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Utility Master Plan

Project No. 17-467

Volume IV – Water and Wastewater Infrastructure Master Plan

The City of Thornton

Project Number: 60560104

March 2020

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Quality information

Prepared by	Checked by	Verified by	Approved by
Marcela Durán	Brock Hodgson	Nathan Walker	Nathan Walker

Revision History

Revision	Revision date	Details	Authorized	Name	Position

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Prepared for:

The City of Thornton

Prepared by:

AECOM
6200 South Quebec Street
Greenwood Village, CO 80111

T: +1 (303) 694 2770
F: +1 (303) 694 3946
aecom.com

Water and Wastewater Infrastructure Master Plan

List of Chapters

Water and Wastewater Infrastructure Master Plan

Executive Summary

Executive Summary Table of Contents

List of Acronyms

%	percent
2009 Plan	City of Thornton 2009 Water and Wastewater Systems Master Plan
AACE	Association for the Advancement of Cost Engineering
ADD	average daily demand
ADWQ	average dry weather flow
AWWA	American Water Works Association
CIP	Capital Improvement Program
ENR	Engineering News-Record
FF	fire flow
fps	feet per second
ft	feet
gpm	gallons per minute
hr	hour(s)
ID	identification
in	inch
Integrated MP	Integrated Master Plan
KPI	key performance index(ices)
MDD	maximum day demand
MG	million gallons
mgd	million gallons per day
mi	mile(s)
MinDD	minimum daily demand
MinM	minimum month
MWRD	Metro Wastewater Reclamation District
N/A	not applicable
NWTP	Northern Water Treatment Plant
O&M	operation and maintenance
PDWQ	Peak Dry Weather Flow
PHD	peak hour demand
PRV	pressure reducing valves
psi	pounds per square inch
Thornton	city of Thornton
TWTP	Thornton Water Treatment Plant
TM	technical memorandum
UMP	Utility Master Plan
WBWTP	Wes Brown Water Treatment Plant
WGL	West Gravel Lakes
WTP	water treatment plant
W/WW	water and wastewater
W/WW IMP	Water/Wastewater Infrastructure Master Plan

1. Introduction

The city of Thornton (Thornton) has complex water distribution and wastewater collection systems that provide service to over 166,000 customers within the city as well as outside its limits, including service to Western Hills, Welby, Unincorporated Adams County, and Federal Heights (wastewater service only) communities. Thornton must cost effectively serve its customer base and plan for future growth, while meeting high standards of service. At buildout (anticipated to occur by 2065), the systems are expected to serve a population of 268,843.

This Water and Wastewater Infrastructure Master Plan (W/WW IMP) demonstrates the need for capital investment and summarizes the expected capital planning. The recommendations contained in this W/WW IMP were developed with the ultimate goal of providing a buildout water and wastewater system that meets the required performance criteria and is capable of accommodating the planned future residents and businesses.

Utility Master Plan

Thornton's Utility Master Plan (UMP) has completed planning analysis across the Water Transmission and Distribution System, Wastewater Collection System, Water Treatment Facilities, and Raw Water Supply System. These planning evaluations and subsequent Capital Improvement Program (CIP) identified for each system were based on a consistent planning basis and growth projections documented in this W/WW IMP.

A master plan was developed for each of the disciplines, addressing the impact of each of the three future supply alternatives. Results from individual master plans were combined into the Integrated Master Plan (Integrated MP) that establishes the preferred alternative and related CIP, phasing, prioritization, and budgets for the UMP.

W/WW IMP Purpose

This W/WW IMP report provides a comprehensive update to Thornton's Water and Wastewater System Master Plan developed in 2010. This report presents the data sources, methodology, and key findings required to evaluate the existing system, the projected population growth and estimated demands for buildout conditions, and the performance criteria that dictate if new infrastructure is required.

The proposed W/WW CIP is based on a combination of data review, hydraulic tools, and technical evaluations, including invaluable input from Thornton's staff. This document describes the results of observations and analyses and provides strategies and recommendations, including cost opinions for the proposed new infrastructure.

For the water transmission and distribution system, improvements were developed for three future alternatives: a new Northern Water Treatment Plant (NWTP); expansion of the existing Thornton Water Treatment Plant (TWTP); and expansion of the Wes Brown Water Treatment Plant (WBWTP). The W/WW IMP identified the improvements required for each of these alternatives; however, the selection of the preferred alternative was performed during the Integrated MP considering not only the improvements recommended in this report but also water supply and water treatment improvements.

The wastewater collection system improvements are not impacted based on the three future alternatives; therefore, a single set of improvements was developed to meet the design criteria and accommodate projected buildout conditions.

W/WW IMP Report Organization

This report is organized into seven chapters, as described in Table 1. Each chapter was developed as an independent Technical Memorandum (TM that includes detailed technical information and supporting documents. The TMs were then compiled into this report to document the methodology and findings that led to the CIP development.

Table 1. W/WW IMP Report Organization

Chapter	Description	System
1. Initial Data and Hydraulic Model Review	Description of initial planning and network data review and hydraulic models for both water and wastewater collection systems	Water Wastewater
2. Planning Area and Future Growth Analysis	Description of planning area and population projections and development of future water use projections	Water Wastewater Raw Water Treatment
3. System Performance Criteria	Description of the performance criteria that was used in evaluating Thornton's water transmission and distribution system and wastewater collection system	Water Wastewater
4. Raw Water, Water Treatment, and Water Quality Update	Overview of the raw water and water treatment systems and provides a summary on the water quality requirements for the integrated planning efforts	Water Wastewater Raw Water
5. Water Distribution System Analysis	Description of the water distribution system analyses and recommended improvements needed to serve buildout conditions	Water
6. Wastewater Collection System Evaluation	Description of the wastewater collection system evaluation, existing system deficiencies, and future improvements necessary to serve buildout system needs	Wastewater
7. Water and Wastewater Rehabilitation and Replacement Program	Description of the proposed pipeline rehabilitation and replacement program, long-term funding plan, and prioritization of pipeline improvements	Water Wastewater

The individual chapters noted above were developed and finalized separately during the development of the W/WW IMP. Each chapter is a standalone document; therefore, any differences or discrepancies between the documents caused by the evolution of the studies will be resolved in the Integrated MP.

2. Planning Area and Future Growth Alternatives

Thornton's current city limits encompass approximately 37.3 square miles (23,846 acres), and the future growth boundary encompasses approximately 60.3 square miles (38,609 acres). The existing city limits are made up of four wards. Outside of the city limits, Thornton's service area also includes Western Hills, Welby, Federal Heights, and portions of Unincorporated Adams County. Federal Heights is part of the wastewater service area but not the water service area, and its land use characteristics are not included in the W/WW IMP analyses. The existing and future service area inside the city limits, the future growth boundary, and regions outside the future growth boundary served by Thornton are described in **Chapter 2.** Figure 4 (included at the end of the Executive Summary) shows the service and planning areas.

Thornton's existing and future population projections for the water and wastewater (W/WW) service area are shown in Table 2. The future population projections serve as the basis for the population-based planning area and future growth analysis for the UMP including the W/WW IMP.

Table 2. Existing and Future Population for Thornton's Water and Wastewater Service Area

Service Area Component	Population			
	2017	2025	2035	Buildout (2065)
Within City Limits				
Total[1]	137,443	168,437	197,764	238,513
Ward 1	33,366	33,596	33,734	35,637
Ward 2	34,496	38,250	41,466	44,235
Ward 3	33,550	49,314	70,394	106,471
Ward 4	36,031	47,277	52,170	52,170
Outside City Limits				
Western Hills[2]	10,500	10,500	10,500	10,500
Welby[3]	1,886	1,886	1,886	1,886
Unincorporated Adams County[2]	4,444	4,444	4,444	4,444
Federal Heights (wastewater only) [2]	12,100	12,300	12,800	13,500
Total Water Service Area Customers	**154,273**	**185,267**	**214,594**	**255,343**
Total Wastewater Service Area Customers	**166,373**	**197,567**	**227,394**	**268,843**

[1] Provided by Thornton Planning Department

[2] From the 2009 Plan

[3] Calculated based on 16,830 population, assumed outside city limits

A pseudo population and land use-based approach was used for the development of future water system demand projections. This approach accounts for the per capita population demands as well as a land use-based approach for the future commercial demands as land use shifts to a larger percentage of commercial and mixed-use development. At buildout, the average daily demand (ADD) water use is estimated to be up to 39.1 million gallons per day (mgd) during hot and dry (drought) climate conditions. Under wetter and cooler (non-drought) climate conditions, the typical buildout ADD demand is estimated to be 32.9 mgd.

The historical water use, related peaking factors (PFs), and apparent system losses were used to complete an integrated water balance across each utility system including supply, treatment, distribution and collection. The integrated water balance establishes the flow requirements for each system for the buildout demand projections. The estimated future system demands translated across the water systems were developed, as shown on Figure 1 including ADD, maximum day demand (MDD), minimum month (MinM), average dry weather flow (ADWQ) and Peak Dry Weather Flow (PDWQ).

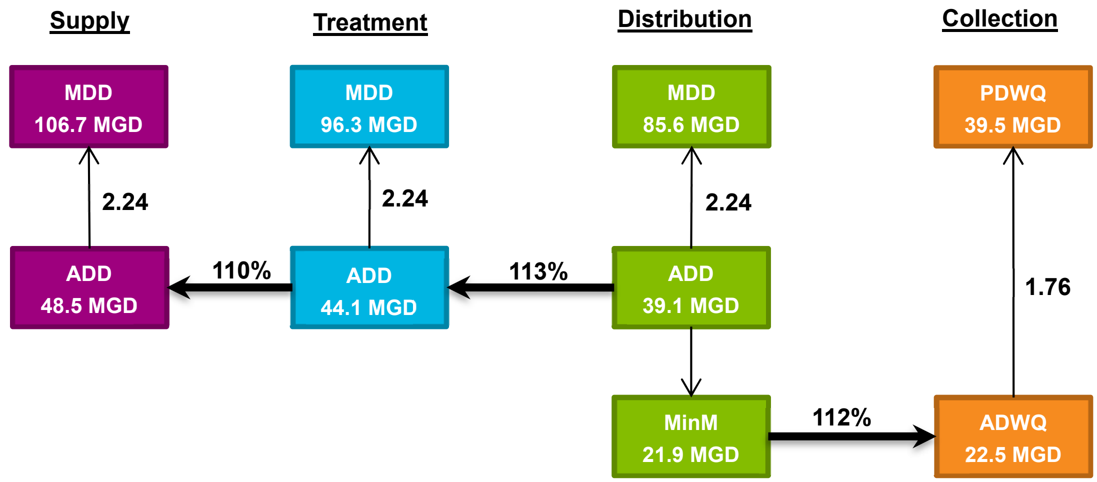


Figure 1. Translated Future System Demands

3. Performance Criteria

Chapter 3 describes the performance criteria used in evaluating Thornton existing water distribution and wastewater collection systems and used in identifying future improvements. The criteria have been developed based on a thorough review of the 2009 Water and Wastewater Master Plan (2009 Plan), city, state, and federal standards, and applicable industry standards including those of the American Water Works Association (AWWA).

The criteria for each system are divided into three tiers to establish differences in the levels of system performance and to provide Thornton flexibility in selecting improvements based on increased levels of service that may result from different criteria. The three tiers can be summarized as follows:

- Tier 1: Criteria that must be met by the system
- Tier 2: Criteria that represent best practice and should be met by the system, but may not be required
- Tier 3: Criteria that are desired and should be met if practicable, but are not required

Resiliency criteria include important considerations necessary to provide reasonable reliability of the water distribution system. System performance criteria pertaining to looped water mains, standby power, and firm pumping capacity, along with meeting required operating capacity with a large out-of-service transmission main comprise the water distribution system resiliency criteria. These resiliency criteria are included in Tier 1 and Tier 3.

4. Raw Water, Water Treatment, and Water Quality Update

Chapter 4 provides an overview of the raw water and water treatment systems for Thornton and provides an update to the water quality requirements for the integrated planning efforts across the city's water systems. This chapter identifies the system components that were evaluated in the Raw Water Master Plan and Water Treatment Master Plan to maintain consistent planning and evaluation with the W/WW IMP.

The Thornton raw water system currently diverts water from the South Platte River, Upper Clear Creek, and Lower Clear Creek. Raw water is conveyed from the respective diversion points to three main raw water storage facilities. Water from the South Platte River is conveyed to the East Gravel Lakes (EGL) System, water from Upper Clear

Creek is conveyed to Standley Lake, and water from Lower Clear Creek is conveyed to the West Gravel Lakes (WGL) facility. Raw water from storage is then conveyed for treatment to either the WBWTP or the TWTP.

The raw water and treatment systems are generally sufficient to meet current demands. However, at buildout, Thornton will need to provide additional water supplies and expand treatment capacity to meet future system demands associated with planned population growth and development described in **Chapter 2**.

5. Water Transmission and Distribution System

Chapter 5 describes the analyses of Thornton's water distribution system, identifying recommended improvements required to serve buildout conditions. The service area is expected to grow significantly, which will require increasing the existing network's capacity, thereby expanding both transmission and distribution infrastructure to accommodate the estimated future demands.

System evaluations included assessment of storage, pumping, distribution (<16-in diameter pipes), and transmission (≥16-inch diameter pipes) capacities. The results of these analyses were compared against the system performance criteria described in **Chapter 3**.

System Overview

The existing Thornton water distribution system consists of over 580 miles of pipeline. Currently, there are five main pressure zones with 13 subzones, seven pump stations, ten storage tanks, and approximately 65 pressure reducing valves (PRVs). The majority of the buildout growth is expected to occur in Zone 1 and Zone 3A within the northern portion of the system. The existing system and pressure zones are described in detail in **Chapter 1** and are shown on Figure 5 (included at the end of the Executive Summary).

Alternatives Evaluation

Currently, Thornton's water distribution system is served by two water treatment facilities: WBWTP and TWTP. The current treatment facilities have the capacity to serve existing demands but are not sufficient to serve the expected growth. Thornton is considering three alternatives to provide the expected required treatment facility capacity:

- Alternative 1 includes construction of a new NWTP to supply buildout demands as development occurs. The location of the NWTP was evaluated by considering criteria including practicable site locations identified by Thornton; ease of land acquisition; proximity to existing storage tanks; efficiency of mixing treated water within the system; and ease of raw water supply conveyance. Based on this review, the parcel north of 140th Avenue between Colorado Boulevard and Holly Street was identified as the preferred location for construction of the NWTP. The proposed NWTP site would be approximately 14.5 acres and is currently privately owned and part of Unincorporated Adams County. Thornton would have to acquire the land and complete zoning activities to permit construction and operation of a treatment facility at this location. At buildout, the NWTP will have a capacity of 21.5 mgd. For this alternative, the future capacity of the TWTP would be 20 mgd, and the future capacity of the WBWTP would be 54.8 mgd.
- Alternative 2 includes expansion of the new TWTP to supply buildout demands as development occurs. The new TWTP is a conventional plant currently under construction and will have a firm capacity of 20 mgd. At buildout, the TWTP would be expanded by 21.5 mgd to a permitted production capacity of 41.5 mgd. For this alternative, the future capacity of the WBWTP would be 54.8 mgd.
- Alternative 3 includes expansion of the WBWTP from a firm capacity of 54.8 to 76.3 mgd to meet buildout production requirements. The existing WBWTP site location is approximately 17 acres located in the southeastern portion of the system. Thornton currently owns property at the site to allow for the expansion. Depending on the layout, some systems may be required to be relocated, and the existing plant roadway system would be required to be modified. For this alternative, the future capacity of the TWTP would be 20 mgd.

The W/WW IMP identified improvements required for each alternative. The selection of a future alternative in the Integrated MP will lead to the development of final sizing, phasing, and prioritization of these improvements.

Water System Analysis

The following subtasks were completed to evaluate the water distribution system:

- Distribution improvements to serve future developments
- Storage facility improvements
- Pumping station improvements
- Transmission improvements required to implement each alternative
- Distribution improvements for existing service areas

In general, the water system analysis results indicate that the existing system has storage and transmission deficiencies, and infrastructure improvements are needed to meet buildout requirements. After analyzing the existing infrastructure under buildout conditions for the three supply alternatives, the following main conclusions were drawn:

- The location of the new system supply source does not affect the size and location of improvements recommended for future development service, storage, or distribution.
- Pumping improvements are common for all alternatives, except for improvements recommended for the WBWTP High Service Pump Station.
- Current storage infrastructure is not large enough to serve future buildout requirements. Zone 1 and Zone 3 will require additional storage capacity.

Consistent with the findings in the 2009 Plan, the water distribution system evaluation shows a deficiency in transmission capacity from the WBWTP and the TWTP to the northern portion of the buildout service area, where most of the growth is expected to occur. The resulting CIP for each alternative includes transmission and distribution improvements in addition to three new storage tanks, including two in Zone 1, and one in Zone 3, and the replacement of pumping equipment in Zone 3A, Zone 5, and at the WBWTP High Service Pump Stations.

Capital Improvement Program

The developed CIP for the water distribution system is comprised of five different types of improvements: future development distribution, storage, pumping, transmission, and distribution. Based on the results from the water system evaluation, a list of CIP projects was developed that identified improvements to accommodate the expected growth by buildout for each alternative. The improvement list will be finalized in the Integrated MP based on the selection of a single preferred alternative.

Project costs for identified improvements were developed by applying unit costs accounting for material and installation for water infrastructure, pump stations, and storage facilities.

Table 3 summarizes the cost for each improvement type. A detailed list of the improvements in each category is provided in **Chapter 5**.

Table 3. Water Transmission and Distribution CIP Cost Summary

Type	Length (ft)	Alternative 1	Alternative 2	Alternative 3
Future Development Distribution Infrastructure Projects[1]	217,900	$105,913,230	$105,913,230	$105,913,230
Distribution System Improvements	45,200	$27,957,030	$27,957,030	$27,957,030
Storage Facility Improvements		$38,595,300	$38,595,300	$38,595,300
Pumping Station Improvements		$5,914,400	$5,914,400	$5,495,000
Transmission Improvements	86,400	$90,373,100	$160,213,500	$160,213,500
TOTAL CIP	**349,500**	**$268,753,060**	**$338,593,460**	**$338,174,060**

[1] Only a portion of these projects will be funded by Thornton; the majority will be the responsibility of developers.

6. Wastewater Collection System Evaluation

Chapter 6 provides an evaluation of Thornton's wastewater collection system and identifies existing system deficiencies and future improvements necessary to serve buildout system needs. A hydraulic model provided by Thornton was used to allocate future flows and evaluate the performance of the system at buildout, which is anticipated to be in 2065.

System Overview

The existing wastewater collection system review is included in **Chapter 1**. Thornton's system is divided into 12 basins that convey flow to metered connections with Metro Wastewater Reclamation District (MWRD) and includes more than 97 miles of interceptors and six lift stations currently in operation. The Todd Creek Lift Station was recently abandoned with the completion of the Todd Creek Interceptor, which conveys flows by gravity to the MWRD Northern Water Treatment Plant. Additionally, in 2020, Thornton will increase the operational capacity of the Big Dry Creek Lift Station and install the Big Dry Creek Forcemain and Interceptor to convey flows to the Todd Creek Interceptor. Figure 6 (included at the end of the Executive Summary) shows the existing wastewater collection system.

Collection System Analysis

The basis and approach for the wastewater collection system evaluation are described in **Chapter 6**. This chapter provides insight into the existing wastewater collection system's performance, deficiencies, and future infrastructure necessary to serve buildout.

The following subtasks were completed to evaluate the system:

- Existing System Review – Review of existing system infrastructure
- Future Infrastructure Plan – Review and identification of future backbone infrastructure needed to serve the planning area through buildout
- Flow Allocation – Spatial allocation of future growth wastewater flows
- System Evaluation – System evaluation identifying deficiencies based on the design criteria
- System Improvements – Necessary improvements to existing infrastructure and confirmation of future infrastructure based on the future infrastructure plan identifying buildout collection system needs

The wastewater collection system was evaluated based on the existing and future infrastructure extensions necessary to accommodate buildout flows. The existing hydraulic model was initially developed, calibrated, and validated by Thornton, and was used as the basis for development of the buildout hydraulic model. The hydraulic model was reviewed with Thornton and was revised to include anticipated infrastructure based on previously identified CIPs and current/future development projects consistent with the 2012 Comprehensive Plan working with the Thornton Planning Department.

Using the developed buildout model, the collection system performance at buildout was evaluated against the wastewater performance criteria presented in **Chapter 3**.

Capital Improvement Program

The developed CIP for the wastewater collection system was divided into three categories: 1) existing improvements necessary to meet the Tier 1 performance criteria; 2) proposed future infrastructure to accommodate new development; and 3) existing improvements necessary to meet the Tier 2 performance criteria. Improvement and future infrastructure areas were grouped into CIPs. Project cost was developed by applying unit costs accounting for material and installation for collection infrastructure, lift stations, and forcemains. The CIP cost and length required for buildout are summarized in Table 4. The proposed CIP is discussed in detail in **Chapter 6**.

Table 4. Wastewater Collection CIP Cost Summary

CIP Type	Length (ft)	Total Cost
Existing Tier 1 Improvement	20,030	$7,325,000
Future Infrastructure	29,783	$7,075,000
Existing Tier 2 Improvement	1,056	$357,000
TOTAL CIP Plan	**50,869**	**$14,757,000**

7. Rehabilitation and Replacement Program

Chapter 7 describes the risk-based planning and decision-making components used to complete an evaluation of the existing water distribution and wastewater collection system pipeline infrastructure following modern asset management practices. Infrastructure-related risk exposure is typically assessed based on the probability and consequence of asset failure and is used to drive the selection and prioritization of asset-related actions that are based on organizational risk tolerance thresholds and sustainable funding levels.

Utilizing a risk-based approach in this manner provides a clear direction for the overall rehabilitation and replacement process in terms of balancing priorities and assisting in ascertaining prudent level of investment for each specific asset. It also provides transparency to demonstrate that decisions are made in an impartial and consistent manner, without unreasonable bias, and in accordance with agreed upon policies and priorities.

Risk exposure was used to develop a prioritization model of Thornton’s water distribution and wastewater collection pipeline infrastructure. The prioritization model was developed as an ArcGIS tool for Thornton. This tool provides a way for Thornton to prioritize and program operation and maintenance (O&M) projects based on the risk-based approach.

A long-term funding plan was developed based on results from the risk model, current age of infrastructure, and pipeline unit costs.

After the potable water pipelines were prioritized and assigned a replacement year, cash flow was created by assuming $19 per inch-diameter per foot, which accounts for the average cost, assuming rehabilitation and replacement are equally utilized.

Using the prioritization model and the assumed installed unit pipe costs, the cash flow graph for the water system is shown below on Figure 2 and for the wastewater system on Figure 3.

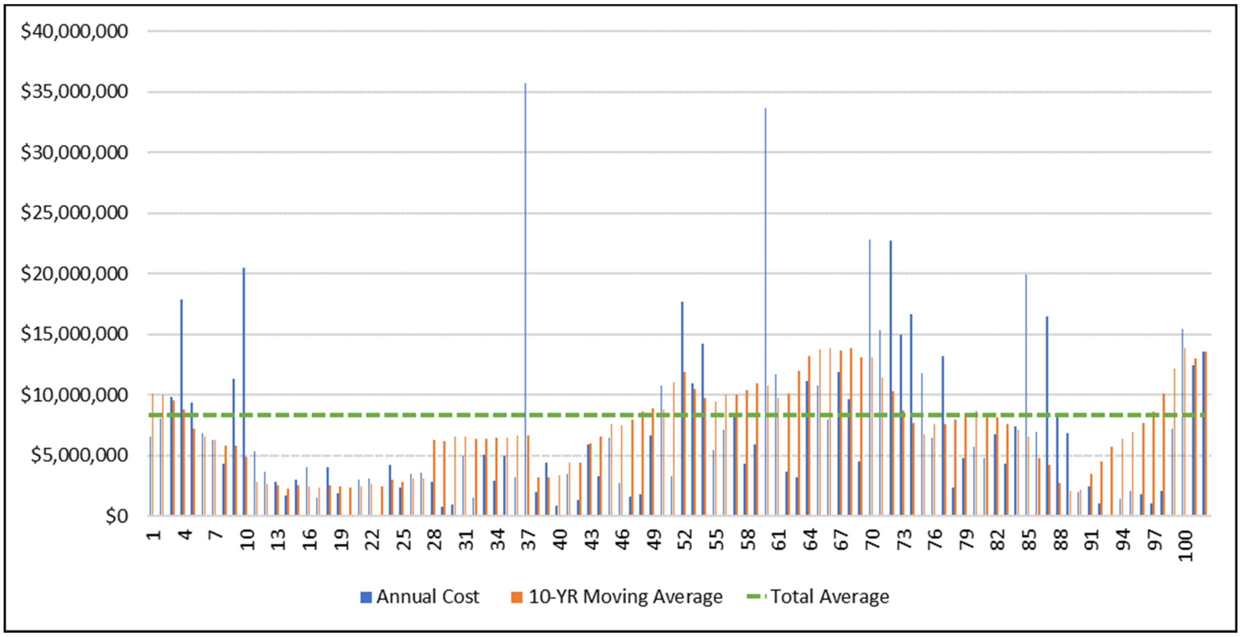


Figure 2. Projected Annual Potable Water Pipelines R&R Funding Level

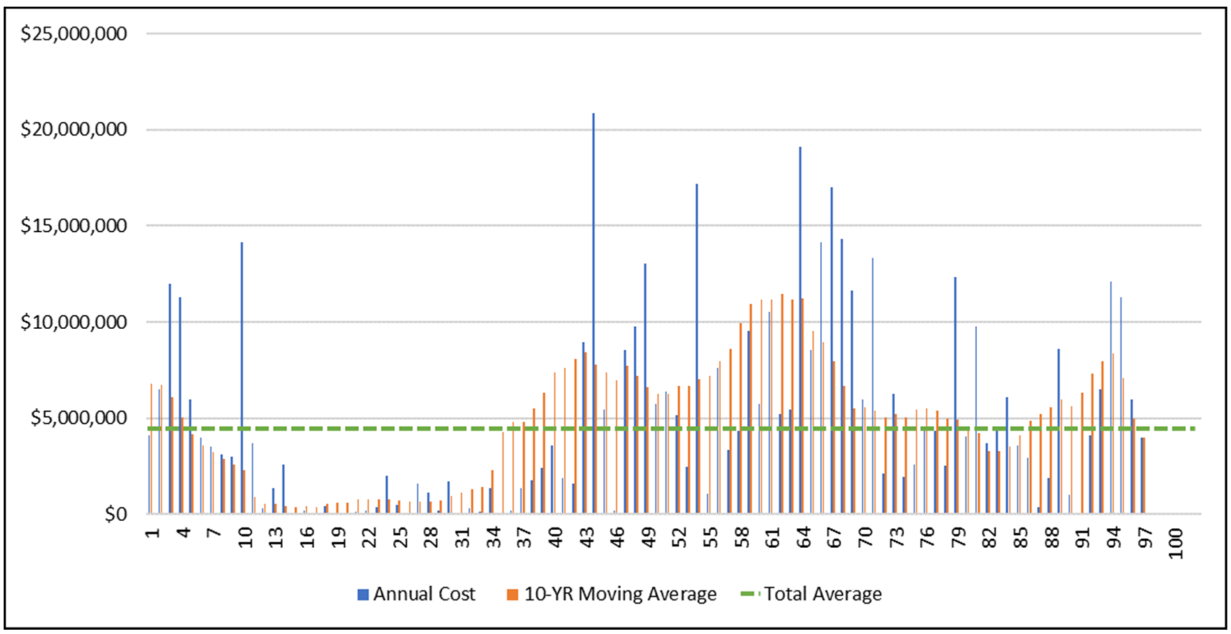
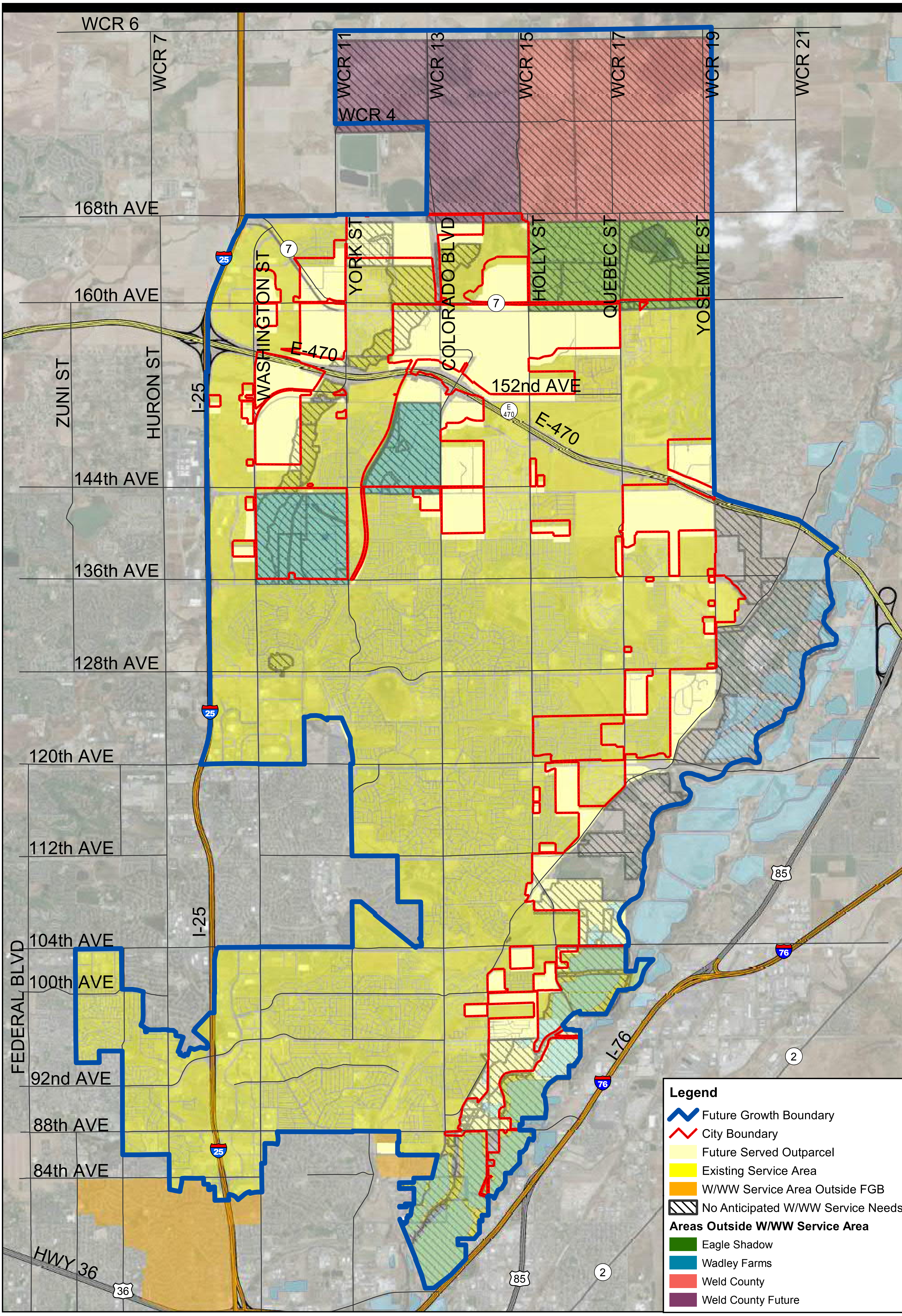


Figure 3. Projected Annual Potable Wastewater Pipelines R&R Funding Level



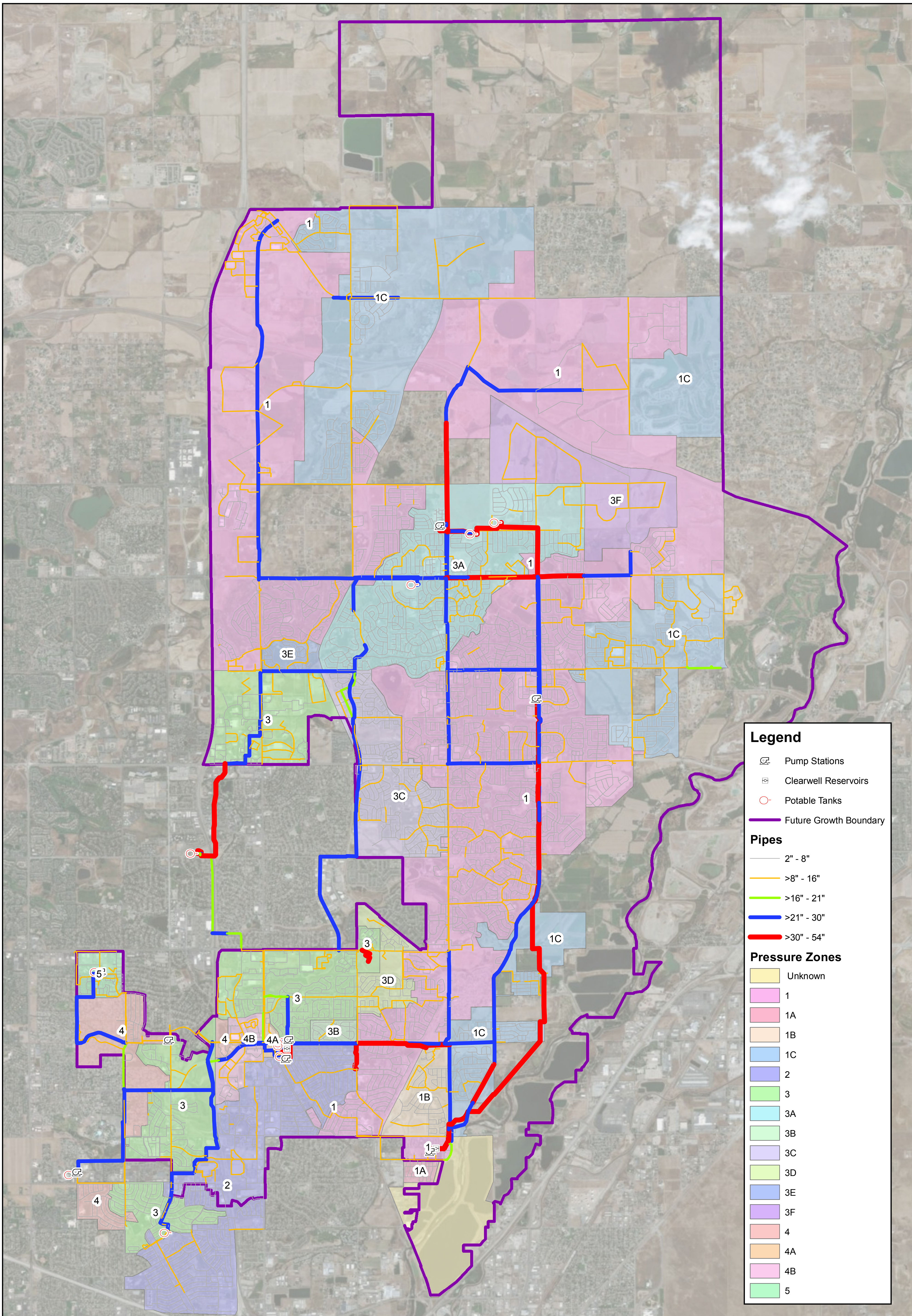
City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Figure 4
Service and Planning Areas

6/27/2018
1 inch = 5,000 feet

\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure 1 - City and Service Boundaries.mxd



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9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Figure 5

Water Distribution System Overview

2/2/2018
1 inch = 5,000 feet

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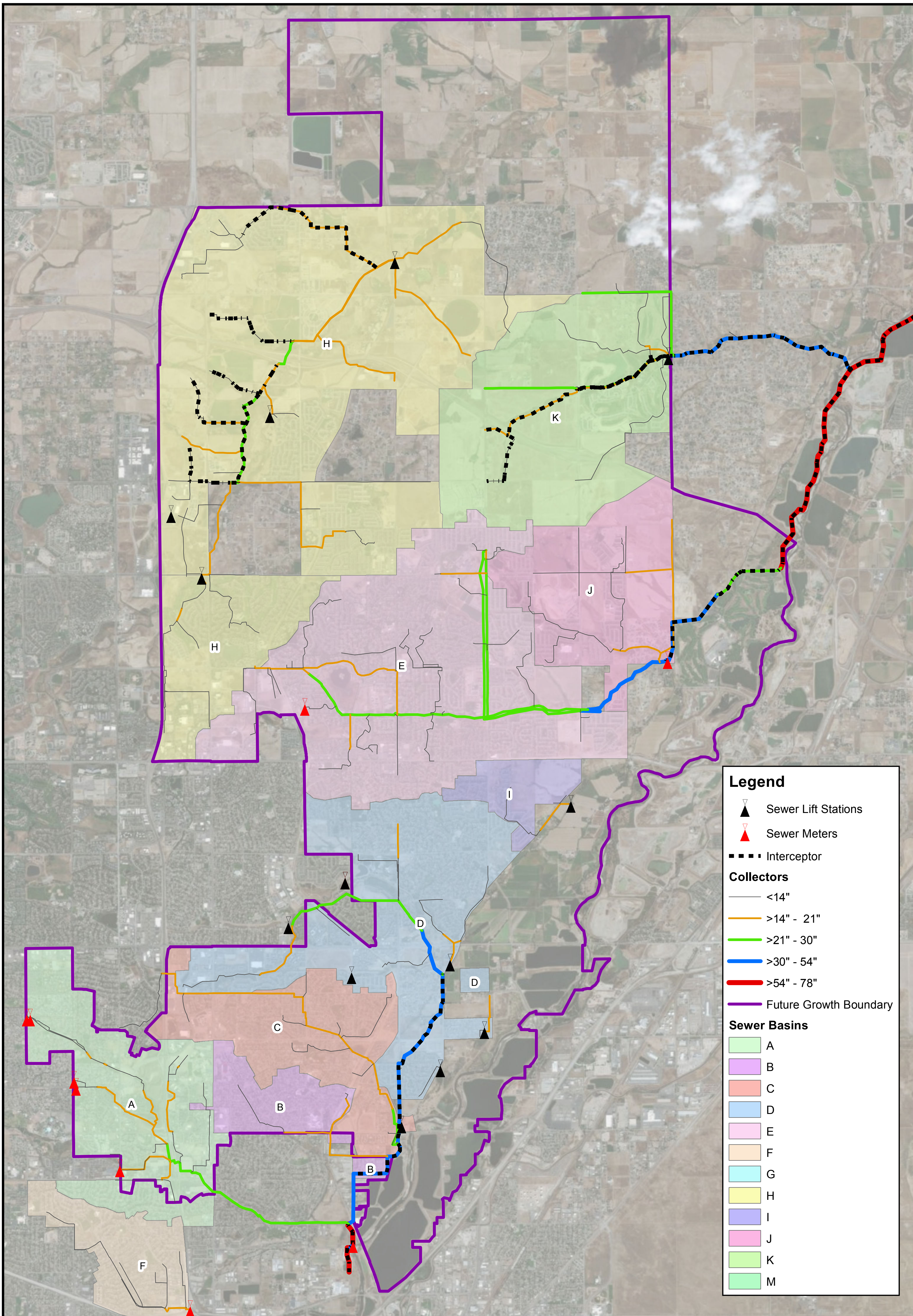

City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Figure 6
Wastewater Collection System Overview

2/2/2018
1 inch = 5,000 feet

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Initial Data and Hydraulic Model Review

Chapter 1

Utility Master Plan

Project No. 17-467

Water and Wastewater Infrastructure Master Plan

Initial Data and Hydraulic Model Review

The City of Thornton

Project number: 60560104

AECOM

March 7, 2018

Quality information

Prepared by	Checked by	Verified by	Approved by
Fletcher McKenzie Brock Hodgson	Nathan Walker	Tom Mueller	

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Distribution List

# Hard Copies	PDF Required	Association / Company Name

Prepared for:

The City of Thornton

Prepared by:

AECOM
6200 South Quebec Street
Greenwood Village, CO 80111

T: +1 (303) 694 2770
F: +1 (303) 694 3946
aecom.com

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Figures

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List of Acronyms

ADD – Average Day Demand
ADWQ – Average Dry Weather Flow
ARV – Air Release Valve
CIP – Cast Iron Pipe
DIP – Ductile Iron Pipe
EPS – Extended Period Simulation
FCV – Flow Control Valve
FT – Feet
GPCD – Gallons per Capita per Day
GPM – Gallons per Minute
IN - Inches
MDD – Peak Hour Demand
MGD – Million Gallons per Day
MWRD – Metro Wastewater Reclamation District
NTP – Northern Treatment Plant
PHD – Peak Hour Demand
PRV – Pressure Reducing Valve
PSV – Pressure Sustaining Valve
PVC – Polyvinyl Chloride
RCP – Reinforced Concrete Pipe
RDII – Rainfall Dependent Infiltration and Inflow
TM – Technical Memorandum
TWTP – Thornton Water Treatment Plant
VFD – Variable Frequency Drive
WBWTP – Wes Brown Water Treatment Plant

1. Introduction

This technical memorandum (TM) describes the initial data review and hydraulic model review for both the water distribution system and the wastewater collection system performed by AECOM for the Utility Master Plan project for the city of Thornton (Thornton). The data and models provided by Thornton on December 14, 2017 provide understanding of system records to date, and will serve as the basis for subsequent system analyses. The initial data reviewed included the 2009 Water and Wastewater Master Plan (2009 Plan) and relevant planning and development data, including pertinent GIS data; planning and development data; and historical raw water, water distribution, wastewater collection, and water treatment data. The model reviews provided understanding and confirmation of the existing InfoWater water distribution system model and InfoSewer wastewater collection model.

This TM is specific to Thornton's 2009 Plan. A data review specific to the Raw Water Supply Master Plan and Water Treatment Facilities Master Plan will be provided separately.

2. Planning Data Review

Planning data were primarily provided as a GIS geodatabase comprising of planning areas, current and future land uses, ward boundaries, hydrology data, pressure zones, sewer basins, and other data. A table of the reference files provided is included in Appendix A.

A table of population projections is provided in Table 1, and will serve as the initial basis for the planning area and future growth analysis task. These population projections were compared with Thornton's 2012 Comprehensive Plan and the population projections in the 2009 Plan. This population information will be reviewed further and confirmed with Thornton during the planning area development and future growth analysis task.

Table 1: Baseline Population Projections for Thornton Water and Wastewater Service Areas

Service Area	Population			
	2018	2025	2035	2065 (Buildout)
Within City Limits				
Total[1]	137,500	160,000	184,571	242,000
Ward 1	33,366			
Ward 2	34,496			
Ward 3	33,550			
Ward 4	36,031			
Outside City Limits				
Western Hills[2]	10,500	10,500	10,500	10,500
Welby[2]	1,152	1,152	1,152	1,152
Federal Heights (Wastewater Only) [2]	12,100	12,600	12,900	13,500
Unincorporated Adams County[2]	4,444	4,444	4,444	4,444
Total Water Service Area Customers	**153,596**	**176,096**	**200,667**	**258,096**
Total Wastewater Service Area Customers	**165,696**	**188,696**	**213,567**	**271,596**

[1]: From Initial Data Request provided by Thornton
[2]: From 2009 Plan

Additional information provided by Thornton included population and housing inventory summaries, and current and projected population data. The projected population data indicates an annual growth rate of approximately 1.9 percent until a population of 175,000 is reached, followed by a slower rate of 0.9 percent.

These combined data represent the existing and buildout population within the City of Thornton limits. AECOM understands that the current and buildout water and wastewater service areas include some areas outside the city limits including: unincorporated Adams County, Western Hills, Welby, and Federal Heights.

The database's land use information, along with the population data, will be used as the initial basis for identifying the spatial distribution of future water demands and wastewater sources. These population and land use distributions will be reviewed with Thornton during the planning area and future growth analysis task, and will serve as the basis for developing future system water needs.

Additionally, AECOM understands that Thornton has already identified certain areas of the system that will require review as part of these master plan efforts. These include:

- **124th Street RTD Station:** Anticipated concerns for proposed 12″ sanitary sewer parallel to Claude Court with concerns over planned capacity.
- **104th Street RTD Station:** Proposed infrastructure through the ACHA development based on mixed use development.
- **88th Street RTD Station:** Proposed infrastructure necessary to accommodate growth around this station based on planned development densities and current development projects.

For these specific areas, AECOM will work with Thornton during the planning area and future growth analysis task to align the subsequent planning and evaluation basis consistently with the other ongoing planning efforts.

3. InfoWater Model Review

Purpose

This section summarizes the review of the hydraulic water distribution model provided by Thornton as part of the initial data review. AECOM reviewed the provided model in InfoWater, version 12.4, Update #1; using ArcMap software version 10.5. Thornton indicated during the Water and Wastewater Master Plan Kickoff meeting that the InfoWater distribution system model has been internally calibrated to a satisfactory level and should therefore be assumed to be a validated hydraulic model. AECOM will further validate the water distribution model supply and demands in coordination with the raw water supply, water treatment production, and wastewater collection systems to check that there is agreement with respect to a system-wide water balance.

Background

The 2009 Plan developed a hydraulic model to evaluate demand scenarios at populations of 137,000; 172,000; and 242,000 (buildout). The distribution system was divided into five main pressure zones with 13 sub zones serving elevations between 5,040 and 5,550 feet. The growth projection was 2 percent per year until population 172,000, thereafter 1 percent per year until buildout of 242,000 (plus about 16,000 outside the city limits). Most of the growth was expected in the northern portion of the study area, in pressure zone 1. Ultimate requirements include 15 MG of additional storage capacity and a total average day demand (ADD) of 40 MGD at buildout.

Thornton provided AECOM with a water model information document that details the water model element control data, tank set points, pressure reducing valve (PRV) settings, and pump settings as well as data regarding how different zones are fed. A list of all of the initially provided documents is included in Appendix A.

Water Distribution Model Overview

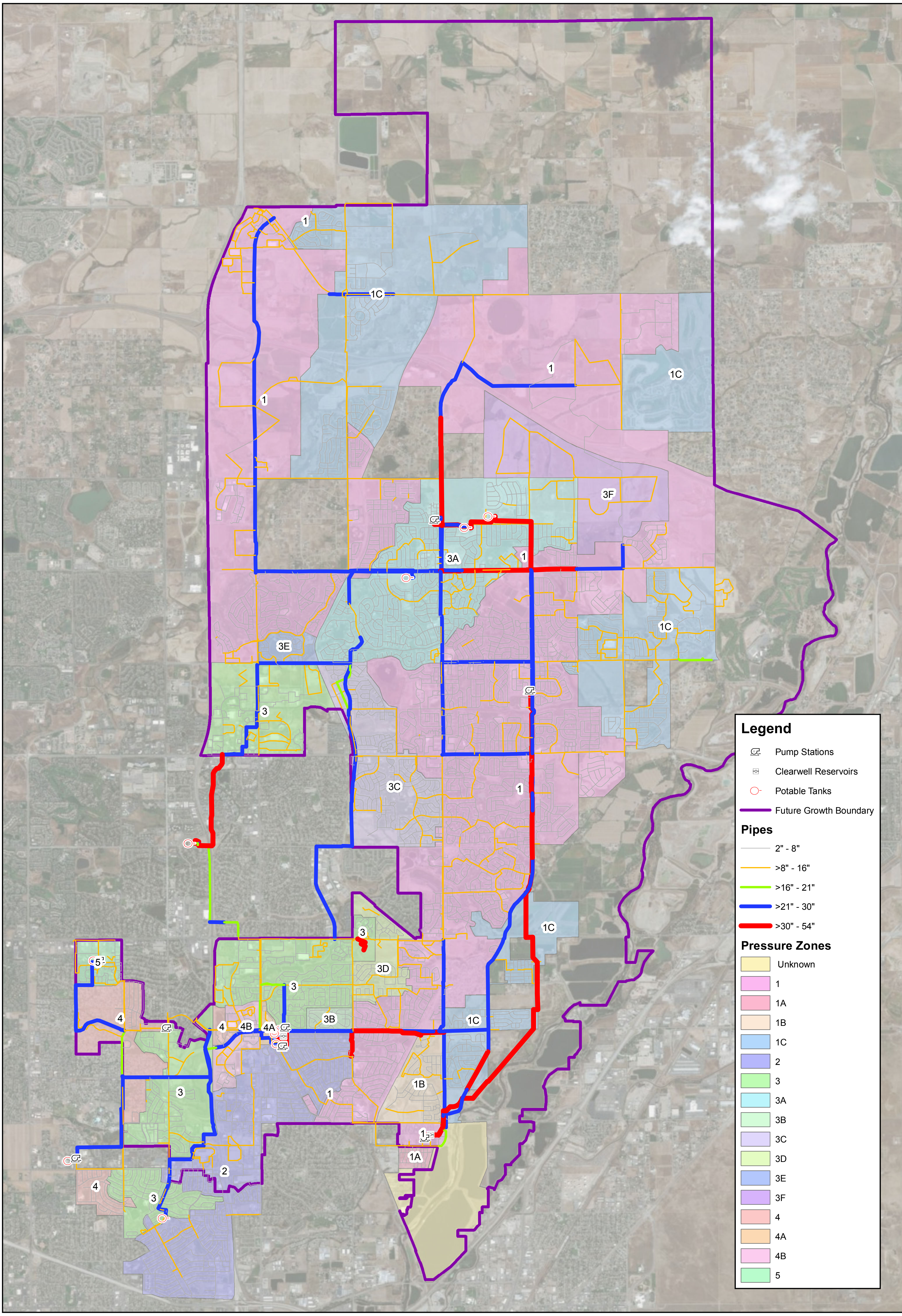
The water distribution model contains approximately 9,311 links and 7,366 nodes, representing approximately 585 miles of pipeline. A pressure zone map of the distribution system is shown on Figure 1. Water is delivered to the system via seven Thornton-owned and -operated pump stations. The pressure zones are controlled with approximately 65 pressure reducing valves. There are also ten storage tanks in the system for a total storage capacity of 29.75 million gallons.

System Piping

A summary of the existing InfoWater model system piping by material and diameter, as well as Hazen-Williams C factors, is presented below in Table 2. The modeled system totals approximately 585 miles of pipeline, geographically depicted below in Figure 1. However, the GIS shapefile of water mains included in the GIS data from Thornton has approximately 625 miles of pipe, a 6.4 percent increase in total length, after filtering out data that was not assigned a pressure service zone. This discrepancy will be discussed with Thornton to resolve this difference. Hazen Williams C factors vary from approximately 120 to130. The system is primarily composed of polyvinyl chloride (PVC), asbestos cement and ductile iron pipe. Diameters of the distribution system pipes are depicted on Figure 2, as well as listed in Table 2, indicating 8-inch diameter pipe is the most prevalent size in the system, with the largest distribution mains ranging from 24″ to 54″.

Table 2: Water Distribution System Piping Summary

Diameter (in)	Asbestos Cement Length (ft)	Cast Iron Length (ft)	Ductile Iron	PVC Length (ft)	Steel Length (ft)	Total Length (ft)
2			9			9
3	1,383		24			1,408
4	6,656		1,846	8,754		17,255
6	330,497	2,414	19,026	67,190		419,128
8	370,380	2,011	106,068	1,184,482		1,662,941
10	22,989		12,142	10,831		45,962
12	127,298		39,961	293,918		461,176
14	2,304					2,304
16	35,759		53,247	73,518		162,525
18			1,851	2,079		3,931
20	1,011		7,689		6,955	15,655
24	13,992		134,377	9,953	2,494	160,815
30	499		60,364		4,257	65,119
36			26,972		8,213	35,185
42			18		31,652	31,670
48			1,000			1,000
54			78			78
Grand Total	912,768	4,425	464,673	1,650,724	53,571	3,086,161
Hazen-Williams C Factor	**130**	**128**	**130**	**130**	**130**	**NA**



City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Water Distribution System Pressure Service Map

2/2/2018

1 inch = 5,000 feet

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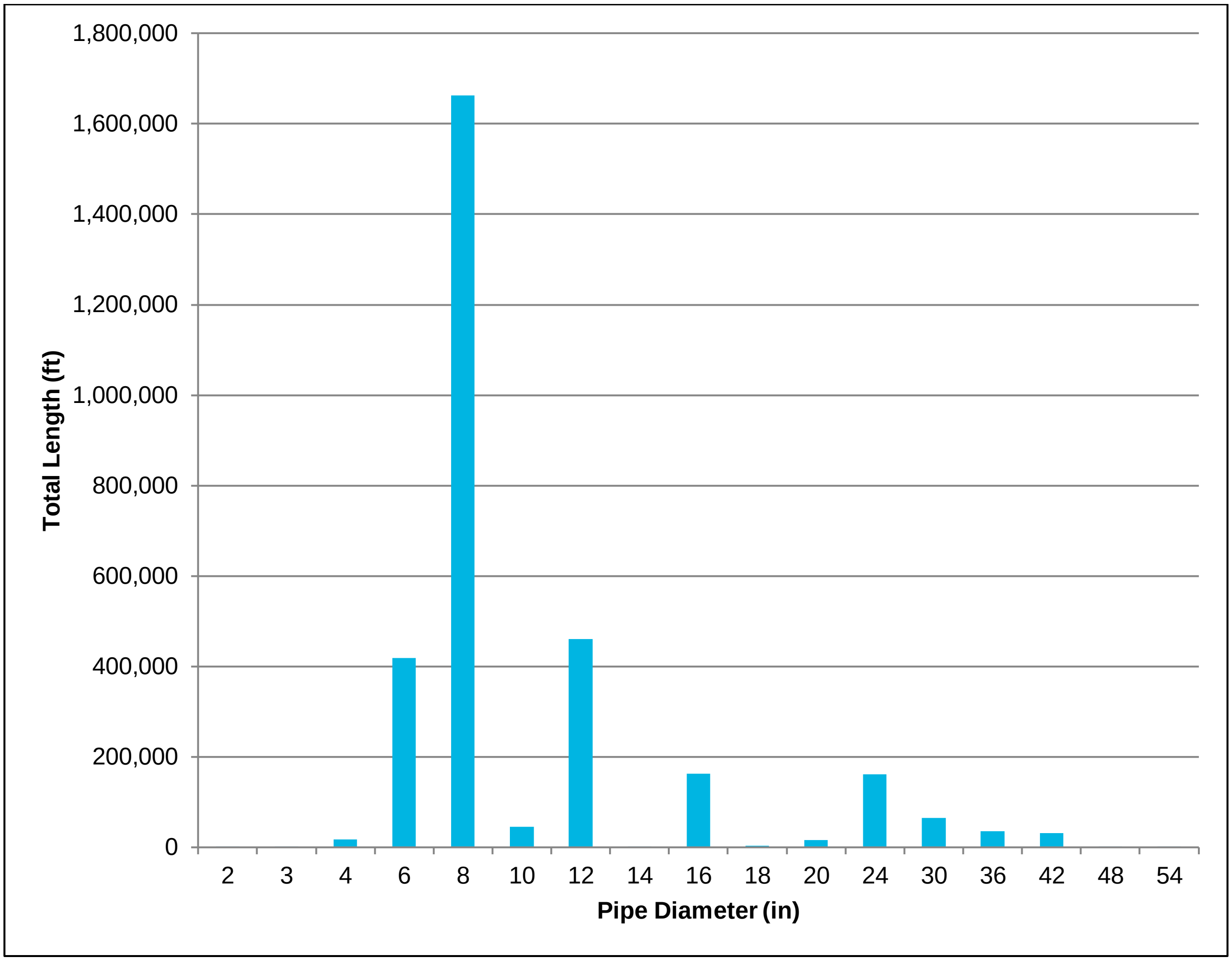


Figure 2: Pipe Diameter Summary

The modeled pipe performance was reviewed and some instances of very high headloss were noted; for example pipes 9905 and 9903 have pressure drops of 24 psi and 16.5 psi over a length of less than 10 feet, respectively. This was discussed with Thornton and the pressure drops were deemed appropriate as these pipes have a velocity above 10 feet per second and generally have a large quantity of minor losses over a relatively short length.

System Nodes

The system nodes were generally reviewed for the model inputs and outputs, primarily the input elevations and output system pressures. Pressures during the existing maximum day demand (MDD) analysis range from -10 psig to 140 psig. Some nodes with missing elevation data (J58, J66, J62, J64 and J60) were identified, and Thornton was notified and subsequently provided AECOM with these elevation values, which were added to the model. The instances of negative pressure will be further reviewed during the water distribution and wastewater collection system design criteria task.

Pump Stations

The pump stations included in the model were reviewed to identify average and maximum output flow and head. A summary of the pump hydraulic model output for the existing distribution system with MDD is shown in Table 3. Due to the controls of these pumps, the maximum and average flow were reported because the pumps are either not on during the entire simulation or are set on variable frequency drive (VFD) control. Some pumps never turn on during this simulation, but were reported here for informational purposes, only.

Table 3: Water Distribution System Pump Summary

ID	Number of Operational Pumps	Max. Flow per Pump (gpm)	Average Flow per Pump (gpm)	Max. Total Dynamic Head (ft)	Average Total Dynamic Head (ft)
BRIGHTON		1,250	1,250	75.6	75.6
HOLLYPS_1		7,405	1,822	44.2	10.5
HOLLYPS_2		7,407	1,823	44.1	10.5
HOLLYPS_3		0	0	0.0	0.0
HOLLYPS_4		0	0	0.0	0.0
PMP-3-1		0	0	0.0	0.0
PMP-3-2		3,374	3,199	214.7	203.4
PMP-3-3		2,830	2,606	195.4	185.4
PMP-4-1		0	0	0.0	0.0
PMP-4-2		3,176	2,609	364.2	296.6
PMP-4-3		0	0	0.0	0.0
WBWTP_HSPS		25,106	19,798	268.8	268.8
Z2_1		7,041	1,304	107.9	22.7
Z3A_BPS		6,136	3,848	118.1	112.2
Z3_4_EM		0	0	0.0	0.0
Z3_BPS		2,386	1,474	169.4	146.5
Z5_P-1		0	0	0.0	0.0
Z5_P-2		449	296	50.6	46.5
Z5_P-3		0	0	0.0	0.0

Storage Tanks

The modeled storage tank operations were reviewed based on the existing scenarios included in the model. A summary of the storage tank flows and water levels for the existing MDD scenario can be found below in Table 4.

Table 4: Water Distribution System Storage Tank Summary

ID	Max. Inflow (gpm)	Max. Outflow (gpm)	Max. Level (%)	Min. Level (%)	Average Level (%)
T_102NDAVE	503	1,188	86	66	76
T_136THAVE	3,197	4,150	89	58	75
T_CHEROKEE	1,354	3,018	77	63	71
T_CW1	9,304	13,705	59	0	23
T_HILLTOP	3,279	4,695	84	46	64
T_WHILLS	411	207	83	82	82
T_Z1CW2	13,957	10,479	68	0	38
T_Z2N	2,154	916	81	58	70
T_Z2S	4,002	2,523	86	56	70
T_ZUNI	742	2,273	91	74	82

Tank graphs showing percent full during the MDD with an extended period simulation (EPS) of 48 hours are shown below on Figure 3. This tank graph conveys that the tanks are on average above half full during the simulation.

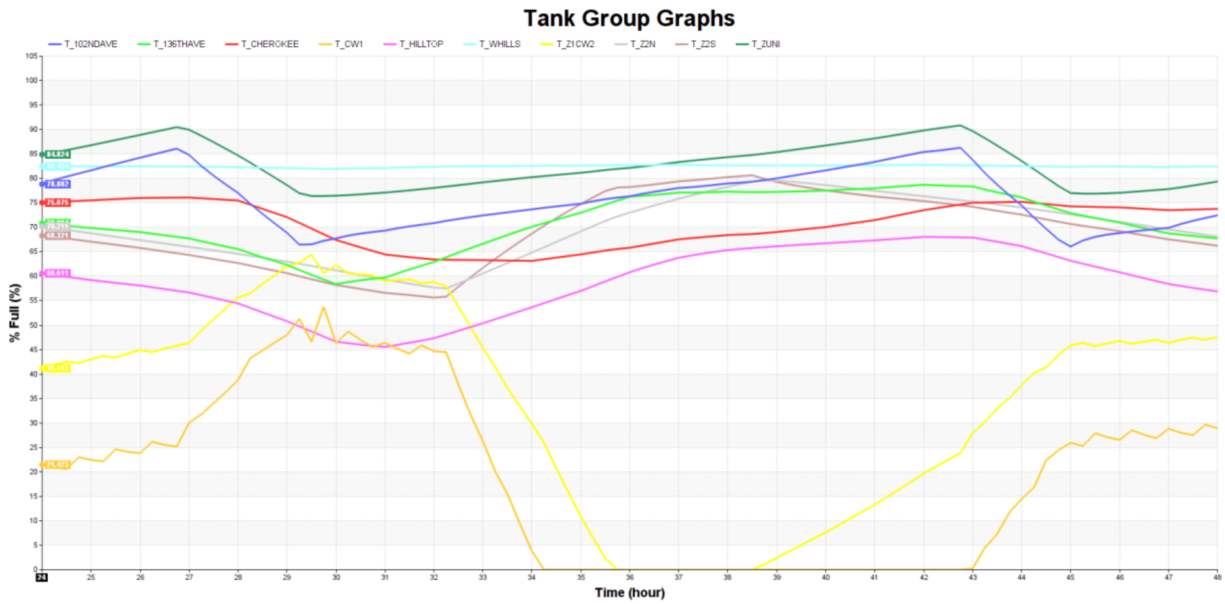


Figure 3: Tank Level Graphs for Existing Maximum Day Demand Scenario from 24 to 48 Hours

System Valves

The PRV operations were generally reviewed to understand the pressure zone operations and identify any potential concerns based on current model configuration. A summary of the PRV and flow control valve (FCV) modeled parameters for the existing water distribution system under MDD is provided in Table 5. This table only includes valves that have a maximum modeled headloss greater than 1 foot, and have a difference between maximum and minimum velocity, which indicates they are not just wide open valves, but rather are modulating to induce a headloss based on the service conditions.

Table 5: Water Distribution System Modulating Valve Summary (PRVs, FCVs, and Throttling Valves)

ID	Max. Velocity (ft/s)	Min. Velocity (ft/s)	Max. Headloss (ft)	Min. Headloss (ft)
19925	0.90	0.31	31	4
19930	0.89	0.29	31	3
PRV-1	1.00	0.23	133	130
PRV-12	3.38	1.28	51	51
PRV-15	0.72	0.16	109	108
PRV-16	4.13	1.86	65	42
PRV-22	6.47	0.00	130	0
PRV-22_LF	18.26	17.12	129	114
PRV-23	4.47	1.77	87	78
PRV-24	4.90	2.47	59	50
PRV-29	1.09	0.55	49	37
PRV-31	2.01	0.67	75	72
PRV-32	2.91	1.05	49	37
PRV-34	1.99	0.74	2	0
PRV-36	0.84	0.27	72	66
PRV-4	1.27	0.39	83	70
PRV-41	0.90	0.00	32	0
PRV-42	2.13	1.20	32	19

ID	Max. Velocity (ft/s)	Min. Velocity (ft/s)	Max. Headloss (ft)	Min. Headloss (ft)
PRV-43	0.80	0.00	32	0
PRV-45	2.70	1.21	32	18
PRV-46	5.10	2.40	4	1
PRV-49	2.84	0.93	55	53
PRV-50	0.50	0.24	72	69
PRV-52	0.80	0.11	58	42
PRV-54	1.94	0.40	49	36
PRV-55	4.36	0.00	62	0
PRV-56	2.81	2.45	74	59
PRV-57	1.53	0.00	74	0
PRV-58	1.66	0.53	74	60
PRV-59	2.93	1.25	1	0
PRV-6	0.60	0.00	42	0
PRV-60	1.99	0.63	63	49
PRV-62	0.72	0.40	75	63
PRV-7	2.71	1.26	44	29
PRV-8	0.91	0.28	75	74
PRV-PARK_N_2	3.15	0.98	4	0

Operational Controls

The operational controls for Thornton water distribution model involve several pumps on VFDs with set points to control downstream pressures. Other pumps are set up with tank level controls to turn on and off based on tank levels. Finally, there are some pumps and PRVs set up based on clock time controls. Most of the PRVs are set up to maintain downstream pressures, while FCVs are set to control flow rates out of either pump stations or tanks. Table 6 summarizes the node control for the pumps and PRVs, and the VFD controls are summarized in Table 7. In addition to the node controls, there are initial node settings for three of the pumps in the distribution system. The pump IDs are Brighton (setting of 0.90), PMP-3-2 (setting of 0.95) and PMP-3-3 (setting of 0.92). These controls are assumed to be part of the internal model calibration done by Thornton, which will be further investigated as part of the water distribution evaluation task.

Table 6: Water Distribution System Node Control Summary (Pumps and PRVs)

ID (Char)	Status (Int)	Setting (Double)	Control Method (Int)	Control ID (Char)	Control Context (Int)	Control Value (Double)	Clock Style (Int)	Clock Time (Char)
HOLLYPS_1	2: Setting	0.95	4: By Clock Time		0: Above	0	1: AM	6
HOLLYPS_1	0: Closed	0	4: By Clock Time		0: Above	0	2: PM	12
HOLLYPS_2	2: Setting	0.95	4: By Clock Time		0: Above	0	1: AM	6
HOLLYPS_2	0: Closed	0	4: By Clock Time		0: Above	0	2: PM	12
PMP-3-3	2: Setting	0.92	1: By Node Level	T_CHEROKEE	0: Above	20	0: 24hr	
PMP-3-3	0: Closed	0	1: By Node Level	T_CHEROKEE	0: Above	32	0: 24hr	
PMP-4-2	1: Open	0	1: By Node Level	T_102NDAVE	1: Below	25	0: 24hr	
PMP-4-2	0: Closed	0	1: By Node Level	T_102NDAVE	0: Above	32.5	0: 24hr	
PRV-22	1: Open	0	4: By Clock Time		0: Above	0	1: AM	4
PRV-22	0: Closed	0	4: By Clock Time		0: Above	0	1: AM	10
Z2_1	1: Open	0	1: By Node Level	T_Z2N	1: Below	20.5	0: 24hr	
Z2_1	0: Closed	0	1: By Node Level	T_Z2N	0: Above	28	0: 24hr	

Table 7: Water Distribution System Pump VFD Control Summary

ID (Char)	Control Type (Int)	Control Setting (Double)	Maximum Speed (Double)	Parallel Pumps (Long)	Minimum Speed (Double)
WBWTP_HSPS	1: Discharge Pressure	113	1	4	0.6
Z3A_BPS	1: Discharge Pressure	82	1	3	0.5
Z3_BPS	1: Discharge Pressure	69	1	1	0.6
Z5_P-2	1: Discharge Pressure	62	1	1	0.4

Model Scenarios

The hydraulic model is set up to model a total of five scenarios. There are three scenarios of the existing system and two scenarios of future systems incorporating growth within the service area. The scenarios are listed below:

Existing System Scenarios:

1. Steady state
2. Minimum day demand with a 48-hour simulation time
3. Maximum day demand with a 48-hour simulation time

Future System Scenarios:

4. Year 2025 system with MDD and a 48-hour simulation time
5. Year 2065 (buildout) system with MDD and a 48-hour simulation time

The existing steady state scenario runs with no errors or warnings.

The minimum day demand with an extended period simulation of 48-hours runs with a yellow light warning, indicating that the hydraulic run failed at 4:45 hours into the 48-hour simulation. Warnings encountered during the run indicate that the Wes Brown Water Treatment Plant (WBWTP) pump and the PMP-4-2 are open but exceed maximum flow; Pump PMP-3-3 is closed due to inability to deliver head; as well as some PRV control warnings, and finally the run ends due to a system unbalance. AECOM noticed that there was no control set up for the WBWTP high side pump. This control was re-established to maintain a downstream pressure based on VFD operation of these pumps, and this change allowed the minimum day demand scenario to run for the total duration of 48-hours.

The MDD with an EPS of 48 hours runs to completion but with a yellow warning light, indicating the Holly pump station exceeds maximum flow, as well as reporting various nodes that have negative pressures during the simulation.

The future year 2025 MDD with an EPS of 48 hours runs with a yellow warning light. The report indicates that the hydraulic run failed at 12:15:10 hours into the 48-hour simulation. Warnings reported are that the Holly Pump Station exceeds maximum capacity, and the system is unbalanced. After discussion with Thornton, it was determined that this scenario is for looking at near-term growth, but isn't a finalized scenario. AECOM will further develop this scenario during upcoming tasks.

The future year 2065 MDD with an EPS of 48 hours runs with a yellow warning light. The report indicates that the hydraulic run failed due to disconnection error. After discussions with Thornton, it was determined that this scenario is more of a place holder for future scenarios, and therefore shouldn't be expected to run without errors. This scenario will be developed further during upcoming tasks.

System Demand

The MDD utilized in the distribution system model for the existing scenario is 44 MGD (30,556 gpm). This demand is broken down as follows:

- 30.7 MGD (21,308 gpm) Residential
- 4.1 MGD (2,881 gpm) Commercial
- 7.4 MGD (5,117 gpm) Irrigator
- 1.8 MGD (1,250 gpm) Brighton

The total treated water supplied for the existing MDD is 43.5 MGD (30,198 gpm); with 14 MGD (9,722 gpm) supplied from Thornton Water Treatment Plant (TWTP) and an average of 29.5 MGD (20,475 gpm) from WBWTP. This difference between supplied flow and demanded flow is accounted for by the tanks in the system. If the model run time is extended, it shows more flow being supplied from WBWTP, which is set up on a VFD to control the downstream pressure. Eventually, with a long enough simulation time, this supplied flow will balance out the demand by supplying more flow from WBWTP.

This results in a residential unit rate of approximately 200 gallons per capita per day (gpcd) for MDD. By contrast, the existing minimum day demand results in a unit rate usage of 60 gpcd. AECOM understands that these demands include an 8 percent leakage factor on top of the base demands. In comparison with Thornton standards, the specified per capita use is 150 gpcd for ADD; however, Thornton indicated for the current land use mix, the actual ADD is approximately 135 gpcd. Treatment plant records (TWTP and WBWTP) generally indicate MDD is a factor of 1.2 to 1.7 times ADD, and therefore the modeled MDD is in line with these factors.

The minimum day demand scenario utilized in the model for the existing system has a total demand of 12.15 MGD (8,434 gpm), which represents winter day demands and is broken down as follows:

- 9.21 MGD (6,399 gpm) Residential
- 1.13 MGD (786 gpm) Commercial
- 0 MGD Irrigator
- 1.8 MGD (1,250 gpm) Brighton

The total water supplied for the existing minimum day demand is 12.15 MGD (8,434 gpm) from TWTP. Due to no controls at the WBWTP pumps, they are initially on at full speed with an average flow of 11.24 MGD (7,804 gpm). This scenario doesn't run to completion of 48 hours, but it is understood that this scenario is not pertinent to the scope of working moving forward and will therefore this is considered a moot point.

The demand is broken down into five diurnal demand patterns for the MDD scenario; three residential, one irrigation, and one commercial. The general population residential summer demand pattern is called "RES_SUMMER", with specific areas having distinct patterns (Redwood Summer, and Pine Lakes Summer), as seen on Figure 4. The City of Thornton irrigation and commercial summer demand patterns are "COT_SUMMER" and "COM," respectively, also shown on Figure 4. The minimum day demand represents winter conditions and also utilizes three residential demand patterns, "RES_WINTER" for general population and REDWOOD SUMMER and PINE LAKES SUMMER for those specific areas. The winter commercial demand pattern is the same as the summer commercial demand pattern, "COM." The only irrigator for the winter demands is Brighton, which is just a constant flow of 1,250 gpm year-round.

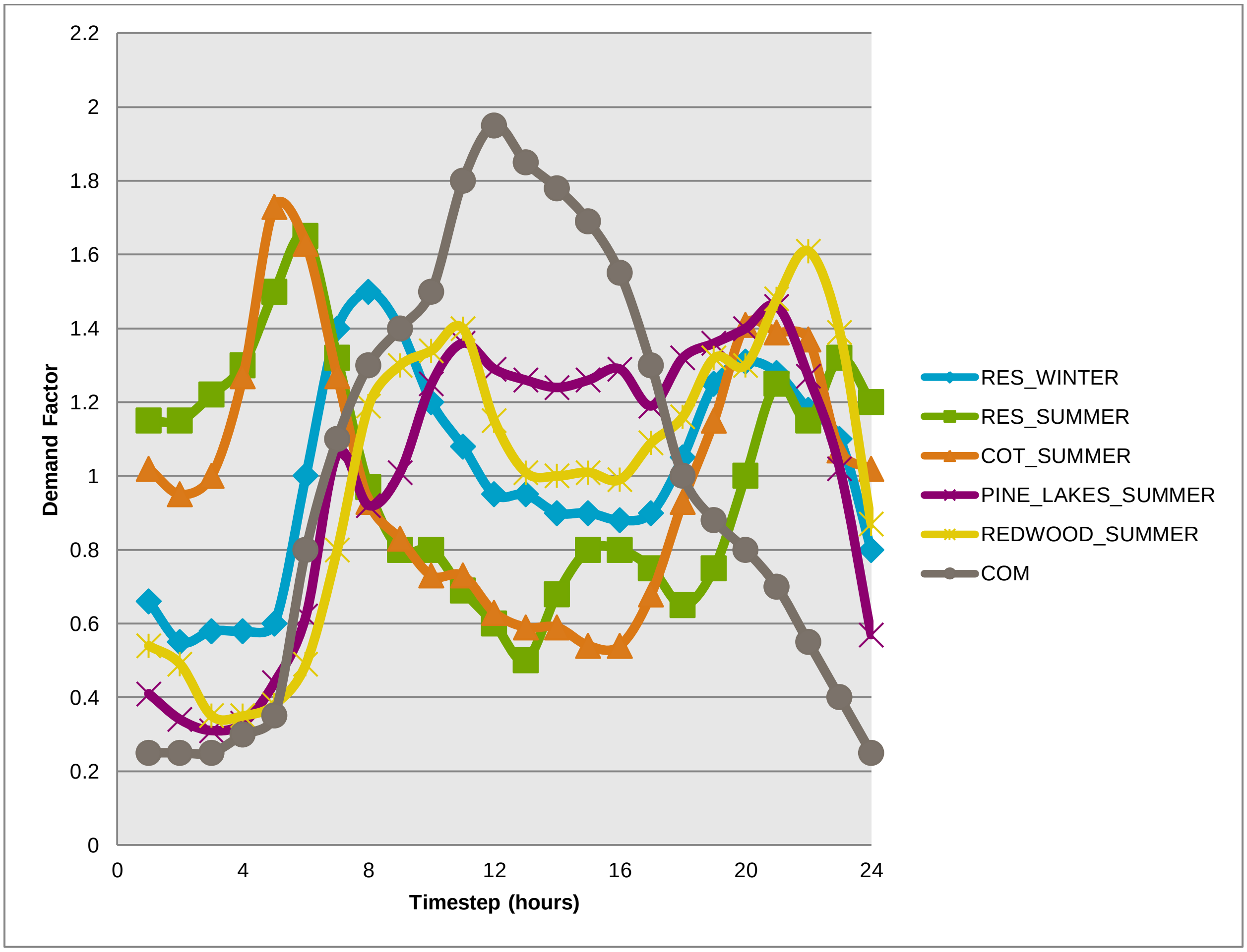


Figure 4: City of Thornton Diurnal Demand Patterns

4. InfoSewer Model Review

Purpose

As part of the data review, Thornton provided the current InfoSewer model that will serve as the basis for evaluation of the existing and future wastewater collection system needs. This section summarizes the review of the wastewater collection model provided by Thornton, which was reviewed using InfoSewer model, version 12.3, Update #7; using ArcMap software version 10.5.1. As previously mentioned in Section 3, AECOM will further validate the wastewater distribution model loads and flows in coordination with the raw water supply, water treatment production, and water distribution systems to facilitate agreement with respect to a system-wide water balance.

Background

Based on the 2009 Plan, the historical average dry weather flow (ADWQ) through the collection system ranged from 8.9 to 9.5 MGD (65 to 84 gpcd). The 2009 Plan developed a hydraulic model to evaluate demand scenarios at populations of 137,000, 172,000, and 242,000 (buildout) assuming a per capita unit flow rate of 72 gpcd for future population contributions. The collection system includes 14 major basins. At buildout the ADWQ for the system was estimated to be 19.4 MGD. A list of all of the initially provided documents is presented in Appendix A.

Wastewater Collection Model Overview

The existing wastewater collection system is divided into 11 basins, with a total of approximately 515,074 feet of existing pipe. The model identifies some pipes as PVC, concrete, and reinforced concrete pipe (RCP), but in general most of the pipe material type is not identified. Pipe material information may be available from the proved ArcGIS geodatabase, if necessary, for the pipe materials that are unknown. Additionally, it is important to note that AECOM understands that the collection hydraulic model is a skeletonized model and does not include all infrastructure, and generally does not include collector lines less than 12" in diameter. The hydraulic performance of infrastructure not included in the model will not be documented as part of this master plan development. The numbers as presented in this section are consistent with the hydraulic model. Tasks that require considerations outside of the hydraulic model will utilize the provide ArcGIS geodatabase as the basis for additional infrastructure.

The wastewater collection system currently collects and conveys wastewater flows to the Metro Wastewater Reclamation District South Platte interceptor and flows are ultimately conveyed to the Metro Wastewater Reclamation District (MWRD) Central Treatment Plant. In the future, flows will also be conveyed to MWRD Northern Treatment Plant (NTP) Currently, Thornton manages six lift stations to convey flows where gravity flow is not possible. In addition to these lift stations; AECOM understands that there are various other private lift stations that also convey flows to the wastewater collection system.

System Piping

The collection system piping was reviewed based on basin and pipe diameter. A summary of the existing system piping based on major stormwater basins is included in Table 8, and Figure 5 shows a breakdown of the pipe lengths based on pipe diameter. The collection system includes interceptors generally ranging from 24″ to 60″.

Table 8: Pipe Length by Basin

Basin	Pipe Length (feet)
Basin A	273
	40,815
	82,856
Basin B	157,387
Basin C	1,717
Basin D	1,208
Basin E	62,009
Basin F	780
Basin G	54,799
Basin H	1,001
	24,324
	230
Basin J	23,824
Basin K	16,577
Not Identified	17,800
	10,357
	4,921

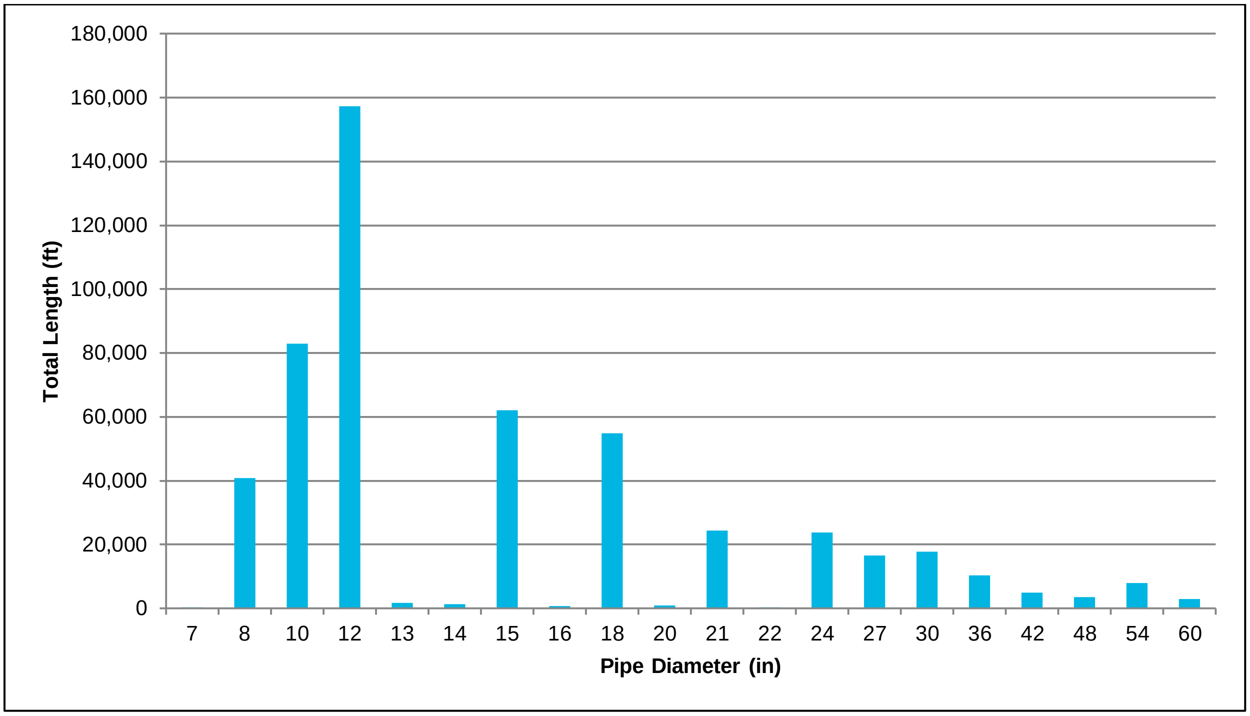


Figure 5: Pipe Diameter Summary

System Loads

The model includes 2,062 manholes with an average dry weather loading of approximately 10.4 MGD. Based on discussions with Thornton, AECOM's understanding of what each load represents is outlined in the load classification column.

- 7.87 MGD (5,465 gpm) Residential [Load 1]
- 1.1 MGD (786 gpm) Commercial [Load 2]
- 1.4 MGD (5,117 gpm) Federal Heights [Load 6]
- 0 MGD Base Infiltration (accounted for as part of user flows)

It's important to note that the Thornton InfoSewer model currently includes contributions from base infiltration or rain dependent inflow and infiltration into the customer loads. Therefore, the existing model provides an estimate of system ADWQ and peak dry weather flow (PDWQ) for evaluating the system performance. The difference between the distribution system minimum day demand (12.2 MGD) and the collection system ADWQ (10.4 MGD) is approximately 1.8 MGD. AECOM understands that this difference is due to treated water supplied to Brighton. It is worth noting that the wastewater service area does have a slightly larger service area population, but the model does not appear to account for a reduction in potable water use based on return flows.

The input loads are allocated based on average dry weather flow and then are peaked in EPS simulation using selected diurnal curves. The diurnal curves were developed by Thornton based on different basin or development areas.

Lift Stations

The existing lift station operations were reviewed based on model flow and system controls. The model operation of these lift stations will impact the system performance evaluation; therefore, it is important to review and document the lift station configurations in the model. A summary of the six active lift stations and two abandoned lift stations is provided in Table 9. These lift stations include approximately 50,861 feet of force mains that connect the lift stations to the gravity collectors or interceptors. The existing firm and permitted capacity will be reviewed during the system performance evaluation.

Table 9: Existing Lift Station Summary

Lift Station	Existing Model Flow (gpm)	Control	Pump Descriptions
Todd Creek	Abandoned	By Level	TC-1: Operational TC-2: Standby
Big Dry Creek	1478.5	By Inflow	BCD-1: Operational
Sky Lake Ranch	309.82	By Level	SKYLAKE1: Operational SKYLAKE2: Standby SKYLAKE3: Standby
Riverdale	321.7	By Level	Riverdale 1: Operational Riverdale 2: Standby
Remington	33.5	By Inflow	REM_3: Operational
Thornton Crossing	289.6	By Level	Pump-Thornton Crossing: Operational
Haven	Abandoned	By Inflow	Haven 1: Operational Haven 2: Standby
Grange Hall Creek	1,419.9	By Level	GHC_1: Operational GHC_2: Standby GHC_3: Standby

Model Scenarios

The existing wastewater collection system was reviewed based off of the “Existing_EPS” model scenario.

The model simulation is set up with standard general parameters and includes modeling of flow attenuation using dynamic wave flow routing. The steady state scenery is set up to simulate ADWQ and does not estimate peak flow. The EPS simulation is set up to run for a duration of 48 hours and peaks the ADWQ based on the diurnal patterns and lift station operations to evaluate the PDWQ in the system. As previously indicated, there is no base infiltration or rainflow dependent inflow and infiltration (RDII) that is currently included in the model; therefore, there is no ability to evaluate the system based on wet weather performance. There are some future scenarios built into the model (2025 and 2065), but AECOM understands that these model scenarios will need revisions to future loads and future infrastructure consistent with the current planning data prior to analysis.

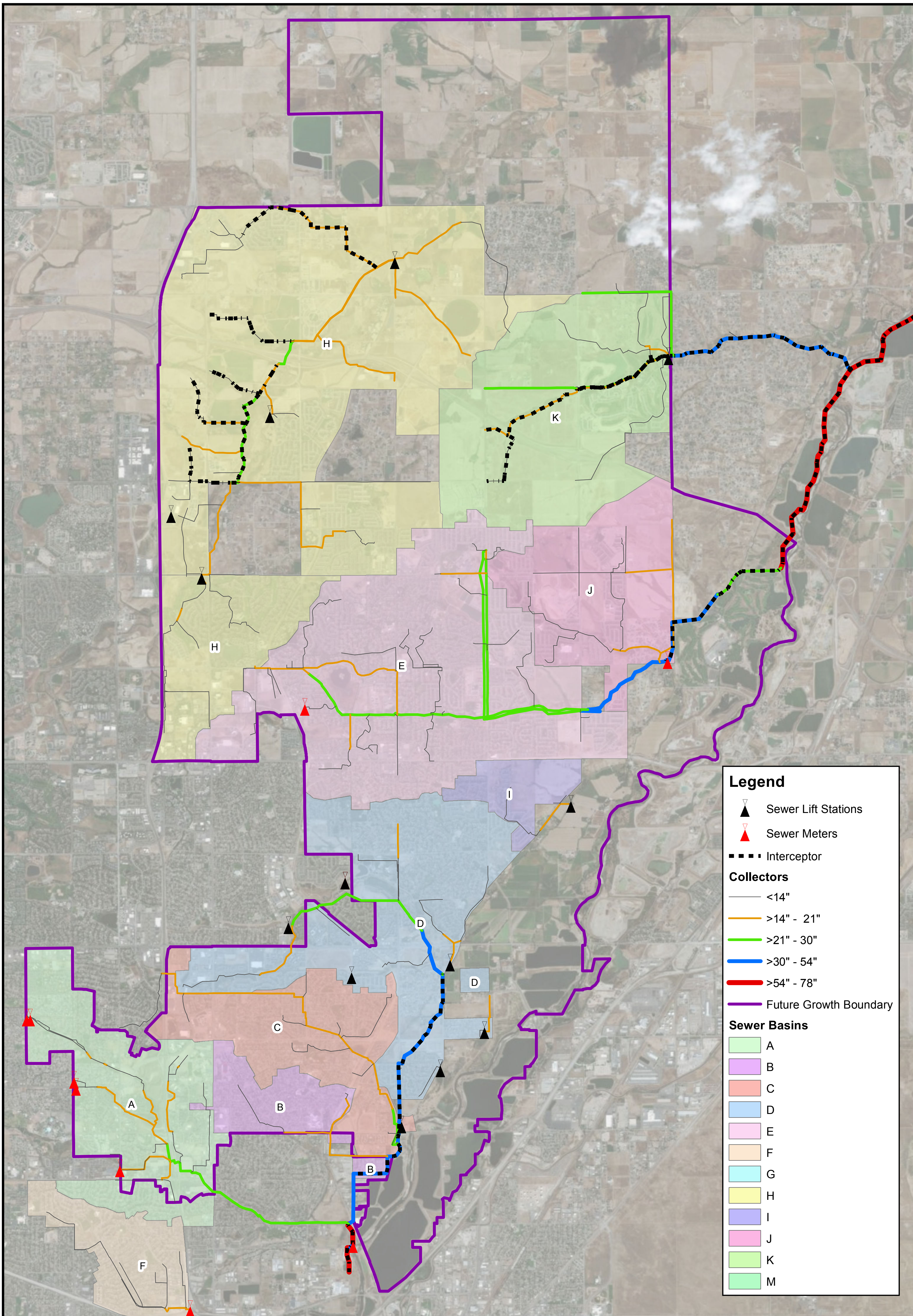
Figure 6 indicates the general arrangement of the Thornton collection system with key interceptors identified that represent the existing higher capacity collection segments.

