

November 12, 2018

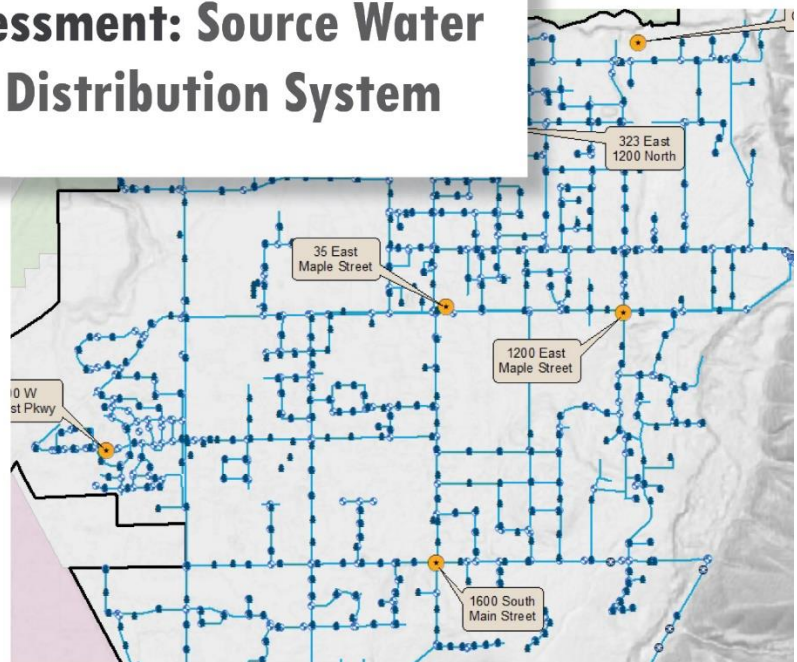


Risk-Based Water Quality Assessment: Source Water and Distribution System

Prepared for:

MAPLETON CITY

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Prepared by:



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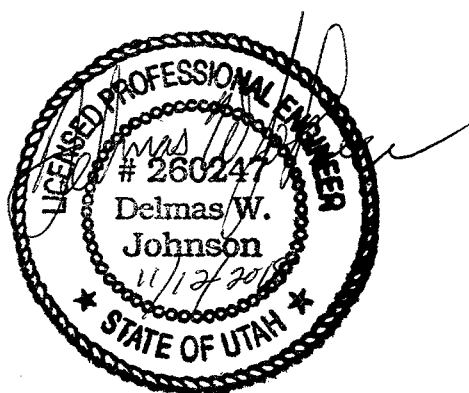


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Prepared by: J-U-B Engineers, Inc



Submitted to: Mapleton City, UT

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List of Acronyms

GDB:	geo-database
GIS:	Geographic Information System
H ₂ S:	Hydrogen Sulfide
MCL:	Maximum Contaminant Level
mg/L:	Milligram per liter
ppm:	Parts Per Million
SCADA:	Supervisory Control and Data Acquisition
TDS:	Total Dissolved Solids
Mgal:	Million Gallons
O&M:	Operation and Maintenance
BMP:	Best Management Practices
ERC:	Equivalent Residential Connections
UDF:	Uni-Directional Flushing
Fe:	Iron
Mn:	Manganese
SO ₄ :	Sulfate
RO:	Reverse Osmosis

1 Introduction & Background

1.1 Background

In decades past, Mapleton City has provided drinking water to its residents from spring collection areas in Maple Canyon. Historically, the water provided by the springs was provided at a low cost with superior water quality. As Mapleton has experienced growth, increasing drinking water system demands has required the addition of new sources of water. Existing wells were purchased, retrofitted to drinking water standards and incorporated as additional sources. Over the years, new wells have also been constructed. These wells were initially used to meet peak seasonal demands. As growth and increased demand continues, reliance upon the Carnesecca, Seal, Westwood and Crowd Canyon wells has resulted in increased withdrawals with longer pumping periods and increased drawdown in the wells. Mapleton's heavier reliance upon these wells appears to correlate with increased concerns of drinking water quality.

1.2 Scope of Professional Services

J-U-B's professional services have provided a system-wide analysis of source and distribution system water quality and provide recommendations for improvements according to the following phases of approach:

- PHASE 1 – Perform water quality testing and identify issues.
- PHASE 2 – Identify solution alternatives and make recommendations.

The scope of work for each phase was included in the submitted response to Request for Qualifications and is included below for reference.

PHASE 1 – Perform water quality testing and identify water quality issues.

100. Project Coordination & Field Visits.

Purpose: Coordinate with the City and conduct field visits after finalizing the scope and executing the contract.

101. Review Water Master Plan & Source Protection Documents for Source Water Determination.

Purpose: Gather source water determination data from the 2016 Culinary Master Plan and 2018 Water Resources master plan and source protection documents, provided by the City; determine whether additional work is required.

102. Collection and Laboratory Analysis of Water Quality Samples.

Purpose: The intent for Task 102 is to help Mapleton City understand the quality of water produced by their wells and springs. As part of Task 102, we will (1) compile existing water quality data from Mapleton City, the DDW, and other sources, (2) review data and identify issues related to water quality that require further investigation, (3) develop and implement a plan to sample wells and springs and conduct laboratory analyses to better understand water quality, and (4) combine existing and new water quality data into tables that can be integrated into a GIS database. On a preliminary basis, our plan will likely

include analysis of samples from selected wells and springs for iron and sulfur reducing bacteria, constituents of energetic materials (CEMs), nitrate and nitrite, iron and other trace metals, sulfate and other major ions, and other constituents.

103. Interpretation of Water Quality Analytical Results

Purpose: The intent for Task 103 is to help Mapleton City review and interpret the water quality data obtained as part of Task 102. We will (1) conduct a Quality Assurance/Quality Control (QA/QC) review of the analytical data, (2) compare reported concentrations of DDW-regulated constituents to the Primary and Secondary Drinking Water Standards outlined in Utah Administrative Code (UAC) R309-200, (3) compare reported concentrations of non-DDW regulated constituents to other existing and proposed Maximum Contaminant Limits (MCLs), (4) assess and identify sources of problems with aesthetic qualities such as taste, odor, and color quality, and (5) identify and assess any changes or trends in water quality that may have occurred.

104. Evaluation of Crowd Canyon Well

Purpose: The intent for Task 104 is to identify, evaluate, and recommend actions to address scaling, water quality, and other issues associated with the Crowd Canyon Well. As part of Task 104, we will compile and review well construction, geologic, water quality, yield, production, water level, and other data for the well, (2) if necessary, recommend a course of action for further investigation, such as pulling the pump, brushing and bailing, collecting and analyzing samples of scale and water quality, and other actions such as chemical treatment, (3) identify and assess the causes of scaling, water quality, and other issues associated with the well, and (4) provide recommendations for operational changes, such as reduction in pumping rate if necessary to remediate scaling, water quality, and/or other issues associated with the well.

105. Water Condition Statement

Purpose: Provide an engineering assessment of water quality risks.

106. Memorandum of Findings (Phase 1)

Purpose: Provide a technical memorandum summary that describes findings, assumptions, and background to interpret GIS (metadata); GIS data is preferred over paper maps.

PHASE 2 – Identify solution alternatives and make recommendations.

200. Alternatives Analysis & Risk Assessment Workshop

Purpose: Develop an array of alternatives to address the water quality issues identified in Phase 1 and work with the City to identify preferred alternatives.

201. Memorandum of Findings (Phase 2)

Purpose: provide a technical memorandum summary that describes findings, assumptions, and background to interpret GIS (metadata); GIS data is preferred over paper maps.

1.3 Water Quality Risks

There are two types of risk that pertain to Mapleton's water quality. First there is risk associated with impact to a consumer's health. Providing safe drinking water is an essential practice to Mapleton City as a service provider and mandated by the federal Safe Drinking Water Act and associated Utah state law. Drinking water is monitored for health-related chemical constituents, both organic and inorganic, biological constituents and radiological parameters. Those constituents that are required by State drinking water rules to be sampled and reported have defined MCL's (maximum contaminant levels). The constituents required to be sampled and monitored have been established through epidemiological studies to create risk of health impairment when consumed. Biological constituents can be harmful with one-time ingestion, whereas other chemical and radiological constituents create health risks with continuous consumption over a duration of time. Mapleton City has been and continues to sample and monitor those constituents required by law. The results are reported annually in a system consumer confidence report.

A secondary or alternate risk is one associated with water aesthetics and may or may not correlate with health-related risks as previously outlined. Aesthetic risk is created by public perception of taste, odor and color of the provided drinking water to each water service connection. In some circumstances, observed taste, odor and color may be indications of other water quality concerns that could correlate to health-related risk. As the City monitors all required MCL's to ensure compliance, health-related risk can be substantially reduced or eliminated. The risk created by the presence of objectionable tastes, odors and color is a loss of confidence by consumers in the drinking water being provided. Because this aesthetic risk is important to consumers, it is prudent for a public water system to address these concerns where practicable. While not required for system compliance, this aesthetic risk of taste, odor and color can undermine the consumer confidence in providing a drinking water supply that is safe and healthy.

The American Water Works Association (AWWA, 2017) identifies a water system's responsibility to address taste, odor and appearance issues as two levels of service as outlined in M68, Manual of Water Supply Practices – *Water Quality in Distribution Systems*. First is a basic level of service, where all water systems perform this action as part of standard practice for addressing an aesthetic issue. Second, is an advanced level of service for water systems with persistent taste, odor and appearance issues that may need to perform this action, which is beyond standard practice. Figure 5-1 and Table 5-7 from the M68 manual are included in Appendix A – Excerpts of M68 Water Quality in Distribution Systems.

1.4 Mapleton City Demographics

The city of Mapleton is reported to have an estimated population of 10,000 according to the 2018 Mapleton City Water Resources Plan document. The same document reports predictions that the population will reach a buildout capacity of 29,000 residents by 2061. Figure 1 shows the estimated demographics by sex and age.

