PRELIMINARY REPORT

CITY OF BEL AIRE

WATER MASTER PLAN

PEC PROJECT NO. 35-220925-000-2564

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1.0 Introduction

The City of Bel Aire retained the services of Professional Engineering Consultants to develop a working computer model of the City's water distribution system and perform a detailed analysis of the system's capabilities in order to prepare a plan for addressing current and projected future system deficiencies. This Water Distribution System Master Plan presents the information utilized to prepare the hydraulic water model, evaluation of the model to determine system deficiencies, alternatives to address identified system deficiencies, and a summary of recommended system improvements.

1.1 Study Objective

The primary objective of this study is to determine water distribution system improvements needed to address current system deficiencies and anticipated future conditions. This included analyzing potential demand growth and system expansion, distribution system piping, pumping capabilities, and storage volumes.

The computerized model of the distribution system was developed using the Bentley WaterGEMS software. The model was analyzed to determine if there was adequate system pressure, available fire flows, water storage, and conveyance infrastructure for current and future flows. This study presents an evaluation of alternatives to address current and anticipated future deficiencies. The study period for analysis of the distribution system is twenty years (2043) divided into three development-based scenarios. Total project cost estimates were prepared for each recommended improvement for incorporation into the City's Capital Improvement Plan.

1.2 Scope of Study

This study includes the following elements:

- Description of the existing water distribution system.
- Development of projected water demands for a 20-year planning period based on projected development and historical water usage data.
- Development of a computerized water model of the existing distribution system with 4-inch piping and larger, and smaller piping as necessary.
- Calibration of the water model based on field flow testing information.
- Evaluation of the water model for current and projected average day, maximum day, and peak hour demands to determine distribution system deficiencies.
- Evaluation of the water model for fire flow scenarios to determine available fire flow with existing infrastructure.
- Evaluation of the water model to determine water age throughout the distribution system.
- Development of system improvement alternatives and recommendations to address identified deficiencies.
- Development of preliminary construction cost estimates for recommended improvements.

2.0 Water Demands

Current water demands and demands for in-progress development must be determined to accurately analyze current system performance and identify improvements needed for future growth. Average daily demand (ADD) usage is typically utilized as the base demand for a water system. In addition to the average daily use, the distribution system must also be able to supply adequate flow and pressure for the maximum daily demand (MDD) and peak hour demand (PHD) conditions.

The MDD accounts for seasonal and annual fluctuations in flow while PHD accounts for typical daily usage patterns. Water usage is typically higher in dry years and during the summer months. The increase in demand in summer months is mainly due to the increase in irrigation and water recreation (pools, splashpads, etc.). Water usage also typically follows a diurnal pattern during the day with low usage at night and peak usage in the early morning and early evening hours. The high water use during the early morning and early evening is due to the normal daily pattern of typical residential customer water use activities (showering, cooking, laundry, etc.).

2.1 Historical Water Demands

The City provided historical water use reports from 2017 through 2022. The monthly reported quantity of total water pumped from Wichita and CCUA was utilized to determine the ADD. The ADD was calculated by dividing the total water usage for the year by 365 days for each year. The MDD was calculated by taking the maximum amount of raw water diverted in one month for each year and dividing by 31 days. The City's historical demand data is summarized in Table 1.

Table 1: Historical Water Demands

Year	Total Annual Usage (MGY)	Average Day Demand (MGD)	Maximum Day Demand (MGD)
2017	240.44	0.66	1.07
2018	284.17	0.78	1.31
2019	261.49	0.72	1.52
2020	318.84	0.87	1.79
2021	314.71	0.86	1.51
2022	335.53	0.92	1.84
Average	**292.53**	**0.80**	**1.51**

The average annual usage over this period was 292.53 million gallons per year (MGY) or 0.80 million gallons per day (MGD). This demand divided by the City's population of 8,262 people (per 2020 US Census Bureau data) equates to an average water demand per capita in the system of approximately 97 gallons per day (gpd). For comparison, the City of Derby and the City of Haysville currently have an average water demand per capita of approximately 92 gpd and 84 gpd, respectively. The approximate annual growth rate over this period is 6.9%.

Since the City has seen significant growth over the last five years, the 2022 water demand is likely a more accurate representation of the City's existing system compared to utilizing the average use of the last five years. Therefore, the 2022 ADD and MDD will be utilized as the existing baseline demand for this evaluation.

MDD factors are calculated by determining the ratio between the maximum day and average day demands to account for the higher use days of the year. Based on the available data, the calculated factor for maximum day to average day demand over the six-year period is 1.88. Based on 2022 data only, the calculated factor for maximum day to average day demand is 2.01. A typical peaking factor between peak hour and average day demands is between 2.0 and 3.5 for most systems, depending on the type of usage. A typical peak hour to average day peaking factor of 3.0 was utilized for all users in the system.

Water loss refers to the water pumped that is not included in the quantity of water sold. This can include water lost during fire hydrant testing, waterline flushing, waterline breaks, raw water to waste stream discharge, or due to inaccurate/faulty meters. The monthly water loss percentages ranged from roughly 1% to 30% of the total water pumped with an average loss of 8% from 2017 through 2022, excluding months with negative or no water loss.

2.2 Top Water Users

The City provided billing records from April through September of 2022 for the top 10 users. The top users account for approximately 20% of the total demand with the Catholic Care Center being the top water user accounting for approximately 6% of the City's total demand. Similar to the total system demand, the MDD factor of 2.01 was utilized for the top users when calculating their individual MDD. Water demand for the top 10 users is summarized in Table 2. A map showing the locations of the top 10 users in the City is shown in Figure 1.

Table 2: Top Water Users

User	Average Day Demand (GPD)	Maximum Day Demand (GPD)	% of Total City Demand
Catholic Care Center	50,367	101,238	6.3%
Courtyards at Elk Creek HOA	24,834	49,916	3.1%
Villas at Elk Creek	18,690	37,568	2.4%
Tree Top Nursery	17,702	35,581	2.2%
Central Park 4th HOA	15,393	30,940	1.9%
Broadstone Villas	10,805	21,718	1.4%
Irongate HOA	7,238	14,547	0.9%
Villas at Prestwick	5,699	11,455	0.7%
USD 259	4,114	8,269	0.5%
Bel Aire Recovery Center	3,499	7,032	0.4%

2.3 Projected Water Demands

Due to the large amount of current and planned development in the City, a straight growth projection analysis for the planning period was not utilized due to concerns of inaccuracies.

Rather, projections for future water demands were calculated using a scenario-based approach, where scenarios were designated as shown below. A visual representation of the existing and scenario-based development areas is shown in Figure 2.

- **Scenario 1:** In-Progress Development
- **Scenario 2:** Planned Development
- **Scenario 3:** Full Comprehensive Plan Growth

When calculating the projections, the 2022 water use was utilized as the existing ADD and MDD. The demand associated with growth areas was calculated using the Kansas Department of Health and Environment (KDHE) assumed flowrates based on the land use. The projected demand for each growth area is shown in Table 3.

Table 3: Projected Demand of Growth Areas

Development		Lots/Area	Units	Projected ADD (GPD)
1	Homestead Senior Living	120	Lots	34,340
2	Chapel Landing, Phase 2	40	Lots	11,447
3	Prairie Preserve	12	Lots	3,434
4	Chapel Landing 6th	50	Lots	14,308
5	Chapel Landing 3rd	86	Lots	24,610
6	Bristol Hollows	122	Lots	34,912
7	Chapel Landing 5th	113	Lots	32,336
8	Chapel Landing	58	Lots	16,597
9	Chapel Landing 4th	12	Lots	3,434
10	Chapel Landing 2nd	0	Lots	0
11	Central Park 3rd	69	Lots	19,745
12	Villas at Prestwick	36	Lots	10,302
13	Elk Creek	37	Lots	10,588
14	Courtyards at Elk Creek*	0	Lots	0
15	Elk Creek 2nd	9	Lots	2,575
16	Elk Creek 3rd	10	Lots	2,862
17	Deer Run	130	Lots	37,201
18	Rock Spring*	0	Lots	0
19	Rock Spring	23	Lots	6,582
20	Rock Spring 2nd*	0	Lots	0
21	Rock Spring 3rd	112	Lots	32,050
22	Sham Way Estate	213	Lots	60,953
23	Cedar Pass (Rock Spring 5th)	177	Lots	50,651
24	Rock Spring 4th	108	Lots	30,906
25	Skyview at Block 49	108	Lots	30,906
26	Skyview at Block 49 2nd	90	Lots	25,755

27	Skyview at Block 49 3rd	16	Acres	15,521
28	Tierra Verde	60	Acres	100,000
29	Bel Aire Industrial Park	60	Acres	200,000
30	Sunflower Commerce Park	87	Acres	145,000
31	Sunflower Commerce Park 2nd	65	Acres	108,333
32	Integra Technologies	-	-	1.2/2.4M
A1	Residential	160	Acres	155,207
A2	Commercial	40	Acres	66,667
A3	Commercial	80	Acres	133,333
A4	Light Industrial	240	Acres	400,000
A5	Commercial	320	Acres	533,333
A6	Light Industrial	160	Acres	266,667
A7	Commercial	40	Acres	66,667

*Due to the amount of lots already developed by the end of 2022, it was assumed that the demand associated with this development was already captured in the 2022 demand data.

Scenario 1 development areas represent the developments in progress of construction with individual lots expected to be developed within the next 1-2 years. The majority of these developments are residential. The City's existing demand (2022 use) and the projected demand from the Scenario 1 developments (which were calculated based on lot counts) were added together to get a total Scenario 1 demand. The Scenario 1 distribution system analysis will analyze the system based on this combined demand.

Scenario 2 development areas represent the developments that are planned/platted but individual lots are expected to be developed in approximately 5 years. The demand for the Scenario 2 developments is based on residential lot counts or approximate commercial/ industrial areas. In addition, Scenario 2 also includes the demand of one new 1.2-MGD water user, Integra Technologies (Integra), that the City will be adding to their system. It is assumed this Integra water demand will be constant over 24 hours and that it will not have any increase for MDD or PHD. The Scenario 2 total demand and distribution system analysis will include existing demand, Scenario 1 developments, Scenario 2 developments, and Integra (1.2-MGD user).

Scenario 3 development areas were determined based on the remaining development in the "Preferred Balanced Growth Scenario" of the City's 2018 Comprehensive Plan and upgrading Integra to a 2.4-MGD user. These areas are expected to be developed within the next 20 years. The demand for the remaining comprehensive plan growth is based on approximate areas since the majority of the development was identified as being either commercial or industrial. The Scenario 3 total demand and distribution system analysis will include existing demand, Scenario 1 developments, Scenario 2 developments, Scenario 3 developments, and Integra (2.4-MGD user).

Cumulative projected demands for each scenario can be found in Table 4.

Table 4: Cumulative Projected Demands

Scenario	Cumulative ADD (MGD)	Cumulative MDD (MGD)	Cumulative PHD (MGD)
1	1.52	3.04	4.55
2	3.19	5.18	7.17
3	6.01	9.62	13.23

For comparison purposes only, annual growth rates to approximately match the Scenarios' projections were calculated. The growth rate determined is specifically based on water demands and not population. To match Scenario 2 demands based on a 2028 (5-year) projection, the annual growth rate is 28.2%. To match Scenario 3 demands based on a 2043 (20-year) projection, the annual growth rate is 9.8%. To match Scenario 3 demands based on a quicker 2033 (10-year) projection, the annual growth rate is 20.6%.

3.0 Existing Water Distribution System

The City of Bel Aire gets water supplied from the City of Wichita and from the Chisholm Creek Utility Authority (CCUA). Water supplied from Wichita enters the distribution system near 37th & Woodlawn and water supplied from CCUA enters the distribution system near 53rd & Hillside. Bel Aire also has a water supply connection with the City of Park City, located near 45th & Hydraulic, but this connection only serves a few meters and is isolated from the remainder of the distribution system. The distribution system includes approximately 68 miles of water mains, 400+ fire hydrants serving over 2,600 service connections, two storage towers, and one booster pump station. An overview of the existing water distribution system is presented in Figure 3.