Metro Wastewater Reclamation District Connections

The collected wastewater is conveyed to three existing MWRD metered connections. Thornton indicated that recently an additional meter was installed along the Todd Creek interceptor to convey flows to MWRD’s NTP. This infrastructure is not currently in the model but will be added as part of the future system model development. The future infrastructure will also include completion of the Big Dry Creek interceptor, which may impact the existing meter outlets. Table 10 identifies the current average and peak flow at the metered outlets.

Table 10: Model Estimated Dry Weather Flow

Outlets	ADWQ (MGD)	PDWQ (MGD)
MH-SPI Outlet to NTP	4.3	6.6
Steele Outlet to CTP	5.4	7.4
Barr Outlet to CTP	0.7	1.1
Todd Creek Interceptor Outlet to NTP	Online 2018	Online 2018
TOTAL	10.4	15.1



City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Wastewater Collection Infrastructure Map

2/2/2018

1 inch = 5,000 feet

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5. Summary

AECOM has reviewed the initial data provided by Thornton primarily including: planning and development data, water distribution data and hydraulic model, and wastewater collection data and hydraulic model. These data have provided AECOM with an adequate understanding of the existing system configurations and baseline data that will be used as the starting point for development of the Water and Wastewater Infrastructure Master Plan.

Some minor issues with the hydraulic models were identified with Thornton during the data review process. These issues will be coordinated with Thornton during the system evaluation process. Additionally, Thornton has identified some model revisions/updates that will need to be made prior to the existing performance evaluation. AECOM will coordinate with Thornton on a workflow for managing these model updates. Additionally, AECOM will use the initial planning data provided to work with Thornton on the future planning data that will be used for determining future water system needs consistent with the City of Thornton's Comprehensive Plan population and growth projections. These future water needs will serve as the basis for the Raw Water Supply Master Plan, Water Treatment Facilities Master Plan, and Water and Wastewater Infrastructure Master Plan, which will be incorporated into an Integrated Master Plan.

Appendix A - Data Review Summary Tables

This document outlines the initial data received from the City of Thornton on December 14, 2017.

GIS Data

Table A.1: GIS Data Overview

Document Title	Type of Document	Details
Utility Master Plan – GDB – 20171215	ArcGIS ArcMap	Geodatabase file of existing water distribution and wastewater collection infrastructure.
Sewer_Systems	PDF	City of Thornton map outlining the 2017 City of Thornton sewer system including locations of: sewer lift stations, sewer meters, Metro WW connections, sewer lines, sewer mains, and City boundaries. This map also depicts wastewater Basin A-K locations.
Mac_map ver 2	PDF	City of Thornton map depicting the water distribution system. Included on this map are the locations (and various information) of the water pressure zones, water mains by zone, treated water pump stations, raw water pump stations, water tanks, check valves, zone valves, and City boundaries. This map includes information on PRV locations, elevations, inlet and outlet pressures, positions, valve sizes and line sizes. Other information includes the location and information on the Thornton Water Treatment Plant.
Utility Master Plan – Shapefiles – 20171215	ArcGIS ArcMap	Shapefiles for the Utility Master Plan saved in .mxd and individually per shapefile. Shapefiles include: basemapping, ditches, future land use, growth boundaries, gravel lakes, pressure zones, parks, sewer basins, parcels, force main information, sewer mains, sewer grease traps, sewer lift stations, sewer manholes, sewer meters, Metro connections, sewer service lines, service line blowoffs, service line manholes, pipelines, valves, storm surface flows, storm box culverts, storm chase points, storm grates, storm inlets, mains and manholes, storm overflow points, subdivision polygons, tanks, trails, water easements, water air release valve (ARV), blowoff, hydrants, mains, and manholes, water meters, water plugs, water PRVs, water pump stations, water reducers, water service lines, water structures, water valves, and zone shapefiles.
Utility_Master_Plan.gdb	ArcGIS ArcMap	Geodatabase containing information for the Utility Master Plan.

Planning and Development Data

Table A.2: Planning and Development Data Overview

Document Title	Type of Document	Details
3Q17 Population and Housing Summary	PDF	Summary of the "Third Quarter 2017 Population Estimate and Housing Inventory Report." The adjusted total population estimate for the City of Thornton at the end of Q3 (July 1, 2017 – September 30, 2017) was 136,547; and the total housing unit count was 47,498. This document also outlines projected future housing unit counts, and information on types of housing and development.
4Q16 Population and Housing Summary	PDF	Summary of the "Fourth Quarter 2016 Population Estimate and Housing Inventory Report." The adjusted total population estimate for the City of Thornton at the end of Q4 (October 1, 2016 – December 31, 2016) was 134,149; and the total housing unit count was 46,654. This document also outlines projected future housing unit counts, and information on types of housing and development.
WWMP pop proj 020217	Excel	City of Thornton's growth projections: 2017 – 137,500 projected population 2020 – 146,000 projected population 2025 – 160,000 projected population 2030 – 175,000 projected population Build Out – 242,000 projected population
Comp Plan Link	Email Message	Link to the City of Thornton Comprehensive Plan: http://www.cityofThornton.net/government/citydevelopment/planning/Pages/comprehensive-plan.aspx
Current Development Projects_ Dec 2016	PDF	PDF map showing current development projects as of December 12, 2016, distinguished by multi-family or single family unit counts. Current development types depicted include: Residential – Proposed, Residential – Approved, Residential – Active, Commercial – Proposed, Commercial – Approved, Commercial – Active, Institutional – Proposed, Institutional – Approved, Institutional – Active, Mixed – Proposed, and Mixed – Approved.
FW RTD Station Area Utility Studies	Email Message	Email correspondence indicating need to address/evaluate existing and proposed development at RTD stations within the Utilities Master Plan. This email includes information regarding the 124th Station, 104th Station and 88th Station.

Water and Wastewater Infrastructure Data

Table A.3: Water and Wastewater Data Overview

Document Title	Type of Document	Details
Sewer Model	ArcGIS ArcMap	Infrastructure sewer model containing both the .mxd and .IEDB files to be used in InfoSewer. The model contains information and data regarding controls, manholes, maps, pipes, pumps, wetwells, and meters. Scenarios include existing and future scenarios (2025 & 2065).
Water Model	ArcGIS ArcMap	InfoWater model containing .mxd, .IWDB and .out files. The model contains information and data regarding controls, demands, pipes, tanks and valves. Existing scenarios include EPSs at both max day and min day demands, as well as steady state. Future scenarios include 2025 EPS and 2065 EPS.
PRV_Map_02122017	PDF	City of Thornton map including water pressure zones, PRVs, tank locations, and other information dated March 2017.
Sewer_Basins_3_2_2017	PDF	City of Thornton map depicting the wastewater collection system including sewer lift stations, sewer meters, sewer lines, private lines, Metro mains and force mains. Wastewater Basins A-K are outlined on the map, dated March 2017.
Slip_Line_CIP	PDF	City of Thornton map depicting CIPP Sliplined Pipes. Distinctions are made between CIP Year 1981-1988, CIP Year 1993-1999, CIP Year 2000-2017, and sewer line pipes. The map is dated May 24, 2017.
Water Modeling Information	Word Document	City of Thornton document describing the controls and operations of the water distribution system model. Specifically, document discusses WTP operations, pump station controls, PRV settings and controls, and tank set points.

Planning Area and Future Growth Analysis

Chapter 2

Utility Master Plan

Project No. 17-467

Water and Wastewater Infrastructure Master Plan

Planning Area and Future Growth Analysis

The City of Thornton

Project number: 60560104

AECOM

Final - August 9, 2018
Rev 1 – September 13, 2018

Quality information

Prepared by	Checked by	Verified by	Approved by
Brock Hodgson	Nathan Walker	Kathy Schlosser	Richard Hope

Revision History

Revision	Revision date	Details	Authorized	Name	Position
Issued Draft	6/28/2018	Draft	Nathan Walker	Brock Hodgson	Engineer
Final	8/9/2018	Final	Nathan Walker	Brock Hodgson	Engineer
Final – Rev 1	9/13/2018	Rev 1	Nathan Walker	Brock Hodgson	Engineer

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The City of Thornton

Prepared by:

AECOM
6200 South Quebec Street
Greenwood Village, CO 80111

T: +1 (303) 694 2770
F: +1 (303) 694 3946
aecom.com

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List of Acronyms

AAD	average annual demand
ADD	average day demand
ADWQ	average dry weather flow
CII	commercial, industrial, and institutional
CIP	capital improvement plan
GPCD	gallons per capita per day
MDD	maximum day demand
MinM	minimum month demand
MGD	million gallons per day
MMD	maximum month demand
MWRD	Metro Wastewater Reclamation District
PF	peaking factor
PHD	peak hour demand
PDWQ	peak dry weather flow
Plan	Utility Master Plan
PWD	peak weekly demand
RDII	rain derived infiltration and inflow
ROW	right-of-way
Thornton	City of Thornton
TM	technical memorandum
UAW	unaccounted water
USDM	United States Drought Monitor
W/WW	water and wastewater

1. Introduction and Purpose

This technical memorandum (TM) describes the planning area and population projections used as the planning basis in the City of Thornton (Thornton) Utility Master Plan (Plan), and develops future water use projections that will be used in the Plan. This planning basis was carefully developed, using data provided by Thornton and working closely with Thornton staff to maintain consistency with Thornton's ongoing planning efforts. The utility systems include the raw water supply system, water treatment facilities, water distribution system, and wastewater collection system. The basis, approach, and findings for these analyses are documented in this TM and provide an integrated planning framework for establishing future requirements for each of the utility systems.

The TM includes:

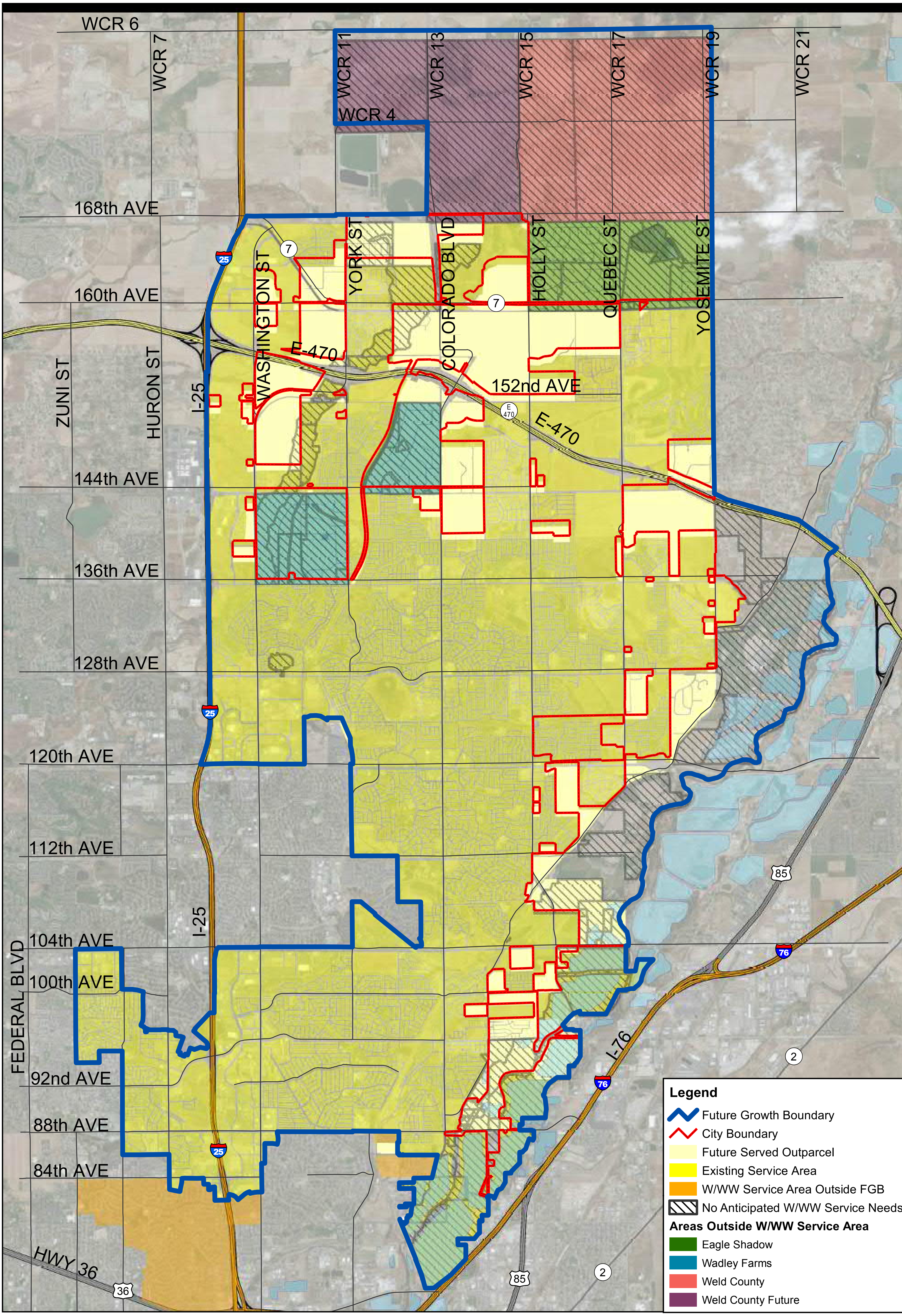
- Review of the existing and buildout planning areas
- Review of current and anticipated future population
- Analysis of existing and planned future land uses
- Review of historical water use across each utility system
- Review of drought and non-drought climate conditions
- Review of potential non-potable water savings and development of future water use projections across each utility system.

2. Updated Planning Area Characteristics

Thornton has developed projections for buildout population and land use that define the planning area, planned growth, and changes in land use expected as Thornton continues to develop. The planning area primarily includes the existing city limits and unincorporated portions of Adams County that will be incorporated as Thornton grows.

Service and Planning Area

Thornton's current city limits encompass approximately 37.3 square miles (23,846 acres), and the future growth boundary encompasses approximately 60.3 square miles (38,609 acres). The existing city limits are made up of four wards. In addition to the city limits, the service area also includes Western Hills, Welby, Federal Heights, and portions of unincorporated Adams County. Federal Heights is part of the wastewater service area but not the water service area, and its land use characteristics are not included in the Plan analyses. Existing and future service area inside the city limits, the future growth boundary, and regions outside the future growth boundary served by Thornton are shown in Figure 1. With the exception of mild growth in the Federal Heights region, growth of the service area outside the planning boundary is not expected.



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9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

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Figure 1
City of Thornton
Service and Planning Areas

6/27/2018
1 inch = 5,000 feet

\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure 1 - City and Service Boundaries.mxd

Population

Thornton's existing and future projections of population for the water and wastewater (W/WW) service area are shown in Table 1. The future population projections serve as the basis for the population-based planning area and future growth analysis for the Plan. The projected population data indicates an annual growth rate of approximately 3.2 percent until 2025, a 1.7 percent population growth between 2025 and 2035, and a growth of 0.7 percent between 2035 and 2065.

Table 1. Existing and Future Population for Thornton's Water and Wastewater Service Area

Service Area Component	Population			
	2017	2025	2035	Buildout (2065)
Within City Limits				
Total[1]	137,443	168,437	197,764	238,513
Ward 1	33,366	33,596	33,734	35,637
Ward 2	34,496	38,250	41,466	44,235
Ward 3	33,550	49,314	70,394	106,471
Ward 4	36,031	47,277	52,170	52,170
Outside City Limits				
Western Hills[2]	10,500	10,500	10,500	10,500
Welby[3]	1,886	1,886	1,886	1,886
Unincorporated Adams County[2]	4,444	4,444	4,444	4,444
Federal Heights (wastewater only)[2]	12,100	12,300	12,800	13,500
Total Water Service Area Customers	**154,273**	**185,267**	**214,594**	**255,343**
Total Wastewater Service Area Customers	**166,373**	**197,567**	**227,394**	**268,843**

[1] Provided by Thornton Planning Department

[2] From the 2009 Master Plan

[3] Calculated based on 16,830 population, assumed outside city limits.

Land Use

In addition to population growth, understanding how land use will change as future development occurs is important in identifying future water system needs. To accomplish this, AECOM reviewed the current land use, future land use, and current development projects which were provided by the Thornton Development Department. The current development projects reflects the most up to date estimate of near term development and is actively updated by the Thornton Development Department based on proposed development. AECOM used these three files and worked with Thornton to develop the buildout land use characteristics and population distribution that serves as the basis for the Plan.

To develop the buildout land use characteristics, current land use classifications were assigned a generalized land use classification, consistent with the future land use classifications, as shown in Table 2. The generalized land use treated commercial as a single category that represents commercial, industrial, and institutional (CII).

Table 2. Land Use Classifications

Generalized Land Use	Current Land Use		Future Land Use	
Parks and Open Space, Right-of-Way, Agriculture	Public Parks and Recreation Lake Transportation	Mine Detention Pond Agriculture	Parks and Open Space Urban Reserve	
Residential	Residential Estate Single Family Detached Single Family Attached	Manufactured Home Park Multi-Family	Residential Estate Residential Low Residential Medium	Residential High Urban Village
Commercial, Industrial, and Institutional (CII)	Commercial Institutional		Commercial Institutional Regional Commercial	Employment Center Employment Center–North Washington Overlay
Mixed Use	—		Mixed Use Gateway	
Other	Unknown/Outside Thornton		Unknown	
Vacant	Vacant		Vacant	

The current land use is shown in Figure 3, and the future land use and current development projects are included in Appendix A, Figures A.1 and A.2 respectively. Using this data, a geospatial analysis was performed with the current land use and future land use to identify the buildout land use area, which included:

- Intersect current land use and future land use
- Remove areas identified as no anticipated W/WW service needs and right-of-way (ROW) areas
- Exclude existing parks and open space, ROW, and vacant land that is undeveloped at buildout
- Exclude areas with no change in land use

Lastly, the current development projects were overlaid with the geospatial land use analysis, to update the future land use area to be consistent with the current development projections. Where the future land use differed from the current development projections, the current development projection classification was assumed to better reflect updated planned growth characteristics.

This analysis identifies the projected buildout land use and additional population at buildout as shown in Figure 4, which serves as the basis for the Plan and will be used for capital improvement plan (CIP) development. The buildout land use characteristics identifies the future CII areas that will require water service, and the population distribution identifies the additional residential population that will require water service at buildout. With the projected buildout land use characteristics and population distribution defined, AECOM worked with the Thornton Planning Department to distribute the future growth over the three planning periods (2025, 2035, and 2065 or buildout) as shown in Figure 2. The future growth distribution phased over each of the three planning periods is shown in Appendix B.

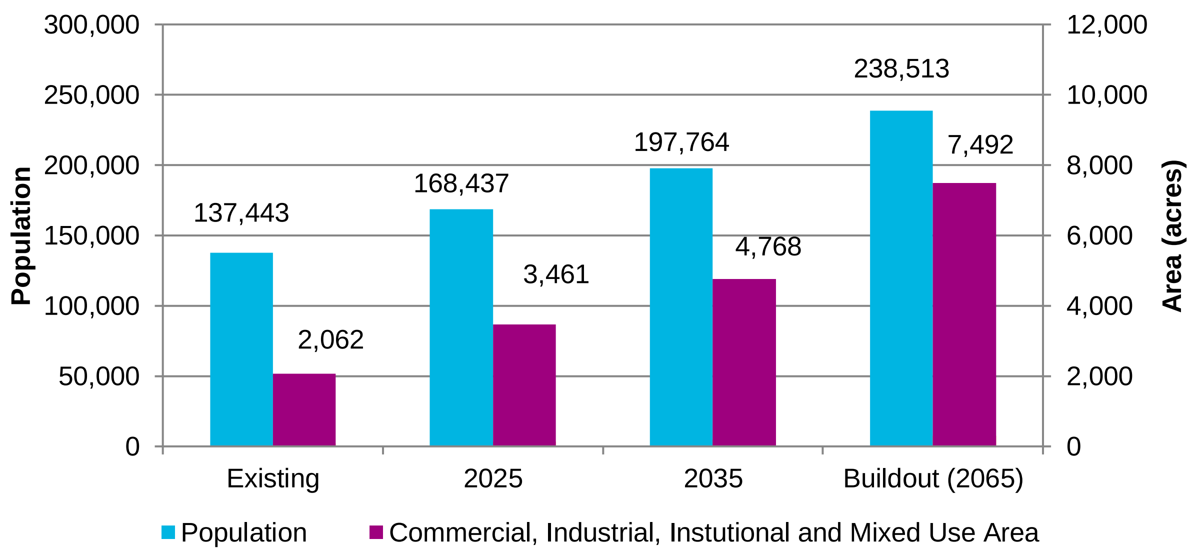

Figure 2. Projected Population and Commercial Growth

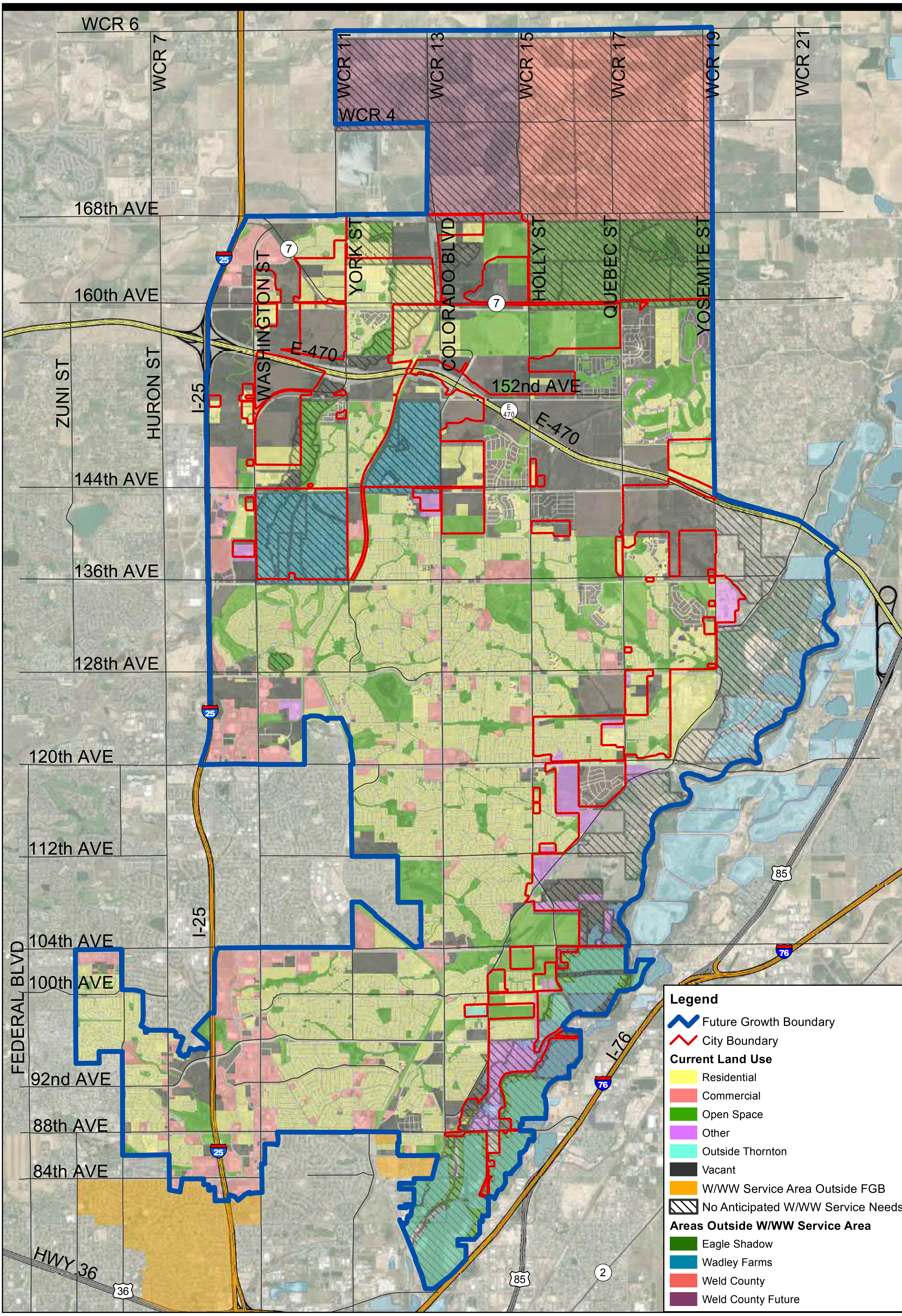

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Figure 3
Current Land Use

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\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure 3 - Existing Land Use.mxd

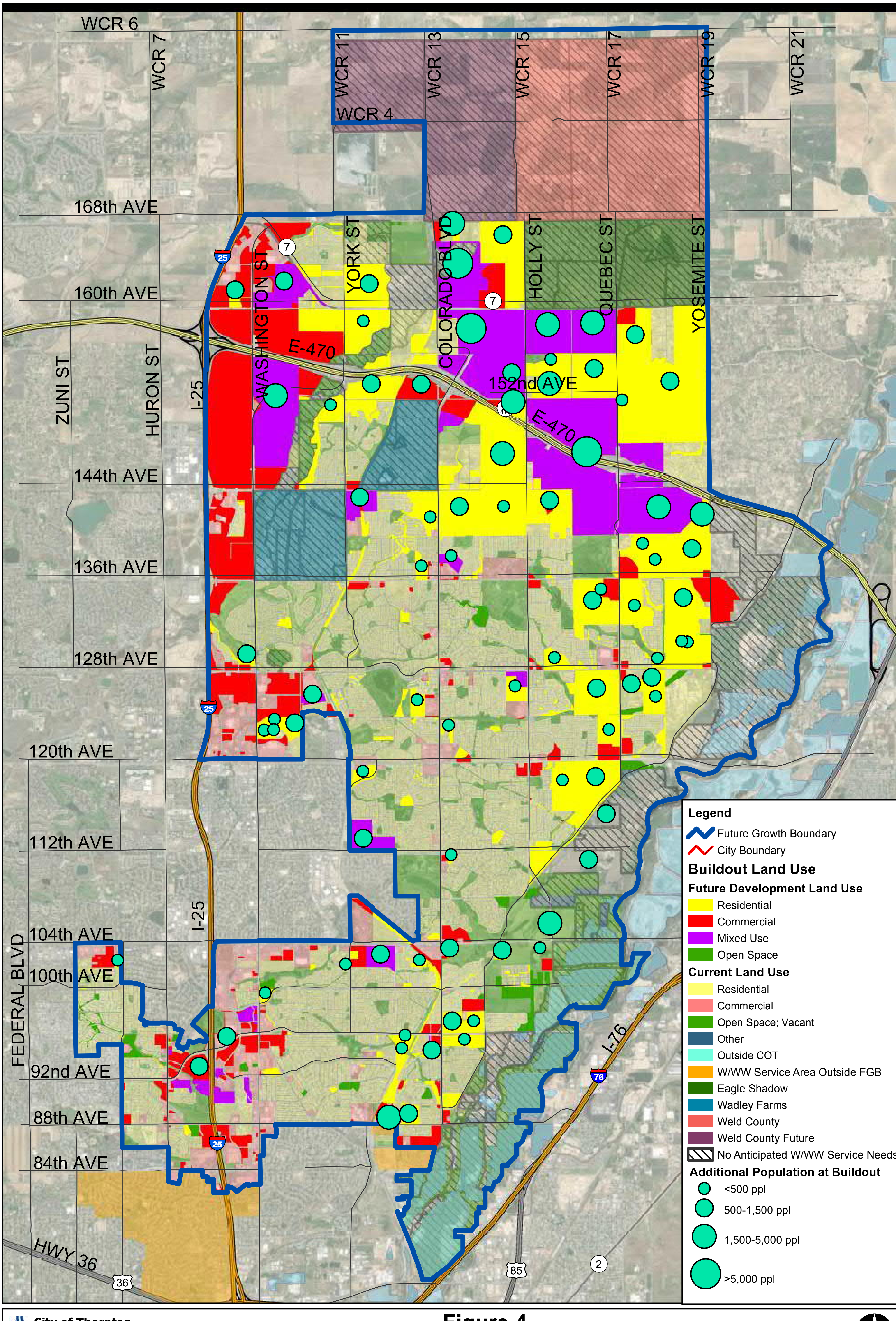

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Figure 4
Projected Buildout Land Use and Additional Population

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1 inch = 5,000 feet

\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure 4 - Projected Buildout Land Use and Future Population.mxd

The current service area land use and projected buildout service area land use characteristics are shown in Figure 5 and Figure 6, respectively. The current residential and commercial area includes 8,553 acres within the city limits and an additional 4,532 acres outside the city limits, for a total service area of 13,085 acres. The remaining area includes a total area of 18,628 acres (inside and outside Thornton), made up of parks and open space, ROW, and agriculture and vacant land that typically have highly variable water service requirements.

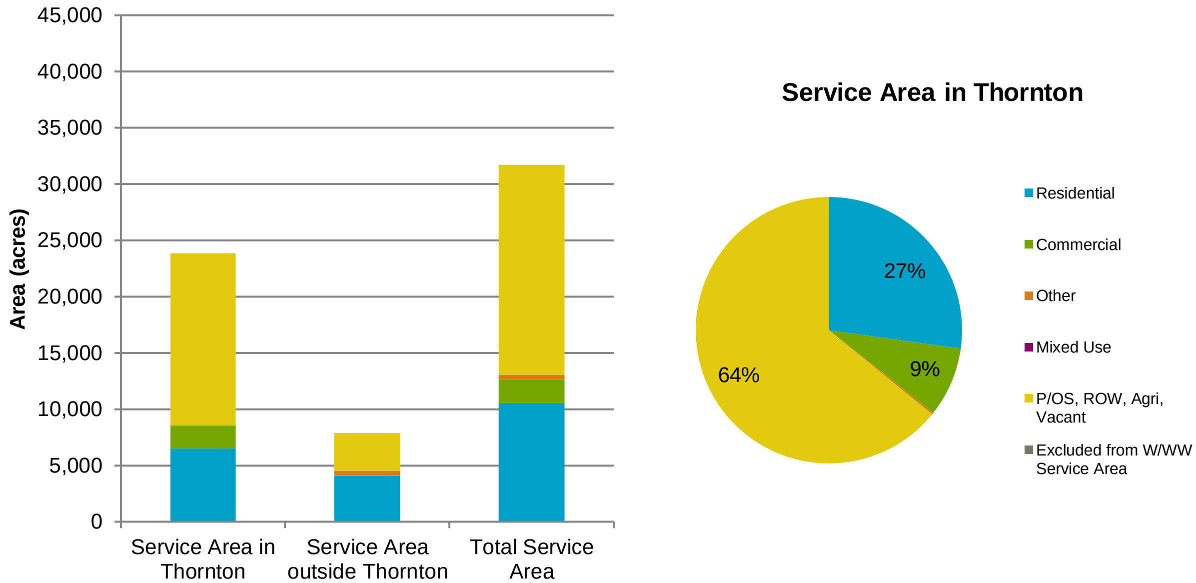

Figure 5. Current Service Area Land Use

As Thornton grows, a significant increase in both residential and commercial areas will occur. At buildout, it is projected that the residential, commercial and mixed use areas would be a total of 18,184 acres within the future growth boundary and an additional 1,336 outside the future growth boundary, for a total service area of 19,520 acres. At buildout, there is an estimated total of 15,827 acres (inside and outside Thornton) of parks and open space, ROW, and agriculture and vacant land that typically will have highly variable water service requirements.

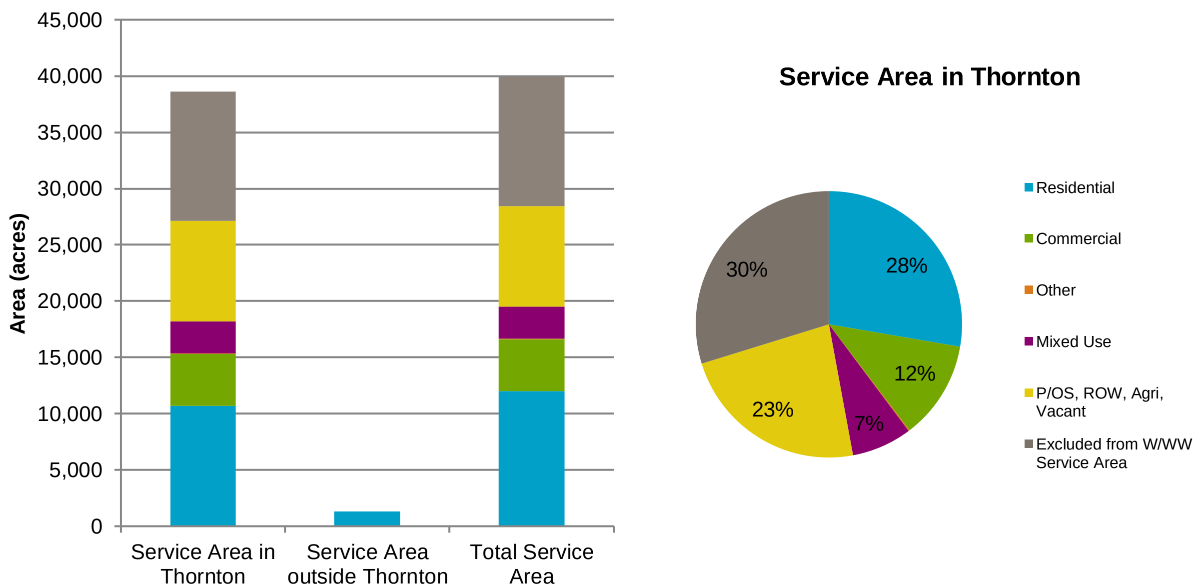

Figure 6. Buildout Service Area Land Use

The future growth boundary includes a total of 4,598 acres in Weld County that currently is not planned to be annexed or served by Thornton; therefore, no water or wastewater service is included for these areas in the Plan. However, Thornton includes this area, which is north of 168th Avenue, as part of the future growth boundary, to account for the possibility of future annexations. Infrastructure to accommodate the potential future inclusion of Weld County will be handled as part of a separate annexation study and is not included as part of this Plan.

As discussed previously, the current and buildout utility systems' needs are driven primarily by the residential, CII, and mixed use developments. Therefore, the distribution between residential and commercial areas for current and buildout land use was evaluated by excluding the parks and open space, ROW, agricultural, vacant areas, and Weld County from the service areas as shown in Figure 7. The water service area is primarily residential (81 percent) but will become slightly more commercial as development occurs and will include more areas of mixed use, reflecting commercial and residential development.

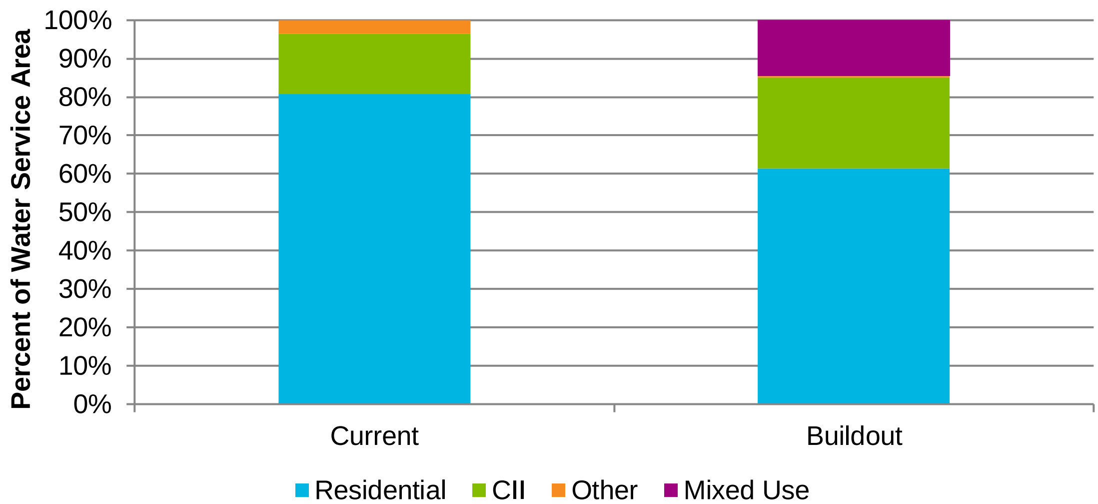

Figure 7. Current and Buildout Water Service Area Residential to Commercial Distribution*

*Excludes parks and open space, right-of-way, agriculture, vacant, and Weld County, to highlight residential/commercial distribution; "Other" represents areas with unknown land use but assumed to have a water service demand.

3. Historic Water Use

The historical water supply, treatment, distribution and wastewater collection records characterize historic water use for Thornton. The raw water supply represents the supply inlet to the water treatment plants but does not account for other supply losses, including seepage, evaporation, or transmission losses. An analysis of historic water use considered the total use and per capita use rates along with observed peaking factors (PFs). The analysis of historic water use included the following datasets:

- **Population Data**: annual data taken from the 2009 Master Plan, public records, and/or provided by Thornton
- **Raw Water Supply Data**: monthly supply flows to the water treatment facilities, taken from pump station data from 2008–2017 and Standley Lake pipeline from 2008–2016
- **Water Treatment Production Data**: monthly metered treatment plant production records from 2007–2017
- **Water Distribution System Demand Data**: monthly aggregated customer water meter data from 2012–2017
- **Wastewater Collection System Flow Data**: monthly Metro Wastewater Reclamation District (MWRD) meter data from 2010–2017
- **Climate Data**: United States Drought Monitor (USDM) drought categorization from 2007–2017

The objective the historic water use review is to define the following flow conditions:

- **Average Annual Demand (AAD):** The total volume of water delivered to the system in a full year expressed in gallons. When demand fluctuates up and down over several years, an average is used.
- **Average Daily Demand (ADD):** The total volume of water delivered to the system over a year divided by 365 days. The average use in a single day expressed in gallons per day.
- **Minimum Month Demand (MinM):** The gallons per day average during the month with the lowest water demand. The lowest monthly usage typically occurs during a winter month.
- **Maximum Month Demand (MMD):** The gallons per day average during the month with the highest water demand. The highest monthly usage typically occurs during a summer month.
- **Peak Weekly Demand (PWD):** The greatest 7-day average demand that occurs in a year expressed in gallons per day.
- **Maximum Day Demand (MDD):** The largest volume of water delivered to the system in a single day expressed in gallons per day.
- **Peak Hour Demand (PHD):** The maximum volume of water delivered to the system in a single hour expressed in gallons per day.

Climate Considerations

Annual precipitation will have significant impacts on the system water ruse, primarily during MMD. Consideration of water use under varying climate conditions was done by using the USDM index, which categorizes the presence and severity of drought based on the Palmer Drought Severity Index, Climate Prediction Center Soil Moisture Model, United States Geological Survey Weekly Streamflow, Standardized Precipitation Index, and Objective Drought Indicator Blends. The USDM index provides a classification of drought conditions between Abnormally Dry–D0, Moderate Drought–D1, Severe Drought–D2, Extreme Drought–D3, and Exceptional Drought–D4.

The average monthly drought categorizations for Adams County between 2007 and 2017 are shown in Table 3. In the last decade, a significant drought was observed in the second half of 2012 and the start of 2013. However, the climate conditions improved by the middle of 2013 and extended half-way through 2016. In general, over the past 10 years, with the exception of 2012, minor drought occurrences were common in Adams County.

Table 3. Monthly Average USDM Drought Index for Adams County

Month	Year										
	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17
January	D1	D0	D0	-	D1	-	D3	-	-	-	D1
February	D1	D0	D0	-	D1	-	D3	-	-	-	D1
March	D0	D0	D1	-	D2	-	D3	-	-	-	D2
April	D0	D0	D1	-	D2	D0	D2	-	D0	-	D1
May	-	D0	D0	-	D1	D0	D2	-	-	-	D0
June	-	D0	-	-	D0	D1	D2	-	-	-	-
July	-	D1	-	-	-	D3	D2	-	-	-	-
August	D0	D1	-	-	-	D3	D1	-	-	D0	-
September	D0	D0	-	D0	D0	D3	D0	-	-	D1	D0
October	D0	D0	-	D1	-	D3	-	-	D0	D1	-
November	D0	D0	-	D1	-	D3	-	-	-	D1	-
December	D0	D0	-	D1	-	D3	-	-	-	D1	D0
Annual Average	D0	D0	D0	D0	D0	D1	D1	-	-	D0	D0
Maximum Month	D1	D1	D1	D1	D2	D3	D3	-	D0	D1	D2

Thornton's historic water use was reviewed along with the drought occurrences to characterize water use trends under drought and non-drought conditions. For the review period, extended periods of drought were not observed. Therefore, the drought conditions identified in 2012 reflect short-term impacts of drought on water use but do not reflect long-term water supply issues that are associated with extended drought conditions.

2009–2017 Drought and Non-Drought Water Use Rates

The historical water usage was reviewed with considerations to population growth and drought conditions to document the historical water usage across the water utility systems, and to inform future system water needs. Total water use data was normalized based on service population, to develop historical per capita use trends for the raw water supply provided to the treatment facilities (Figure 8,) production from the treatment facilities (Figure 9), water distribution system customer demands (Figure 10), and wastewater collection systems flows (Figure 11). The compiled data is provided in Appendix C. These figures were plotted with USDM annual average drought categorization for Adams County where drought conditions are scored between D0 (representing abnormally dry conditions) to D4 (representing exceptional drought). The per capita use rates exclude 1.8 million gallons per day (MGD) flow provided to Brighton per Thornton's agreement with the Westminster Treated Water Lease.

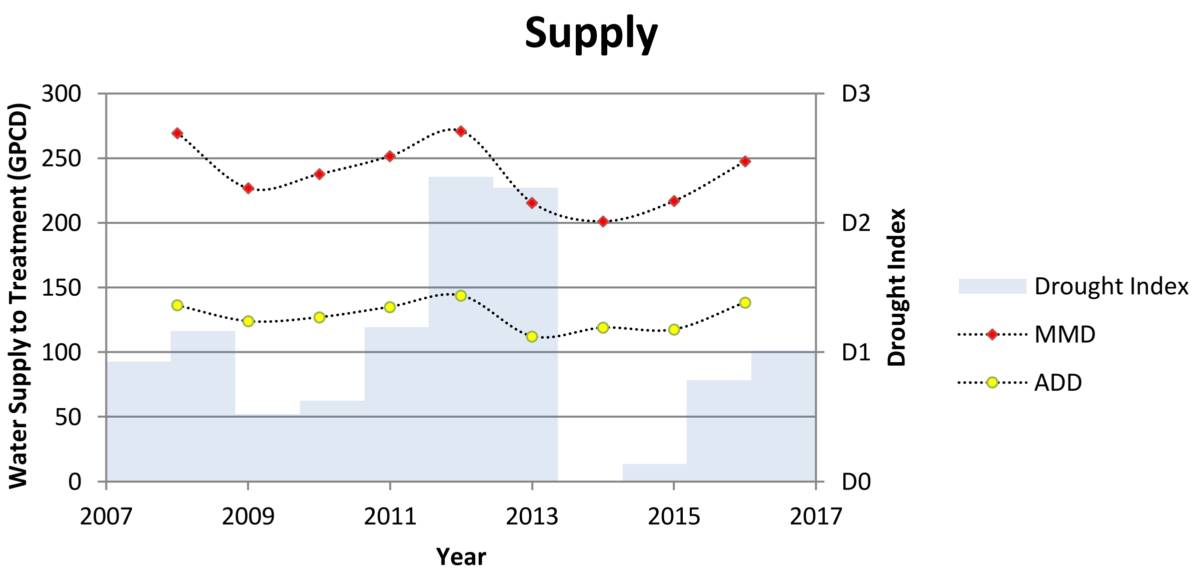

Figure 8. Historical Pumped Raw Water Supply to Thornton WTP and Wes Brown WTP (Per Capita)

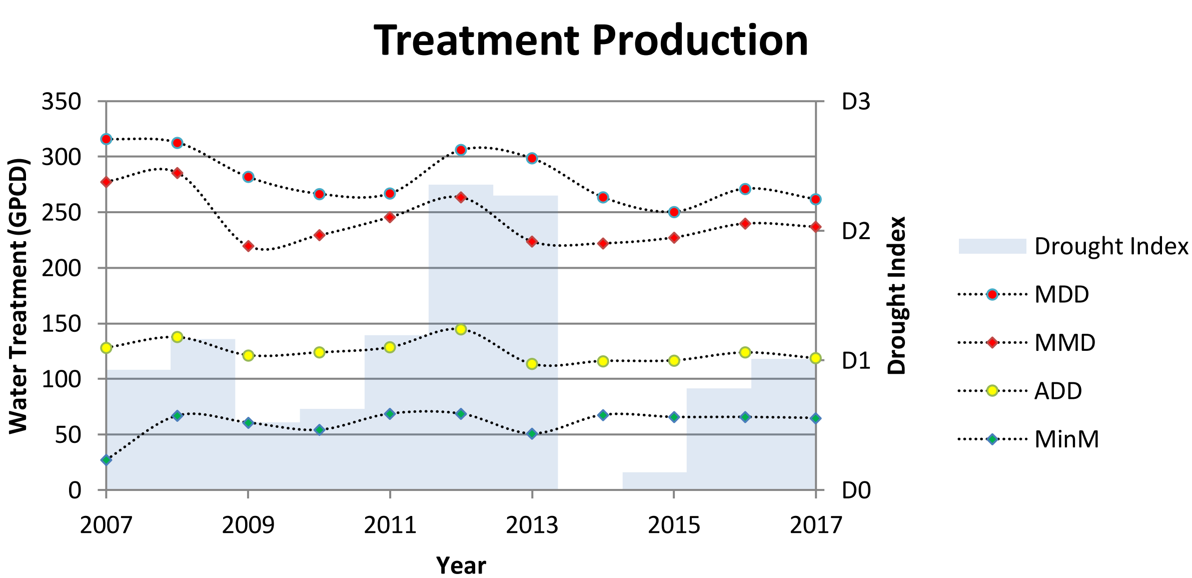

Figure 9. Historical Treatment Production from Thornton WTP and Wes Brown WTP (Per Capita)

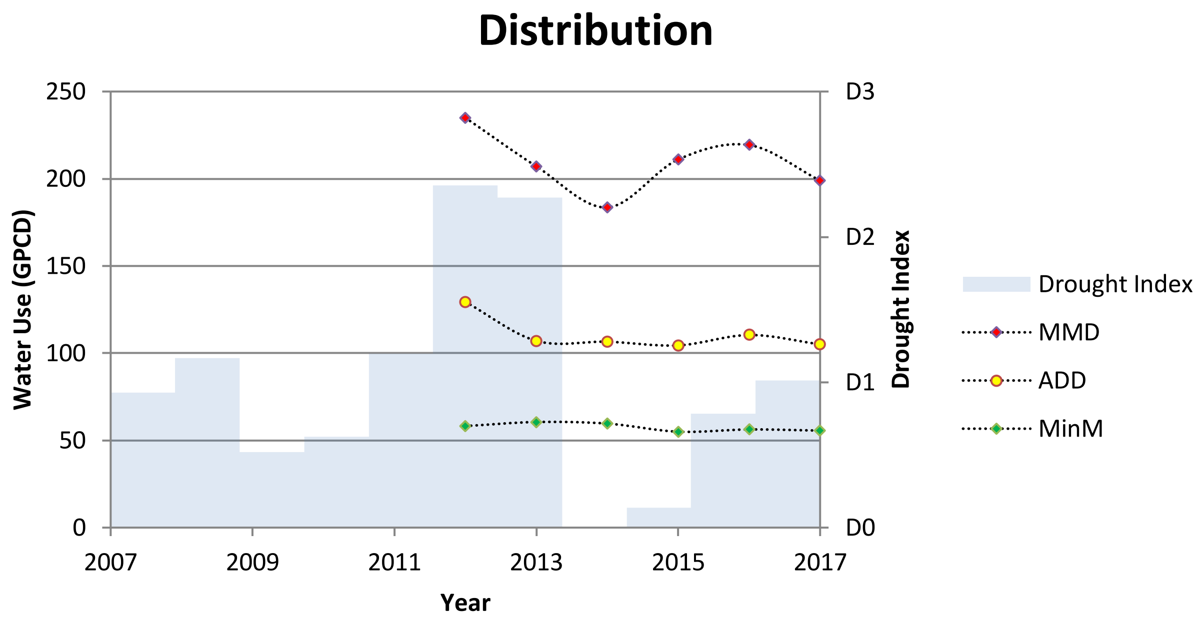

Figure 10. Historical Metered Water Distribution System Customer Demands (Per Capita)

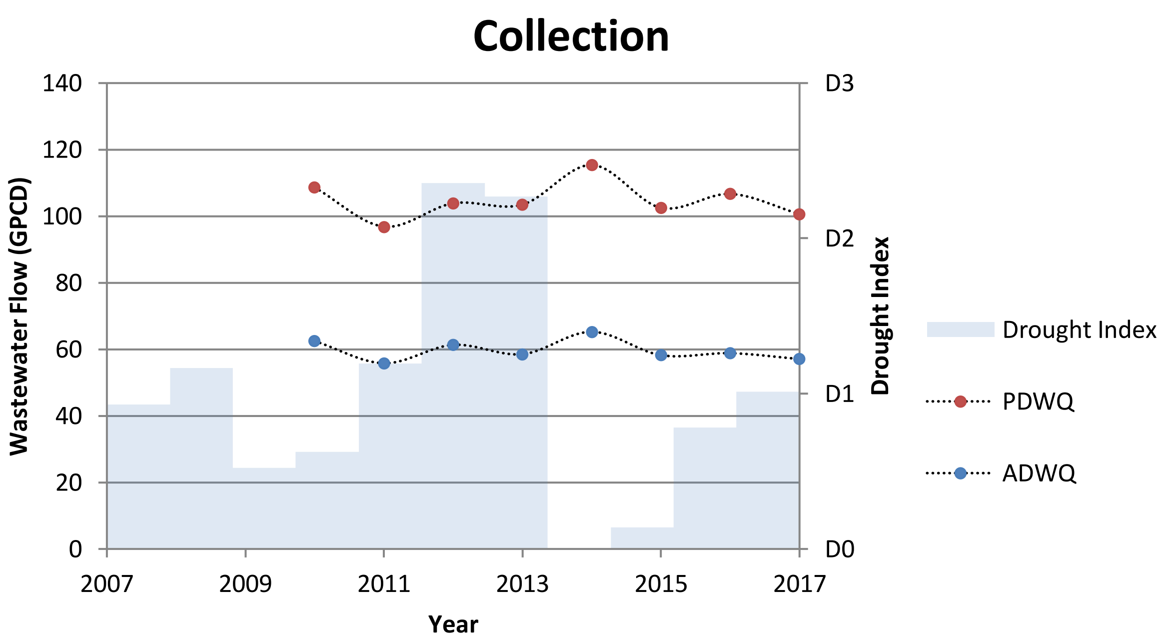

Figure 11. Historical MWRD Metered Wastewater Flows (Per Capita)

Historic water use rates in the supply, treatment, distribution, and wastewater collection systems were used to develop drought and non-drought use rates that will serve as the basis of future water use estimates for the Plan. Like many utilities in Colorado, the minimum month water use typically occurs in December, January, or February, and the maximum month water use typically occurs in July or August. The water production data from 2007 and 2008 indicate noticeably higher per capita water use than from 2009-2017. The difference in metered water production data may reflect improvement projects and/or conservation efforts completed prior to 2009. Excluding 2007 and 2008 production data, negligible change occurred in the minimum month water use. In 2012 during the extreme drought (D3) conditions, an increase occurred in the average and maximum water use.

The extreme drought conditions in 2012 had a notable impact on water use because of dry climate conditions. As a result, Thornton administered watering restrictions during this period. Based on this information, 2012 was identified as best representation of the utility system requirements under drought conditions for the ADD, MMD, MDD, and PHD. Negligible change occurred in the minimum month water use in the distribution system and average dry weather flow (ADWQ) in the wastewater collection system under drought conditions. This reflects that the drought conditions observed in the last 10 years primarily resulted in an increase in potable demands because of irrigation and had negligible impacts on indoor, non-consumptive water use.

Outside of 2012, frequent periods of abnormally dry (DO) to moderate drought (D1) have been common. Although the start of 2013 also reflected extreme drought conditions (D3), by the summer months when water use was higher the climate conditions had improved resulting in more typical water use. Based on the historical water use outside of 2012, the water use has been fairly consistent in terms of per capita water use for ADD, MMD, and MDD. Therefore 2009-2011 and 2013-2017 is representative of typical non-drought conditions. As previously discussed, for minimum month water use in the distribution system and ADWQ in the wastewater collection system the historical data indicates negligible impacts under drought condition, and presumably 2009–2017 is representative of typical conditions.

Total use and per capita use rates for drought and non-drought conditions were calculated and are shown in Table 4. Demand/use PFs were identified based on the average and maximum per capita use rates and are shown in Table 4. The PFs indicate limited variation across drought and non-drought conditions. Prior year use rates and PFs also are shown in Table 4 for a comparison of these current use trends. The per capita and peaking factors were calculated, excluding 1.8 MGD for the Westminster Treated Water Lease, which is included in the total water use values.

Table 4. Historic Total and Per Capita System Use for Prior Year, Non-Drought and Drought Conditions

		Prior Year (2017)		Non-Drought		Drought	
		Per Capita Use (GPCD)	Total Use (MGD)	Per Capita Use (GPCD)	Total Use (MGD)	Per Capita Use (GPCD)	Total Use (MGD)
Supply	ADD	---	---	124.9	21.1	143.9	24.0
	MMD	---	---	228.2	37.0	271.1	43.6
	MMD/ADD[1]	---		1.83		1.88	
Treatment (Produced)	MinM	64.9	11.8	63.4	11.6	63.4	11.6
	ADD	118.7	20.1	120.4	20.4	144.8	24.1
	MMD	236.9	38.3	230.6	37.4	263.5	42.4
	MDD	261.9	42.2	270.2	43.5	306.2	49.0
	MDD/ADD[1]	2.21		2.24		2.11	
Distribution	MinM	55.6	10.4	57.5	10.7	57.5	10.7
	ADD	105.1	18.0	106.7	18.3	129.4	21.8
	MMD	198.9	32.5	204.0	33.3	235.0	38.0
	MDD (at MDD/ADD = 2.24)[1]	233.6	38.2	237.3	38.8	288.2	46.6
	PHD (at PF=1.5)[1]	353.8	56.4	359.3	57.2	435.7	69.0
	MinM/ADD[1]	0.53		0.54		0.44	
	MMD/ADD[1]	1.89		1.91		1.82	
Collection	ADWQ	57.1	9.5	59.7	9.9	59.7	9.9
	PDWQ	100.6	16.7	104.8	17.4	104.8	17.4
	PDWQ/ADWQ	1.76		1.76		1.76	

1. Calculation excludes 1.8 MGD for the Westminster Treated Water Lease

Estimate of Utility System Losses

Based on the historical water use rates, an integrated water balance was performed, to characterize the losses estimated between each utility system based on prior year, non-drought, and drought conditions. The calculated losses are shown in Table 5. The integrated water balance identified the estimated losses between the treatment and distribution systems, and potential infiltration in the wastewater collection system. This also accounts Thornton's agreement with Westminster Treated Water Lease to supply 1.8 MGD to Brighton. The integrated water balance is further summarized in the subsequent section and is shown in Figure 12.

Table 5. Apparent Losses

	Prior Year (2017)		Non-Drought		Drought	
	ADD	MMD	ADD	MMD	ADD	MMD
(Supply–Treatment)/Treatment[1]	10%		10%		10%	
(Treatment–Distribution)/Distribution	12%	18%	13%	12%	11%	12%
(Distribution-Collection)/Distribution[2]	-11%		-12%		-12%	

1 Based on daily supply and production data between April 1 and June 30, 2017.
2. Calculation excludes 1.8 MGD from distribution for the Westminster Treated Water Lease; values represent infiltration estimates. Distribtuion uses MinM and Collection uses ADWQ.

When comparing the water supply and treatment system meter records, the difference between the reported WTP influent and production data is negligible. This is believed to be primarily a function of flow meter inaccuracies. To better estimate the losses at the treatment system, daily influent and production data was reviewed from Wes Brown Water Treatment Plant and Thornton Water Treatment Plant between April 1 and June 30, 2017, which indicated production losses of 11 percent and 5 percent respectively, and an average total production loss of 10 percent. These production losses are believed to represent typical production losses at the facilities, and the production loss was assumed to be consistent under non-drought, drought and MMD.

In terms of the water distribution system, the prior year, non-drought and drought use rates indicate relatively consistent rates of apparent loss, or unaccounted water (UAW). The distribution system UAW under ADD was 2.1 MGD and 2.4 MGD for non-drought and drought conditions, respectively. This UAW during maximum month increased to 4.1 MGD and 4.4 MGD for non-drought and drought conditions, respectively, representing a noteworthy percentage of the treatment production (11 percent).

The variation between the water distribution system use rates and wastewater collection system flow rates determines the return flow rates to the collection system accounting for base infiltration. Base infiltration typically occurs from groundwater but may also originate from stormwater as rain derived infiltration and inflow (RDII) that enters the collection system. Distribution system demands during the minimum month period typically represent indoor water use, because no irrigation occurs in Thornton during this period and there is negligible RDII. Typical indoor water use includes approximately 10 percent loss due to consumptive use, and therefore typical flow rates to the wastewater collection system are approximately 90 percent of distribution system indoor use. Most collection systems experience some level of base infiltration, typically estimated to be approximately 10 percent of nightly minimum wastewater flow during dry periods. Excluding the 1.8 MGD that is supplied to the Westminster Treated Water Lease, the collection system indicates an increase of 1.1 MGD in both non-drought and drought conditions due to infiltration compared to minimum month in the distribution system. The variation between the water distribution system use rates and the wastewater collection system flows rates suggests that the collection system may include approximately 11 percent of ADWQ as base infiltration, assuming no consumptive loss.

Integrated Water Balance and Peaking Factors

The historical water use, PFs, and apparent system losses were used to complete an integrated water balance across each utility system. The integrated water balance establishes the flow requirements for each system for the buildout demand projections. A schematic diagram is shown in Figure 12, summarizing the integrated water balance, and includes the various system PFs, apparent losses, and return flow rates. These relationships exclude 1.8 MGD for the Westminster Treated Water Lease.

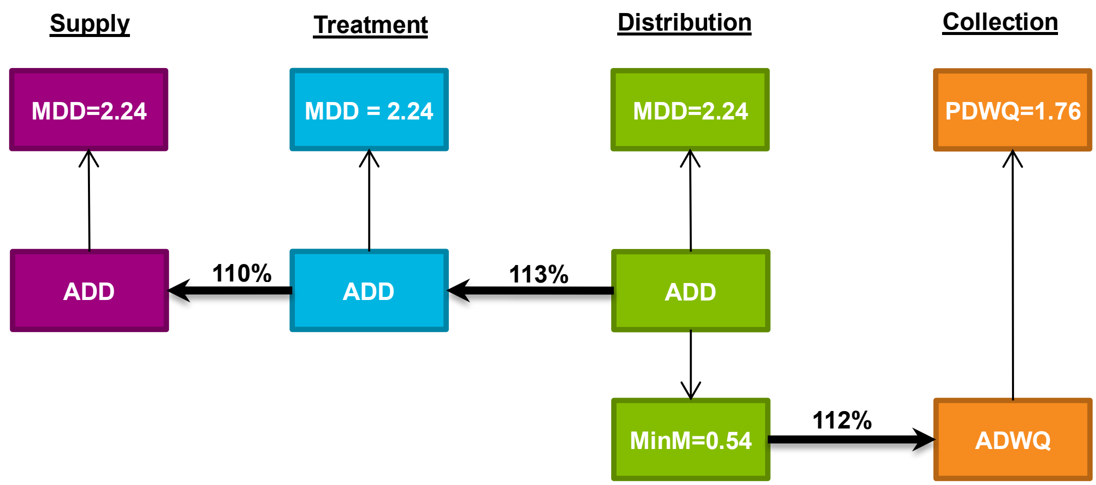

Figure 12. Integrated Water Balance with Peaking Factors, Apparent Loss and Return Flow Rates

Land Use Water Use Rates

Historic water use records associated with various land use categories indicates how observed use compares to Thornton's design standards (Thornton Standards and Specifications 2012) for water use, on a gallons per acre basis. The monthly water use based on land use was reviewed from 2012 to 2017. The customer meter data was aggregated into general classifications, either inside or outside Thornton. These classifications were generalized to residential, commercial, or parks and open space. A box and whisker plot was prepared for the non-drought period of record (2013–2017), to identify the typical water use as gallons per acre per day, as shown in Figure 13. The land use water use rates are within typical ranges used for design purposes and conservatively within Thornton's design criteria identified in the 2012 Thornton Standards and Specifications.

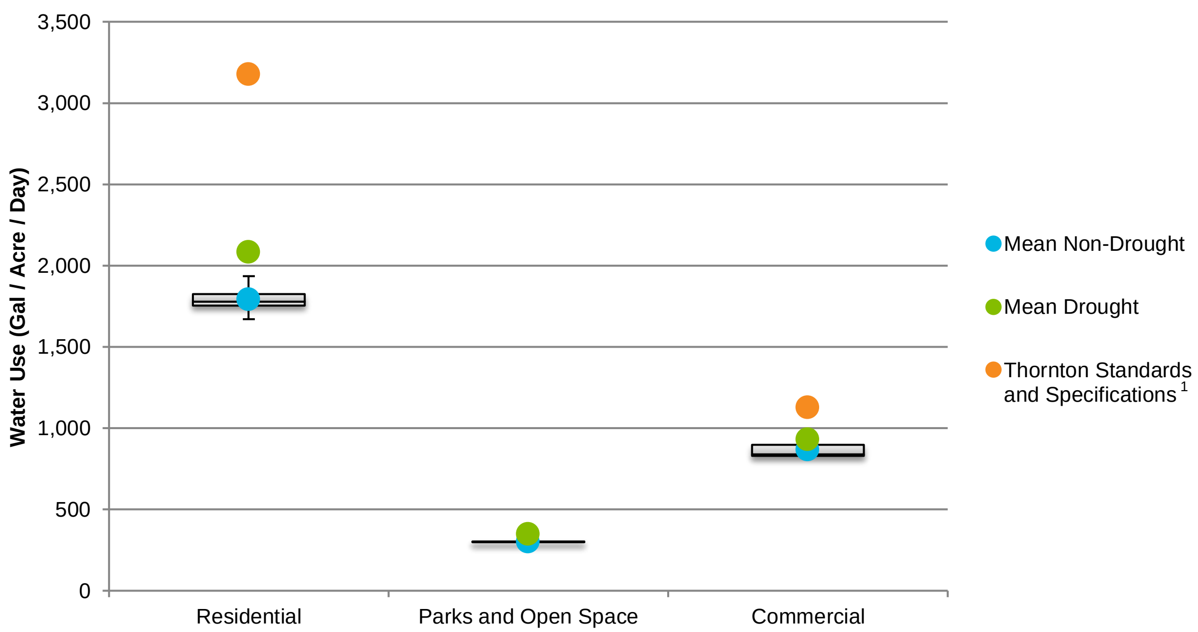

Figure 13. Land Use Water Use Rates

[1]Adopted from Thornton 2012 Standards and Specifications. Residential design standard calculated based on 150 gpcd x 137,443 people / 6,491 acres which is the 2017 residential area and population. Commercial design standard calculated based on wastewater generation of 600 gallons per acre per day for commercial and industrial areas x 150 gpcd / 80 gpcd which is flow split between ADD / wastewater flow design criteria. There is no design criteria for Parks and Open Space.

4. Non-Potable Water Savings

Thornton currently has a raw water system for irrigation that provides a non-potable water source, reducing the potable water demands on the water system. In 2017, Thornton used a total of 64 million gallons or an average of 0.18 MGD for raw water irrigation, and used a maximum of 0.58 MGD in October. Additional opportunities exist for non-potable water savings in the system, primarily at existing irrigation sites where high summer demands can be met with a non-potable water source. The irrigation meter records were reviewed for 2012–2017, to identify potential non-potable water savings based on the MMD and ADD, as shown in Figure 14. Summing up the irrigation supplies in Thornton shows an opportunity to offset 7.2 MGD with a non-potable water sources during MMD and 2.3 MGD during ADD that could be supplied from a non-potable source. Additional treatment and infrastructure would be necessary to distribute non-potable water which was not identified as part of this Plan. This represents opportunity for reducing the treatment requirements at the plant along with reduced requirements of the potable distribution system. Additional water savings opportunities may occur, primarily from high water users (typically CII).

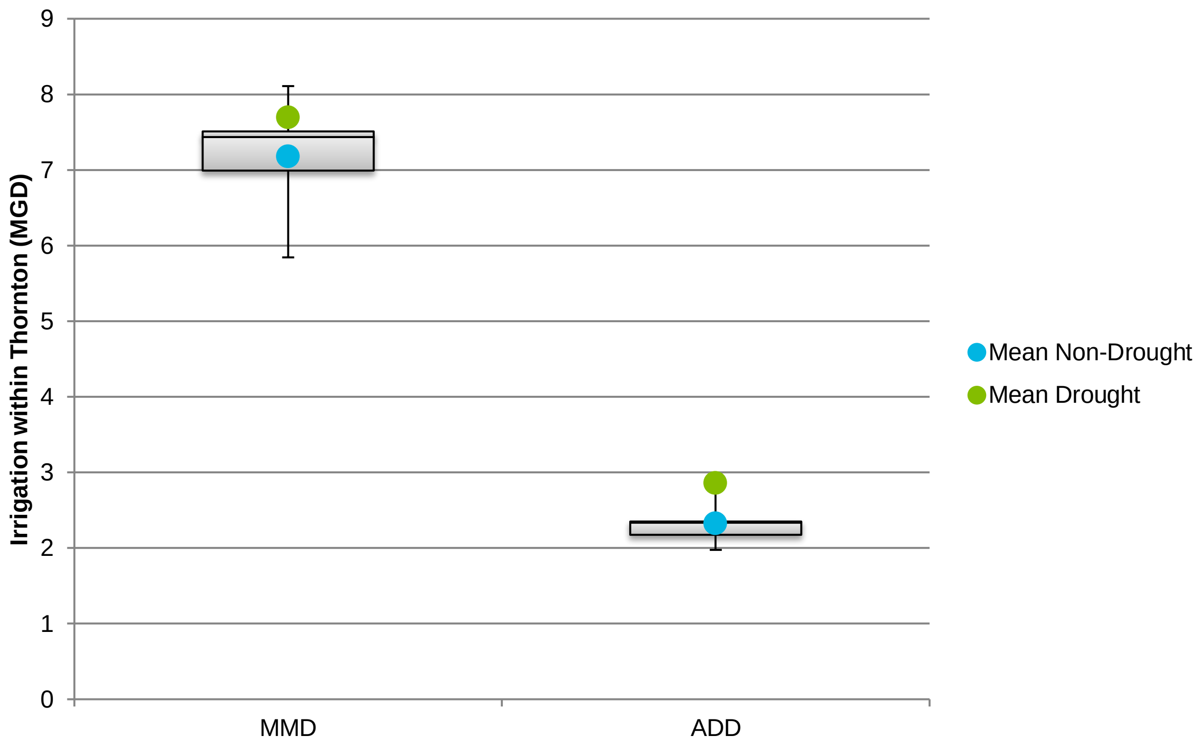

Figure 14. 2012–2017 Thornton Irrigation Water Demands

5. Future Water Use Projections

Three approaches were used for estimating future water system use; a population-based method, land use-based method, and a pseudo method using a combined population and land use approach. The population-based method used historical water use rates (Table 4) along with the buildout population projections (Table 1) to estimate customer demands on the water distribution system at buildout. The second approach used historical land use water use (Figure 13) and buildout land use areas (Figure 4) to estimate future system demands. Lastly, the pseudo method utilized a population based approach to estimate the residential and parks and open space water use, and utilized a land use based approach to estimate future commercial water use.

Population-Based Approach

Historical per capita ADD use rates for the water distribution system are 106.7 gallons per capita per day (GPCD) for non-drought conditions and 129.4 GPCD for drought as shown in Table 4. Applying these use rates to the buildout population projection, along with the existing PFs and including 1.8 MGD for the Westminster Treated Water Lease, the estimated buildout customer demands were established and are shown in Figure 15. The population-based approach assumes no significant future change in per capita water use rates and does not consider possible impacts from changes in water use based on the relative amount of residential and commercial land use in the service area. For reference, Figure 15 also includes the ADD based on the 2012 Thornton Standards and Specifications ADD design criteria of 150 gpcd.

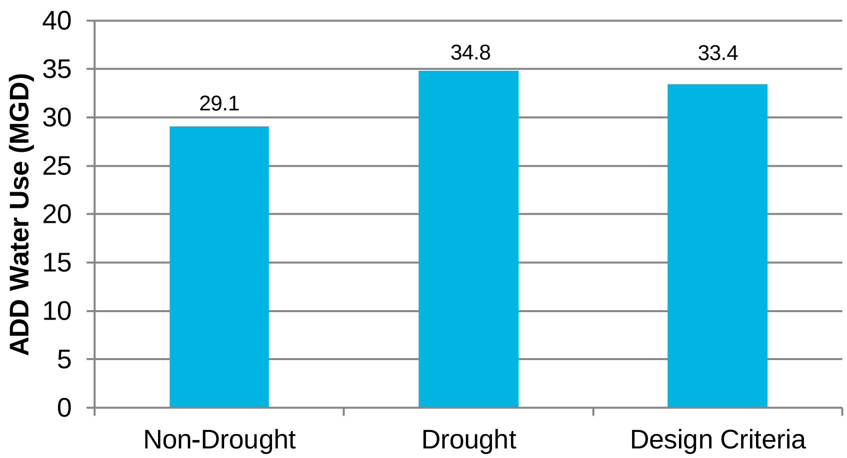

Figure 15. Population Based Estimate of Buildout Customer Demands in the Distribution System

Land Use-Based Approach

The land use-based approach used the historic land use water use rates and buildout land use projections to estimate the buildout customer ADD demands as shown in Figure 16. This approach provides a higher overall system requirement with largest water demands, coming primarily from residential users and parks and open space demands. For comparison, Figure 16 also includes an ADD demand based on the 2012 Thornton Standards and Specifications using the design criteria as identified in Figure 13.

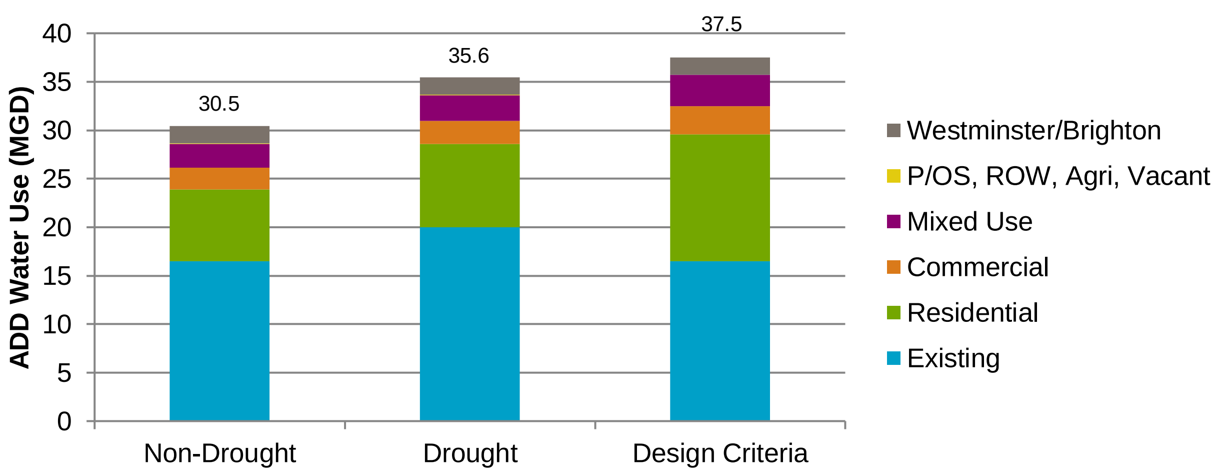

Figure 16. Land Use-Based Estimate of Buildout Customer Demands in the Distribution System

Pseudo Population and Land Use-Based Approach

A pseudo population and land use-based approach was developed to account for differences in the growth characteristics between the population growth, commercial growth, and mixed-use growth as Thornton develops. This method accounts for residential growth and parks and open space water use assuming a per capita flow estimate, and accounts for commercial growth using a land use-based approach. This analysis was performed using the 2012–2017 water meter data to identify the residential per capita water use, the parks and open space per capita water use, and the commercial water use per acre. A breakdown of the unit flows is shown in Table 6, and the estimated buildout customer demands are shown in Figure 17.

Table 6. Pseudo Population and Land Use-Based Assumptions

Source	ADD Non-Drought	ADD Drought
Residential	80.9 gallons per capita per day	98.3 gallons per capita per day
Commercial	867 gallons per acre per day	929 gallons per acre per day
Parks and Open Space, Right-of-Way, Agriculture	17.8 gallons per capita per day	23.6 gallons per capita per day

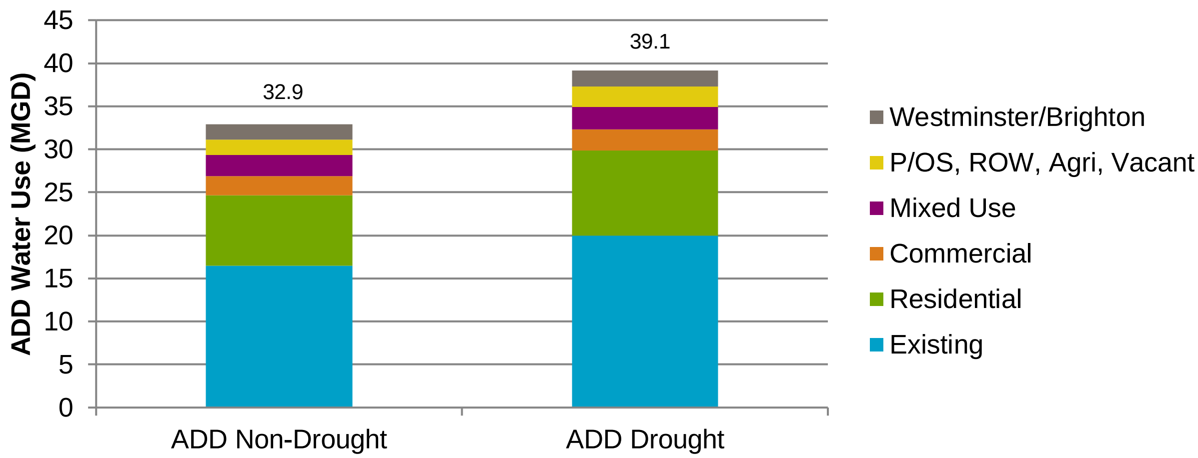

Figure 17. Pseudo Population and Land Use-Based Estimate of Buildout Customer Demands in the Distribution System

Approach Comparison and Discussion

The different approaches provide a range of estimated flow conditions based on different methodologies, shown in Table 7. The population, land use, and pseudo-based approaches yield very similar estimates of future water system needs. All estimates suggest lower buildout system demands, compared to the 2009 Master Plan.

Table 7. Buildout Flow Estimates of Distribution Demands

Approach	ADD	MDD[1]
2009 Plan, Population-Based Approach	39.3 MGD	86.0 MGD
2009 Plan, Land Use-Based Approach	39.7 MGD	86.9 MGD
Current Plan, Population-Based Approach	29.1 MGD (Non-Drought) 34.8 MGD (Drought)	63.0 MGD (Non-Drought) 76.0 MGD (Drought)
Current Plan, Land Use-Based Approach	30.5 MGD (Non-Drought) 35.6 MGD (Drought)	66.2 MGD (Non-Drought) 77.7 MGD (Drought)
Current Plan, Pseudo Population and Land Use-Based Approach	32.9 MGD (Non-Drought) 39.1 MGD Drought)	71.6 MGD (Non-Drought) 85.6 MGD (Drought)

1. Based on MDD/ADD of 2.24 and excluding a constant flow of 1.8 MGD for the Westminster Treated Water Lease.

The main difference between the estimates for the 2009 Master Plan and the current Plan are the per capita flow rates. The 2009 Master Plan assumed an average per capita flow of 154 GPCD, based on the 2008 system water use. However, the 2008 water treatment production data indicate an ADD of 137.6 GPCD, excluding the 1.8 MGD provided to the Westminster Treated Water Lease, indicating that this was not done as part of the 2009 Master Plan (Figure 9). Based on the current Plan, the typical water use under non-drought conditions is 106.7 GPCD. Under drought conditions, the water use is estimated to increase to 129.4 GPCD based on the 2012 meter data primarily because of an increase in irrigation demands under dry climate conditions. The estimated water use represents a substantial decrease compared to the 2009 Master Plan per capita flow of 154 gpcd. The decrease in water use is reflective of Thornton's various conservation efforts that are highlighted in the 2018 Water Efficiency Plan and have included the following programs to name a few: Residential Water Report Card, City Parks Water Efficiency, Public Outreach and Education, Water-Wise Landscape Installation Incentives, and Landscape Design Consultations.

6. Conclusions

The pseudo population and land use-based approach was selected as the best representation of future water system needs. This approach accounts for the per capita population demands as well as future commercial demands as the Thornton land use changes with a larger percentage of commercial and mixed-use development. At buildout, the ADD water use is estimated to be 39.1 MGD during drought conditions, resulting in higher than typical system demands. Under typical climate conditions, the buildout ADD demand is estimated to be 32.9 MGD. The estimated future system demands translated across the water systems were developed, as shown in Figure 18, based on the water balance (Figure 12). Lastly, the future system demands were distributed based on the population growth and buildout land use (Figure 4) as shown in Figure 19.

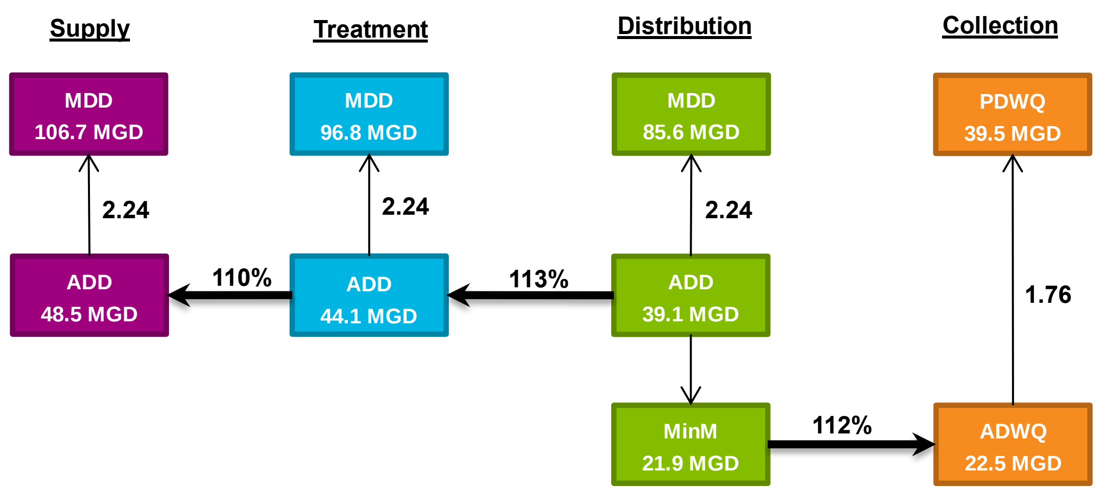

Figure 18. Translated Future System Demands

Based on the pseudo population and land use-based approach, the distribution demands were developed for 2025, 2035 and buildout as indicated in Table 8. The top future users were identified representing the largest areas of residential and/or commercial development. The top 20 future users based on a future system demand of 39.1 MGD are identified in Table 9. The top 10 users reflect approximately 53% of the future water users.