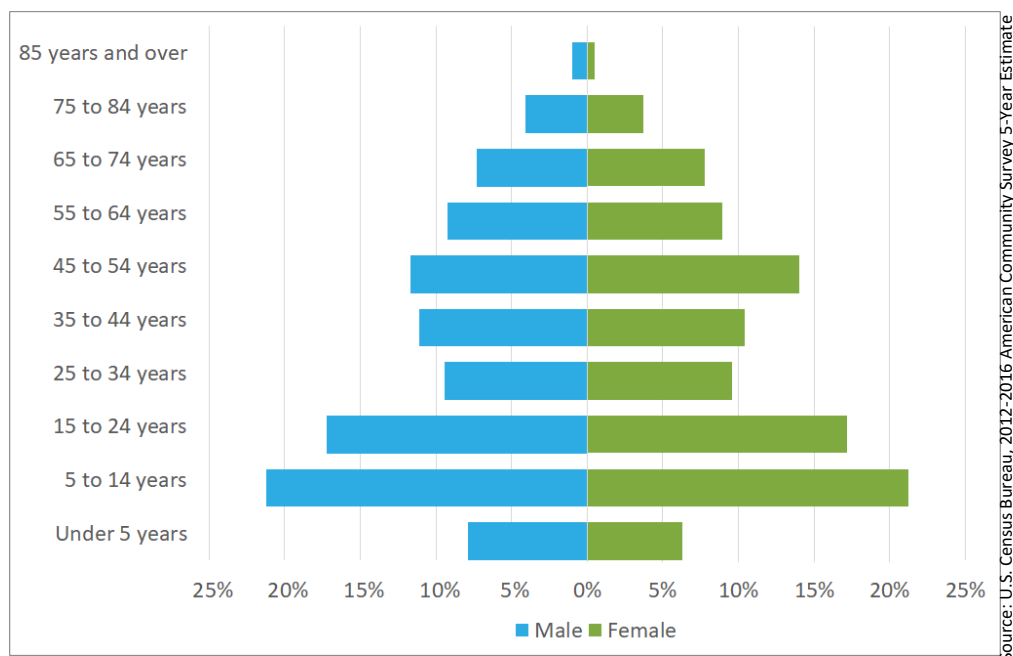


Figure 1: Age Demographics for Mapleton City by Sex.

2 Mapleton Drinking Water System

The 2018 Mapleton City Water Resources Plan document reported having a total of 2,610 culinary water connections equating to 2,714 equivalent residential connections (ERC). The City has also been reported to have a peak day demand of 3,040 gpm and a peak instantaneous demand of 6,080 gpm. Of the 2,610 connections, 1,210 also have access to a secondary water source and do not use the culinary water system for outdoor/irrigation uses. Over time, the city plans to reduce the number of connections using drinking or culinary water for outdoor/irrigation uses.

The 2016 Culinary Master Plan calculated the total water storage capacity required to be 3.74 million gallons (Mgal) of water in 2016 with a total buildout capacity of 7.68 Mgal. The 2018 Water Resources Master Plan calculated a greater water storage capacity due to more outdoor storage requirements for domestic irrigation. Thus, the 2018 total water storage capacity is estimated to be 5.36 million gallons (Mgal) of water currently with a total buildout capacity of 7.50 Mgal.

2.1 Description of the Drinking Water System

There is a total of five storage tanks connected to the Mapleton city culinary system. As reported in the Water Resources Plan from 2018, the combined system storage within the culinary system of these tanks was calculated to be 9.5 million gallons (Mgal) of water with an additional 1.3 Mgal storage in the distribution piping. The system also includes three pressure zones separated by pressure reducing valves and/or closed valves.

The culinary system for the city of Mapleton receives drinking water from different sources. These include springs and wells. There are currently 4 wells supplying drinking water to the city’s culinary system, the locations of which are shown in Figure 2.

- Carnesecca Well
- Seal Well
- Westwood Well
- Crowd Canyon Well

These wells are currently operated on an “as needed” basis and supply most to meet system demands from water users. Table 1 shows the minimum reliable flow expected for each well. The springs are a primary source and are used on a continuous basis with yields varying seasonally and annually as impacted by precipitation and recent snow-packs.

Table 1: Minimum Reliable Flow for Source Wells.

Minimum Reliable Flow (GPM) ^(A)	
Carnesecca Well	1000
Seal Well	1650
Westwood Well	1800
Crowd Canyon Well	1750

(A) Source: (RB&G, 2018)

2.2 Description of the Hydrogeology

The hydrogeology of the Mapleton City region has been studied and a summary of the hydrogeologic properties can be seen for each well in Table 2. For more information about the hydrogeology of the region near each well, refer to the individual drinking water source protection plans listed in the references at the end of this report. These same resources can also be used to gather more information on the well construction such as total depths, depth to screen, and diameters. A summary of these details is also included in the Phase 1 Technical Memo prepared by J-U-B Engineers, which can be found in Appendix B – Technical Memo. For additional information on the hydrogeology of the area, refer to the Loughlin Water Associates report.

3 Approach

J-U-B Engineers approach to this analysis was to perform water quality testing and identify potential water quality issues. This approach included reviewing existing master plans and source protection documents, performing water quality tests, interpreting the water quality results, summarizing the findings in a technical memorandum, holding a workshop to discuss and address the issues discovered, and then summarizing the issues and recommendations in a final report (this report).

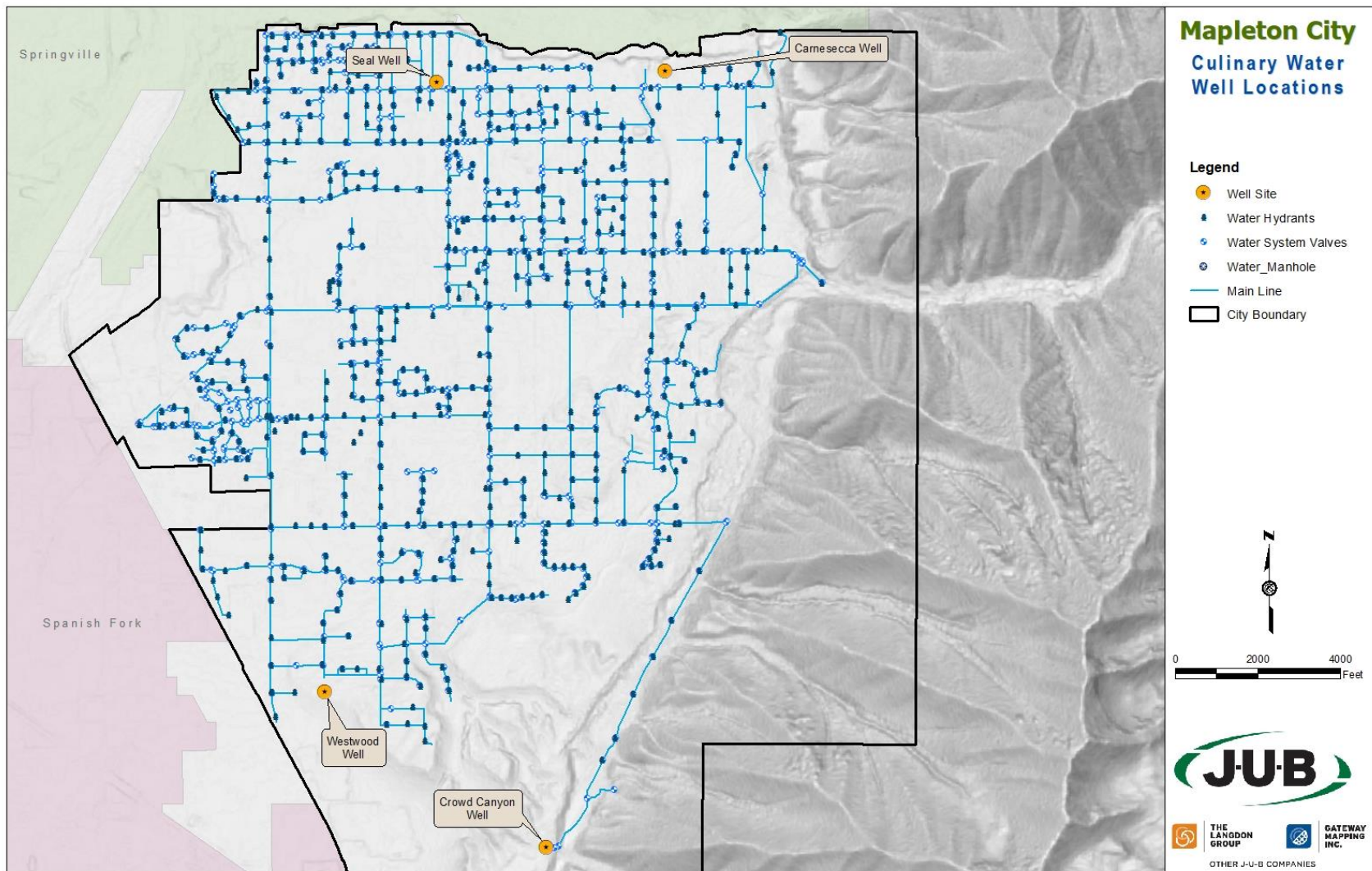


Figure 2: Mapleton City Drinking Water Well Locations.

Table 2: Summary of Hydrogeologic Properties listed for Mapleton City Culinary Wells.

	Seal Well	Carnesecca Well	Westwood Well	Crowd Canyon Well	Springs
	Aquifer Properties (A)				
Aquifer	deep Pleistocene alluvial artesian aquifer	deep Pleistocene alluvial artesian aquifer	Tertiary artesian aquifer and/or deep Pleistocene alluvial artesian aquifer	fractured bedrock of the Oquirrh Formation (carbonate aquifer)	fractured shallow bedrock of the Oquirrh Formation, east and above the Wasatch Fault
Geology	Aquifer consists of unconsolidated basin-fill deposits, protected due to clay	Aquifer consists of unconsolidated basin-fill deposits, protected due to clay	Aquifer consists of unconsolidated deposits, protected due to clay	Aquifer consists of fractured bedrock, unprotected due to absence of clay; Wasatch Fault Zone; high groundwater volume; loss of drilling fluids during construction	Unprotected water movement through cracks, seams, fractures, channels, and other openings in the bedrock formation (quartzitic limestone and sandstone)
Flow Direction	E, SE to W, NW	ESE to WNW	SE to NW	N60°W	
Reliable Flow (B)	1650 gpm	1000 gpm	1800 gpm	1750 gpm	Varies
	Recharge Areas (A)				
Recharge Areas	faults	faults and Hobbie Creek (Potential)	faults; perennial streams, mountain watershed, subsurface inflow from consolidated rock; superficial infiltration	faults (water pathways direct flow from Spanish Fork Canyon and bedrock)	faults and snow melt

(A) Data from Drinking Water Source Protection Plans (2005-2013)

(B) Data from Mapleton City Water Resources Master Plan (2018)

For the water quality laboratory tests, J-U-B partnered with Loughlin Water Associates who conducted the assessments by sampling several distribution system locations, including the groundwater source wells, for any parameters exceeding the recommended levels for safe drinking water. Loughlin Water Associates was included on the team of experts because of their experience and history with the EBCo contaminant groundwater plume which is south of the City's drinking water sources. The assessment report prepared by Loughlin Water Associates can be found in Appendix C – Loughlin Report. The results were compiled and delivered to the city in the form of a technical memo that was prepared by J-U-B Engineers which can be found in Appendix B – Technical Memo. These writeups show that the water quality in the Mapleton City drinking water system is good, and that consumption of the drinking water does not pose a health risk based on the conducted testing results.

