Preserving

Groundwater Quality Survey and Contaminant Trends Study

2023 Report

THE MIAMI CONSERVANCY DISTRICT

Executive Summary

To better understand human impact on groundwater quality and identify contaminant trends, the Miami Conservancy District monitors groundwater in the buried valley aquifer system of the Great Miami River Watershed. In 2023, Miami Conservancy District collected groundwater samples from 13 monitoring wells installed. The groundwater samples were analyzed for the presence of *E. coli*; major ions; metals; and nutrients. Samples were also analyzed for a list of 36 per- and polyfluoroalkyl substances (PFAS).

The results of this study show low levels of anthropogenic contaminants including PFAS are common in sensitive, shallow sand and gravel aquifer settings within the watershed. PFAS are also present in the Great Miami River. These findings emphasize the need for groundwater protection strategies to manage the quality of buried valley aquifer resources in southwest Ohio.

Introduction

Since 2014, MCD has managed a groundwater monitoring program in the Great Miami River Watershed. The purpose of the program is to provide a better understanding of the impact of human activities on groundwater quality. In 2023, MCD staff collected samples from 13 groundwater monitoring wells to survey groundwater quality in the buried valley aquifer (see Figure 1). Staff also collected samples for analysis of per- and polyfluorinated alkyl substances (PFAS) at one location on the Great Miami River. The wells included in the study are surrounded by land uses with the potential to release contaminants into the aquifer.

The wells selected for the study are installed in unconfined sand and gravel aquifers with permeable soils at the surface. Nine of the wells are situated within 400 feet of a river or lake. A comparison of static water level measurements for those nine wells suggests hydraulic interactions occur between groundwater and surface water.

Eight of the wells are screened at shallow (< 50 feet) depths. Table 1 summarizes depths and screened intervals for all the monitoring wells in this survey as well as the period of record for which groundwater monitoring activities have occurred.

Each monitoring well is equipped with a bladder pump installed within the screened interval of the well. The bladder pumps allow low flow purging techniques to be used (Puls and Barcelona, 1996).

Samples are collected twice a year. The samples are analyzed for *Escherichia coli (E. coli)*, major ions, metals, nutrients, and in the case of monitoring well BUT10014, volatile organic compounds (VOCs). These parameters are measured every sampling event to provide a baseline for groundwater quality. Additional parameters including VOCs, semi volatile organic compounds (SVOCs), pharmaceuticals, as well as other emerging contaminants are analyzed on a less frequent basis to provide additional data on groundwater quality. In 2023, the Miami Conservancy District contracted with Pace Analytical for analysis of baseline parameters and a list of 36 PFAS using a modified version of EPA Method 537.1.

Duplicate samples are collected from one monitoring well during each sampling event to evaluate laboratory precision. Field blanks were also collected to assess potential contamination from field conditions during sampling.

The results of this study are compared with federal drinking water standards and human health-based screening levels. Drinking water standards are generally more stringent than other water standards, so when groundwater meets drinking water standards it should be suitable for other uses.

The National Primary Drinking Water Regulations are legally enforceable standards set by the USEPA (United States Environmental Protection Agency) that apply to public water systems. Primary standards set maximum contaminant levels (MCLs) that help protect public health by limiting the contaminant concentrations in drinking water. National Secondary Drinking Water Standards are advisable guidelines addressing secondary maximum contaminant levels (SMCLs) that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The USEPA recommends, but does not require, that public water systems incorporate secondary standards. The USEPA Office of Water also publishes non enforceable Health-Based Screening Levels (HBSLs) for some constituents which may pose potential human-health concerns but do not yet have an enforceable standard. HBSLs are used as a supplement for evaluating contaminants in drinking water in a human-health context. For this study, all MCLs and HBSLs are referred to as human-health benchmarks and used for interpreting analytical results.

It should be noted that none of the monitoring wells in the Miami Conservancy District's groundwater monitoring network are used as a source of drinking water supply. The wells are only used for monitoring purposes.

Groundwater Chemistry and Comparisons to Benchmarks

In 2023, samples were collected twice. Once between June 5 and 14 (spring) and once between September 11 and 20 (fall).

All analytical results are presented in Appendix A of this report.

Table 2 provides a summary of significant detections of analytical parameters.

Groundwater Levels

Continuous "depth to groundwater" readings are recorded with pressure transducer sensors at 12 of the 13 monitoring wells. Most of the wells respond quickly to precipitation events because they are shallow wells installed in sand and gravel aquifers with permeable soils near rivers and streams. Groundwater levels measured during the spring sampling event were higher than those measured during the fall (see Figure 2) reflecting winter and spring seasonal recharge. This is typical for shallow wells in the buried valley aquifer system. Figure 2 shows three significant pulses of groundwater recharge in the monitoring wells between March 4 and April 5 resulting from precipitation events.

Later in the year, three large precipitation events occurred between June 14 and July 4, but these events did not cause groundwater levels in the monitoring wells to rise as high as they did in March and April. The reason is most likely due to higher rates of evapotranspiration in June and July in comparison to March and April. From the figure, it is apparent some level of aquifer recharge was taking place during or shortly after the spring sampling event while little or no aquifer recharge occurred during the fall event.

Groundwater Composition

Analysis of major ions (cations and anions) in groundwater samples show the dominant cation is calcium with significant quantities of magnesium and sodium also present. The average calcium concentration of groundwater samples was 97 mg/L. The dominant anion was bicarbonate with lesser amounts of chloride and sulfate. Bicarbonate content was estimated using alkalinity and pH measurements for each sample. The average bicarbonate concentration in groundwater samples was 350 mg/L. A piper diagram of major cations and anions shows the groundwater has a calcium-magnesium-bicarbonate composition (see Figure 3). Calcium-magnesium-bicarbonate groundwater tends to be present in areas where carbonate rocks comprise a significant amount of the aquifer matrix.

Aquifer Redox Conditions

The redox (reduction-oxidation) state of water exerts control on the water chemistry and what kinds of dissolved constituents are likely to be present. Redox processes can mobilize or immobilize naturally occurring toxic metals in aquifer systems, contribute to degradation or preservation of anthropogenic contaminants or generate undesirable byproducts such as manganese, iron, and hydrogen sulfide gas (U.S. Geological Survey, 2009). For this report, the framework of McMahon and Chapelle (2008) was used for assessing redox conditions in the buried valley aquifer at each monitoring well location. The redox framework is based on the dissolved concentrations of five water-quality parameters (O_2, NO_3^-, Mn^{2+}, Fe^{2+}, and SO_4^{2-}) all of which were measured in the groundwater samples collected for this report. Table 3 shows the redox framework. Analysis of groundwater samples and application of the redox framework allowed MCD to determine the general redox category for groundwater sampled in each of the 13 monitoring wells. The results are summarized in table 4.

The chart below depicts a conceptualized sequence of redox zones in an aquifer system (see Figure 4). They may or may not all be present in each location. In general, oxic waters have dissolved oxygen present and no iron or manganese. Suboxic waters have little or no dissolved oxygen but may have nitrate or manganese. Anoxic groundwaters do not have any dissolved oxygen and may have dissolved iron, hydrogen sulfide gas, and even methane. Arsenic could be present in anoxic groundwaters but is generally not present in oxic groundwaters. The reason is arsenic tends to bind with the iron hydroxides and moves with them in groundwater when the iron hydroxides are dissolved (Thomas, 2007).

The redox category remained constant at all monitoring wells for spring and fall sampling events with one exception, monitoring well BUT10014. The redox category at this well changed from oxic conditions to suboxic. Th reason for the change was a decrease in dissolved oxygen from 3.87 mg/L during the spring event to 0.19 mg/L in the fall. The change in the amount of dissolved oxygen may be related to timing of aquifer recharge as well as possible mixing of groundwaters from different aquifer zones.

Exceedances of Primary Drinking Water Standards and Human-Health Benchmarks

Groundwater samples collected from monitoring wells CLA10011, HAM10010, MON10016, PRE10007, WAR10003, and WAR10004 met all human-health benchmarks including MCLs and HBSLs for both sampling events (see Table 5). Concentrations of one or more parameters exceeded human-health benchmarks in groundwater samples collected from monitoring wells BUT10014, BUT10016, BUT10017, CLA10018, MIA00205, MON00022, and SHE00089. Table 5 provides a summary of all parameters exceeding human-health benchmarks. Parameters exceeding human-health benchmarks in at least one groundwater sample included E. coli, hexavalent chromium, manganese, and the PFAS compounds PFOA, PFOS, PFBS, PFHxS, and PFNA).

E. coli was detected at 11.0 MPN/100mL in the spring groundwater sample collected from monitoring well BUT10017. The MCL for *E. coli* is 0 MPN/100 mL. *E. coli* was not detected in any of the groundwater samples collected during the fall event.

Hexavalent chromium has an HBSL of 0.02 mg/L. There is an MCL of 0.05 mg/L for total chromium which is applicable for hexavalent chromium as well. Hexavalent chromium was detected in the groundwater samples collected from monitoring wells CLA10018, MIA00205, and SHE00089 at concentrations above the HBSL but below the MCL. However, hexavalent chromium was not detected in any of the groundwater samples collected in the fall event.

Lithium has an HBSL of 10 µg/L for drinking water. The fall groundwater sample collected from monitoring well MON0022 exceeded this level.

Manganese concentrations exceeded the HBSL of 300 µg/L in groundwater samples collected from monitoring wells BUT10016 and SHE00089 for both sampling events.

USEPA has proposed MCLs for the PFAS compounds PFOA, PFOS, PFBS, PFHxS, PFBS, and HFPO-DA (GenX). The proposed MCL for PFOA and PFOS is 4 nanograms per liter (ng/L). Groundwater samples collected from monitoring wells BUT10014, and BUT10017 had concentrations of PFOA and PFOS above this standard for spring and fall sampling events. USEPA proposed a hazard index for the remaining compounds including PFBS, PFHxS, PFBS, and HFPO-DA (GenX).

The hazard index is a tool USEPA uses to address chemical mixtures. The hazard index is made up of a sum of fractions. Each fraction compares the level of a measured PFAS compound in the water to the highest level determined not to have risk of health effects. The hazard index is calculated by the following equation. The abbreviation (ppt) refers to parts per trillion which is the same as ng/L.

Hazard Index = ([HFPO-DA]/ [10 ppt]) + ([PFBS]/ [2000 ppt]) + ([PFNA]/ [10 ppt]) + ([PFHxS]/ [9.0 ppt])

If the hazard index in a groundwater sample is greater than 1.0, it is a violation of the proposed MCL. When hazard index for the concentrations of PFBS, PFHxS, and PFNA measured in the fall groundwater sample was computed, the value was greater than 1. The PFAS compound HFPO-DA was not detected in the sample.

Exceedances of Secondary Drinking Water Standards

Groundwater samples collected from monitoring wells CLA10018, MIA00205, and WAR10004 met all secondary drinking water standards (SMCLs) for both sampling events (see Table 6). Table 6 provides a summary of all parameters exceeding SMCLs. Parameters exceeding applicable SMCLs in at least one groundwater sample included iron, manganese, and total dissolved solids.

Anthropogenic Contaminants

Chemical parameters detected in groundwater samples that likely reflect anthropogenic sources include chloride, hexavalent chromium, nitrate nitrogen, sodium, and the presence of PFAS compounds. Chloride and sodium are present in groundwater naturally, but human activities can elevate their concentration significantly above natural levels. Likewise, nitrogen primarily in the form of nitrate can be naturally present in groundwater, but anthropogenic sources of nitrogen can elevate nitrate concentrations above levels that would be present in the absence of human activities. PFAS are manufactured compounds that are not present in groundwater unless anthropogenic sources are present. A summary of parameters detected in at least one groundwater sample and thought to reflect anthropogenic sources of contaminants follows.

Chloride and Sodium

Chloride has an SMCL of 250 mg/L in drinking water. There are no drinking water standards (health based benchmarks or aesthetic) for sodium. Background levels of chloride in the buried valley aquifer system typically do not exceed 50 mg/L (Spieker, 1968), and (Debrewer and others, 2000). Kunz and Sroka (2004) reported mean background concentrations of chloride ranging from 13 to 23 mg/L in shallow unconsolidated aquifers in Champaign, Clark, and Pickaway counties in Ohio. Chloride concentrations above 70 mg/L and sodium concentrations above 43 mg/L in local sand and gravel aquifers likely reflect anthropogenic sources (Kunz and Sroka, 2004; Ohio EPA, 2015). These concentrations reflect the 90^{th}

percentile for Ohio EPA groundwater data collected from sand and gravel aquifers in Ohio (Ohio EPA, 2015).

Chloride concentrations measured in groundwater samples from monitoring wells BUT10014 and WAR10003 exceeded 70 mg/L in at least one sampling event in 2023 and likely reflect anthropogenic sources. Sodium concentrations in groundwater samples from monitoring wells BUT10014, MON10016, and WAR10003 exceeded 43 mg/L in one or both sampling events also reflecting anthropogenic sources. Anthropogenic sources of chloride and sodium include road salt application for deicing and private and municipal wastewater from homes with water softeners.

Hexavalent Chromium

Chromium (Cr) is a metallic element that exists in the environment in various forms or oxidation states. The most common are trivalent, hexavalent, and metallic forms. Hexavalent chromium was detected in groundwater samples collected from monitoring wells CLA10018, MIA00205, and SHE00089 during the spring sampling event. There were no detections of hexavalent chromium in any of the samples collected during the fall event. Hexavalent chromium can occur naturally but is often associated with industrial processes. Major industrial uses of hexavalent chromium include steel production, pulp mills, metal plating, wood preservation, and production of dyes and pigments.

Nitrogen as Nitrate

Nitrogen in groundwater is found in inorganic and organic forms. Inorganic nitrogen is present as ammonia, nitrite, and nitrate. Of these three inorganic forms, nitrate is the dominant species. According to Madison and Brunett (1985), nitrate concentrations above 3.0 mg/L in groundwater are often indicative of anthropogenic sources. Nitrate concentrations measured in groundwater samples during the spring and fall sampling events for monitoring wells BUT10017, CLA10018, and MIA00205 exceeded 3.0 mg/L. Common sources of nitrate in groundwater include fertilizers, domestic or municipal wastewater, and animal waste or manure applied as fertilizer. Monitoring wells CLA10018 and MIA 00205 are particularly vulnerable to sources of nitrate. Both wells are located within or adjacent to agricultural fields used for corn and soybean production and screened at shallow depths. Wells BUT10017 and CLA10018 had oxic groundwater conditions which tend to allow nitrate to remain stable (McMahon and Chapelle, 2008). In contrast, monitoring well MIA00205 had anoxic groundwater conditions yet still had detectable concentrations of nitrate.

Analysis of nitrogen and oxygen isotopes measured in groundwater samples collected from BUT10017 and CLA10018 in 2017 and 2018 suggested an inorganic fertilizer source for the nitrate present in those wells (Bedaso and Ekberg, 2019).

Per- and polyfluoroalkyl substances (PFAS)

PFAS are a group of manufactured chemicals used in industry and consumer products since the 1940s because of their properties that resist heat, grease, and water. There are thousands of different kinds of PFAS, some of which have been more widely used and studied than others (USEPA, 2023).

One or more PFAS compounds were detected in groundwater samples collected from monitoring wells BUT10014, BUT10017, HAM10010, MON00022, MON10016, PRE10007, and WAR10003.PFAS compounds detected in one or more groundwater samples include PFBA, PFBS, PFPeA, PFHxA, PFHxS, PFHpA, PFOA, PFOS, and PFNA. The most detected PFAS compounds were PFBA and PFBS.

The highest concentrations of PFAS compounds were detected in the groundwater samples from monitoring well BUT10014. This well is located near an industrial park and airport where it is likely that PFAS have been stored and used in the past.