Table 8. Distribution Demands for the 2018 Utility Master Plan

	ADD	MDD
Existing	21.76 MGD	46.60 MGD
2025	26.84 MGD	58.01 MGD
2035	32.92 MGD	71.65 MGD
Buildout	39.12 MGD	85.57 MGD

Table 9. Top 10 Future User Demands

Rank	Name	ADD (gpm)
1	Stonehocker (SFA/MF) btn Colo &Holly/152nd-160th	1608.6
2	Parterre	1572.0
3	North End Station	984.2
4	City Creek	562.7
5	Kortum (east of Parterre & South of 470)	432.5
6	Stonehocker (SFA)	303.6
7	Stonehocker (SF) east most qtr Section	258.2
8	North of North end Station - SFA	230.0
9	Willow Bend MF - north of E-470	230.0
10	Employment Center - North Washington Overlay	192.2
TOTAL		6,373.9

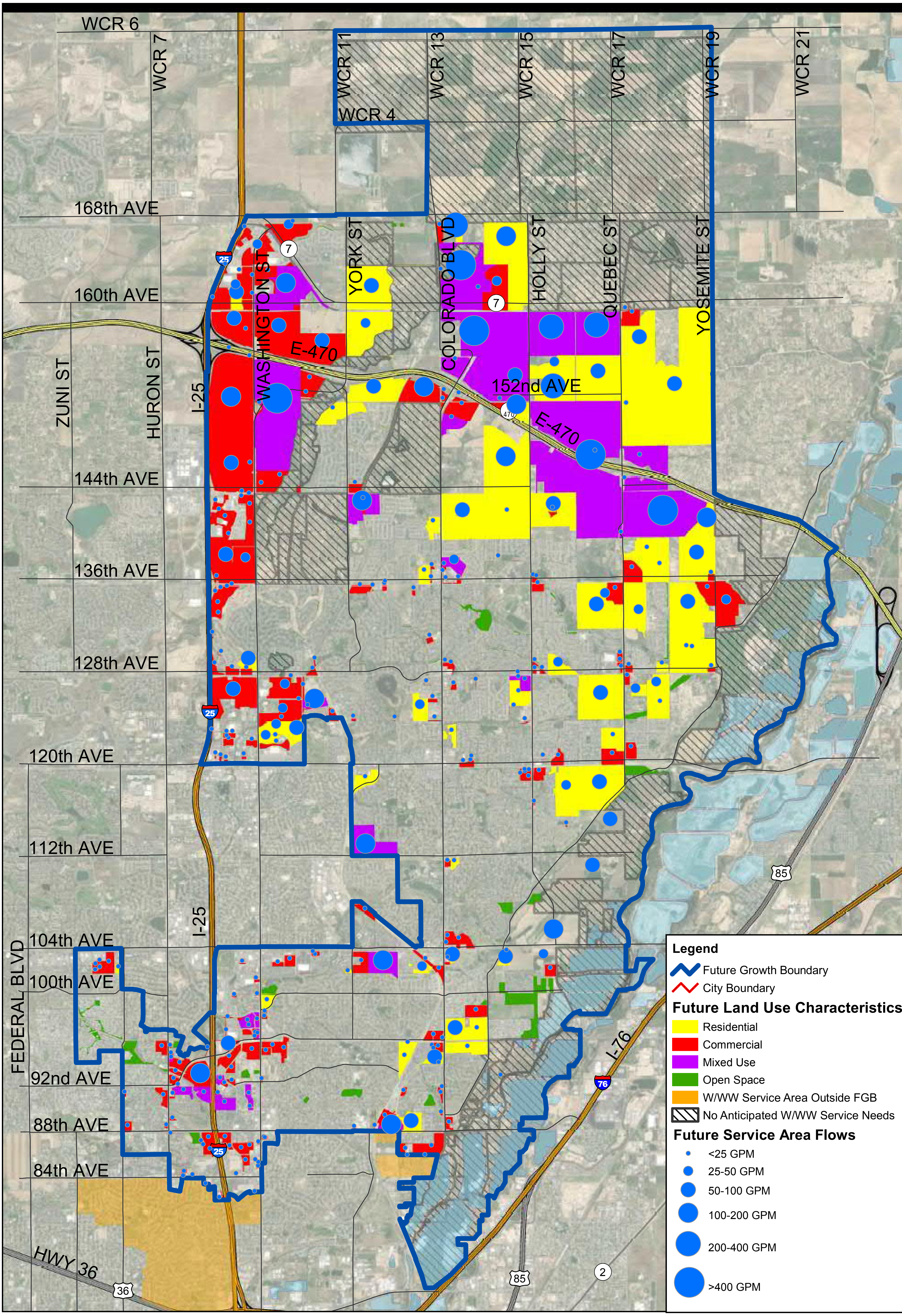

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Figure 19
Allocated Future System Demands

8/8/2018
1 inch = 5,000 feet

\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure 19 - Allocated Future System Demands.mxd

Appendix A Planning Figures

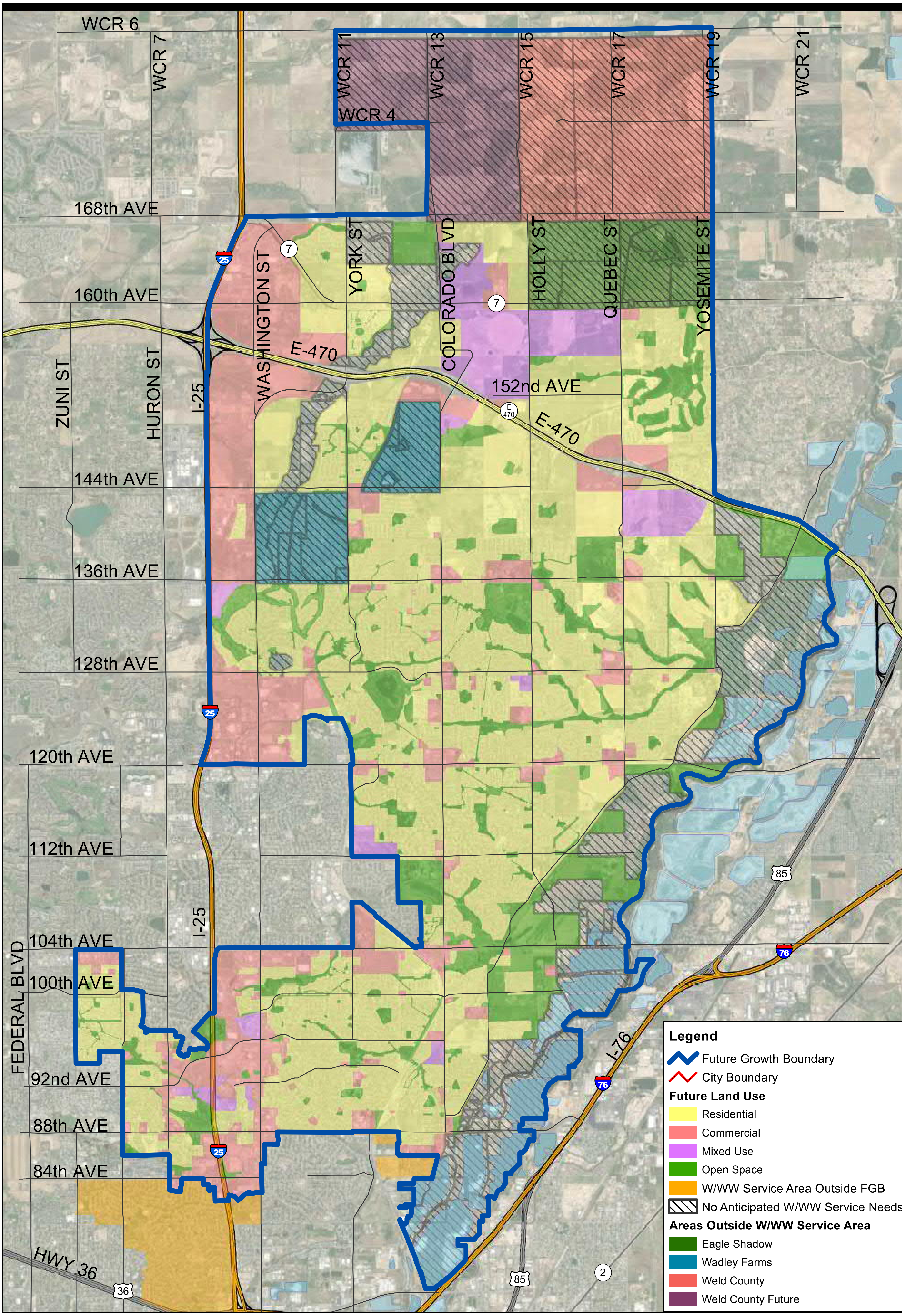

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Figure A.1
Future Land Use

9/6/2018
1 inch = 5,000 feet

\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure A.1 - Buildout Land Use.mxd

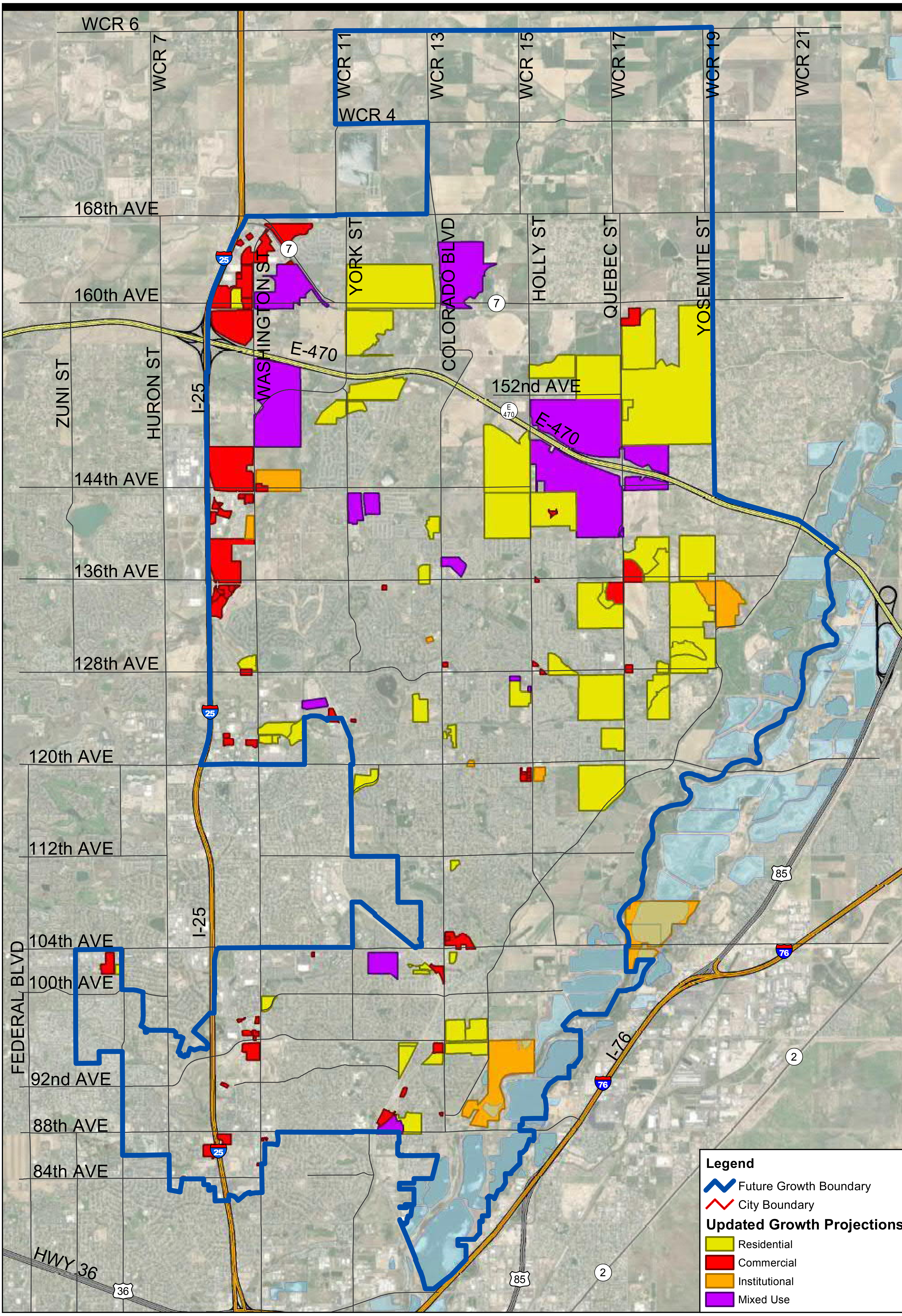

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Figure A.2
Current Development Projects

9/6/2018
1 inch = 5,000 feet

\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure A.2 - Current Growth Projections.mxd

Appendix B Future Growth Distribution

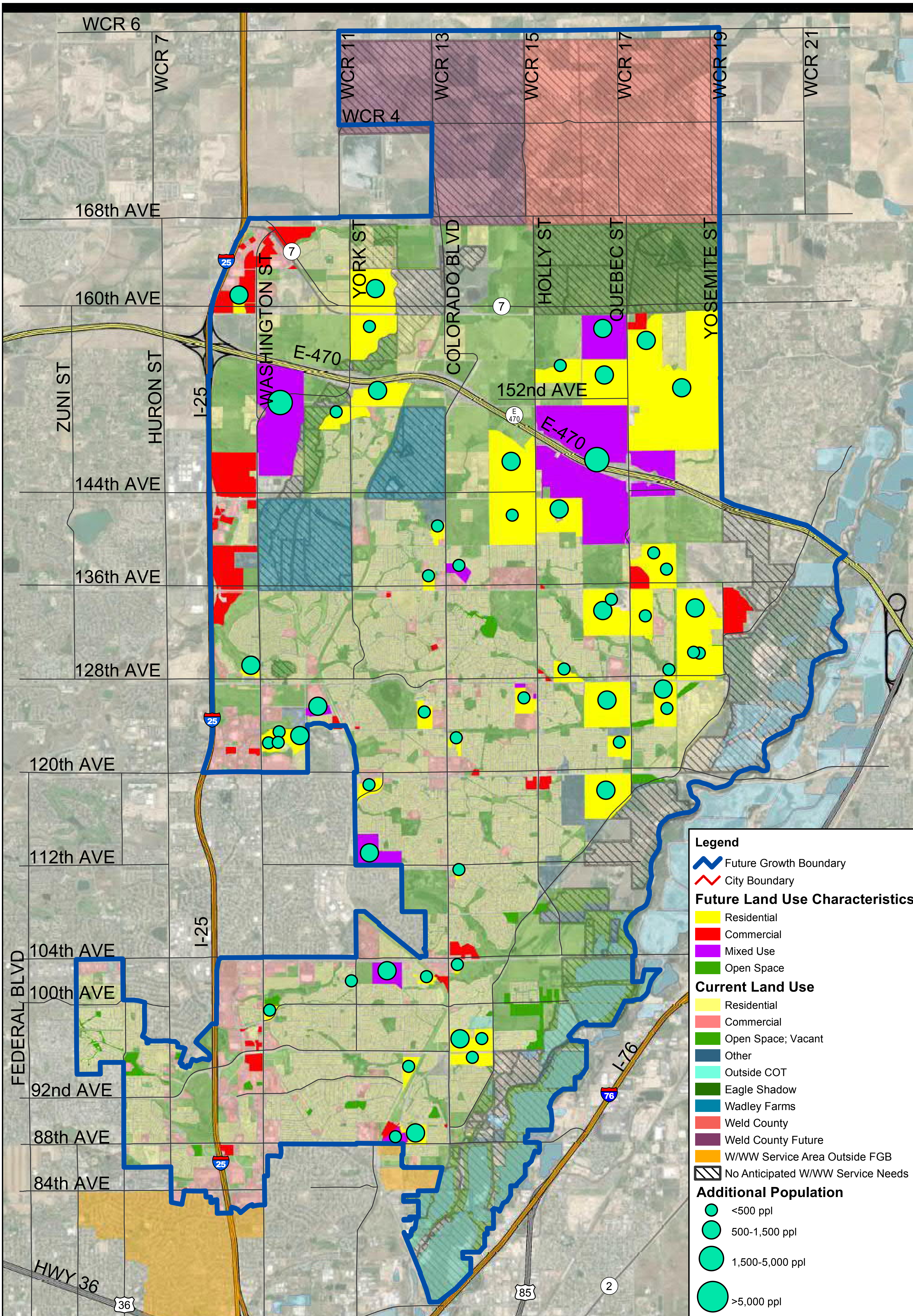

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Figure B.1
Projected 2018-2025
Land Use and Additional Population

9/12/2018
1 inch = 5,000 feet

\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure B.1 - Projected 2025 Land Use and Additional Population.mxd

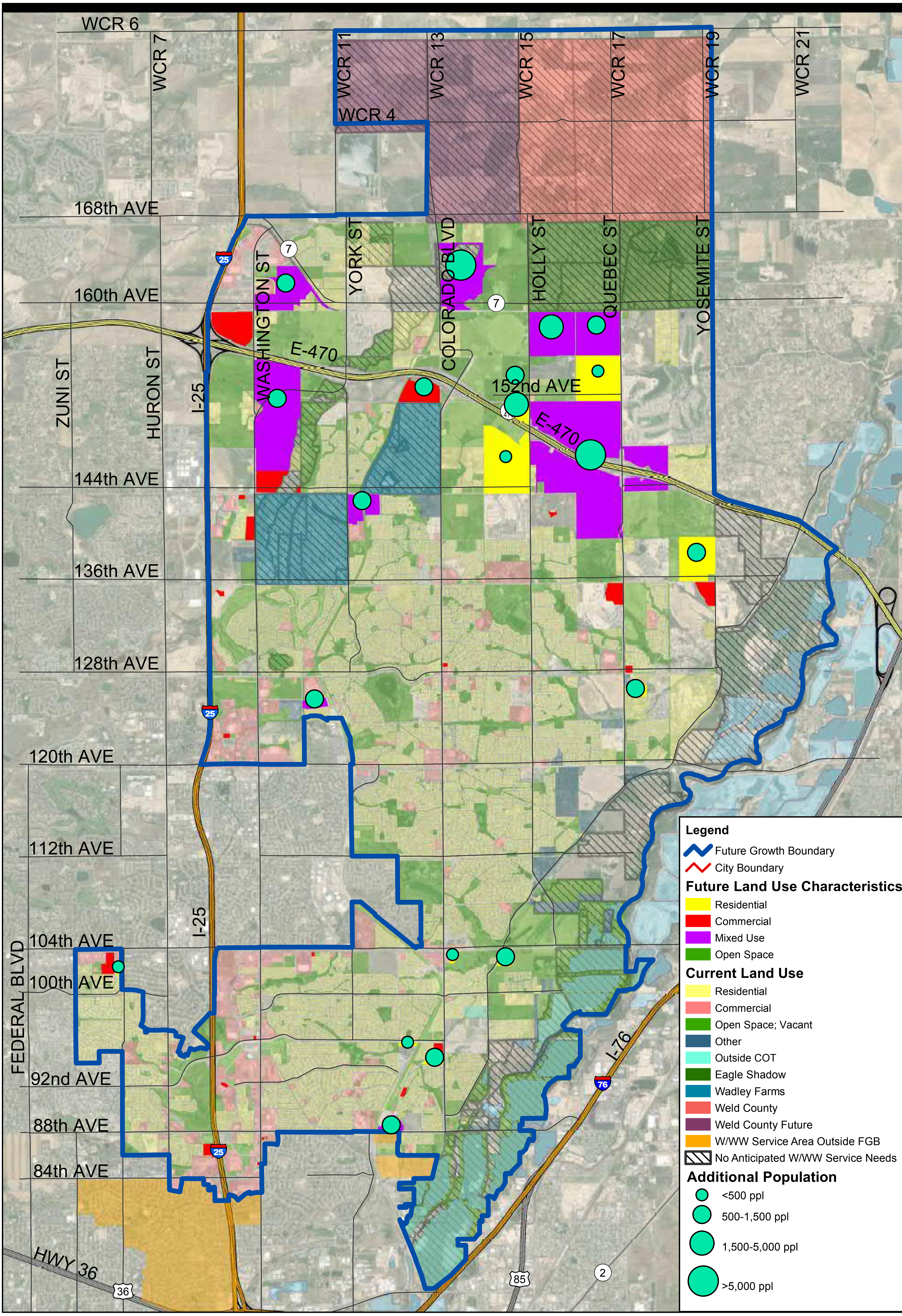

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Figure B.2
Projected 2025-2035
Land Use and Additional Population

9/12/2018
1 inch = 5,000 feet

\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure B.2 - Projected 2035 Land Use and Additional Population.mxd

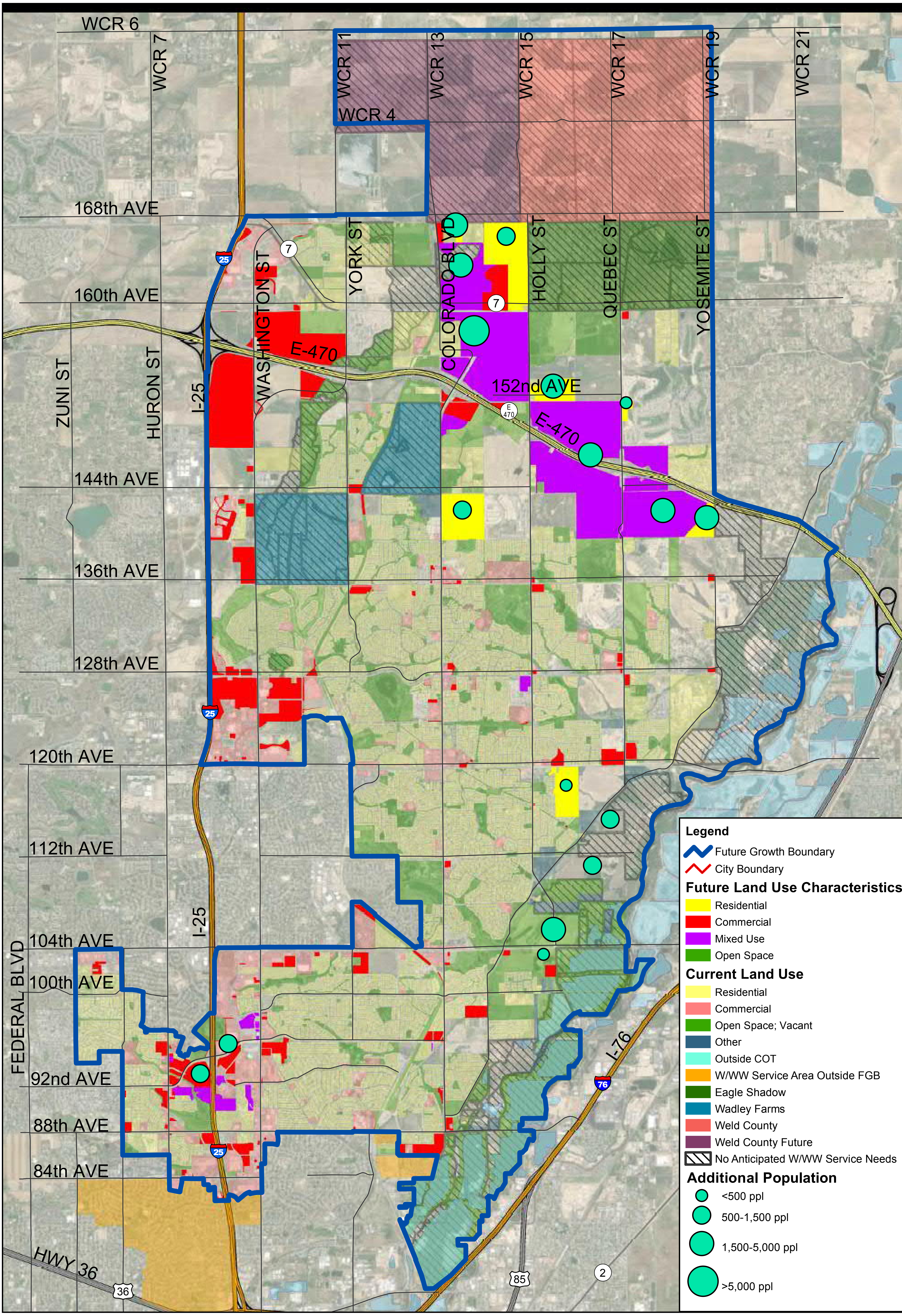

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Figure B.3
Projected 2035-Buildout
Land Use and Additional Population

9/12/2018
1 inch = 5,000 feet

\\Denver.na.aecomnet.com\Denver\DCS\Projects\WTR\60560104_Thornton M\900-CAD-GIS\920-GIS\Planning\Figure B.3 - Projected Buildout Land Use and Additional Population.mxd

Appendix C Water Balance Data

Thornton System Flow Balance Trends (2007-2017) and Projections (2025-2065)

*All values in MGD unless otherwise noted		Historical											Non-Drought	Drought	Projected			Historical Statistic			
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2009-2017	2012	2025	2035	2065	Mean	Max	Min	Std. Dev
Population	City of Thornton[1]	117,873	119,688	120,897	122,105	123,368	121,211	122,643	123,648	132,000	135,000	137,443	137,443		168,437	197,764	238,513				
	Other[2]	16,096	16,096	16,096	16,096	16,096	16,830	16,830	16,830	16,830	16,830	16,830	16,830		16,830	16,830	16,830				
	Federal Heights[3]	11,872	11,737	11,602	11,467	11,557	11,648	11,738	11,829	11,919	12,010	12,100	12,100		12,300	12,800	13,500				
	Total Water Service Area	133,969	135,784	136,993	138,201	139,464	138,041	139,473	140,478	148,830	151,830	154,273	154,273		185,267	214,594	255,343				
	Total Wastewater Service Area	145,841	147,521	148,595	149,668	151,021	149,689	151,211	152,307	160,749	163,840	166,373	166,373		197,567	227,394	268,843				
Climate	Min Month Drought Index	D1.8	D1.0	D0.0	D0.0	D0.0	D0.0	D0.0	D0.0	D0.0	D0.0	D2.0	---	---	---	---	---	0.4	2.0	0.0	0.8
	Average Drought Index	D0.9	D1.2	D0.5	D0.6	D1.2	D2.4	D2.3	D0.0	D0.1	D0.8	D1.0	---	---	---	---	---	1.0	2.4	0.0	0.8
	Max Month Drought Index	D0.4	D1.6	D0.0	D0.0	D0.4	D2.0	D3.0	D0.0	D0.0	D0.0	D0.3	---	---	---	---	---	0.7	3.0	0.0	1.0
Supply[(6)]	Annual Suppy (AC-FT)	---	22,735	21,054	21,688	23,125	24,263	19,578	20,748	21,636	25,582	---	23,591	26,879	25,910	30,012	35,711	*22,268*	*25,582*	*19,578*	*1,860*
	Annual Average (MGD)	---	20.3	18.8	19.4	20.7	21.7	17.5	18.5	19.3	22.8	---	21.1	24.0	23.1	26.8	31.9	*19.9*	*22.8*	*17.5*	*1.66*
	Max Month (MGD)	---	38.4	32.9	34.7	36.9	39.2	31.9	30.1	34.1	39.4	---	37.0	43.6	42.3	49.0	58.3	*35.3*	*39.4*	*30.1*	*3.37*
Treatment (Produced)[(6)]	Annual Production (AC-FT)	21,241	22,942	20,640	21,198	22,090	24,396	19,743	20,297	21,467	23,077	22,519	22,823	27,045	15,161	17,242	20,134	*21,783*	*24,396*	*19,743*	*1,375*
	Min Month (MGD)	5.4	10.9	10.1	9.3	11.4	11.3	8.9	11.3	11.6	11.8	11.8	11.6		13.5	15.4	18.0	*10.4*	*11.8*	*5.4*	*1.90*
	Average Day (MGD)	19.0	20.5	18.4	18.9	19.7	21.8	17.6	18.1	19.2	20.6	20.1	20.4	24.1	24.1	27.6	32.5	*19.5*	*21.8*	*17.6*	*1.23*
	Max Month (MGD)	39.0	40.6	31.9	33.5	36.1	38.2	33.0	33.0	35.6	38.2	38.3	37.4	42.4	44.5	51.3	60.7	*36.1*	*40.6*	*31.9*	*2.94*
	Max Day (MGD)	44.1	44.3	40.4	38.7	39.0	44.1	43.4	38.8	39.1	43.0	42.2	43.5	49.0	51.9	59.8	70.8	*41.6*	*44.3*	*38.7*	*2.37*
Distribution[(6)]	Min Month (MGD)[(4)]	---	---	---	---	---	9.8	10.2	10.2	10.0	10.3	10.4	10.7		12.5	14.1	16.5	*10.2*	*10.4*	*9.8*	*0.21*
	Average Day (MGD)	---	---	---	---	---	19.7	16.7	16.8	17.3	18.6	18.0	18.3	21.8	21.6	24.7	29.1	*17.8*	*19.7*	*16.7*	*1.14*
	Max Month (MGD)	---	---	---	---	---	34.2	30.7	27.6	33.2	35.1	32.5	33.3	38.0	39.6	45.6	53.9	*32.2*	*35.1*	*27.6*	*2.73*
	Max Day (MGD)	---	---	---	---	---	41.9	35.3	35.4	36.7	39.4	38.2	38.8	46.6	42.8	49.3	58.4				
	Peak Hour (PF = 1.5) (MGD)[(5)]	---	---	---	---	---	61.9	52.1	52.2	54.1	58.2	56.4	57.2	69.0	68.4	78.9	93.6	*55.8*	*61.9*	*52.1*	*3.83*
Collection	Average Dry Weather Flow[4]	---	---	---	9.4	8.4	9.2	8.9	9.9	9.4	9.6	9.5	9.9		11.8	13.6	16.0	*9.3*	*9.9*	*8.4*	*0.47*
	Peak Dry Weather Flow[4]	---	---	---	16.3	14.6	15.6	15.6	17.6	16.5	17.5	16.7	17.4		20.7	23.8	28.2	*16.3*	*17.6*	*14.63*	*1.00*

Notes:

1. 2007-2010 based on 2009 Water/Wastewater Systems MP and linear interpolation.
   2010-2016 based on COT planning data.
   2017 based on COT Quarterly Housing & Population Report (4Q'17).
   2017-2065 based on COT planning data.
2. "Other" population includes, Western Hills, Welby, and other unincorporated Adams County. Does not include Federal Heights (sewer service only).
3. Population interpolated between 2009 Water/Wastewater Systems MP, 2010 Census data, and COT planning data.
4. No Steele data for 2009; no Barr data for 2011; 128th Avenue data only avalable for 2017.
5. Assumed Peaking Factor
6. Supply, Treatment, and Distribution includes 1.8 MGD based on historical average flow provided to Westminster/Brighton

Per Capita Thornton System Flow Balance Trends (2007-2017) and Projections (2020-2065)

		Historical											Non-Drought	Drought	Projected			Historical Statistic			
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2009-2017	2012	2025	2035	2065	Mean	Max	Min	Std. Dev
Supply[2]	Annual Average (GPCD)	---	136.3	124.1	127.1	135.2	143.9	112.4	119.1	117.7	138.6	---	124.9	143.9	124.9	124.9	124.9	*128.3*	*143.9*	*112.4*	*10.8*
	Max Month (GPCD)	---	269.7	226.8	237.7	251.6	271.1	215.7	201.2	216.9	247.5	---	228.2	271.1	228.2	228.2	228.2	*237.6*	*271.1*	*201.2*	*24.5*
	Max Month / ADD	---	2.0	1.8	1.9	1.9	1.9	1.9	1.7	1.8	1.8	---	1.8	1.9	1.8	1.8	1.8	*1.9*	*2.0*	*1.7*	*0.1*
Treatment (Produced)[2]	MinM (GPCD)	27.2	66.9	60.7	54.2	68.8	68.8	50.9	67.7	65.8	65.8	64.9	63.4		63.4	63.4	63.4	*60.2*	*68.8*	*27.2*	*12.42*
	ADD (GPCD)	128.1	137.6	121.4	123.9	128.5	144.8	113.5	116.2	116.7	123.9	118.7	120.4	144.8	120.4	120.4	120.4	*124.9*	*144.8*	*113.5*	*9.5*
	Max Month (GPCD)	277.7	285.7	219.5	229.4	245.6	263.5	223.7	222.1	227.3	239.9	236.9	230.6	263.5	230.6	230.6	230.6	*242.8*	*285.7*	*219.5*	*23.0*
	Max Day (GPCD)	316.0	312.9	281.9	266.6	266.9	306.2	298.6	263.6	250.6	271.3	261.9	270.2	306.2	270.2	270.2	270.2	*281.5*	*316.0*	*250.6*	*23.0*
	MDD / ADD	2.5	2.3	2.3	2.2	2.1	2.1	2.6	2.3	2.1	2.2	2.2	2.25	2.1	2.2	2.2	2.2	*2.3*	*2.6*	*2.1*	*0.2*
Distribution[2]	Min Month (GPCD)	---	---	---	---	---	58.2	60.5	59.6	55.0	56.3	55.6	57.5		57.5	57.5	57.5	*57.5*	*60.5*	*55.0*	*2.26*
	Average Day (GPCD)	---	---	---	---	---	129.4	107.1	106.6	104.5	110.4	105.1	106.7	129.4	106.7	106.7	106.7	*110.5*	*129.4*	*104.5*	*9.49*
	Max Month (GPCD)	---	---	---	---	---	235.0	207.1	183.6	211.1	219.3	198.9	204.0	235.0	204.0	204.0	204.0	*209.2*	*235.0*	*183.6*	*17.5*
	Max Day (GPCD)	---	---	---	---	---	267.9	221.7	220.7	217.1	229.7	218.7	221.6	267.9	221.6	221.6	221.6	*229.3*	*267.9*	*217.1*	*19.4*
	Peak Hour (PF = 1.5)[3]	---	---	---	---	---	435.7	360.6	358.9	351.7	371.8	353.8	359.3	435.7	359.3	359.3	359.3	*372.1*	*435.7*	*351.7*	*32.0*
	Max Month / ADD	---	---	---	---	---	1.8	1.9	1.7	2.0	2.0	1.9	1.9	1.8	1.9	1.9	1.9	*1.9*	*2.0*	*1.7*	*0.1*
Collection	Average Dry Weather Flow (GPCD)[1]	---	---	---	62.5	55.8	61.3	58.5	65.3	58.2	58.8	57.1	59.7		59.7	59.7	59.7	*59.7*	*65.3*	*55.8*	*3.1*
	Peak Dry Weather Flow (GPCD)[1]	---	---	---	108.6	96.9	103.9	103.5	115.4	102.5	106.7	100.6	104.8		104.8	104.8	104.8	*104.8*	*115.4*	*96.9*	*5.6*
	PDWQ / ADWQ	---	---	---	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8		1.8	1.8	1.8	*1.8*	*1.8*	*1.7*	*0.0*

Notes:

1. No Steele data for 2009; no Barr data for 2011; 128th Avenue data only avalable for 2017.
2. Per Capita and Peaking Factor excludes 1.8 MGD based on historical average flow provided to Westminster/Brighton
3. Assumed Peaking Factor

Water Distribution and Wastewater Collection System Performance Criteria

Chapter 3

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Utility Master Plan

Project No. 17-467

Water and Wastewater Infrastructure Master Plan

Water Distribution and Wastewater Collection System Performance Criteria

The City of Thornton

Project number: 60560104

AECOM

April 18, 2018

FINAL

Quality information

Prepared by	Checked by	Verified by	Approved by
Fletcher McKenzie Brock Hodgson Jason Coontz	Nathan Walker	Tom Mueller	Richard Hope

Revision History

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Distribution List

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Prepared for:

The City of Thornton

Prepared by:

AECOM
6200 South Quebec Street
Greenwood Village, CO 80111

T: +1 (303) 694 2770
F: +1 (303) 694 3946
aecom.com

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Tables

List of Abbreviations and Acronyms

2009 Plan – City of Thornton 2009 Water and Wastewater Systems Master Plan
ADD – average daily demand
BOD – biochemical oxygen demand
AWWA – American Water Works Association
CMOM – Capacity, Management, Operation, and Maintenance
d/D – maximum depth of flow to diameter of pipe ratio
EQ – equalization
FF – fire flow
fps – feet per second
ft – feet
gpm – gallons per minute
hrs – hours
in – inches
ISO – Insurance Services Office
MDD – maximum daily demand
MinDD – minimum daily demand
MP– master plan
N/A – not applicable
PHD – peak hour demand
PF – peaking factor
psig – pounds per square inch gauge
Thornton – City of Thornton
TM – technical memorandum
WWTP – wastewater treatment plant

1. Introduction

This technical memorandum (TM) describes the performance criteria to be used in evaluating the City of Thornton's (Thornton) existing water distribution and wastewater collection systems, along with identifying future improvements. The criteria have been developed based on a thorough review of the 2009 Water and Wastewater Master Plan (2009 Plan), city, state, and federal standards, and applicable industry standards including those of the American Water Works Association (AWWA).

The criteria for each system are divided into three tiers to recognize differences in the levels of system performance and to provide Thornton flexibility in selecting improvements based on increased levels of service that may result from different criteria. The three tiers can be summarized as follows:

- Tier 1: Criteria that must be met by the system
- Tier 2: Criteria that represent best practice and should be met by the system, but may not be required
- Tier 3: Criteria that are desired and should be met if practical, but are not required

2. Water Distribution System Criteria

Criteria Development

Development of system performance criteria for the water distribution and wastewater collection systems was based on review of the 2009 Thornton Water and Wastewater Systems Master Plan (2009 Plan) , master plans (MPs) of other local municipalities, and various water distribution standards, including:

- The City of Thornton's Standards and Specifications for the Design and Construction of Public and Private Improvements
- The State of Colorado Design Criteria for Potable Water Systems
- ISO Guide for Determination of Needed Fire Flow
- AWWA M50 Water Resources Planning
- AWWA M32 Computer Modeling of Water Distribution Systems
- AWWA M31 Distribution System Requirements for Fire Protection
- AWWA M19 Emergency Planning for Water Utilities

Based on the standards review, selected criteria have been identified in Tables 1, 2, and 3 below. A detailed summary comparing the selected criteria to the 2009 Plan and other standards reviewed during the criteria development is included in Appendix A.

Tier 1 Criteria

The Tier 1 water distribution system criteria are described in Table 1.

Table 1: Tier 1 Water Distribution System Performance Criteria

Performance Parameter	Criteria	Criteria Source
Minimum System Pressure	• 50 psig static • 20 psig for MDD+FF • 40 psig for PHD	Thornton Standard 203.2.B
Maximum System Pressure	• 110 psig	Thornton Standard 203.2.B
Water Main Sizing	• 6-inch minimum diameter water mains where no hydrants are connected to mainline. • 8-inch minimum diameter water mains where hydrants are connected to mainline or when connected to transmission mains greater than 16 inches in diameter. • Water services for non-residential facilities and high density residential areas shall be constructed from looped water mains.	Thornton Standard 203.3
Fire Flow	• Thornton to provide minimum required fire flow (per ISO requirements) for evaluation of the distribution system.	Thornton Standard 203.3.B ISO
Storage Requirements	• Largest single hydrant FF volume within the zone + 25% MDD for EQ + 15% MDD for emergency storage	2009 Plan AWWA M50
Firm Pumping Capacity	• MDD for gravity storage • PHD or MDD plus FF for pumped storage (whichever is greater)	Essential capability associated with foregoing storage requirements
Standby Power	• A true secondary power source required for each pump station, or the ability to mobilize backup power within the timeframe provided by the 15% MDD emergency storage. • Alternatively, if zone has a backup water feed, such as PRVs, which can meet MDD and Minimum System Pressure Criteria	Essential capability associated with foregoing power requirements

Tier 2 Criteria

The Tier 2 water distribution system criteria are described in Table 2.

Table 2: Tier 2 Water Distribution System Performance Criteria

Performance Parameter	Criteria	Criteria Source
Maximum Velocity	• 5 fps for PHD • 10 fps for MDD+FF	Thornton Standard 203.2.B
Maximum Headloss	• ≤ 7 ft/1000 ft for pipes < 16" diameter • ≤ 3 ft/1000 ft for pipes ≥ 16" diameter	AWWA M32
Maximum Water Age	• 20-30 days for MinDD	N/A

Tier 3 Criteria

The Tier 3 water distribution system criteria are described in Table 3.

Table 3: Tier 3 Water Distribution System Performance Criteria

Performance Parameter	Criteria	Criteria Source
Main Failure	• MDD still met at 40 psig minimum service pressure with large transmission main (≥ 10,000 gpm for MDD) out of service	N/A

Resiliency Criteria

Resiliency criteria include important considerations necessary to ensure reasonable reliability of the water distribution system. System performance criteria involving looped water mains, standby power, firm pumping capacity, and meeting required operating capacity with a large transmission main out of service together make up the water distribution system resiliency criteria. These resiliency criteria are included in the Tier 1 and Tier 3 criteria in Table 1 and Table 3.

3. Wastewater Collection System Criteria

Criteria Development

AECOM conducted a review of the 2009 Plan, the MPs of other local municipalities, and various wastewater collection standards, including:

- The City of Thornton's Standards and Specifications for the Design and Construction of Public and Private Improvements
- The State of Colorado Design Criteria for Domestic Wastewater Treatment Works
- Colorado Department of Public Health and Environment Regulation 22: Site Location and Design Approval Regulations for Domestic Wastewater Treatment Works
- Great Lakes—Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (10 States Standards) Recommended Standards for Wastewater Facilities
- USEPA Guide for Evaluating Capacity, Management, Operation, and Maintenance (CMOM) Programs at Sanitary Sewer Collection Systems

It should be noted that the 2009 Plan did not contain any wastewater collection system performance criteria.

Based on the standards review, criteria have been identified in Tables 4 and 5 below. A detailed summary comparing the selected criteria to other standards reviewed during the criteria development is included in Appendix A.

Tier 1 Criteria

The Tier 1 wastewater collection system performance criteria are described in Table 4.

Table 4: Tier 1 Wastewater Collection System Performance Criteria

Performance Parameter	Criteria	Criteria Source
Maximum Dry Weather Flow Capacity	• d/D = 0.7 for pipes < 15" diameter • d/D = 0.8 for pipes ≥ 15" diameter	Thornton Standard 303.2.A (Revised per discussion with Thornton)
Minimum Velocity	• 2 fps	Thornton Standard 303.4.C
Peaking Factor[1]	• $PF = \frac{1.72}{F^{0.295}}$ • Where PF is peaking factor (3.0 max, 2.6 min) and F is average flow in MGD	Thornton Standard 303.3.C (Revised per discussion with Thornton)
Maximum Velocity	• 10 fps	Good practice to reduce turbulence, scour, and corrosion
Maximum Velocity (Force Main)	• 8 fps	Thornton Standard 303.4.C ISO (Revised per discussion with Thornton)
Sewer Main Pipe Sizing	• Minimum diameter 8"	Thornton Standard 303.2.B
Pipe Roughness	• n=0.013	Thornton Standard 303.2.C
Lift Station Firm Capacity	• Peak Hour	By definition, to prevent sewer flooding
Lift Station Backup Power	• Emergency Power is required for 24 hours.	Thornton Standard 303.4.G

[1] AECOM will evaluate this PF equation on a case by case basis.

Tier 2 Criteria

The Tier 2 wastewater collection system criteria are described in Table 5.

Table 5: Tier 2 Wastewater Collection System Performance Criteria

Sewer Size (in)	Minimum Slope	Maximum Slope
Sanitary Sewer Services[1]		
4	2.00%	8.00%
6	1.00%	8.00%
Sanitary Sewer Collection and Outfall Mains		
8	0.40%	5.00%
10	0.28%	4.00%
12	0.22%	3.00%
15	0.15%	2.50%
18	0.12%	2.00%
21	0.10%	1.50%
24	0.08%	1.20%
30	0.06%	0.90%

[1] The entire table is from Thornton Standard 303.2.C

Criteria such as pump run time, pump cycle time, wet well volume, overflow volume, and standby power could be considered Tier 2 criteria. However, AECOM believes these criteria would be more appropriately considered during the development of each individual capital improvement project. Therefore, they are not included in this section.

Tier 3 Criteria

Criteria such as biochemical oxygen demand (BOD) loading and other wastewater characterization parameters could be considered Tier 3 wastewater collection system criteria. However, these criteria are applicable to wastewater treatment plants (WWTPs) and have not been included since there are no WWTPs within the Thornton wastewater collection system. No Tier 3 performance criteria have been identified for the wastewater collection system.

Appendix A - Performance Criteria Comparison Tables

Appendix A presents the water distribution and wastewater collection systems' performance criteria comparison tables. A comparison of the selected water distribution system criteria to those in the 2009 Plan and other local municipalities is detailed in Table A.1. A comparison of the selected wastewater collection system criteria to those of local municipalities is detailed in Table A.2.

Table A.1: Water Distribution System Performance Criteria Comparison Table

	Criterion	Selected Criteria	Criteria Source	2009 Plan	Broomfield MP	Westminster MP	Colorado Springs Utilities MP
Tier 1	Minimum System Pressure	• 50 psig static • 20 psig for MDD+FF • 40 psig for PHD	Thornton Standard 203.2.B	• 40 psig for PHD • 50 psig for PHD in future developments • 20 psig for MDD+FF	• 40 psig static at PHD • 20 psig during FF	• 40 psig • 50 psig recommended • 20 psig during FF	**Non-Emergency**: 50 psig MDD for new customers, 40 psig MDD for existing customers **Emergency:** 40 psig MDD for all, 20 psig MDD+FF for all, 60 psig steady state
	Maximum System Pressure	110 psig	Thornton Standard 203.2.B	100 psig static	125 psig static	120 psig, 100 psig recommended	225 psig, 150 psig preferred
	Water Main Sizing	• 6-inch minimum diameter water mains where no hydrants are connected to mainline • 8-inch minimum diameter water mains where hydrants are connected to mainline or where connected to transmission mains greater than 16 inches diameter • Water services for non-residential facilities and high density residential areas shall be constructed from looped mains	Thornton Standard 203.3	• 6-inch minimum diameter pipes in network • 8-inch minimum diameter branching pipes (dead ends) • 8-inch minimum diameter pipes in high value district • 8-inch minimum diameter for water mains connected to fire hydrants • 12-inch minimum diameter pipes on principal streets in central district • Dead end mains should be minimized by looping whenever practical • Exceptions to this criterion allowed	None specified	None specified	None specified
	Fire Flow	Thornton to provide minimum required fire flow (per ISO requirements) for evaluation of the distribution system	Thornton Standard 203.3.B, ISO	None specified	**Residential**: 1,500 gpm for 2 hrs **Commercial**: 3,500 gpm for 3 hrs	**Residential**: 1,500 gpm for 2 hrs **Commercial**: 3,000 gpm for 3 hrs	

	Criterion	Selected Criteria	Criteria Source	2009 Plan	Broomfield MP	Westminster MP	Colorado Springs Utilities MP
	Storage Requirements	Largest single hydrant FF volume within the zone + 25% MDD for EQ + 15% MDD for emergency storage	2009 Plan, AWWA M50	Fire storage (per ISO) + 25% MDD EQ storage +15% MDD emergency storage	FF + 20% MDD operational storage +100% MDD for emergency storage OR FF + 30% ADD operational storage +100% ADD for emergency storage	FF +20% MDD operational storage + 30% MDD emergency storage	**Non-emergency**: maintain 50% storage at all times **Emergency**: maintain 25% storage at all times
	Firm Pumping Capacity	MDD for gravity storage PHD or MDD plus FF for pumped storage (whichever is greater)	Essential capability associated with foregoing pumping requirements	None specified	None specified	None specified	MDD still met with largest pump out of service.
	Standby Power	A true secondary power source required for each pump station, or the ability to mobilize backup power within the timeframe provided by the 15% MDD emergency storage. Alternatively, if zone has a backup water feed, such as PRVs, which can meet MDD and Minimum System Pressure Criteria	Essential capability associated with foregoing power requirements	None specified	None specified	Pump stations supplying storage water are required to have standby electric power that will fulfil the pumping requirement. If > 50% of storage is met with pumping, a redundant pump station with standby power is required.	None specified
Tier 2	Maximum Velocity	• 5 fps for PHD • 10 fps for MDD+FF	Thornton Standard 203.2.B	• 5 fps PHD • 10 fps during FF	10 fps	• 5 fps • 7 fps during FF	• 7 fps for MDD and MDD+FF for pipes > 16" diameter • 10 fps for MDD+FF for pipes ≤ 16" diameter
Tier 2	Maximum Headloss	• ≤ 7 ft/1000 ft for pipes < 16" diameter • ≤ 3 ft/1000 ft for Pipes ≥ 16" diameter	AWWA M32	• ≤ 10 ft/1000 ft for pipes < 16" diameter • ≤ 3 ft/1000 ft for Pipes ≥ 16" diameter	None specified	None specified	• ≤ 3 ft/1000 ft for pipes ≤ 16" diameter • ≤ 2 ft/1000 ft for pipes > 16" diameter
Tier 2	Maximum Water Age	20-30 days for MinDD	N/A	None specified	None specified	None specified	• < 9 days for future portions of system • < 14 days for current system, < 9 days preferred
Tier 3	Main Failure	MDD still met at 40 psig minimum service pressure with large transmission main (≥ 10,000 gpm for MDD) out of service	N/A	None specified	None specified	None specified	None specified

Table A.2: Wastewater Collection System Tier 1 Performance Criteria Comparison Table

Criterion	AECOM Recommended	Criteria Source	Lakewood MP	Aurora MP
Maximum Dry Weather Flow Capacity	d/D = 0.7 for pipes < 15" diameter d/D = 0.8 for pipes ≥ 15" diameter	Thornton Standard 303.2.A	d/D = 0.8	• d/D = 0.75 for pipes ≤ 12" diameter • d/D = 0.8 for pipes > 12" diameter
Peaking Factor[1]	$PF = \frac{1.72}{F^{0.295}}$ Where PF is peaking factor (3.0 max, 2.6 min) and F is average flow in MGD	Thornton Standard 303.3.C	$Q_{peaked} = KQ_{base}^{\rho}$ where K and ρ are peaking factors of 2.085 and 0.998	$PF = \frac{5}{\frac{population^{0.295}}{1,000}}$ 4 max, 1.7 min
Minimum Velocity	2 fps	Thornton Standard 303.4.C	2 fps	2 fps
Maximum Velocity	10 fps	Good practice to reduce turbulence, scour, and corrosion	10 fps	10 fps
Maximum Velocity (Force Main)	8 fps	Thornton Standard 303.4.C ISO	none specified	8 fps, 5 fps preferred
Sewer Main Pipe Sizing	Minimum diameter 8"	Thornton Standard 303.2.B	none specified	none specified
Pipe Roughness	n=0.013	Thornton Standard 303.2.C	none specified	n=0.011
Lift Station Firm Capacity	Peak Hour	By definition, to prevent sewer flooding	none specified	Peak Flow
Lift Station Backup Power	Emergency Power is required for 24 hours.	Thornton Standard 303.4.G	none specified	none specified

[1] AECOM will evaluate this PF equation on a case by case basis.

Appendix B – Water Distribution System Storage Requirement Comparison Table

Table B.1 – Water Distribution System Performance Criteria Comparison Table

Storage Criteria Alternative	Assumed MDD (MG)	Equalization Storage (MG)	Emergency Storage (MG)	Assumed Fireflow (2,000 gpm for 2 hours)	Total Required Storage (MG)
AECOM Selected Criteria	5.00	1.25	0.75	0.24	2.24
Broomfield MP (Alternative 1)	5.00	1.00	5.00	0.24	6.24
Broomfield MP (Alternative 2)	5.00	1.13	3.76	0.24	5.13
Westminster MP	5.00	1.00	1.50	0.24	2.74
Colorado Springs MP (Non-Emergency)	5.00	2.50	0.00	0.00	2.50
Colorado Springs MP (Emergency)	5.00	1.25	0.00	0.00	1.25

Raw Water, Water Treatment, and Water Quality Update

Chapter 4

Utility Master Plan

Project No. 17-467

Water and Wastewater Infrastructure Master Plan

Raw Water, Water Treatment and Water Quality Update

The City of Thornton

Project number: 60560104

AECOM

October 3, 2018

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Prepared by	Checked by	Verified by	Approved by
Brock Hodgson Amanda Smokoff	Laure Abercrombie	Nathan Walker	Nathan Walker

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Greenwood Village, CO 80111

T: +1 (303) 694 2770
F: +1 (303) 694 3946
aecom.com

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List of Abbreviations and Acronyms

ac-ft – acre-feet
CDPHE – Colorado Department of Public Health and Environment
cfm – cubic feet per minute
EGL – East Gravel Lakes
$FeCl_3$ – ferric chloride
FRICO – Farmers Reservoir and Irrigation Company
FRP – fiberglass reinforced plastic
gpm – gallons per minute
HCl – hydrochloric acid
Hp - horsepower
$KMnO_4$ – potassium permanganate
LAS – liquid ammonia sulfate
LOX – liquid oxygen
MG – million gallon
MGD – million gallons per day
mg/L – milligrams per liter
NaOH – sodium hydroxide/caustic
$NaMnO_4$ – sodium permanganate
NH_3 - ammonia
PAC – powder activated carbon
PCCP – pre-stressed concrete cylinder pipe
pH – potential hydrogen
RWPS - Raw Water Pump Station
SDWA – Safe Drinking Water Act
SF – square feet/foot
Thornton – City of Thornton
TM – technical memorandum
TWP – Thornton Water Project
TWTP – Thornton Water Treatment Plant
UMP – Utility Master Plan
UV - ultraviolet
WBWTP – Wes Brown Water Treatment Plant
WGL – West Gravel Lakes
WSSC – Water Supply and Storage Company
WTP – Water Treatment Plant

1. Introduction and Summary

This technical memorandum (TM) provides an overview of the raw water and water treatment systems for the City of Thornton (Thornton) and provides an update to the water quality requirements for the integrated planning efforts across the water systems. This memo sets the stage for subsequent analysis and identifies the system components that will be evaluated in the Raw Water Master Plan and Water Treatment Master Plan to maintain consistent planning and evaluation with the Water and Wastewater Infrastructure Master Plan. This TM is a bridging document between the Raw Water Supply Master Plan and the Water Treatment Facilities Master Plan as part of the integrated planning approach to the Utility Master Plan (UMP). Analysis for the Raw Water Master Plan will include raw water quality, supply, and infrastructure. The Water Treatment Master Plan will include analysis on water treatment infrastructure and future improvements.

The Thornton raw water system currently diverts water from the South Platte River, Upper Clear Creek, and Lower Clear Creek. Raw water is conveyed from the respective diversion points to three main raw water storage facilities. Water from the South Platte River is conveyed to the East Gravel Lakes (EGL) System, water from Upper Clear Creek is conveyed to Standley Lake, and water from Lower Clear Creek is conveyed to the West Gravel Lakes (WGL) facility. Raw water from storage is then conveyed for treatment to either the Wes Brown Water Treatment Plant (WBWTP) or the Thornton Water Treatment Plant (TWTP) with a combined permitted treatment capacity of 71.5 million gallons per day (MGD) (Table 5).

The raw water and treatment systems are generally sufficient to meet current demands. However, at buildout, the future system average day demand is estimated to be 32.9 MGD during non-drought conditions increasing to 39.1 MGD during dry climatic drought conditions as outlined in the Planning Area and Future Growth Analysis TM. Thornton will need to provide additional water supplies and expand treatment capacity to meet future system demands associated with planned population growth and development. A portion of the additional water supplies will be delivered as part of the Thornton Water Project (TWP), which will convey water from the Cache La Poudre River. Figure 1 shows the projected system population growth and minimum system capacities necessary to meet future demands. Population projections and future system demands were developed as part of the Planning Area and Future Growth Analysis TM.

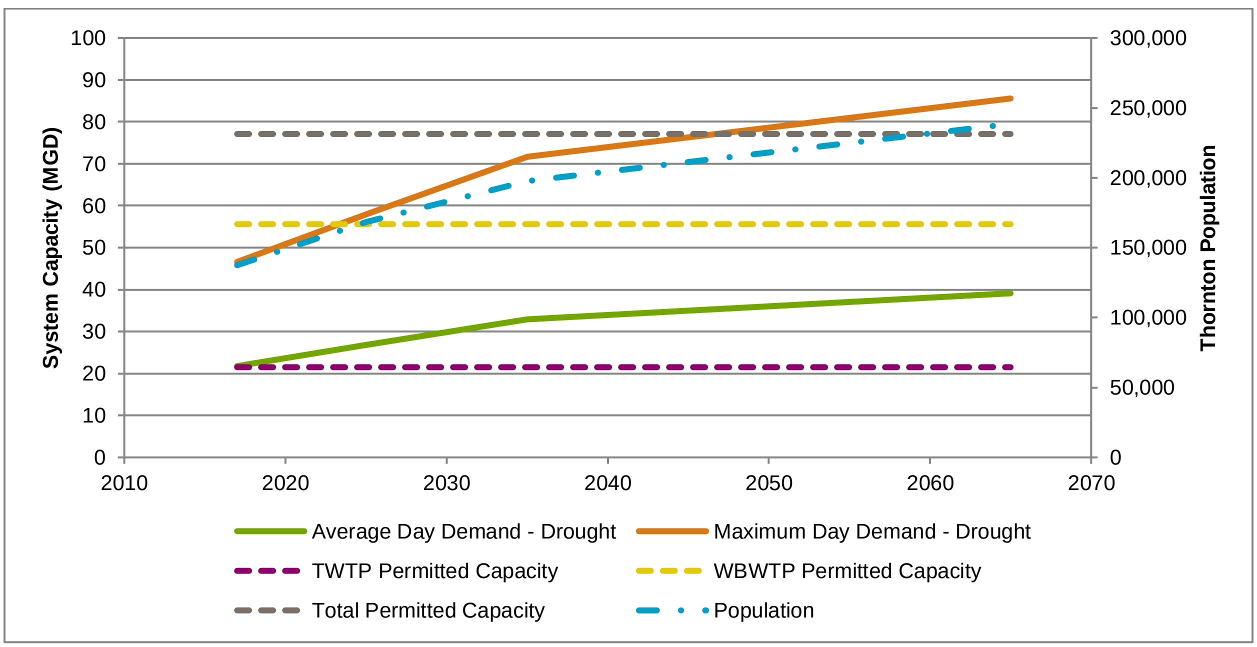


Figure 1. Population Growth versus Treatment Capacity and Annual Water Supply

2. Raw Water System

The current raw water system annual firm yield includes 6,000 acre-feet (ac-ft) from Standley Lake with variable yield from the South Platte River depending on the gravel lake operations. Upon completion of the TWP, the average annual yield specified by Thornton, considering recent drought, will increase by 14,000 ac-ft.

Systems Overview

Thornton diverts water primarily from the Clear Creek, the South Platte River and, in the future, the Cache La Poudre River through various ditches and conveyance pipelines. Thornton is able to divert prorated shares of the water rights in the ditches through stock ownership in ditch companies. The primary mutual ditch companies in which Thornton owns stock include the following:

- Burlington Ditch Reservoir and Land Company
- Colorado Agricultural Ditch Company
- Farmers' High Line Canal and Reservoir Company
- Farmers' Reservoir and Irrigation Company (FRICO)
- Jackson Ditch Company
- Lower Clear Creek Ditch Company
- Mandalay Irrigation Company
- Water Supply and Storage Company
- Wellington Reservoir Company

A summary of the annual firm yield considering recent drought for each component of the raw water system is provided in Table 1, and Figure 2 provides an overview of the current raw water system. Each system is further discussed in the sections below.

Table 1. Thornton Raw Water Supply Overview

Supply	Source	Storage Capacity	Yield
Standley Lake System	Upper Clear Creek	Standley Lake: 11,832 ac-ft	6,000 ac-ft (firm)
WGL System	Lower Clear Creek	Brannan Lakes: 508 ac-ft WGL: 2,840 ac-ft	Varies
East Gravel Lake System	South Platte River	South Tani Reservoir: 7,241 ac-ft East Gravel Lake #4: 2,807 ac-ft South Dahlia Reservoir: 1,777 ac-ft North Dahlia Reservoir: 2,568 ac-ft West Cooley Reservoir: 4,282 ac-ft West-Sprat Platte Reservoir: 983 ac-ft East Cooley Reservoir: 5,100 ac-ft	Varies
TWP	Cache La Poudre River	Rocky Ridge: 2,221 ac-ft WSSC Reservoir #3: 2,297 ac-ft Kluver: 734 ac-ft WSSC Reservoir #4: 614 ac-ft	14,000 ac-ft (average annual)

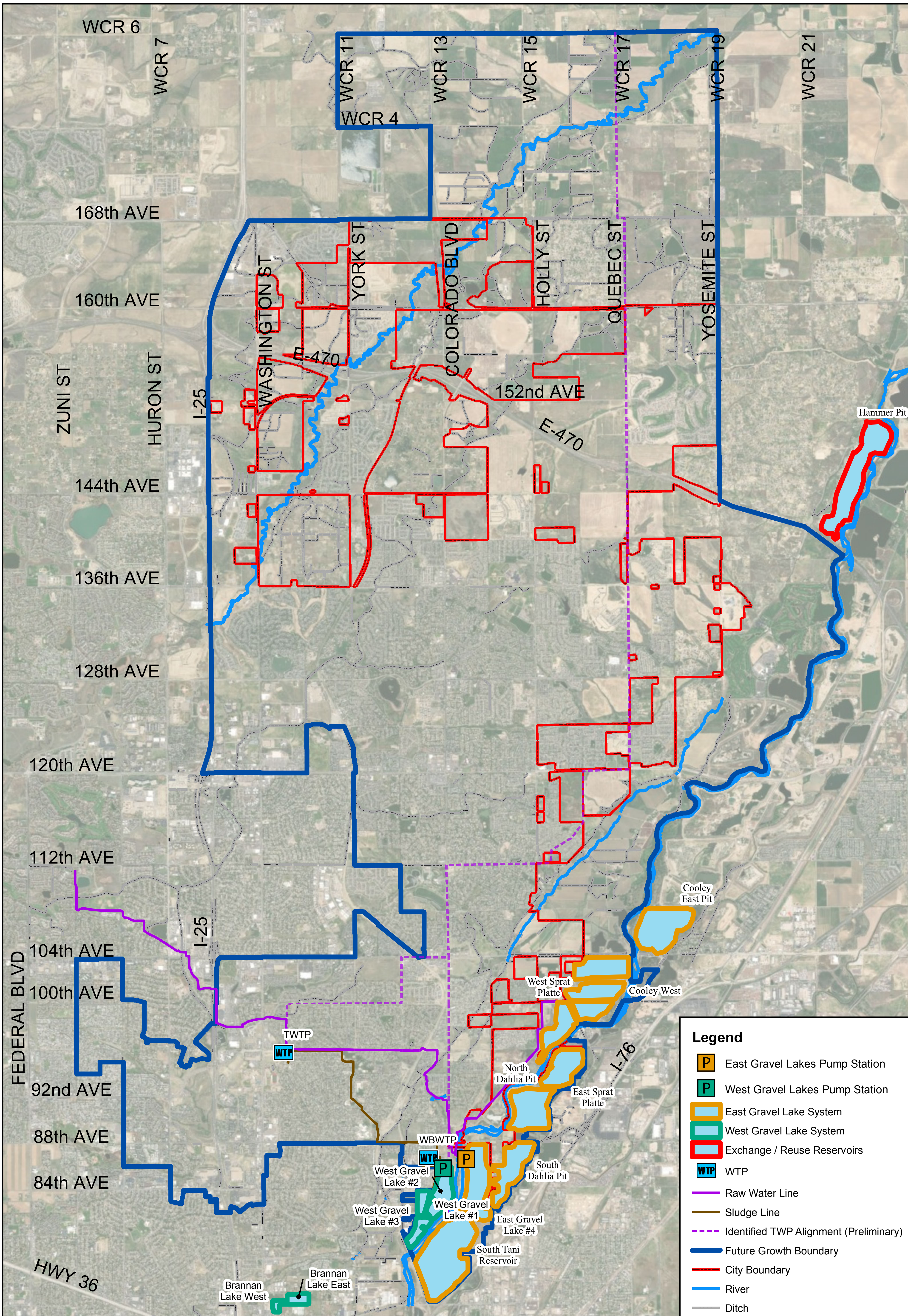
[1]Future Storage Capacity and Average Annual Firm Yield upon completion of TWP

An overview of the raw water systems is discussed below including the source, storage, and conveyance components. The Raw Water Supply Master Plan includes a review of the overall system but does not evaluate Thornton's existing diversion structures, storage capacity, or drought management plan. The raw water system also includes two exchange reservoirs, Rogers Pit and Hammers Pit, which were not included in the raw water system evaluation.

The raw water system evaluation was focused on existing and future improvement projects for the following raw water system components:

- Standley Lake
    - Conveyance from Standley Lake
- WGL
    - Conveyance associated with WGL
    - WGL Raw Water Pump Station (WGL2)
    - Water Quality at WGL
- EGL
    - Conveyance associated with EGL
    - East Gravel Lakes Raw Water Pump Station
    - McKay Raw Water Pump Station
    - Burlington Ditch Operation
    - Water Quality from EGL
- TWP
    - Conveyance within the Future Growth Boundary
    - Source blending with existing water systems

Up to four improvement alternatives will be considered to meet the future system demands; each will require different raw water system improvement projects. These alternatives will be discussed in a separate alternative evaluation TM in the Raw Water Supply Master Plan.



City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

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Figure 2
Thornton Raw Water System Overview

10/1/2018
1 inch = 5,021 feet

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Standley Lake System

Thornton water supplies diverted from Clear Creek are conveyed to Standley Lake for storage via the Farmers' High Line Canal and the Croke Canal and then are delivered to the TWTP. Water can also be divert water from Coal Creek and convey the water in the Kinnear Ditch Pipeline to Standley Lake. The firm annual yield from the Upper Clear Creek System is 6,000 ac-ft, as specified by Thornton. A schematic diagram of Standley Lake and associated supply components is shown in Figure 3.

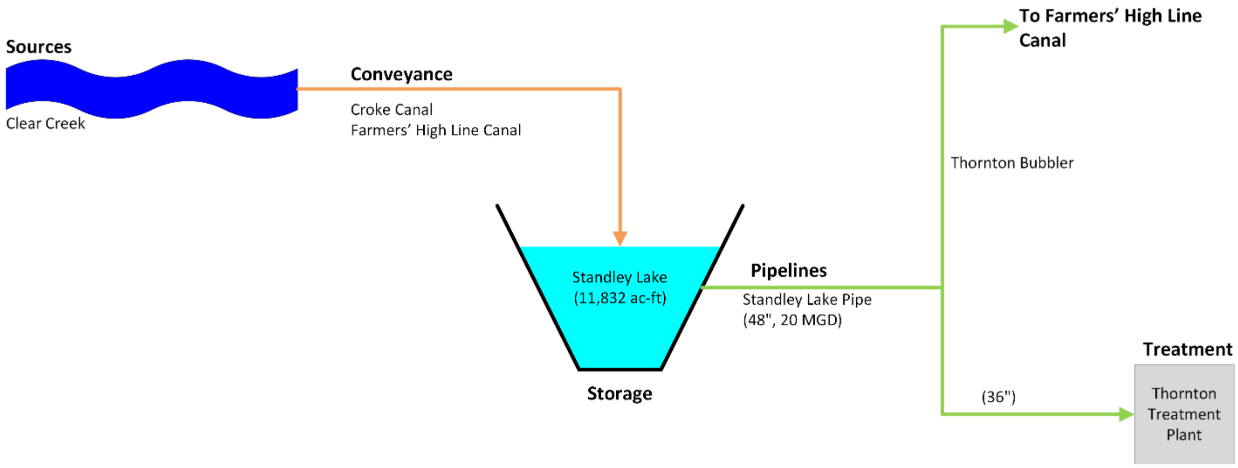

Figure 3. Schematic Diagram of Standley Lake Components

Source

Thornton diverts water from Clear Creek near Golden, Colorado, and conveys the flows through the Farmers' High Line Canal and the Croke Canal to Standley Lake. During the winter, water is diverted from Clear Creek almost exclusively through the Croke Canal, and during the spring, summer, and fall water is diverted into Farmers' High Line Canal.

Storage

Standley Lake is owned and operated by the Farmers Reservoir and Irrigation Company (FRICO) with a total storage capacity of 42,734 ac-ft and provides raw water storage for the cities of Thornton, Westminster, Northglenn, and for FRICO. Thornton controls 11,832 ac-ft (27%) of the overall storage capacity. Standley Lake is located in Jefferson County at West 88th and Kipling Street on Big Dry Creek and receives water from Clear Creek, Ralston Creek, Van Bibber Creek, and Coal Creek.

Conveyance

Water stored in Standley Lake flows by gravity to the TWTP through the Standley Lake Pipeline. The pre-stressed concrete cylinder pipe (PCCP) extends 10.3 miles from the Standley Lake Dam to the TWTP and also continues to the Northglenn Water Treatment Plant. The 48-inch transmission line has a capacity of 20.0 MGD and follows Big Dry Creek for 33,978 feet from the dam to 112th Avenue and Vrain Street and then runs to the east parallel to 112th Avenue. At 112th Avenue and Alcott Street, the pipeline splits into two 36-inch transmission lines, one continuing to the Northglenn Water Treatment Plant (WTP) and one traveling 20,500 additional feet to the TWTP.

Water can also be released from the Standley Lake Pipeline to the Farmers' High Line Canal through the Thornton Bubbler located south of 112th Avenue and Alcott Street.

West Gravel Lakes

Thornton diverts water from Lower Clear Creek to the WGL complex or Brannan Lakes and is ultimately delivered to the WBWTP. The annual yield for the Lower Clear Creek System varies based on the storage and operation of the gravel lakes. A schematic diagram of WGL including associated supply components is shown in Figure 4.

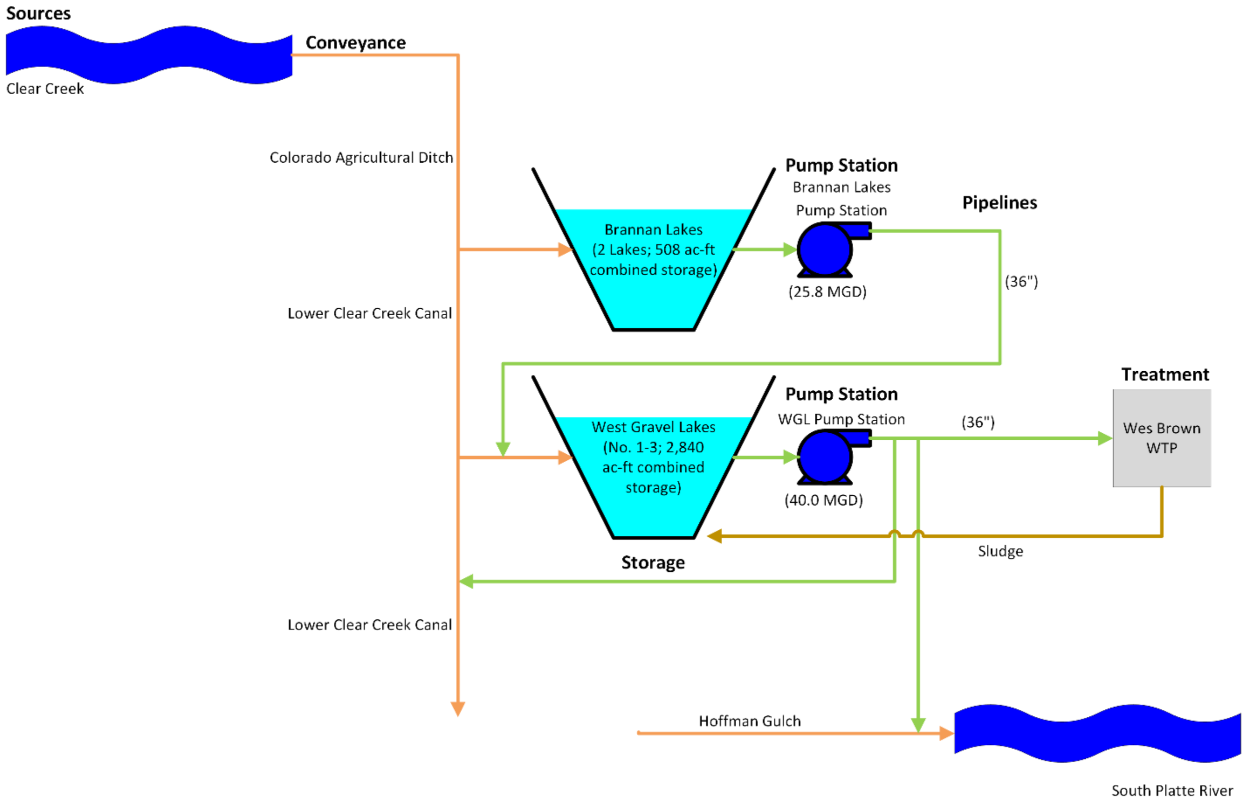

Figure 4. Schematic Diagram of West Gravel Lakes Components

Source

Thornton diverts water from Clear Creek near 68th Avenue and Pecos Street into Lower Clear Creek and Colorado Agricultural ditches using a common headgate. Approximately one-half mile downstream from the headgate, the two ditches diverge and run parallel for approximately ten miles. Thornton uses two headgates on the Colorado Agricultural ditch to deliver the water to storage; one headgate delivers water to the Brannan Lakes and one headgate delivers water into the Lower Clear Creek Canal, which delivers the water to the WGL.

Storage

The WGL storage is composed of five reservoirs grouped into two storage components: Brannan Lakes and WGL. Both storage systems were formerly gravel mining operations now repurposed for raw water storage. The Brannan Lakes consist of two gravel lakes located east of 75th Avenue and Washington Street, separated by a berm. The lakes provide a total operational storage capacity of 508 ac-ft. A wet well located on the berm allows water to pass between the two lakes. The WGL are located south of 88th Avenue and Colorado Boulevard, and the complex consists of three lined gravel pits and provides 2,840 ac-ft of total operational storage capacity. The raw water flows in series through West Gravel Lakes No.1, No.3, and No. 2.

Conveyance

A pump station located between the two Brannan Lakes allows water to be conveyed from the lakes to the Lower Creek Canal for delivery to the WGL Complex. The pump station has a total capacity of 25.8 MGD and conveys water to the Lower Clear Creek Canal via Thornton's 36-inch diversion pipeline, which is then delivered to the WGL.

Water from the WGL can be delivered to the WBWTP through Thornton's 36 inch pipeline, to the Lower Clear Creek Canal, or to the South Platte River (via Hoffman Gulch) by the WGL pump station, which has a total capacity of 22.0 MGD.

Table 2 provides capacity and infrastructure details for the WGL Pump Station.

Table 2. West Gravel Lakes Conveyance Capacity

Water Delivery Location	Installed Capacity	Transmission Line Size
Brannan Lakes Pump Station	25.8 MGD	36-inch
WGL Pump Station	40.0 MGD	36-inch

East Gravel Lakes

Water from the South Platte River is diverted and conveyed through the Burlington Ditch to South Tani Reservoir and East Gravel Lake 4. The raw water is then delivered to the WBWTP for treatment. The annual firm yield of the EGL varies based on the storage and operations of the gravel lakes. A schematic diagram of the EGL and associated supply components is shown in Figure 5.

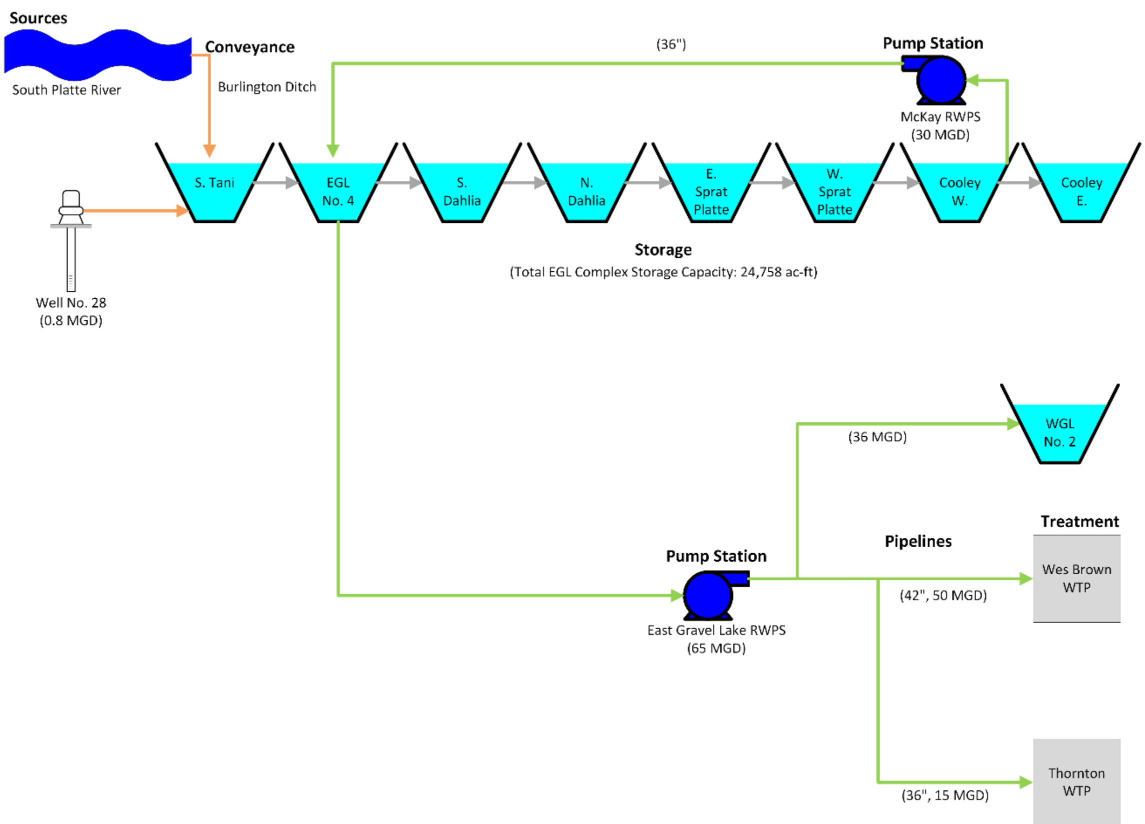

Figure 5. Schematic Diagram of East Gravel Lakes Components

Source

Water is primarily supplied from the South Platte River and diverted through the Burlington Ditch, which delivers water to the South Tani Reservoir. Additionally, Thornton owns eleven wells that deliver water to the South Platte System Reservoirs. Well No. 28 has the capacity to deliver 0.8 MGD to South Tani Reservoir. There are ten alluvial wells (constructed in 2002) located adjacent to the North Dahlia Reservoir and the East Sprat Platte Reservoir that discharge water into the South Dahlia Reservoir.

Storage

With the addition of East Cooley Reservoir, the EGL Complex provides 24,758 ac-ft of storage. This complex consists of ten former gravel mining pits that were converted into raw water storage facilities. The storage is made up of: South Tani Reservoir, East Gravel Lake #4, South Dahlia Reservoir, North Dahlia Reservoir, East Sprat Platte Reservoir, West Sprat Platte Reservoir, West Cooley Complex (three reservoirs), and East Cooley Reservoir.

Raw water delivered to the East Gravel Lakes flows in series through the South Tani Reservoir, East Gravel Lake No. 4, South Dahlia Reservoir, then to North Dahlia Reservoir. The series of lakes serve as pre-sedimentation basins for water diverted in the Burlington Ditch.

Conveyance

Water from EGL can be delivered to the WBWTP at up to 50.0 MGD and TWTP at 16.0 MGD via the EGL Raw Water Pump Station (RWPS) which has a total capacity of 65.0 MGD as shown in Figure 5. Water can be returned to EGL No. 4 from downstream reservoirs via the McKay Pump Station at a rate of 30.0 MGD Water can also be delivered from the RWPS to WGL No. 2 at a rate of 36.0 MGD. The capacity of the pump stations and conveyance are indicated in Table 3.

Table 3. East Gravel Lakes Raw Water Conveyance Capacity

Water Delivery Location	Installed Capacity	Transmission Line Size
East Gravel Lake Pump Station to WBWTP	50 MGD	42 inch
East Gravel Lake Pump Station to TWTP	16 MGD	36 inch
McKay Pump Station to EGL No. 4	30 MGD	36 inch

Thornton Water Project

The TWP was initiated to help meet future system demands, improve raw water quality, and provide a more robust raw water supply system. The TWP will deliver an average annual yield 14,000 ac-ft from the Cache La Poudre River basin to Thornton in 2065. A preliminary hydraulic and economic analysis has been prepared for the TWP identifying potential alignments, system capacity, and cost (CH2MHILL, 2017), which was used as the basis for this section. A schematic diagram of the TWP is shown in Figure 6.

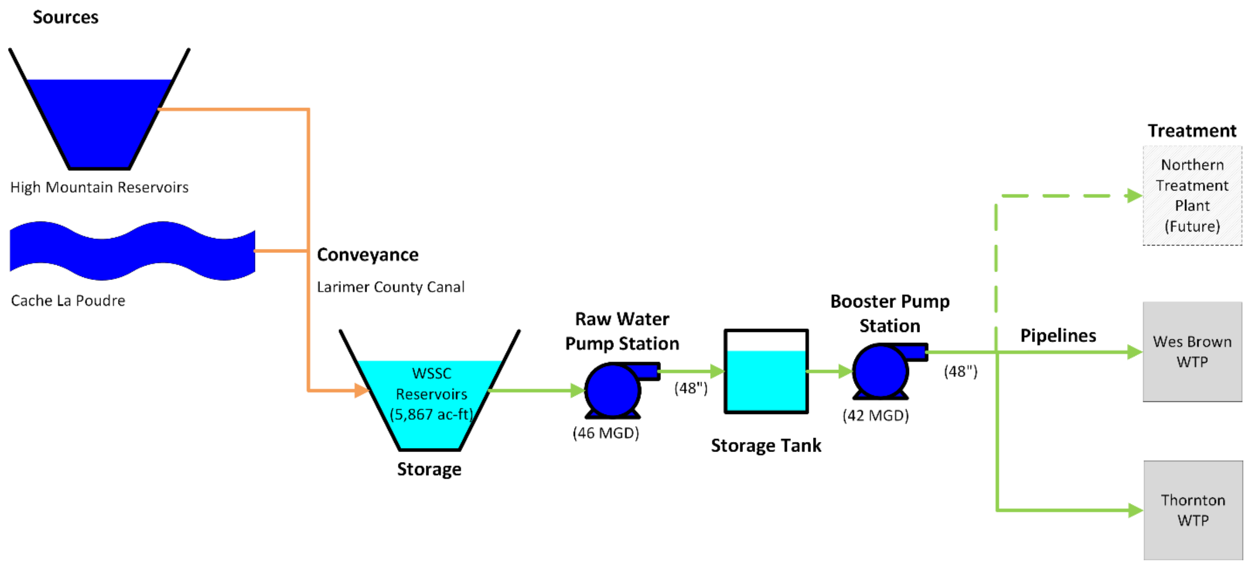

Figure 6. Schematic Diagram of the Thornton Water Project

Source

The TWP is supplied from the Cache La Poudre River via the Larimer County Canal to WSSC shareholders. To accomplish this, Thornton purchased a total of 283.345 shares in the Water Supply and Storage Company (WSSC). The source water operations will vary depending on the shareholder needs and amount of water available. Water can be diverted at the Larimer County Canal when WSSC water rights are in priority or if water is being released from the upstream reservoirs.

Storage

The TWP includes storage obtained based on Thornton's WSSC ownership and agreements for the use of excess storage capacity. The total pro rata Thornton share of the storage will be 5,867 ac-ft distributed in the Rocky Ridge Reservoir, WSSC Reservoir #3, Kluver Reservoir, and WSSC Reservoir #4. WSSC diverts flows from the Cache la Poudre River for storage and later use when water rights are in priority. The TWP also includes first right to 6,615 ac-ft excess storage in the reservoirs, if available, which would allow Thornton a total of 12,482 acre-feet of storage depending on WSSC operations.

Conveyance

The raw water will be conveyed from either WSSC Reservoir #4 to Thornton through a single proposed 48-inch diameter pipeline. The pipeline is anticipated to run east through Larimer County and then south primarily along Weld County Road 13 and Weld County Road 17, which ultimately turns into Quebec Street. In order to convey the water, it is anticipated that two pump stations and a storage tank will be required, with a total capacity of 40 MGD for each pump station. One of the pump stations would be located at the storage reservoir, the storage tank would be located in between the pump stations and a booster pump station would be necessary in Firestone, Colorado. The proposed pump station capacities are identified in Table 4.

Table 4. Thornton Water Project Raw Water Conveyance Capacity

Water Delivery Location	Installed Capacity	Firm Capacity	Transmission Line Size
TWP Raw Water Pump Station	46 MGD[1]	40 MGD	48-inch
TWP Booster Pump Station	42 MGD[1]	40 MGD	48-inch

[1]Subject to final design

3. Water Treatment Update

System Overview

Thornton operates two water treatment facilities, the WBWTP and the TWTP. The permitted and designed capacity of each treatment plant is presented in Table 5. At buildout, additional treatment capacity will be necessary to meet the water distribution system demands associated with planned growth.

Table 5. Current Capacity of Water Treatment Facilities

Water Treatment Facility	Permitted Capacity	Firm Design Capacity[1]
WBWTP	55.6 MGD	41.0 MGD
TWTP	21.5 MGD	20.0 MGD
TOTAL	**77.1 MGD**	**61.0 MGD**

[1]The Firm Design Capacity from Colorado Department of Public Health and Environment (CDPHE) Public Water System Record of Proof Waterworks. The actual Firm Capacity is being reviewed and defined as part of the water treatment evaluation in the Water Treatment Facilities Master Plan. The number provided here is an estimate. Actual capacity varies based on influent water quality and temperature.

The Water Treatment Facilities Master Plan focuses on the evaluation of existing and future improvement projects for the following water treatment facility components:

- Existing Operations
    - WBWTP

- Future Requirements
  - WBWTP
  - TWTP
  - Possible Northern Water Treatment Plant

The existing TWTP will be replaced with a new facility within the next couple of years and, therefore, has been excluded from existing operations evaluation.

Like the Raw Water Supply Master Plan, the future water treatment facility improvements will consider up to four alternatives to meet the future system demands. Each alternative will require different water treatment facility improvements. These development and evaluation of these alternatives will be discussed in a separate alternative evaluation TM within the Water Treatment Facilities Master Plan.

Wes Brown Water Treatment Plant

The WBWTP, located at 3651 East 86th Avenue, was constructed in 1964. Initially, the WBWTP had a capacity of 30 MGD, but has since been upgraded to a permitted capacity of 55.6 MGD. However, the actual firm capacity of the plant is limited to 41.0 MGD due to influent water quality limiting the filtration capacity of the membrane filters. A process flow diagram for the treatment plant is depicted in Figure 7.

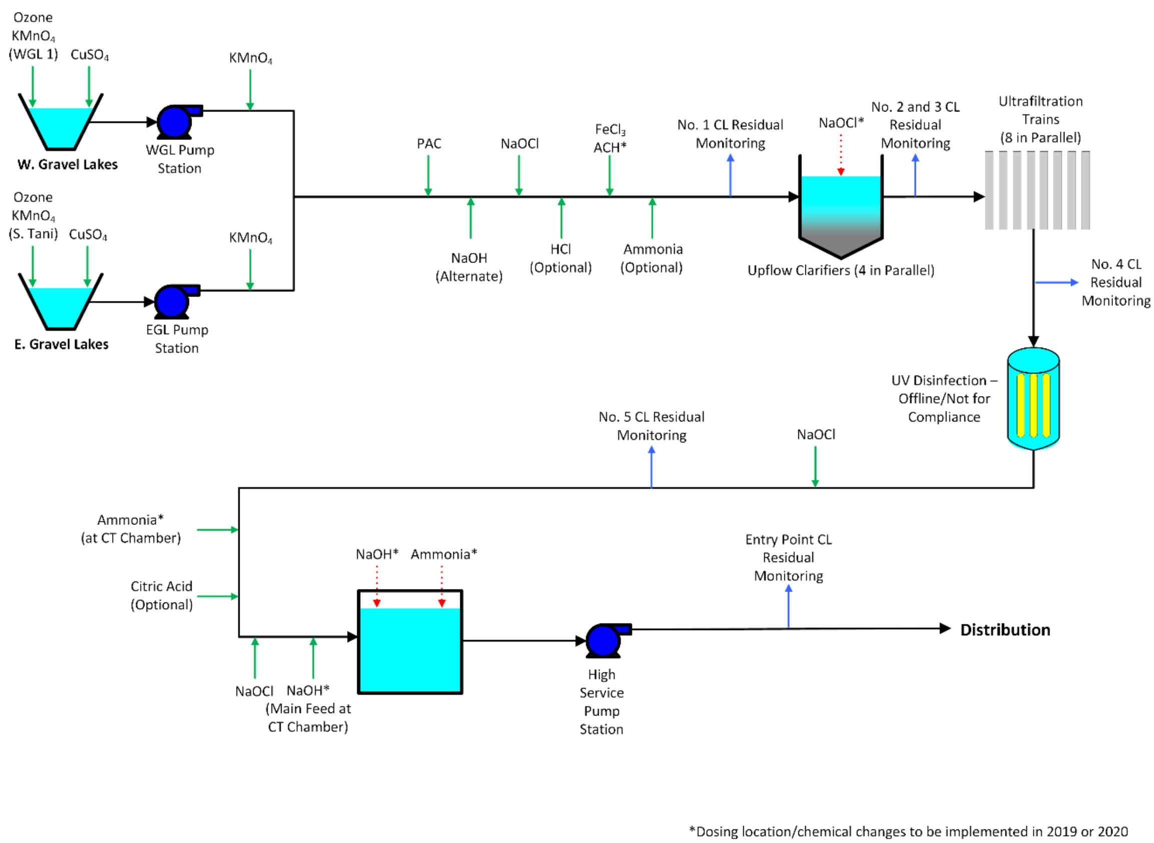

Figure 7. WBWTP Process Flow Diagram

The WBWTP draws water from the WGL and EGL and utilizes upflow clarifiers and ultrafiltration as the primary treatment processes. Pre-treatment at the facility includes chemical additions for iron removal, manganese removal, and taste and odor control. The WBWTP houses an ultraviolet (UV) disinfection system; however, it is currently offline and not used for Safe Drinking Water Act (SDWA) compliance. Water treated at the plant is pumped through a high service pump station to distribution. A general overview of the treatment processes is provided in Table 6.

Table 6. WBWTP Process Descriptions

Treatment Process	Description[1]

Raw Water	EGL
	- EGL Pump Station
	    - Eight raw water pumps
	WGL
	- WGL Pump Station
	    - Six raw water pumps
	Thornton - Wes Brown Interconnect
	- Gravity flow pipeline

Pre-Treatment and Chemical Feeds	Potassium Permanganate (Dry $KMnO_4$) - Used for iron and manganese removal - One ½ horsepower (Hp) mixer, solution tank, and chemical feed pump at each raw water pump station Powder Activated Carbon (PAC) - Used for taste and odor control - One 66,000 gallon concrete slurry tank, 26.6 Hp mixer, and two diaphragm chemical meter pumps located after the pump stations prior to the upflow clarifiers Hydrochloric Acid (30% HCl) - Used for pre-filtration for potential hydrogen (pH) adjustment for optimization of coagulation and post-filtration pH adjustment for finished water and disinfection contact time - Primary injection location is upstream of the upflow clarifiers - Two chemical feed pumps, two 3,000 gallon fiberglass reinforced plastic (FRP) chemical storage tanks Sodium Hydroxide/Caustic (32-50% NaOH) - Used for pH elevation and corrosion control. Softened water to be used as carrier water. - Primary injection location: Prior to contact tank - Secondary injection location: Prior to upflow clarifiers - Two chemical feed pumps and two 11,630 gallon FRP tanks with curb secondary containment
Flocculation / Sedimentation	Coagulant Feed: Ferric Chloride (38-40% $FeCl_3$) - Three chemical feed pumps, three 25,000 gallon FRP tanks with curb secondary containment - Coagulant is injected prior to the upflow clarifiers Sedimentation: Upflow Clarifiers - Four upflow clarifier trains with tube settlers (Dimensions: 65-foot diameter x 17-foot depth) - Each upflow clarifier has a 0.5 MGD capacity
Filtration	Eight Parallel GE Zenon 500D Submerged Membrane Ultrafiltration Trains - Train #1: 10 membrane cassettes with 60 membrane modules each (340 square feet [SF] per module) - Train #2-7: 10 membrane cassettes with 50 membrane modules each (440 SF per module) - Train #2-7: 10 membrane cassettes with 50 membrane modules each (440 SF per module) - Train #8: 5 membrane cassettes with 50 membrane modules each (440 SF per module) Eight Permeate Pumps - Seven permeate pumps for Trains #1-7: 5,660 gallons per minute (gpm) capacity each - One permeate pump for Train #8: 1,785 gpm capacity Five Membrane Blowers - Three positive displacement blowers for Trains #1-7: 125 Hp, 4,000 cubic feet per minute (cfm) capacity - Two positive displacement blowers for Train #8: 50 Hp, 2,000 cfm capacity
Primary Disinfection	- 12.5% Sodium Hypochlorite injected at the plant inlet piping upstream of the upflow clarifiers - Primary disinfection credit is obtained through the upflow clarifiers, membrane filter basins, process piping. - As part of the 2017 Carollo Alternative Coagulation Study, it was determined hypochlorite also assists in the oxidation of manganese. Therefore, in 2019 or 2020 it is planned to dose approximately 2 mg/L of hypochlorite ahead of the clarifiers and 0.5 mg/L in the clarifier troughs. This will be accomplished using four chemical feed pumps and softened carrier water for clarifier trough dosing.
Secondary Disinfection	Chloramine Disinfection - Three aqueous ammonia (29%) chemical feed pumps, One 8,000 gallon FRP chemical storage - Ammonia is injected downstream of post-filtration hypochlorite injection and upstream of the 3 MG clearwell to establish residual disinfectant

[1]Data obtained from CDPHE Public Water System Record of Approved Waterworks (1/31/2017). CDPHE is reviewing new designs and coagulant/corrosion study to be completed and submitted in 2018/2019.

