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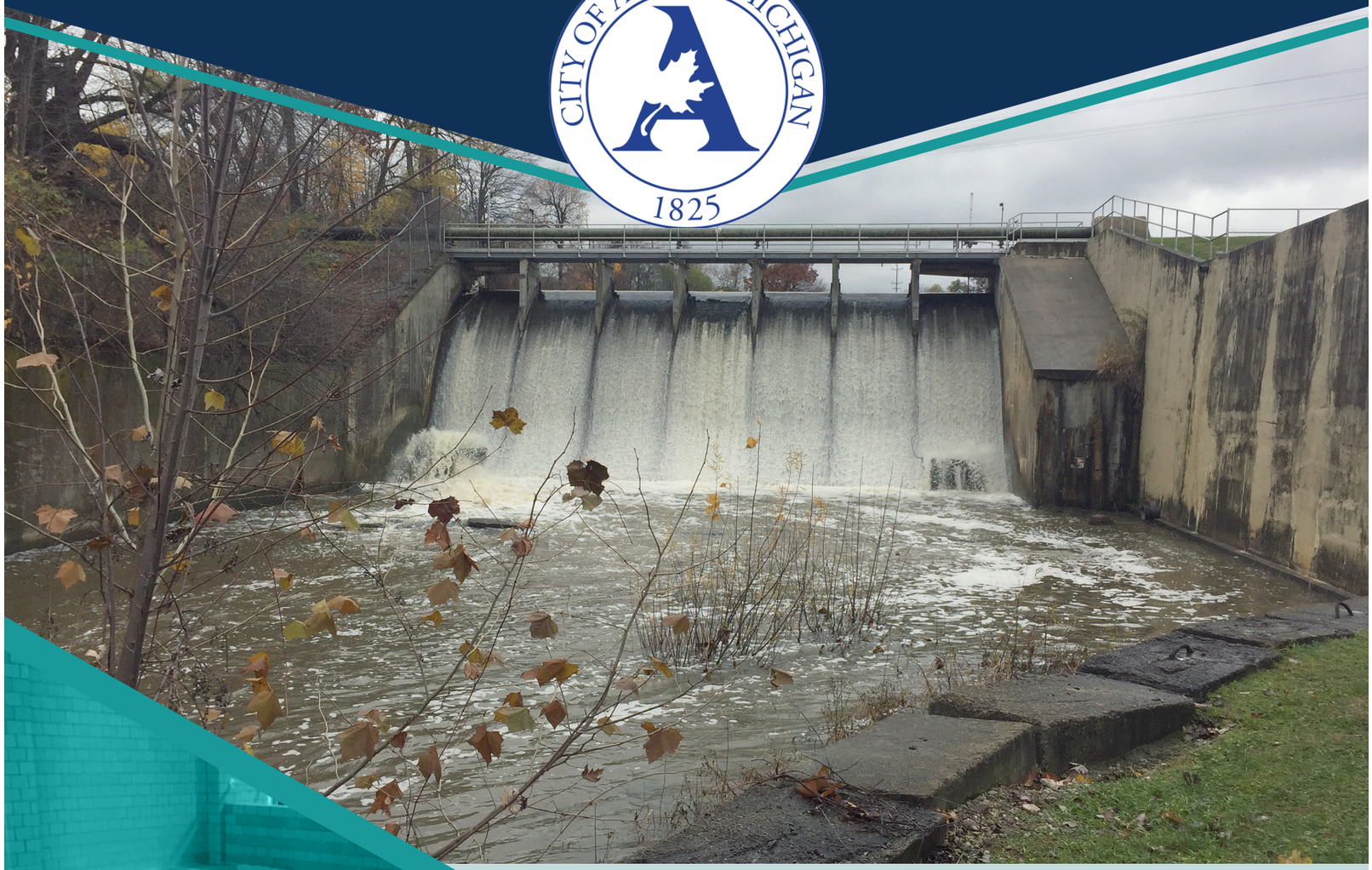
1825



Water Treatment Plant **Optimization Study** for **Taste** and **Odor**

TETRA TECH

June 2019

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APPENDICES

APPENDIX A - SONIC WAVE GENERATOR LITERATURE

APPENDIX B - PUBLIC ENGAGEMENT DOCUMENTATION

EXECUTIVE SUMMARY

This study was commissioned in the wake of the 2018 complaints to study means to optimize the existing WTP regarding improving taste and odor of the treated drinking water. Specifically, the following goals were identified for this study:

- Screen short-term and long-term options for improving taste and odor of the treated water
- Better understand the long-term yield of the City's wellfield and provide next steps should increasing the groundwater supply be desired
- Engage the public during the study to better understand their concerns and priorities

To assist with addressing the groundwater questions, Tetra Tech subcontracted with Williams & Works who has performed the majority of the work at the City's wellfield. Tetra Tech also subcontracted with Q+M Agency to lead the public engagement aspects of this project.

This study is an office analysis to screen next steps for the City's consideration. Future phases will be necessary to test the feasibility of new technologies before investing in capital projects. This study was scoped to focus on taste and odor concerns and only briefly touches upon the potential for treatment technologies to address algal toxins.

Means to control taste and odors can be grouped into the following three categories:

- Source optimization
- Source treatment
- WTP treatment optimization

Treatment technologies were evaluated in each of these areas and potential alternatives screened.

Within processes at the WTP to improve taste and odor, the processes in Table ES-1 were considered to be feasible and were evaluated in greater detail.

Table ES-1 - Summary of Recommended Alternatives for Pilot Testing

Technology Evaluated	Design Flow	Capital Cost	Pilot Cost	Algal Toxin Removal*	Comments
Ozone	2 MGD	$4,000,000	$140,000	Y	
Advanced Oxidation	2 MGD	$4,200,000	$140,000	Y	
Ozonation + Biofiltration (Ozone w/ Existing Filters)	5 MGD	$5,000,000	$260,000	Y (Polishing Step)	More stable effluent relative to ozonation or advanced oxidation only
Ozonation + Biofiltration (w/ New GAC Filters)	2 MGD	$5,600,000	$260,000	Y (Polishing Step)	More stable effluent relative to ozonation or advanced oxidation only
Nanofiltration (Reverse Osmosis)	4.2 MGD	$10,500,000	$340,000	Y	Will reduce operating costs associated with lime residual disposal

*Anatoxin-a, Cylindrospermopsin and Microcystin

The short-term and long-term recommendations resulting from this study are summarized below.

Short-Term Recommendations (2019)

Source Treatment:

- Apply copper sulfate in Lake Adrian
- Consider purchasing and installing the LG Sonics Master Control Station in the southern portion of the lake so that it can control algae growth in the area around the intake and provide continuous monitoring data about the water quality in the lake. Our opinion of cost to install this device is $300,000 and there is a current Michigan grant program that may fund 80% of this cost.

WTP Optimization:

- Consider splitting the treatment of the two source waters into two separate treatment trains at the WTP
- Implement the planned permanganate addition
- Dose the surface water train with Powdered Activated Carbon (similar to the City's existing practice)
- Consider optimizing the existing filter media and operation to enhance biological removal of taste and odor causing compounds

Groundwater Supply:

- The City should operate the well field in accordance to the recommendations in this report. Pumpage rates exceeding 2 MGD for extended periods without corresponding resting periods during warm months may lead to drawdown that may take a year or more to recover from.

Intermediate-Term Recommendations (Late 2019 and 2020)

The following actions are recommended to be immediately taken after the short-term control methods have been implemented:

- Evaluate effectiveness of short-term recommendations
- If the evaluation determines that the implementation of the short-term recommendations did not reduce the level of taste and odor compounds in the finished water to a generally acceptable level, conduct pilot testing on the following treatment technologies:
    - Nanofiltration
    - Ozonation
    - Advanced oxidation (w/ ozone and peroxide)
    - Ozonation or advanced oxidation followed by biofiltration

  These could be sequenced over a few years' time.
- Consider replacing the anthracite layer of the filter media with GAC
- Consider running jar tests to evaluate the frequency and mass of the alum or ferric dose required to effectively treat the surface water.

Long-Term Recommendations (2021 and beyond)

The following actions are recommended to be taken to further increase the effectiveness of control and reduction of taste and odor compounds in the finished water after the performance of the short-term and intermediate-term recommendations have been implemented and the public response to the improvement of the finished water quality evaluated.

- Reevaluate the treatment effectiveness and life cycle costs of the treatment alternatives outlined in the intermediate-term pilot tests. Upon selection of a technology, the project should proceed to design and construction.
- The City should continue to seek additional groundwater sources when opportunities present themselves. Given the City's long history of seeking a new groundwater supply without success, we are not optimistic that nonspecific attempts to find new sources will be fruitful. However, as new leads for groundwater supplies are found, testing to determine yield should be considered. We approximate that each test will cost $25,000 or more, thus these tests should not arbitrarily be completed.

1.0 BACKGROUND

1.1 PROBLEM STATEMENT

The City of Adrian's water supply has historically been provided by the surface waters of Lake Adrian which is an impoundment of Wolf Creek. The water customers have periodically made complaints regarding the taste and odor of the water with some city records dating to the 1950s. At numerous times in the City's history, attempts were made to locate groundwater supplies to replace or augment the surface water supply. In 2007, the City did locate a groundwater source adjacent to Hamilton Highway in Adrian Township. The City installed wells, pumps and a transmission system to deliver this water to the City's existing WTP on Bent Oak Avenue.

Groundwater now represents about 80% of the source water used by the City and taste/odor complaints largely ceased until 2017. When some complaints occurred, the City pumped more water from the wellfield with the result of dropping the groundwater table. The lowered groundwater table continued into 2018 and decreased the amount of groundwater available. When the City used more surface water in 2018, a preponderance of complaints regarding taste/odor were received. Sampling results provided by the City suggest that elevated levels of the taste and odor causing compound MIB are responsible for the complaints, sometimes reaching levels 60 times the taste and odor threshold in the source water. Sampling results also show that elevated levels of geosmin, another taste and odor causing compound, have historically been a concern. Both MIB and geosmin are by products of algae. Especially, the blue-green species of algae which is also referred to as cyanobacteria.

This study was commissioned in the wake of the 2018 complaints to study means to optimize the existing WTP regarding improving taste and odor of the treated drinking water. Specifically, the following goals were identified for this study:

- Screen short-term and long-term options for improving taste and odor of the treated water
- Better understand the long-term yield of the City's wellfield and provide next steps should increasing the groundwater supply be desired
- Engage the public during the study to better understand their concerns and priorities

To assist with addressing the groundwater questions, Tetra Tech subcontracted with Williams & Works who has performed the majority of the work at the City's wellfield. Tetra Tech also subcontracted with Q+M Agency to lead the public engagement aspects of this project.

1.2 WTP DESCRIPTION

The Adrian WTP serves 21,000 residents with a permitted design plant capacity of 8 million gallons a day (MGD). The WTP has both ground and surface water sources and prefers to rely on the ground water source to the extent possible. The well field's firm capacity (largest pump out of service) is approximately 3.2 mgd. Broadly, the processes utilized by the WTP are coagulation, flocculation, sedimentation, softening, filtration, and disinfection.

The plant operates two settling processes in series. To achieve coagulation in both, the plant feeds ferric sulfate into rapid mix chambers. The first settling process is carried out via circular clarifiers with solids recycle. The second settling process consists of a flocculation basin followed by a sedimentation basin. Lime is fed prior to flocculation to elevate the pH and soften the water. Following sedimentation, the water is fed with carbon dioxide to reduce the pH. The water then enters granular media filters. Disinfection via chlorine is achieved after filtration and the WTP maintains a disinfectant residual with chlorine. If necessary, as was the case in 2018, the WTP can add powdered activated carbon upstream of the settling processes to remove dissolved constituents such as MIB and geosmin. The WTP has historically fed permanganate to address taste and odor concerns and this process was restarted late in 2018. The City has also previously dosed Lake Adrian with copper sulfate to control algae blooms to reduce taste and odor compounds at the source, but did not implement this technique in 2018.

1.3 RAW WATER SOURCES

Historically, the City relied on Lake Adrian as the sole source to the WTP. Lake Adrian was formed from an impoundment of Wolf Creek and 86 acres across and contains approximately 300 million gallons of water.

In 2009, the City located a groundwater source. Since then, the WTP has used groundwater to meet 50 to 98% of its demand, averaging 80% over 2009 to 2018. Figure 1-1 shows the trend of water source usage between 2015 and 2018. The WTP relied more heavily on surface water in the summer of 2018, likely leading to the taste and odor complaints.

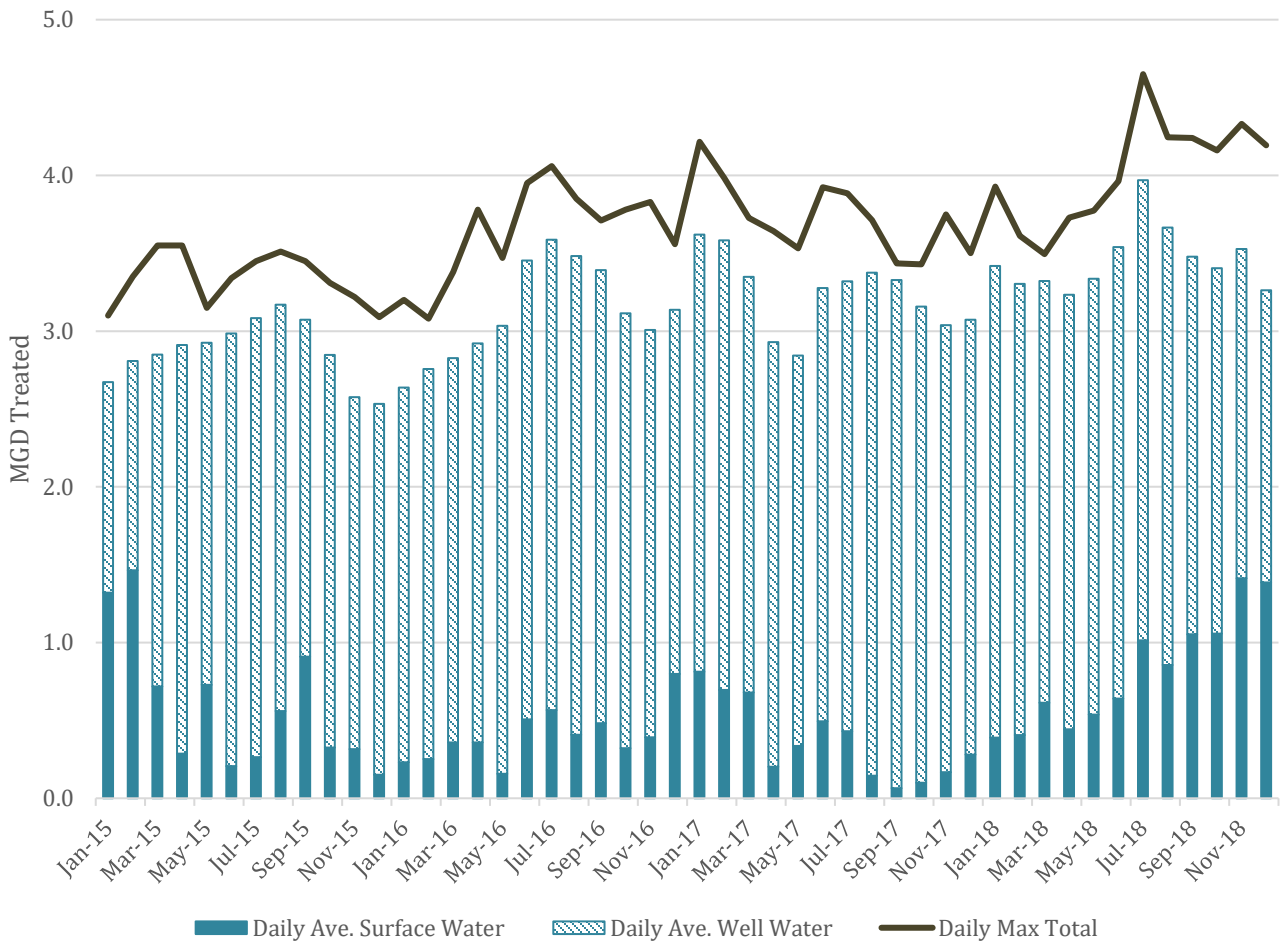

Figure 1-1 - Adrian WTP Historical Drinking Water Source

Figure 1-1 shows that the average monthly daily flow and the maximum daily flow have been increasing over the period shown. The average annual daily flow was approximately 2.9 MGD in 2015 and has increased to 3.5 MGD in 2018. The maximum daily flow was 3.6 MGD in 2015 and 4.7 MGD in 2018. In the absence of significant growth within the service area and assuming the increase in demand does not represent a long-term trend, an average annual daily demand of 3.6 MGD and a maximum daily demand of 5 MGD seem reasonable for planning purposes for this report. During this period average monthly surface water use has varied between 0.1 MGD and 1.5 MGD and groundwater withdrawals have varied between 1.3 MGD and 3.3 MGD. Considering that the

groundwater use was oversubscribed during this period, a surface water treatment capacity of up to 2 MGD will be assumed to provide the flexibility to reduce ground water withdrawals and maintain acceptable water quality. Therefore, surface water treatment options discussed in this report will be based upon a capacity of 2 MGD, with a few exceptions clearly noted.

2.0 GROUNDWATER MANAGEMENT TECHNIQUES

In 2009, The City established a well field at the intersection of US-223 and Hamilton Highway in Adrian Township. The City operates four production wells at the wellfield. Well Nos. 1, 2, 3 and 4, each have capacities ranging between 600 and 800 gpm, and each well is rotated as the lead well throughout a typical week schedule. In rare instances, all four wells will operate during exceptionally high demands or during certain summer months when the surface water is more challenging to treat. The peak production month is generally in August of the year, with a demand rate of about 76.2 million gallons, therefore, the average day of the peak month is about 2.46 million gallons per day. Three production wells can meet this demand for a limited period of time before the withdrawal rate must be reduced to allow the aquifer to recover.

The City has been monitoring water levels in each production well since the wellfield was put on-line in 2009. During this time, pumpage from the wellfield has always been augmented by surface water; typically, the finished water supply in the summer will consist of a greater percentage of groundwater during the months when the Lake water is warmer. During the colder months, a greater percentage of the City water supply is derived from the Lake, and this allows the wellfield to recover from its heavier summer use. Under this scenario, groundwater elevations will rise and fall throughout a typical year, but the overall aquifer storage will maintain in balance on an annual basis as long as aquifer recharge rates and annual precipitation rates are normal or above normal.

During the initial operation of the wellfield (and mainly during warmer months), individual wells were pumped two at a time, and rotated on a regular basis; for example, Well Nos. 1 and 3 were pumped simultaneously for a period of about 7 days, then Well Nos. 2 and 4 were pumped simultaneously for the same period of time, and so on. A third well will be operated every other week where three wells will be pumped simultaneously off and on for a period of seven days. During this time, water levels within the aquifer will typically decline throughout the warmer summer months. During the colder months, however, wellfield production is dropped back to two wells which allowed the aquifer water levels to recover. Hydrologically, snowmelt and early spring precipitation add to the basin recharge component which is a major part of the aquifer recovery process.

Continued heavy use of groundwater from the West Side Wellfield throughout the year at the full City water system demand rate is not sustainable. **The basic principle of pumping an aquifer must be met; when a well is pumped for a period of time, it must be rested for at least the same period of time to allow the aquifer to recover. Generally, this rule can be extended to include larger increments of time, but so must the recovery period be extended to an equally large increment of time.** In the case of the wellfield, Wolf Creek helps moderate falling aquifer water levels by providing a recharge boundary which effectively dampens the drawdowns caused by the production wells; part of the production of groundwater at the wellfield is aided by the Wolf Creek. Despite the presence of the Wolf Creek, the same rule of equal production and recovery periods applies.

Therefore, this section is intended to address in practical terms the approximate annual mean capacity of the wellfield.

2.1 GENERAL HYDROGEOLOGIC DESCRIPTION

Regionally, the City of Adrian wellfield lies within the lower reaches of the Wolf Creek Basin, a higher sub-basin of the River Raisin Basin. Within the Wolf Creek Basin, numerous smaller streams (including the Black Creek) form a highly networked drainage system that reaches to the northwest edge of Lenawee County into Cambridge and Franklin Townships, encompassing a watershed area of about 74 square miles (see Figure 2-1).