3.1 Water Mains

The original water distribution system was constructed in the mid 1900's to serve the core area of the City with upgrades occurring as required to accommodate new service areas. The City has also completed many waterline replacement projects of the older lines. All distribution system pipes installed since roughly 1970 are polyvinyl chloride (PVC) piping. Before the 1970s, the City primarily installed either CI piping or transite (asbestos cement) piping. The distribution system piping materials are shown in Figure 4.

Distribution system hydraulics are influenced by waterline material and age. As waterlines age, buildup may occur within the pipe that reduces the effective inner diameter and creates poor hydraulic flow characteristics. Roughness coefficients are assigned to pipes in the model to represent the anticipated hydraulic conditions within the pipe.

Waterline sizes in the distribution system also greatly affect the amount of water that can be distributed throughout the system. Generally, larger diameter water mains provide flow to each major service area with smaller service lines branching off as required. Current waterline sizes are shown in Figure 5.

3.2 Fire Hydrant Coverage Area

The distribution system was evaluated to determine current fire hydrant coverage assuming each hydrant covers a 400-foot radius based on standard fire department hose lengths. A map showing the fire hydrant coverage for the City is shown in Figure 6. In general, the overall system has adequate fire hydrant coverage.

Evaluation of fire hydrant coverage should also consider the ability to serve future development areas. As additional development occurs, fire hydrants should be installed to ensure that the system can continue to provide adequate coverage.

3.3 Water Metering System

The majority of water service connections in the City are residential meters. The number of meters by customer type are shown in Table 5.

Table 5: Number of Customers

Year	Water Service Connections				
	Residential	Commercial	Common	Bulk	Total
2017	2,767	91	2	0	2,860
2018	2,854	92	2	0	2,947
2019	2,967	95	5	8	3,075
2020	3,055	95	2	3	3,155
2021	3,142	100	2	4	3,247
2022	3,285	100	1	4	3,390

3.4 Storage

The City currently has 1.5 MG of storage capacity in the distribution system with a summary of the system storage facilities shown in Table 6.

Table 6: Summary of System Storage Facilities

Name	Type of Storage Tank	Size
53rd St Tower	Elevated	1.00 MG
45th St Tower	Elevated	0.50 MG

3.5 Pump Stations

The distribution system pressure is supplied by the CCUA supply connection and with four booster pumps (BPs) at Wichita's water supply connection. The design flow and head conditions for all the Wichita connection pumps are 600 GPM and 130 feet of head, respectively.

3.6 System Controls

The Supervisory Control and Data Acquisition (SCADA) system is utilized to implement the City's system controls. There are two flow control valves at the CCUA water supply connection that open and close based on the 53rd St water tower level. Both valves are currently set to allow approximately 600 gpm each to flow through them when open. The Wichita connection booster pumps do not have setpoints for operation, but rather, they are manually operated on a day-to-day basis to supply the remainder of the demand that CCUA cannot. Current distribution system control setpoints are summarized in Table 7.

Table 7: Distribution System Control Setpoints

Location	Setpoint Based On	Pump/Valve	Open	Close
CCUA Connection	53rd St Tower Level	North Flow Control Valve (600 gpm) South Flow Control Valve (600 gpm)	21 ft 21 ft	26 ft 26 ft

4.0 Distribution System Model

A computer model of the City's existing distribution system was developed utilizing the WaterGEMS software program from Bentley Systems, Incorporated. The WaterGEMS program is a network model that allows the user to construct a graphical pressure system and analyze the hydraulics with the program's algorithms. The program calculates theoretical system pressures at pipe junctions (nodes) for specific water demands and can estimate how a system operates over an extended period. The user can manipulate demands and other input parameters to model different usage conditions or improvements that are planned for the system.

The computer model is used as a tool to evaluate the distribution system. Final recommendations for improvements are based on a balance of the computer results, experience, and input from the City.

4.1 Information Required

The WaterGEMS model operates based on characteristics of each pipe, pump, and storage unit that is entered into the computer program. Parameters required for each pipe section include the diameter, length, and roughness coefficient. The roughness coefficient, or "C" value, is a measure of the relative roughness of the pipe. The rougher the interior of the pipe is, the more pressure loss that will occur as water travels through the pipe. The values are initially estimated during model development based on the type and age of the pipe and are modified during calibration.

Storage units can include below grade reservoirs, at grade standpipes, or elevated tanks. Each storage unit is included in the model as a tank of a known diameter (or cross-sectional area) with a maximum water surface elevation, a minimum water surface elevation, and an assumed starting water surface elevation for model analysis. The head and flow conditions for each pump are modeled based on the manufacturer's pump curve. Additional system elements that can be analyzed by WaterGEMS include system isolation, pressure reducing, or flow control valves; fire hydrants; and system operational controls.

4.2 Model Development

The computer model was developed utilizing GIS files and mapping information provided by the City. All pipes, hydrants, and valves (isolation and pressure reducing) were added to the model. All distribution system pumps were specified with design flow and head conditions, and the storage towers were dimensionally specified.

Based on SCADA data, the City of Wichita connection was modeled with a constant 58 psi supply and the CCUA connection was modeled with a constant 80 psi supply. While the CCUA connection is controlled/limited by the flow control valves, the model does not include any limitation on the volume of water available from the source itself.

4.3 Demand Distribution

Demands are modeled by applying an outlet flow load to junctions (nodes) in the system. The total demands established for the current system and projected future growth scenarios must be distributed among the model nodes to reasonably represent the actual allocation of demand throughout the City's system.

Concentrations of high demand should be modeled as closely as possible to their actual location. Demands associated with the top 10 water users were included in the model on a single node or various nodes near the user's meter address(es) as indicated on the City's billing reports.

Based on the determined existing demand, the remaining ADD was evenly distributed throughout the distribution system.

The demands associated with the projected increases in water use due to areas of potential development indicated for future scenarios were added to the model. The demands were distributed among nodes in the model at the locations of the identified growth areas.

The MDD and PHD factors were added to the model to simulate the MDD and PHD. The demand associated with Integra was held constant.

4.4 Model Calibration

The model was calibrated using data collected from field flow testing to confirm that the model represents actual system conditions. PEC conducted the field flow testing with City staff in May 2023 at the ten locations shown in Figure 7.

There are typically two tests performed at each location. The first test isolates a single water line from the system and measures the pressure loss through that section of pipe. This information is utilized to calculate the "C" value of that specific pipe. The first test is most effective for older pipe materials such as cast iron where there is significant pressure loss. It is not as effective at determining "C" values for newer plastic pipes because the pressure loss is low and challenging to accurately capture with field testing. Due to this, the first test was only performed at a single location (Location 4).

The second test simply captures flow and pressure information, without any isolation, to be utilized during calibration. All tower levels and flows from the water supply connections were obtained for each location at the exact time of each test location.

Initial "C" values were defined to be universally accepted values for the various materials. Using the flow and tower level information, the pressure readings from the second test were then compared to the modeled pressure result to adjust the initial "C" values. The initial "C" values are summarized in Table 8 along with the final "C" values after the model calibration.

The results from the model calibration are summarized in Table 9.

Table 8: "C" Values Before and After Model Calibration

Pipe Material	Initial "C" Value	Final "C" Value
AC	140	145
CI	130	130
PVC	150	130

Table 9: Model Calibration Results

Area	Location	Field Pressure (psi)	Model Pressure (psi)	Pressure Difference (psi)
1	Along Auburn St between 39th and Cox	50	49	-1
2	Along Harding St and Battin St north of 39th St	51	50	-1
3	Along Auburn St between 45th and Memphis	46	46	0
4	Along Glendale St between 46th and 48th St	41	40	-1
5	Along Homestead St between 47th and 49th St	39	39	0
6	Along Saint James Pl/Mission Rd north of Danbury St	46	48	2
7	Along Indian Oak St north of Elk Creek Dr	51	50	-1
8	Along Tierra Lakes Pkwy south of 49th St	42	44	2
9	Along Toler Dr south of between 50th and 53rd St	44	45	1
10	Along Chris St and Rock Spring St east of Lycee St	45	47	2

5.0 System Analysis

The model was evaluated under two operational conditions, Steady State Simulation (SSS) and Extended Period Simulation (EPS). The SSS is a snapshot evaluation of the system at a specific point in time. The model was analyzed for average day, maximum day, and peak hour demand conditions to assess the performance of the existing system. Available fire flows were evaluated under the maximum day demand SSS. These conditions were evaluated with the scenario-based demands.

An EPS was used to model how the system operates and behaves over a specified time frame. The EPS was conducted for a 72-hour time frame and 240-hour time frame with current and projected demands using a standard American Water Works Association (AWWA) diurnal curve. This evaluation indicated when water towers drain and fill, if there is sufficient storage provided, how often pumps operate to supply adequate flow and pressure, if the pumps have adequate capacity, how system pressure fluctuates, and what the water age is based on the scenario-based demands.

Pumping system and water storage analyses were subsequently performed to determine if the system's existing pump capacity and storage capacity, respectively, is adequate for current and projected future demands.

5.1 Existing Distribution System with Scenario 1 Demands

The model was evaluated under the existing system conditions using Scenario 1 demands to determine existing deficiencies and problem areas.

5.1.1 System Pressures

System pressures range from approximately 38 (along 53rd St between Woodlawn and Rock) to 71 psi (downstream of the CCUA connection) at the ADD. The lower pressure location on 53rd Street between Woodlawn and Rock Road is mainly due to higher elevation.

System pressures range from approximately 37 to 71 psi at the MDD and at peak hour conditions. The ADD, MDD, and PHD pressure distributions are similar. The MDD pressure distribution is shown in Figure 8.

All observed pressures are above Kansas Department of Health and Environment's (KDHE's) minimum system pressure requirement of 20 psi. The lowest observed pressure for all demand conditions is above or equal to 37 psi.

5.1.2 Fire Flow Analysis

The most strenuous demands on a distribution system are the flows required for fire suppression. Fire flows are applied in the model in addition to the MDD to simulate the worst-case scenario of a fire on a hot summer day. The maximum available fire flow is found at each hydrant to correspond with the minimum pressure at any location in the distribution system being equal to 20 psi per KDHE. The existing system was analyzed to determine the available fire flow at each system hydrant.

Typical fire flow requirements are 1,000 to 1,500 gpm for residential development, 1,500 to 2,000 gpm for commercial development, and 2,500 to 3,000 gpm for industrial development. For the purposes of this model analysis, the minimum fire flow required varies between 1,200 gpm and 3,000 gpm depending on the associated type of development.

Analysis of the model indicates that approximately 97% of the system hydrants can provide at least 1,200 gpm, 85% can provide at least 2,000 gpm, and 67% can provide at least 3,000 gpm under the current MDD. Only one hydrant in the modeled system provided less than 500 gpm of fire flow. Fire hydrants that did not meet flow requirements in the model generally fall into one of two location categories: hydrants located on waterline dead ends and hydrants on CI pipes. The available fire flow based on current system demands is shown in Figure 9.

5.1.3 Extended Period Simulation

Since the City manually controls the Wichita connection booster pumps, an EPS was run utilizing only the CCUA connection per the current controls. Under Scenario 1 MDD, both the 53rd St and 45th St towers empty over a 72-hour EPS. However, by turning on a City of Wichita connection pump, as the City manually does, the system is able to sustain tower levels and system pressures. Additional pumps and control options would allow for better regulation of the tower levels.

It should be noted that the single pump operating has a flowrate in the model of approximately 1500 gpm throughout the EPS. This is significantly above the pump design point of 600 gpm and the pump operates far right on the pump curve. Based on SCADA information, it appears this may be typical. This is likely due to differing head conditions potentially associated with higher City of Wichita pressure and lower tower water level. Operating outside the approved operating range may cause damage to the pumps.

5.1.4 Water Age

Water age refers to the length of time water has been in the system. Typically, the oldest water in the distribution system contains the highest levels of disinfection byproducts (DBPs) and the lowest chlorine residuals. DBPs are formed through naturally occurring reactions of the treated water with organic matter. DBPs can include Chloroform, Bromodichloromethane, Dibromochloromethane, and Bromoform which have been linked to adverse health effects. Analyzing water age is important so that system operation can be adjusted to reduce the levels of DBPs while maintaining an adequate chlorine residual.