Thornton Water Treatment Plant

The TWTP was originally constructed for the Northwest Utilities Company in 1953, and purchased by Thornton in 1963. The TWTP will be decommissioned and a new plant constructed in the next couple of years with a completely new process configuration capable of providing a permitted capacity of 21.5 MGD and a firm treatment capacity of 20.0 MGD. A process flow diagram showing the new treatment plant processes is depicted in Figure 8. The plant is currently under construction with an anticipated completion date of 2020.

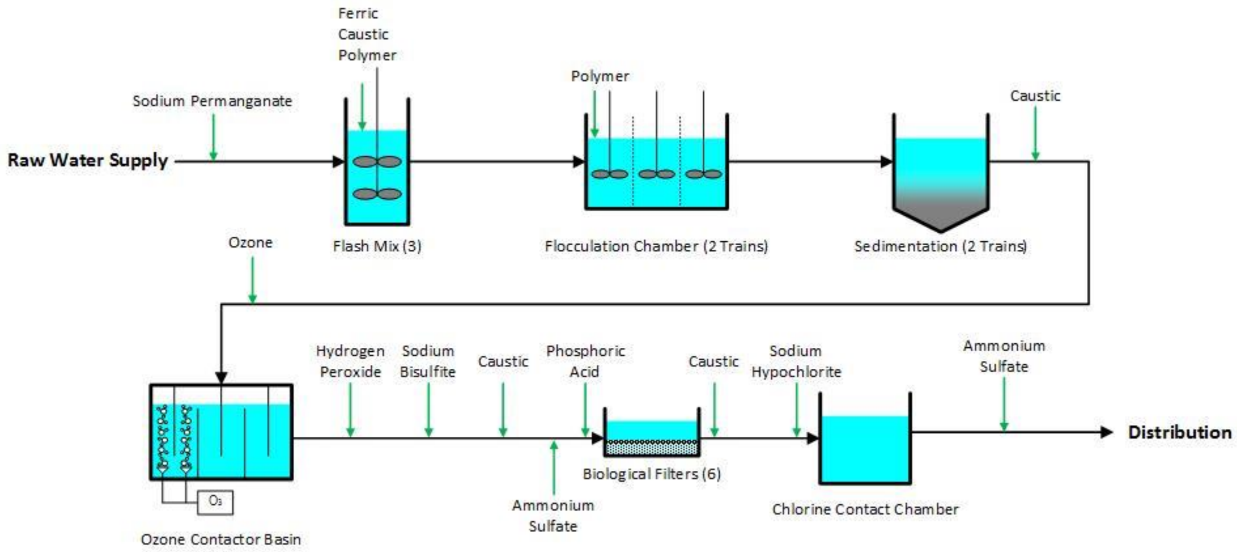

Figure 8. TWTP Process Flow Diagram

The TWTP treats water supplied from Standley Lake using traditional flocculation/sedimentation and granular media filters as the primary treatment process. Water treated at the plant will flow via gravity to Clearwell 2, within the distribution system. A general overview of the treatment processes is provided in Table 7.

Table 7. TWTP Process Descriptions

Treatment Process	Description[1]
Raw Water	Standley Lake - 20 MGD (Gravity Flow) East Gravel Lake No. 4 - 15 MGD via EGL Pump Station and Interconnect TWP from Northern Colorado (Future) - Initially 5 MGD via TWP Pump Station(s) - Buildout 20 MGD via TWP Pump Station(s)
Pre-Treatment	Sodium Permanganate ($NaMnO_4$) - Used for Iron and Manganese Removal - Injection Locations: Raw Water Systems - Storage: Two 2,700 gallon stainless steel tanks (providing 25 days of storage at maximum flow) - Dose: 0.1-2.5 milligrams per liter (mg/L) Caustic Soda (Caustic) - Used for pH Adjustment - Injection Locations: Standley Lake flash mix, settled water, filter influent, and filter effluent
Flocculation / Sedimentation	Coagulant Feed - Ferric Sulfate or Ferric Chloride - Injection Location: Flash Mix via three peristaltic metering pumps - Storage: Two 14,100 gallon FRP storage tanks - Dose: 40% Ferric Chloride or 50% Ferric Sulfate dosed at 5-50 mg/L ferric chloride/sulfate

	Flash Mix - Two 16.09 MGD flash mixers Flocculation - Two 16.09 MGD flocculation trains, with three stages per train, and three flocculators per stage Sedimentation - Two 16.09 MGD sedimentation trains with Lamella plate settlers
Ozone	Ozone - Used for oxidation of taste and odor causing compounds - Supply: Liquid-oxygen (LOX) system consisting of one storage tank and three vaporizers, ozone generation system consisting of three on-site ozone gas generators, one nitrogen boost system and a cooling water system - Injection Location: Combined settled water prior to the ozone contactor basin - Dose: 0.75-4 mg/L Ozone Contactor Basin - One 135,625 gallon contact basin Hydrogen Peroxide - Used for quenching excess ozone residuals and decrease bromate formation, AOC generation, and oxidize MIB and Geosmin - Injected at end of ozone contact basin - Two 2,700 gallon stainless steel tanks - Solution Strength: 34% - Dose 0.5-5.0 mg/L Sodium Bisulfate - Used for dechlorination and residual ozone quenching - Injected at end of ozone contact basin - 250 gallon totes - Solution Strength: 38% - Dose 0.1-1.0 mg/L
Filtration	Biological Filters - Six, granular activated carbon media biological filters (624 SF per filter) Filter Drain Pump - One, 2 Hp pump with 355 gpm capacity
Primary Disinfection	Chlorine Contact Chamber - 1,020,000 gallon chlorine contact chamber Sodium Hypochlorite for Disinfection - Injected at the chlorine contact chamber entrance baffle wall
Secondary Disinfection	Chloramine Disinfection - Liquid Ammonia Sulfate (LAS) solution of 38% via three disinfection pumps - Dosed for chloramination injected at chlorine contact chamber exit weir, stored onsite in two 4,000 gallon chemical storage tanks. - Dose 0.5-1.5 mg/L NH_3

[1]Data obtained from Thornton Water Treatment Plant Replacement Project – Basis of Design Report (Burns and McDonnell, 2017)

4. Water Quality Update

A water quality update was included as part of the Water Treatment Facilities Master Plan Regulatory Compliance Evaluation TM. The Regulatory Compliance Evaluation TM evaluates regulation updates (2016-present), the Contaminants Candidate List, and potential regulatory impacts at the WBWTP.

5. References

The following references were used to compile the data in this report:

- *2009 Water and Wastewater Systems Master Plan*, The Engineering Company, 2010.
- *Thorton Water Project Hydraulic and Economic Analysis*, CH2MHILL, 2017.
- *Planning Area and Future Growth Analysis TM*, AECOM, 2018.
- *Regulatory Compliance Evaluation TM*, AECOM, 2018.
- *Public Water System Record of Approved Waterworks*, CDPHE, 2017.
- *Thornton Water Treatment Plant Replacement Project – Basis of Design Report, Burns and McDonnell, 2017.*

Water Distribution System Analysis

Chapter 5

AECOM Imagine it. Delivered.

Utility Master Plan

Project No. 17-467

Water and Wastewater Infrastructure Master Plan

Water Distribution System Analysis

The City of Thornton

Project number: 60560104

AECOM

Final – August 17, 2019
Rev 1 – September 7, 2019

FINAL

Quality information

Prepared by	Checked by	Verified by	Approved by
Marcela Duran	Jason Coontz	Gwen Zuber	Nathan Walker

Revision History

Revision	Revision date	Details	Authorized	Name	Position
Final	8/16/2019	Final	Nathan Walker	Marcela Durán	Engineer
Final – Rev 01	9/5/2019	Final Rev 1	Nathan Walker	Marcela Durán	Engineer

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Table of Contents

Figures

Tables

List of Abbreviations and Acronyms

%	percent
2009 Master Plan	City of Thornton 2009 Water and Wastewater Systems Master Plan
AACE	Association for the Advancement of Cost Engineering
ADD	average daily demand
AWWA	American Water Works Association
CIP	Capital Improvement Program
ENR	Engineering News-Record
FF	fire flow
fps	feet per second
ft	feet
gpm	gallons per minute
hr	hour(s)
ID	identification
in	inch
KPI	key performance index(ices)
MDD	maximum day demand
MG	million gallons
mi	mile(s)
MinDD	minimum daily demand
N/A	not applicable
NWTP	Northern Water Treatment Plant
O&M	operation and maintenance
PHD	peak hour demand
PRV	pressure reducing valves
psi	pounds per square inch
system	water distribution system
Thornton	city of Thornton
TWTP	Thornton Water Treatment Plant
TM	technical memorandum
WBWTP	Wes Brown Water Treatment Plant
WTP	water treatment plant

1. Introduction

This technical memorandum (TM) describes the analyses of the city of Thornton's (Thornton's) water distribution system (system) identifying recommended improvements required to serve buildout conditions (2065). The service area is expected to grow significantly, which will require increasing the existing network's capacity, thereby expanding both transmission and distribution infrastructure to accommodate the future demands.

System evaluations included assessment of storage, pumping, distribution (pipes with diameters smaller than 16 inches), and transmission (pipes with diameters equal or larger than 16 inches) capacities. The results of these analyses were compared against the system performance criteria established in the Water Distribution and Wastewater Collection System Performance Criteria TM (April 2018, AECOM).

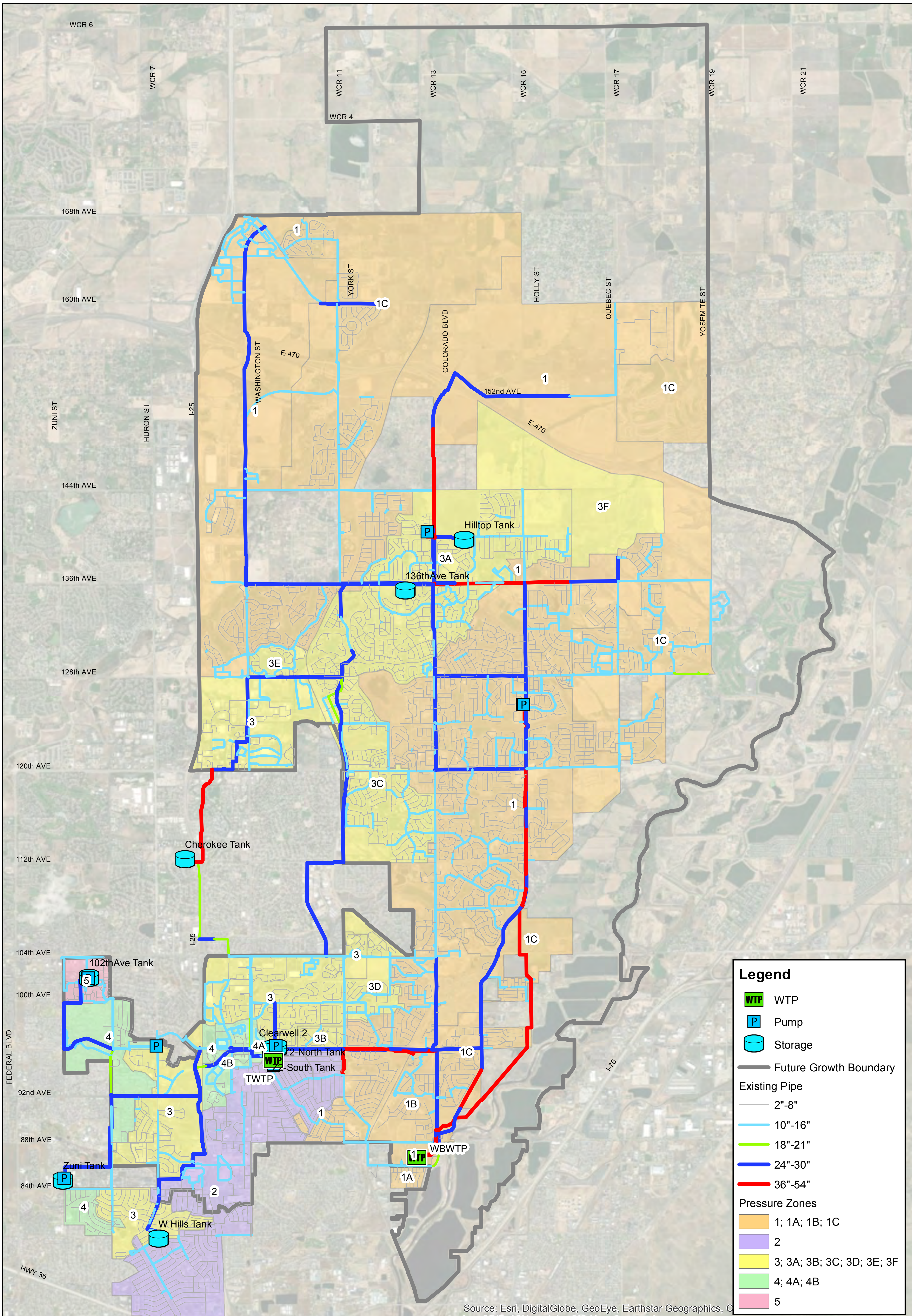
System improvements were developed for three future alternatives: a new Northern Water Treatment Plant (NWTP); expansion of the existing Thornton Water Treatment Plant (TWTP); and expansion of the Wes Brown Water Treatment Plant (WBWTP). The selection of a future alternative will determine the specific nature and sizing of final improvements; however, the system will require an improved north-south transmission backbone regardless of the selected future alternative.

In general, the results of the water system analysis indicate that the existing system has storage and transmission deficiencies, and infrastructure improvements are needed to meet buildout requirements. The majority of the recommended distribution improvements are inherently related to the system expansion that would serve currently undeveloped areas. Those improvements will typically be the funding responsibility of developers and are not included in the recommended improvements.

The resulting Capital Improvement Program (CIP) for each alternative includes transmission and distribution improvements in addition to three new storage tanks, including two in Zone 1, and one in Zone 3, and the replacement of pumping equipment in the Zone 5 Pump Station and at the Wes Brown High Service Pump Station.

2. Review of Existing System

The existing Thornton system consists of over 580 miles of pipeline and serves over 150,000 people. Currently, there are five main pressure zones with 13 subzones, seven pump stations, ten storage tanks, and approximately 65 pressure reducing valves (PRVs). The buildout system is projected to serve approximately 260,000 people, with the majority of the expansion occurring in Zone 1 and Zone 3A within the northern portion of the system. The existing system and pressure zones are shown on Figure 1.



City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Figure 1
Existing Water System and Pressure Zones

8/16/2019
1 inch = 5,000 feet

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3. Development of Future Water Demands

Currently, Thornton is approximately 50 percent (%) developed with respect to its buildout potential, with full development anticipated by buildout. Average daily water demand is 21.8 million gallons per day (mgd), including demand from Brighton, Colorado (1.8 mgd) based on 2017 consumption records. The anticipated buildout average daily demand (ADD) is 44.2 mgd, assuming drought conditions and an allowance for unaccounted-for losses. This information is based on the Planning Area and Future Growth Analysis TM (AECOM, 2018; see Table 8 and Figure 18).

Thornton developed the location of current water demands using billing meter data and historical records at their water treatment plants (WTPs). Water demand projections for buildout conditions were developed using detailed planning information and historical water demand information to establish estimated usage for future developments. Figure 2 shows the location of the future developments.

For system analysis, the system performance was evaluated under peak hour demand (PHD) conditions. Maximum day demand (MDD) conditions were used to evaluate the ability of the system to meet fire flow (FF). Maximum day to average day peaking factors and diurnal patterns were obtained from historical water use records. Table 1 summarizes the existing and buildout demands for Thornton's pressure zones; the largest growth is expected to impact Zones 1 and 1A.

Table 2 presents the peaking factors used to estimate MDDs. Buildout MDD is estimated at 96.3 mgd (also based on the August 2018 Planning Area and Future Growth Analysis TM, AECOM). In order to analyze the PHD conditions, it was recommended to use the peaking factors from the American Water Works Association (AWWA) Manual of Water Supply Practices M32 for residential demands (peak hour multiplier of 1.8) for future customers.

The system analyses described in this TM were completed assuming drought conditions exist; future demand includes unaccounted-for losses throughout the system, as outlined in the Planning Area and Future Growth Analysis TM (AECOM, 2018).

Table 1: Existing and Buildout Demands by Pressure Zone

Zone	2017		Buildout		Expected Growth	
	ADD (gpm)	MDD (gpm)	ADD (gpm)	MDD (gpm)	Absolute Increase in MDD (gpm)	% Increase in MDD
1	5,556	11,946	15,221	33,030	21,084	176%
1A	35	76	39	86	10	13%
1B	275	592	307	671	79	13%
1C	2,226	4,786	2,229	4,871	85	2%
2	1,324	2,846	1,526	3,333	487	17%
3	1,719	3,696	3,936	8,600	4,904	133%
3A	1,895	4,074	4,913	10,735	6,661	164%
3B	59	127	86	188	61	48%
3C	741	1,593	852	1,861	268	17%
3D	220	474	240	524	50	11%
3E	123	265	127	278	13	5%
3F	0	0	58	126	126	0%
3H	0	0	4	10	10	0%
4	521	1,120	612	1,337	217	19%
4A	32	69	60	131	62	90%

Zone	2017		Buildout		Expected Growth	
	ADD (gpm)	MDD (gpm)	ADD (gpm)	MDD (gpm)	Absolute Increase in MDD (gpm)	% Increase in MDD
4B	179	385	218	476	91	24%
5	145	313	258	564	251	80%
Total (gpm)	15,052	32,361	30,687	66,822	34,461	106%
Total (mgd)	21.8	46.6	44.2	96.3	49.7	

Note: gpm: gallons per minute

Table 2: Water Demands Peaking Factors

Peaking Factors	
MDD/ADD – System-Wide	2.2
PHD/MDD – System-Wide	1.8
Treatment/Distribution	1.1
Drought/Non-Drought	1.2

Source: Planning Area and Future Growth Analysis Technical Memorandum (AECOM, 2018) and AWWA Manual M32

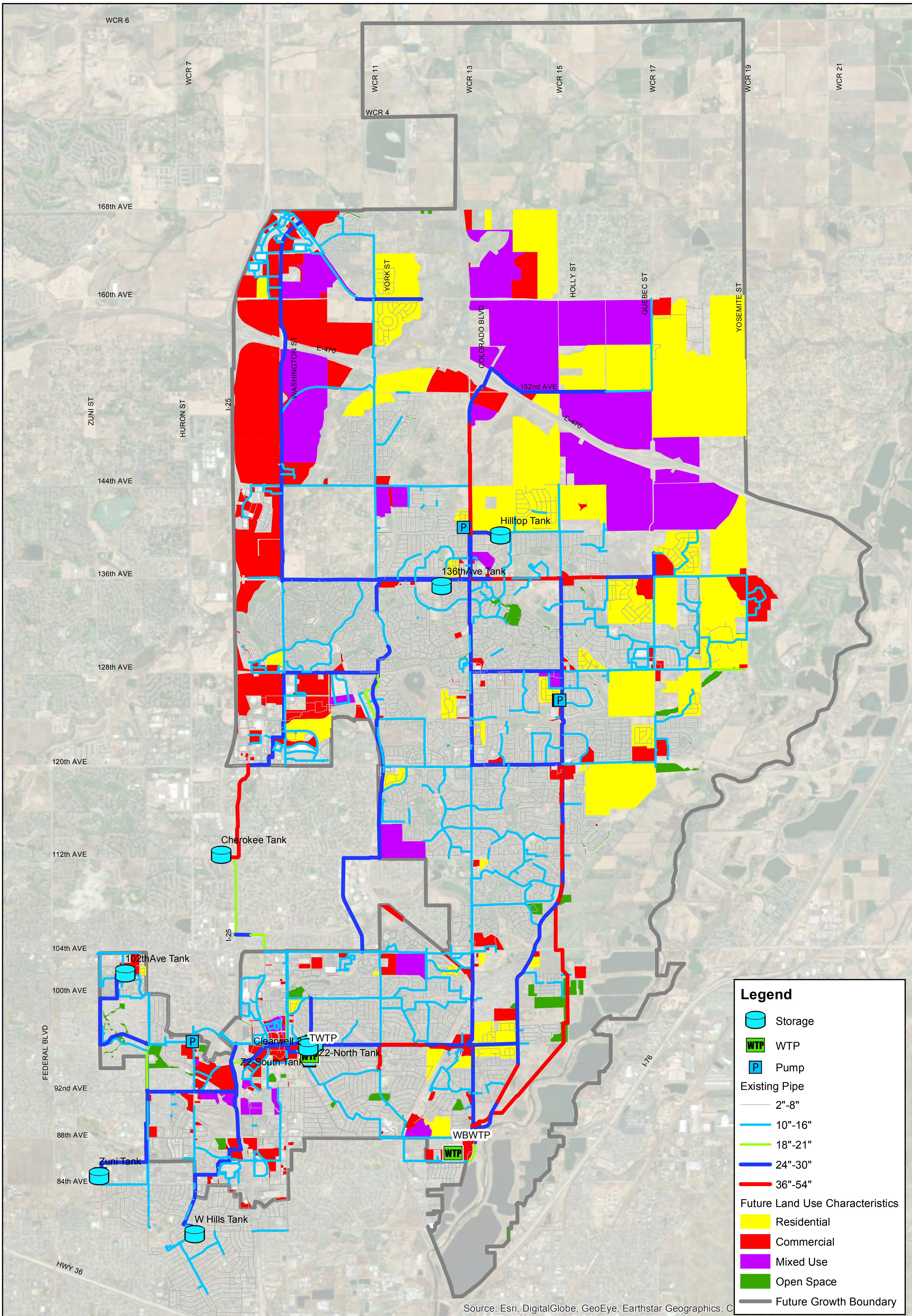

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Figure 2
Future Developments

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1 inch = 5,000 feet

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4. Future Alternatives

Currently, Thornton's system is supplied by two WTPs: WBWTP and TWTP. The current treatment facilities have the capacity to serve existing demands but are not sufficient to serve the expected growth. The existing and future demands, along with the additional system treatment capacity required, are summarized in Table 3.

Table 3: Water Treatment Facility Capacity Requirements

Existing and Future Demands	MDD[1] (mgd)
Existing	46.6
2025	65.1
2035	80.4
Buildout (2065)	96.3

[1] System MDDs system include unaccounted-for losses

Thornton is considering three alternatives for providing the required treatment facility capacity:

- Alternative 1 includes construction of a new NWTP to better serve the northern portion of the system. The location of the NWTP was evaluated by considering criteria including practicable site locations identified by Thornton; ease of land acquisition; proximity to existing storage tanks; efficiency of mixing treated water within the system; and ease of raw water supply conveyance. Based on this review, the parcel north of 140th Avenue between Colorado Boulevard and Holly Street was identified as the preferred location for construction of the NWTP. The proposed NWTP site would be approximately 14.5 acres and is currently privately owned and part of unincorporated Adams County. Thornton would have to acquire the land and complete zoning activities to permit construction and operation of a treatment facility at this location. At buildout, the NWTP will have a capacity of 21.5 mgd. For this alternative, the future capacity of the TWTP would be 20 mgd, and the future capacity of the WBWTP would be 54.8 mgd.
- Alternative 2 includes expansion of the new TWTP to supply buildout demands as development occurs. The new TWTP is a conventional plant currently under construction and will have a firm capacity of 20 mgd. At buildout, the TWTP would be expanded by 21.5 mgd to a permitted production capacity of 41.5 mgd. For this alternative, the future capacity of the WBWTP would be 54.8 mgd.
- Alternative 3 includes expansion of the WBWTP from a firm capacity of 54.8 to 76.3 mgd to meet buildout production requirements. The existing WBWTP site location is approximately 17 acres located in the southeastern portion of the system. Thornton currently owns property at the site to allow for the expansion. Depending on the layout, some systems may be required to be relocated, and the existing plant roadway system would be required to be modified. For this alternative, the future capacity of the TWTP would be 20 mgd.

The location of treatment facilities associated with the future alternatives is shown on Figure 3. Table 4 summarizes the production requirements for the three alternatives during MDD events. The information in the table is derived from values originally published in the Planning Area and Future Growth Analysis TM (AECOM, 2018).

Table 4: Summary of Future Alternative Production Requirements

Facility	WBWTP (mgd)	TWTP (mgd)	NWTP (mgd)	Total (mgd)
Alternative 1	54.8	20	21.5	96.3
Alternative 2	54.8	41.5	-	96.3
Alternative 3	76.3	20	-	96.3

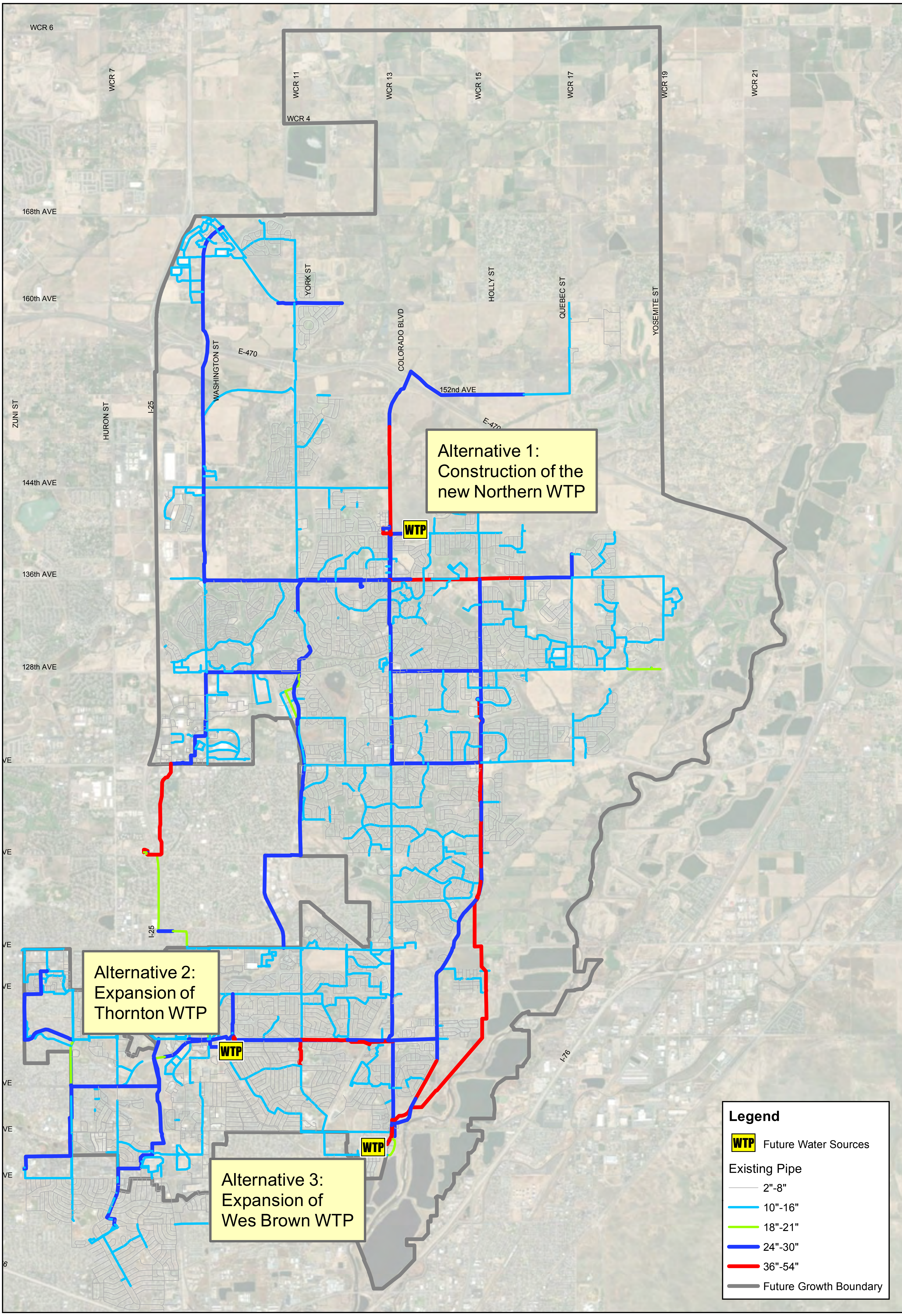

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Figure 3
Location of Water Treatment Facilities for Future Alternatives

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1 inch = 5,000 feet

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5. Hydraulic Model Update

Thornton provided a calibrated InfoWater model of the system with 2017 MDD demands (non-drought conditions; adjusted for losses throughout the system). The water distribution model contains over 9,300 links and 7,300 nodes with approximately 580 miles of pipeline. This model represents the system's five main pressure zones and 13 subzones, with an elevation range of 5,040 to 5,550 feet (ft). The pressure zones are supplied through 65 pressure-reducing valves. The hydraulic model includes seven Thornton-owned and operated pump stations and nine storage tanks for a total storage capacity of 27.2 million gallons (MG). The base model is discussed in detail in the April 2018 Initial Data and Hydraulic Model Review TM (AECOM).

AECOM updated the model demands to represent existing drought conditions and incorporated future demands. Future demands were allocated in the hydraulic model using the following process:

- Future demands from currently undeveloped parcels that will develop within the growth boundary were estimated using expected future population and current consumption rates.
- Future demands for the new developments were estimated for drought conditions and adjusted for unaccounted-for losses.
- Parcel demand was assigned to the upstream junction of the closest pipe using the InfoWater Allocator Tool.
- Future residential, commercial, and irrigation demands were assigned in separate demand fields in the hydraulic model, consistent with existing demand allocation assessed by Thornton, with maximum day peaking factors and diurnal patterns for each consumer type.
- Future demand was assigned to existing junctions in areas currently developed. In areas where there is no system, a preliminary conceptual alignment was developed in the model, and future demands were assigned to new junctions.
- Pressure zone boundaries were observed when allocating demands, checking that the closest pipe was in the pressure zone where the new development will be built.

The buildout (2065) scenario was used for distribution and transmission capacity analysis, fire flow analysis, system improvements development.

6. Performance Criteria

The adequacy of the system components was evaluated by comparing the existing performance to the performance criteria outlined in the Water Distribution and Wastewater Collection System Performance Criteria TM (AECOM, 2018).

The performance criteria pertinent to the system are summarized in Tables 5, 6, and 7, respectively. Table 5 summarizes Tier 1 performance criteria that must be met by the system. Table 6 summarizes Tier 2 performance criteria that represents best practices, but may not be required. Table 7 summarizes Tier 3 performance criteria that represents desired performance that should be met, if practicable, but are not required.

Resiliency criteria include important considerations necessary to provide reasonable reliability of the system. System resiliency criteria are comprised of system performance criteria pertaining to looped water mains, standby power, and firm pumping capacity, as well as meeting required operating capacity with a large transmission main out of service . Resiliency criteria are included in the Tier 1 and Tier 3 criteria.

Table 5: Tier 1 Water Distribution System Performance Criteria

Performance Parameter	Criteria	Criteria Source
Minimum System Pressure	• 50 pounds per square inch (psi) static • 20 psi for MDD + fire flow • 40 psi for PHD	Thornton Standard 203.2.B
Maximum System Pressure	• 110 psi	Thornton Standard 203.2.B
Water Main Sizing	• 6-inch minimum diameter water mains where no hydrants are connected to mainline • 8-inch minimum diameter water mains where hydrants are connected to mainline or when connected to transmission mains greater than 16 inches in diameter • Water services for non-residential facilities and high-density residential areas shall be constructed from looped water mains	Thornton Standard 203.3
Fire Flow	• Thornton recently adopted the International Fire Code • Assumed minimum fire flow and duration for land use type: - Residential: 1,000 gallons per minute (gpm) for 1 hour - Commercial: 2,500 gpm for 2 hours - Industrial: 4,000 gpm for 4 hours	Thornton Standard 202.2 International Fire Code
Storage Requirements	• Largest single hydrant fire flow volume within the zone - + 25% of MDD for equalization - + 15% of MDD for emergency storage	2009 Master Plan AWWA Manual M50
Firm Pumping Capacity	• Equal or larger than MDD for gravity storage • Equal or larger than PHD or MDD plus fire flow for pumped storage (whichever is greater)	Essential capability associated with forgoing storage requirements
Standby Power	• A true secondary power source required for each pump station, or the ability to mobilize backup power within the timeframe provided by the 15% of MDD emergency storage • Alternatively, if zone has a backup water feed, such as PRVs, that can meet MDD and minimum water system pressure requirements	Essential capability associated with forgoing power requirements

Table 6: Tier 2 Water Distribution System Performance Criteria

Performance Parameter	Criteria	Criteria Source
Maximum Velocity	• 5 feet per second (fps) for PHD • 10 fps for MDD + fire flow	Thornton Standard 203.2. B
Maximum Unit Head Loss	• ≤ 7 feet/1,000 feet for pipes < 16-inch diameter • ≤ 3 feet/1,000 feet for pipes ≥ 16-inch diameter	AWWA Manual M32
Maximum Water Age	• 20-30 days for minimum daily demand (MinDD)	N/A

N/A = not applicable
Thornton 2009 Water and Wastewater Systems Master Plan (2009 Master Plan)

Table 7: Tier 3 Water Distribution Performance Criteria

Performance Parameter	Criteria	Criteria Source
Main Failure	• MDD still met at 40 psi minimum service pressure with large transmission main (≥ 10,000 gpm for MDD) out of service	N/A

7. Buildout System Performance Evaluation

This section provides a summary of the evaluations performed to identify areas in Thornton's system that have insufficient capacity to accommodate the buildout growth and require improvements.

Evaluations were completed for buildout conditions, including storage and pumping. The hydraulic model was used to assess the transmission and system's capacity to convey flows under maximum day, peak hour, and maximum day plus fire flow conditions, while meeting the performance criteria.

Based on the results of the system analyses, recommended improvement projects were developed for the following categories:

- Distribution improvements to serve future developments
- Storage facility improvements (Tier 1 Criteria)
- Pumping station improvements (Tier 1 Criteria)
- Transmission improvements required to implement each alternative
- Distribution improvements to meet Tier 1 criteria:
  - Distribution improvements to improve fire flow availability
  - Distribution improvements to improve service pressure
- Distribution improvements to meet Tier 2 criteria:
  - Distribution improvements to meet velocity and unit head loss requirements
  - Distribution and operational improvements to improve water quality
- Transmission improvements to meet Tier 3 criteria:
  - Transmission improvements to meet minimum service pressure when large transmission main is out-of-service

The results of these evaluations and the key findings are summarized herein.

7.1 Distribution Improvements to Serve Future Developments

Some of the parcels that will be developed within the future growth boundary are currently not served by Thornton's system; a preliminary transmission network was developed to convey these potential water needs. The proposed alignments are presented on Figure 4. The extension of the existing network was sized to meet Tier 1 and Tier 2 performance criteria. The level of detail is approximately one-half square mile, focusing on future transmission, as there is not enough information available to develop distribution alignments.

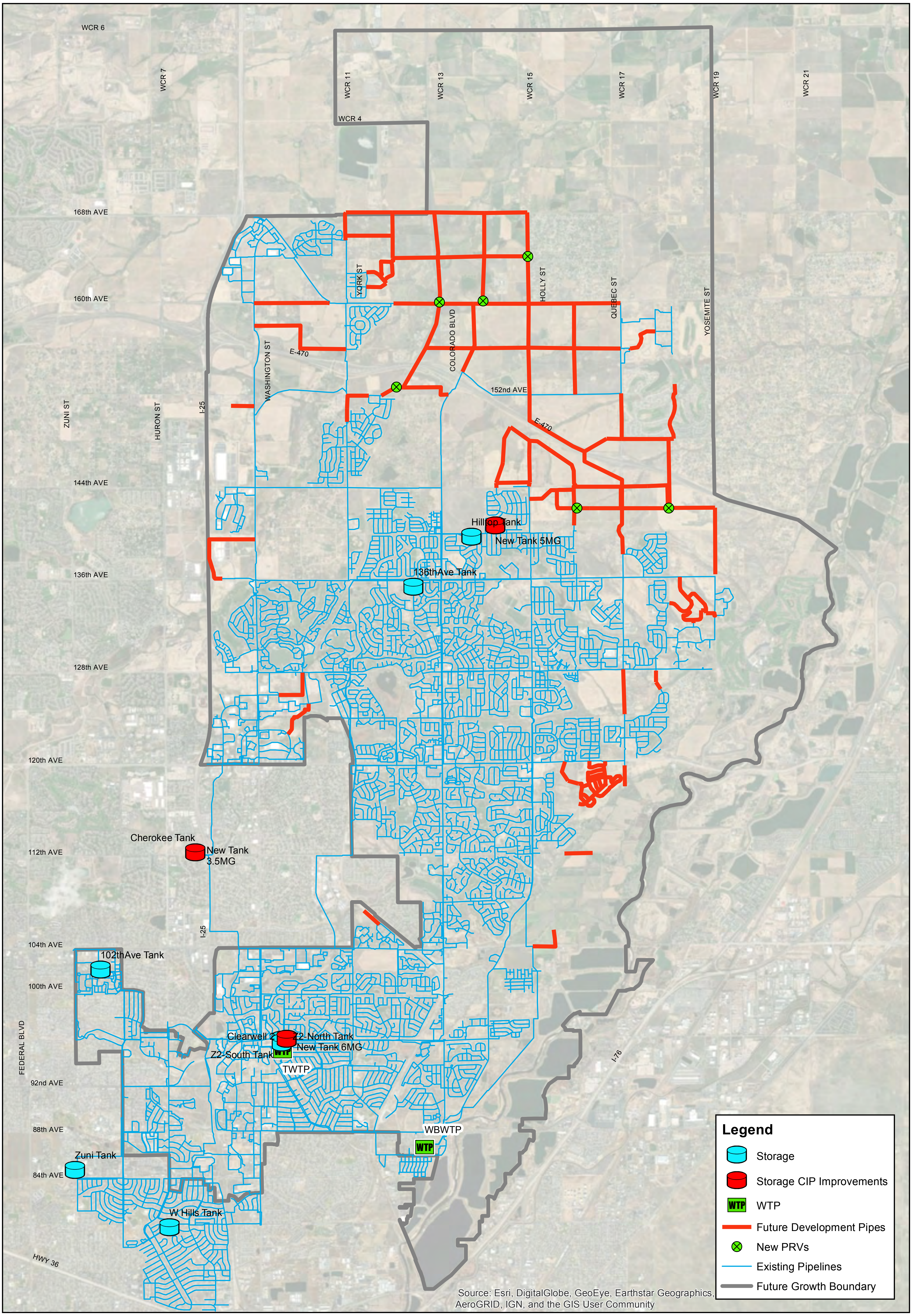
Onsite distribution mains and pipelines are the responsibility of each developer, per Thornton City Code (distribution lines with diameter equal to or smaller than 16 inches). These pipes have been estimated and summarized in Table 8 but will not be included in Thornton's CIP project list.

New PRV stations were also recommended at some locations to serve new areas within acceptable pressure ranges and to help prevent existing pressure boundaries from being affected. The new PRVs are also presented on Figure 4. The proposed alignments and sizes of these recommended system improvements are the same for each of the future alternatives. A summary of the recommended distribution improvements to serve future developments is presented in Table 8.

Table 8: Recommended Distribution Improvements to Serve Future Developments

Diameter (in)	Total Length (ft)	Total Length (mi)	Primary Funding Source
8	21,500	4.1	Developer
10	200	0.0	Developer
12	126,200	23.9	Developer
16	30,500	5.8	Developer
20	2,900	0.5	Thornton
24	13,400	2.5	Thornton
36	2,600	0.5	Thornton
42	20,600	3.9	Thornton
Total	217,900	41.3	

Note: mi - miles; in - inch



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9500 Civic Center Drive Thornton, Colorado 80229
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Figure 4
Recommended Distribution Improvements to Serve Future Developments

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1 inch = 5,000 feet

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7.2 Storage Facility Improvements

Based on the performance criteria, the components of water storage are described as follows:

- Fire suppression storage - Volume needed to support fire flow; the storage volume should be sufficient to provide the highest fire flow required in the service area for the required minimum duration.
- Equalization storage- Storage to compensate for the difference between maximum supply or pumping capacity and PHD; the storage volume should be sufficient to provide 25% of MDD for equalization purposes.
- Emergency storage - Volume to provide water when sources of supply are not available; the storage volume should be sufficient to provide 15% of MDD for emergency purposes.

To determine if the existing system has adequate storage capacity, the existing usable storage (storage that can be provided at or above minimum service pressure) was compared to the combined requirements for fire suppression, equalization, and emergency purposes. Existing storage capacities were obtained from the system hydraulic model. The system will have a total of 26.7 MG available for future use after the removal of Clearwell 1 in the TWTP facility. The results of the storage capacity analysis are presented in Table 9.

For pressure zones without a gravity tank, the fire flow, emergency, and equalization storage requirements were assumed to be provided by the pressure zone feeding it. As a result, Zone 5 storage requirements were assumed to be part of Zone 4, and Zone 3A was assumed to be part of Zone 1.

Recommended storage improvements and key findings can be summarized as follows:

- Zone 1 existing storage capacity will not be adequate to serve buildout needs. The deficiency can be partially addressed through available excess storage in Zone 2, but it will require additional storage totaling 11.4 MG in buildout. Zone 2 can partially supplement the storage deficiency in Zone 1 by back-feeding Clearwell 2 through valves located at the Zone 2/3 Pump Station facility or by adjusting the operation of pumps feeding Zone 2 to supply less than MDD.
- Zone 3 is deficient and requires 3.1 MG of additional storage capacity.
- Zones 2, 4, and 5 have sufficient storage capacity through buildout.
- These storage improvements are representative of each of the future alternatives.

Table 9: Storage Capacity Analysis Results

Storage System	Existing Storage Tanks	Usable Storage Capacity (MG)	Pressure Zones	Buildout MDD (gpm)	Largest Fire Flow[1] (gpm)	Fire Flow Duration (hour)	Equalization 25% of MDD (MG)	Emergency 15% of MDD (MG)	Fire Flow Volume (MG)	Required Volume (MG)	Deficiency (-) or Surplus Storage (+) (MG)
Zone 1	Hilltop	5.0	1, 1A, 1B, 1C, 3A, 3F, 3H								
	136th Ave.	5.0									
	Clearwell 1	0.0									
	Clearwell 2	1.5									
Total Zone 1		11.5		49,529	5,000	3	17.8	10.7	0.9	29.4	-17.9 (-11.4 after deducting storage excess in Zone 2)
Zone 2	Western Hills	3.0	2								
	Zone 2 North	2.9									
	Zone 2 South	2.9									
Total Zone 2		8.8		3,333	3,000	2	1.2	0.7	0.4	2.3	+6.5
Zone 3	Cherokee	3.9	3, 3B, 3C, 3D, 3E								
Total Zone 3		3.9		11,452	3,000	2	4.1	2.5	0.4	7.0	-3.1
Zones 4&5	102nd Ave.	0.5	4, 4A, 4B, 5								
	Zuni	2.0									
Total Zones 4&5		2.4		2,508	3,000	2	0.9	0.5	0.4	1.8	+0.6
Grand Total		26.7		66,822			24.0	14.4	2.1	40.5	-13.8

[1] Assumption based on general land use in pressure zone

7.3 Pumping Station Improvements

Based on the performance criteria, the pumping capacity required for the two types of service, pumping to a storage tank and pumping to a distribution network, are:

1) Firm capacity (assuming the largest pump out of service) of the pumping system should be at least equal to MDD when pumping to a storage tank.

2) Firm capacity (assuming the largest pump out of service) of the pumping system should be at least equal to the largest of MDD plus fire flow or PHD when pumping directly to a distribution network (with no storage tank).

To determine if the system has adequate pumping capacity, the existing capacity was compared to the requirements for each pressure zone. The pumping capacity evaluation results are summarized in Table 10. Existing pumping capacities were obtained from the system hydraulic model and supplemented with the 2009 Master Plan.

Recommended pumping improvements and key findings can be summarized as follows:

- The pumping requirements for the Wes Brown High Service Pump Station are higher for Alternative 3, as expected with the capacity increase of the WBWTP. For Alternatives 1 and 2, this pump station requires 3,000 gpm of additional firm capacity; for Alternative 3, this pump station requires 18,000 gpm of additional firm capacity. This additional capacity could be met by replacing existing units with equipment of larger capacity or by adding an additional unit or units.
- In Zone 5, additional pumping capacity is required to meet fire flow requirements. The pump station requires 1,500 gpm in additional firm capacity. This upgrade could be achieved by replacing the existing units with larger capacity or by installing an additional unit.
- Current Zone 1 pumping limitations during high demand periods are addressed by the transmission improvements proposed for each alternative in Section 7.4. The operation of the Holly Pump Station was assumed for emergency purposes only and not for regular system operation. Transmission improvements were developed assuming all tanks located in Zone 1 will float of each other, working hydraulically interconnected. Holly Pump Station operation is known to cause high pressures in pipelines around, which is not sustainable due to material and age.
- Zone 3A is supplied by Pump Station Zone 3A, which shows a deficiency of 7,742 gpm for buildout conditions. Even though this zone can also be supplied via PRV from Zone 3, the deficiency in pumping capacity is proposed to be addressed by installing an additional pump unit at the pump station facility. The operation of the PRV is assumed only for emergency conditions.
- As shown in Table 10, the existing pumping capacity in Zones 2, 3, and 4 is sufficient to meet future requirements.
- It is assumed that a secondary power source, or the ability to mobilize backup power within the timeframe provided by the 15% of MDD emergency storage, is available for each pump station.

Table 10: Pumping Capacity Analysis Results

Pumping System	Pumping From	Pumping To	Total Capacity per System[1] (gpm)	Firm Capacity (gpm)	Pressure Zones	Pressurized System	Largest Fire Flow[2] (gpm)	MDD (gpm)	MDD + Fire Flow (gpm)	PHD (gpm)	Pumping Capacity Required (gpm)	Deficiency (-) or Surplus (+) (gpm)
Zone 5	Zone 4: 102nd Ave.	Zone 5, no tank	1,056	556	5	yes	1,500	564	2,064	1,127	2,064	**-1,508**
Zone 4	Zone 1: Clearwell 1	Zone 4: 102nd Ave, Zuni	10,500	7,000	4, 4A, 4B, 5	no	3,000	2,508	5,508	5,016	2,508	**+4,492**
Zone 3	Zone 1: Clearwell 1	Zone 3: Cherokee	20,216	16,016	3, 3B, 3C, 3D, 3E	no	3,000	11,452	14,452	22,903	11,452	**+4,564**
Zone 3A	Zone 1: Hilltop Tank	Zone 3A, no tank	21,000	14,000	3A, 3F, 3H	yes	3,000	10,871	13,871	21,742	21,742	**-7,742**
Zone 2	Zone 1: Clearwell 1	Zone 2: Zones 2N and 2S	13,000	6,500	2	no	3,000	3,333	6,333	6,666	3,333	**+3,167**
Zone 1 (Alternatives 1 and 2)	WBWTP	Zone 1: Clearwell 1	70,801	63,801	All zones	no	5,000	66,822	71,822	133,644	66,822	**-3,021**
Zone 1 (Alternative 3)	WBWTP	Zone 1: Clearwell 2	55,880	48,880	All zones	no	5,000	66,822	71,822	133,644	66,822	**-17,942**

[1] Total capacity per system includes gravity supply to the pumping zone.

[2] Assumption based on general land use in pressure zone.

7.4 Transmission Capacity Evaluation: Alternatives Development

As discussed in Section 4, additional treatment facility capacity will be required to serve buildout needs, and Thornton is considering three different alternatives:

- Alternative 1 includes construction of a new NWTP to better serve the northern portion of the system. The location of the NWTP was evaluated by considering criteria including practicable site locations identified by Thornton; ease of land acquisition; proximity to existing storage tanks; efficiency of mixing treated water within the system; and ease of raw water supply conveyance. Based on this review, the parcel north of 140th Avenue between Colorado Boulevard and Holly Street was identified as the preferred location for construction of the NWTP. The proposed NWTP site would be approximately 14.5 acres and is currently privately owned and part of unincorporated Adams County. Thornton would have to acquire the land and complete zoning activities to permit construction and operation of a treatment facility at this location. At buildout, the NWTP will have a capacity of 21.5 mgd. For this alternative, the future capacity of the TWTP would be 20 mgd, and the future capacity of the WBWTP would be 54.8 mgd.
- Alternative 2 includes expansion of the new TWTP to supply buildout demands as development occurs. The new TWTP is a conventional plant currently under construction and will have a firm capacity of 20 mgd. At buildout, the TWTP would be expanded by 21.5 mgd to a permitted production capacity of 41.5 mgd. For this alternative, the future capacity of WBWTP would be 54.8 mgd.
- Alternative 3 includes expansion of the WBWTP from a firm capacity of 54.8 to 76.3 mgd to meet buildout production requirements. The existing WBWTP site location is approximately 17 acres located in the southeastern portion of the system. Thornton currently owns property at the site to allow for the expansion. Depending on the layout, some systems may be required to be relocated, and the existing plant roadway system would be required to be modified. For this alternative, the future capacity of the TWTP would be 20 mgd.

Once the future storage and pumping requirements had been defined, the system was evaluated to determine what transmission improvements would be required to adequately convey treated water from each of the water treatment facilities to the storage tanks in Zone 1. These transmission improvements are different for each alternative; however, improvements for the system are not discussed hereunder because they are common to all alternatives.

The transmission improvements were developed based on the following system operational assumptions:

- Zone 1 storage including the new reservoirs should operate in conjunction, floating off each other; therefore, transmission improvements are required to connect Clearwell 2 to Hilltop Tank.
- Holly Pump Station is assumed to operate during emergencies only, not for normal operation, to allow the north and south Zone 1 storage to stay hydraulically connected.
- Tanks in Zone 1, at the north side of the system (Hilltop tank and the recommended new storage tank) are assumed to be supplied by the Wes Brown High Service Pump Station and by gravity from the TWTP for Alternatives 2 and 3.
- Current Zone 1 pumping limitations during high demand periods are addressed by the transmission improvements proposed for each of the alternatives.
- The proposed transmission improvements are sized for adequate tank storage levels recovery during MDD conditions.

Table 11 summarizes the transmission improvements for each alternative by diameter and length. The diameter of these pipeline improvements varies for each alternative, but the alignment is relatively consistent. Figure 5 presents the recommended transmission improvements that are directly affected by the future supply alternative. The following sections summarize the results obtained from the hydraulic simulations for each supply alternative.

Table 11: Summary of CIP Transmission Improvements by Alternative

Diameter (in)	Alternative 1		Alternative 2		Alternative 3	
	Total Length (ft)	Total Length (mi)	Total Length (ft)	Total Length (mi)	Total Length (ft)	Total Length (mi)
16	2,640	0.50	0	0.00	0	0.00
20	0	0.00	5,020	0.95	5,020	0.95
24	770	0.15	770	0.15	770	0.15
36	10,010	1.90	1,870	0.35	1,870	0.35
42	0	0.00	7,100	1.34	7,100	1.34
48	65,820	12.47	210	0.04	210	0.04
72	0	0.00	68,790	13.03	71,430	13.53
Total	79,240	15.01	83,760	15.86	86,400	16.36

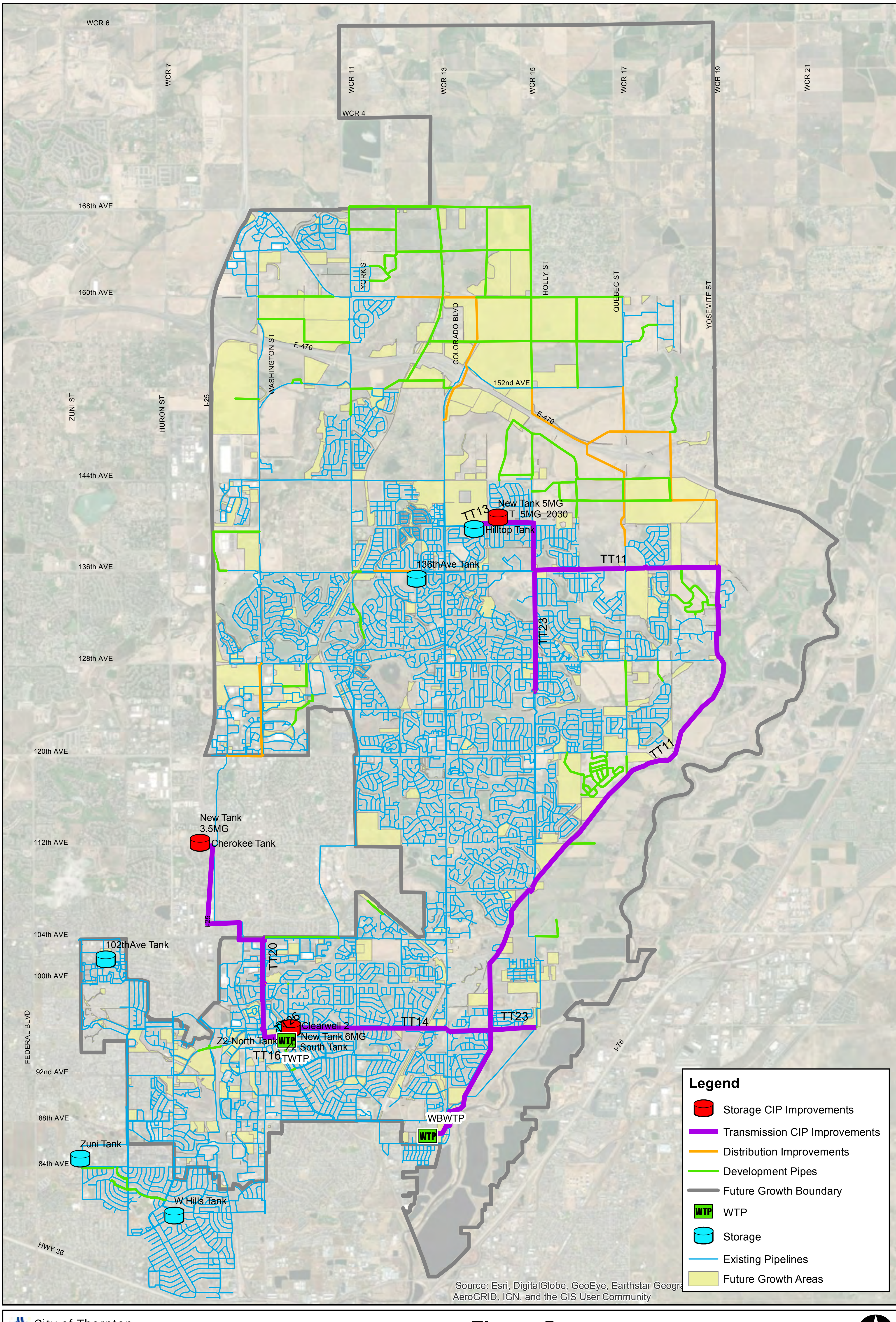

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Figure 5
Recommended Transmission Improvements Affected by Future Alternatives

9/6/2019
1 inch = 5,000 feet

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7.4.1 Alternative 1 – System Performance

Alternative 1 includes construction of a new NWTP to better serve the northern portion of the system. At buildout, the NWTP will have a capacity of 21.5 mgd. For this alternative, the future capacity of the TWTP would be 20 mgd, and the future capacity of the WBWTP would be 54.8 mgd. The system impacts resulting from this alternative are summarized as follows:

- The two existing water treatment facilities are located in the southern portion of the system. The location of the NWTP provides flexibility of service by spatially distributing points of treated water delivery throughout the system.
- Most of the future growth is expected at the northern side of the service area. Having a WTP in this area would typically tend to minimize water age and related system water quality considerations within this portion of the system.
- The addition of a new WTP in the northern portion of the system will result in reduced transmission improvement requirements, not only in size but also in length of piping, as shown in Table 11. The largest diameter of required transmission pipelines is 48 inches in Alternative 1, and 72 inches in the other two alternatives.
- As discussed in Section 7.3, pumping improvements for Alternative 1 are different than those for Alternative 3, as the Wes Brown High Service Pump Station will require fewer pumping improvements in Alternative 1.
- Storage and transmission improvements for other zones are the same for all alternatives.

In addition to the CIP projects to serve new developments (described in Section 7.1), storage improvements (described in Section 7.2), and pumping improvements (described in Section 7.3), the system will require the following improvements to provide adequate service, thereby meeting the criteria detailed in Section 6:

- TT20: New 36-inch transmission pipes connecting Pump Station Z3/4 and Cherokee Tanks (existing and proposed).
- TT11: New 48- and 36-inch transmission pipe connecting the WBWTP to the new 5 MG tank in the northern part of Zone 1. This major transmission line is intended to function as the backbone of Zone 1 and will support the growth in the north side of the service area.
- TT23: New 42-inch pipe to increase the capacity of the existing transmission along Holly Street.
- TT13: New 48-inch transmission pipe connecting the new storage proposed for the northern Zone 1 to the existing Hilltop Tank.
- TT14: New 48-inch transmission pipe between the new storage proposed near Clearwell 2 and the new transmission line connecting the WBWTP to the northern tanks (new storage and Hilltop Tank).
- TT16: New 24-inch transmission line that improves the connection from the TWTP to the proposed transmission line TT14.

The location of these projects is presented on Figure 5. Alternative 1 was evaluated for new water supply source trace, water age, and redundancy. The results of these evaluations are presented below.

Alternative 1 – New Treatment Plant Supply Trace

Thornton has the clear goal of providing high quality water to all residents. In order to quantify the mixing of sources in the system for each alternative, a source trace analysis from each treatment plant was performed for future conditions assuming the storage, pumping, and transmission improvements are in place. For Alternative 1, the analysis provides a general overview of the area of influence of water from the NWTP. The distribution extent is a function of the NWTP's connection to the system, its distance to other WTPs, and the storage, pumping, and piping improvements proposed to serve buildout under Alternative 1.

Table 12 summarizes the maximum, minimum, and average amount of water from the NWTP trace results for each storage tank in the system during a 20-day period. Figure 6 shows the results for source trace for the portion of the supply from the Thornton Water Project (TWP) that will be delivered to the system at the NWTP. The results show that approximately 27% of the system will receive at least 5% of supply from the NWTP under this alternative.

This analysis and the results thereof are conservative, as actual distribution of the new water supply from the TWP will be greater than shown herein, given this new water supply will also be treated and distributed up to 20 MGD during MDD from the TWTP and/or the WBWTP.

These results show that water entering the system at the NWTP directly serve the northern portion of the system. To effectively provide water from the TWP under this alternative to all customers, efficient mixing should occur at the other two treatment plants.

Table 12: Alternative 1 – New Water Supply Source Trace Results at Storage Tank

Source Trace amount of New Water Supply at System Storage Tanks				
Tank	Max. Value (%)	Min. Value (%)	Average (%)	Difference (%)
102nd Ave.	0.0	0.0	0.0	0.0
136th Ave.	0.3	0.1	0.2	0.2
Cherokee (Existing and Proposed)	0.0	0.0	0.0	0.0
Hilltop	100	100	100	0.0
New Tank Zone 1 North	100	100	100	0.0
New Tank Zone 1 South	0.0	0.0	0.0	0.0
Western Hills	0.0	0.0	0.0	0.0
Zone 2 North	0.0	0.0	0.0	0.0
Zone 2 South	0.0	0.0	0.0	0.0
Zuni	0.0	0.0	0.0	0.0

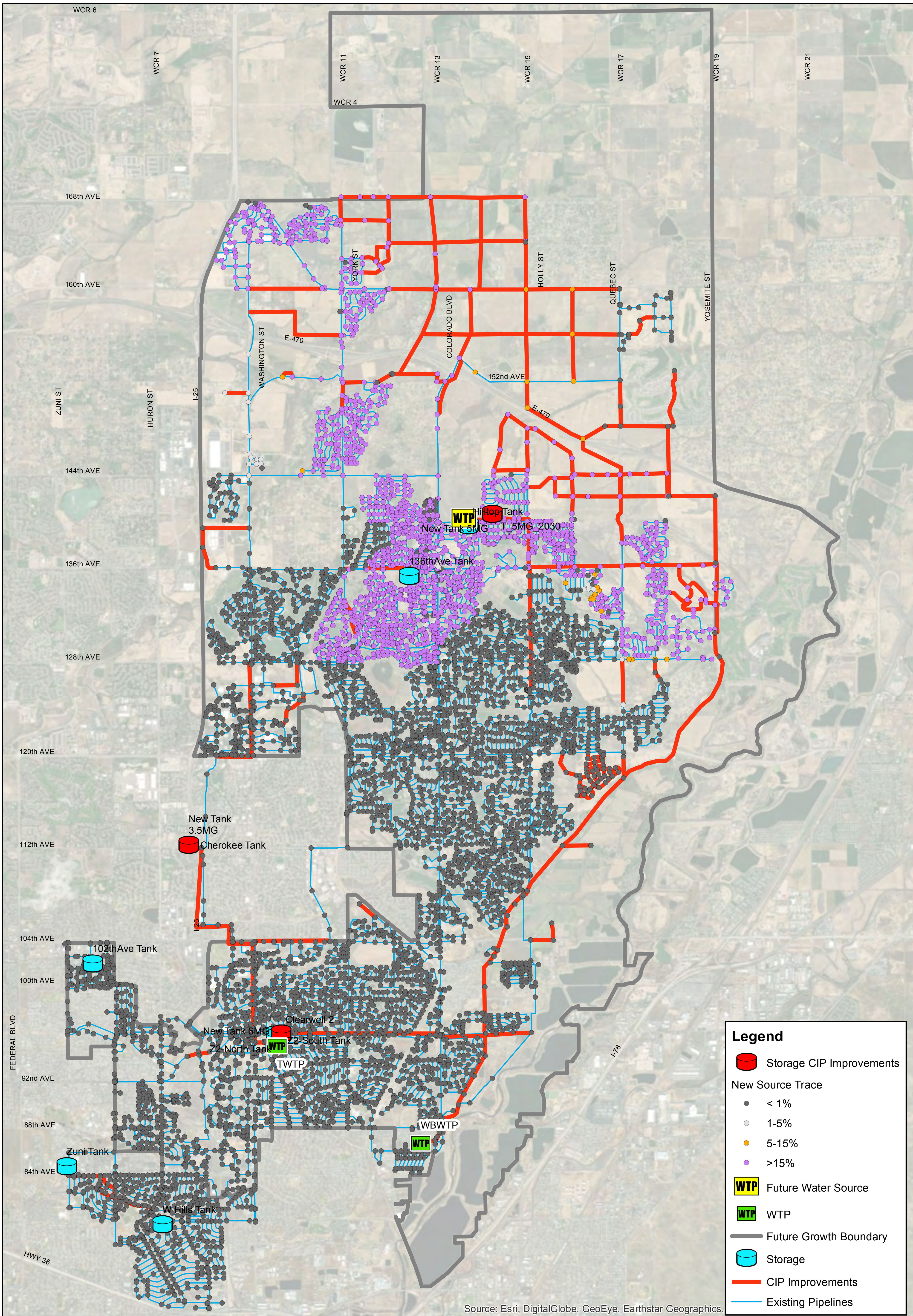

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Figure 6
Alternative 1 New Source Trace Results

8/16/2019
1 inch = 5,000 feet

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Alternative 1 – Water Age

The hydraulic model was used to evaluate overall water age through the system for MDDs under the Alternative 1 supply configuration. Water age results were used to characterize the performance of improvements developed for this alternative. The simulation was performed for several weeks in succession to identify water quality trends for MDD, which doesn't represent worst conditions for water age in the system but provides a measure of operational effectiveness.

Table 13 summarizes the results of the evaluation, showing average water age in system tanks. Figure 7 presents water age in the system for this alternative, after equilibrium was reached. The results show acceptable water age values for all tanks except for the Western Hills Tank.

Table 13: Alternative 1 – Water Age Results by Reservoir

Water Age at System Storage Tanks				
Tank	Max. Value (hours)	Min. Value (hours)	Average (hours)	Difference (hours)
102nd Ave.	198.2	31.9	181.3	166.3
136th Ave.	179.8	44.5	167.2	135.3
Cherokee (Existing and Proposed)	145.3	59.6	139.2	85.7
Hilltop	104.9	104.2	104.6	0.8
New Tank Zone 1 North	119.7	87.8	118.2	31.9
New Tank Zone 1 South	149.7	63.0	141.7	86.6
Western Hills	1266.1	24.1	676.6	1,242
Zone 2 North	229.5	31.7	205.2	197.8
Zone 2 South	210.1	35.1	187.4	175.0
Zuni	372.1	26.7	303.9	345.4

Note: 1 week = 168 hours

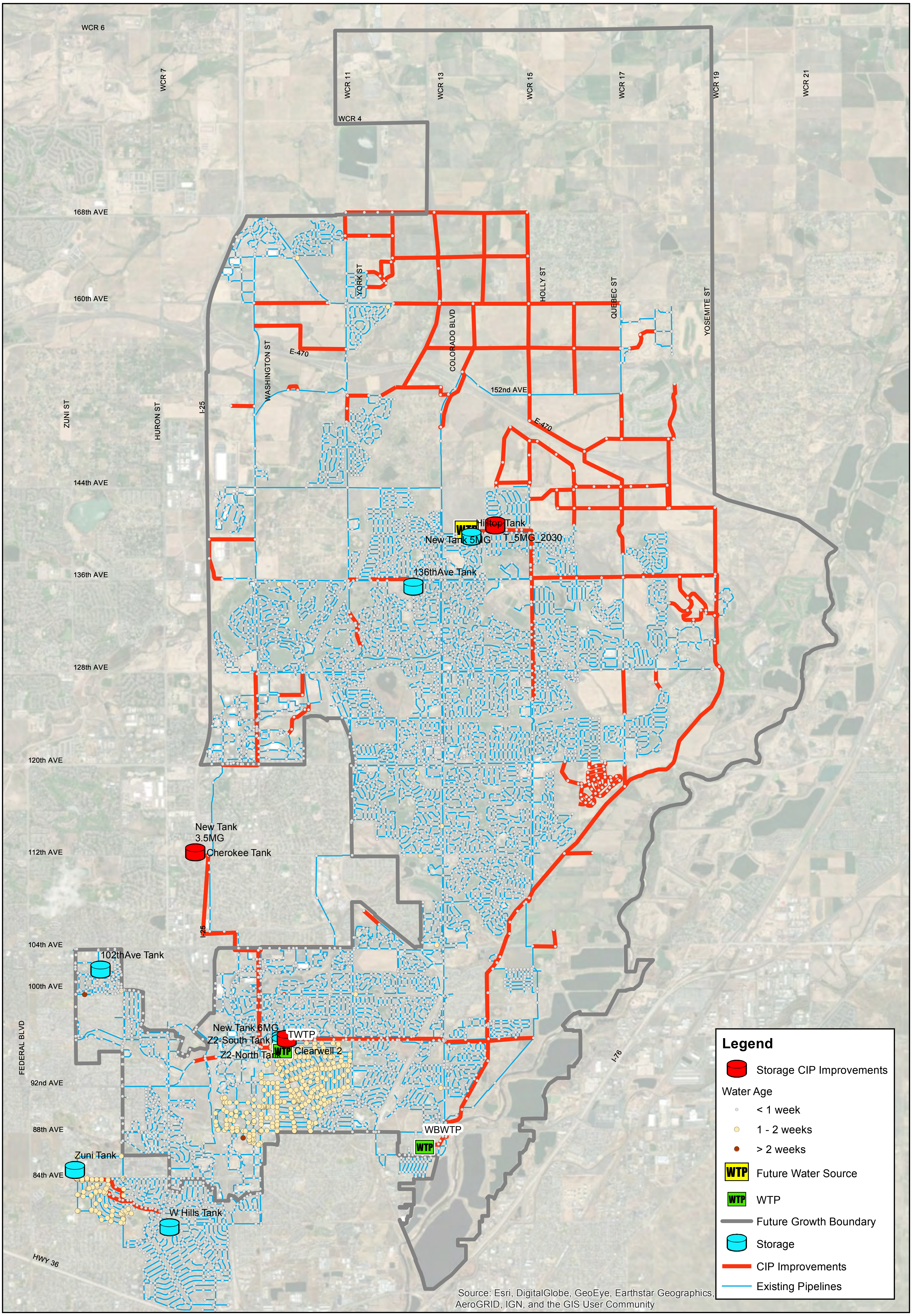

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Figure 7
Alternative 1
Water Age Results

8/16/2019
1 inch = 5,000 feet

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Alternative 1 – Redundancy

To evaluate the redundancy of the system, or the system's ability to respond to emergency conditions, the following conditions were evaluated:

- Condition 1: NWTP offline
- Condition 2: TWTP offline
- Condition 3: WBWTP offline

These evaluations were performed for buildout ADD. With the improvements proposed under Alternative 1, the ability of the system to provide adequate service pressure was assessed in order to determine if additional improvements were required to improve system redundancy. Table 14 displays a summary of the treatment facility assumptions for each condition. Table 15 displays a summary of the system results for each condition. Pressures lower than 20 psi were observed in nodes near tanks, pump stations or valves, or in transmission lines crossing (not connected) pressure zones. Appendix A includes a system performance map with the minimum service pressure for each condition.

Table 14: Alternative 1 – Redundancy Conditions Treatment Facility Assumptions

Treatment Facility	Production Capacity (mgd)	Condition 1 (mgd)	Condition 2 (mgd)	Condition 3 (mgd)
NWTP	21.5	0	21.5	21.5
TWTP	20	20	0	20
WBWTP	54.8	54.8	54.8	0
Total	96.3	74.8	76.3	41.5
Buildout ADD (mgd)	44			

Table 15: Alternative 1 – Redundancy Conditions Model Results Summary

Pressure Range (psi)	Number of Junctions by Pressure Range		
	Condition 1 NWTP Offline	Condition 2 TWTP Offline	Condition 3 WBWTP Offline
20	54	54	53
40	85	76	77
60	742	629	773
80	3,034	3,157	3,241
100	2,953	2,953	2,831
120	525	525	447
>120	112	111	83

Note: Pressure lower than 20 psi was observed near storage tanks and in distribution lines running through, but not connecting to pressure zones. The location of the low pressure observed here was not a cause of concern.

7.4.2 Alternative 2 – System Performance

For Alternative 2, the future treatment capacity for the TWTP expansion is 41.5 mgd and the system impacts for this alternative can be summarized as follows:

- The expansion of the TWTP results in larger transmission improvement requirements when compared to Alternative 1, not only in size but also in length of piping, as shown in Table 11. The largest diameter of required transmission pipelines is 72 inches in this alternative, compared to 48 inches for Alternative 1.

- As discussed in Section 7.3, pumping improvements for this alternative are different than those required for Alternative 3. The Wes Brown High Service Pump Station will require fewer pumping capacity improvements in Alternative 2.
- Storage capacity improvements are the same for all supply alternatives.

In addition to the CIP projects to serve new developments (described in Section 7.1), storage improvements (described in Section 7.2), and pumping improvements (described in Section 7.3), the system will require the following improvements to provide adequate service, thereby meeting the criteria detailed in Section 6:

- TT20: New 36-inch transmission pipes connecting Pump Station Z3/4 and Cherokee Tanks (existing and proposed).
- TT11: New 72-inch transmission pipe connecting the WBWTP to the new tank in the northern part of Zone 1. This major transmission line is intended to function as the backbone of Zone 1 and will support the growth in the north side of the service area.
- TT23: New 42-inch pipe to increase the capacity of the existing transmission along Holly Street.
- TT13: New 36-inch transmission pipe connecting the new storage proposed for the northern Zone 1 to the existing Hilltop Tank.
- TT14: New 72-inch transmission pipe between the new storage proposed near Clearwell 2, and the new transmission line connecting the WBWTP to the northern tanks (new storage and Hilltop Tank).
- TT16: New 24-inch transmission line that improves the connection from the TWTP to the proposed transmission line TT14.
- TT23: New 42-inch transmission pipe that connects two existing transmission mains from the WBWTP.

Alternative 2 was evaluated for new water supply source trace, water age, and redundancy. The results of these evaluations are presented hereunder.

Alternative 2 – New Treatment Plant Supply Trace

Table 16 summarizes the source trace results for each storage tank in the system. Figure 8 shows the results for source trace, assuming the new water supply from the TWP is supplied up to 40 MGD through the system at the TWTP.

Approximately 92% of the system will receive at least 5% of supply from the new source under this supply configuration, while 58% will receive at least 15%. The tracing extent is the function of the new source's point of connection to the system, its distance to other WTPs, and the storage, pumping, and piping improvements proposed to serve buildout demand conditions under Alternative 2. The results show a larger extent of distribution for the water entering the system at the TWTP, including all tanks in the system. This alternative will result in better mixing of the additional supply than Alternative 1.

If the new supply from the TWP is treated at both the TWTP and the WBWTP, the blending of the new source water would be increased further beyond the results shown below.

Table 16: Alternative 2 – New Supply Source Trace Results at Storage Tanks

Source Trace amount of New Water Supply at System Storage Tanks				
Tank	Max. Value (%)	Min. Value (%)	Average (%)	Difference (%)
102nd Ave.	24.2	23.1	23.9	1.1
136th Ave.	4.3	3.9	4.1	0.5
Cherokee (Existing and Proposed)	24.2	24.2	24.2	0.0
Hilltop	4.4	3.4	3.9	1.0
New Tank Zone 1 North	5.1	2.9	3.9	2.1
New Tank Zone 1 South	24.2	24.2	24.2	0.0
Western Hills	24.2	24.2	24.2	0.0
Zone 2 North	24.1	22.3	23.6	1.8
Zone 2 South	24.2	23.1	23.9	1.0
Zuni	20.7	14.8	18.3	6.0

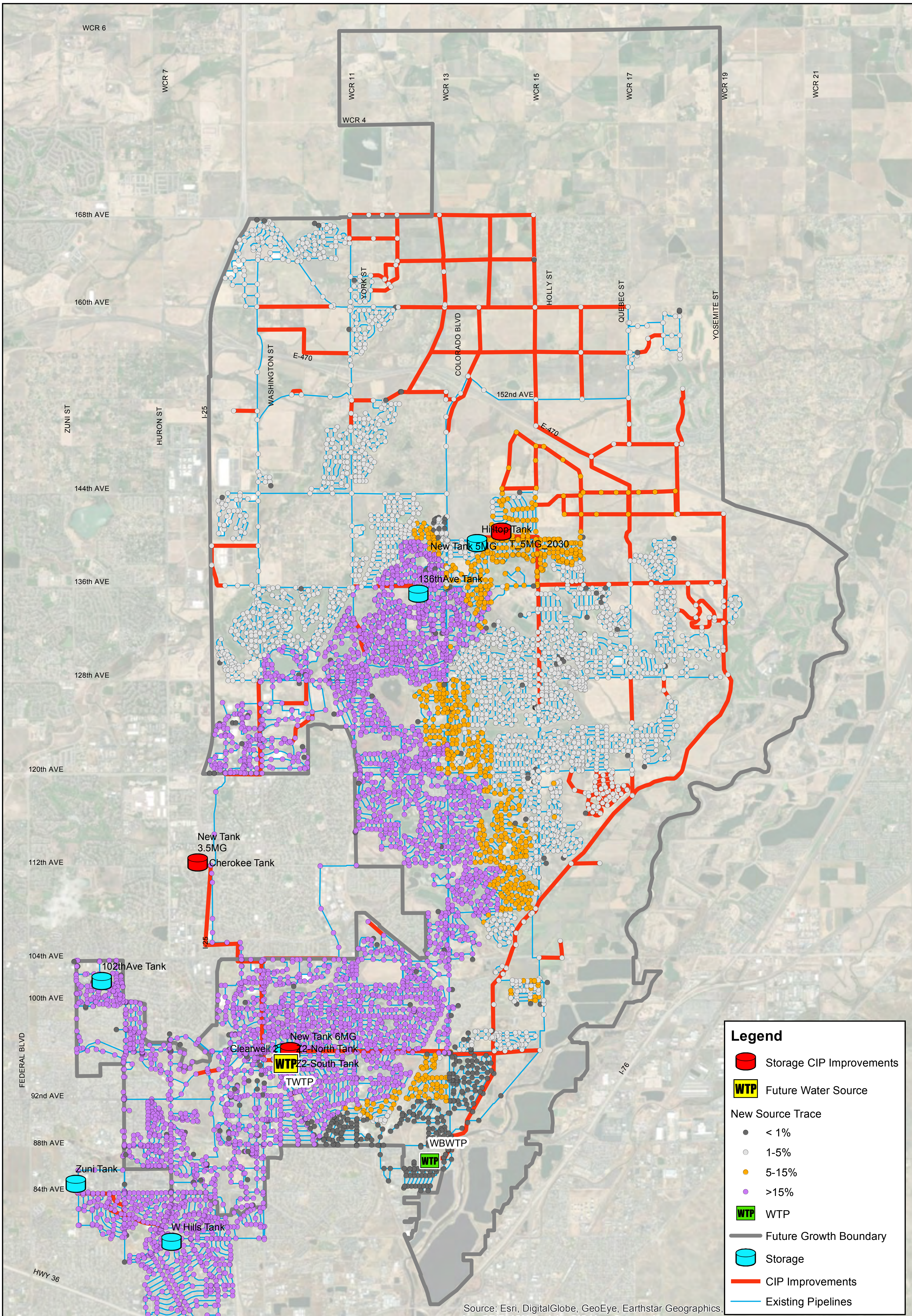

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Figure 8
Alternative 2 New Source Trace Results

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1 inch = 5,000 feet

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Alternative 2 – Water Age

The hydraulic model was used to evaluate overall water age through the system for MDDs, under the Alternative 2 configuration. Water age results were used to characterize the performance of improvements developed for this alternative. The simulation was performed for several weeks in succession to identify water quality trends for MDD, which doesn't represent worst conditions for water age in the system but provides a measure of operational effectiveness.

Table 17 summarizes the results of the evaluation, showing average water age in system tanks. Figure 9 presents water age in the system for this alternative. These results show acceptable ranges of water age for MDD conditions, supporting the results obtained for the source trace analysis, showing adequate water distribution in the system.

Table 17: Alternative 2 – Water Age Results by Reservoir

Water Age at System Storage Tanks				
Tank	Max. Value (hours)	Min. Value (hours)	Average (hours)	Difference (hours)
102nd Ave.	169.5	43.4	159.3	126.1
136th Ave.	198.5	41.8	177.9	156.7
Cherokee (Existing and Proposed)	139.4	67.8	134.9	71.6
Hilltop	124.0	84.5	121.7	39.5
New Tank Zone 1 North	119.1	99.9	117.4	19.3
New Tank Zone 1 South	132.0	67.7	126.2	64.3
Western Hills	152.4	55.0	147.4	97.3
Zone 2 North	207.4	31.5	187.2	175.9
Zone 2 South	193.0	35.7	172.0	157.2
Zuni	193.1	42.4	179.6	150.8

Note: 1 week = 168 hours

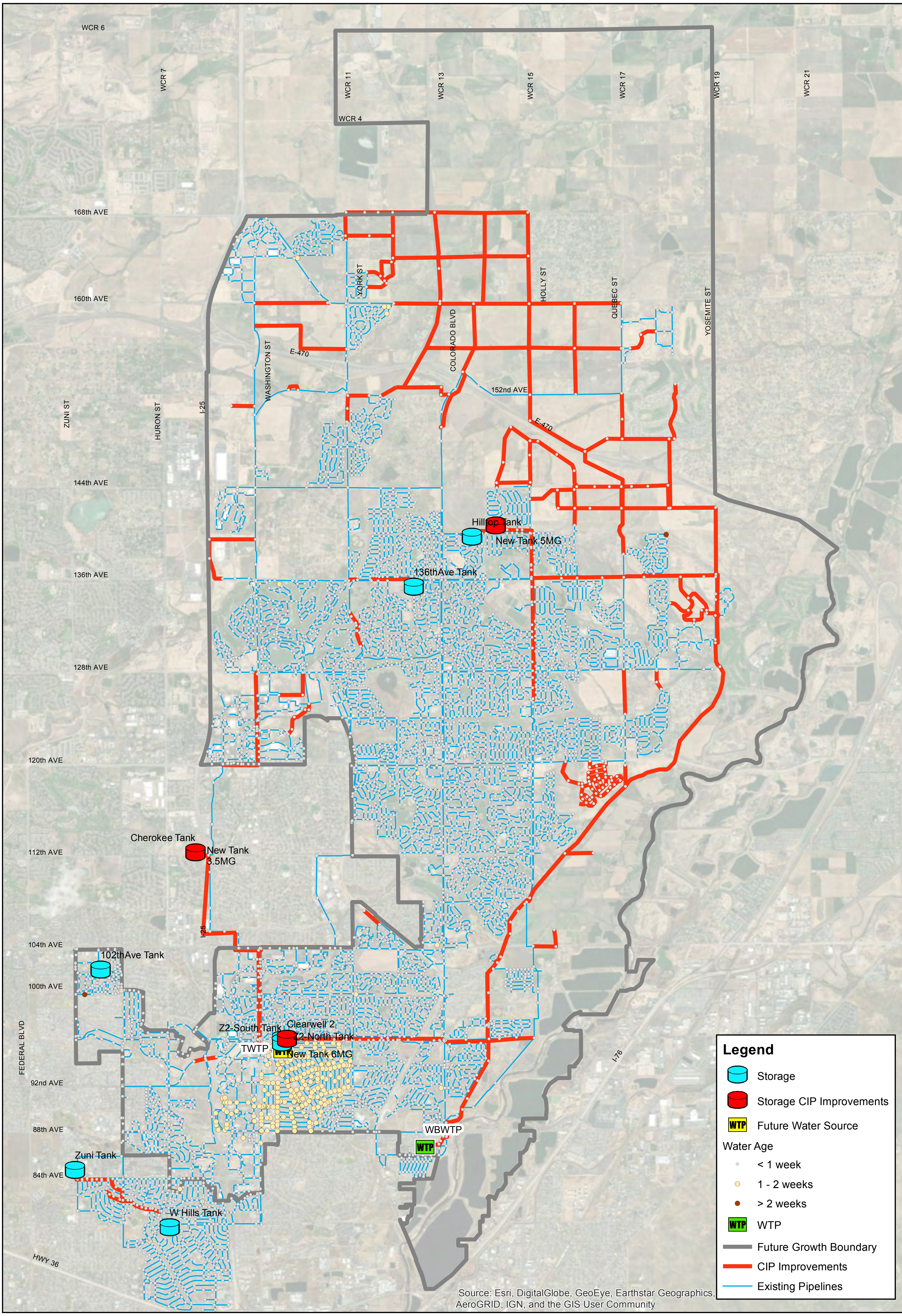

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Figure 9
Alternative 2
Water Age Results

8/16/2019

1 inch = 5,000 feet

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Alternative 2 – Redundancy

To evaluate the redundancy of the system, or the system's ability to respond to emergency conditions, the following conditions were evaluated:

- Condition 1: TWTP offline
- Condition 2: WBWTP offline

These evaluations were performed for buildout ADD. With the improvements proposed under Alternative 2, the ability of the system to provide adequate service pressure was assessed in order to determine if additional improvements were required to improve system redundancy. Table 18 displays the treatment facility assumptions for each condition. Table 19 displays a summary of the system results for each condition. Appendix A includes a system performance map with the minimum service pressure for each condition.

Table 18: Alternative 2 – Redundancy Conditions Water Treatment Facility Assumptions

Treatment Facility	Production Capacity (mgd)	Condition 1 (mgd)	Condition 2 (mgd)
TWTP	41.5	0	41.5
WBWTP	54.8	54.8	0
Total	96.3	54.8	41.5
Buildout ADD (mgd)	44		

Table 19: Alternative 2 – Redundancy Conditions Model Results Summary

Pressure Range (psi)	Number of Junctions by Pressure Range	
	Condition 2	Condition 3
	TWTP Offline	WBWTP Offline
20	54	54
40	81	80
60	612	623
80	3,051	3,050
100	3,058	3,055
120	547	542
>120	102	101

Note: Pressure lower than 20 psi was observed near storage tanks and in distribution lines running through, but not connecting to pressure zones. The location of the low pressure observed here was not a cause of concern.

7.4.3 Alternative 3 – System Performance

The future treatment capacity for the WBWTP expansion is 76.3 mgd. The additional transmission required to convey water from the WBWTP to future storage serving the northern portion of the system is presented in Table 18. Similar to Alternative 2, the system impacts based on this alternative can be summarized as follows:

- The expansion of the WBWTP results in larger transmission improvement requirements when compared to Alternative 1, not only in size but also in length of piping, as shown in Table 11. The largest diameter of CIP pipes is 72 inches in this alternative, compared to 48 inches for Alternative 1.
- As discussed in Section 7.3, pumping improvements for this alternative are different than those for Alternatives 1 and 2. The Wes Brown High Service Pump Station will require additional pumping improvements in Alternative 3.
- Storage capacity improvements are the same for all supply alternatives.

In addition to the CIP projects to serve new developments (described in Section 7.1), storage improvements (described in section 7.2), and pumping improvements (described in Section 7.3), the system will require the following improvements to provide adequate service, meeting the criteria described in Section 6:

- TT20: New 36-inch transmission pipes connecting Pump Station Z3/4 and Cherokee Tanks (existing and proposed).
- TT11: New 72-inch transmission pipe connecting the WBWTP to the new tank in the northern part of Zone 1. This major transmission line is intended to function as the backbone of Zone 1 and will support the growth in the north side of the service area.
- TT23: New 42-inch pipe to increase the capacity of the existing transmission along Holly Street.
- TT13: New 36-inch transmission pipe connecting the new storage proposed for the northern Zone 1 to the existing Hilltop Tank.
- TT14: New 72-inch transmission pipe between the new storage proposed near Clearwell 2, and the new transmission line connecting the WBWTP to the northern tanks (new storage and Hilltop Tank).
- TT16: New 24-inch transmission pipe that improves the connection from the TWTP to the proposed transmission pipe TT14.
- TT23: New 42-inch transmission pipe that connects two existing transmission mains from the WBWTP.

Alternative 3 was evaluated for new water supply source trace, water age, and redundancy. The results of these evaluations are presented herein.

Alternative 3 – New Treatment Plant Supply Trace

Table 20 summarizes the source trace results for each storage tank in the system. Figure 10 shows the results for source trace assuming the new water supply from the TWP is supplied through the system at the WBWTP. Approximately 97% of the system will receive at least 5% of supply from the new source under this alternative configuration. The tracing extent is the function of the new source's point of connection to the system, its distance to other WTPs, and the storage, pumping, and piping improvements proposed to serve buildout under Alternative 3.