PFAS compounds were also detected in water samples collected from the Great Miami River near monitoring well HAM10010. PFAS compounds present in the Great Miami River were PFBA, PFBS, PFPeA, PFHxA, PFHxS, PFOA, and PFOS. Monitoring well HAM10010 is located within the University of Cincinnati's Theis Environmental Monitoring and Modeling Site (TEMMS). Previous studies conducted at the site show clear evidence of stage-driven mixing of water in the river and the aquifer in which monitoring well HAM10010 is installed (Wallace and Soltanian, 2021a and 2021b). This suggests the river could be a source for the PFAS detected in HAM10010.

Naturally Occurring Contaminants

Arsenic

Arsenic occurs naturally in regional groundwater and concentrations of arsenic are largely controlled by redox conditions. The dominant mechanism for moving arsenic into groundwater is thought to be the release of arsenic from iron oxides in the aquifer under reducing conditions (Thomas and others, 2008). The MCL for arsenic is 10 µg/L. Groundwater samples collected from monitoring wells BUT10016, CLA10011, PRE10007, and WAR10003 had detectable concentrations of arsenic for spring and fall sampling events. Groundwater samples from all these wells indicated anoxic conditions with elevated levels of iron and low levels of dissolved oxygen suggesting reducing conditions present in the aquifer zone in which the wells are screened.

Lithium

Lithium is a metal that occurs naturally in groundwater from aquifers that contain lithium minerals or saline water. The HBSL for lithium is 10 µg/L. At least one groundwater sample collected from monitoring wells BUT10014, HAM10010, MON00022, PRE10007, and WAR10003 had detectable concentrations of lithium. The lithium concentration measured in the fall groundwater sample collected from monitoring well MON00022 (16.7 µg/L) exceeded the HBSL.

Nuisance Contaminants

Hardness, iron, manganese, and total dissolved solids are generally considered to be "nuisance" contaminants. These contaminants are present naturally in groundwater from the buried valley aquifer system. Their presence does not typically pose a health threat. Nevertheless, they can have adverse aesthetic impacts that cause water to appear cloudy or colored. They can also adversely impact plumbing fixtures, stain laundry, and cause taste and odor issues. At high enough concentrations manganese may pose health concerns. In 2004, U.S. EPA issued a lifetime health advisory level of 300 µg/L for manganese in drinking water. This benchmark indicates a safe level of exposure over the course of a lifetime.

Hardness is a measure of the amount of dissolved calcium and magnesium in a water sample. When the hardness value exceeds 180 mg/L the water is very hard (USGS, 2018). All groundwater samples collected in 2023 had hardness values exceeding 180 mg/L. There is no SMCL for water hardness.

The SMCL for Iron is 300 µg/L. Iron concentrations measured in samples collected from monitoring wells BUT10016, CLA10011, HAM10010, PRE10007, and WAR10003 exceeded this standard in both sampling events.

The SMCL for manganese is 50 µg/L. Manganese concentrations in groundwater samples collected from monitoring wells BUT10016 and SHE00089 exceeded this standard during both sampling events. Manganese also has a HBSL (lifetime advisory level) of 300 µg/L. Both groundwater samples collected from well BUT10016 in 2023 exceeded this standard while the fall sample collected from SHE00089 exceeded the standard.

Total dissolved solids (TDS) are comprised of inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates). TDS is the sum of cations and anions in a water sample. The SMCL for TDS is 500 mg/L. Groundwater samples collected from wells BUT10014, CLA10011, MON00022, MON10016, and WAR10003 exceeded this standard for at least one sampling event.

Contaminant Trends

Groundwater quality data collected in 2023, and in previous years, was analyzed for trends in contaminant concentrations. MCD selected the chemical parameters chloride, nitrate, sodium, and TCE as parameters indicative of anthropogenic sources. The parameters arsenic, iron, lithium, and manganese were selected to examine trends in naturally occurring contaminant concentrations.

Chloride and Sodium

Chloride concentrations measured in samples collected from monitoring wells BUT10014, MON10016 and WAR10003 are often higher than 70 mg/L and consistently above the concentrations measured in samples from the other monitoring wells (see figure 5). Chloride concentrations in monitoring well WAR10003 seem to be trending upward, while 2023 concentrations in monitoring wells BUT10014 and MON10016 declined. Likewise, sodium concentrations measured in the three wells (BUT10014, MON10016, and WAR10003) are consistently higher than concentrations measured at other monitoring wells (see figure 6). As with chloride, the sodium concentration in monitoring well WAR10003 shows an increasing trend. Seasonal fluctuations in chloride and sodium are often more pronounced in wells with the highest concentrations of those parameters. These fluctuations may reflect infiltration of saline water from snow melt and rainfall events after seasonal applications of road salt.

Nitrogen as Nitrate

Nitrate concentrations measured at monitoring wells BUT10017, CLA10018 and MIA00205 consistently exceed 3 mg/L and likely reflect anthropogenic sources of nitrate to the aquifer screened by those wells (see figure 7). Concentrations of nitrate in groundwater samples from all three monitoring wells fluctuate from year to year. Nitrate concentrations for monitoring well CLA10018 appear to be trending downward since 2017.

Trichloroethene (TCE)

Since 2014, concentrations of TCE in groundwater samples from monitoring well BUT10014 have declined (see figure 8). TCE in the fall 2018 sample was below the reporting limit of 1 µg/L and below the MCL for the first time since sampling began. Groundwater concentrations measured since fall 2018 have remained close to or below the reporting limit. TCE has not been detected in any groundwater samples collected from BUT10014 since the spring sampling event in 2021.

Arsenic

Arsenic was detected in groundwater samples collected from monitoring wells BUT10016, CLA10011, HAM10010, PRE10007, and WAR10003 (see figure 9). Groundwater samples from all these monitoring wells show either anoxic or mixed groundwater redox conditions. Overall, arsenic concentrations in samples collected from PRE10007 seem to be showing significant fluctuations from sampling event to sampling event and may reflect mixing of groundwater from different aquifer zones. Arsenic concentrations measured in monitoring wells BUT10016 and CLA10011 fluctuate between 4 and 9 µg/L but don’t appear to show an upward or downward trend.

Iron

There are large fluctuations in iron concentrations measured in groundwater samples collected from monitoring well PRE10007. The large fluctuations in arsenic and iron concentrations could be an indication of mixing of oxic and anoxic groundwater in the vicinity of the well. Groundwater samples showed anoxic groundwater redox conditions in 2023. However, monitoring well PRE10007 is in a municipal well field. MCD staff noted fluctuating dissolved oxygen levels in the well during previous sampling events as nearby production wells turned on and off. This suggests there could be fluctuating redox conditions at the well. There does not appear to be any upward or downward trend in iron concentrations in the other monitoring wells.

Concentrations of dissolved iron greater than 0.1 mg/L in groundwater are often associated with the presence of arsenic in the glacial aquifer system of the northern United States (Thomas, 2007). When compared with previous studies, iron concentrations in groundwater samples collected from monitoring wells BUT10016, CLA10011, PRE10007, and WAR10003 consistently exceed the drinking water SMCL of 0.3 mg/L (see figure 10). Groundwater samples from all four of those monitoring wells consistently have detectable concentrations of arsenic.

Lithium

Lithium is consistently detected at concentrations above the reporting limit in groundwater samples collected from monitoring wells MON00022 and WAR10003 (see figure 11). Lithium concentrations in MON00022 fluctuate above and below the HBSL of 10 µg/L but do not show an upward or downward trend. Previous concentrations of lithium in monitoring well WAR10003 have been consistent from sampling event to sampling event and ranged between 5 and 7 µg/L. However, the fall 2023 groundwater samples had a lithium concentration of 9.8 µg/L - just below the HBSL.

Manganese

Manganese concentrations in groundwater samples collected from monitoring wells BUT10016, CLA10011, MIA00205, MON10016, SHE00089, and WAR10003 consistently exceeded the SMCL of 50 µg/L in previous sampling events.

In 2023, the laboratory performing the metals analysis increased the reporting limit from 5 µg/L to 100 µg/L. This reporting limit exceeds the SMCL for manganese and is likely too high to detect manganese in samples from monitoring wells CLA10011, MIA00205, MON10016, and WAR10003 based results from previous years of monitoring. Two monitoring wells consistently have manganese concentration greater than 100 µg/L, monitoring wells BUT10016 and SHE00089. The HBSL for manganese is 300 µg/L. Manganese concentrations measured in groundwater samples from monitoring well BUT10016 consistently exceed the HBSL.

Prior to 2023, manganese concentrations measured in groundwater samples collected from monitoring well SHE00089 were below the HBSL. However, in 2023, manganese concentrations equaled or exceeded the HBSL. Groundwater redox conditions in both monitoring wells were anoxic in 2023 which favors reduction of manganese into its soluble form. There does not appear to be a strong upward or downward trend in manganese concentrations for either monitoring well (see figure 12).

Conclusions

The sample set of the groundwater monitoring program is insufficient in size and scope to characterize in detail the health of the entire buried valley aquifer system. Yet, the results can be used to better understand which contaminants to target for further investigation and studies. Furthermore, when the 2023 results are compared with previous rounds of sampling and other studies, some themes related to groundwater quality in the aquifer begin to emerge.

Contaminants originating from anthropogenic sources are sometimes present in groundwater samples from sensitive aquifer settings such as shallow unconfined sand and gravel aquifers. This conclusion is supported by other studies which collected groundwater samples from shallow zones in the buried valley aquifer and found similar results (Buszka and others, 2023), (Ohio Environmental Protection Agency, 2015), (Rowe and others, 2004), and (Stuck, 2021a and 2021b).

Naturally occurring contaminants including arsenic and nuisance contaminants are often present in groundwater samples collected from the buried valley aquifer system. Arsenic concentrations may exceed the MCL. Nuisance contaminants often exceed secondary drinking water standards and in some cases health-based screening levels. Water softening as well as iron and manganese removal may be necessary to deliver the desired water quality.

PFAS are present in the Great Miami River and the river could act as a PFAS source to shallow aquifer zones where groundwater and surface water mixing occur.

These findings emphasize the importance of managing land use over the buried valley aquifer to preserve the quality of the water. They also highlight the interconnected nature of the Great Miami River and the underlying buried valley aquifer system. Anthropogenic constituents present in rivers and streams can also be found in buried valley aquifers. Proactive groundwater protection strategies are critical to ensure the quality of groundwater in our region.

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Table 1 – Construction details for groundwater quality monitoring wells

Monitoring Well	Casing Diameter (in)	Well Depth (ft)	Screened Interval (ft)	Aquifer Screened	Distance to River or Lake (ft)	Start of Sampling Record
BUT10014	2	40	35 - 40	Sand and Gravel	120	Spring 2014
BUT10016	2	65	60 - 65	Sand and Gravel	120	Spring 2014
BUT10017	2	39	34 - 39	Sand and Gravel	120	Spring 2016
CLA10011	2	60	55 - 60	Sand and Gravel	135	Spring 2016
CLA10018	2	16	11 - 16	Sand and Gravel	2,810	Spring 2014
HAM10010	2	30	28 - 30	Sand and Gravel	340	Spring 2023
MIA00205	2	24	19 - 24	Sand and Gravel	1,130	Spring 2015
MON00022	2	15	10 - 15	Sand and Gravel	110	Spring 2015
MON10016	2	108	88 - 108	Sand and Gravel	355	Spring 2014
PRE10007	2	60	40 - 60	Sand and Gravel	960	Spring 2016
SHE00089	2	43	38 - 43	Sand and Gravel	600	Spring 2015
WAR10003	2	67	62 - 67	Sand and Gravel	85	Spring 2016
WAR10004	2	32.5	27.5 - 32.5	Sand and Gravel	90	Spring 2015

Table 2. Summary of significant detections of analytical parameters. **Numbers in bold exceed a benchmark**

Spring 2023		**Benchmark**		**Sample Sites**						
Parameter	**Units**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**MIA00205**
Chloride	mg/L	SMCL	250	77.1						
Chromium, Hexavalent	mg/L	HBSL	0.02					**0.034**		**0.021**
Nitrogen, Nitrate-Nitrite	mg/L	MCL	10			4.5		7.1		4.5
Sodium	mg/L	—	—	49.6						
E. coli	MPN/100mL	MCL	0			**11**				
PFBA	ng/L	—	—	3.1		3.1			3.2	
PFBS	ng/L	MCL	HI	3.6		18			3.8	
PFPeA	ng/L	—	—			4.0				
PFHxA	ng/L	—	—	2.4		3.3				
PFHxS	ng/L	MCL	HI	5.3					3.5	
PFHpA	ng/L	—	—							
PFOA	ng/L	MCL	4	**18**		**9.7**			3.0	
PFOS	ng/L	MCL	4	**12**		**13**			2.7	
PFNA	ng/L	MCL	HI	3.7						
Arsenic	ug/L	MCL	10		5.2		6.4			
Iron	μg/L	HBSL, SMCL	4000, 300		**1,200**		**3,010**		**437**	
Lithium	μg/L	HBSL	10	5.8					5.2	
Manganese	μg/L	HBSL, SMCL	300, 50		**497**					
Total Dissolved Solids	mg/L	SMCL	500	**600**			**560**			
Total Hardness	μg/L	—	—	378,000	303,000	340,000	416,000	351,000	447,000	360,000

Table 2 cont. Summary of significant detections of analytical parameters. **Numbers in bold exceed a benchmark**

Spring 2023		**Benchmark**		**Sample Sites**						
Parameter	**Units**	**Type**	**Value**	**MON00022**	**MON10016**	**PRE10007**	**SHE00089**	**WAR10003**	**WAR10004**	**GMR**
Chloride	mg/L	SMCL	250					131		
Chromium, Hexavalent	mg/L	HBSL	0.02				**0.030**			
Nitrogen, Nitrate-Nitrite	mg/L	MCL	10							
Sodium	mg/L	—	—					53.6		
E. coli	MPN/100mL	MCL	0							
PFBA	ng/L	—	—			2.1		1.9		5.4
PFBS	ng/L	MCL	HI		1.9					6.8
PFPeA	ng/L	—	—							6.8
PFHxA	ng/L	—	—							6.0
PFHxS	ng/L	MCL	HI							4.8
PFHpA	ng/L	—	—							2.0
PFOA	ng/L	MCL	4							3.7
PFOS	ng/L	MCL	4							7.8
PFNA	ng/L	MCL	HI							
Arsenic	ug/L	MCL	10			4.6		2.5		
Iron	µg/L	HBSL, SMCL	4000, 300			**3,050**		**2,180**		
Lithium	µg/L	HBSL	10	7.0						
Manganese	µg/L	HBSL, SMCL	300, 50				**304**			
Total Dissolved Solids	mg/L	SMCL	500	**680**		**600**		**640**		
Total Hardness	µg/L	—	—	446,000	317,000	362,000	372,000	456,000	248,000	

[PFBA, perfluorobutanoic acid, PFBS, perfluorobutanesulfonic acid, PFPeA, perfluoropentanoic acid, PFHxA, perfluorohexanoic acid, PFHxS, perfluorohexanesulfonic acid, PFHpA, perfluoroheptanoic acid, PFOA, perfluorooctanoic acid, PFOS, perfluorooctanesulfonic acid, PFNA, perfluorononanoic acid]

HI - Hazard Index GMR - Great Miami River at UC Theis Environmental Monitoring and Modeling Site

Table 2 cont. Summary of significant detections of analytical parameters. **Numbers in bold exceed a benchmark**