Water age was evaluated using an EPS at the ADD for ten consecutive days (240 hours). For modeling purposes of this scenario, the City's typical operation was assumed to include CCUA controls and a closed Wichita connection. As Figure 10 illustrates, the water age in the system is relatively low near the CCUA connection and increases as water travels through the system southward and eastward. The water age is the greatest east of Rock Road. This indicates insufficient turnover of water in the system due to the presence of only one modeled water supply source and the lack of turnover in the water towers. Turning the Wichita connection pumps on may reduce the water age, as long as the towers are allowed to cycle, but the east end of the system will still have the highest age.

Water quality and chlorine residuals are typically acceptable if the water age is less than 10 days. Model results indicate a water age of up to 8 to 10 days east of Rock Road, which may cause a low chlorine residual. Other causes of low chlorine residual may include inadequate dosing at the source, poor turnover in storage towers, or contamination entering the distribution system.

5.2 Distribution System with Scenario 3 Demands

Scenario 3 includes serving all of the growth areas. In order to do this, additional piping will be required to supply water to these areas. This recommended piping is shown in Figure 11. These pipe improvements were added to the model and the adjacent growth area demands were applied to these proposed lines.

With the new lines added, Scenario 3 was evaluated in the model. It was determined the existing system was not able to supply the projected demands. Under an EPS, the towers would empty, and the system would fail. The water supply into the system was not adequate to fill and maintain tower levels.

Due to this, additional recommended system improvements required to maintain the system with Scenario 3 demands were determined. These recommended improvements include a new connection to the City of Wichita's system at 53rd and Rock and a new water tower. The recommended improvements are further discussed below and are fully presented in Section 6.0.

Because Scenario 2 includes a significant demand increase and the timing between the Integra development building phases may be short, Scenario 2 was not evaluated sperate from Scenario 3. The recommended improvements will accommodate both Scenario 2 and Scenario 3.

5.2.1 System Pressures

With the improvements, system pressures range from approximately 34 (at Integra) to 71 psi (downstream of the CCUA connection) under ADD. System pressures range from approximately 33 to 71 psi at the MDD and 32 to 71 psi at the peak hour conditions. The MDD, ADD, and PHD pressure distributions are similar. The MDD pressure distribution is shown in Figure 12.

All observed pressures are above Kansas Department of Health and Environment's (KDHE's) minimum system pressure requirement of 20 psi. The lowest observed pressure for all demand conditions is above or equal to 32 psi.

5.2.2 Fire Flow Analysis

The system with improvements was evaluated to determine available fire flows under the Scenario 3 MDD. Approximately 97% of the modeled system hydrants can provide at least 1,200 gpm under Scenario 3 maximum day demands, 87% can provide at least 2,000 gpm, and 73% can provide at least 3,000 gpm. Only 1 hydrant in the modeled system provided less than 500 gpm of fire flow. Like Scenario 1 demand conditions, most of the fire hydrants not meeting flow requirements in the model fall into one of two location categories: hydrants located on waterline dead ends and hydrants on CI pipes. The available fire flow based on Scenario 3 system demands is shown in Figure 13.

5.2.3 Extended Period Simulation

The model was evaluated under an EPS for 72 hours using the projected Scenario 3 ADD and MDD. As noted above, the existing system without improvements cannot sustain tower levels and pressures. This is mostly correlated to the large Integra demand and the limitation of the water supply into the system.

To increase supply into the system an additional connection to Wichita's system is recommended near 53rd St and Rock Road. The City of Wichita has an existing waterline at this location within their Northeast pressure zone. From discussions with the City of Wichita, it is believed that this connection can supply approximately 3.2 MGD at 55 psi.

To better sustain system pressures near the large demand of Integra, it is recommended that a 2.0 MG water tower be added to the system in the proximity of 53rd St and Webb Road. For this evaluation, it is assumed that the operating elevations of the tower will match that of the existing towers.

Conceptual set points for the system with the proposed improvements are as follows:

- If the 45th St Tower percent full is ≤ 70% and ≥ 95%, then three Wichita booster pumps will turn on and off, respectively.
- If the 53rd St Tower percent full is ≤ 70% and ≥ 95%, then both CCUA FCVs will open (600 gpm each) and close, respectively.
- If the New 2.0 MG Tower percent full is ≤ 70% and ≥ 95%, then the new Wichita FCV will open (maximum allowable flowrate of 2,222 gpm) and close, respectively.

Under a MDD EPS, the 45th St Tower had a turnover rate of approximately 2-3 times per day with water volumes oscillating between approximately 65% and 95%. The 53rd St Tower had a turnover rate of approximately 1-2 times per day with water volumes oscillating between approximately 50% and 80%. The proposed tower had a turnover rate of approximately 1 time per day with water volumes oscillating between approximately 30% and 65%.

The three Wichita connection pumps operate approximately 20 hours a day with a combined flowrate of approximately 4,300 gpm. Note that this flowrate is well above the design flowrate of the pumps. The CCUA connection and new Wichita connection remain open all day with flowrates of 1,200 GPM and 2,222 GPM, respectively.

With these improvements, the lowest pressure observed in the MDD EPS is 29 psi.

The system does struggle to fill the proposed storage tower. The system would benefit from additional water supply above what this scenario provides. An additional 4,000 gpm supply into the system allowed all the towers to maintain levels between 70-95% with consistent oscillations.

5.2.4 Water Age

An EPS was completed using the Scenario 3 ADD for ten consecutive days (240 hours). The water age in the system is relatively low throughout the majority of the City where the water age typically doesn't exceed 48 hours. The water age is the greatest within the distribution system east of Webb Road. Model results indicate that water age in this area decreases from 8-10 days based on Scenario 1 ADD conditions to approximately 3 days based on Scenario 3 ADD conditions. The Water Age for Scenario 3 is shown in Figure 14.

5.3 Pumping System Analysis

The distribution system needs to have the ability to pump or otherwise supply water at adequate pressure to meet the MDD. The current water supply to Bel Aire from Wichita and CCUA are not adequate to deliver the Scenario 3 MDD to the distribution system. The existing Wichita connection booster pumps and the total allowable flowrate from the existing CCUA connection have a total capacity of approximately 5.21 MGD.

Total capacity assumes that all the Wichita connection pumps are in service and CCUA is able to supply their total allowable flowrate (per contract) of 1.75 MGD. However, KDHE requires that the Firm capacity, not total capacity, be equal to or greater than the MDD. Firm capacity is typically calculated as the total pumping capacity of a pump station when the largest pump is out of service. For Bel Aire's system, Firm capacity can be evaluated using two different situations:

- **Situation 1:** CCUA is not able to supply any flow and one of the Wichita connection pumps is out of service.
- **Situation 2:** The largest pump at the CCUA WTP is out of service and one of the Wichita connection pumps is out of service.

The total projected MDD for Scenario 3 for the overall system is 9.62 MGD. The firm capacity in Situation 1 is 2.59 MGD, and the firm capacity in Situation 2 is 4.34 MGD. In Situation 2, CCUA can supply the total allowable flowrate of 1.75 MGD with their largest pump out of service. So, the 1.75 MGD volume is the limiting factor.

An additional 5.28 MGD of supply is needed in the system. With the potential 3.2 MGD proposed connection to Wichita, an additional 2.08 MGD supply is still required.

It is recommended that either the Wichita connection pumps be upsized, the total allowable flowrate from CCUA be increased, or both in order for either firm capacity to meet or exceed the Scenario 2 MDD and Scenario 3 MDD. The ability for those flows to be increased may be limited by the City of Wichita's system or CCUA's system.

This shortage indicates that the system will not be able to sustain itself with these future demands. That aligns with the Scenario 3 modeling which showed the system struggling to keep towers filled and in need of additional supply. The Wichita connection pumps were well above design flows during the EPS, which helped prevent the system from failing.

5.4 Water Storage Analysis

The pressure in the City's distribution system is primarily maintained with the 53rd St. and 45th St. water towers. The water storage also provides flow equalization and storage for emergency use and fire flows. The City has a total storage volume of approximately 1.5 MG.

5.4.1 Flow Equalization Volume

Pump stations are designed to deliver the volume of water required to meet the MDD into the system. System storage provides the difference between the MDD volume and the peak hourly demand volume, which is the maximum quantity of water utilized during one hour of the day. The peak hour demand is approximately 1.49 times higher than the MDD. Supplying this peak hour demand from source water pumping significantly increases the pump capacity needed for only a few hours a day. This operation is not efficient; thus, storage is utilized to provide this peak flow volume.

The required flow equalization volume can be determined through multiple methods. One method is to take the difference between water demand in the system and the water being supplied to the system. This method produces a volume specific to the system but requires hourly flow data from the time period with the highest demand. An alternative method is to assume an equalization volume based on a percentage of the MDD. Most water systems require a volume equal to 10% to 15% of the MDD. For this study, the volume required for equalization was calculated as 15% of the MDD to provide a conservative estimate.

5.4.2 Emergency Volume

Emergency water storage may be required for a loss of water supply due to a water supply main failure, a power failure at the source water wells/WTP, or other catastrophic failures. The amount of water volume needed depends on the reliability of the distribution system and how quickly repairs can be made to place the system back into normal operation. The emergency storage volume is typically calculated as the volume corresponding to anywhere from 8 to 24 hours of MDD, depending on the estimated time to restore water supply. For this study, a period of 8 hours was utilized to calculate the emergency storage volume.

5.4.3 Fire Protection Volume

Fire protection volume is the amount of water storage needed to meet the desired fire demand flow for the system. The City mainly consists of residential users, a few prominent commercial users, and a major incoming industrial user (Integra) on the north side of the City. Based on current and future development, a fire flow of 3,000 gallons per minute (gpm) for a duration of 3 hours was utilized for the total system analysis, resulting in a required fire flow storage volume of 0.54 MG.

5.4.4 System Storage Analysis

Two methods are commonly utilized to calculate the total elevated, or pump-independent, water storage volume recommended for a system. The first method is to assume a worst-case scenario by adding the flow equalization, emergency storage, and fire protection volumes together for the total needed volume. This method provides a very conservative estimate but also increases water age in the system since a much higher demand is needed for turnover.

The second and more common method is to add the emergency storage volume to the flow equalization volume and the fire protection volume to the flow equalization volume and utilize the higher resulting volume. This method is still conservative but reduces the amount of storage volume required while still providing an adequate volume in case of emergency. These two volume sums are shown in Table 10 and can be used to make storage capacity decisions for the future.

Table 10: Recommended Total System Storage Volumes

Scenario	Average Day Demand (MGD)	Maximum Day Demand (MGD)	Equalization Volume (MG)	Emergency Volume (MG)	Fire Protection Volume (MG)	Sum of Equalization and Emergency Volume (MG)	Sum of Equalization and Fire Protection Volume (MG)
1	1.52	3.04	0.46	1.01	0.54	1.47	1.00
2	3.19	5.18	0.78	1.73	0.54	2.51	1.32
3	6.01	9.62	1.44	3.21	0.54	4.65	1.98

The current storage volumes provide adequate storage for Scenario 1 demands but do not provide the recommended storage for Scenario 2 or 3 demands (the sum of the equalization and emergency volume). If the lower resulting volume acquired utilizing the second method is used (in this case, the sum of the equalization and fire protection volume), then the current storage volumes would be expected to provide enough storage for Scenario 2 demands but not Scenario 3 demands.

Based on the results from the storage capacity analysis and the City's risk tolerance, decisions based on the reliability of the existing infrastructure can be made to determine what is and isn't necessary for emergency readiness. Factors to consider when evaluating system reliability may include the condition of the existing system infrastructure, reliability of water supply sources, and the magnitude of emergency vulnerability.

6.0 Conclusions and Recommendations

Recommendations for improvements were identified based on the current condition assessment of the existing water distribution system and water flow projections. Pipe looping improvements supply projected growth demand for Scenario 3 while maintaining adequate system pressures. Water storage improvements address the need for additional water storage in the future. The water supply improvements address the need for additional water supply to meet future demands and maintain system operation. System-wide improvements will reduce pressure losses in the system, increase available fire flows, and reduce the long-term operation and maintenance cost of the system by replacing old pipes.

6.1 Pipe Looping Improvements

Based on the City's projected development for Scenarios 2 and 3, it is recommended that the City create pipe loops to service these new users north and east of the existing system. The primary recommended pipe improvements are to connect and loop together the areas shown in Figure 13 with primarily 12" piping. The pipe sizing was determined with considerations to water demands and available fire flows.