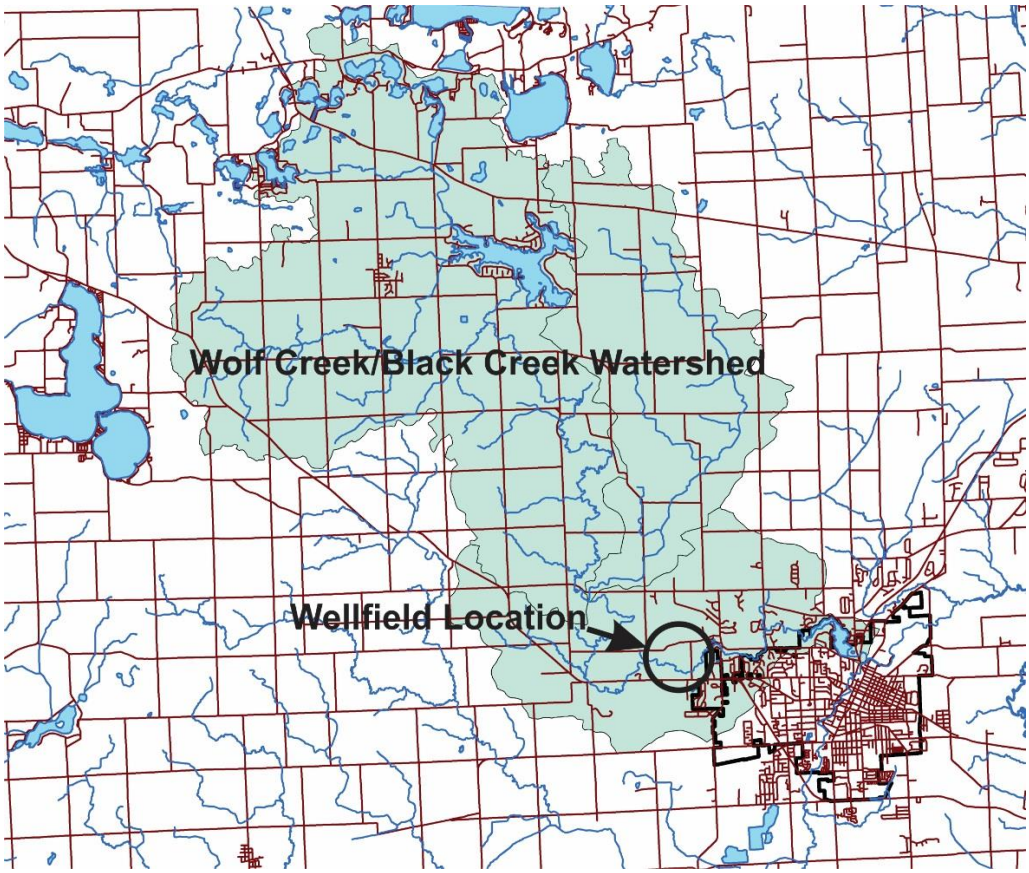

Figure 2-1 - Wolf Creek/Black Creek Watershed Area

The Quaternary map of Michigan shows that most of the northwest part of Lenawee County consists of discontinuous till plains and end moraines of fine textured till (see Figure 2-2). Across the mid-section of the County lie narrow belts of post glacial alluvium associated with the River Raisin drainageway (shown as pink areas in Figure 2-2).

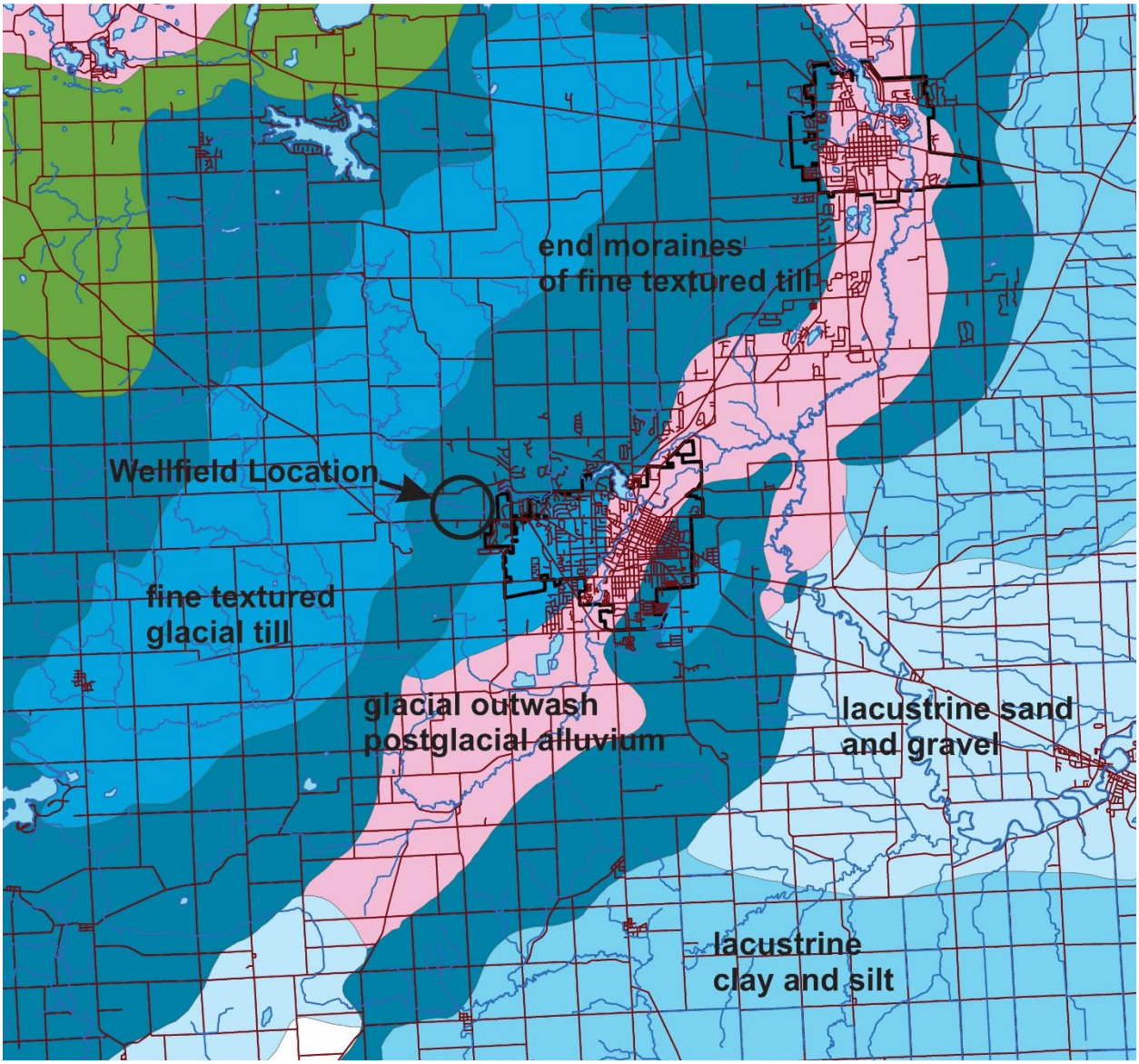

Figure 2-2 - Glacial Deposits in North-Central Lenawee County (after Farrand, W.R., and Bell, D.L., 1982)

The thickness of the drift package in this area varies from 150 feet along the lower elevations of the Wolf Creek, up to 200 feet or more in the higher elevations along the north part of Lenawee County. The area lies along a regional lacustrine depositional environment, primarily associated with the former beach and near-offshore littoral deposits of the glacial great lakes. At its margin lie narrow linear belts of hummocky relief marking the morainal deposits of the former stillstands of the ice sheet margin. These morainal deposits typify most of the area west and north of the City including the entire Wolf Creek Basin.

The uppermost bedrock in this region is the Coldwater Shale, with its structure contours lying generally southeast toward the base of the River Raisin Drainageway. Given its poor permeability, the Coldwater Shale is not considered an important source of groundwater. In this region, therefore, the bulk groundwater basin within the Wolf Creek Sub-basin lies within the laminated drift material with its gradient generally coincident with the trend of the drainageway. Figure 2-3 shows the locations of selected wells that were used to illustrate the area drift

geology, along with the locations of cross-section lines. Figure 2-4 and Figure 2-5 show the local geology in cross-sectional views.

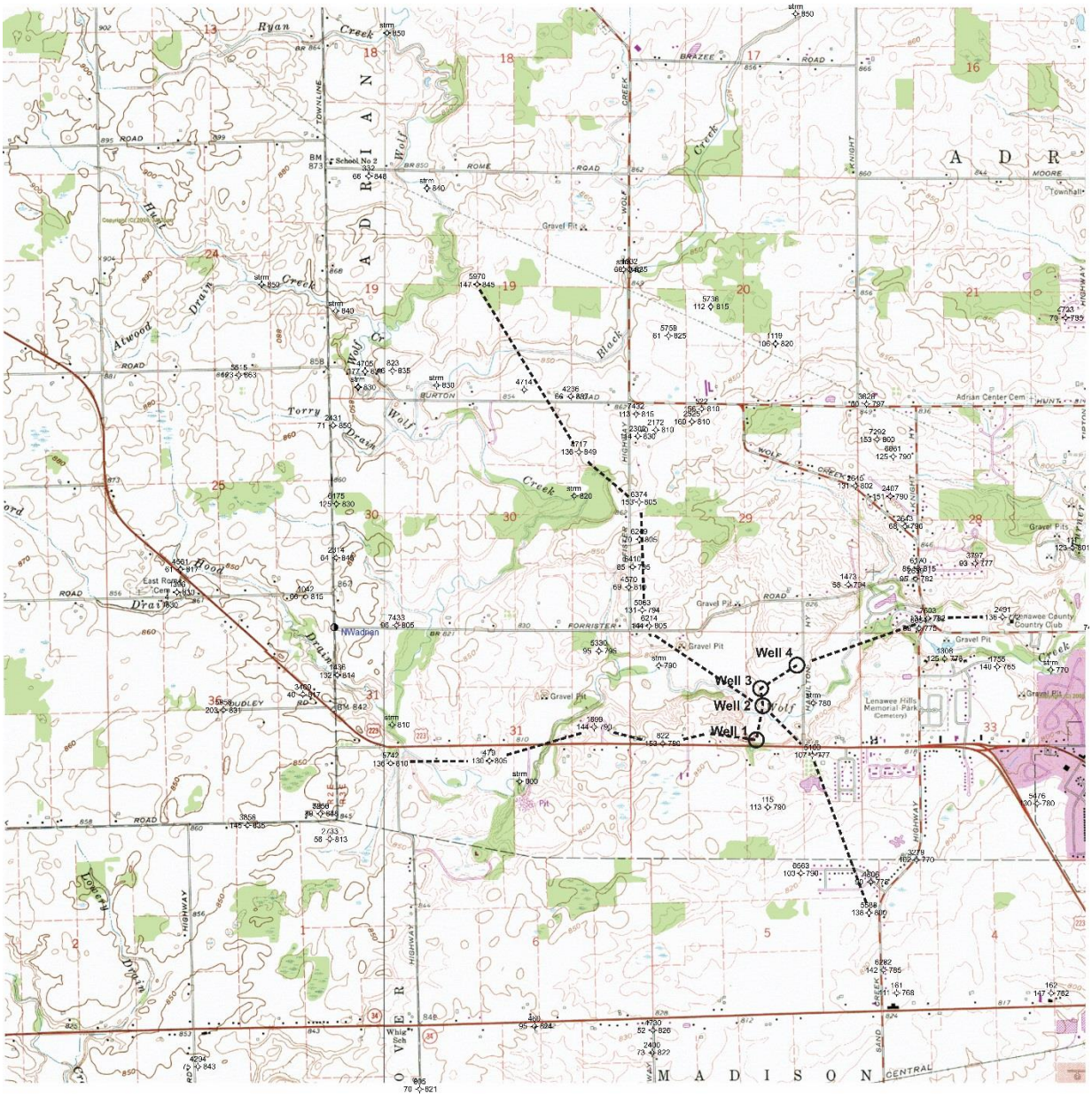

Figure 2-3 - Selected Water Wells and Cross-Section Locations

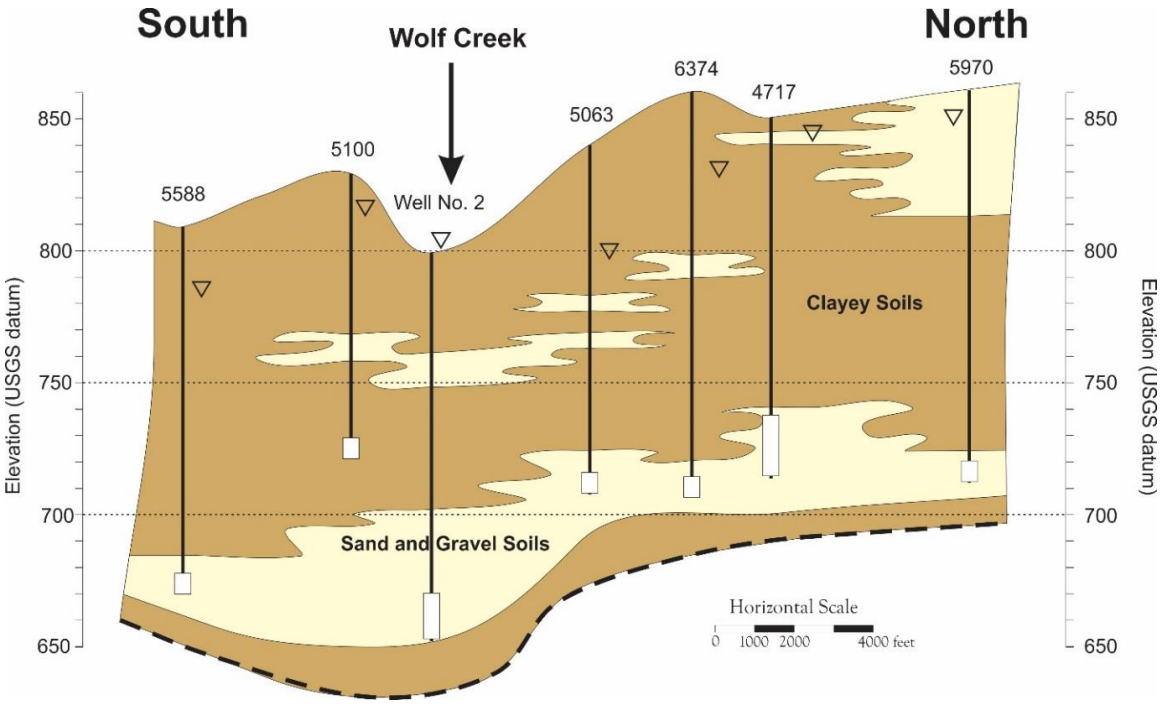

Figure 2-4 - Geologic Cross-Section A-A, Viewing West

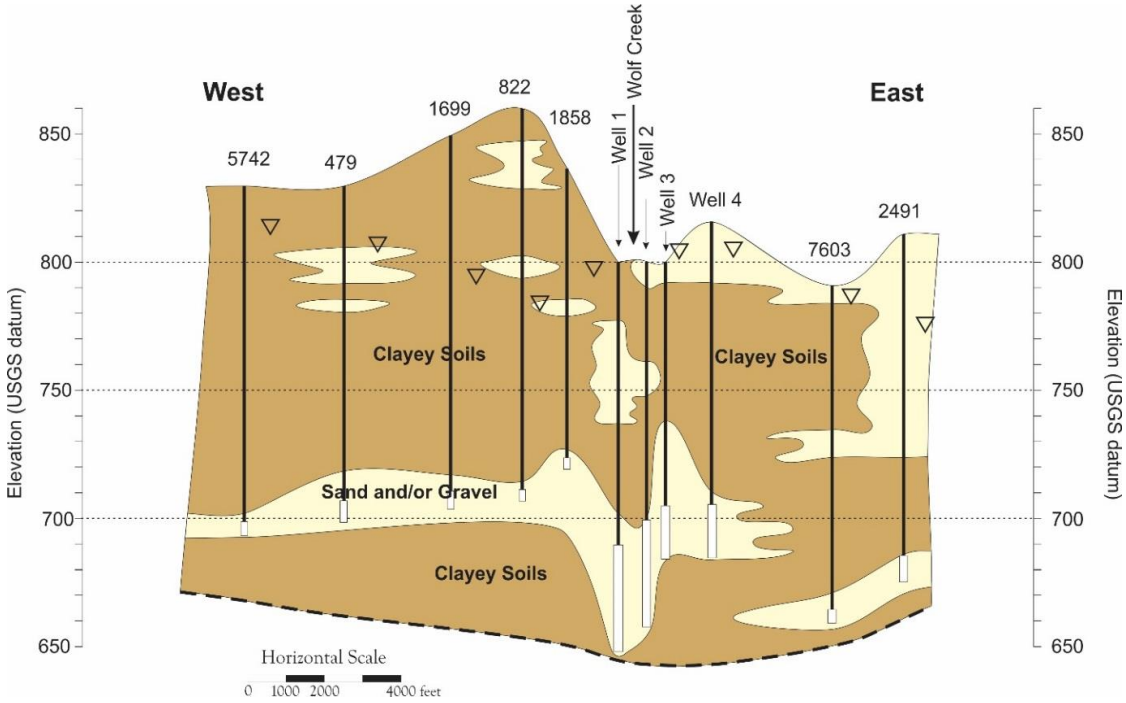

Figure 2-5 - Geologic Cross-Section B-B, Viewing North

Generally, the drift geology in this area is typified by a greater percentage of clayey soils with thin laminations of sand and gravel within the upper 150 feet of drift. Private well logs in the upper part of the Wolf Creek Basin indicate many of the sand and gravel intervals are less than ten feet in thickness that will produce water adequately for a private water supply but not a community water supply. Many of these thin sandy layers are not extensive and quickly thin, preventing detailed mapping over larger areas of the basin.

Along the lower reaches of the Wolf Creek at the City of Adrian wellfield, there are significantly thicker sand and gravel packages which have the capability to produce significant well yields. **These thicker sections of sand and gravel are rare for this area and rare for Lenawee County overall.** Since much of the basin sediments are rich in clayey soils, and only the lower part of the basin is anomalously thick with sandy sediments, higher yielding wells must be managed to avoid over pumping and lowering of groundwater levels since its extent is limited and does not appear to extend or interconnect with the thin sandy packages throughout the Wolf Creek groundwater basin.

At each production well the geology typically consists of upper clayey soils with occasional sandy layers from the surface to about 100 feet below grade, and a sand and gravel aquifer package between about 100 and 140 feet. Depending on the location and elevation, the lower aquifer thickness at the wellfield varies between 24 feet at Well No. 4, and 53 feet at Well No. 1. Each of the production wells are installed within this lower sand and gravel aquifer. The illustration in Cross-Section A-A' in Figure 2-4 shows the typical drift profile at Well No. 2. This figure implies that the "bulk" aquifer rapidly thins north of the Creek, and grades to a highly laminated package of thin and discontinuous sandy layers in the north part of the Basin. Cross-Section B-B' in Figure 2-5 reveals that much of the aquifer utilized by the production wells lies mainly along the lower elevations. If this were a reasonable geologic model, then the bulk of the aquifer utilized by the City lies along and near the lower elevations of the Wolf Creek, and depends significantly on the Wolf Creek and its connection with the wellfield aquifer to dampen aquifer drawdowns caused by the production wells.

2.2 GROUND WATER PUMPING LEVEL RECORDS ANALYSIS

Over the history of the operation of the wellfield, the months of highest groundwater production typically occur between March and September, or about seven months of higher groundwater production. The production year of 2018, however, is shown below to illustrate the effects this pumping schedule has on pumping water levels when the aquifer was not allowed its typical winter month rest period.

Figure 2-6 shows the pumping water levels at each production well for the year 2018 to the present. The overall production rate is shown as an overlay on the plot. This snapshot of water levels and production rates depicts when wellfield production was considered extraordinary during the months when Lake Adrian water quality was very poor and difficult to treat. In this case, most of 2018 experienced poor Lake water quality causing the City to rely more heavily on groundwater throughout 2018.

