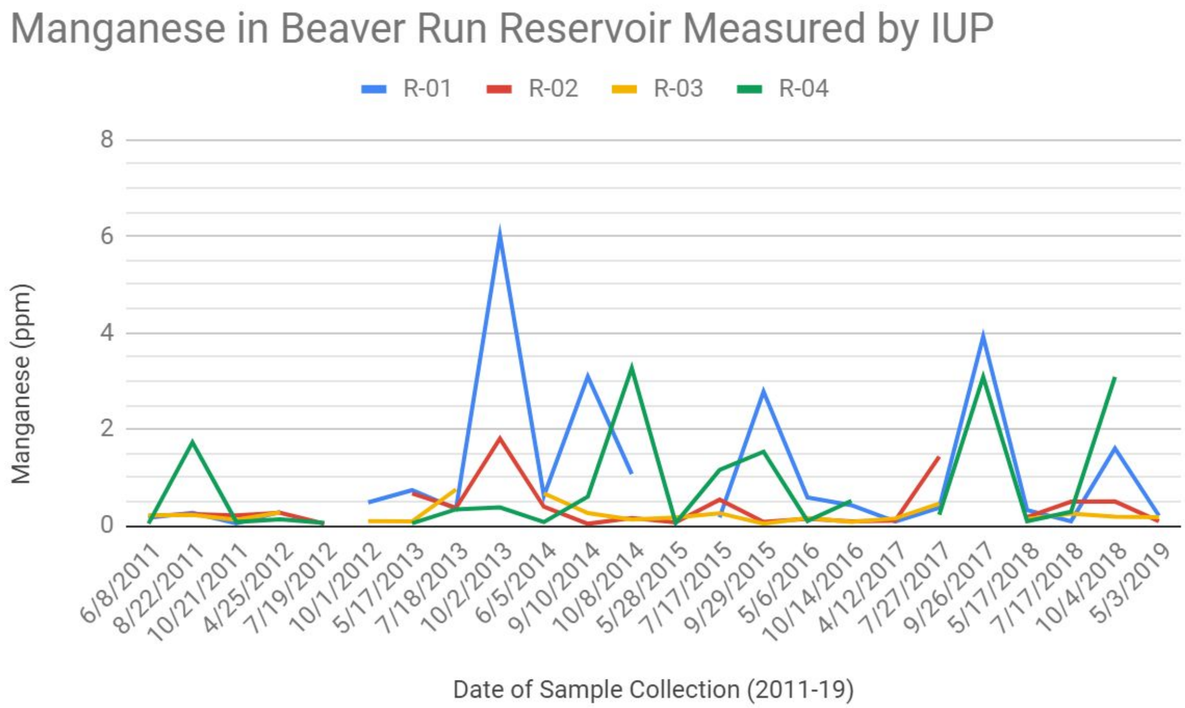


Most of the sulfate values were measured between 50 ppm and 75 ppm. In October 2012, sites R-01 and R-04 had the lowest sulfate values of any site across the monitoring period, being 25.19 ppm and 27.4 ppm, respectively. In mid-2012 to mid-2013, sulfates at sites R-01, R-04, and R-06 had noticeable drops in numerical value while sites R-02, R-03, and R-06 had a significant jump in value.

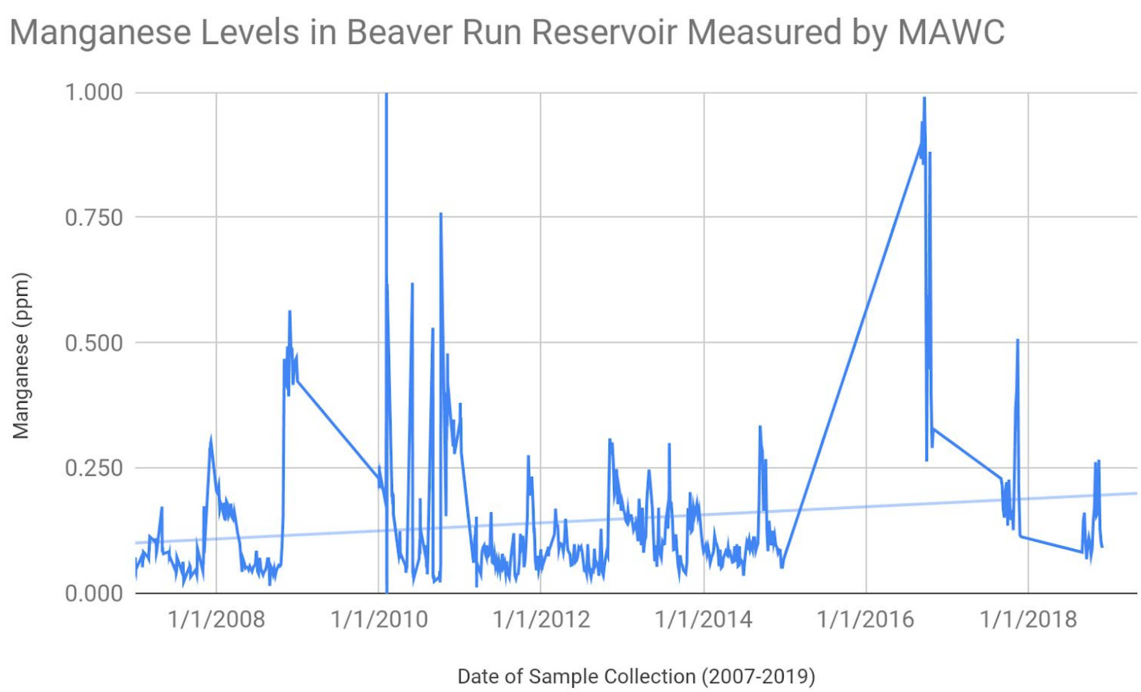
The levels of sulfate in the Beaver Run Reservoir are well below the 500 ppm that would lead to laxative effects if consumed. The highest value measured in the reservoir by IUP was 81.11 ppm in October 2016. The sulfates in the reservoir remain fairly consistent across the 2011 to 2019 testing period. Typical sulfate concentrations in freshwater lakes range from 2 ppm to 250 ppm and groundwater sources range from 0 ppm to 230 ppm [48]. The values recorded by IUP fall within those normal concentration ranges.

Manganese

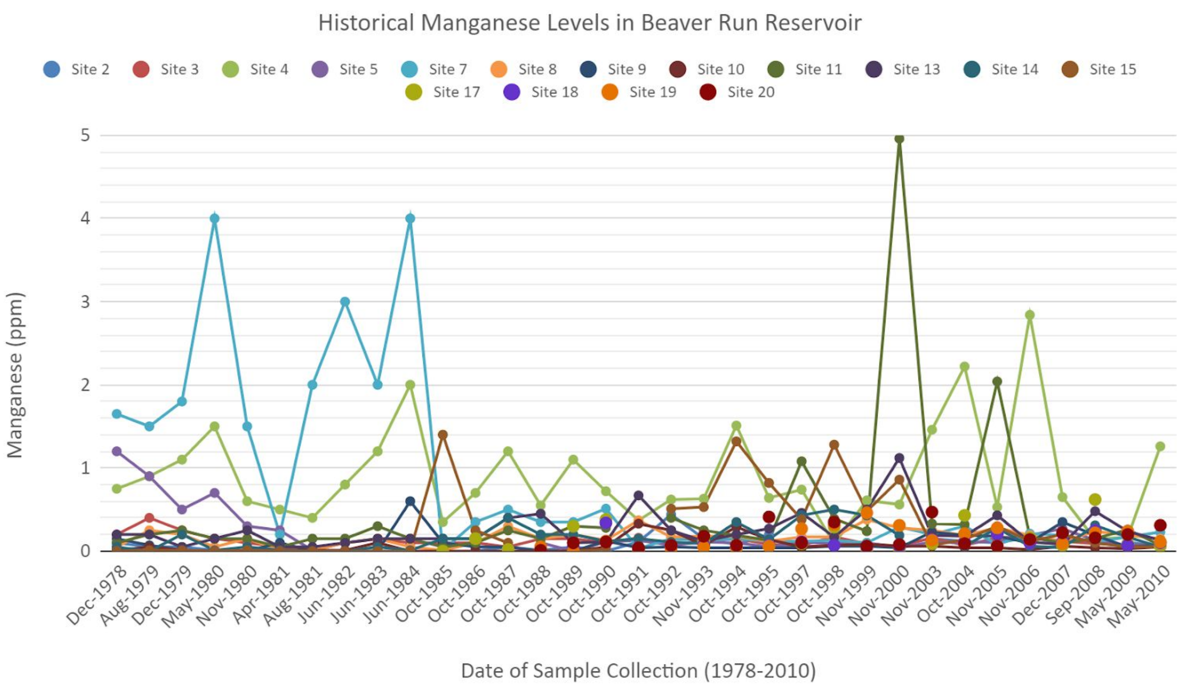
Manganese (Mn) is a naturally occurring metal that mixes into water sources from weathered rock or soil. While some manganese is beneficial to health, it can cause health problems when humans are exposed to excessive amounts [49]. Infants that drink water with excess manganese can develop behavioral and learning problems [49]. In general, water with high levels of manganese leads to issues with motor skills and memory [49]. The Pennsylvania Department of Environmental Protection set limits of 1.0 ppm of manganese for potable water [10].



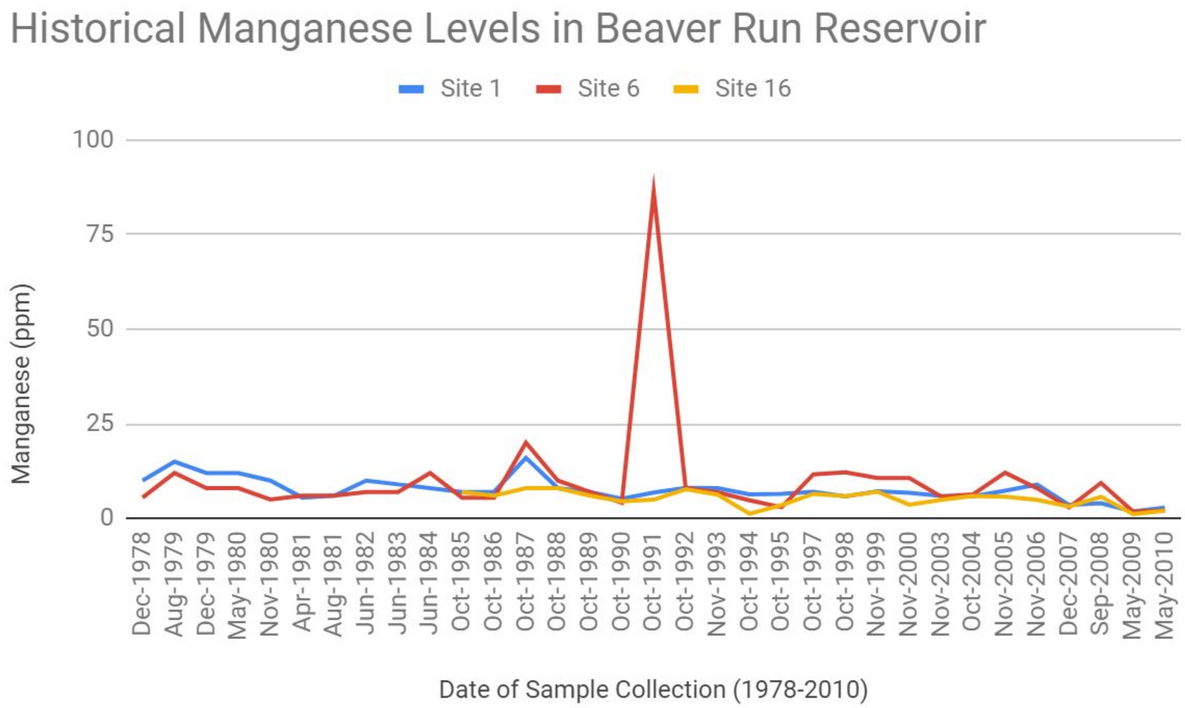
The manganese levels show much variability between sampling sites. The largest values of manganese are typically found in the autumn months, between September and October. In each given sampling set, the R-01 site usually had the highest recorded levels, reaching as high as 6.015 ppm in October of 2013.



The manganese measured in the reservoir by MAWC at the raw water intake of the Sweeney Treatment Plant reached nearly 1.0 ppm on at least two occasions. One being 0.999 ppm on February 4th, 2010 and the other being 0.991 ppm on September 21st, 2016. Most of the recorded data stayed below 0.250 ppm.



Historical manganese across 20 sampling sites in Beaver Run Reservoir was tested from 1978 to 2010. Due to issues of graphing scale, sites that had manganese consistently below 5 ppm are displayed separately from the ones with manganese consistently above 5 ppm. It should be noted that the historical data is only a one time value and not an average. The largest manganese values were 4.96 ppm in November 2000 and 4.0 ppm in May 1980 and June 1984. A vast majority of recorded values were found to be below 0.4 ppm.



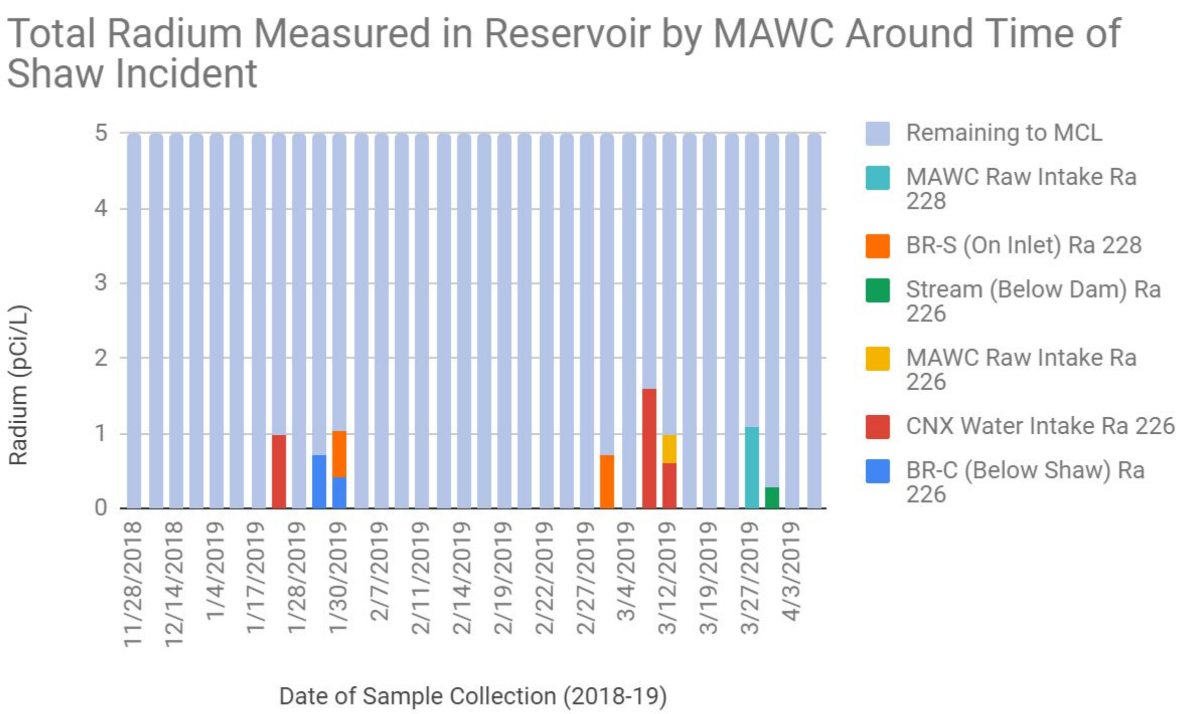
Sites 1, 6, and 16 were the only sites to routinely exceed manganese of 5 ppm. Site 6 had a large spike in manganese up to 86.2 ppm in October of 1991, while all other sites showed no similar increase in manganese. It could be a result of a recording error, although that cannot be said with certainty. Other samples that tested high for manganese were taken in October 1987 at 20 ppm and 16 ppm as well as August 1979 at 15 ppm. The lowest manganese of these three sites was found to be 1.17 ppm.

Currently, the PA DEP has limits of 1.0 ppm of manganese for discharged water into Pennsylvania waters but the EPA has no recommended limits for protecting aquatic life [50]. From the data compiled directly from MAWC records, manganese in the Beaver Run Reservoir has not exceeded 1 ppm. Sampling conducted by IUP has recorded an excess of 1 ppm of manganese on 13 separate occasions among four sampling sites. While the current manganese levels seem to fall within historical manganese trends, there is no public data presenting the amounts of manganese in streams near well pads around the reservoir. Most of the recorded values from MAWC match with the historical trends of staying below 0.40 ppm.

Radionuclides

Radionuclides are found in rocks and minerals and are useful for determining the age of groundwater or sediment cores [51]. They are reported in various measures, including as “gross alpha”, “gross beta”, Uranium and two common forms of Radium, Ra-226 and Ra-228. Radioactive elements most often found in sediments and waters in this region include Uranium and Radium which decays into Radon. Each element releases a characteristic form of radiation called alpha, beta and gamma radiation which are measured using different methods. Exposure to radiation or accumulation of radionuclides in the body is linked to increased cancer risks as well as other health issues [51]. In 2019, MAWC sent water samples to a Pennsylvania accredited lab, Pace Analytical, to be tested for radionuclides. Pace Analytical reported the values in units of picoCuries per liter (pCi/L) and followed EPA method 900.0.

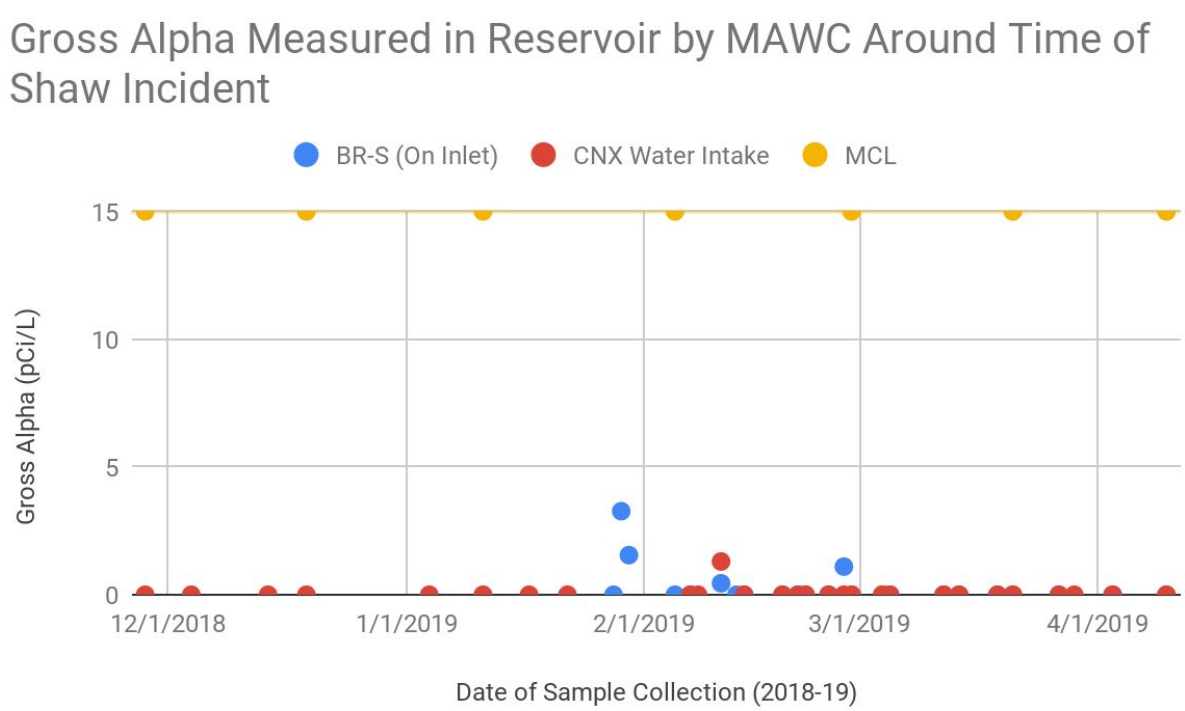
In 2011, Pace Analytical tested raw water samples from MAWC for Gross Alpha, Radium 226, Radium 228, and Total Uranium. Values (with uncertainty) reported were -0.051 (±1.05) pCi/L, 0.275 (±.475) pCi/L, 0.276 (±0.439) pCi/L, and -0.026 (±0.001) (µg/L) for Gross Alpha, Radium 226, Radium 228, and Total Uranium, respectively. MAWC had samples tested by CWM Environmental for Radium 226, Radium 228, and Gross Alpha in 2014. These values all were recorded as not detected (ND). Values reported were stated in the 2011 Consumer Confidence Report as not detected for Gross Alpha, Gross Beta, Combined Radium (226+228), and Total Uranium. In the 2014 Consumer Confidence Report, Gross Alpha was recorded as 3.0 pCi/L and Combined Radium was 1.9 pCi/L. IUP displayed the results of fall 2017 radionuclide testing by Environmental Services Laboratories. Gross Alpha and Radium 226 all were measured to be below the minimum detection concentration (MDC). Radium 228 had only one value higher than the MDC which was 1.38 (±0.713) pCi/L on October 24th. Gross Beta was found on four of the eight sampling dates with values of 1.42 (±0.440) pCi/L, 1.92 (±0.556) pCi/L, 2.93 (±1.02) pCi/L, and 1.69 (±0.476) pCi/L on September 27th, October 3rd, October 10th, and October 17th. The locations of these samples were near the Aikens well pad but specific locations were only available for MAWC and CNX.



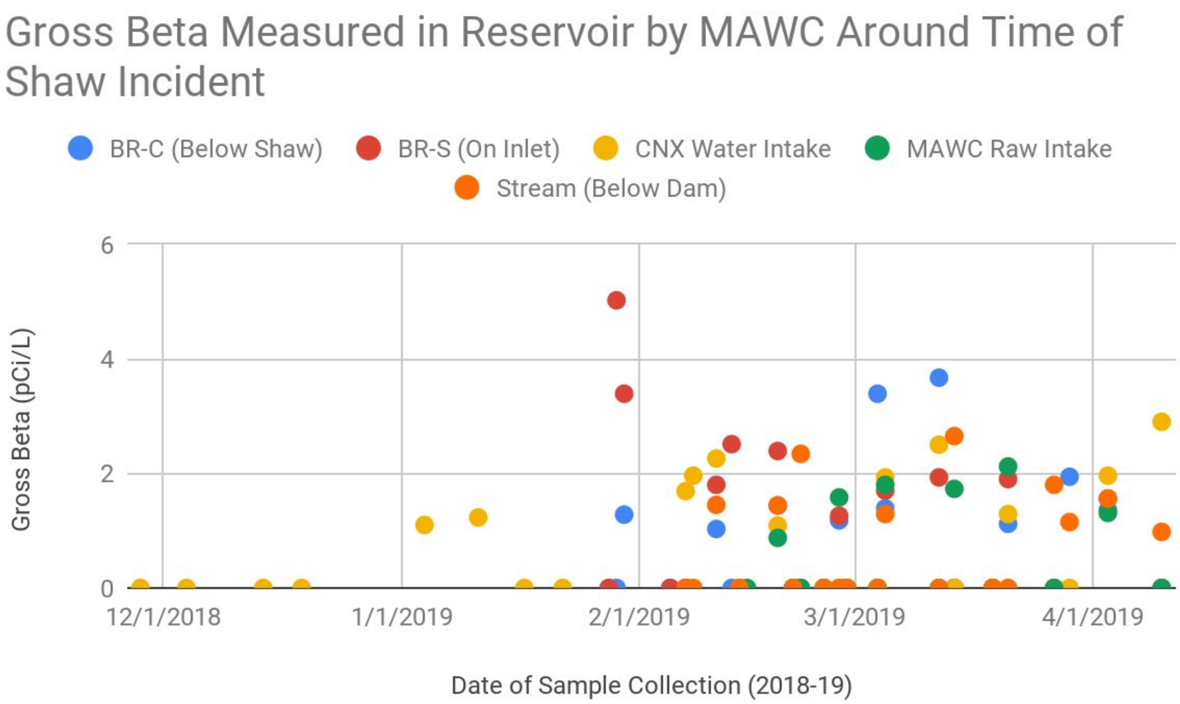
In 2019, CNX provided a report of radionuclide testing at various locations around the reservoir and dates. Radium 226 was recorded at six different times in the reservoir after the Shaw incident, with another value measured days before at the CNX water intake site. Two of these values, 1.6 pCi/L on March 5th and 0.595 pCi/L on March 12th, were measured at the CNX water intake. At the BR-C site, two additional values were measured as 0.709 pCi/L and 0.414 pCi/L on January 29th and 30th, respectively. These values were reported days after the incident. The testing lab is assumed to be Environmental Services Laboratories as the datasheet only said "ESL" and the method of testing is unknown.

Both the MAWC raw water intake and stream site below the dam had a single measurable value of Radium 226 following the Shaw incident. The value recorded at the MAWC raw water intake was 0.394 pCi/L on March 12th and the value from the stream was 0.286 pCi/L on March 29th. The method of analysis Pace Analytical followed was EPA method 900.0. Radium 228 was measured three separate times in the Beaver Run Reservoir following the Shaw incident. Two of these values, 0.629 pCi/L and 0.7 pCi/L, were recorded at the BR-S site on January 30th and February 28th. The largest value, taken at the MAWC raw water intake on March 27th, was 1.08 pCi/L.