6.2 Water Storage Improvements

Based on the storage analysis, it is recommended that at least 2.0 MG of elevated storage is added to the system. This would meet all of the equalization and fire protection needs. Along with the existing towers, this would provide approximately 8 hours of emergency water. It is recommended that this tower be added to the system in proximity to 53rd and Webb as this location is near the area of large future demands. Other locations in the area could be considered, including the Integra property.

6.3 Water Supply Improvements

Due to the projected demands, and limited water supply, water supply improvements will be required. This can include the 3.2 MG connection with Wichita at 53rd and Rock, but an additional 2.08 MG supply above that will still be required. This additional supply could potentially come from CCUA or a new pipeline/connection with the City of Wichita capable of that larger flowrate.

6.4 System Wide Improvements

All CI piping is recommended to be replaced with 8" PVC piping. The City has already completed some of these replacements, but it is recommended to complete all of them. The replacement of these results in reduced pressure losses and an increase in available fire flow due to the material roughness difference between CI and PVC and the occasional pipe upsizing. It is recommended that the order of replacement is first based on which CI pipes break the most frequently. The next set of criteria should then be based on pipe size, where CI pipes are replaced from smallest to largest.

7.0 Cost Estimates

The estimated costs for the pipe looping improvements are summarized in Table 11, as outlined in Section 6.1. The estimated costs are typical costs based on the type of work and on the engineer's opinion of probable construction cost. Actual costs will vary based on contractor availability and market conditions at the time of construction, outside of the control of PEC. To see a cost breakdown of each individual line, refer to Appendix A.

The recommended tower improvements are shown below. This includes the tower itself along with associated piping and site improvements.

An estimate for the 3.2 MGD Wichita connection is shown below. Additional estimates for water supply are not included as an additional study will be required to evaluate supply options.

The recommended system-wide improvements include the replacement of all CI piping in the system, as outlined in Section 6.3. A minimum pipe diameter of 8" is recommended for all replacement pipes to support system pressures and available fire flows. The approximate per linear foot cost of line replacement for the pipe diameters in the system are as follows. These estimated costs are a guideline for replacement of pipe only, as actual total costs will depend on the location of the project, number of services to be reconnected, when a project is constructed, and property and easement issues.

- 8" Pipe $180/LF
- Service Connection (Short) $1,200/EA
- Service Connection (Long) $2,000/EA

Cost for service reconnections have been noted separately since this is typically a significant project cost for replacement projects.

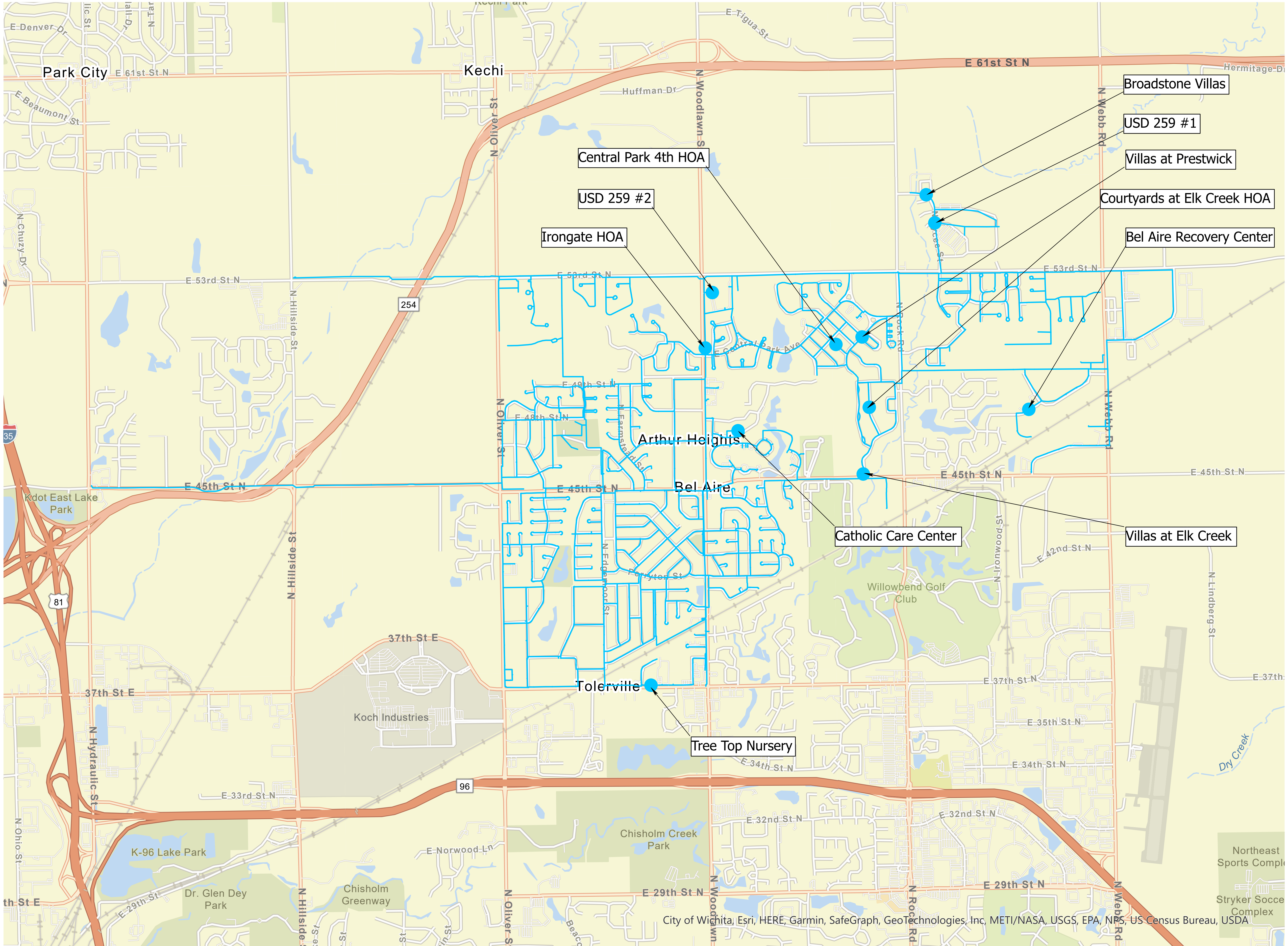
Table 11: Recommended Pipe Looping and EPZ Improvements – Estimated Project Costs

Improvement Type	Item	Project Cost
PIPE LOOPING		$
		$
STOARGE	2.0 MG Elevated Tower	$
WATER SUPPLY	3.2 MGD Wichita Connection	$
Total		**$**

Appendix A

(Will be included in Final Report)

Figures



Legend

- Top 10 Water Users
- Existing Waterline

N

0 0.25 0.5 1 Miles

CITY OF BEL AIRE

Figure 1

Top 10 Water Users

Bel Aire Water Master Plan

Bel Aire PEC

June 2023

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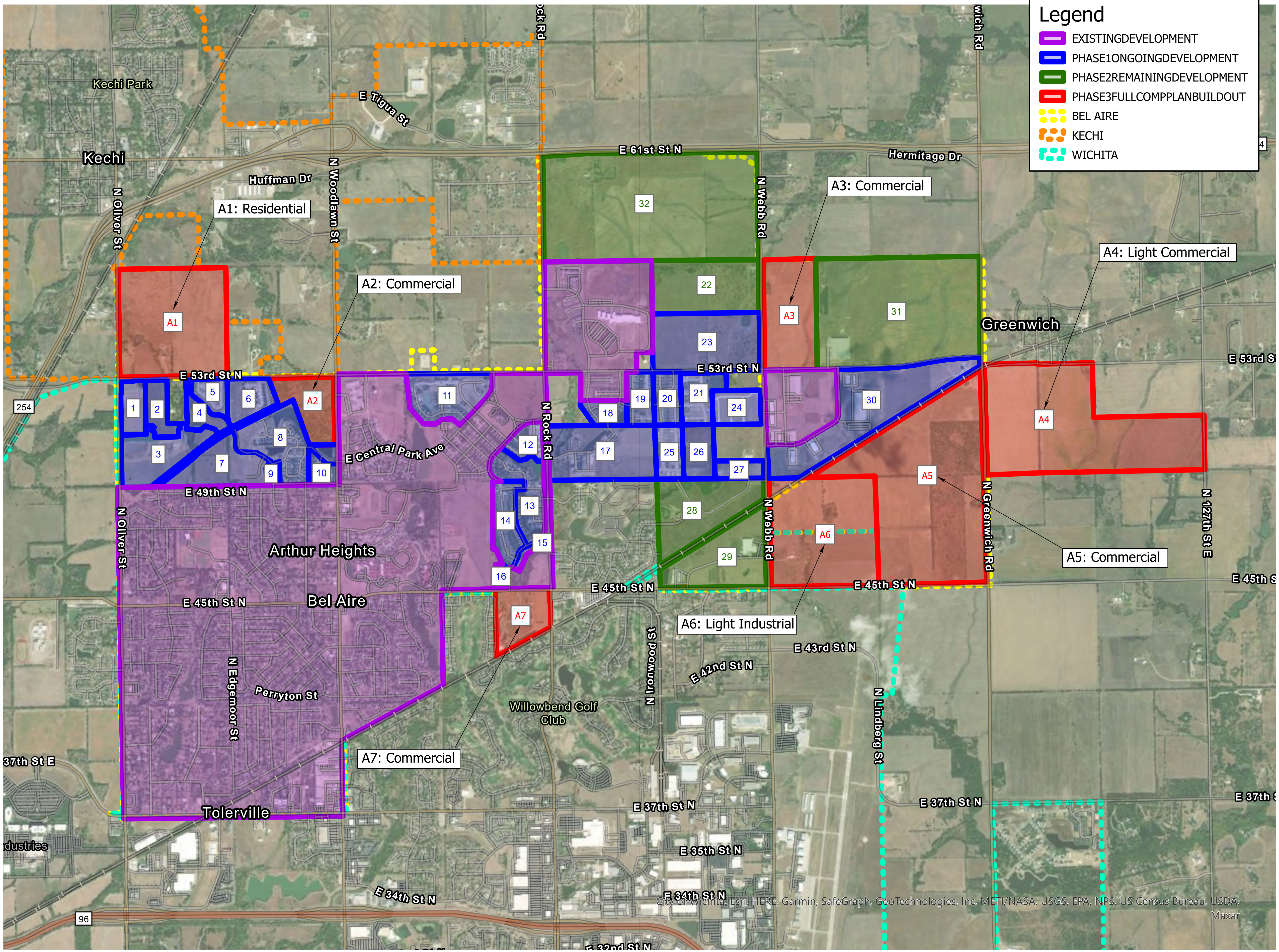

NUMBER	DEVELOPMENT NAME
1	Homstead Senior Landing
2	Chapel Landing, Phase 2
3	Prairie Preserve
4	Chapel Landing 6th
5	Chapel Landing 3rd
6	Bristol Hollows
7	Chapel Landing 5th
8	Chapel Landing
9	Chapel Landing 4th
10	Chapel Landing 2nd
11	Central Park 3rd
12	Villas at Prestwick
13	Elk Creek
14	Courtyards at Elk Creek
15	Elk Creek 2nd
16	Elk Creek 3rd
17	Deer Run
18	Rock Spring
19	Rock Spring
20	Rock Spring 2nd
21	Rock Spring 3rd
22	Sham Way Estate
23	Cedar Pass (Rock Spring 5th)
24	Rock Spring 4th
25	Skyview at Block 49
26	Skyview at Block 49 2nd
27	Skyview at Block 49 3rd
28	Tierra Verde
29	Bel Aire Industrial Park
30	Sunflower Commerce Park
31	Sunflower Commerce Park 2nd
32	Integra Technologies