3.1 Water Quality Assessment

The water quality assessment that was performed by Loughlin Water Associates aimed to help Mapleton City and J-U-B better understand the quality of water produced from the connecting wells and water

present in the distribution system. As part of the assessment, Loughlin Water Associates performed the following:

- compiled existing water quality data
- reviewed the data to identify any issues that would merit further investigation
- prepared and implemented additional sampling at selected locations
- combined the old and new data into tables that can be integrated into a GIS database

For the assessment, samples were taken from various locations in the distribution system, including at each well. All sample locations are displayed in Figure 3. The samples were tested for any violations to the Primary Drinking Water Standards, or Primary Maximum Contaminant Levels (MCLs) and evaluated against the Secondary Drinking Water Standards, or Secondary MCLs (SMCLs). Most of the samples were taken on March 05, 2018, but the seal well and a second sample of the Westwood well was taken on May 25, 2018. All of the samples that were taken and analyzed represent a specific window of time with the water conditions at that moment in time. The City continues to monitor water quality to track and log water quality conditions through time, as well as to detect any violation of the MCLs if they were to occur. For more information on the sampling and testing of the samples, see the report prepared by Loughlin Water Associates (2018).

3.2 Review of Current Water Quality Standards

MCLs are drinking water standards described as the “maximum permissible level of a contaminant in water that is delivered to any user of a public water system”. These are established to maintain human health. Proven exceedance of these standards in any part of the system would cause the water distribution system to be out of compliance with drinking water rules with potential violations that might cause the water source to be out of service. Likewise, if exceedance of an MCL standard is found somewhere in the distribution system, residents would be advised not to consume the water until the standards are once again in compliance.

SMCLs are standards described to “affect the aesthetic quality of drinking water” or in other words the taste, odor, and color of the water. The exceedance of these standards can bring about unpleasant effects related to taste, odor, and color of the drinking water, however consuming water that has exceeded the SMCLs (without exceeding the MCLs) does not pose a known health risk to the consumer.

3.3 Provide Recommendations

With review of the current water quality conditions and applicable standards, the results were reviewed to provide the City with operations and maintenance strategies and recommended Capital Improvements that are thought to accomplish the scope of the study. The recommendations are detailed and prioritized for the City in Section 5 of this report. They also include estimated costs and a rank for the expected level of effectiveness at reducing water quality risk to Mapleton City.

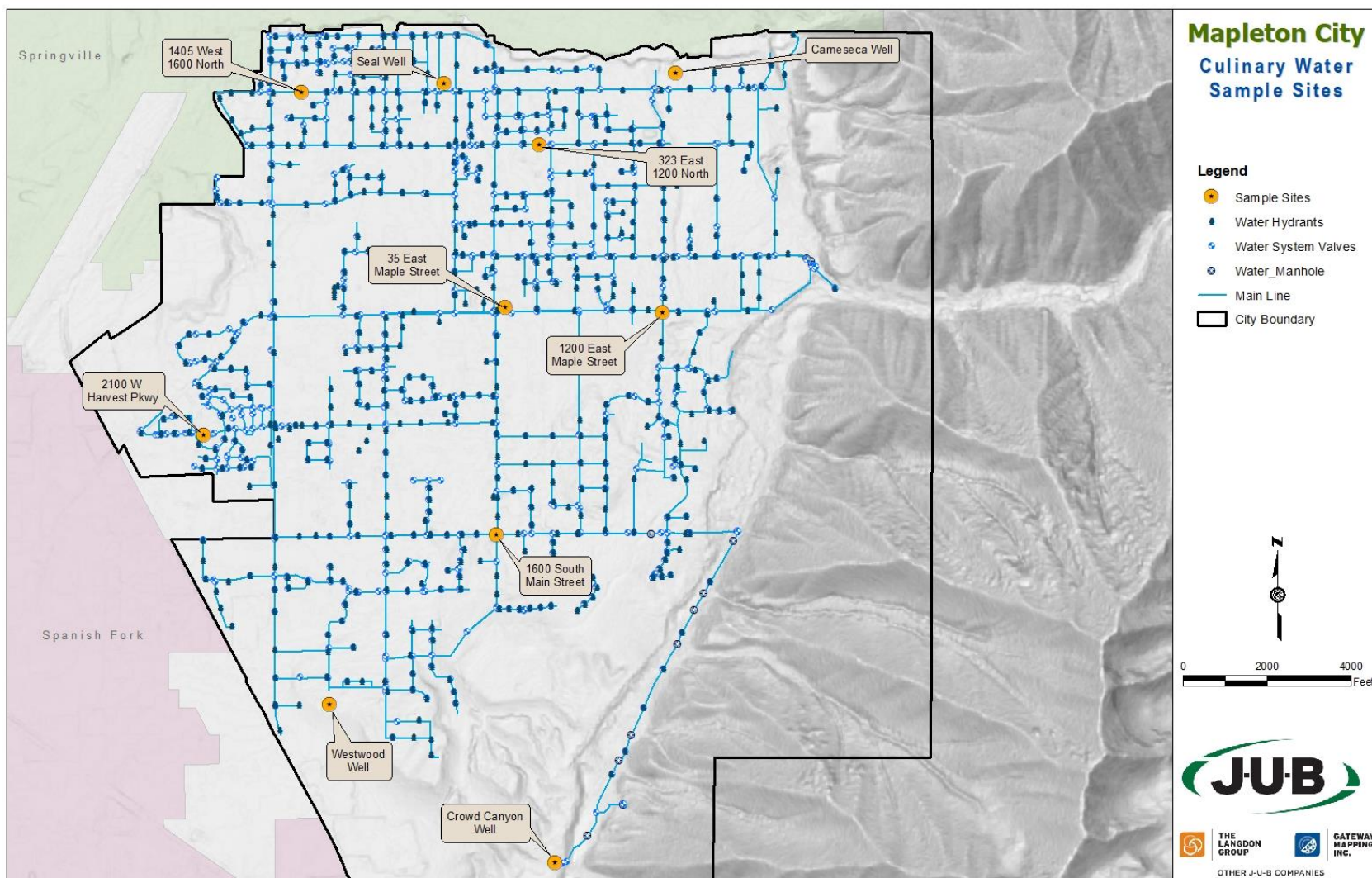


Figure 3: Culinary Water Sample Sites.

4 Results

The results from the water quality assessment provide information that the quality of water found in the culinary system is of good quality having no parameters exceeding the established MCL standards.

Areas of interest relating to taste, color and odor, were identified by the testing that could be improved to overall enhance the water quality aesthetics found in the Mapleton drinking water system. These include sulfide odors in the Crowd Canyon Well. Two locations were shown to have exceeded the SMCL levels for Manganese and approaching the SMCL levels for TDS (total dissolved solids) concentrations. These locations were located at the Westwood Well and 1600 S and Main locations.

4.1 Water Quality Analysis

A summary of the results can be seen in Table 3. Note the MCL and SMCL limits for each parameter that have been provided in the table, where they exist. None of the water quality parameters exceed or approach the enforceable MCL limits, confirming that there is no perceived health risk based on the sampling. Aside from the fact that the quality of the water is good there are a few areas of interest that the City should address to further improve the quality of water that is delivered to the residents of Mapleton. These include sulfide odors indicating the minor presence of sulfides in the Crowd Canyon Well and total dissolved solids and manganese results for the Westwood Well.

4.1.1 Crowd Canyon Well Sulfides

Despite no detection of total sulfides above 0.1 mg/L in the aquifer, hydrogen sulfide odors have been detected at the Crowd Canyon Well head. Hydrogen sulfide is characterized by a “rotten egg” smell and can be concerning for water consumers. The minimum reporting limit for hydrogen sulfide is 0.1 mg/L, however, odors can begin to be detected with as little as 0.02 mg/L. Although the small presence of hydrogen sulfide does not pose any risk to consumers the city has sought, and continues to seek, a solution to eliminate it. Previous efforts to remediate the odor have included shock chlorination, mechanical brushing, and partial plugging of the Crowd Canyon Well casing. See the subsequent sections of this report for proposed solutions to eliminating the hydrogen sulfide, manganese, and TDS concerns.

4.1.2 Westwood Well Total Dissolved Solids (TDS) & Manganese

In Table 3, there are two locations (1600 S Main and Westwood Well) which exceed the recommended SMCL limit for Manganese. The same two locations also begin to approach the SMCL limit for TDS. As these are SMCL limits, this means that the aesthetic quality or perceived water quality can be affected, namely taste, odor, and color of the water. However, health risks have not been determined to be associated with exceeding the SMCL limits. Undesirable effects of higher manganese concentrations could include brown tinted water and black or brown staining. Undesirable effects of higher TDS values could include corrosion; or a mineral taste to the water. For additional information on parameters effecting taste, odor, and color, including potential solutions, see the Phase 1 Technical Memo prepared by J-U-B Engineers. Solutions for reducing the manganese and TDS can be found in subsequent report sections.

4.2 Public Perception

Mapleton city has received complaints over the years regarding the quality of supplied drinking water. These complaints have likely been related to the two areas of interest presented in the previous report sections. As mentioned, each of the areas of interest that have been discovered can have a direct effect on the perception of water quality, such as unpleasant odors from low concentrations of hydrogen sulfide, coloration of the water from the manganese, and mineral tastes from the TDS. The perception based on taste, color, and odor, however, should not outweigh the reality that the water is of good quality and poses no known risk to consumer health (Figure 4.)

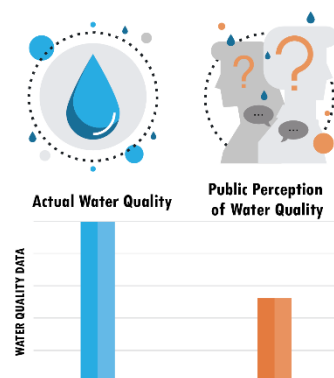


Figure 4: Actual Water Quality vs. Perception of Water Quality.

5 Recommendations

The recommendations presented in this section each have two rankings assigned. One rank is the level of cost and the other is the level of effectiveness at reducing water quality risk. The rankings are assigned by the symbols to the right (Figure 5.)

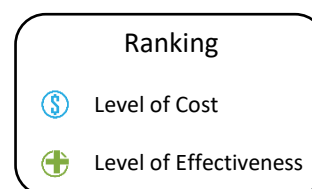


Figure 5: Ranking Legend.

The more the number of cost ranking symbols or effectiveness ranking symbols the higher the cost or the more impactful the effectiveness of the recommendation at reducing risk, respectively.