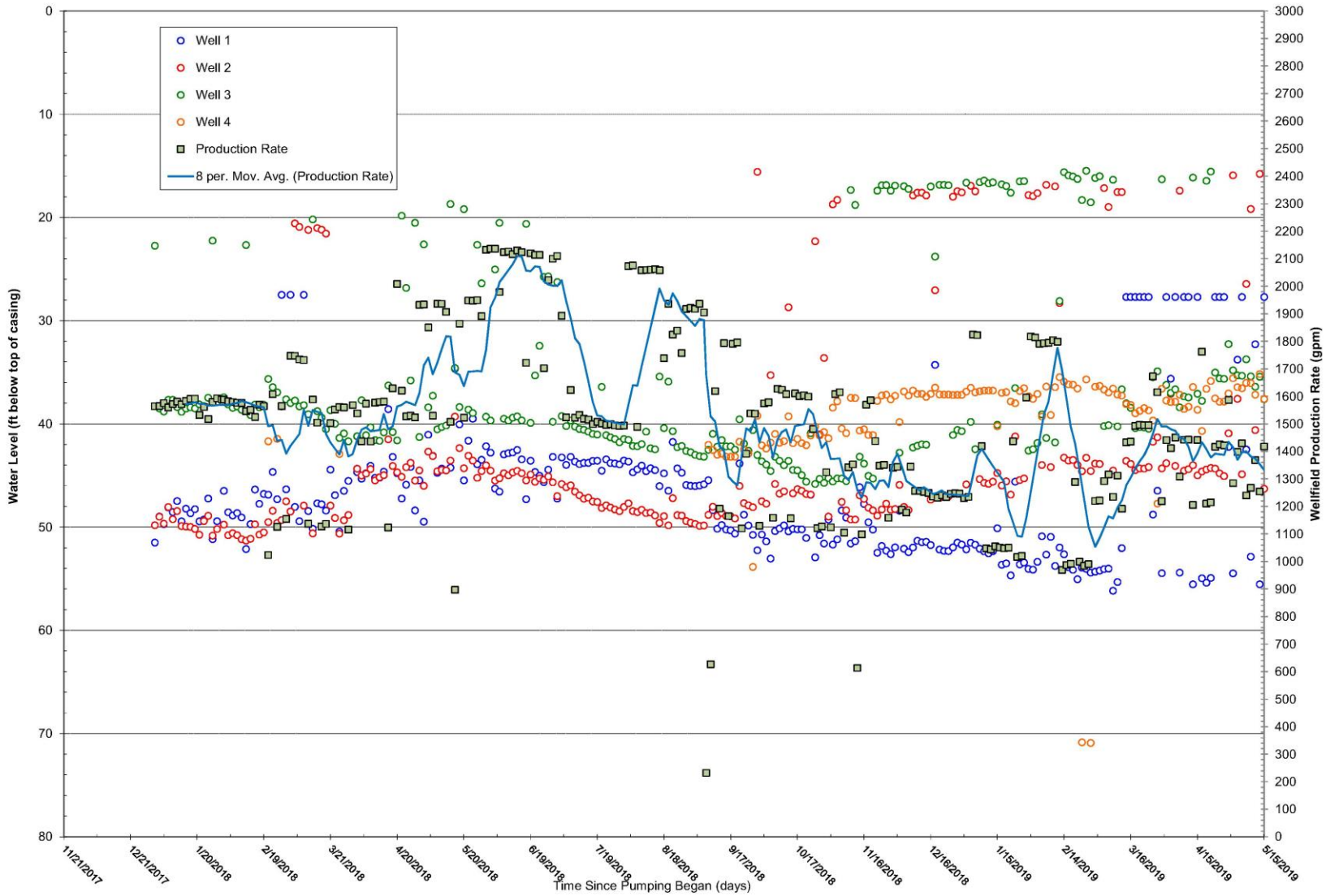

Figure 2-6 - Pumping Water Levels

Empirically, it can be seen that as overall production increased in early March to about 2.5 to 3 MGD, the overall aquifer water levels lowered between 10 and 15 feet over the course of this higher pumping period. This is observed approximately between the months of March and September of 2018 (this pattern can be observed in prior years, however, with less stress on the aquifer). Fundamentally, as aquifer production was reduced to about 2 MGD or less, the aquifer water levels began to recover through February 2019. This pattern has been consistent throughout the history of operating the wellfield.

Therefore, on an empirical basis, which is based upon many years of water level observation, **the average withdrawal rate of 2.5 to 3.0 MGD is considered excessive** unless this withdrawal rate is short in duration; to be conservative, this period of high withdrawal should not exceed 60 days in duration. **The normal operating withdrawal rate, however, should be generally maintained at or less than 2.0 MGD.** A winter rest period of 1.0 to 1.5 MGD should be allowed to accommodate a reasonable recharge period.

Although this production schedule is based on many years of water level and production observation, there are several factors that can affect the operation of the wellfield. These are as follows;

1. **Precipitation and climate**. Annual precipitation and climatic conditions during the winter months will affect the normal recharge rates into the groundwater basin. A warmer, wet winter will likely enhance recharge rates throughout the Basin, while extended dry periods will have a negative effect on recharge rates. The recharge rates into the Basin are observed only over long periods of time; for example, the effects of a wet winter recharge period may not be seen until later in the year. This factor is difficult to gauge and cannot be easily used to manage the operation of the wellfield. Instead, it is best to operate the wellfield conservatively and appreciate the years of extraordinary recharge for its corresponding gain.
2. **Well and pump performance**. Over time, mineral precipitation (mainly calcium) will accumulate along the well screen openings and affectively reduce the entrance area of the screened interval which reduces the pumping performance of the well (this is normal). As the screen becomes more “plugged”, the pumping water levels in the well are lowered, causing greater head on the pump and consequently, lowering the pump discharge. The time frame this occurs is gradual and highly variable, and depends largely on groundwater quality and the duration of pumping. Generally, a well that is pumped continuously will likely exhibit this characteristic quicker than a well that is pumped only a few hours per day. Since the City Production wells are typically operated on a continual basis throughout a typical week, a greater emphasis should be placed on monitoring the performance of each production well through regular well performance testing. The gradual wear on the pump impellors will have a similar effect on pump discharge. Again, regular testing record keeping of pump and well performance will alert to either well or pump performance changes.
3. **Alternative equipment to control pumpage**. The use of variable frequency drives can modulate individual well production rates more effectively than traditional “across the line” starting and stopping of the pump motors. This is because the frequency of each motor can be adjusted to change the speed of the motor, and thus, changing the pumping rate of the well pump. The use of variable frequency drives for the pump motors can control the production rates of each well, which can be used to balance the production between any of the four wells. The City is in the process of adding variable frequency drives to the well field.

2.3 ALTERNATIVE PUMPING STRATEGIES

The ability to operate well pumps on a regular schedule is largely dependent on the operation of the treatment plant. In an ideal case, the wellfield would operate wells on an “off and on” pattern; pumps would be turned on for a certain period of time, then turned off for the same period of time. The duration of pumping time can be hours, days or several months, but the recovery time (all pumps off) would automatically be the same amount of time. In this way, pumpage and recharge would be balanced, and ideally the aquifer would fully recovery after each operating cycle.

Since the treatment plant operations depends on a regular flow of water from either source, a regular pumping strategy can consist of 1.5 to 2.0 MGD during the summer months (with short peak periods of production), followed by a winter production rate of 1.0 MGD to 1.5 MGD. During the winter production schedule, all wells would be rotated and operated in the lead position one at a time.

3.0 TASTE AND ODOR CONTROL TECHNIQUES

The techniques available to the City for the control of taste and odor broadly fit into three categories: source optimization, source treatment, and treatment options within the WTP. Source optimization involves managing and understanding the ground water supply to reduce the reliance on surface water during taste and odor outbreaks. Source treatments are methods that the City can implement to reduce the prevalence of taste and odor compounds in the surface water prior to entering the WTP. Treatment options within the WTP include chemical and physical processes that can be incorporated into the existing WTP process train to remove taste and odor.

The projected construction costs of the alternatives should be considered as order of magnitude references for information and comparison purposes only. The projected construction costs must be further refined as the work proceeds.

3.1 SOURCE OPTIMIZATION

3.1.1 Seasonal Management of Supplies

Ground water is relatively inert and free of taste- and odor-causing compounds. Thus the City has been absent of most complaints since the well field went on line. As described in the previous section, the City will need to limit its use of the aquifer or risk drawing down the aquifer which would prevent it being available in a subsequent season. As suggested in the previous section, the City should consider withdrawing at a rate of 1 to 1.5 mgd in the winter and 1.5 to 2 mgd in the summer. As Lake Adrian water should have low concentrations of MIB and geosmin in the winter, it makes sense to use more surface water in winter months.

3.1.2 Increasing the Ground Water Supply

The City has a long history of investigating for new water supplies and being unable to locate one with ample yield to serve as a municipal supply. Williams & Works does not see much value in random drilling and testing of wells as each test may cost $25,000 or more. However, as potential aquifer locations may be discovered through residential or industrial well drilling, the City should consider conducting testing of these candidate sites.

3.2 SOURCE TREATMENT

Source treatment involves treating the surface water source to reduce or prevent algal growth to reduce the concentrations of taste and odor compounds in the water prior to entering the WTP.

3.2.1 Copper Sulfate

Soluble copper, especially the cupric ion, is toxic to algae at varying concentrations and acts to inhibit photosynthesis, cell division and nitrogen fixation. The solubility and speciation of the copper added to the water body is controlled by the pH, alkalinity and total organic carbon content of the water. Waters that are more acidic tend to favor copper solubility as compared to more alkaline waters from which the copper is rapidly lost from the water column. In alkaline waters a higher dose is required to provide the same level of effectiveness as more acidic waters. The various species of algae have different sensitivities to copper concentrations with the blue-green algae Anabaena being relatively sensitive and Chlorella, a small, unicellular green algae, being very resistant to copper treatment. Therefore, to determine the dose and most effective type of copper to apply for algae control some knowledge of the water quality and the type of algae to be controlled is required.

Soluble copper added to a water body in the form of copper sulfate or chelated copper has historically been one of the most widely used for algae control in surface water bodies. Copper is applied in the form of fine copper

sulfate pentahydrate crystals to the surface to control phytoplankton in waters with suspended growths of algae in the water column. The copper sulfate crystals can be applied by boat using mechanical spreaders or sprayers or by helicopter for larger treatment areas. Copper sulfate or chelated copper can be added to the water entering the lake, however, this approach may be less successful due to precipitation of the applied copper and therefore, it is unable to increase concentrations sufficiently for control throughout the entire water body.

Copper is also applied as copper sulfate chelated with citrate or ethanolamine which allows the copper to stay in solution longer in alkaline waters. Blue-green algae which are of interest because of their ability to produce geosmin and MIB are reportedly able to be controlled with a copper dose of 1.0 mg/L. Copper sulfate can also be applied in the form of larger crystals which sink to the bottom to control periphyton algae (algae attached to aqatic plants). One algae species, Oscillatoria, is known to produce MIB and can be controlled in this manner. Generally, higher doses are required for periphyton control because portions of the copper dissolve and are released into the water column as they sink to the bottom.

The application of chemicals for the control on nuisance plants and algae in Michigan is regulated under Part 31, Water Resource Protection, and Part 33, Aquatic Nuisance Control, of the Natural Resources and Environmental Protection Act, 1994. The regulations require that written permission be obtained from the MDEQ (now referred to as the Michigan Department of Environment, Great Lakes, and Energy or EGLE) prior to chemical treatment. The regulations are administered by the Water Resources Division of the MDEQ in the Aquatic Nuisance Control section. The Department has published a table which lists the herbicides permitted for algae control and both copper sulfate and chelated copper are listed for control of filamentous, macro and planktonic algae. The Department has also published a list of approved chemicals for algae control and the maximum application rates. Copper concentration is also regulated under the Safe Drinking Water Act in drinking water with a secondary maximum contaminant level (MCL) of 1.0 mg/L. Therefore, copper could not be applied to the lake in a manner that would cause the copper concentration in the finished water to exceed the secondary MCL. However, precipitation of the copper applied and blending with ground water would allow higher concentrations than the secondary MCL to be applied without violating the secondary MCL.

The use of copper for algae control has the advantages that is relatively easy to handle and apply, is relatively economical, is readily available, permission can be obtained for application and it is effective when the right form and dose are applied. One significant disadvantage of the use of copper for algae control is that the effects are usually short term since the copper concentration in the water column will decrease over time due to precipitation, especially in alkaline waters; absorption by the sediments; water withdrawals from the lake and flow out of the lake over the outlet control structure. There are a number of other potential disadvantages which are briefly described in the following. Higher copper concentrations in the water can be detrimental to other life forms which are beneficial to the lake ecosystem including zooplankton which feed on the algae and various freshwater fish and their fry. When heavy algae blooms are controlled with copper addition the dead algae cells can cause rapid decrease in the dissolved oxygen level in the lake and the dying algae cells, depending upon the species, can cause an accelerated release of odor causing compounds and toxins into the water column. Some studies have noted that continuous feeding of copper compounds can cause certain algae species to become resistant to copper treatment and require higher concentrations for control. Prolonged use of copper can also lead to build up of high concentrations of copper in the sediments which can be rereleased into the water column if the water body becomes more acidic.

The water surface of Lake Adrian is approximately 85 acres and the average depth appears to be around 8 feet so that total volume is approximately 680 acre feet. According to the MDEQ table copper sulfate is approved for application to control planktonic/filamentous algae at a maximum application rate of 2.6 pounds per acre-foot. Therefore, up to 1768 pounds of copper sulfate would be required for a complete application to the entire lake. The retail price for copper sulfate fine crystals was around $2.1 per pound so that the chemical cost for a treatment of the entire lake would be approximately $3,700 per application. Copper sulfate would need to applied three to four times per season with an estimated cost of $24,000 including chemicals, labor and boat rental.

3.2.2 Sonic Wave Generator

A relatively new technique that has been applied to ponds and lakes to control algae growth is the use of sonic wave generators. For control of blue-green algae the sonic wave generator is operated at a frequency that causes the air vacuoles within the algae cells to collapse and the algae cells settle to the bottom where there is insufficient light penetration to sustain their growth and multiplication. Although Lake Adrian is relatively shallow, the manufacturer indicates that the units can function where the depth is greater than 6 feet. The 1941 bathymetric map of the lake prepared by the Michigan Department of Natural Resources indicates that most of the lake is 8 feet or greater depth. The sonic frequency that is applied does not lyse the cells and cause the intracellular contents to be released. Ideally, the units are deployed and operated year-round or prior to and during the period of the year in which algae growth is most prolific. Equipment has been manufactured and installed for this purpose, including the use in potable water reservoirs, by LG Sonics.

The LG Sonics product is the MPC-Buoy. The buoy consists of the sonic wave transmitter and is solar powered. Installation requires that the buoy be anchored into place in strategic locations to provide coverage of the pond or lake being treated. Each unit has a maximum effective radius of 1600 feet and can therefore, treat an area up to 185 acres depending upon the geometry of the water body and the type of algae that is being controlled. The MPC-Buoy Pro unit also comes with a water quality sensor package that monitors the water body quality every 10 minutes for pH, temperature, dissolved oxygen, redox potential, chlorophyll a, phycocyanin and turbidity. These measurements are used to control the sonic wave transmitter and adjust the frequency in response to changes in the types of algae present. There is also web-based software that can be used to receive the water quality data in real time and display it in charts, tables and spreadsheets so that the operator can continuously be apprised of the water quality within the water body and apprised of any changes that occur.

LG Sonics was contacted to provide a proposed system design for Lake Adrian and a budgetary cost estimate. The proposed system for Lake Adrian would consist of four buoy units placed in the locations shown in Appendix A. The projected total cost to design and install this equipment is $300,000. The budget for a single unit is approximately $80,000. Since the units are solar powered no external source of power is required and the monitoring equipment operates without reagents. The installation consists of anchoring the units in place and the operation and maintenance would only be what is required to maintain the monitoring equipment. The buoys could be removed, cleaned and stored in the winter time if algae growth was at a minimum to maximize the unit life. If the units were effective in preventing algae growth in Lake Adrian as indicated in the manufacturer's literature, this would be a low operating cost, environmentally friendly approach to reducing the taste and odor concentration in the raw water. Even if the system was not totally effective there would be a benefit to receiving the monitoring data to gage the status of the lake and prepare for changes in water quality.

3.2.3 Bank Filtration

Bank filtration uses the natural soils along the perimeter and bottom of a water body to act as a filter to remove suspended solids, organics, metals and other contaminants from the water. The soil materials remove suspended solids by physical straining and impingement of particles of greater size than the effective pore size of the native soils. Heavy metals are removed by complexing with organic material in the soil which is negatively charged and attracts the positively charge metal ions. Organic compounds are removed by biological activity of naturally occurring microbes within the soil. These microbes are often aerobic or facultative which means this activity takes place at shallow depths or deeper depths when oxygen is present. Sometimes the bank filtration system must undergo alternate withdrawal and resting cycles to achieve a significant level of organic compound removal. Lower levels of filtration are achieved when the soils are primarily large granular materials but the yields are higher as opposed to soils that have high concentrations of fines, clays and organics which result in lower yields but more effective filtration.

Location of collector wells or infiltration galleries along the edges of Lake Adrian offers the advantage of the lake providing a constant source of recharge due to the large upstream water capture area as opposed to the existing

groundwater wells whose yield is limited by recharge within the immediate well field area. In this study, bank filtration would primarily benefit the reduction of tastes and odors by removing the algae cells from the raw water stream. Therefore, they would not be present in the raw water and could not be broken down by the chemical and physical processes used in the water treatment process causing the cells to lyse and release taste and odor compounds. Unless the system could be specifically designed to achieve a high level of organic compound removal or destruction, some concentration taste and odor compounds would still be present in the raw water if they were present in the lake.

The Microbial Toolbox that was developed as part of the promulgation of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) provides a 0.5 log Cryptosporidium removal credit for bank filtration. The rule provides a 0.5 log reduction credit if the wells are located at least 25 feet from the water surface and a 1.0 log reduction credit if the wells are located at least 50 feet from the water surface. This indicates that the wells can be located close to the water body and achieve some level of removal of *Cryptosporidium* oocysts which are 4 to 10 µm in size. Cyanobacteria (blue-green algae) which are primarily associated with producing taste and odor causing compounds range from 1 µm in size for unicellular types up to 30 µm for multicellular types. Since some of these organisms are smaller in size a longer flow path, > 50 feet, may be required to achieve similar levels of removal based upon removal of *Cryptosporidium* oocysts.

A bank filtration system could be constructed using either a radial collector well (Ranney well) or a horizontal infiltration gallery. The radial collector well consists of a cast-in-place reinforced concrete caisson, at least 12 feet in diameter, which is constructed to a depth of 50 feet or greater. Up to 16 horizontal collectors are jacked or driven into the aquifer from the central caisson radially ranging in length from 100 to 300 feet. A pump house is constructed at the surface which is used to pump water from the caisson. Infiltration galleries which are typically used to collect water percolating thru the soil from above can also be used as a means of bank filtration, although the LT2ESWTR does not recognize them as eligible to receive log removal credits for Cryptosporidium removal due to the short path between the surface and the infiltration gallery. The system would be designed to use horizontal slotted or perforated collector pipes that would be constructed parallel to the bank of the lake by constructing a trench and installing the collector pipes. Concrete wet wells would be placed at intervals along the collector pipe form which the water collected could be pumped to the treatment plant. These collector pipes would generally be constructed at a depth of 10 to 25 feet below land surface depending upon the soil conditions and type of equipment used for installation. The radial collector wells have the advantage of a smaller foot print required on the surface and a higher yield due to the deeper depth and higher gradient versus the infiltration galleries which require more property to be disturbed and have a lower yield due to the lower groundwater gradient between the lake surface and the pumping level in the wet wells. The costs of these systems would be primarily dependent upon the depth of the collectors and the length of the collectors.