Table 20: Alternative 3 – New Supply Source Trace Results at Storage Tanks

Source Trace amount of WBWTP Supply at System Storage Tanks				
Tank	Max. Value (%)	Min. Value (%)	Average (%)	Difference (%)
102nd Ave.	49.0	48.3	48.7	0.7
136th Ave.	28.3	27.2	28.0	1.0
Cherokee (Existing and Proposed)	46.2	45.6	45.9	0.6
Hilltop	28.3	28.3	28.3	0.0
New Tank Zone 1 North	28.3	28.3	28.3	0.0
New Tank Zone 1 South	30.7	30.2	30.5	0.5
Western Hills	48.9	48.1	48.5	0.8
Zone 2 North	33.3	30.7	32.5	2.6
Zone 2 South	33.3	31.9	32.9	1.5
Zuni	48.7	47.0	48.2	1.8

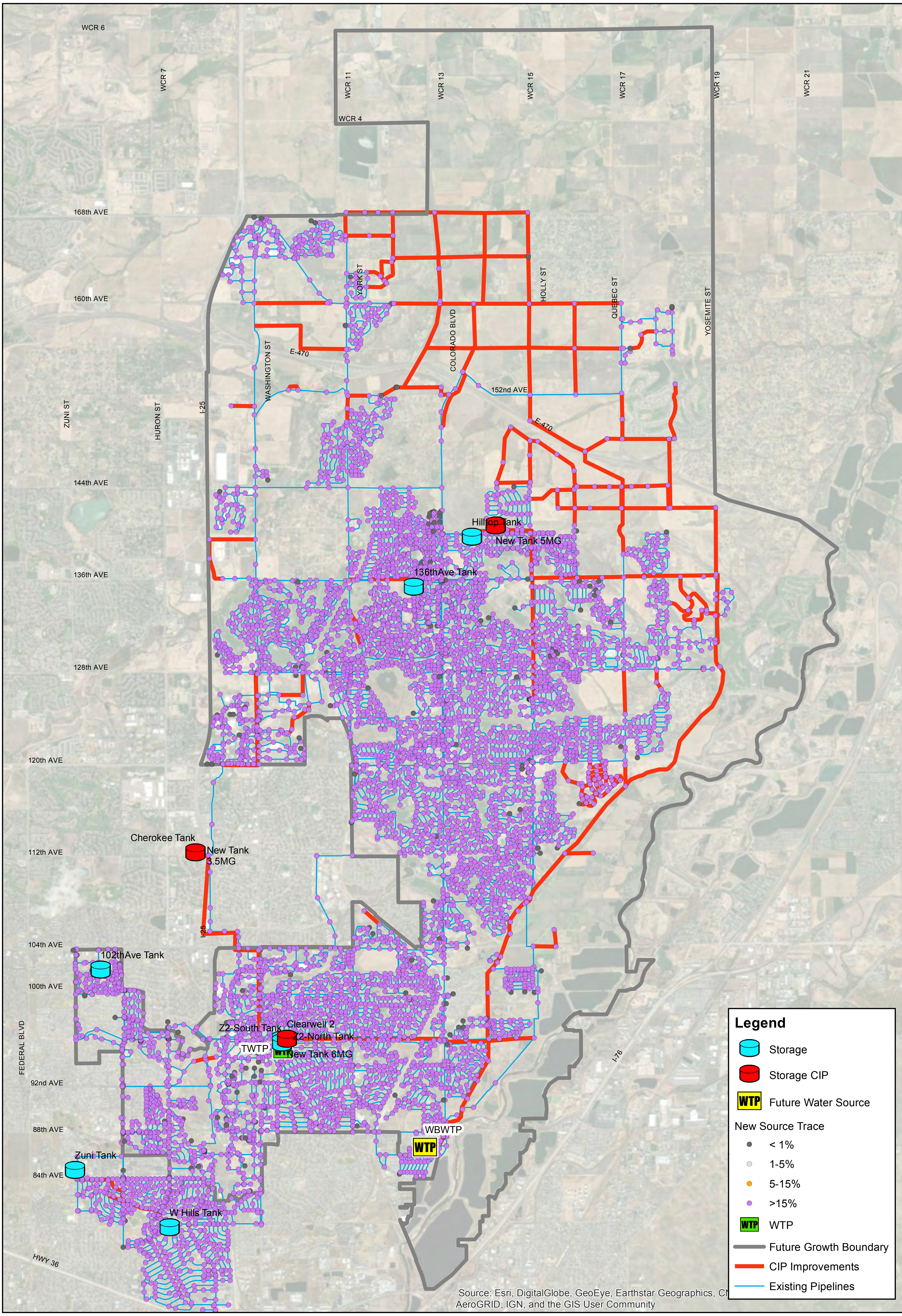

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Figure 10
Alternative 3 New Source
Trace Results

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1 inch = 5,000 feet

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Alternative 3 – Water Age

The hydraulic model was used to evaluate overall water age through the system for MDDs, under Alternative 3. Water age results were used to characterize the performance of improvements developed for this alternative. The simulation was done for several weeks in succession to identify water quality trends. Table 21 summarizes the results of the evaluation, showing average water age in system tanks. Figure 11 presents water age in the system for this alternative.

Table 21: Alternative 3 – Water Age Results by Reservoir

Water Age at System Storage Tanks				
Tank	Max. Value (hours)	Min. Value (hours)	Average (hours)	Difference (hours)
102nd Ave.	174.1	41.2	163.0	132.9
136th Ave.	192.8	43.9	178.6	148.9
Cherokee (Existing and Proposed)	144.1	75.7	134.8	68.4
Hilltop	130.2	68.0	128.8	62.3
New Tank Zone 1 North	122.9	96.6	119.9	26.3
New Tank Zone 1 South	253.1	65.8	190.5	187.3
Western Hills	141.1	63.5	136.9	77.6
Zone 2 North	315.5	30.1	243.8	285.3
Zone 2 South	299.2	33.1	228.5	266.1
Zuni	195.8	42.0	182.0	153.8

1 week = 168 hours

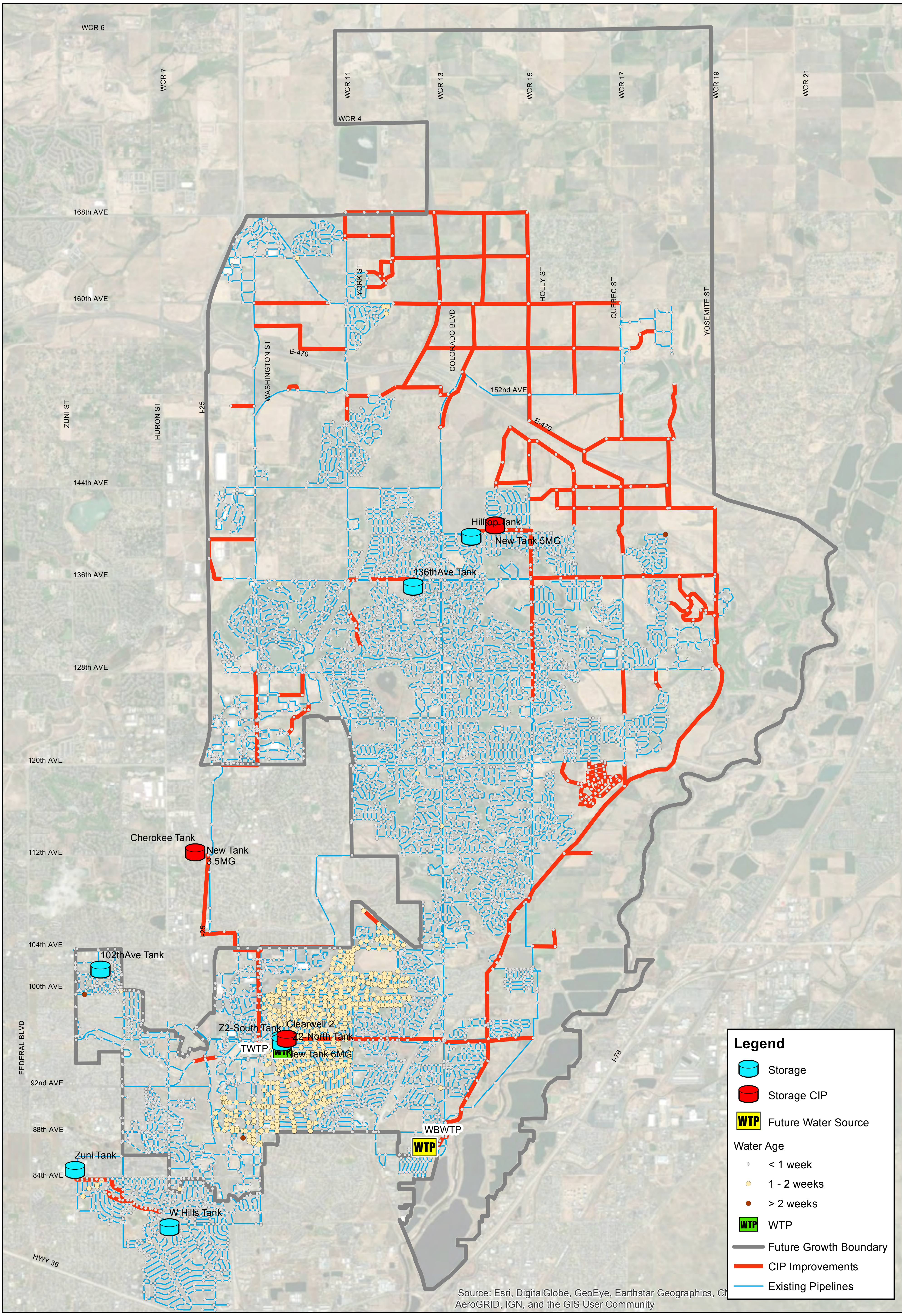

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Figure 11
Alternative 3
Water Age Results

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Alternative 3 – Redundancy

To evaluate the redundancy of the system, or the system's ability to respond to emergency conditions, the following conditions were evaluated:

- Condition 1: TWTP offline
- Condition 2: WBWTP offline

These evaluations were performed for buildout ADD. With the improvements proposed under Alternative 3, the ability of the system to provide adequate service pressure was assessed in order to determine if additional improvements were required to improve system redundancy. Table 22 displays the treatment facility assumptions for each condition. Table 23 displays a summary of the system results for each condition. Appendix A includes a system performance map with the minimum service pressure for each condition.

Table 22: Alternative 3 – Redundancy Conditions Supply Assumptions

Treatment Facility	Production Capacity (mgd)	Condition 1 (mgd)	Condition 2 (mgd)
TWTP	20	0	20
WBWTP	76.3	76.3	0
Total	**96.3**	**76.3**	**20**
Buildout ADD (mgd)	44		

Table 23: Alternative 3 – Redundancy Conditions Model Results Summary

Pressure Range (psi)	Number of Junctions by Pressure Range	
	Condition 2	Condition 3
	TWTP Offline	WBWTP Offline
20	54	54
40	86	88
60	611	679
80	3,012	3,021
100	3,065	3,029
120	570	535
>120	107	99

Note: Pressure lower than 20 psi is observed near storage tanks and in distribution lines running through, but not connecting to pressure zones. The location of the low pressure observed here was not a cause of concern.

7.5 Distribution System Capacity Evaluation

As discussed previously, improvements to serve future needs in the Thornton's service area were developed in five stages: improvements to serve future growth areas (currently not served); improvements to serve future storage needs; future required improvement to increase pumping capacity; and transmission improvements to connect supply at treatment plants with storage and distribution facilities. The last stage was to determine if these system improvements would meet Tier 1 and 2 criteria, or if additional improvements would be required for the existing system. The hydraulic model was used to assess the system's ability to meet the performance criteria:

- **Tier 1 Performance Criteria:**
  - Maximum and minimum system pressure: A 48-hour extended period simulation was conducted for buildout maximum day conditions, which included peak hour conditions. Locations where system pressure did not meet maximum or minimum requirements were considered deficiencies.
  - Fire flow availability: The hydraulic model was used to determine locations where the system does not have the capacity to provide minimum fire flow requirements under maximum day conditions. The minimum required fire flow for residential land use is 1,000 gpm.
- **Tier 2 Performance Criteria:**
  - Velocity and head loss constraints: Velocity and head loss results from peak hour simulation were used to identify this type of deficiency.
  - Water quality: MinDD was simulated to assess water age in the system and to identify changes in operation or additional infrastructure for improvement.

The results of peak hour simulations, fire flow availability, and water quality simulations are presented in Appendix B. Overall, a large portion of the system meets the performance criteria for buildout conditions. The key findings from these evaluations are as follows:

- Overall, the system meets minimum pressure criteria for buildout conditions. Without distribution improvements, a few locations in Zone 1 (north of Zone 3E near Washington Street and north of 130th Avenue) do not meet minimum pressure criteria during peak hour conditions. Additionally, a few locations in Zone 2 and Zone 3 near the boundary with the upper zone do not meet minimum pressure criteria. To address these deficiencies, new piping or pipe replacement and a change in the pressure zone boundary are recommended. Minimum pressure results are presented on Figure B-1.
- Overall, the system meets maximum pressure criteria for buildout conditions. Maximum pressure limits are exceeded in a few areas of the system. These locations are at the southern portion of Zone 4, around Sherrelwood Drive, and in Zone 1, near Zone 1C, where maximum pressure values range from 110-120 psi. Improvements required to address this type of service goal typically include the modification of pressure zone boundaries or the creation of new pressure zones. These will involve installation of new PRVs, relocation of existing PRVs, and opening/closing of existing gate valves. Due to the pressure range and the limited number of service connections affected by this violation, no improvements are recommended as part of this master plan. Pressure higher than 110 psi in transmission lines was not considered a deficiency. Maximum pressure results are presented on Figure B-2.
- Maximum velocity criterion is overall met by the system for buildout conditions. A few pipes across the system exceed the maximum velocity and improvements (pipe replacements) were recommended to meet requirements. Maximum velocity results are presented on Figure B-3.
- Maximum unit head loss criterion is overall met by the system for buildout conditions. A few pipes across the system exceed maximum unit head loss limits and improvements (pipe replacements) were recommended to address these deficiencies. Maximum unit head loss results are presented on Figure B-4.
- A fire flow availability map is presented on Figure B-5. The map shows the available fire flow at each junction in the system, with a residual pressure of 20 psi. Improvements (new pipe or pipe replacements) were recommended to increase availability at areas where fire flow did not reach 1,000 gpm. Those areas are as follows:
  - Zone 1, north of Zone 3E, near Washington Street, north of 130th Avenue;

- Zone 2, near Hoffman Way, west of Mountain View Park;
- Zone 3, near Thornton Parkway, south of Badding Reservoir;
- Zone 1, near Hoffman Way and Poze Boulevard;
- Zone 2, west of Greenwood Boulevard, north of El Paso Boulevard; and
- Zone 3, several service connections near boundary with Zone 4 and Zone 2.

- For the water age simulation, the system was tested during MinDD conditions. The results are presented on Figure B-6. The system meets water quality criteria for buildout conditions and no water age related projects have been identified.

7.6 Water System Analysis Conclusions

After analyzing the existing infrastructure under buildout conditions for the three supply alternatives, the following main conclusions were drawn:

- The location of the new source of supply for the system does not affect the size and location of improvements recommended for future development service, storage, or distribution.
- Transmission improvements are different for each supply alternative. Some improvements are common to all alternatives in purpose and location, but different in size.
- Pumping improvements are common for all alternatives, except for improvements recommended for the WBWTP High Service Pump Station.
- Current Zone 1 pumping limitations during high demand periods are addressed by the transmission improvements proposed for each alternative in Section 7.4. The operation of the Holly Pump Station was assumed for emergency purposes only and not for normal regular system operation. Transmission improvements were developed assuming all tanks located in Zone 1 will float of each other, working hydraulically interconnected. Holly Pump Station operation is known to cause high pressures in pipelines around, which is not sustainable due to material and age.
- Current storage infrastructure is not enough to serve future buildout requirements. Zone 1 and Zone 3 will require additional storage capacity.
- Zone 2 has a surplus of storage capacity. This surplus is assumed to supplement and address the storage deficiency of Zone 1. This can be achieved by feeding Clearwell 2 through a valve located in the Pump Station 2/3 facility, or by modifying the operation of Pump Station Z2.
- Pump Station Zone 5 requires an upgrade to meet fire flow requirements.
- Zone 3A can be served by Pump Station 3A from Zone 1 or by PRV 3A from Zone 3. For this study, it was assumed that future service will be from Zone 1 through the pump station. PRV 3A is assumed for emergencies only.
- Consistent with the findings in the 2009 Master Plan, the system evaluation shows a deficiency in transmission capacity from the WBWTP and the TWTP to the northern portion of the buildout service area, where most of the growth is expected to occur.

8. Capital Improvement Program

The overall CIP for the water system is comprised of five different types of improvements: future development distribution, storage, pumping, transmission, and distribution. Based on the results described in this TM, a preliminary list of CIP projects was developed identifying improvements to accommodate the expected growth by buildout. A project cost was developed by applying unit costs accounting for material and installation for water infrastructure, pump stations, and storage facilities. Table 24 summarizes the cost for each improvement type.

The unit costs are consistent with Association for the Advancement of Cost Engineering (AACE) Class V estimating guidance. This opinion of probable costs is based on conceptual design and the basis of estimate summarized in this report. All costs were developed in March 2019 dollars based on an Engineering News-Record (ENR) Construction Cost Index of 9668. All project descriptions and cost estimates in this CIP represent planning-level accuracy and opinions of costs (+50%, -30%). The estimated unit cost includes the sum of materials, labor, and equipment of reasonably identified features of a project. The estimated total project cost includes the sum of construction costs with additional allowances for direct and indirect costs. The indirect costs include engineering design, legal and administrative, construction management, and contingency. The following items are not included as part of the unit cost estimate: land or right-of-way acquisition; finance charges during planning, design, or construction of assets; remediation or fines associated with system violations; and operation, maintenance, and energy costs. No costs were inflated or discounted to account for future pricing. The development of unit costs is provided in Appendix C.

CIP improvements are summarized as follows:

- System improvements required to serve new developed areas are presented in Table 25; these projects are expected to be funded by developers and will not be included in Thornton's CIP.
- Table 26 summarizes projects recommended to address Tier 1 and Tier 2 deficiencies, such as minimum and maximum pressure, fire flow availability, and maximum velocity.
- Storage capacity improvements are summarized in Table 27.
- Pumping capacity improvements ae summarized in Table 28.
- Transmission improvements are summarized in Table 29.

Figure 12 shows the location of the recommended CIP projects, and Figure 13 shows the improvements by size.

Table 24: CIP Cost Summary

Type	Length (ft)	Alternative 1	Alternative 2	Alternative 3
Future Development Distribution Infrastructure Projects[1]	217,900	$105,913,230	$105,913,230	$105,913,230
Distribution System Improvements	45,200	$27,957,030	$27,957,030	$27,957,030
Storage Facility Improvements		$38,595,300	$38,595,300	$38,595,300
Pumping Station Improvements		$5,914,400	$5,914,400	$5,495,000
Transmission Improvements	86,400	$90,373,100	$160,213,500	$160,213,500
TOTAL CIP	349,500	$268,753,060	$338,593,460	$338,174,060

[1] Only a portion of these projects will be funded by Thornton, the majority will be the responsibility of developers.

Table 25: Future Development Distribution Infrastructure Projects

CIP ID	Diameter (in)	Length (ft)	Unit Cost	Cost	Primary Funding Source
DD01	16	10,500	511	$5,475,550	Developer
DD02	12	100	395	$39,490	Developer
DD03	12	6,900	395	$2,724,760	Developer
DD04	8	2,800	308	$861,930	Developer

CIP ID	Diameter (in)	Length (ft)	Unit Cost	Cost	Primary Funding Source
DD05	8	5,800	308	$1,785,410	Developer
DD06	12	4,100	395	$1,619,060	Developer
DD07	12	2,800	395	$1,105,700	Developer
DD08	12	10,500	395	$4,146,370	Developer
DD09	16	2,600	511	$1,329,890	Developer
DD10	12	2,300	395	$908,260	Developer
DD11	12	3,600	395	$1,421,620	Developer
DD12	12	33,500	395	$13,438,610	Developer
DD15	12	3,500	395	$1,382,130	Developer
DD16	12	1,200	395	$473,880	Developer
DD17	12	2,600	395	$1,026,720	Developer
DD18	8	11,700	308	$3,601,610	Developer
DD19	12	1,300	395	$513,360	Developer
DD20	12	400	395	$157,960	Developer
DD21	10	200	351	$70,280	Developer
DD22	12	1,300	395	$513,360	Developer
DD23	12	1,700	395	$671,320	Developer
DD24	12	2,300	395	$908,260	Developer
DD36	8	1,200	308	$369,400	Developer
DD39	16	2,600	511	$1,329,890	Developer
DD40	12	2,700	395	$1,066,210	Developer
DD43	12	5,400	395	$2,132,420	Developer
DD45	12	1,400	395	$552,850	Developer
DD49	36	2,600	861	$2,239,380	Thornton
DD50	16	2,700	511	$1,381,040	Developer
DD51	12	600	395	$236,940	Developer
DD52	12	400	395	$262,820	Developer
DD53	24	1,400	650	$909,810	Thornton
DD54	16	2,500	511	$1,278,740	Developer
DD55	16	700	511	$358,050	Developer
DD56	12	900	395	$355,410	Developer
DD57	12	6,600	395	$2,606,290	Developer
DD58	12	2,700	395	$1,066,210	Developer
DD59	12	2,800	395	$1,105,700	Developer
DD60	12	2,700	395	$1,066,210	Developer
DD61	12	100	395	$39,490	Developer
DD62	12	100	395	$39,490	Developer
DD63	12	2,700	395	$1,171,080	Developer
DD64	12	2,200	395	$868,770	Developer
DD65	12	400	395	$157,960	Developer
DD66	12	2,500	395	$987,240	Developer
DD67	12	2,700	395	$1,066,210	Developer
DD68	12	2,600	395	$1,026,720	Developer
DD69	12	3,200	395	$1,263,660	Developer
DD70	12	2,700	395	$1,066,210	Developer
DD71	12	2,700	395	$1,066,210	Developer
TT01	16	4,500	511	$2,406,590	Developer
TT02	20	200	558	$111,630	Thornton

CIP ID	Diameter (in)	Length (ft)	Unit Cost	Cost	Primary Funding Source
TT03	16	4,400	511	$2,250,580	Developer
TT04	24	4,600	650	$2,989,370	Thornton
TT07	42	5,200	1,000	$5,198,280	Thornton
TT08	42	15,400	1,000	$15,394,890	Thornton
TT09	20	2,700	558	$1,506,970	Thornton
TT10	24	7,400	650	$4,808,980	Thornton
Total		**217,900**		**$105,913,230**	
Total - Developer		**178,400**		**$72,753,920**	
Total - Thornton		**39,500**		**$33,159,310**	

Note: Cost of PRV Facility included in projects DD01, DD12, DD52, DD63, and TT01

Table 26: Proposed Distribution System Improvement Projects

CIP ID	Diameter (in)	Length (ft)	Project Type	Unit Cost ($/ft)	Cost
DD27	12	400	Tier 1 - Capacity	395	$ 157,960
DD28	8	3,300	Tier 1 - Capacity	308	$ 1,015,840
DD30	12	800	Tier 1 - Capacity	395	$ 315,920
DD31	12	300	Tier 1 - Capacity	395	$ 118,470
DD32	16	700	Tier 1 - Capacity	511	$ 358,050
DD34	16	700	Tier 1 - Capacity	511	$ 358,050
DD35	16	100	Tier 1 - Capacity	511	$ 51,150
DD46	12	900	Tier 1 - Capacity	395	$ 355,410
DD25	12	1,700	Tier 2 - Capacity	395	$ 671,320
DD26	12	2,000	Tier 2 - Capacity	395	$ 789,790
DD29	16	700	Tier 2 - Capacity	511	$ 358,050
DD37	16	4,300	Tier 2 - Capacity	511	$ 2,199,430
DD41	16	2,200	Tier 2 - Capacity	511	$ 1,125,290
DD42	16	600	Tier 2 - Capacity	511	$ 306,900
DD48	12	100	Tier 2 - Capacity	395	$ 39,490
TT06	24	3,800	Tier 2 - Capacity	650	$ 2,469,480
TT21	24	7,700	Tier 2 - Capacity	650	$ 5,003,940
TT22	24	2,700	Tier 2 - Capacity	650	$ 1,754,630
TT17	36	12,200	Storage	861	$ 10,507,860
Total		45,200			$ 27,957,030

Table 27: Proposed Storage Facility Improvement Projects

CIP ID	Project Description	Project Location	Zone	Volume (MG)	Unit Cost ($/gal)	Cost ($)
SS-01	New ground storage	Near Sintra Lewis Pointe Park, north of 140th Avenue	1	5	$2.64	$13,214,900
SS-02	New ground storage	Near existing Cherokee Tank	3	3.5	$2.72	$9,522,500
SS-03	New ground storage	Adjacent to TWTP Clearwell 1	1	6	$2.64	$15,857,900
Total						$38,595,300

Table 28: Proposed Pumping Station Improvement Projects

CIP ID	Project Description	Project Location	Zone	Additional Capacity (gpm)	Recomm. Firm Capacity (gpm_	Unit Capacity (gpm)	TDH (ft)	Power (HP)	Unit Cost $/HP	Cost
Projects common to all alternatives										
PS-01	Pump unit replacement	Zone 5 Pump Station	5	Two units of 1,500gpm	2,050	1,500	150	70	$2,097	$146,900
PS-02	Additional pump unit	Zone 3A Pump Station	3A	One unit of 8,000 gpm	22,000	8,000	226	1,100	$2,097	$1,153,500
Projects common to Alternatives 1 and 2										
PS-03	Pump unit replacement and additional pump unit	Zone 1 - Wes Brown High Service Pump Station	1	Two units of 10,000 gpm	66,800	20,000	363	2,200	$2,097	$4,614,000
Projects for Alternative 3										
PS-03[1]	Pump unit replacement	Zone 1 - WB HSPS	1	Two units of 9,000gpm	66,800	18,000	363	2,000	$2,097	$4,194,500
Total									Alternatives 1 and 2	$5,914,400
Total									Alternative 3	$5,495,000

[1] The addition of two new units for this scenario might require modifications to existing structure. Cost for building remodeling or upgrade is not included.

Table 29: Proposed Transmission Improvement Projects

CIP ID	Length (ft)	Project Description	Project Type	Diameter (in)			Unit Cost ($/ft)			Cost		
				Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
TT20	5,100	New transmission pipe	Storage	36	36	36	861	861	861	$4,392,700	$4,392,700	$4,392,700
TT25	400	Connection to existing pipe	Storage	24	24	24	650	650	650	$260,000	$260,000	$260,000
TT11	57,400	New transmission pipe	Supply	48	72	72	1,163	2,046	2,046	$66,751,100	$117,439,100	$117,439,100
TT13	1,900	New transmission pipe	Supply	48	36	36	1,163	861	861	$2,209,600	$1,636,500	$1,636,500
TT14	14,300	New transmission pipe	Supply	48	72	72	1,163	2,046	2,046	$16,629,700	$29,257,500	$29,257,500
TT16	200	Connection to existing pipe	Supply	24	24	24	650	650	650	$130,000	$130,000	$130,000
TT23	7,100	New transmission pipe	Supply	0	42	42	0	1,000	1,000	$0	$7,097,700	$7,097,700
Total	86,400									$90,373,100	$160,213,500	$160,213,500

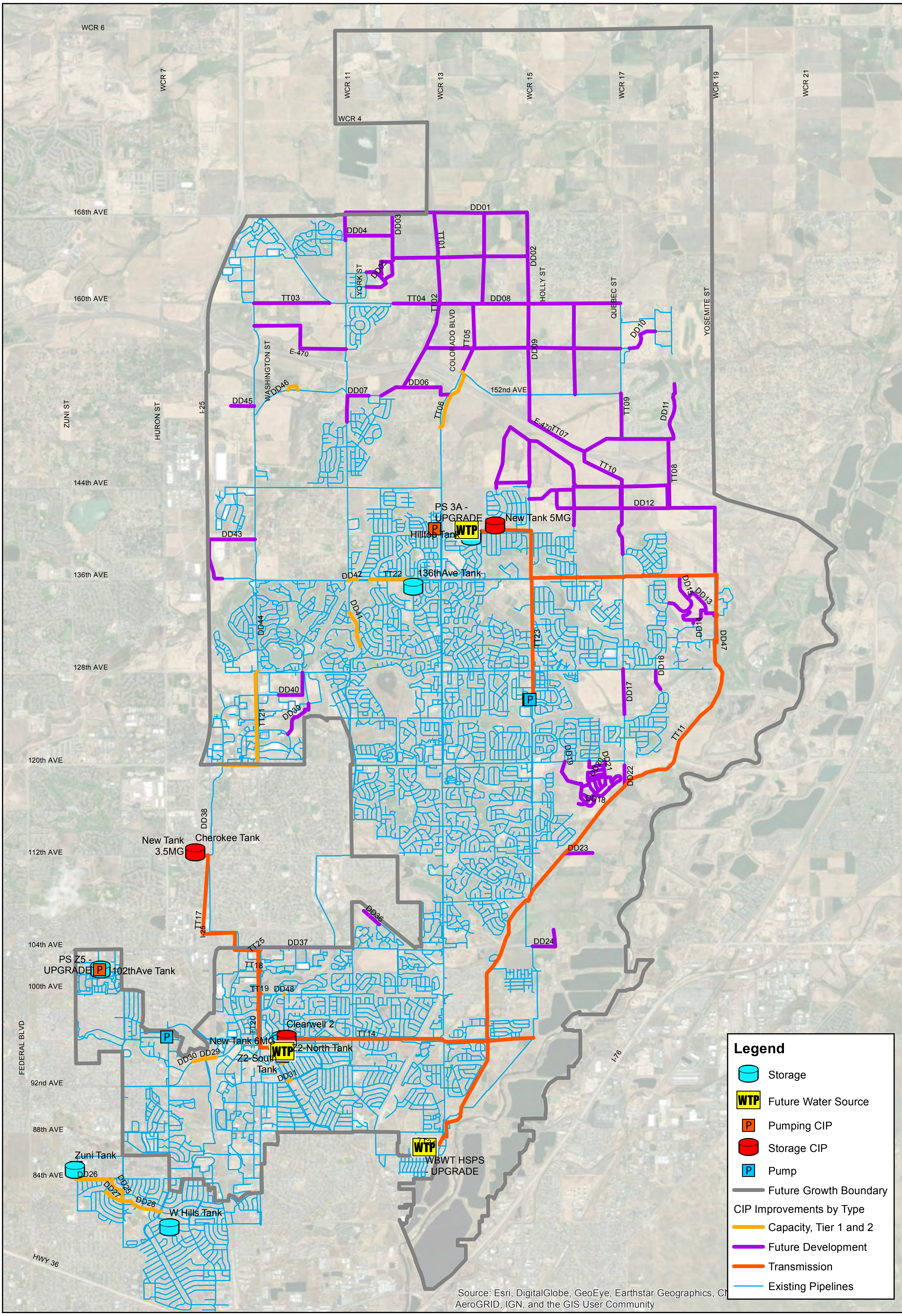

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Figure 12
Proposed Distribution and Transmission CIP Projects

9/3/2019
1 inch = 5,000 feet

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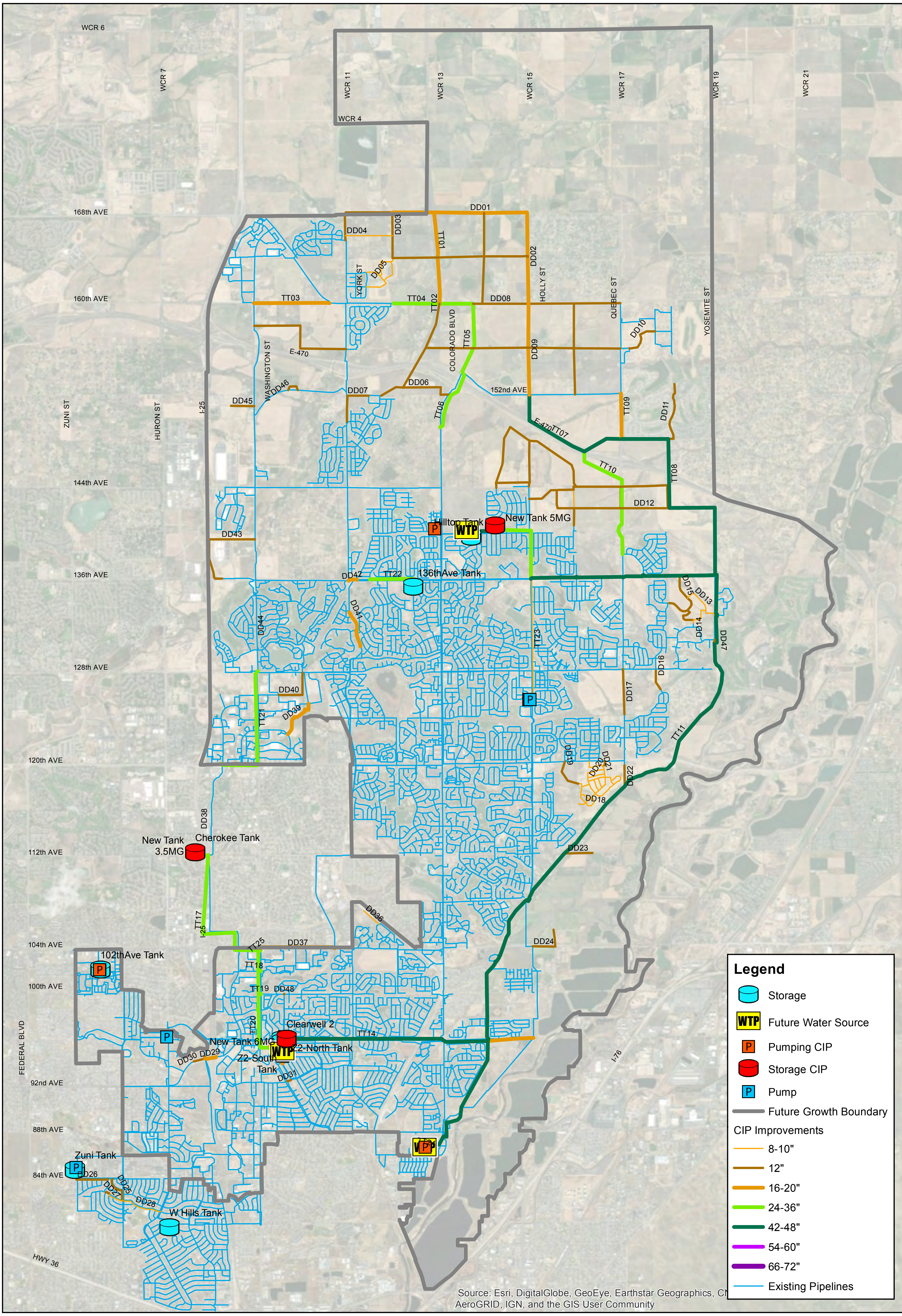

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Figure 13
CIP Projects - Diameter

8/16/2019
1 inch = 5,000 feet

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8.1 Alternative Evaluation

The purpose of this section is to compare key performance indices (KPIs) for each alternative's CIP to provide Thornton with an objective overview of performance and potential effect on key issues such as water quality, supply blending, and operation and maintenance (O&M) costs.

The basis for evaluation is the performance criteria that were established in the System Performance Criteria. The tables in the following sections provide the evaluation of KPIs for each alternative based on:

- Performance: The basis for developing the CIP projects for each alternative was the ability to meet the performance criteria. As such, all alternatives are anticipated to meet the Tier 1 and Tier 2 criteria. The evaluation therefore is intended to reflect instances where any particular alternative may meet the criteria in a manner that provides greater benefit to Thornton relative to the other alternatives.
- Other Considerations: Evaluation of the performance of each alternative CIP projects relative to KPIs that are important considerations for Thornton but are not considered System Performance Criteria.

8.1.1 Performance Evaluation

Table 30 summarizes the performance of each alternative relative to the Tier 1 and Tier 2 criteria for water transmission and distribution. Each alternative has been configured to meet all Tier 1 requirements, which are considered fundamental requirements for the Thornton system. CIP for each alternative is comprised of storage, pumping, distribution improvements (common to all alternatives), and transmission improvements.

The information in Table 30 has been annotated to identify potential differentiators between alternatives, with a "±" used to indicate no specific advantage when compared to the other two alternatives, a "+" used to indicate that the alternative has an advantage relative to the other options, and a "-" used to indicate that the alternative has a disadvantage relative to the other options.

Table 30: KPI Evaluation – Tier 1 and Tier 2 Water Transmission and Distribution Performance Criteria

Performance Parameter	Criteria	Alternative 1	Alternative 2	Alternative 3
Minimum System Pressure	• 50 psi static • 20 psi for MDD+FF • 40 psi for PHD	±	±	±
Maximum System Pressure	110 psi	±	±	±
Storage Requirements	Largest single hydrant FF volume within the zone + 25% MDD for equalization + 15% MDD for emergency storage	±	±	±
Firm Pumping Capacity	• MDD for gravity storage • PHD or MDD plus FF for pumped storage (whichever is greater)	+	+	-
Maximum Velocity	• 5 fps for PHD • 10 fps for MDD+FF	±	±	±
Maximum Unit Head Loss	≤ 3 feet/1,000 feet for pipes ≥ 16-inch diameter	±	±	±
Maximum Water Age	20-30 days for MinDD conditions	+	+	-

8.1.2 Other Considerations

Table 31 shows the performance of alternatives relative to KPIs that are important considerations for Thornton but are not considered Tier 1 or Tier 2 system performance criteria. These KPIs are:

- Number of Facilities: Does the alternative require land acquisition, additional personnel.
- New Source Water Blending: Effectiveness of the hydraulic configuration to provide supply from the Thornton Water Project to customers within the service area.
- Redundancy and Resiliency: How the system responds to emergency supply conditions (one WTP out of service).
- O&M Costs: Operational and maintenance considerations.
- Energy Costs: Based on pumping requirements for the system.
- Spatial Distribution of Sources: Location of treatment facilities within the system.

Table 31 indicates any differences in meeting goals that may identify one alternative as preferential to the others based on the same factor.

Table 31: KPI Evaluation – Other Considerations

KPI	Description	Alternative 1	Alternative 2	Alternative 3
Number of Facilities	Implication of an increase number of facilities	-	+	+
Water Blending	Approach maximizes the potential for raw and/or finished water blending for full benefit of majority of Thornton residents	-	+	+
Redundancy and Resiliency	Overall infrastructure designed to minimize impacts of outages or other operational disruptions	++	+	-
O&M Costs	Operational considerations	-	+	+
Energy Costs	Pumping costs for the water distribution system	+	+	-
Spatial Distribution of Sources	Benefits of alternative in terms of location of sources	++	+	- -

Appendix A : Transmission System Capacity Evaluation – Redundancy and Resilience Figures

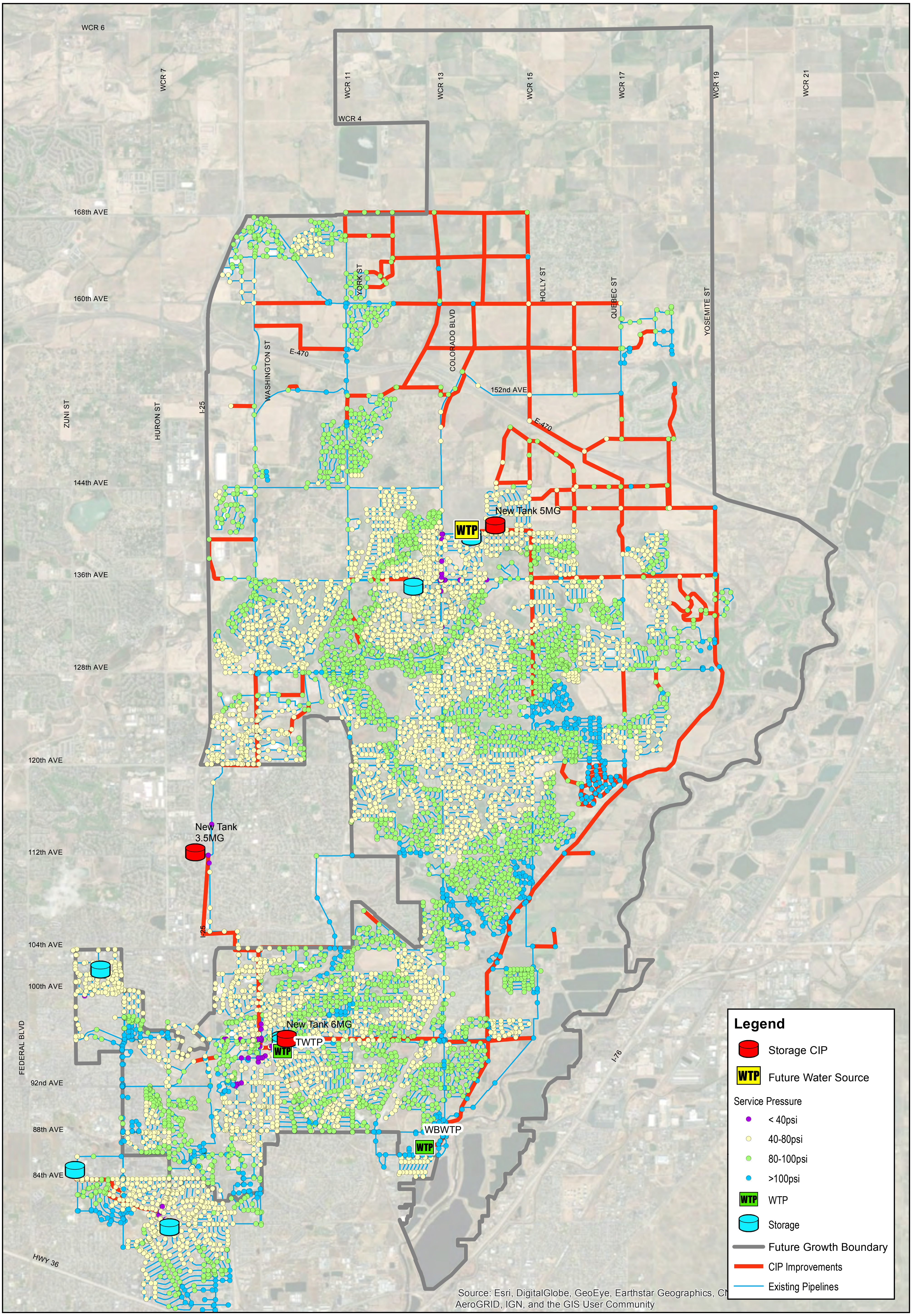

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Figure A1
Alternative 1
Condition 1: NWTP Offline - Pressure

8/16/2019
1 inch = 5,000 feet

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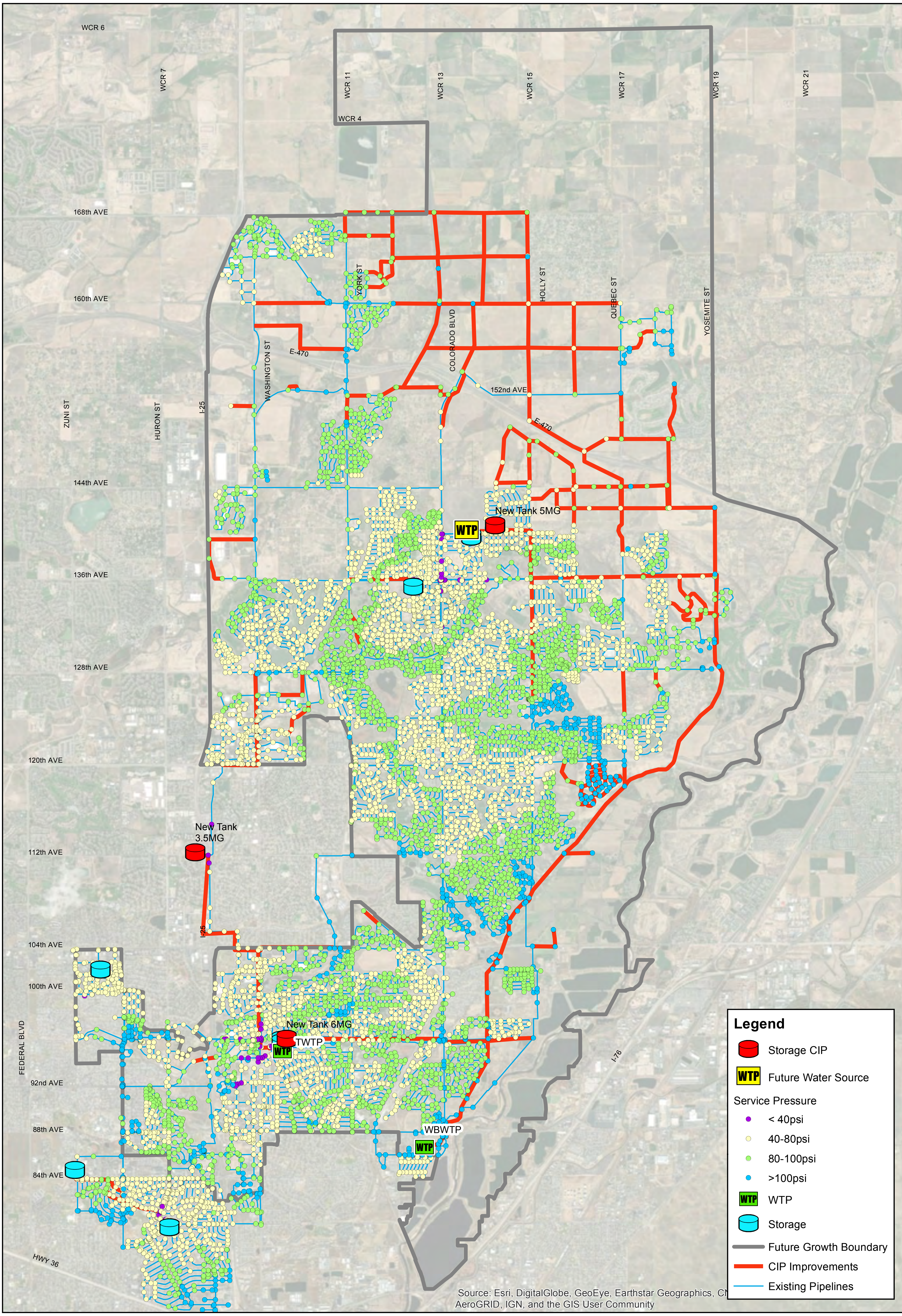

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Figure A2
Alternative 1
Condition 2: TWTP Offline - Pressure

8/16/2019
1 inch = 5,000 feet

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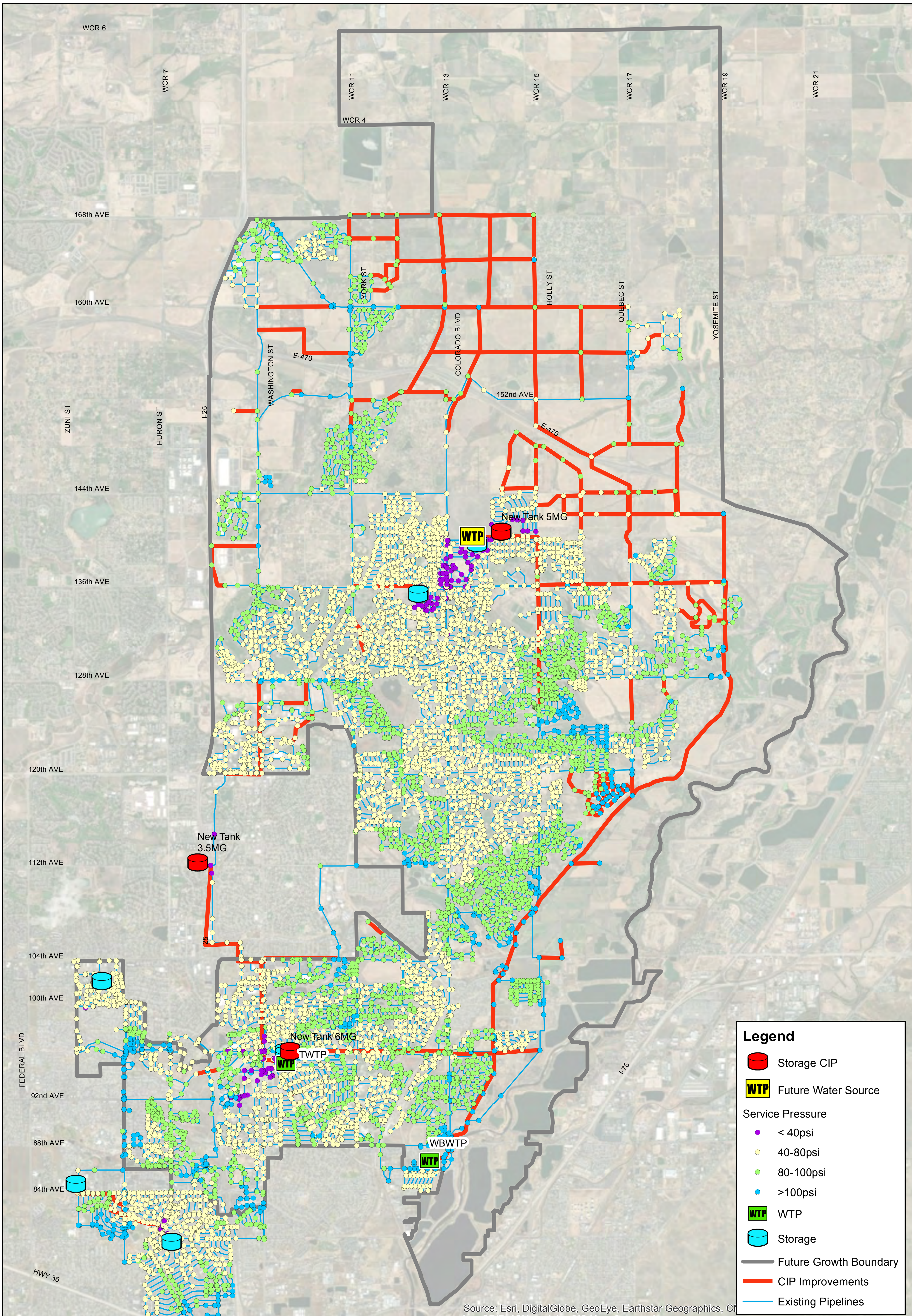

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Figure A3
Alternative 1
Condition 3: WBWTP Offline - Pressure

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1 inch = 5,000 feet

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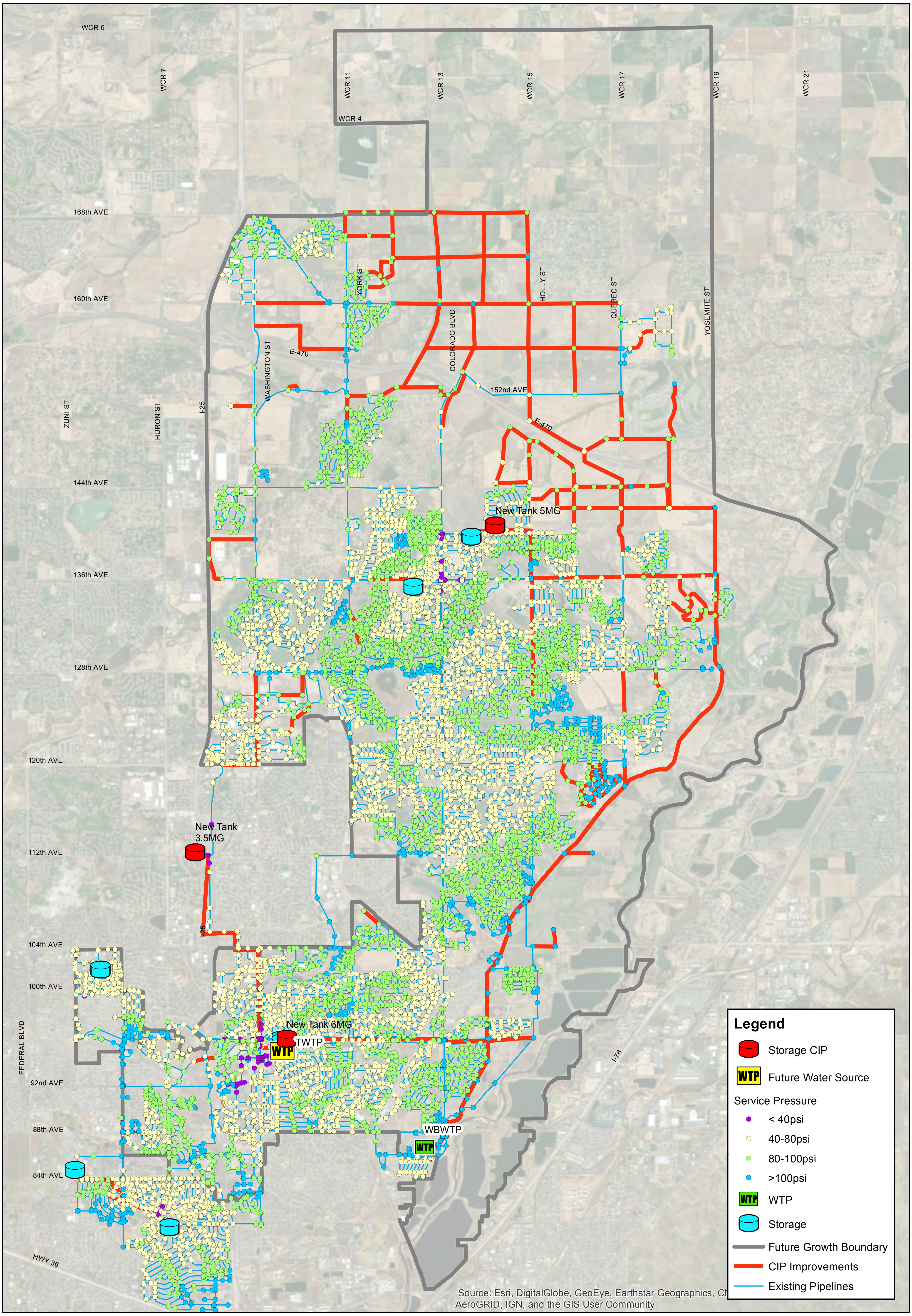

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Figure A4
Alternative 2
Condition 1: TWTP Offline - Pressure

8/16/2019
1 inch = 5,000 feet

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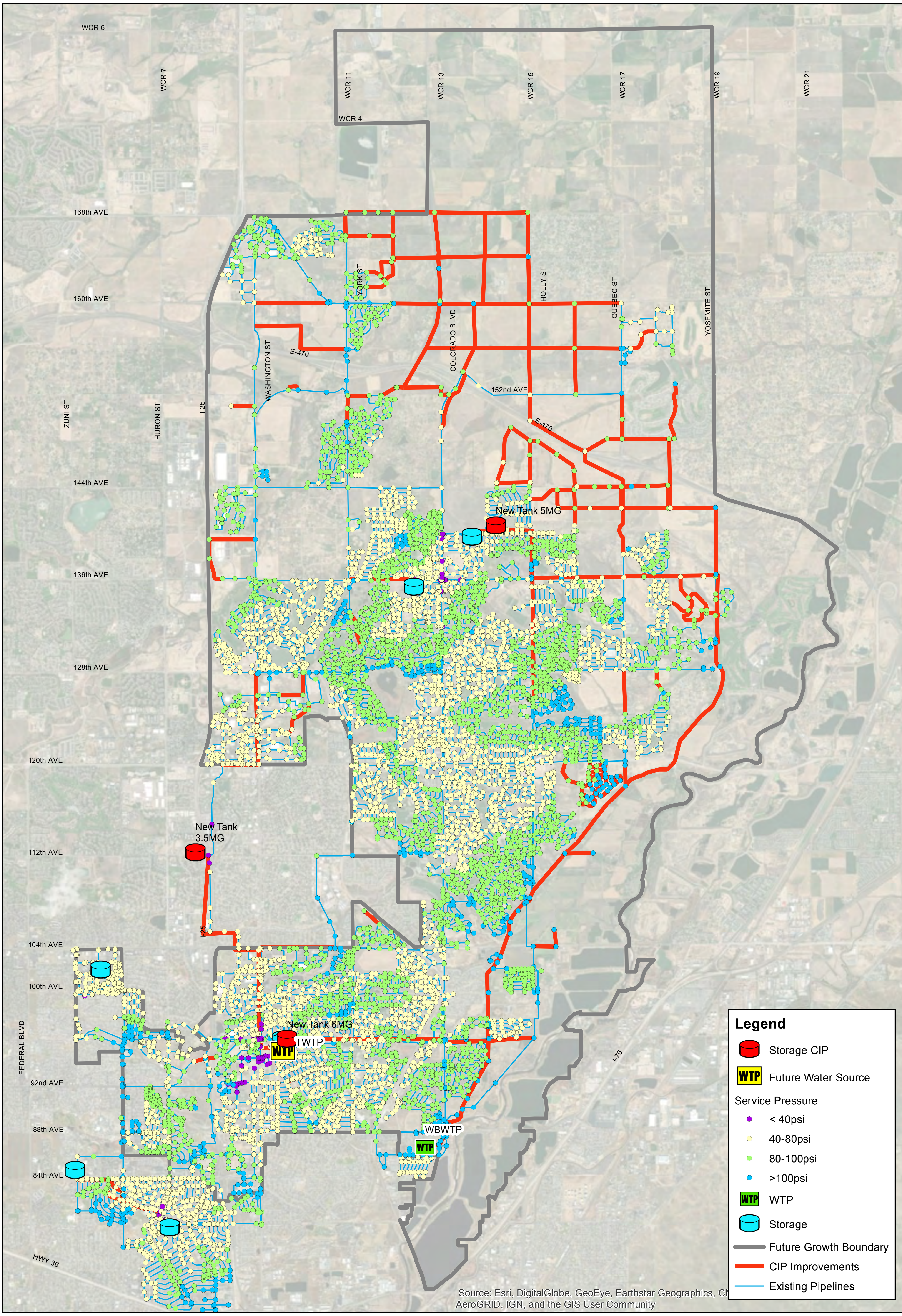

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Figure A5
Alternative 2
Condition 2: WBWTP Offline - Pressure

8/16/2019
1 inch = 5,000 feet

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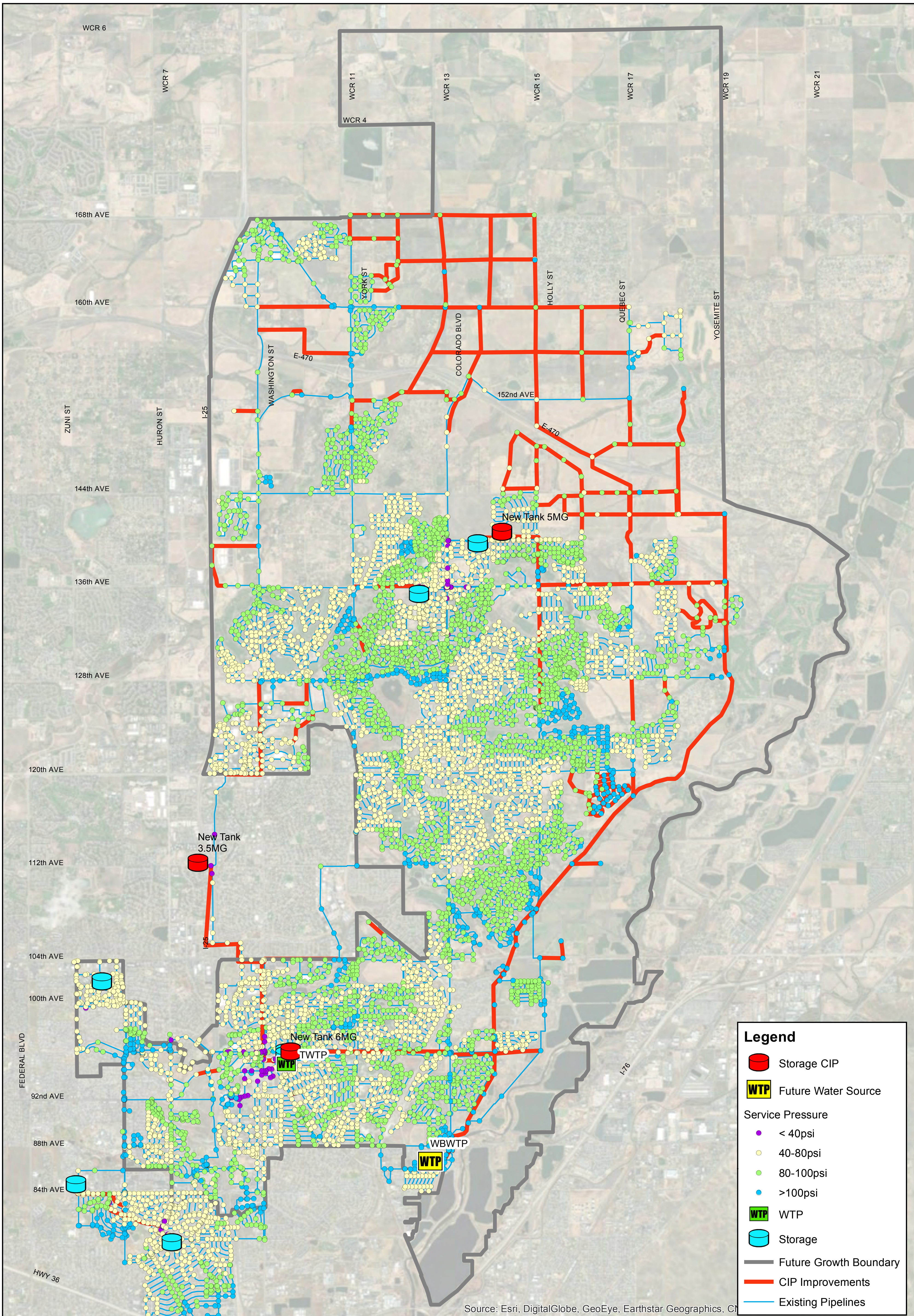

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Figure A6
Alternative 3
Condition 1: TWTP Offline - Pressure

8/16/2019
1 inch = 5,000 feet

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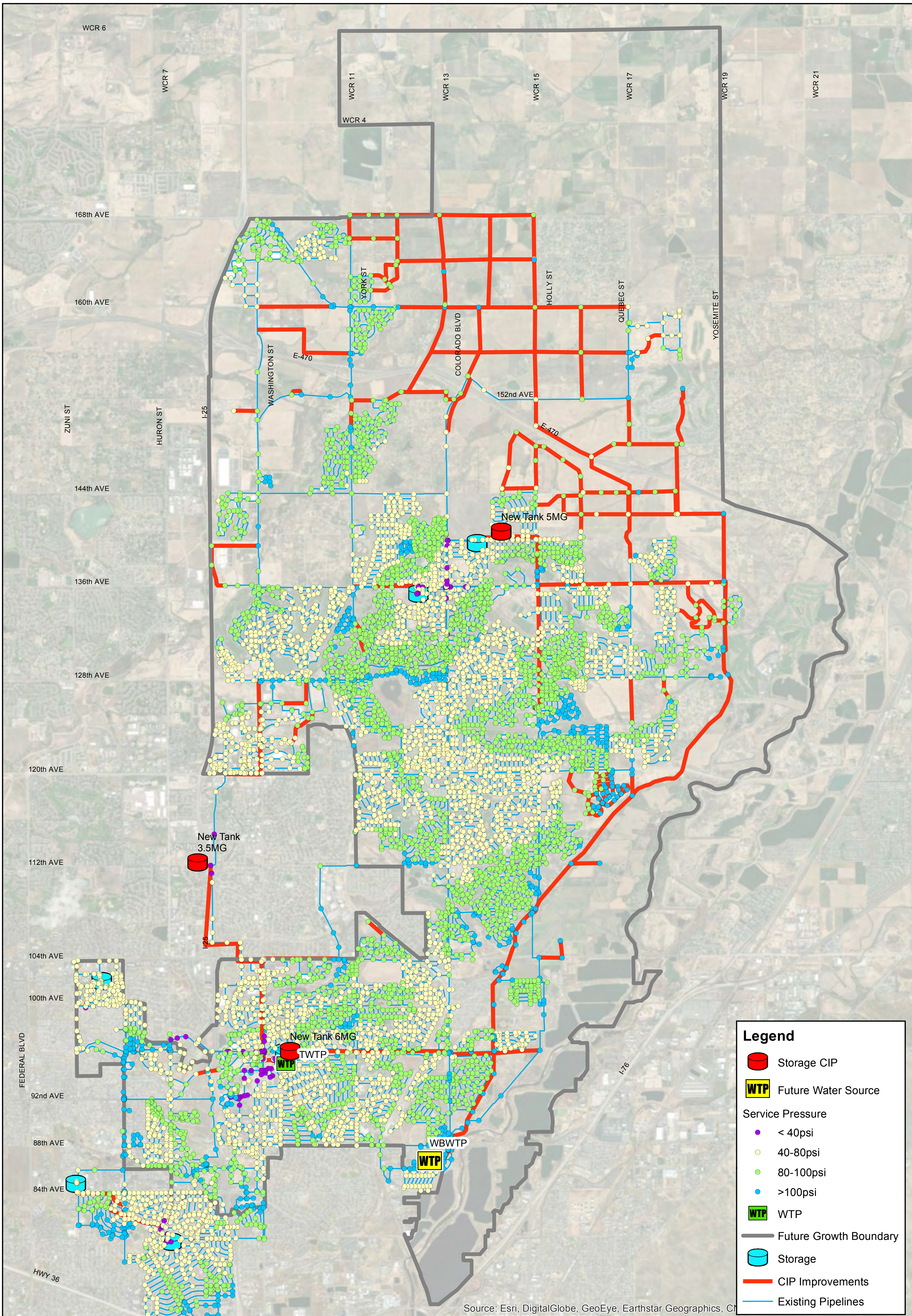

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Figure A7
Alternative 3
Condition 2: WBWTP Offline - Pressure

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1 inch = 5,000 feet

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Appendix B : Distribution System Capacity Evaluation – Figures

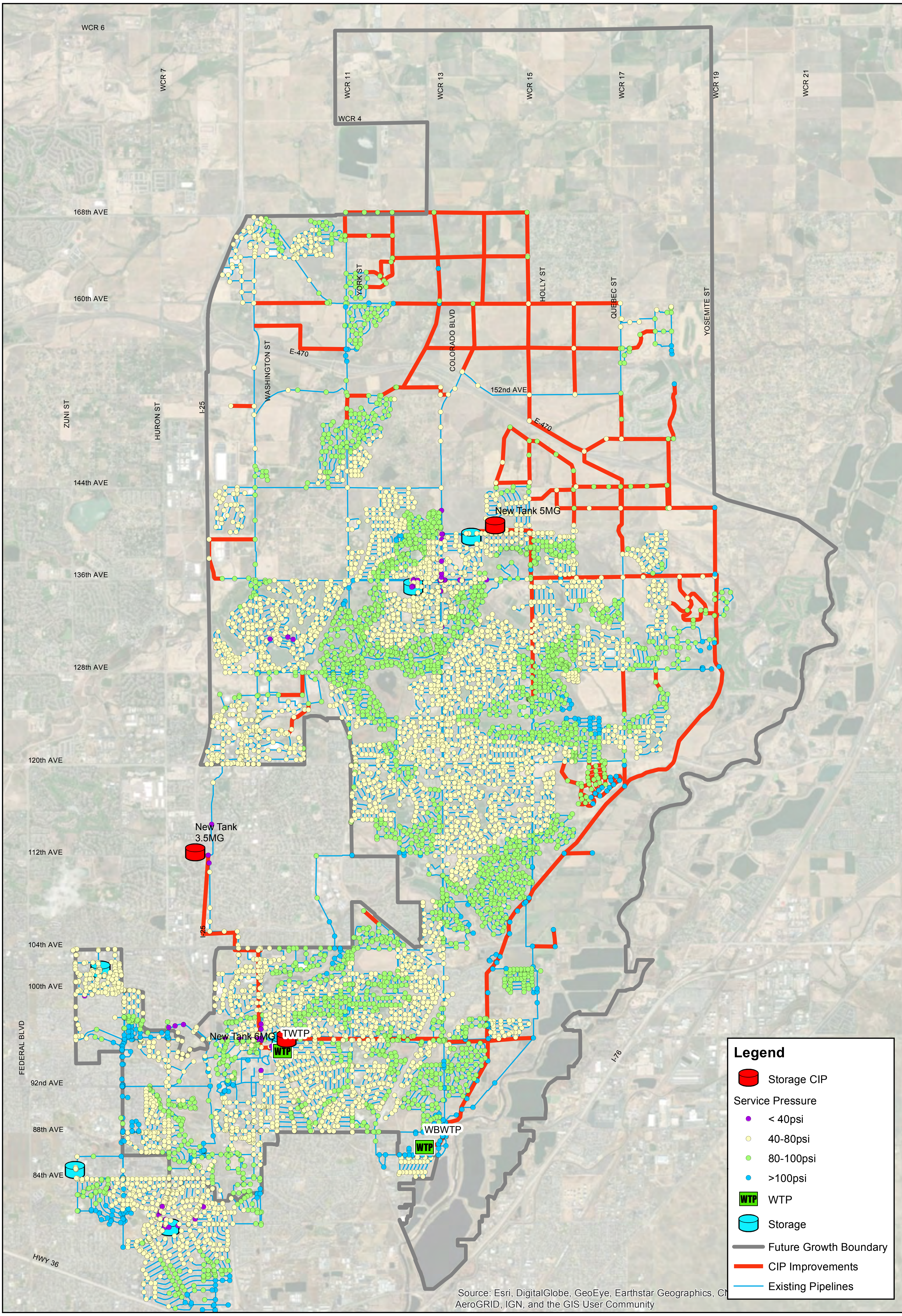

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Figure B1
Buildout Conditions
PHD Minimum Pressure

9/3/2019

1 inch = 5,000 feet

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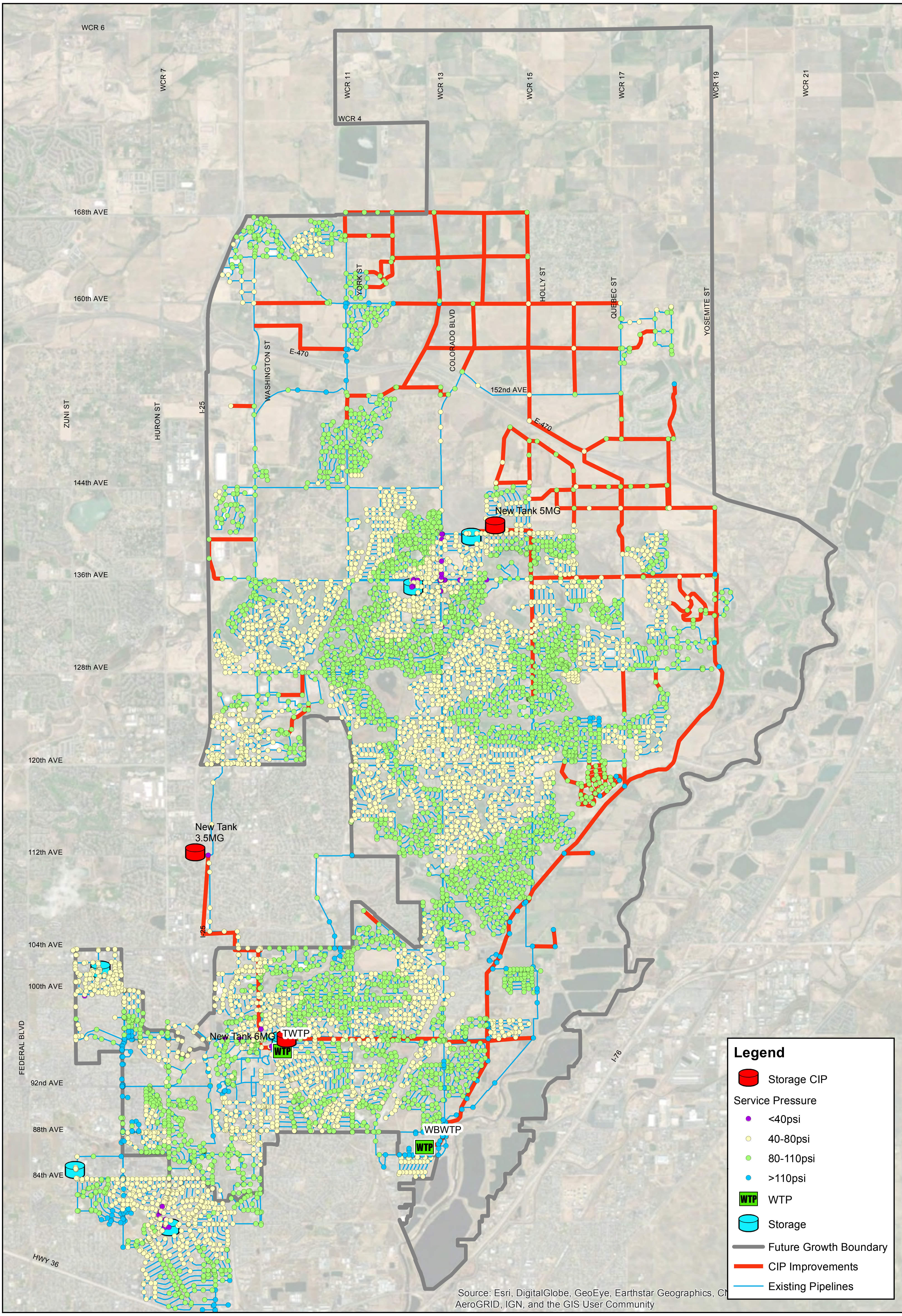

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Figure B2
Buildout Conditions
PHD Maximum Pressure

9/3/2019
1 inch = 5,000 feet

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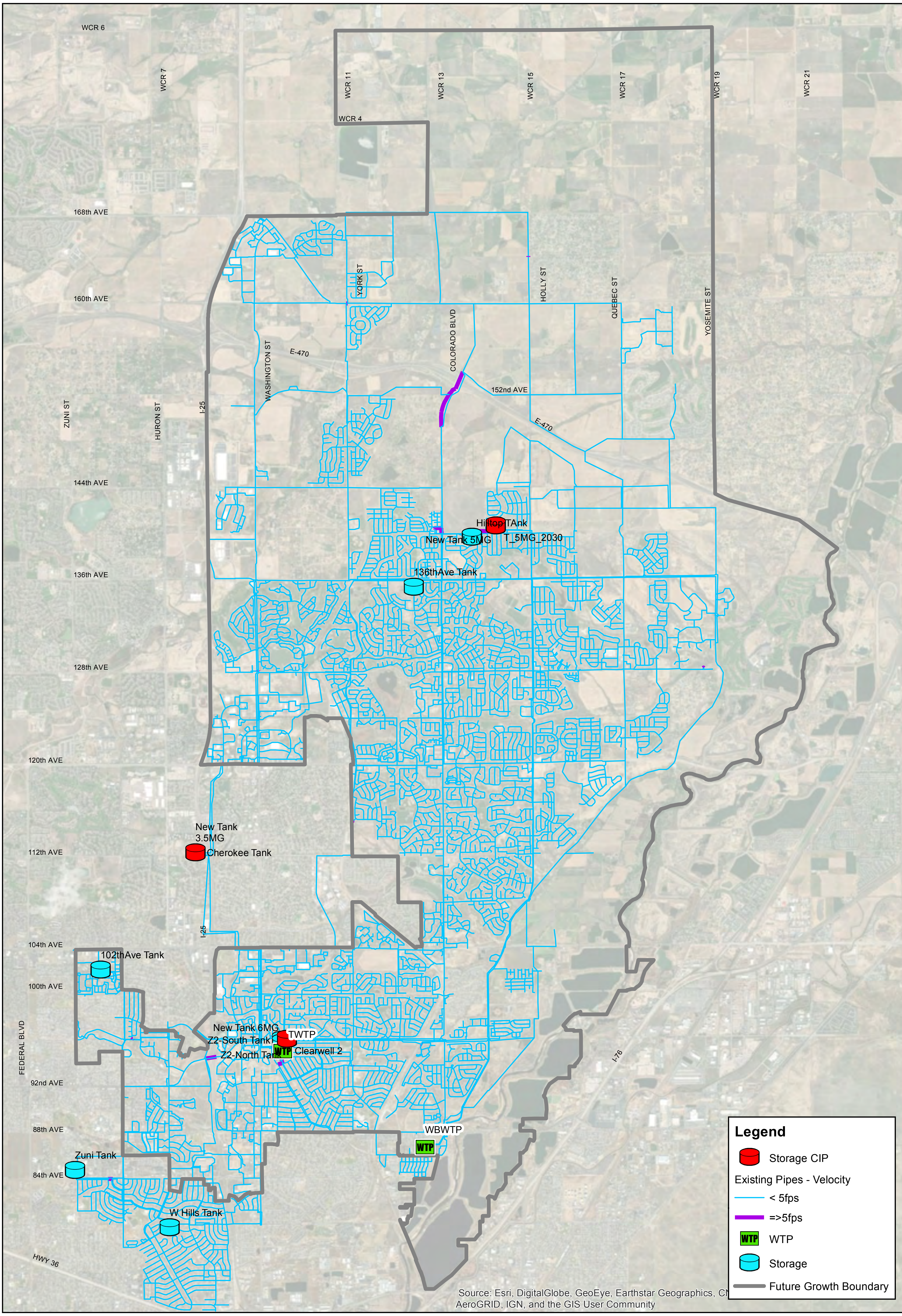

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Figure B3
Existing System - Buildout Conditions
PHD Maximum Velocity

8/16/2019
1 inch = 5,000 feet

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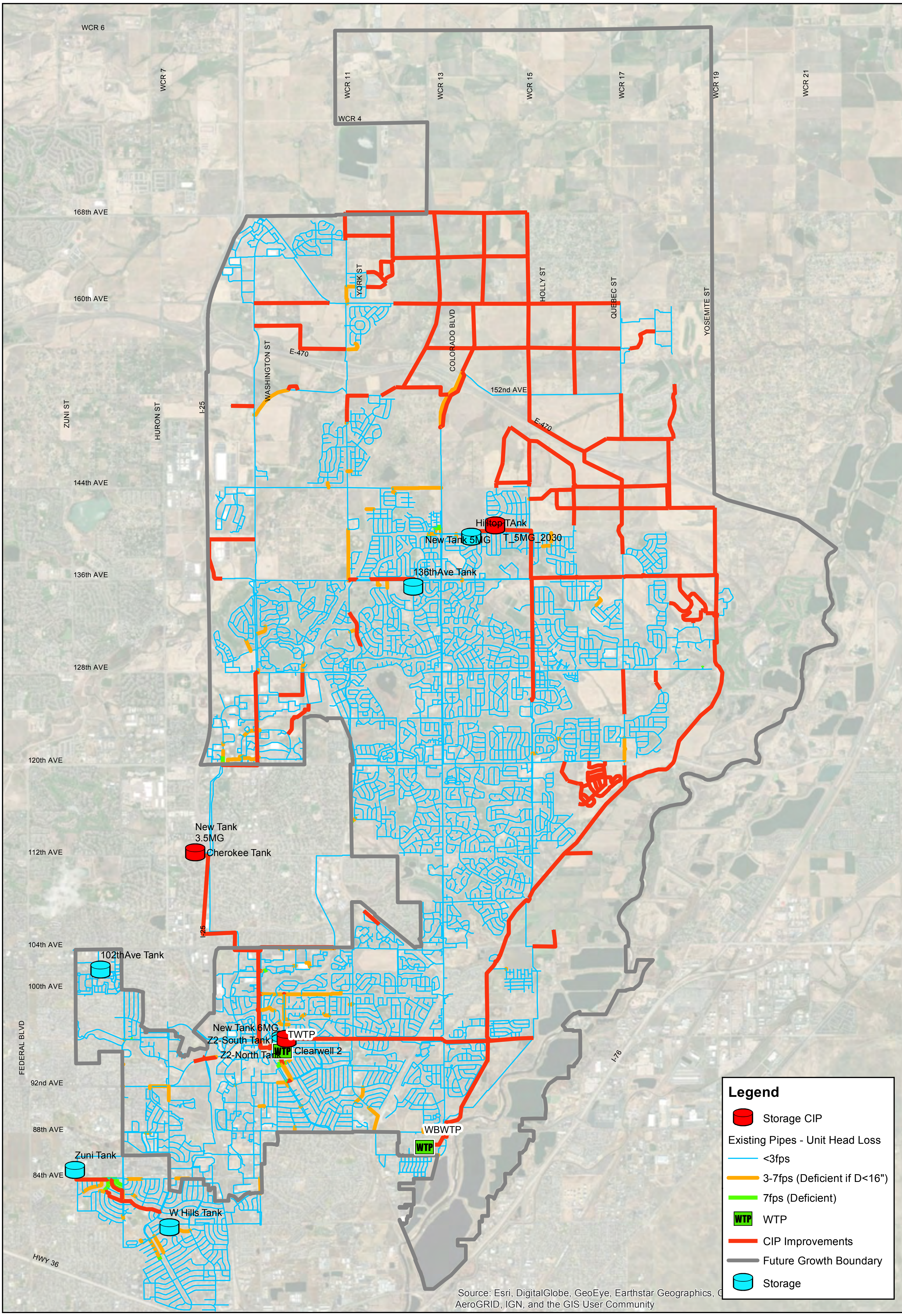

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Figure B4
Buildout Conditions
PHD Unit Head Loss

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1 inch = 5,000 feet

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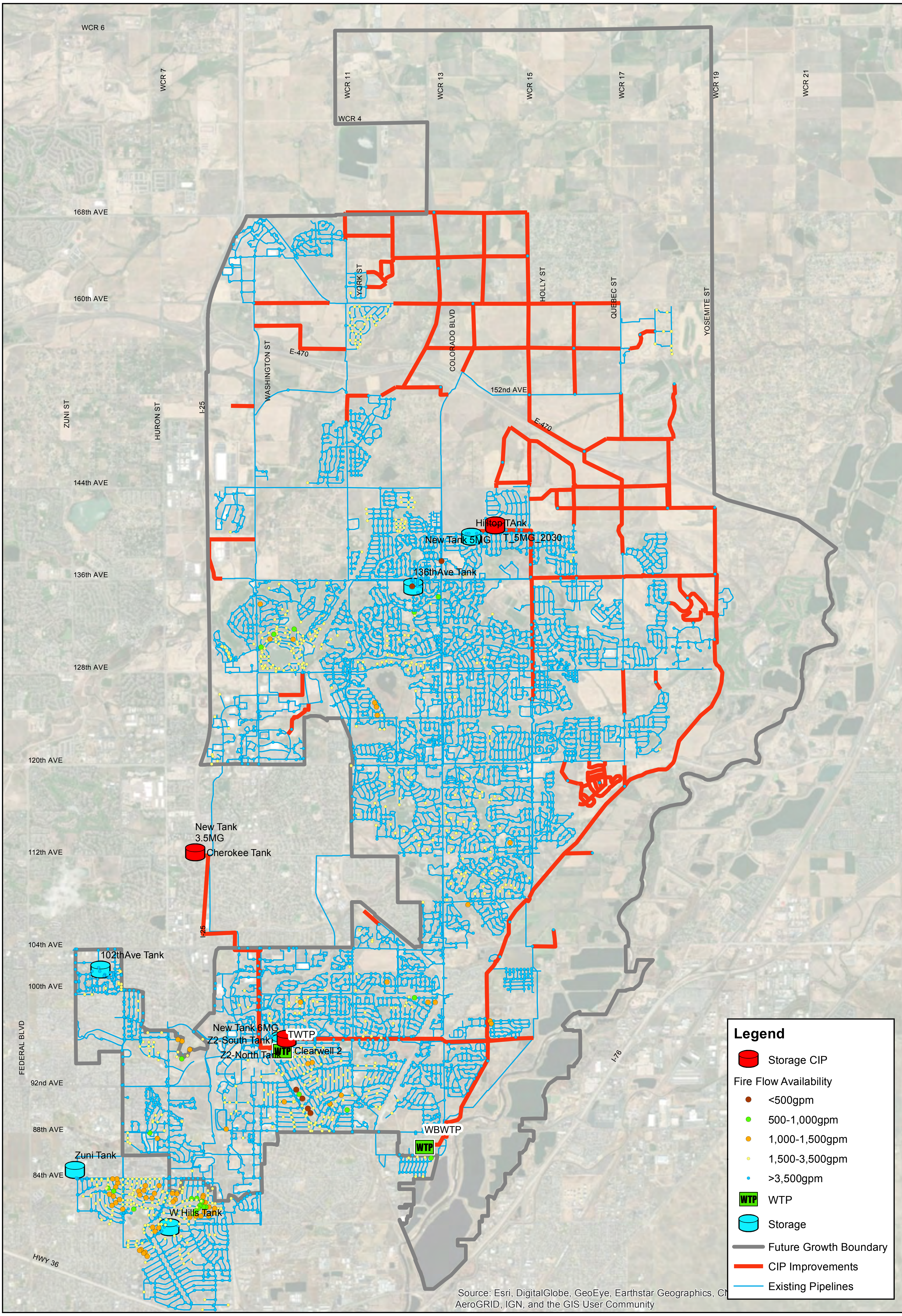

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Figure B5
Buildout Conditions
Fire Flow Availability

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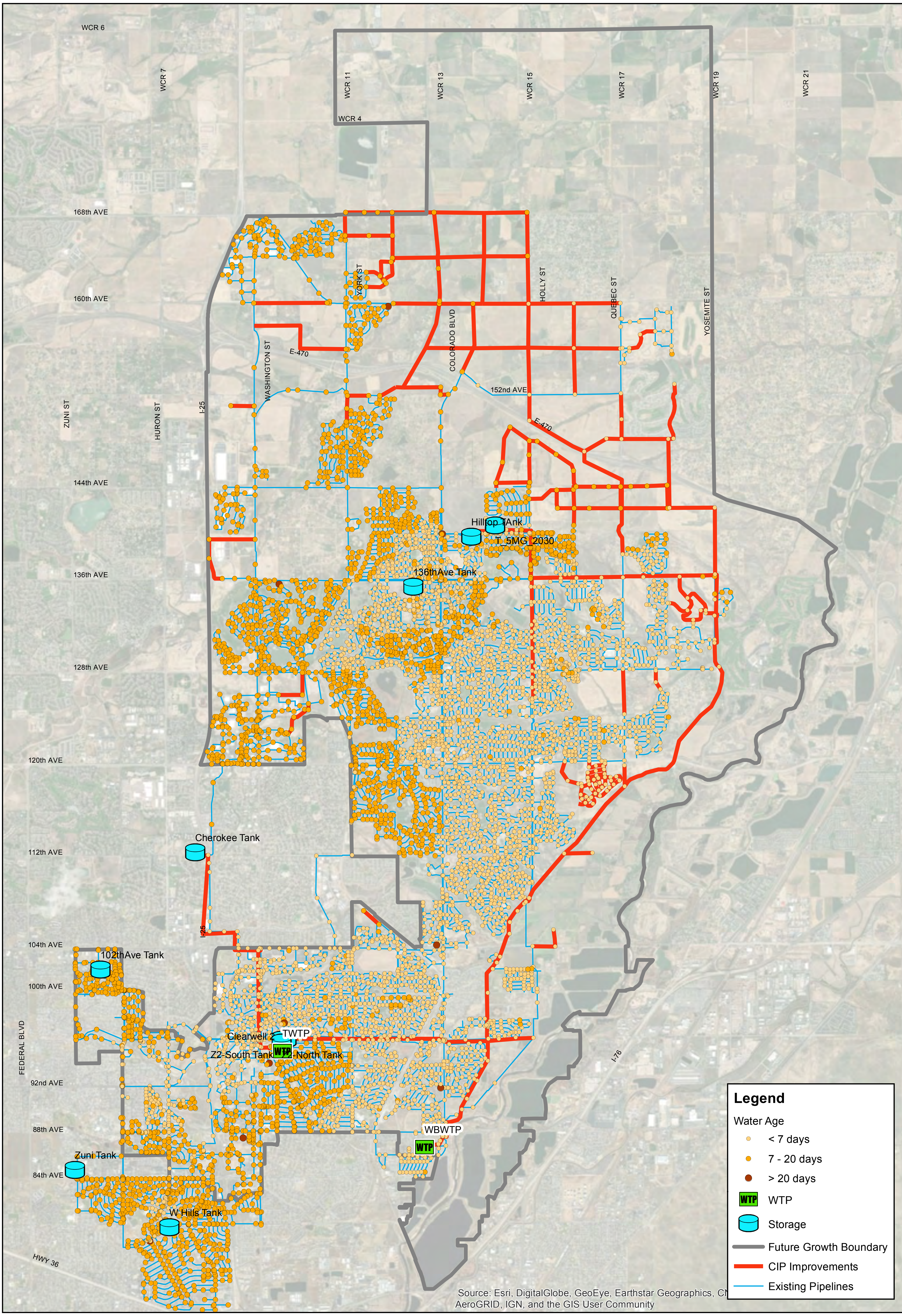

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Figure B6
Buildout Conditions
Water Age on Minimum Day

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1 inch = 5,000 feet

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Appendix C: Unit Cost Assumptions

Unit Cost Assumptions for Water Distribution and Transmission Projects

AECOM was requested by the city of Thornton (Thornton) to develop project costs for identified Capital Improvement Projects (CIP) as part of the Water and Wastewater Infrastructure Master Plan. Unit costs were developed to account for the various components that make up the identified CIP costs. This memo presents the basis for the unit costs.

