Memorandum

To: *Lynnfield Center Water District*

From: *Angela Moulton, P.E., CDM Smith*
Adrien Fleury, CDM Smith

Date: *April 9, 2020*

Subject: *Task Order 7: Apple Hill Water Quality Investigation – Summary of Results*

In accordance with our Agreement with Lynnfield Center Water District (the District) dated October 30, 2019, CDM Smith Inc. (CDM Smith) is pleased to submit the analysis from the 'Apple Hill' Water Quality Investigation. The investigation included a public workshop to inform residents of the study, a customer survey, analysis of water quality sampling results and the distribution system hydraulic model evaluation.

1.0 Background & Introduction

The District supplies drinking water to approximately 70% of the Town of Lynnfield through four groundwater sources as shown on **Figure 1**:

- Station 1 - Phillips Road tubular wellfield (North Coastal Basin; not currently in use)
- Station 2 - Main Street wellfield (Ipswich River Basin)
- Station 3 - Phillips Road bedrock and gravel-packed wells (North Coastal Basin)
- Station 4 - Glen Drive wellfield (Ipswich River Basin)

Station 1 is not currently active due to elevated levels of nitrate detected. The District also owns and operates two storage tanks, one at Knoll Road and one at Wing Road.

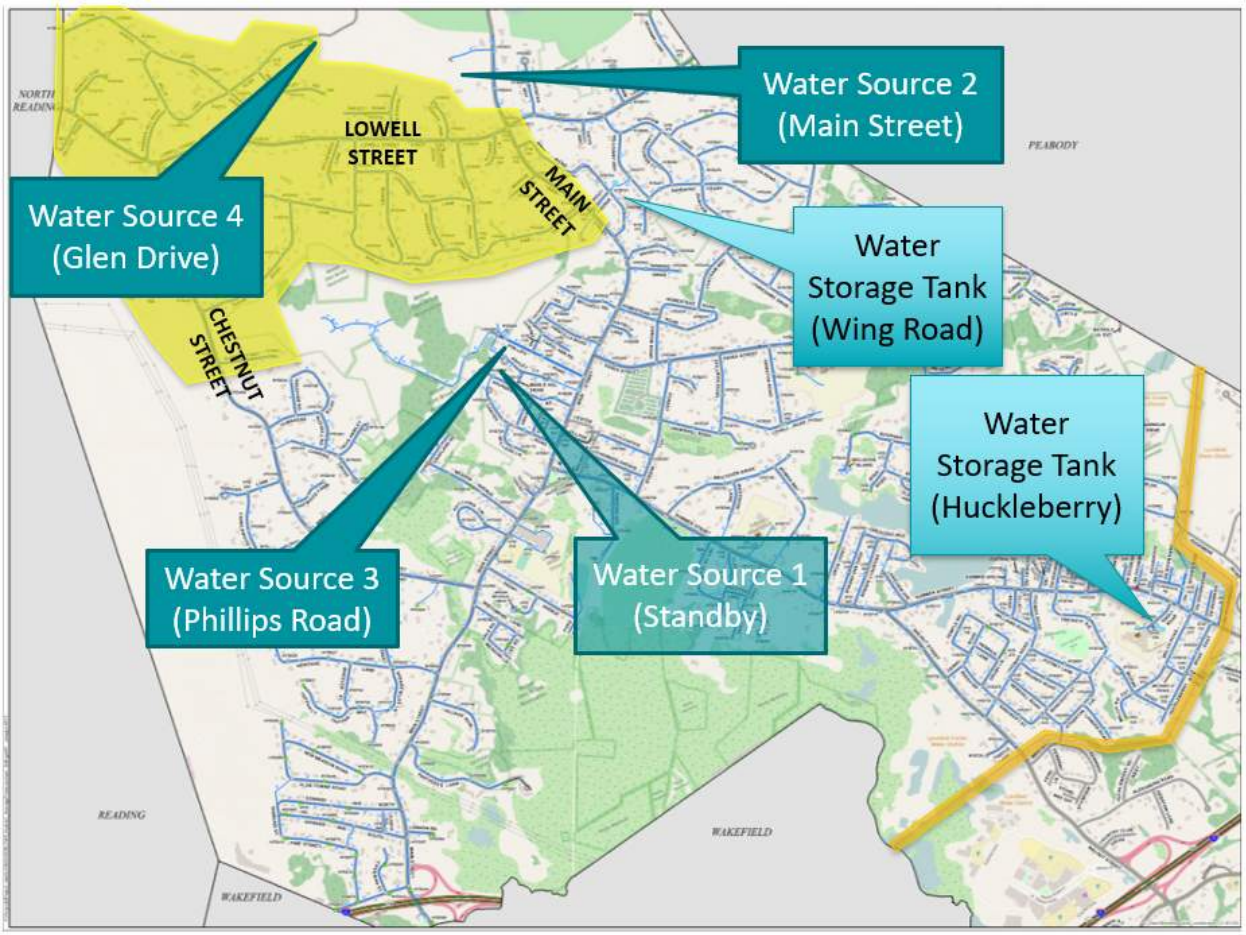


Figure 1: The District's Distribution System

For the purposes of this study, the 'Apple Hill' neighborhood is considered the northwest corner of the District, west of Main Street including Lowell Street and Chestnut Street. The District has consistently received discolored water complaints from customers in the 'Apple Hill' neighborhood. Residents have noted changes in taste, color, and odor.

Iron (Fe) and manganese (Mn) are metals that occur naturally in the groundwater sources and are not regulated by primary drinking water standards. The secondary maximum contaminant levels (SMCL) for iron and manganese in drinking water are 0.3 milligrams per liter (mg/L) and 0.05 mg/L, respectively. Water with values above these levels may have a metallic taste and can cause water discoloration and staining of plumbing fixtures. At concentrations below the SMCL, sediment buildup in pipes and water discoloration may still occur.

Elevated levels of iron and manganese have been detected at the well at Glen Drive (Station 4), which is a source that provides water to the Apple Hill area. As the particulate form of the iron and manganese travel through the distribution system, it deposits in the pipes as sediment. Sudden flow changes or flow reversals can stir up the sediment and contribute to discolored water issues.

In spring 2018, District staff closed three gate valves in the Apple Hill neighborhood in an effort to reduce flow reversals in the area. The three valves are located on:

- Tophet Road at Chestnut Street,
- Cooks Farm Lane at Chestnut Street and
- Pine Hill Road.

The locations of the closed valves are shown in **Figure 2**.

The District perform unidirectional flushing (UDF) in the Apple Hill neighborhood in late October 2019 to remove precipitated material (iron and manganese) from the distribution system.

Figure 2 – Location of Valves Closed by District Staff in 2018

In October (before UDF) and November 2019 (after UDF), three rounds of sampling were performed at 25 residential locations in the Apple Hill neighborhood to test for manganese, iron and other parameters. Sampling was also performed at each of the District's water sources, including Glen Drive. The goal of sampling was to determine the water quality throughout the Apple Hill neighborhood, the District's water sources, and the impact of UDF.

A neighborhood-wide customer survey was also conducted to quantify the location and frequency of water quality issues in Apple Hill. The survey was sent just after completion of UDF to capture potential water quality improvements. This memorandum summarizes the results of the water

quality sampling and customer survey, then combines that data with source tracing and water age analysis, with a focus on the Apple Hill neighborhood and its water quality complaints.

2.0 Community Outreach - Public Participation Workshop

A public participation workshop was held on December 12, 2019 at the Lynnfield Meeting House to collaborate with the District customers relating to water quality concerns in the Apple Hill neighborhood. The District advertised the workshop on their website to encourage resident participation, approximately 20 residents were in attendance. The workshop included a discussion of the Apple Hill Water Quality Evaluation Study and other short-term improvements underway by the District, and how this work fits into the long-term planning by the District. The workshop presentation was uploaded to the District's website following the workshop, and is included in **Attachment A**.

3.0 Community Outreach - Customer Survey

CDM Smith and the District developed a customer survey consisting of 18 questions to solicit feedback from residents of the Apple Hill neighborhood regarding water quality issues. Residents were asked questions related to the frequency that they experience discolored, cloudy or poor tasting water during the past 90 days, with the intent of capturing any impacts from the UDF that occurred in October 2019. A copy of the survey is included in **Attachment A**. The survey was mailed to approximately 360 residential addresses on Friday, December 6, 2019. The addresses were provided by the District. Residents had the option to complete the survey electronically or by hand (paper copy) and deliver it themselves to the District. A QR code was provided on the notice mailed to residents. Residents could simply point their smart phone at the QR code and would be directed to the survey. The survey was then linked to the District's GIS such that all survey results were geolocated to their address in GIS. The electronic version of the survey had drop down menus embedded in certain questions to make the process of completing the survey as user friendly as possible. The survey also allowed residents to include text, however, residents could not attach photos.

Survey responses were received from 115 households, for a response rate of approximately 35%. **Figure 3** summarizes the results of questions related to the frequency that residents experience discolored, cloudy or poor tasting water, and staining of plumbing fixtures, during the past 90 days. Maps showing the results of customer survey responses to select questions are included in **Attachment A** as **Figures A-1 through A-4**.

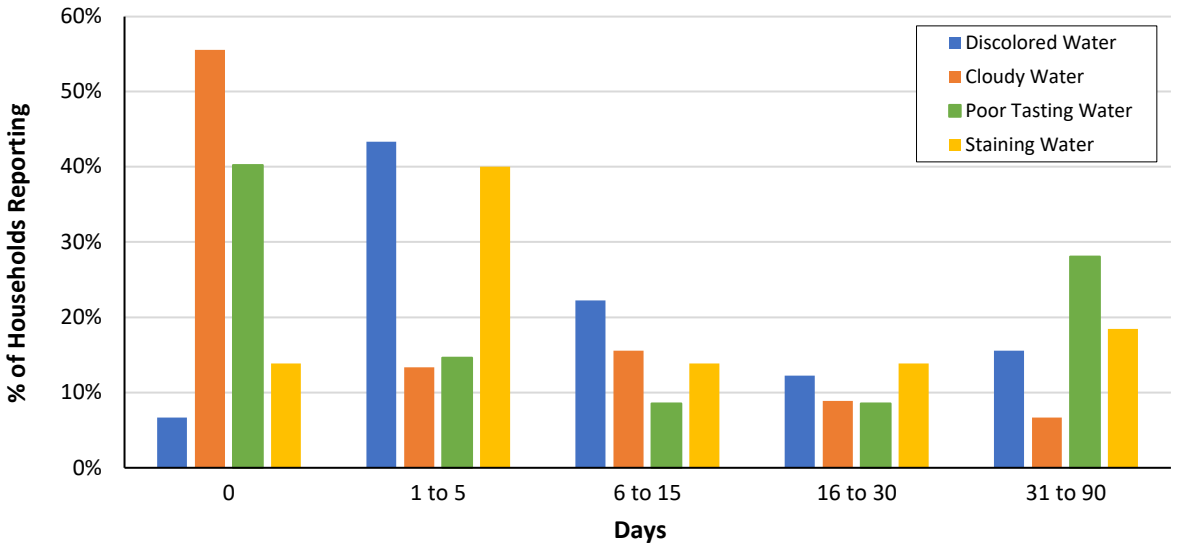


Figure 1 – Results of Water Quality Survey Responses

Figure A-1 shows the frequency in which customers experienced discolored water within the last 90 days. Results indicate that 93% of customers surveyed reported experiencing discolored water at least once within the last 90 days. A significant "cluster" of customers reporting at least 16 days with discolored water was located near the intersection of Glen Drive and North Hill Drive, proximal to the Glen Drive well.

Figure A-2 shows the frequency in which customers experienced cloudy water. Cloudy water is typically caused by air bubbles in the water or high levels of dissolved oxygen and can be function of both temperature and pressure. Hardness of water also cause cloudiness. Overall, fewer residents report experiencing cloudy water as compared to discolored water, with 44% reporting cloudy water at least once in the past 90 days. Customers reporting cloudy water also appeared to be more spread out through the Apple Hill area.

Figure A-3 shows the frequency in which customers experienced staining water. Overall, 86% of customers surveyed reported experiencing black, brown or red staining of their plumbing fixtures at least once within the last 90 days, again with a cluster adjacent to the Glen Drive well.

Figure A-4 shows the frequency in which customers experienced poor-tasting water. Drinking water taste can be subjective and can be affected by a number of factors, including the change chlorine species over time and concentration of manganese. In total, 60% of customers surveyed reported experiencing poor tasting water within the last 90 days. While there is a cluster of customers reporting poor tasting water near the Glen Drive well, quite a few customers throughout the Apple Hill area reported poor tasting water the majority of the time (46-90 days).

The District performed UDF in the Apple Hill neighborhood during October 2019. Survey results indicate that 35% of customers noticed an improvement in water quality after flushing. It was

anticipated that houses with filters would experience fewer days of cloudy, discolored or staining water than houses without filters. However, the results of the customer survey did not indicate such, as several of the customers with filters reported experiencing discolored or staining water at over 15 times over the past 90 days. However, depending on the type and location of the water filters (whole house, point-of-entry (POE), etc.), the survey responders may have observed discolored or staining water in non-filtered water.

4.0 Water Quality Sampling

Water quality sampling was performed in the fall of 2019. Locations of sampling sites (**Figure B-1**) and sampling results are included in **Attachment B**. Collection of Sample A and Sample B was performed on October 10-11, 2019, before a round of UDF of the Apple Hill neighborhood. A third round of sampling, Sample C was performed on November 13-15, 2019, approximately one month after the completion of UDF. Sample A was collected as a first flush (just after the faucet is turned on), to represent water that has been stagnant in the homeowner's plumbing. Both Sample B and C were collected after the tap water ran for enough time to ensure the water being collected was directly from the water main in the street, and not household plumbing.

Samples were tested for the parameters summarized in **Table 1**.

Table 1 – Apple Hill Water Quality Evaluation Parameters

Parameter	Water Quality Indicator
Iron (Total and Dissolved)	Presence can cause discoloring of water and staining of fixtures, taste issues. Total iron is combination of particulate and dissolved iron. Oxidation of dissolved form to particulate can result in deposition of material in the distribution system.
Manganese (Total and Dissolved)	Presence can cause discoloring of water and staining of fixtures, taste issues. Total manganese is combination of particulate and dissolved manganese. Oxidation of dissolved form to particulate can result in deposition of material in the distribution system.
Chlorine Residual	Chlorine is added to the finished water to provide disinfection, as it is a strong oxidant. Chlorine residual decreases through the distribution system as water age increases and the chlorine oxidizes material, including dissolved iron and manganese.
pH	pH impacts the speed of oxidation of the iron and manganese. Changes in pH also can be an indicator of water quality changes.
Dissolved Oxygen (DO)	DO is another oxidant source for transitioning dissolved iron and manganese to particulate iron and manganese.
Alkalinity	Indicator of the "buffering" capacity of the water, ability to resist changes to pH.
Apparent Color	Indicator of dissolved and suspended material in the water.
Total Dissolved Solids (TDS)	Combination of dissolved material in the water: calcium, magnesium, potassium, sodium, bicarbonates, chloride and sulfates. Elevated levels can result in taste issues and deposition of material on fixtures.
Total Suspended Solids (TSS)	Measure of the material suspended in the water (not dissolved). Increased TSS can result in colored or cloudy water.

In total, 3 residential homes during the B and C sampling rounds exceeded the SMCL of 0.05 mg/L for manganese, 2 of the 3 homes are within close proximity to the Glen Drive wellfield. **Table 2** summarizes the results of water quality sampling performed at Glen Drive, Main Street and Philips Road sources. Levels of both total and dissolved manganese were found to be highest at Glen Drive, with all three samples exceeding the SMCL. Levels of dissolved oxygen and chlorine varied across the three sources.