MAWC is required to test radionuclides every five years at a minimum. The combined total for Radium 226 and Radium 228 is recommended by the EPA to not exceed 5 pCi/L. The highest total radium measured on any particular day was 1.6 pCi/L on March 5th. That value was measured as only Radium 226 and resulted in a buffer of 3.4 pCi/L from the recommended MCL. Two other days, January 30th and March 27th had total radium above 1 pCi/L, with values of 1.043 pCi/L and 1.08 pCi/L, respectively. The five other days in which either radium 226, radium 228, or both were measured were below 1 pCi/L.



The CNX report listed measurable Gross Alpha values in five samples collected following the Shaw incident. Four of these values were measured at the BR-S site with those values being 3.27 pCi/L on January 29th, 1.55 pCi/L on January 30th, 0.449 pCi/L on February 11th, and 1.1 pCi/L on February 27th. The remaining value, 1.3 pCi/L, was from a sample taken from the CNX water intake on February 11th. These values cannot be compared to the Gross Alpha at these sites prior to the Shaw incident because only the CNX water intake was being monitored for Gross Alpha at that time. The Gross Alpha emitters from Consumer Confidence Reports were 3.0 pCi/L which is similar to the high value measured following the Shaw incident. As with the Radium values reported by CNX above, the testing laboratory is assumed to be Environmental Services Laboratories and the method is unknown.



The largest Gross Beta measured in the reservoir after the Shaw well pad incident was 5.02 pCi/L on January 29th. Among these larger values are 3.67 ppm on March 12th, and 3.39 ppm on both January 30th and March 4th. There is a large cluster of recorded values following the Shaw incident. This cannot be compared to the water prior to the incident because only the CNX water intake was being monitored for Gross Beta at that time. Gross Beta was provided in pCi/L but a conversion could not be found to compare to the MCL of 4 mrem/yr. Additionally, Gross Beta particles have not been displayed in the annual Consumer Confidence Reports since 2010 in spite of having a reported value of 0 from 2011 appearing in that report.

Disinfection Byproducts

Disinfection byproducts are chemical substances formed when organic compounds present in water react with disinfectants such as chlorine or chloramines added to prevent microbial growth. Hundreds of compounds have been identified as disinfection byproducts, but two classes of these chemicals are currently used as indicator chemicals for regulated disinfection byproducts: trihalomethanes (THMs) and haloacetic acids (HAAs). Due to their status as indicator chemicals and because some forms of THMs and HAAs are potential carcinogens, state and federal regulations limit the concentration of THMs and HAAs in drinking water to 80 ppm and 60 ppm, respectively [52].

Disinfection by-products (DBP) include a range of over 600 known and unknown compounds that form when organic compounds react with chlorine or chloramine during water treatment [29]. DPB compounds also form when bromine, a substance common in fracking waste, is present in source waters. For example, concentrations of Pittsburgh drinking water DPBs increased due to increased bromine in source waters when gas and oil industry waste was released into the Allegheny River [29].

DPBs are considered carcinogenic, in part, because the use of chlorinated water is associated with increases in cancer, especially bladder and colorectal cancer [53, 54]. Other effects of DBPs include adverse reproductive outcomes such as low birth weight and health problems in children whose mothers used chlorinated drinking water during pregnancy. DPBs are permitted in drinking water as a compromise because, thus far, chlorine is a cost-effective substance to limit bacteria in large water distribution systems, such as MAWC.

The EPA regulates a few DBPs for drinking water, requiring regular testing, reporting and limits; others DPBs have yet to be regulated or even measured by water treatment operators. For example, Haloacetic acids (HAs) are formed when chlorine reacts with organic compounds in water such as methane, ethane or more complex compounds. Currently, the EPA sets limits of Total Haloacetic Acids (THA) at 80 ppb and Haloacetic Acid 5 (HA5) at 60 ppb, but these limits may be lowered in the future due to public health concerns. MAWC reports THA, HA5, HA9 and bromide concentrations.

Unregulated DBPs such as haloacetonitriles (HANs) are formed when chloramines are used to control bacterial growth. HANs are more toxic than HAs. As seen in Fig 3, current measures of some regulated DBP's might make one water sample appear to be acceptable and less harmful than another water sample. Newer measures of more DBP's using toxicity show the accepted water sample is more toxic [53]. At BRR, managers switch from treatment with chlorine to chloramines on a regular basis. They do not report HANs [11].

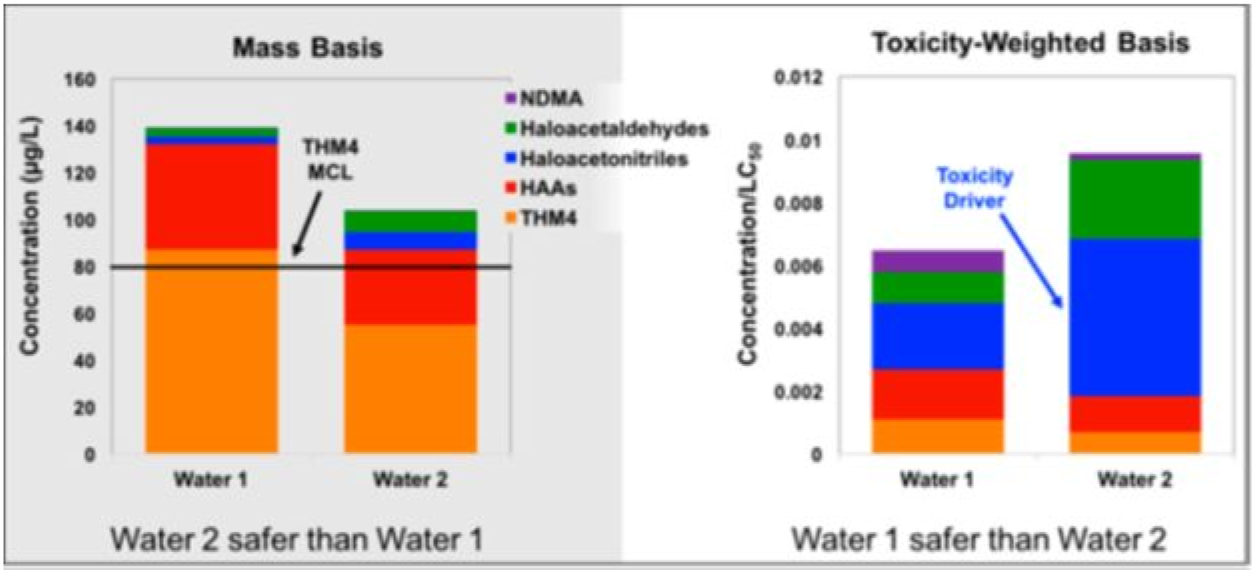
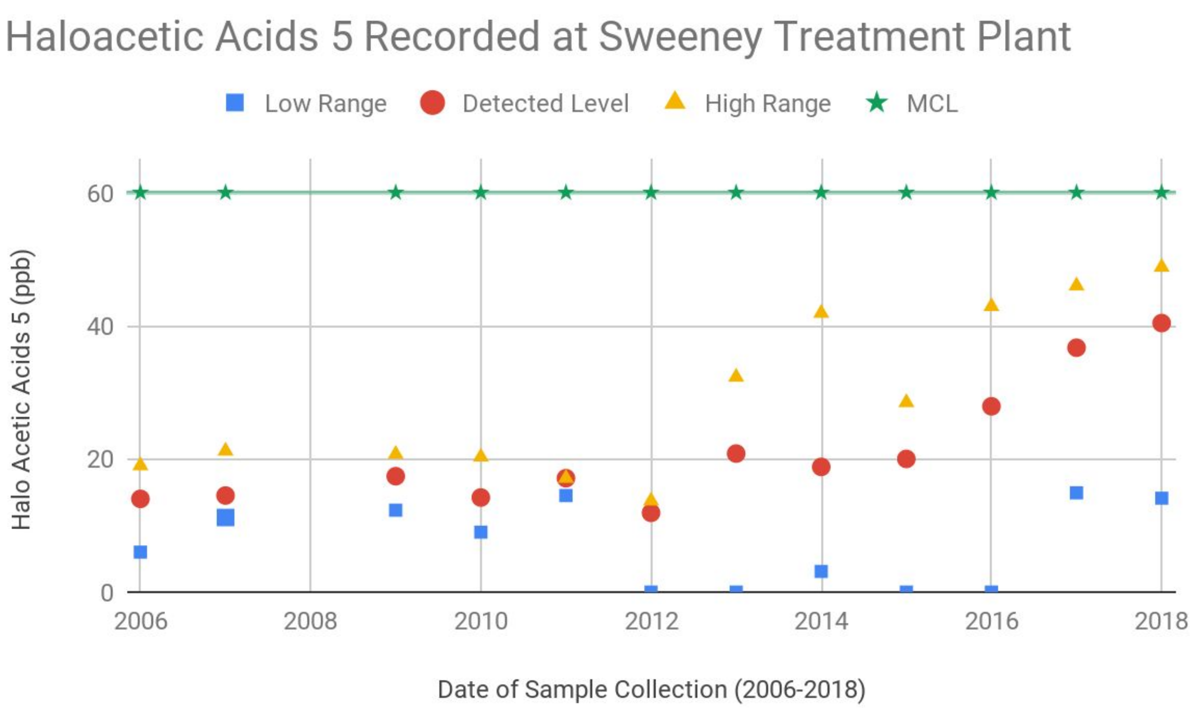


Fig 3. Left graph illustrates the conventional evaluation of disinfection byproducts by mass in which Water 1 is assumed to be more harmful than Water 2 and Water 1 is out of compliance, especially because Trihalomethane 4 (THM4) is above the 80 ppb limit. Right graph illustrates the proposed evaluation of disinfection byproducts by toxicity in which Water 2 is more toxic than Water 1, especially because Haloacetonitriles are more toxic than Halomethanes. Source: Li and Mitch 2018 [53].

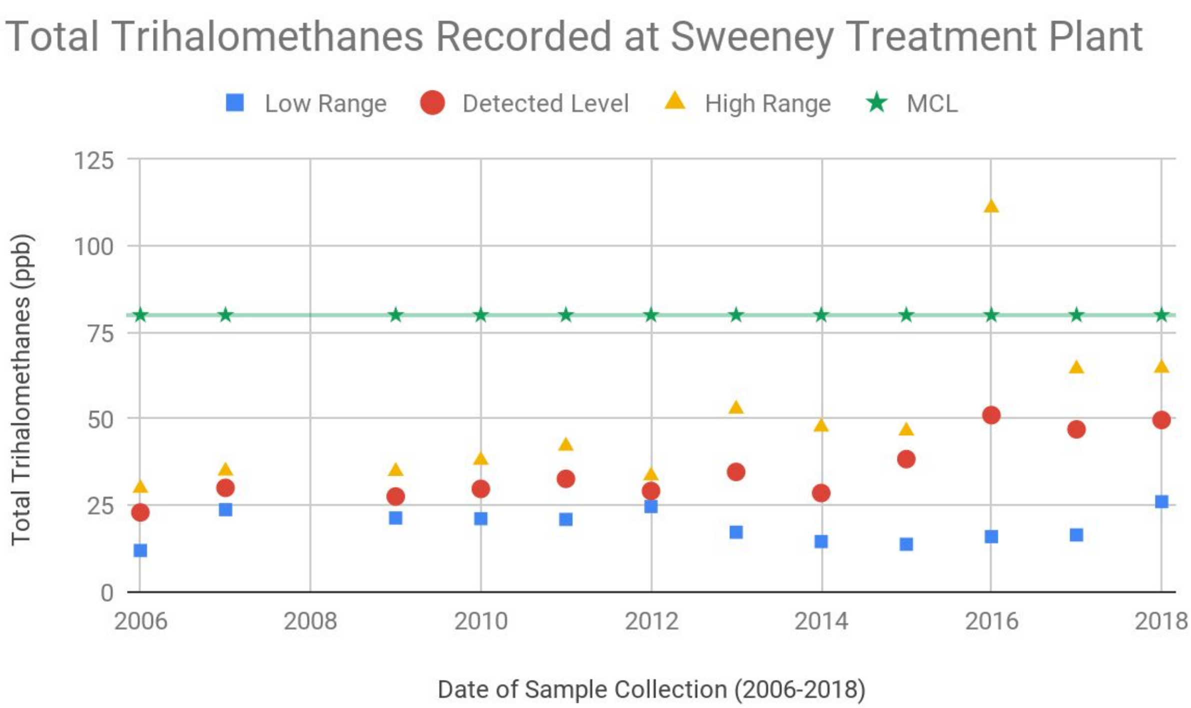
Haloacetic Acids 5



The data was collected through the annual Consumer Confidence Reports that are supplied by MAWC where values are reported as a “Detected Level” and a range of two values above and below the detected value. The detected levels are assumed to be averages of measurements taken throughout the year since there was no other specification and it was not the midpoint of the range. The detection level of Haloacetic Acids 5 (HAA5) has been on a rising trend since at least 2010. The highest detected value was measured in 2018 and was 40.4 ppb. Furthermore, the high end of the range measured in 2018 was found to be 48.8 ppb. The maximum contaminant level (MCL) for HAA5 is 60 ppb meaning the high end of the range came within 11.2 ppb of reaching that level.

HAA5 was recorded twice in the 2018 Consumer Confidence Report to show an additional breakdown of disinfection byproducts. The broken-down values should have summed to the total HAA5; instead, they exceeded that value.

Total Trihalomethanes

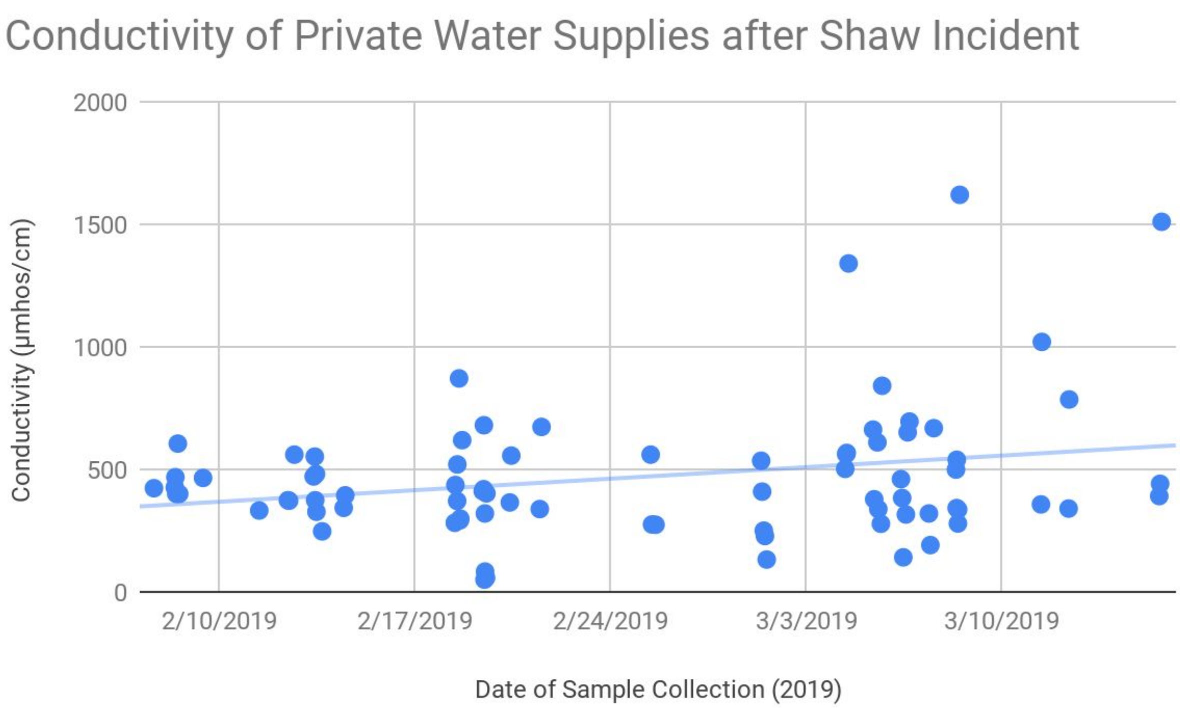


Total Trihalomethane information was collected through the annual Consumer Confidence Report created by MAWC where values are reported as a “Detected Level” and a range of two values above and below the detected value. The MCL level for total trihalomethanes is 80 ppb while the highest detected level was 51.1 ppb in 2016. The largest high range, also measured in 2016, was 111 ppb which is 31 ppb over the MCL. There appears to be a clear increase in Total Trihalomethanes measured at the Sweeney Treatment Plant from 2006 to 2018, with a notable rise after 2014. The initial detected level in 2006 was 23 ppb, while the most recent detected level was 49.7 ppb, an increase of over double the original level. The high and low ranges also have more than doubled when compared to the 2006 levels.

CNX Report Data Regarding Private Water Supplies

Following the Shaw incident, CNX sent water samples from private parcels to Microbac Laboratories for testing. These testing parameters included general chemistry constituents, metals, anions, gases, and BTEX's (benzene, toluene, ethylbenzene, and xylenes.) For example, some of the various parameters that were measured for were conductivity, manganese, methane, and benzene. The findings in the CNX Report claimed the gas chemistry in the private water wells was "consistent with gas from the Mississippian and Upper Devonian formations in this area of the basin, and not from the Utica Formation" [55].

Conductivity in Private Water Supplies

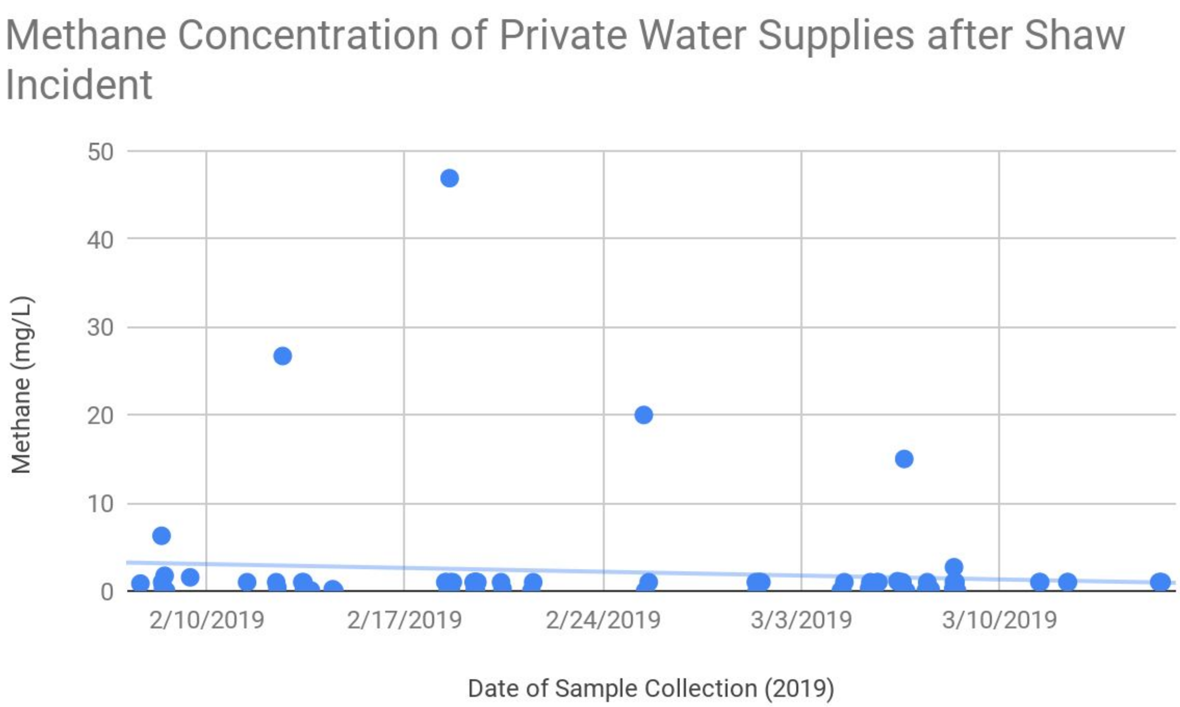


Many of the conductivities were above 500 µS, including four samples above 1,000 µS. The two highest conductivity values were found to be 1,620 µS on March 8th and 1,510 µS on March 15th. All samples tested were above 125 µS with the exceptions of 82.9 µS and 57.7 µS, both on February 19th.

The conductivity values measured after the Shaw well pad are within expected values considering freshwater has a conductivity that ranges between 100 µS/cm and 2,000 µS/cm [41]. Despite this, the reservoir was found to have conductivity well below the values in the CNX report. The reservoir had conductivity concentrations that never exceeded 500 µS, which is less than half that of some of the concentrations recorded in the CNX report. Potable water typically has a conductivity that falls between 30 µS and 1,500 µS [41]. That means that a few of the recorded values are approaching levels that fall outside that range if they have not already.

Methane in Private Water Supplies

Methane is a combustible gas that can enter water sources through natural means. It also can contaminate water sources through nearby gas well drilling or coal mining. While drinking it may not be harmful, excessive concentrations of methane gas from private water wells could leak into homes and lead to a dangerous explosion [56]. MAWC does not explicitly test for methane but claims to test for chemical compounds that are mixed with methane, such as bromomethane and chloromethane. Microbac Laboratories, hired by CNX to test water samples collected around the Shaw well pad after the January pressure incident, measured methane in milligrams per liter (mg/L) while following EPA method RSK175.



Four private water sources measured for methane concentrations at greater than 10 mg/L. These values were 26.7 mg/L, 46.9 mg/L, 20.0 mg/L, and 15.0 mg/L on February 12th, 18th, 25th and March 6th ,respectively. Roughly half of the privately tested parcels had detectable levels of methane in the water samples taken.

Wells than have 10 mg/L of methane are considered safe, but anything above should be regularly monitored to ensure levels do not increase. In total, four private water samples had methane above 10 mg/L, meaning they all are recommended to have regular monitoring to ensure levels do not increase to dangerous values. It is recommended that a well with 28 mg/L or more of methane receive immediate action to decrease the amount in the water. It should be noted that one of the private samples had methane above 28 mg/L, at 46.9 mg/L, on February 18th, 24 days after the incident occurred. This private parcel was located approximately 1 mile from the Shaw well pad and the owner of the private well should have immediately taken actions to reduce the amount of methane in the water from which the sample was taken. The report did not indicate if residents of that home were informed.

Benzene in Private Water Supplies

Benzene is a chemical compound often used as a solvent and additive for industrial purposes [57]. Benzene that is found in water can come from natural occurrences, such as volcanoes, or chemical spills [58]. Benzene can also occur in Produced Fluids as part of the many organic compounds formed in shale and brought to the surface in fracking. Benzene occurs in water and other liquids and escapes into the air. Exposure to benzene can occur by drinking water or showering and bathing in contaminated water. Exposure to benzene can be dangerous to humans and has been linked to an increased risk of cancer. Contaminated groundwater has been measured to have benzene levels of 0.03 mg/L to 0.3 mg/L [57]. Microbac Laboratories followed EPA method 8260B/5030C to measure the amount of benzene in the samples taken after the January Shaw incident. Microbac Laboratories measured the methane concentration in units of micrograms per liter (μg/L).

Benzene was never detected above the reporting limit of 5.00 micrograms per liter (μg/L) throughout any of the samples taken following the Shaw incident.

Future Actions: Requirements and Recommendations

Several improvements in managing water at BRR should be begun immediately. These are listed here with explanations and details following the list.

1. Update emergency planning to ensure compliance with new EPCRA regulations and the capacity for rapid, independent testing of water, air and soils following incidents.
2. Take actions to reduce disinfection byproducts in drinking water, using standards that exceed regulations, thus ensuring daily water provides public health protection.
3. Bring water quality testing protocols in line with recommendations from TetraTech.
4. Engage a specialist on sediment hydrology to plan collection and regular testing of sediment in BRR and its tributaries.
5. Do not permit CNX or any future operators to store large quantities of diesel or fluid waste such as Produced Fluid on well pads in the vicinity of BRR or its tributaries.
6. MAWC Board should request no further UNGD on BRR property by contacting CNX and the PA DEP.

1. Updated Emergency Planning

New emergency planning efforts are warranted at BRR.

A. New Regulations - The 2017 EPA Water Infrastructure Act outlines special responsibilities of public water suppliers [59].
   a. *Action:* MAWC must have an updated list of all the chemicals present on all well pads and in vehicles or other containers. Chemicals must be fully described using standard chemical nomenclature and CAS reference numbers, not names used by the operators. MSDS sheets should be provided for all chemicals. Any substance that presents a biological, chemical or physical hazard must receive special attention.

      Rationale: Operators are frequently revising operations and chemicals they use. The chemical list helps BRR water testing under normal operations. After an accident, even small releases of substances of special concern would trigger enhanced monitoring for those substances. Full chemical information is required to predict and test for the substances after they have interacted with highly reactive chemicals such as chlorine, or if they adhered to sediments.

B. Improve Accident Responses - MAWC should immediately take the following steps to ensure rapid collection of samples after an accident for scientific and legal use.
   a. *Action:* Engage a specialized emergency testing service to collect and analyze relevant samples of water, air and/or soil after an accident. This service should be able to begin sampling within 24 hrs. after notification.

      Rationale: For the past decade, responses from the DEP and CNX have proven to be inadequate. Records for the 20 accidents at BRR indicate sample collection and testing were conducted by CNX and operators at well pads. Rarely DEP or MAWC collected and tested samples. Most recently, after the Shaw incident, CNX and their consultant collected most samples days after the accident and used a flawed sampling design, thus preventing any meaningful conclusions. Days after the incident, MAWC contacted IUP faculty to collect water and air samples. IUP faculty have a contract and expertise in monitoring conditions under normal operations, however, and their laboratories are not certified.

   b. *Action*: Engage a consultant to plan the collection of samples of water, air and soil following an accident. Prepare to use BRR staff to begin simple sample collections within hours of an accident, with follow up by an emergency testing service.