Fall 2023		**Benchmark**		**Sample Sites**						
Parameter	**Units**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**MIA00205**
Chloride	mg/L	SMCL	250							
Chromium, Hexavalent	mg/L	HBSL	0.02							
Nitrogen, Nitrate-Nitrite	mg/L	MCL	10			4.1		5.4		3.8
Sodium	mg/L	—	—							
E. coli	MPN/100mL	MCL	0							
PFBA	ng/L	—	—	14.6		4.0			3.2	
PFBS	ng/L	MCL	HI	**3.5**		9.7			3.5	
PFPeA	ng/L	—	—	15.0						
PFHxA	ng/L	—	—	14.4						
PFHxS	ng/L	MCL	HI	**5.7**		2.1			3.7	
PFHpA	ng/L	—	—	3.8						
PFOA	ng/L	MCL	4	**34.3**		**4.5**			2.8	
PFOS	ng/L	MCL	4	**12.3**		**8.6**			3.4	
PFNA	ng/L	MCL	HI	**6.7**						
Arsenic	ug/L	MCL	10		5.1		6.0		1.1	
Iron	µg/L	HBSL, SMCL	4000, 300		**1,380**		**3,190**		**791**	
Lithium	µg/L	HBSL	10				5.8			
Manganese	µg/L	HBSL, SMCL	300, 50		**496**					
Total Dissolved Solids	mg/L	SMCL	500	**660**		**540**	**560**			
Total Hardness	µg/L	—	—	345,000	316,000	336,000	440,000	366,000	379,000	367,000

Table 2 cont. Summary of significant detections of analytical parameters. **Numbers in bold exceed a benchmark**

Fall 2023		**Benchmark**		**Sample Sites**						
Parameter	**Units**	**Type**	**Value**	**MON00022**	**MON10016**	**PRE10007**	**SHE00089**	**WAR10003**	**WAR10004**	**GMR**
Chloride	mg/L	SMCL	250					132		
Chromium, Hexavalent	mg/L	HBSL	0.02							
Nitrogen, Nitrate-Nitrite	mg/L	MCL	10							
Sodium	mg/L	—	—		43.6			58.1		
E. coli	MPN/100mL	MCL	0							
PFBA	ng/L	—	—	2.2						3.9
PFBS	ng/L	MCL	HI		1.7					9.3
PFPeA	ng/L	—	—							6.8
PFHxA	ng/L	—	—							5.3
PFHxS	ng/L	MCL	HI							5.7
PFHpA	ng/L	—	—							
PFOA	ng/L	MCL	4							8.3
PFOS	ng/L	MCL	4							7.8
PFNA	ng/L	MCL	HI							
Arsenic	ug/L	MCL	10			4.8		2.3		
Iron	µg/L	HBSL, SMCL	4000, 300			**2,510**		**2,280**		
Lithium	µg/L	HBSL	10	**16.7**		6.3	6.8	9.8		
Manganese	µg/L	HBSL, SMCL	300, 50				**300**			
Total Dissolved Solids	mg/L	SMCL	500	**740**	**580**			**700**		
Total Hardness	µg/L	—	—	654,000	324,000	386,000	376,000	464,000	262,000	

[PFBA, perfluorobutanoic acid, PFBS, perfluorobutanesulfonic acid, PFPeA, perfluoropentanoic acid, PFHxA, perfluorohexanoic acid, PFHxS, perfluorohexanesulfonic acid, PFHpA, perfluoroheptanoic acid, PFOA, perfluorooctanoic acid, PFOS, perfluorooctanesulfonic acid, PFNA, perfluorononanoic acid]

HI - Hazard Index

GMR - Great Miami River at UC Theis Environmental Monitoring and Modeling Site

Table 3. Threshold concentrations for identifying redox processes in groundwater (modified from McMahon and Chapelle, 2008; Chapelle and others, 2009).

[O_2, dissolved oxygen; NO_3, dissolved nitrate as nitrogen; Mn^{2+}, dissolved manganese; Fe^{2+}, dissolved iron; SO_4, dissolved sulfate; H_2S, hydrogen sulfide; Mn(IV), oxidized manganese; Fe(III), ferric iron: mg/L, milligrams per liter; —, not applicable, ≥, greater than or equal to; ≤, less than or equal to]

General redox category	Predominant redox process	Distinguishing Fe(III)–from SO_4^{2-}-reduction	Water-chemistry criteria (mg/L)					Fe^{2+}/H_2S mass ratio	Comments
			O_2	NO_3^--N	Mn^{2+}	Fe^{2+}	SO_4^{2-}		
Oxic	O_2 reduction	—	≥0.5	—	< 0.5	< 0.1	—	—	—
Suboxic	—	—	< 0.5	< 0.5	< 0.5	< 0.1	—	—	(1)
Anoxic	NO_3^- reduction	—	< 0.5	≥0.5	< 0.5	< 0.1	—	—	—
	Mn(IV) reduction	—	< 0.5	< 0.5	≥0.5	< 0.1	—	—	—
	Fe(III)/SO_4^{2-} reduction	—	< 0.5	< 0.5	—	≥0.1	≥0.5	—	—
	—	Fe(III) reduction	< 0.5	< 0.5	—	≥0.1	≥0.5	> 10	—
	—	Mix - Fe(III)/SO_4^{2-} reduction	< 0.5	< 0.5	—	≥0.1	≥0.5	≥0.3 and ≤10	—
	—	SO_4^{2-} reduction	< 0.5	< 0.5	—	≥0.1	≥0.5	< 0.3	—
	Methanogenesis	—	< 0.5	< 0.5	—	≥0.1	< 0.5	—	—
Mixed	—	—	—	—	—	—	—	—	(2)

[1]Further definition of redox processes not feasible.

[2]Criteria for more than one redox process are met.

Table 4. General redox category for groundwater in each monitoring well.

Monitoring Well	Redox Category	
	Spring 2023	Fall 2023
BUT10014	Oxic	Suboxic
BUT10016	Anoxic	Anoxic
BUT10017	Oxic	Oxic
CLA10011	Anoxic	Anoxic
CLA10018	Oxic	Oxic
HAM10010	Mixed	Mixed
MIA00205	Anoxic	Anoxic
MON00022	Suboxic	Suboxic
MON10016	Suboxic	Suboxic
PRE10007	Anoxic	Anoxic
SHE00089	Anoxic	Anoxic
WAR10003	Anoxic	Anoxic
WAR10004	Oxic	Oxic

Table 5. Summary of exceedances of human-health benchmarks.

Monitoring Well	Spring 2023	Fall 2023
BUT10014	PFOA, PFOS	PFOA, PFOS, PFBS, PFHxS, PFNA
BUT10016	Manganese	Manganese
BUT10017	*E. coli*, PFOA, PFOS	PFOA, PFOS
CLA10011		
CLA10018	Hexavalent Chromium	
HAM10010		
MIA00205	Hexavalent Chromium	
MON00022		Lithium
MON10016		
PRE10007		
SHE00089	Hexavalent Chromium, Manganese	Manganese
WAR10003		
WAR10004		

[*E. coli*, Escherichia coli, PFOA, perfluorooctanoic acid, PFOS, perfluorooctanesulfonic acid, PFBS, perfluorobutanesulfonic acid, PFHxS, perfluorohexanesulfonic acid, PFNA, perfluorononanoic acid]

Table 6. Summary of exceedances of secondary maximum contaminant levels (SMCLs).

Monitoring Well	Spring 2023	Fall 2023
BUT10014	TDS	TDS
BUT10016	Iron, Manganese	Iron, Manganese
BUT10017		TDS
CLA10011	Iron, TDS	Iron, TDS
CLA10018		
HAM10010	Iron	Iron
MIA00205		
MON00022	TDS	TDS
MON10016		TDS
PRE10007	Iron, TDS	Iron
SHE00089	Manganese	Manganese
WAR10003	Iron, TDS	Iron, TDS
WAR10004		

Figure 1 – Map showing locations of monitoring wells and Great Miami River sampling site.

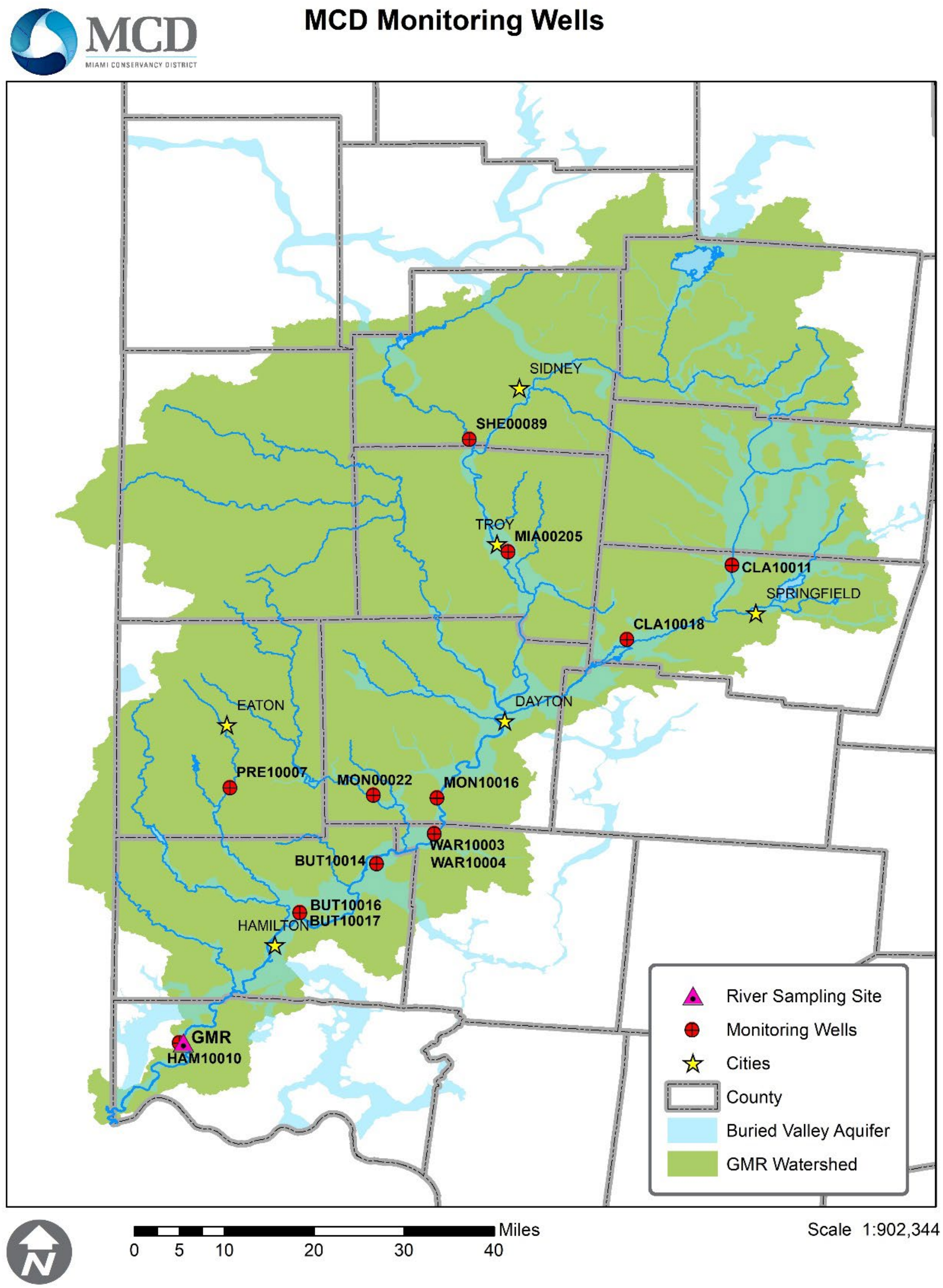


Figure 2 – Chart showing depths to groundwater and daily precipitation measured in the watershed. Gray areas show time intervals for the spring and fall sampling events.

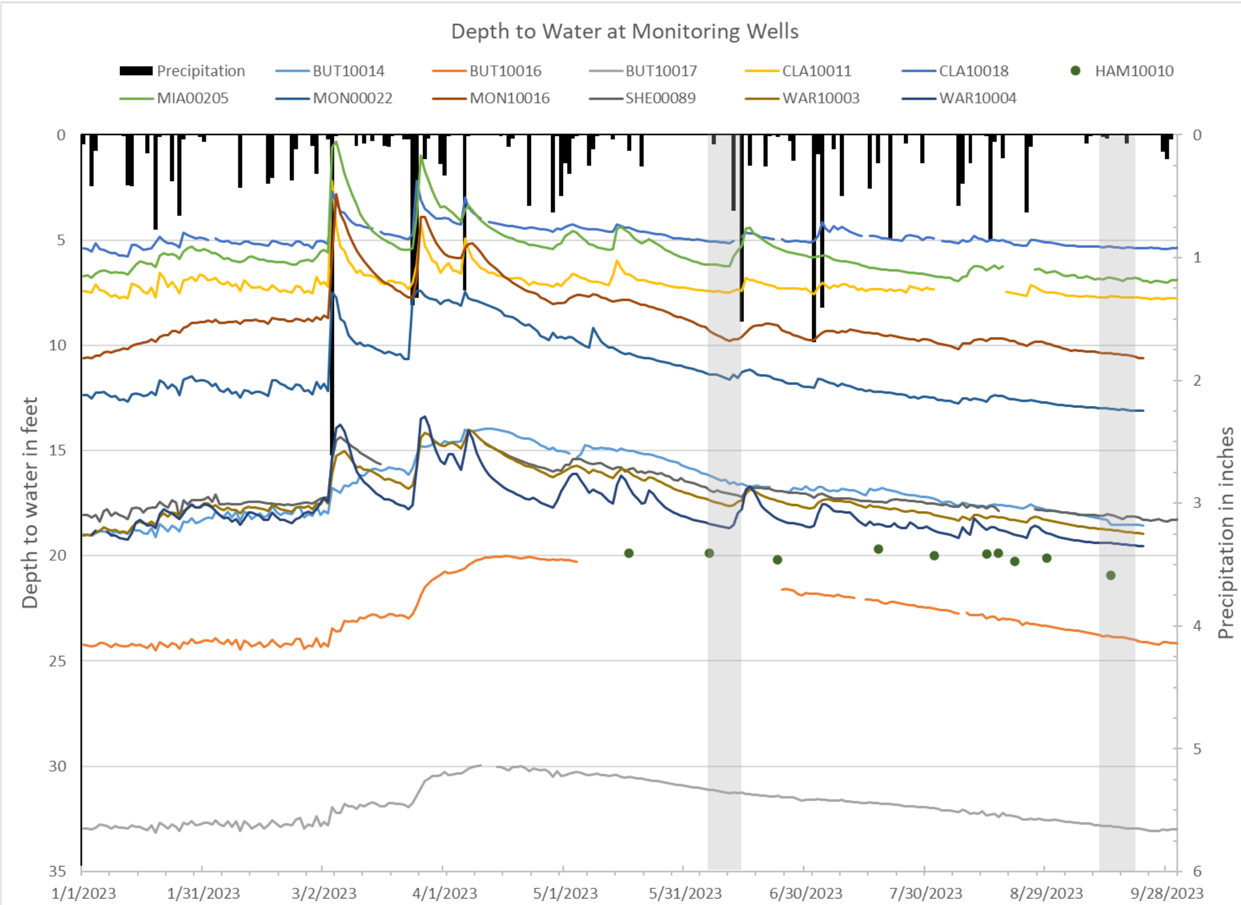


Figure 3 – Piper diagram illustrating dominant cations, anions, and water type of samples.