Table 2– Results of Water Quality Sampling at Active Sources

Parameter Sampled		Glen Drive Station	Main Street Station	Phillips Road Station
Total Manganese (mg/L)	Sample A	0.255	0.088	ND
	Sample B	0.129	0.037	0.024
	Sample C	0.089	0.034	ND
Dissolved Manganese (mg/L)	Sample A	0.08	0.039	ND
	Sample B	0.091	0.032	ND
	Sample C	0.076	0.033	ND
Free Chlorine (mg/L)	Sample A	-	-	-
	Sample B	0.87	0.98	0.68
	Sample C	0.93	0.75	1.19
Total Iron (mg/L)	Sample A	0.154	0.03	0.006
	Sample B	0.025	0.023	0.009
	Sample C	0.005	0.009	ND
Dissolved Iron (mg/L)	Sample A	ND	ND	ND
	Sample B	0.01	0.017	0.007
	Sample C	ND	ND	ND
Dissolved Oxygen (mg/L)	Sample A	-	-	-
	Sample B	2.8	8.1	6.8
	Sample C	7.6	5	8.8

Dissolution of iron and manganese in water depends on contact with an oxidant (such as chlorine residual or dissolved oxygen)and is inversely related to water age. Over time, the dissolved form of the iron and manganese is oxidized to the particulate form and can settle out of solution. Water age analysis was performed using Infowater. Full results of the water age analysis are included in this memorandum. To analyze the relationship of dissolved manganese to the oxidants over time, the following plots were created:

- **Figure 4 and 5**: Dissolved manganese and dissolved oxygen vs. average modeled water age at each sampling location
- **Figure 6 and 7**: Dissolved manganese and residual chlorine vs. average modeled water age at each sampling location
- **Figure 8 and 9**: Dissolved manganese and total manganese vs. average modeled water age at each sampling location

It should be noted that residual chlorine and dissolved oxygen were not sampled during Sample A.

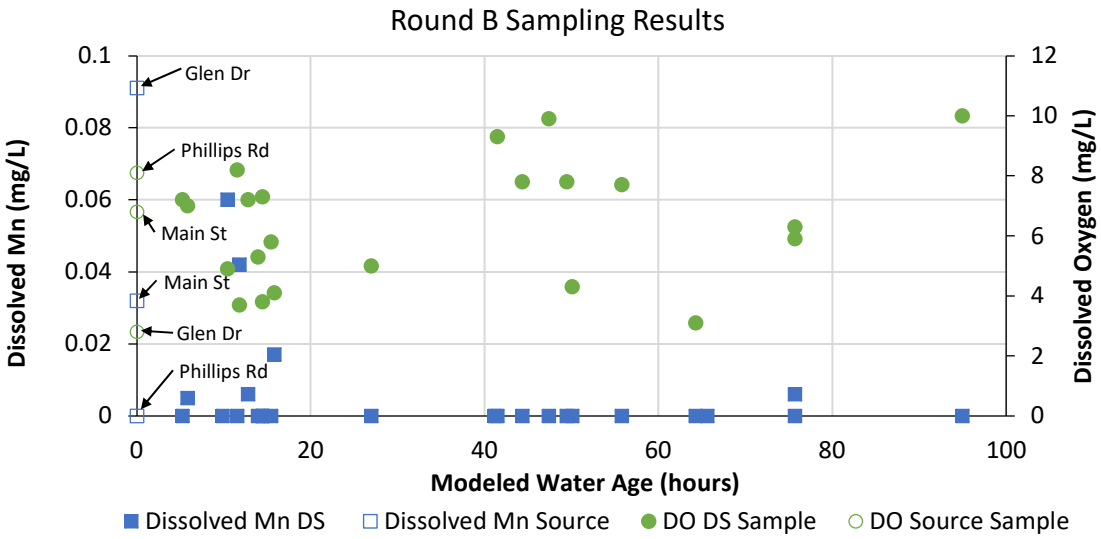


Figure 4 – Dissolved Manganese and Dissolved Oxygen vs. Modeled Water Age (Sample B)

Figure 4 shows dissolved oxygen levels recorded in Sample B were found to vary across all samples collected. Typically, dissolved oxygen levels in water are highest at the source and decrease as water travels through the distribution system. However, dissolved oxygen levels can be affected by blending of multiple sources, as dissolved oxygen levels vary by source (**Table 2**). Additionally, dissolved oxygen can vary with time at a source. Dissolved manganese levels appear to decrease with increases in water age, as manganese becomes oxidized and becomes particulate manganese.

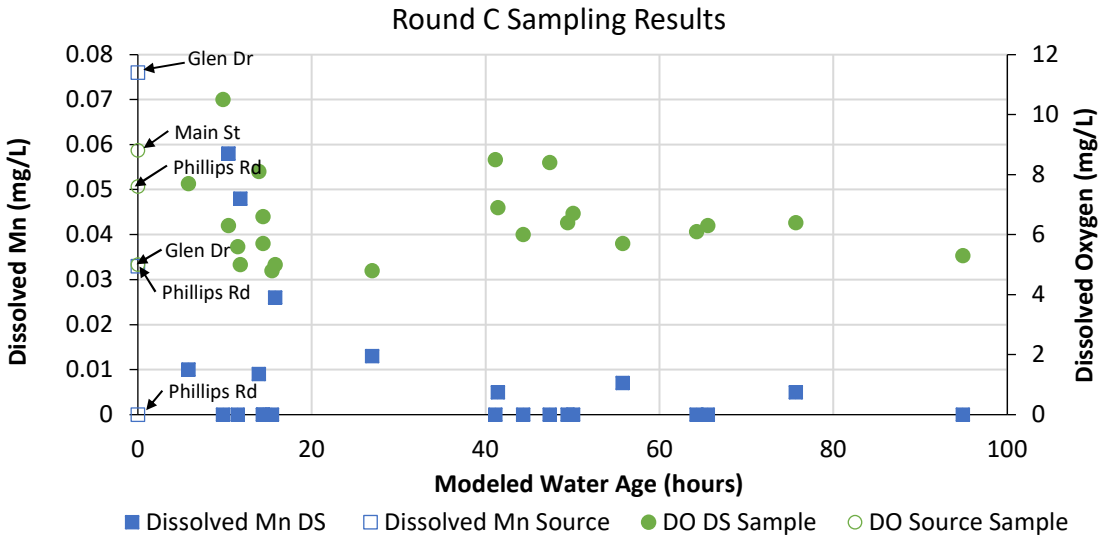


Figure 2 – Dissolved Manganese and Dissolved Oxygen vs. Modeled Water Age (Sample C)

Figure 5 shows dissolved oxygen levels recorded in Sample C varies across all samples. Typically, dissolved oxygen levels in water are highest at the source and decrease as water travels through the distribution system. Dissolved manganese levels appear to decrease with increases in water age, as manganese becomes oxidized and becomes particulate manganese.

Overall, elevated levels of dissolved manganese do not exist with older water age, as dissolved manganese goes to total (particulate form) as the water becomes oxidized.

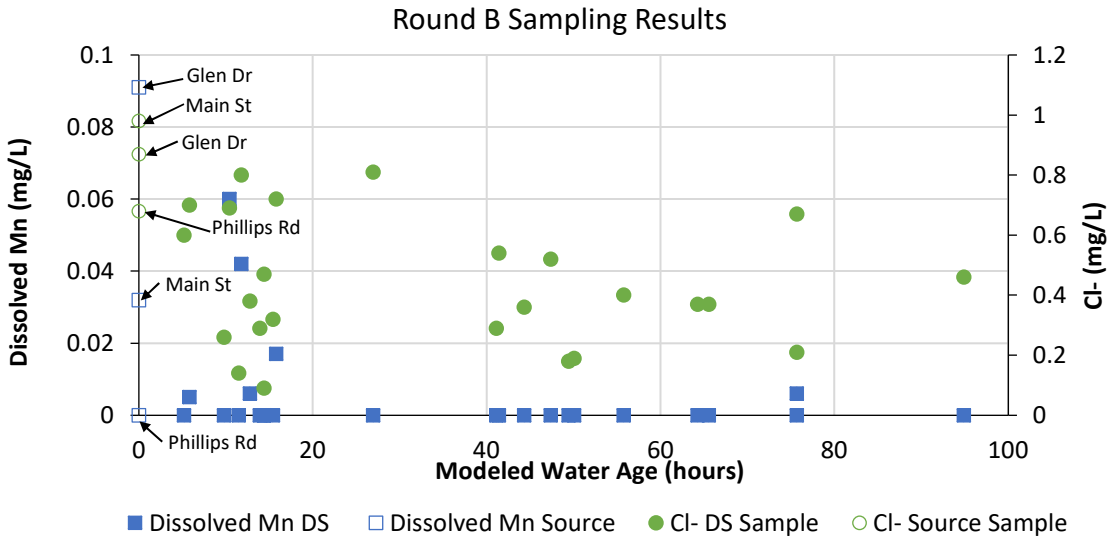


Figure 6 - Dissolved Manganese and Free chlorine Residual vs. Modeled Water Age (Sample B)

Figure 6 shows that both dissolved manganese and chlorine residual were found to have a generally inverse relationship with water age during Sample B.

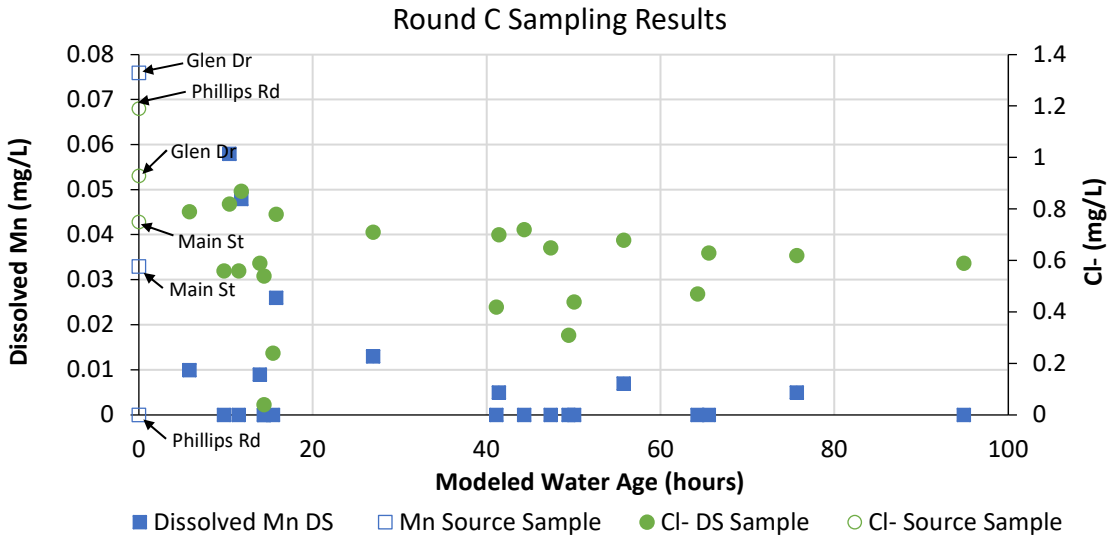


Figure 7 - Dissolved Manganese and Free Chlorine Residual vs. Modeled Water Age (Sample C)

Figure 7 shows that chlorine residual and dissolved manganese were found to have a generally inverse relationship with water age during Sample C, similar to the trend observed in **Figure 5**.

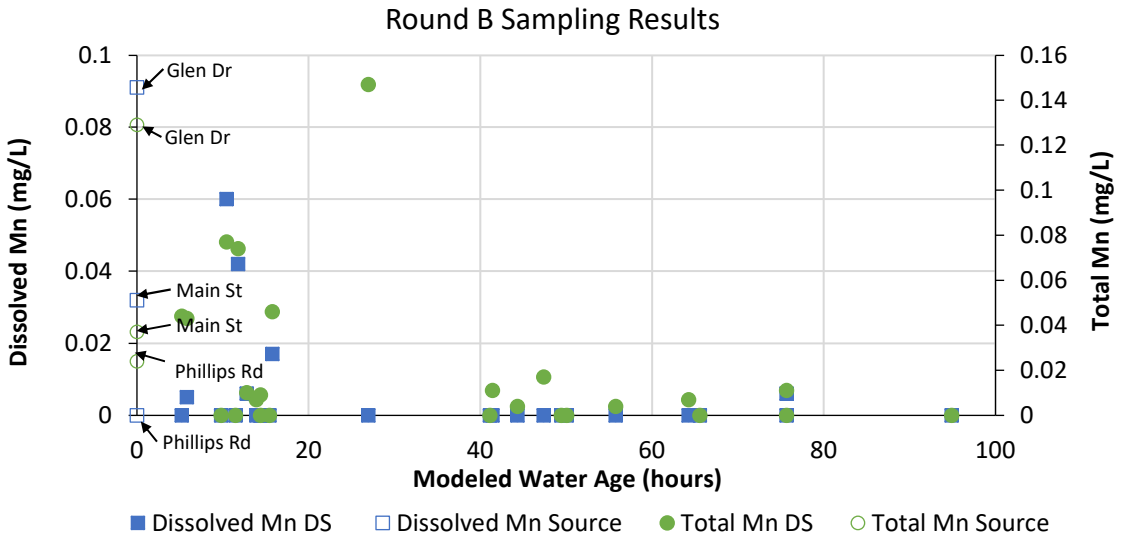


Figure 8 - Dissolved Manganese and Total Manganese vs. Modeled Water Age (Sample B)

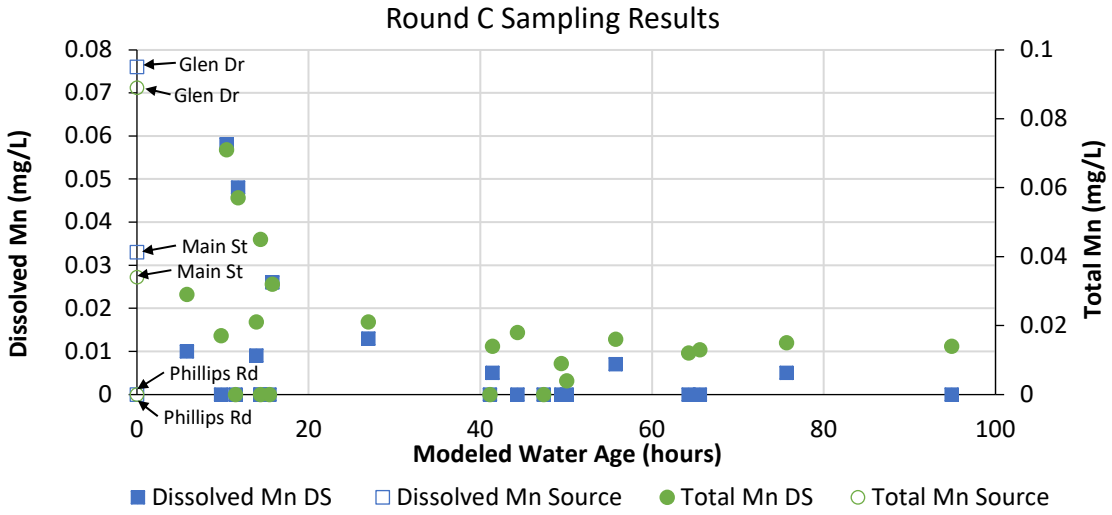


Figure 9 - Dissolved Manganese and Total Manganese vs. Modeled Water Age (Sample C)

Figures 8 and **9** show the sampling results for both total and dissolved manganese at each of the sites sampled. Both total and dissolved manganese results are highest as they first enter the system and remain relatively low after 24 hours in the distribution system. The decrease can be attributed to dissolved manganese oxidizing into the particulate form and precipitating out of the water. In both Sample B and C, manganese sampling results at Glen Drive are among the highest levels recorded, for both dissolved and total manganese.

Overall, there was not a significant difference observed between Sample B and C dissolved manganese results, which were meant to represent water quality before and after UDF. There are several reasons for this result:

- Water quality issues due to deposition in the pipes can be intermittent and dependent on a number of factors including flow reversal and system demands. Sample B may have not captured the water quality challenges present prior to UDF due to material settled in the pipes. If the settled material was not disturbed, the water sampled during both events would be representative of water flowing from the source water and would therefore be similar.

- Source water quality can vary over time and could influence the results of Sample C versus Sample B (i.e., if manganese levels were higher at the time of Sample C than Sample B, it would mask water quality improvements due to flushing).

- Sediment may be building up quickly over time from precipitation of the iron and manganese and therefore the effect of UDF may be short-term. Additionally, there could be other sources of sediment, such as unlined cast iron pipes in the distribution system.

General trends in chlorine residual compared to water age show that modeled water age appears to be consistent with expected results, which validates the theoretical water age produced in the

model. Additionally, the decrease of dissolved and total manganese with water age reinforces that the material is precipitating into the water mains and building up over time.

Based on the results of Sample B and C, the District's water contains relatively high levels of dissolved oxygen. In the presence of unlined cast iron piping, this can release precipitated iron, further adding to the sediment in the distribution system and discolored water challenges. The District should institute a program for checking for unlined cast iron in their distribution system and target for replacement or lining to minimize water quality impacts.