N

0 0.25 0.5 1 Miles

CITY OF BEL AIRE

Figure 2

Development Map

Bel Aire Water Master Plan

Bel Aire PEC

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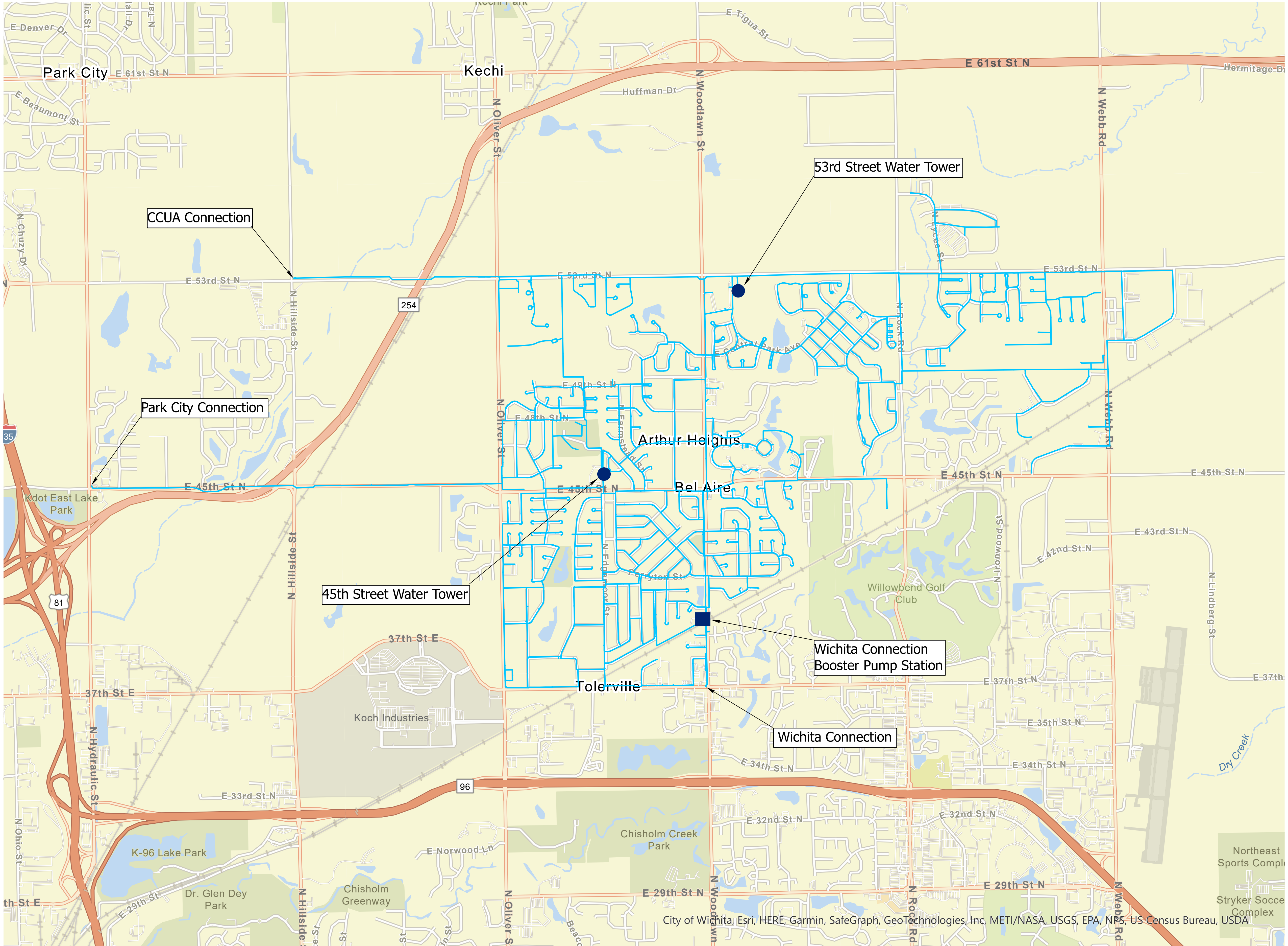

Legend

- Storage Tank
- Pump Station
- Existing Waterline

N

0 0.25 0.5 1 Miles

CITY OF BEL AIRE

Figure 3

Existing Water Distribution System

Bel Aire Water Master Plan

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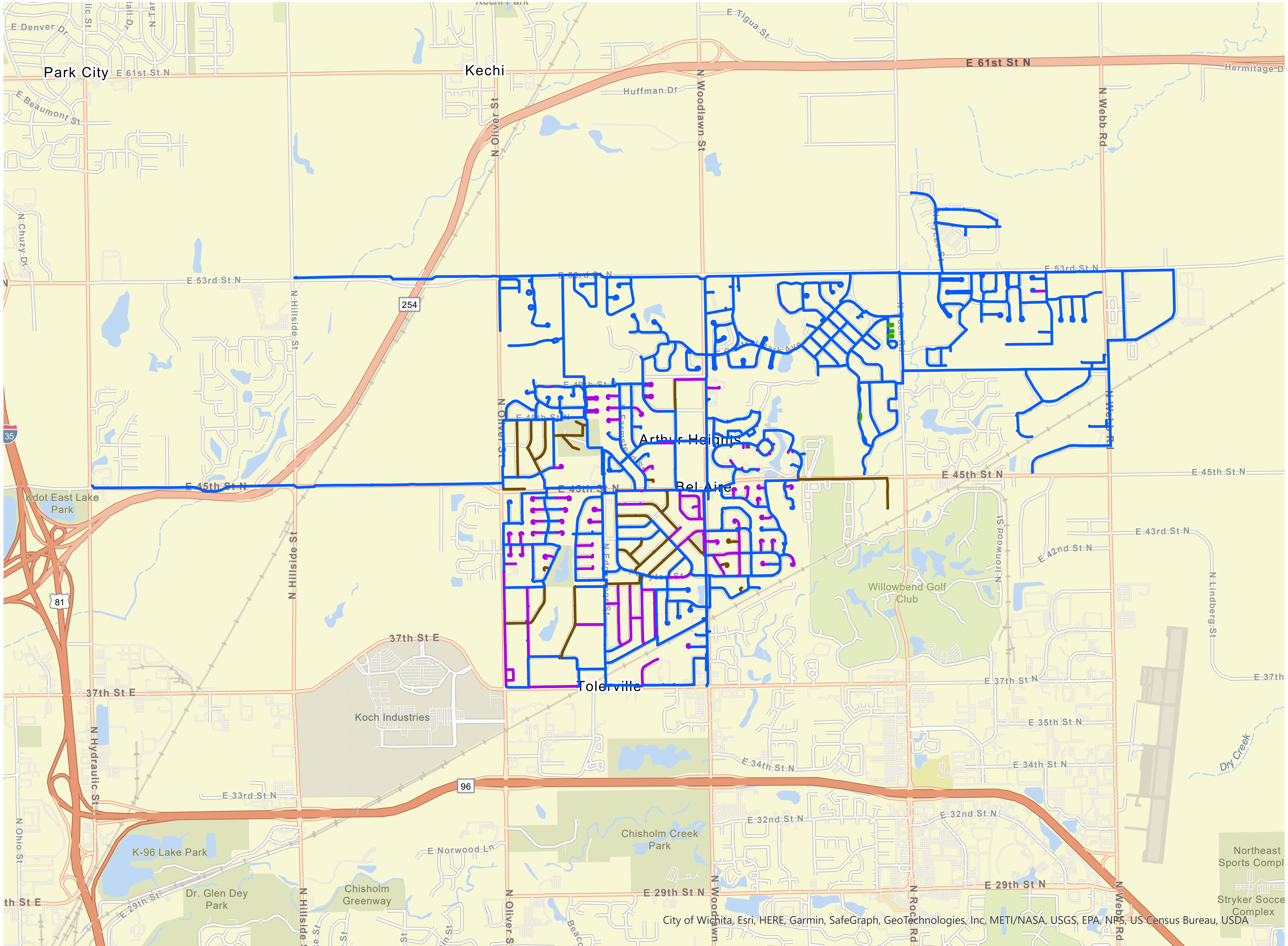

Legend

Pipe Material

- Asbestos Cement
- Cast Iron
- Ductile Iron
- Polyvinyl Chloride

N

0 0.25 0.5 1 Miles

CITY OF BEL AIRE

Figure 4
Pipe Material

Bel Aire Water Master Plan

Bel Aire PEC

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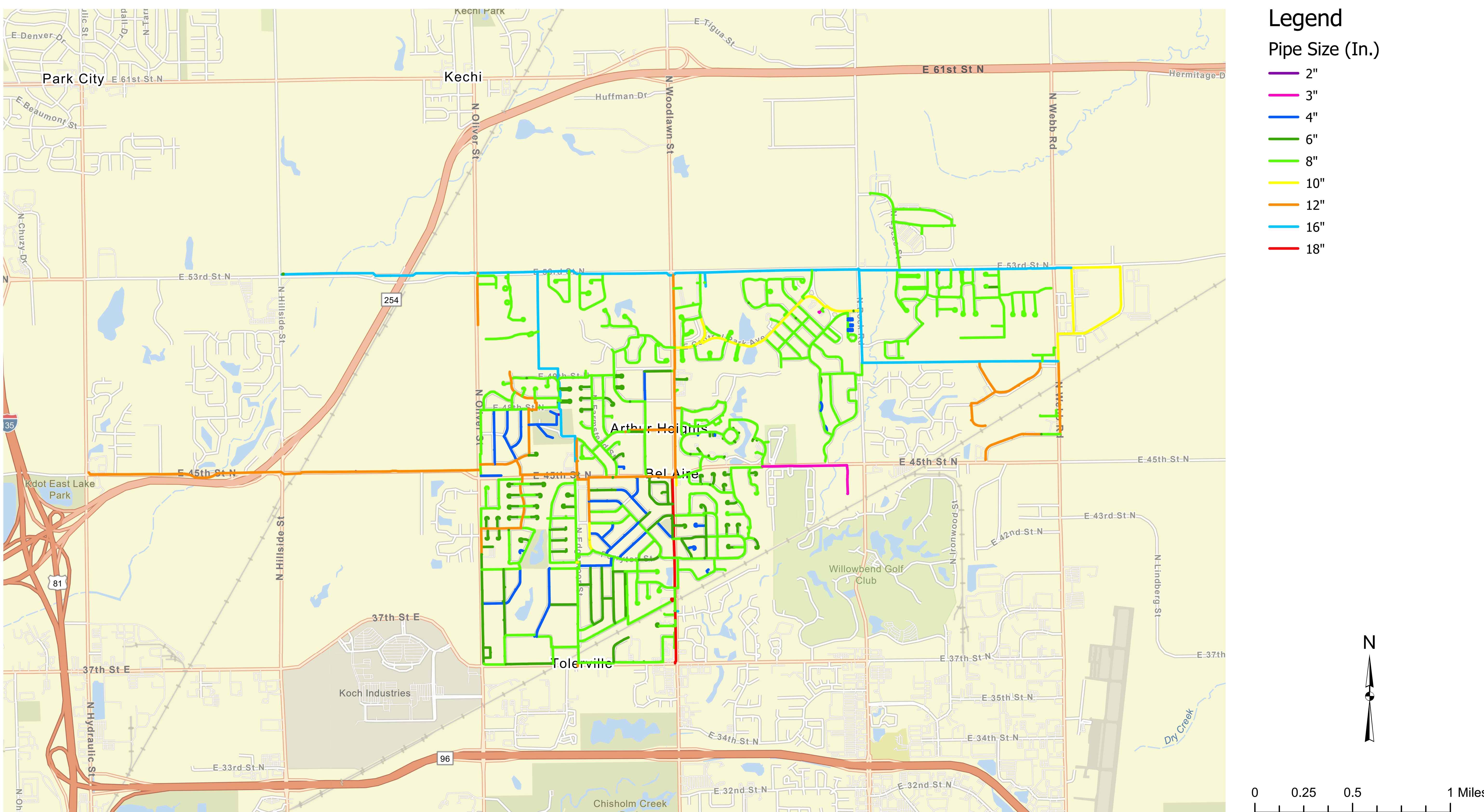