      Rationale: Simulations of likely accidents and proper sampling are needed before an accident. Then, BRR staff and the emergency testing service can obtain relevant information. For example, after an incident such as the Shaw, BRR staff could have begun collecting water and air samples at predetermined locations based on a simulation. Water bottles for multi-parameter testing and air test Summa canisters can be stored at BRR. Staff can easily be trained for this initial sample collection. Then, within 24 hrs., the emergency testing service will continue and enhance sampling as needed.

2. Reduce Disinfection Byproducts and Improve Consumer Notification

Disinfection byproducts (DBD) in BRR water have reached levels of concern. Values shifted from consistently low numbers for the average and range in 2007-2009 to steadily rise after 2010 to averages that now approach the Maximum Contaminant Level (MCL) and ranges that exceed the MCL. Several simultaneous steps are needed to understand and manage the steady rise of DBP at BRR. This is critical because DBP is linked to cancer and other health problems.

A. *Action:* Investigate the types of substances, algae and bacteria that contribute to organic compounds and the formation of DPB. This requires additional sampling in the reservoir, tributaries and runoff from well pads and access roads.

   Rationale: Currently, in compliance with laws for quarterly tests, MAWC monitors raw and treated water for Total Organic Compounds (TOC). This measure is too general and too infrequent. The varieties of organic compounds and microorganisms must be known. Frequent monitoring will identify where and when carbon sources enter the reservoir.

B. *Action*: Begin an in-depth, ongoing assessment of source water through analysis of activities that contribute organic matter to surface waters.

   Rationale: Thus far, MAWC has been relying on occasional efforts to address source water protection and an outdated assessment. For example, the 2018 Consumer Confidence Report describes a 2002 Source Water Assessment by the DEP that states the waters of Sweeney, McKeesport and Indiana plants are "potentially most susceptible to accidental spills along major transportation corridors, releases of raw and/or under-treated sewage, and stormwater runoff from developed and/or agricultural areas. Also, Beaver Run is potentially susceptible to the cumulative release of petroleum products from nearby tank farms." Clearly, an updated effort is needed. MAWC should begin an analysis to link increased organic substances at certain tributaries or reservoir sites in relation to specific sources. They can compare logs of CNX operation schedules on well pads and truck deliveries, municipal records regarding sewage function and malfunctions, Army Corps of Engineer data regarding stream overflows, and the Conservation District records of schedules for construction and logging projects that require erosion and sedimentation control. This data collection and analysis should be ongoing to detect and anticipate problems with organic matter in BRR.

C. *Action*: MAWC should begin testing for disinfection byproducts from their chloramine treatment. These are called Haloacetonitriles (HAN) and are even more toxic than Haloacetic acids (HAA) [53].

Rationale: For several years, BRR managers shift seasonally to add both chlorine and ammonia to water just prior to distribution to customers. Research on this chloramine treatment shows it produces a variety of toxic compounds called Haloacetonitriles. The measurement of HAN is not currently required, but it is likely to be added. MAWC should start monitoring HAN now, given problems with TOC and increasing HAA. Measures of HAN should be added to the Consumer Confidence Report with an explanation.

D. *Action*: MAWC should quickly inform the public of problems with TOC and rising disinfection byproducts as soon as managers have measures. Customers can then explore options to treat their water or use alternate supplies.

Rationale: MAWC waited until spring 2019 to inform customers of problems with organic carbon that began the summer of 2018. For months, people unknowingly consumed water with elevated organic carbon and disinfection byproducts. Although this delay in notification might meet certain EPA guidelines, it does not protect the health of consumers. Numerous studies show disinfection byproducts are associated with serious health problems. Also, the letter MAWC sent to customers was copied from documents provided by the EPA and acknowledges health effects, as in the FAQ section quoted below.

"What should I do?

You do not need to do anything. No alternative (i.e. bottled water) water supply or boiling the water is necessary. However, if you have specific health concerns, consult your doctor.

What does this mean?

Total Organic Carbon (TOC) has **NO HEALTH EFFECTS**. TOC may provide a medium for the formation of disinfection byproduct. These byproducts include trihalomethanes (TTHM's) and haloacetic acids (HAA5's). Drinking water containing these TTHMs and HAA5s in **EXCESS of their MCL's** may lead to adverse health effects, liver, or kidney problems, or nervous system effects, and may lead to increased risk of getting cancer. [Emphases were in the original letter.]"

3. **Follow all recommendations for testing protocols and internally review compliance.**

Records indicate substantial gaps between testing recommended in 2016 and actual testing. Only a limited number of substances have been regularly tested and testing frequency falls far short of guidelines.

A. *Action*: Bring water testing in line with consultant recommendations.

   Rationale: Records show that substances on the recommended lists for testing were omitted or only rarely tested. The gaps extend to items recommended by the gas industry itself on web sites such as fracfocus.org. Poorly monitored substances include those important to health, such as radioactive elements and several organic substances. Also, the schedule for testing was not followed for routine conditions nor when changes occurred on well pads. Records indicate only one new drill site, Aikens, received weekly testing for a few months in 2017. In contrast, the consultant specified monthly water testing around every site for three months prior, during the work, and six months after any well pad activity.

   The consulting company has decades of experience in tracking water pollution from industrial sources and their protocols are designed to anticipate issues of health and possible legal action against industrial polluters. In contrast, BRR managers have experience treating healthy, rural water with traditional methods. Even top scientists continue to learn more pollution pathways from UNGD. Certainly, BRR managers do not have the time to gain expertise to qualify them to modify and reduce testing protocols.

B. *Action*: Engage a professional service with a certified laboratory to collect and test the water.

   Rationale: MAWC uses a changing mix of people to collect and test water samples, and this leaves gaps that prevent tracking pollution. MAWC contracted in 2011 with a local university for quarterly sampling. The lab is not certified. The project is educational, but it cannot establish the safety of a drinking water source. The need for professional services became most evident when IUP faculty were asked to collect water after a major accident at Shaw.

4. **Study sediments to track pollution and anticipate water quality problems.**

A. *Action*: MAWC should engage a specialist on sediment hydrology to plan collection and regular testing of sediments in the reservoir and its tributaries.

   Rationale: Recent research indicates sediments reveal water pollution history and risks that surface water testing does not track [60, 61]. Sediments release substances into surface waters. If any of those substances are toxic, upper layers of water become contaminated. Changing water treatment at the Sweeney facility takes time, sometimes months. If sediments show a problem, BRR managers can act more quickly to start changing water treatment. As with the water testing above, testing for relevant substances at a proper frequency is critical, or tests will give a false sense of security for reservoir managers and consumers

5. **Prohibit storage of large quantities of diesel, produced water, fracking fluid waste, or other hazardous material on well pads.**
   A. *Action:* Engage a qualified, independent engineer to recommend limits for the storage of hazardous fluids at reservoir sites that maximizes water safety.

   Rationale: Information from operators at CNX wells at BRR reveal millions of gallons of produced fluids (PF), fracking fluid waste (FF) and similar fluids are routinely present at well pads and thousands of gallons of diesel are stockpiled prior to fracking. This storage pattern may be permitted at UNGD well pads, but state regulations developed when UNGD occurred far from drinking water supplies or residents. The BRR property not only holds the water needed by 130,000 customers, but it is also a neighbor to nearby residents. Serious spills of diesel, PF and FF are likely, based on real-world incidents of large spills near the reservoir and the many smaller incidents at CNX wells at BRR. Reducing the volume and duration of hazard material storage reduces the risk of catastrophic loss of water quality.

6. **MAWC Board should request no further development of gas extraction efforts at BRR.**
   A. *Action*: MAWC Board should inform CNX and the PA DEP that they are opposed to further development of gas extraction efforts at BRR. This includes but is not limited to new or expanded well pads, new or repeat fracking, and adding a compressor station or other processing facility.

   Rationale: Every additional UNGD activity at BRR increases the chance for harm to the water supply. Improved testing recommended in this report will not prevent an accident, only document it. In 2009, when the MAWC board chose to receive money to allow well pads at BRR, less was known about the risks from the new form of fracking. Now, the Board has been informed of numerous relevant studies of hazards such as the likelihood of well-head failure, contamination from highly toxic produced fluids, and harm to human health from UNGD operations. The Board has seen a map showing lateral wells that extend throughout the entire reservoir. After 55 wells have been drilled over nine years, the Board has read 19 reports of spills of toxic fluids, a fire and most recently, a "catastrophic loss of containment" at the newest well. The Board must now act to reduce further risks.

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Appendix

Tables

Testing Frequency Matrix

Table 2A: Inorganic Constituent Recommended and Actual Testing Frequency			
Parameter	**Recommended Testing Frequency**	**Testing Frequency**	**Testing Method/Tool**
Alkalinity	Quarterly	Daily (MAWC)	Hach Model 1720E turbidimeter
Aluminum	Quarterly	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Arsenic	Quarterly	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Barium	Annually in October	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Boron	Quarterly		
Bromide	Quarterly	Periodically (IUP)	Ion Chromatography
Cadmium	Quarterly	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Calcium	Quarterly	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Chloride	Quarterly	Daily (MAWC)	Hach Model 1720E turbidimeter
Chromium	Quarterly	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Cobalt	Quarterly		
Copper	Quarterly		
Zinc	Quarterly		
Fluoride	Quarterly	Periodically (IUP)	Ion Chromatography
Gross Alpha Emitters	Annually in October	5 Years (MAWC)	EPA Method 900
Gross Beta Emitters	Annually in October	5 Years* (MAWC)	EPA Method 900
Hardness	Quarterly	Daily (MAWC)	Hach Model 1720E turbidimeter
Iron	Annually in October	Daily (MAWC)	Hach Model 1720E turbidimeter
Lead	Quarterly	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Lithium	Quarterly		
Magnesium	Quarterly	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Manganese	Annually in October	Daily (MAWC)	Hach Model 1720E turbidimeter
Molybdenum	Quarterly		
Nickel	Quarterly		
pH	Quarterly	4 Hours (MAWC)	Hach Model 1720E turbidimeter
Potassium	Quarterly		
Radium 226	Annually in October	5 Years (MAWC)	EPA Method 903.1
Radium 228	Annually in October	5 Years (MAWC)	EPA Method 904.0
Selenium	Quarterly		
Silver	Quarterly		
Sodium	Quarterly		
Specific Conductivity	Quarterly	Daily (MAWC)	Hach Model 1720E turbidimeter
Strontium	Annually in October	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Sulfate	Annually in October	Periodically (IUP)	Ion Chromatography
Sulfide	Quarterly		
Total Dissolved Solids	Quarterly	Periodically (IUP)	pH Combination meter
Total Mercury	Quarterly	Periodically (IUP)	Inductively Coupled Plasma-Optical Emission Spectroscopy
Total Suspended Solids	Quarterly		
Turbidity	Quarterly	4 Hours (MAWC)	Hach Model 1720E turbidimeter
Uranium	Annually in October	2011 (MAWC)	ASTM D5174.97
Vanadium	Annually in October		

Bold Constituents represent parameters that are recommended to be measured annually in October
All parameters refer to raw water tests unless otherwise stated

Table 2B: Organic Constituents Recommended by TetraTech and Actual Testing Frequency			
Parameter	**Recommended Testing Frequency**	**Actual Testing Frequency**	**Testing Method/Tool**
1,2 Propylene Glycol	Annually		
1,4 Dioxane	Annually		
Acetone	Annually	Quarterly* (MAWC)	
Acetophenone	Annually		
Benzyl Alcohol	Annually	Quarterly* (MAWC)	
BTEX	Annually	Quarterly* (MAWC)	
Carbon Disulfide	Annually		
Chloroform	Annually	Quarterly* (MAWC)	
Coliform (Total)	Quarterly	Daily* (MAWC)	
Cumene	Annually		
Cyanide	Annually		
Dichloromethane	Annually	Quarterly* (MAWC)	
Di-n-butyl phthalate	Annually		
E. Coli	Quarterly		
Ethane	Annually	Quarterly* (MAWC)	
Ethylene Glycol	Annually		
Fluoranthene	Annually	Quarterly* (MAWC)	
Fluorene	Annually	Quarterly* (MAWC)	
Formic Acid	Annually		
Isopropylbenzene	Annually	Quarterly* (MAWC)	
MBAS	Annually	Quarterly* (MAWC)	
Methane	Annually	Quarterly* (MAWC)	
Methanol	Annually		
Naphthalenes	Annually	Quarterly* (MAWC)	
Nitrate as Nitrogen	Monthly near farming activities	Periodically (IUP)	Ion Chromatography
Nitrite as Nitrogen	Monthly near farming activities		
Oil and Grease	Quarterly		
Volatile Organic Compounds	Annually	Quarterly* (MAWC)	EPA Method 8260B
Propane	Annually	Quarterly* (MAWC)	
Propargyl Alcohol	Annually		
Pyrene	Annually	Quarterly* (MAWC)	
Pyridine	Annually	Quarterly* (MAWC)	
Surfactants	Annually		
Total Petroleum Hydrocarbons	Annually	Quarterly* (MAWC)	
Phenol	Annually	Quarterly* (MAWC)	

*Claimed to be tested by MAWC but could not be substantiated for the purposes of this report

Bold Constituents represent parameters that are recommended to be measured annually in October

All parameters refer to raw water tests unless otherwise stated

Table 3. Inorganic Parameters Recommended by TetraTech as Needed to be Tested Annually		
Barium	Manganese	Sulfate
Gross Alpha Emitters	Radium 226	Uranium
Gross Beta Emitters	Radium 228	Vanadium
Iron	Strontium	

Table 4. Organic Parameters Recommended by TetraTech as Needed to be Tested Annually		
1,2-Propylene Glycol	Cumene	Methane
1,4 Dioxane	Cyanide	Methanol
Acetone	Dichloromethane	Naphthalenes
Acetophenone	Di-n-butyl phthalate	Volatile Organic Compounds
Benzyl Alcohol	Ethane	Propane
Benzene	Ethylene Glycol	Propargyl Alcohol
Toluene	Fluoranthene	Pyrene
Ethylbenzene	Fluorene	Pyridine
Xylenes	Formic Acid	Surfactants
Carbon Disulfide	Isopropylbenzene	Total Petroleum Hydrocarbons
Chloroform	Methylene Blue Activated S	Phenol

Table 5. Inorganic Parameters Recommended by TetraTech as Needed to be Tested Quarterly		
Alkalinity	Copper	Potassium
Aluminum	Zinc	Selenium
Arsenic	Fluoride	Silver
Boron	Hardness	Sodium
Bromide	Lead	Specific Conductivity
Cadmium	Lithium	Sulfide
Calcium	Magnesium	Total Dissolved Solids
Chloride	Molybdenum	Total Mercury
Chromium	Nickel	Total Suspended Solids
Cobalt	pH	Turbidity

Well Data

Table 6. Field Data from around the Shaw Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/16/2013	W-01	87	163
6/14/2013	W-01		
9/14/2013	W-01	137	274
1/2/2014	W-01	75	149
3/29/2014	W-01		
6/28/2014	W-01		
9/21/2014	W-01		
12/13/2014	W-01		
3/16/2013	W-02	82	164
6/14/2013	W-02		
9/14/2013	W-02		
1/2/2014	W-02		
3/29/2014	W-02		
6/28/2014	W-02		
9/21/2014	W-02		
12/13/2014	W-02		
3/16/2013	W-03	42	84
6/14/2013	W-03	47	95
9/14/2013	W-03	82	164
1/2/2014	W-03		
3/29/2014	W-03	60	120
6/28/2014	W-03	71	141
9/21/2014	W-03	89	178
12/13/2014	W-03	60	121
3/21/3015	W-03	39	77
6/26/2015	W-03	52	105
9/19/2015	W-03	106	213
12/15/2015	W-03	59	121
3/20/2016	W-03	53	105
6/25/2016	W-03	66	134
9/10/2016	W-03	76	154
12/18/2016	W-03	24	48
3/25/2017	W-03	47	92
6/24/2017	W-03	43	86
9/30/2017	W-03		
12/9/2017	W-03	43	84
3/23/2018	W-03	31	63
6/22/2018	W-03	30	61
9/22/2018	W-03	49	97
12/8/2018	W-03	52	105
2/3/2019	W-03	58	116
2/15/2019	W-03	38	76
2/22/2019	W-03	44	88
2/28/2019	W-03	50	101
3/6/2019	W-03	53	106

Table 6. Field Data from around the Shaw Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/21/2019	W-03	58	117
3/31/2019	W-03	69	139
3/16/2013	W-04	40	93
6/14/2013	W-04	56	113
9/14/2013	W-04	94	188
1/2/2014	W-04	53	105
3/29/2014	W-04	54	109
6/28/2014	W-04	58	117
9/21/2014	W-04	116	236
12/13/2014	W-04	86	166
3/21/3015	W-04	62	123
6/26/2015	W-04	70	141
9/19/2015	W-04	137	276
12/15/2015	W-04	71	142
3/20/2016	W-04	70	141
6/25/2016	W-04	85	171
9/10/2016	W-04	129	259
12/18/2016	W-04	28	57
3/25/2017	W-04	58	118
6/24/2017	W-04	50	99
9/30/2017	W-04	133	268
12/9/2017	W-04	75	151
3/23/2018	W-04	44	90
6/22/2018	W-04	45	91
9/22/2018	W-04	90	180
12/8/2018	W-04	74	151
2/3/2019	W-04	79	157
2/15/2019	W-04	57	113
2/22/2019	W-04	74	150
2/28/2019	W-04	67	136
3/6/2019	W-04	77	146
3/21/2019	W-04	58	117
3/31/2019	W-04	89	177
3/16/2013	W-05	55	111
6/14/2013	W-05	56	112
9/14/2013	W-05	107	213
1/2/2014	W-05	63	124
3/29/2014	W-05	84	167
6/28/2014	W-05	81	165
9/21/2014	W-05	126	252
12/13/2014	W-05	87	174
3/21/3015	W-05	56	111
6/26/2015	W-05	76	151
9/19/2015	W-05	150	302
12/15/2015	W-05	82	164

Table 6. Field Data from around the Shaw Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/20/2016	W-05	76	152
6/25/2016	W-05	91	183
9/10/2016	W-05		
12/18/2016	W-05	42	83
3/25/2017	W-05	70	139
6/24/2017	W-05	55	109
9/30/2017	W-05	136	274
12/9/2017	W-05	85	171
3/23/2018	W-05	82	164
6/22/2018	W-05	49	98
9/22/2018	W-05	94	188
12/8/2018	W-05	78	157
2/3/2019	W-05	85	169
2/15/2019	W-05	66	131
2/22/2019	W-05	69	138
2/28/2019	W-05	77	153
3/6/2019	W-05	85	170
3/21/2019	W-05	88	176
3/31/2019	W-05	92	185
3/16/2013	W-06	56	112
6/14/2013	W-06	66	133
9/14/2013	W-06	107	215
1/2/2014	W-06	54	107
3/29/2014	W-06	85	109
6/28/2014	W-06	92	183
9/21/2014	W-06	132	263
12/13/2014	W-06	88	178
3/21/3015	W-06	56	113
6/26/2015	W-06	77	152
9/19/2015	W-06	152	305
12/15/2015	W-06	84	169
3/20/2016	W-06	77	154
6/25/2016	W-06	93	189
9/10/2016	W-06	141	280
12/18/2016	W-06	42	86
3/25/2017	W-06	71	141
6/24/2017	W-06	56	112
9/30/2017	W-06		
12/9/2017	W-06	85	172
3/23/2018	W-06	83	166
6/22/2018	W-06	48	97
9/22/2018	W-06	92	185
12/8/2018	W-06	84	166
2/3/2019	W-06	89	177
2/15/2019	W-06	66	132

Table 6. Field Data from around the Shaw Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
2/22/2019	W-06	70	140
2/28/2019	W-06	80	160
3/6/2019	W-06	87	175
3/21/2019	W-06	90	181
3/31/2019	W-06	94	188
3/16/2013	W-07	41	82
6/14/2013	W-07	44	89
9/14/2013	W-07	74	148
1/2/2014	W-07	53	107
3/29/2014	W-07	68	137
6/28/2014	W-07	93	182
9/21/2014	W-07	105	210
12/13/2014	W-07	81	160
3/21/3015	W-07	54	107
6/26/2015	W-07	68	135
9/19/2015	W-07	130	261
12/15/2015	W-07	64	128
3/20/2016	W-07	62	124
6/25/2016	W-07	70	140
9/10/2016	W-07	119	238
12/18/2016	W-07	41	81
3/25/2017	W-07	54	110
6/24/2017	W-07	47	95
9/30/2017	W-07		
12/9/2017	W-07	65	129
3/23/2018	W-07	62	130
6/22/2018	W-07	47	93
9/22/2018	W-07	98	195
12/8/2018	W-07	62	128
2/3/2019	W-07	77	153
2/15/2019	W-07	68	135
2/22/2019	W-07	87	175
2/28/2019	W-07		
3/6/2019	W-07		
3/21/2019	W-07	77	154
3/31/2019	W-07	81	163
3/16/2013	W-08	43	88
6/14/2013	W-08	40	80
9/14/2013	W-08	51	102
1/2/2014	W-08	48	93
3/29/2014	W-08		
6/28/2014	W-08		
9/21/2014	W-08		
12/13/2014	W-08		
3/16/2013	W-09	37	72

Table 6. Field Data from around the Shaw Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
6/14/2013	W-09		
9/14/2013	W-09		
1/2/2014	W-09	54	105
3/29/2014	W-09		
6/28/2014	W-09		
9/21/2014	W-09		
12/13/2014	W-09		
3/16/2013	W-10	46	93
6/14/2013	W-10	55	111
9/14/2013	W-10	84	170
1/2/2014	W-10	58	117
3/29/2014	W-10	47	94
6/28/2014	W-10		
9/21/2014	W-10	109	218
12/13/2014	W-10	78	158
3/21/3015	W-10	46	93
6/26/2015	W-10	66	132
9/19/2015	W-10	121	245
12/15/2015	W-10	80	161
3/20/2016	W-10	61	121
6/25/2016	W-10	79	160
9/10/2016	W-10	117	240
12/18/2016	W-10	34	68
3/25/2017	W-10	56	112
6/24/2017	W-10	50	99
9/30/2017	W-10	119	241
12/9/2017	W-10	71	141
3/23/2018	W-10	64	127
6/22/2018	W-10	44	87
9/22/2018	W-10	86	170
12/8/2018	W-10	70	142
2/3/2019	W-10	71	143
2/15/2019	W-10	56	112
2/22/2019	W-10	64	127
2/28/2019	W-10	62	126
3/6/2019	W-10	73	145
3/21/2019	W-10	77	157
3/31/2019	W-10	79	158
3/16/2013	W-11	47	94
6/14/2013	W-11	57	112
9/14/2013	W-11		
1/2/2014	W-11		
3/29/2014	W-11	66	132
6/28/2014	W-11	75	150
9/21/2014	W-11		

Table 6. Field Data from around the Shaw Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
12/13/2014	W-11		
3/16/2013	W-12	47	92
6/14/2013	W-12	56	112
9/14/2013	W-12	75	151
1/2/2014	W-12	59	122
3/29/2014	W-12	65	131
6/28/2014	W-12	73	146
9/21/2014	W-12	89	177
12/13/2014	W-12	71	143
3/21/3015	W-12	46	93
6/26/2015	W-12	54	108
9/19/2015	W-12	101	206
12/15/2015	W-12	69	138
3/20/2016	W-12	61	122
6/25/2016	W-12	70	140
9/10/2016	W-12	101	202
12/18/2016	W-12	34	69
3/25/2017	W-12	54	107
6/24/2017	W-12	47	94
9/30/2017	W-12	99	199
12/9/2017	W-12	67	135
3/23/2018	W-12	61	121
6/22/2018	W-12	43	86
9/22/2018	W-12	76	152
12/8/2018	W-12	64	128
2/3/2019	W-12	68	138
2/15/2019	W-12	52	104
2/22/2019	W-12	56	112
2/28/2019	W-12	59	118
3/6/2019	W-12	67	133
3/21/2019	W-12	67	133
3/31/2019	W-12	72	143
3/16/2013	W-13	52	101
6/14/2013	W-13	56	111
9/14/2013	W-13	74	149
1/2/2014	W-13	57	116
3/29/2014	W-13	68	136
6/28/2014	W-13	74	148
9/21/2014	W-13	86	172
12/13/2014	W-13	73	144
3/21/3015	W-13	48	96
6/26/2015	W-13	54	107
9/19/2015	W-13	94	188
12/15/2015	W-13	70	141
3/20/2016	W-13	60	119

Table 6. Field Data from around the Shaw Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
6/25/2016	W-13	70	139
9/10/2016	W-13	96	193
12/18/2016	W-13	33	66
3/25/2017	W-13	55	109
6/24/2017	W-13	45	89
9/30/2017	W-13	102	208
12/9/2017	W-13	67	133
3/23/2018	W-13	59	119
6/22/2018	W-13	44	88
9/22/2018	W-13	75	149
12/8/2018	W-13	64	128
2/3/2019	W-13	65	133
2/15/2019	W-13	52	104
2/22/2019	W-13	55	110
2/28/2019	W-13	60	119
3/6/2019	W-13	66	132
3/21/2019	W-13	67	133
3/31/2019	W-13	60	120
3/16/2013	W-14	48	97
6/14/2013	W-14		
9/14/2013	W-14	73	147
1/2/2014	W-14	58	118
3/29/2014	W-14	65	131
6/28/2014	W-14	74	146
9/21/2014	W-14	88	175
12/13/2014	W-14	76	151
3/21/3015	W-14	46	94
6/26/2015	W-14	66	131
9/19/2015	W-14	94	188
12/15/2015	W-14	73	146
3/20/2016	W-14	60	120
6/25/2016	W-14	73	146
9/10/2016	W-14	93	185
12/18/2016	W-14	32	64
3/25/2017	W-14	57	114
6/24/2017	W-14	47	93
9/30/2017	W-14	100	203
12/9/2017	W-14	68	136
3/23/2018	W-14	60	120
6/22/2018	W-14	44	88
9/22/2018	W-14	75	150
12/8/2018	W-14	66	131
2/3/2019	W-14	67	135
2/15/2019	W-14	52	103
2/22/2019	W-14	52	104
2/28/2019	W-14	60	120
3/6/2019	W-14	66	133
3/21/2019	W-14	68	135
3/31/2019	W-14	71	142