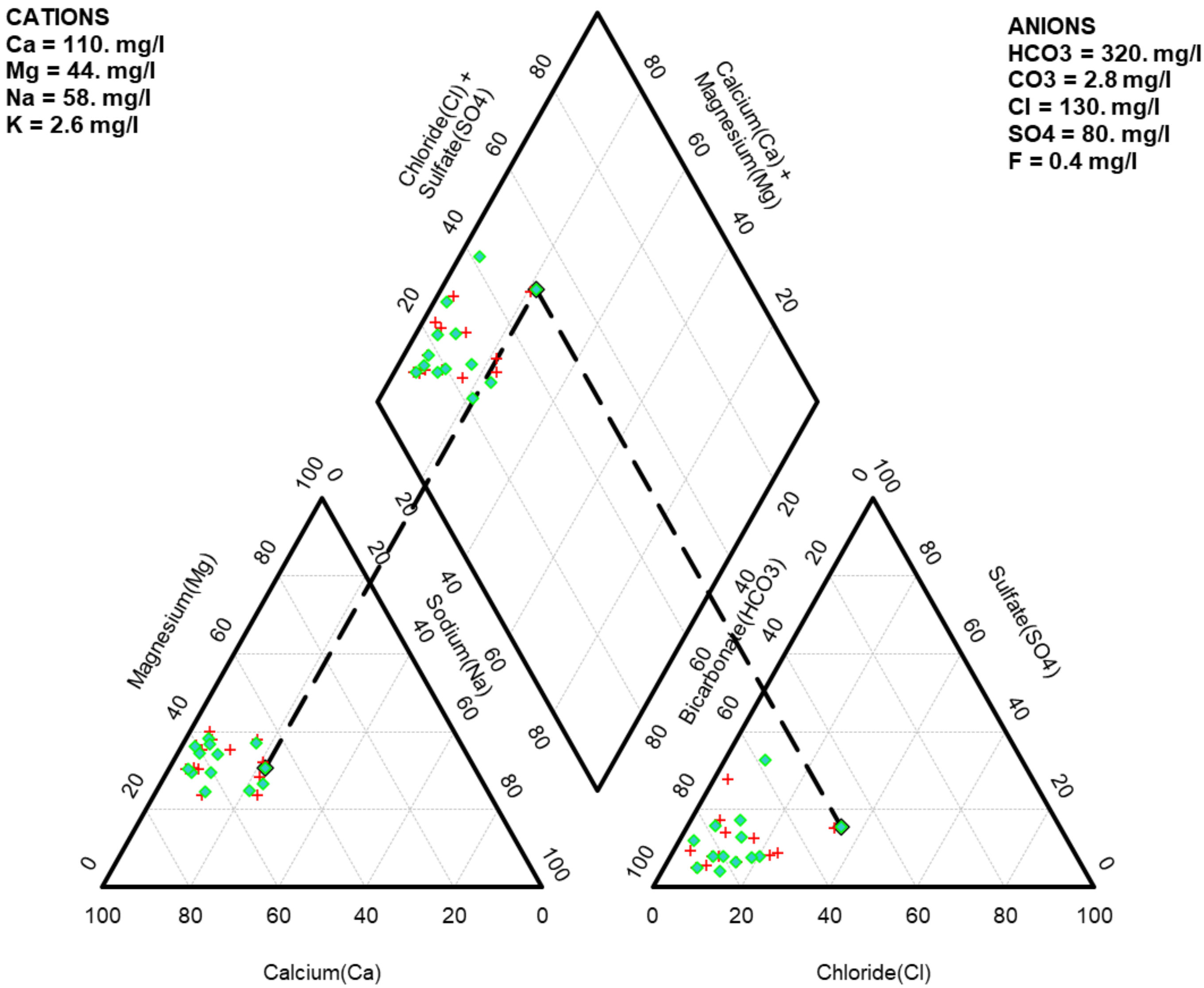


Figure 4 – Conceptualized sequence of redox zones and parameter changes with depth (Ohio EPA, 2014).

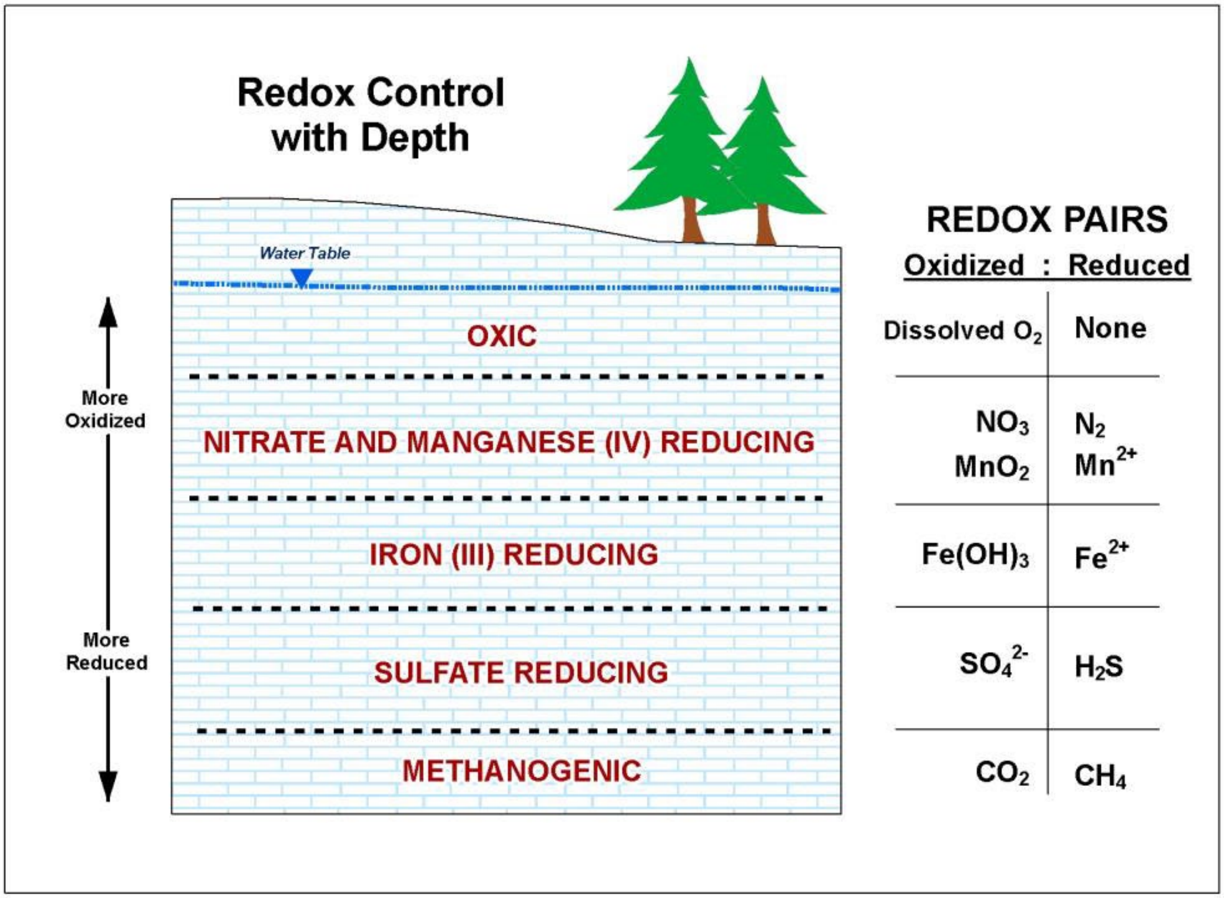


Figure 5 – Chloride concentrations in monitoring wells.

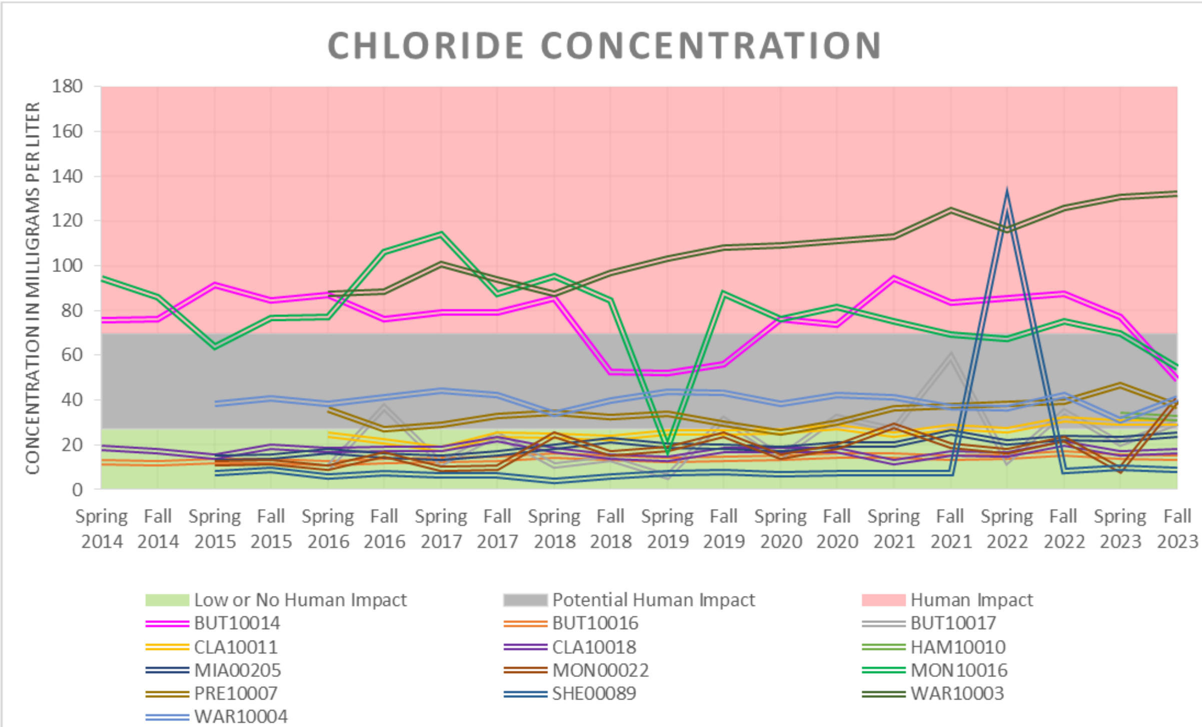


Figure 6 – Sodium concentrations in monitoring wells.

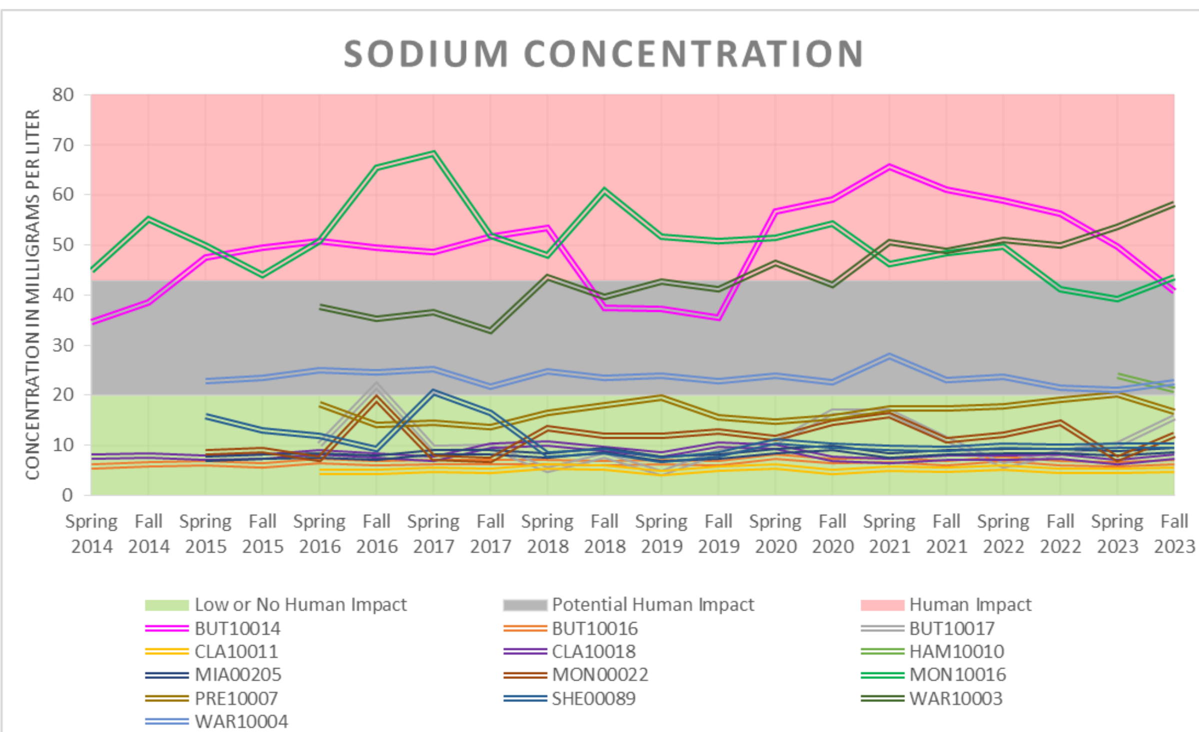


Figure 7 – Nitrate nitrogen concentrations in monitoring wells.

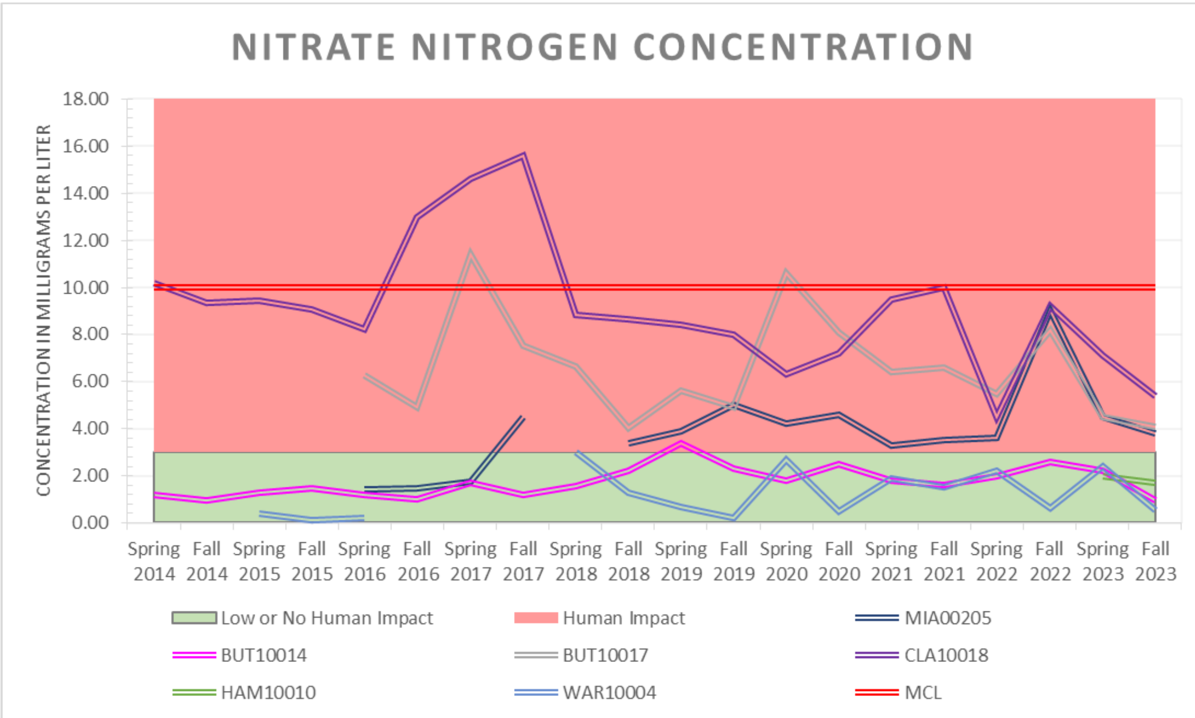


Figure 8 – TCE concentrations in monitoring well BUT10014.