The flow into the horizontal well can be estimated using the formula for a shallow unconfined well modified for linear flow per foot instead of radial flow from the circumference of the well. The basic equation is:

$$Q = K/2\ (H^2 - H_1^2)\ /\ \ln(R_H/R_1)$$

where:

H_2 = the level of the water above the impermeable layer at the lake at distance H, feet

H_1 = the elevation of the water table above the impermeable layer at distance R1, feet

K = the hydraulic conductivity, feet/day

R_H = distance from the well to the water table at H, feet

R_1 = distance from the well to the water table at H_1, feet

The elevation of the impermeable layer was set equal to the maximum depth of the lake, 25 feet. The horizontal well was assumed to be located 8 feet below the lake surface and the drawdown 1 foot away from the well was

assumed to be one half foot above the well. Flow from the landward side of the well was neglected. The best way to determine the hydraulic conductivity would be to install some test collector sections since the materials around the lake may contain silty sands to silty clays with varying amounts of organic materials built up on the bottom. If we assume that a reasonable range of hydraulic conductivity for the most restrictive soils is between 0.1 and 1.0 ft/day and the collector pipes would be placed 50 to 100 hundred feet from the water's edge, an estimate of the flow per unit collector pipe can be calculated. Table 3-1 below summarizes the results of the calculations using the range of hydraulic conductivity and the distance between the lake and collector pipes described above.

Table 3-1 - Flow Per Unit Collector Pipe Estimate

Scenario	Hydraulic Conductivity, ft/day	Distance to Collector, ft	Unit Flow to Collector, gpdx100/linear foot
1	0.1	50	3,700
2	1.0	50	37,000
3	0.1	100	3,100
4	1.0	100	31,000

The initial calculations summarized above based upon the assumed hydraulic conductivity of the soils adjacent to and underlying the lake indicates that it would take 1 mile to 10 miles of horizontal well to be able to capture up to 2 MGD of surface water from the lake. The actual length required would need to be verified based upon site specific testing to determine the hydraulic conductivity of the soils adjacent to the lake. At the lower hydraulic conductivity this is not considered to be feasible because it would be difficult to obtain access and the necessary property rights to construct a ten mile well around the lake. If the hydraulic conductivity was closer to the high end of the range and the flow could be obtained from approximately one mile of linear well field, the total cost to design, install, and integrate this system would be approximately $1,500,000. This represents the low end of the cost of this method and the actual cost could be much higher. This cost does not include the costs for design, interconnecting raw water piping, raw water pumps, site preparation or property acquisition. Significant additional investigation would be needed to vet this option.

3.2.4 Alum

A technique that has been successfully used in many lake restoration and lake maintenance programs is the treatment of the water column with a liquid alum solution (aluminum sulfate). The alum works in a very similar manner to the mechanism used in conventional surface water treatment in that an aluminum hydroxide floc is formed which attracts suspended solids in the water column, including algae, to create large floc particles which are heavier that water and settle to the bottom. Alum treatment is used in wastewater treatment applications to remove phosphorus from the effluent when the aluminum ions combine with orthophosphate ions in the water column to form an insoluble precipitate that settles to the bottom. Following alum treatment, the suspended solids, algae, and dissolved phosphorus has been removed from the water column and the precipitated alum floc tends to seal the bottom preventing release of phosphorus from the organic portion of the sediments. Adding alum to water causes the pH to be lowered and if there is not sufficient alkalinity in the lake, additional alkalinity might need to be added to control the pH within an acceptable range for aquatic life and alum flow precipitation. The alum is usually applied as a liquid solution from a boat using a sprayer to distribute the chemical over the area being treated.

Increased levels of phosphorus that can be contributed by runoff, fertilizers, wastewater discharges, septic tanks and other activities in the upstream watershed lead to increasing levels of eutrophication of the downstream water bodies and algae blooms, especially those water bodies that are slow moving and impounded. Phosphorus concentration is especially important because it is often the limiting nutrient required for algae and plant growth. Alum treatment can remove most of the dissolved phosphorus from the water column which will bring about an improvement in water quality and a distinct reduction in algae growth. After treatment the water column will be clear and the algae will be removed with the alum floc and settled on the bottom. This type of treatment may not prevent the release of intercellular byproducts that contribute to taste and odor in the raw water and could lead to a short-term spike or a longer term slightly elevated level of taste and odor compounds as the algae cells decompose and are broken down by parasitic bacteria. This could be especially true if the alum was applied to the lake when it was undergoing a heavy algae bloom.

The length of time that this technique would yield effective results to control the algae population is not known. To answer this question an investigation of the nutrient loading to the lake from the upstream tributaries and the lake surroundings would have to be undertaken. The rate of nutrient uptake within the lake and the flow rate and nutrient load leaving the lake would have to be understood. Finally, the rate of decomposition of organic matter from microorganisms, plants and animals remaining within the lake and removed by alum treatment which will release phosphorus upon their death and decomposition leading to nutrient cycling and further growth would also need to be understood. If the nutrient loading to the lake is high, alum treatment might be required to be performed once per year or more frequently to be totally effective. Costs of implementing this alternative cannot be determined without a more detailed knowledge of the chemistry of the lake and until jar testing is performed.

3.3 TREATMENT OPTIONS

The following is a review of the processes that were evaluated as potential alternatives to reduce geosmin and MIB down to generally acceptable levels. As these compounds are not present in the groundwater, we recommend treating the surface water source separately. This will provide an opportunity to most efficiently and cost effectively remove these compounds.

Historical data in Figure 1-1 suggests that the maximum daily demand for surface water at the WTP is less than or equal to 2 MGD. Consequently, the baseline flow used to evaluate equipment cost for each alternative was 2 MGD. The average flow of surface water treated is approximately 0.5 MGD. Due to the existing uncertainties in sustainable ground water yields, an average flow rate of 1 MGD was selected for estimating operating costs. Options to treat combined flow of groundwater and surface water would be sized to treat at least 5 MGD and an average daily demand of 3.6 MGD.

3.3.1 Oxidation

3.3.1.1 Ozone

Ozone oxidation (ozonation) is typically accomplished by diffusing on-site generated ozone (O3) into the water to obtain a desired ozone dose. In water, ozone oxidation occurs through two dominant mechanisms—direct oxidation by ozone and indirect oxidation by hydroxyl free radicals formed by the reaction between ozone and hydroxide ions. The decay of these hydroxyl radicals is pH dependent; therefore, pH is a key parameter in determining the concentration of ozone and hydroxyl radicals and the oxidations rates. Additionally, hydroxyl radicals react with target compounds or are consumed by bicarbonate and carbonate alkalinity.

The major process components of ozone systems include a gas feed system, an ozone generator, cooling water supply, an ozone contactor, and an off-gas destruction system.

The gas feed system provides a clean, dry source of oxygen to the generator. Gas feed systems typically consist of liquid oxygen-based systems. The liquid oxygen feed system components include: a storage tank, an

evaporator to convert the liquid to a gas, filters to remove impurities, and pressure regulators to limit the gas pressure to the ozone generators. Liquid oxygen feed systems are simpler and less capital and operationally intensive relative to atmospheric air-based systems.

Ozone generators convert the oxygen gas feed to ozone gas using electrodes through concentric tube cylinders or parallel plates. Cooling water is supplied to maintain generator efficiency. The generated ozone rich gas is applied to the process water to achieve adequate contact and reaction time for oxidation. Ozone application systems include fine bubble diffusers, injectors/static mixers and turbine mixers. Off gas destruction is required as ozone is toxic in the concentrations that may be present in the off-gas. Some systems also include a quench chamber to remove ozone residual in the ozonated water.

The common functions of ozonation are to provide primary disinfection, destroy color, taste, and odor causing constituents (including MIB and geosmin), enhance coagulation, increase biodegradability of organic compounds, reduce regulated DBP formation potential by direct oxidation of DBP precursors, and reduce chlorine demand. Ozonation has been shown to remove up to 90% and 95% of MIB and geosmin, respectively.

Process design considerations for ozone systems include the water flow rate, desired ozone dose, and contact time as dictated by removal efficiency requirements. The process flow and ozone dose are used to estimate the required ozone production in pounds per day (ppd). This required ozone production provides the basis for equipment sizing. The required ozone dose depends on the treatment application and site specific conditions. For geosmin and MIB destruction, an ozone dose of about 2.5 mg/L or greater is typically required. For iron oxidation, an ozone dose of 0.45 mg ozone per mg of iron is generally applied. The effectiveness of ozone oxidation is influenced by site-specific water quality, including temperature, pH, alkalinity, and concentration of reduced species (sulfide, iron, and manganese). Therefore, ozone dosing requirements should be evaluated through bench-scale and pilot-scale testing.

Ozone for destruction of taste and odor compounds would be most effective when applied to the raw surface water prior to other treatment processes. The ozone would destroy the taste and odor causing compounds, kill any algae in the raw water and break down larger organic molecules. The breakdown of the larger organic molecules has reduced the coagulant dose and increased the overall effectiveness of organics removal at other facilities. A 2 MGD system would be required to apply ozone to the raw water prior to treatment. Ozone is also applied prior to filtration to destroy taste and odor causing compounds and break down organics into more biologically assimilable compounds which can increase the effectiveness of biofiltration and produce a more biologically stable finished water. In order to apply ozone prior to filtration the settled water would have to be diverted to a new ozone contact chamber and a transfer pumping system provided to send the ozone treated water back to the filters. To treat the entire flow stream would require at least a 5 MGD ozone system.

Ozonation may result in a shift towards brominated DBPs and produce a significant quantity of regulated bromate (0.010 mg/L MCL) in waters with bromide concentrations greater than 50 µg/L.

Although ozone systems are complex, the process is highly automated and typically reliable. Back-up generator units are usually installed to help maintain reliability. However, there are many electro-mechanical components that must be regularly inspected to maintain system performance and reliability. Generator maintenance typically requires skilled technicians. If trained maintenance staff are not available at the plant, generator maintenance can be performed by the equipment manufacturer. Additional monitoring of bromate levels in the plant effluent will be required.

The ozonation process has high power requirements, which are a function of the required ozone output and system size. Generally, approximately 7 to 16 kWh per pound of ozone is required for the oxygen supply system, ozone generation, generator cooling, and ozone injection. Assuming a 3 mg/L ozone dose, the power consumption would be approximately 200 to 400 kWh/MGD. A 480 VAC power supply and low frequency (50 or 60 Hz) to medium frequency (60 to 1,000 Hz) generators are most commonly used in the water industry.

Projected construction costs for a completely redundant system capable of treating 2 MGD of surface water is $4.0 million. Constructing a similar 5 MGD system is projected to cost $5.0 million, which may be necessary in the event that the WTP elects to ozonate ground water as well as surface water to enhance biofiltration. These costs include construction, engineering, electrical work, piping, oxygen supply, ozone generation, generator cooling ozone injection, ozone destruction facilities, controls, and other ancillary system components. Due to high power requirements, electrical and operating costs are approximately $1.0 per pound of ozone produced. Achieving a 3 mg/L O_3 dose at an average of 1 MGD of surface water treatment, will require 25 lbs/day of ozone generation, resulting in annual operating costs of approximately $10,000. Operating costs can be reduced if the WTP operates ozonation seasonally or at a lower dose when taste and odor concentrations are low.

Ozonation has recently been added to the treatment process to address taste and odor concerns in Frenchtown, MI and Monroe, MI. Similar to Adrian, both utilities' source water had been adversely impacted by algal growth.

3.3.1.2 Advanced Oxidation

The term "advanced oxidation" applies to any process designed with the intent to increase the degree of free hydroxyl radical generation. Free hydroxyl radicals are powerful oxidants capable of effectively oxidizing taste and odor compounds, including geosmin and MIB. As discussed in Section 2.3.1.1, ozonation of natural waters typically does result in some formation of free hydroxyl radicals, and an advanced oxidation process (AOP) would enhance this free hydroxyl generation further.

A common approach to achieve advanced oxidation in drinking water is with the addition of hydrogen peroxide prior to ozonation. The process, costs, and equipment to generate ozone are discussed in Section 2.3.1.1. The hydrogen peroxide dosing system requires chemical storage tanks, chemical feed pumping, instrumentation, and piping. Refer to section 2.3.1.5 for more details on peroxide dosing. A typical dose is 0.5 mg/L H_2O_2, however, the effectiveness of the process is site specific and dosing requirements should be evaluated via bench and pilot scale testing. Well operated advanced oxidation systems have been found to achieve up to 99% removal of geosmin and MIB. More typical removal efficiencies via advanced oxidation are 90 to 95%.

The total construction cost for an advanced oxidation system treating 2 MGD at an ozone dose of 5 mg/L and hydrogen peroxide dose of 0.5 mg/L is approximately $4.2 million. This cost includes all necessary ozone and hydrogen peroxide feed equipment, interconnecting piping and valves, site work, equipment installation, and engineering and contractor fees. To treat an annual average of 1 MGD of surface water, will result in an operating cost of approximately $12,500.

3.3.1.3 Chlorine Dioxide

Chlorine dioxide is applied in drinking water treatment for disinfection, and oxidation to control tastes and odor, iron, manganese, hydrogen sulfide, and TTHM and HAA formation potential. While chlorine dioxide is effective at treating some odor causing compounds produced by algae, its effectiveness removing MIB and geosmin is limited. At a 3 mg/L dose, only up to 10% and 20% removal is achieved of MIB and geosmin, respectively. The upper limit of chlorine dioxide dosages is typically 2 mg/L which is governed by regulatory limits on the chloride dioxide residual and chlorite formation. Chlorine dioxide is also known to lyse cells which may cause the release of additional taste and odor causing compounds.

Chlorine dioxide will not provide an acceptable resolution to the WTPs taste and odor issue.

3.3.1.4 Permanganate

Permanganate is typically added to drinking water via a chemical feed pump and injection system. Permanganate solutions can be purchased or produced on site from permanganate salt crystals, and then stored in suitable chemical storage tanks.

Permanganate is an oxidant often applied to the influent of drinking water treatment plants to oxidize iron and manganese, oxidize taste and odor compounds, and oxidize precursors to DBPs. An additional benefit of permanganate addition is that it reduces disinfectant demand downstream. Permanganate is often fed at the intake of surface water treatments plants to kill algae, partially oxidize organics, improve organics removal and improve water quality. However, high doses of permanganate have been found to lyse cells which may cause the release of additional taste and odor compounds. Permanganate must also not be permitted to persist in the distribution system as it will lead to a noticeable pink color and the deposition of black particles. If necessary, excess permanganate can be removed with the addition of PAC.

Our review found that while permanganate is effective at removing some taste and odor compounds, it has limited effectiveness at removing geosmin and MIB. At a chemical feed rate of 0.8 mg/L, typical removal efficiencies are approximately 10 to 40% and 10 to 30% for geosmin and MIB, respectively. The WTP has an existing permanganate feed system and is planning to begin adding permanganate early in the algae season. A low dose of permanganate at the WTP may improve general water quality but will not likely on its own resolve the geosmin and MIB taste and odor issue. Further analysis is required to determine to what extent permanganate will remove geosmin and MIB at the WTP.

Permanganate is often purchased as a 20% liquid solution at a cost of approximately $1 per lb. At a feed rate of 0.8 mg/L, the annual cost to treat 1 MGD of surface water is approximately $13,000. Operating costs can be reduced if the WTP feeds permanganate seasonally or at a lower dose when taste and odor concentrations are low.

3.3.1.5 Hydrogen Peroxide

Hydrogen peroxide is typically added to drinking water via a chemical feed pump, dilution, and injection system. Concentrated peroxide solutions are readily available for purchase and can be stored in suitable chemical storage tanks. Depending on the hydrogen peroxide feed location, a process to quench the hydrogen peroxide may also be necessary. Quenching can be achieved using a simple chemical feed of sodium bisulfate or calcium bisulfate.

When hydrogen peroxide is used for drinking water treatment, it is often for the purpose of oxidizing iron and sulfides. Hydrogen peroxide is also fed prior to biofiltration in some systems to increase oxygen supply to the filters, the bioavailable carbon, and increase the filter run time. Hydrogen peroxide has also been shown to oxidize the taste and odor compounds geosmin and MIB. When dosed in isolation at 1.0 mg/L, typical removal efficiencies can range between 30% to 70%. Hydrogen peroxide can also be used in combination with ozone to achieve up to 99% removal of geosmin and MIB via advanced oxidation. Refer to Section 2.3.1.2 for more detail on advanced oxidation.

The hydrogen peroxide could be fed to the surface water stream before it entered the treatment plant to kill algae and oxidize the taste and odor causing compounds in the raw water. Alternately, the peroxide could be fed as part of an advanced oxidation system upstream of the application of ozone. Both of these alternatives would require a 2 MGD system to treat the raw surface water. Hydrogen peroxide could also be fed upstream of the filters to oxidize organics and taste and odor compounds remaining after conventional treatment and to help maintain a downstream biologically active filtration system. In this case a 5 MGD peroxide system would be required unless the surface and groundwater flows could be directed into separate sets of filters.

The projected cost to construct a complete hydrogen peroxide feed system treating a 2 MGD flow is $80,000. This includes the cost of additional piping and valves, site work, equipment installation, and engineering and contractor fees. A 50% hydrogen peroxide solution costs approximately $3/gallon. The WTP will require 700 gallons per year to treat an annual average of 1 MGD surface water at a dose of 1 mg/L, resulting in an annual chemical cost of $2,500.

3.3.2 Adsorption

3.3.2.1 PAC

Powdered activated carbon (PAC) is a treatment additive that encourages dissolved compounds to adhere to the exterior of the carbon particles. These particles can then be settled out in downstream processes. PAC adsorption systems consist of a PAC feed mechanism, slurry mixing, a contact chamber, and subsequent separation. The WTP has an existing PAC feed system. The existing system follows a common approach which efficiently achieves PAC contact time by feeding the PAC upstream of the rapid mix, flocculation, and settling process. PAC media is manufactured from natural, carbonaceous materials, such as coal, peat, and coconuts by various high temperature processes.

The addition of PAC and subsequent separation via clarifiers naturally leads to an increase in the quantity of sludge that must be handled by the WTP. The PAC must either be disposed of similar to the other generated sludge or separated and regenerated.

PAC adsorption is used to remove a wide assortment of dissolved contaminants. These contaminants include geosmin, MIB, but also include other taste and odor causing compounds, synthetic organic chemicals, color forming organics, and other natural organic matter. Studies suggest PAC is capable of achieving between 60% to 97% and 50% to 90% for MIB and geosmin, respectively. Jar tests have been conducted for the WTP which suggest that the WPH1000 PAC from Calgon Carbon at a dose of 25 mg/L will achieve 97% removal of MIB with a 4-hour contact time. The same study found that PAC doses of 5 and 10 mg/L would achieve 55% and 80% removal, respectively, when treating a water with an MIB concentration of approximately 650 ng/L.

The PAC testing was performed on a blend of 20% surface water and 80% groundwater which would simulate the addition of PAC to the combined flow stream. The PAC could be applied at various points in the treatment process where sufficient contact time could be achieved with the PAC to create the required removal. The PAC could also be applied to the surface water stream as it enters the treatment plant which would reduce the flow being treated. The required doses might be somewhat different than the bench scale testing because of the higher concentration of organics in the surface water. Application of the PAC to the surface water stream will also remove organics and may reduce the required coagulant dose. It also possible that the PAC could be added after the initial settling process prior to the flocculators or another location downstream in the treatment process where lower concentrations of organic compounds might reduce the dose or make it more effective. This should be tested to determine the most effective and least costly location for PAC addition.

Given that the WTP already features a functional PAC dosing system, the capital cost is negligible at low PAC doses. If the WTP pursues greater than 90% removal of geosmin and MIB then there may need to be additional capital improvements to achieve the elevated PAC doses required. Assuming a cost of $1.50 per lb of PAC, the annual cost of using PAC to treat an annual average of 1 MGD of surface water is approximately $112,500 at the highest tested dose of 25 mg/L.

3.3.2.2 GAC

Granular activated carbon (GAC) adsorption systems consist of either pressure vessels or open gravity contact tanks, which hold a prescribed quantity of GAC media. GAC media is manufactured from natural, carbonaceous materials, such as coal, peat, and coconuts by various high temperature processes. A GAC adsorption system is operated similar to how the eight existing sand filters at the WTP are operated. The process water to be treated flows through the GAC media generally in a downward direction to promote the removal of dissolved species by chemical and physical adsorption onto active carbon sites.

The GAC contactor vessels or tanks are equipped with a media support system that allows the carbon bed to be backwashed. Piping and valves are provided for the isolation of the process units, backwash supply, and spent

backwash collection. Support facilities include a source of clean water for backwash, backwash pumps and controls, and facilities to handle and recycle or dispose of the spent backwash water.