CITY OF BEL AIRE

Figure 5

Pipe Size

Bel Aire Water Master Plan

Bel Aire

PEC

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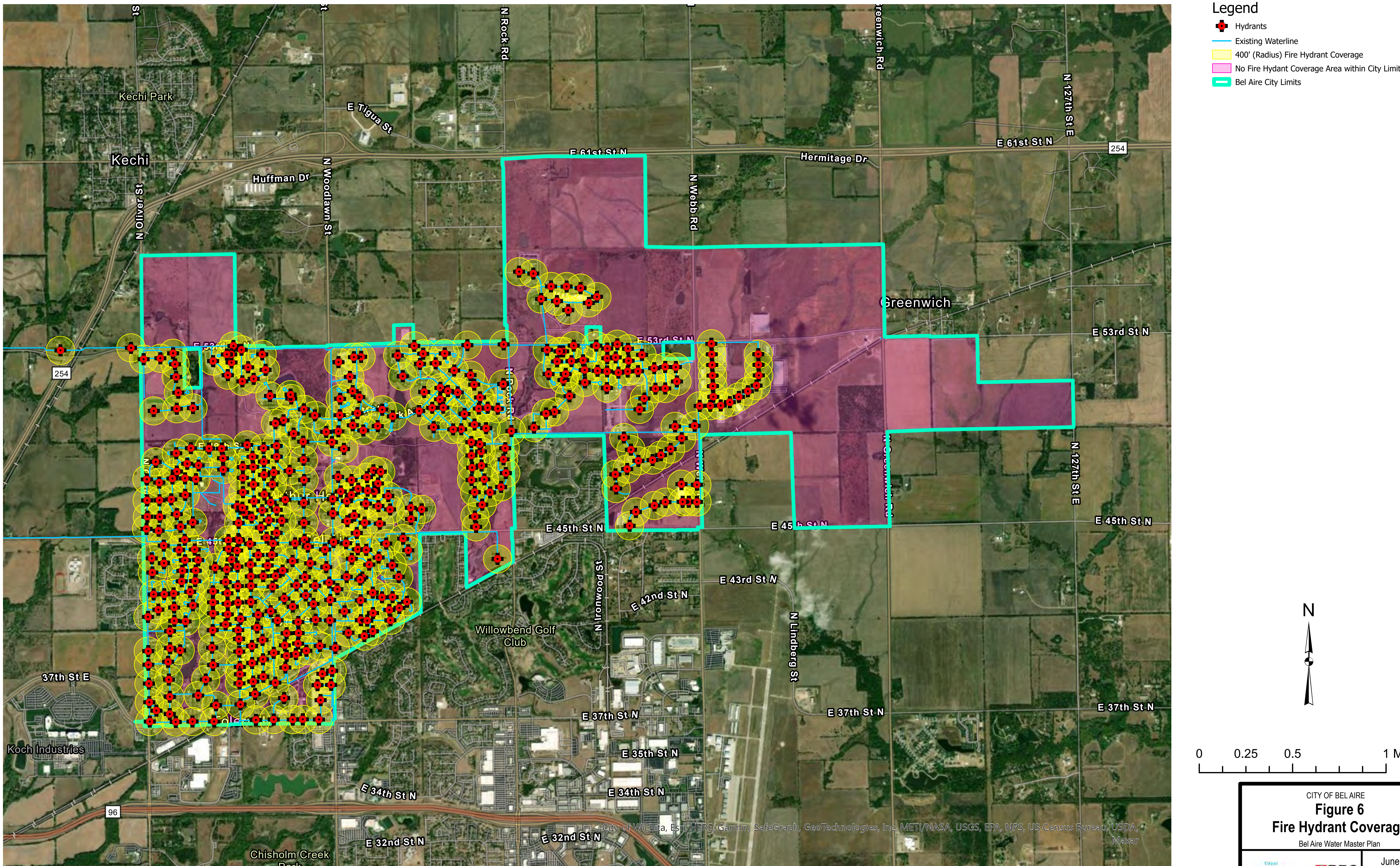

CITY OF BEL AIRE

Figure 6
Fire Hydrant Coverage

Bel Aire Water Master Plan

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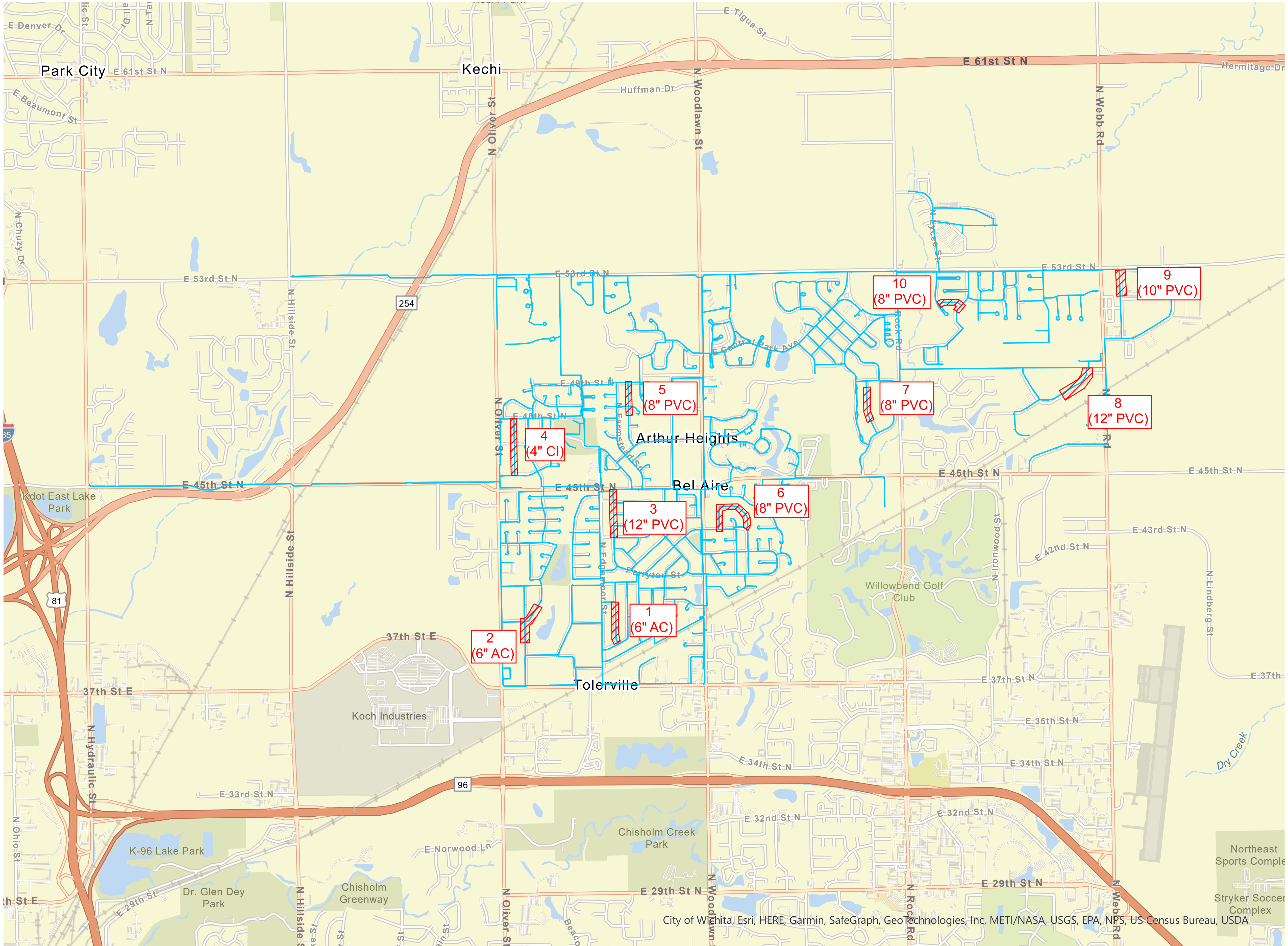

Legend

- Fire Hydrant Flow Test Location w/ ID
- Existing Waterline

N

0 0.25 0.5 1 Miles

CITY OF BEL AIRE

Figure 7

Fire Hydrant Flow Test Locations

Bel Aire Water Master Plan

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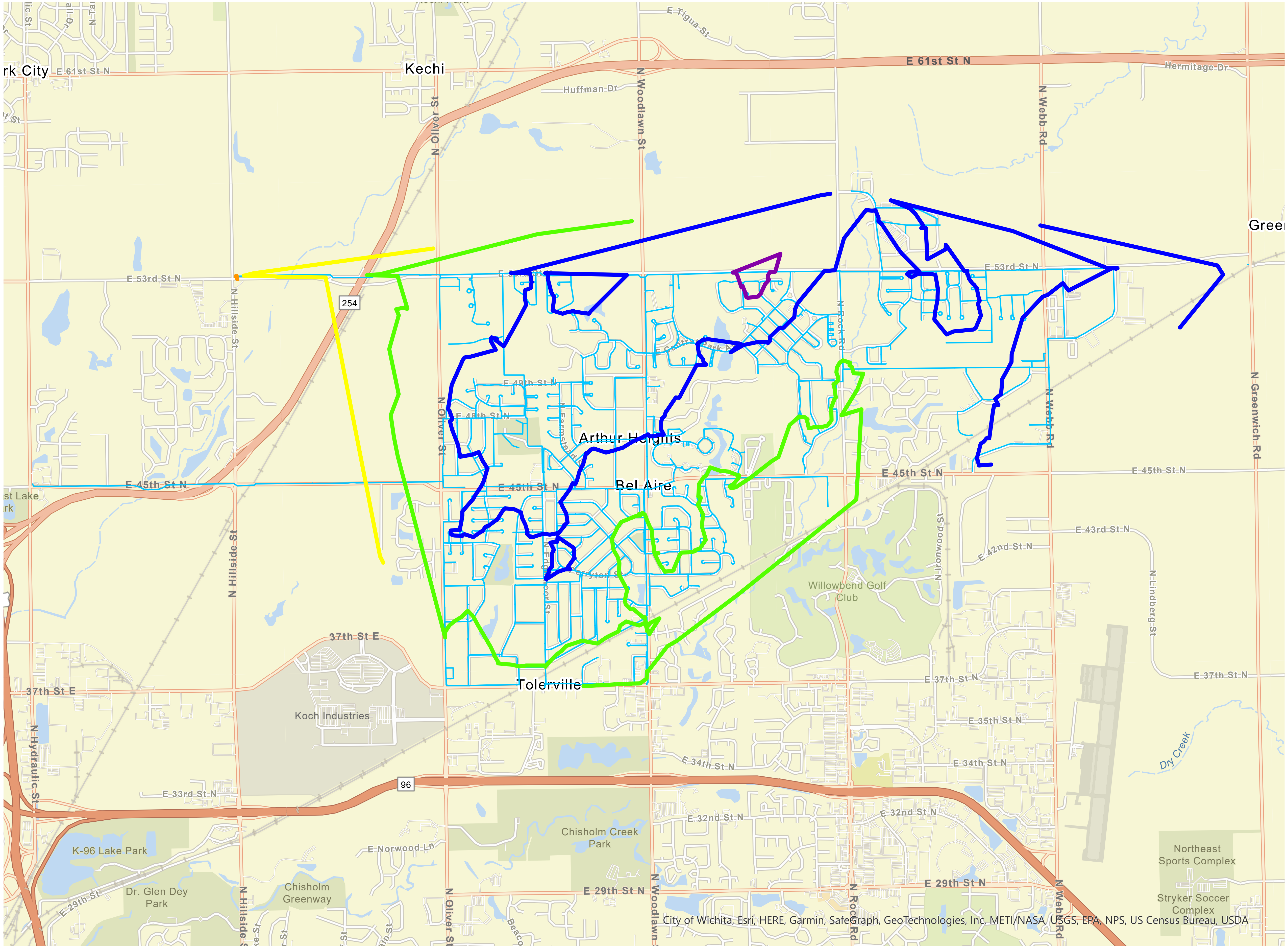