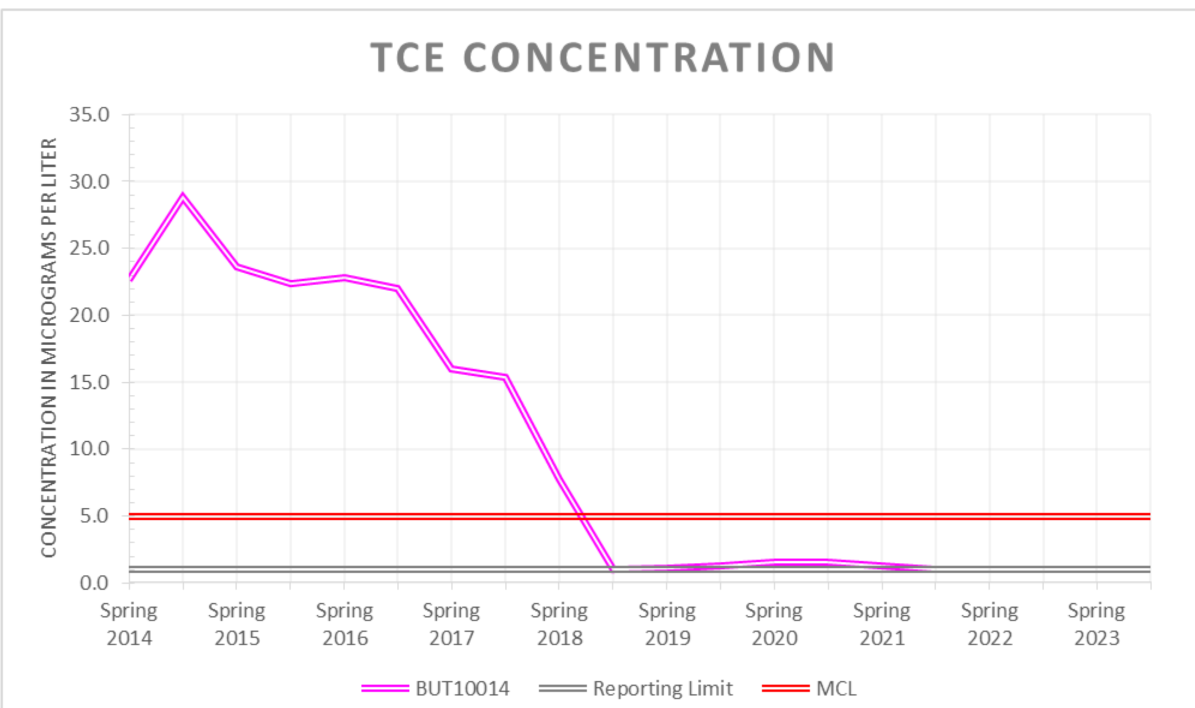


Figure 9 – Arsenic concentrations in monitoring wells.

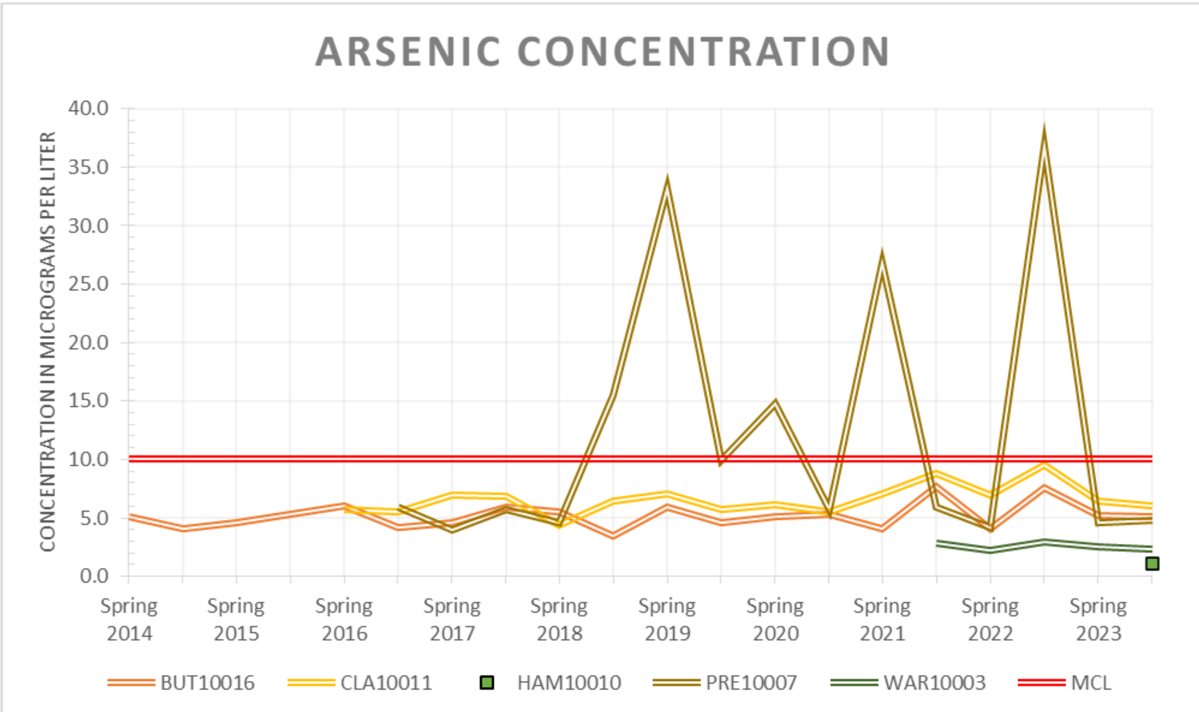


Figure 10 – Iron concentrations in monitoring wells.

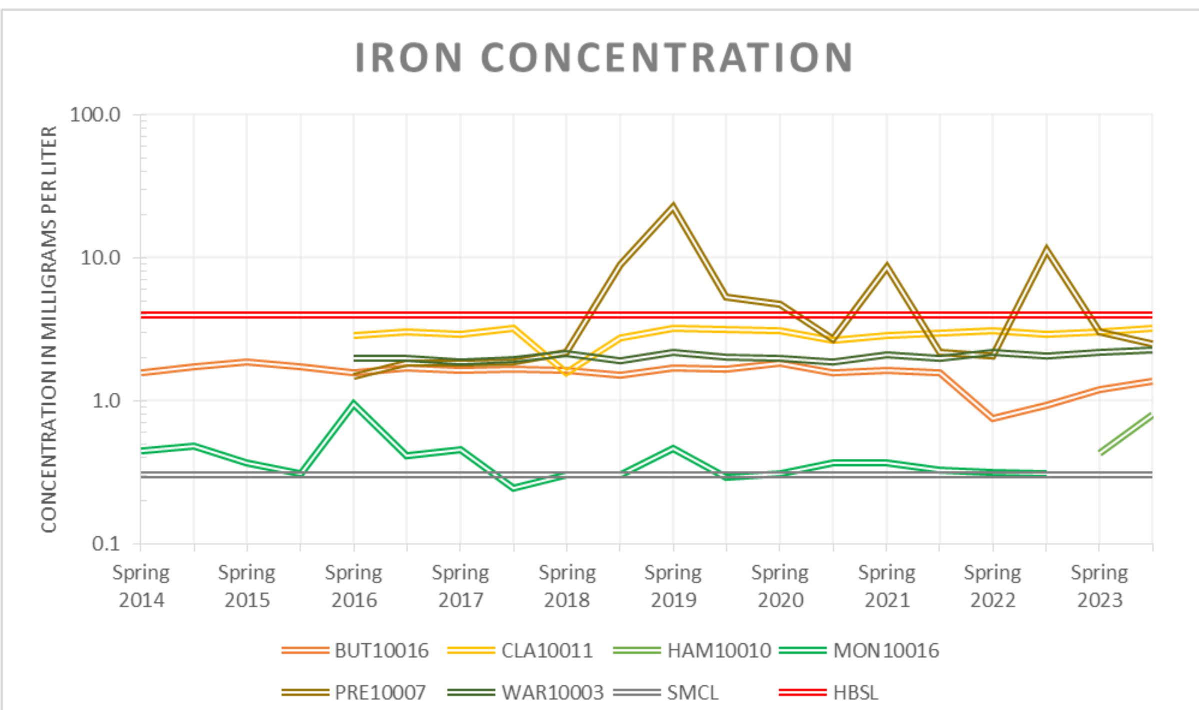


Figure 11 - Lithium concentrations in monitoring wells.

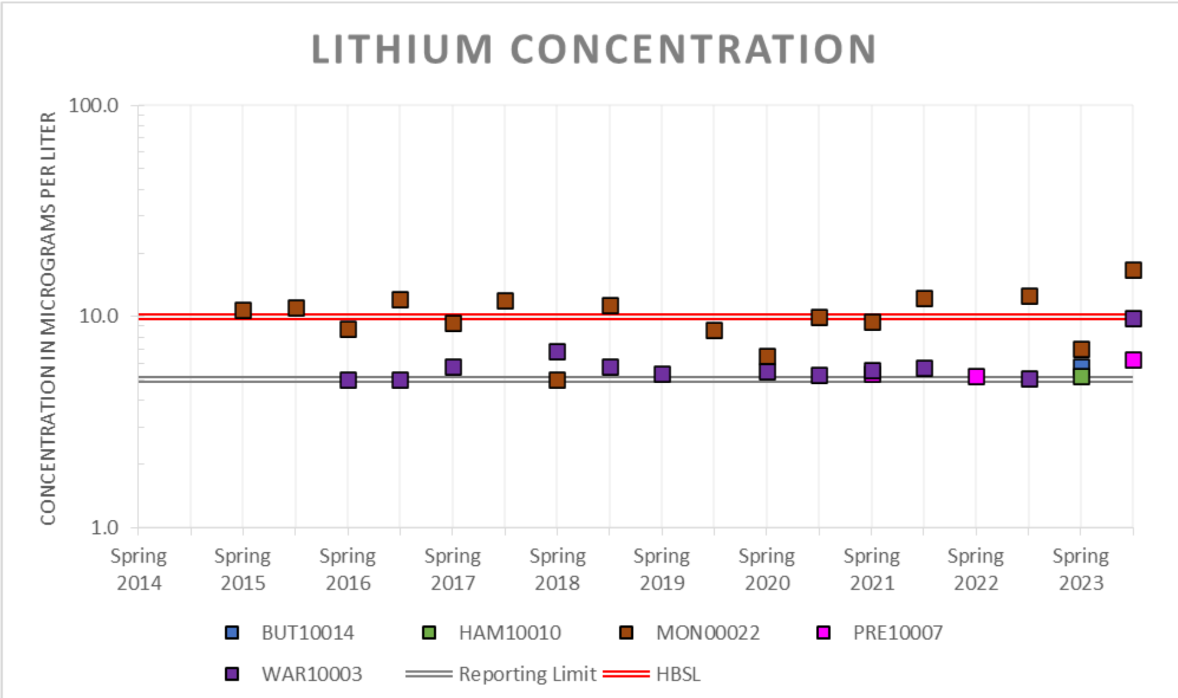
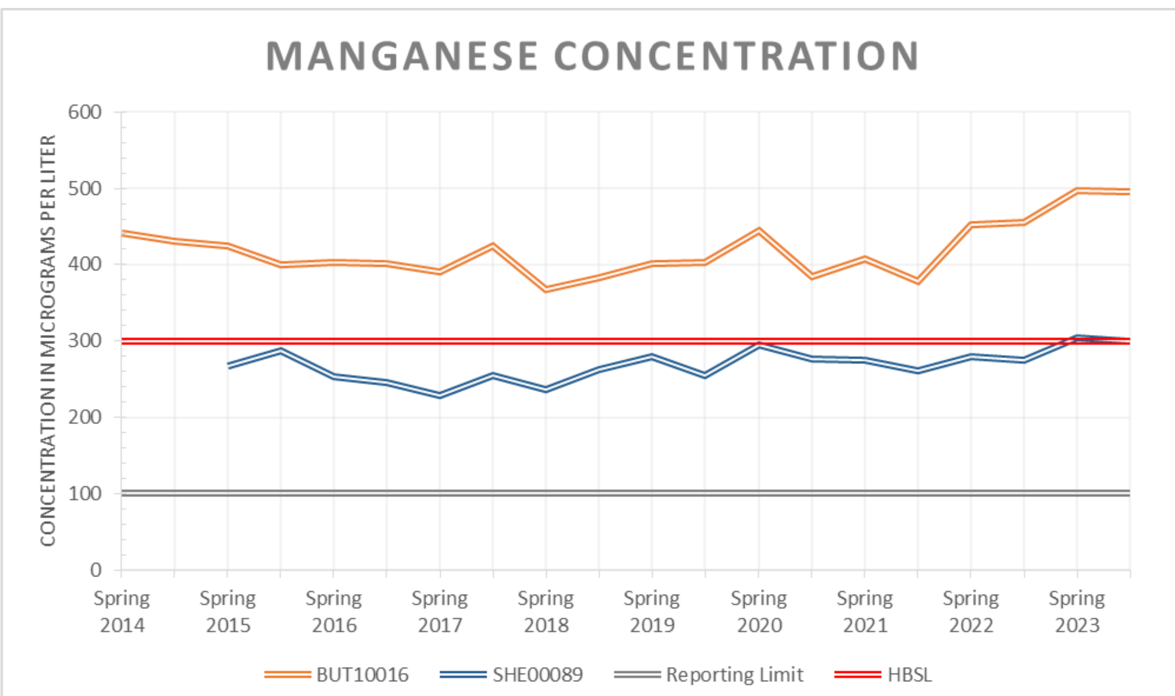


Figure 12 – Manganese concentrations in monitoring wells.