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
5/17/2011	A-01	130	
3/1/2012	A-01	88	174
9/12/2011	A-01	229	461
12/2/2011	A-01	157	310
3/1/2012	A-01	88	174
6/15/2012	A-01	212	425
9/7/2012	A-01	233	470
12/5/2012	A-01		
3/7/2013	A-01	112	227
6/14/2013	A-01	146	293
9/14/2013	A-01	185	370
12/30/2013	A-01	140	281
3/29/2014	A-01	184	369
6/28/2014	A-01	221	445
9/21/2014	A-01	204	412
12/12/2014	A-01	199	398
3/21/2015	A-01	111	222
6/26/2015	A-01	156	315
9/19/2015	A-01	253	522
12/15/2015	A-01	157	315
3/20/2016	A-01	151	302
6/25/2016	A-01	171	342
9/10/2016	A-01	208	415
12/18/2016	A-01	63	125
3/25/2017	A-01	138	274
6/24/2017	A-01	97	191
9/23/2017	A-01		
12/9/2017	A-01	105	214
3/23/2018	A-01	102	203
6/22/2018	A-01	118	240
9/22/2018	A-01	133	266
12/8/2018	A-01	129	259
3/31/2019	A-01	159	318
3/1/2012	A-02	105	210
5/17/2011	A-02	125	
9/12/2011	A-02	232	464
12/2/2011	A-02	161	321
3/1/2012	A-02	105	210
6/15/2012	A-02	211	423
9/7/2012	A-02	233	470
12/5/2012	A-02	144	289
3/7/2013	A-02	122	242
6/14/2013	A-02	162	325
9/14/2013	A-02	166	332
12/30/2013	A-02	140	282

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/29/2014	A-02	195	390
6/28/2014	A-02	201	402
9/21/2014	A-02	224	452
12/12/2014	A-02	198	396
3/21/2015	A-02	143	287
6/26/2015	A-02	168	335
9/19/2015	A-02	219	442
12/15/2015	A-02	164	330
3/20/2016	A-02	156	313
6/25/2016	A-02	173	347
9/10/2016	A-02	192	384
12/18/2016	A-02	70	141
3/25/2017	A-02	147	292
6/24/2017	A-02	111	222
9/23/2017	A-02	199	392
12/9/2017	A-02	123	332
3/23/2018	A-02	116	232
6/22/2018	A-02	122	244
9/22/2018	A-02	135	270
12/8/2018	A-02	135	269
3/31/2019	A-02	162	319
3/1/2012	A-03	107	214
5/17/2011	A-03	113	
9/12/2011	A-03	72	148
12/2/2011	A-03	144	291
3/1/2012	A-03	107	214
6/15/2012	A-03	184	364
9/7/2012	A-03		
12/5/2012	A-03	139	279
3/7/2013	A-03	113	228
6/14/2013	A-03	137	293
9/14/2013	A-03	170	341
12/30/2013	A-03	131	266
3/29/2014	A-03	167	334
6/28/2014	A-03	82	167
9/21/2014	A-03	193	386
12/12/2014	A-03	182	368
3/21/2015	A-03		
3/1/2012	A-04	64	127
5/17/2011	A-04	71	
9/12/2011	A-04	144	272
12/2/2011	A-04	58	114
3/1/2012	A-04	64	127
6/15/2012	A-04	108	215
9/7/2012	A-04	106	213

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
12/5/2012	A-04	93	186
3/7/2013	A-04	72	148
6/14/2013	A-04	75	150
9/14/2013	A-04	110	221
12/30/2013	A-04	91	188
3/29/2014	A-04	78	155
6/28/2014	A-04	91	180
9/21/2014	A-04	109	218
12/12/2014	A-04	101	208
3/21/2015	A-04	59	118
6/26/2015	A-04	75	150
9/19/2015	A-04	136	270
12/15/2015	A-04	74	146
3/20/2016	A-04	59	119
6/25/2016	A-04	88	178
9/10/2016	A-04	139	278
12/18/2016	A-04	56	112
3/25/2017	A-04	64	127
6/24/2017	A-04	62	124
9/23/2017	A-04	105	211
12/9/2017	A-04	157	307
3/23/2018	A-04	89	178
6/22/2018	A-04	59	118
9/22/2018	A-04	82	165
12/8/2018	A-04	97	194
3/31/2019	A-04	96	191
3/1/2012	A-05	61	122
5/17/2011	A-05		
9/12/2011	A-05	72	144
12/2/2011	A-05	57	114
3/1/2012	A-05	61	122
6/15/2012	A-05	106	211
9/7/2012	A-05	108	218
12/5/2012	A-05	87	176
3/7/2013	A-05	64	128
6/14/2013	A-05	69	139
9/14/2013	A-05	100	199
12/30/2013	A-05	73	148
3/29/2014	A-05	74	147
6/28/2014	A-05	90	181
9/21/2014	A-05	110	222
12/12/2014	A-05	83	166
3/21/2015	A-05		
3/1/2012	A-06	60	123
5/17/2011	A-06	61	

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
9/12/2011	A-06	70	140
12/2/2011	A-06	56	112
3/1/2012	A-06	60	123
6/15/2012	A-06	107	211
9/7/2012	A-06	108	215
12/5/2012	A-06	87	175
3/7/2013	A-06	64	128
6/14/2013	A-06	69	138
9/14/2013	A-06	98	198
12/30/2013	A-06	73	147
3/29/2014	A-06	76	147
6/28/2014	A-06	90	177
9/21/2014	A-06	109	220
12/12/2014	A-06	83	164
3/21/2015	A-06		
3/1/2012	A-07	61	120
5/17/2011	A-07		
9/12/2011	A-07	72	141
12/2/2011	A-07	56	112
3/1/2012	A-07	61	120
6/15/2012	A-07	107	214
9/7/2012	A-07	110	223
12/5/2012	A-07	87	173
3/7/2013	A-07	63	129
6/14/2013	A-07	69	138
9/14/2013	A-07	99	198
12/30/2013	A-07	72	147
3/29/2014	A-07	73	146
6/28/2014	A-07	90	179
9/21/2014	A-07	108	214
12/12/2014	A-07	83	169
3/21/2015	A-07		
3/1/2012	A-08	61	121
5/17/2011	A-08	66	
9/12/2011	A-08	69	139
12/2/2011	A-08	55	110
3/1/2012	A-08	61	121
6/15/2012	A-08	98	198
9/7/2012	A-08	103	205
12/5/2012	A-08	85	171
3/7/2013	A-08	63	125
6/14/2013	A-08	68	137
9/14/2013	A-08	95	187
12/30/2013	A-08	72	144
3/29/2014	A-08	70	140

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
6/28/2014	A-08	87	176
9/21/2014	A-08	101	202
12/12/2014	A-08	80	166
3/21/2015	A-08	64	128
6/26/2015	A-08	82	163
9/19/2015	A-08	135	272
12/15/2015	A-08	78	156
3/20/2016	A-08	61	121
6/25/2016	A-08	91	184
9/10/2016	A-08	128	256
12/18/2016	A-08	49	97
3/25/2017	A-08	66	132
6/24/2017	A-08	66	132
9/23/2017	A-08	104	210
12/9/2017	A-08	73	146
3/23/2018	A-08	74	149
6/22/2018	A-08	63	127
9/22/2018	A-08	80	160
12/8/2018	A-08	70	139
3/31/2019	A-08	86	173
3/1/2012	A-09	48	99
5/17/2011	A-09		
9/12/2011	A-09	71	148
12/2/2011	A-09	47	92
3/1/2012	A-09	48	99
6/15/2012	A-09	98	197
9/7/2012	A-09	109	218
12/5/2012	A-09	85	173
3/7/2013	A-09	62	124
6/14/2013	A-09	66	133
9/14/2013	A-09	94	188
12/30/2013	A-09	72	144
3/29/2014	A-09	70	138
6/28/2014	A-09	82	165
9/21/2014	A-09	101	202
12/12/2014	A-09	81	162
3/21/2015	A-09	63	127
6/26/2015	A-09	65	131
9/19/2015	A-09	132	266
12/15/2015	A-09	77	156
3/20/2016	A-09	59	119
6/25/2016	A-09	91	181
9/10/2016	A-09	125	250
12/18/2016	A-09	47	92
3/25/2017	A-09	65	128

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
6/24/2017	A-09	64	129
9/23/2017	A-09	106	213
12/9/2017	A-09	74	148
3/23/2018	A-09	71	141
6/22/2018	A-09	62	125
9/22/2018	A-09	81	163
12/8/2018	A-09	70	140
3/31/2019	A-09	91	183
3/1/2012	A-10	59	115
5/17/2011	A-10		
9/12/2011	A-10	71	143
12/2/2011	A-10	54	109
3/1/2012	A-10	59	115
6/15/2012	A-10	96	190
9/7/2012	A-10	102	205
12/5/2012	A-10	84	164
3/7/2013	A-10	63	125
6/14/2013	A-10	58	129
9/14/2013	A-10	92	183
12/30/2013	A-10	69	139
3/29/2014	A-10	69	138
6/28/2014	A-10	84	168
9/21/2014	A-10	101	201
12/12/2014	A-10	78	155
3/21/2015	A-10	61	120
6/26/2015	A-10	77	154
9/19/2015	A-10	120	242
12/15/2015	A-10	75	151
3/20/2016	A-10	59	118
6/25/2016	A-10	89	179
9/10/2016	A-10	115	230
12/18/2016	A-10	46	92
3/25/2017	A-10	64	128
6/24/2017	A-10	63	127
9/23/2017	A-10	103	208
12/9/2017	A-10	72	142
3/23/2018	A-10	68	139
6/22/2018	A-10	60	118
9/22/2018	A-10	79	159
12/8/2018	A-10	68	135
3/31/2019	A-10	89	179
3/1/2012	A-11	56	113
5/17/2011	A-11	68	
9/12/2011	A-11	74	149
12/2/2011	A-11	56	110

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/1/2012	A-11	56	113
6/15/2012	A-11	107	212
9/7/2012	A-11	118	238
12/5/2012	A-11	82	164
3/7/2013	A-11	62	125
6/14/2013	A-11	65	130
9/14/2013	A-11	93	187
12/30/2013	A-11	68	136
3/29/2014	A-11	70	140
6/28/2014	A-11	83	165
9/21/2014	A-11	100	201
12/12/2014	A-11	79	158
3/21/2015	A-11	58	117
6/26/2015	A-11	78	156
9/19/2015	A-11	106	213
12/15/2015	A-11	76	153
3/20/2016	A-11	58	117
6/25/2016	A-11	89	178
9/10/2016	A-11	110	217
12/18/2016	A-11	44	87
3/25/2017	A-11	63	125
6/24/2017	A-11		
9/23/2017	A-11	104	209
12/9/2017	A-11	74	147
3/23/2018	A-11	68	137
6/22/2018	A-11	58	117
9/22/2018	A-11	79	158
12/8/2018	A-11	68	137
3/31/2019	A-11	88	175
3/1/2012	A-12	54	112
5/17/2011	A-12	49	
9/12/2011	A-12		
12/2/2011	A-12		
3/1/2012	A-12	54	112
6/15/2012	A-12	83	166
9/7/2012	A-12		
12/5/2012	A-12		
3/7/2013	A-12	73	145
6/14/2013	A-12	72	144
9/14/2013	A-12	107	214
12/30/2013	A-12	100	190
3/29/2014	A-12		
6/28/2014	A-12		
9/21/2014	A-12		
12/12/2014	A-12		

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/21/2015	A-12	84	171
6/26/2015	A-12	85	169
9/19/2015	A-12		
12/15/2015	A-12		
3/20/2016	A-12	90	180
6/25/2016	A-12	112	223
9/10/2016	A-12		
12/18/2016	A-12	60	121
3/25/2017	A-12	90	182
6/24/2017	A-12	88	175
9/23/2017	A-12		
12/9/2017	A-12		
3/23/2018	A-12		
6/22/2018	A-12	72	147
9/22/2018	A-12		
12/8/2018	A-12		
3/31/2019	A-12		
3/1/2012	A-13		
5/17/2011	A-13	29	
9/12/2011	A-13		
12/2/2011	A-13		
3/1/2012	A-13		
6/15/2012	A-13		
9/7/2012	A-13		
12/5/2012	A-13		
3/7/2013	A-13		
6/14/2013	A-13		
9/14/2013	A-13		
12/30/2013	A-13		
3/29/2014	A-13		
6/28/2014	A-13		
9/21/2014	A-13		
12/12/2014	A-13		
3/1/2012	A-14	129	257
5/17/2011	A-14	80	
9/12/2011	A-14		
12/2/2011	A-14	147	294
3/1/2012	A-14	129	257
6/15/2012	A-14		
9/7/2012	A-14		
12/5/2012	A-14		
3/7/2013	A-14	84	176
6/14/2013	A-14		
9/14/2013	A-14		
12/30/2013	A-14	138	270

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/29/2014	A-14		
6/28/2014	A-14		
9/21/2014	A-14		
12/12/2014	A-14		
3/21/2015	A-14	17	35
6/26/2015	A-14	165	329
9/19/2015	A-14		
12/15/2015	A-14		
3/20/2016	A-14		
6/25/2016	A-14		
9/10/2016	A-14		
12/18/2016	A-14		
3/25/2017	A-14		
6/24/2017	A-14		
9/23/2017	A-14		
12/9/2017	A-14		
3/23/2018	A-14	143	286
6/22/2018	A-14	124	250
9/22/2018	A-14		
12/8/2018	A-14		
3/31/2019	A-14		
3/1/2012	A-15	88	174
5/17/2011	A-15		
9/12/2011	A-15		
12/2/2011	A-15		
3/1/2012	A-15	88	174
6/15/2012	A-15		
9/7/2012	A-15		
12/5/2012	A-15		
3/7/2013	A-15		
6/14/2013	A-15		
9/14/2013	A-15		
12/30/2013	A-15	91	181
3/29/2014	A-15		
6/28/2014	A-15	117	234
9/21/2014	A-15		
12/12/2014	A-15	92	182
3/21/2015	A-15	57	115
6/26/2015	A-15	168	336
9/19/2015	A-15		
12/15/2015	A-15		
3/20/2016	A-15		
6/25/2016	A-15		
9/10/2016	A-15		
12/18/2016	A-15	38	75

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/25/2017	A-15		
6/24/2017	A-15	71	141
9/23/2017	A-15		
12/9/2017	A-15		
3/23/2018	A-15		
6/22/2018	A-15	69	138
9/22/2018	A-15	79	160
12/8/2018	A-15		
3/31/2019	A-15		
3/1/2012	A-16	59	117
5/17/2011	A-16	197	
9/12/2011	A-16	73	147
12/2/2011	A-16	56	113
3/1/2012	A-16	59	117
6/15/2012	A-16	148	296
9/7/2012	A-16	160	320
12/5/2012	A-16		
3/7/2013	A-16	76	153
6/14/2013	A-16	75	165
9/14/2013	A-16	126	250
12/30/2013	A-16	83	164
3/29/2014	A-16	83	165
6/28/2014	A-16	100	200
9/21/2014	A-16		
12/12/2014	A-16	95	188
3/21/2015	A-16	85	169
6/26/2015	A-16	124	248
9/19/2015	A-16	173	350
12/15/2015	A-16	113	227
3/20/2016	A-16	78	156
6/25/2016	A-16	109	219
9/10/2016	A-16	190	381
12/18/2016	A-16	58	115
3/25/2017	A-16	87	173
6/24/2017	A-16	89	179
9/23/2017	A-16	153	302
12/9/2017	A-16	100	202
3/23/2018	A-16	91	182
6/22/2018	A-16	86	171
9/22/2018	A-16	100	201
12/8/2018	A-16	87	173
3/31/2019	A-16	103	204
3/1/2012	A-17	54	109
5/17/2011	A-17		
9/12/2011	A-17	110	219

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (μS)
12/2/2011	A-17	58	116
3/1/2012	A-17	54	109
6/15/2012	A-17	119	240
9/7/2012	A-17		
12/5/2012	A-17	108	211
3/7/2013	A-17	77	154
6/14/2013	A-17	82	164
9/14/2013	A-17	119	238
12/30/2013	A-17	83	159
3/29/2014	A-17	81	161
6/28/2014	A-17	101	202
9/21/2014	A-17	149	300
12/12/2014	A-17	94	187
3/21/2015	A-17	82	162
6/26/2015	A-17	111	220
9/19/2015	A-17	171	343
12/15/2015	A-17	113	226
3/20/2016	A-17	75	151
6/25/2016	A-17	106	212
9/10/2016	A-17	190	379
12/18/2016	A-17	59	117
3/25/2017	A-17	85	169
6/24/2017	A-17	82	163
9/23/2017	A-17	151	304
12/9/2017	A-17	97	196
3/23/2018	A-17	90	180
6/22/2018	A-17	74	146
9/22/2018	A-17	100	201
12/8/2018	A-17	90	179
3/31/2019	A-17	103	206
3/1/2012	A-18	90	182
5/17/2011	A-18		
9/12/2011	A-18	143	287
12/2/2011	A-18	95	184
3/1/2012	A-18	90	182
6/15/2012	A-18	522	1070
9/7/2012	A-18		
12/5/2012	A-18		
3/7/2013	A-18	120	240
6/14/2013	A-18	95	184
9/14/2013	A-18	109	217
12/30/2013	A-18		
3/29/2014	A-18	84	167
6/28/2014	A-18	73	150
9/21/2014	A-18		

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
12/12/2014	A-18	102	204
3/21/2015	A-18	60	121
6/26/2015	A-18	66	130
9/19/2015	A-18	92	187
12/15/2015	A-18	70	143
3/20/2016	A-18	57	109
6/25/2016	A-18	75	150
9/10/2016	A-18		
12/18/2016	A-18	219	438
3/25/2017	A-18	129	255
6/24/2017	A-18	146	291
9/23/2017	A-18	168	339
12/9/2017	A-18	150	301
3/23/2018	A-18	132	265
6/22/2018	A-18	75	148
9/22/2018	A-18	108	216
12/8/2018	A-18	102	204
3/31/2019	A-18	109	216
3/1/2012	A-19	56	105
5/17/2011	A-19	52	
9/12/2011	A-19	64	127
12/2/2011	A-19	54	107
3/1/2012	A-19	56	105
6/15/2012	A-19	114	228
9/7/2012	A-19		
12/5/2012	A-19	97	193
3/7/2013	A-19	79	158
6/14/2013	A-19	79	158
9/14/2013	A-19	117	236
12/30/2013	A-19	78	108
3/29/2014	A-19	81	161
6/28/2014	A-19	107	200
9/21/2014	A-19	142	288
12/12/2014	A-19	89	176
3/21/2015	A-19	86	171
6/26/2015	A-19	125	250
9/19/2015	A-19	168	331
12/15/2015	A-19	112	227
3/20/2016	A-19	84	169
6/25/2016	A-19	115	235
9/10/2016	A-19	174	348
12/18/2016	A-19	35	69
3/25/2017	A-19	88	177
6/24/2017	A-19	106	211
9/23/2017	A-19	146	296

Table 7. Field Data from around the Aikens Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
12/9/2017	A-19	95	189
3/23/2018	A-19	83	167
6/22/2018	A-19	81	162
9/22/2018	A-19	95	191
12/8/2018	A-19	83	164
3/31/2019	A-19	99	202
6/15/2012	A-20	83	163
9/7/2012	A-20		
12/5/2012	A-20		
3/7/2013	A-20	54	107
6/14/2013	A-20		
9/14/2013	A-20	98	195
12/30/2013	A-20		
3/29/2014	A-20		
6/28/2014	A-20		
9/21/2014	A-20		
12/12/2014	A-20		

Table 8. Field Data from around the Kuhns Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/3/2012	K-01	117	234
6/13/2012	K-01		
9/7/2012	K-01		
12/16/2012	K-01	96	192
3/16/2013	K-01	137	277
6/14/2013	K-01	150	302
9/15/2013	K-01		
1/2/2014	K-01	128	255
3/29/2014	K-01	145	295
6/29/2014	K-01		
9/21/2014	K-01		
12/13/2014	K-01		
3/22/2015	K-01	139	282
6/26/2015	K-01		
9/18/2015	K-01		
12/14/2015	K-01	183	371
3/19/2016	K-01	147	294
6/25/2016	K-01	187	375
9/10/2016	K-01		
12/19/2016	K-01	121	243
3/24/2017	K-01	186	374
6/25/2017	K-01	114	227
9/23/2017	K-01	210	416
12/11/2017	K-01	146	291
3/23/2018	K-01	178	358
6/23/2018	K-01	113	225
9/22/2018	K-01	120	244
12/8/2018	K-01	140	280
3/31/2019	K-01	137	275
3/3/2012	K-02	115	231
6/13/2012	K-02		
9/7/2012	K-02		
12/16/2012	K-02	93	187
3/16/2013	K-02	135	267
6/14/2013	K-02	140	282
9/15/2013	K-02	157	316
1/2/2014	K-02	121	244
3/29/2014	K-02	133	267
6/29/2014	K-02	143	286
9/21/2014	K-02		
12/13/2014	K-02		
3/22/2015	K-02	130	262
6/26/2015	K-02	124	250
9/18/2015	K-02		
12/14/2015	K-02		

Table 8. Field Data from around the Kuhns Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (μS)
3/19/2016	K-02	101	273
6/25/2016	K-02	159	319
9/10/2016	K-02		
12/19/2016	K-02	119	237
3/24/2017	K-02	168	336
6/25/2017	K-02	128	255
9/23/2017	K-02		
12/11/2017	K-02	137	274
3/23/2018	K-02	171	347
6/23/2018	K-02	102	205
9/22/2018	K-02	116	232
12/8/2018	K-02	141	282
3/31/2019	K-02	146	292
3/3/2012	K-03	293	587
6/13/2012	K-03	244	480
9/7/2012	K-03	403	805
12/16/2012	K-03	99	198
3/16/2013	K-03	293	579
6/14/2013	K-03	246	489
9/15/2013	K-03	254	506
1/2/2014	K-03	268	533
3/29/2014	K-03	196	595
6/29/2014	K-03		
9/21/2014	K-03	347	692
12/13/2014	K-03	252	508
3/22/2015	K-03	300	603
6/26/2015	K-03	232	463
9/18/2015	K-03	310	622
12/14/2015	K-03	313	630
3/19/2016	K-03	298	595
6/25/2016	K-03	276	552
9/10/2016	K-03	271	543
12/19/2016	K-03	211	422
3/24/2017	K-03	379	758
6/25/2017	K-03	190	386
9/23/2017	K-03	308	615
12/11/2017	K-03	289	580
3/23/2018	K-03	266	535
6/23/2018	K-03	204	406
9/22/2018	K-03	182	366
12/8/2018	K-03	305	607
3/31/2019	K-03	266	539
3/3/2012	K-04	255	514
6/13/2012	K-04	240	484
9/7/2012	K-04	402	783

Table 8. Field Data from around the Kuhns Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (μS)
12/16/2012	K-04	159	315
3/16/2013	K-04	297	595
6/14/2013	K-04	240	482
9/15/2013	K-04		
1/2/2014	K-04	254	511
3/29/2014	K-04		
3/3/2012	K-05	232	468
6/13/2012	K-05	230	470
9/7/2012	K-05	352	711
12/16/2012	K-05	152	307
3/16/2013	K-05	290	586
6/14/2013	K-05	236	472
9/15/2013	K-05	243	487
1/2/2014	K-05	244	493
3/29/2014	K-05	270	540
6/29/2014	K-05	245	490
9/21/2014	K-05	326	652
12/13/2014	K-05	252	506
3/22/2015	K-05	271	542
6/26/2015	K-05	231	462
9/18/2015	K-05	288	575
12/14/2015	K-05	279	552
3/19/2016	K-05	269	539
6/25/2016	K-05	261	523
9/10/2016	K-05	254	508
12/19/2016	K-05	174	350
3/24/2017	K-05	331	663
6/25/2017	K-05	178	355
9/23/2017	K-05	280	561
12/11/2017	K-05	265	526
3/23/2018	K-05	329	662
6/23/2018	K-05	170	338
9/22/2018	K-05	170	340
12/8/2018	K-05	295	585
3/31/2019	K-05	294	587
3/3/2012	K-06		
6/13/2012	K-06		
9/7/2012	K-06		
12/16/2012	K-06		
3/16/2013	K-06	101	205
6/14/2013	K-06	118	237
9/15/2013	K-06	248	498
1/2/2014	K-06		
3/29/2014	K-06	284	569
6/29/2014	K-06		