After reviewing all the water quality test results and after holding workgroups with the City, it became apparent that there is a disconnect between the good water chemistry results coming from the wells and the perception of unsatisfactory water being delivered to some customer's taps which have resulted in taste, color, and odor complaints. The water quality results alone were not able to pinpoint a specific source contributing to the perceived water quality issues. Therefore, a holistic approach is recommended to address this issue. These strategies consist of:

- GIS-Based Approach to Documenting Reported Water Quality Concerns in Space and Time and Logging and Recording of Key Water System Parameters from SCADA
- Operation & Maintenance (O&M) Best Management Practices
- Water Treatment Strategies

First, a GIS-Based System is recommended as a decision making and communication tool. GIS data will help the City identify the source(s) contributing to taste, odor, and color as well as document reported concerns from residents. A fully-functional GIS system integrated with Supervisory Control and Data Acquisition (SCADA) logging will help the City monitor and report issues and provide a framework for future analysis of water quality sampling results.

Second, O&M (Operations and Maintenance) best management practices (BMPs) are recommended to physically improve the water aesthetics in the storage and distribution systems. BMPs for tank turnover frequency and main flushing are necessary since water quality coming from the wells can change as it is stored and sent throughout the City's 77 miles of distribution water mains.

Third, water treatment strategies implemented at the respective wells can significantly reduce certain contaminants that can cause taste, color, and odor concerns. These treatment strategies can be as simple as chemical oxidation prior to storage at the Crowd Canyon Well to reduce low levels of H₂S and iron. Or it may require installing a filtration system at the Westwood Well to address manganese levels above the SMCL.

The following sections discuss these three strategies in more detail.

5.1 GIS-Based Approach to Reporting and Logging

A GIS-based approach to manage the drinking water quantity and quality within the city is highly recommended. At this point, the approach is divided into the following categories; i.e. Asset Management, Monitoring and Logging and SCADA Integration. This approach is scalable which will allow additional datasets to be included based on future City needs.

5.1.1 Asset Management

Integrate the current spatial data available at the City to build a city-wide water system geo-database; i.e. Mapleton Water GDB (Figure 6). The current data may come from different sources including, current desktop and online GIS, spreadsheet, CAD, As-built, SCADA, models, system leaks, current staff knowledge, etc. as indicated in Figure 9.

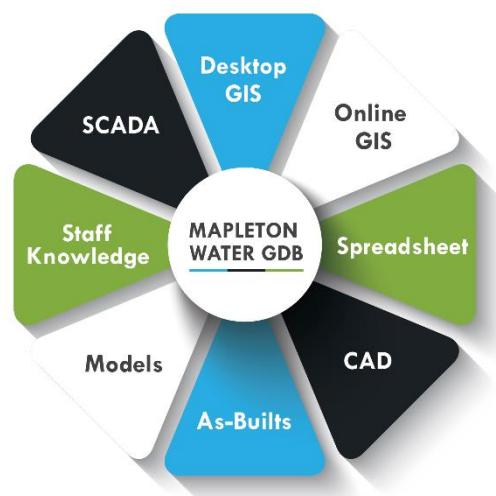


Figure 6: Mapleton Water GDB.

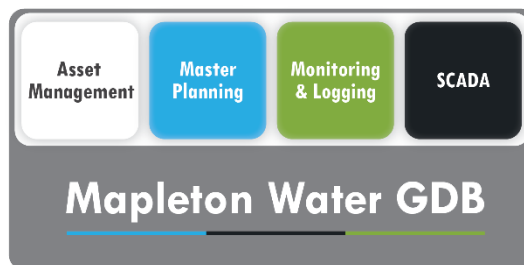


Figure 7: Mapleton Water GDB Integration.

This water geo-database (Mapleton Water GDB) (Figure 6) can serve as a foundation for operation and maintenance, new system improvement, master planning, monitoring and logging, treatment and SCADA integration (Figure 7).

5.1.2 Monitoring and Logging

The next level of the GIS-based approach is to monitor and log water quality complaints historic, current and future water quality sampling of the water infrastructure within the City.



Figure 8: Mapleton Water Quality Portal.

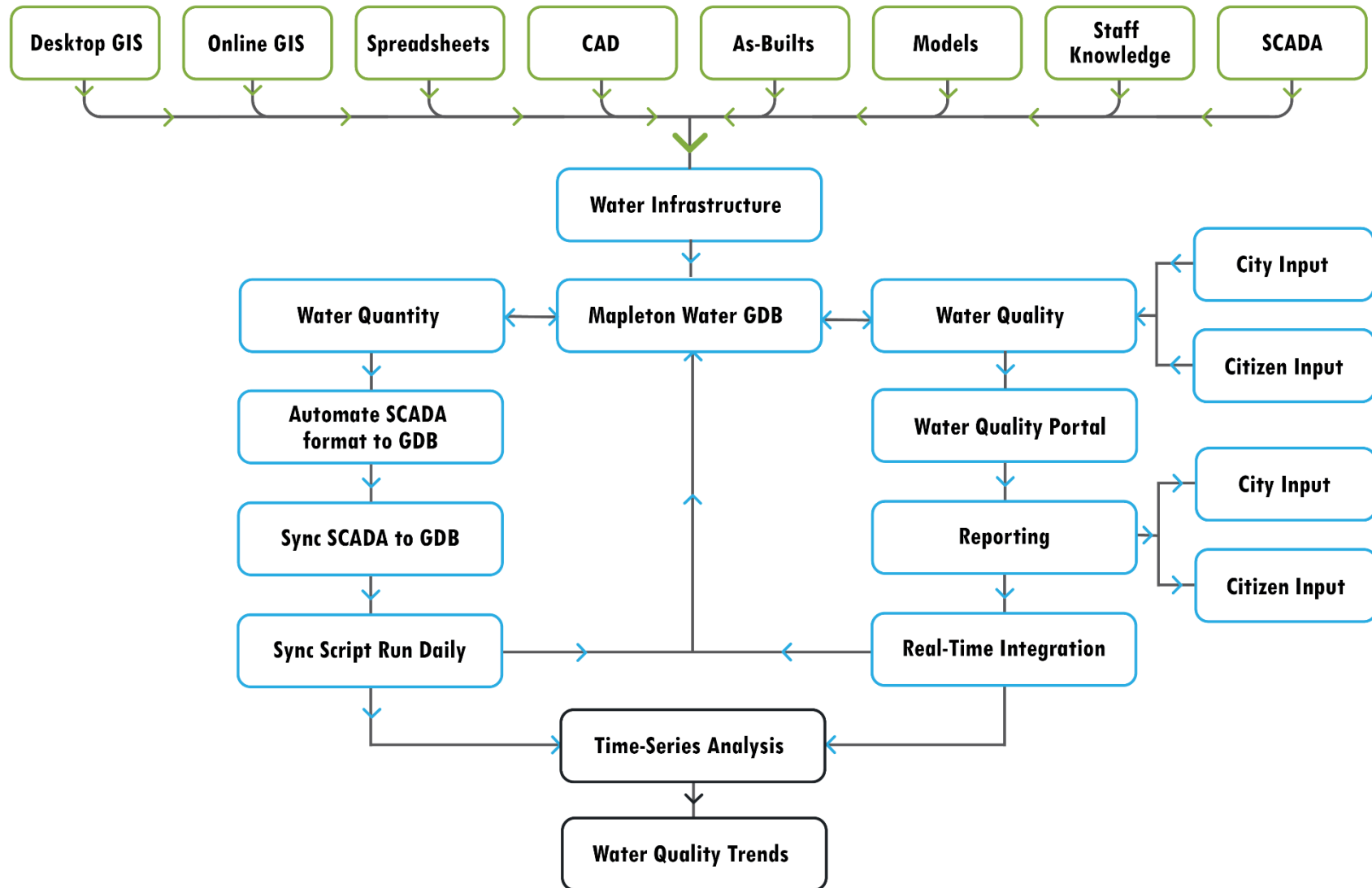


Figure 9: Conceptual System of GIS Data Process Organization.

A web-based GIS portal (Figure 8) is strongly recommended to be a live and interactive tool to house historic monitoring and collect future water quality data as well as citizen complaints using an online form.

To help with the efficient logging of water quality issues, the portal should be available to citizens to use their smart devices and record complaints based on the type; i.e. physical, chemical or biological, complaint, add comments and take pictures and post them to the same point (Figure 9) At the same time, the portal can be used by city staff in case a citizen calls in to report a problem. This way, all complaints are recorded with location and time for future reference.

The portal will allow citizens and city staff to include records following the “Customer Complaint Form” (Appendix D – Sample Online GIS Portal & Customer Complaint Form). All points recorded on the portal will have the form information in a digital data base form for easy and efficient retrieval by city staff in the future. A similar portal, serving a different purpose, was developed for Bluffdale City. The portal is available to citizens to report various problems on different categories, including drinking water, using their smart devices or a computer. The city filters through the submitted incidents and address accordingly before approving content. Unauthorized content is not published back to the public. Sample screen shots from this portal are included in the appendix (Appendix D – Sample Online GIS Portal & Customer Complaint Form) after approval from the City to share for this purpose.

This GIS-based approach can be used to prepare and disseminate annual or quarterly water quality reporting to the consumers. The city should also be able to utilize this portal to:

1. Interactively prepare water quality reports with mapping;
2. Efficiently generate hot-spot mapping of problem areas;
3. Quickly prepare time-series analysis and water quality trends;

The key benefits of the Mapleton City Water System Portal (Figure 10) are:

1. Record historic data – minimize data loss and maximize data integrity;
2. Record location and time – capture the four dimensions of the water quality issue; i.e. X, Y, Z and time (Figure 11);
3. Collect future water quality analysis – help the city determine the frequency of future water quality data collection;
4. Collect citizen water quality complaints – provide a user friendly and live reporting mechanism to citizens to file complaints to the city;
5. Real-time report to City Council – provide City staff a real-time interactive reporting tool to present and discuss;
6. Annually report to citizens – include a map and quick summary report in mailers. This is expected to help bridge the gap between public perception and actual water quality analysis;
7. Based on City available software – no need for third party tools;

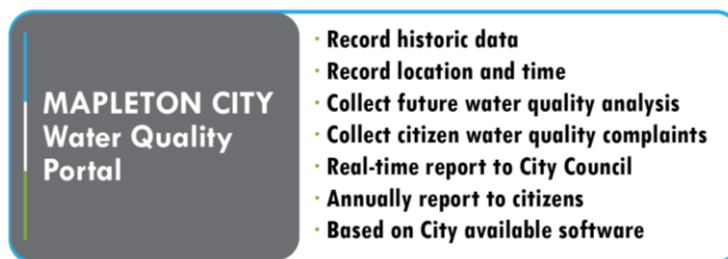


Figure 10: Mapleton Water Quality Portal Benefits.