Appendix A - Water Analytical Data

Spring 2023				Benchmark		Sample Sites							
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**HAM10010[1]**	**MIA00205**
Dissolved Oxygen	mg/L	Field Measured	—	—	—	3.87	0.00	9.27	0.00	6.06	9.50	9.50	0.00
pH	S.U.	Field Measured	—	SMCL	6.5 - 8.5	7.07	7.39	7.16	7.13	7.19	7.02	7.02	7.01
Specific Conductance	mS/cm	Field Measured	—	—	—	924	580	652	749	664	815	815	691
Temperature	°C	Field Measured	—	—	—	13.90	12.90	13.00	12.30	12.20	12.30	12.30	11.10
Chloride	mg/L	SM 4500-Cl E-11	2.0	SMCL	250	**77.1**	14.5	20.4	30.0	16.2	33.5	33.9	22.7
Fluoride	mg/L	SM 4500-F C-11	0.20	MCL	4	0.41	0.25	< 0.20	0.3	0.22	0.24	0.24	< 0.20
Nitrogen, Ammonia	mg/L	EPA 350.1	0.10	—	—	0.65	0.18	< 0.10	0.16	< 0.10	0.13	< 0.10	< 0.10
Nitrogen, Kjeldahl, Total	mg/L	SM 4500-Norg D-11	0.50	—	—	0.70	< 0.50	0.90	< 0.50	1.6	1.1	0.50	0.76
Nitrogen, Nitrite	mg/L	SM 4500-NO3 F-11	0.10	MCL	1	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Nitrogen, NO2 plus NO3	mg/L	SM 4500-NO3 F-11	0.10	MCL	10	2.2	< 0.10	**4.5**	< 0.10	**7.1**	2.0	2.0	**4.5**
Orthophosphate as P	mg/L	SM 4500-P F	0.10	—	—	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Phosphorus, Total	ug/L	EPA 6010B	100	—	—	< 100	103	< 100	< 100	< 100	< 100	< 100	< 100
Sulfate	mg/L	SM 4500-SO4 D	5.0	SMCL	250	39.3	51.9	17.3	61.7	15.2	32.3	33.3	25.9
Total Hardness by 2340B	ug/L	EPA 6010B	2000	—	—	378,000	303,000	340,000	416,000	351,000	447,000	417,000	360,000
Aluminum, Total	ug/L	EPA 6010B	150	HBSL, SMCL	6000, 200	< 150	< 150	< 150	< 150	< 150	182	180	< 150
Antimony, Total	ug/L	EPA 6020A	1.0	MCL	6	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Arsenic, Total	ug/L	EPA 6020A	1.0	MCL	10	< 1.0	5.2	< 1.0	6.4	< 1.0	< 1.0	< 1.0	< 1.0
Barium, Total	ug/L	EPA 6010B	5.0	MCL	2000	210	226	47.9	61.2	75.2	102	94.1	116
Beryllium, Total	ug/L	EPA 6010B	1.0	MCL	4	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Boron, Total	ug/L	EPA 6010B	200	HBSL	5000	< 200	< 200	< 200	< 200	< 200	< 200	< 200	< 200
Cadmium, Total	ug/L	EPA 6020A	0.20	MCL	5	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Calcium, Total	ug/L	EPA 6010B	550	—	—	104,000	76,000	91,600	104,000	81,600	132,000	120,000	97,100
Chromium, Hexavalent	mg/L	SM 3500-Cr	0.0040	MCL, HBSL	0.05, 0.02	< 0.0040	< 0.0040	< 0.0040	< 0.0040	**0.034**	< 0.020	**0.036**	**0.021**
Cobalt, Total	ug/L	EPA 6010B	5.0	HBSL	2	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Copper, Total	ug/L	EPA 6010B	5.0	MCL	1300	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Iron, Total	ug/L	EPA 6010B	200	HBSL, SMCL	4000, 300	< 200	**1,200**	< 200	**3,010**	< 200	**437**	**440**	< 200
Lead, Total	ug/L	EPA 6020A	1.0	MCL	15	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Lithium, Total	ug/L	EPA 200.7	5.0	HBSL	10	5.8	< 5.0	< 5.0	< 5.0	< 5.0	5.2	< 5.0	< 5.0
Magnesium, Total	ug/L	EPA 6010B	150	—	—	28,500	27,400	27,000	38,300	35,800	28,900	28,300	28,500
Manganese, Total	ug/L	EPA 6010B	100	HBSL, SMCL	300, 50	< 100	**497**	< 100	< 100	< 100	< 100	< 100	< 100
Molybdenum, Total	ug/L	EPA 6010B	10.0	HBSL	30	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0
Nickel, Total	ug/L	EPA 6010B	5.0	HBSL	10	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Potassium, Total	ug/L	EPA 6010B	2000	—	—	5,770	< 2,000	< 2,000	< 2,000	< 2,000	< 2,000	< 2,000	< 2,000
Silica, Total	ug/L	EPA 6010B	100	—	—	8,740	12,600	10,100	14,700	8,730	10,600	9,610	9,190
Silver, Total	ug/L	EPA 6010B	2.0	HBSL	100	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Sodium, Total	ug/L	EPA 6010B	2000	—	—	**49,600**	6,120	10,200	4,910	6,720	**24,000**	**22,000**	8,330
Strontium, Total	ug/L	EPA 6010B	5.0	HBSL	4000	630	416	168	325	2,110	479	442	353
Thallium, Total	ug/L	EPA 6020A	1.0	MCL	2	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Vanadium, Total	ug/L	EPA 6010B	5.0	—	—	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Zinc, Total	ug/L	EPA 6010B	160.0	HBSL	2000	< 160	< 160	< 160	< 160	< 160	< 160	< 160	< 160
Alkalinity, Total as CaCO3	mg/L	SM 2320B	5.0	—	—	335	234	267	347	279	347	303	283
BOD, 5 day	mg/L	SM 5210B	2.0	—	—	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Carbonaceous BOD, 5 day	mg/L	SM 5210B	2.0	—	—	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Chemical Oxygen Demand	mg/L	HACH 8000	20.0	—	—	41.4	30.7	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0
Cyanide	mg/L	EPA 335.4	0.0050	MCL	0.2	0.043	< 0.0050	< 0.0050	< 0.010	< 0.0050	< 0.0050	< 0.0050	< 0.0050
Phenolics, Total Recoverable	ug/L	EPA 420.4	2.0	—	—	2.4	2.8	< 2.0	2.9	2.6	4.6	5	2.5
Total Dissolved Solids	mg/L	SM 2540C	100	SMCL	500	**600**	320	120	**560**	460	200	200	420
Total Organic Carbon	mg/L	SM 5310C-11	1.0	—	—	< 1.0	< 1.0	1.0	1.2	< 1.0	1.1	1.0	1.7
E.coli	MPN/100mL	SM 9223B	1.0	MCL	0	< 1.0	< 1.0	**11.0**	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0

Appendix A - Water Analytical Data

Spring 2023				Benchmark		Sample Sites							
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**HAM10010[1]**	**MIA00205**
1,1,1-Trichloroethane	ug/L	SW 8260B	1.0	MCL	200	< 1.0							
1,1,2,2-Tetrachloroethane	ug/L	SW 8260B	1.0	HBSL	0.0002	< 1.0							
1,1,2-Trichloroethane	ug/L	SW 8260B	5.0	MCL	5	< 5.0							
1,1-Dichloroethane	ug/L	SW 8260B	1.0	HBSL	1000	< 1.0							
1,1-Dichloroethene	ug/L	SW 8260B	1.0	MCL	7	< 1.0							
1,2,3-Trichlorobenzene	ug/L	SW 8260B	5.0	—	—	< 5.0							
1,2,3-Trichloropropane	ug/L	SW 8260B	5.0	HBSL	30	< 5.0							
1,2,4-Trichlorobenzene	ug/L	SW 8260B	5.0	MCL	70	< 5.0							
1,2-Dibromo-3-chloropropane	ug/L	SW 8260B	5.0	MCL	0.2	< 5.0							
1,2-Dibromoethane (EDB)	ug/L	SW 8260B	1.0	MCL	0.05	< 1.0							
1,2-Dichlorobenzene	ug/L	SW 8260B	1.0	MCL	600	< 1.0							
1,2-Dichloroethane	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
1,2-Dichloropropane	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
1,3-Dichlorobenzene	ug/L	SW 8260B	1.0	HBSL	600	< 1.0							
1,3-Dichloropropane	ug/L	SW 8260B	1.0	HBSL	100	< 1.0							
1,4-Dichlorobenzene	ug/L	SW 8260B	1.0	MCL	75	< 1.0							
2,2-Dichloropropane	ug/L	SW 8260B	1.0	—	—	< 1.0							
2-Butanone (MEK)	ug/L	SW 8260B	10.0	—	—	< 10.0							
2-Chlorotoluene	ug/L	SW 8260B	1.0	—	—	< 1.0							
2-Hexanone	ug/L	SW 8260B	10.0	HBSL	30	< 10.0							
4-Chlorotoluene	ug/L	SW 8260B	1.0	HBSL	100	< 1.0							
4-Methyl-2-pentanone (MIBK)	ug/L	SW 8260B	10.0	—	—	< 10.0							
Acetone	ug/L	SW 8260B	10.0	HBSL	6000	< 10.0							
Acetonitrile	ug/L	SW 8260B	10.0	—	—	< 10.0							
Benzene	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
Bromobenzene	ug/L	SW 8260B	1.0	HBSL	50	< 1.0							
Bromochloromethane	ug/L	SW 8260B	1.0	HBSL	60	< 1.0							
Bromodichloromethane	ug/L	SW 8260B	1.0	MCL	80	< 1.0							
Bromoform	ug/L	SW 8260B	1.0	MCL	80	< 1.0							
Bromomethane	ug/L	SW 8260B	1.0	HHBP	140	< 1.0							
Carbon tetrachloride	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
Chlorobenzene	ug/L	SW 8260B	1.0	MCL	100	< 1.0							
Chloroethane	ug/L	SW 8260B	1.0	—	—	< 1.0							
Chloroform	ug/L	SW 8260B	1.0	MCL	80	< 1.0							
Chloromethane	ug/L	SW 8260B	1.0	—	—	< 1.0							
cis-1,2-Dichloroethene	ug/L	SW 8260B	1.0	MCL	70	< 1.0							
cis-1,3-Dichloropropene	ug/L	SW 8260B	1.0	HBSL	0.3	< 1.0							
Dibromochloromethane	ug/L	SW 8260B	1.0	MCL	80	< 1.0							
Dibromomethane	ug/L	SW 8260B	1.0	—	—	< 1.0							
Dichlorodifluoromethane	ug/L	SW 8260B	1.0	HBSL	1000	< 1.0							
Ethylbenzene	ug/L	SW 8260B	1.0	MCL	700	< 1.0							
Hexachloro-1,3-butadiene	ug/L	SW 8260B	1.0	—	—	< 1.0							
m&p-Xylene	ug/L	SW 8260B	1.0	MCL	10000	< 1.0							
Methylene Chloride	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
Methyl-tert-butyl ether	ug/L	SW 8260B	1.0	—	—	< 1.0							
Naphthalene	ug/L	SW 8260B	1.0	HBSL	100	< 1.0							
o-Xylene	ug/L	SW 8260B	1.0	MCL	10000	< 1.0							
p-Isopropyltoluene	ug/L	SW 8260B	1.0	—	—	< 1.0							
Styrene	ug/L	SW 8260B	1.0	MCL	100	< 1.0							
Tetrachloroethene	ug/L	SW 8260B	1.0	MCL	5	< 1.0							

Appendix A - Water Analytical Data

Spring 2023				Benchmark		Sample Sites							
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**HAM10010[1]**	**MIA00205**
Toluene	ug/L	SW 8260B	1.0	MCL	1000	< 1.0							
trans-1,2-Dichloroethene	ug/L	SW 8260B	1.0	MCL	100	< 1.0							
trans-1,3-Dichloropropene	ug/L	SW 8260B	1.0	HBSL	0.3	< 1.0							
Trichloroethene	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
Trichlorofluoromethane	ug/L	SW 8260B	1.0	HBSL	2000	< 1.0							
Vinyl acetate	ug/L	SW 8260B	5.0	—	—	< 5.0							
Vinyl chloride	ug/L	SW 8260B	1.0	MCL	2	< 1.0							
Xylene (Total)	ug/L	SW 8260B	1.0	MCL	10000	< 1.0							

Appendix A - Water Analytical Data

Spring 2023				Benchmark		Sample Sites							
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**HAM10010[1]**	**MIA00205**
Perfluorobutanoic acid (PFBA)	ng/L	EPA 537.1	1.9	—	—	**3.1**	< 1.7	**3.1**	<1.6	< 1.8	**3.2**	**3.7**	<1.8
Perfluorobutanesulfonic acid (PFBS)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	**3.6**	< 1.7	**18**	<1.6	< 1.8	**3.8**	**4.5**	<1.8
Perfluoropentanoic acid (PFPeA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	**4.0**	<1.6	< 1.8	<1.9	**2.0**	<1.8
Perfluorohexanoic acid (PFHxA)	ng/L	EPA 537.1	1.9	—	—	**2.4**	< 1.7	**3.3**	<1.6	< 1.8	<1.9	**2.0**	<1.8
11Cl-PF3OUdS (F35B Major)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
9Cl-PF3ONS (F35B Minor)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
4,8-Dioxa-3H-perfluorononanoic acid (ADONA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Hexafluoropropylene oxide dimer acid (HFPO-DA)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
8:2 Fluorotelomersulfonic acid (8:2FTS A)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluorodecanoic acid (PFDA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluorododecanoic acid (PFDoA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluoroheptanesulfonic acid (PFHpS)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
N-EtFOSAA (NEtFOSAA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
N-MeFOSAA (NMeFOSAA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluorotetradecanoic acid (PFTA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluorotridecanoic acid (PFTrDA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
4:2 Fluorotelomersulfonic acid (4:2FTS A)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluorodecanesulfonic acid (PFDS)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluorooctanesulfonamide (FOSA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluorononanesulfonic acid (PFNS)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluoro-1-hexanesulfonamide (FHxSA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluoro-1-butanesulfonamide (FBSA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluorohexanesulfonic acid (PFHxS)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	**5.3**	< 1.7	<1.9	<1.6	< 1.8	**3.5**	**4.2**	<1.8
Perfluoro-4-oxapentanoic acid (PFMPA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluoro-5-oxahexanoic acid (PFMBA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
6:2 Fluorotelomersulfonic acid (6:2FTS A)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluoropentanesulfonic acid (PFPeS)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluoroundecanoic acid (PFUnA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Nonafluoro-3,6-dioxaheptanoic acid (NFDHA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluoroheptanoic acid (PFHpA)	ng/L	EPA 537.1	1.9	—	—	<1.9	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8
Perfluorooctanoic acid (PFOA)	ng/L	EPA 537.1	1.9	MCL	4	**18**	< 1.7	**9.7**	<1.6	< 1.8	**3.0**	**3.3**	<1.8
Perfluorooctanesulfonic acid (PFOS)	ng/L	EPA 537.1	1.9	MCL	4	**12**	< 1.7	**13**	<1.6	< 1.8	**2.7**	**3.2**	<1.8
Perfluorononanoic acid (PFNA)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	**3.7**	< 1.7	<1.9	<1.6	< 1.8	<1.9	<1.9	<1.8