GAC adsorption is used to remove dissolved compounds, typically from water with low suspended solids. These compounds include geosmin, MIB, other taste and odor causing compounds, synthetic organic chemicals, color forming organics, and other natural organic matter.

Pressure vessel-type contactors are supplied by a number of manufacturers, including Calgon Carbon Corporation, Evoqua, Norit, Tonka Water, and WesTech. Gravity-type contactors can be designed by a consulting engineer and constructed by a specialty or general contractor. To reuse existing infrastructure, replacing the existing media in the filters at the WTP with GAC may be a viable alternative to achieving GAC adsorption. Further evaluation is required to ensure GAC filtration meets existing surface water treatment permit requirements. As an alternative to complete replacement of the filter media, the anthracite coal layer of the filters could be replaced by GAC. The GAC media is supplied by several entities including Calgon Carbon Corporation, Ingevity, Cabot Corporation, and Evoqua.

GAC adsorption systems are typically designed based upon the empty bed contact time (EBCT) and the hydraulic loading rate. The EBCT is the retention time in the contactor when the media is absent and determines the volume of activated carbon that the contactor will hold. Typical values for the removal of taste and odor compounds are 5 to 30 minutes. The surface loading rate determines the depth of the bed after the EBCT has been determined. Surface loading rates of 2.0 to 8.0 gpm/square foot are typically applied. Vessels can be arranged in series to achieve lower surface loading rates and greater bed depth where higher removal efficiency is required. A four- to six-month pilot testing program is recommended to select the design parameters due to variations in performance between different types of carbon, competing adsorbates in the water, and optimization of bed change out frequency.

Many studies have investigated and demonstrated the effectiveness of using GAC for removing geosmin and MIB. In some cases, GAC adsorption has been shown to achieve complete removal of geosmin and MIB with sufficient EBCT, but more typical sustained removal efficiencies of these compounds are between 50% to 90%. Treatment effectiveness also typically decreases over time. The rate of decay generally depends upon the concentration of competing substances in the water and the EBCT. Higher EBCT tends to provide a longer runtime before breakthrough occurs, at the expense of larger contactors and volumes of carbon. Multiple vessels with staggered carbon change outs can provide steady removal rates. The WTP's existing filters would have an empty bed contact time of 16.6 minutes at flows of 1 MGD per filter. If the WTP elects to replace only the anthracite coal layer with GAC, the GAC EBCT would then be 4.8 minutes at 1 MGD.

The presence of other organic compounds having a higher affinity than geosmin and MIB will result in competition for adsorption sites. This will lower the removal of geosmin and MIB and will use up adsorption sites, causing an increase in the carbon change out frequency. Chlorine and other oxidants in the water will tend to degrade the activated carbon by breaking it down via oxidation.

GAC which is operated in the absorption, not the biological mode, is normally placed downstream of filtration as a polishing step after the majority of the contaminants have been removed. This achieves the longest life of the carbon between change outs. The GAC can also be placed as part of the filtration step by replacing the upper filter layer of anthracite with GAC as opposed to placing it in separate contactors. The disadvantage is that the filter cells are generally not designed for frequent media change out making this task more labor intensive. The GAC could most cost effectively be applied at Adrian if the flows could be segregated and the carbon only applied to the filtered surface water. Although the GAC contactors could be used to treat the raw surface water in the absorption mode, the frequency of the carbon change outs would make this cost prohibitive versus operating in the biologically active mode.

Operating requirements for the system are generally low and include monitoring of the contactor effluent concentration, periodic backwashing of the contactors to remove solids and prevent compaction and carbon replacement.

When geosmin and MIB levels start to elevate in the filter effluent, the GAC media can be removed from the contactors and replaced with fresh or regenerated carbon. The carbon change-out frequency when operating the system via adsorption (instead of via biological removal discussed in 2.3.2.3) may vary between 30 and 120 days depending on the geosmin, MIB, TOC, and other adsorbable constituent concentrations in the untreated water, target geosmin and MIB concentrations in the treated water, and system design. Typical carbon consumption rates for the adsorptive removal of MIB have been found to be in the range of 0.3 to 1.0 lbs GAC per 1000 gallons of water treated.

Chemicals are not required for normal operation of this system. A caustic soak and rinse may be required after extended shutdowns (greater than 2 to 3 weeks) to eliminate excess biological growth prior to start-up.

Residuals generated by the process include the spent carbon that must either be disposed of or regenerated and the spent backwash water that must be disposed of or treated to recycle the flow. Carbon suppliers offer turnkey carbon change-out services, which include carbon removal and disposal via reactivation and delivery and installation of fresh or reactivated carbon.

The projected total cost to construct a 2 MGD carbon contactor system consisting of three (3) 1.0 MGD pressure vessels and 120,000 pounds of total carbon is $1,600,000. Carbon change-out services by the supplier are about $1.25/lb ($50,000 per 40,000 lb vessel) for removal and replacement with reactivated carbon and about $1.70/lb ($68,000 per 40,000 lb vessel) for removal and replacement with fresh carbon. Using the typical carbon consumption rates for MIB removal of 0.3 to 1.0 lbs GAC per 1,000 gallons of water treated, the carbon replacement cost to treat an annual average of 1 MGD of surface water is approximately $190,000 to $620,000 per year.

3.3.2.3 Biofiltration

Biofiltration applications consist of operating granular media filters to promote the attachment and growth of a biofilm. Biofilms can support a wide variety of microbial groups, but generally form in the same sequential manner: deposition and adsorption of organic molecules to form a “conditioning film”, adsorption of microorganisms on the film, secretion of extracellular polymeric substances (EPS) to fortify the film, and growth of microorganisms.

Biofiltration can be applied as conventional open, gravity filters or within pressure vessels, such as the same applied for GAC adsorption. The process water is filtered through biologically active granular media in a down-flow configuration. Similar to GAC systems, the biofiltration vessels or tanks are equipped with a media support system that allows the media bed to be backwashed.

Biofiltration can be applied to remove taste and odor caused by geosmin and MIB, biodegradable natural organic matter, ammonia, nitrate, iron, and manganese.

Pressurized biofiltration equipment is the same as the vessel-type contactors used for GAC adsorption and is supplied by the same manufacturers, including Calgon Carbon Corporation, Evoqua, Norit, Tonka Water, and WesTech. These manufacturers supply the process equipment for biofiltration, but do not typically market equipment as a biofiltration system. Gravity type contactors can be designed by a consulting engineer and constructed by a specialty or general contractor. The anthracite and GAC media is supplied by several entities including Calgon Carbon Corporation, Ingevity, Cabot Corporation, Evoqua, and Northern Filter Media. The existing sand filters at the WTP may also have the potential to be optimized to more effectively achieve biofiltration.

Biofiltration design considerations include the EBCT, hydraulic loading rate, granular media type, and availability of nutrients in the source water. The EBCT is a chief design parameter that sets the retention time of the water in

contact with the biologically active media and dictates the size of the filter bed. Generally, increasing the EBCT increases the taste and odor removal efficiency at the expense of larger filter bed requirements. A balance between this trade-off can typically be reached with an EBCT of about 10 to 15 minutes; however, pilot testing is necessary to gauge and confirm treatment effectiveness. The WTP's existing filters would have an empty bed contact time of 16.6 minutes at flows of 1 MGD per filter. If the WTP elects to replace the anthracite coal layer with GAC, the GAC EBCT would then be 4.8 minutes at 1 MGD.

Traditionally, biofilters have been operated at slow hydraulic loading rates (0.5 to 2 gpm/ft^2). However, more rapid filtration rates (2 to 6 gpm/ft^2) have been shown to still maintain effective MIB removal efficiencies. Assuming a 1 MGD flow through each, the WTP's existing filters have a hydraulic loading rate of approximately 1.6 gpm/ft^2.

Biofiltration can be employed on adsorptive media, such as GAC, or on non-adsorptive media, such as sand and anthracite. While sand and anthracite biofilters have been demonstrated to achieve similar biodegradable DOC removal rates as biologically active carbon (BAC) filters, BAC tends to achieve more favorable removals under colder or otherwise less favorable conditions.

The major water quality parameters that influence biofiltration performance include nutrients, biodegradable natural organic matter, temperature, pH, and alkalinity. Therefore, "engineered biofiltration" strategies can be applied to enhance biofilter performance. These engineered biofiltration strategies include: supplementing nutrient availability; applying ozone as a pre-oxidant to increase the fraction of biodegradable organic matter and improve the overall organic removal. One solution is to alternate backwashing with chlorinated and non-chlorinated water.

The MIB and geosmin removal effectiveness of biofiltration depends on many site specific factors. Therefore, on-site pilot testing is necessary to gauge MIB and geosmin removal effectiveness. MIB and geosmin removal by biofiltration can range from about 50 to 99% with 90% being a typical removal efficiency for EBCTs of 10 minutes or greater.

Biofiltration processes require minimal operation requirements. Backwashing is necessary to avoid high pressure drops caused by deposited particles and excess bio-growth (biofouling). Backwashing frequencies can vary from once a day to every other week. Backwashing with water containing a disinfectant residual (0.5 to 1.0 mg/L as Cl2) may help biofilters operate at the longer biweekly run times. However, a chlorinated backwash may reduce treatment effectiveness, especially immediately after backwashing.

For conventional open, gravity filters, media would need to be replaced to account for media loss or excessively broken-down media. Eventual non-adsorptive media replacement will be necessary depending on biofilter performance (possibly up to 20-year media life). Operating GAC media in biological mode extends the bed life of the carbon as compared to operating in GAC adsorptive mode. The GAC bed life could be extended by up to year, but depends on monitored system performance.

Residuals generated by the process include replaced BAC media and spent backwash water that require disposal.

The WTP may already be achieving some level of biofiltration with the existing filters. However, as taste and odor concerns still persist, this existing process must be further evaluated and optimized where possible in order for biofiltration to become an acceptable resolution to the taste and odor concerns. The WTP may also consider installing dedicated BAC contactors for the surface water flow at the front of the WTP process train. Capital cost for installing a new BAC contactor would be comparable to GAC treatment. BAC change-out frequencies would be significantly reduced; thus, overall operational cost are typically lower than GAC. The projected cost to construct a 2 MGD carbon contactor system consisting of three (3) 1 MGD pressure vessels and 120,000 pounds of total carbon is approximately $1,600,000. This includes the costs for interconnecting yard piping for influent, effluent and backwash water, electrical, controls, site work, support slab, backwash water supply and handling, equipment installation, engineering and contractor fees.

3.3.2.4 Ion Exchange

Tetra Tech's review did not reveal any applications of this technology for the purpose of MIB and geosmin removal from drinking water.

3.3.3 Precipitation

Tetra Tech's review did not reveal any applications of stand-alone precipitative processes capable of achieving geosmin and MIB removal from drinking water down to a concentration that would not be detected by segments of the population who are sensitive to these compounds. Precipitative processes such as those used at the existing plant can remove a large portion of the taste and odor causing compounds, but must be coupled with other technologies (including PAC, GAC, BAC and ozonation) to achieve the highest overall level of treatment effectiveness.

3.3.4 Separation

Separation involves creating a physical barrier that separates the flow of taste and odor compounds from the finished water. Separation generally involves using treatment membranes. These membranes are classified by their pore size with ultrafiltration being the larger pore and nanofiltration being the smaller pore..

3.3.4.1 Ultrafiltration

Ultrafiltration (UF) is a physical removal process that works by rejecting particles based on size. UF membranes vary widely, being manufactured in pore sizes ranging from approximately 0.003 µm at the very low end up to 0.1 µm. These pore sizes correspond to the rejection (and, therefore, treatment effectiveness) of compounds with molecular weights of 1,000 daltons up to 100,000 daltons. Given that geosmin and MIB are dissolved constituents with molecular weights close to 200 daltons, UF membranes are not completely successful at removing these compounds without an upstream coagulation step. UF membranes are highly effective at removing algae, preventing potential taste and odor compound release downstream in the treatment process. However, UF membranes with high algae loading foul more rapidly and require more frequent backwashing, which then requires the system to be oversized to compensate. Manufactured UF membrane systems are designed in three distinct configurations: cross-flow, dead-end and vacuum. UF membranes for drinking water treatment are typically sold as packaged "black box" systems.

UF systems are typically designed and manufactured as proprietary "black box" processes. The designer coordinates to ensure the process is integrated within the larger WTP process framework.

The removal efficiencies of geosmin and MIB that are achieved by different UF membranes range significantly from 4% to 94%. This range is explained by the variations in source water, pore sizes, configuration, and coagulation used. The highest removals are achieved when using a coagulant such as alum or PAC.

The cost of constructing a 2 MGD UF system is estimated to be between $1.0 to $2.0 per gallon, so construction of a 2 MGD UF process is expected to cost $2 to $4 million. UF systems will typically generate concentrated waste streams that must be handled. High and low pH membrane cleaning solutions are periodically required. Coagulant is fed continuously to the raw water. Operating a UF system typically costs $0.10 per 1,000 gallons treated, resulting in approximately $35,000 per year in operating cost to treat an annual average of 1 MGD of surface water.

Given the questionable effectiveness of ultrafiltration removing taste and odor compounds, Tetra Tech does not recommend this technology be considered further.

3.3.4.2 Nanofiltration (Reverse Osmosis)

Osmosis is the natural process in which water from a dilute solution passes thru a semipermeable membrane to a more concentrated solution to equalize the salt content on both sides of the membrane. The driving force across the membrane is called the osmotic pressure. If pressure is applied to the side with the more concentrated solution water will flow in reverse of the natural process toward the more dilute solution side. This process is called reverse osmosis which is a pressure-driven process. Manufacturers have developed special reverse osmosis membranes to separate dissolved substances such as salt from a feed water stream to produce a purified water product generally referred to as permeate. Pressure must be applied to the membranes to overcome the membrane resistance to flow, the osmotic pressure, the pressure loss thru the membrane elements and the permeate pressure. The osmotic pressure is roughly equal to 1 psi for every 100 mg/L of dissolved salts. Basically, the higher the concentration of dissolved substances in the feed water, the higher the osmotic pressure of the solution and the higher the feed pressure required to produce permeate. Reverse osmosis membranes were produced to remove dissolved salts in the form of ions from solution such as from brackish groundwaters and seawater and have pore sizes that are typically less than 1 nm. Due to the small pore size required to remove these low molecular weight ions (, reverse osmosis membranes remove (reject) larger molecular weight compounds to a very high degree. The rejection (and, therefore, treatment effectiveness) of reverse osmosis membranes for larger organic molecules like MIB and geosmin would be greater than 95%.

Starting in the 1990's the membrane manufacturers began to offer membranes that are referred to as nanofiltration membranes. The nanofiltration process is simply a reverse osmosis system with nanofiltration membranes instead of brackish water RO or seawater RO membranes installed. The nanofiltration membranes were specifically manufactured to provide a high rejection, >90%, of hardness (calcium and magnesium) and dissolved organics and a lower rejection, <70%, of monovalent ions such as sodium and chloride (salt). These membranes are normally applied to feed waters that are high in hardness, color or dissolved organics and lower in total dissolved solids caused by other salts found in brackish water and seawater. The advantage of the nanofiltration membranes is their ability to soften water and remove dissolved organics at a much lower pressure than the brackish water RO membranes.

Nanofiltration membranes are designed to remove dissolved constituents from the water and the feed channels within the membrane elements are only 31 to 34 µm, therefore, pretreatment of the feed water is required to prevent fouling and scaling within the membrane feed channels which reduce water flow, increase operating pressure and decrease salt rejection. The minimum pretreatment commonly applied to all systems consists of prefiltration thru 5 to 20 µm cartridge type filters to remove suspended solids and the addition of a commercial scale inhibitor and/or acid to control scaling in the concentrate end. These systems have been predominantly applied to ground water supplies because they are low in suspended solids and lower in biological activity. There are membrane systems treating surface waters, but they generally require a higher level of pretreatment to remove suspended solids prior to the membranes and remove or control biological growth within the membrane elements. This pretreatment may include conventional treatment and media or ultrafiltration before the feed water is introduced to the membranes. The membrane surface material that creates the salt water separation cannot tolerate any oxidants such as chlorine, ozone, hydrogen peroxide or permanganate, so biological control is typically done by adding chloramines to the feed. Whenever a membrane system is going to be applied to treat a surface water, a three month or longer pilot study of the pretreatment system and membrane system should be performed to assess the fouling potential of the water and the frequency and type of cleaning that will be required to maintain the membrane performance.

In a RO, or nanofiltration system, membranes are placed in series in pressure vessels and as the feed water passes from the feed end to the end of the vessel purified water is removed by each membrane element and the remaining feed stream becomes more concentrated in the constituents that are rejected by the membranes. The feed water after it has passed thru the membrane pressure vessels and the design recovery of purified water has been achieved is referred to as the concentrate or reject. This stream which has a high concentration of

dissolved solids must be disposed of as a byproduct of the process. The recovery of nanofiltration systems generally range between 80 and 90% which means that 80 to 90% of the feed water is recovered as purified water and 10 to 20% of feed water must be disposed of as concentrate. Depending upon the quality and volume of the concentrate and location of the facility, concentrate is disposed of by surface water discharge, deep well injection, discharge to a wastewater system and combined with reclaimed water for land application.

A nanofiltration system could be applied at the City of Adrian to treat only the surface water flow to remove the odor causing compounds, or treat the combined flow of surface and groundwater to remove the odor causing compounds and most of the hardness from the water. In 2015, the City investigated using nanofiltration to replace the softening processes at the existing WTP. The motivation for conducting this 2015 study was the escalating cost of disposing of lime residuals. The 2015 study proposed sending the nanofiltration reject to the sanitary sewer for disposal at the WWTP. This 2015 study placed the cost of a nanofiltration system at $4.5 million which Tetra Tech understands was to include the installation of approximately 4.2 mgd of membrane permeate capacity within an existing building at the WTP.

For this alternative, Tetra Tech continued the evaluation with this 4.2 MGD rate. Should the City implement nanofiltration to treat for taste and odor, it is probable that they would also wish to use nanofiltration for softening. Furthermore, Tetra Tech believes that nanofiltration will be more effective treating a blend of groundwater and surface water than surface water alone.

Tetra Tech projects the cost of constructing a 4.2 MGD nanofiltration system to be $10.5 million. This is a higher cost per gallon treated than the 2015 study due to inflation, new building construction, and additional conservatism used in developing the cost. Nanofiltration systems will generate concentrated waste streams that must be handled. High and low pH membrane cleaning solutions are periodically required. Operating a nanofiltration system typically costs $0.15 per 1,000 gallons treated, resulting in approximately $50,000 per year in operating cost to treat an annual average of 1 MGD of surface water.

However, the City of Adrian incurs an annual cost of approximately $300,000 to use lime and dispose of the residuals from the lime treatment. With using nanofiltration to perform some or all of this softening, the costs to operate the lime process will be reduced. Operating a 2 MGD nanofiltration system may reduce the current operating costs $100,000 or more.

4.0 PUBLIC ENGAGEMENT

Q+M Agency of Ann Arbor led a brief public engagement effort as part of this project. Their scope included conducting an online survey and assisting with two focus group meetings.

The survey results are included in Appendix B. The high number of responses and the nature of the responses clearly chow that the surveyed citizens are concerned about the quality of their drinking water. Additional conclusions can also be drawn, such as a general agreement that the aesthetic water quality in 2018 was lower than prior years. Question 10 inquired about willingness to receive higher utility rates to pay for improvements to the treatment process. The results for Question 10 indicated that 41% of the responders did not support any increase and an additional 21% only supported an increase of less than $5 per month.

The first focus group was conducted on May 1, 2019 at the Adrian WTP. The meeting was sparsely attended, with only three water customers present. The citizens at this meeting only provided a few comments regarding water quality. Some specific comments and questions asked included:

- “What improvements are being looked at in the long term?”
- “Water filters and bottled water have assisted with concerns over the water’s taste. Homebound consumers may not have these options.”
- “Is the Adrian WTP outdated?”
- “The recent Flint situation is a big part of the citizens’ concerns.”

5.0 SUMMARY AND RECOMMENDATIONS

5.1 FUNDING OPPORTUNITIES

The State of Michigan has recently initiated a grant program to remediate emerging contamination threats. While this grant program was implemented to target PFAS, the grant guidelines are broad enough that it would be worth Adrian seeking funds. The grant has a 20% local match and money is granted on a first-come, first-served basis.