5.0 Model Evaluation

The objective of CDM Smith's hydraulic model evaluation is to investigate the following:

- Flow paths and blending of the different source water sources, with a focus on what areas Glen Drive well feeds.
- Water age (used above in the water quality evaluation).
- Potential patterns between the customer survey responses and the water sampling results.

A diurnal demand curve was applied to the hydraulic model based on patterns in similar communities. The simulations were performed using the District's InfoWater Model (Version 12.4), which was developed in 2017 as part of the Water Distribution System Study performed for the District by CDM Smith. The results of source-tracing and water age analysis are included as **Attachment C**.

The model evaluation utilizes the October 2018 average day demand (ADD) of 0.56 million gallons per day (MGD), obtained from the District's 2018 Annual Statistical Report (ASR). This demand was then applied to all the "nodes" in the model. There are 1,390 nodes in the model used for this investigation, therefore, an average demand of 0.28 gpm was applied to each node. The District provided SCADA printouts of tank levels so the model could reflect the way the system was operated during the investigation period. **Table 3** shows the actual pumping rates observed on October 10, 2019, the day the District collected water Samples A and B.

Table 3 - Modeled supply at each source

Station	Well ID	Modeled Station Supply Rate from 10/10/19 (GPM)
Main Street (Station 2)	N/A	120
WTP (Station 3)	Well 6	35
	Well 7	150
	Well 9A	40
	Well 9B	45
	Well 10	20
	Total	290
Glen Drive (Station 4)	Well 1	120
	Well 2	70
	Well 3	70
	Well 4	40
	Total	300

An extended period simulation was used in the hydraulic model rather than steady state. Extended period allows the model to run for several hours which helps "normalize" the model. The model results for the first few hours are not always the most accurate, since it can take the model several hours to show reasonable results for tank elevations and flow rates. Extended model runs of 600 hours (25 days) were applied in this evaluation to achieve normalized results. Water age and source tracing analyses were performed using the LWCD's model. For each analysis run, a "valve-open" and "valve-closed" scenario was evaluated to assess if the three valves closed in the fall of 2018 had an effect on hydraulics or water quality. Tank levels from the "valve-open" analysis are included in **Figure 10**. Tank levels did not vary at all compared to the "valve-closed" scenario. This indicates that flow from the tanks are not affected by the status of the three gate valves of interest.

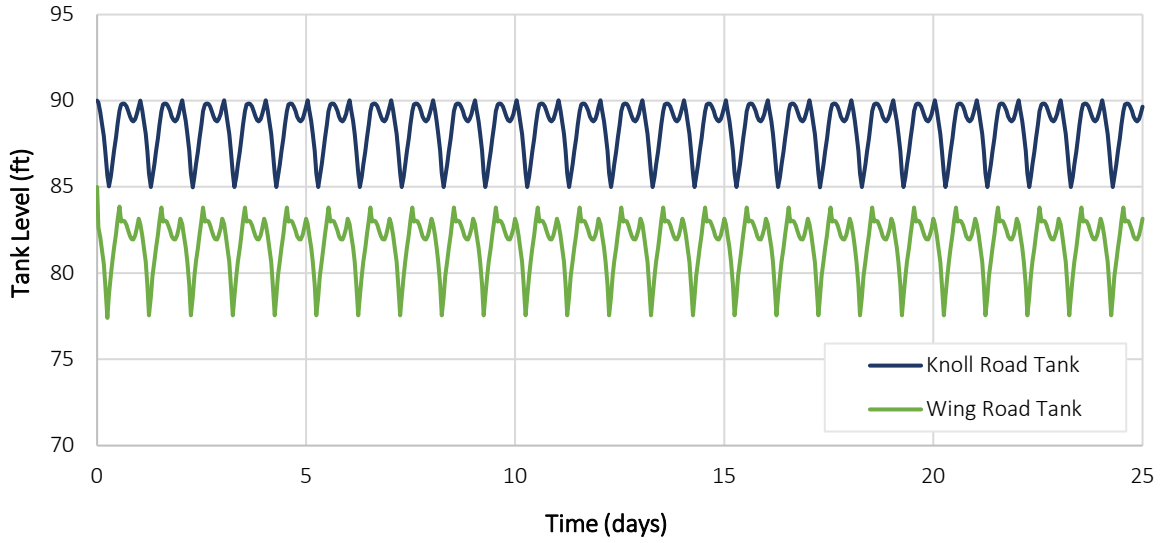


Figure 10 – Tank Levels During "Valve-Open" Scenario Evaluation

5.1 Water Age Analysis

As water travels through a distribution system, the time it takes to reach the customer is called "water age." Increasing water age can have an impact on water quality, such as decreasing chlorine residual and increasing precipitation of dissolved iron and manganese. A water age analysis was performed within the extended period simulation to obtain average and maximum water age throughout the distribution system for both the "valve-open" and "valve-closed" scenarios. **Figures C-1 and C-2** (attached) show the predicted maximum water age in the Apple Hill neighborhood over the 25 days (600 hours).

In the scenarios evaluated, the distribution has a high storage to demand ratio (2.68 MG of storage compared to an average demand of 0.56 MGD). This ratio can limit the turnover of tanks and increase the water age in portions of the system. Although water age was not found to be an issue in most of the Apple Hill neighborhood, the high storage to demand ratio is a reason why the area is

primarily served directly from the Glen Drive well (i.e., the demands in the Apple Hill neighborhood can be directly fed from Glen Drive and doesn't need to be supplemented by the tank storage).

It should be noted that some isolated pipes may be shown with higher water age than neighboring pipes. In these cases, pipes with a higher water age shown may be dead end mains with low demands. Additionally, water age varies throughout the distribution over the course of the day as a result of varying demands and blending of sources.

Generally, the water age did not change significantly in the Apple Hill neighborhood due to the closure of the valves. The biggest change is in the vicinity of the Wing Road Tank, where certain areas (such as Pine Hill Road) increased in water age, likely due to an increased influence from the tank.

5.2 Flow Reversals

Changes in flow direction in water distribution systems can result from daily changes in demands and well operation, as well as changes in valve position (closed or open). Flow changes can scour built-up sediment and scales on pipe walls and degrade water quality. Results of the model evaluations indicate that changes in flow direction, or "flow reversals," were found to occur on a daily basis in several locations in the Apple Hill neighborhood. However, no significant variation in flow reversals was observed between the two valve operation scenarios modeled.

5.3 Source Tracing Analysis

In distribution systems with multiple sources supplying demands, source tracing is a means of determining the origin of the water at a particular pipe or junction at any given time. Performing a source trace analysis within an extended period simulation allows the model to determine a realistic average source allocation across the distribution system.

A source trace analysis was performed for both the "valve-open" and "valve-closed" scenarios. **Attachments Figure C-3 and C-4** illustrate the average source distribution in the Apple Hill neighborhood over the 25 days (600 hours). In both scenarios, the Apple Hill neighborhood receives the majority (>60%) of its water directly from the wells at Glen Drive, and the closing of the valves did not make a significant difference.

Independent of this analysis, inspections of the Wing Road and Knoll Road storage tanks were performed on November 14, 2019. Tank inspections included coating adhesion tests, as well as assessments related to level of service, safety and structural integrity. Underwater remotely operated vehicle (ROV) inspection of the interior of the tanks was also performed to assess the condition of the interiors of both tanks. The results of ROV inspections estimated approximately 12" of sediment buildup in the Wing Road tank, and approximately 1" of sediment buildup in the Knoll Road tank.

Despite the relatively small fluctuations modeled in the Wing Road tank shown in **Figure 10**, any water from the tank that is drawn into the distribution system may be pulling the tank particulate material into the system, contributing to discolored water.

5.4 Blending

Source tracing evaluations indicate that the 'Apple Hill' neighborhood is served primarily by Glen Drive. Blending water from Glen Drive with water from Philips Road and Main Street could reduce manganese levels in Apple Hill. Three additional valve scenarios listed in **Table 4** were simulated to determine how blending would be impacted by valve closings that would limit the direct impact of Glen Drive water in Apple Hill.

Table 4 – Location of valves closed in blending scenarios modeled

Scenario	Cider Mill Road @ Lowell Street	Apple Hill Lane @ Lowell Street	Chestnut Street @ Lowell Street	Pine Hill Road
Scenario 1	X	X	-	-
Scenario 2	X	X	X	-
Scenario 3	X	X	X	X

5.4.1 Blending – Source Trace Analysis

For each blending scenario, a source trace analysis was performed to determine what percentage of water was coming from Glen Drive. Attachments **Figure C-5 through C-7** illustrate the average source distribution in the Apple Hill neighborhood over the 25 days (600 hours). In Scenario 1 (**Figure C-5**), the western portion of Apple Hill, including Chestnut Street, receives water primarily from Glen Drive. In Scenario 2 (**Figure C-6**), the influence of Glen Drive on Chestnut Street is significantly reduced when the valve at the intersection Chestnut Street and Lowell Street is closed. In Scenario 3 (**Figure C-7**), a valve on Pine Hill Road (off of Main Street) is closed, further reducing the portion of water in Apple Hill coming from Glen Drive. With the closure of each additional valve around the Apple Hill neighborhood, the influence of the Phillips Road and Main Street wells in the area increases, delivering more blended water to customers.

Based on the results of these analyses, Scenario 2 would best increase blending throughout most of the Apple Hill neighborhood. With valves closed along Lowell Street, more water from the Main Street and Philips Road wells would blend with water from Glen Drive. In this case, the area of Lowell Street west of Chestnut Street and North Hill Drive would still receive the majority of its water from Glen Drive and would require frequent flushing to maintain water quality.

5.4.2 Blending – Fire Flow Analysis

A fire flow evaluation was performed to determine residual pressure under each of the blending scenarios modeled. According to ISO, the needed fire flow for buildings separated by 11-30 feet is 1,000 gpm. Using this assumed fire flow, the model was used to simulate a fire flow and to observe residual pressures with this fire flow demand. Under each of the blending scenarios modeled, the

residual pressures decreased to less than 20 psi in several locations, indicating that closing the selected valves to achieve blending would result in a decrease of fire protection. MassDEP has established a minimum water system pressure requirement of 20 psi under all operating conditions. This standard helps to avoid potential cross-connections and negative pressure.

6.0 Investigation Conclusions and Recommendations

6.1 Water Quality and Customer Complaints

Over 90% of customers that responded to the water quality survey reported experiencing discolored water at least once within the last 90 days.

Continued unidirectional flushing may help to improve issues related to discolored water in Apple Hill, as 35% of customers surveyed reported an improvement in water quality after flushing was performed.

CDM Smith also recommends cleaning the Wing Road tank to improve water quality. However, source tracing modeling indicates that Glen Drive is the primary source in most of the Apple Hill neighborhood, and therefore the cleaning of the Wing Road tank will have a limited impact on Apple Hill water quality.

6.2 Water Age Analysis

Maximum water age in most of the Apple Hill neighborhood was found to be less than one week. A majority of the area experienced a maximum water age of less than 48 hours. From the water quality analysis, the elevated levels of manganese (both dissolved and total) were found in the lower water age areas. The results of the customer survey further reinforced this result, with areas of highest discoloration in the younger water age areas.

As shown in **Figure C-2**, areas of water age exceeding one week include the area in the vicinity of the Wing Road storage tank and Main Street. The likely cause of higher water age in this area is the limited turnover of the Wing Road storage tank. To improve water quality CDM Smith recommends adding mixing systems in both storage tanks. Tank mixing systems help to increase turnover and reduce water age in tank, which helps to maintain a higher chlorine residual in delivered water.

6.3 Source Tracing and Blending Analysis

Results of the source trace analysis performed indicate that the Apple Hill neighborhood is primarily served directly by the Glen Drive well. The source tracing analysis did not indicate a significant difference between the two valve operation scenarios evaluated.

Results of the blending analysis indicate that opening the three closed valves in Apple Hill and closing the gate valves on Cider Mill Road at Lowell Street, Apple Hill Lane at Lowell Street, and Chestnut Street at Lowell Street would increase blending and potentially improve water quality in the area, however, fire protection would decrease. Although blending would reduce the acute accumulation of sediment in the distribution system in the Apple Hill neighborhood, the same

amount of material is still entering the distribution system and will need to be removed to prevent buildup and impact to the other neighborhoods the District serves.

6.4 Recommendations

The following recommendations are based on the results of the Apple Hill Water Quality Evaluation:

- Continue UDF to move precipitated material out of the entire distribution system, not just the Apple Hill neighborhood.
- Regularly clean Wing Road tank of precipitated material.
- Install mixers in the storage tanks reduce areas of stagnation on the tanks and reduce water age.
- The District should institute a program for checking for unlined cast iron in their distribution system and target for replacement or lining to minimize water quality impacts.

Note that CDM Smith does not recommend closing gate valves on Cider Mill Road at Lowell Street, Apple Hill Lane at Lowell Street, and Chestnut Street at Lowell Street to increase blending and potentially improve water quality in the area because of the modeled effects this has on fire protection.

These are all short-term/immediate recommendations to help reduce water quality/discolored water challenges in the Apple Hill neighborhood while long-term solutions are implemented, as the only way to significantly reduce or eliminate the discolored water quality challenges from the Glen Drive well is to install treatment at the source, or discontinue use of the source.

cc: Michael Nelson, P.E., CDM Smith

Attachments:

Attachment A

December 2019 Public Presentation Slide

Apple Hill Water Customer Survey December 2019

Figure A-1 – Discolored Water Survey Results

Figure A-2 – Cloudy Water Survey Results

Figure A-3 – Staining Water Survey Results

Figure A-4 – Poor Tasting Water Survey Results

Attachment B

Water Quality Sampling Locations

Water Quality Sampling Results Table

Attachment C

Figure C-1 – Water Age Analysis Results (Valves Open)

Figure C-2 – Water Age Analysis Results (Valves Closed)

Figure C-3 – Source Tracing Analysis Results (Valves Open)

Figure C-4 – Source Tracing Analysis Results (Valves Closed)

Figure C-5 – Source Tracing Blending Analysis Results (Scenario 1)

Figure C-6 – Source Tracing Blending Analysis Results (Scenario 2)

Figure C-7 – Source Tracing Blending Analysis Results (Scenario 3)