1. Summary

The following summarizes the methodology used to develop the unit costs for capital improvements including pipe replacement cost per linear foot, installation of a new PRV, new storage, and pump station upgrade costs. The unit cost estimate reflects the opinion of AECOM of probable construction costs utilizing information available at the time the document was prepared.

AECOM has no control over future costs of construction labor, materials, equipment, nor of contractors' methods of determining prices, nor of competitive construction industry market conditions. The accuracy of the estimates is not guaranteed, and they are not intended to predict the outcome of the construction bidding.

AECOM has based the unit costs on AACE Class V estimating guidance. This opinion of probable costs is based on conceptual design and the basis of estimate summarized in this report. All costs were developed in March 2019 dollars based on an ENR Construction Cost Index of 7484. All project descriptions and cost estimates in this CIP represent planning-level accuracy and opinions of costs (+50%, -30%).

The unit costs have been developed based on cost estimating resources including:

- Local vendor estimates for specialized materials and equipment;
- Construction and installation costs from similar AECOM projects in the Denver Metro Area;
- Historical data and prices for similar facilities designed and/or constructed by AECOM estimates from senior engineers with construction experience;
- Where applicable historic costs have been inflated based on Engineering News Record construction indices.

The following items are not included as part of the unit cost estimate: land or right-of-way acquisition, finance charges during the planning, design, or construction of assets, remediation or fines associated with system violations, and operation, maintenance and energy costs. No costs were inflated or discounted to account for future pricing.

The estimated unit cost includes the sum of materials, labor, and equipment of reasonably identified features of a project. The estimated total project cost is the sum of construction costs with additional allowances for direct and indirect costs and contingencies. The engineering costs include design and surveying. This memo presents the opinion of probable costs for the following major elements:

- Pipelines
- PRV stations
- Storage tanks
- Pump Stations
- Additional Costs: Direct Cost, Indirect Costs, and Contingencies

2. Pipelines

Water pipeline unit costs have been developed based on diameter, project location category and pipe material costs and are assumed to be constructed within public right-of-way.

The project location will have a significant impact on pipeline installation costs, based on construction complexity, site access, and installation rates. For example, installing pipe in a dense urban area will be costlier than an undeveloped, wide open field. Unit costs were developed for the following two project locations.

- Developed – reflects existing pipe replacement in dense urban areas where roadway rehabilitation and/or concrete replacement will be required; includes major cost components
- Undeveloped – reflects new pipe construction or replacement of existing pipes in undeveloped areas with minimal constructability barriers; neglecting roadway replacement and utility crossing

Each CIP pipe segment was reviewed based on the site plan and engineering judgment was used to identify the pipe segment as either developed or undeveloped to account for the constructability and cost implications based on the CIP location.

The estimated unit cost for pipelines includes the following reasonably identified features:

- Piping, fittings, valves and water service connections
- Excavation
- Waste of material associated with trenching
- Imported bedding and zone material
- Native backfill
- Testing and disinfection
- Abandonment of the existing pipe for existing water pipelines
- Surface restoration
- Dewatering groundwater
- Contractor overhead and profit

Pipeline unit costs are presented in Table 1, and estimated costs for bores, tunnels and river crossing are summarized in Table 2. Project Cost includes direct and indirect costs.

Table 1: Water Pipelines Unit Costs Opinions

Diameter (in)	Construction Costs		Project Cost	
	Undeveloped Cost	Developed Cost	Undeveloped Cost	Developed Cost
8	$126	$181	$215	$308
10	$137	$191	$247	$351
12	$164	$232	$280	$395
16	$191	$300	$325	$511
20	$218	$327	$372	$558
24	$245	$381	$418	$650
30	$274	$436	$466	$743
36	$314	$505	$535	$861
42	$368	$586	$628	$1,000
48	$409	$682	$697	$1,163
54	$478	$791	$815	$1,349
60	$545	$900	$930	$1,534
66	$627	$1,037	$1,070	$1,768
72	$709	$1,200	$1,210	$2,046

Table 2: Bores, Tunnels and River Crossing Unit Cost

Pipe Diameter (in)	Construction Cost		Project Cost	
	Bores and Tunnels	River Crossings	Bores and Tunnels	River Crossings
	Undeveloped	Developed Cost	Undeveloped	Developed Cost
12-24	$729	$729	$1,242	$1,242
24-48	$1,021	$1,458	$1,741	$2,486
48-72	$1,458	$2,624	$2,486	$4,474
72-108	$2,333	$2,917	$3,978	$4,973

Unit cost by location. Project Cost includes direct and indirect cost.

3. PRV Facilities

Pressure reducing valve (PRV) facilities construction costs were developed from AECOM's project experience and projects recently estimated in the Denver Metro Area. The estimated unit costs assume the following major components for construction:

- Mainline PRV
- Low flow bypass PRV
- Mainline piping
- Bypass piping
- Concrete vault

The unit costs are summarized in Table 3.

Table 3: PRV Construction and Project Costs

Valve Size	Construction Cost	Project Cost
8"	$61,503	$104,862
12"	$123,005	$209,724
16"	$184,508	$314,586
20"	$246,011	$419,448
24"	$307,513	$524,310
30"	$338,264	$576,741
36"	$369,016	$629,172

Project Cost includes direct and indirect cost.

4. Storage Facilities

New storage construction costs were developed from AECOM's project experience and projects recently estimated in the Denver Metro Area. It was assumed that proposed facilities will be circular, at grade structures with an exterior wall height between 25 and 35 feet. Costs were calculated per gallon of constructed storage volume, which is oversized by 25% of the hydraulic requirement to allow for headspace and freeboard. The unit costs for storage facilities are summarized in Table 4.

Table 4: Storage Facilities Unit Costs

Tank type	Construction Cost	Project Cost
< 5MG	$1.60	$2.72
5 - 15 MG	$1.55	$2.64

MG: Million Gallons. Project Cost includes direct and indirect cost

5. Pump Stations

The improvements related to pump stations include increase in pump station capacity and don't include the construction of new facilities. Increasing the capacity of existing facilities will require the replacement of pumps with larger pumps or, if there is space, increasing the number of pumps. The construction cost includes:

- Removal of the exiting pump(s)
- Addition of new pump, motor
- Modifications to pipes and valves
- Modification to existing electrical system and telemetry

The unit costs for pump station upgrade are summarized in Table 5. A representative unit cost per HP was developed based on recent projects and unit cost used by other utilities in the Denver Metro Area. Table 5 summarizes the estimated cost for different pump sizes. Project Cost includes direct and indirect additional costs.

Table 5: Pump Station Upgrade Unit Costs

HP	Unit Construction Cost ($/HP)	Unit Project Cost ($/HP)	Construction Cost	Project Cost
50	$1,230	$2,097	$61,502.63	$104,862
100	$1,230	$2,097	$123,005	$209,724
150	$1,230	$2,097	$184,508	$314,586
200	$1,230	$2,097	$246,011	$419,448

Project Cost includes direct and indirect costs.

6. Additional Costs

The following additional direct and indirect costs were assumed for each CIP

Direct:

- Erosion Control 5%
- Mobilization and Site Setup 5%

Indirect:

- Engineering Design 15%
- Legal and Administrative 5%
- Construction Management 10%
- Contingencies 25% (AACE Class V)

Appendix D : Proposed PRV Facilities

Some projects required to serve future developments, detailed in Section 7.1, involve the construction of a PRV facility, as the proposed pipes are crossing pressure zone boundaries. The following table and figure summarize the location and main characteristics of the proposed PRV facilities.

Table D.1: PRV Facilities for Distribution Improvements to Serve Future Developments

PRV	CIP	Pipe Size	From Pressure Zone	To Pressure Zone	Location
1	DD63	12	1	1C	E 160th Ave east of Colorado Blvd
2	DD12	12	3F	1	Southeast of E 144th Ave and Quebec St
3	DD01	16	1	1C	Holly St and E 165th Pl
4	TT01	24	1	1C	Colorado Blvd and E 160th Ave
5	DD52	12	1	1C	Northeast of E 152nd Pl and Saint Paul St
6	DD12	12	3A	3F	E 141st Dr and Locust St

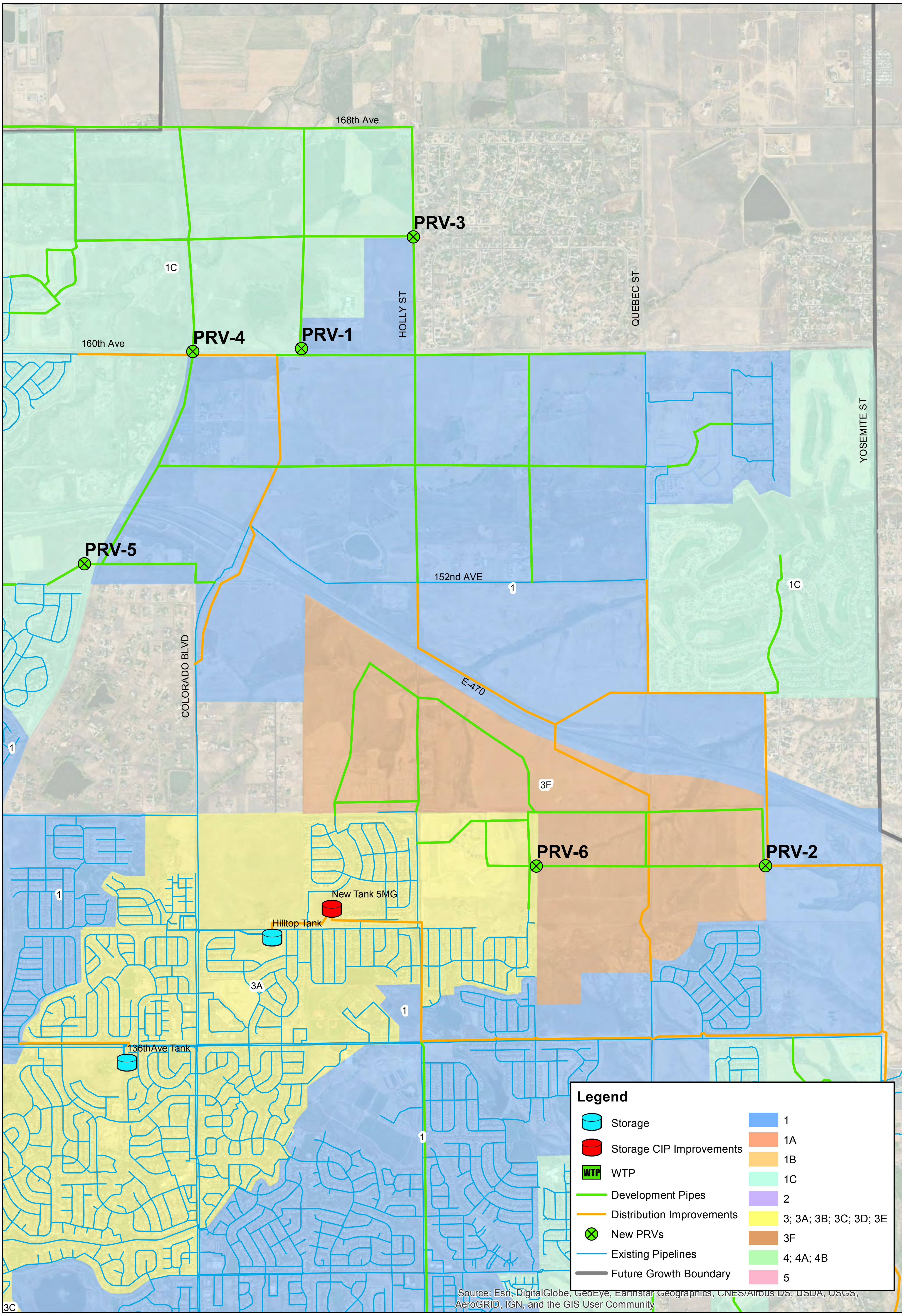

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Figure D.1
Recommended Distribution Improvements to Serve Future Developments - PRV Location

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1 inch = 2,000 feet

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Wastewater Collection System Evaluation

Chapter 6

AECOM Imagine it. Delivered.

Utility Master Plan

Project No. 17-467

Water and Wastewater Infrastructure Master Plan

Wastewater Collection System Evaluation

The City of Thornton

Project number: 60560104

AECOM

June 17, 2019

Quality information

Prepared by	Checked by	Verified by	Approved by
Brock Hodgson	Amanda Smokoff	Marcela Duran	Nathan Walker

Revision History

Revision	Revision date	Details	Authorized	Name	Position

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Prepared for:

The City of Thornton

Prepared by:

AECOM
6200 South Quebec Street
Greenwood Village, CO 80111

T: +1 (303) 694 2770
F: +1 (303) 694 3946
aecom.com

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Tables

List of Acronyms

AACE	Association for the Advancement of Cost Engineering
ADD	average daily demand
ADWQ	average dry weather flow
BOUT	Buildout
CDPHE	Colorado Department of Public Health and Environment
CIP	Capital Improvement Program
ENR	Engineering News Record
EPS	extended period simulation
fps	feet per second
gpm	gallons per minute
MGD	million gallons per day
MWRD	Metro Wastewater Reclamation District
N/A	Not Applicable
PDWQ	peak dry weather flow
PWWQ	peak wet weather flow
Thornton	City of Thornton
TM	technical memorandum

1. Introduction

This technical memorandum (TM) provides an evaluation of the wastewater collection system for the City of Thornton (Thornton) and identifies existing system deficiencies and future improvements necessary to serve buildout system needs. The hydraulic model provided by Thornton was used to allocate future growth flows and evaluate the hydraulic performance of the system at buildout, which is anticipated to be in 2065. The following subtasks were completed to evaluate the system:

- **Existing System Review** – Review of existing system infrastructure
- **Future Infrastructure Plan** – Review and identify future backbone infrastructure needed to serve the planning area through buildout
- **Flow Allocation** – Spatial allocation of future growth wastewater flows
- **System Evaluation** – System evaluation identifying deficiencies based on the design criteria
- **System Improvements** – Improvements necessary to existing infrastructure and confirm future infrastructure based on the future infrastructure plan to identify the buildout collection system needs.

The basis and approach for the wastewater collection system evaluation are described in the subsequent sections of this TM and provide insight into the existing wastewater collection system hydraulic system performance and deficiencies, and future infrastructure necessary to serve buildout.

2. Review of Existing System

The existing wastewater collection system was reviewed as part of the Initial Data and Hydraulic Model Review TM and is briefly summarized here. Thornton's collection system is divided into 12 basins which convey flow to metered connections with Metro Wastewater Reclamation District (MWRD). The average dry weather flow (ADWQ) and peak dry weather flow (PDWQ) at the outlets measured in July 2017 are summarized in Table 1.

Table 1. 2017 Metered Dry Weather Flows

Meter	ADWQ (MGD)	PDWQ (MGD)	Peaking Factor
Barr	0.5	1.0	1.9
South Platte Interceptor	4.2	7.5	1.8
Steele	5.1	8.4	1.6
Todd Creek Interceptor	Online 2018	Online 2018	-
TOTAL	**9.8**	**16.9**	**1.7[2]**

[1]Flows based on metered data for January through April 2017

[2]Represents average peaking factor of totalized PDWQ / ADWQ

Thornton's existing collection system includes six lift stations currently in operation. The Todd Creek Lift Station was recently abandoned with the completion of the Todd Creek Interceptor which conveys flows by gravity to the MWRD Northern Water Treatment Plant. Additionally, in 2020 Thornton will increase the operational capacity of the Big Dry Creek Lift Station and install the Big Dry Creek Forcemain and Interceptor to convey flows to the Todd Creek Interceptor. The permitted capacity and average operating flow for the existing lift stations are indicated in Table 2.

Table 2. Existing Lift Station Permitted Capacity and Operating Flow

Lift Station	Permitted Capacity		Average Flow (MGD)[2]	Peak Flow (MGD)[2]
	Hydraulic Design Capacity (MGD)[1]	Peak Hydraulic Capacity (MGD)[1]		
Big Dry Creek[3]	3.5[3]	8.1[3]	1.60	2.47
Grange Hall Creek	1.0	2.6	0.38	0.57
Remington[4]	N/A	N/A	0.09	0.17
Riverdale[5]	Unknown	0.3	0.18	0.26
Skylake	0.23	0.60	0.10	0.15
Thornton Crossing	0.08	0.27	0.00	0.00
TOTAL	**-**	**-**	**2.35**	**3.62**

[1]Per Colorado Department of Public Health and Environment (CDPHE) Regulation 22, hydraulic design capacity represents maximum month daily average flow, peak hourly flow based on peak hourly flow.
[2]Flows based on existing Thornton Collection System Model developed, calibrated and validated by Thornton.
[3]Big Dry Creek Lift Station is programmed to be replaced by 2020.
[4]Remington Lift Station is programmed to be abandoned in 2019.
[5]Permitted Capacity as reported by CDPHE. Thornton has programmed list station improvements to increase peak hydraulic capacity to 0.5 MGD.

3. Development of Wastewater Flows

The projected increase in wastewater flows were developed based on the planned land use and population projections provided by Thornton and documented in the Planning Area and Future Growth and Analysis TM. This TM evaluated historical consumption and future land use and population to develop future growth flow estimates based on a pseudo population and land used based approach. A summary of this approach is restated in this section for reference. The Planning Area and Future Growth Analysis TM should be referenced for a more detailed description on the historical flow review and future growth analysis.

As part of the future growth flow evaluation, the historical flows were reviewed to identify the appropriate baseline for the existing collection system. As indicated in Table 1, in 2017 the ADWQ was 9.8 MGD and the PDWQ was 16.9 MGD equating to a peaking factor of 1.7. Accounting for population, the historic ADWQ is 9.9 MGD and PDWQ is 17.4 MGD equating to a peaking factor of 1.8 (average 2010-2017). The existing flows in the model previously developed by Thornton were based on an ADWQ of 10.9 MGD and PDWQ of 15.0 MGD equating to a peaking factor of 1.4 and an overestimate of the ADWQ but an underestimate of the PDWQ compared to the historical data. For this reason, the existing ADWQ flows in the model were scaled to provide a model estimate consistent with the PDWQ for evaluating future infrastructure. However, this results in a higher modeled ADWQ due to the existing diurnal patterns which is discussed in more detail in Section 5.

The future growth potable water demands were developed for drought and non-drought conditions based on the future population and land use as identified in the Planning Area and Future Growth and Analysis TM. The historical water use indicated negligible difference between ADWQ under drought and non-drought conditions because drought primarily impacts outdoor irrigation water use. Therefore, considerations for drought had no impact on evaluating the collection system performance. Based on historical data comparing minimum month flows and average daily demand (ADD), the average indoor water use was determined to be 0.54 x ADD under non-drought conditions. Based on comparison of minimum month demands and ADWQ, the average non-consumptive fraction and base infiltration was determined to be 112% x indoor water use. Therefore, the ADWQ was calculated by multiplying the projected ADD non-drought x 0.54 x 112%. Table 3 outlines the existing, future growth and buildout flows.

Thornton does not believe they have significant impacts to the collection system during wet weather events, however the ADWQ in the summer was observed to be 14% higher than observed in the winter based on historical meter data. Therefore, wet weather flows were evaluated by conservatively assuming a 25% increase in ADWQ.

Table 3. Thornton Wastewater Flows

	ADWQ (MGD)	PDWQ (MGD)
Existing	9.9[1]	17.4
Future Growth	8.8	-
Buildout (Existing + Future Growth)	18.7	-

[1]Existing flows in the model are loaded as 12.5 ADWQ to achieve a PDWQ of 17.4 MGD.

The wastewater collection system evaluation and sizing of required additional infrastructure was performed based on ADWQ, assuming negligible impacts due to wet weather flows per the direction of Thornton. Future growth flows were loaded in the hydraulic model as residential and commercial future growth wastewater flows. Table 4 outlines the anticipated increase in future flows for each basin.

Table 4. Future Flow Growth per Basin

Basin	Existing ADWQ (MGD)[1]	Future Growth ADWQ (MGD)	Buildout ADWQ (MGD)	% Increase
A	2.8	0.3	3.1	10%
B	0.3	0.0	0.4	10%
C	0.7	0.2	0.9	25%
D	1.4	0.5	1.9	28%
E	2.0	0.5	2.5	19%
F	0.6	0.0	0.6	0%
H[3]	1.5	0.2	5.7	74%
I	0.1	4.0	0.3	64%
J	0.3	0.2	0.9	68%
K	0.2	0.7	2.5	91%
TOTAL (MGD)	**9.9**	**8.6**	**18.8**	

[1]Existing flows in the model are loaded as 12.5 ADWQ to achieve a PDWQ of 17.4 MGD.
[2]Basin extents are shown on Figure 1.
[3]Includes ADWQ from Basin L which was created for Lower Big Dry Creek.

4. Future Infrastructure Plan

The collection system was evaluated based on the existing and future infrastructure extensions necessary to accommodate buildout loads. The existing hydraulic model was initially developed, calibrated and validated by Thornton and was used as the basis for development of the buildout hydraulic model. The hydraulic model was reviewed to include future infrastructure that is anticipated based on current development projections and/or has been previously evaluated as part of other planning studies. The buildout model development considerations are described in Appendix A. The collection system existing infrastructure and future extensions are shown in Figure 1. The future infrastructure plan reflects extensions to the existing system to collect future development flows. Improvements necessary to existing infrastructure were evaluated based on these identified extensions. Thornton has already planned some improvements to the existing infrastructure. These projects were assumed completed as part of the future infrastructure plan and include:

- Big Dry Creek Lift Station Improvements (Programmed for 2020)
- Big Dry Creek Forcemain / Interceptor (Programmed for 2020)
- Remington Lift Station Abandoned and Improvements to Riverdale Lift Station
- Big Dry Creek Parallel (Construction 2019)
- Cloud Court Development

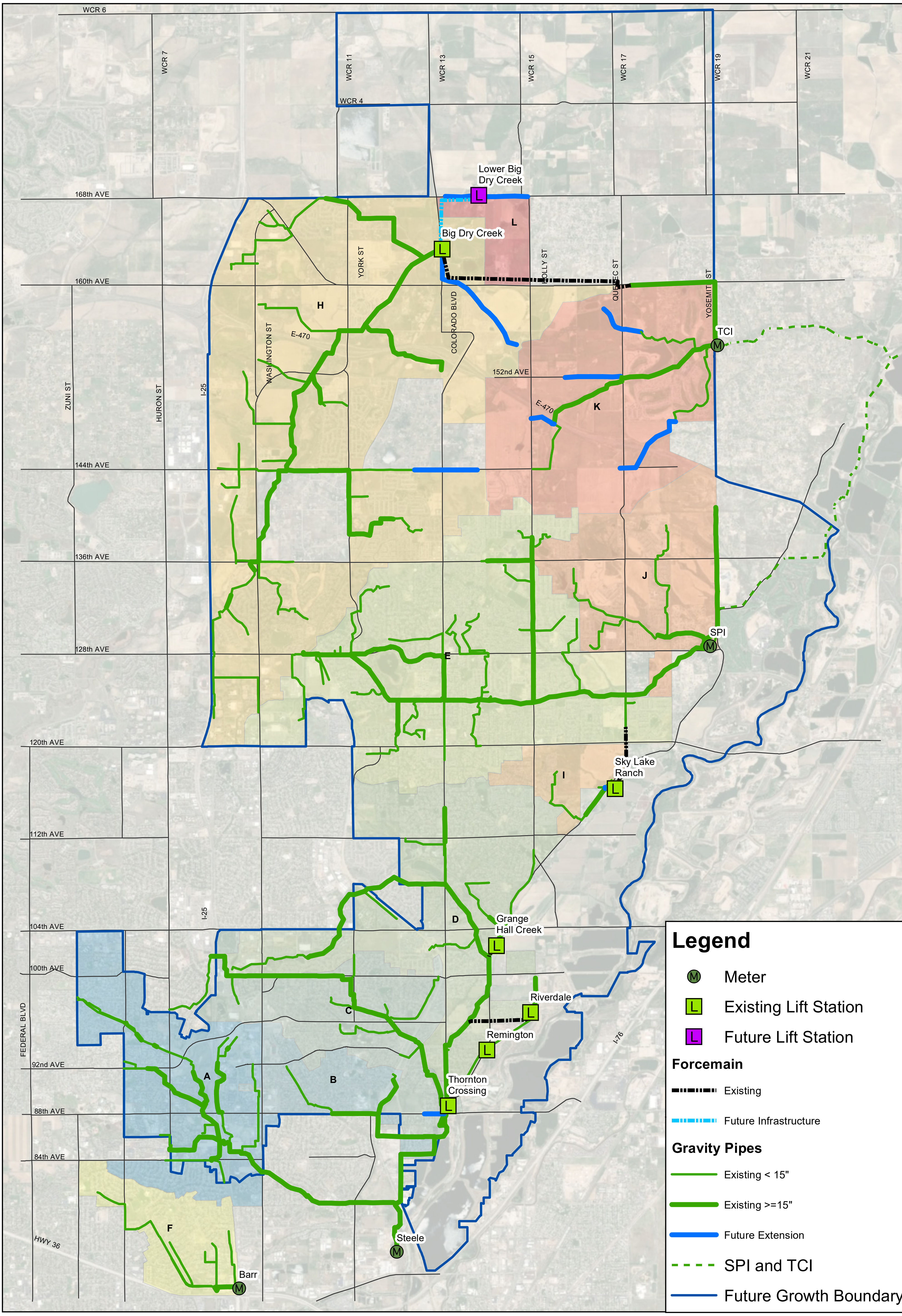

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Figure 1
Existing Collection System and Future Collector Extensions

6/15/2019
1 inch = 5,000 feet

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5. Load Allocation and Peaking Factors

Load Allocation

Loads were allocated spatially per sub-basin to the closest receiving manhole. Figure 2 depicts spatial allocation of loads to the baseline alternative. The top ten future loads were reviewed, and careful attention was given to how these flows were allocated in the model. The top fifteen users are summarized in Table 5 and represent 58% of the future wastewater flows into the collection system.

Table 5. Top 15 Future Development Anticipated Wastewater Flows

Development	Land Use	Basin	Future Development ADWQ (MGD)
Parterre	Mixed Use	K	1.18
Stonehocker (SFA/MF) between Colo & Holly/152nd-160th	Mixed Use	H	1.09
North End Station	Mixed Use	H	0.63
City Creek	Mixed Use	H	0.44
Kortum (east of Parterre & South of 470 [300 acres])	Mixed Use	J	0.34
Stonehocker (SFA) 100 acres at 8 DU's/acre	Mixed Use	K	0.23
Employment Center - North Washington Overlay	Commercial	H	0.21
Stonehocker (SF) east most quarter Section	Mixed Use	K	0.20
Front Range Crossings	Mixed Use	H	0.14
North of North end Station - SFA (75 acres at 12 DU's)	Residential	H	0.14
Willow Bend MF - north of E-470 (roughly 50 acres)	Residential	K	0.14
Employment Center - North Washington Overlay	Commercial	H	0.10
Welby Station	Mixed Use	C	0.10
Rio	Commercial	H	0.10
112/York (60 acres at 8 DU's/acre)	Mixed Use	D	0.09
TOTAL			**5.1**

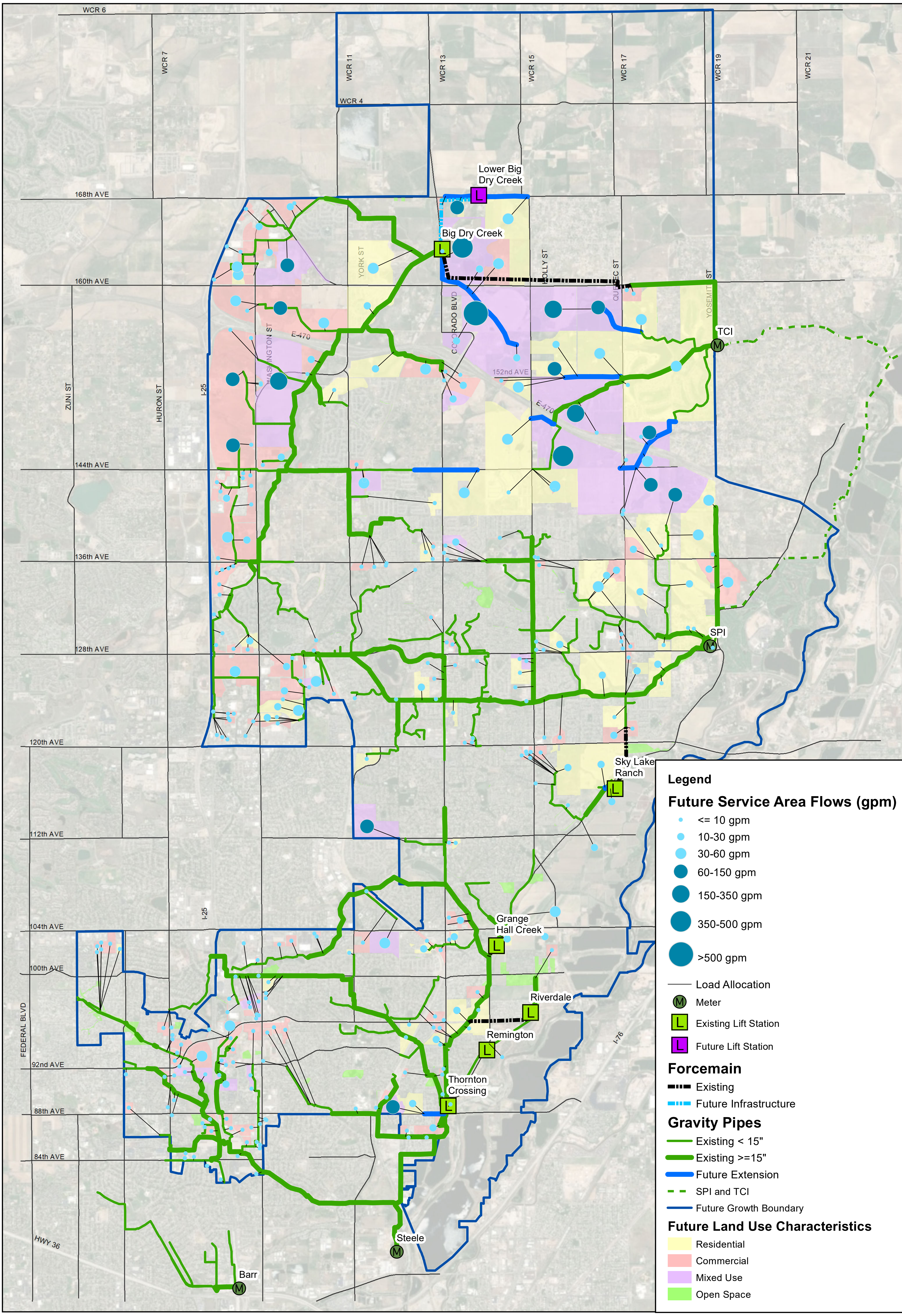

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Figure 2
Future Load Allocation

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Peaking Factors

The buildout model was loaded with existing and future ADWQ based on residential or commercial/industrial use. The existing residential and commercial flows were peaked based on the diurnal patterns previously developed by Thornton. The existing diurnal patterns are shown in Figure 3. The sewer patterns were developed based on sewer flow monitoring data and engineering judgment to best reflect the existing collection system performance.

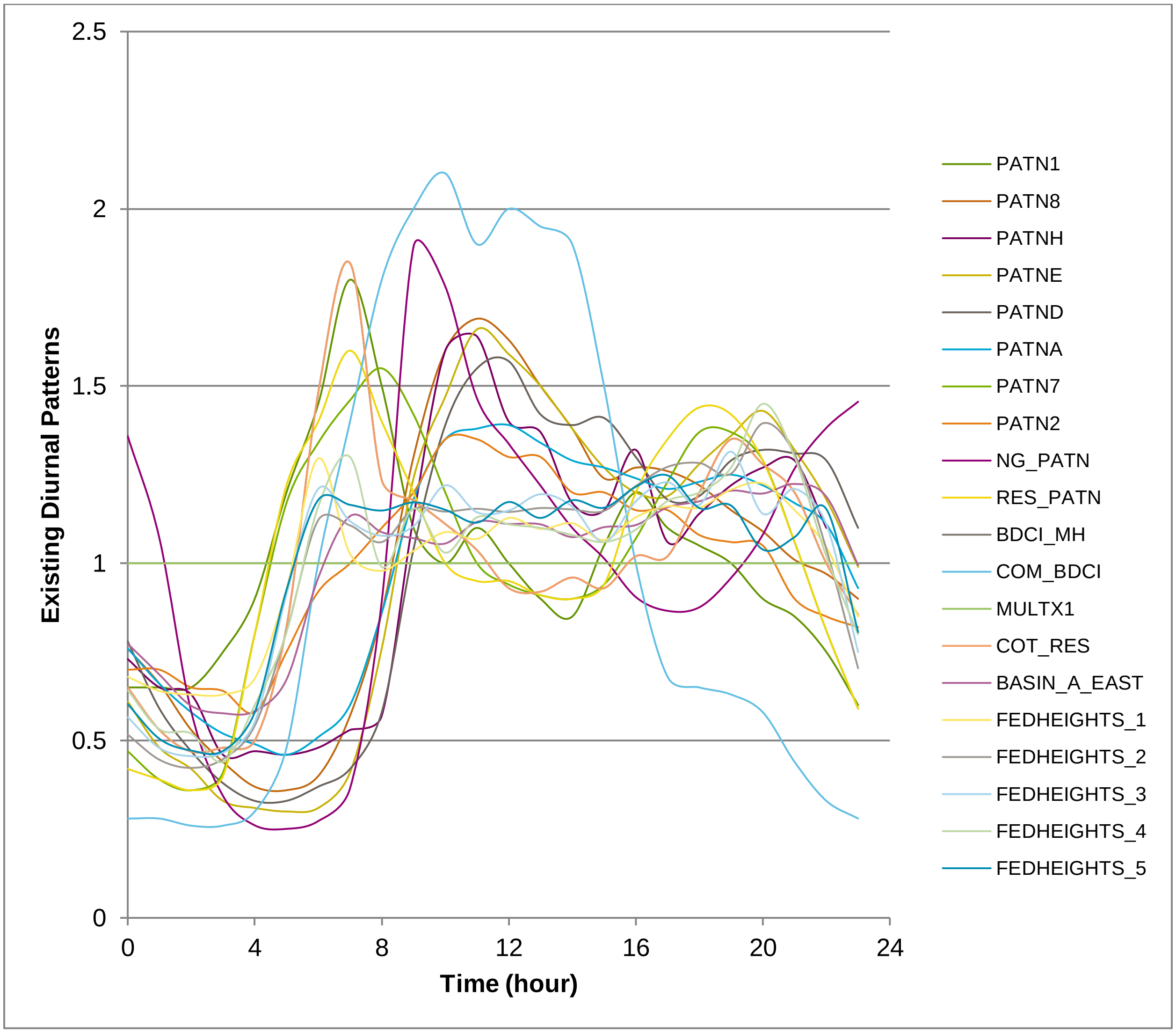

Figure 3. Existing Diurnal Patterns

The existing diurnal patterns were developed by Thornton to reflect the existing system usage which reflects a peaking factor below the design standard. For this reason, AECOM developed a step-wise diurnal residential and commercial/industrial diurnal pattern based on the flow distribution identified in the existing diurnal patterns but adjusted to meet the peaking factor design requirements in the Thornton Standards and Specifications for future flows. According to Thornton's 2012 Standards and Specifications, peak wastewater flows shall be designed based on ADWQ with a maximum peaking factor of 3.5 and a minimum peaking factor of 2.6. The Thornton Standard was reviewed against the top 10 future flows as shown in Figure 4. Step-wise peaking factor diurnals were developed with a peak of 2.6 (minimum peaking factor) and 3.5 (maximum peaking factor) corresponding to the peak timing consistent with the existing diurnal patterns and the pattern adjusted to average 1.0. Figure 5 shows the developed future residential and commercial diurnal patterns used for future wastewater flows in the buildout system evaluation.

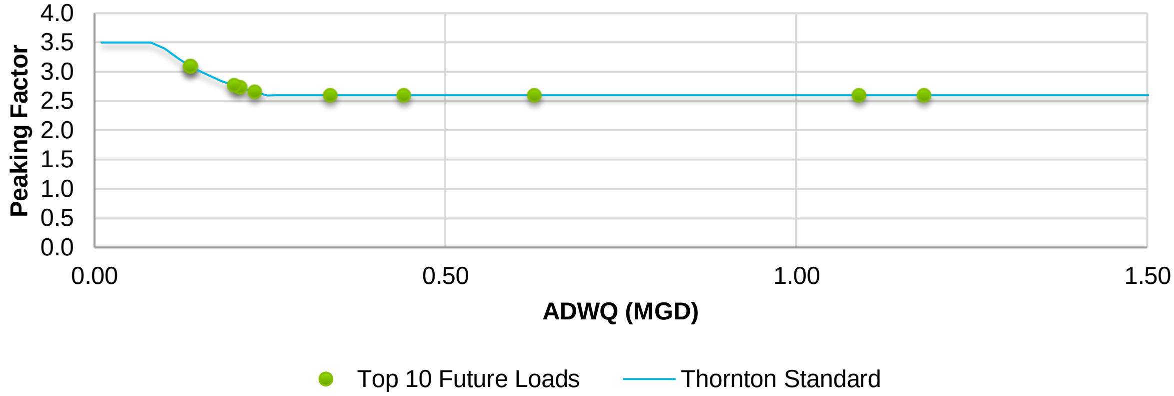

Figure 4. Peaking Factor Design Standard and Top 10 Future Loads

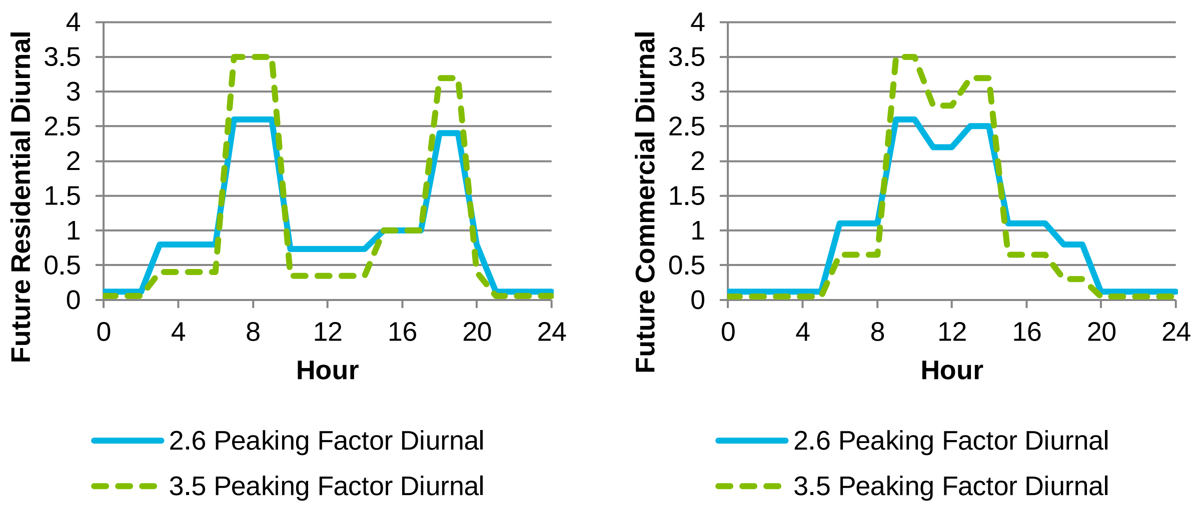

Figure 5. Future Residential and Commercial Diurnal Curve

Consistent with the Thornton's 2012 Standards and Specifications, all future wastewater flows greater than 170 gallons per minute (gpm) were assigned a diurnal pattern associated with a 2.6 peaking factor and all future wastewater flows less than 170 gpm were conservatively assigned a diurnal pattern associated with a 3.5 peaking factor. Using this approach, the modeled ADWQ, PDWQ and peaking factors for the model loads and combined outlet is summarized in Table 6 where loading represents the wastewater flows generated at the source and outlet represents the downstream metered wastewater flows in the collection system accounting for attenuation. Historic data indicates the peaking factors at the outlets have flow weighted peaking factor of 1.76. Using the diurnal patterns discussed above for current and future flows, the flow weighted average buildout peaking factor is 2.06 which is comparable and slightly more conservative than the anticipated PDWQ from historical data.

Table 6. Buildout Flows and Calculated Peaking Factors at Outlets

Meter	ADWQ (MGD)	PDWQ (MGD)	Peaking Factor
Loading	18.7	43.8	2.34
Outlet	18.7	38.5	2.06

6. System Evaluation

Using the developed buildout model, the collection system performance at buildout was evaluated against the wastewater performance criteria. This criteria was developed in the Water Distribution and Wastewater Collection System Performance Criteria TM which identifies the system performance requirements including d/D, velocity, and lift station capacity. Performance of the existing collection system and design of existing improvements and future infrastructure, were evaluated and designed based on the criteria outlined in Table 7. The collection system performance based on this criteria served as the basis for identifying and developing Capital Improvement Programs (CIPs) to meet buildout conditions.

Table 7. Performance Criteria

Performance Parameter	Criteria
Tier 1 - PDWQ	
Gravity Main d/D	d/D = 0.7 for pipes <15” diameter d/D = 0.8 for pipes => 15” diameter
Gravity Main Velocity	2-8 fps
Forcemain Velocity	2-6 fps
Lift Station Firm Capacity	Adequate Capacity for PDWQ
Tier 2 - PWWQ	
Gravity Main d/D	Pipe does not exceed full flow capacity under 25% flow increase

Tier 1 – Gravity Main Performance

The Tier 1 performance evaluation identified improvements necessary to existing infrastructure. Most of the future growth in Thornton will occur north of 136th Avenue. Therefore, the infrastructure most impacted by future development with be the infrastructure associated with Big Dry Creek Interceptor and Heritage Interceptor. The gravity main PDWQ d/D performance is depicted in Figure 6 where there is a total of 20,534 feet of existing pipe that exceeds the PDWQ d/D criteria. These areas were reviewed with Thornton to develop Tier 1 CIPs as discussed in Section 7. Some areas where d/D performance issues were reviewed and determined to not be critical and therefore no CIPs were developed.

The gravity main PDWQ velocity performance is depicted in Figure 7 where there is a total of 14,989 feet of existing pipe that exceed the PDWQ maximum velocity criteria. These areas were also discussed with Thornton, but do not represent significant issues to the collection system and therefore no CIPs were created based on the minimum and maximum velocity criteria.

The existing collection system Tier 1 gravity main performance can be summarized as follows:

- PDWQ d/D >=0.8 and Diameter >=15” = 11,848 feet
- PDWQ d/D >=0.7 and Diameter <15” = 8,686 feet
- PDWQ Velocity >8 ft/s = 14,989 feet
- PDWQ Velocity <2 ft/s = 141,584 feet

Tier 1 – Lift Stations and Forcemains

The permitted peak hydraulic capacity of the lift stations were evaluated against performance criteria for buildout PDWQ and is summarized in Table 8. Based on the hydraulic analysis, Thornton Crossing and Grange Hall Creek have adequate capacity to meet buildout PDWQ. Remington Lift Station is scheduled to be abandoned and flows will be diverted to Riverdale Lift Station which will require expansion to 0.5 MGD to convey buildout PDWQ.

Skylake and Big Dry Creek Lift Stations will require improvements to convey buildout PDWQ. Development adjacent to Skylake Lift Station result in the need for an additional 0.11 MGD capacity to meet buildout PDWQ. Given this requirement is driven by development immediately adjacent to the lift station, it is assumed that the cost would be incurred by the developer and a CIP was not developed for improvements to this lift station.

Thornton has already planned for additional pumping capacity that will be required at Big Dry Creek Lift Station to facilitate growth in the northwest portion of the future growth boundary. The Big Dry Creek Lift Station expansion currently underway is designed and constructed to meet buildout PDWQ with the exception of the pumps which have been designed to accommodate the 20-year flows. At buildout, the four pumps at the Big Dry Creek Lift Station will be removed and replaced with larger pumps capable of meeting buildout PDWQ. The masterplan estimates the required peak hydraulic capacity will be 12.1 MGD which is an increase of 4.0 MGD of the planned 2020 permitted capacity.

Lastly, there are a number of small development parcels projected to develop at buildout that are downstream of the Big Dry Creek Lift Station where gravity flow would be challenging due to the topography. To facilitate development in this area, a Lower Big Dry Creek Lift Station is anticipated to be necessary with a peak hydraulic capacity of 0.72 MGD.

Table 8. Lift Station Performance and Requirements

Lift Station	Permitted Capacity		ADWQ (MGD)	PDWQ (MGD)	Total Dynamic Head at Peak Flow (ft)	Available Capacity at Buildout (MGD)
	Hydraulic Design Capacity (MGD)	Peak Hydraulic Capacity (MGD)				
Lower Big Dry Creek	Future Lift Station		0.20	0.72	43	0.00
Big Dry Creek[1]	3.5	8.10	6.02	12.10	222	-4.00
Grange Hall Creek	1.0	2.60	0.58	1.01	22	1.59
Riverdale[2]	Unknown	0.50	0.33	0.50	64	0.00
Skylake	0.23	0.60	0.28	0.71	92	-0.11
Thornton Crossing	0.08	0.27	0.01	0.02	17	0.25

[1]Based on the near-term peak hydraulic capacity (Installed 2020)
[2]Remington Lift Station will be abandoned and existing and future flows will be conveyed via gravity to Riverdale Lift Station; peak hydraulic capacity assumed 0.5 MGD as directed by Thornton

Performance of the forcemains were evaluated at buildout PDWQ and are summarized in Table 9. The existing forcemains have adequate capacity based on the design criteria except for the Big Dry Creek forcemain where the velocity at buildout PDWQ slightly exceeds the design criteria. This was reviewed with Thornton and is not viewed as a significant issue requiring a CIP. Additionally, Thornton Crossing forcemain has a maximum velocity less than 2 feet per second (fps) which may result in additional maintenance but does not require a CIP.

Table 9. Forcemain Performance

Forcemain	Diameter (in)	Hydraulic Capacity at 6 fps (MGD)	PDWQ (MGD)	Maximum Velocity (fps)	Available Capacity at Buildout (MGD)
Lower Big Dry Creek (Future)	8	1.35	0.72	3.21	0.63
Big Dry Creek	22.7[1]	10.90	12.10	6.66	-1.20
Grange Hall Creek	12	3.05	1.01	1.98	2.04
Riverdale[2]	8	1.35	0.50	2.20	0.85
Skylake	8	1.35	0.71	3.14	0.64
Thornton Crossing	4	0.34	0.02	0.34	0.32

[1]Equivalent diameter of two 16" forcemains
[2]Remington Lift Station will be abandoned and flows will be conveyed via gravity to Riverdale Lift Station

Tier 2 – Gravity Main Performance

The system was also evaluated against 125% increase in ADWQ conservatively representing wet weather flow conditions. The buildout collection system was evaluated with completion of the Tier 1 CIPs discussed in Section 7 and evaluated against the buildout peak wet weather flow (PWWQ) criteria. The gravity main PWWQ d/D performance is depicted in Figure 8 where there is a total of 6,469 feet of existing pipe that would flow full. These areas were reviewed, and Tier 2 CIPs were developed to meet the buildout PWWQ criteria. Similar to the Tier 1 CIP development, the performance results were reviewed with Thornton and some areas were identified as not critical and therefore no CIPs were developed.

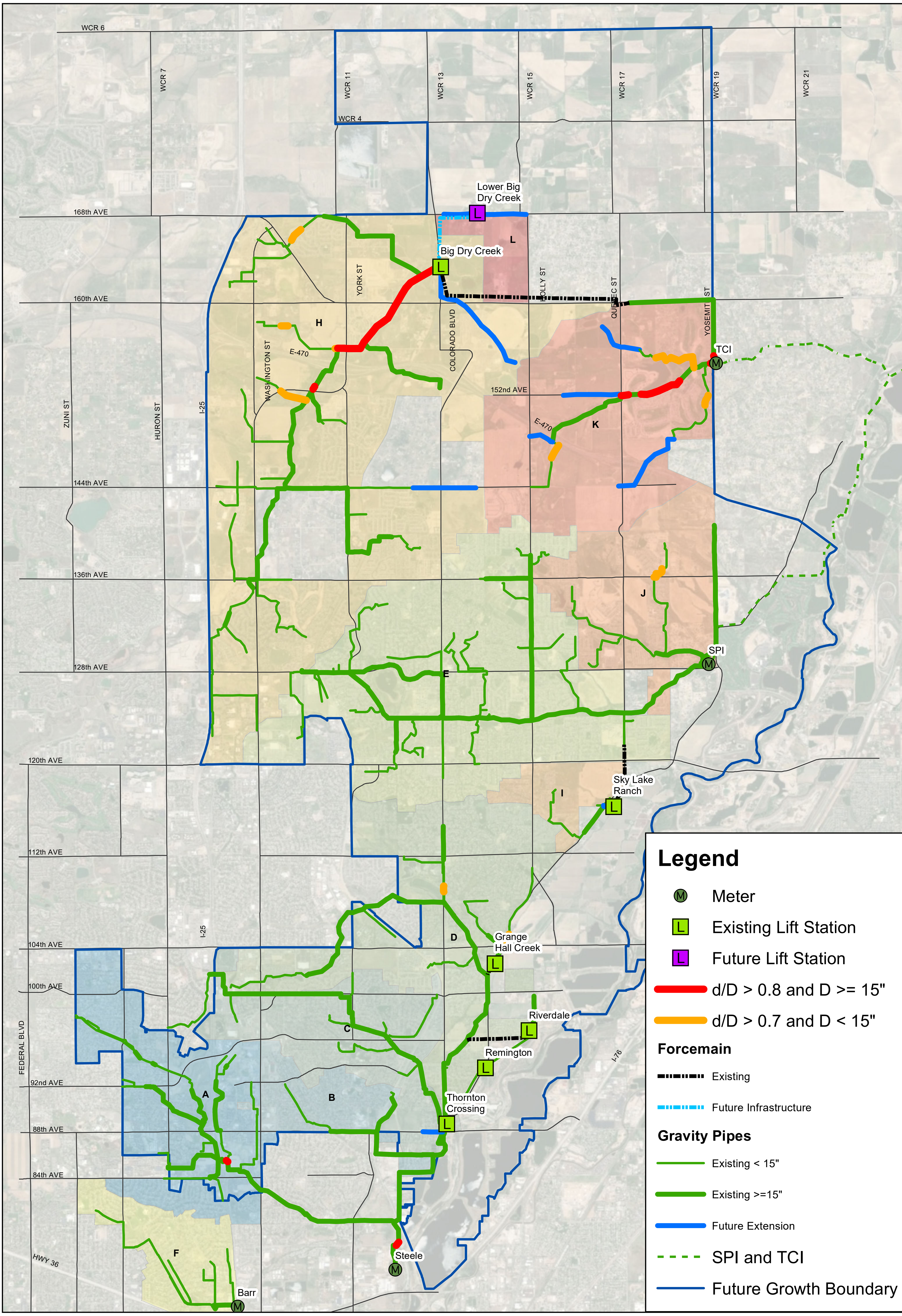

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Figure 6
Buildout PDWQ d/D Performance

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1 inch = 5,000 feet

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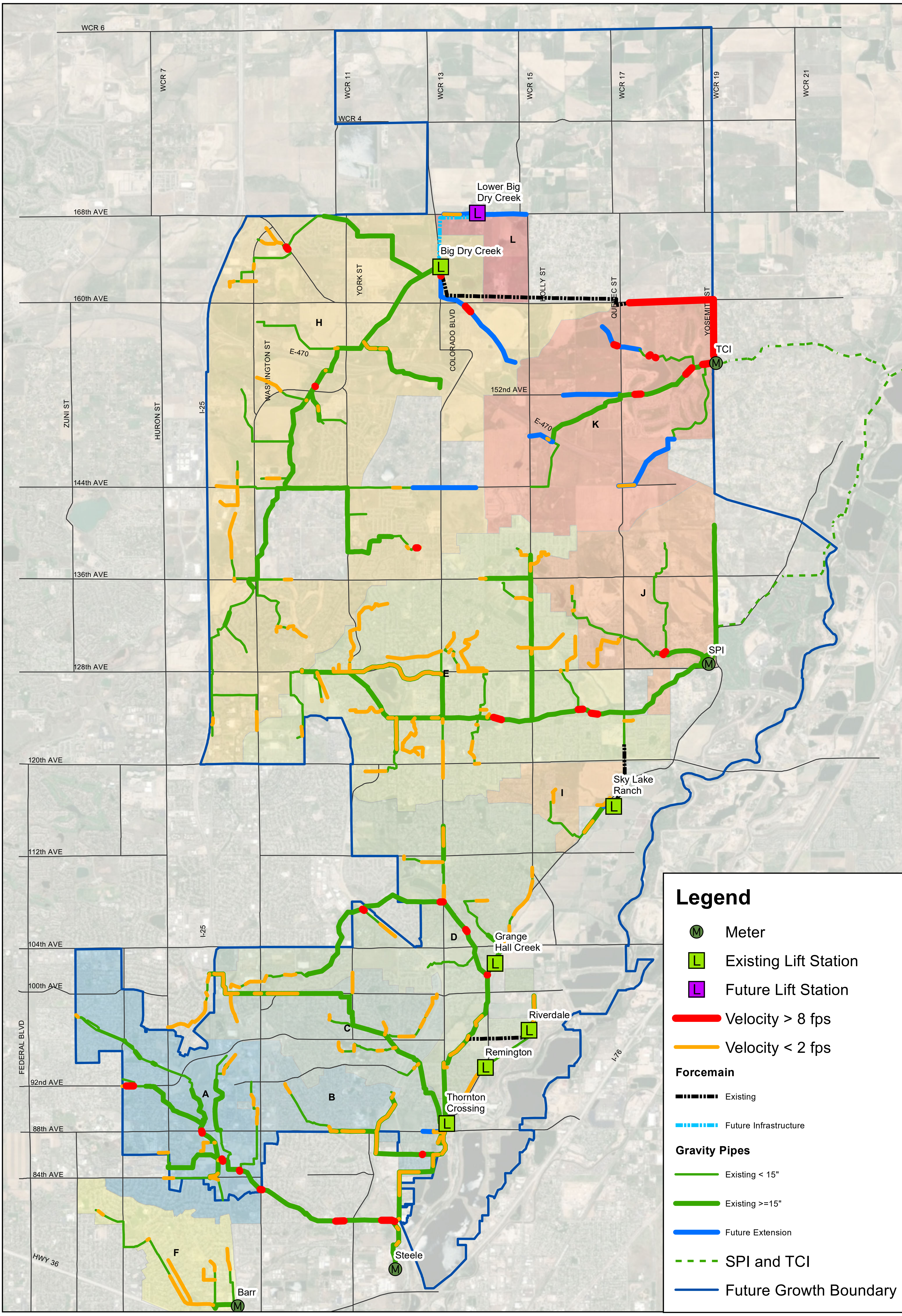

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Figure 7
Buildout PDWQ Velocity Performance

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1 inch = 5,000 feet

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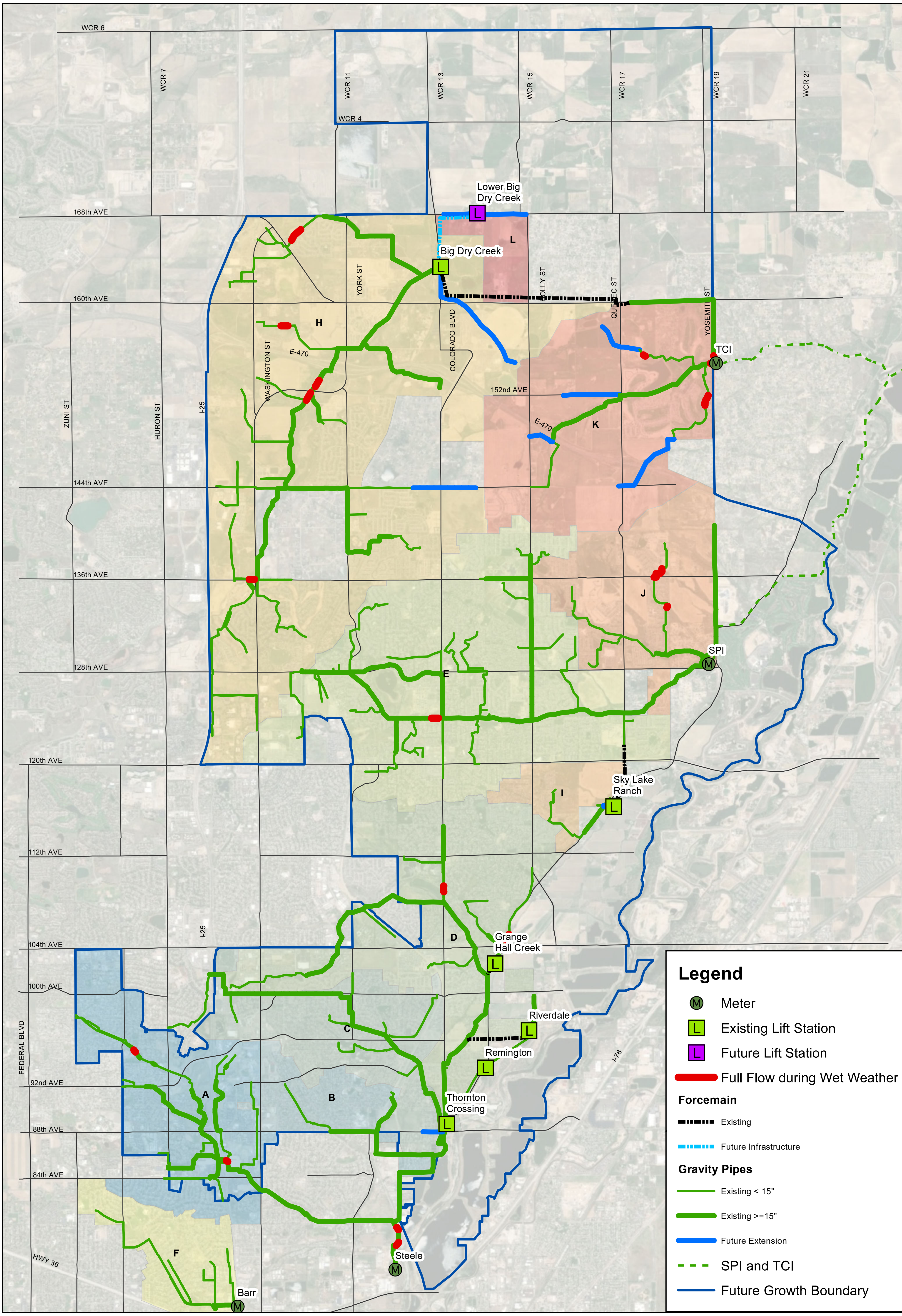

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Figure 8
Buildout PWWQ d/D Performance with Tier 1 Improvements

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7. Capital Improvement Program Development

The collection system performance results were reviewed with Thornton to develop CIPs necessary to meet buildout conditions. These CIPs were categorized as existing improvements necessary to meet the Tier 1 performance requirements, proposed future infrastructure to accommodate new development, and existing improvements necessary to meet the Tier 2 performance requirements. Improvement and future infrastructure areas were grouped into CIPs. Project cost was developed by applying unit costs accounting for material and installation for collection infrastructure, lift stations and forcemains.

The unit costs are consistent with AACE Class V estimating guidance. The developed cost is based on conceptual design and the basis of estimate summarized in this report. All costs were developed in March 2019 dollars based on an ENR Construction Cost Index of 9668. All project descriptions and cost estimates in this CIP represent planning-level accuracy and opinions of costs (+50%, -30%). The estimated unit cost includes the sum of materials, labor, and equipment of reasonably identified features of a project. The estimated total project cost is the sum of construction costs with additional allowances for direct and indirect costs. The indirect costs include engineering design, legal and administrative, construction management and contingency. The following items are not included as part of the unit cost estimate: land or right-of-way acquisition, finance charges during the planning, design, or construction of assets, remediation or fines associated with system violations, and operation, maintenance and energy costs. No costs were inflated or discounted to account for future pricing. The development of unit costs is provided in Appendix B.

The CIPs were developed to meet the performance criteria and in accordance with Thornton's Standards and Specifications. The resulting collection system CIPs required for buildout are summarized in Table 10, and Figure 9 shows an overview of the CIP Plan. CIPs were developed for the majority of the collection system where performance issues where identified, with the exception of some known issues that were reviewed and identified by Thornton as non-critical. A mapbook of the developed CIPs is provided in Appendix C.

Table 10. CIP Cost Summary

Type	Length (ft)	Total Cost
Existing Tier 1 Improvement	20,030	$7,325,000
Future Infrastructure	29,783	$7,075,000
Existing Tier 2 Improvement	1,056	$357,000
TOTAL CIP Plan	**50,869**	**$14,757,000**

The existing Tier 1 CIP's and associated cost are presented in Table 11 and identify improvements necessary to the existing system to meet buildout PDWQ conditions. A total of seven CIPs were identified that primarily occur in the northern portion of the collection system where most the growth is planned. The largest CIPs include completion of a parallel to the Big Dry Creek Interceptor (1) necessary as growth occurs in the northwest portion of the collection system, and the Heritage Todd Creek Interceptor parallel (6a and 6b) necessary to accommodate planned growth in the northeast portion of the collection system. The remaining CIPs represent smaller but necessary existing improvement projects along the Big Dry Creek Interceptor (2 and 3) or Heritage Todd Creek Interceptor (4 and 5).

Table 11. Tier 1 CIP – Existing Improvements to meet Buildout PDWQ d/D Requirement*

#	Description	Type	Length (ft)	Diameter (in)	Buildout PDWQ (gpm)	Buildout PWWQ (gpm)	Total Cost
1	Big Dry Creek Interceptor Parallel	Parallel Gravity Main	8,197	15" to 24"	4,043	5,053	**$2,819,000**
2**	Upstream Big Dry Creek Interceptor Improvement	Gravity Main Replacement	188	24"	3,410	4,246	**$57,000**
3	Big Dry Creek Lateral Improvement	Gravity Main Replacement	1,600	12"	1,155	1,436	**$225,000**
4	Todd Creek Collector Improvements	Gravity Main Replacement	3,068	12" to 15"	1,147	1,434	**$624,000**
5	Upstream Heritage Todd Creek Interceptor Improvement	Gravity Main Replacement	1,269	15"	1,195	1,494	**$578,000**
6a	Heritage Todd Creek Interceptor Parallel – Phase 1	Parallel Gravity Main	1,845	21"	1,882	2,353	**$1,131,000**
6b	Heritage Todd Creek Interceptor Parallel – Phase 2	Parallel Gravity Main	3,863	18" to 21"	3,029	3,786	**$1,891,000**
						Total	**$7,325,000**

*CIP triggered by PDWQ requirement of d/D < 0.8 for pipes ≥ 15" and d/D < 0.7 for pipes < 15"
**Monitor prior to completion to evaluate if project can be mitigated with modifications to upstream flow split

As development occurs, portions of the collection system will need to be extended to collect new developments. These areas were identified as proposed future infrastructure CIPs and are presented in Table 12. A total of eight CIPs were identified. The future infrastructure is primarily located in the northern portion of the collection system where the majority of future growth is planned except for construction of an 88th Avenue Interceptor which is necessary for planned infill development. The future infrastructure CIPs are often partially or completely the responsibility of the developer to complete but have been included as part of the CIP Plan to indicate preliminary alignments, flow requirements, and estimated cost consistent with the master planning efforts.

Table 12. Future Infrastructure CIP – Extension of Collection System to Facilitate Growth*

#	Description	Type	Length (ft)	Diameter (in)	Buildout PDWQ (gpm)	Buildout PWWQ (gpm)	Primary Funding Source	Total Cost
7	144th Ave Extension	Gravity Main Extension	3,593	8"	160	199	Developer	**$1,256,000**
8	Lower Big Dry Creek Lift Station	New Lift Station and Gravity Main	4,740	12"	397	492	Developer	**$2,059,000**
9	Todd Creek Collector Extension	Gravity Main Extension	2,756	12"	1,077	1,337	Developer	**$313,000**
10	152nd Ave Todd Creek Collector Extension	Gravity Main Extension	3,191	10"	654	813	Developer	**$456,000**
11	Sanitary Line D	Gravity Main Extension	4,788	12" to 15"	772	965	Developer	**$1,123,000**
12**	88th Ave Interceptor	Gravity Main Extension	1,141	10"	341	427	Developer	**$220,000**
13	Stonehocker Collector	Gravity Main Extension	7,693	12" to 18"	3,491	4,363	Developer	**$1,081,000**
14	E-470 and Holly St Collector	Gravity Main Extension	1,882	8"	211	261	Developer	**$567,000**
							Total	**$7,075,000**

*CIP required to extend collection system to meet future growth. Sized to supply PDWQ at d/D < 0.8 for pipes ≥ 15" and d/D < 0.7 for pipes < 15"
**Minimum diameter; to be confirmed by Developer

The CIP Plan was primarily developed to meet the PDWQ and future infrastructure requirements necessary for buildout. However, additional improvements were identified to meet PWWQ requirements (Tier 2). The Tier 2 CIPs are presented in Table 13 and represent improvements to existing pipes to meet PWWQ. A total of three projects were developed all of which occur along Big Dry Creek.

Table 13. Tier 2 CIP – Existing Improvements to meet Buildout PWWQ d/D Requirement*

#	Description	Type	Length (ft)	Diameter (in)	Buildout PDWQ (gpm)	Buildout PWWQ (gpm)	Total Cost
15**	Big Dry Creek Lift Station Inlet	Gravity Main Replacement	141	27"	6,033	7,481	**$53,000**
16**	Upstream Big Dry Creek Interceptor Improvement	Gravity Main Replacement	498	24"	3,427	4,250	**$141,000**
17**	Upstream Big Dry Creek Interceptor Parallel Improvement	Gravity Main Replacement	417	24"	3,066	3,802	**$163,000**
						Total	**$357,000**

*CIP triggered by PWWQ requirement of d/D < 1.0

**Monitor prior to completion to ensure additional capacity is required to meet actual PWWQ

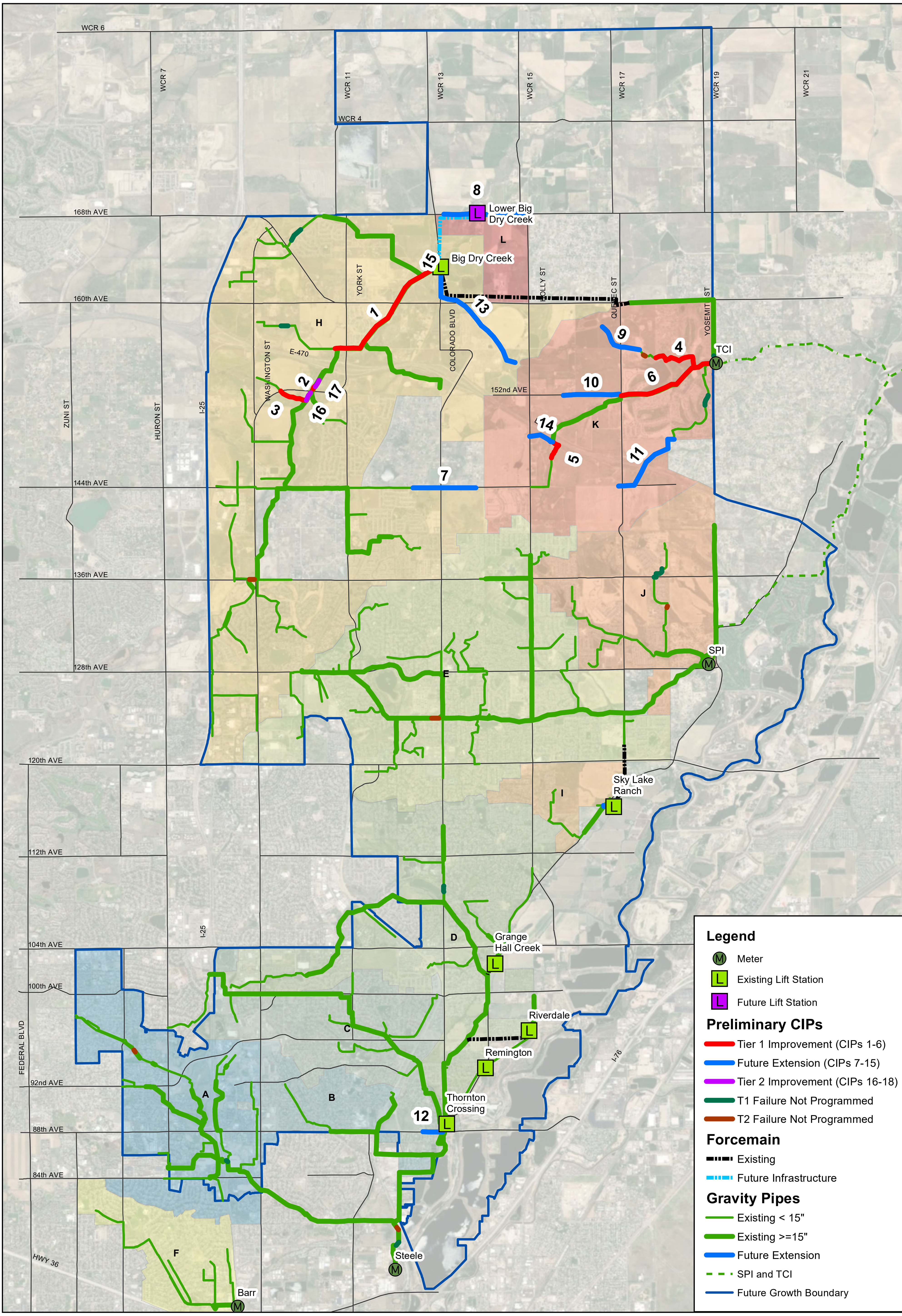

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Figure 9
CIP Overview

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Appendix A Buildout Scenario Development and Model Update

Buildout Scenario Development and Model Update

Infrastructure

To create the buildout scenario, AECOM copied the Thornton scenario "EXISTING_EPS" as the basis for existing loads and future pipe alignments, diameters and inverts, manhole rim elevations, and existing residential and commercial loads and loading patterns. Planned and proposed future infrastructure referencing previous studies and evaluating the collection area. AECOM reviewed and revised the future infrastructure to meet future system needs, including extending infrastructure north of the existing Big Dry Creek Interceptor.

Loads

Existing loads were scaled to reflect use identified in the Task 3 TM by using a multiplier of 1.16 to achieve the desired PDWQ. Future loads were spatially allocated to the nearest receiving manhole on a sub basin level. AECOM developed diurnal patterns for future commercial and residential loads consistent with the Thornton Design Criteria to achieve a minimum peaking factor of 2.6 and a maximum peaking factor of 3.5.

Lift Station Operations

Lift stations were set in the model as inflow equals outflow to avoid performance issues that would be avoidable with revised lift station operation. To accomplish this, pumped flow conservation was checked on for the simulations and all pump controls were changed to pump inflow to simulate the outflow from the wetwell equal to the inflow.

Controls and Evaluation

The buildout scenario was modeled for 48 hours using an extended period simulation (EPS). The model was modeled with flow attenuation and advanced forcemain support checked on. Under EPS modeling, all load peaking is accomplished via diurnal patterns, therefore the peaking factor information was not utilized. The second 24 hours of the 48-hour simulation was used for all reporting and hydraulic analysis.

Appendix B Unit Cost Assumptions

Unit Cost Assumptions

AECOM was requested by the City of Thornton (Thornton) to develop project costs for identified Capital Improvement Programs (CIP) as part of the Wastewater Master Plan. Unit costs were developed to account for the various components that make up the identified CIP costs. This memo presents the basis for the unit costs.

1. SUMMARY

The following summarizes the methodology used to develop the unit costs for capital improvements including sewer replacement cost per linear foot, manhole costs, and lift station costs. The engineers estimate reflects the opinion of AECOM of probable construction costs utilizing information available at the time the estimate was prepared. The unit cost estimates were developed from information provided by material suppliers, previous projects, and standard industry guidelines for construction cost estimating and assumes standard construction practices are utilized. AECOM has no control over future costs of construction labor, materials, equipment, nor of contractors' methods of determining prices, nor of competitive construction industry market conditions. The accuracy of the estimates is not guaranteed, and they are not intended to predict the outcome of the construction bidding.

AECOM has based the unit costs on Association for the Advancement of Cost Engineering (AACE) Class V estimating guidance. This opinion of probable costs is based on conceptual design and the basis of estimate summarized in this report. The expected confidence level for this estimate is approximately + 50, -30%. The unit costs have been developed based on cost estimating resources including:

- Vendor estimates for specialized materials and equipment;
- Construction and installation costs from similar AECOM projects;
- Historical data and prices for similar facilities designed and/or constructed by AECOM estimates from senior engineers with construction experience;
- RSMeans construction costs database; and
- Where applicable, historic costs have been inflated based on Engineering News Record construction indices.

This memo presents the opinion of probable costs and includes the following major elements:

- Pipe
- Manhole
- Bypass Pumping
- Lift Stations
- Forcemains
- Direct Cost
- Indirect Costs
- Contingencies

All costs were adjusted to present value cost at the time of the study based on Engineering News Record (ENR) most recent Construction Cost Indices (March 2019); no costs were inflated or discounted to account for future pricing.

2. Pipelines

Sewer line unit costs have been developed based on the project location category, pipe material costs, and the average invert depth. The unit costs are presented in Table 1.

The project location will have a significant impact on sewer installation costs, based on construction complexity, site access, and installation rates. For example, installing pipe in a dense urban area will be more costly than an undeveloped, wide open field. Unit costs were developed for the following two project locations:

- Developed – reflects existing pipe replacement in dense urban areas where roadway rehabilitation and/or concrete replacement will be required; includes major cost components
- Undeveloped – reflects new pipe construction or replacement of existing pipes in undeveloped areas with minimal constructability barriers; neglecting roadway replacement and utility crossing

Typical material unit cost and the pipe installation equipment and labor cost were determined from RSMeans, referencing previous projects and based on supplier information. Each CIP pipe segment was reviewed based on the site plan and engineering judgment was used to identify the pipe segment as either developed or undeveloped to account for the constructability and cost implications based on the CIP location.

In addition to the pipe material, equipment, and labor, costs were calculated for the following items:

- Excavation, based on average invert depth
- Bedding, based on average invert depth
- Backfill and Compaction, based on average invert depth
- Sewer Pipe Removal, where applicable
- Roadway Replacement, where applicable
  - Saw Cut, Asphalt Removal and Disposal, Asphalt Base and Paving, Curb and Gutter Replacement
- Testing
- Utility Crossings
- Dewatering

Pipe cost were calculated per linear foot for the three invert depth ranges based on 10-feet deep, 20-feet deep, and 40-feet deep (Table 1). Unit costs were obtained from RSMeans, and testing, utility crossing and dewatering cost were assumed to be percentages of the sewer line unit cost. These unit costs were developed based on recent project experience, vendor provided data, and construction estimates to meet the cost estimating needs for the Wastewater Collection System Master Plan as identified in Table 1.

Forcemain unit costs were developed with the same methodology as open cut sewer lines, and it was assumed that material cost are comparable to the vendor quotations obtained for the gravity sewer lines. The forcemains were sized based on the dry weather peak flow and velocity of 5 ft/s.

Table 1. Sewer Lines, Open Cut Unit Costs

Diameter (in)	Depth (ft)	Units	Developed	Undeveloped
8"	0'-10'	$/LF	$87	$29
	10'-20'	$/LF	$111	$51
	20'-40'	$/LF	$366	$217
10"	0'-10'	$/LF	$90	$32
	10'-20'	$/LF	$113	$54
	20'-40'	$/LF	$369	$219
12"	0'-10'	$/LF	$97	$38
	10'-20'	$/LF	$120	$60
	20'-40'	$/LF	$376	$226
15"	0'-10'	$/LF	$104	$45
	10'-20'	$/LF	$128	$67
	20'-40'	$/LF	$383	$232
18"	0'-10'	$/LF	$110	$50
	10'-20'	$/LF	$133	$72
	20'-40'	$/LF	$389	$238
21"	0'-10'	$/LF	$124	$64
	10'-20'	$/LF	$148	$85
	20'-40'	$/LF	$403	$251
24"	0'-10'	$/LF	$137	$75
	10'-20'	$/LF	$160	$97
	20'-40'	$/LF	$416	$262
27"	0'-10'	$/LF	$158	$93
	10'-20'	$/LF	$184	$117
	20'-40'	$/LF	$446	$289
30"	0'-10'	$/LF	$214	$143
	10'-20'	$/LF	$244	$170
	20'-40'	$/LF	$512	$348
36"	0'-10'	$/LF	$230	$154
	10'-20'	$/LF	$265	$187
	20'-40'	$/LF	$545	$375
42"	0'-10'	$/LF	$325	$238
	10'-20'	$/LF	$366	$276
	20'-40'	$/LF	$659	$476
48"	0'-10'	$/LF	$377	$283
	10'-20'	$/LF	$425	$327
	20'-40'	$/LF	$730	$538
54"	0'-10'	$/LF	$455	$351
	10'-20'	$/LF	$508	$400
	20'-40'	$/LF	$825	$623
60"	0'-10'	$/LF	$508	$397
	10'-20'	$/LF	$567	$451
	20'-40'	$/LF	$897	$686

3. Manholes

Unit price construction cost estimates were developed for the construction costs associated with replacing existing manholes or installing new manholes. It is difficult to rehabilitate an existing manhole particularly in the event that there are changes to pipe diameters and inverts. Therefore, it was assumed that CIPs associated with existing infrastructure will require removal and disposal of the existing manhole in addition to installation of a new manhole. CIPs for new construction will reflect only the cost for the material and installation of a new manhole. Manhole spacing were assumed to be installed every 450 feet in accordance with Thornton's Standards and Specifications. The manhole unit costs were calculated for three depths based on average invert depth. The manhole diameters are based on the accompanying pipe diameter as specified by Thornton's Standards and Specifications. Table 3 presents the manhole unit costs. The costs were developed based on recent project experience, vendor provided data, and construction estimates as identified in Table 3.

Table 3. Manhole Unit Cost

Manhole Diameter	New Cost ($)		Replacement Cost ($)		
Depth:	0'-10'	10'-20'	0'-10'	10'-20'	20'-40'
4' Diameter Manhole (Pipe ≤ 18")	$1,510	$2,420	$2,100	$3,010	$4,800
5' Diameter Manhole (Pipe 21" - 27")	$3,460	$4,880	$4,120	$5,550	$8,290
6' Diameter Manhole (Pipe >27")	$4,150	$5,750	$4,910	$6,510	$9,880

4. Bypass Pumping

Bypass pumping costs have been developed based on vendor provided data. Rain-For-Rent provided costs for similar projects for a range of peak flow rates assuming one week of bypass pumping. A unit cost was developed by taking a linear regression of the cost per day to bypass pump as a function of the peak flow. The resulting regression equation relationship is Cost ($/day) = $436/day+0.95*Peak Q (GPM). For each CIP, the peak pumping rate required will be identified and an estimate will be made for the construction duration (based on length and diameter of pipe) to identify the total cost of bypass pumping. An example cost calculation is shown below.

Cost ($/day) = $436/day + 0.95*Peak Q (GPM)

- Peak pumping rate is 2,500 gpm
- Construction duration is 8 days
- Bypass Pumping Cost = ($436/day + 0.95 x 2,500 GPM) x 8 Days = $22,488

The construction duration was assumed based on pipe diameter as follows:

- 6”-21” can be constructed at 300 ft/day
- 24”-42” can be constructed at 250 ft/day
- 48”-84” can be constructed at 200 ft/day

5. Lift Stations

Based on the hydraulic analysis to date, the existing lift stations have sufficient capacity; therefore, no cost is necessary to rehabilitate or expand the existing facilities. New lift stations will need to be constructed to convey future flows. Costs for construction of new lift stations were developed using a parametric power-law approach based on pump station capacity. The power-law multiplier and exponent values were obtained from data in Chapter 29 of *Pumping Station Design, Revised 3rd Ed.* (Jones *et al.* 2006).

Figure 1 presents a revised version of Figure 29-5 from *Pumping Station Design*. The revision includes updated costs based on ENR indices and includes a Selected Ratio cost in addition to the High and Low costs.

Equations for the Low, High, and Selected Ratio correlation lines are as follows:

- **Low Limit** – Cost($) = $1,583 x (Capacity in gpm)^0.77
- **High Limit** – Cost($) = $22,500 x (Capacity in gpm)^0.62
- **Selected Ratio** – Cost($) = $10,506.88 x (Capacity in gpm)^0.72

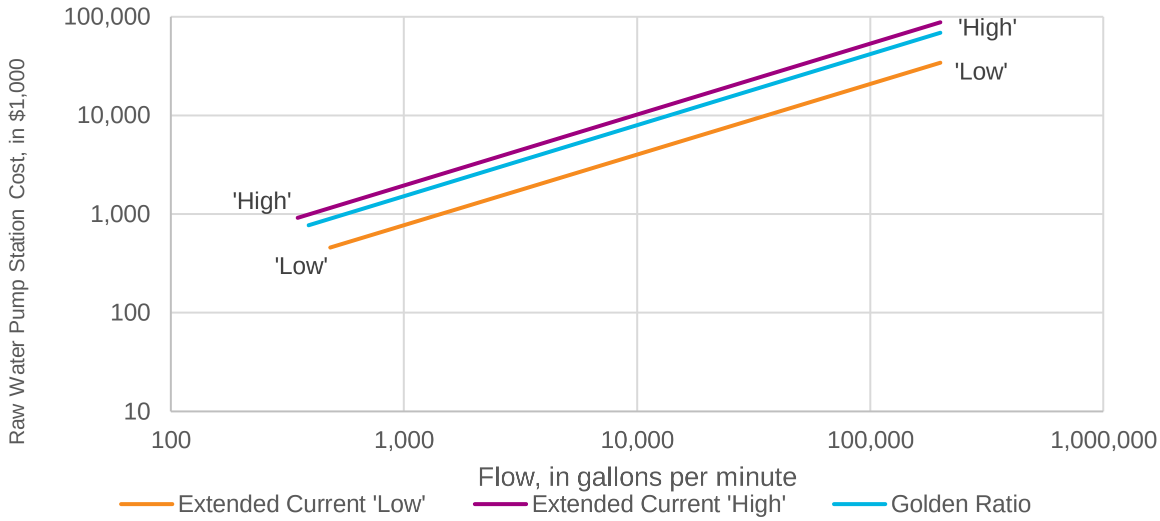

Figure 1. Reproduced Fig. 29-3 (Updated) from Pumping Station Design (Jones *et al.* 2006)

Regarding the costs of lift stations in general:

Costs can be corrected for locale, and for the distance from the nearest city. However, the accuracy of those corrections is “entirely overshadowed by the construction conditions, the designer’s concept of appropriate design, the amount of instrumentation, the addition of standby power, and, especially, the bidding climate” (Sanks *et al*. 1998).

These pre-budget estimates are for construction of the lift stations only. Charges for engineering, legal fees, land, administration, and interest during construction must be added to obtain total estimated project costs for the pump stations. The lift station cost includes all lift station infrastructure including pumps, wet well, building, instrumentation, electrical, etc. Costs for items beyond the lift station battery limits (e.g., pipelines, access roads, power lines, etc.), are not included.

6. Other Costs Considerations

The following additional direct and indirect costs were assumed for each CIP:

Direct:

- Erosion Control 5%
- Mobilization and Site Setup 5%

Indirect:

- Engineering Design 15%
- Legal and Administrative 5%
- Construction Management 10%

Contingencies:

The unit costs presented in this memo have been developed based on AACE Class IV estimates as described in Section 1. A 25% contingency should be applied to each CIP for planning purposes.