Table 8. Field Data from around the Kuhns Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (μS)
9/21/2014	K-06		
12/13/2014	K-06		
3/3/2012	K-07		
6/13/2012	K-07		
9/7/2012	K-07		
12/16/2012	K-07	38	78
3/16/2013	K-07	42	98
6/14/2013	K-07		
9/15/2013	K-07	142	287
1/2/2014	K-07	47	96
3/29/2014	K-07	45	92
6/29/2014	K-07	68	135
9/21/2014	K-07		
12/13/2014	K-07		
3/22/2015	K-07	38	78
6/26/2015	K-07	51	104
9/18/2015	K-07		
12/14/2015	K-07	46	92
3/19/2016	K-07	45	93
6/25/2016	K-07		
9/10/2016	K-07		
12/19/2016	K-07	40	80
3/24/2017	K-07	48	97
6/25/2017	K-07	46	94
9/23/2017	K-07		
12/11/2017	K-07	51	101
3/23/2018	K-07	40	79
6/23/2018	K-07	42	85
9/22/2018	K-07	47	93
12/8/2018	K-07	66	131
3/31/2019	K-07	60	120
3/3/2012	K-08	40	80
6/13/2012	K-08	56	110
9/7/2012	K-08		
12/16/2012	K-08	38	78
3/16/2013	K-08	37	74
6/14/2013	K-08	36	72
9/15/2013	K-08	37	78
1/2/2014	K-08	49	94
3/29/2014	K-08	37	78
6/29/2014	K-08	42	81
9/21/2014	K-08	46	95
12/13/2014	K-08	43	89
3/22/2015	K-08	39	78
6/26/2015	K-08	36	72

Table 8. Field Data from around the Kuhns Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
9/18/2015	K-08	121	239
12/14/2015	K-08	47	101
3/19/2016	K-08	36	72
6/25/2016	K-08	44	89
9/10/2016	K-08	89	174
12/19/2016	K-08	36	72
3/24/2017	K-08	36	74
6/25/2017	K-08	33	72
9/23/2017	K-08	50	99
12/11/2017	K-08	43	86
3/23/2018	K-08	30	61
6/23/2018	K-08	34	70
9/22/2018	K-08	36	70
12/8/2018	K-08	46	90
3/31/2019	K-08	43	86
3/3/2012	K-09	36	76
6/13/2012	K-09	38	74
9/7/2012	K-09		
12/16/2012	K-09		
3/16/2013	K-09		
6/14/2013	K-09		
9/15/2013	K-09		
1/2/2014	K-09		
3/29/2014	K-09		
6/29/2014	K-09		
9/21/2014	K-09		
12/13/2014	K-09		
3/3/2012	K-10	37	74
6/13/2012	K-10	46	95
9/7/2012	K-10		
12/16/2012	K-10	175	349
3/16/2013	K-10	39	85
6/14/2013	K-10	58	117
9/15/2013	K-10	67	134
1/2/2014	K-10	68	138
3/29/2014	K-10	82	164
6/29/2014	K-10	103	199
9/21/2014	K-10	120	242
12/13/2014	K-10	88	178
3/22/2015	K-10	76	153
6/26/2015	K-10	74	148
9/18/2015	K-10	127	254
12/14/2015	K-10	88	177
3/19/2016	K-10	74	145
6/25/2016	K-10	102	204

Table 8. Field Data from around the Kuhns Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (μS)
9/10/2016	K-10	122	246
12/19/2016	K-10	47	95
3/24/2017	K-10	71	142
6/25/2017	K-10	53	107
9/23/2017	K-10	120	246
12/11/2017	K-10	99	199
3/23/2018	K-10	84	167
6/23/2018	K-10	52	104
9/22/2018	K-10	65	131
12/8/2018	K-10	86	171
3/31/2019	K-10	94	187
3/16/2013	K-11	54	112
6/14/2013	K-11	51	97
9/15/2013	K-11	96	192
1/2/2014	K-11	68	137
3/29/2014	K-11		
3/3/2012	K-12		
6/13/2012	K-12		
9/7/2012	K-12		
12/16/2012	K-12		
3/16/2013	K-12	60	126
6/14/2013	K-12		
9/15/2013	K-12	102	205
1/2/2014	K-12	66	130
3/29/2014	K-12	90	182
6/29/2014	K-12	107	213
9/21/2014	K-12	138	277
12/13/2014	K-12	93	190
3/22/2015	K-12	62	125
6/26/2015	K-12	77	154
9/18/2015	K-12	153	304
12/14/2015	K-12	98	198
3/19/2016	K-12	79	160
6/25/2016	K-12	111	221
9/10/2016	K-12	144	287
12/19/2016	K-12	50	101
3/24/2017	K-12	86	172
6/25/2017	K-12	59	116
9/23/2017	K-12	123	245
12/11/2017	K-12	105	212
3/23/2018	K-12	103	204
6/23/2018	K-12	63	126
9/22/2018	K-12	65	131
12/8/2018	K-12	91	182
3/31/2019	K-12	105	210

Table 8. Field Data from around the Kuhns Well Pad Measured by IUP

Date	Site ID	TDS (ppm)	Conductivity (µS)
3/3/2012	K-13		
6/13/2012	K-13		
9/7/2012	K-13		
12/16/2012	K-13		
3/16/2013	K-13	52	104
6/14/2013	K-13	56	114
9/15/2013	K-13	104	210
1/2/2014	K-13	64	127
3/29/2014	K-13	87	172
6/29/2014	K-13	102	205
9/21/2014	K-13	140	281
12/13/2014	K-13		
3/22/2015	K-13	59	118
6/26/2015	K-13	75	150
9/18/2015	K-13	137	273
12/14/2015	K-13	93	187
3/19/2016	K-13	74	148
6/25/2016	K-13	107	214
9/10/2016	K-13	134	270
12/19/2016	K-13	44	89
3/24/2017	K-13	70	141
6/25/2017	K-13	50	100
9/23/2017	K-13	138	278
12/11/2017	K-13	101	204
3/23/2018	K-13	101	203
6/23/2018	K-13	51	103
9/22/2018	K-13	69	139
12/8/2018	K-13	89	176
3/31/2019	K-13	102	204
9/22/2018	K-14	66	132
12/8/2018	K-14	66	133
3/31/2019	K-14	66	132

Reservoir Data

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
1/1/2007	0.072	
1/2/2007	0.048	
1/3/2007	0.046	
1/4/2007	0.059	
1/5/2007	0.050	
1/6/2007	0.051	
1/7/2007	0.051	
2/1/2007	0.076	
2/2/2007	0.052	
2/3/2007	0.063	
2/4/2007	0.076	
2/5/2007	0.073	
2/6/2007	0.067	
2/7/2007	0.082	
3/1/2007	0.071	
3/2/2007	0.070	
3/3/2007	0.082	
3/4/2007	0.084	
3/5/2007	0.091	
3/6/2007	0.101	
3/7/2007	0.113	
4/1/2007	0.103	
4/2/2007	0.106	
4/3/2007	0.110	
4/4/2007	0.099	
4/5/2007	0.099	
4/6/2007	0.081	
4/7/2007	0.083	
5/1/2007	0.173	
5/2/2007	0.086	
5/3/2007	0.086	
5/4/2007	0.092	
5/5/2007	0.082	
5/6/2007	0.081	
5/7/2007	0.079	
6/1/2007	0.083	
6/2/2007	0.076	
6/3/2007	0.078	
6/4/2007	0.066	
6/5/2007	0.071	
6/6/2007	0.064	
6/7/2007	0.071	
7/1/2007	0.045	
7/2/2007	0.049	
7/3/2007	0.048	

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
7/4/2007	0.041	
7/5/2007	0.043	
7/6/2007	0.051	
7/7/2007	0.072	
8/1/2007	0.040	
8/2/2007	0.056	
8/3/2007	0.063	
8/4/2007	0.059	
8/5/2007	0.044	
8/6/2007	0.042	
8/7/2007	0.024	
9/1/2007	0.052	
9/2/2007	0.051	
9/3/2007	0.041	
9/4/2007	0.055	
9/5/2007	0.054	
9/6/2007	0.048	
9/7/2007	0.033	
10/1/2007	0.048	
10/2/2007	0.044	
10/3/2007	0.039	
10/4/2007	0.039	
10/5/2007	0.037	
10/6/2007	0.044	
10/7/2007	0.091	
11/1/2007	0.044	
11/2/2007	0.060	
11/3/2007	0.060	
11/4/2007	0.076	
11/5/2007	0.161	
11/6/2007	0.174	
11/7/2007	0.080	
12/1/2007	0.271	
12/2/2007	0.288	
12/3/2007	0.288	
12/4/2007	0.289	
12/5/2007	0.294	
12/6/2007	0.301	
12/7/2007	0.303	
1/1/2008	0.204	N/A
1/6/2008	0.200	N/A
1/11/2008	0.212	N/A
1/16/2008	0.168	N/A
1/21/2008	0.179	N/A
1/26/2008	0.173	N/A

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
1/31/2008	0.163	N/A
2/5/2008	0.181	N/A
2/10/2008	0.145	N/A
2/15/2008	0.184	N/A
2/20/2008	0.179	N/A
2/25/2008	0.154	N/A
3/1/2008	0.160	N/A
3/6/2008	0.179	N/A
3/11/2008	0.152	N/A
3/16/2008	0.148	N/A
3/21/2008	0.164	N/A
3/26/2008	0.151	N/A
3/31/2008	0.136	N/A
4/5/2008	0.121	N/A
4/10/2008	0.111	N/A
4/15/2008	0.100	N/A
4/20/2008	0.072	N/A
4/25/2008	0.043	N/A
4/30/2008	0.068	N/A
5/5/2008	0.061	N/A
5/10/2008	0.051	N/A
5/13/2008	0.053	N/A
5/15/2008	0.052	N/A
5/20/2008	0.052	N/A
5/25/2008	0.047	N/A
5/30/2008	0.054	N/A
6/4/2008	0.049	N/A
6/9/2008	0.044	N/A
6/14/2008	0.051	N/A
6/19/2008	0.055	N/A
6/24/2008	0.056	N/A
6/29/2008	0.085	N/A
7/4/2008	0.044	N/A
7/9/2008	0.039	N/A
7/14/2008	0.071	N/A
7/19/2008	0.049	N/A
7/24/2008	0.043	N/A
7/29/2008	0.037	N/A
8/3/2008	0.043	N/A
8/8/2008	0.046	N/A
8/13/2008	0.054	N/A
8/18/2008	0.069	N/A
8/23/2008	0.069	N/A
8/28/2008	0.015	N/A
9/2/2008	0.054	

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
9/7/2008	0.049	
9/12/2008	0.039	
9/17/2008	0.05	
9/22/2008	0.036	
9/27/2008	0.046	
10/2/2008	0.051	
10/7/2008	0.056	
10/12/2008	0.054	
10/17/2008	0.057	
10/22/2008	0.094	
10/27/2008	0.153	
11/1/2008	0.468	
11/6/2008	0.422	
11/11/2008	0.416	
11/16/2008	0.493	
11/21/2008	0.393	
11/26/2008	0.565	
12/1/2008	0.491	
12/6/2008	0.488	
12/11/2008	0.416	
12/16/2008	0.447	
12/21/2008	0.465	
12/26/2008	0.47	
12/31/2008	0.423	
1/1/2010	0.229	290
1/2/2010	0.21	290
1/3/2010	0.254	300
1/4/2010	0.227	310
1/5/2010	0.229	300
1/6/2010	0.227	310
1/7/2010	0.237	300
2/1/2010	0.179	290
2/2/2010	0.217	280
2/3/2010	0.34	280
2/4/2010	0.999	300
2/5/2010	0.0465	310
2/6/2010	0	310
2/7/2010	0.618	310
3/1/2010	0.192	290
3/2/2010	0.197	290
3/3/2010	0.202	280
3/4/2010	0.178	280
3/5/2010	0.192	270
3/6/2010	0.198	260
3/7/2010	0.159	270

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (μS)
4/1/2010	0.076	260
4/2/2010	0.079	260
4/3/2010	0.089	260
4/4/2010	0.079	260
4/5/2010	0.069	260
4/6/2010	0.124	260
4/7/2010	0.081	260
5/1/2010	0.055	270
5/2/2010	0.051	220
5/3/2010	0.041	260
5/4/2010	0.045	270
5/5/2010	0.062	270
5/6/2010	0.053	280
5/7/2010	0.049	300
6/1/2010	0.62	280
6/2/2010	0.04	280
6/3/2010	0.06	300
6/4/2010	0.045	300
6/5/2010	0.032	300
6/6/2010	0.04	300
6/7/2010	0.03	300
7/1/2010	0.069	310
7/2/2010	0.086	320
7/3/2010	0.094	310
7/4/2010	0.107	320
7/5/2010	0.078	310
7/6/2010	0.19	310
7/7/2010	0.129	320
8/1/2010	0.07	330
8/2/2010	0.096	350
8/3/2010	0.058	330
8/4/2010	0.051	330
8/5/2010	0.085	330
8/6/2010	0.067	340
8/7/2010	0.038	330
9/1/2010	0.53	340
9/2/2010	0.036	340
9/3/2010	0.032	340
9/4/2010	0.032	340
9/5/2010	0.036	360
9/6/2010	0.029	340
9/7/2010	0.024	340
10/1/2010	0.033	340
10/2/2010	0.045	340
10/3/2010	0.022	340

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
10/4/2010	0.03	340
10/5/2010	0.039	320
10/6/2010	0.056	320
10/7/2010	0.76	320
10/29/2010	0.193	320
10/30/2010	0.154	320
10/31/2010	0.197	320
11/1/2010	0.356	320
11/2/2010	0.306	320
11/3/2010	0.401	320
11/4/2010	0.359	320
11/5/2010	0.357	320
11/6/2010	0.479	320
11/7/2010	0.421	320
12/1/2010	0.293	290
12/2/2010	0.316	300
12/3/2010	0.318	300
12/4/2010	0.347	300
12/5/2010	0.304	300
12/6/2010	0.307	300
12/7/2010	0.278	300
1/1/2011	0.342	280
1/2/2011	0.38	280
1/3/2011	0.342	280
1/4/2011	0.329	280
1/5/2011	0.351	280
1/6/2011	0.308	260
1/7/2011	0.28	260
3/3/2011	0.061	280
3/8/2011	0.107	270
3/10/2011	0.117	240
3/11/2011	0.097	280
3/12/2011	0.133	260
3/13/2011	0.119	260
3/14/2011	0.087	260
3/15/2011	0.12	280
3/16/2011	0.153	260
3/17/2011	0.012	250
3/18/2011	0.061	300
4/5/2011	0.038	310
4/10/2011	0.083	310
4/15/2011	0.092	310
4/20/2011	0.096	300
4/25/2011	0.079	304
4/30/2011	0.072	300

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
5/1/2011	0.096	300
5/6/2011	0.073	300
5/11/2011	0.076	296
5/16/2011	0.095	310
5/21/2011	0.162	301
5/26/2011	0.062	300
5/31/2011	0.060	305
6/5/2011	0.078	295
6/10/2011	0.054	300
6/15/2011	0.066	300
6/20/2011	0.049	294
6/25/2011	0.064	290
6/30/2011	0.049	290
7/1/2011	0.056	292
7/6/2011	0.051	296
7/11/2011	0.079	320
7/16/2011	0.055	297
7/21/2011	0.062	290
7/26/2011	0.041	290
7/31/2011	0.064	295
8/1/2011	0.046	295
8/6/2011	0.038	297
8/11/2011	0.032	298
8/16/2011	0.061	299
8/21/2011	0.084	292
8/26/2011	0.100	297
8/31/2011	0.120	298
9/5/2011	0.036	298
9/10/2011	0.029	299
9/15/2011	0.038	300
9/20/2011	0.039	290
9/25/2011	0.062	295
9/30/2011	0.119	294
10/1/2011	0.086	297
10/6/2011	0.095	298
10/11/2011	0.115	296
10/16/2011	0.052	295
10/21/2011	0.066	294
10/26/2011	0.106	295
10/31/2011	0.152	294
11/5/2011	0.276	295
11/10/2011	0.195	290
11/15/2011	0.213	294
11/20/2011	0.233	296
11/25/2011	0.184	295

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (μS)
11/30/2011	0.121	297
12/1/2011	0.131	291
12/6/2011	0.067	296
12/11/2011	0.046	300
12/16/2011	0.075	295
12/21/2011	0.048	294
12/26/2011	0.062	294
12/31/2011	0.088	295
1/1/2012	0.056	298
1/2/2012	0.071	296
1/3/2012	0.06	297
1/4/2012	0.076	295
1/5/2012	0.047	295
1/6/2012	0.066	297
1/7/2012	0.054	290
2/1/2012	0.089	284
2/2/2012	0.093	290
2/3/2012	0.084	295
2/4/2012	0.074	295
2/5/2012	0.082	285
2/6/2012	0.093	285
2/7/2012	0.087	285
3/1/2012	0.118	280
3/6/2012	0.169	282
3/11/2012	0.135	282
3/16/2012	0.135	279
3/21/2012	0.088	282
3/26/2012	0.1	285
3/31/2012	0.099	286
4/5/2012	0.095	283
4/10/2012	0.083	286
4/15/2012	0.104	281
4/20/2012	0.149	291
4/25/2012	0.117	289
4/30/2012	0.087	290
5/5/2012	0.082	290
5/10/2012	0.078	289
5/15/2012	0.056	287
5/20/2012	0.057	289
5/25/2012	0.066	289
5/30/2012	0.098	293
6/4/2012	0.063	290
6/9/2012	0.066	293
6/14/2012	0.075	296
6/19/2012	0.092	298

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (μS)
6/24/2012	0.089	299
6/29/2012	0.093	303
7/4/2012	0.082	303
7/9/2012	0.064	299
7/14/2012	0.045	306
7/19/2012	0.045	308
7/21/2012	0.045	309
7/24/2012	0.039	297
7/29/2012	0.098	309
8/3/2012	0.06	305
8/8/2012	0.042	304
8/13/2012	0.032	307
8/18/2012	0.046	308
8/23/2012	0.044	312
8/28/2012	0.089	313
9/2/2012	0.056	312
9/7/2012	0.061	313
9/12/2012	0.056	319
9/17/2012	0.035	322
9/22/2012	0.074	320
9/27/2012	0.129	318
10/2/2012	0.043	316
10/7/2012	0.036	319
10/12/2012	0.056	311
10/17/2012	0.071	318
10/22/2012	0.082	320
10/27/2012	0.076	316
11/1/2012	0.215	315
11/6/2012	0.309	310
11/11/2012	0.277	303
11/16/2012	0.301	300
11/21/2012	0.262	298
11/26/2012	0.197	304
12/1/2012	0.208	300
12/6/2012	0.248	299
12/11/2012	0.178	296
12/16/2012	0.211	295
12/21/2012	0.197	294
12/26/2012	0.165	291
12/31/2012	0.183	289
1/1/2013	0.181	284
1/6/2013	0.168	274
1/11/2013	0.159	275
1/16/2013	0.145	274
1/21/2013	0.141	270

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
1/26/2013	0.166	273
1/31/2013	0.147	271
2/5/2013	0.155	273
2/10/2013	0.155	274
2/15/2013	0.141	270
2/20/2013	0.126	273
2/25/2013	0.132	278
3/2/2013	0.141	278
3/7/2013	0.125	285
3/12/2013	0.104	279
3/17/2013	0.189	279
3/22/2013	0.129	287
3/27/2013	0.096	285
4/1/2013	0.171	276
4/6/2013	0.081	283
4/11/2013	0.105	287
4/16/2013	0.112	286
4/21/2013	0.184	289
4/26/2013	0.218	293
5/1/2013	0.247	295
5/6/2013	0.222	300
5/11/2013	0.196	296
5/16/2013	0.167	300
5/21/2013	0.111	300
5/26/2013	0.064	300
5/31/2013	0.096	306
6/1/2013	0.089	306
6/5/2013	0.053	305
6/10/2013	0.106	310
6/13/2013	0.171	309
6/15/2013	0.092	314
6/20/2013	0.079	311
6/25/2013	0.071	310
6/30/2013	0.103	308
7/5/2013	0.098	301
7/10/2013	0.099	299
7/15/2013	0.142	303
7/20/2013	0.159	301
7/25/2013	0.129	294
7/30/2013	0.202	303
7/31/2013	0.300	305
8/4/2013	0.176	306
8/9/2013	0.178	309
8/14/2013	0.147	305
8/19/2013	0.087	313

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
8/24/2013	0.088	313
8/29/2013	0.118	310
9/3/2013	0.086	296
9/8/2013	0.058	298
9/13/2013	0.044	302
9/18/2013	0.076	295
9/23/2013	0.059	302
9/28/2013	0.056	300
10/3/2013	0.046	299
10/8/2013	0.043	300
10/13/2013	0.040	299
10/18/2013	0.060	303
10/23/2013	0.170	313
10/28/2013	0.126	319
11/2/2013	0.202	209
11/7/2013	0.123	304
11/12/2013	0.126	306
11/17/2013	0.170	306
11/22/2013	0.156	322
11/27/2013	0.167	321
12/2/2013	0.179	318
12/7/2013	0.155	319
12/12/2013	0.167	317
12/17/2013	0.145	319
12/22/2013	0.119	316
12/27/2013	0.097	318
1/1/2014	0.083	316
1/6/2014	0.088	313
1/11/2014	0.095	316
1/16/2014	0.079	317
1/21/2014	0.092	321
1/26/2014	0.079	321
1/31/2014	0.061	330
2/5/2014	0.07	324
2/6/2014	0.074	328
2/10/2014	0.076	325
2/15/2014	0.084	330
2/20/2014	0.114	327
2/25/2014	0.102	343
3/2/2014	0.097	338
3/7/2014	0.088	344
3/12/2014	0.054	342
3/14/2014	0.063	351
3/17/2014	0.087	339
3/22/2014	0.051	346

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
3/27/2014	0.054	346
4/1/2014	0.071	330
4/6/2014	0.077	325
4/11/2014	0.084	321
4/16/2014	0.079	331
4/21/2014	0.088	328
4/22/2014	0.092	330
4/26/2014	0.077	330
5/1/2014	0.081	329
5/6/2014	0.071	318
5/11/2014	0.062	329
5/16/2014	0.063	329
5/21/2014	0.094	329
5/26/2014	0.063	327
5/31/2014	0.098	339
6/5/2014	0.054	341
6/10/2014	0.056	336
6/12/2014	0.094	337
6/13/2014	0.074	339
6/15/2014	0.062	338
6/20/2014	0.066	340
6/25/2014	0.063	344
6/30/2014	0.035	342
7/5/2014	0.064	343
7/10/2014	0.085	345
7/15/2014	0.102	347
7/20/2014	0.095	353
7/25/2014	0.106	349
7/30/2014	0.088	350
8/4/2014	0.096	365
8/9/2014	0.088	349
8/10/2014	0.099	348
8/14/2014	0.111	349
8/19/2014	0.111	342
8/24/2014	0.085	348
8/29/2014	0.093	331
9/3/2014	0.1	351
9/8/2014	0.182	347
9/13/2014	0.335	344
9/18/2014	0.296	349
9/23/2014	0.284	350
9/28/2014	0.165	351
10/3/2014	0.187	344
10/7/2014	0.202	342
10/8/2014	0.268	342

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
10/13/2014	0.126	340
10/18/2014	0.084	344
10/23/2014	0.145	341
10/28/2014	0.117	341
11/2/2014	0.096	341
11/7/2014	0.125	341
11/12/2014	0.101	339
11/17/2014	0.115	344
11/22/2014	0.096	341
11/27/2014	0.092	340
12/2/2014	0.081	342
12/7/2014	0.087	345
12/12/2014	0.086	343
12/17/2014	0.052	337
12/22/2014	0.052	337
12/27/2014	0.067	339
09/01/2016	0.889	341
09/06/2016	0.867	348
09/11/2016	0.942	350
09/16/2016	0.855	343
09/21/2016	0.991	343
09/26/2016	0.87	347
10/01/2016	0.263	337
10/06/2016	0.595	342
10/11/2016	0.447	340
10/16/2016	0.881	344
10/21/2016	0.402	340
10/26/2016	0.29	340
10/31/2016	0.328	342
9/1/2017	0.229	295
9/6/2017	0.216	299
9/11/2017	0.167	300
9/16/2017	0.151	298
9/21/2017	0.206	296
9/26/2017	0.222	295
10/1/2017	0.135	290
10/6/2017	0.227	296
10/11/2017	0.176	298
10/16/2017	0.146	295
10/21/2017	0.166	298
10/26/2017	0.126	288
10/31/2017	0.238	296
11/5/2017	0.368	298
11/10/2017	0.404	291
11/15/2017	0.508	291

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (μS)
11/20/2017	0.204	288
11/25/2017	0.116	276
11/30/2017	0.113	280
09/01/2018	0.082	296
09/06/2018	0.144	273
09/11/2018	0.161	273
09/16/2018	0.103	236
09/21/2018	0.068	234
09/26/2018	0.097	241
10/01/2018	0.111	238
10/06/2018	0.099	239
10/11/2018	0.076	233
10/16/2018	0.089	240
10/21/2018	0.146	243
10/26/2018	0.17	243
10/31/2018	0.262	246
11/05/2018	0.156	246
11/10/2018	0.161	244
11/15/2018	0.267	247
11/20/2018	0.129	240
11/25/2018	0.102	230
11/30/2018	0.091	240
1/1/2019		227
1/2/2019		227
1/3/2019		226
1/4/2019		229
1/5/2019		227
1/6/2019		227
1/7/2019		229
1/8/2019		226
1/9/2019		229
1/10/2019		229
1/11/2019		227
1/12/2019		226
1/13/2019		228
1/14/2019		225
1/15/2019		226
1/16/2019		226
1/17/2019		222
1/18/2019		220
1/19/2019		226
1/20/2019		219
1/21/2019		234
1/22/2019		236
1/23/2019		233