Appendix A - Water Analytical Data

Spring 2023				Benchmark		Sample Sites						
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**MON00022**	**MON10016**	**PRE10007**	**SHE00089**	**WAR10003**	**WAR10004**	**GMR**
Dissolved Oxygen	mg/L	Field Measured	—	—	—	0.00	0.00	0.29	0.00	0.00	3.47	
pH	S.U.	Field Measured	—	SMCL	6.5 - 8.5	7.03	7.31	7.30	7.18	7.30	7.46	
Specific Conductance	mS/cm	Field Measured	—	—	—	787	768	726	664	1,059	548	
Temperature	°C	Field Measured	—	—	—	12.60	12.00	13.20	12.10	14.60	14.30	
Chloride	mg/L	SM 4500-Cl E-11	2.0	SMCL	250	8.8	**69.8**	**46.9**	10.0	**131**	31.0	
Fluoride	mg/L	SM 4500-F C-11	0.20	MCL	4	0.21	< 0.20	0.22	0.36	0.23	0.25	
Nitrogen, Ammonia	mg/L	EPA 350.1	0.10	—	—	0.32	0.16	< 0.10	< 0.10	0.34	< 0.10	
Nitrogen, Kjeldahl, Total	mg/L	SM 4500-Norg D-11	0.50	—	—	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	0.99	
Nitrogen, Nitrite	mg/L	SM 4500-NO3 F-11	0.10	MCL	1	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Nitrogen, NO2 plus NO3	mg/L	SM 4500-NO3 F-11	0.10	MCL	10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	2.4	
Orthophosphate as P	mg/L	SM 4500-P F	0.10	—	—	0.60	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Phosphorus, Total	ug/L	EPA 6010B	100	—	—	< 100	< 100	< 100	< 100	< 100	< 100	
Sulfate	mg/L	SM 4500-SO4 D	5.0	SMCL	250	107	35.4	48.0	36.2	81.3	17.9	
Total Hardness by 2340B	ug/L	EPA 6010B	2000	—	—	446,000	317,000	362,000	372,000	456,000	248,000	
Aluminum, Total	ug/L	EPA 6010B	150	HBSL, SMCL	6000, 200	< 150	< 150	< 150	< 150	< 150	< 150	
Antimony, Total	ug/L	EPA 6020A	1.0	MCL	6	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Arsenic, Total	ug/L	EPA 6020A	1.0	MCL	10	< 1.0	< 1.0	4.6	< 1.0	2.5	< 1.0	
Barium, Total	ug/L	EPA 6010B	5.0	MCL	2000	77.6	103	263	150	214	56.1	
Beryllium, Total	ug/L	EPA 6010B	1.0	MCL	4	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	< 1.0	
Boron, Total	ug/L	EPA 6010B	200	HBSL	5000	< 200	< 200	< 200	< 200	218	< 200	
Cadmium, Total	ug/L	EPA 6020A	0.20	MCL	5	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	
Calcium, Total	ug/L	EPA 6010B	550	—	—	122,000	81,100	86,900	88,900	109,000	54,200	
Chromium, Hexavalent	mg/L	SM 3500-Cr	0.0040	MCL, HBSL	0.05, 0.02	< 0.020	< 0.0040	< 0.020	**0.030**	< 0.0040	< 0.0040	
Cobalt, Total	ug/L	EPA 6010B	5.0	HBSL	2	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Copper, Total	ug/L	EPA 6010B	5.0	MCL	1300	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Iron, Total	ug/L	EPA 6010B	200	HBSL, SMCL	4000, 300	< 200	< 200	**3,050**	< 200	**2,180**	< 200	
Lead, Total	ug/L	EPA 6020A	1.0	MCL	15	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Lithium, Total	ug/L	EPA 200.7	5.0	HBSL	10	7.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Magnesium, Total	ug/L	EPA 6010B	150	—	—	34,300	27,800	35,200	36,400	44,800	27,400	
Manganese, Total	ug/L	EPA 6010B	100	HBSL, SMCL	300, 50	< 100	< 100	< 100	**304**	< 100	< 100	
Molybdenum, Total	ug/L	EPA 6010B	10.0	HBSL	30	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	
Nickel, Total	ug/L	EPA 6010B	5.0	HBSL	10	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Potassium, Total	ug/L	EPA 6010B	2000	—	—	2,100	< 2,000	< 2,000	< 2,000	< 2,000	< 2,000	
Silica, Total	ug/L	EPA 6010B	100	—	—	7,210	9,070	10,800	11,000	13,900	8,080	
Silver, Total	ug/L	EPA 6010B	2.0	HBSL	100	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	
Sodium, Total	ug/L	EPA 6010B	2000	—	—	7,210	**39,100**	**20,200**	9,930	**53,600**	**21,000**	
Strontium, Total	ug/L	EPA 6010B	5.0	HBSL	4000	364	557	841	491	1,120	394	
Thallium, Total	ug/L	EPA 6020A	1.0	MCL	2	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Vanadium, Total	ug/L	EPA 6010B	5.0	—	—	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Zinc, Total	ug/L	EPA 6010B	160.0	HBSL	2000	< 160	< 160	< 160	< 160	< 160	< 160	
Alkalinity, Total as CaCO3	mg/L	SM 2320B	5.0	—	—	275	275	279	343	279	214	
BOD, 5 day	mg/L	SM 5210B	2.0	—	—	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	
Carbonaceous BOD, 5 day	mg/L	SM 5210B	2.0	—	—	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	
Chemical Oxygen Demand	mg/L	HACH 8000	20.0	—	—	28.6	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0	
Cyanide	mg/L	EPA 335.4	0.0050	MCL	0.2	< 0.0050	< 0.0050	< 0.010	< 0.0050	< 0.0050	< 0.0050	
Phenolics, Total Recoverable	ug/L	EPA 420.4	2.0	—	—	3.5	< 2.0	2.2	2.6	2.0	< 2.0	
Total Dissolved Solids	mg/L	SM 2540C	100	SMCL	500	**680**	380	**600**	400	**640**	260	
Total Organic Carbon	mg/L	SM 5310C-11	1.0	—	—	1.7	< 1.0	1	1.1	< 1.0	< 1.0	
E.coli	MPN/100mL	SM 9223B	1.0	MCL	0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	

Appendix A - Water Analytical Data

Spring 2023				Benchmark		Sample Sites						
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**MON00022**	**MON10016**	**PRE10007**	**SHE00089**	**WAR10003**	**WAR10004**	**GMR**
Perfluorobutanoic acid (PFBA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	**2.1**	< 1.9	**1.9**	< 1.8	**5.4**
Perfluorobutanesulfonic acid (PFBS)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	< 1.9	**1.9**	< 1.8	< 1.9	< 1.9	< 1.8	**6.8**
Perfluoropentanoic acid (PFPeA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	**6.8**
Perfluorohexanoic acid (PFHxA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	**6.0**
11Cl-PF3OUdS (F35B Major)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
9Cl-PF3ONS (F35B Minor)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
4,8-Dioxa-3H-perfluorononanoic acid (ADONA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Hexafluoropropylene oxide dimer acid (HFPO-DA)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
8:2 Fluorotelomersulfonic acid (8:2FTS A)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluorodecanoic acid (PFDA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluorododecanoic acid (PFDoA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluoroheptanesulfonic acid (PFHpS)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
N-EtFOSAA (NEtFOSAA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
N-MeFOSAA (NMeFOSAA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluorotetradecanoic acid (PFTA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluorotridecanoic acid (PFTrDA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
4:2 Fluorotelomersulfonic acid (4:2FTS A)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluorodecanesulfonic acid (PFDS)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluorooctanesulfonamide (FOSA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluorononanesulfonic acid (PFNS)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluoro-1-hexanesulfonamide (FHxSA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluoro-1-butanesulfonamide (FBSA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluorohexanesulfonic acid (PFHxS)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	**4.8**
Perfluoro-4-oxapentanoic acid (PFMPA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluoro-5-oxahexanoic acid (PFMBA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
6:2 Fluorotelomersulfonic acid (6:2FTS A)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluoropentanesulfonic acid (PFPeS)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluoroundecanoic acid (PFUnA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Nonafluoro-3,6-dioxaheptanoic acid (NFDHA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9
Perfluoroheptanoic acid (PFHpA)	ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	**2.0**
Perfluorooctanoic acid (PFOA)	ng/L	EPA 537.1	1.9	MCL	4	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	**3.7**
Perfluorooctanesulfonic acid (PFOS)	ng/L	EPA 537.1	1.9	MCL	4	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	**7.8**
Perfluorononanoic acid (PFNA)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	< 1.9	< 1.9	< 1.8	< 1.9	< 1.9	< 1.8	< 1.9

MCL - Maximum Contaminant Level set by USEPA
SMCL - Secondary Maximum Contaminant Level set by USEPA

HBSL - Non enforceable Health Based Screening Level based on (1) latest USEPA Office of Water policies for establishing drinking water benchmarks and (2) most recent USEPA peer reviewed toxicity information

HHBP - Human Health Benchmark for Pesticides set by USEPA
— No drinking water benchmark set for the compound
[1] Duplicate sample result
Numbers in bold exceed a benchmark and/or indicate anthropogenic sources

Appendix A - Water Analytical Data

Fall 2023				Benchmark		Sample Sites							
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**MIA00205**	**MON00022**
Dissolved Oxygen	mg/L	Field Measured	—	—	—	0.19	0.00	9.04	0.00	5.93	5.72	0.00	0.10
pH	S.U.	Field Measured	—	SMCL	6.5 - 8.5	7.22	7.40	7.22	7.11	7.22	7.12	7.18	6.85
Specific Conductance	mS/cm	Field Measured	—	—	—	643	463	529	596	584	588	552	955
Temperature	°C	Field Measured	—	—	—	14.80	12.90	12.90	12.80	16.80	12.80	12.90	16.90
Oxidation Reduction Potential	mv	Field Measured	—	—	—	120.4	-118.8	166.2	-91.8	198.4	218.4	126.4	133.0
Chloride	mg/L	SM 4500-Cl E-11	2.0	SMCL	250	49.2	14.3	30.1	30.1	17.0	31.9	24.8	40.4
Fluoride	mg/L	SM 4500-F C-11	0.20	MCL	4				0.23		0.22	0.37	0.22
Nitrogen, Ammonia	mg/L	EPA 350.1	0.10	—	—	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Nitrogen, Kjeldahl, Total	mg/L	SM 4500-Norg D-11	0.50	—	—	< 0.50	< 0.50	< 0.50	0.50	< 0.50	0.50	< 0.50	< 0.50
Nitrogen, Nitrite	mg/L	SM 4500-NO3 F-11	0.10	MCL	1	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Nitrogen, NO2 plus NO3	mg/L	SM 4500-NO3 F-11	0.10	MCL	10	0.94	< 0.10	**4.1**	< 0.10	**5.4**	1.7	**3.8**	< 0.10
Orthophosphate as P	mg/L	SM 4500-P F	0.10	—	—	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.13	< 0.10
Phosphorus, Total	ug/L	EPA 6010B	100	—	—	< 100	114	< 100	< 100	< 100	< 100	< 100	< 100
Sulfate	mg/L	SM 4500-SO4 D	5.0	SMCL	250	27.2	50.0	12.8	63.0	15.4	28.4	27.4	200
Total Hardness by 2340B	ug/L	EPA 6010B	2000	—	—	345,000	316,000	336,000	440,000	366,000	379,000	367,000	654,000
Aluminum, Total	ug/L	EPA 6010B	150	HBSL, SMCL	6000, 200	< 150	< 150	< 150	< 150	< 150	338	< 150	< 150
Antimony, Total	ug/L	EPA 6020A	1.0	MCL	6	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Arsenic, Total	ug/L	EPA 6020A	1.0	MCL	10	< 1.0	5.1	< 1.0	6.0	< 1.0	1.1	< 1.0	< 1.0
Barium, Total	ug/L	EPA 6010B	5.0	MCL	2000	191	239	49.9	65.6	91.5	88.7	127	127
Beryllium, Total	ug/L	EPA 6010B	1.0	MCL	4	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Boron, Total	ug/L	EPA 6010B	200	HBSL	5000	< 200	< 200	< 200	< 200	< 200	< 200	< 200	< 200
Cadmium, Total	ug/L	EPA 6020A	0.20	MCL	5	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Calcium, Total	ug/L	EPA 6010B	550	—	—	94,800	80,700	90,300	110,000	87,200	110,000	101,000	179,000
Chromium, Hexavalent	mg/L	SM 3500-Cr	0.0040	MCL, HBSL	0.05, 0.02	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040
Cobalt, Total	ug/L	EPA 6010B	5.0	HBSL	2	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Copper, Total	ug/L	EPA 6010B	5.0	MCL	1300	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Iron, Total	ug/L	EPA 6010B	200	HBSL, SMCL	4000, 300	< 200	**1,380**	< 200	**3,190**	< 200	**791**	< 200	< 200
Lead, Total	ug/L	EPA 6020A	1.0	MCL	15	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Lithium, Total	ug/L	EPA 200.7	5.0	HBSL	10	< 5.0	< 5.0	< 5.0	5.8	< 5.0	< 5.0	< 5.0	**16.7**
Magnesium, Total	ug/L	EPA 6010B	150	—	—	26,300	27,800	26,900	39,800	35,900	25,400	28,100	50,600
Manganese, Total	ug/L	EPA 6010B	100	HBSL, SMCL	300, 50	< 100	**496**	< 100	< 100	< 100	< 100	< 100	< 100
Molybdenum, Total	ug/L	EPA 6010B	10.0	HBSL	30	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0
Nickel, Total	ug/L	EPA 6010B	5.0	HBSL	10	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Potassium, Total	ug/L	EPA 6010B	2,000	—	—	3,450	< 2,000	2,430	< 2,000	2,120	< 2,000	< 2,000	4,130
Silica, Total	ug/L	EPA 6010B	100	—	—	10,800	13,600	10,200	15,600	10,400	9,810	9,760	9,030
Silver, Total	ug/L	EPA 6010B	2.0	HBSL	100	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Sodium, Total	ug/L	EPA 6010B	2,000	—	—	40,700	6,580	15,600	5,240	7,800	21,100	8,950	12,100
Strontium, Total	ug/L	EPA 6010B	5.0	HBSL	4000	583	438	162	344	2,390	394	360	574
Thallium, Total	ug/L	EPA 6020A	1.0	MCL	2	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Vanadium, Total	ug/L	EPA 6010B	5.0	—	—	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Zinc, Total	ug/L	EPA 6010B	160	HBSL	2000	< 160	< 160	< 160	< 160	< 160	< 160	< 160	< 160
Alkalinity, Total as CaCO3	mg/L	SM 2320B	5.0	—	—	343	251	264	269	277	301	297	368
BOD, 5 day	mg/L	SM 5210B	2.0	—	—	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	148	< 2.0
Carbonaceous BOD, 5 day	mg/L	SM 5210B	2.0	—	—	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Chemical Oxygen Demand	mg/L	HACH 8000	20.0	—	—	< 20.0	< 20.0	< 20.0	39.3	< 20.0	< 20.0	53.3	< 20.0
Cyanide	mg/L	EPA 335.4	0.010	MCL	0.2	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Phenolics, Total Recoverable	ug/L	EPA 420.4	2.0	—	—	2.8	9.9	18.6	< 2.0	10.6	3.8	< 2.0	< 2.0
Total Dissolved Solids	mg/L	SM 2540C	100	SMCL	500	**660**	460	**540**	**560**	220	460	< 100	**740**
Total Organic Carbon	mg/L	SM 5310C-11	1.0	—	—	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.1
E.coli	MPN/100mL	SM 9223B	1.0	MCL	0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0

Appendix A - Water Analytical Data

Fall 2023				Benchmark		Sample Sites							
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**MIA00205**	**MON00022**
1,1,1-Trichloroethane	ug/L	SW 8260B	1.0	MCL	200	< 1.0							
1,1,2,2-Tetrachloroethane	ug/L	SW 8260B	1.0	HBSL	0.0002	< 1.0							
1,1,2-Trichloroethane	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
1,1-Dichloroethane	ug/L	SW 8260B	1.0	HBSL	1000	< 1.0							
1,1-Dichloroethene	ug/L	SW 8260B	1.0	MCL	7	< 1.0							
1,2,3-Trichlorobenzene	ug/L	SW 8260B	1.0	—	—	< 1.0							
1,2,3-Trichloropropane	ug/L	SW 8260B	1.0	HBSL	30	< 1.0							
1,2,4-Trichlorobenzene	ug/L	SW 8260B	1.0	MCL	70	< 1.0							
1,2-Dibromo-3-chloropropane	ug/L	SW 8260B	5.0	MCL	0.2	< 5.0							
1,2-Dibromoethane (EDB)	ug/L	SW 8260B	1.0	MCL	0.05	< 1.0							
1,2-Dichlorobenzene	ug/L	SW 8260B	1.0	MCL	600	< 1.0							
1,2-Dichloroethane	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
1,2-Dichloropropane	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
1,3-Dichlorobenzene	ug/L	SW 8260B	1.0	HBSL	600	< 1.0							
1,3-Dichloropropane	ug/L	SW 8260B	1.0	HBSL	100	< 1.0							
1,4-Dichlorobenzene	ug/L	SW 8260B	1.0	MCL	75	< 1.0							
2,2-Dichloropropane	ug/L	SW 8260B	1.0	—	—	< 1.0							
2-Butanone (MEK)	ug/L	SW 8260B	10.0	—	—	< 10.0							
2-Chlorotoluene	ug/L	SW 8260B	1.0	—	—	< 1.0							
2-Hexanone	ug/L	SW 8260B	10.0	HBSL	30	< 10.0							
4-Chlorotoluene	ug/L	SW 8260B	1.0	HBSL	100	< 1.0							
4-Methyl-2-pentanone (MIBK)	ug/L	SW 8260B	10.0	—	—	< 10.0							
Acetone	ug/L	SW 8260B	10.0	HBSL	6000	< 10.0							
Acetonitrile	ug/L	SW 8260B	10.0	—	—	< 10.0							
Benzene	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
Bromobenzene	ug/L	SW 8260B	1.0	HBSL	50	< 1.0							
Bromochloromethane	ug/L	SW 8260B	1.0	HBSL	60	< 1.0							
Bromodichloromethane	ug/L	SW 8260B	1.0	MCL	80	< 1.0							
Bromoform	ug/L	SW 8260B	1.0	MCL	80	< 1.0							
Bromomethane	ug/L	SW 8260B	1.0	HHBP	140	< 1.0							
Carbon tetrachloride	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
Chlorobenzene	ug/L	SW 8260B	1.0	MCL	100	< 1.0							
Chloroethane	ug/L	SW 8260B	1.0	—	—	< 1.0							
Chloroform	ug/L	SW 8260B	1.0	MCL	80	< 1.0							
Chloromethane	ug/L	SW 8260B	1.0	—	—	< 1.0							
cis-1,2-Dichloroethene	ug/L	SW 8260B	1.0	MCL	70	< 1.0							
cis-1,3-Dichloropropene	ug/L	SW 8260B	1.0	HBSL	0.3	< 1.0							
Dibromochloromethane	ug/L	SW 8260B	1.0	MCL	80	< 1.0							
Dibromomethane	ug/L	SW 8260B	1.0	—	—	< 1.0							
Dichlorodifluoromethane	ug/L	SW 8260B	1.0	HBSL	1000	< 1.0							
Ethylbenzene	ug/L	SW 8260B	1.0	MCL	700	< 1.0							
Hexachloro-1,3-butadiene	ug/L	SW 8260B	1.0	—	—	< 1.0							
m&p-Xylene	ug/L	SW 8260B	1.0	MCL	10000	< 1.0							
Methylene Chloride	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
Methyl-tert-butyl ether	ug/L	SW 8260B	1.0	—	—	< 1.0							
Naphthalene	ug/L	SW 8260B	1.0	HBSL	100	< 1.0							
o-Xylene	ug/L	SW 8260B	1.0	MCL	10000	< 1.0							
p-Isopropyltoluene	ug/L	SW 8260B	1.0	—	—	< 1.0							
Styrene	ug/L	SW 8260B	1.0	MCL	100	< 1.0							
Tetrachloroethene	ug/L	SW 8260B	1.0	MCL	5	< 1.0							