Attachment A

Community Outreach: Public Presentation Slides & Customer Survey Results

December 2019 Public Presentation Slide

Apple Hill Water Customer Survey December 2019

Figure A-1 – Discolored Water Survey Results

Figure A-2 – Cloudy Water Survey Results

Figure A-3 – Staining Water Survey Results

Figure A-4 – Poor Tasting Water Survey Results

December 12, 2019

Lynnfield Center Water District

"Apple Hill" (Northwest Corner) Neighborhood Public Workshop

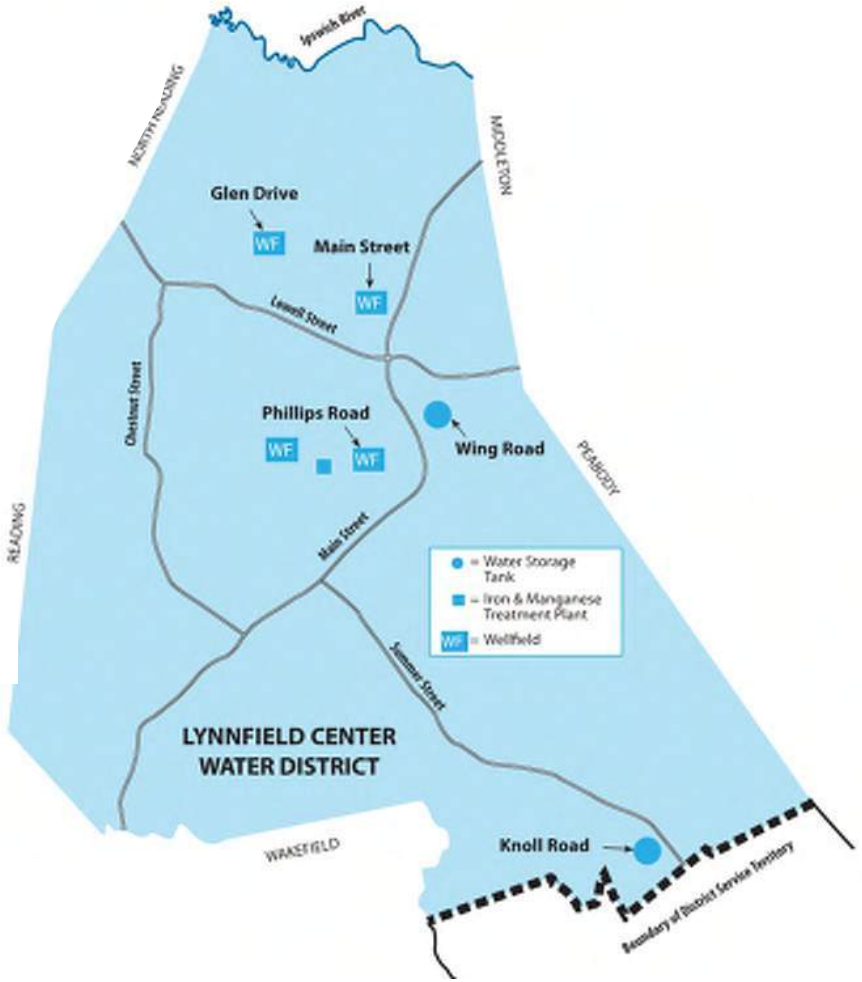
CDM Smith

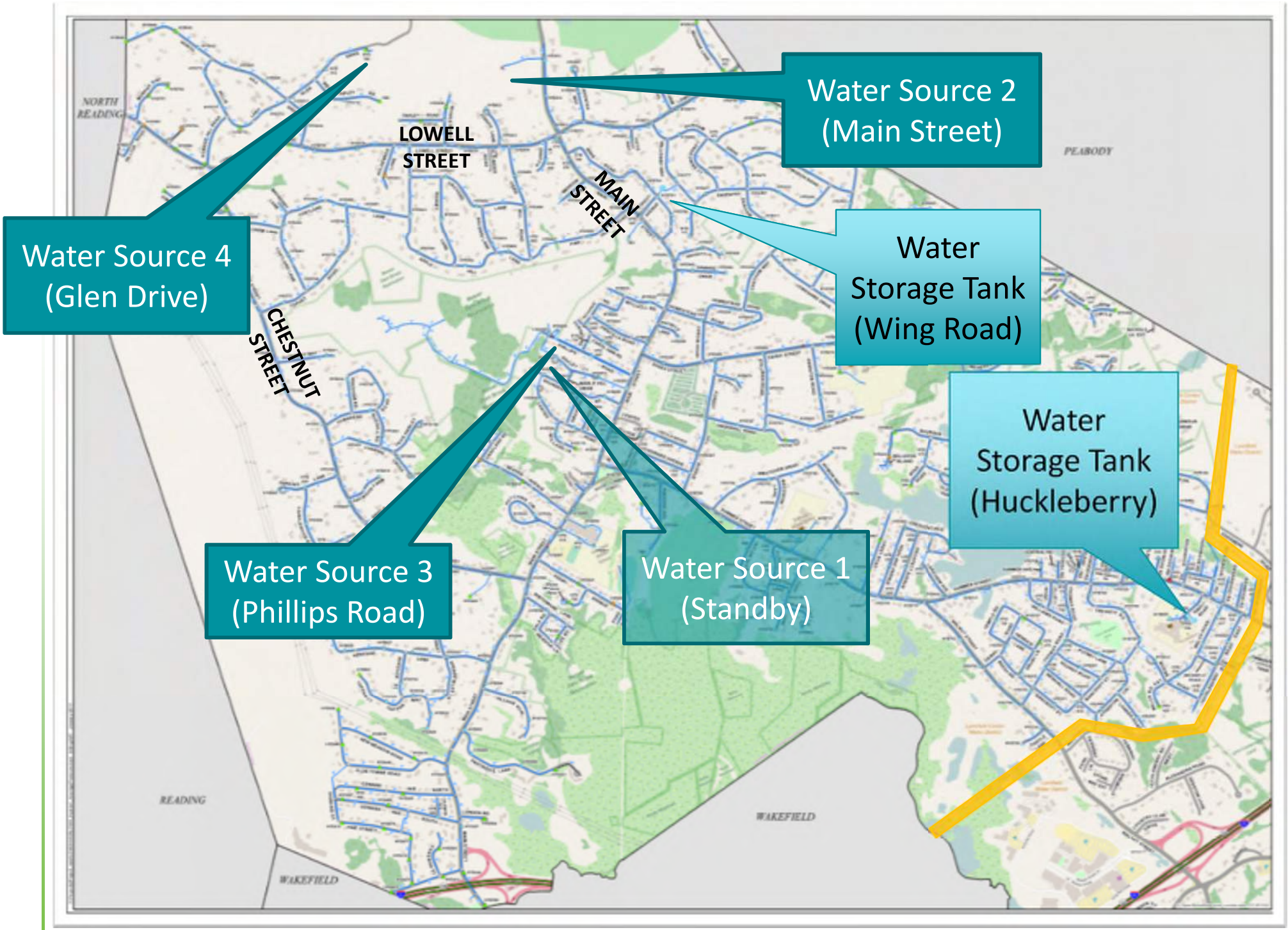
Agenda

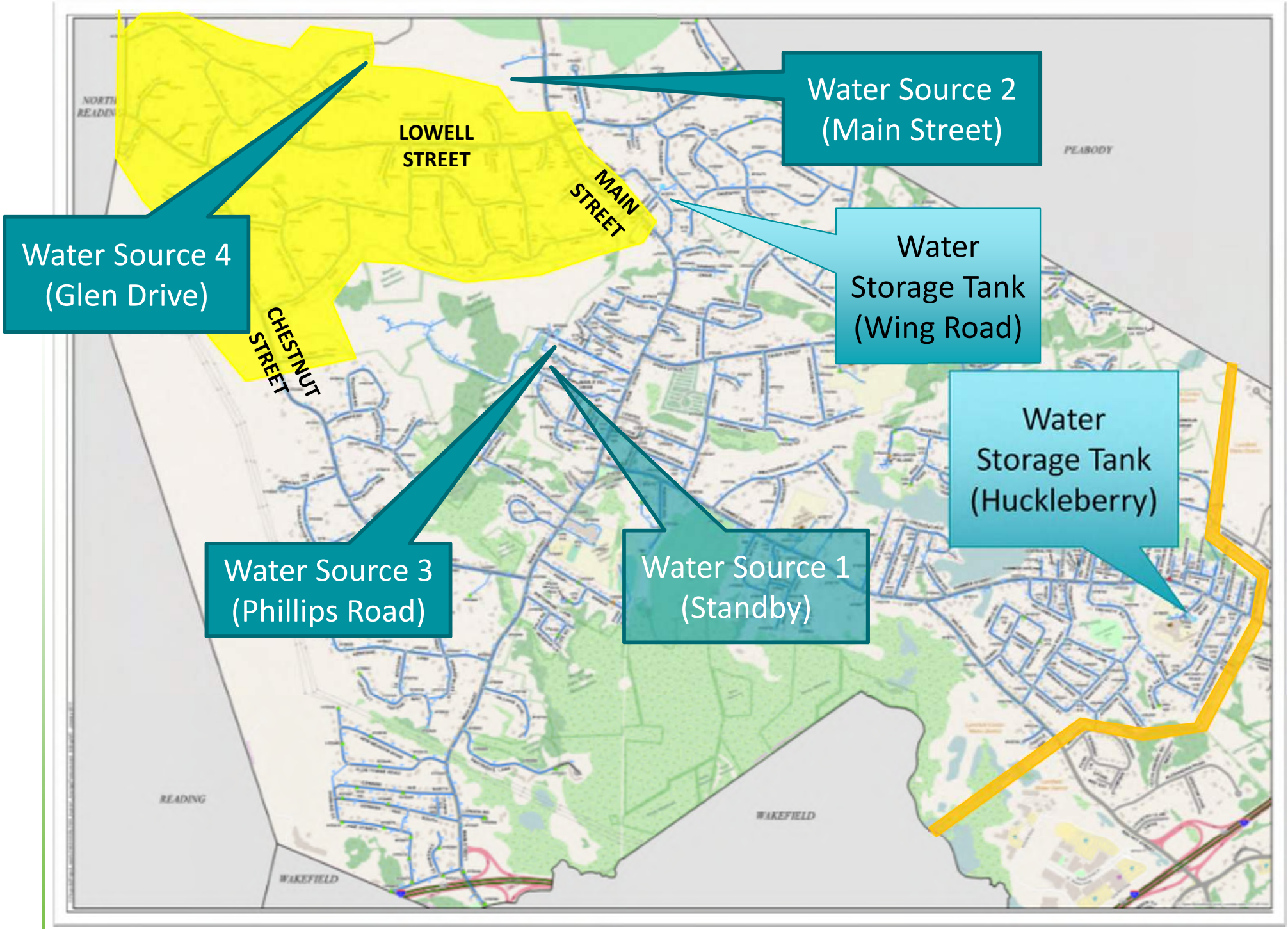
- Welcome by LCWD Superintendent
- Overview of District's Water System and Where "Apple Hill" Fits In
- "Apple Hill" Area Study & Short-Term Improvements
- Big Picture & Long-Term Solutions

Overview of District's Water System

- Sources: four groundwater well sites (three active, one standby)
- Treatment: treatment plant and at pump stations
- Storage: two water storage tanks
- Distribution: 48 miles of water main
- Questions from Audience




Water Source 2
(Main Street)
Water Source 4
(Glen Drive)
Water
Storage Tank
(Wing Road)
Water
Storage Tank
(Huckleberry)
Water Source 3
(Phillips Road)
Water Source 1
(Standby)
LOWELL
STREET
MAIN
STREET
CHESTNUT
STREET
NORTH
READING
PEABODY
READING
WAKEFIELD
WAKEFIELD


Water Source 2
(Main Street)
LOWELL
STREET
MAIN
STREET
Water Source 4
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STREET
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Storage Tank
(Wing Road)
Water
Storage Tank
(Huckleberry)
Water Source 3
(Phillips Road)
Water Source 1
(Standby)
PEABODY
READING
WAKEFIELD
WAKEFIELD

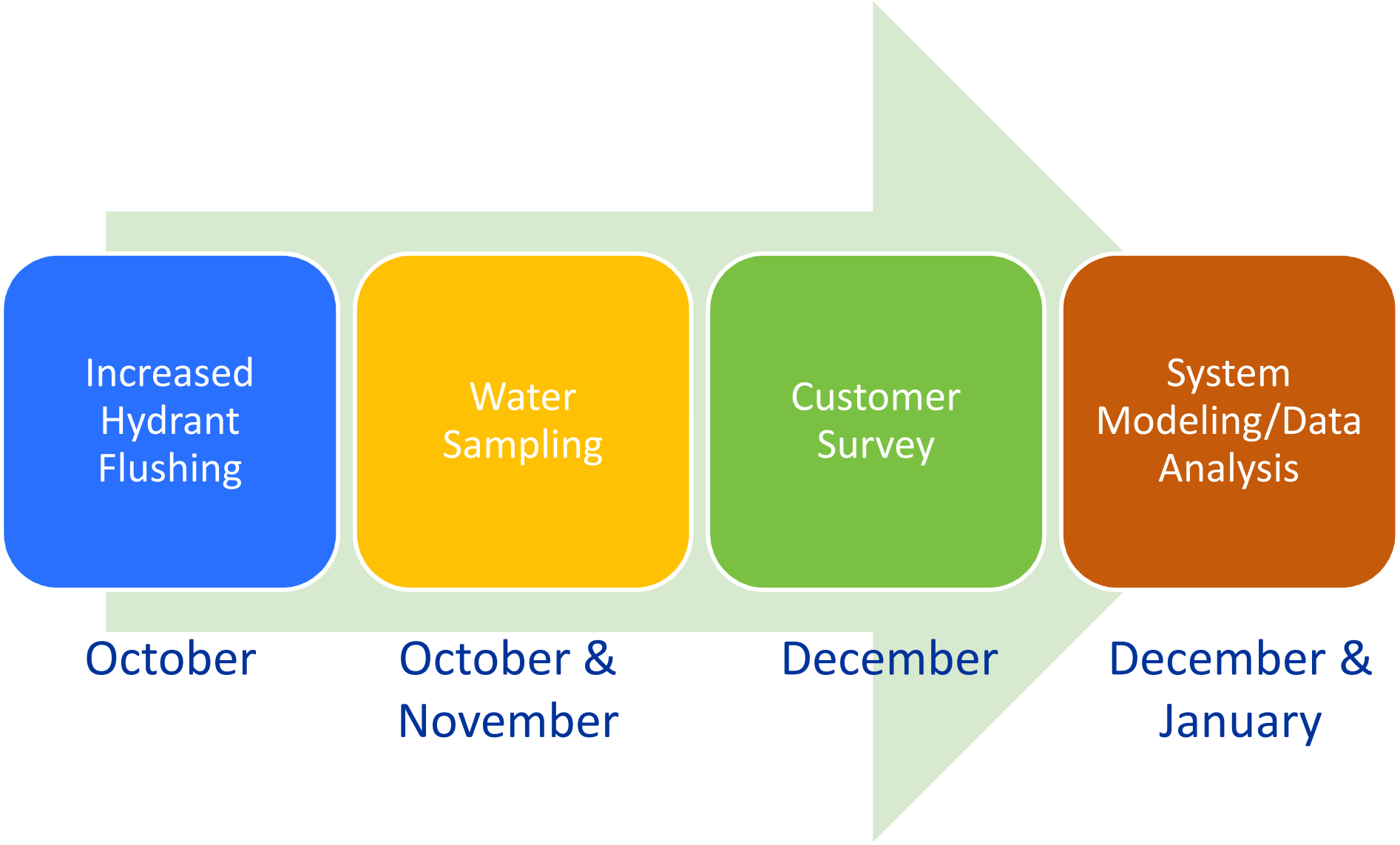
Apple Hill Neighborhood Study

Scope of Study

- **Why** is Apple Hill more affected by "Dirty Water" than other neighborhoods?
- What is the **extent** of the problem?
- How can LCWD **alleviate** the problem?
- Why is **iron and manganese** in my water / should I be concerned?

Apple Hill Neighborhood Study

Four Elements of Study



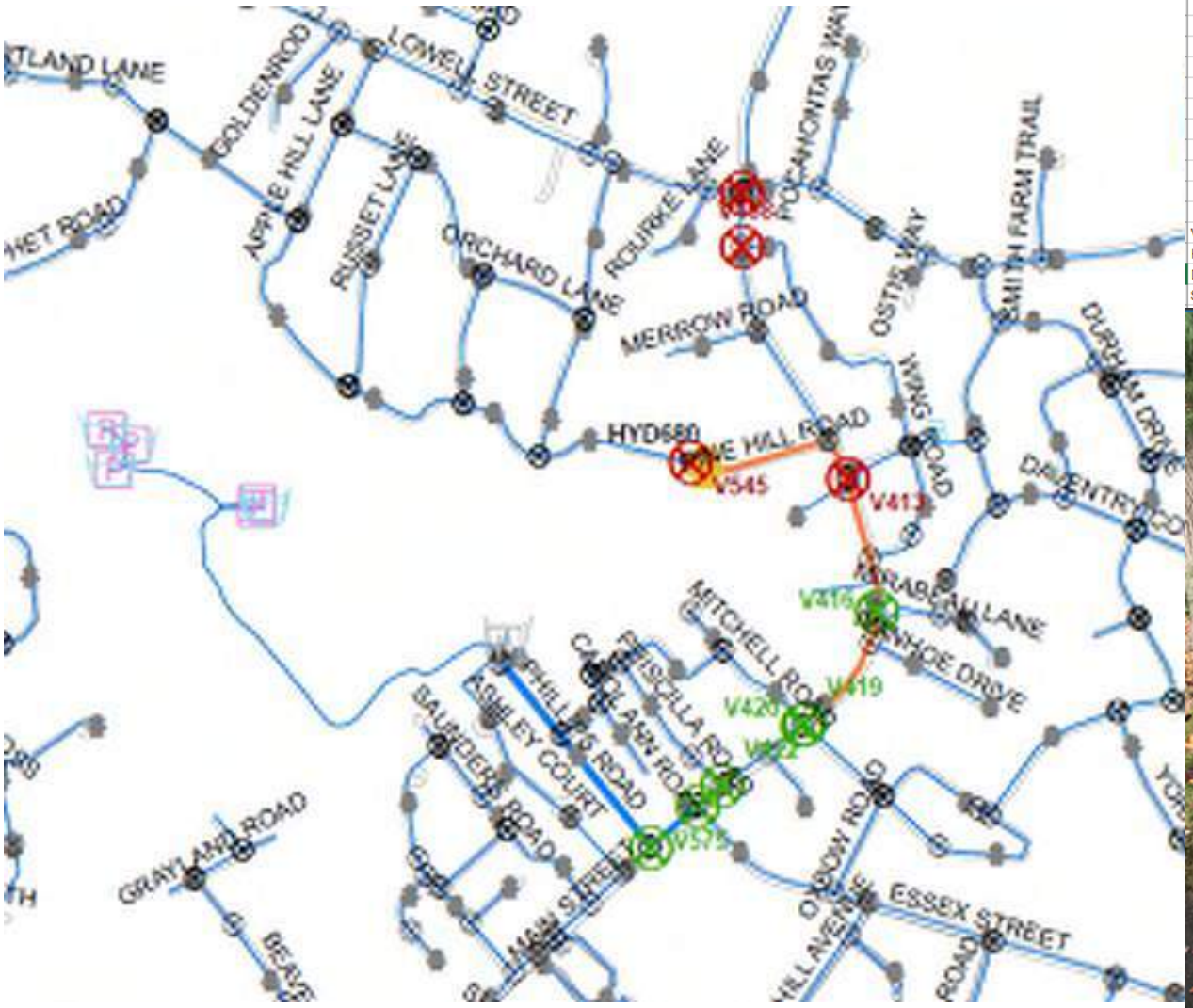
Hydrant Flushing

Alleviating the Problem

- Why do we Flush Water Mains?
- Increased frequency: annually → 2x annually
- What to do if your water is discolored