Appendix C CIP Mapbook

Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

T1 IMPROVEMENT

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CIP 1

6/16/2019

1 inch = 980 feet

Legend

Meter

Existing Lift Station

Future Lift Station

CIP

Forcemain

Existing

Future Infrastructure

Gravity Pipes

Existing < 15"

Existing >=15"

Future Extension

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CIP 2

6/16/2019

1 inch = 30 feet

Legend

Meter

Existing Lift Station

Future Lift Station

CIP

Forcemain

Existing

Future Infrastructure

Gravity Pipes

Existing < 15"

Existing >=15"

Future Extension

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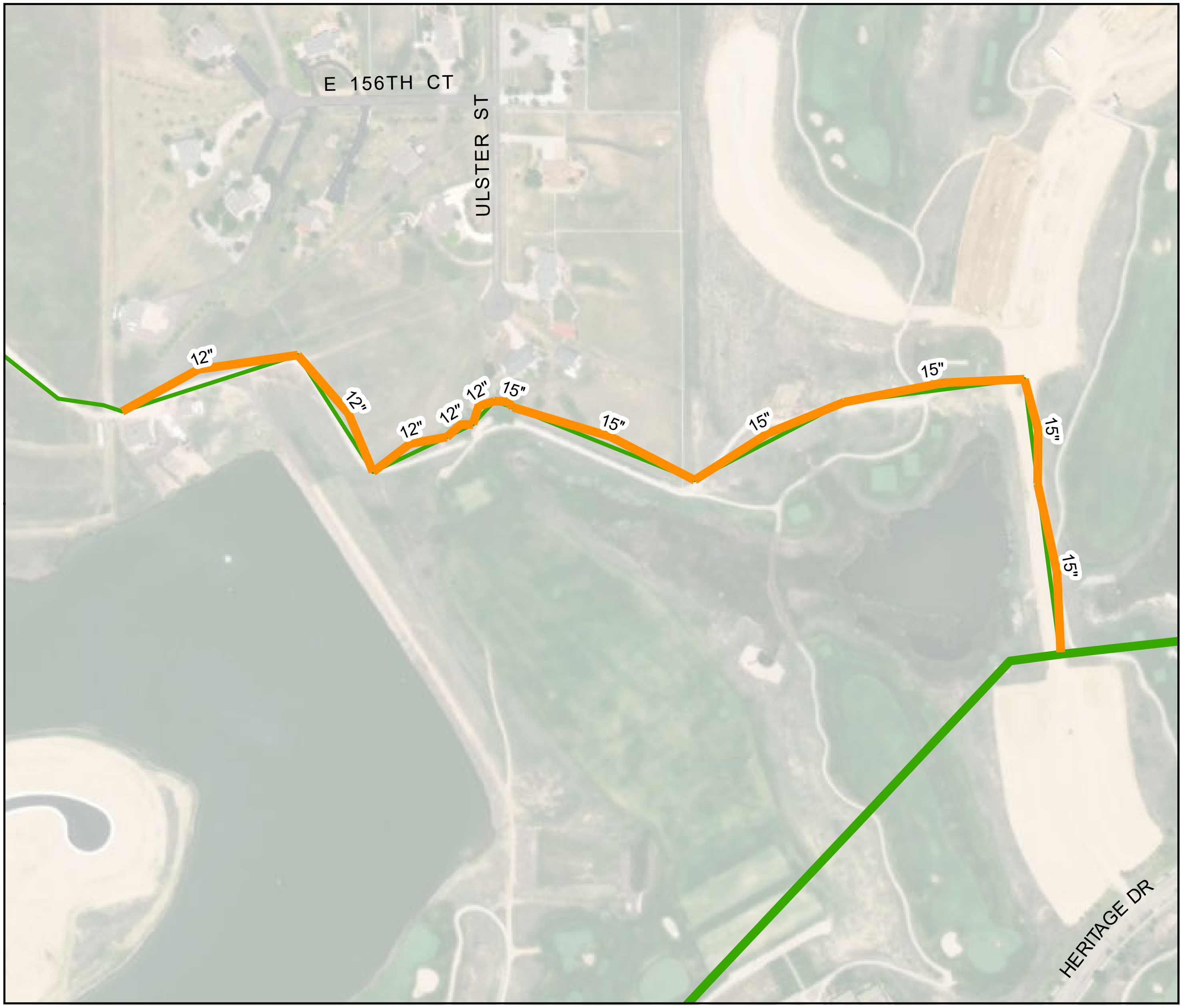
CIP 3

6/16/2019

1 inch = 238 feet



Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

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CIP 4

6/16/2019

1 inch = 356 feet

Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

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CIP 5

6/16/2019

1 inch = 178 feet

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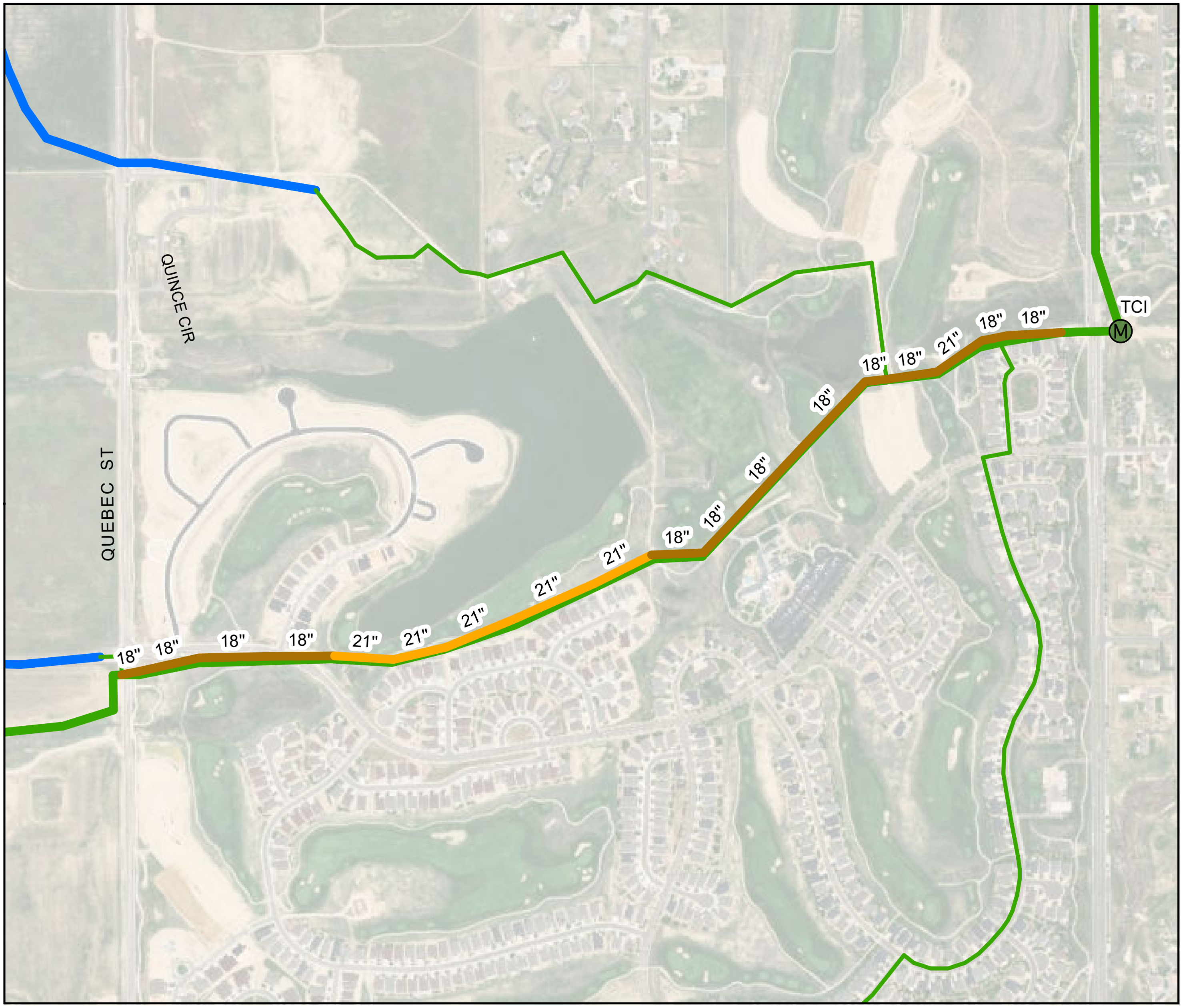

Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP 6a - Phase 1
- CIP 6b - Phase 2

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

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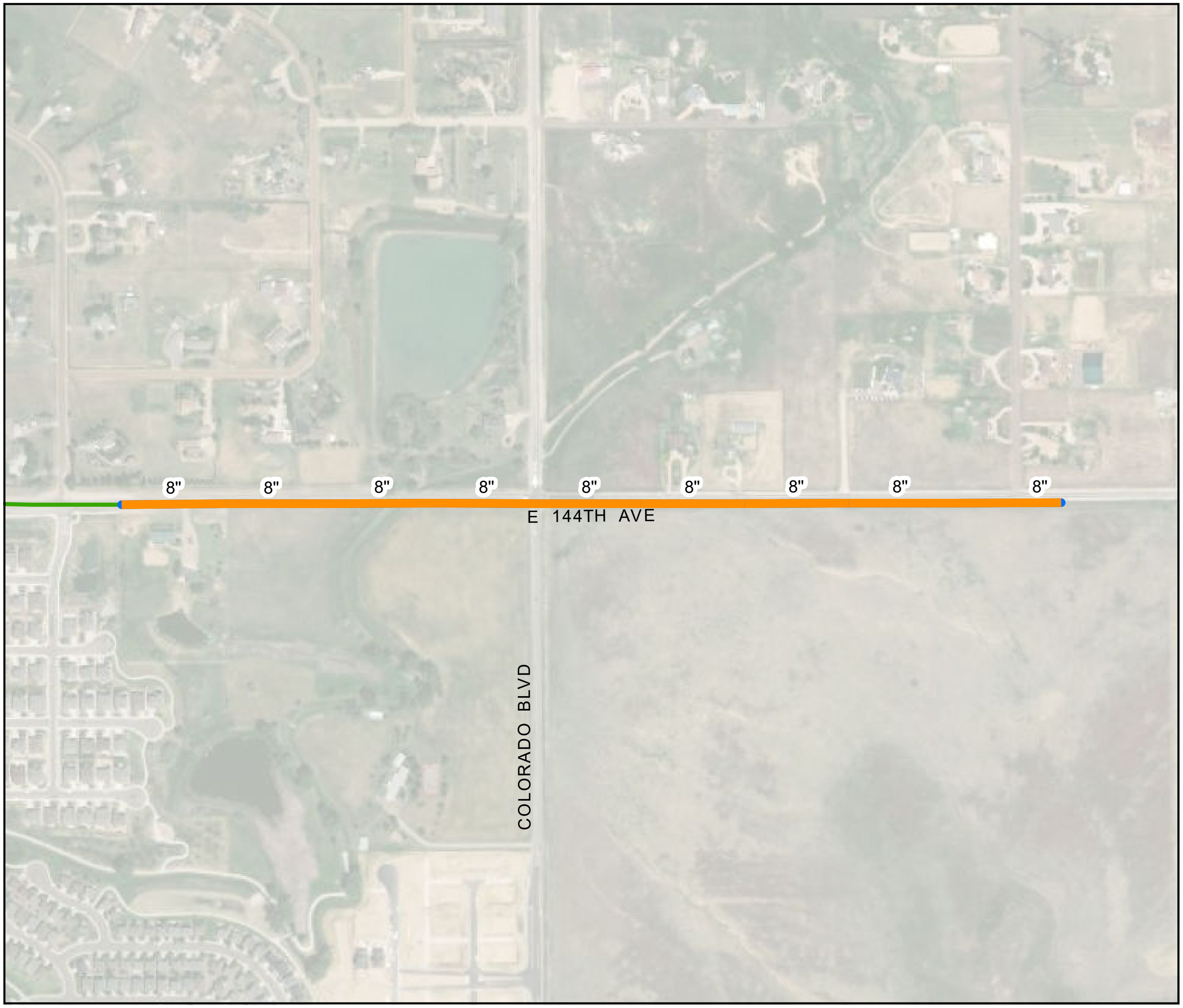
CIP 6

6/16/2019

1 inch = 837 feet



Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

FUTURE

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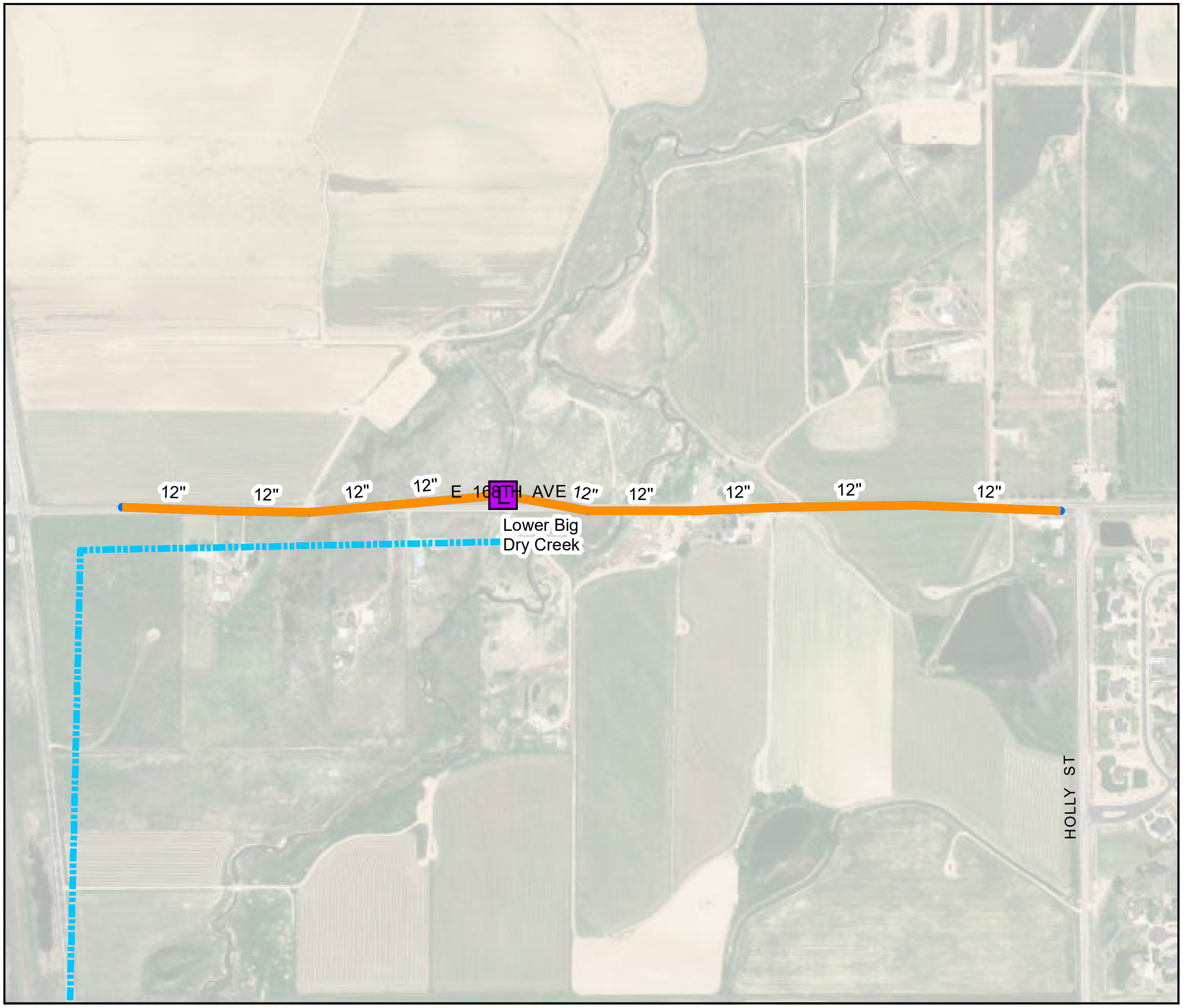
CIP 7

6/16/2019

1 inch = 588 feet



Legend

Meter

Existing Lift Station

Future Lift Station

CIP

Forcemain

Existing

Future Infrastructure

Gravity Pipes

Existing < 15"

Existing >=15"

Future Extension

FUTURE

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CIP 8

6/16/2019

1 inch = 773 feet

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Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

FUTURE

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CIP 9

6/16/2019

1 inch = 348 feet

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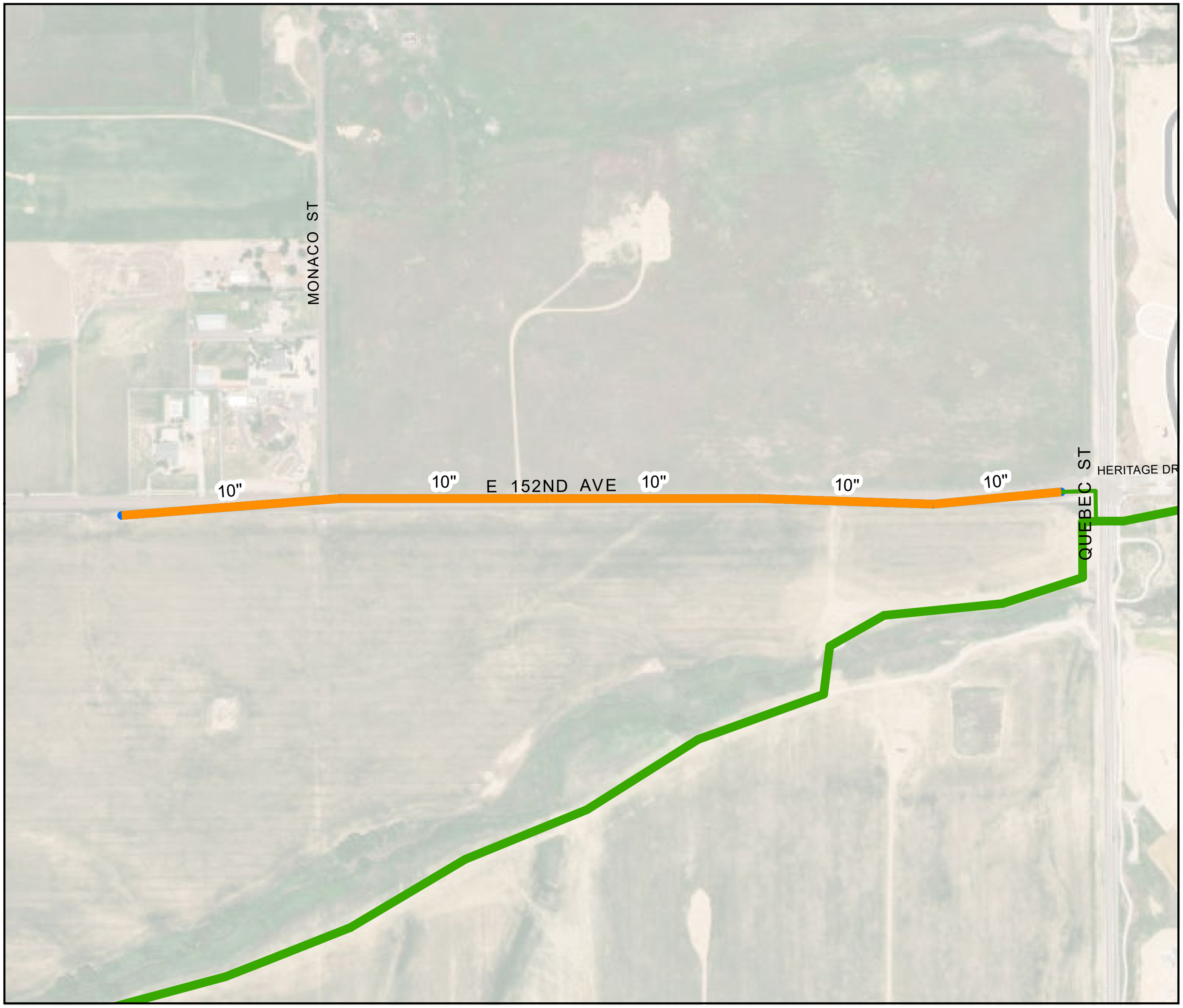

Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

FUTURE

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CIP 10

6/16/2019

1 inch = 521 feet

Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

FUTURE

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CIP 11

6/16/2019

1 inch = 522 feet

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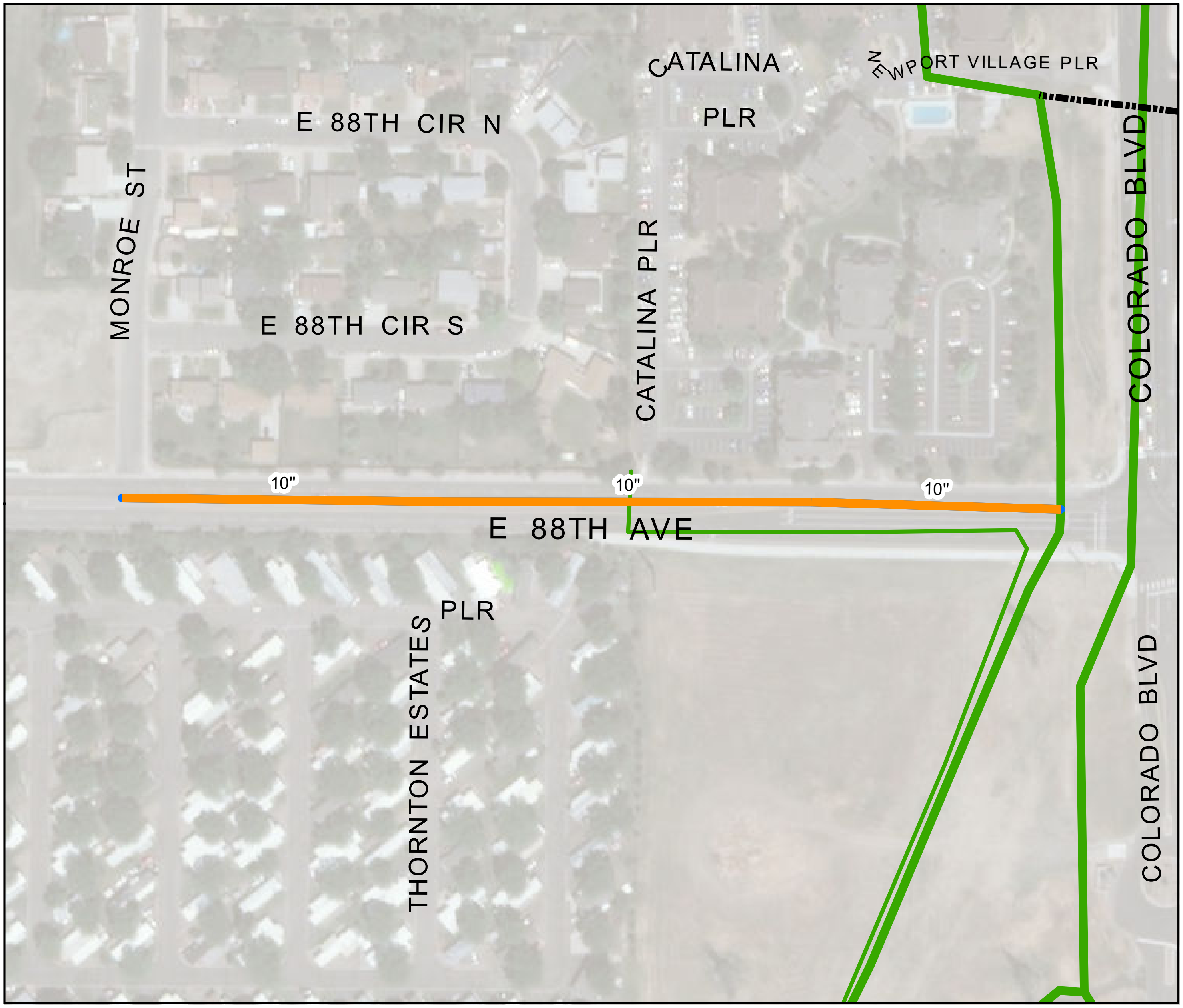

Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

FUTURE

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CIP 12

6/16/2019

1 inch = 187 feet

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Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

FUTURE

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CIP 13

6/16/2019

1 inch = 1,056 feet

Legend

Meter
Existing Lift Station
Future Lift Station
CIP

Forcemain

Existing
Future Infrastructure

Gravity Pipes

Existing < 15"
Existing >=15"
Future Extension

FUTURE

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CIP 14

6/16/2019

1 inch = 216 feet

Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

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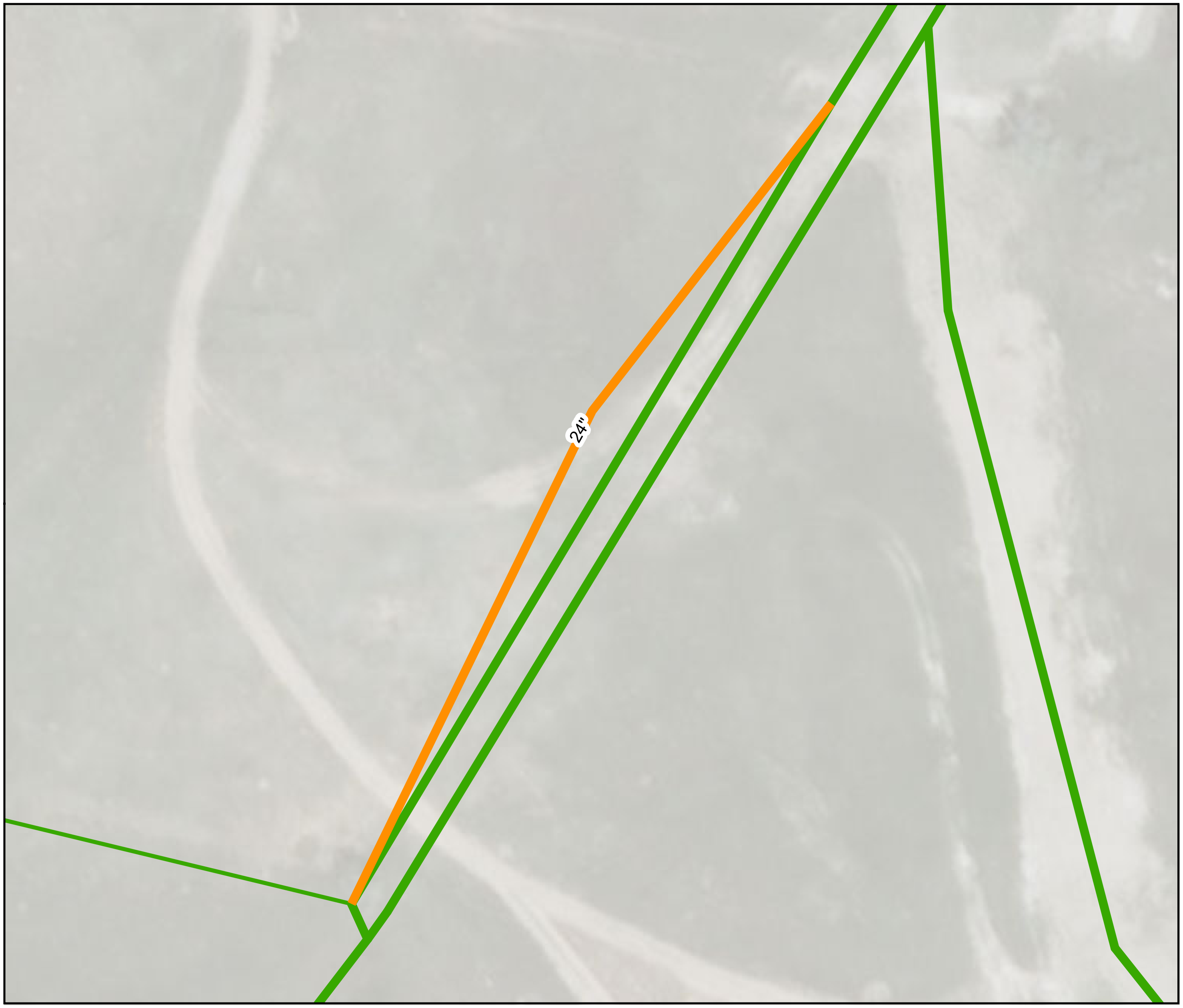
CIP 15

6/16/2019

1 inch = 18 feet



Legend

- Meter
- Existing Lift Station
- Future Lift Station
- CIP

Forcemain

- Existing
- Future Infrastructure

Gravity Pipes

- Existing < 15"
- Existing >=15"
- Future Extension

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CIP 16

6/16/2019

1 inch = 82 feet

Legend

Meter
Existing Lift Station
Future Lift Station
CIP

Forcemain

Existing
Future Infrastructure

Gravity Pipes

Existing < 15"
Existing >=15"
Future Extension

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CIP 17

6/16/2019

1 inch = 68 feet

Water and Wastewater Rehabilitation and Replacement Program

Chapter 7

Utility Master Plan

Project No. 17-467

Water and Wastewater Infrastructure Master Plan

Water and Wastewater Rehabilitation and Replacement Program

The City of Thornton

Project number: 60560104

AECOM

May 23, 2019

Quality information

Prepared by	Checked by	Verified by	Approved by
Marcela Duran	Brock Hodgson	Sean Berzins	Nathan Walker

Revision History

Revision	Revision date	Details	Authorized	Name	Position

Distribution List

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Prepared for:

The City of Thornton

Prepared by:

AECOM
6200 South Quebec Street
Greenwood Village, CO 80111

T: +1 (303) 694 2770
F: +1 (303) 694 3946
aecom.com

Table of Contents

Figures

Tables

List of Acronyms

AC –	Asbestos Cement
ASCE –	American Society of Civil Engineers
Ca –	Age Constant
CCTV –	Closed Circuit Television
CI –	Cast Iron
CIP –	Capital Improvement Project
CIPP –	Cured in Place Pipe
CoF –	Consequence of Failure
DI –	Ductile Iron
GIS –	Geographic Information System
IN –	Inches
O&M –	Operation and Maintenance
PCCP –	Prestressed Concrete Cylinder Pipe
PoF –	Probability of Failure
PSI –	Pounds per Square Inch
PVC –	Polyvinyl Chloride
RCP –	Reinforced Concrete Pipe
RFEC –	Remote Field Eddy Current Technology
TM –	Technical Memorandum
UV –	Ultraviolet
VCP –	Vitrified Clay Pipe
WERF –	Water Environment Research Federation

1. Introduction

The city of Thornton (Thornton) identified a need to evaluate the current water distribution and wastewater collection system pipeline Rehabilitation and Replacement Program to determine if current funding is adequate to maintain the respective systems. The evaluation involved assessing the risk exposure, development of associated long-term funding and the prioritization of pipeline improvements.

The risk exposure assessment involved development of a risk model based on available information on pipe age, pipe material, and other key factors. A prioritization model was developed to establish a year of replacement for each asset based on the results of the risk model. Long-term funding development was based on the results of the prioritization model.

Risk exposure is typically assessed based on the probability and consequence of asset failure and is used to drive the selection and prioritization of asset related actions that are based on organizational risk tolerance thresholds and sustainable funding levels. Utilizing a risk-based approach provides a clear direction for the overall rehabilitation and replacement process in terms of balancing priorities and assisting in the clarification of what level of investment is prudent to be made with each specific asset. It also provides transparency to demonstrate that decisions are made in an impartial and consistent manner, without unreasonable bias, and in accordance with agreed upon policy and priorities.

The ultimate purpose of the analyses presented in this document and the tools developed to perform such analyses is to provide Thornton with additional information, based on current inventories and georeferenced information, to be used in the final selection of an annual budget, and to reduce asset failure risk through a rules-based decision model.

1.1 Key Findings

The key findings, after the risk exposure evaluation, prioritization analysis, and applying a unit cost of $19/foot-inch to develop annual projected expenditures, are:

- Per the risk exposure evaluation, most of the water system (86%) and most of the wastewater system (97%) fall in the Monitor and Forecast category; this action level implies that the assets are at a relatively low risk and monitoring can be done on a more opportunistic basis.
- Per the risk exposure evaluation, only three pipes in the water system and none in the wastewater system fall in the Urgent Rehab/Replace category; this action level implies immediate attention to avoid catastrophic system failures and expensive emergency repairs.
- The current annual funding level for water main replacement of $1M is significantly below the estimated required funding level of approximately $7M/year.
- The estimated annual level of funding will address approximately 1% of the system in a 100-year average, while addressing approximately 2% of the system in the short-term.
- The current annual funding level for wastewater main replacement of $1M is significantly below the estimated required funding level of approximately $4.7M/year.
- The estimated annual level of funding will address approximately 1.1% of the system in a 100-year average, while addressing approximately 2.2% of the system in the short-term.

2. Infrastructure and Operational Data Collection and Review

Thornton's water distribution system and wastewater collection system is comprised of approximately 1,094 miles of pipeline assets in total, with approximately 617 miles of water distribution pipelines and 477 miles of wastewater collection pipelines (mains and forced mains), based on the GIS asset datasets in 2018. These totals do not include hydrant laterals, abandoned, private, Metro lines, or raw water lines.

The data associated with these assets was examined in terms of the following characteristics that are fundamental building blocks for risk-based management of water mains:

- Age
- Material
- Diameter

To perform the probability of failure analysis, data from the following source were used; the water distribution hydraulic model, the wastewater collection system hydraulic model, and data from the Thornton GIS databases. This GIS information is populated with attributes representing the characteristics for each pipe segment and provides spatial orientation for the pipes. The provided data sets contained water and wastewater main line assets that are owned by Thornton.

The data provided by Thornton was used as-is and was understood to accurately represent the existing system. Obvious data errors or discrepancies that were discovered during the project analysis have been identified in this report for Thornton to address and revise at a later date. One notable exception to this data was the use of GIS spatial joins to transfer data from the GIS database to the hydraulic model pipe dataset. This spatial join involved joining the GIS and InfoWater pipe data, as well as using the GIS database to attempt to fill in missing installation dates for pipes by proximity to other pipes with known installation dates.

2.1 Asset Age Profile

The age of an asset plays a role in the assessment of condition due to the general assumption that an old asset will have a greater probability of failure than a newer one. Within the context of water main pipe, this can be a little more complex as different eras of the same material type can be subtly different in a counterintuitive manner. Improvements to the manufacturing process for CI and its evolution to DI, for example, resulted in the manufacturing thinner walls that fail in shorter time periods due to corrosion than earlier versions of the same material with thicker pipe walls. Subtle changes in many material standards such as pre-stressed concrete cylinder pipe (PCCP), Asbestos Cement (AC) pipe and Polyvinyl Chloride (PVC) also have resulted in lower safety factors being used in later years of construction with the same apparent material being used.

In the absence of more detailed, structural-based information from formal condition assessment programs, age is typically used as a proxy for structural condition. Within materials of unique characteristics (e.g. in instances when the change in standard or manufacturing process can be clarified) age is a useful proxy.

It was assumed that pipes with an unknown installation date are 40 years old. This was estimated by taking the weighted average (by length) age of the pipes from the GIS database (rounded average). Figure 1 and Figure 2 summarize the age profile of the Thornton water and wastewater main asset inventory, respectively, as percentage of total length. It can be observed from these figures that approximately 40% of pipelines in the water and wastewater systems are more than 40 years old.

When looking at the average age of the pipelines in the water distribution and wastewater collection inventory, mean median and weighted average can give more insight into the breakdown of the systems, as seen below in Table 1.

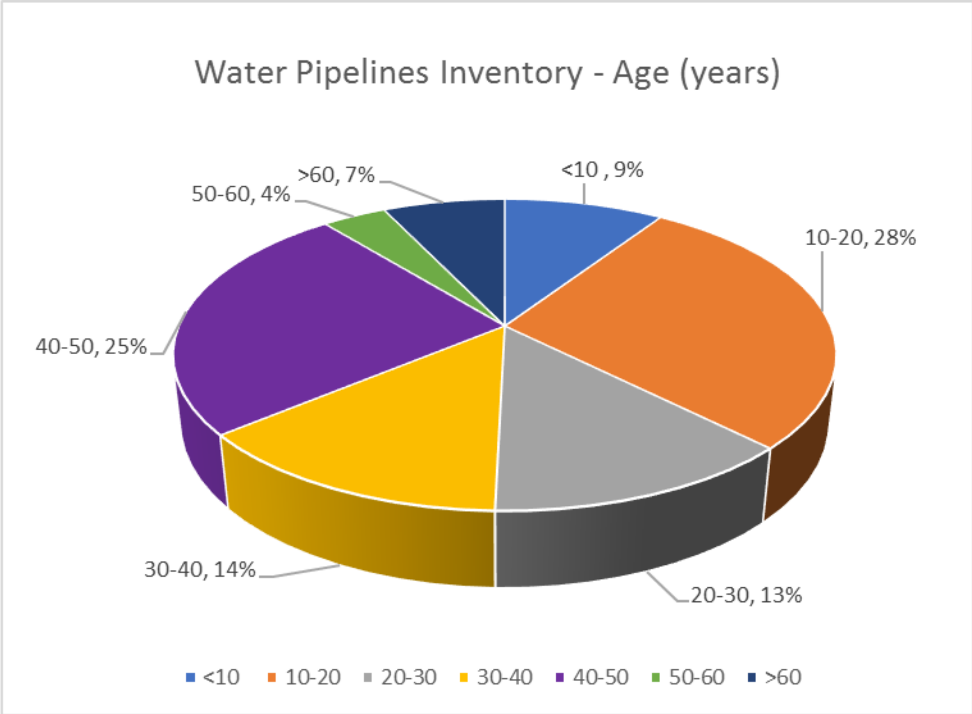

Figure 1: Water Pipelines Inventory - Age Profile

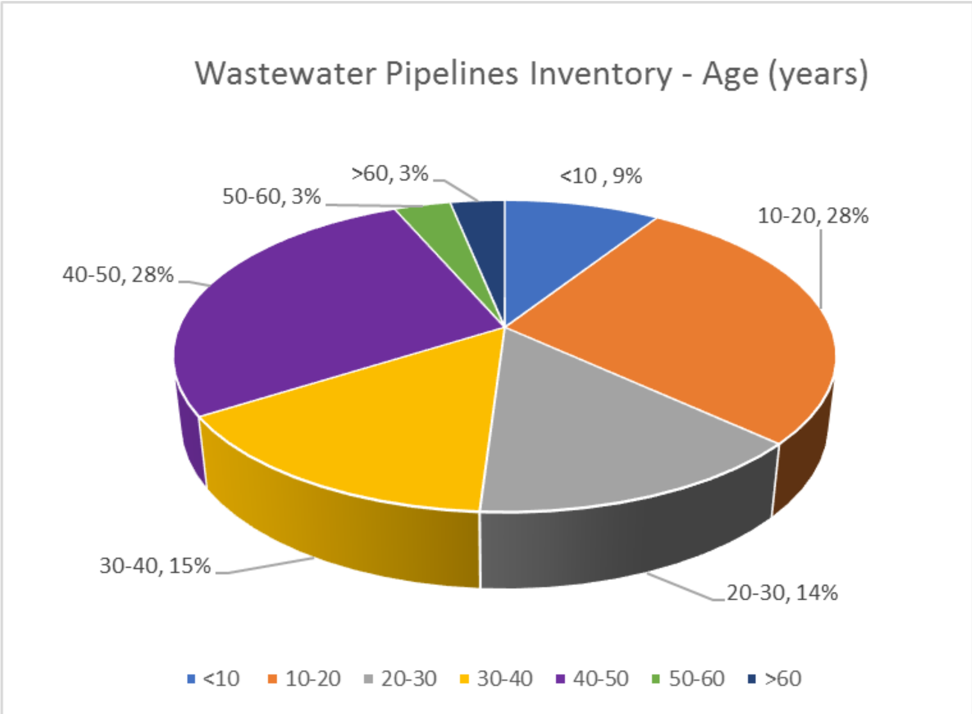

Figure 2: Wastewater Collection Pipelines Inventory - Age Profile

Table 1: Average Age of Pipelines

Parameter	Age (Years)
Water Distribution	
Mean	26
Median	20
Weighted Average by Length	28
Wastewater Collection	
Mean	26
Median	22
Weighted Average by Length	22

2.2 Asset Material Profile

The material types within the water pipeline GIS database reflect the actual pipe material used, sometimes with a more colloquial description of that material. For the purposes of condition assessment, it is useful to reference pipe materials in common grouping related to the base fabric they are made from. These base descriptions of materials have common drivers for deterioration and often have similar approaches for monitoring and assessment. For this reason, pipe materials were grouped within 5 categories, outlined as follows:

- Cementitious (e.g. Asbestos Concrete, Concrete Reinforced / Nonreinforced)
- Ferrous (e.g. Cast Iron, Ductile Iron, Steel etc.)
- Plastic (e.g. PVC, HDPE etc.)
- Clay (e.g. Vitrified Clay Pipe, etc.)
- Unknown (empty data field)

A cross-reference table was rationalized such that the Thornton material types from the GIS could be classified within these previous groupings, and is outlined below in Table 2:

Table 2: Material Classification Cross Reference – Water Pipes

Material	Material Class	% of Total
Asbestos Cement	Cementitious	26%
Cast Iron	Ferrous	0.2%
Ductile Iron	Ferrous	16%
Steel	Ferrous	2%
PVC	Plastic	56%

Figure 3 and Figure 4 summarize the material profile of the Thornton water pipeline and wastewater collection pipeline inventory, respectively, as percentages of total length.

The primary observation that can be made from these profiles is that plastic pipe material represents the largest portion for both, the water and wastewater pipeline inventory. This could indicate a large amount of recent expansion and/or replacement programs within the water distribution system since these materials have become widely available and accepted only within the last 30 years or so. This also suggests that some emphasis should be made on understanding the potential deteriorating mechanisms associated with plastic pipe for both systems.

When pipe material is compared with the age of installation, some general conclusions can be developed regarding risk exposure when there is existing background knowledge of the average useful life of pipe materials within the local conditions. Figure 5 and Figure 6 summarize the material profiles of the Thornton water and wastewater collection pipeline inventory when compared with age.

The primary observation that can be made from these profiles is that PVC pipe is the most prevalent pipe installed within the last 40 years based on the available data, in both water and wastewater systems. Pipes installed before 1980 were mainly Asbestos Cement for water and Concrete or Cured-in-Place for wastewater.

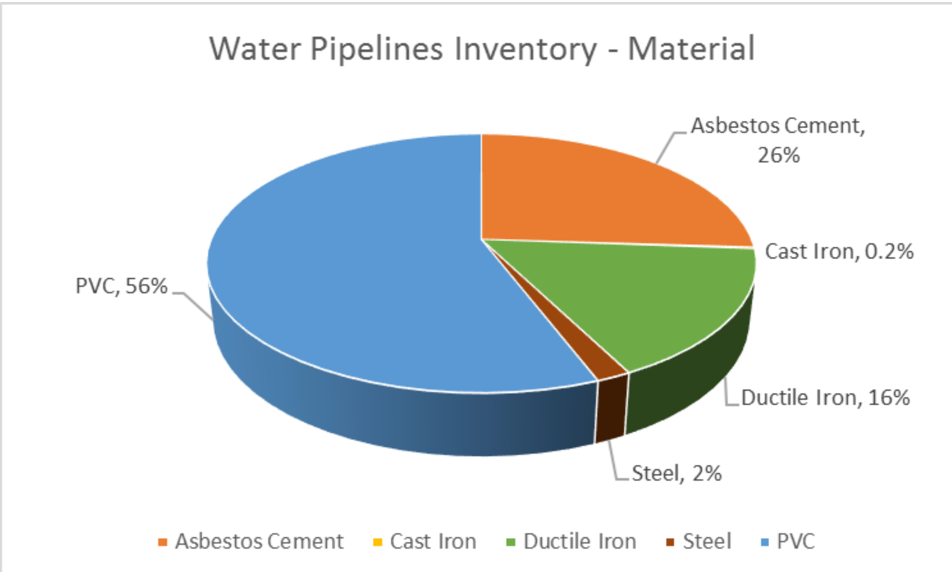

Figure 3: Water Pipelines Inventory - Material Profile

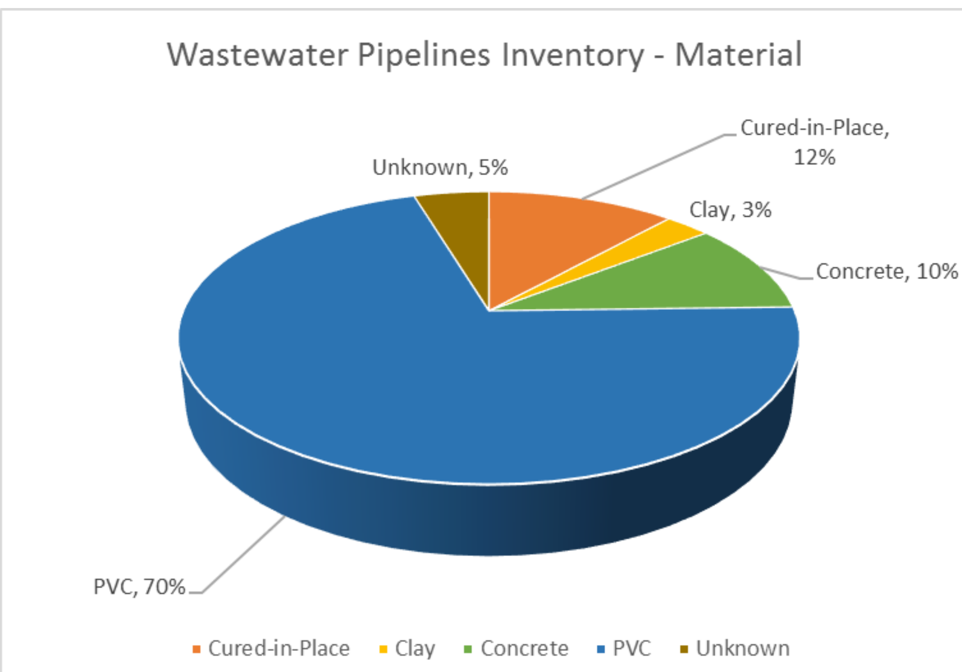

Figure 4: Wastewater Collection Pipelines Inventory - Material Profile

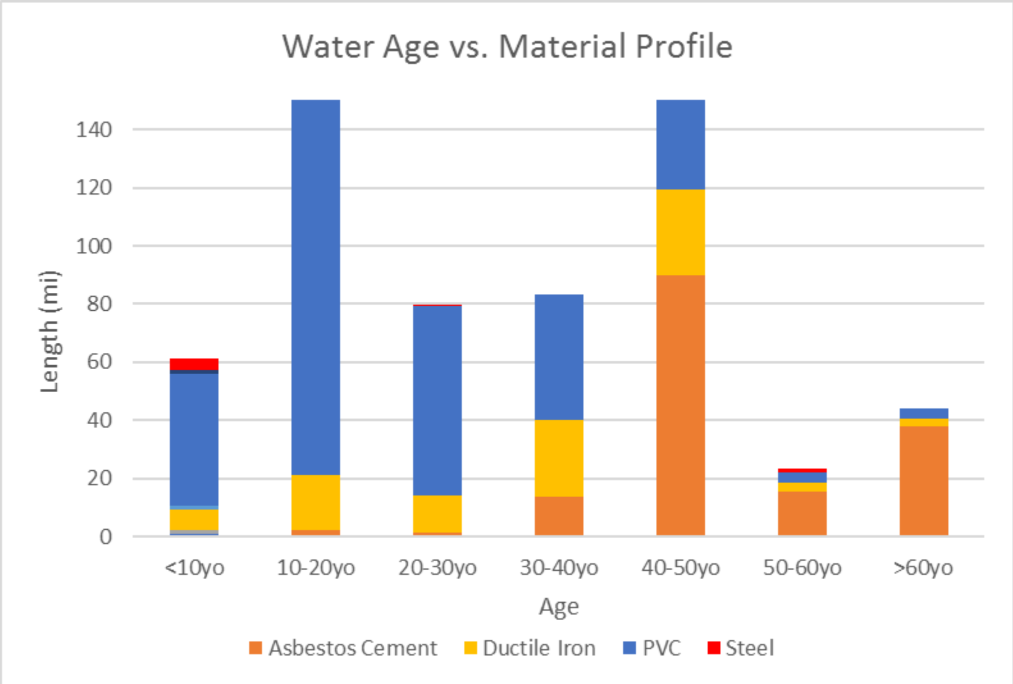

Figure 5: Water Pipelines Inventory - Age vs. Material Profile

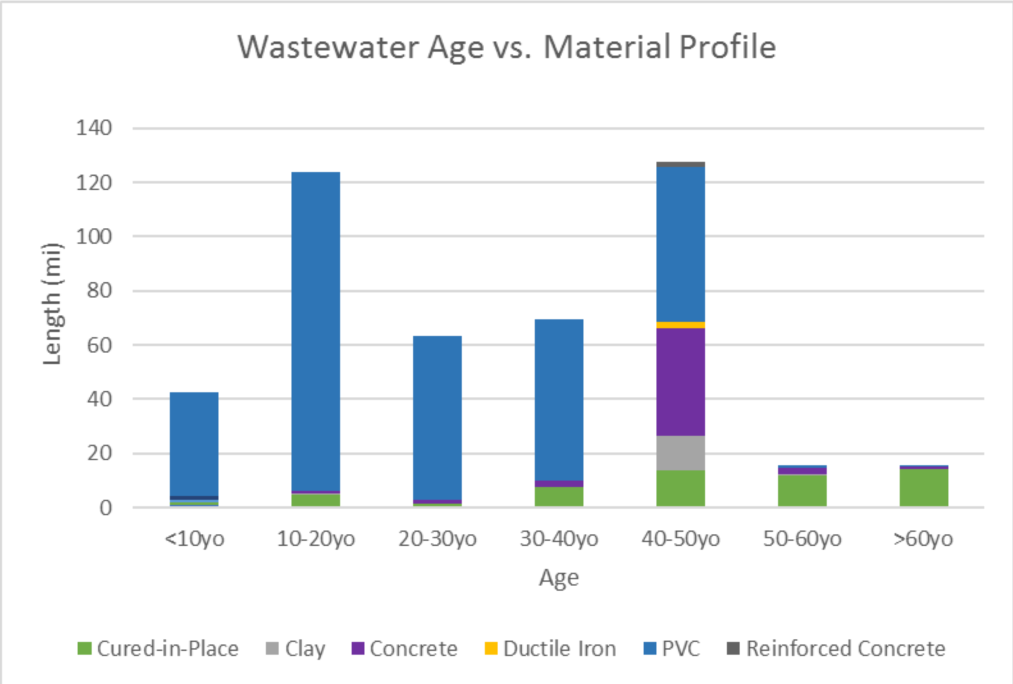

Figure 6: Wastewater Collection Pipelines Inventory - Age vs. Material Profile

2.3 Asset Diameter Profile

Figure 7 and Figure 8 summarize the diameter profile of the Thornton water pipelines and wastewater collection pipelines inventory, respectively, as percentage of total length. Pipes greater than 12" diameter are generally considered transmission mains with the remainder considered distribution lines. Transmission mains would be considered strategically more important from an operational point of view and would thus carry higher consequences upon failure.

Similarly, for wastewater collection pipelines, 14” and larger pipe diameters are interceptor lines, which would be considered more important, and thus are assigned higher consequence of failure values.

The primary observation that can be made from the previous figures is that roughly 82% of the water pipelines are 12” diameter or less and thus considered distribution lines and of lower consequence, with respect to their failure. This value is right at the national average[1]. The wastewater collection pipelines inventory has a similar breakdown, with approximately 91% of pipes 12” diameter or less.

Additional clarity of risk exposure related to pipe diameter can be attained by looking at the specific material types within each diameter range. Where material types that have a higher risk of failure are in a higher consequence grouping (based on diameter) this can be used to better understand and develop overall priorities. Figure 9 and Figure 10 below break down for each diameter grouping by material type.

The primary observations that can be made are:

- PVC was used for over half of the distribution pipes (small diameter) and for over 75% of small wastewater pipes.
- Ferrous materials were used in most of the larger diameter, higher consequence water transmission mains.
- Cementitious materials were used for most large diameter wastewater mains.

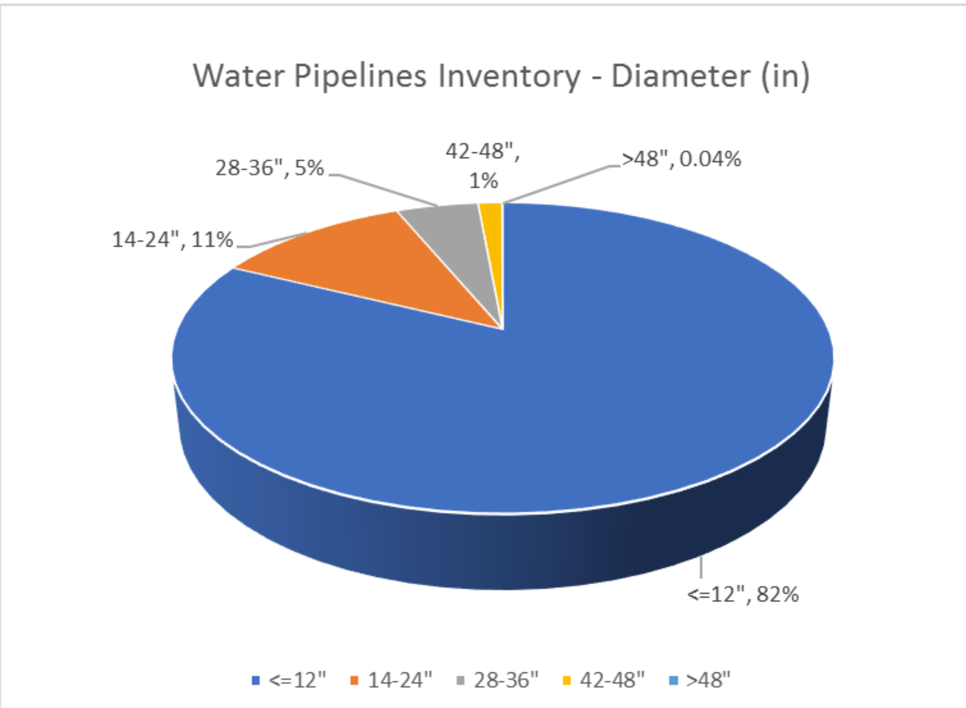

Figure 7: Water Pipeline Inventory - Diameter Profile

[1] Folkman, Steven, "Water Main Break Rates in the USA and Canada: A Comprehensive Study" (2018).*Mechanical and Aerospace Engineering Faculty Publications.* Paper 174. https://digitalcommons.usu.edu/mae_facpub/174

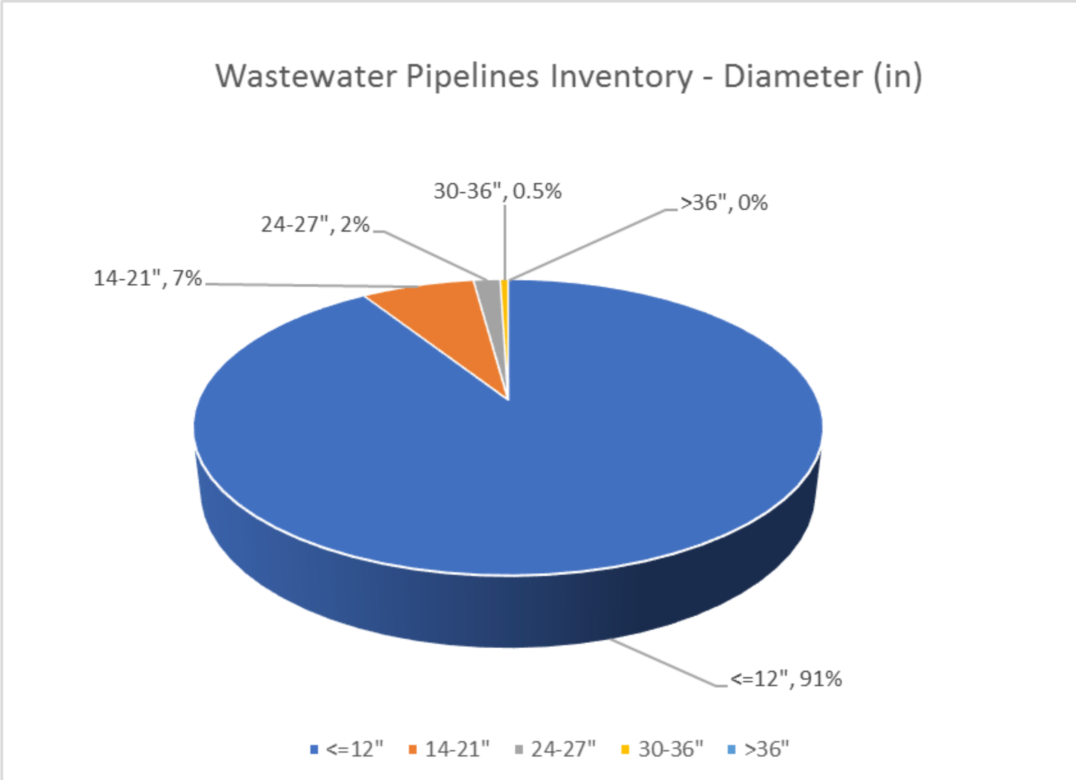

Figure 8: Wastewater Collection Pipeline Inventory - Diameter Profile

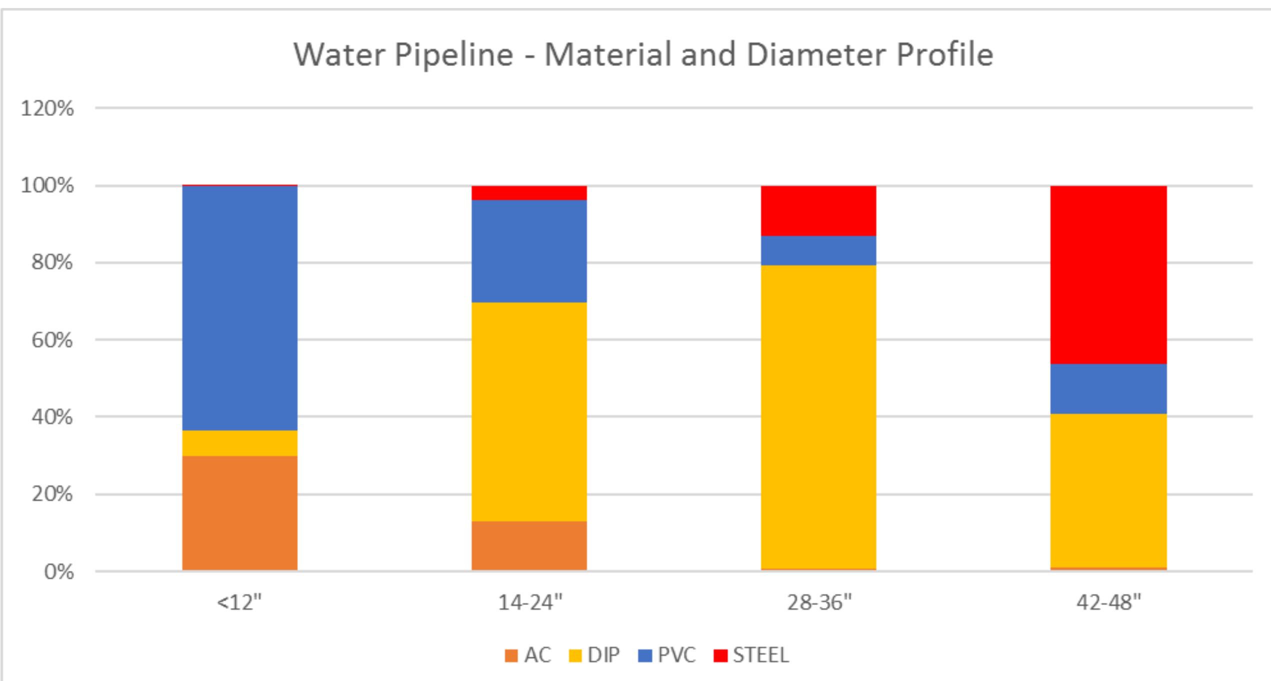

Figure 9: Water Pipeline Inventory - Diameter vs. Material Profile

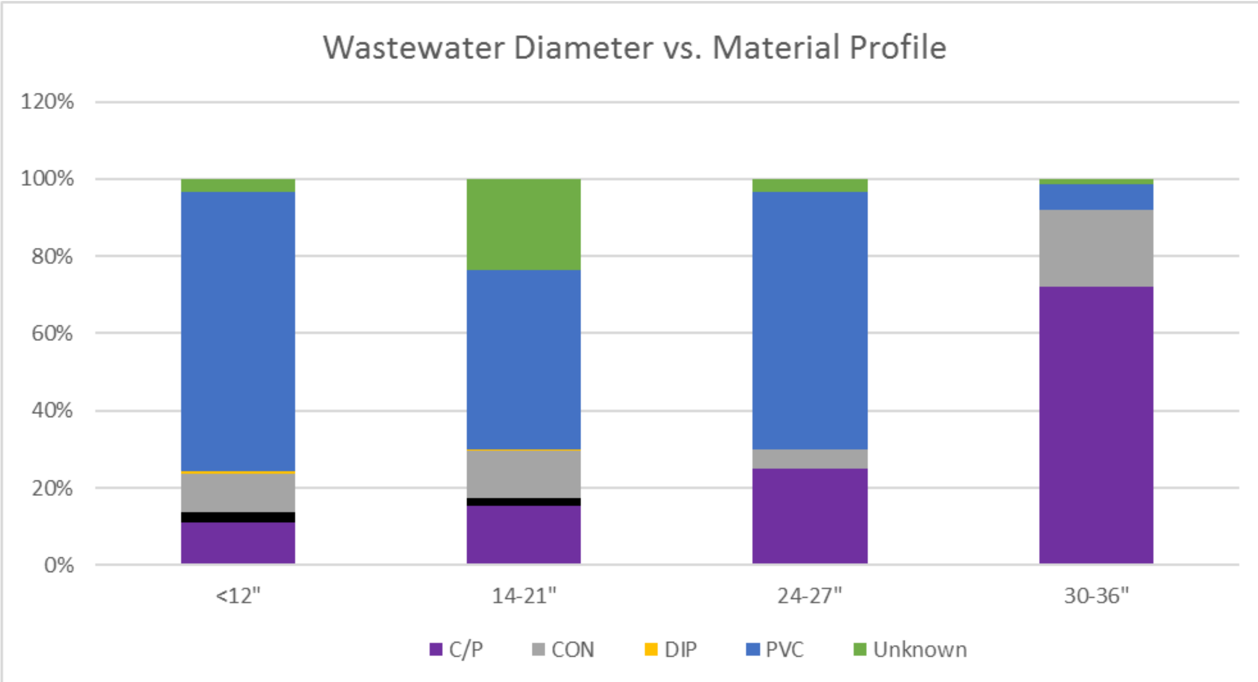

Figure 10: Wastewater Collection Pipeline Inventory - Diameter vs. Material Profile

3. Repair and Replacement Program History

Thornton currently owns, operates and maintains approximately 1,049 miles of water (617 miles) and wastewater collection (477 miles) mains, with a significant portion of which likely reaching the end of its useful life in the near future, based on discussions with Thornton. Thornton Utilities Operations (Divisions 10532, 10534, 10537) have an average annual maintenance budget of approximately $4 million which includes personnel, and capital outlay[2]. The average annual budget for the water distribution Repair and Replacement program is approximately $1 million.

3.1 Typical Infrastructure Condition Assessment and Prioritization

It is common for utilities to implement a water and wastewater pipeline replacement prioritization process that identifies improvements by first utilizing information such as leak or failure data, internal or external condition based on field observations (usually during leak repairs), and historical or organizational knowledge of problem areas. The improvements are then prioritized based on several factors identified and is further explained as follows:

1. **Age** - A higher rating is given for older aged pipe.
2. **Leak per Foot** - A higher rating is given to pipes that have multiple failures in close proximity.
3. **Criticality** - A relative factor that quantifies how the system and water customers will be impacted if a specific water main is out of service for any period of time.
4. **NPV** - A Net Present Value analysis is completed by comparing the cost/benefit of spending the capital dollars to replace the pipe versus repairing leaks (based on a historical frequency) over a 30-year period.
5. **Major Street** - A higher rating is given to water mains in major thoroughfares because breaks will impact the public substantially more than if they occur in alleys or residential streets.
6. **Overall** - The previous ratings are compiled into a single overall prioritization value through a weighted averaging calculation.

3.2 Rehabilitation Techniques

Many local utilities specify that pipe replacement projects shall utilize corrosion resistant pipe materials such as Polyvinyl Chloride (PVC) and High Density Polyethylene (HDPE). PVC is the preferred alternative for many local utilities since it is less costly than other materials, easier to install and does not corrode. HDPE is used in areas with high incidence of soil movement, high working or burst pressures, and for specific applications such as directional boring. Steel and ductile iron pipe are also typically used when larger diameter, higher pressure pipe is required. Cathodic protection is a technique used to control corrosion in ferrous metal pipes and fittings by electrically connecting the asset to another more easily corroded sacrificial metal. Water pipeline installation crews often protect metal fittings and hardware by installing sacrificial anodes and applying epoxy to and wrapping vulnerable metal bolts with wax tape.

In the event of corrosion or other condition issues it may be necessary to rehab the pipe. A common rehabilitation technique that has been employed by Thornton on the water distribution system is slip lining. Slip lining is the insertion of liners of various materials directly into the existing pipes by either pushing or pulling. This technology s has been widely used by water, wastewater collection, and gas utilities since the early 1980s. Either continuous or jointed discrete lengths of pipe are pulled and/or pushed through the existing pipes. Slip lining creates a new, integral pressure pipe inside the old main, without requiring a complete excavation. The slip lined pipe is then reconnected to the existing pipe at both ends.

[2] *2018 Budget*. City of Thornton, 2018, pp. 1–496, *2018 Budget*.

The advantage of slip lining is the cost saving. A potential disadvantage is the reduction in cross-sectional area; however, the reduction in the friction factor (Hazen-Williams C-values) of the lined pipe compared to the previous, unlined pipe can compensate for the reduced internal diameter. Hydraulic requirements must be considered carefully before selecting slip lining as a preferred alternative.

An applied lining system is another rehabilitation option that could be utilized (non-structural, semi-structural, and fully structural). The liners materials used are cement-mortar, epoxy resin, and rapid setting resins. Cement mortar is typically applied to the pipe wall by a rotating head, electric or pneumatic. Resin liners are typically applied by a rotating robotic head with computerized machinery with heating devices in order to get the correct mixture and temperature for optimal durability and adhesion, which are critical for a liner to protect the host pipe from corrosion.

Finally, a rehabilitation strategy could involve cured-in-place pipe (CIPP), which has been utilized by Thornton on the wastewater collection system. This process involves a polymer fabric tube or hose impregnated with a thermosetting resin before insertion into the host pipe. The resin is then cured in the host pipe by ambient conditions, heat, steam, water or ultraviolet (UV) light. This produces a flexible pipe within the host pipe. The combination of the fabric material, with fibers and the resin can be designed to produce a new pipe that has full structural capabilities, semi-structural capabilities or non-structural capabilities. The resins used for water applications must meet ANSI/NSF 61 and/or local health authority approvals. The fabric material can be tailored in the factory to suit the diameter of the host pipe. CIPP liners can negotiate 90° bends within the host pipe.

4. Existing System Performance

Condition and performance assessment, along with subsequent rehabilitation planning of pipeline infrastructure starts with an understanding of how the infrastructure fails in service. Typical pipeline failure modes are outlined as follows:

- **Structurally -** due to material degradation and their inability to resist applied loads
- **Functionally -** due to a loss of capacity or their inability to meet quality objectives

The nature of failure can be summarized as follows:

- Catastrophically with large releases of transported fluids (usually due to non-ductile failure modes)
- Localized failures with smaller releases of fluids (usually due to more ductile failure behavior)

Utilities traditionally identify pipeline replacement projects by utilizing leak or failure data, internal or external condition based on field observations (usually during leak repairs), and historical, organizational knowledge of problem areas. The projects are then prioritized based on several factors such as age and criticality. Based on current Thornton practice, failure history has been the primary driver for assessing condition and performance. Due to the documented history of leakage and structural failure within the Thornton water pipeline inventory, especially for Asbestos Cement (AC) pipe, it was rationalized that the primary focus of rehabilitation would be failure history. Limited work has been completed previously with respect to formalized condition assessment.

4.1 Structural Performance

Thornton has maintained a failure database since 1999 to log the performance of the water pipeline inventory. The failure database includes details on 371 failures at the time of this report. Failure data was aggregated and summarized based on pipe material information.

It should be noted that a significant amount of failures had been reported on AC pipe, which may be because this pipe is generally older within the system. Another concern for the AC pipe within the system is that exposure to rapid pressure fluctuations may contribute to the material degradation and premature failure; however, this failure mode has not been verified by this study. The failure database doesn't include information on cause of failure. Figure 11 illustrates the failures that have been recorded by Thornton for the water distribution system.

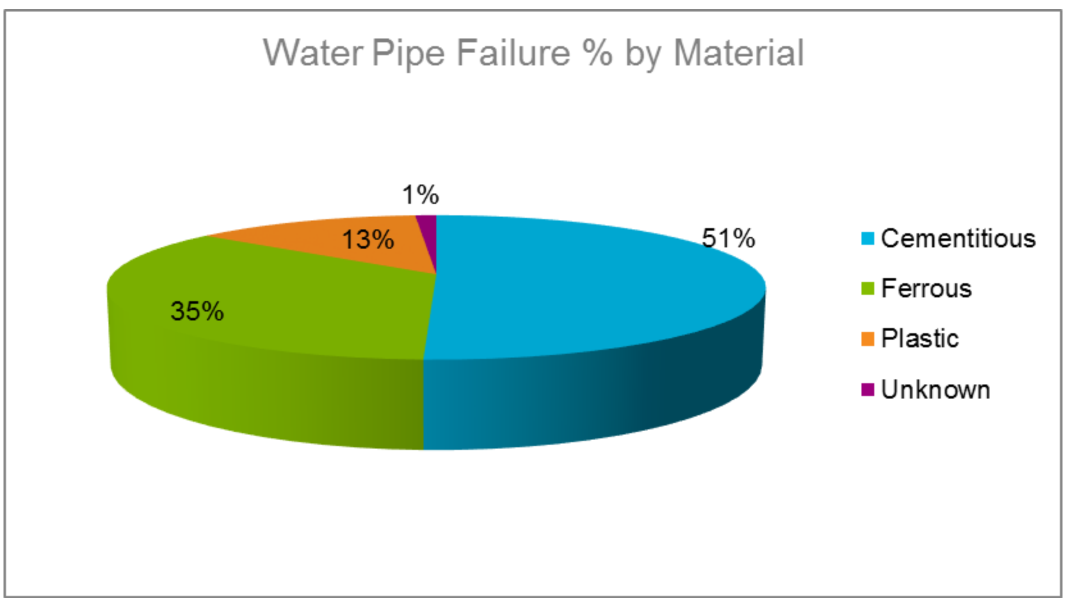

Figure 11: Water Pipeline Failures by Material Type

4.2 Structural Failure Drivers

Structural failures within pipelines are typically driven by the deterioration of the pipe material and by the resultant inability of the pipe to resist the applied loads during normal system operating conditions. These key drivers of structural failure are further examined within the following sections.

Because the previous examination of failure history identifies AC as the pipe material that represents the vast majority of structural failures within the inventory, the deterioration of this material type was identified for the primary area for review. Within other local non-Thornton systems previously studied, ferrous pipes represented the highest failure rates.

Age typically plays a major role in understanding material deterioration and subsequent failure. However, with ferrous metal pipes the era of pipe manufacture can play a much larger role. As manufacturing methods improved the strength of materials over time, the corresponding wall thickness of CIP and DIP has decreased. Significant changes in manufacturing processes are usually measured in the following increments:

- Pre-1950 CI (non-standardized spun cast pipe, pit cast pipe, etc.) – **thickest walls**
- CI from 1950 to the early 1970's – modern spun cast CI – **thinner walls**
- DIP from the 1970's to date – **thinnest walls**

In utilities across North America, failure occurrence in ferrous metal pipes has been shown to be very closely related to wall thickness as deterioration is inevitably driven by corrosion and corrosion itself is not impacted by material strength or subtleties in manufacturing process. In Romanoff's landmark work of the 1950's and 60's it was concluded that all ferrous metal pipes (CI, DIP, and steel) all corrode at approximately the same rate when exposed to the same external environment[3].

The failures in the Thornton water distribution inventory do not directly indicate this correlation but do show that the older pipe break rates are only slightly higher for the 1950 to early 1970's era, as shown below in Figure 12.

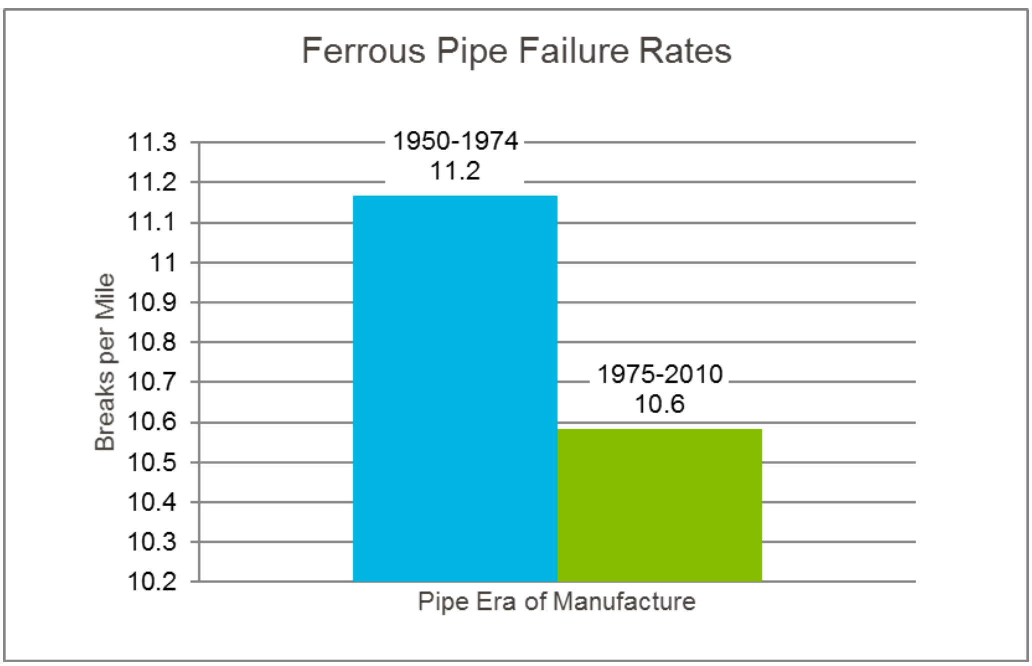

Figure 12: Water Pipeline DIP Failures by Era of Manufacture

Figure 13 below illustrates that the diameter range of 8-12 inch has the second highest failure rate at 16.1 breaks per mile, while the largest number of brakes per mile is in the 48-inch diameter pipe group which fails at a rate of 20.1 breaks per mile.

[3] *Melvin Romanoff," Underground Corrosion", published by NACE 1989*

The diameter range of 8-12 inch had the greatest total length of pipe and the most failures recorded. This is consistent with material degradation being a major deterioration driver due to loss of wall thickness from corrosion. This also suggests that soil movement can play a role in triggering failures because smaller diameter CIP and DIP have lower factors of safety with respect to bending as the diameter decreases.

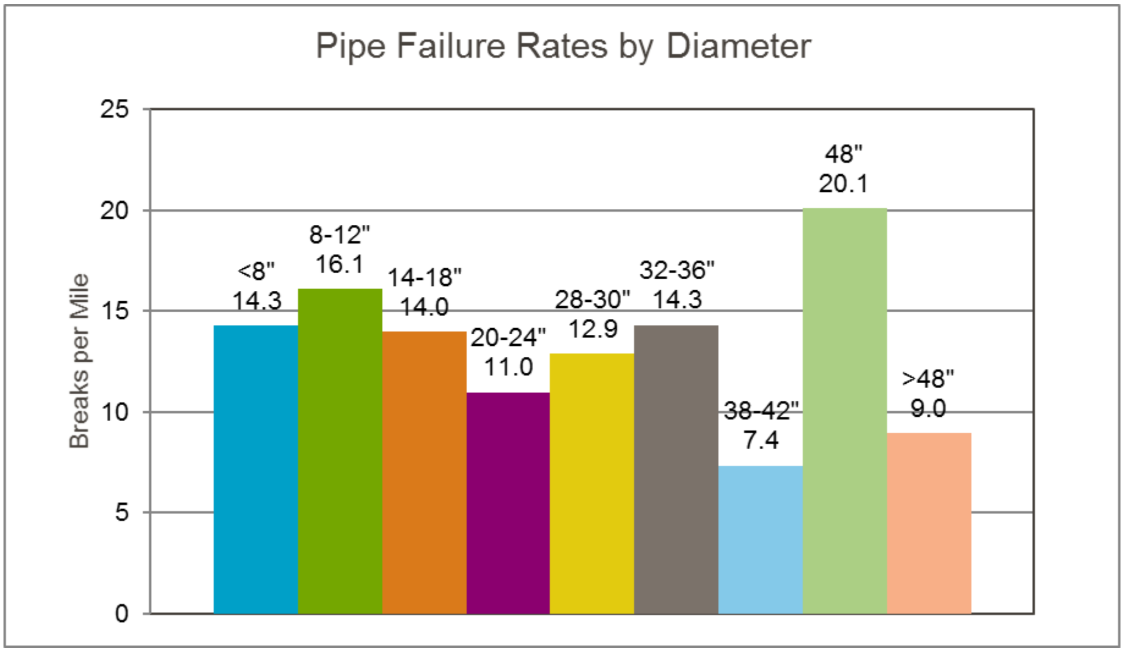

Figure 13: Water Pipeline Failures by Diameter Range

5. Rehab and Replacement Program Approach

One of the primary objectives for this evaluation was to consider the effectiveness of the current water and wastewater main replacement prioritization process identified previously and to recommend improvements. This was conducted through an examination of the characteristics of the pipeline inventory, and its overall structural performance to date. Recommendations for improvement were then drawn from this information based on experience with risk-based infrastructure asset management of water and wastewater pipelines. The results of this evaluation are outlined within the following sections.

5.1 Consequence Assessment

Current industry best-practices for risk-based infrastructure management recommend that a consequence model be generated from a spatial data analysis that is automated and repeatable; and would consider the following impacts of failure:

- Economic
- Environmental
- Operational
- Social

Typically, the project prioritization method used is based on a hybrid risk-based model, with consequence factors largely managed outside of a spatial database environment within a spreadsheet tool that would be difficult to maintain over the long-term due to the extensive data entry requirements.

A consequence model was developed to cover the associated impacts on the water distribution system and wastewater collection system managed by Thornton is documented within a GIS based data management system that utilizes automated processes to keep the data current and consistent with minimal user intervention. The process of developing this consequence model would benefit further from a subsequent calibration process such that the model results are compared with real-world situations to ensure that the results are consistent with organizational goals.

5.2 Probability Assessment

Current industry best-practices for water and wastewater pipeline condition assessment would recommend that a proactive condition assessment of the most critical pipelines should be conducted to schedule the rehabilitation or replacement of such pipes prior to failure.

Current Thornton practices for the assessment of pipeline condition are centered upon estimations of useful life and failure analysis for the purpose of identifying mains for replacement. The primary limitation with this approach is that to get scheduled for replacement, the pipe has to be very old or will have to fail multiple times. This approach may have been effective for scheduling replacement of low-priority and failure prone mains; however there is currently no process in place to identify critical pipes for condition assessment to pro-actively rehabilitate or replace prior to a catastrophic failure.

The condition assessment of critical pipes is a complex process due to the following issues:

- Dewatering is difficult and permitting is challenging
- A purely visual inspection may not be effective because by the time a serious defect becomes visible, the pipe will have already failed
- Although new pipeline assessment technology is increasingly available, economics need to be considered in the assessment process as the cost to ascertain condition can easily approach the cost of managing failure
- The certainty of the condition observations collected with new pipeline assessment technologies is not consistent between assessment techniques both based on the nature of technology employed and the degree of coverage obtained in point and continuous measurement tools.

Due to the risk exposure of having a highly critical asset fail, the condition assessment of such pipes should still be considered, even with the associated complexity. Pilot projects are a valuable means to assess effectiveness of available tools with calibration of observations and precise quantification of actual likelihood of failure and associated costs.

Improved simplified methods of assessing condition should also be developed by looking at factors that tend to increase the likelihood of structural failure, identified previously as material type, manufacturing era, operating pressure and localized soil corrosivity. For highly critical pipelines, these factors will assist in formulating current priorities and highlight opportunities for more detailed condition assessment. The revised condition assessment model should be made available within a GIS based data management system that utilizes automated processes to keep the data current and consistent with minimal user intervention. The process of deriving this condition model should involve a calibration process such that the results are compared with real-world situations to ensure that the results are consistent with organizational goals.

5.3 Risk Assessment

Current industry best-practices for risk-based infrastructure management specify that risk mitigation should involve an assessment of consequence and probability of failure with the objective of prioritizing treatments to reduce risk exposure.

The consideration of alternate rehabilitation treatments (other than replacement), that are viable for local conditions and unique system requirements is recommended. There are also two recommended areas that are believed to warrant further study to produce a more cost effective approach to mitigating future failure rates:

- Increased use of cathodic protection both in water pipeline repairs and as a mitigation strategy.
- Targeted focus of pressure reduction in high risk areas

Cathodic protection has played a prominent role in failure mitigation for post-1950 CIP and DIP in numerous centers across North America. The Cities of Winnipeg, MB, Canada and Calgary, AB, Canada have both demonstrated massive reductions in failures using anode retrofit techniques in maintenance and other program approaches. Numerous case studies were presented in Workshops where cathodic protection programs varying from purely opportunistic programs (e.g. installing anodes at failure repairs) to comprehensive cathodic protection have markedly reduced future failure rates. While it is difficult to quantify the potential effectiveness in the Thornton inventory without more detailed study, the level of investment is typically very small versus increases in annual funding levels and should be explored in greater detail.

The other program that also has some merit to pursue is the targeted reduction of pressure in high risk areas. There is approximately 245 miles of Thornton’s water pipelines that are currently exposed to pressures in excess of 80 psi. If it is feasible to reduce pressures in these areas, it could effectively extend the useful design life of the post-1950 CIP/DIP and the AC pipe for a considerable period. The cost effectiveness of this would need to be explored in greater detail, but the reduced failure rates in lower pressure areas should certainly be explored as the increased failure rates in these areas is readily apparent.

Of the two approaches, increased use of cathodic protection has the largest potential impact obtaining better service levels in the most cost-effective manner and should be explored in considerable detail.

While reduced pressure zones should be examined for feasibility on an opportunistic basis, it is not likely to be feasible on a widespread basis. There may be specific opportunities though, in higher risk soils to reduce failure risk and this should be explored in more detail.

5.4 Long-Term Funding

Long-term funding models are one of the most effective ways to illustrate the relationship between condition assessment and replacement or rehabilitation versus the resultant level of service in the system. These models are also useful to ascertain a better estimate of the sustainable funding rate for the system.

Thornton indicated that they have an average of 60-90 water pipeline breaks per year and at most replace 0.1% of their water distribution pipelines in a given year, not including service connections. Recommended national average rate of replacement is between 1% and 1.6%. If the average cost of replacement or rehabilitation is approximately $1 million dollars per mile, then a sustainable annual budget for replacement should be from approximately $5.8 to $9.3 million per year. Based on a detailed survey of utility districts, the average expected life of installed water pipe today is approximately 84 years[4], which would require a replacement rate of approximately 1.2% per year (annual expenditure of $7 million) to be sustainable.

[4] Folkman, Steven, "Water Main Break Rates in the USA and Canada: A Comprehensive Study" (2018).*Mechanical and Aerospace Engineering Faculty Publications.* Paper 174.

6. Consequence of Failure Assessment

Successful implementation of risk-based planning and decision making requires the identification of critical infrastructure to determine the consequence of failure side of the risk equation. A methodology for classifying consequence of failure within categories that rank the infrastructure with respect to high benefit/cost ratio for risk mitigation are typically custom developed for each utility with direct input from stakeholders to help ensure organizational infrastructure management goals will be met. Consequences of failure are semi-quantitative and are developed to reflect an organization's policy and goals as closely as possible.

Because water pipelines are geographically dispersed over a wide area with many external influences, the consequence model is typically generated from a spatial data analysis that is automated and repeatable. Current industry best-practices for risk-based infrastructure management identify a consequence model as considering the impact of failure in the following areas:

- **Economic:** potential impact to the organization's financial situation in the event of pipeline failure. Considers the magnitude of the spill and the potential collateral damage to neighboring properties and structures. Numeric values representing economic impact are typically proportional to the cost to repair.
- **Environmental:** potential impact to the environment based on pipeline proximity. The main concern is the type of constituents within the transported liquid and whether it has a detrimental effect on terrestrial life or aquatic life within neighboring water bodies in the event of a spill resulting from failure.
- **Operational**: potential impact to system operations in the event of pipeline failure. Considers both customer impact and system impact in terms of whether there is enough redundancy within the system to circumvent the failed asset for an extended period of time.
- **Social**: potential impact to society in the event of pipeline failure. Considers the magnitude of the spill and potential disruption to nearby roadway traffic and commercial activity.

Weights are typically applied to each impact category and are dependent on the perspective of the stakeholders. The weightings must form a balance among different stakeholder requirements in an environment where an asset manager may weigh the operational category higher than a water customer who may weigh the social impact higher. The weightings can be altered in the future when stakeholder views change over time. The ultimate weight given to each category is subjective and a reflection of overall goals and policy. There is a practical consideration of weighting determinations and the ultimate rating system should reasonably delineate the assets in broad categories of low, medium and high consequence.

6.1 Consequence Model Parameters and Weightings

The parameters and weightings for the consequence model were developed in conjunction with Thornton. Figure 14 and Figure 15 depicts the wastewater pipe consequence model parameters and weightings. Each index consists of individual parameters that when combined, represent the overall consequence of failure. Each of these parameters is given a value from 0 to 10 such that 0 would indicate no impact while 10 would indicate the highest impact.

Combination of parameters pertinent to each index are weighted against each other from 0 to 100%, with the total of all being required to equal 100%. Then indexes are weighted against each other in the same way to develop the consequence of failure factor (COF).

The development of a consequence model for pipeline infrastructure typically involves either the application of query criteria based on the physical properties of the infrastructure, or the overlay of other spatial data for deriving external influences. The application of the external influences typically involves the use of spatial analysis functions within GIS software that are executed on the available data.

From the consequence model parameters, the following parameters were available from Thornton's GIS database:

- Diameter
- Material

The following parameters were derived from external data sources and applied through the overlay of spatial data on the water main centerline geometry with GIS spatial analysis functions:

- Pressure
- Public Health
- Major Customer
- Water Body
- Road Type

The following sections identify the criteria and the required data processing used to develop the Consequence Model parameters and scoring.