Legend

- Existing Waterline
- 40 PSI
- 50 PSI
- 60 PSI
- 70 PSI
- 80 PSI

N

0 0.25 0.5 1 Miles

CITY OF BEL AIRE

Figure 8

Scenario 1 Max Day Pressures

Bel Aire Water Master Plan

City of Bel Aire | PEC

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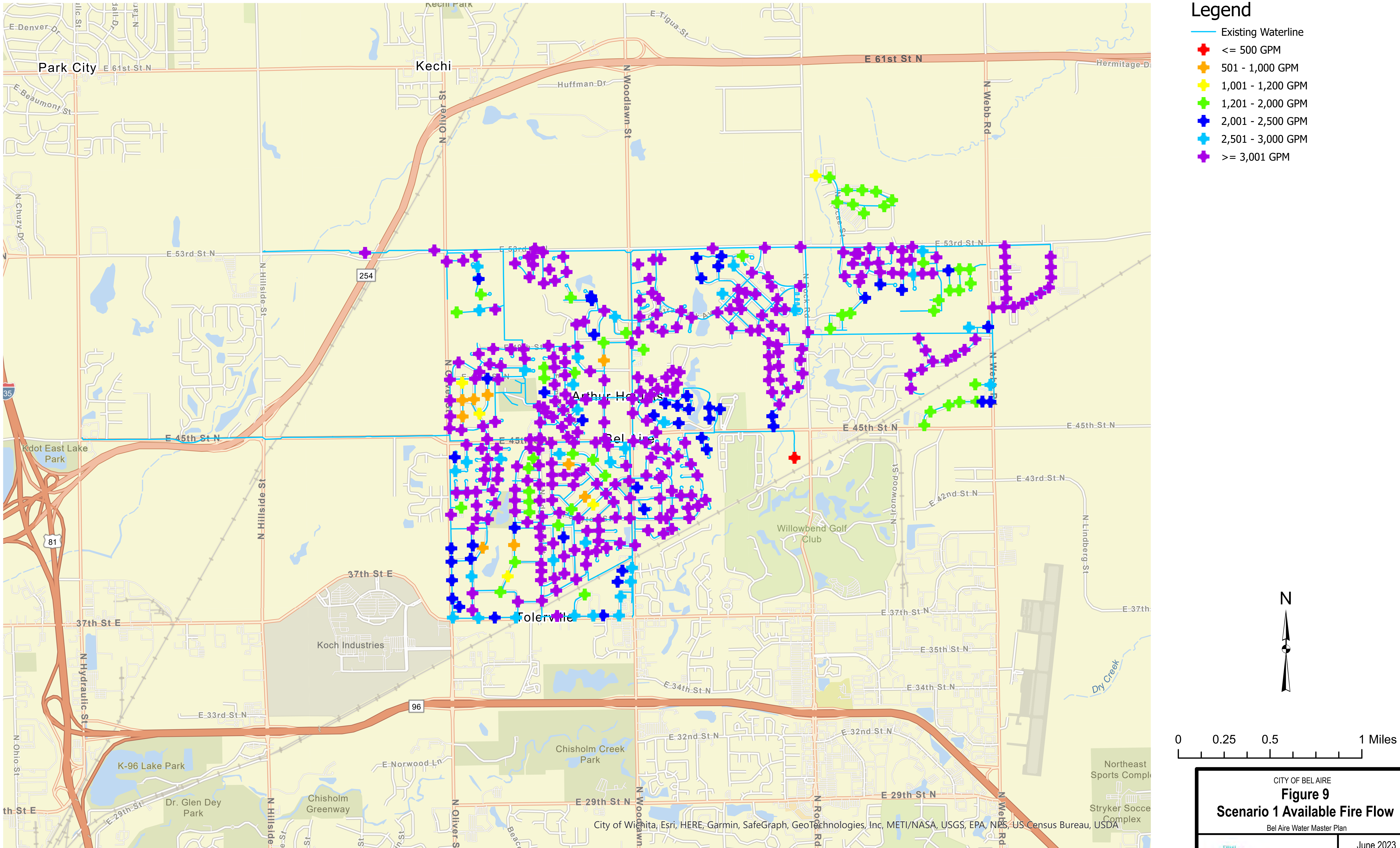

CITY OF BEL AIRE

Figure 9

Scenario 1 Available Fire Flow

Bel Aire Water Master Plan

Bel Aire | PEC

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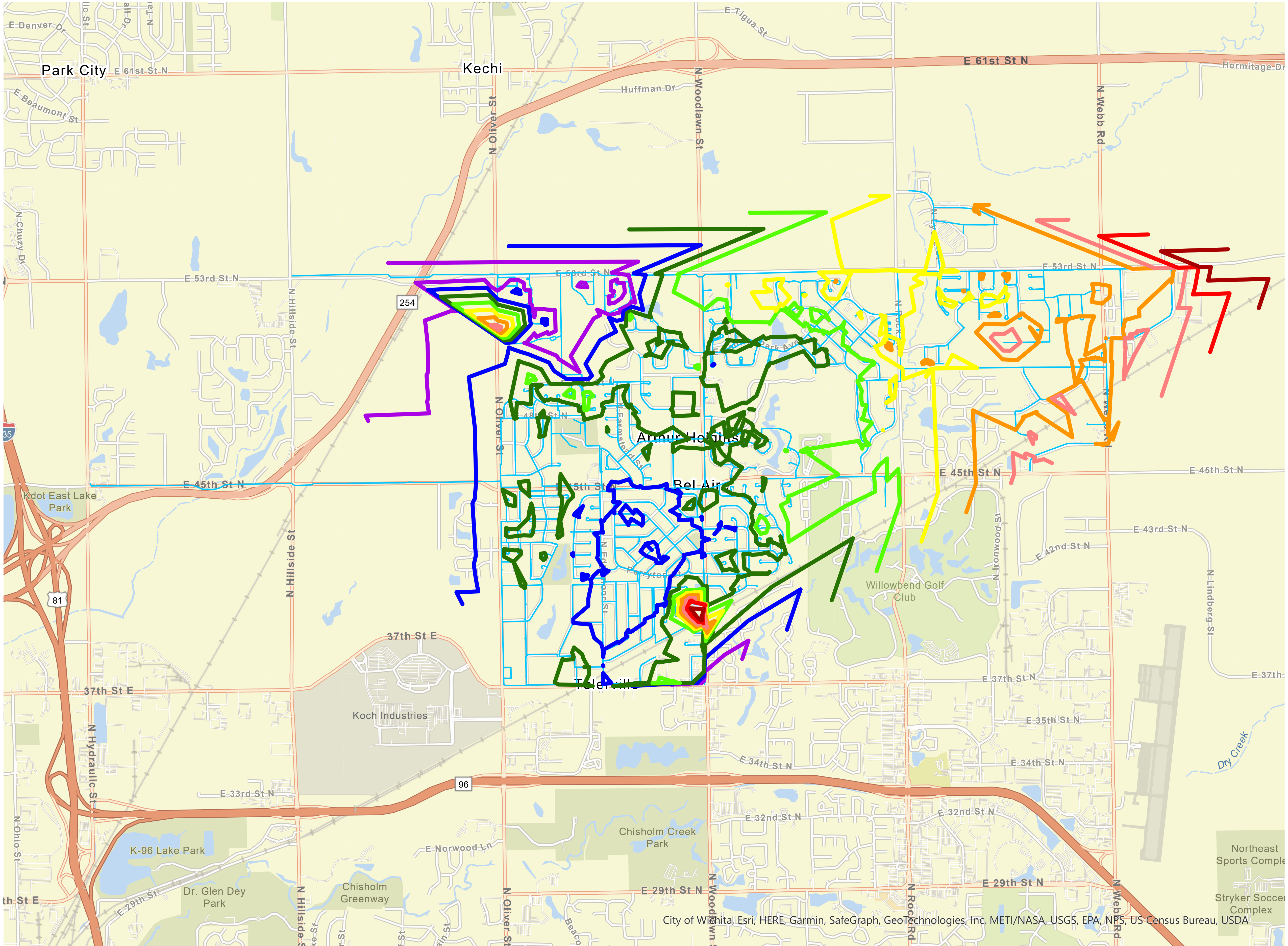

Legend

- Existing Waterline
- 24 Hours
- 48 Hours
- 72 Hours
- 96 Hours
- 120 Hours
- 144 Hours
- 168 Hours
- 192 Hours
- 216 Hours

N

0 0.25 0.5 1 Miles

CITY OF BEL AIRE

Figure 10

Scenario 1 Water Age

Bel Aire Water Master Plan

City of Bel Aire | PEC

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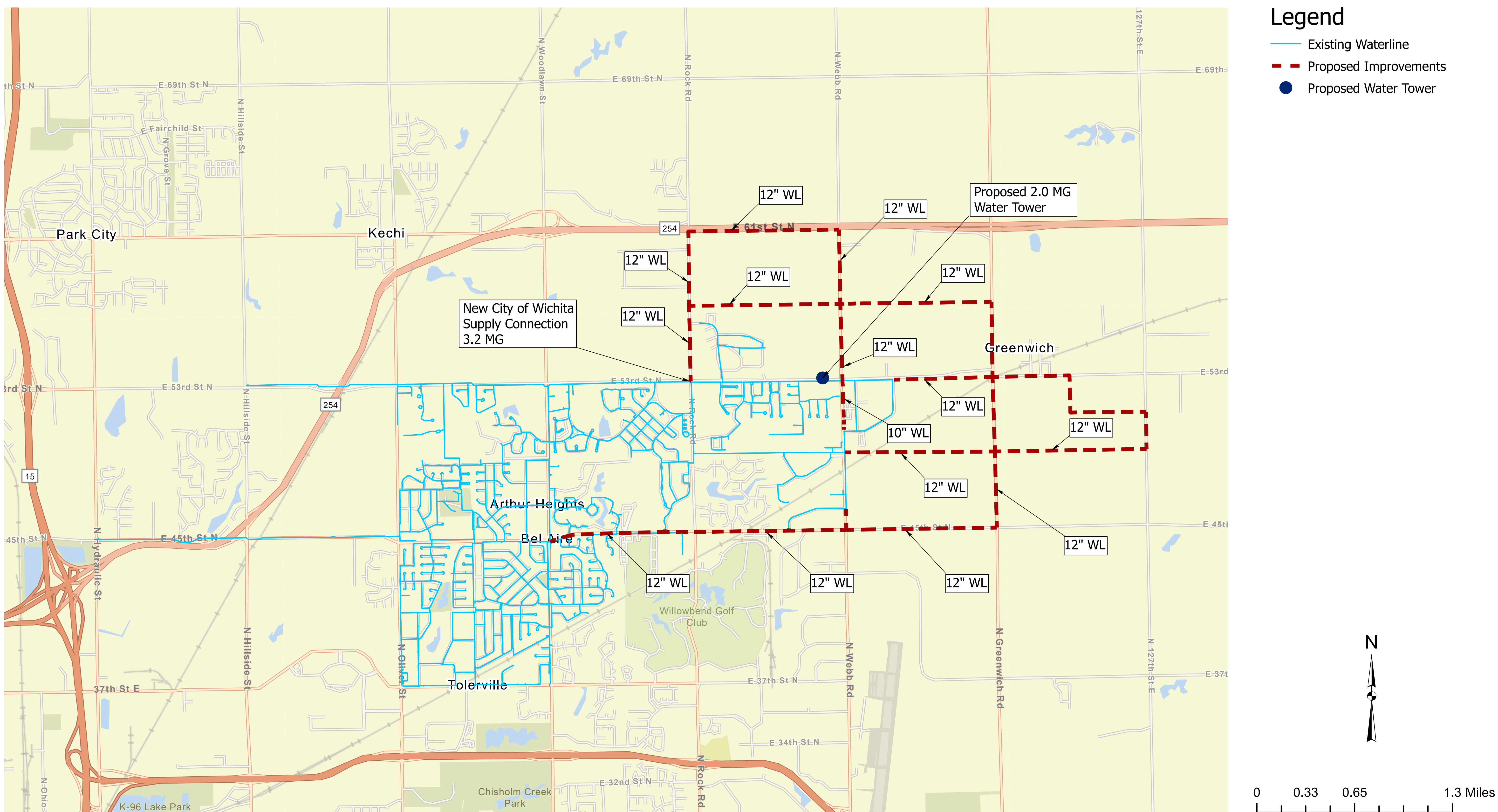