Hydrant Flushing

Alleviating the Problem

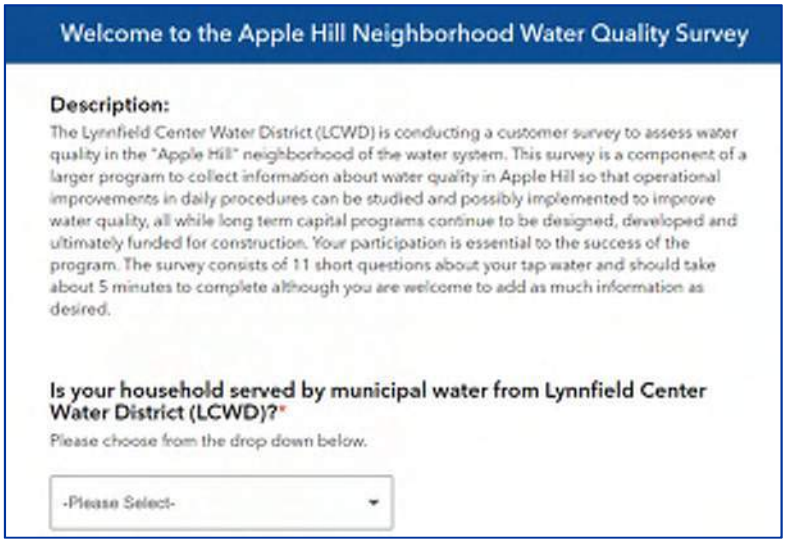


Water Main Flushing - Fall 2019			
Day:	1	Date: 10/15/2019	Time: 11:35AM - 12:00PM
Sequence - and Location			
1	Joseph Lane Hydrant at End		Miles of Main 0.7
	Closed:		
	V411	Main @ Strout towards Lowell Street	
	V297	Lowell @ Main Street towards Peabody	
	V377	Cidermill @ Lowell Street	
	V375	Lowell Inliner @ #375	
	Opened:		
Velocity		4.5	FPS
Hydrohitch		16	PSI
Diffuser		650	GPM
Static		75	PSI

Customer Feedback Survey

Extent of Problem

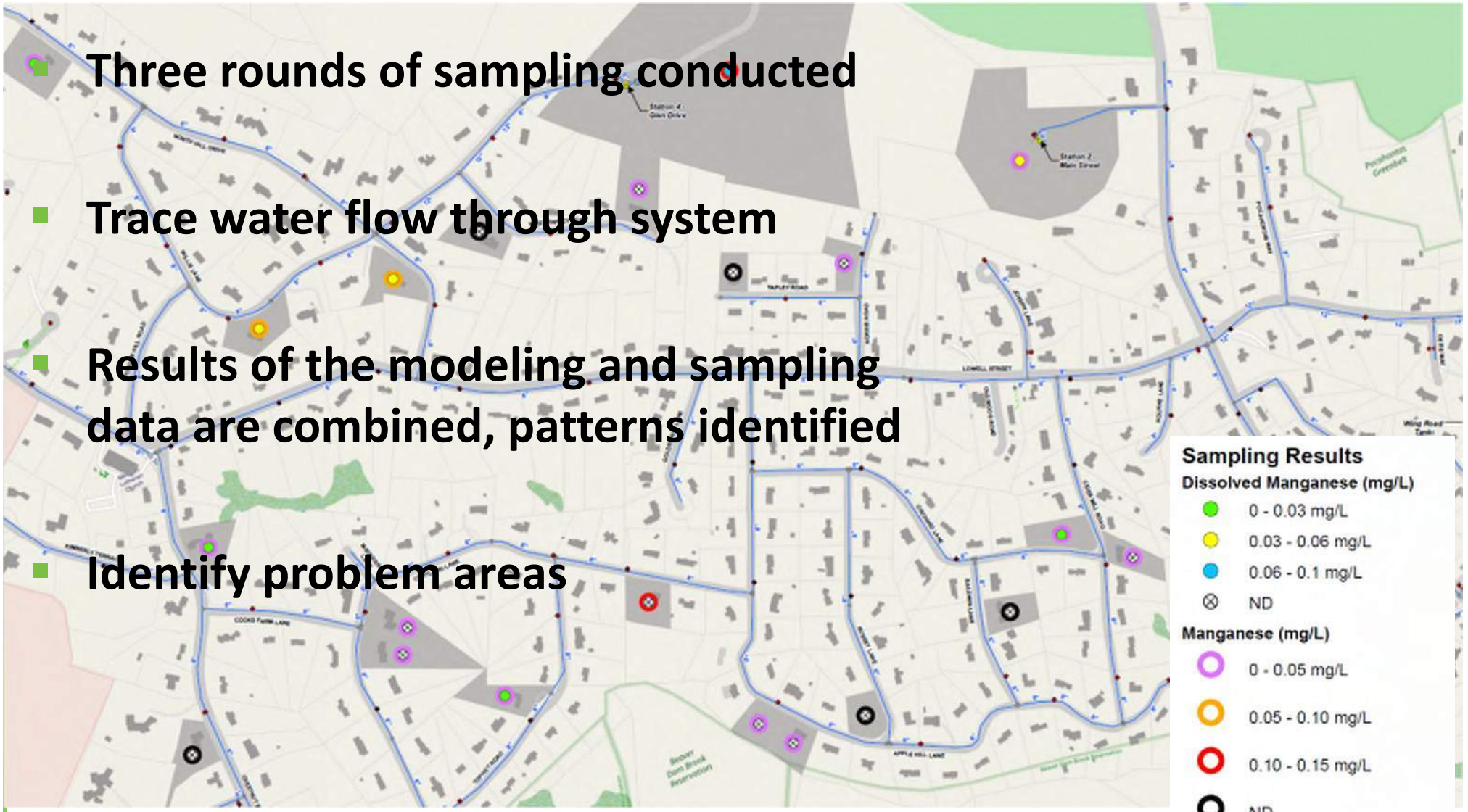
- Survey was mailed to you earlier this week
- Please respond online if possible
- Wide-spread participation is crucial whether you have problem or don't!
- Questions on Survey



Point Smartphone camera at me!

Water Sampling and Hydraulic Modeling

- Three rounds of sampling conducted
- Trace water flow through system
- Results of the modeling and sampling data are combined, patterns identified
- Identify problem areas



Apple Hill Neighborhood Study

- What water quality regulations govern the District?
  - Primary = health based, *required* to meet
  - Secondary = aesthetics (staining, odor, etc.), *not required* to meet
- Iron and manganese = secondary
  - Iron = 0.3 ppm
  - Manganese = 0.05 ppm
- Manganese health advisory (not regulation)
  - 0.3 ppm lifetime exposure for adults
  - 1.0 ppm “acute” exposure
  - LCWD manganese levels < 0.3 ppm

Apple Hill Water Quality Study

Apple Hill Neighborhood Study

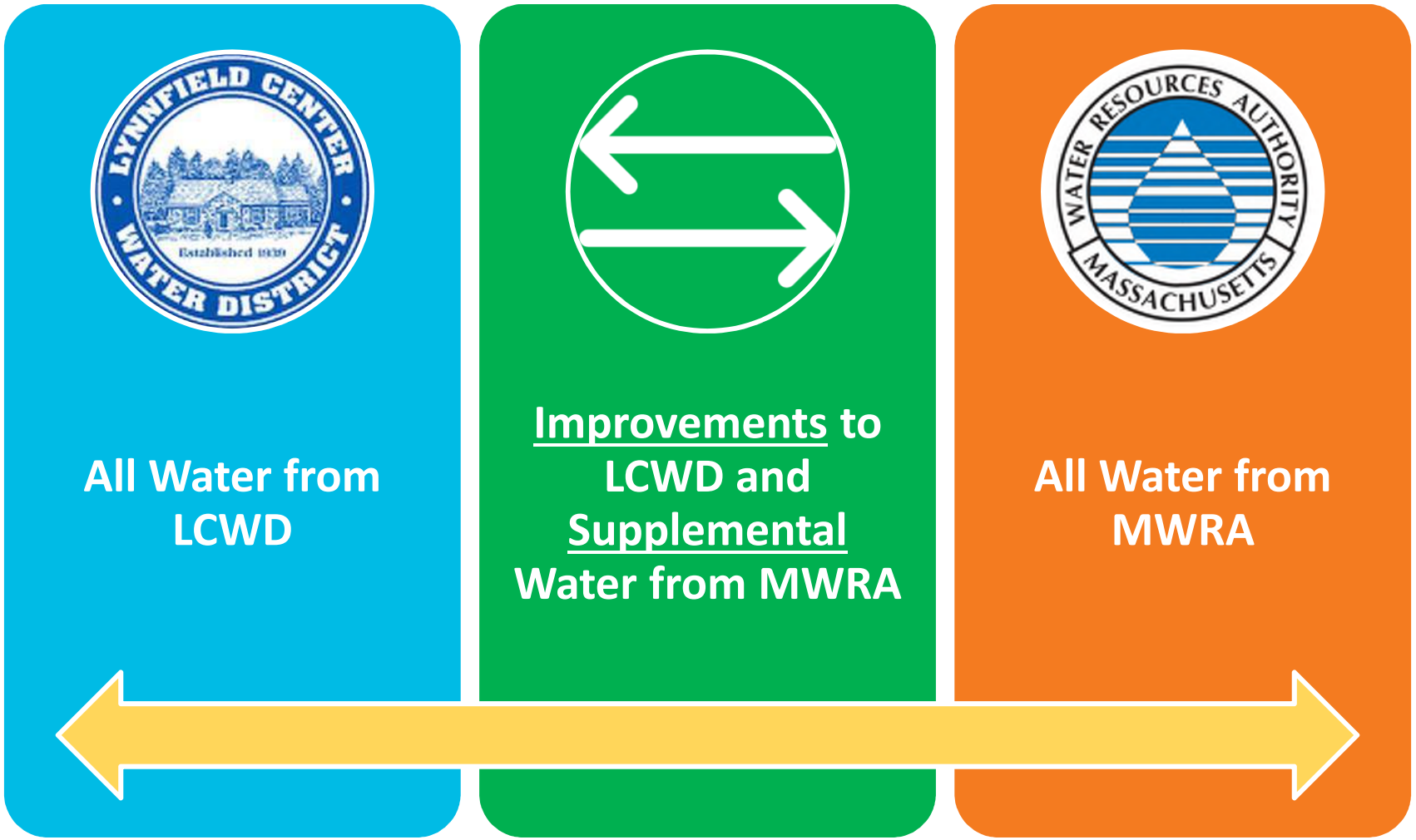
- Why these parameters?
  - Total and dissolved iron and manganese
  - Dissolved oxygen, chlorine residual
  - Temperature, pH, color
- How will the data be analyzed?
  - Water sampling results
  - Hydraulic modeling
- Goals
  - Confirm water quality meets standards
  - Look for patterns, problem areas and potential solutions
  - Samples collected pre and post flushing

Short Term Solutions

- Continue hydrant flushing 2X per year

- Low cost interim improvements
  - Promote blending or prevent flow reversal by operating valves

Big Picture and Long-Term Solutions



Big Picture and Long Term Solutions

- Study hydraulics of **receiving MWRA water** through the Lynnfield Water District
- Revisit studies for **water treatment options** at Glen Drive
- Develop plan to **investigate new wells** at existing sites (*especially sites in the less restricted North Coastal Basin where the District is not pumping to our permitted capacity)*
- Identify **deferred preventative maintenance** concerns, items and projects on existing infrastructure

Questions?

Point Smartphone camera at me!

Remember to take the Survey!

Water Customer Survey

Lynnfield Center Water District

CDM Smith

December 6, 2019

"Owner Name"
"Owner Mailing Address"
"City, State Zip Code"

Subject: Water Customer Survey
Lynnfield Center Water District
83 Phillips Road
Lynnfield, MA 01940-1763

Dear Lynnfield Water Customer:

The Lynnfield Center Water District (LCWD) is conducting a customer survey to assess water quality in the "Apple Hill/Chestnut/Lowell" neighborhoods of the water system. This survey is a component of a larger program to collect information about water quality at homes within these neighborhoods. Operational improvements in daily procedures will be studied and possibly implemented as a result of this work to improve consistency in water distribution and quality, all while long term capital programs continue to be designed, developed and ultimately funded for construction. Your participation is essential to the success of the program. The survey consists of 11 short questions about your tap water and should take about 5 minutes to complete, although you are welcome to add as much information as desired.

LCWD would like you to complete this survey online; and it has been formatted for your smart phone. Simply point your smartphone camera at the QR code below (square barcode image) and your phone will take you directly to the survey. Just click the notification that pops up on the top of your screen. If you prefer to take the survey from your computer, please visit www.lcwd.us and click the survey button on the home page. For those who choose not to take the survey on your phone or online, the printed survey on the back of this letter can be filled out and dropped off at the District's office at 81 Phillips Road, Monday – Friday from 8am to 4pm. Again, wide-spread participation in this survey is essential to the success of this program. We thank you in advance for your cooperation.

In addition to this survey, water main flushing & additional water sampling have already taken place in your area and CDM Smith plans to begin analyzing information obtained immediately. All of these efforts will be discussed in further detail at a public meeting to be held at the Meeting House at the intersection of Summer & Main St on December 12th at 7pm. An RSVP to LCWD is appreciated if you are planning to attend. Parking is available in the main lot of Town Hall and on street in permitted spaces.