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
1/24/2019		236
1/25/2019		235
1/26/2019		234
1/27/2019		233
1/28/2019		232
1/29/2019		226
1/30/2019		227
1/31/2019		226
2/1/2019		226
2/2/2019		227
2/3/2019		229
2/4/2019		233
2/5/2019		236
2/6/2019		235
2/7/2019		218
2/8/2019		228
2/9/2019		240
2/10/2019		250
2/11/2019		247
2/12/2019		256
2/13/2019		260
2/14/2019		248
2/15/2019		248
2/16/2019		242
2/17/2019		257
2/18/2019		257
2/19/2019		262
2/20/2019		257
2/21/2019		258
2/22/2019		265
2/23/2019		269
2/24/2019		259
2/25/2019		227
2/26/2019		228
2/27/2019		229
2/28/2019		237
3/1/2019		239
3/2/2019		239
3/3/2019		238
3/4/2019		238
3/5/2019		239
3/6/2019		241
3/7/2019		241
3/8/2019		241
3/9/2019		239

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
3/10/2019		243
3/11/2019		244
3/12/2019		239
3/13/2019		240
3/14/2019		240
3/15/2019		240
3/16/2019		238
3/17/2019		240
3/18/2019		239
3/19/2019		248
3/20/2019		246
3/21/2019		247
3/22/2019		248
3/23/2019		246
3/24/2019		251
3/25/2019		240
3/26/2019		240
3/27/2019		241
3/28/2019		239
3/29/2019		241
3/30/2019		240
3/31/2019		241
4/1/2019		242
4/2/2019		250
4/3/2019		249
4/4/2019		246
4/5/2019		248
4/6/2019		249
4/7/2019		242
4/8/2019		249
4/9/2019		247
4/10/2019		245
4/11/2019		249
4/12/2019		247
4/13/2019		248
4/14/2019		249
4/15/2019		253
4/16/2019		254
4/17/2019		253
4/18/2019		253
4/19/2019		252
4/20/2019		254
4/21/2019		254
4/22/2019		251
4/23/2019		249

Table 9. Data Recorded from Beaver Run Reservoir by MAWC

Dates	Manganese (ppm)	Conductivity (µS)
4/24/2019		252
4/25/2019		251
4/26/2019		250
4/27/2019		252
4/28/2019		249
4/29/2019		251
4/30/2019		251
5/1/2019		253
5/2/2019		254
5/3/2019		251
5/4/2019		252
5/5/2019		251
5/6/2019		254
5/7/2019		249

Table 10. Field Testing Data from Beaver Run Reservoir by IUP

Date	Site ID	Conductivity (µS)
6/8/2011	R-01	310
8/22/2011	R-01	374
10/21/2011	R-01	359
4/25/2012	R-01	326
7/19/2012	R-01	349
10/1/2012	R-01	331
5/17/2013	R-01	391
7/18/2013	R-01	396
10/2/2013	R-01	414
6/5/2014	R-01	412
9/10/2014	R-01	415
10/8/2014	R-01	369
5/28/2015	R-01	379
7/17/2015	R-01	362
9/29/2015	R-01	479
5/6/2016	R-01	375
10/14/2016	R-01	426
4/12/2017	R-01	435
7/27/2017	R-01	339
9/26/2017	R-01	370
5/17/2018	R-01	336
7/17/2018	R-01	345
10/4/2018	R-01	308
5/3/2019	R-01	375
6/8/2011	R-02	310
8/22/2011	R-02	344
10/21/2011	R-02	362
4/25/2012	R-02	322
7/19/2012	R-02	338
10/1/2012	R-02	317
5/17/2013	R-02	394
7/18/2013	R-02	386
10/2/2013	R-02	364
6/5/2014	R-02	398
9/10/2014	R-02	409
10/8/2014	R-02	376
5/28/2015	R-02	367
7/17/2015	R-02	329
9/29/2015	R-02	360
5/6/2016	R-02	364
10/14/2016	R-02	383
4/12/2017	R-02	391
7/27/2017	R-02	349
9/26/2017	R-02	326
5/17/2018	R-02	339

Table 10. Field Testing Data from Beaver Run Reservoir by IUP

Date	Site ID	Conductivity (µS)
7/17/2018	R-02	341
10/4/2018	R-02	256
5/3/2019	R-02	362
6/8/2011	R-03	305
8/22/2011	R-03	351
10/21/2011	R-03	344
4/25/2012	R-03	285
7/19/2012	R-03	340
10/1/2012	R-03	319
5/17/2013	R-03	385
7/18/2013	R-03	363
10/2/2013	R-03	337
6/5/2014	R-03	416
9/10/2014	R-03	404
10/8/2014	R-03	372
5/28/2015	R-03	373
7/17/2015	R-03	280
9/29/2015	R-03	337
5/6/2016	R-03	375
10/14/2016	R-03	381
4/12/2017	R-03	387
7/27/2017	R-03	329
9/26/2017	R-03	325
5/17/2018	R-03	328
7/17/2018	R-03	337
10/4/2018	R-03	262
5/3/2019	R-03	362
6/8/2011	R-04	305
8/22/2011	R-04	343
10/21/2011	R-04	308
4/25/2012	R-04	277
7/19/2012	R-04	313
10/1/2012	R-04	291
5/17/2013	R-04	328
7/18/2013	R-04	362
10/2/2013	R-04	313
6/5/2014	R-04	335
9/10/2014	R-04	346
10/8/2014	R-04	371
5/28/2015	R-04	328
7/17/2015	R-04	345
9/29/2015	R-04	364
5/6/2016	R-04	297
10/14/2016	R-04	328
4/12/2017	R-04	351

Table 10. Field Testing Data from Beaver Run Reservoir by IUP

Date	Site ID	Conductivity (µS)
7/27/2017	R-04	323
9/26/2017	R-04	356
5/17/2018	R-04	299
7/17/2018	R-04	324
10/4/2018	R-04	351
5/3/2019	R-04	290
6/8/2011	R-05	305
8/22/2011	R-05	299
10/21/2011	R-05	303
4/25/2012	R-05	320
7/19/2012	R-05	297
10/1/2012	R-05	291
5/17/2013	R-05	322
7/18/2013	R-05	323
10/2/2013	R-05	298
6/5/2014	R-05	343
9/10/2014	R-05	344
10/8/2014	R-05	320
5/28/2015	R-05	321
7/17/2015	R-05	247
9/29/2015	R-05	301
5/6/2016	R-05	302
10/14/2016	R-05	325
4/12/2017	R-05	348
7/27/2017	R-05	309
9/26/2017	R-05	305
5/17/2018	R-05	300
7/17/2018	R-05	286
10/4/2018	R-05	261
5/3/2019	R-05	290
6/8/2011	R-06	301
8/22/2011	R-06	300
10/21/2011	R-06	300
4/25/2012	R-06	294
7/19/2012	R-06	300
10/1/2012	R-06	289
5/17/2013	R-06	323
7/18/2013	R-06	333
10/2/2013	R-06	295
6/5/2014	R-06	343
9/10/2014	R-06	343
10/8/2014	R-06	320
5/28/2015	R-06	325
7/17/2015	R-06	264
9/29/2015	R-06	298

Table 10. Field Testing Data from Beaver Run Reservoir by IUP

Date	Site ID	Conductivity (µS)
5/6/2016	R-06	300
10/14/2016	R-06	322
4/12/2017	R-06	346
7/27/2017	R-06	300
9/26/2017	R-06	304
5/17/2018	R-06	305
7/17/2018	R-06	273
10/4/2018	R-06	245
5/3/2019	R-06	295
6/8/2011	R-07	
8/22/2011	R-07	
10/21/2011	R-07	
4/25/2012	R-07	
7/19/2012	R-07	
10/1/2012	R-07	
5/17/2013	R-07	
7/18/2013	R-07	324
10/2/2013	R-07	314
6/5/2014	R-07	335
9/10/2014	R-07	341
10/8/2014	R-07	320
5/28/2015	R-07	319
7/17/2015	R-07	249
9/29/2015	R-07	369
5/6/2016	R-07	302
10/14/2016	R-07	325
4/12/2017	R-07	349
7/27/2017	R-07	295
9/26/2017	R-07	312
5/17/2018	R-07	295
7/17/2018	R-07	310
10/4/2018	R-07	355
5/3/2019	R-07	286

Table 11. Lab Testing Data from Beaver Run Reservoir by IUP

Date	Site ID	TDS	Br-	NO_3-	SO_4^{2}-	Mn
6/8/2011	R-01	192	0.488	5.52	56.43	0.164
8/22/2011	R-01	190	0.326	2.45	53.84	0.265
10/21/2011	R-01	292	0.254	1.65	52.77	0.049
4/25/2012	R-01	77	0.243	3.63	56.64	0.288
7/19/2012	R-01	262	0.231	2.61	55.76	<LD
10/1/2012	R-01	103	0.089	1.05	25.19	0.484
5/17/2013	R-01	252	0.074	4.31	74.57	0.737
7/18/2013	R-01	258	<LD	2.53	75.57	0.353
10/2/2013	R-01	223	0.057	0.88	71.03	6.015
6/5/2014	R-01	186	0.049	3.86	72.46	0.62
9/10/2014	R-01	206	0.057	2.27	69.33	3.095
10/8/2014	R-01	275	0.057	0.58	72.96	1.073
5/28/2015	R-01	230	0.009	4.25	68.35	DNQ
7/17/2015	R-01	234	0.042	4.51	70.62	0.172
9/29/2015	R-01	234	0.046	1.12	63.93	2.781
5/6/2016	R-01	245	0.045	3.8	73.03	0.587
10/14/2016	R-01	218	0.049	0.88	76.86	0.425
4/12/2017	R-01	195	0.055	4.55	70.03	0.085
7/27/2017	R-01	213	0.052	3.47	64.82	0.374
9/26/2017	R-01	257	0.059	<LD	59.51	3.92
5/17/2018	R-01	211	0.083	4.79	67.84	0.323
7/17/2018	R-01	236	0.05	4.49	68.28	0.093
10/4/2018	R-01	207	0.049	DNQ	53.09	1.602
5/3/2019	R-01	167	0.055	4.24	59.91	0.209
6/8/2011	R-02	103	0.36	3.36	54.29	0.204
8/22/2011	R-02	62	0.304	2.9	54.17	0.242
10/21/2011	R-02	114	0.246	3.47	53.17	0.215
4/25/2012	R-02	145	0.235	3.88	58.55	0.269
7/19/2012	R-02	178	0.241	2.08	54.92	0.042
10/1/2012	R-02	162	0.118	1.34	77.1	<LD
5/17/2013	R-02	256	0.074	3.89	77.34	0.669
7/18/2013	R-02	251	0.061	2.32	72.8	0.371
10/2/2013	R-02	211	0.06	1.43	69.36	1.806
6/5/2014	R-02	246	0.046	3.79	73.3	0.392
9/10/2014	R-02	222	0.055	0.65	73.99	0.04
10/8/2014	R-02	268	0.057	0.61	75.89	0.162
5/28/2015	R-02	201	0.009	3.48	71.78	0.068
7/17/2015	R-02	168	0.04	4.11	68.52	0.54
9/29/2015	R-02	168	0.04	<LD	75.21	0.079
5/6/2016	R-02	236	0.045	3.9	77.12	0.145
10/14/2016	R-02	205	0.054	<LD	81.19	0.091
4/12/2017	R-02	206	0.053	4.5	75.1	0.107
7/27/2017	R-02	211	0.054	2.85	66.86	1.433
9/26/2017	R-02	240	0.055	<LD	68.45	DNQ
5/17/2018	R-02	195	0.085	4.81	75.28	0.179
7/17/2018	R-02	240	0.05	3.57	67.33	0.498
10/4/2018	R-02	175	0.049	3.12	43.46	0.503
5/3/2019	R-02	166	0.054	4.03	61.26	0.092

Table 11. Lab Testing Data from Beaver Run Reservoir by IUP

Date	Site ID	TDS	Br-	NO_3-	SO_4^{2}-	Mn
6/8/2011	R-03	228	0.375	2.56	45.87	0.213
8/22/2011	R-03	96	0.462	2.82	49.83	0.227
10/21/2011	R-03	291	0.235	2.81	53.92	0.121
4/25/2012	R-03	74	0.233	3.95	57.34	0.273
7/19/2012	R-03	25	0.245	1.21	58.85	DNQ
10/1/2012	R-03	293	0.374	0.98	79.01	0.093
5/17/2013	R-03	233	0.078	3.27	79.28	0.088
7/18/2013	R-03	225	0.066	3.19	60.18	0.752
10/2/2013	R-03	213	0.063	1.73	72.98	DNQ
6/5/2014	R-03	251	0.052	3.45	79.66	0.671
9/10/2014	R-03	194	0.057	0.91	72.7	0.261
10/8/2014	R-03	238	0.054	0.58	76.49	0.128
5/28/2015	R-03	227	DNQ	2.85	79.59	0.169
7/17/2015	R-03	148	0.035	3.53	68.05	0.259
9/29/2015	R-03	148	0.037	<LD	74.26	0.043
5/6/2016	R-03	233	0.045	3.86	78.27	0.162
10/14/2016	R-03	199	0.053	0.81	78.56	0.079
4/12/2017	R-03	169	0.049	4.8	64.83	0.152
7/27/2017	R-03	206	0.055	2.71	66.95	0.458
9/26/2017	R-03	232	0.055	<LD	68	DNQ
5/17/2018	R-03	200	0.085	4.59	74.18	0.141
7/17/2018	R-03	237	0.053	2.86	61.85	0.252
10/4/2018	R-03	183	0.05	2.86	48.53	0.187
5/3/2019	R-03	164	0.055	3.76	60.3	0.175
6/8/2011	R-04	311	0.701	3.84	46.25	0.045
8/22/2011	R-04	251	0.569	3.17	47.12	1.73
10/21/2011	R-04	176	0.278	2.76	45.73	0.078
4/25/2012	R-04	185	0.253	3.64	45.38	0.133
7/19/2012	R-04	209	0.24	2.69	47.24	0.057
10/1/2012	R-04	179	0.083	0.97	27.4	<LD
5/17/2013	R-04	199	0.07	2.85	61.79	0.05
7/18/2013	R-04	237	<LD	2.93	65.75	0.34
10/2/2013	R-04	180	0.022	3.22	63.62	0.379
6/5/2014	R-04	187	0.038	3.17	61.11	0.076
9/10/2014	R-04	157	0.046	2.89	57.32	0.603
10/8/2014	R-04	227	0.048	0.75	61.28	3.267
5/28/2015	R-04	160	0.012	2.91	57.4	0.055
7/17/2015	R-04	174	0.044	3.86	62.94	1.158
9/29/2015	R-04	174	0.042	1.67	51.07	1.535
5/6/2016	R-04	193	0.043	3.31	60.19	0.098
10/14/2016	R-04	176	0.048	<LD	64.3	0.515
4/12/2017	R-04	171	0.055	2.98	58.13	DNQ
7/27/2017	R-04	181	0.053	3.73	55.25	0.226
9/26/2017	R-04	241	0.057	0.87	55	3.085
5/17/2018	R-04	179	0.085	4.48	56.04	0.093
7/17/2018	R-04	216	0.049	4.27	57.74	0.29
10/4/2018	R-04	227	0.052	DNQ	54.2	3.087
5/3/2019	R-04	129	0.051	3.86	49.01	DNQ

Table 11. Lab Testing Data from Beaver Run Reservoir by IUP

Date	Site ID	TDS	Br-	NO_3-	SO_4^{2}-	Mn
6/8/2011	R-05	107	0.535	4.43	48.97	0.065
8/22/2011	R-05	200	0.618	2.42	42.88	DNQ
10/21/2011	R-05	211	0.255	1.88	45.77	0.097
4/25/2012	R-05	99	0.243	4	45.48	0.139
7/19/2012	R-05	209	0.247	1.48	49.88	<LD
10/1/2012	R-05	229	0.264	1.16	70.98	<LD
5/17/2013	R-05	199	0.07	2.8	63.46	0.05
7/18/2013	R-05	202	<LD	1.9	61.03	DNQ
10/2/2013	R-05	104	0.055	1.61	63.27	DNQ
6/5/2014	R-05	194	0.045	2.93	62.91	0.06
9/10/2014	R-05	183	0.047	0.68	61.74	<LD
10/8/2014	R-05	197	0.046	0.91	62.9	0.04
5/28/2015	R-05	190	0.009	2.71	57.1	<LD
7/17/2015	R-05	107	0.035	3	46.36	DNQ
9/29/2015	R-05	107	0.037	<LD	57.56	DNQ
5/6/2016	R-05	173	0.043	3.28	60.63	DNQ
10/14/2016	R-05	192	0.045	<LD	66.2	0.035
4/12/2017	R-05	176	0.054	3.05	57.99	DNQ
7/27/2017	R-05	177	0.051	3.27	56.28	0.061
9/26/2017	R-05	216	0.05	0.86	58.26	0.05
5/17/2018	R-05	190	0.087	4.68	58.65	0.62
7/17/2018	R-05	190	0.047	3.14	52.71	0.096
10/4/2018	R-05	180	0.048	DNQ	44.66	DNQ
5/3/2019	R-05	132	0.051	3.46	48.75	DNQ
6/8/2011	R-06					
8/22/2011	R-06	149	0.312	1.97	47.76	DNQ
10/21/2011	R-06	81	0.252	2.32	45.91	0.079
4/25/2012	R-06	165	0.23	3.24	45.45	0.124
7/19/2012	R-06	148	0.24	1.5	48.75	<LD
10/1/2012	R-06	228	0.083	0.97	36.06	<LD
5/17/2013	R-06	196	0.064	2.81	63.65	0.053
7/18/2013	R-06	206	<LD	1.82	64.04	DNQ
10/2/2013	R-06	160	0.061	1.66	63.47	<LD
6/5/2014	R-06	204	0.044	3.01	63.07	0.045
9/10/2014	R-06	163	0.046	0.66	61.02	<LD
10/8/2014	R-06	189	0.046	0.91	63.25	DNQ
5/28/2015	R-06	123	DNQ	2.17	59.64	DNQ
7/17/2015	R-06	111	0.035	2.58	51.33	DNQ
9/29/2015	R-06	111	0.037	0.86	56.89	0.073
5/6/2016	R-06	270	0.043	3.28	60.22	DNQ
10/14/2016	R-06	181	0.046	<LD	66.01	0.031
4/12/2017	R-06	169	0.054	3.07	58.83	DNQ
7/27/2017	R-06	197	0.052	2.35	57.22	0.116
9/26/2017	R-06	218	0.051	<LD	59.05	DNQ
5/17/2018	R-06	185	0.086	4.2	60.84	DNQ
7/17/2018	R-06	160	0.046	DNQ	50.35	DNQ
10/4/2018	R-06	172	0.046	2.69	40.54	0.085
5/3/2019	R-06	131	0.051	3.84	47.97	<LD

Table 11. Lab Testing Data from Beaver Run Reservoir by IUP

Date	Site ID	TDS	Br-	NO_3-	SO_4^{2}-	Mn
6/8/2011	R-07					
8/22/2011	R-07					
10/21/2011	R-07					
4/25/2012	R-07					
7/19/2012	R-07					
10/1/2012	R-07					
5/17/2013	R-07					
7/18/2013	R-07	203	<LD	1.96	63.08	<LD
10/2/2013	R-07	168	0.053	3.4	64.93	0.551
6/5/2014	R-07	203	0.044	2.87	61.61	DNQ
9/10/2014	R-07	146	0.046	0.65	61.56	<LD
10/8/2014	R-07	161	0.046	0.9	63.37	DNQ
5/28/2015	R-07	166	0.011	2.67	57.01	<LD
7/17/2015	R-07	199	0.033	2.92	48.88	DNQ
9/29/2015	R-07	199	0.045	2.26	55.64	1.371
5/6/2016	R-07	155	0.04	3.18	60.56	0.134
10/14/2016	R-07	180	0.045	<LD	65.38	0.038
4/12/2017	R-07	163	0.056	3.1	59.23	DNQ
7/27/2017	R-07	197	0.054	1.77	60.56	0.014
9/26/2017	R-07	210	0.052	1.07	54.4	0.476
5/17/2018	R-07	185	0.087	4.46	58.44	0.325
7/17/2018	R-07	209	0.05	3.98	54.17	0.289
10/4/2018	R-07	224	0.052	DNQ	53.92	2.337
5/3/2019	R-07	141	0.051	3.82	48.66	0.066

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 1	12-Dec-78	10	
Site 1	21-Aug-79	15	
Site 1	6-Dec-79	12	
Site 1	20-May-80	12	
Site 1	3-Nov-80	10	
Site 1	20-Apr-81	5.5	
Site 1	10-Aug-81	6	
Site 1	22-Jun-82	10	
Site 1	9-Jun-83	9	
Site 1	13-Jun-84	8	
Site 1	10-Oct-85	7	
Site 1	8-Oct-86	7	
Site 1	19-Oct-87	16	
Site 1	27-Oct-88	8	
Site 1	25-Oct-89	7	
Site 1	25-Oct-90	5.2	
Site 1	22-Oct-91	6.86	
Site 1	29-Oct-92	8.08	
Site 1	5-Nov-93	8	2.2
Site 1	19-Oct-94	6.34	3.1
Site 1	17-Oct-95	6.5	2.9
Site 1	23-Oct-97	7.05	2.46
Site 1	9-Oct-98	5.8	3.2
Site 1	18-Nov-99	7.2	4.3
Site 1	8-Nov-00	6.76	4.6
Site 1	12-Nov-03	5.93	3.4
Site 1	21-Oct-04	5.87	4.1
Site 1	9-Nov-05	7.34	1
Site 1	28-Nov-06	8.94	2.4
Site 1	12-Dec	3.59	2.1
Site 1	1-Sep-08	4.02	5.8
Site 1	1-May-09	1.83	2
Site 1	1-May-10	2.86	0
Site 2	12-Dec-78	0.1	
Site 2	23-Aug-79	0.05	
Site 2	6-Dec-79	0.05	
Site 2	20-May-80	0.01	
Site 2	20-Nov-80	0	
Site 2	20-Apr-81	0	
Site 2	10-Aug-81	0	
Site 2	22-Jun-82	0	
Site 2	9-Jun-83	0	
Site 2	13-Jun-84	0	
Site 2	1-Oct-85		
Site 2	8-Oct-86	0	

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 2	19-Oct-87	0.05	
Site 2	27-Oct-88	0.01	
Site 2	25-Oct-89	0.05	
Site 2	25-Oct-90	0	
Site 2	22-Oct-91	0.11	
Site 2	28-Oct-92	0.44	
Site 2	4-Nov-93	0.15	
Site 2	19-Oct-94	0.08	
Site 2	16-Oct-95	0.2	
Site 2	23-Oct-97		
Site 2	9-Oct-98		
Site 2	15-Nov-99		
Site 2	8-Nov-00		
Site 2	12-Nov-03	0.15	1.4
Site 2	21-Oct-04	0.12	1.7
Site 2	9-Nov-05	0.1	0.5
Site 2	28-Nov-06	0.17	0.8
Site 2	11-Dec-07	0.09	0.8
Site 2	Sep-08		
Site 2	May-09	0.11	1
Site 2	May-10	0.05	0.1
Site 3	12-Dec-78	0.2	
Site 3	21-Aug-79	0.4	
Site 3	6-Dec-79	0.25	
Site 3	20-May-80	0.15	
Site 3	3-Nov-80	0.1	
Site 3	20-Apr-81	0.05	
Site 3	10-Aug-81	0.01	
Site 3	22-Jun-82	0.1	
Site 3	10-Jun-83	0.15	
Site 3	12-Jun-84	0.1	
Site 3	2-Oct-85	0.1	
Site 3	9-Oct-86	0.1	
Site 3	19-Oct-87	0.05	
Site 3	28-Oct-88	0.15	
Site 3	25-Oct-89	0.15	
Site 3	26-Oct-90	0.1	
Site 3	23-Oct-91	0.16	
Site 3	28-Oct-92	0.08	
Site 3	4-Nov-93	0.12	1.1
Site 3	18-Oct-94	0.15	0.4
Site 3	16-Oct-95	0.08	0.9
Site 3	30-Oct-97	0.07	0.14
Site 3	15-Oct-98	0.17	0.14
Site 3	15-Nov-99	0.09	0.3

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 3	8-Nov-00	0.06	0.1
Site 3	12-Nov-03	0.16	1.3
Site 3	22-Oct-04	0.07	0.5
Site 3	7-Nov-05	0.16	0.7
Site 3	28-Nov-06	0.18	1
Site 3	11-Dec-07	0.12	1.2
Site 3	Sep-08	0.09	1.2
Site 3	May-09	0.07	1.2
Site 3	May-10	0.07	0.2
Site 4	12-Dec-78	0.75	
Site 4	23-Aug-79	0.9	
Site 4	6-Dec-79	1.1	
Site 4	20-May-80	1.5	
Site 4	20-Nov-80	0.6	
Site 4	20-Apr-81	0.5	
Site 4	10-Aug-81	0.4	
Site 4	22-Jun-82	0.8	
Site 4	9-Jun-83	1.2	
Site 4	13-Jun-84	2	
Site 4	1-Oct-85	0.35	
Site 4	8-Oct-86	0.7	
Site 4	19-Oct-87	1.2	
Site 4	27-Oct-88	0.55	
Site 4	25-Oct-89	1.1	
Site 4	25-Oct-90	0.72	
Site 4	22-Oct-91	0.37	
Site 4	28-Oct-92	0.62	
Site 4	4-Nov-93	0.63	0.9
Site 4	19-Oct-94	1.51	0.3
Site 4	16-Oct-95	0.64	0.4
Site 4	23-Oct-97	0.74	0.09
Site 4	9-Oct-98	0.09	0.03
Site 4	15-Nov-99	0.61	0.3
Site 4	8-Nov-00	0.56	0.1
Site 4	12-Nov-03	1.46	0.5
Site 4	21-Oct-04	2.22	0.2
Site 4	9-Nov-05	0.53	0.5
Site 4	28-Nov-06	2.84	1
Site 4	11-Dec-07	0.65	0.9
Site 4	Sep-08	0.14	0.7
Site 4	May-09	0.17	0.5
Site 4	May-10	1.26	0.6
Site 5	12-Dec-78	1.2	
Site 5	21-Aug-79	0.9	
Site 5	12-Dec-79	0.5	