Figure 9 Shows a conceptual layout of the proposed GIS data process and integration. As shown, multiple data sources are used to compile water infrastructure to the Mapleton Water geo-database. This geo-database houses both, water quantity and quality. Where the water quantity integrates with the SCADA systems available, the water quality integrates with the water quality portal and reporting tools. Both City staff and citizens will be able to add data to the water quality portal. City staff will quality-control the citizen input before it is published back as a communication tool to the citizens. Mapleton City Water GDB will be used to provide time series analysis and water quality trends.

5.1.3 SCADA Integration

The water infrastructure is spatial and tabular in nature. SCADA systems are thus ideally suited to be managed on a GIS-based approach. SCADA systems have two key components; i.e. hardware and software. The hardware component collects the data and the software component handles the on-site data management, logging, transmitting from the remote terminal to a central office server. Depending on the system, transmitting the data to the central server can be:

1. Manual: data to be uploaded from on-site on a mobile drive and copied back to office server
2. Automatic: where data is transmitted in real-time to office or an online server

Similarly, and on the other hand, controlling the on-site equipment can be done from the office using the software tools. This report focuses on the data acquisition since most current SCADA system has some sort of a GIS interface to control the on-site equipment. Irrespective of the transmitting method, integrating the SCADA data with Mapleton Water GDB can be done to maximize integrity of data and keep a running record of future data. Historic records should also be uploaded to the geo-database.

Integrating SCADA includes two key components:

1. Data Acquisition: structuring the geo-database to house and archive the relevant data collected on-site. The geo-database schema should be designed to include the tabular data exported by the SCADA software in an automated or

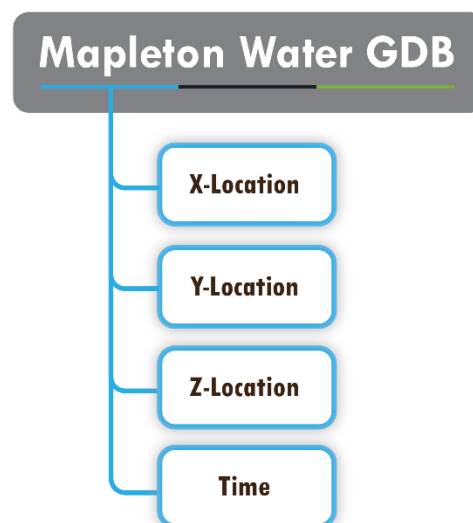


Figure 11: Mapleton Water GDB - 4-Dimensions.

semi-automated approach. Depending on the SCADA data format, a GIS script may need to be developed to convert the format to an import-ready. This script can be run on a preset frequency (i.e. daily, weekly) or on an as-needed basis

- On-site controls: existing SCADA system software tools to manage on-site equipment can be linked to GIS systems. Further detail is beyond the scope of this report.

5.2 O&M Best Management Practices

Water Quality Testing and a GIS-Based System are the first steps to identify where the taste, color, and odor complaints are coming from. Once identified, different O&M or water treatment strategies can be implemented to physically mitigate the problem areas. Figure 12 provides a decision tree for determining which solutions to use for each problem area.

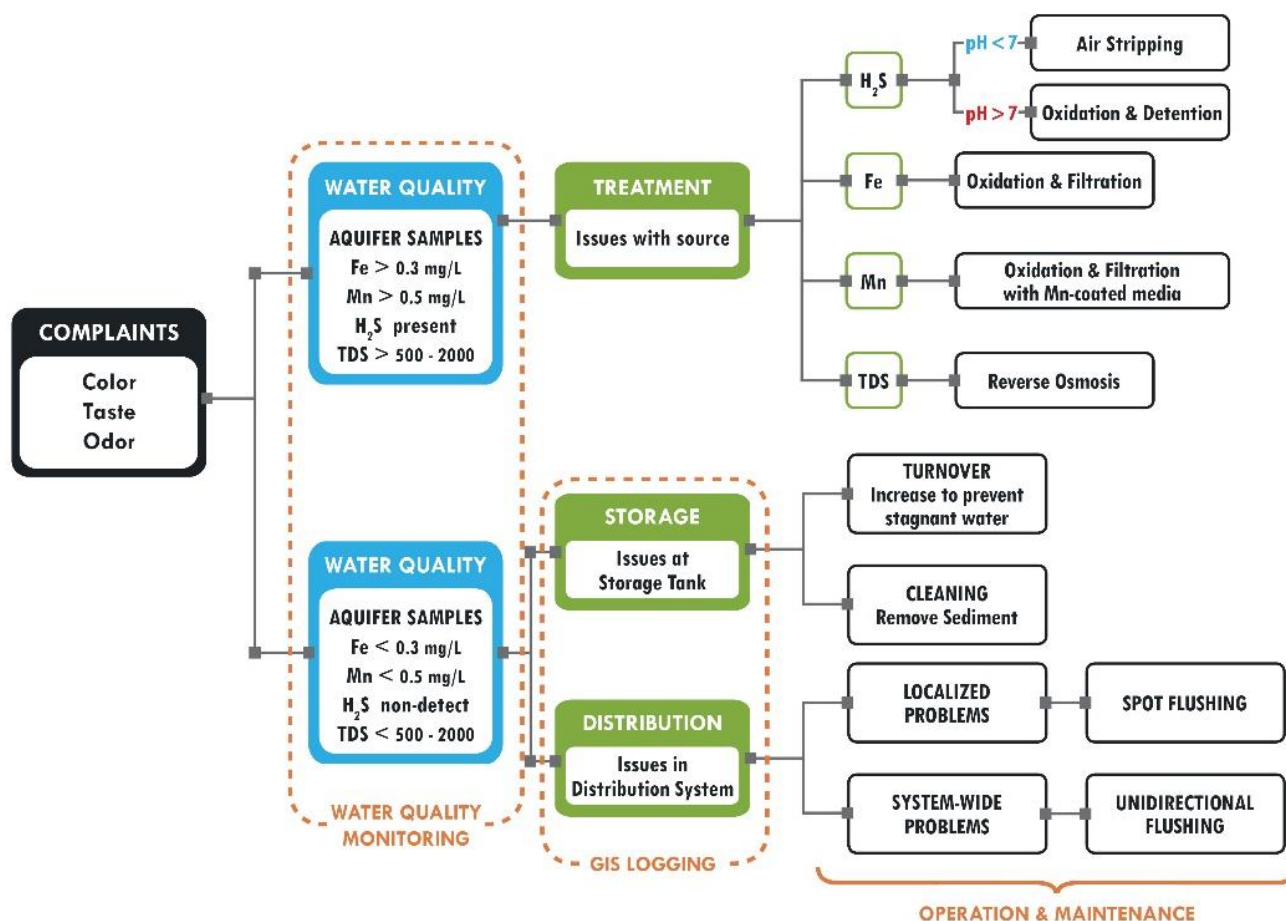


Figure 12: Decision Tree for Determining a Solution to Color, Taste, and Odor Issues.

5.2.1 Background

O&M strategies for the distribution system are required when water quality coming from the well is good, yet water quality is poor coming out of the customer's tap. Results from this study indicated that O&M strategies would be required since most aquifer samples were below the SMCLs and none

exceeded the MCLs. It is recommended that the City implement storage and flushing O&M procedures to reduce the risk of color, taste, and odor issues in the storage and distribution system.

5.2.2 Storage

Stagnant water from a well or storage tank can be a source of taste, color, and odor complaints. “Aged, stale water provides an environment conducive to the growth and formation of taste and odor causing microorganisms and substances” (AWWA, 2002). Long contact times, especially after chlorination, converts dissolved iron and manganese into solid particles that can settle out in stagnant areas (e.g., storage tanks and water mains). Providing fresh water and keeping the water mains clean significantly reduces taste, color, and odor issues.

Excessive water storage time can lead to stagnant water. Mapleton City has more than double the required water storage tank capacity than is currently required (see Section 2) which poses a risk to water quality. In fact, the available water storage is already almost double the calculated water storage requirements in the year 2040 according to the 2018 Water Resources Master Plan. J-U-B recommends that the City address water storage risks by increasing tank turnover frequency, periodic tank cleaning, and routine flushing.

5.2.2.1 Tank Turnover

In addition to having excessive water storage capacity system-wide, the Crowd Canyon storage tank has had periods of time when the water sat stagnant for 3 to 4 months at a time. J-U-B recommends operating all storage tanks, as illustrated in Figure 13, to have a maximum 3-day turnover or daily turnover volume (daily demand) of 33% of the reservoir’s capacity (J-U-B, 2018 Phase 1 Memorandum). Currently, the operations at Crowd Canyon have been adjusted so that tank turnover equals 14 days (3 days drawdown to 50% volume + 4 days fill = 7 days for 50% turnover) which still falls short of the recommended turnover frequency.

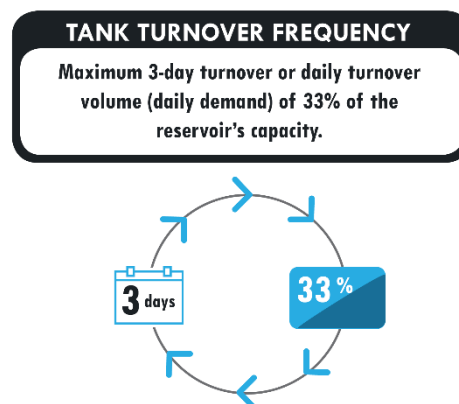


Figure 13: Tank Turnover Frequency Recommendation.

The following equations can be used to determine daily turnover volume:

$$\text{Required Daily Turnover Volume (Mgal)} = \text{Working Storage Tank Volume} \times 33\% \text{ per Day}$$

Equation 1: Required Daily Turnover Volume.

$$\text{Turnover Time (days)} = \text{Drawdown Time} + \text{Fill Time}$$

Equation 2: Turnover Time.

$$\text{Turnover Volume (Mgal)} = \frac{(\text{Fill Level} - \text{Drawdown Level})}{\text{Fill level}} * \text{Working Storage Tank Volume}$$

Equation 3: Turnover Volume.

$$\text{Actual Daily Turnover Volume (MGal)} = \frac{\text{Turnover Volume}}{\text{Turnover Time}}$$

Equation 4: Actual Daily Turnover Volume.