CITY OF BEL AIRE

Figure 11

Proposed Pipe Looping Improvements

Bel Aire Water Master Plan

City of Bel Aire | PEC

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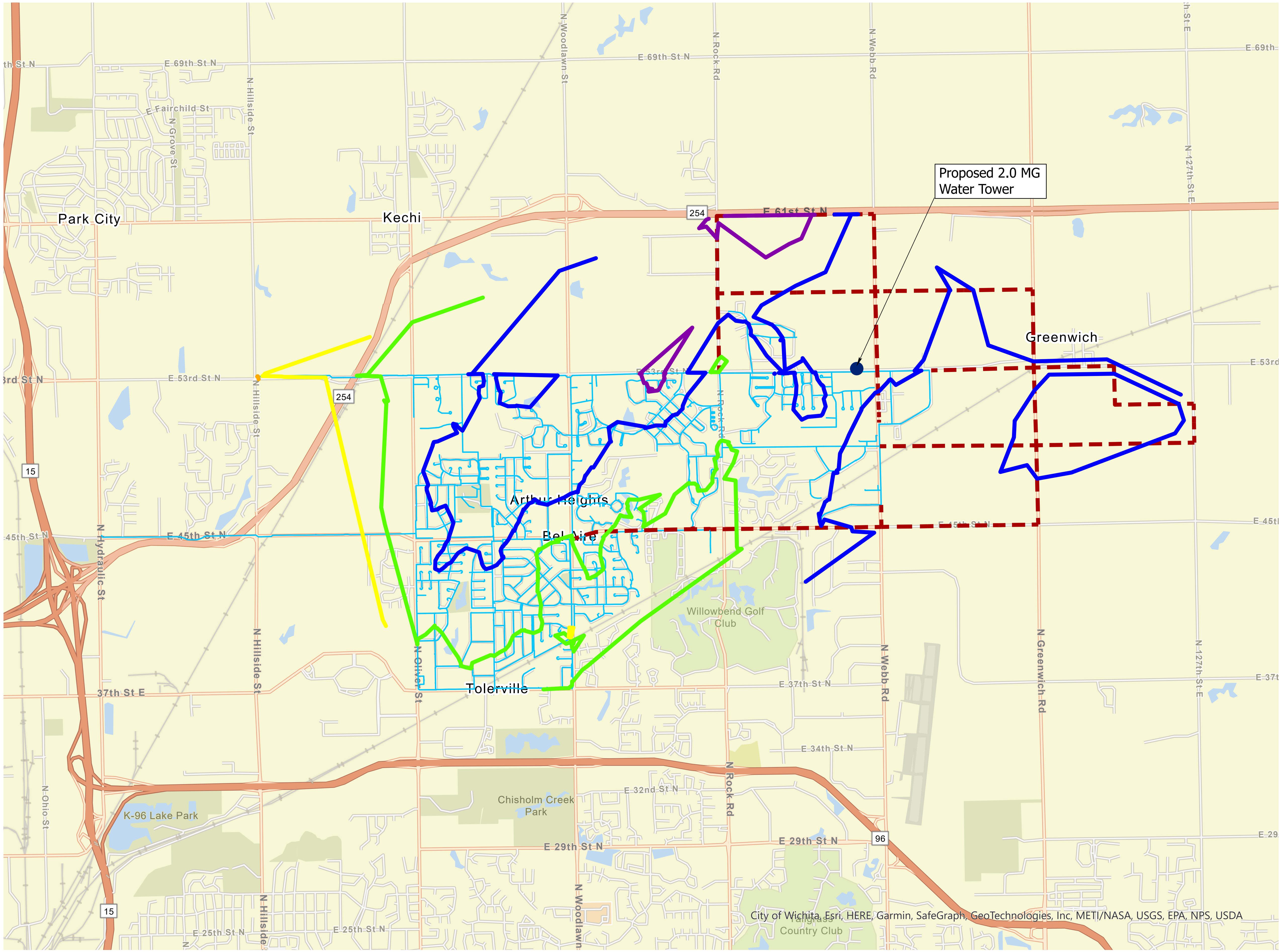

Legend

- Existing Waterline
- Proposed Improvements
- 40
- 50
- 60
- 70
- 80
- Proposed Water Tower

N

0 0.33 0.65 1.3 Miles

CITY OF BEL AIRE

Figure 12 - Scenario 3
Max Day Pressures with Improvements

Bel Aire Water Master Plan

City of Bel Aire PEC

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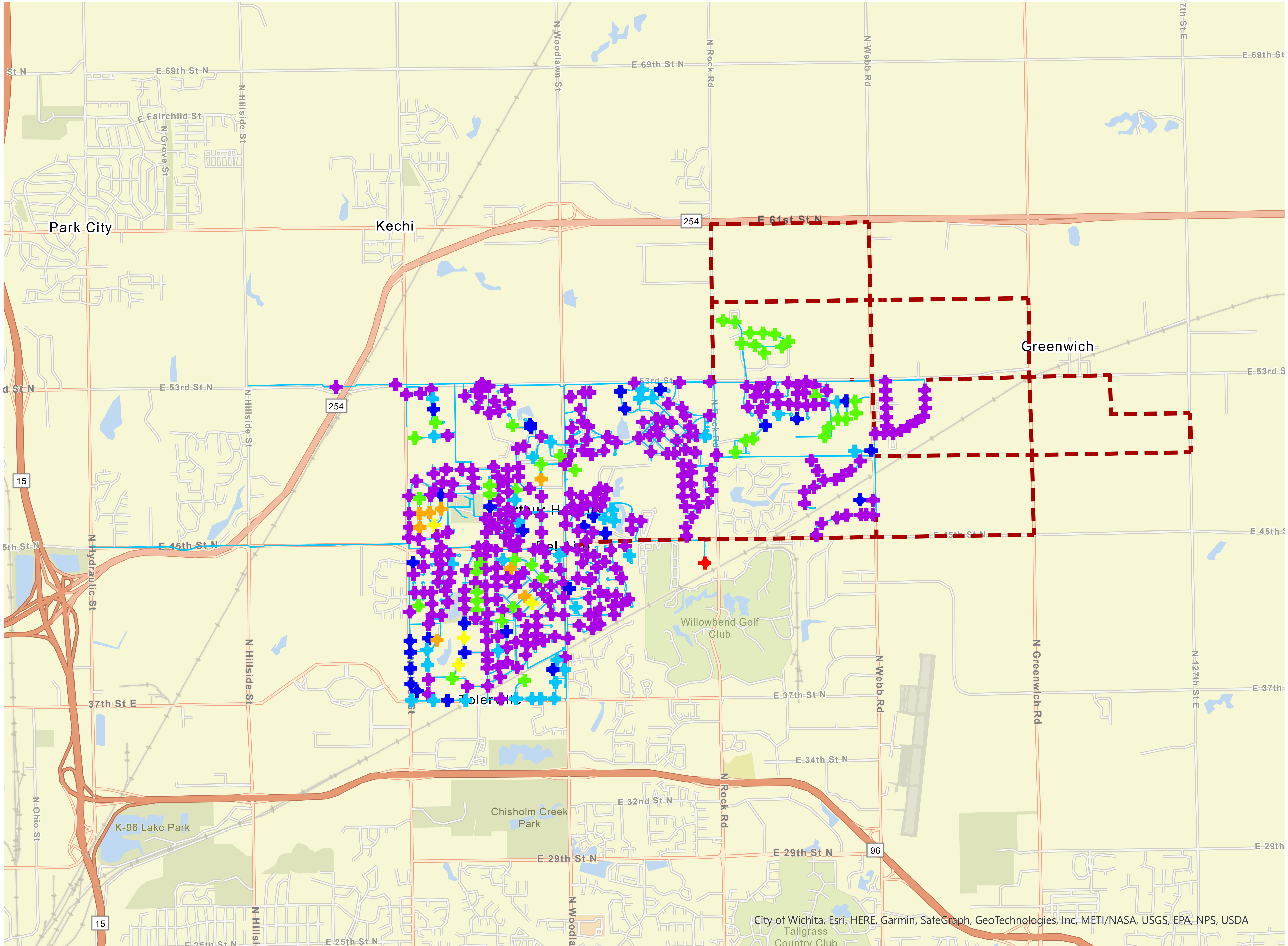

Legend

- Existing Waterline
- Proposed Improvements
- <= 500 GPM
- 501 - 1,000 GPM
- 1,001 - 1,200 GPM
- 1,201 - 2,000 GPM
- 2,001 - 2,500 GPM
- 2,501 - 3,000 GPM
- >= 3,001 GPM

N

0 0.33 0.65 1.3 Miles

CITY OF BEL AIRE

Figure 13 - Scenario 3
Available Fire Flow with Improvements

Bel Aire Water Master Plan

City of Bel Aire PEC

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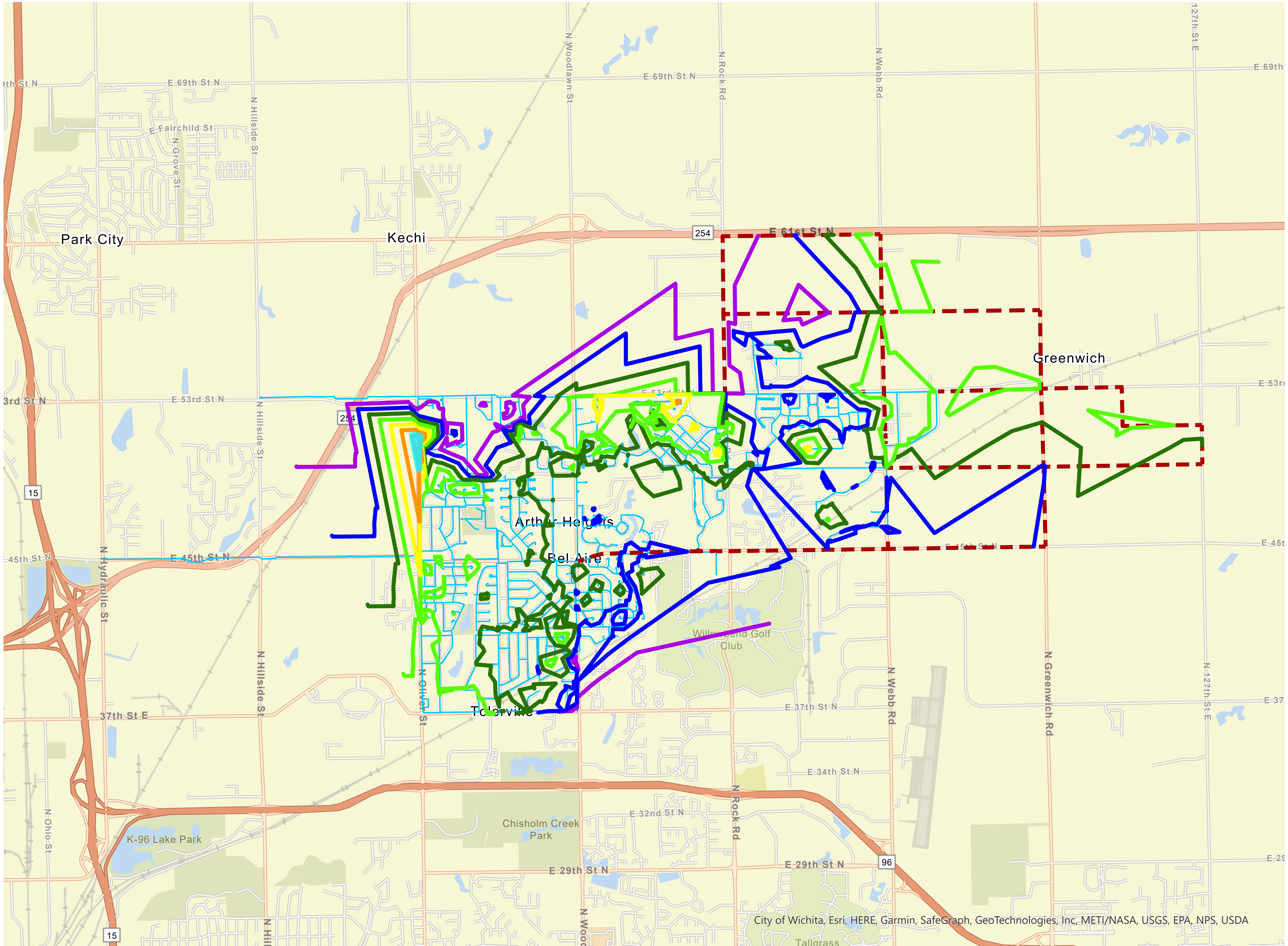

Legend

- Existing Waterline
- Proposed Improvements
- 24 Hours
- 48 Hours
- 72 Hours
- 96 Hours
- 120 Hours
- 144 Hours
- 168 Hours
- 192 Hours
- 216 Hours

N

0 0.33 0.65 1.3 Miles

CITY OF BEL AIRE

Figure 14 - Scenario 3
Water Age with Improvements

Bel Aire Water Master Plan

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