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 5	22-May-80	0.7	
Site 5	3-Nov-80	0.3	
Site 5	20-Apr-81	0.25	
Site 5	10-Aug-81	0.01	
Site 5	22-Jun-82		
Site 5	9-Jun-83		
Site 5	13-Jun-84		
Site 5	1-Oct-85		
Site 5	8-Oct-86		
Site 5	19-Oct-87		
Site 5	28-Oct-88	0.1	
Site 5	26-Oct-89	0	
Site 5	26-Oct-90	0.11	
Site 5	23-Oct-91	0.13	
Site 5	28-Oct-92	0.07	
Site 5	4-Nov-93	0.11	1
Site 5	18-Oct-94	0.1	0.7
Site 5	16-Oct-95	0.05	0.7
Site 5	30-Oct-97	0.11	0.34
Site 5	15-Oct-98	0.09	0.13
Site 5	15-Nov-99	0.1	0.7
Site 5	8-Nov-00	0.04	0.6
Site 5	12-Nov-03	0.11	1.5
Site 5	22-Oct-04	0.1	0.55
Site 5	7-Nov-05	0.12	0.5
Site 5	28-Nov-06	0.19	1.9
Site 5	11-Dec-07	0.27	1.3
Site 5	Sep-08	0.13	0.9
Site 5	May-09	0.06	1
Site 5	May-10	0.07	0
Site 6	12-Dec-78	5.5	
Site 6	21-Aug-79	12	
Site 6	12-Dec-79	8	
Site 6	22-May-80	8	
Site 6	3-Nov-80	5	
Site 6	20-Apr-81	6	
Site 6	10-Aug-81	6	
Site 6	22-Jun-82	7	
Site 6	10-Jun-83	7	
Site 6	12-Jun-84	12	
Site 6	2-Oct-85	5.5	
Site 6	9-Oct-86	5.5	
Site 6	19-Oct-87	20	
Site 6	28-Oct-88	10	
Site 6	26-Oct-89	7	

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 6	26-Oct-90	4.13	
Site 6	23-Oct-91	86.2	
Site 6	28-Oct-92	8.03	
Site 6	4-Nov-93	6.9	0.7
Site 6	18-Oct-94	4.79	0.9
Site 6	16-Oct-95	2.95	0.5
Site 6	30-Oct-97	11.66	0.02
Site 6	15-Oct-98	12.2	0.28
Site 6	18-Nov-99	10.66	0.9
Site 6	8-Nov-00	10.7	0.6
Site 6	12-Nov-03	5.78	0.7
Site 6	22-Oct-04	6.39	1.5
Site 6	7-Nov-05	12.08	1.6
Site 6	28-Nov-06	7.96	1.6
Site 6	11-Dec-07	2.88	0.8
Site 6	Sep-08	9.38	2.6
Site 6	May-09	1.81	5.4
Site 6	May-10	2.12	1
Site 7	21-Dec-78	1.65	
Site 7	23-Aug-79	1.5	
Site 7	6-Dec-79	1.8	
Site 7	20-May-80	4	
Site 7	3-Nov-80	1.5	
Site 7	20-Apr-81	0.2	
Site 7	10-Aug-81	2	
Site 7	22-Jun-82	3	
Site 7	9-Jun-83	2	
Site 7	13-Jun-84	4	
Site 7	1-Oct-85	0.01	
Site 7	8-Oct-86	0.35	
Site 7	19-Oct-87	0.5	
Site 7	27-Oct-88	0.35	
Site 7	25-Oct-89	0.35	
Site 7	25-Oct-90	0.51	
Site 7	22-Oct-91	0.03	
Site 7	29-Oct-92	0.15	
Site 7	5-Nov-93	0.13	0.3
Site 7	19-Oct-94	0.15	0.2
Site 7	17-Oct-95	0.12	0.2
Site 7	23-Oct-97	0.12	0.12
Site 7	9-Oct-98	0.13	0.1
Site 7	15-Nov-99	0.1	0.3
Site 7	9-Nov-00	0.29	0.1
Site 7	13-Nov-03	0.2	0.5
Site 7	21-Oct-04	0.3	1.32

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 7	9-Nov-05	0.08	0.3
Site 7	28-Nov-06	0.21	0.7
Site 7	11-Dec-07	0.19	0.7
Site 7	Sep-08	0.11	1
Site 7	May-09	0.17	0.7
Site 7	May-10	0.23	0
Site 8	21-Dec-78	0.05	
Site 8	23-Aug-79	0.25	
Site 8	6-Dec-79	0.2	
Site 8	20-May-80	0.05	
Site 8	3-Nov-80	0.15	
Site 8	20-Apr-81	0.01	
Site 8	10-Aug-81	0.01	
Site 8	22-Jun-82	0.1	
Site 8	9-Jun-83	0.15	
Site 8	13-Jun-84	0.05	
Site 8	1-Oct-85	0.01	
Site 8	8-Oct-86	0.1	
Site 8	19-Oct-87	0.3	
Site 8	27-Oct-88	0.15	
Site 8	25-Oct-89	0.2	
Site 8	25-Oct-90	0.13	
Site 8	22-Oct-91	0.37	
Site 8	29-Oct-92	0.17	
Site 8	5-Nov-93	0.18	0.5
Site 8	19-Oct-94	0.18	0.2
Site 8	17-Oct-95	0.12	0.2
Site 8	23-Oct-97	0.17	0.05
Site 8	9-Oct-98	0.17	0.19
Site 8	15-Nov-99	0.38	0.3
Site 8	9-Nov-00	0.28	0.1
Site 8	13-Nov-03	0.25	1
Site 8	21-Oct-04	0.19	0.5
Site 8	9-Nov-05	0.28	0.3
Site 8	28-Nov-06	0.19	0.7
Site 8	11-Dec-07	0.11	1.1
Site 8	Sep-08	0.24	1.5
Site 8	May-09	0.19	1.5
Site 8	May-10	0.15	0
Site 9	12-Dec-78	0.15	
Site 9	27-Aug-79	0.07	
Site 9	12-Dec-79	0.01	
Site 9	22-May-80	0	
Site 9	3-Nov-80	0	
Site 9	20-Apr-81	0.1	

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 9	10-Aug-81	0	
Site 9	22-Jun-82	0	
Site 9	10-Jun-83	0	
Site 9	12-Jun-84	0.6	
Site 9	2-Oct-85	0.1	
Site 9	9-Oct-86	0.05	
Site 9	19-Oct-87	0.05	
Site 9	28-Oct-88	0	
Site 9	26-Oct-89	0	
Site 9	26-Oct-90	0.12	
Site 9	23-Oct-91	0.04	
Site 9	28-Oct-92	0.05	
Site 9	4-Nov-93	0.04	4
Site 9	18-Oct-94	0.04	2.3
Site 9	16-Oct-95	0.04	1.3
Site 9	30-Oct-97	0.04	0.76
Site 9	15-Oct-98	0.06	0.56
Site 9	15-Nov-99	0.06	1.1
Site 9	8-Nov-00	0.04	1.3
Site 9	13-Nov-03	0.23	3
Site 9	22-Oct-04	0.19	7
Site 9	7-Nov-05	0.18	0.9
Site 9	28-Nov-06	0.1	2
Site 9	11-Dec-07	0.35	2.4
Site 9	Sep-08	0.19	1.6
Site 9	May-09	0.05	2.1
Site 9	May-10	0.07	0.2
Site 10	21-Dec-78	0.01	
Site 10	27-Aug-79	0.05	
Site 10	12-Dec-79	0.01	
Site 10	22-May-80	0	
Site 10	3-Nov-80	0	
Site 10	20-Apr-81	0.01	
Site 10	10-Aug-81	0.01	
Site 10	22-Jun-82	0.01	
Site 10	10-Jun-83	0.1	
Site 10	12-Jun-84	0	
Site 10	2-Oct-85	0	
Site 10	9-Oct-86	0	
Site 10	19-Oct-87	0	
Site 10	28-Oct-88	0	
Site 10	26-Oct-89	0	
Site 10	26-Oct-90	0.05	
Site 10	23-Oct-91	0.33	
Site 10	28-Oct-92	0.25	

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 10	4-Nov-93	0.07	1.8
Site 10	18-Oct-94	0.29	0.7
Site 10	16-Oct-95	0.14	0.3
Site 10	30-Oct-97	0.05	0.23
Site 10	15-Oct-98	0.07	0.3
Site 10	15-Nov-99	0.08	0.4
Site 10	8-Nov-00	0.06	0.2
Site 10	13-Nov-03	0.06	1.2
Site 10	22-Oct-04	0.04	0.5
Site 10	7-Nov-05	0.04	1.2
Site 10	28-Nov-06	0.02	1.7
Site 10	11-Dec-07	0.06	1.7
Site 10	Sep-08	0.04	1
Site 10	May-09	0.03	1.2
Site 10	May-10	0.05	0.2
Site 11	21-Dec-78	0.1	
Site 11	23-Aug-79	0.2	
Site 11	6-Dec-79	0.25	
Site 11	20-May-80	0.15	
Site 11	3-Nov-80	0.15	
Site 11	20-Apr-81	0.05	
Site 11	10-Aug-81	0.15	
Site 11	22-Jun-82	0.15	
Site 11	9-Jun-83	0.3	
Site 11	13-Jun-84	0.15	
Site 11	1-Oct-85	0.05	
Site 11	9-Oct-86	0.1	
Site 11	19-Oct-87	0.25	
Site 11	27-Oct-88	0.15	
Site 11	25-Oct-89	0.3	
Site 11	25-Oct-90	0.28	
Site 11			
Site 11	29-Oct-92	0.4	
Site 11	5-Nov-93	0.25	0.7
Site 11	19-Oct-94	0.19	0.2
Site 11	17-Oct-95	0.13	0.1
Site 11	23-Oct-97	1.08	0.12
Site 11	9-Oct-98	0.39	0.15
Site 11	18-Nov-99	0.24	0.4
Site 11	9-Nov-00	4.96	0.4
Site 11	13-Nov-03	0.33	0.9
Site 11	21-Oct-04	0.32	0.4
Site 11	9-Nov-05	2.04	0.1
Site 11	28-Nov-06	0.17	0.9
Site 11	11-Dec-07	0.1	1

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 11	Sep-08	0.15	1.3
Site 11	May-09	0.26	1.4
Site 11	May-10	0.07	0
Site 13	21-Dec-78	0.2	
Site 13	23-Aug-79	0.2	
Site 13	6-Dec-79	0.05	
Site 13	20-May-80	0.15	
Site 13	3-Nov-80	0.25	
Site 13	20-Apr-81	0.05	
Site 13	10-Aug-81	0.05	
Site 13	22-Jun-82	0.1	
Site 13	9-Jun-83	0.15	
Site 13	13-Jun-84	0.15	
Site 13	1-Oct-85	0.15	
Site 13	8-Oct-86	0.15	
Site 13	19-Oct-87	0.4	
Site 13	27-Oct-88	0.45	
Site 13	25-Oct-89	0.1	
Site 13	25-Oct-90	0.11	
Site 13	22-Oct-91	0.67	
Site 13	29-Oct-92	0.25	
Site 13	5-Nov-93	0.12	0.6
Site 13	19-Oct-94	0.2	0.3
Site 13	17-Oct-95	0.27	0.2
Site 13	23-Oct-97	0.46	0.12
Site 13	9-Oct-98	0.17	0.2
Site 13	18-Nov-99	0.5	0.3
Site 13	9-Nov-00	1.12	0.1
Site 13	13-Nov-03	0.19	1.1
Site 13	21-Oct-04	0.18	0.5
Site 13	9-Nov-05	0.43	0
Site 13	28-Nov-06	0.11	0.8
Site 13	11-Dec-07	0.08	1
Site 13	Sep-08	0.48	1.2
Site 13	May-09	0.24	0.2
Site 13	May-10	0.13	0.1
Site 14	21-Dec-78	0.05	
Site 14	23-Aug-79	0	
Site 14	6-Dec-79	0.2	
Site 14	20-May-80	0.01	
Site 14	3-Nov-80	0.05	
Site 14	20-Apr-81	0.01	
Site 14	10-Aug-81	0	
Site 14	22-Jun-82	0	
Site 14	9-Jun-83	0.05	

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 14	13-Jun-84	0.01	
Site 14	1-Oct-85	0.15	
Site 14	8-Oct-86	0.15	
Site 14	19-Oct-87	0.4	
Site 14	27-Oct-88	0.2	
Site 14	25-Oct-89	0.2	
Site 14	25-Oct-90	0.12	
Site 14	22-Oct-91	0.15	
Site 14	29-Oct-92	0.11	
Site 14	5-Nov-93	0.09	0.7
Site 14	19-Oct-94	0.35	0.3
Site 14	17-Oct-95	0.14	0.1
Site 14	23-Oct-97	0.43	0.05
Site 14	9-Oct-98	0.5	0.09
Site 14	15-Nov-99	0.43	0.3
Site 14	9-Nov-00	0.19	0.1
Site 14	12-Nov-03		
Site 14	21-Oct-04	0.06	1
Site 14	7-Nov-05	0.28	0.5
Site 14	28-Nov-06	0.06	1.7
Site 14	11-Dec-07	0.04	1.7
Site 14	Sep-08	0.31	1.1
Site 14	May-09	0.17	0.6
Site 14	May-10	0.05	0.5
Site 15	12-Dec-78	0	
Site 15	21-Aug-79	0.01	
Site 15	21-Dec-79	0.01	
Site 15	22-May-80	0	
Site 15	3-Nov-80	0.01	
Site 15	20-Apr-81	0	
Site 15	10-Aug-81	0	
Site 15	22-Jun-82	0	
Site 15	10-Jun-83	0	
Site 15	12-Jun-84	0	
Site 15	2-Oct-85	1.4	
Site 15	9-Oct-86	0.25	
Site 15	19-Oct-87	0.1	
Site 15			
Site 15	26-Oct-89	0	
Site 15	26-Oct-90	0.02	
Site 15			
Site 15	28-Oct-92	0.51	
Site 15	4-Nov-93	0.53	0.2
Site 15	18-Oct-94	1.32	0.5
Site 15	16-Oct-95	0.82	0.1

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 15	30-Oct-97	0.38	0.15
Site 15	15-Oct-98	1.28	0.07
Site 15	15-Nov-99	0.48	0.3
Site 15	8-Nov-00	0.86	0
Site 15	12-Nov-03	0.07	1.4
Site 15	22-Oct-04	0.14	0.3
Site 15	7-Nov-05	0.3	0.4
Site 15	28-Nov-06	0.12	1.2
Site 15	11-Dec-07	0.2	0.9
Site 15	Sep-08	0.1	1
Site 15	May-09	0.05	0.8
Site 15	May-10	0.05	0.5
Site 16	12-Dec-78		
Site 16	21-Aug-79		
Site 16	21-Dec-79		
Site 16	22-May-80		
Site 16	3-Nov-80		
Site 16	20-Apr-81		
Site 16	10-Aug-81		
Site 16	22-Jun-82		
Site 16	10-Jun-83		
Site 16	12-Jun-84		
Site 16	1-Oct-85	7	
Site 16	8-Oct-86	6	
Site 16	19-Oct-87	8	
Site 16	27-Oct-88	8	
Site 16	25-Oct-89	6	
Site 16	25-Oct-90	4.5	
Site 16	22-Oct-91	4.96	
Site 16	29-Oct-92	7.7	
Site 16	5-Nov-93	6.3	1.3
Site 16	19-Oct-94	1.25	0.9
Site 16	17-Oct-95	3.5	1
Site 16	23-Oct-97	6.5	0.34
Site 16	9-Oct-98	5.9	0.28
Site 16	18-Nov-99	7.06	0.9
Site 16	8-Nov-00	3.64	0.4
Site 16	12-Nov-03	4.93	1.8
Site 16	21-Oct-04	5.93	1.6
Site 16	9-Nov-05	5.73	1
Site 16	28-Nov-06	4.93	2
Site 16	11-Dec-07	3.16	1.1
Site 16	Sep-08	5.72	2.1
Site 16	May-09	1.17	1.8
Site 16	May-10	2.06	0

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 17	12-Dec-78		
Site 17	21-Aug-79		
Site 17	21-Dec-79		
Site 17	22-May-80		
Site 17	3-Nov-80		
Site 17	20-Apr-81		
Site 17	10-Aug-81		
Site 17	22-Jun-82		
Site 17	10-Jun-83		
Site 17	12-Jun-84		
Site 17	2-Oct-85	0	
Site 17	9-Oct-86	0.15	
Site 17	19-Oct-87	0.02	
Site 17	28-Oct-88	0.01	
Site 17	26-Oct-89	0.3	
Site 17	26-Oct-90	0.38	
Site 17	23-Oct-91	0.02	
Site 17	28-Oct-92	0.04	
Site 17	4-Nov-93	0.12	0.7
Site 17	18-Oct-94	0.04	1.7
Site 17	16-Oct-95	0.06	0.7
Site 17	30-Oct-97	0.09	0.66
Site 17	15-Oct-98	0.29	0.29
Site 17	15-Nov-99	0.02	1.1
Site 17	8-Nov-00	0.02	0.4
Site 17	13-Nov-03	0.09	1.1
Site 17	22-Oct-04	0.43	0.3
Site 17	7-Nov-05	0.06	0.4
Site 17	28-Nov-06	0.16	1.2
Site 17	11-Dec-07	0.07	1
Site 17	Sep-08	0.62	1.5
Site 17	May-09	0.09	1.3
Site 17	May-10	0.06	0.6
Site 18	12-Dec-78		
Site 18	21-Aug-79		
Site 18	21-Dec-79		
Site 18	22-May-80		
Site 18	3-Nov-80		
Site 18	20-Apr-81		
Site 18	10-Aug-81		
Site 18	22-Jun-82		
Site 18	10-Jun-83		
Site 18	12-Jun-84		
Site 18	2-Oct-85		
Site 18	9-Oct-86		

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 18	19-Oct-87		
Site 18	27-Oct-88	0	
Site 18	26-Oct-89	0.05	
Site 18	25-Oct-90	0.34	
Site 18	22-Oct-91	0.01	
Site 18	29-Oct-92	0.05	
Site 18	5-Nov-93	0.08	0.6
Site 18	19-Oct-94	0.06	0.3
Site 18	17-Oct-95	0.07	0.3
Site 18	23-Oct-97	0.11	0.05
Site 18	9-Oct-98	0.07	0.23
Site 18	18-Nov-99	0.05	0.3
Site 18	9-Nov-00	0.06	0.1
Site 18	13-Nov-03	0.14	1.1
Site 18	21-Oct-04	0.11	0.6
Site 18	9-Nov-05	0.21	0.2
Site 18	28-Nov-06	0.1	0.9
Site 18	11-Dec-07	0.11	1.4
Site 18	Sep-08	0.25	1.4
Site 18	May-09	0.07	0.3
Site 18	May-10	0.1	0.3
Site 19	12-Dec-78		
Site 19	21-Aug-79		
Site 19	21-Dec-79		
Site 19	22-May-80		
Site 19	3-Nov-80		
Site 19	20-Apr-81		
Site 19	10-Aug-81		
Site 19	22-Jun-82		
Site 19	10-Jun-83		
Site 19	12-Jun-84		
Site 19	2-Oct-85		
Site 19	9-Oct-86		
Site 19	19-Oct-87		
Site 19	27-Oct-88	0.05	
Site 19	25-Oct-89	0	
Site 19	26-Oct-90	0.12	
Site 19	22-Oct-91	0.02	
Site 19	29-Oct-92	0.03	
Site 19	5-Nov-93	0.05	0.5
Site 19	19-Oct-94	0.04	0.3
Site 19	17-Oct-95	0.06	0.2
Site 19	23-Oct-97	0.27	0.05
Site 19	9-Oct-98	0.32	0.6
Site 19	18-Nov-99	0.46	0.4

Table 12. Historical Data Around Beaver Run Reservoir

Location	Date	MN (mg/L)	NO3-N (mg/L)
Site 19	9-Nov-00	0.31	0
Site 19	13-Nov-03	0.13	1.1
Site 19	21-Oct-04	0.21	1
Site 19	9-Nov-05	0.28	0.4
Site 19	28-Nov-06	0.14	1.1
Site 19	11-Dec-07	0.09	1.6
Site 19	Sep-08	0.22	1.1
Site 19	May-09	0.24	0.9
Site 19	May-10	0.11	0.2
Site 20	12-Dec-78		
Site 20	21-Aug-79		
Site 20	21-Dec-79		
Site 20	22-May-80		
Site 20	3-Nov-80		
Site 20	20-Apr-81		
Site 20	10-Aug-81		
Site 20	22-Jun-82		
Site 20	10-Jun-83		
Site 20	12-Jun-84		
Site 20	2-Oct-85		
Site 20	9-Oct-86		
Site 20	19-Oct-87		
Site 20	27-Oct-88	0.01	
Site 20	25-Oct-89	0.1	
Site 20	25-Oct-90	0.11	
Site 20	22-Oct-91	0.04	
Site 20	28-Oct-92	0.07	
Site 20	4-Nov-93	0.18	0.6
Site 20	19-Oct-94	0.07	0.6
Site 20	16-Oct-95	0.41	1.6
Site 20	23-Oct-97	0.1	0.15
Site 20	9-Oct-98	0.35	0.43
Site 20	15-Nov-99	0.06	0.4
Site 20	8-Nov-00	0.08	0.1
Site 20	12-Nov-03	0.47	0.7
Site 20	21-Oct-04	0.09	0.4
Site 20	9-Nov-05	0.06	0.3
Site 20	28-Nov-06	0.14	1.3
Site 20	11-Dec-07	0.22	1.5
Site 20	Sep-08	0.16	3
Site 20	May-09	0.2	0
Site 20	May-10	0.31	0

Table 13. Data for TOC at the Sweeney Treatment Plant

PLANT ID	Date	Performance Ratio	Raw TOC Avg	Treated TOC Avg	% Removal Required	% Removal Achieved
302	7/2008	1	2.3	1.7	35	25
302	8/2008	1	1.9	1.7	.	.
302	9/2008	1	2.1	1.7	35	18
302	10/2008	1	1.9	1.6	.	.
302	11/2008	1	2	1.8	35	13
302	12/2008	1	2	1.7	35	16
302	1/2009	1	2.1	1.7	35	22
302	2/2009	1	1.9	1.5	.	.
302	3/2009	1	1.9	1.6	.	.
302	4/2009	1	1.7	1.5	.	.
302	5/2009	1	1.8	1.5	.	.
302	6/2009	1	1.9	1.6	.	.
302	7/2009	1	1.9	1.6	.	.
302	8/2009	1	1.9	1.6	.	.
302	9/2009	1	1.8	1.6	.	.
302	10/2009	1	1.8	1.5	.	.
302	11/2009	1	1.8	1.6	.	.
302	12/2009	1	2	1.6	35	21
302	1/2010	1	1.8	1.6		
302	2/2010	1	2.1	1.7	35	16
302	3/2010	1	2	1.7	.	.
302	4/2010	1	1.7	1.5	.	.
302	5/2010	1	1.9	1.8	.	.
302	6/2010	0.31	2.3	2	35	11
302	7/2010	1	2	1.7	35	14
302	10/2010	1	2.1	1.5	35	26
302	1/2011	1	2.1	1.8	35	14
302	4/2011	1	2.2	1.8	35	17
302	7/2011	1	2.3	1.9	35	21
302	10/2011	1	2.3	1.8	35	21
302	1/2012	1	2	1.8	.	.
302	4/2012	1	2	1.6	.	.
302	7/2012	1	1.8	1.7	.	.
302	10/2012	1	2.3	2	35	13
302	1/2013	.	2.5	2.2		
302	4/2013	1	2.1	1.9		
302	7/2013	1	2.2	1.7		
302	10/2013	.	2.3	2		
302	1/2014	1	2.1	2	35	7
302	4/2014	1	2	1.4	.	.
302	7/2014	1	1.8	1.3	.	.
302	10/2014	1	2	1.3	.	.
302	1/2015	1	2	1.7	.	.
302	4/2015	1	1.9	1.6	.	.
302	7/2015	1	2.1	1.7	35	19

Table 13. Data for TOC at the Sweeney Treatment Plant

PLANT ID	Date	Performance Ratio	Raw TOC Avg	Treated TOC Avg	% Removal Required	% Removal Achieved
302	10/2015	0.66	2.7	2.1	35	23
302	1/2016	1	2.2	1.9		
302	4/2016	1	2.5	1.9		
302	7/2016	1	1.9	1.6	.	.
302	10/2016	.	2.5	2.2		
302	1/2017	1	1.5	1.1	.	.
302	4/2017	1	1.3	0.9	.	.
302	7/2017	1	1.9	1.1	.	.
302	10/2017	0.4	2.6	2.3	35	14
302	1/2018	0.69	2.7	2.1	35	24
302	4/2018	0.58	2.5	2	35	20
302	7/2018	1	2.2	1.9		
302	10/2018	0.51	2.9	2.4	35	18
302	11/2018	0.42	2.7	2.3	35	15
302	12/2018	1	2.5	1.9	35	26
302	1/2019	1	2.5	1.9	35	24
302	2/2019	1	2.3	1.8	35	23
302	3/2019	1	2.1	1.6	35	26
302	4/2019	1.2	3	1.8	35	42
302	5/2019	1	2.2	1.7	35	21
302	6/2019	1	2	1.6	35	23

Table 14. Data for TOC at the Indian Creek Water Treatment Plant

PLANT ID	Date	Performance Ratio	Raw TOC Monthly Avg	Treated TOC Monthly Avg	% Removal Required	% Removal Achieved
300	1/2008	1	1.5	0.9	.	.
300	4/2008	1	1.3	0.9	.	.
300	7/2008	1	2.2	1.7	35	21
300	10/2008	1	2.4	1.8	35	25
300	1/2009	1	1.9	1	.	.
300	4/2009	1	1.7	1.1	.	.
300	7/2009	1	1.5	1.2	.	.
300	10/2009	1	1.9	1.4	.	.
300	1/2010	1	1.2	0.7	.	.
300	4/2010	1	1.3	0.9		
300	7/2010	1	1.7	1.4	.	.
300	10/2010	1	2.3	1.7	35	26
300	1/2011	1	1.4	1	.	.
300	4/2011	1	1.4	0.8	.	.
300	7/2011	1	2.3	1.7	35	24
300	10/2011	1.08	2.9	1.8	35	38
300	1/2012	1	1.3	0.9	.	.
300	4/2012	1	1.2	0.8	.	.
300	7/2012	1	1.7	1.3	.	.
300	10/2012	1	1.9	1.5	.	.
300	1/2013	1	1.5	1	.	.
300	4/2013	1	1.7	1.1		
300	7/2013	1	1.8	1.6	.	.
300	10/2013	1.42	3.6	1.8	35	50
300	1/2014	1	1.7	1.1	.	.
300	4/2014	1	1.5	1	.	.
300	7/2014	1	1.9	1.3	.	.
300	10/2014	1	2.3	1.6	35	32
300	1/2015	1	1.5	0.9	.	.
300	7/2015	1.32	2.4	1.3	35	46
300	10/2015	1	2.5	1.8	35	28
300	1/2016	1	1.6	1	.	.
300	4/2016	1	1.3	1	.	.
300	7/2016	1	1.8	1.3	.	.
300	10/2016	1.05	3.4	2.2	35	37
300	1/2017	1	1.9	1.1	.	.
300	4/2017	1	1.7	1.1	.	.
300	7/2017	1	2.2	1.5	35	31
300	10/2017	1	2.5	1.8	35	30
300	1/2018	1	1.6	1.1	.	.
300	4/2018	1	1.9	1.1	.	.
300	7/2018	1	2	1.3	.	.
300	10/2018	1	2.4	1.6	35	34
300	1/2019	1	1.5	0.9	.	.
300	4/2019	1	1.6	0.9	.	.