The City should consult its financial advisor for advice on funding other capital projects. Most communities elect to fund water projects with the Drinking Water Revolving Fund (DWRF) low interest loan program administered by the State of Michigan. Project plans (a first step in applying) for this program are due by April 1 of each year.

5.2 ALTERNATIVES FOR FURTHER CONSIDERATION

The review of potential source water control alternatives indicates that alum addition, copper treatment and a sonic control system may be effective in significantly reducing the algae population in the lake during the period from late spring to early fall when algae blooms are most likely to occur and higher taste and odor complaints have been experienced. Alum treatment can effectively remove the phosphorus from the water column and therefore remove the primary nutrient supporting the algae growth, depending upon the flow and nutrient load into the lake although its effect may not last a long time. Copper treatments can effectively kill the algae as long as the proper compound is used and the application is performed when algae concentrations are rising, but not during a full bloom. Multiple treatments will likely be required to maintain a high level of control. The sonic system has been shown to be an effective control method when the program detects the correct species of algae and applies the best frequency and duration to control it. The LG system offers the advantage of providing near real time data about the water quality in the lake which could be useful for anticipating and controlling algae growth. There are not a large number of these units installed in reservoirs in the United States and therefore, its effectiveness in this application cannot be guaranteed.

The review of the potential treatment alternatives indicates that PAC addition, ozonation, biologically active carbon and nanofiltration can achieve a higher level of removal of the odor causing compounds MIB and geosmin and other similar compounds. The first technique will not require a significant additional capital cost expenditure or require additional bench scale or pilot scale testing as will be required for the last three alternatives. The remaining techniques will require some time to fully investigate and test their effectiveness, design and permit and to construct.

5.3 NEXT STEPS

5.3.1 Short-Term Recommendations (2019)

The following actions are recommended to increase the effectiveness of control and reduction of taste and odor compounds in the finished water which can be implemented without significant capital investment during the summer of 2019:

5.3.1.1 Source Treatment

- Apply copper treatments as necessary to control algae growth in Lake Adrian during the warmer months when algae growth is most likely to significantly increase in number and coverage. The lake should be regularly monitored for chlorophyll a and/or phycocyanin or another surrogate which will indicate an increase in the algal population and the need to treat with copper to prevent a bloom and a significant increase in MIB, geosmin and other taste and odor causing compounds in the raw water.

- Consider purchasing and installing a single LG Sonics Master Control Station in the southern portion of the lake so that it can control algae growth in the area around the intake and provide continuous monitoring data about the water quality in the lake. The purpose of the installation of the LG Sonic master control station is two-fold. First, to test the effectiveness of the unit to control algae growth within its area of influence as compared to the balance of the lake. More complete control could only be achieved if additional units were installed to provide complete coverage of the lake. Therefore, this is the initial step to determine Secondly, to receive and compile the monitoring data on the lake quality to correlate it with taste and odor events to be able to adjust treatment or reduce the percentage of surface water being treated during times of high algae concentration. The next step before purchasing is to check references who have installed this equipment in the United States.

5.3.1.2 WTP Optimization

- Consider splitting the treatment of the two source waters into two separate treatment trains to optimize treatment of the surface water to remove organics. Tetra Tech understands that the piping and valving exists to operate the WTP in this manner with little or no capital costs. The City and MEGLE may wish to initiate jar testing of this treatment change to confirm such factors as treatment chemical feed rates and detention times before implementing at full scale.
- Implement the planned permanganate addition also based on chlorophyll a measurement. The City may also consider a low dose of permanganate shortly after the source water intake.
- Dose the surface water with PAC to remove taste and odor compounds. If operating in a split treatment mode, the dose can be applied so that a minimum of four hours of contact time is achieved which proved to be effective in the bench scale testing. We forecast that split treatment will increase the effectiveness of the PAC and reduce the cost of application.
- Consider optimizing the existing filter media and operation to enhance biological removal of geosmin and MIB. Broadly, the existing filtration process meets the suggested requirements to achieve biofiltration. The EBCT and hydraulic loading rate are both within typical ranges and the WTP chlorinates downstream of the filters. The first action will be to determine to what extent biofiltration is already occurring and to what extent, if any, the chlorinated backwash is adversely impacting biofiltration. An example sampling protocol to answer both these questions would be to grab one sample immediately upstream of the filters prior to flow splitting, and three samples immediately after filtration (before flows are recombined) for filters at different runtimes. Example runtimes could be 2 hours, 24 hours, and 100 hours. Note that the samples should be taken within as short a period of time as possible to reduce variation of the influent entering the filters. These sampling runs could coincide with the WTP's existing geosmin and MIB sampling schedule. The biological filtration would be utilized as a polishing step to remove as much of the remaining organics as possible to further reduce the taste and odor compounds in the finished water.

5.3.1.3 Groundwater Supply

- The City should operate the well field in accordance to the recommendations in this report. Pumpage rates exceeding 2 MGD during warm months may lead to drawdown that may take a year or more to recover from.

5.3.2 Intermediate-Term Recommendations (Late 2019 and 2020)

The City should implement the short-term recommendations before late summer 2019. The following actions are recommended to be immediately taken after the short-term control methods have been implemented:

- A review of the water quality data, customer complaints, treatment effectiveness, operational issues, changes in operational costs and overall effectiveness of the short-term recommendations should be

performed. Actions to improve the effectiveness of the short-term recommendations should be developed and evaluated.

- If the evaluation determines that the implementation of the short-term recommendations did not reduce the level of taste and odor compounds in the finished water to a generally acceptable level, a pilot testing program should be developed to test one or several of the alternatives that will require the construction of new facilities. We recommend pilot testing the following technologies. The pilot tests should include both a measure of the effectiveness of treatment at Adrian and the cost effectiveness for implementing each process.
    - Nanofiltration
    - Ozonation
    - Advanced oxidation (w/ ozone and peroxide)
    - Ozonation or advanced oxidation followed by biofiltration

  Refer to Table 5-1 for cost opinions to complete pilot testing and additional information for each alternative.

Table 5-1 - Summary of Recommended Alternatives for Pilot Testing

Technology Evaluated	Design Flow	Capital Cost	Pilot Cost	Algal Toxin Removal*	Comments
Ozone	2 MGD	$4,000,000	$140,000	Y	
Advanced Oxidation	2 MGD	$4,200,000	$140,000	Y	
Ozonation + Biofiltration (Ozone w/ Existing Filters)	5 MGD	$5,000,000	$260,000	Y (Polishing Step)	More stable effluent relative to ozonation or advanced oxidation only
Ozonation + Biofiltration (w/ New GAC Filters)	2 MGD	$5,600,000	$260,000	Y (Polishing Step)	More stable effluent relative to ozonation or advanced oxidation only
Nanofiltration (Reverse Osmosis)	4.2 MGD	$10,500,000	$340,000	Y	Will reduce operating costs associated with lime residual disposal

*Anatoxin-a, Cylindrospermopsin and Microcystin

- The replacement of the anthracite layer of the existing granular media filters with granular activated carbon (GAC) should be evaluated and will not require new capital construction. A GAC layer will reduce geosmin and MIB levels directly via adsorption, and may also increase the stability of biofiltration, especially under cold (sub 40°F) temperatures. Anthracite/sand filters have been found to achieve similar levels of biofiltration as GAC/sand filters. For example, testing performed for the City of Dallas prior to conversion to biological filtration did not show very significant difference in performance of the two media, at least for total organic carbon removal. As a pilot, the City could also replace the anthracite media in a single filter with GAC and do a side by side comparison of the effectiveness of the two different media types.
- Consider running jar tests to evaluate the frequency and mass of the alum dose required to effectively treat the surface water.

5.3.3 Long-Term Recommendations (2021 and beyond)

The following actions are recommended to be taken to further increase the effectiveness of control and reduction of taste and odor compounds in the finished water after the performance of the short-term and intermediate-term recommendations have been implemented and the public response to the improvement of the finished water quality evaluated.

- Reevaluate the treatment effectiveness and life cycle costs of the treatment alternatives outlined in the intermediate-term pilot tests. Upon selection of a technology, the project should proceed to design and construction.
- The City should continue to seek additional groundwater sources when opportunities present themselves. Given the City's long history of seeking a new groundwater supply without success, we are not optimistic that nonspecific attempts to find new sources will be fruitful. However, as new leads for groundwater supplies are found, testing to determine yield should be considered. We approximate that each test will cost $25,000 or more, thus these tests should not arbitrarily be completed.

APPENDIX A – SONIC WAVE GENERATOR LITERATURE

Algae Control Proposal

Tetratech - Lake Adrian

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Executive summary

In this proposal you will find an installation advice for monitoring and controlling algae in Lake Adrian.

Benefits for ultrasonic algae control

- Reduce algal blooms by up to 70-90%*
- Prevent growth of algae
- Reduce chemical use
- Payback period of ±1.8 years

Ultrasound technology

In all water bodies, a basic level of algae is present. These algal concentrations belong to the normal lake ecology and are also important for the ecological balance within the water. However, when a specific algal type starts growing exponentially, it can suffocate other organisms within the water that are important for a balanced lake ecology. The ultrasonic algae control devices from LG Sonic emit specific ultrasonic parameters to control algae in lakes, reservoirs, and industrial applications. Ultrasound waves create a sound layer in the top layer of the water, which has a direct impact on the buoyancy of the algae. The algae cells will sink to the deeper and darker layers of the water column and are unable to photosynthesise, thus will eventually die due to a lack of light.

The advantages of ultrasound technology

- No release of toxins
- Environmentally friendly
- Safe for fish, plants, zooplankton and insects

Project proposal

Based on the dimensions the Lake Adrian, we advise to install a total of 4 systems MPC-Buoy. The system MPC-Buoy is a floating, solar powered, platform that combines continuous online water quality monitoring, web-based software, and ultrasonic technology to effectively control harmful algal blooms in large water surfaces, such as lakes and larger ponds.

Similar projects

AMERICAN WATER

Bournemouth Water

epm®

*In optimal conditions, depends on the specific water quality characteristics.

Total project costs

Table 1: Total project costs

Prod code	Product Name	Qty	List Price	Total
10100	MPC-Buoy Pro	1	$50,100.00	$ 50,100.00
10020	MPC Anchor System	4	$ 3,640.00	$ 14,560.00
10200	MPC Buoy - Lite	3	$40,800.00	$122,400.00
87316	Sim Card	48	$ 25.00	$ 7,800.00
	Shipping		$ 7,000.00	$ 7,000.00
	Install Supervision		$ 5,000.00	$ 5,000.00
	First year monitoring included			
			Grand Total	$199,060.00

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1. Treatment proposal

The algae control systems developed by LG Sonic offer an environmentally friendly solution to control algae by making use of ultrasound waves.

1.1. Proposed solution

Based on the dimensions of Lake Adrian, we advise the installation of 4 MPC-Buoy systems.

The MPC-Buoy is a floating, solar-powered platform that combines continuous online water quality monitoring, web-based software, and ultrasonic technology to effectively control harmful algal blooms in large water surfaces, such as lakes and larger ponds. The MPC-Buoy eliminates up to 90% of the exiting algae and prevents the growth of new algae.

One MPC-Buoy system can treat large surface areas up to 500-meter (1600 ft) diameter coverage. The MPC-Buoy is anchored in the centre of the lake, ensuring correct coverage of the ultrasound waves.

1.2. Proposed installation

Below you will find an installation proposal to reduce the algae level in Lake Adrian. A total of 4 MPC-Buoy systems should be anchored in the raw water lake. The blue icons indicate the MPC-Buoy systems, and the yellow icons the MPC-Buoy Lite systems. The MPC-Buoy Lite systems do not contain water quality sensors since it is not necessary to measure the water quality every 500 meters; this way, we can offer our customers a more cost-effective solution. Each buoy system has a treatment range of 500-meter diameter coverage.

FAQ

Is ultrasound harmful for fish, plants, zooplankton, or insects?

No. The effects of LG Sonic products have been tested by various universities and are proven to be safe for fish, plants, zooplankton, and insects.

What happens to the algae after the ultrasonic treatment?

The ultrasound creates a sound layer in the top layer of the water. This ultrasonic sound barrier prevents the algae from rising to the surface and absorbing light for photosynthesis. Therefore, algae are no longer capable of growing further. The algae will die while the cell wall remains intact, preventing the release of toxins from the algae into the water. The algae will sink to the bottom of the water reservoir and are degraded by the bacteria present.

Does the algae release toxins in the water?

Algae control by ultrasound is based on the interference with their buoyancy and hence preventing their photosynthetic activity. Ultrasound does not break or lyse the cells, and as such toxins are not released into the water. As the ultrasound process is generally a longer process (3-4 weeks) and growth of new algae is being prevented, you can see a gradual reduction in toxin concentration once ultrasound is introduced.

How is the system installed?

The MPC-Buoy is anchored in the water reservoir. Each system has 4 ultrasonic transmitters ensuring complete 360-degree sound coverage.

Do you want to receive more information or have any other questions? Please contact your account manager.

1.3. Initial costs

Table 2: Total project costs

Prod code	Product Name	Qty	List Price	Total
10100	MPC-Buoy Pro	1	$50,100.00	$ 50,100.00
10020	MPC Anchor System	4	$ 3,640.00	$ 14,560.00
10200	MPC Buoy - Lite	3	$40,800.00	$122,400.00
87316	Sim Card	48	$ 25.00	$ 7,800.00
	Shipping		$ 7,000.00	$ 7,000.00
	Install Supervision		$ 5,000.00	$ 5,000.00
	First year monitoring included			
			Grand Total	$199,060.00

Table 3: Product/service description

Product/Service	Amount	Included
MPC-Buoy	1	• Ultrasonic treatment • Water quality sensor package • Solar panels • 1-year of interactive algae control services • Web-based software package • Floating buoy construction
MPC-Buoy Lite	3	• Ultrasonic treatment • Solar panels • 1-year of interactive algae control services Web-based software package • Floating buoy construction

		The MPC-Buoy lite receives ultrasonic program updates from the MPC-Buoy in lakes where more than one buoy is required
Installation		Installation supervision and start-up of the software

Recommended by LG Sonic

Table 4: Recommended product/service description

Product/Service	Amount	Included
Spare parts package	Optional	• 1 Transmitter + aquawiper • 1 Regulator • 1 Ultrasonic box • 1 Datalogger box • 1 USB cable • 1 Antenna • 1 cable regulator/datalogger box • 1 cable datalogger box / Ultrasonic box • 4 solar extension cables • 1 transmitter arm left • 1 transmitter arm right • Bolts + nuts
Dual Tester	Optional	To test the ultrasound in the water with a sound meter
Anchor system	4	Complete anchor system incl. anchor, D-shackles, marine rope, sinker, galvanized, chains and swivels
Sim Card	48	It is possible to order a SIM card from LG Sonic
Solar-powered warning light	Optional	Marking of algae control systems in lakes and reservoirs

1.4. Maintenance and annual service costs

The sensors and ultrasonic transmitters on the MPC-Buoy are all equipped with wipers to ensure they stay clean. This keeps the efficiency and specificity of the MPC-Buoy optimal and makes frequent maintenance to the system redundant.

Besides that, the technical status of the system can also be monitored through the MPC-View software, minimizing visits to the MPC-Buoy itself. What is left for maintenance is the calibration of the sensors. LG Sonic can do this for you simply by you sending the sensor package to us once a year.

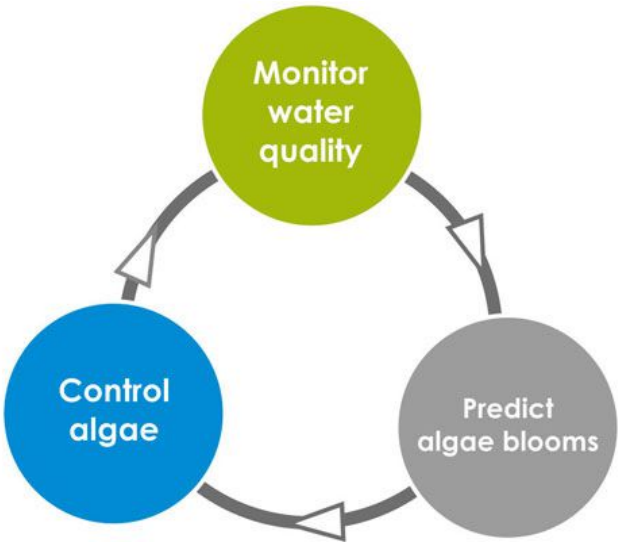
We recommend performing an on-site physical inspection bi-monthly to check the state of all the parts comprising the MPC–Buoy.

Table 5: Maintenance and annual service costs

Type	Included	Costs
Interactive algae control services	• Interactive algae control services • Data management • Web hosting • Setup of server • Software licensing	The first 12 months are included in the price. After 12 months, use can be paid for on a yearly basis: Project service costs of €5100/year + • Each MPC-Buoy: €900/year • Eachl MPC-Buoy lite: €300/year
Calibration of the water quality sensors	• Fluorobrobe (phycocyanin, turbidity, Chlorophyll a) • DO sensor • Replacement of pH cartridge • Revision of sensor wiper engine	€945/ year

2. Specifications

2.1. Concept: monitor, predict and control algae



The MPC-Buoy is specially designed for large water surfaces and combines online water quality monitoring, web-based software and ultrasound technology to provide complete and cost-effective treatment against algae in lakes, ponds and drinking water reservoirs.

1. Monitor water quality

The MPC-Buoy provides a complete overview of the water quality by collecting the following parameters every 10 minutes: Chlorophyll α (green algae), Phycocyanin (blue-green algae), pH, Turbidity, Dissolved Oxygen, and Temperature.

2. Predict algal blooms

The collected data is delivered in real time via radio, GPRS, or 3G to web-based software. Based on our developed algorithm we are able to modify the ultrasonic program to the specific water conditions and predict algal blooms a few days ahead.

3. Control algae

Based on the received information, the ultrasonic program can be activated according to the water conditions and type of algae present. In this way, it is possible to eliminate existing algae and prevent the growth of new algae.

2.2. Key system elements

1. Ultrasonic treatment
2. Water quality sensor package
3. Solar panels
4. Floating construction anchored at the bottom of a lake
5. Data communication for remote control
6. Water quality software package

1. Ultrasonic treatment for algae control

The MPC-Buoy is equipped with 4 ultrasonic transmitters for 360-degree algae control. Each transmitter has an ultrasonic treatment range of 500m/1600ft in diameter. Based on the measured water quality data, the system can remotely activate the right ultrasonic program. Web-based software (MPC-View) allows users to visually track the water quality and the progress of the ultrasonic treatment.

The transmitters send ultrasonic sound waves of several specific frequencies, amplitudes, waveforms and durations into the water. The specific ultrasonic waves create a sound layer in the top layer of the water, which has a direct impact on the buoyancy of the algae. The algae cells will sink to the deeper and darker layers of the water column and are not able to photosynthesize and will eventually die due to a lack of light. However, for the efficiency of the technology it is important that specific frequency programs are used, based on the algae that require a control strategy.

Affected algae cells will sink to the bottom of the water reservoir, where they will be degraded by the bacteria present in the soil. After 3 to 4 weeks, the LG Sonic® devices control the growth of new algae from 70% to 90%.

The LG Sonic products are not based on cavitation; the LG Sonic technology uses low-power ultrasound to control algae growth. This prevents the release of algal toxins into the water.

4 ultrasonic transmitters for complete 360-degree algae control

- Treatment range of 500m/1600ft in diameter
- Integrated Aquawiper™, an automatic cleansing system for the ultrasonic transmitters
- Chameleon Technology™, adjusts the ultrasonic program to the specific water conditions

2. Water quality sensors for effective algae control

The MPC-Buoy is equipped with a set of sensors that monitor important parameters of your water quality in real time. The basic set of sensors are:

- Chlorophyll a (Algae)
- Phycocyanin (Blue-green algae)
- Dissolved Oxygen
- Turbidity
- Temperature
- pH
- Redox

*Optional sensors are available based your needs and preferences.

These sensors can be used to provide a good overview of the concentration and type of algae present in your water reservoir. Besides that, levels of pH, temperature and turbidity can be used to predict the formation of new algal blooms and anticipate them before any problems arise. Levels of Dissolved oxygen provides you with vital information about the health of your water and condition of fish and plants within the lake.