Crowd Canyon Storage Tank Example Calculations Figure 14:

Required Daily Turnover Volume = 4 Mgal x 33% = 1.33 Mgal per day (or 3 days per turnover)

Turnover Time = 3 days + 4 days = 7 days

Turnover Volume = [(22 ft – 11 ft) / 22 ft] x 4 Mgal = 2 Mgal

Actual Daily Turnover Volume = 2 Mgal / 7 days = 0.3 Mgal per day (or 14 days per turnover)

Figure 14: Crowd Canyon Storage Tank Example Calculations.

Increasing tank turnover may be one of the least costly solutions with the highest benefit. It would also have the advantage of increasing the water availability to the City by facilitating greater access to the well production capacity provided by the Crowd Canyon Well. If increasing the turnover rate at Crowd Canyon also has the negative effect of resulting in more taste and odor complaints due to hydrogen sulfide, then it is recommended that the City chlorinate the source water and pump directly to the storage tank (see **Section 5.3.2.1**).

In order to meet the recommended 3-day tank turnover frequency, the excess water storage capacity needs to be addressed. Several strategies exist to address this issue:

- Adjust the water levels in the storage tanks to operate only partially full (e.g. only fill ½ or ¾ full). This is counter-intuitive to most cities since they prefer to keep tanks as full as possible; however, it is a simple solution to increasing tank turnover for systems with excess storage capacity.
- Alternate storage tanks so that storage time is similar for each tank. This may require installing an altitude control valve at each tank to ensure that they drain a specific volume of water before refilling.
- Take source(s) offline in order to decrease the available storage capacity. Certain management practices such as draining the stagnant water in the tank before bringing back online should be considered to avoid sending a slug of stagnant water into the distribution system.

An analysis using the City's hydraulic water model of the system will need to be used in order to optimize the operating levels for each storage tank or source use as mentioned above. It is estimated that this effort would require approximately 4 hours up to 3 days of modeling time depending on whether an existing modeling scenario is already set up or needs to be created.

5.2.2.2 Tank Cleaning 💰 ➕

AWWA recommends that all water reservoirs or storage tanks be cleaned and inspected at least every five years. Benefits of cleaning include reduced bacterial activity and removing accumulated sediment. Routine tank inspection and maintenance is an important part of distribution system maintenance. Typical inspection includes: draining, cleaning, sediment removal, coating repair, disinfecting and total coliform testing. Appropriate frequency of inspection and maintenance varies between system-specific needs. Tank maintenance is important in balancing capacity and water age. Other tank maintenance strategies may include adding a tank coating, ensure that the tank has adequate venting and tank mixing systems (M68 - AWWA, 2017).

The Crowd Canyon storage tank was last cleaned in 2017 (**Potable Divers, 2017**). The report concluded that the storage tank was all around in good satisfactory condition. The report found an average of 0.5-inch sediment which is nothing out of the ordinary.

Excessive accumulation of sediments in the Crowd Canyon storage tank does not appear to be an issue. If high iron and manganese concentrations were present in the Crowd Canyon well water, then that source water probably would have caused noticeable sediment in the storage tank since it is chlorinated right out of the well.

5.2.3 Flushing

“Low-flow and dead-end areas within a distribution system generally accumulate sediments; during high-demand periods, these sediments may be stirred up, resulting in discolored water” (**EPA, 2008**). GIS-Based approaches will be very useful to determine when and where complaints are coming from. Based on this information, a flushing technique can be selected to significantly reduce the taste, odor, and color complaints. Several flushing techniques exist varying from basic spot-flushing to advanced unidirectional-flushing (**AWWA M68, 2018, Appendix B** included in Appendix E – Flushing Techniques). Spot-flushing is recommended for the City of Mapleton if the problems are localized near dead-end mains. Unidirectional flushing is recommended if the problems are broader in nature. Flushing can significantly improve water quality aesthetics for minimal to moderate costs.

5.2.3.1 Spot (Dead-End Mains) 💰 ➕ ➕

Spot-flushing replaces stagnant water in specific locations—typically dead-end mains—by flushing at a velocity of 2.5 fps (**Utah Code R309-550-5.7(b)**). Periodic flushing of dead-end mains is recommended. Flushing at 2.5 fps is not a high enough velocity to scour sediment and so it is not considered a water main cleaning strategy, but only a bulk water turnover process. A quasi-unidirectional flushing technique at higher velocities is recommended to get rid of those sediments in specific areas.

GIS information was used to identify approximately 105 dead-end mains in the City of Mapleton as shown in Figure 15. This information can be useful for determining if complaints are coming from areas near dead-end mains. If so, J-U-B recommends the City create an O&M maintenance schedule to spot-flush at those specific locations. If complaints are frequent enough, then it may require looping those dead-end main(s) back into the distribution system. All flushing activities should be recorded in the GIS water geodatabase, pertaining to flushing methodology, date, duration and any observations relative to the nature of the discharged water.

5.2.3.2 Unidirectional

Unidirectional-flushing (UDF) cleans local and upstream pipes at a velocity of 5-10 fps in order to scour sediments out of the pipe. One case study found that by implementing a UDF program one community was able to reduce customer complaints from a high of 1,300 in 2006 to less than 100 the year following the UDF program (**WaterWorld, 2013**). In addition, the UDF program reduced iron concentrations by 77 percent. This type of flushing technique requires extensive upfront planning and modeling to create a schedule and map for each flushing sequence. The flushing sequences are designed to transport the sediments from an initial point A (typically highest elevation) to a final point Z (typically lowest elevation). Each flushing sequence requires opening/closing specific water main valves in order to maximize the flow rate or origin of the flush water. Below is a summary of general guidelines and advantages of an UDF program:

General UDF Guidelines

- Distribution system divided up into Flushing Zones (approx. 50-100 sequences per zone)
- Flushing Zones divided up into Flushing Sequences (approx. 1200-1500 ft per sequence)
- Flushing crew of 2-3 people complete 6-7 Flushing Sequences per day on average
- Flushing crew field documents time, location, effectiveness, water quality, etc. into GIS
- Flushing crew provides public notice before flushing and site cleanup afterwards

Advantages

- Cleaner water mains, improved distribution system water quality and reduced number of customer complaints;
- Operators open/close valves with each flushing sequence which in turn results in higher confidence that valves are working correctly and in the right position. In addition, it helps operators have more confidence when addressing water main breaks or other problems with the system. Operators may discover that 15-25% of the valves are not accessible or in good working condition during the first year of implementing the UDF program;
- Field documentation by operators results in improved and updated GIS maps and/or models for future use.

Quasi-unidirectional or strict unidirectional flushing (**AWWA M68, 2018, Appendix B** included in Appendix E – Flushing Techniques) provides bulk water turnover and a temporary reduction in water age over a broader area of the system. Where chronic concerns are identified with a particular water main, we would suggest that unidirectional flushing be combined with brushing or ice-pigging to more aggressively remove internal pipeline wall deposits. Not only can this more focused effort improve water quality, but hydraulic capacity of individual mains can be substantially improved. Brushing or pigging would require a post-flush disinfection before returning to service.

Figure 16 identifies some low elevation sections of the distribution system that may represent different Flushing Zones. Working with a model, the City can optimize the best flushing routine which can be used year after year. To give an idea of what it would take to implement a UDF program, the City of Mapleton's 77 miles of distribution water mains may require a crew of 2-3 people to complete a UDF cycle in 40 working days.

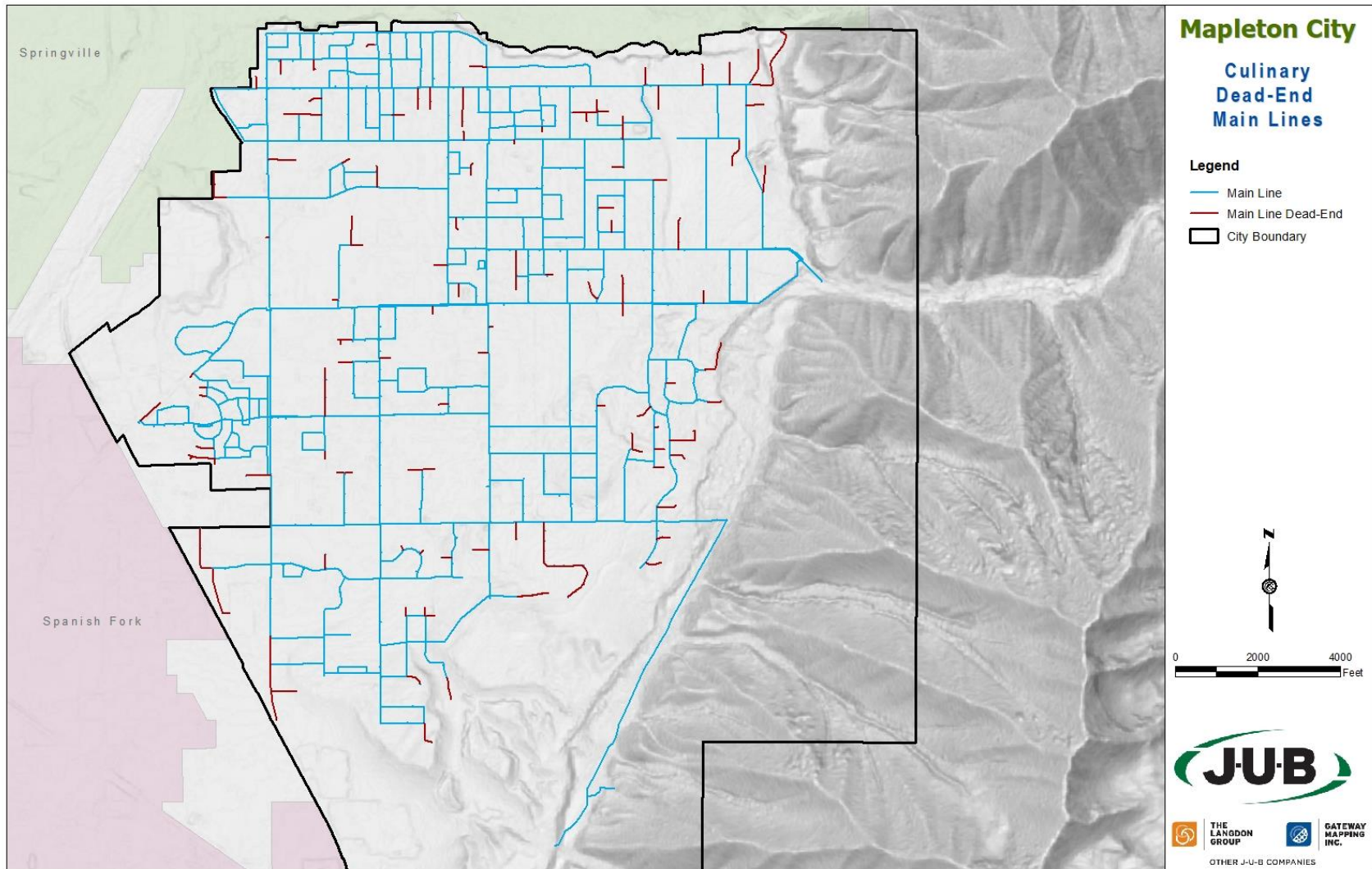


Figure 15: Dead End Mains Identified in the City of Mapleton.