Table 15. Consumer Confidence Report Data on Disinfection Byproducts and Radionuclides

Disinfection Byproduct	Date Tested	MCL	MCLG	Detected Level	Low Range	High Range
Halo Acetic Acids 5 (ppb)	2006	60	0	14	6	19
Halo Acetic Acids 5 (ppb)	2007	60	0	14.5	11.2	21.2
Halo Acetic Acids 5 (ppb)	2009	60	0	17.4	12.3	20.7
Halo Acetic Acids 5 (ppb)	2010	60	0	14.2	9	20.3
Halo Acetic Acids 5 (ppb)	2011	60	0	17.1	14.5	17.1
Halo Acetic Acids 5 (ppb)	2012	60	0	11.9	0	13.7
Halo Acetic Acids 5 (ppb)	2013	60	0	20.8	0	32.3
Halo Acetic Acids 5 (ppb)	2014	60	0	18.8	3.1	41.9
Halo Acetic Acids 5 (ppb)	2015	60	0	20	0	28.48
Halo Acetic Acids 5 (ppb)	2016	60	0	27.9	0	42.9
Halo Acetic Acids 5 (ppb)	2017	60	0	36.7	14.9	46
Halo Acetic Acids 5 (ppb)	2018	60	0	40.4	14.1	48.8
Total Trihalomethanes (ppb)	2006	80	0	23	12	30
Total Trihalomethanes (ppb)	2007	80	0	30.1	23.8	35
Total Trihalomethanes (ppb)	2009	80	0	27.6	21.4	34.9
Total Trihalomethanes (ppb)	2010	80	0	29.8	21.2	38.1
Total Trihalomethanes (ppb)	2011	80	0	32.7	21	42.2
Total Trihalomethanes (ppb)	2012	80	0	29.2	24.7	33.6
Total Trihalomethanes (ppb)	2013	80	0	34.7	17.3	52.9
Total Trihalomethanes (ppb)	2014	80	0	28.6	14.6	47.7
Total Trihalomethanes (ppb)	2015	80	0	38.4	13.79	46.56
Total Trihalomethanes (ppb)	2016	80	0	51.1	16	111
Total Trihalomethanes (ppb)	2017	80	0	47	16.5	64.5
Total Trihalomethanes (ppb)	2018	80	0	49.7	26.1	64.7
HAA5 (ppb)	2018	NE	NE	44.4	13.9	70.5
HAA9 (ppb)	2018	NE	NE	5.32	0.9	8.4
HAABr (ppb)	2018	NE	NE	49.7	15.6	76.8
IDSE HAA 5 (ppb)	2010	60	0	12.2	0	19
IDSE HAA 5 (ppb)	2011	60	0	12.2	0	19
IDSE HAA 5 (ppb)	2012	60	0	12.2	0	19
IDSE Total Trihalomethanes (ppb)	2010	80	0	24.9	13.3	32.7
IDSE Total Trihalomethanes (ppb)	2011	80	0	24.9	13.3	32.7
IDSE Total Trihalomethanes (ppb)	2012	80	0	24.9	13.3	32.7
Combined Radium (226+228) (pCi/L)	2002	5		1		
Combined Radium (226+228) (pCi/L)	2004	5		0.1		
Combined Radium (226+228) (pCi/L)	2011	5		0		
Combined Radium (226+228) (pCi/L)	2014	5		1.9		
Gross Alpha Particles (pCi/L)	2002	15		0.9		
Gross Alpha Particles (pCi/L)	2004	15		0.1		
Gross Alpha Particles (pCi/L)	2011	15		0		
Gross Alpha Particles (pCi/L)	2014	15		3		
Gross Beta Particles (pCi/L)	2003	4		3.5		
Gross Beta Particles (pCi/L)	2004	4		0.4		
Gross Beta Particles (pCi/L)	2011	4		0		
Total Uranium (ug/L)	2002	30		1		
Total Uranium (ug/L)	2011	30		0		

Table 16. Radionuclides Recorded by Environmental Services Lab Following Shaw Incident

Date	Site	Radium 226 (pCi/L)	Radium 228 (pCi/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
	MCL#:	5 pCi/L Radium Total		15 pCi/L	4 mrem/yr
11/28/2018*	BR-C (Below Shaw)				
12/4/2018*	BR-C (Below Shaw)				
12/14/2018*	BR-C (Below Shaw)				
12/19/2018	BR-C (Below Shaw)				
1/4/2019	BR-C (Below Shaw)				
1/11/2019	BR-C (Below Shaw)				
1/17/2019	BR-C (Below Shaw)				
1/22/2019	BR-C (Below Shaw)				
1/28/2019	BR-C (Below Shaw)	0	0	0	0
1/29/2019	BR-C (Below Shaw)	0.709	0	0	0
1/30/2019	BR-C (Below Shaw)	0.414	0	0	1.28
2/5/2019	BR-C (Below Shaw)	0	0	0	0
2/7/2019	BR-C (Below Shaw)	0	0	0	0
2/8/2019	BR-C (Below Shaw)				
2/11/2019	BR-C (Below Shaw)	0	0	0	1.03
2/13/2019	BR-C (Below Shaw)	0	0	0	0
2/14/2019	BR-C (Below Shaw)	0	0	0	0
2/15/2019	BR-C (Below Shaw)				
2/19/2019	BR-C (Below Shaw)	0	0	0	1.44
2/21/2019	BR-C (Below Shaw)	0	0	0	0
2/22/2019	BR-C (Below Shaw)	0	0	0	0
2/25/2019	BR-C (Below Shaw)	0	0	0	0
2/27/2019	BR-C (Below Shaw)	0	0	0	1.18
2/28/2019	BR-C (Below Shaw)	0	0	0	0
3/4/2019	BR-C (Below Shaw)	0	0	0	3.39
3/5/2019	BR-C (Below Shaw)	0	0	0	1.39
3/12/2019	BR-C (Below Shaw)	0	0	0	3.67
3/14/2019	BR-C (Below Shaw)	0	0	0	0
3/19/2019	BR-C (Below Shaw)	0	0	0	0
3/21/2019	BR-C (Below Shaw)	0	0	0	1.12
3/27/2019	BR-C (Below Shaw)	0	0	0	0
3/29/2019	BR-C (Below Shaw)	0	0	0	1.94
4/3/2019	BR-C (Below Shaw)	0	0	0	1.36
4/10/2019	BR-C (Below Shaw)	0	0	0	0
11/28/2018*	BR-S (On Inlet)				
12/4/2018*	BR-S (On Inlet)				
12/14/2018*	BR-S (On Inlet)				
12/19/2018	BR-S (On Inlet)				
1/4/2019	BR-S (On Inlet)				
1/11/2019	BR-S (On Inlet)				
1/17/2019	BR-S (On Inlet)				
1/22/2019	BR-S (On Inlet)				
1/28/2019	BR-S (On Inlet)	0	0	0	0
1/29/2019	BR-S (On Inlet)	0	0	3.27	5.02

Table 16. Radionuclides Recorded by Environmental Services Lab Following Shaw Incident

Date	Site	Radium 226 (pCi/L)	Radium 228 (pCi/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
	MCL#:	5 pCi/L Radium Total		15 pCi/L	4 mrem/yr
1/30/2019	BR-S (On Inlet)	0	0.629	1.55	3.39
2/5/2019	BR-S (On Inlet)	0	0	0	0
2/7/2019	BR-S (On Inlet)	0	0	0	0
2/8/2019	BR-S (On Inlet)				
2/11/2019	BR-S (On Inlet)	0	0	0.449	1.8
2/13/2019	BR-S (On Inlet)	v	0	0	2.51
2/14/2019	BR-S (On Inlet)	0	0	0	0
2/15/2019	BR-S (On Inlet)				
2/19/2019	BR-S (On Inlet)	0	0	0	2.39
2/21/2019	BR-S (On Inlet)	0	0	0	0
2/22/2019	BR-S (On Inlet)	0	0	0	0
2/25/2019	BR-S (On Inlet)	0	0	0	0
2/27/2019	BR-S (On Inlet)	0	0	1.1	1.26
2/28/2019	BR-S (On Inlet)	0	0.7	0	0
3/4/2019	BR-S (On Inlet)	0	0	0	0
3/5/2019	BR-S (On Inlet)	0	0	0	1.7
3/12/2019	BR-S (On Inlet)	0	0	0	1.93
3/14/2019	BR-S (On Inlet)	0	0	0	0
3/19/2019	BR-S (On Inlet)	0	0	0	0
3/21/2019	BR-S (On Inlet)	0	0	0	1.9
3/27/2019	BR-S (On Inlet)	0	0	0	0
3/29/2019	BR-S (On Inlet)				
4/3/2019	BR-S (On Inlet)	0	0	0	1.56
4/10/2019	BR-S (On Inlet)	0	0	0	0
11/28/2018*	CNX Water Intake	0	0	0	0
12/4/2018*	CNX Water Intake	0	0	0	0
12/14/2018*	CNX Water Intake	0	0	0	0
12/19/2018	CNX Water Intake	0	0	0	0
1/4/2019	CNX Water Intake	0	0	0	1.1
1/11/2019	CNX Water Intake	0	0	0	1.23
1/17/2019	CNX Water Intake	0	0	0	0
1/22/2019	CNX Water Intake	0.981	0	0	0
1/28/2019	CNX Water Intake				
1/29/2019	CNX Water Intake				
1/30/2019	CNX Water Intake				
2/5/2019	CNX Water Intake				
2/7/2019	CNX Water Intake	0	0	0	1.69
2/8/2019	CNX Water Intake	0	0	0	1.96
2/11/2019	CNX Water Intake	0	0	1.3	2.26
2/13/2019	CNX Water Intake				
2/14/2019	CNX Water Intake	0	0	0	0
2/15/2019	CNX Water Intake				
2/19/2019	CNX Water Intake	0	0	0	1.09
2/21/2019	CNX Water Intake	0	0	0	0

Table 16. Radionuclides Recorded by Environmental Services Lab Following Shaw Incident

Date	Site	Radium 226 (pCi/L)	Radium 228 (pCi/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
	MCL#:	5 pCi/L Radium Total		15 pCi/L	4 mrem/yr
2/22/2019	CNX Water Intake	0	0	0	0
2/25/2019	CNX Water Intake	0	0	0	0
2/27/2019	CNX Water Intake	0	0	0	0
2/28/2019	CNX Water Intake	0	0	0	0
3/4/2019	CNX Water Intake	0	0	0	0
3/5/2019	CNX Water Intake	1.6	0	0	1.93
3/12/2019	CNX Water Intake	0.595	0	0	2.5
3/14/2019	CNX Water Intake	0	0	0	0
3/19/2019	CNX Water Intake	0	0	0	0
3/21/2019	CNX Water Intake	0	0	0	1.29
3/27/2019	CNX Water Intake	0	0	0	0
3/29/2019	CNX Water Intake	0	0	0	0
4/3/2019	CNX Water Intake	0	0	0	1.96
4/10/2019	CNX Water Intake	0	0	0	2.9
11/28/2018*	MAWC Raw Intake				
12/4/2018*	MAWC Raw Intake				
12/14/2018*	MAWC Raw Intake				
12/19/2018	MAWC Raw Intake				
1/4/2019	MAWC Raw Intake				
1/11/2019	MAWC Raw Intake				
1/17/2019	MAWC Raw Intake				
1/22/2019	MAWC Raw Intake				
1/28/2019	MAWC Raw Intake				
1/29/2019	MAWC Raw Intake				
1/30/2019	MAWC Raw Intake				
2/5/2019	MAWC Raw Intake				
2/7/2019	MAWC Raw Intake				
2/8/2019	MAWC Raw Intake				
2/11/2019	MAWC Raw Intake				
2/13/2019	MAWC Raw Intake				
2/14/2019	MAWC Raw Intake				
2/15/2019	MAWC Raw Intake	0	0	0	0
2/19/2019	MAWC Raw Intake	0	0	0	0.875
2/21/2019	MAWC Raw Intake	0	0	0	0
2/22/2019	MAWC Raw Intake	0	0	0	0
2/25/2019	MAWC Raw Intake	0	0	0	0
2/27/2019	MAWC Raw Intake	0	0	0	1.58
2/28/2019	MAWC Raw Intake	0	0	0	0
3/4/2019	MAWC Raw Intake	0	0	0	0
3/5/2019	MAWC Raw Intake	0	0	0	1.8
3/12/2019	MAWC Raw Intake	0.394	0	0	0
3/14/2019	MAWC Raw Intake	0	0	0	1.73
3/19/2019	MAWC Raw Intake	0	0	0	0
3/21/2019	MAWC Raw Intake	0	0	0	2.12

Table 16. Radionuclides Recorded by Environmental Services Lab Following Shaw Incident

Date	Site	Radium 226 (pCi/L)	Radium 228 (pCi/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
	MCL#:	5 pCi/L Radium Total		15 pCi/L	4 mrem/yr
3/27/2019	MAWC Raw Intake	0	1.08	0	0
3/29/2019	MAWC Raw Intake				
4/3/2019	MAWC Raw Intake	0	0	0	1.31
4/10/2019	MAWC Raw Intake	v	0	0	0
11/28/2018*	Stream (Below Dam)				
12/4/2018*	Stream (Below Dam)				
12/14/2018*	Stream (Below Dam)				
12/19/2018	Stream (Below Dam)				
1/4/2019	Stream (Below Dam)				
1/11/2019	Stream (Below Dam)				
1/17/2019	Stream (Below Dam)				
1/22/2019	Stream (Below Dam)				
1/28/2019	Stream (Below Dam)				
1/29/2019	Stream (Below Dam)				
1/30/2019	Stream (Below Dam)				
2/5/2019	Stream (Below Dam)				
2/7/2019	Stream (Below Dam)	0	0	0	0
2/8/2019	Stream (Below Dam)	0	0	0	0
2/11/2019	Stream (Below Dam)	0	0	0	1.45
2/13/2019	Stream (Below Dam)				
2/14/2019	Stream (Below Dam)	0	0	0	0
2/15/2019	Stream (Below Dam)				
2/19/2019	Stream (Below Dam)	0	0	0	1.44
2/21/2019	Stream (Below Dam)	0	0	0	0
2/22/2019	Stream (Below Dam)	0	0	0	2.34
2/25/2019	Stream (Below Dam)	0	0	0	0
2/27/2019	Stream (Below Dam)	0	0	0	0
2/28/2019	Stream (Below Dam)	0	0	0	0
3/4/2019	Stream (Below Dam)	0	0	0	0
3/5/2019	Stream (Below Dam)	0	0	0	1.29
3/12/2019	Stream (Below Dam)	0	0	0	0
3/14/2019	Stream (Below Dam)	0	0	0	2.65
3/19/2019	Stream (Below Dam)	0	0	0	0
3/21/2019	Stream (Below Dam)	0	0	0	0
3/27/2019	Stream (Below Dam)	0	0	0	1.8
3/29/2019	Stream (Below Dam)	0.286	0	0	1.15
4/3/2019	Stream (Below Dam)	0	0	0	1.56
4/10/2019	Stream (Below Dam)	0	0	0	0.979

*This date was given as 2019, we assumed it was a typo.

CNX Data

Table 17. Data Recorded in CNX Report Following Shaw Incident				
Date Collected	**Date Received**	**Conductivity (umhos/cm)**	**Methane (mg/L)**	**Benzene (µg/L)**
2/7/2019 15:50:00	2/8/2019 8:07:00	423	0.842	N/A
2/8/2019 9:45:00	2/11/2019 8:24:00	426	6.27	N/A
2/8/2019 10:15:00	2/11/2019 8:13:00	468	N/A	N/A
2/8/2019 11:00:00	2/11/2019 8:19:00	400	0.376	N/A
2/8/2019 12:20:00	2/11/2019 8:19:00	605	1.73	N/A
2/8/2019 13:30:00	2/11/2019 8:13:00	400	0.0333	N/A
2/9/2019 10:00:00	2/12/2019 8:06:00	465	1.55	N/A
2/11/2019 10:15:00	2/12/2019 8:02:00	332	N/A	N/A
2/12/2019 10:55:00	2/13/2019 8:08:00	374	N/A	N/A
2/12/2019 11:54:00	2/13/2019 8:08:00	372	0.406	N/A
2/12/2019 16:25:00	2/13/2019 8:08:00	560	26.7	N/A
2/13/2019 9:00:00	2/14/2019 8:06:00	471	N/A	N/A
2/13/2019 10:00:00	2/14/2019 8:06:00	552	N/A	N/A
2/13/2019 10:20:00	2/14/2019 8:06:00	374	0.072	N/A
2/13/2019 11:00:00	2/14/2019 8:06:00	481	0.164	N/A
2/13/2019 11:24:00	2/14/2019 8:06:00	327	0.0667	N/A
2/13/2019 16:20:00	2/14/2019 8:06:00	247	0.0582	N/A
2/14/2019 10:50:00	2/15/2019 8:02:00	343	0.201	N/A
2/14/2019 12:10:00	2/15/2019 8:02:00	394	0.0276	N/A
2/18/2019 10:15:00	2/19/2019 8:54:00	282	N/A	N/A
2/18/2019 10:45:00	2/19/2019 8:45:00	436	N/A	N/A
2/18/2019 12:15:00	2/19/2019 8:45:00	371	0.685	N/A
2/18/2019 12:25:00	2/19/2019 8:45:00	520	0.0277	N/A
2/18/2019 13:55:00	2/19/2019 8:45:00	871	46.9	N/A
2/18/2019 14:35:00	2/19/2019 8:45:00	292	N/A	N/A
2/18/2019 14:55:00	2/19/2019 8:45:00	299	0.187	N/A
2/18/2019 16:35:00	2/19/2019 8:45:00	619	N/A	N/A
2/19/2019 10:15:00	2/20/2019 8:12:00	411	N/A	N/A
2/19/2019 11:00:00	2/20/2019 8:12:00	419	N/A	N/A
2/19/2019 11:15:00	2/20/2019 8:12:00	680	0.25	N/A
2/19/2019 11:45:00	2/20/2019 8:12:00	N/A	N/A	N/A
2/19/2019 12:05:00	2/20/2019 8:12:00	320	N/A	N/A
2/19/2019 12:15:00	2/20/2019 8:12:00	82.9	0.0112	N/A
2/19/2019 13:05:00	2/20/2019 8:12:00	57.7	N/A	N/A
2/19/2019 13:25:00	2/20/2019 8:12:00	402	N/A	N/A
2/20/2019 9:30:00	2/21/2019 7:49:00	365	N/A	N/A
2/20/2019 10:45:00	2/21/2019 7:49:00	556	0.258	N/A
2/21/2019 11:15:00	2/22/2019 8:03:00	338	0.00771	N/A
2/21/2019 12:45:00	2/22/2019 8:03:00	673	N/A	N/A
2/25/2019 10:30:00	2/26/2019 8:16:00	560	20	N/A
2/25/2019 11:40:00	2/26/2019 8:16:00	275	0.0192	N/A
2/25/2019 14:40:00	2/26/2019 8:16:00	274	N/A	N/A
3/1/2019 9:25:00	3/4/2019 8:21:00	535	N/A	N/A
3/1/2019 10:15:00	3/4/2019 8:21:00	409	0.0227	N/A
3/1/2019 11:40:00	3/4/2019 8:21:00	250	N/A	N/A
3/1/2019 12:40:00	3/4/2019 8:21:00	228	N/A	N/A

Table 17. Data Recorded in CNX Report Following Shaw Incident				
Date Collected	**Date Received**	**Conductivity (umhos/cm)**	**Methane (mg/L)**	**Benzene (μg/L)**
3/1/2019 14:10:00	3/4/2019 8:21:00	132	N/A	N/A
3/4/2019 9:35:00	3/5/2019 8:16:00	502	0.0587	N/A
3/4/2019 10:25:00	3/5/2019 8:16:00	562	0.00838	N/A
3/4/2019 10:55:00	3/5/2019 8:16:00	567	0.0276	N/A
3/4/2019 12:30:00	3/5/2019 8:16:00	1340	N/A	N/A
3/5/2019 9:30:00	3/6/2019 8:00:00	662	0.308	N/A
3/5/2019 10:30:00	3/6/2019 8:00:00	378	N/A	N/A
3/5/2019 13:15:00	3/6/2019 8:00:00	610	0.32	N/A
3/5/2019 14:00:00	3/6/2019 8:00:00	338	0.205	N/A
3/5/2019 16:15:00	3/6/2019 8:00:00	278	N/A	N/A
3/5/2019 17:20:00	3/6/2019 8:00:00	841	N/A	N/A
3/6/2019 9:30:00	3/7/2019 8:04:00	460	1.11	N/A
3/6/2019 10:30:00	3/7/2019 8:04:00	383	N/A	N/A
3/6/2019 11:30:00	3/7/2019 8:04:00	141	N/A	N/A
3/6/2019 13:44:00	3/7/2019 8:04:00	316	N/A	N/A
3/6/2019 15:15:00	3/7/2019 8:04:00	651	15	N/A
3/6/2019 16:48:00	3/7/2019 8:04:00	695	0.00504	N/A
3/7/2019 9:30:00	3/8/2019 8:13:00	320	0.0223	N/A
3/7/2019 10:45:00	3/8/2019 8:13:00	191	N/A	N/A
3/7/2019 13:40:00	3/8/2019 8:13:00	668	0.174	N/A
3/8/2019 8:45:00	3/9/2019 8:19:00	499	0.261	N/A
3/8/2019 9:20:00	3/9/2019 8:19:00	342	N/A	N/A
3/8/2019 9:25:00	3/9/2019 8:19:00	539	2.7	N/A
3/8/2019 10:24:00	3/9/2019 8:19:00	279	N/A	N/A
3/8/2019 10:35:00	3/9/2019 8:19:00	336	N/A	N/A
3/8/2019 12:00:00	3/9/2019 8:19:00	1620	0.0151	N/A
3/11/2019 9:45:00	3/12/2019 8:34:00	357	N/A	N/A
3/11/2019 10:30:00	3/12/2019 8:34:00	1020	N/A	N/A
3/12/2019 9:30:00	3/13/2019 8:14:00	340	N/A	N/A
3/12/2019 10:00:00	3/13/2019 8:14:00	785	N/A	N/A
3/15/2019 15:20:00	3/18/2019 8:07:00	391	N/A	N/A
3/15/2019 16:05:00	3/18/2019 8:07:00	441	N/A	N/A
3/15/2019 17:25:00	3/18/2019 8:07:00	1510	N/A	N/A

Acknowledgments and Contact Information

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For raw data to benefit future studies, please email info@protectpt.org or call 724-392-7023.