In-situ water quality sensors to provide real-time water quality data

- **Monitors chlorophyll α, phycocyanin, DO, turbidity, temperature pH, and redox**
- **Automatic antifouling wiper ensures optimal readings**
- **Optional sensors are available according to your needs and preferences**

3. Solar panels for power supply

The MPC-Buoy is equipped with 3 solar panels of 195 Wp and 40-amp lithium batteries for autonomous power supply. The device has a power consumption of 5-20 Watts. The MPC-Buoy can provide power all year round anywhere around the world. During low battery charge, the device automatically powers off the ultrasonic transmitters. Furthermore, the device automatically switches to an energy-saving program during periods of low sun radiation.

Solar panels for autonomous power supply

- 3x 195 Wp high-quality solar panels that provide power, all year round in any country
- 1x 24 Volt, 40 AMP lithium battery
- Switches to energy-saving program during periods of low sun radiation
- Solar regulator

4. UV- resistant buoy construction

The MPC-Buoy system consists of three unsinkable floats that carry the weight of the system. The aluminium powder coated frame is both UV and corrosion resistant. Because the construction is relatively light (250 kg), you only need a small boat to drag the device to the required installation spot, where the unit can be installed and moored.

Floating construction anchored to the bottom of a lake

- Aluminium powder-coated frame
- UV and corrosion resistant construction
- Unsinkable floats

5. Data communication for remote control

The LG Sonic data logger is designed specifically for its application in a watery environment, where monitored data needs to be continuously delivered. The LG Sonic datalogger will communicate with the online software from LG Sonic (MPC-View) through a 2G or 3G data connection. Other data connections are available on request (GPRS, Satellite).

Smart communication system for remote control

- GSM/GPRS Telemetry Quadband (CDMA, Radio, GPS and Iridium Satellite optional)
- Real-time water quality data with the MPC-View software
- Integrated alarm functions

6. Water quality software package: MPC-View

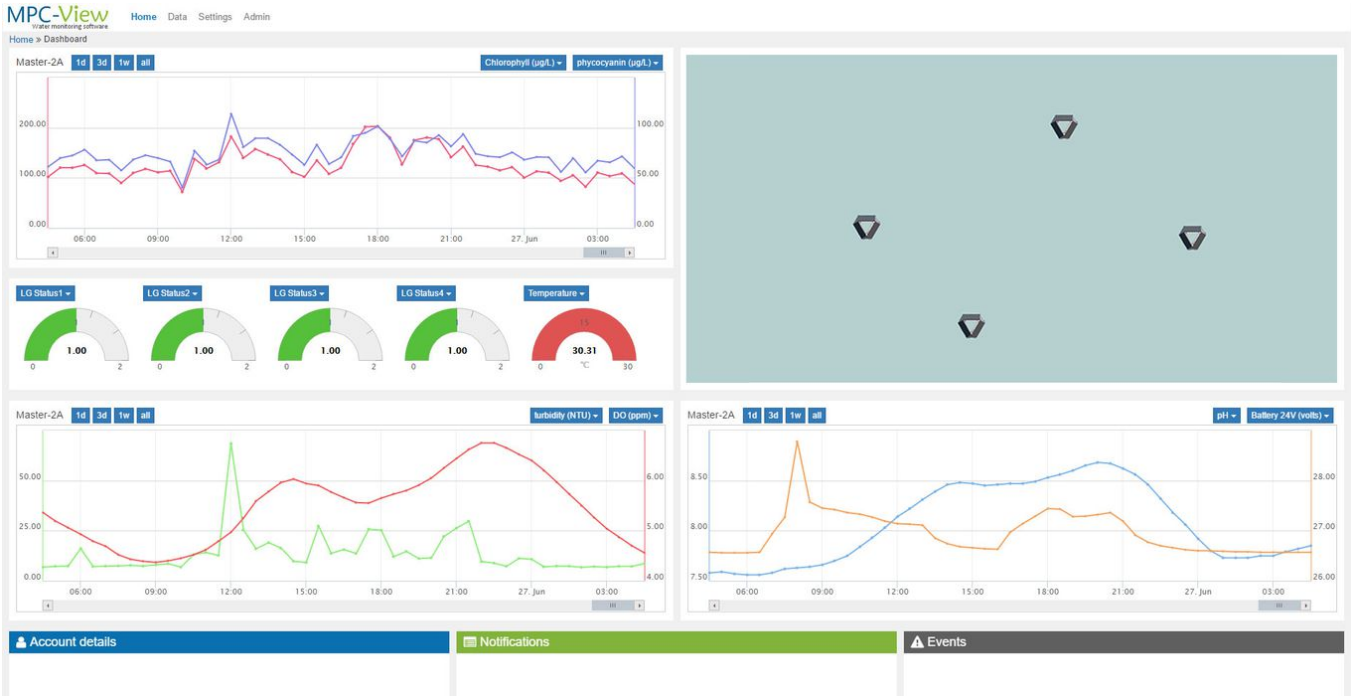
The MPC-View software allows you to visually track the water quality in your lake or reservoir. The software receives its data from advanced water quality sensors that are integrated into the MPC-Buoy.

You can log in to the software where you will find a personal dashboard displaying an overview of your algae control projects. The software provides insight into the water quality, algae trends, and the progress of the ultrasonic treatment. Furthermore, the software displays technical parameters, such as the status of the ultrasonic transmitters, signal strength, and battery strength. This way, customers and employees of LG Sonic can remotely monitor to see whether the devices are working properly. Generated reports can be exported to Excel or converted to PDF, and from there they can be shared or published.

MPC-View

- Dashboard with an overview of the water quality
- Set up alarms for changing water conditions and maintenance activities
- Visual insight into various parameters at a specific moment in time

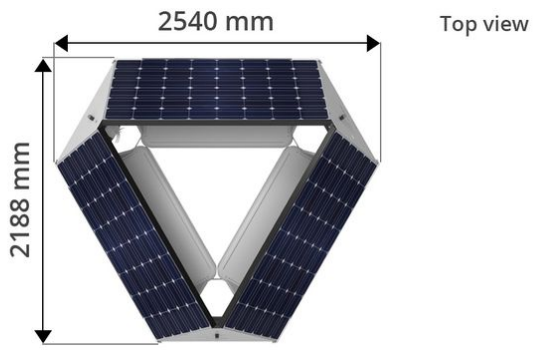
Dashboard with an overview of the algae control project



Visual insight into various parameters at a specific moment in time

2.3. Technical specifications

Frame	• Aluminum framed polyethylene buoy • Material: Rotationally-moulded UV-stabilized HDPE polyethylene • Filling: Closed-cell polyurethane foam • Buoy frame: Anodized aluminum • Weight: 15 kg • Size: 1200x600x200mm • Buoyancy capacity 95 kg
Solar panels (3x)	• Solar cell: Monocrystalline cell • Rated Power (Pmax): 195Wp • Weight: 16 kg • Connectors IP67 • Size: 1580x808x35mm
Battery	• 1 x 24 volt lithium lifepo4 • Capacity: 40 Ah • Weight: 15kg
Data acquisition system	• 4 x analog channel (user-configurable for either 4-20mA) • 1 x RS485 port for instruments • 1 x high frequency pulse counting channel • 1 SDI-12 input • 3X RS232
Telemetry	• GPRS Telemetry • Quadband (850/ 900 / • 1800 / 1900 MHz) • CDMA optional • Radio (UHF/VHF)
Solar Charge Controller	• Overcharge and Deep discharge protection • Ip68 Protection



Water quality sensor package	
Fluorescence, including anti-fouling Wiper: chlorophyll a, phycocyanin, turbidity • 470nm – Chlorophyll a • 610nm – Phycocyanin • 685nm Turbidity	**Redox** • Combined electrode • (Redox/reference): • Platinum tip, Ag/AgCI • AgAgCl. • Gelled reference (KCI) • Range - 1000 to + 1000 mV • Resolution 0,1 mV • Accuracy ± 2 mV
pH • Combined electrode • (pH/ref): • special glass, Ag/AgCI ref. • Gelled electrolyte (KCI) • Range 0 – 14 pH • Resolution 0,01 pH • Accuracy +/- 0,1 pH	**Temperature** • Technology CTN • Range 0.00 °C à + 50.00°C • Resolution 0,01 °C • Accuracy ± 0,5 °C • Response time < 5 s
Dissolved Oxygen • Optical measure by • luminescence • Measure ranges: • 0.00 to 20.00 mg/L • 0.00 to 20.00 ppm • 0-200%	

3. Delivery and guarantee

3.1. Delivery method

Sea cargo/airfreight/road

Method of shipment: Delivery at Place (DAP)

Delivery time

The products will be shipped within 6 weeks after receiving payment. Shipping time depends on shipping method: 1 and 3 weeks

3.2. Guarantee

LG Sonic BV, the producer, has great confidence in its products and guarantees the quality of assembly and materials used. The warranty is limited to materials and faulty construction and covers terms of ONE, TWO, THREE or FIVE YEARS after purchase date for different parts of the MPC-Buoy.

The system specifications and the assigned years of guarantee coverage are listed in the table below:

System element	Includes	Years of guarantee
Ultrasonic system	• Up to 4 LG Sonic e-line XXL transmitters connected to one control box • Treatment range of 500 meter in diameter • Ultrasonic treatment coverage of 360°	3
Water quality sensor package	Water quality sensors: pH, dissolved oxygen,temperature, redox, turbidity, chlorophyll a, phycocyanin.	1
Solar system	• 3x 195 WP solar panels • 2x 12 Volt, 40 AMP lithium batteries • Solar regulator	5 2 2
Buoy construction	• Aluminum-framed polyethylene buoy • Stainless steel construction for solar panel mount • HDPE enclosure for electronic box and batteries	3

4. LG Sonic company profile

Algae control solutions

LG Sonic is a Dutch, privately owned company with the mission to eliminate harmful chemicals in the environment. Therefore, the company developed a chemical-free technology that controls algae without disturbing the natural balance within water ecosystems. LG Sonic works together with different European Universities and Research institutes, many of which are European funded research and development projects.

Value proposition

Algae cause problems when blooming in lakes and water reservoirs such as damage to filters/ pumps and losses in recreation use. Solutions such as copper-sulfate are besides costly, labor intensive also harmful for the ecosystem. In order to provide an environmentally friendly and cost-effective solution to these problems, LG Sonic developed the MPC-Buoy, a floating, solar powered, platform that combines continuous online water quality monitoring, web-based software, and ultrasonic technology to effectively control harmful algal blooms in large water surfaces, such as lakes and water reservoirs. The MPC-Buoy eliminates up to 90% of the exiting algae and prevents the growth of new algae. Furthermore, the MPC-Buoy allows to reduce TSS, BOD and chemical consumption.

Track record

- Coordinator of several European FP7 projects: ClearWater PMPC and Dronic (€3.2 million)
- Official Innovation Partner of American Water, U.S. largest water and waste water utility
- Winner of several innovation award such as the Aquatech Innovation Award (2015)
- Winner of several entrepreneur awards such as the Shell LiveWIRE Award (2014)

APPENDIX B - PUBLIC ENGAGEMENT DOCUMENTATION

City of Adrian: Water Treatment Taste and Odor Optimization Study

SUMMARY

Q+M spoke with Adrian city officials, water experts and engineers, and conducted an online survey of residents, business owners and employees from the City of Adrian, asking for their opinion of the City's drinking water. This was conducted to get input from the City, experts, and the Adrian community regarding their views on the drinking water.

Many of the respondents expressed their concern for water safety in addition to the taste and odor. The City has communicated that water safety should not be a concern due to ongoing testing, but the results show that this is still a factor and on the minds of the residents. Many did, however, offer to be a part of the process, helping when they can in order to get the results they want.

The following information outlines the survey process, analysis and next steps the City of Adrian and Tetra Tech should take when informing the community on expectations.

SURVEY PROCESS

In order to get feedback from as many residents, employees and visitors as possible, Q+M created an online survey using Survey Planet. The survey asked respondents both multiple choice and open-ended questions to gather input. The survey also asked respondents if they'd be interested in attending a focus group to provide additional feedback on the drinking water and learn more about what next steps the City will be taking. The survey remained open for four weeks from March 22nd to April 19th, 2019. The survey was posted on the City of Adrian Facebook page and promoted through a paid Facebook Campaign to reach residents and business owners.

SURVEY RESULTS OVERVIEW

- A total of 916 respondents completed the survey.
- The Facebook ads received a total of 4,565 link clicks and 175 post likes. The post with the survey was shared over 150 times on Facebook.
- 40% of the respondents are ages 45-54. The lowest age group is 18-24.
- 56% of the respondents live and are homeowners in Adrian.
- Q+M will make all of the raw data available to the City of Adrian – summary data present below.

ANALYSIS & NEXT STEPS

The results of this online survey reveal a great deal about how residents and business owners *view* the drinking water in Adrian. Tetra Tech will use this information while preparing both short and long term solutions for the City drinking water.

The major takeaway here is that a significant number of residents don't trust that the water is safe *whether it is or not*. A consistent, visible, study on the water safety is a valuable reassurance to everyone, along with implementation of any recommendations. Many residents are active on digital platforms, including Facebook, and appreciate updates and communication through these platforms.

Additionally, while folks voiced dissatisfaction with water quality/safety, many are also willing to help. Whether with increased utility bills, or offers to be involved in the process, most residents understand that this is their water and are ready to contribute to making it better.

Consistency is key. We recommend *consistent* communication regarding water in Adrian. This doesn't have to be elaborate or expensive and can be executed by Q+M or done in house by a community relations staff member. It should focus on transparency and building trust. When tests are done, how many tests, full reports with key findings highlighted, any actions taken etc. should be posted to digital platforms. Don't be afraid to speak to the challenges of the water system. The community *understands* and trusting them to be involved will go a long way to building their trust in the water system.

Even if a major investment is put into the water system, building the trust in it will be separate educational effort.

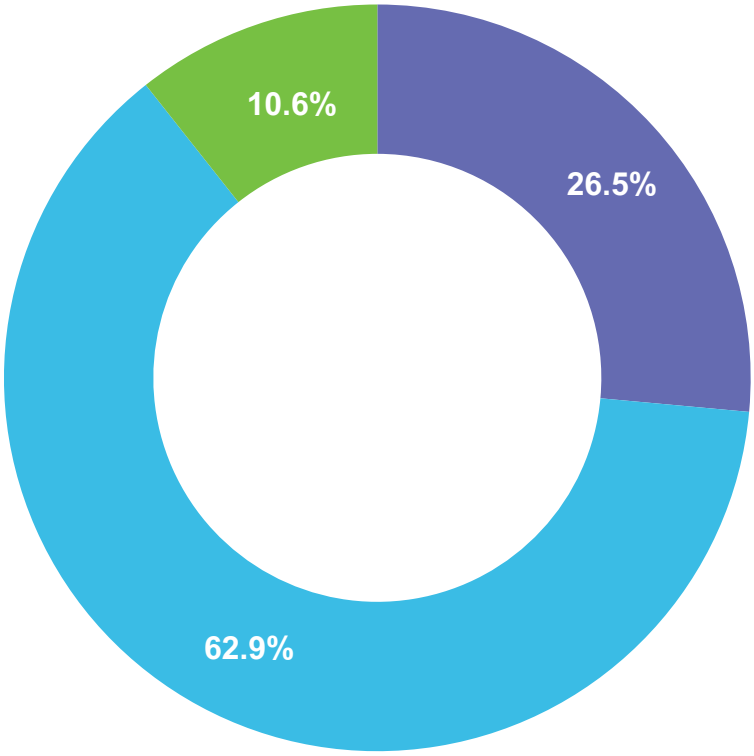
City of Adrian Water Experience: Community Survey

Understanding your experience is our top priority. Please help us understand how you engage with and experience the water in our city.

Q1

Select which best describes your main source of drinking water.

MULTIPLE CHOICE



Answered
911

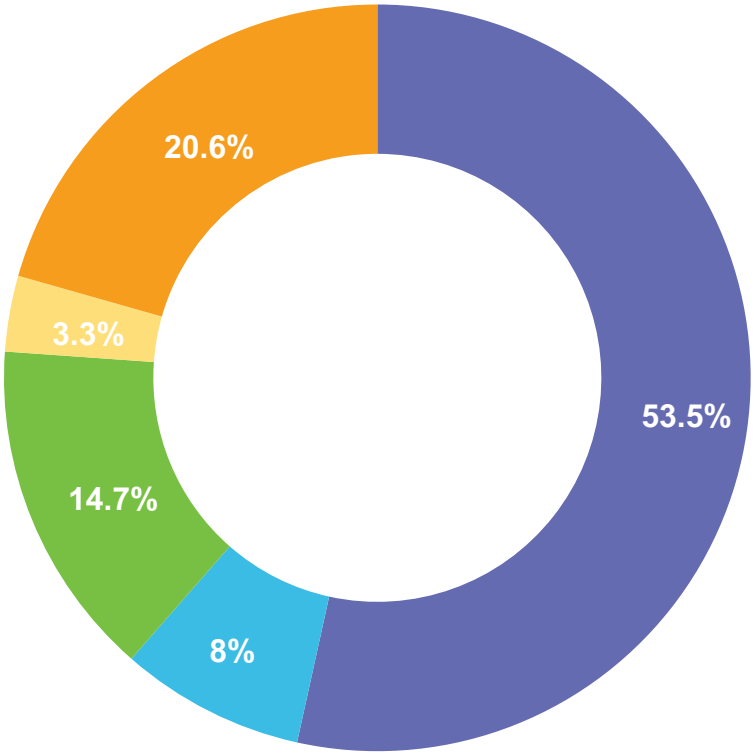
Unanswered
5

Choice	Total
Mostly tap water	241
Mostly bottled water	573
Drink equal amounts	97

Q2

How would you describe your water consumption at home?

MULTIPLE CHOICE



Answered
913

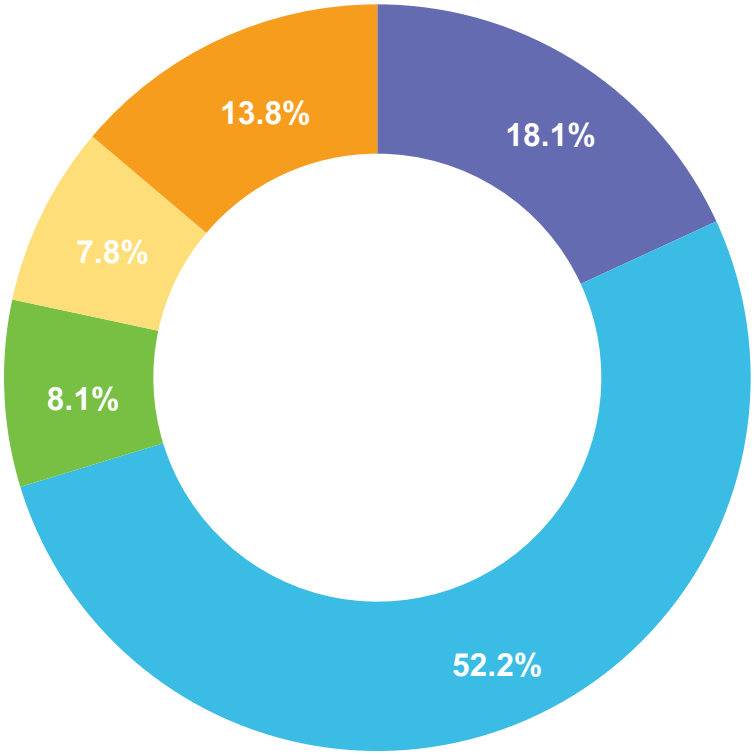
Unanswered
3

Choice	Total
Only drink bottled water at home	488
Only drink tap water at home	73
Drink both tap and bottled water	134
Do not drink water at home	30
Drink filtered water	188

Q3

MULTIPLE CHOICE

If drinking tap water, how do you prefer it?