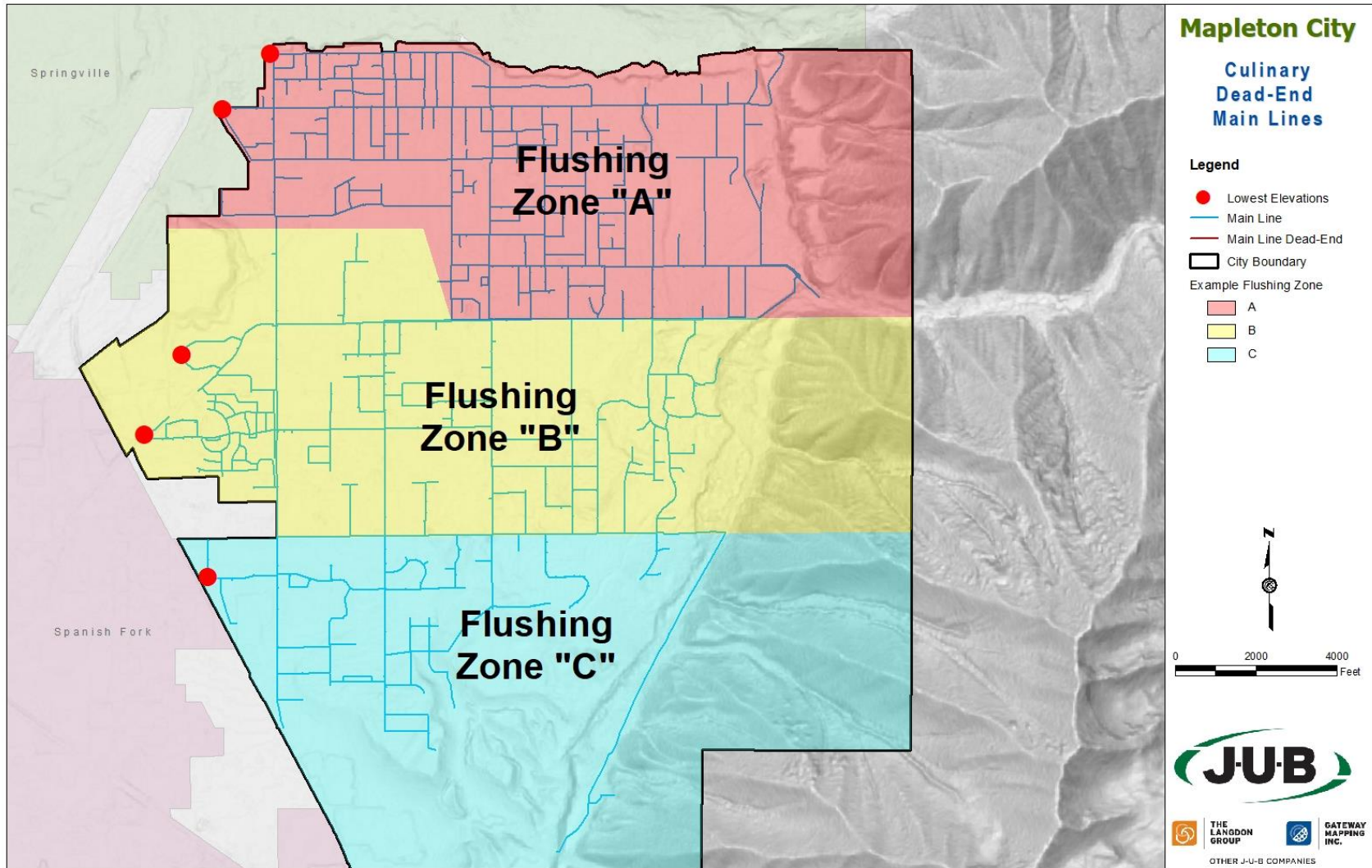


Figure 16: UDF Program Flushing Zones (Example Only).

Table 4 provides a summary of the distribution system along with the flows and volumes typically required for a UDF program. More effort would be required during the first year and also to provide notice to customers when the UDF will take place; however, the benefits of a UDF program significantly outweigh the challenges—especially when looking for ways to reduce taste, color, and odor issues. The case study mentioned earlier implemented a whole-system UDF water main flushing program the first year, followed by quasi-directional unidirectional flushing during the succeeding years in areas where customer complaints increase (phone conversation with City of Melbourne, FL public works).

Table 4: City of Mapleton Water Distribution System and UDF Program Typical Design Criteria.

Pipe Size (inches)	Length (linear feet)	Length (miles)	Flow (gpm) ^(A)	Flush Volume (gallons) ^(B)
4	3,250	0.62	294	2,120
6	62,000	11.7	661	91,013
8	256,650	48.6	1,174	669,777
10	350	0.07	1,835	1,427
12	70,150	13.3	2,642	411,907
16	3,800	0.72	4,697	39,667
18	8,750	1.66	5,945	115,601
20	600	0.11	7,340	9,786
Total	405,550	76.8	294 up to 7,340	1,341,299

(A) UDF cleaning velocities range from 5-10 fps. Flow rate calculated assuming 7.5 fps velocities.

(B) UDF flushing volumes provide greater than 100% bulk water turnover. Flush volume calculated assuming 100% turnover.

5.3 Water Treatment

5.3.1 Background

Water treatment is a good solution when it can easily be shown that water quality coming from the well leads to problems in the distribution system. For example, when high levels of hydrogen sulfide, iron, and/or manganese detected in well water samples are causing taste, color, and odor problems. The Westwood Well detected moderate levels of manganese and TDS levels approaching the SMCL. Hydrogen sulfide has been detected by odor when sampling the Crowd Canyon Well, but sulfide concentrations are below the detection limits which indicate that there are only low levels of H₂S associated with the well.

Water treatment alone will not guarantee a resolution of all color, taste, and odor issues. Trace levels of Fe/Mn could still accumulate in the distribution system even after treatment. In some cases, iron could originate from the transmission piping rather than the aquifer itself. While hydrogen sulfide has been detected inside the well casing and at the Crowd Canyon Well head, it could also form due to biological

activity throughout the distribution system or form at the resident's house (e.g., water heaters and household plumbing).

The following sections give an overview of the Best Available Technologies and processes to treat water for the common contaminants that cause taste, color, and odor issues.

5.3.2 Treatment Processes

5.3.2.1 H_2S Oxidation 💰 💰 🌱 🌱

Hydrogen sulfide can be removed by air stripping or chemical oxidation. In air stripping, a portion of the hydrogen sulfide can be degassed via forced draft aeration. H_2S removal by aeration improves with lower pH levels. It is estimated that the Crowd Canyon Well would only remove approximately 12% H_2S at pH 7.7 by aeration.

It is more common to use chemical oxidation to remove hydrogen sulfide when source water pH is >7. Chemical oxidation with chlorine can be used to convert the H_2S gas into elemental sulfur (S) or to a dissolved sulfate (SO_4) form.

- Convert H_2S to S: Approximately 2.2 mg/L of sodium hypochlorite is required to convert 1 mg/L of hydrogen sulfide to elemental sulfur and filtration is recommended if the hydrogen sulfide concentration is >0.3 mg/L. The elemental sulfur has the potential to be converted back into H_2S by sulfur reducing bacteria in the storage tank or distribution system (**McVay, 2007**).
- Convert H_2S to SO_4 : Approximately 8.8 mg/L of sodium hypochlorite is required to convert 1 mg/L of hydrogen sulfide to dissolved sulfate and filtration would not be required when dealing with the low H_2S levels at Crowd Canyon (**Cadena, 1988**). Both reactions may require up to 20 minutes of contact time.

5.3.2.2 Fe 💰 💰 🌱 🌱

Iron in groundwater can be removed by oxidation followed by filtration. If iron concentrations are low enough (<0.3 mg/L) as in the case of the Crowd Canyon Well, then providing a period of storage for particles to settle out may replace the need to filter.

- Aeration to remove iron: When aeration is used to oxidize the water, a storage tank with 20 minutes of detention time is required and the water needs to be re-pumped through the filters.
- Chemical oxidation to remove iron: Alternatively, the water can be oxidized with chemicals like sodium hypochlorite or potassium permanganate. The reaction time is rapid and so a separate detention tank is unnecessary and no double pumping is required. The oxidized water is filtered with standard sand media (0.45-0.55 mm effective size) or anthracite media (0.6-0.8 mm effective size). Approximately 0.7 mg/L of sodium hypochlorite (as Cl_2) is required to remove 1 mg/L of iron.

5.3.2.3 Mn

Manganese in ground water is removed using chemical oxidation followed by filtration with manganese-coated media. Air-assisted backwash is required. Approximately 1.4 mg/L of sodium hypochlorite (as Cl_2) would be required to remove 1 mg/L of manganese.

5.3.2.4 TDS

The best available technology for TDS removal from groundwater is reverse osmosis (RO). Only a fraction of the water requires treatment. The RO permeate is then blended with the raw groundwater to produce the desirable TDS concentration. RO produces a concentrated brine solution (approximately 20-30% of the treated water volume) which requires additional disposal. RO membranes require pre-treatment filtration to remove the bulk iron and manganese.

5.3.3 Crowd Canyon Improvements

Tank turnover time and hydrogen sulfide odors appear to be the most prominent issues with the Crowd Canyon Well. The Crowd Canyon well samples also detected 0.1 mg/L iron which is already below the SMCL and usually does not require treatment. Filtration can get iron levels below 0.02 mg/L; however, manufacturers usually only guarantee removal down to 0.3 mg/L and may require special performance guarantees or pilot testing to prove it can meet lower levels.

Pumping directly to the distribution system may not provide enough contact time for the complete oxidation of H_2S into elemental sulfur or sulfate before arriving to the customer. Therefore, direct pumping to the storage tank first would be beneficial for H_2S removal.

The following is a list of potential improvements to the Crowd Canyon Well. The recommendations are listed in order of importance:

1. Construct a dedicated transmission pipeline from Crowd Canyon Well to the storage tank (see Figure 17) plus chemical oxidation in order to:
 - a. Improve tank turnover time (see **Section 5.2.2.1**)
 - b. Provide detention time to oxidize H_2S and convert it to elemental sulfur or dissolved sulfate
 - c. Provide detention time for iron to oxidize and settle out (**EPA, 1991**). *Note: assumes tank is not perfectly mixed and the tank will be cleaned periodically (<5 years) to remove any accumulated sediment.*

The system would require approximately 6.3 gallons of sodium hypochlorite per million gallons treated in order to oxidize 0.1 mg/L iron and 0.1 mg/L sulfide.