Sincerely,

John Scenna
Superintendent

Use your smartphone camera to scan:

If you are unable to scan the code, please go the survey's website: lcwd.us/AppleHillSurvey

Water Customer Survey

Lynnfield Center Water District

CDM Smith

1. Is your household served by municipal water from Lynnfield Center Water District (LCWD)?
   ☐ If yes, continue to rest of survey. If no, no need to finish the survey; thanks for your time.
   a. If **yes**, what is your household address?
   _____
   _____

2. In the last 90 days have you experienced discolored water?
   ☐ If yes, how many times? _____ ☐ No

3. In the last 90 days have you experienced cloudy water?
   ☐ If yes, how many times? _____ ☐ No

4. In the last 90 days have you experienced poor tasting water (minerally taste)?
   ☐ If yes, how many times? _____ ☐ No

If you chose **yes** to any of the questions 2-4, continue with the following series of questions:

5. Water main flushing occurred in your area from October 15 to October 29. Did you experience an improvement in your water quality since flushing occurred?
   ☐ Yes ☐ No

6. Do you experience staining on plumbing fixtures such as sinks, toilets, when or after washing clothes, or when cooking?
   ☐ Yes, toilets or sinks ☐ Yes, cooking ☐ Yes, clothes
   ☐ Yes, clothes, sinks, etc. (multiple) ☐ No
   a. If **yes**, what color is the staining?
   ☐ Red (■) ☐ Brown (■) ☐ Black (■)
   b. If **yes**, how many times in the last 90 days did this occur? _____

7. Did the problem occur when using cold water, hot water, or both?
   ☐ Cold water ☐ Hot water ☐ Both

8. What season of the year is the problem most evident?
   ☐ Winter ☐ Spring
   ☐ Summer ☐ Fall ☐ Not correlated to a season

9. How often do you report this problem to LCWD?
   ☐ Always ☐ Sometimes ☐ Never

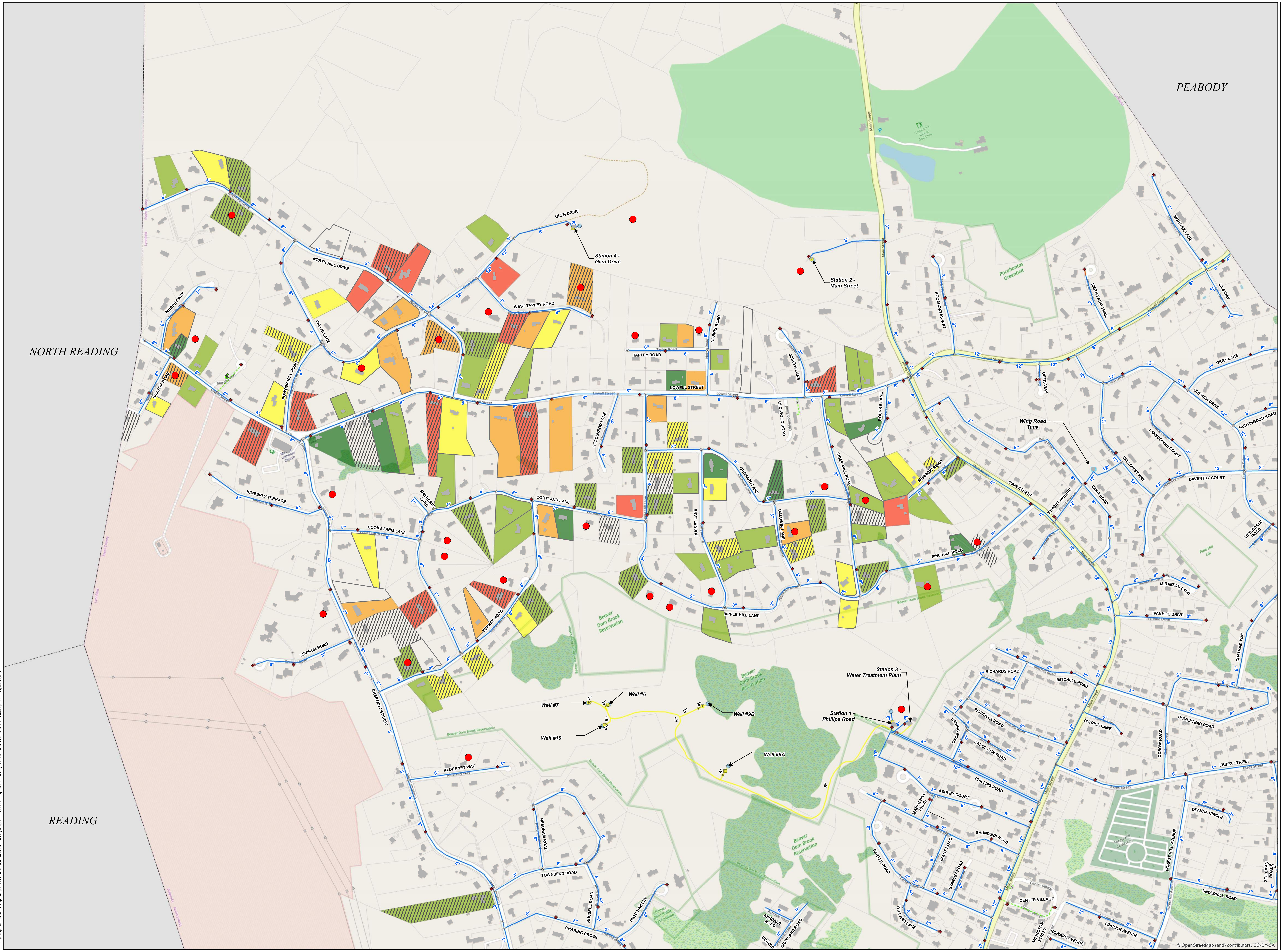
10. Do you have a water filter?
    ☐ Yes ☐ No
    a. If **yes**, what type of water filter do you have?
    ☐ Tap filter on sink ☐ Whole house filter ☐ Refrigerator filter

11. Do you rely on bottled water for drinking or cooking while in your home?
    ☐ Yes ☐ No

OPTIONAL: Enter your phone number (format example: **781-334-3901**): _____

OPTIONAL: Enter your email address (format example: **info@lcwd.us**): _____

Please return to:
Lynnfield Center Water District - Water Customer Survey
83 Phillips Road Lynnfield, MA 01940-1763



NORTH READING
READING
PEABODY
GLEN DRIVE
Station 4 - Glen Drive
Station 2 - Main Street
NORTH HILL DRIVE
WEST TAPLEY ROAD
MURPHY WAY
WILLIS LANE
POWDER HILL ROAD
HILLTOP ROAD
TAPLEY ROAD
NORRIS ROAD
JOSEPH LANE
LOWELL STREET
GOLDENROD LANE
OLD WOOD ROAD
ROURKE LANE
POCAHONTAS WAY
SMITH FARM TRAIL
MOHAWK LANE
LILS WAY
GREY LANE
DURHAM DRIVE
HUNTINGDON ROAD
LANSDOWNE COURT
DAVENTRY COURT
LITTLEDALE ROAD
Wing Road Tank
WING ROAD
WILLOWBY WAY
STROUT AVENUE
MAIN STREET
Pocahontas Greenbelt
KIMBERLY TERRACE
COOKS FARM LANE
MAYBERRY LANE
CORTLAND LANE
RUSSET LANE
ORCHARD LANE
BALDWIN LANE
CIDER MILL ROAD
MENROW ROAD
PINE HILL ROAD
MIRABEAU LANE
IVANHOE DRIVE
CHATHAM WAY
TOPHET ROAD
APPLE HILL LANE
SEVINOR ROAD
Beaver Dam Brook Reservation
CHESTNUT STREET
Well #7
Well #6
Well #10
Well #9B
Well #9A
Station 3 - Water Treatment Plant
Station 1 - Phillips Road
RICHARDS ROAD
MITCHELL ROAD
PRISCILLA ROAD
PATRICE LANE
HOMESTEAD ROAD
CAROL ANN ROAD
PHILLIPS ROAD
ASHLEY COURT
MABLE HILL DRIVE
SAUNDERS ROAD
GRANT ROAD
STANLEY ROAD
CARTER ROAD
WILLARD LANE
ESSEX STREET
OXBOW ROAD
DEANNA CIRCLE
FOREST HILL AVENUE
STILLMAN ROAD
UNDERHILL ROAD
LINCOLN AVENUE
HOWARD AVENUE
CENTER VILLAGE
ARLINGTON STREET
ALDERNEY WAY
NEEDHAM ROAD
TOWNSEND ROAD
RUSSELL ROAD
TROY HAWLEY
CHARING CROSS
ASHDALE ROAD
GRAYLAND ROAD
Pine Hill Lot
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F:\Projects\Main_Projects\LCWD\MXD\CustomerSurvey\FigA1_LCWD_AppleHillSurvey_DiscoloredWater.mxd BillingsMC April-2020

TOWN OF LYNNFIELD

Massachusetts

LYNNFIELD CENTER WATER DISTRICT

Apple Hill Neighborhood Survey Results

April 2020

Sampling Location

Survey Results

- Water Filter
- No Water Filter

No. of Days with Discolored Water in Last 90 Days

- None
- 1-5
- 6-15
- 16-45
- 46-90

Water Network Features

- Hydrant
- Hydrant Valve
- System Valve
- Water Tank
- Distribution Pipe
- Hydrant Lateral
- Private Pipe
- Well Discharge
- Wellfield Raw Water Supply
- Water District Boundary

Basemap

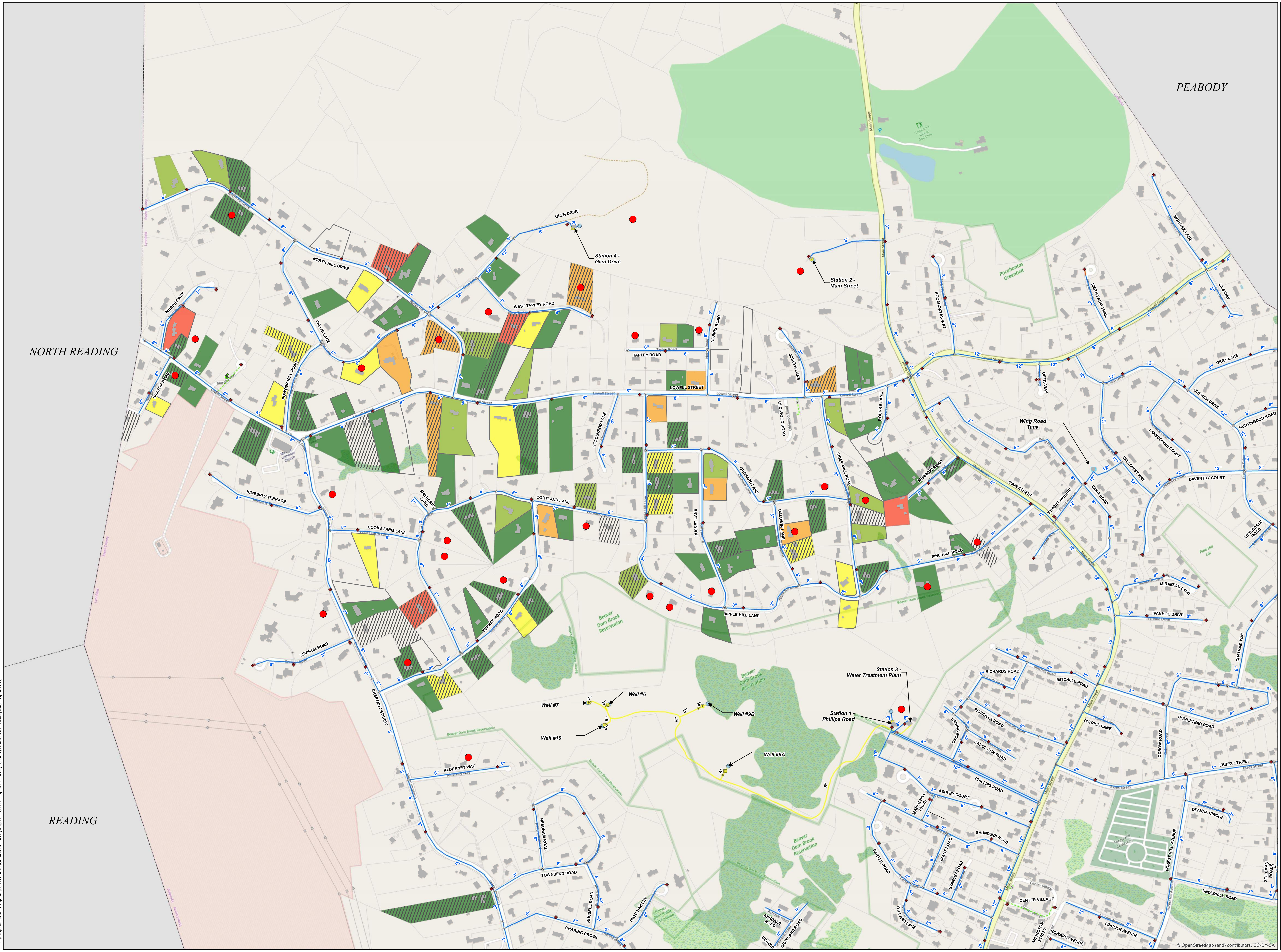
- Town Boundary
- Building Footprints
- Lynnfield Parcels

0 180 360 720 1,080

Feet

Sources: Town of Lynnfield, CDM Smith, and MassGIS
Coordinate System: NAD83 Mass. State Plane Mainland FIPS 2001 Feet

CDM Smith



TOWN OF LYNNFIELD

Massachusetts

LYNNFIELD CENTER WATER DISTRICT

Apple Hill Neighborhood Survey Results

April 2020

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- 46-90

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CDM Smith

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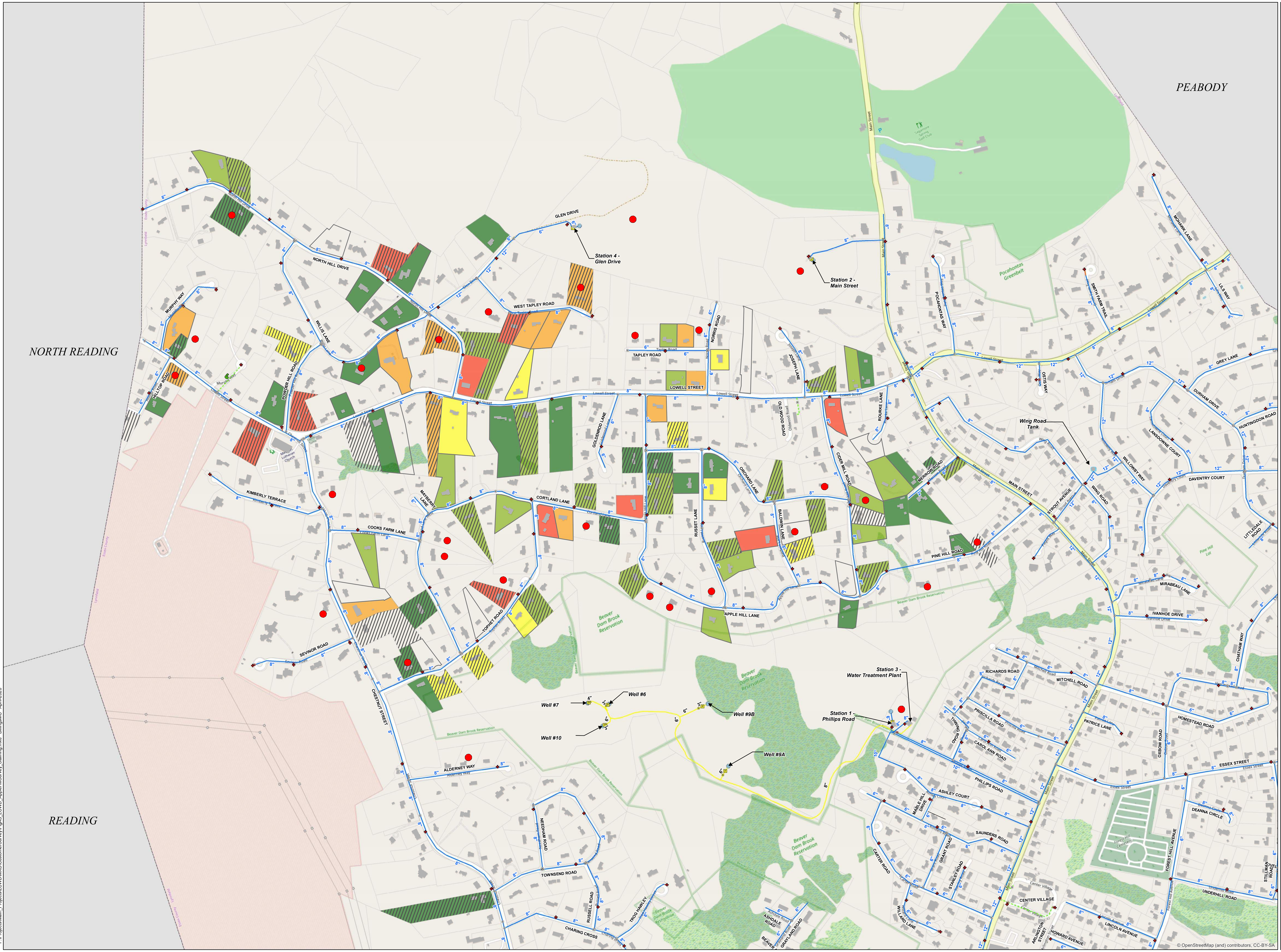