Answered
767

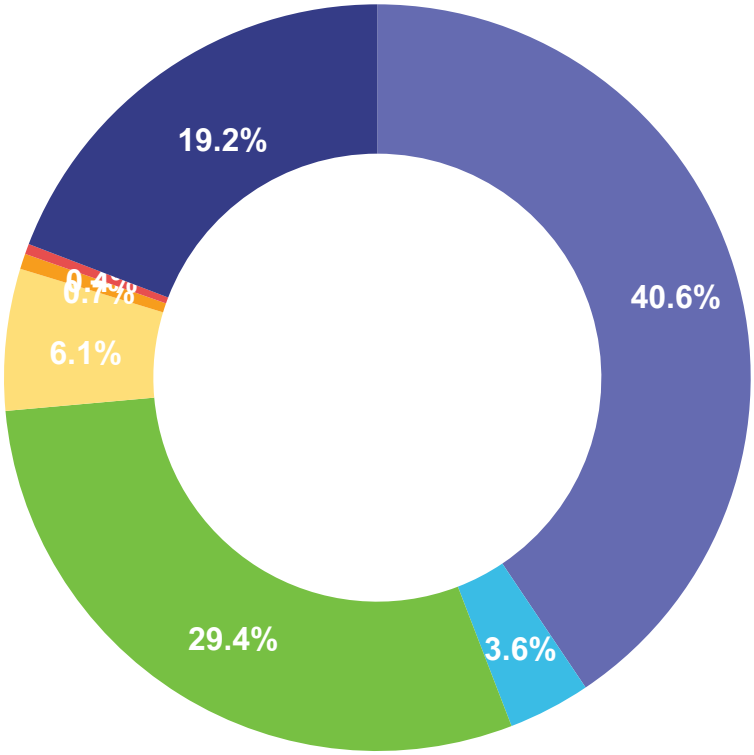
Unanswered
149

Choice	Total
Straight from the tap	139
Through a water filter	400
After it has been chilled	62
Many different ways / not important to me	60
After it has been boiled	106

Q4

MULTIPLE CHOICE

If you don’t drink tap water, why not?



Answered
897

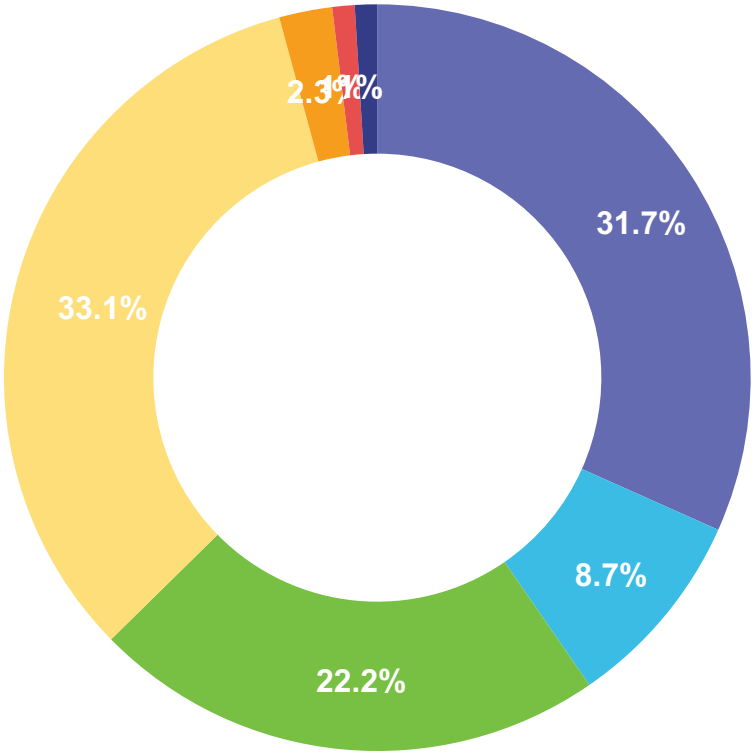
Unanswered
19

Choice	Total
Do not think it’s safe	364
Do not think it’s pure	32
Don’t like the taste of tap water	264
Don’t like the smell of tap water	55
Prefer flavored water	6
Not a water drinker	4
N/A	172

Q5

MULTIPLE CHOICE

If you drink bottled water, why?



Answered
827

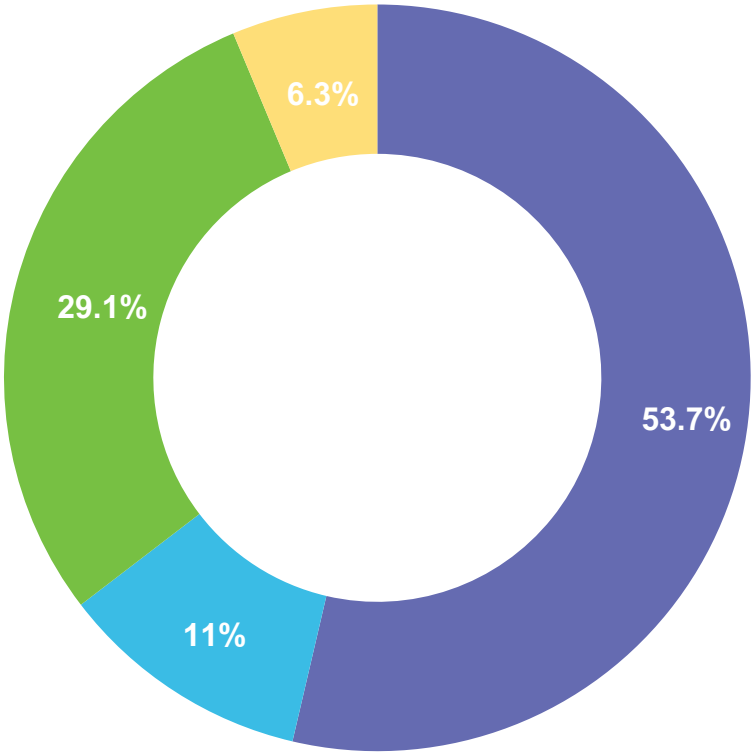
Unanswered
89

Choice	Total
Better taste	262
Convenience	72
Better quality	184
Safer/heathier for children in home	274
Prefer flavored water	19
Prefer sparkling water	8
Habit	8

Q6

When not at home (work, friends, restaurants etc.), how do you consume water?

MULTIPLE CHOICE



Answered
904

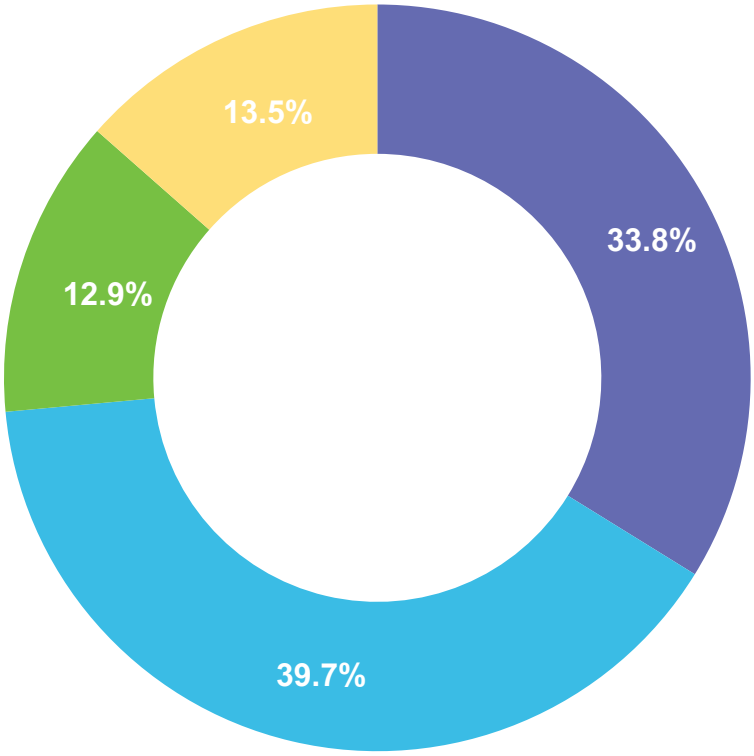
Unanswered
12

Choice	Total
I drink bottled water only	485
I drink tap water only	99
I buy and drink bottled water and tap water	263
I don’t know	57

Q7

How would you like to receive information regarding the City of Adrian's water?

MULTIPLE CHOICE



Answered
895

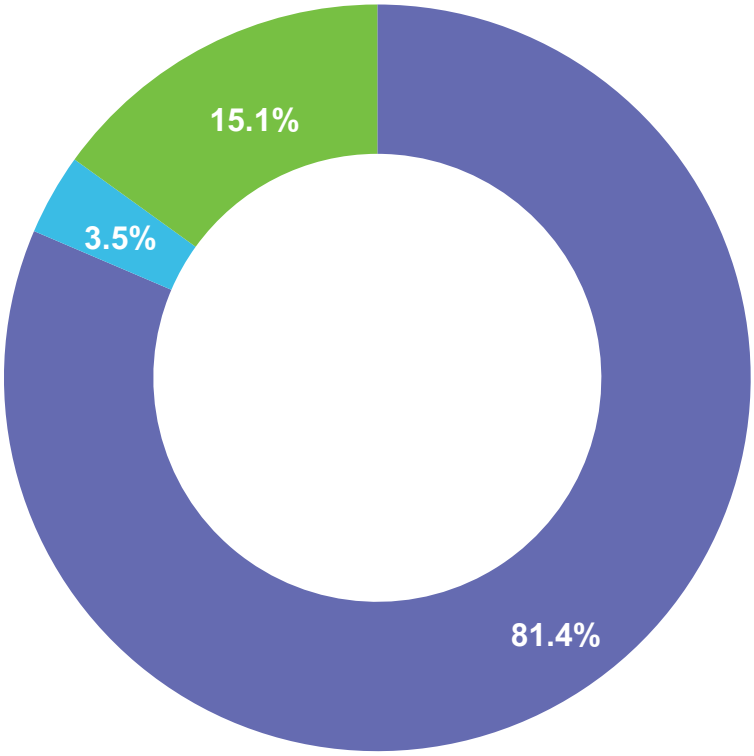
Unanswered
21

Choice	Total
Press releases	303
Facebook posts	356
City of Adrian website	116
Other	121

Q8

If you could improve one thing about the City of Adrian water, what would it be?

MULTIPLE CHOICE



Answered
910

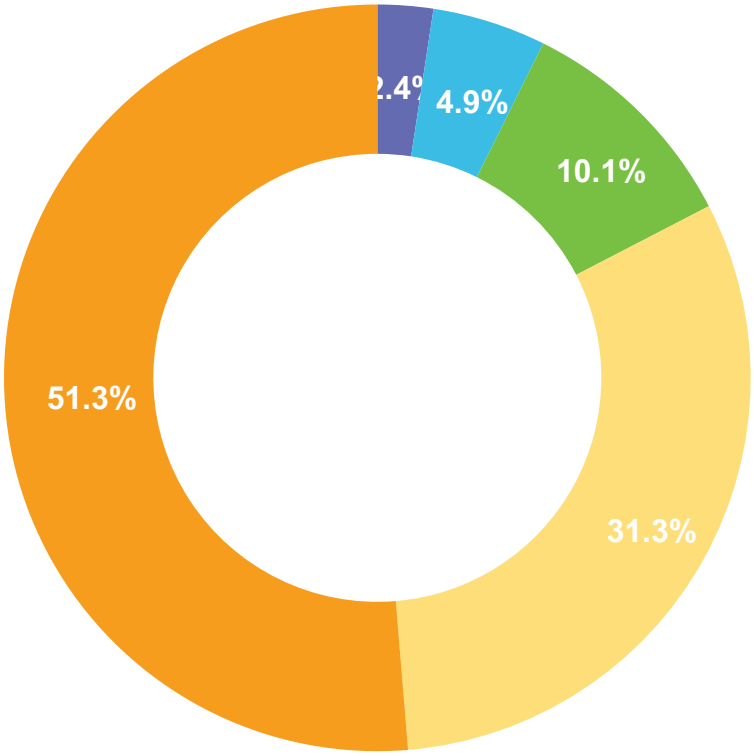
Unanswered
6

Choice	Total
Improve water quality	741
Nothing, no improvement needed	32
Other	137

Q9

How satisfied are you overall with the City of Adrian water supply?

MULTIPLE CHOICE



Answered
914

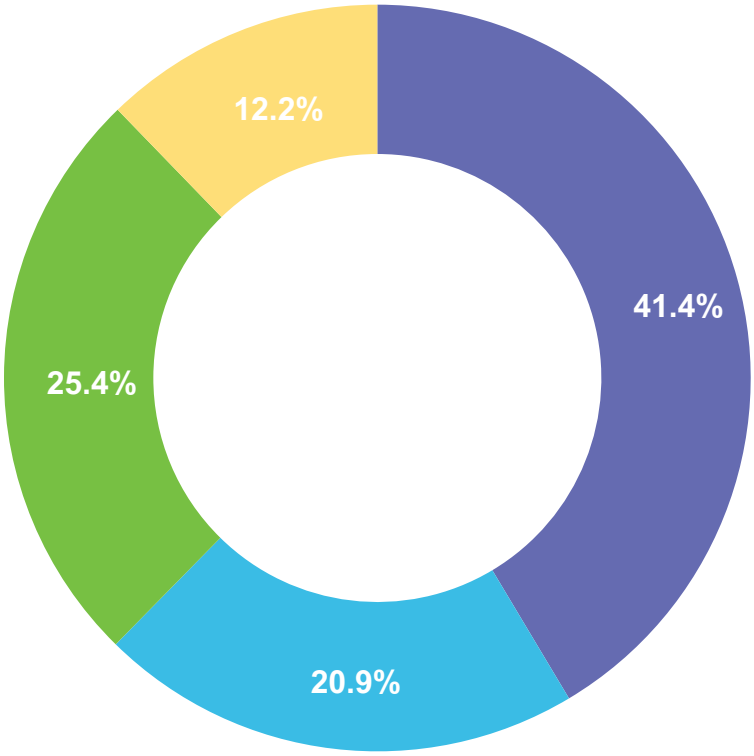
Unanswered
2

Choice	Total
Very satisfied	22
Satisfied	45
Average/fine	92
Dissatisfied	286
Very dissatisfied	469

Q10

If dissatisfied, and a capital project was needed to improve your water, how much more would you be willing to spend?

MULTIPLE CHOICE



Answered
874

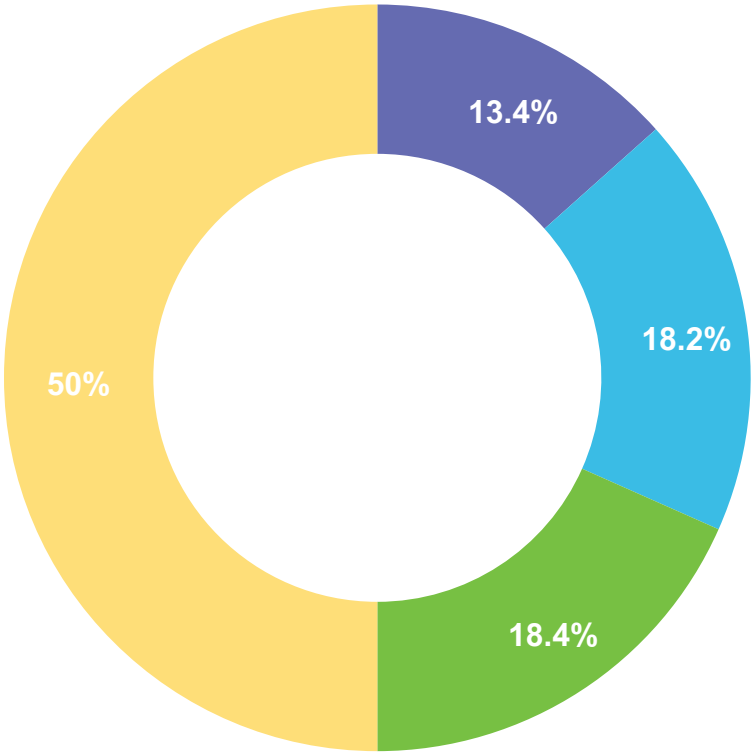
Unanswered
42

Choice	Total
I do not want to see my water bill increased/affected	362
Less than $5/month	183
$ 5-10/month	222
$10-15/month	107

Q12

How long have you been a consumer of Adrian's drinking water?

MULTIPLE CHOICE



Answered
910

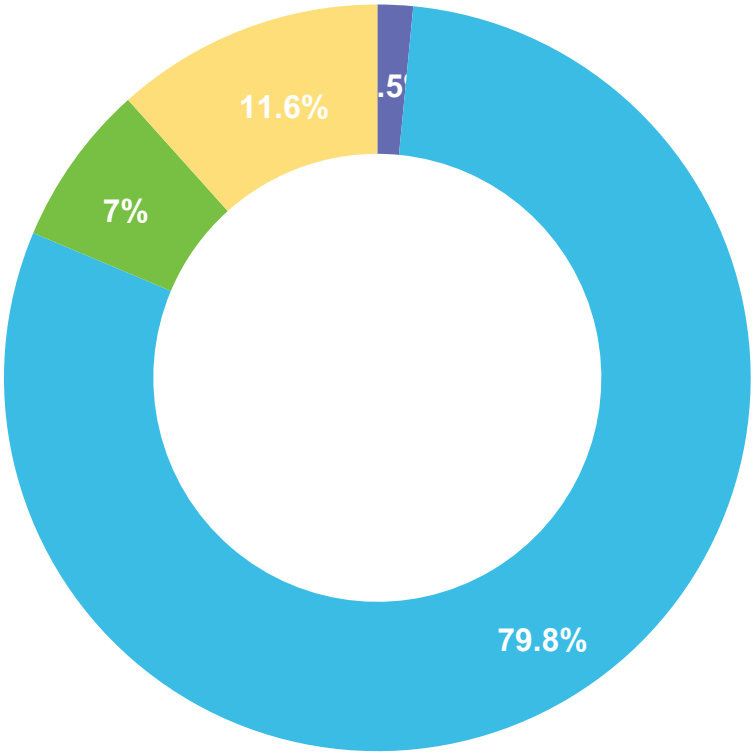
Unanswered
6

Choice	Total
0 to 3 years	122
4 to 10 years	166
11 to 20 years	167
More than 20 years	455

Q13

How did Adrian's drinking water quality in 2018 compare to previous years?

MULTIPLE CHOICE



Answered
911

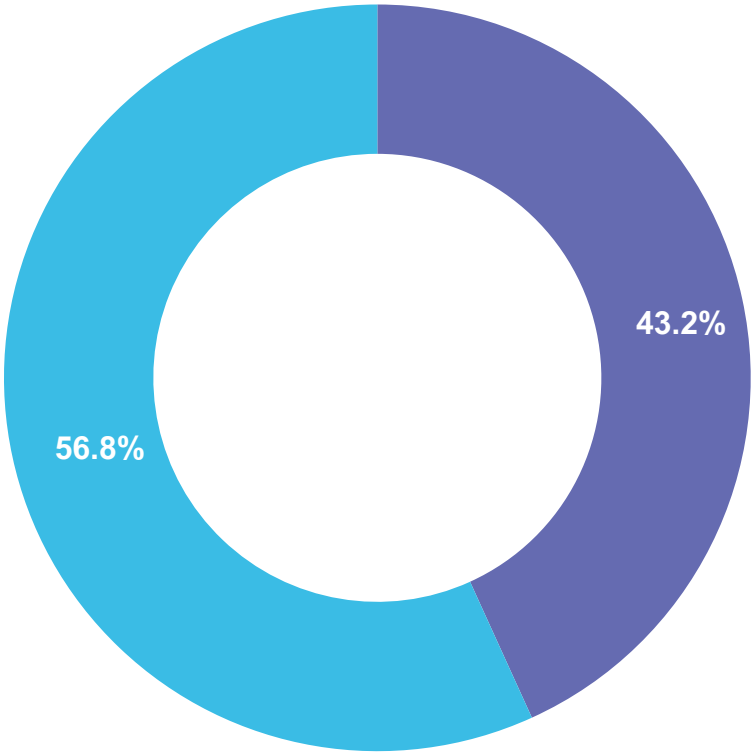
Unanswered
5

Choice	Total
2018 was better than previous years	14
2018 was worse than previous years	727
2018 compared similarly to previous years	64
I'm not sure	106

Q16

Please confirm that you're a resident of the City of Adrian, Michigan*

MULTIPLE CHOICE



Answered
655

Unanswered
261

Choice	Total
Yes, I live/rent in Adrian	283
Yes, I live/am a homeowner in Adrian	372

TETRA TECH

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