Appendix A - Water Analytical Data

Fall 2023				Benchmark		Sample Sites							
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**MIA00205**	**MON00022**
Toluene	ug/L	SW 8260B	1.0	MCL	1000	< 1.0							
trans-1,2-Dichloroethene	ug/L	SW 8260B	1.0	MCL	100	< 1.0							
trans-1,3-Dichloropropene	ug/L	SW 8260B	5.0	HBSL	0.3	< 5.0							
Trichloroethene	ug/L	SW 8260B	1.0	MCL	5	< 1.0							
Trichlorofluoromethane	ug/L	SW 8260B	1.0	HBSL	2000	< 1.0							
Vinyl acetate	ug/L	SW 8260B	5.0	—	—	< 5.0							
Vinyl chloride	ug/L	SW 8260B	1.0	MCL	2	< 1.0							
Xylene (Total)	ug/L	SW 8260B	1.0	MCL	10000	< 1.0							

Appendix A - Water Analytical Data

			Benchmark		Sample Sites							
Units	**Method**	**Report Limit**	**Type**	**Value**	**BUT10014**	**BUT10016**	**BUT10017**	**CLA10011**	**CLA10018**	**HAM10010**	**MIA00205**	**MON00022**
ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.9	< 1.8	< 1.8	< 1.9	< 1.9	< 1.9	< 2.0
ng/L	EPA 537.1	1.8	—	—	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.9	< 1.9	< 2.0
ng/L	EPA 537.1	1.8	—	—	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.9	< 2.0
ng/L	EPA 537.1	1.8	—	—	< 1.8	< 1.9	< 1.8	< 1.8	< 1.9	< 1.9	< 1.9	< 2.0
ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.9	< 1.8	< 1.8	< 1.9	< 1.9	< 1.9	< 2.0
ng/L	EPA 537.1	1.8	—	—	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.9	< 2.0
ng/L	EPA 537.1	1.8	—	—	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.9	< 1.9	< 1.9
ng/L	EPA 537.1	1.9	MCL	Hazard Index	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.0
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	**14.6**	< 1.9	**4.0**	< 1.9	< 1.9	**3.2**	< 2.0	**2.2**
ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.9	< 1.8	< 1.8	< 1.9	< 1.9	< 1.9	< 2.0
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0
ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.9	< 1.8	< 1.8	< 1.9	< 1.9	< 1.9	< 2.0
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.9	< 1.8	< 1.8	< 1.9	< 1.9	< 1.9	< 2.0
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	**15.0**	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.8	< 1.8	< 1.8	< 1.8	< 1.9	< 1.9	< 2.0
ng/L	EPA 537.1	1.7	MCL	Hazard Index	**3.5**	< 1.7	**9.7**	< 1.7	< 1.7	**3.5**	< 1.8	< 1.8
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	**3.8**	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.7	MCL	Hazard Index	**5.7**	< 1.8	**2.1**	< 1.7	< 1.8	**3.7**	< 1.8	< 1.9
ng/L	EPA 537.1	1.9	—	—	**14.4**	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	MCL	Hazard Index	**6.7**	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.8	MCL	4	**12.3**	< 1.9	**8.6**	< 1.8	< 1.8	**3.4**	< 1.9	< 1.9
ng/L	EPA 537.1	1.9	MCL	4	**34.3**	< 1.9	**4.5**	< 1.9	< 1.9	**2.8**	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1
ng/L	EPA 537.1	1.9	—	—	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	< 2.0	< 2.0	< 2.1

Appendix A - Water Analytical Data

Fall 2023				**Benchmark**		**Sample Sites**						
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**MON00022**[1]	**MON10016**	**PRE10007**	**SHE00089**	**WAR10003**	**WAR10004**	**GMR**
Dissolved Oxygen	mg/L	Field Measured	—	—	—	0.10	0.00	0.01	0.00	0.00	1.01	
pH	S.U.	Field Measured	—	SMCL	6.5 - 8.5	6.85	7.30	7.28	7.13	7.28	7.48	
Specific Conductance	mS/cm	Field Measured	—	—	—	955	579	594	531	880	474	
Temperature	°C	Field Measured	—	—	—	16.90	12.90	13.00	12.40	14.60	14.80	
Oxidation Reduction Potential	mv	Field Measured	—	—	—	133.0	-53.4	-88.2	132.5	-108.4		
Chloride	mg/L	SM 4500-Cl E-11	2.0	SMCL	250	18.0	54.5	37.2	8.6	**132**	40.8	
Fluoride	mg/L	SM 4500-F C-11	0.20	MCL	4	0.21			0.22	0.38	0.30	
Nitrogen, Ammonia	mg/L	EPA 350.1	0.10	—	—	< 0.10	< 0.10	< 0.10	< 0.10	0.24	< 0.10	
Nitrogen, Kjeldahl, Total	mg/L	SM 4500-Norg D-11	0.50	—	—	< 0.50	< 0.50	< 0.50	< 0.50	0.58	< 0.50	
Nitrogen, Nitrite	mg/L	SM 4500-NO3 F-11	0.10	MCL	1	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	
Nitrogen, NO2 plus NO3	mg/L	SM 4500-NO3 F-11	0.10	MCL	10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.53	
Orthophosphate as P	mg/L	SM 4500-P F	0.10	—	—	< 0.10	< 0.10	< 0.10	0.13	< 0.10	< 0.10	
Phosphorus, Total	ug/L	EPA 6010B	100	—	—	< 100	< 100	< 100	< 100	< 100	< 100	
Sulfate	mg/L	SM 4500-SO4 D	5.0	SMCL	250	198	29.8	48.0	42.6	80.1	22.6	
Total Hardness by 2340B	ug/L	EPA 6010B	2000	—	—	637,000	324,000	386,000	376,000	464,000	262,000	
Aluminum, Total	ug/L	EPA 6010B	150	HBSL, SMCL	6000, 200	< 150	< 150	< 150	< 150	< 150	< 150	
Antimony, Total	ug/L	EPA 6020A	1.0	MCL	6	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Arsenic, Total	ug/L	EPA 6020A	1.0	MCL	10	< 1.0	< 1.0	4.8	< 1.0	2.3	< 1.0	
Barium, Total	ug/L	EPA 6010B	5.0	MCL	2000	123	114	245	156	228	60.8	
Beryllium, Total	ug/L	EPA 6010B	1.0	MCL	4	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Boron, Total	ug/L	EPA 6010B	200	HBSL	5000	< 200	< 200	< 200	< 200	235	< 200	
Cadmium, Total	ug/L	EPA 6020A	0.20	MCL	5	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	
Calcium, Total	ug/L	EPA 6010B	550	—	—	174,000	84,600	96,300	91,300	113,000	58,200	
Chromium, Hexavalent	mg/L	SM 3500-Cr	0.0040	MCL, HBSL	0.05, 0.02	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	< 0.0040	
Cobalt, Total	ug/L	EPA 6010B	5.0	HBSL	2	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Copper, Total	ug/L	EPA 6010B	5.0	MCL	1300	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Iron, Total	ug/L	EPA 6010B	200	HBSL, SMCL	4000, 300	< 200	< 200	**2,510**	< 200	**2,280**	< 200	
Lead, Total	ug/L	EPA 6020A	1.0	MCL	15	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Lithium, Total	ug/L	EPA 200.7	5.0	HBSL	10	**16.0**	< 5.0	6.3	6.8	9.8	< 5.0	
Magnesium, Total	ug/L	EPA 6010B	150	—	—	49,200	27,300	35,300	35,900	44,400	28,400	
Manganese, Total	ug/L	EPA 6010B	100	HBSL, SMCL	300, 50	< 100	< 100	< 100	**300**	< 100	< 100	
Molybdenum, Total	ug/L	EPA 6010B	10.0	HBSL	30	< 10.0	< 10.0	< 10.0	10.4	< 10.0	< 10.0	
Nickel, Total	ug/L	EPA 6010B	5.0	HBSL	10	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Potassium, Total	ug/L	EPA 6010B	2,000	—	—	4,000	2,580	< 2,000	< 2,000	2,580	2,240	
Silica, Total	ug/L	EPA 6010B	100	—	—	8,890	9,740	10,600	11,100	14,500	8,330	
Silver, Total	ug/L	EPA 6010B	2.0	HBSL	100	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	
Sodium, Total	ug/L	EPA 6010B	2,000	—	—	11,600	**43,600**	16,700	10,000	**58,100**	22,700	
Strontium, Total	ug/L	EPA 6010B	5.0	HBSL	4000	558	647	953	473	1,150	420	
Thallium, Total	ug/L	EPA 6020A	1.0	MCL	2	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Vanadium, Total	ug/L	EPA 6010B	5.0	—	—	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Zinc, Total	ug/L	EPA 6010B	160	HBSL	2000	< 160	< 160	< 160	< 160	< 160	< 160	
Alkalinity, Total as CaCO3	mg/L	SM 2320B	5.0	—	—	404	271	283	309	261	226	
BOD, 5 day	mg/L	SM 5210B	2.0	—	—	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	
Carbonaceous BOD, 5 day	mg/L	SM 5210B	2.0	—	—	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	
Chemical Oxygen Demand	mg/L	HACH 8000	20.0	—	—	< 20.0	< 20.0	< 20.0	44.0	34.7	20.7	
Cyanide	mg/L	EPA 335.4	0.010	MCL	0.2	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	
Phenolics, Total Recoverable	ug/L	EPA 420.4	2.0	—	—	3.5	6.5	15.1	3.6	< 2.0	< 2.0	
Total Dissolved Solids	mg/L	SM 2540C	100	SMCL	500	**620**	**580**	440	260	**700**	340	
Total Organic Carbon	mg/L	SM 5310C-11	1.0	—	—	1.1	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
E.coli	MPN/100mL	SM 9223B	1.0	MCL	0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	

Appendix A - Water Analytical Data

Fall 2023				Benchmark		Sample Sites						
Parameter	**Units**	**Method**	**Report Limit**	**Type**	**Value**	**MON00022[1]**	**MON10016**	**PRE10007**	**SHE00089**	**WAR10003**	**WAR10004**	**GMR**
1H,1H,2H,2H-Perfluorododecanesulfonic acid (10:2 FTS)	ng/L	EPA 537.1	1.8	—	—	< 2.0	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.9
11Cl-PF3OUdS (F35B Major)	ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.8
4:2 Fluorotelomersulfonic acid (4:2FTS A)	ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.8
6:2 Fluorotelomersulfonic acid (6:2FTS A)	ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.8
8:2 Fluorotelomersulfonic acid (8:2FTS A)	ng/L	EPA 537.1	1.8	—	—	< 2.0	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.9
9Cl-PF3ONS (F35B Minor)	ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8	< 1.8
4,8-Dioxa-3H-perfluorononanoic acid (ADONA)	ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.8
Hexafluoropropylene oxide dimer acid (HFPO-DA)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Sulfluramid (NEtFOSA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
N-EtFOSAA (NEtFOSAA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
N-ethyl perfluorooctane sulfonamido ethanol (NEtFOSE)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
N-Methyl Perfluorooctane Sulfonamide (NMeFOSA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
N-MeFOSAA (NMeFOSAA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
N-Methyl Perfluorooctanesulfonamido Ethanol (NMeFOSE)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluorobutanoic acid (PFBA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	**3.9**
Perfluorodecanesulfonic acid (PFDS)	ng/L	EPA 537.1	1.8	—	—	< 2.0	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.9
Perfluorodecane Sulfonic Acid (PFDoS)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.8	< 1.8	< 1.9	< 1.8	< 1.9
Perfluoroheptanesulfonic acid (PFHpS)	ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.8
Perfluorohexadecanoic acid (PFHxDA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluorononanesulfonic acid (PFNS)	ng/L	EPA 537.1	1.8	—	—	< 2.0	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.9
Perfluorooctadecanoic acid (PFODA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluorooctanesulfonamide (PFOSA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluoropentanoic acid (PFPeA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	**6.8**
Perfluoropentanesulfonic acid (PFPeS)	ng/L	EPA 537.1	1.8	—	—	< 1.9	< 1.8	< 1.8	< 1.8	< 1.9	< 1.8	< 1.8
Perfluorobutanesulfonic acid (PFBS)	ng/L	EPA 537.1	1.7	MCL	Hazard Index	< 1.8	**1.7**	< 1.7	< 1.7	< 1.8	< 1.7	**9.3**
Perfluorodecanoic acid (PFDA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluorododecanoic acid (PFDoA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluoroheptanoic acid (PFHpA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluorohexanesulfonic acid (PFHxS)	ng/L	EPA 537.1	1.7	MCL	Hazard Index	< 1.9	< 1.7	< 1.7	< 1.7	< 1.8	< 1.7	**5.7**
Perfluorohexanoic acid (PFHxA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	**5.3**
Perfluorononanoic acid (PFNA)	ng/L	EPA 537.1	1.9	MCL	Hazard Index	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluorooctanesulfonic acid (PFOS)	ng/L	EPA 537.1	1.8	MCL	4	< 1.9	< 1.8	< 1.7	< 1.8	< 1.8	< 1.8	**8.3**
Perfluorooctanoic acid (PFOA)	ng/L	EPA 537.1	1.9	MCL	4	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	**4.1**
Perfluorotetradecanoic acid (PFTA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluorotridecanoic acid (PFTrDA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9
Perfluoroundecanoic acid (PFUnA)	ng/L	EPA 537.1	1.9	—	—	< 2.0	< 1.9	< 1.9	< 1.9	< 2.0	< 1.9	< 1.9

MCL - Maximum Contaminant Level set by USEPA
SMCL - Secondary Maximum Contaminant Level set by USEPA
AMCL - Alternative Maximum Contaminant Level set by USEPA

HBSL - Non enforceable Health Based Screening Level based on (1) latest USEPA Office of Water policies for establishing drinking water benchmarks and (2) most recent USEPA peer reviewed toxicity information
HHBP - Human Health Benchmark for Pesticides set by USEPA
— No drinking water benchmark set for the compound

[1] Duplicate sample result
Numbers in bold exceed a benchmark and/or indicate anthropogenic sources

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The Miami Conservancy District protects communities in southwest Ohio from flooding, preserves water through stewardship, and promotes the enjoyment of our waterways.