TOWN OF LYNNFIELD
Massachusetts

LYNNFIELD CENTER WATER DISTRICT

Apple Hill Neighborhood Survey Results

April 2020

Sampling Location

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Massachusetts
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READING
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Station 2 - Main Street
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TAPLEY ROAD
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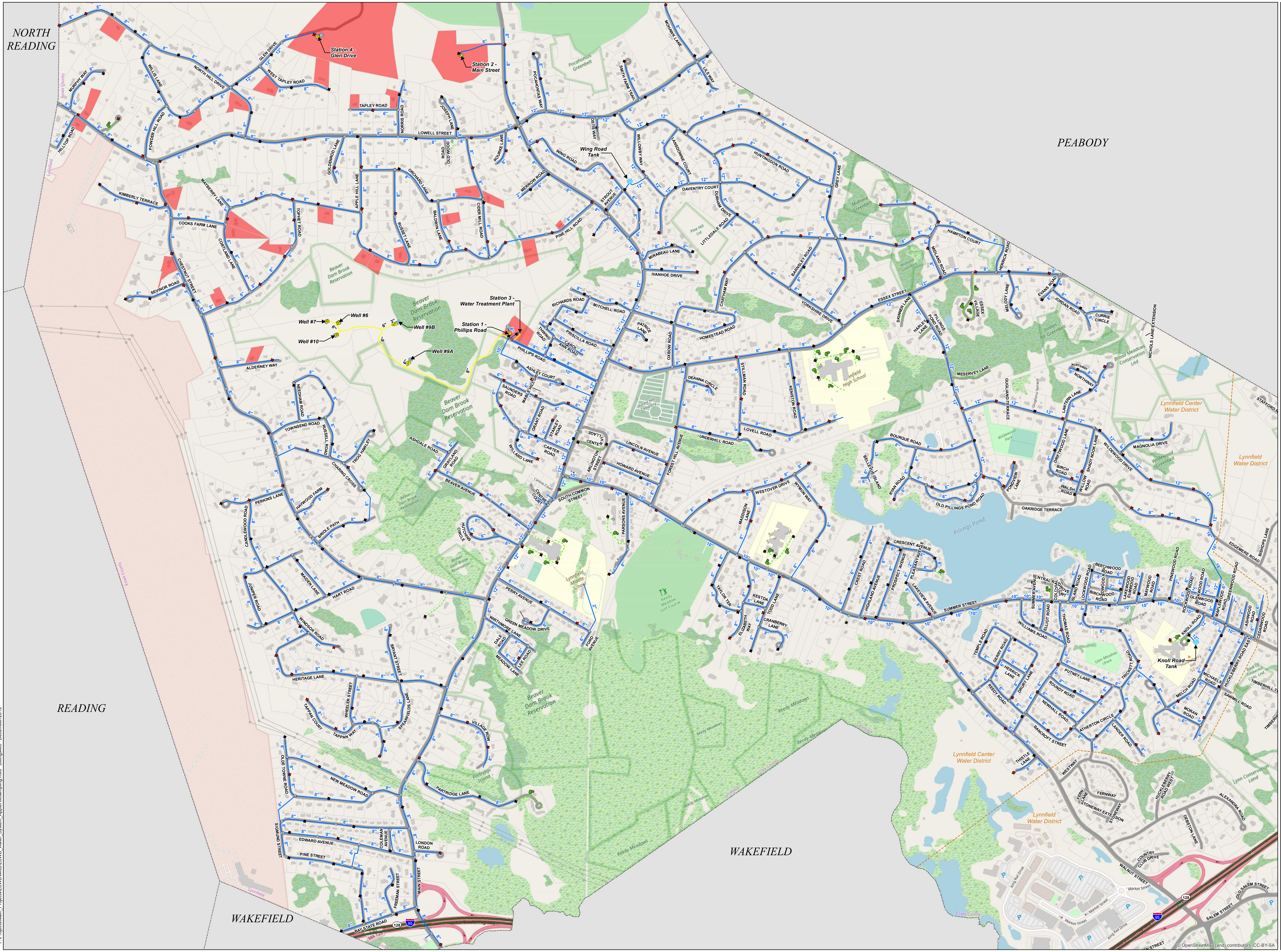
WILLIS LANE
POWDER HILL ROAD
HILLTOP ROAD
KIMBERLY TERRACE
COOKS FARM LANE
CORTLAND LANE
APPLE HILL LANE
CHESTNUT STREET
SEVINOR ROAD
ALDERNEY WAY
MAIN STREET
PINE HILL ROAD
ORCHARD LANE
BALDWIN LANE
CIDER MILL ROAD
RUSSET LANE
GOLDENROD LANE
MAYBERRY LANE
TOPHET ROAD
ROURKE LANE
JOSEPH LANE
NORRIS ROAD
OLD WOOD ROAD
WING ROAD
STROUT AVENUE
WILLOWBY WAY
DAVENTRY COURT
LANSDOWNE COURT
DURHAM DRIVE
HUNTINGDON ROAD
GREY LANE
MOHAWK LANE
LILS WAY
SMITH FARM TRAIL
POCAHONTAS WAY
OTIS WAY
MIRABEAU LANE
IVANHOE DRIVE
CHATHAM WAY
LITTLEDALE ROAD
RICHARDS ROAD
MITCHELL ROAD
PRISCILLA ROAD
CAROL ANN ROAD
PATRICE LANE
HOMESTEAD ROAD
OXBOW ROAD
ESSEX STREET
DEANNA CIRCLE
PHILLIPS ROAD
ASHLEY COURT
SAUNDERS ROAD
GRANT ROAD
STANLEY ROAD
CARTER ROAD
WILLARD LANE
CENTER VILLAGE
HOWARD AVENUE
LINCOLN AVENUE
FOREST HILL AVENUE
UNDERHILL ROAD
NEEDHAM ROAD
TOWNSEND ROAD
RUSSELL ROAD
CHARING CROSS
TROY HAWLEY
ASHDALE ROAD
GRAYLAND ROAD

Attachment B

Water Quality Sampling Locations & Results

Water Quality Sampling Locations

Water Quality Sampling Results Table



TOWN OF LYNNFIELD
Massachusetts

LYNNFIELD CENTER WATER DISTRICT

Apple Hill Neighborhood Sampling Results

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- Water Tank
- Distribution Pipe
- Hydrant Lateral
- Private Pipe
- Well Discharge
- Wellfield Raw Water Supply
- Water District Boundary

Basemap
- Town Boundary
- Interstate
- U.S. Highway
- Local Road

0 300 600 1,200 1,800
Feet

Sources: Town of Lynnfield, CDM Smith, and MassGIS
Coordinate System: NAD83 Mass. State Plane Mainland FIPS 2001 Feet

CDM Smith

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Apple Hill Area Sample Program

Testing for Iron and Manganese (suspended and dissolved) & Other Items

Fall 2019 Pre and Post Flushing Program

SMCL: Secondary Maximum Contaminant Level (EPA Limit)

Managanese Dissolved: 0.05 (mg/l)
Manganese, Suspended: 0.05 (mg/l)

Sample Site	Location		Chlorine (mg/L) A	pH	Dissolved Oxygen (mg/L)	Temperature (F)	Iron, Dissolved, MG/L	Iron, MG/L	Manganese, Dissolved, MG/L	Manganese, MG/L	Alkalinity, MG/L	Color Apparent, CU	Total Dissolved Solids, MG/L	Total Suspended Solids, MG/L
1	19 Apple Hill													
		Sample A	n/a	n/a	n/a	n/a	ND	0.155	ND	0.249	94	15	352	ND
		Sample B	0.54	7.71	9.3	59.9	ND	ND	ND	0.011	92	2	304	ND
		Sample C	0.7	7.94	6.9	56.5	ND	ND	0.005	0.014	92	ND	314	ND
2	21 Apple Hill													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	ND	93	0	330	ND
		Sample B	0.52	7.7	9.9	62.1	ND	0.019	ND	0.017	92	0	332	ND
		Sample C	0.65	8	8.4	57.2	ND	ND	ND	ND	94	ND	302	ND
3	78 Pine Hill													
		Sample A	n/a	n/a	n/a	n/a	0.007	ND	ND	ND	93	0	308	ND
		Sample B	0.46	7.92	10	58.8	ND	ND	ND	ND	93	0	310	ND
		Sample C	0.59	7.9	5.3	53.6	ND	0.011	ND	0.014	93	2	314	ND
4	45 Pine Hill													
		Sample A	n/a	n/a	n/a	n/a	ND	0.29	0.005	0.008	91	0	302	12
		Sample B	0.18	7.9	7.8	60.8	ND	ND	ND	ND	95	0	306	ND
		Sample C	0.31	7.94	6.4	55.9	ND	0.022	ND	0.009	95	ND	312	ND
5	9 Cider Mill													
		Sample A	n/a	n/a	n/a	n/a	ND	0.127	0.028	0.447	94	15	308	2
		Sample B	0.6	7.79	7.2	58.3	ND	0.024	ND	0.044	94	10	326	ND
		Sample C												
6	18 Orchard Lane													
		Sample A	n/a	n/a	n/a	n/a	ND	0.038	ND	0.103	91	5	316	2
		Sample B	0.7	7.77	7	58.1	ND	0.008	0.005	0.043	92	2	316	ND
		Sample C	0.79	7.86	7.7	54.1	ND	ND	0.01	0.029	92	ND	298	ND
7	5 Baldwin													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	0.031	0.03	93	0	320	1
		Sample B	0.26	7.8	11 (error)	62.1	ND	ND	ND	ND	93	0	338	ND
		Sample C	0.56	7.92	10.5	55.4	ND	0.007	ND	0.017	95	ND	302	ND
8	15 Russet Lane													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	ND	94	2	294	ND
		Sample B	0.29	7.78	11 (error)	59.9	ND	ND	ND	ND	92	0	292	ND
		Sample C	0.42	7.97	8.5	55.4	ND	ND	ND	ND	95	ND	306	ND
9	22 Cortland													
		Sample A	n/a	n/a	n/a	n/a	ND	0.019	ND	0.008	94	0	350	ND
		Sample B	0.4	7.89	7.7	61.2	ND	0.011	ND	0.004	93	0	336	ND
		Sample C	0.68	7.97	5.7	54.3	ND	ND	0.007	0.016	95	ND	312	ND
10	24 Cortland													
		Sample A	n/a	n/a	n/a	n/a	ND	0.016	0.009	0.017	93	0	314	ND
		Sample B	0.36	7.96	7.8	60.8	ND	ND	ND	0.004	94	0	304	ND
		Sample C	0.72	7.93	6	53.4	ND	ND	ND	0.018	97	ND	314	ND

Apple Hill Area Sample Program

Testing for Iron and Manganese (suspended and dissolved) & Other Items

Fall 2019 Pre and Post Flushing Program

SMCL: Secondary Maximum Contaminant Level (EPA Limit)

Managanese Dissolved: 0.05 (mg/l)
Manganese, Suspended: 0.05 (mg/l)

Sample Site	Location		Chlorine (mg/L) A	pH	Dissolved Oxygen (mg/L)	Temperature (F)	Iron, Dissolved, MG/L	Iron, MG/L	Manganese, Dissolved, MG/L	Manganese, MG/L	Alkalinity, MG/L	Color Apparent, CU	Total Dissolved Solids, MG/L	Total Suspended Solids, MG/L
11	600 Chestnut													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	ND	93	0	326	ND
		Sample B	0.32	7.83	5.8	62.1	ND	ND	ND	ND	92	0	320	ND
		Sample C	0.24	7.99	4.8	56.5	ND	ND	ND	ND	92	ND	310	ND
12	661 Chestnut													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	0.025	93	0	332	ND
		Sample B	0.72	7.91	4.1	57.4	ND	0.012	0.017	0.046	92	0	326	ND
		Sample C	0.78	7.96	5	52	ND	ND	0.026	0.032	93	ND	316	ND
13	2 North Hill													
		Sample A	n/a	n/a	n/a	n/a	ND	0.029	0.032	0.058	93	0	328	ND
		Sample B	0.69	7.76	4.9	56.1	ND	0.014	0.06	0.077	94	0	322	ND
		Sample C	0.82	7.89	6.3	52	ND	ND	0.058	0.071	95	ND	314	ND
14	18 North Hill													
		Sample A	n/a	n/a	n/a	n/a	ND	0.207	0.005	0.213	94	15	308	1
		Sample B	0.38	7.77	7.2	60.3	ND	ND	0.006	0.01	92	0	304	ND
		Sample C	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
15	6 Willis													
		Sample A	n/a	n/a	n/a	n/a	ND	0.022	0.018	0.072	93	2	326	ND
		Sample B	0.8	7.84	3.7	55.9	ND	0.009	0.042	0.074	93	0	338	ND
		Sample C	0.87	7.99	5	52.9	ND	ND	0.048	0.057	93	ND	320	ND
16	785 Lowell													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	ND	94	0	318	ND
		Sample B	0.09	7.87	7.3	60.3	ND	ND	ND	ND	93	0	316	ND
		Sample C	0.04	7.99	6.6	54.3	ND	ND	ND	ND	93	ND	306	ND
17	794 Lowell													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	0.005	0.008	94	0	342	ND
		Sample B	0.47	7.83	3.8	60.1	ND	ND	ND	0.009	93	0	344	ND
		Sample C	0.54	7.95	5.7	53.8	ND	0.032	ND	0.045	93	5	322	1
19	6 Alderney Way													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	ND	94	0	334	ND
		Sample B	0.37	7.86	11 (error)	60.8	ND	ND	ND	ND	93	0	342	ND
		Sample C	0.63	7.97	6.3	57.4	ND	ND	ND	0.013	96	ND	318	ND
21	17 West Tapley													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	0.007	0.017	92	2	322	4
		Sample B	0.37	7.82	3.1	61	ND	ND	ND	0.007	93	0	328	ND
		Sample C	0.47	7.9	6.1	55.9	ND	ND	ND	0.012	95	ND	308	ND
22	24 West Tapley													
		Sample A	n/a	n/a	n/a	n/a	ND	0.015	0.168	0.279	93	0	326	2
		Sample B	0.14	7.79	8.2	59.9	ND	ND	ND	ND	92	0	324	ND
		Sample C	0.56	7.95	5.6	52.9	ND	ND	ND	ND	92	ND	306	ND

Apple Hill Area Sample Program

Testing for Iron and Manganese (suspended and dissolved) & Other Items

Fall 2019 Pre and Post Flushing Program

SMCL: Secondary Maximum Contaminant Level (EPA Limit)

Managanese Dissolved: 0.05 (mg/l)
Manganese, Suspended: 0.05 (mg/l)

Sample Site	Location		Chlorine (mg/L) A	pH	Dissolved Oxygen (mg/L)	Temperature (F)	Iron, Dissolved, MG/L	Iron, MG/L	Manganese, Dissolved, MG/L	Manganese, MG/L	Alkalinity, MG/L	Color Apparent, CU	Total Dissolved Solids, MG/L	Total Suspended Solids, MG/L
23	9 Tapley													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	0.015	95	2	324	ND
		Sample B	0.19	7.8	4.3	63.5	ND	ND	ND	ND	95	0	308	ND
		Sample C	0.44	7.84	6.7	56.8	ND	ND	ND	0.004	94	ND	304	ND
24	4 Norris													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	0.014	92	0	314	ND
		Sample B	0.29	7.79	5.3	60.3	ND	ND	ND	0.007	93	0	314	ND
		Sample C	0.59	7.77	8.1	55.8	ND	ND	0.009	0.021	94	ND	298	ND
25	6 Cortland													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	0.015	93	0	358	ND
		Sample B	0.81	7.86	5	58.3	ND	0.012	ND	0.147	92	0	348	ND
		Sample C	0.71	7.93	4.8	54.9	ND	ND	0.013	0.021	97	ND	308	ND
26	4 Tophet													
		Sample A	n/a	n/a	n/a	n/a	ND	0.013	ND	0.007	95	0	306	6
		Sample B	0.21	7.98	6.3	63	ND	0.006	ND	ND	96	0	310	ND
		Sample C	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
27	18 Tophet													
		Sample A	n/a	n/a	n/a	n/a	ND	ND	ND	0.009	93	0	308	ND
		Sample B	0.67	7.82	5.9	60.4	ND	ND	0.006	0.011	93	0	304	ND
		Sample C	0.62	7.95	6.4	53.8	ND	ND	0.005	0.015	95	ND	316	ND
28	Glen Drive Station LCWD													
		Sample A	n/a	n/a	n/a	n/a	ND	0.154	0.08	0.255	96	0	380	1
		Sample B	0.87	7.87	2.8	57.9	ND	0.025	0.091	0.129	94	0	358	ND
		Sample C	0.93	7.82	7.6	54.3	ND	0.005	0.076	0.089	94	ND	302	ND
29	Main Street Station LCWD													
		Sample A	n/a	n/a	n/a	n/a	0.01	0.03	0.039	0.088	93	0	476	ND
		Sample B	0.98	7.53	8.1	52	0.017	0.023	0.032	0.037	104	0	484	ND
		Sample C	0.75	7.55	5	55.8	0.007	0.009	0.033	0.034	104	ND	450	ND
30	Phillips Road Station LCWD													
		Sample A	n/a	n/a	n/a	n/a	ND	0.006	ND	ND	97	0	256	ND
		Sample B	0.68	7.67	6.8	60	ND	0.009	ND	0.024	99	0	248	ND
		Sample C	1.19	8.05	8.8	56.5	ND	ND	ND	ND	98	ND	202	ND