2. Air stripping is not recommended due to the higher pH and low Fe and H_2S concentrations. An air stripper option would only be recommended if it could be shown that the chemical savings would justify the capital and O&M expenses of running the air stripper. Assuming that the Crowd Canyon Well supplied 40% of the City's water demand and that the aerator oxidized 12% of the H_2S and all of the iron, then the aerator would only save around \$300 annually. The

savings associated with running the aerator would not provide enough payback to recoup the funds expended to install a \$74,000 aerator.

3. Fe and H₂S concentrations are not high enough to justify installing a filter. Straight chemical oxidation and detention should suffice—unless it is found that particles are leaving the storage tank after implementing recommendation #1 above. A 1750 gpm system for this well would consist of multiple cell horizontal pressure filters designed at 4 gpm/sf filtration rate.

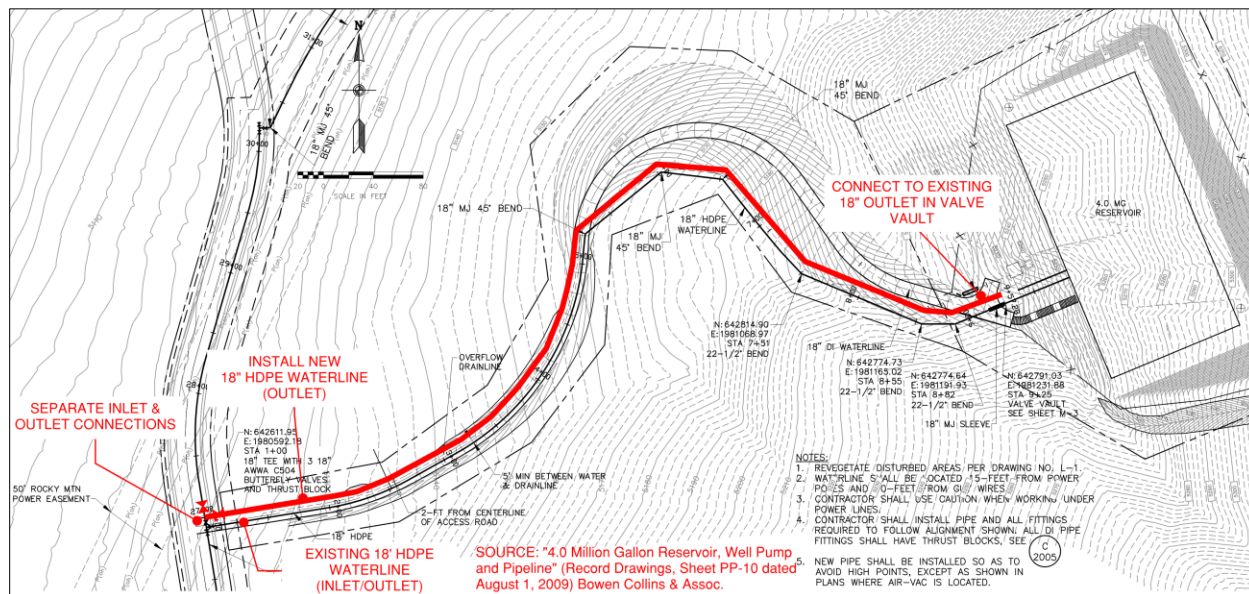


Figure 17: Conceptual Layout - Crowd Canyon Storage Tank New Outlet Transmission Line.

5.3.4 Westwood Well Improvements

The Westwood Well manganese levels are above the SMCL which has been shown to cause color issues. The manganese levels can be reduced below 0.05 mg/L with an oxidation and filtration system. An 1800 gpm system for this well would require approximately 1.5 gallons of sodium hypochlorite per million gallons treated to oxidize 0.16 mg/L of manganese. The system would consist of multiple cell horizontal pressure filters with air/water backwash designed at 4 gpm/sf filtration rate plus a sodium hypochlorite chemical system. Figure 9 shows a manganese filtration system designed by J-U-B Engineers in Meridian, ID.

TDS removal is not recommended. If taste issues continue after implementing all other recommendations, then a reverse osmosis system could be evaluated. The system could be implemented as a phased approach with a pre-treatment Fe/Mn filtration system installed first followed by another phase of RO membranes if residents continue to complain of taste issues.



Figure 18: Manganese pressure filtration system.



Figure 19: Manganese pressure filtration system inside concrete masonry unit (CMU) building.

6 Conclusion

Mapleton City owns and operates a culinary water system that provides groundwater from wells and springs to water service connections throughout the City. Historically, the City has received expressions of concern from customers regarding the quality of water being provided as drinking water. J-U-B has determined from the sampling and analysis, as part of this water quality assessment, that Mapleton City

generally has good quality drinking water. However, we have also determined that while there are no current water quality concerns that pertain directly to health risks, there are concerns of taste, odor and color that pertain to an aesthetic risk. Managing these aesthetic water quality risks is a function of operations and maintenance of both water sources and the distribution system.

Aesthetic water quality concerns (taste, odor and color) can be an indicator of more serious, potentially unhealthful water quality concerns. Along with the recommended strategies below, J-U-B suggests continued monitoring of the required constituents discussed in this report to ensure that the water quality of the sources and distribution system is not deteriorating.

J-U-B recommends various strategies to mitigate the aesthetic (taste, color, and odor) risks through implementation of a holistic approach. The holistic approach would incorporate data logging, operations, and treatment:

1. GIS-based approach to Documenting Reported Water Quality Concerns in Space and Time and Logging and Recording of Key Water System Parameters from SCADA
 - a. Mapleton Water Geo-Database (GDB)
 - b. Mapleton City Water Quality Portal
 - c. SCADA Integration
2. Operation & Maintenance (O&M) Best Management Practice
 - a. Tank Turnover Frequency
 - b. Distribution System Flushing
3. Water Treatment Strategies
 - a. Crowd Canyon Well – pump direct to storage tank with pre-chlorination for H₂S & Iron
 - b. Westwood Well – oxidation + filtration treatment system for Manganese

6.1 Cost Estimate

It is not expected that the City will implement each solution immediately. Therefore, the probable cost to implement each recommendation was evaluated to assist with prioritizing each recommendation. Appendix F – Opinion of Probable Costs provides more detailed cost breakouts for each item. Each option requires an initial upfront cost to implement followed by annual costs thereafter to maintain.

The listed opinion of probable cost to implement the GIS-based approach are preliminary and will be refined after review of the existing City dataset. The Asset Management component assumes reviewing available data, updating the existing water data model and attaching available as-built drawings to GIS dataset. This is strictly for drinking water datasets within the city.

The Monitoring and Logging assumes the City GIS data is available and ready for online implementation. The listed cost to implement includes a citizen interface and a city-only interface to access and manage the citizen complaints. It also includes basic geoprocessing of electronically available water quality data (including hot spot analysis of up to 5 water quality parameters). This approach assumes housing of available historic data available in electronic form to be hosted on City's ArcGIS Online organizational account.

Table 5: City of Mapleton Water Distribution System and UDF Program Typical Design Criteria.

Item	Opinion of Probable Cost to Implement	O&M Cost Opinions after First Year
GIS – Asset Management ^(A)	\$ 13,440	N/A
GIS – Monitoring and Logging ^(A)	\$ 17,360	N/A
GIS – SCADA Integration ^(A)	\$ 24,240	N/A
O&M – Tank Turnover Modeling ^(B)	\$2,250 - \$5,000	N/A
O&M – Spot Flushing	\$ 23,520	\$20,000/yr
O&M – Unidirectional Flushing	\$ 110, 000	\$41,000/yr
Treatment – Crowd Canyon Direct Effluent Transmission Line with Chemical Oxidation for H ₂ S/Fe (Existing)	\$ 162,720	\$12.82/Mgal ^(C) Chemical \$120/Mgal Electrical
Treatment – Westwood Well Manganese Filtration System	\$2,930,400	\$2.94/Mgal ^(C) Chemical \$120/Mgal Electrical

(A) Preliminary numbers – will be refined after review of existing City GIS dataset.

(B) Preliminary numbers – will be refined after review of City's existing WaterGEMS model or other model provided by City, if available

(C) Sodium hypochlorite costs to oxidize Fe, Mn, and H₂S only. Chemical costs to provide chlorine residual not included.

The SCADA integration is highly dependent on the hardware and software available in City. However, the listed cost to implement includes setup and implementation of linking up to 5 parameters from up to 10 locations within the city. This also includes standardizing input to GIS through a spreadsheet. It is assumed that accurate location of the devices is already surveyed and available in GIS format.

6.2 Prioritized Road Map to Recommendations

Based on the beneficial effect and cost of each recommendation, a road map was prepared for the City to begin implementing the recommendations as presented in Figure 20.

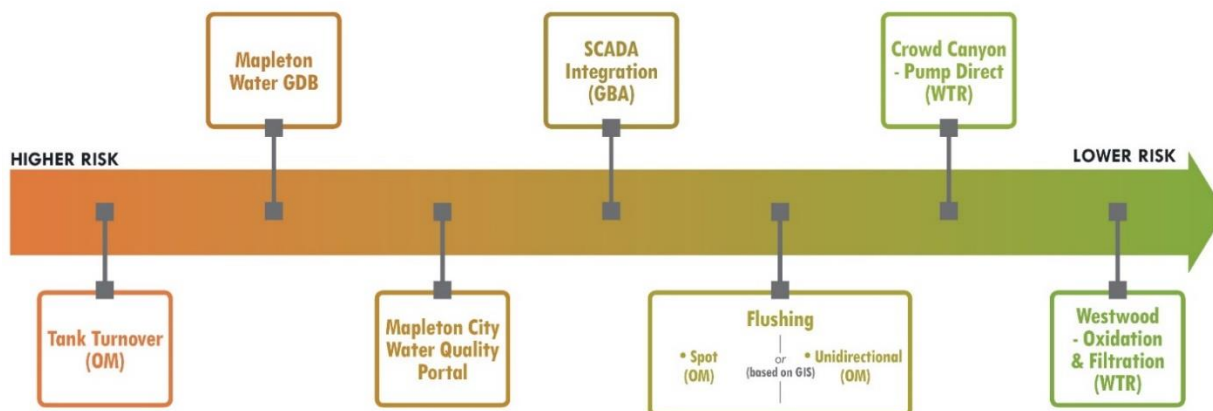


Figure 20: Prioritized Roadmap for Implementation of Recommendations.

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