Attachment C
Hydraulic Modeling Results

TOWN OF LYNNFIELD
Massachusetts

LYNNFIELD CENTER WATER DISTRICT

Apple Hill Neighborhood Modeling Results

February 2020

Maximum Water Age

- < 2 days
- > 2 days, < 1 week
- > 1 week

Water Network Features

- Hydrant
- Hydrant Valve
- System Valve
- Water Tank

Basemap

- Town Boundary
- Interstate
- U.S. Highway
- Local Road

Figure C-1

0 150 300 600 900
Feet

Sources: Town of Lynnfield, CDM Smith, and MassGIS
Coordinate System: NAD83 Mass. State Plane Mainland FIPS 2001 Feet

CDM Smith

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TOWN OF LYNNFIELD
Massachusetts

LYNNFIELD CENTER WATER DISTRICT

Apple Hill Neighborhood Modeling Results

February 2020

Maximum Water Age

- < 2 days
- > 2 days, < 1 week
- > 1 week

Water Network Features

- Hydrant
- Hydrant Valve
- System Valve
- Water Tank

Basemap

- Town Boundary
- Interstate
- U.S. Highway
- Local Road

Figure C-2

0 150 300 600 900
Feet

Sources: Town of Lynnfield, CDM Smith, and MassGIS
Coordinate System: NAD83 Mass. State Plane Mainland FIPS 2001 Feet

CDM Smith

Station 4 - Glen Drive
Station 2 - Main Street
Wing Road Tank
Valve Closed
Valved Closed
Valve Closed
Station 3 - Water Treatment Plant
Station 1 - Phillips Road
Well #6
Well #7
Well #10
Well #9B
Well #9A
Beaver Dam Brook Reservation
Pocahontas Greenbelt

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TOWN OF LYNNFIELD
Massachusetts

LYNNFIELD CENTER WATER DISTRICT

Apple Hill Neighborhood Modeling Results

February 2020

% Glen Drive (Well 4)
- <30%
- 30-60%
- >60%

Water Network Features
- Hydrant
- Hydrant Valve
- System Valve
- Water Tank

Basemap
- Town Boundary
- Interstate
- U.S. Highway
- Local Road

Figure C-3

0 150 300 600 900
Feet

Sources: Town of Lynnfield, CDM Smith, and MassGIS
Coordinate System: NAD83 Mass. State Plane Mainland FIPS 2001 Feet

CDM Smith

Station 4 - Glen Drive
Station 2 - Main Street
Wing Road Tank
Valve Open
Valve Open
Valve Open
Station 3 - Water Treatment Plant
Station 1 - Phillips Road
Well #6
Well #7
Well #10
Well #9B
Well #9A
Beaver Dam Brook Reservation
Pocahontas Greenbelt
Middlesex County
Lynnfield
North Reading
Essex County
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TOWN OF LYNNFIELD
Massachusetts

LYNNFIELD CENTER WATER DISTRICT

Apple Hill Neighborhood Modeling Results

February 2020

% Glen Drive (Well 4)
- <30%
- 30-60%
- >60%

Water Network Features
- Hydrant
- Hydrant Valve
- System Valve
- Water Tank

Basemap
- Town Boundary
- Interstate
- U.S. Highway
- Local Road

Figure C-4

0 150 300 600 900
Feet

Sources: Town of Lynnfield, CDM Smith, and MassGIS
Coordinate System: NAD83 Mass. State Plane Mainland FIPS 2001 Feet

CDM Smith

Station 4 - Glen Drive

Station 2 - Main Street

Valve Closed

Valve Closed

Valve Closed

Station 3 - Water Treatment Plant

Station 1 - Phillips Road

Well #6

Well #7

Well #9B

Well #10

Well #9A

Wing Road Tank

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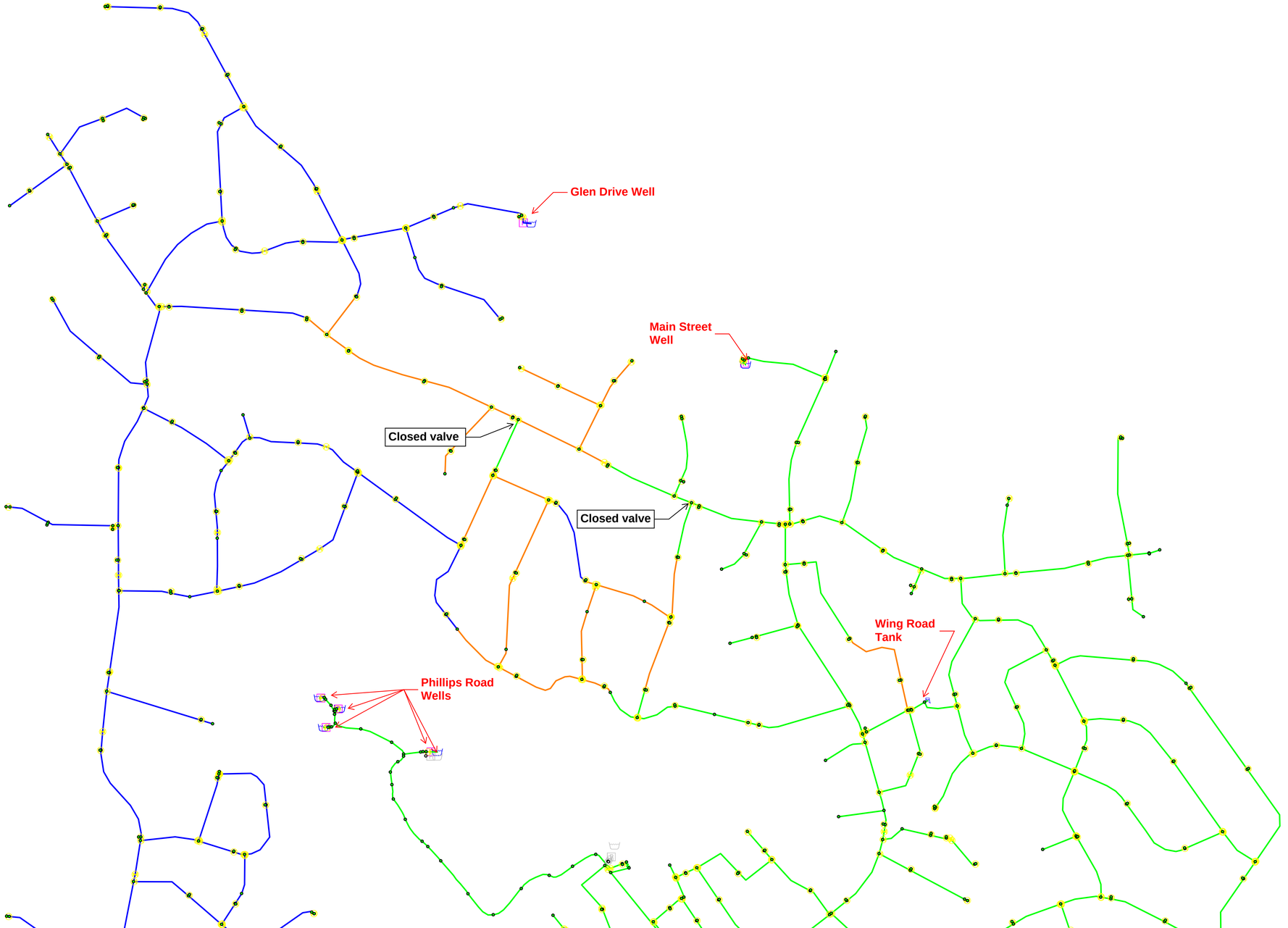


N

Legend

Average % from Glen Drive

- < 30%
- 30% - 60%
- >60%

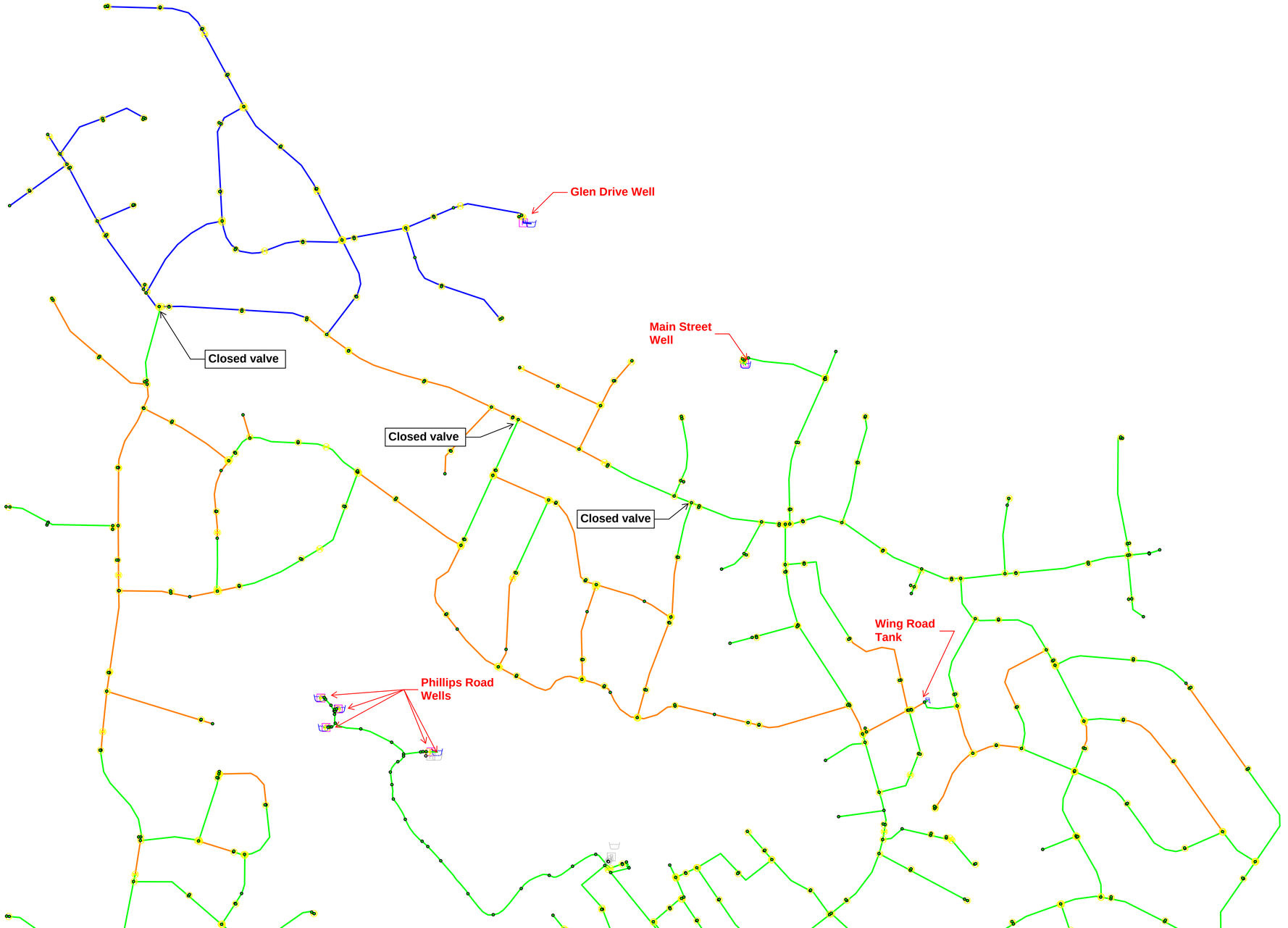
March 2020

Apple Hill Blending Evaluation - Scenario 1
Figure C-5

1 inch = 415 ft

0 410 820 1,230 1,640 Feet

CDM Smith



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Legend

Average % from Glen Drive

- < 30%
- 30% - 60%
- >60%

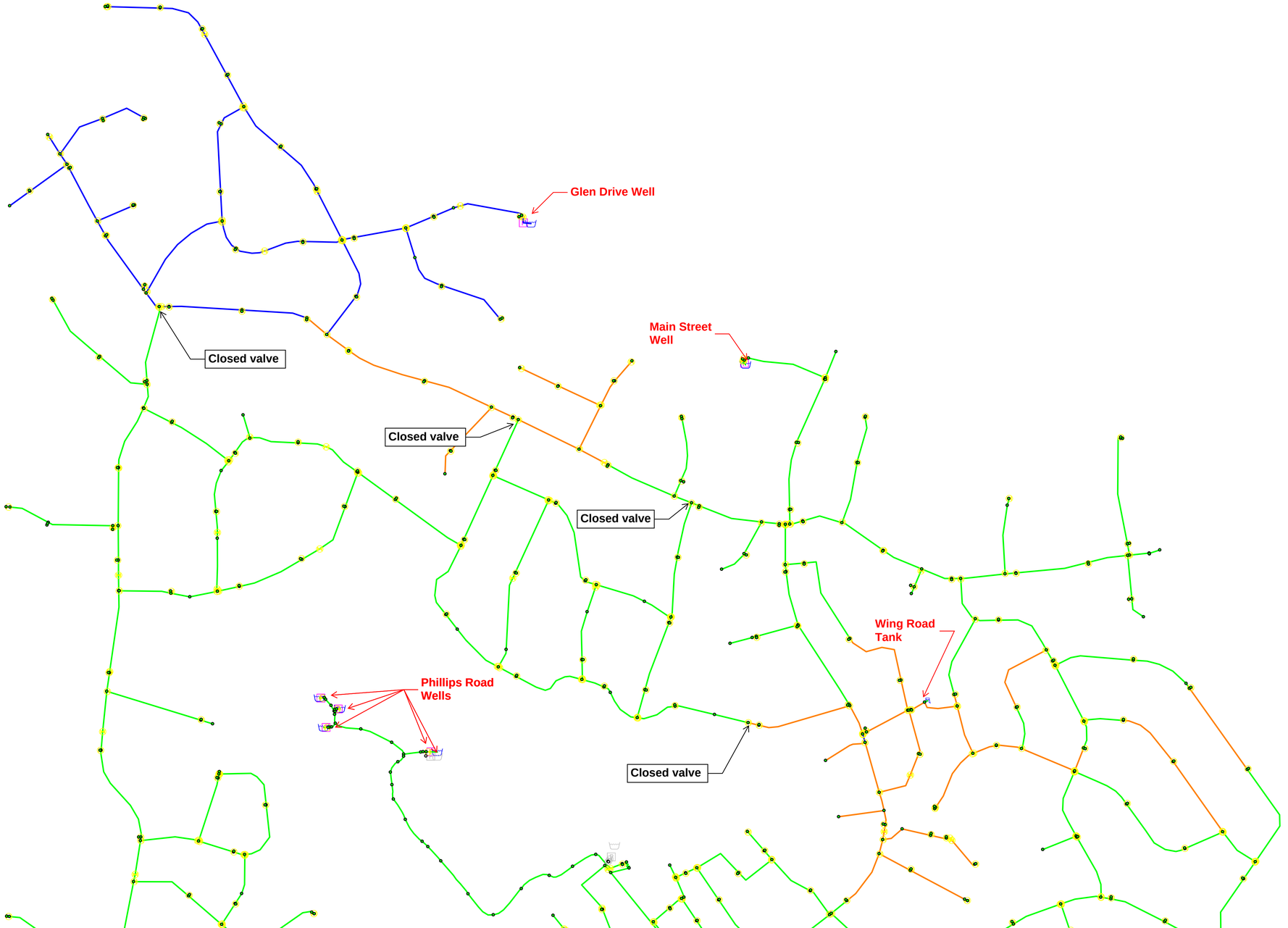
March 2020

Apple Hill Blending Evaluation - Scenario 2
Figure C-6

1 inch = 415 ft

0 410 820 1,230 1,640 Feet

CDM Smith



N

Legend

Average % from Glen Drive

- < 30%
- 30% - 60%
- >60%

March 2020

Hill Blending Evaluation - Scenario 3
Figure C-7

1 inch = 415 ft

0 410 820 1,230 1,640 Feet

CDM Smith