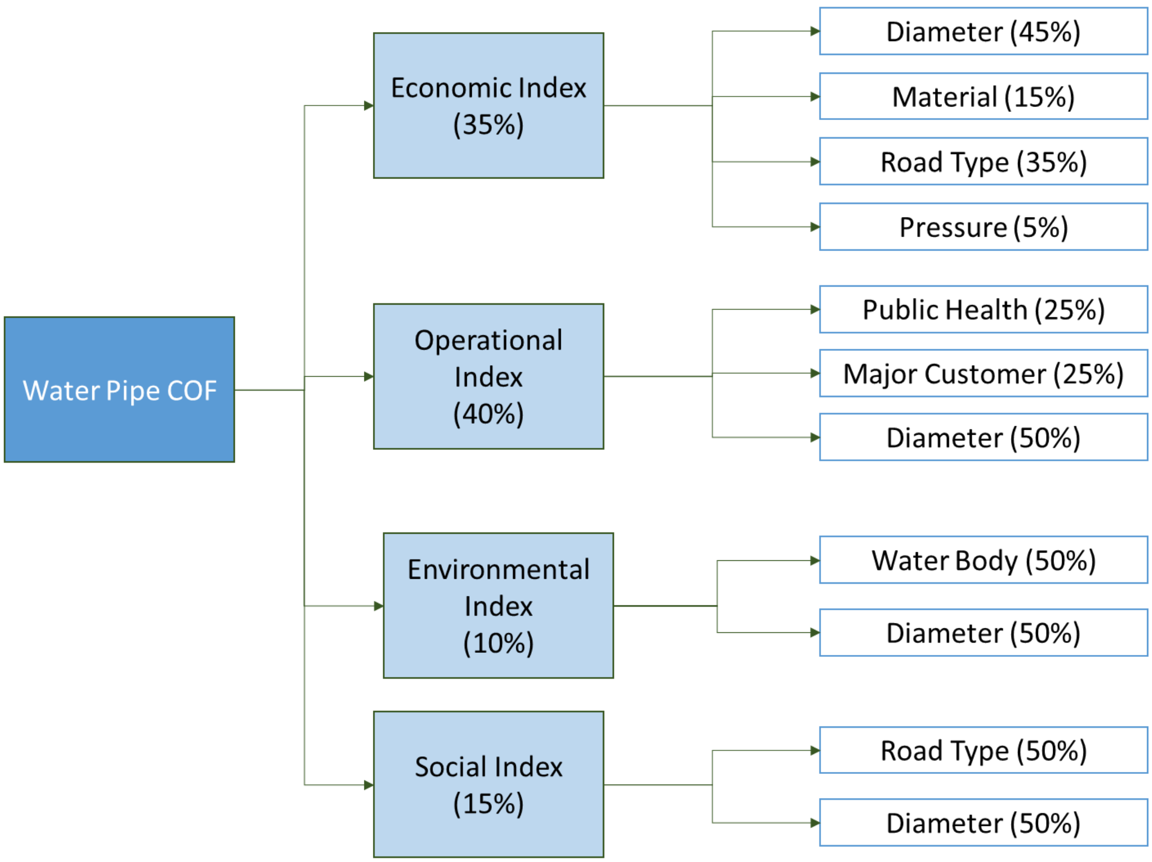

Figure 14: Water Pipe Consequence Model Schematic

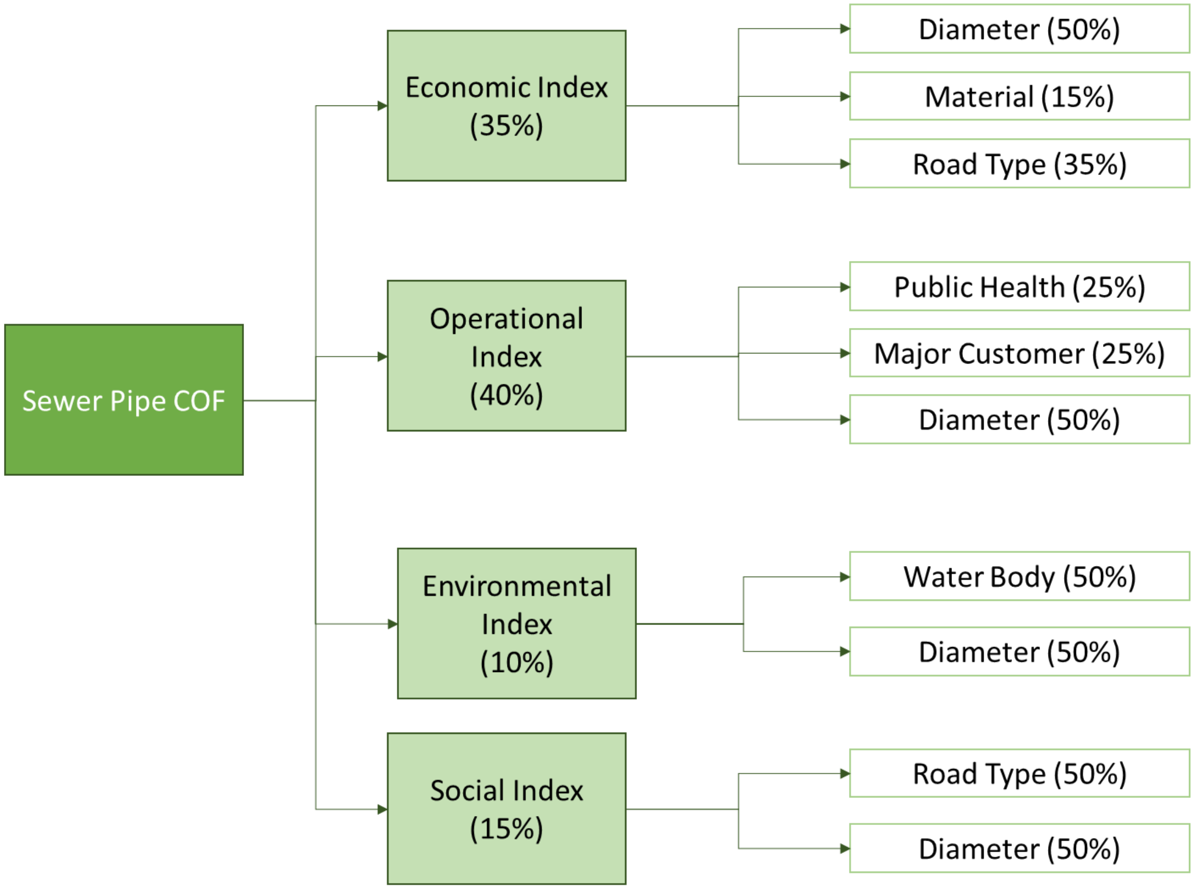

Figure 15: Wastewater Pipe Consequence Model Parameters and Weightings

6.1.1 Model Parameters from Physical Properties

Pipe Diameter

Pipe diameter influences consequence of failure due to the incremental costs required to purchase and install larger diameter pipe. Larger diameter pipe can also result in greater loss of service and greater magnitude of spillage causing extensive collateral damage. The initial ranges used to define pipe diameter scoring are outlined in Table 3.

Table 3: Consequence Scoring for Pipe Diameter

Diameter (in)	Score
0 - 12	0.5
12 - 18	2.5
18 - 30	8
>30	10

Pipe Material

Pipe material influences consequence of failure because certain pipe materials can fail in a localized manner with minimal spillage or can fail catastrophically with large releases of the transported liquids. In most cases, sufficient information on material was available within the Thornton GIS database. The criterion used to define pipe material scoring is outlined in Table 4.

Table 4: Consequence Scoring for Pipe Material

Material	Score
Asbestos Cement	7.5
Cast Iron	10
Ductile Iron	7.5
PVC	2.5
Steel	2.5
Unknown	7.5

Operating Pressure

For water pipes, the operating pressure influences consequence of failure because lower operating pressure will result in a lower degree of spillage while higher operating pressure can cause the pipe to fail catastrophically with extensive collateral damage. For wastewater collection piping, pressure is not a factor.

For this study, pipeline operating pressures for each pipe was obtained from the hydraulic model, maximum day demand conditions. For each pipe, the higher pressure from upstream and downstream junctions was selected as representative. The initial criteria used to determine operating pressure scoring is outlined below in Table 5.

Table 5: Consequence Scoring for Operating Pressure

Pressure (psi)	Score
0 - 60	0
60 - 80	2.5
80 - 100	7.5
100 - 150	10

6.1.2 Model Parameters from External Influences

Public Health

Potential disruption to the water supply or wastewater collection of public health facilities and medical service facilities is an important consideration in determining the criticality of the surrounding infrastructure. GIS data identifying location coordinates of hospitals and clinics in the Thornton area was obtained. Spatial analysis functions within GIS software were then utilized to apply public health values to the pipeline centerlines. This was attained by spatially intersecting the location coordinates and then buffering by 100 feet. The range used to determine public health scoring is outlined in Table 6.

Table 6: Consequence Scoring for Public Health Facilities

Public Health	Score
No Influence	0
Hospitals within 100 ft	10

Major Customer

Potential disruption to the water supply of large industrial, commercial and institutional customers is an important consideration in determining the criticality of surrounding infrastructure. GIS data identifying location coordinates of the top ten major customers (by demand) was obtained from Thornton's water distribution model. Spatial analysis functions within GIS software were then utilized to apply a major customer volume to the pipeline centerlines. This was attained by spatially intersecting the provided location coordinates and then buffering by 100 feet. The criterion used to determine major customer scoring is outlined in Table 7.

Table 7: Consequence Scoring for Major Customers

Top 10 Major Customer	Score
No Influence	0
Within 100 feet	10

Watercourse

The potential for treated water to be spilled into natural watercourses and water bodies is an important environmental consideration in determining infrastructure criticality due to the possibility of adverse effects on aquatic life and the regulatory ramifications of chlorinated discharge to a receiving water with aquatic life, or worse, the discharge of wastewater to a receiving water. The National Hydrography Dataset from the USGS was used to get stream files in GIS. Spatial analysis functions within GIS software were then used to apply watercourse proximity distance values to the pipeline centerlines. The initial criteria used to determine watercourse scoring is outlined below in Table 8.

Table 8: Consequence Scoring for Watercourse Proximity

Watercourse Proximity	Score
No Influence	0
100 to 200 Foot Proximity	2.5
50 to 100 Foot Proximity	5.0
1 to 50 Foot Proximity	10

Road Type

Potential disruption to traffic flow and its effect on society and commerce is an important consideration in determining infrastructure criticality. Road type GIS data was obtained from Thornton in which roads were classified into several categories that could be correlated to consequence of failure. The provided GIS feature represented the road centerline and associated pavement widths were not provided, therefore pavement widths were rationalized based on the road type and are outlined in Table 9.

Spatial analysis functions within GIS software were then utilized to apply a road type value to the water main centerlines. The initial criteria used to determine road type scoring is outlined in Table 9.

Table 9: Consequence Scoring for Road Type

Location	Category	Score
No Influence	No Road	0
Minor Arterial and Major Residential	Tertiary	1
Industrial, Commercial and Principal Arterial	Secondary	5
Expressway, Freeway and Parkway	Primary	10

6.2 Consequence Model Weighting and Calculation

As discussed previously, impacts of failure are organized into four categories consisting of economic, environmental, operational and social criteria, with each category containing one or more parameters used to score or evaluate their respective impact. The validity and applicability of the consequence model is primarily centered upon the importance weightings among these various parameters.

Calculation of an overall consequence of failure score for an asset begins from the parameter score that is applicable for a given database value based on the previous criteria. This parameter score is multiplied by the respective parameter weighting. Each weighted parameter score is then summed within the respective impact of failure category. These values are then multiplied by their respective impact of failure weighting. These final weighted values are then summed to produce an overall consequence of failure rating that must range in numeric value from 0 to 10.

To provide subsequent input into a matrix for selection of an applicable treatment for risk mitigation, the gradations of the calculated CoF are grouped into three categories of high, medium, and low. The criterion used to classify the CoF is outlined in Table 10. Figure 16 illustrates the meaning of these categories within the context of an asset management strategy.

Table 10: Consequence of Failure (CoF) Category Ranges

CoF Value Range	Category
0 – 3.3	Low
3.3 – 6.7	Medium
> 6.7	High

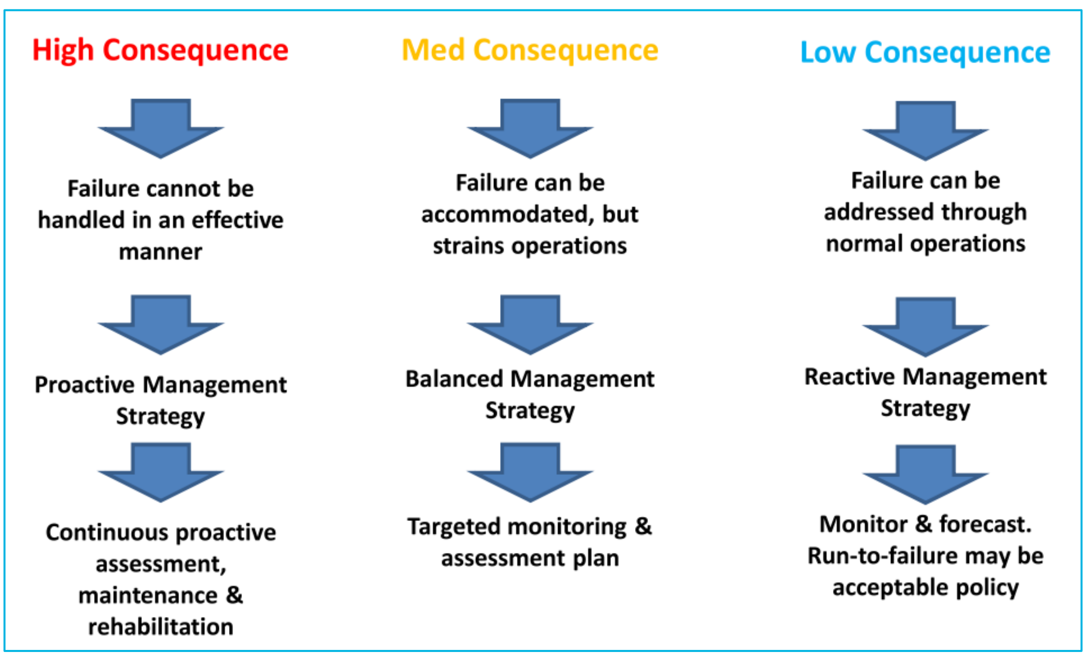

Figure 16: Descriptive Meaning of Low, Medium and High Consequence of Failure

6.3 Consequence Results

The criticality screening process was performed on the entire inventory of Thornton owned, water and wastewater collection pipelines as captured within the available GIS data. The inventory consisted of 9,517 individual water pipeline segments and 12,980 individual wastewater collection pipeline segments at the time the screening process was performed.

The distribution of the length of pipe within each consequence of failure category with respect to the length of the entire Thornton water main inventory is shown below in

Table 11, and the wastewater inventory is shown in Table 12. Figure 17 and 18 display Thornton water and wastewater collection pipelines, respectively, with the consequence of failure results.

Table 11: Water Distribution Consequence of Failure Category Ranges

Consequence of Failure	Percent of Pipe Length
Low	87.9%
Medium	12.0%
High	0.1%

Table 12: Wastewater Distribution Consequence of Failure Category Ranges

Consequence of Failure	Percent of Pipe Length
Low	94.2%
Medium	5.6%
High	0.2%

6.4 Assumptions and Limitations

Through the process of applying the previous criticality screening methodology to the Thornton water and wastewater collection pipeline, the following assumptions and limitations were identified:

- Diameter and material was known for most of the water and wastewater main segments
- Road type was applied through an assumed pavement width as outlined previously. Applying actual pavement widths to each road segment would be recommended in the future to improve model results.
- A detailed examination of a random sampling of high, moderate and low criticality infrastructure in consultation with stakeholders to ensure that real-world situations will reasonably match the results of the modeling process was not performed. A high-level screening was undertaken to confirm that the model reasonably reflects the intent of the analysis; however, a more detailed examination should be carried out to finalize parameter selection.

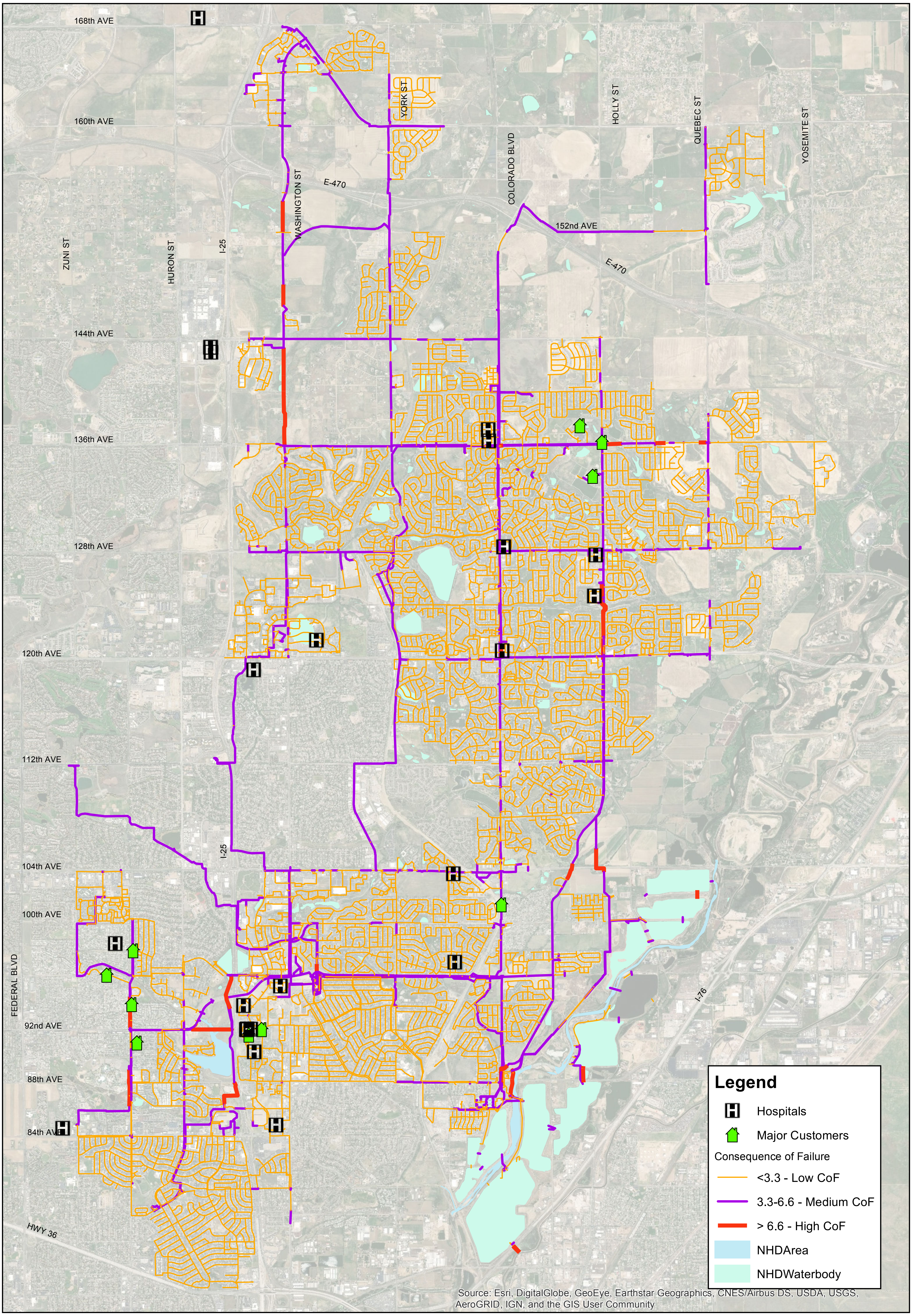

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Figure 17
Water Pipelines
Consequence of Failure

5/23/2019
1 inch = 4,333 feet

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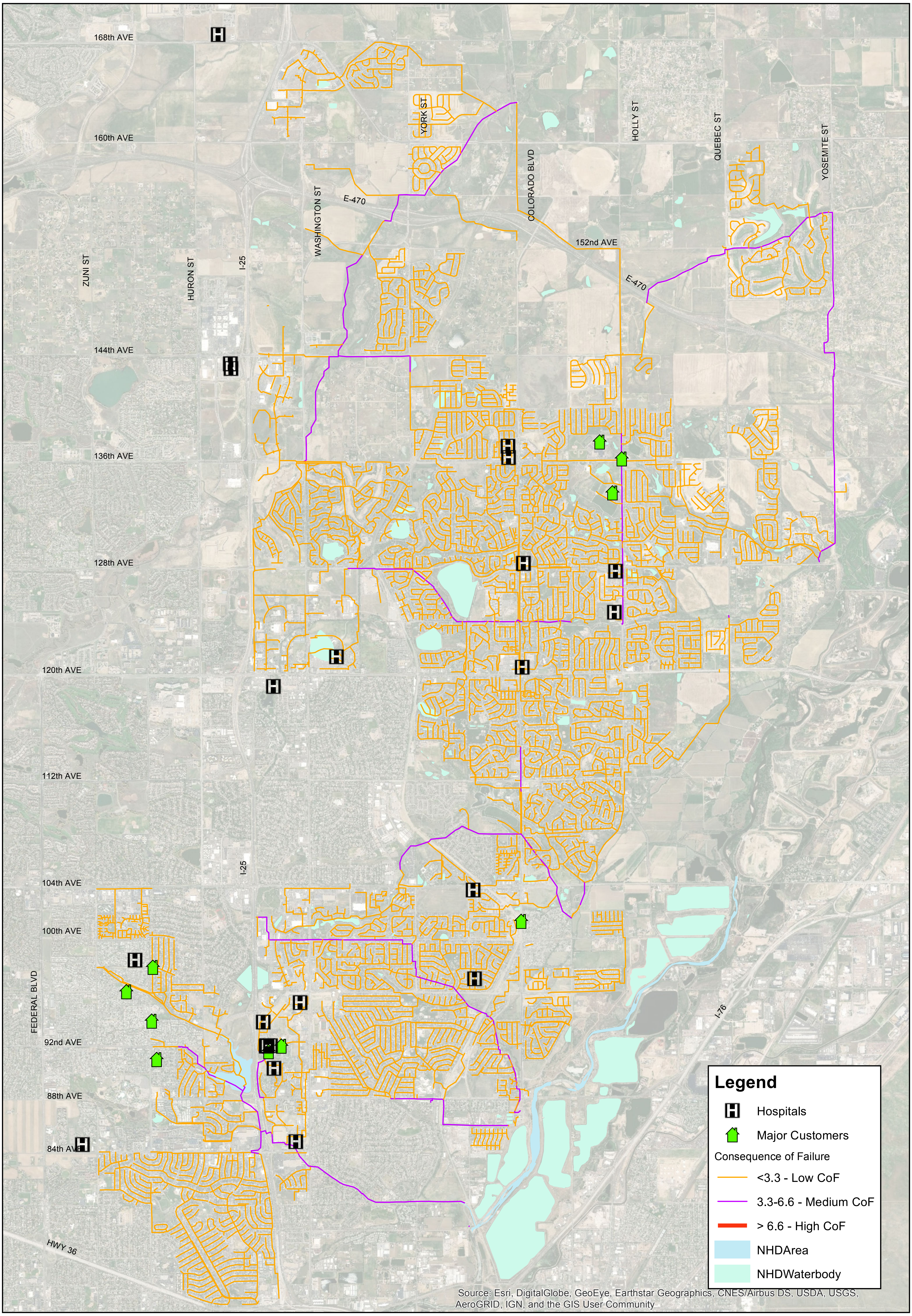

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Figure 18
Wastewater Pipelines
Consequence of Failure

5/20/2019
1 inch = 4,333 feet

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7. Probability of Failure Assessment

Within the context of risk assessment, the probability of failure deals with the pipe condition as it relates to the potential for failure, as compared with consequence of failure which relates to the impact of failure. Establishing probability of failure requires knowledge about the pipe condition and how that condition has changed from a new pipe state to a deteriorated state over time.

The condition assessment process for pressure pipe inventories differs markedly from gravity flow pipelines. While cost effective and simplified methods such as CCTV inspection are available for gravity inspections, pressure pipes are far less accessible and continuous assessment techniques are far more expensive and less understood in terms of their condition significance.

Experience has proven that a phased approach is most prudent, given the considerable cost associated with the deployment of advanced condition assessment tools for pressure pipes and the fact that the benefit of this deployment depends on a thorough understanding of the pipe characteristics, its surrounding environment and the interactions between the two.

7.1 Probability of Failure Model

As identified previously, probability of failure or condition assessment of pipelines is typically at least a two-step process that begins with a preliminary screening to develop “initial condition ratings” based on the range of deterioration factors that a pipe is subjected to. Within a risk-based framework this is used to identify pipelines with high probability of failure and high criticality that would be candidates for more intensive condition assessment techniques. In lower consequence pipes this process would likely be a closer evaluation of actual failure history while medium to high consequence pipes would be subject to more formal condition assessment techniques.

Without any information about the present condition of pipelines within Thornton’s inventory, it is possible to create a simplified failure probability model from the age of the pipe as defined by inventory information typically stored within databases. Knowing the pipe material type in conjunction with the failure modes identified within the previous sections, pipe lifespan can be estimated. Given the current age of the pipe and by comparing this value with this estimated lifespan, a simple probability model can be created based on remaining predicted life, and these results can be mapped to the inventory. These results can be augmented with additional factors related to the external environment or operating conditions, if they are available.

The development of a preliminary condition assessment model for pipelines typically involves either the application of query criteria based on the physical properties of the infrastructure, or the overlay of other spatial data for deriving external environment influences. The application of the external influences typically involves the use of spatial analysis functions within GIS software that are executed on the available data.

7.2 Probability of Failure Model Parameters

The following parameters related to preliminary assessment of condition were used for the Thornton pipelines as representative deterioration factors:

- Estimated lifespan
- Relative Wall Thickness (by era of construction for CI and DI pipe)
- Soil Corrosivity (relative to ferrous metals or cementitious materials)
- Operating Pressure

To develop the preliminary condition model, the impact of each of these parameters would consist of a 0 to 10 rating such that 0 would indicate no impact while 10 would indicate the highest impact. The following sections identify the criteria and the required data processing used to develop the preliminary condition assessment model parameters and scoring.

7.2.1 Baseline Estimated Lifespan

As identified previously, the lifespan of a pipe is related to material type in addition to the pipe diameter due to larger diameter pipes having greater wall thicknesses and thus more resistance to corrosivity and differential pipe loading. These concepts, as well as referencing other local projects completed by AECOM, were used to develop an initial estimate of baseline lifespan (in years) to each material type and diameter range within the inventory, included in Table 13. Each item is also applied a weighting that reflects the importance of age on the material type with respect to overall condition.

With the appropriate lifespan value selected for a given asset, the asset age was then calculated by subtracting the installation date from the current date. These input values were then used within an age score equation, outlined as follows. Data to derive these input values were developed based on analyzing failure data for another utility.

The equation for the age score is:

$$S_a = 10 - 10 \times e^{(-C_a \times {}^{A}/_{E})}$$

Where
Sa – is the age score,
Ca – is the age constant,
A – is the current age of the pipe, and
E – is the expected life of the pipe.

The formula was created to produce a score that increases asymptotically from 0 to 10 with age. The premise of the estimated lifespan equation was based on the assumptions that some pipes will achieve their expected lifespan and a smaller number of them will function for a much longer period of time.

The slope of the curve can be controlled using the age constant (Ca) which can be a function of the pipe material and diameter. The value of Ca is based on experience and engineering judgment. Initially the age constant was set at 1.05389 for all pipes regardless of material or diameter. Adjusting the Ca value up or down determines the slope of the curve and the score the pipe receives when its age is equal to its expected life. With the current value of 1.05389 the score when the pipe's age reaches the expected life is 6.514. Figure 19 below depicts the relationship between age and age score for a pipe with an expected life of 100 years and an age constant of 1.05389.

Table 13: Estimated Baseline Lifespan for Diameter Ranges and Material Types

Material	Diameter (in)					Weight (Water Pipe)	Weight (Wastewater Pipe)
	0-10	12-16	18-36	40-42	>42		
Asbestos Cement	50	100	110	125	150	0.375	0.5
Cast Iron	50	75	90	125	150	0.25	0.33
Clay	70	80	110	150	150	0.5	1
Ductile Iron	50	75	90	125	150	0.25	0.33
PVC	90	100	110	110	110	0.5	1
Steel	60	70	80	80	80	0.5	0.5
Unknown	70	80	110	150	150	0.5	1

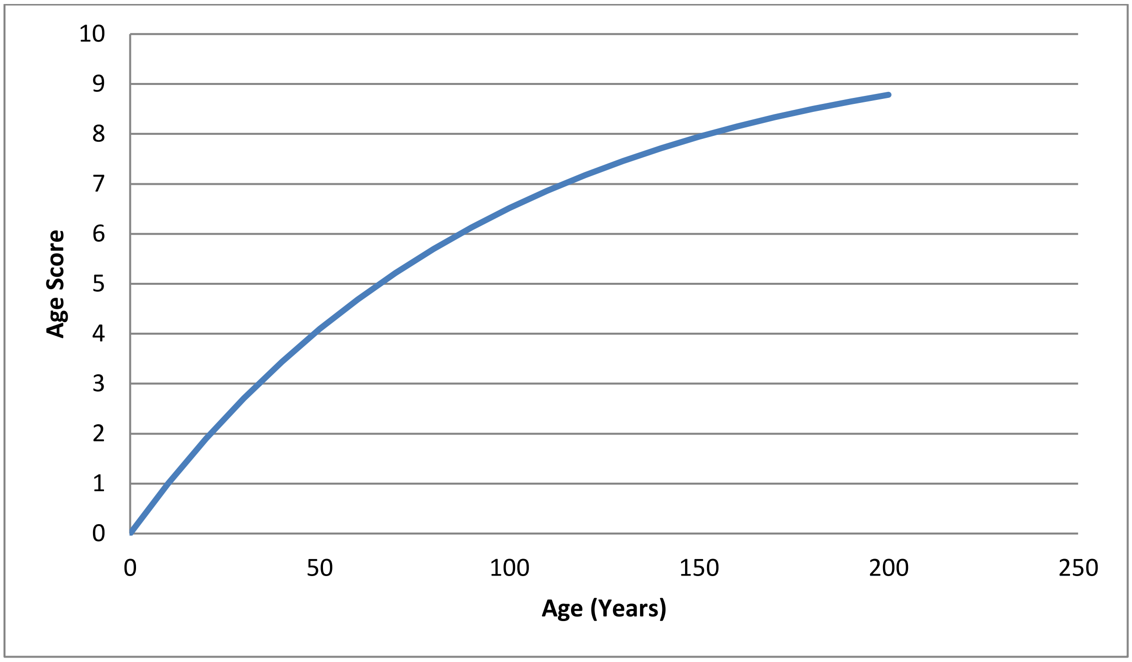

Figure 19: Relationship between Age and Age Score with Assumed Age Constant

7.2.2 Relative Wall Thickness

Pipe wall thickness has been identified as a factor in determining condition because thicker pipe walls have a greater time to failure in response to the same corrosion rate and applied forces. While this factor was partially taken into consideration within the diameter ranges of the previous lifespan estimates, pipes of certain material types such as cast iron were historically constructed with much thicker walls due to limitations in early manufacturing techniques. Thus, wall thickness values can vary, relative to the same material type based on installation year. This concept was used to rationalize the values listed in Table 14, which applies a 0 to 10 condition score for those material types in which this factor is relevant. The condition scoring was rationalized such that 0 indicates no influence on condition while 10 indicates the highest degree of condition influence. Each item is also applied a weighting that reflects the importance of wall thickness on the material type with respect to overall condition. Data to apply these ratings were readily available through installation date information within the Thornton GIS data.

Table 14: Condition Scoring for Relative Pipe Wall Thickness

Material	Installation Year			Weight (Pressure Pipe)	Weight (Gravity Pipe)
	Pre 1950	1950-1970	Post 1970		
Asbestos Cement	0	0	0	0	0
Clay	0	0	0	0	0
Cast Iron	2.5	5	10	0.25	0.33
Ductile Iron	2.5	5	10	0.25	0.33
PVC	0	0	0	0	0
Steel	0	0	0	0	0
Unknown	0	0	0	0	0

7.2.3 Soil Corrosivity

The chemistry and/or electrochemistry of the soil and groundwater are key factors in estimating pipe condition because of associated deterioration effects on several types of pipe materials. Soil chemistry/electrochemistry has a pronounced impact on the deterioration of ferrous metals and pipelines constructed of cementitious materials.

The effects of soil corrosivity were summarized within the following tables that apply a 0 to 10 condition score for those material types in which this factor is relevant. Because cementitious and ferrous materials are affected by different factors, two tables were developed for the respective pipe material types.

The condition scoring was rationalized such that 0 indicates no influence on condition while 10 indicates the highest degree of condition influence. Each item is also applied a weighting that reflects the importance of soil corrosivity on the material type with respect to overall condition.

Data to derive these ratings was available from US Department of Agriculture data base of Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm). Soil data provided by the USDA takes two forms, (1) geographic data in the form of a polygon shapefile to be used with a GIS and (2) separate tabular data describing soil properties. The USDA tabular data provides ratings of low, moderate or high for both ferrous and cementitious corrosivity for minor soil subtypes.

While the cementitious deterioration drivers need not be developed beyond the global scale, the ferrous metal data is a very significant driver and should be developed in a distinctly separate model based on locally collected data to replace the use of the USDA layers.

Table 15 lists the parameters and weighting for soil corrosivity with respect to ferrous pipes; and Table 16 lists parameters and weighting for soil corrosivity with respect to cementitious pipes.

Table 15: Condition Scoring for Soil Corrosivity on Ferrous Materials

Material	Corrosivity				Weight (Pressure Pipe)	Weight (Gravity Pipe)
	Low	Moderate	High	Unknown		
Cast Iron	2.5	5	10	10	0.25	0.33
Ductile Iron	2.5	5	10	10	0.25	0.33
Steel	2.5	5	10	10	0.25	0.50
Unknown	0	0	0	0	0	0

Table 16: Condition Scoring for Soil Corrosivity on Cementitious and Plastic Materials

Material	Corrosivity				Weight (Pressure Pipe)	Weight (Gravity Pipe)
	Low	Moderate	High	Unknown		
Asbestos Cement	2.5	5	10	10	0.25	0.50
Clay	0	0	0	0	0	0
PVC	0	0	0	0	0	0
Unknown	0	0	0	0	0	0

7.2.4 Operating Pressure

Operating pressure has been identified as a factor in determining condition as higher pressures increase pipe loading and requires less deterioration to occur to initiate failure. The condition scoring was rationalized such that 0 indicates no influence on condition while 10 indicates the highest degree of condition influence. Each item is also applied a weighting that reflects the importance of operating pressure on the material type with respect to overall condition. The ratings and scores are shown in Table 17.

Table 17: Condition Scoring for Operating Pressure

Material	Pressure Range (psi)				Weight (Pressure Pipe)	Weight (Gravity Pipe)
	0-60	60-80	80-120	>120		
Asbestos Cement	2.5	5	7.5	10	0.375	0
Clay	2.5	5	7.5	10	0.5	0
Cast Iron	2.5	5	7.5	10	0.25	0
Ductile Iron	2.5	5	7.5	10	0.25	0
PVC	2.5	5	7.5	10	0.5	0
Steel	2.5	5	7.5	10	0.25	0
Unknown	2.5	5	7.5	10	0.5	0

7.3 Initial Project Results

Calculation of a preliminary condition rating for an asset begins from the parameter score that is applicable for a given database value based on the previous criteria. This parameter score is multiplied by the respective parameter weighting. Each weighted parameter score is then summed to produce an overall condition or probability of failure rating that must range in numeric value from 0 to 10.

The preliminary condition assessment process was performed on the Thornton pipelines as captured within the available GIS data. The inventory consisted of 9,517 individual water pipeline segments and 12,980 wastewater collection pipeline segments at the time the screening process was performed. An overall numeric rating was calculated from the values derived through the scoring and weighting process described previously. The calculated numeric rating was categorized into high, medium and low as outlined within

Table 18. The distribution of the length of pipe within each Probability of Failure category with respect to the length of the entire Thornton water main inventory is shown in Table 19, and with respect to the entire wastewater collection inventory is shown in Table 20. Figure 20 displays a map of the Thornton area with the water distribution probability of failure GIS model overlaid, and Figure 21 displays the wastewater collection probability of failure results.

Table 18: Probability of Failure Category Ranges

Probability of Failure Value Range	Category
0 – 3.3	Low
3.3 – 6.7	Medium
> 6.7	High

Table 19: Water Pipeline Probability of Failure Category Ranges

Probability of Failure	Percent of Pipe Length
Low	2.8%
Medium	87.9%
High	9.3%

Table 20: Wastewater Collection Pipeline Probability of Failure Category Ranges

Probability of Failure	Percent of Pipe Length
Low	60.3%
Medium	39.1%
High	0.6%

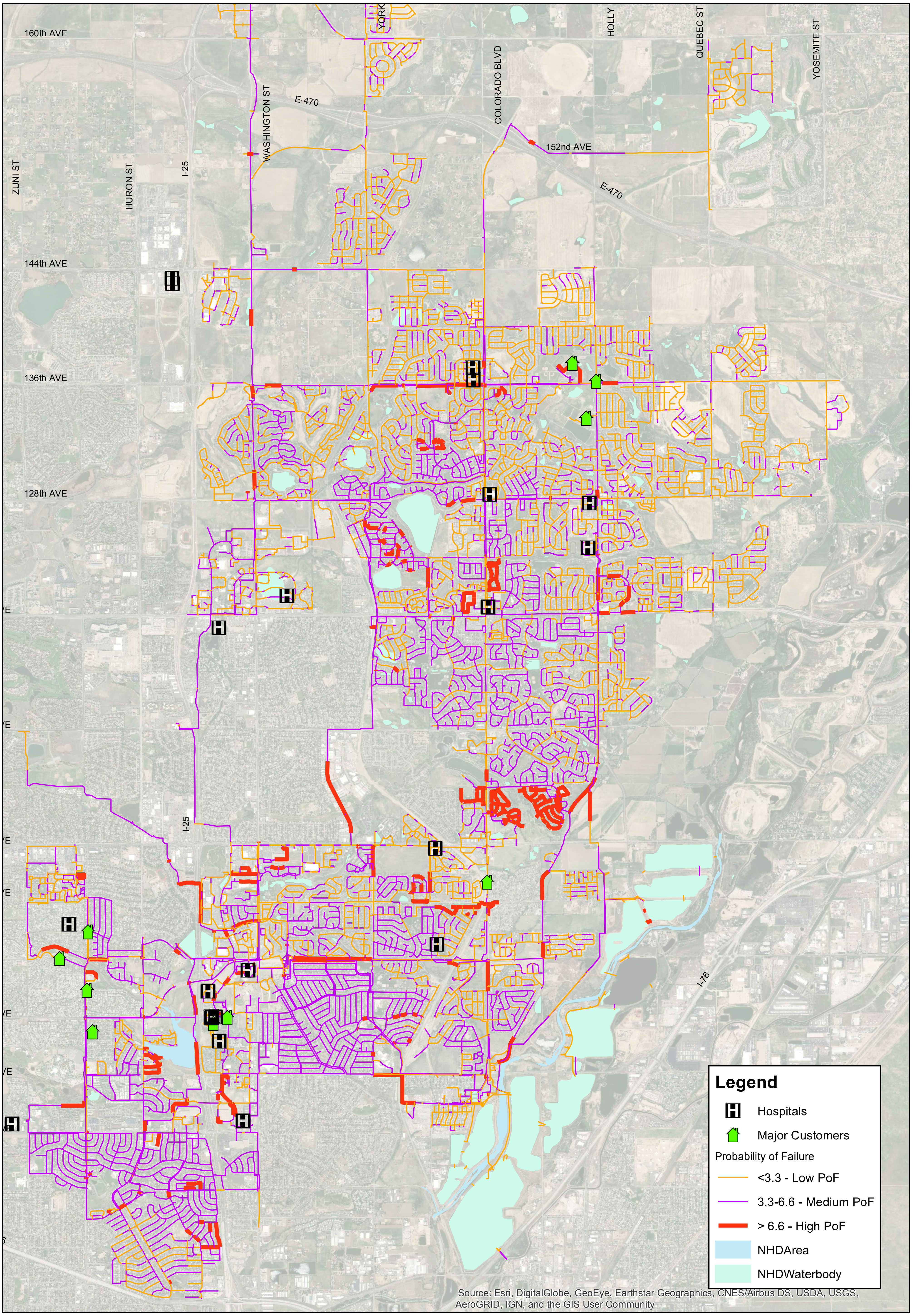

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Figure 20
Water Pipelines
Probability of Failure

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1 inch = 4,000 feet

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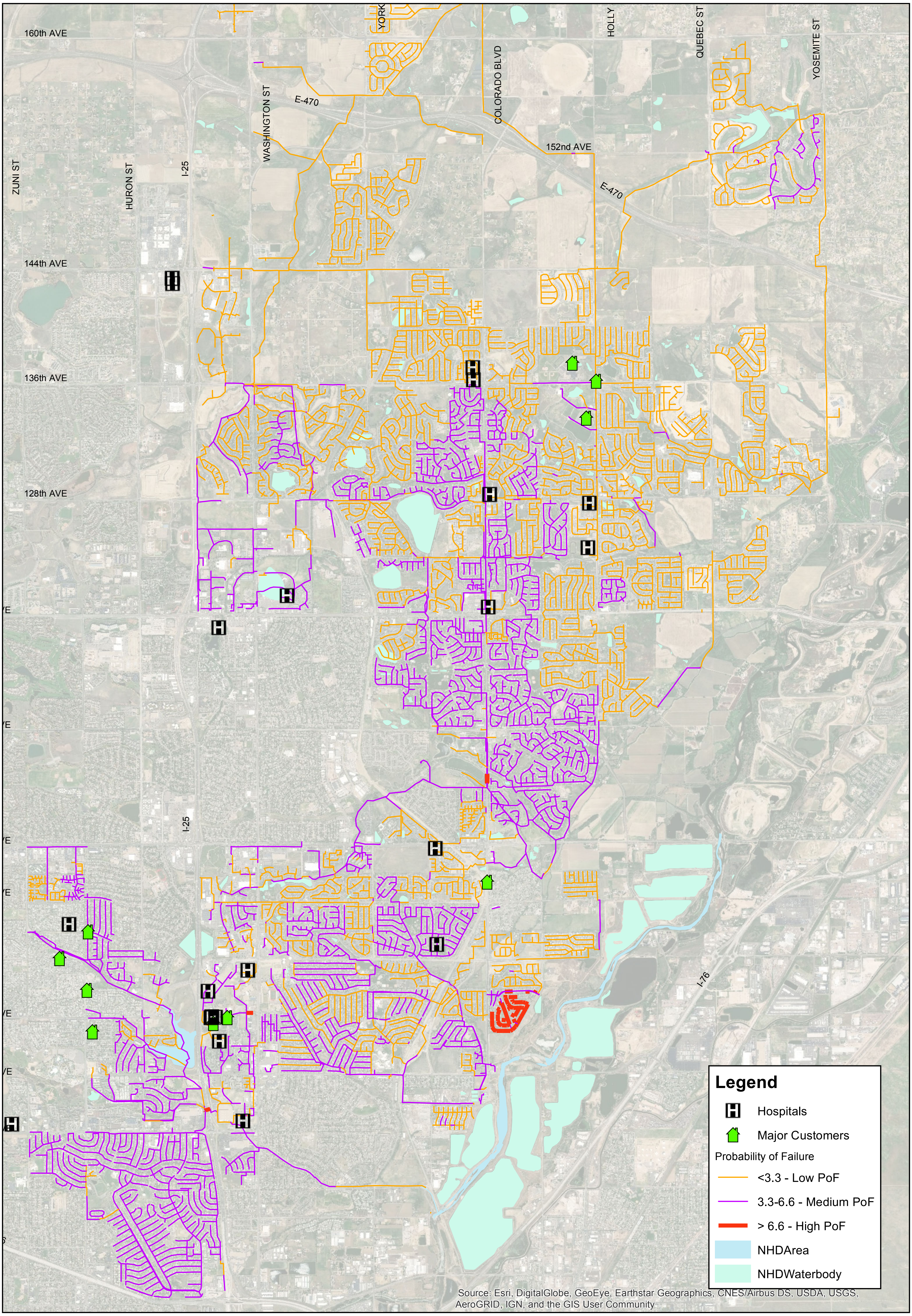

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Figure 21
Wastewater Pipelines
Probability of Failure

5/20/2019
1 inch = 4,000 feet

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7.4 Assumptions and Limitations

Through the process of applying the previous preliminary condition screening methodology to the Thornton water pipelines, the following assumptions and limitations were identified:

- Diameter and material were known for most of the water and wastewater pipe segments
- If the year of installation was unknown, an age value was assumed to be 40 years, based on Thornton comments during the initial project kickoff indicating the system is 40 years old on average
- An assumed value for the age constant was utilized and should be refined in the future according to pipe diameter and material to better match the observed failure data in smaller diameters
- The USDA soil database is limited in granularity

8. Risk Exposure Assessment

Infrastructure related risk exposure is assessed based on the probability and consequence of asset failure and is used to drive the selection and prioritization of asset related actions. Asset risk exposure is measured by the following risk equation:

Risk Exposure = Probability of Failure × Consequence of Failure

Once the criticality assessment and the condition assessment objectives for the infrastructure are complete, the resulting data can be entered into this equation and asset risk exposure can be evaluated. Risk exposure is subsequently used to prioritize advanced condition assessment, rehabilitation and maintenance treatments into short, medium and long term work programs and also to determine inspection frequencies.

Risk exposure was assessed from the results of the initial criticality assessment and the preliminary condition assessment models by using the risk equation within a database. The project results are summarized on Figure 22 and

Figure 23 which illustrate the proportion of the inventory in each risk category for water distribution and wastewater collection, respectively.

8.1 Assumptions and Limitations

Through the process of risk assessment of the Thornton water and wastewater collection pipelines, the following assumptions and limitations were identified:

- The limitations from the criticality and preliminary condition assessments propagate into the risk assessment process. As identified within the criticality and condition assessment sections, an iterative calibration process for the modeled results should be considered in the future to ensure Thornton infrastructure asset management goals can be achieved.
- The risk assessment is based only upon modeled data from the preliminary condition assessment.

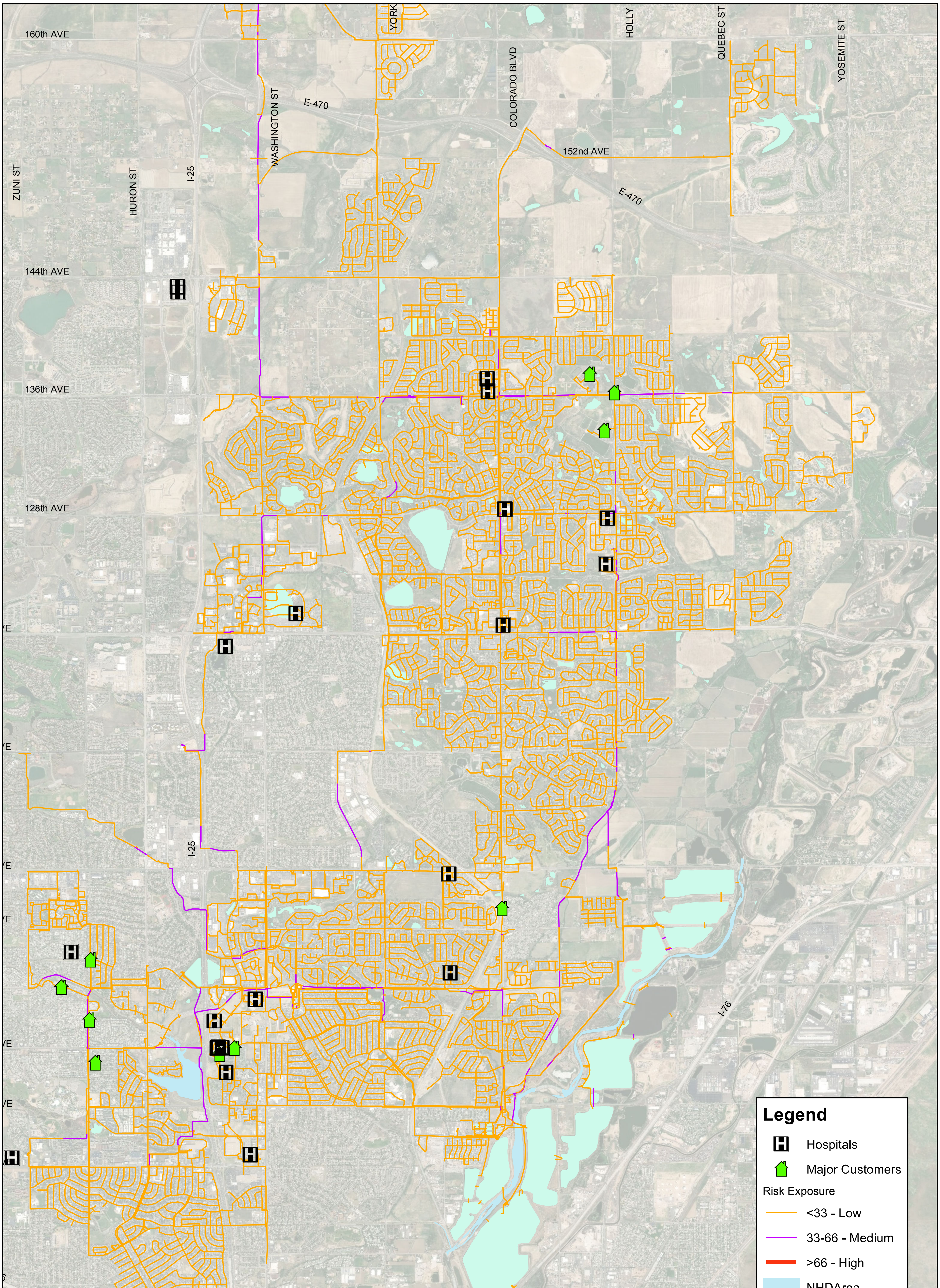

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Figure 22
Water Pipelines Risk Exposure

5/20/2019

1 inch = 4,000 feet

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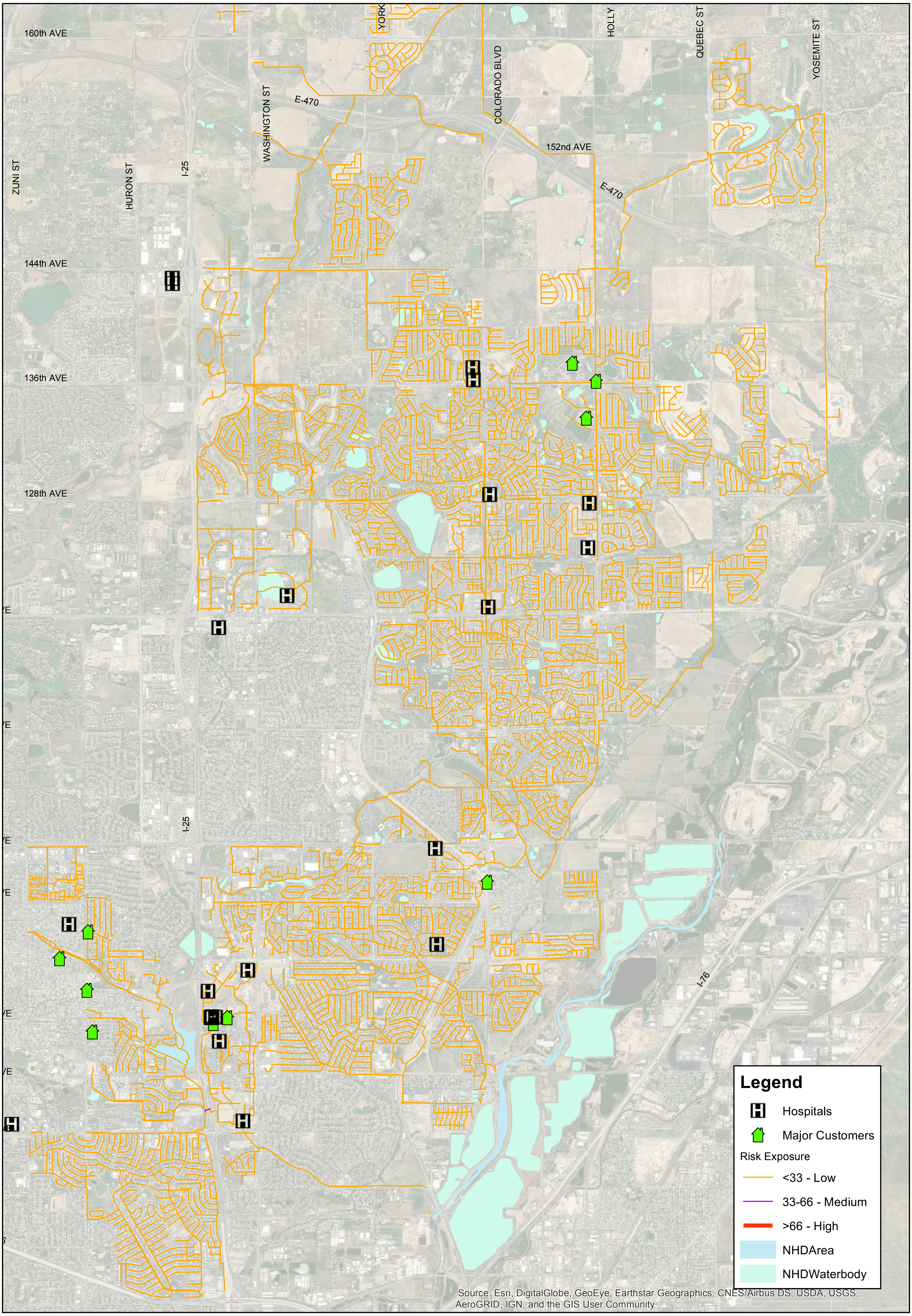

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Figure 23
Wastewater Pipelines Risk Exposure

5/20/2019
1 inch = 4,000 feet

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9. Water Pipeline Prioritization Program

At the core of the risk model is a decision model, which can be represented by a traditional policy driver matrix as depicted in Figure 24. This decision model was used to assign action levels to all the water distribution and wastewater collection pipelines within the Thornton system.

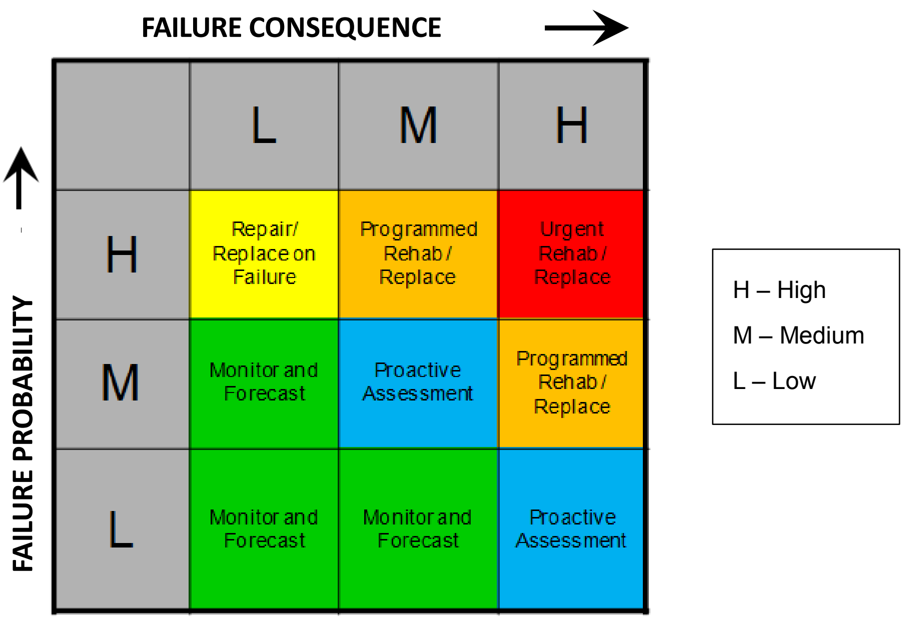

Figure 24: Risk Based Decision Matrix

The action levels are:

- "Urgent Rehab / Replace" – This action level implies immediate attention to avoid catastrophic system failures and expensive emergency repairs.
- "Programmed Rehab / Replace" – This action level implies that this pipe should get programmed for replacement based on the risk score.
- "Repair / Replace on Failure" – This action level implies that these pipes do not have high consequences if they fail and therefore their useful life can be maximized by running until failure.
- "Proactive Assessment" – This action level implies that a formal condition assessment program should be implemented for these pipes.
- "Monitor and Forecast" – This action level implies that the pipe is a relatively low risk asset and monitoring can be done on a more opportunistic basis.

The Prioritization Model is an excel-based tool that uses the risk-based decision matrix shown in Figure 24 to assign a recommended action to each of the pipes based on the consequence and probability of failure scores. The results from the Risk Exposure tool are inputs for the Prioritization Model tool. The pipes' estimated life was then discounted based on the recommendation level. The discounts were assigned based on the recommended action, and then further discounted based on the risk score. Discounts to lifespans based on recommended action are shown below in Table 21. The Prioritization Model assigns the year of replacement based on the year of installation of the asset and the correspondent discount based on the risk exposure factor.

The action levels are summarized for the water distribution system below in Figure 25. Figure 26 shows the recommendations for the pipes in the water system. Figure 27 shows the recommendations for the pipes in the wastewater system.

Applying the Prioritization Model to the water distribution resulted in approximately 86% of the pipes assigned a “Monitor and Forecast” action level, and no pipes fell on “Urgent Rehab / Replace” action level.

Table 21: Discounts to Pipeline Estimated Life based on Action Level

Action Level	Discount Factor (Percent of Estimated Life)	Percent of the Water System	Percent of the Wastewater System
Monitor and Forecast	100%	86%	99%
Proactive Assessment	85%	10%	0.1%
Repair / Replace on Failure	70%	2%	0.8%
Programmed Rehab / Replace	55%	3%	0.1%
Urgent Rehab / Replace	10%	0.1%	0%

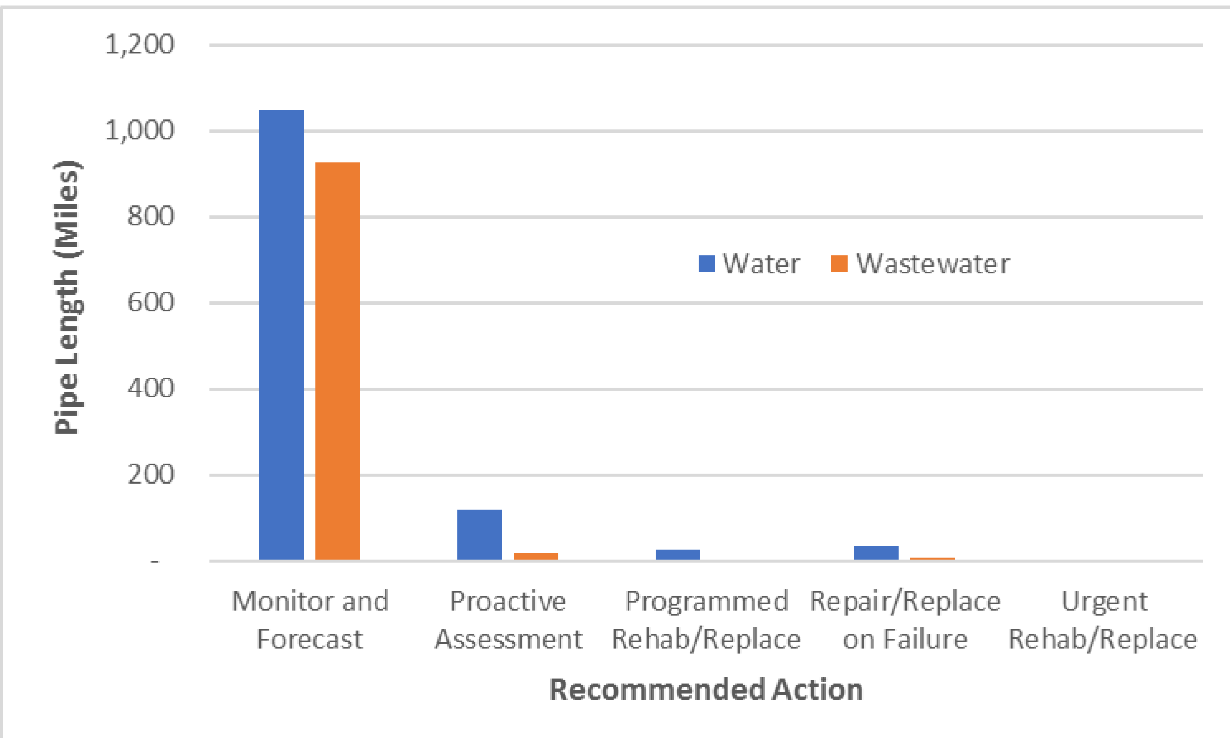

Figure 25: Length of Pipelines with Recommended Action

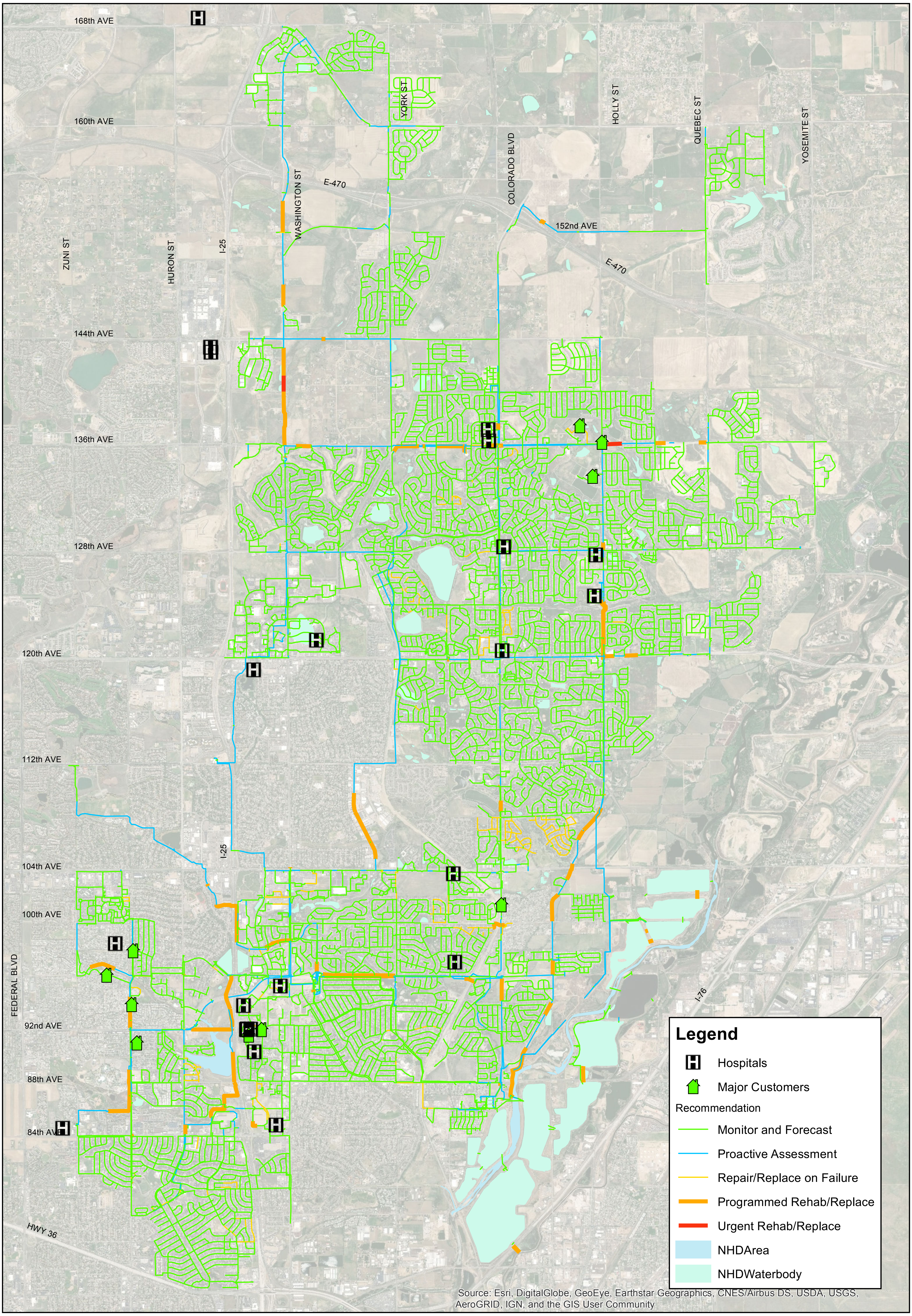

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Figure 26
Water Pipelines Recommendation Map

5/21/2019

1 inch = 4,333 feet

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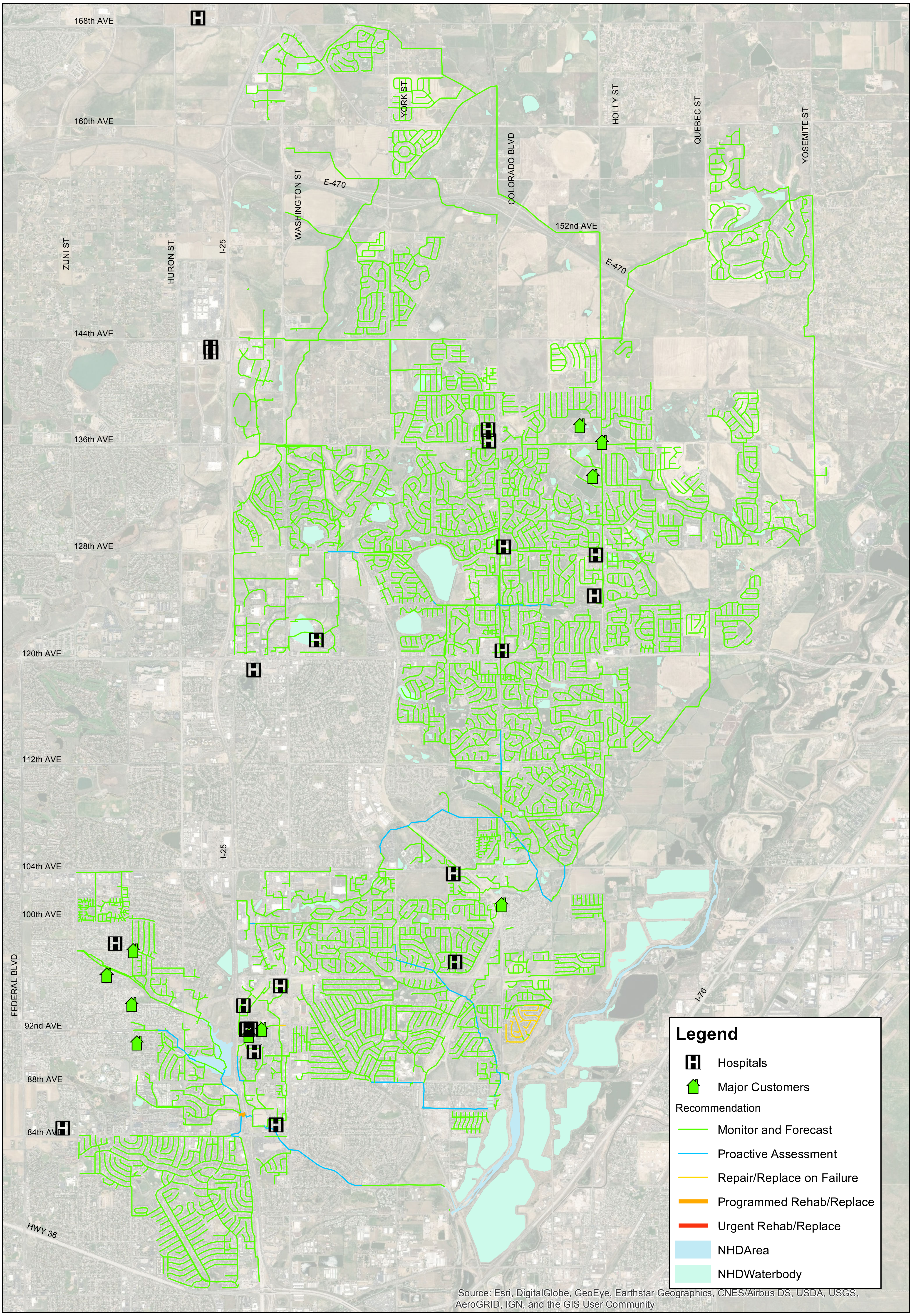

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Figure 27
Wastewater Pipelines Recommendation Map

5/21/2019
1 inch = 4,333 feet

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10. Pipeline Expenditures

With the year of replacement of each asset, the Prioritization Model tool calculates the pipeline expenditures per year for a forecast of up to 200 years. To estimate the required pipeline expenditures for the Rehabilitation and Replacement Program, the unit cost was assumed at $19 dollars per inch diameter per foot, which accounts for the average cost assuming rehabilitation and replacement are equally utilized. This unit cost was applied to both, water and wastewater systems and was provided by Thornton, based on their current programs and recent completed projects. The unit cost for pipe sizes is shown below in Table 22.

Using the Prioritization Model and the assumed installed unit pipe costs, the projected cash flow for the water distribution and transmission system is shown below in Figure 28. Figure 29 shows the Ten-Year Plan. With the assumed combined annual funding level of $1M, the current Rehab and Replacement Program is not sustainable, as shown in Figure 30, which depicts the cumulative funding over time.

A sustainable funding level was determined by taking the average annual funding level from the model results to meet the estimated expenditure over the life of the water distribution system. The estimated required annual expenditure for the water distribution and transmission system is $7M, which will address 1% of the system per year in average. Replacing 1% a year will result in a total replacement of the system in 100 years. Table 23 presents a summary of the rehab and replacement program for the water system.

For the wastewater system, the estimated required annual expenditure is $7M, which will address 1% of the system per year in average. Table 24 presents a summary of the rehab and replacement program for the wastewater system. The projected cash flow is shown in Figure 31, the Ten-Year Plan is presented in Figure 32, and the cumulative funding over time is presented in Figure 33.

As shown in Figure 28 and Figure 33, the investment recommended in the short-term (in the next 10 years) is higher than the investment required in the next 10-year period, for both the water and the wastewater systems, suggesting a current backlog in the current rehab and replacement program. This increases the level of spending in the next years and then slows until reaching a more consistent annual expenditure. The high peaks in the graphs are due to large assets reaching the end of their estimated useful life, causing a large investment as their large diameter and/or large length translates into large cost. Maps of the rehab and replacement program recommended pipeline replacements by year for the water distribution system and wastewater collection system are shown in Figure 34 and Figure 35, respectively.

Appendix B presents the results of the Prioritization Model as a list of water pipes with a year of replacement of 2025 or sooner. Appendix C presents the results of the Prioritization Model as a list of wastewater pipes with a year of replacement of 2025 or sooner.

Table 22: Assumed Pipe Installed Cost per Foot

Pipe Diameter (in)	Installed Cost ($/ft)
8	$ 152
12	$ 228
16	$ 304
20	$ 380
24	$ 456
30	$ 570
36	$ 684
42	$ 798
48	$ 912
54	$ 1,026

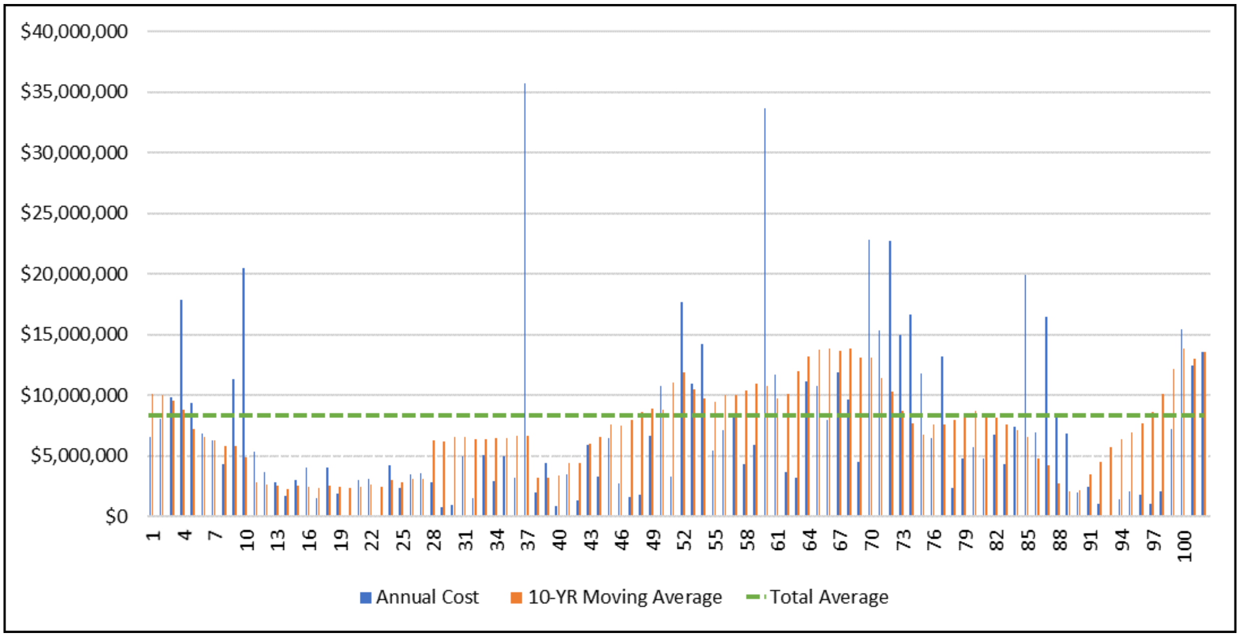


Figure 28: Projected Annual Water System Rehab and Replacement Funding Level

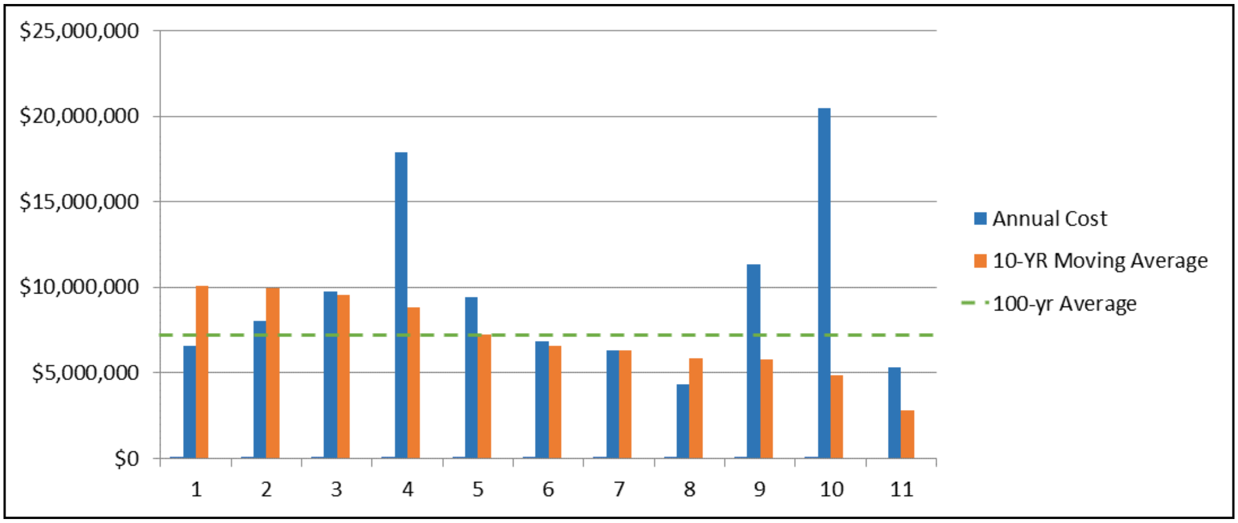


Figure 29: Ten Year Rehab and Replacement – Water Distribution and Transmission System

Table 23: Rehab and Replacement Program Summary – Water Distribution and Transmission System

Timeframe	Average Cost ($/year)	Average Length (ft)	Average Percent of the System (%)
100 years	**7,004,300**	**33,000**	**1.0**
5 years	9,751,600	67,000	2.1
10 years	9,665,400	66,000	2.0
20 years	6,294,800	40,000	1.2

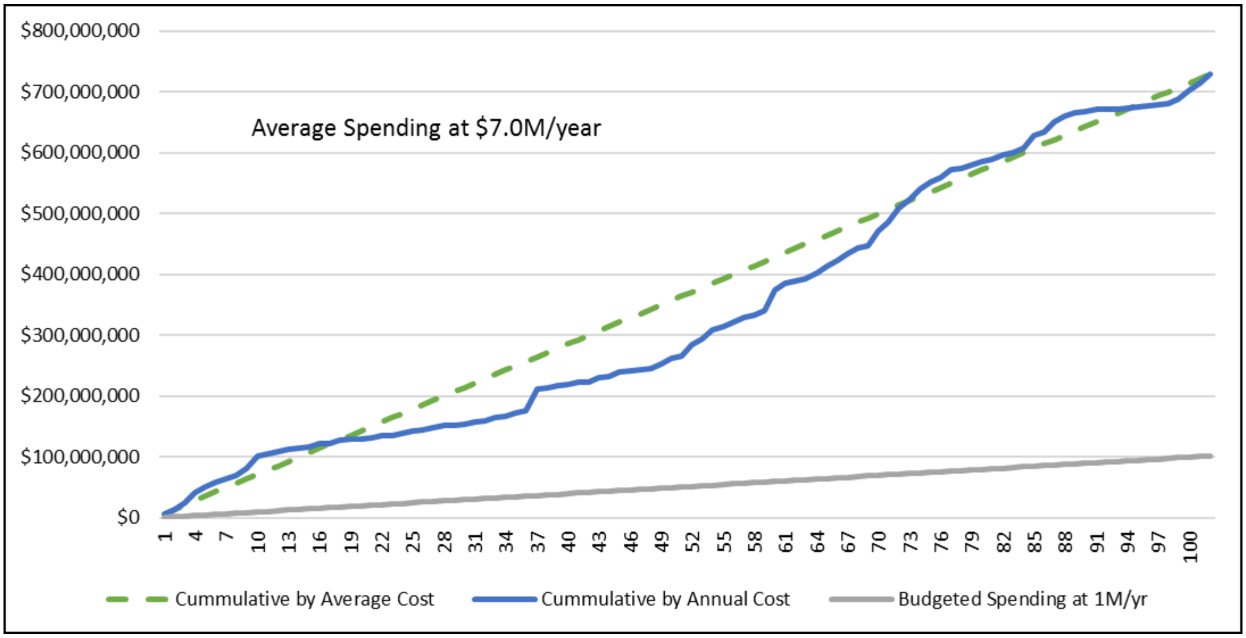


Figure 30: Projected Cumulative Water System Rehab and Replacement Funding Level

Table 24: Rehab and Replacement Program Summary – Wastewater Collection System

Timeframe	Average Cost ($/year)	Average Length (ft)	Average Percent of the System (%)
100 years	**4,710,800**	**26,600**	**1.1**
5 years	10,043,700	53,200	2.1
10 years	9,869,600	53,000	2.1
20 years	5,372,600	33,000	1.3

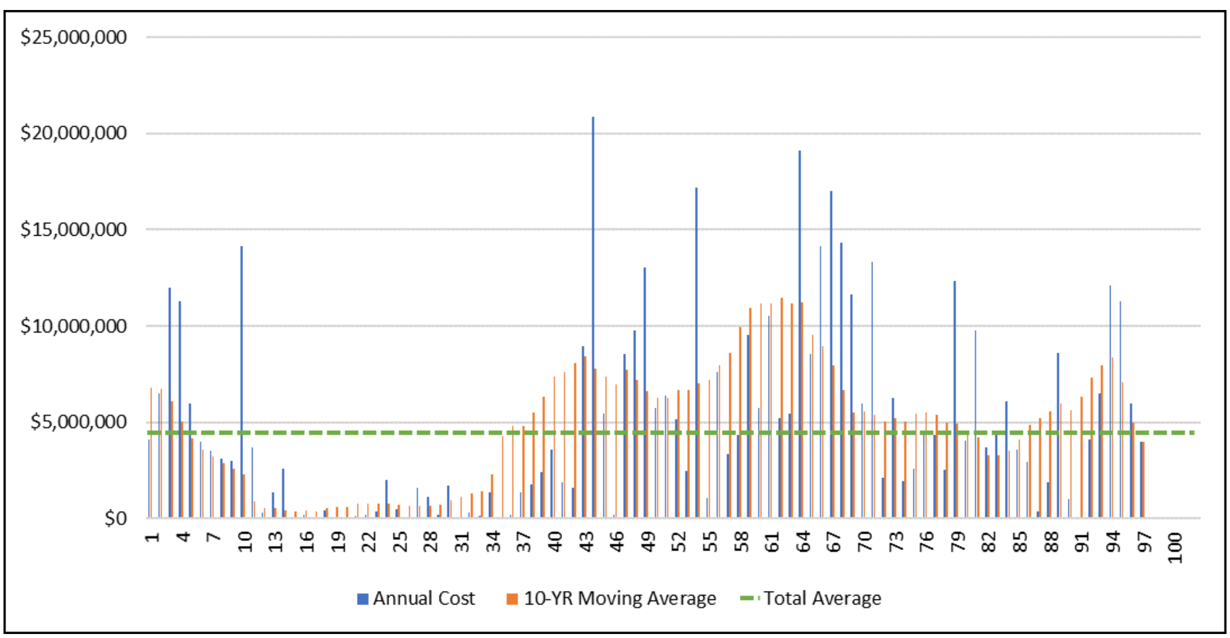


Figure 31: Projected Annual Wastewater Rehab and Replacement Funding Level

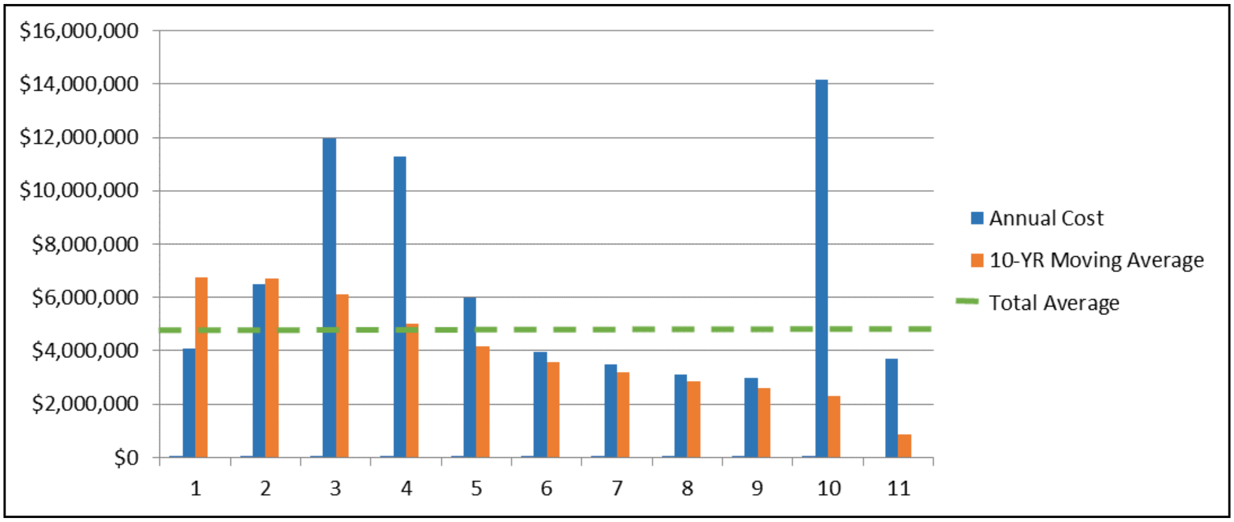


Figure 32: Ten Year Rehab and Replacement – Water Distribution and Transmission System

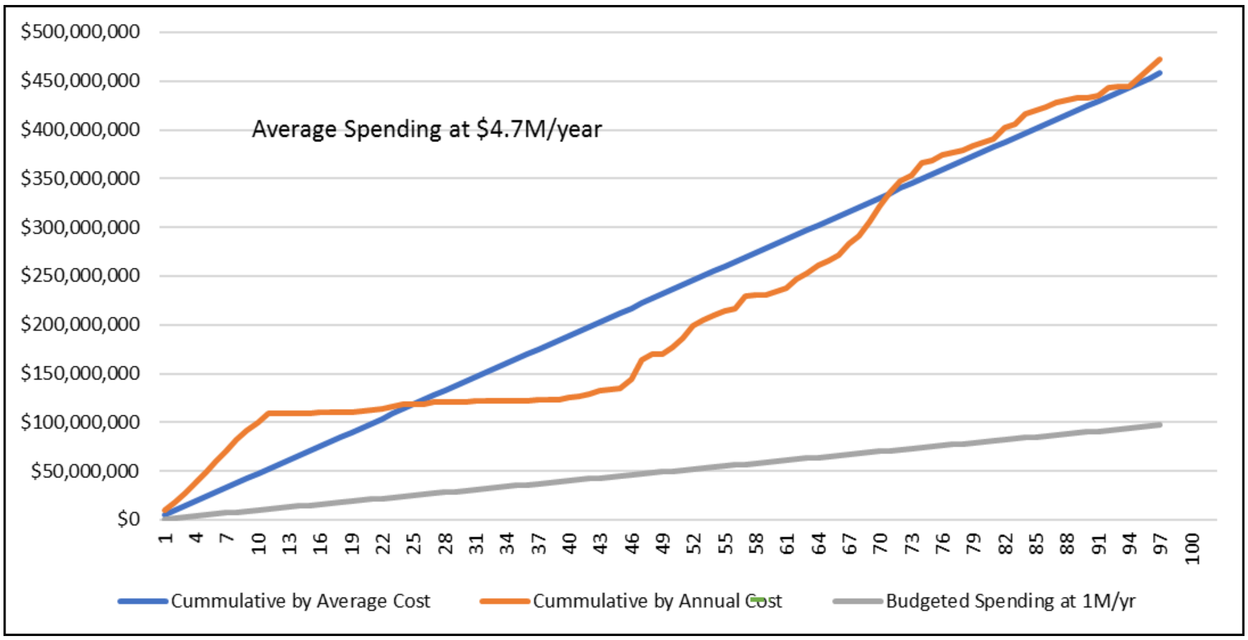
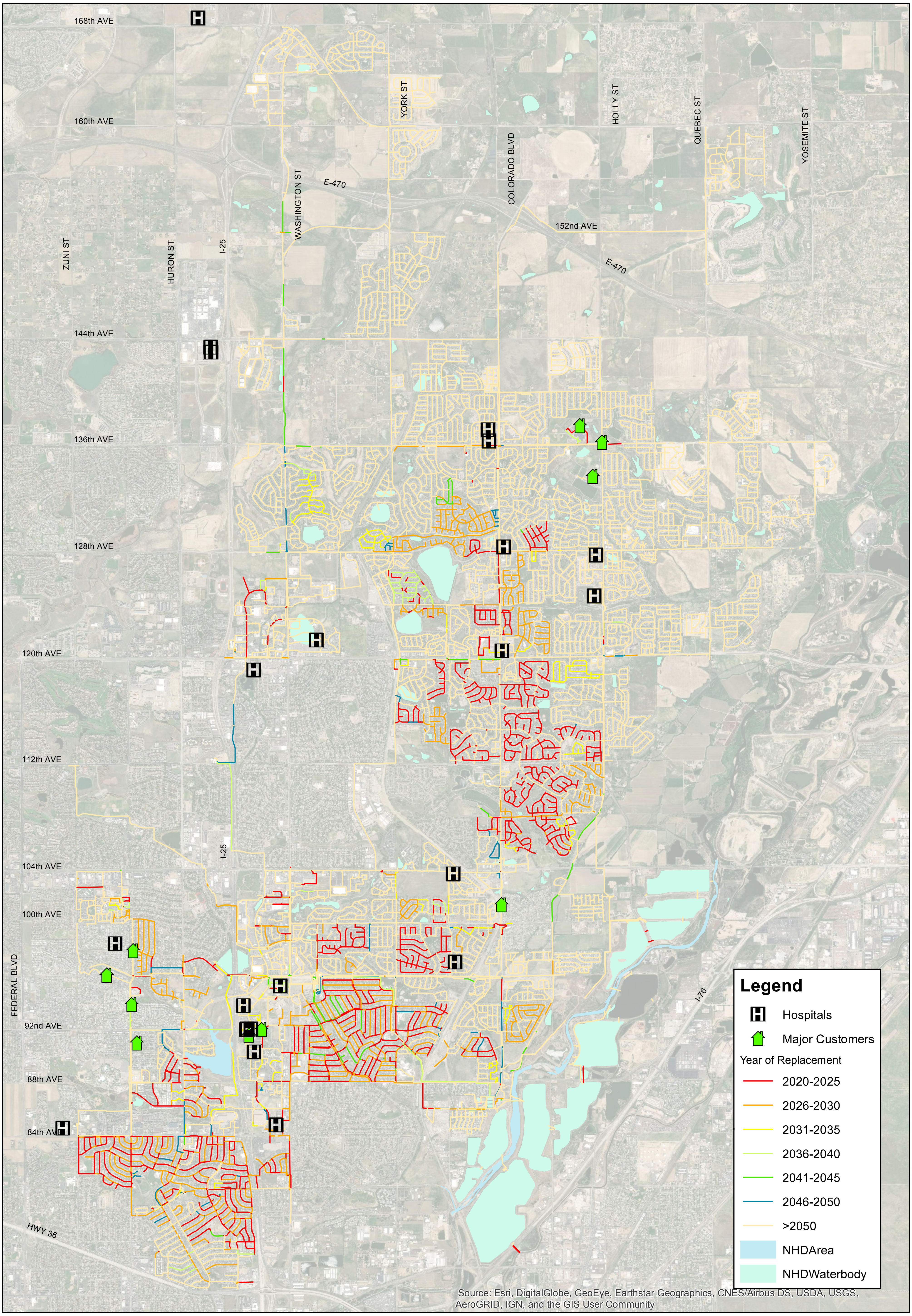


Figure 33: Projected Cumulative Wastewater Rehab and Replacement Funding Level



City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Figure 34
Water Pipelines
Year of Replacement

5/22/2019
1 inch = 4,333 feet

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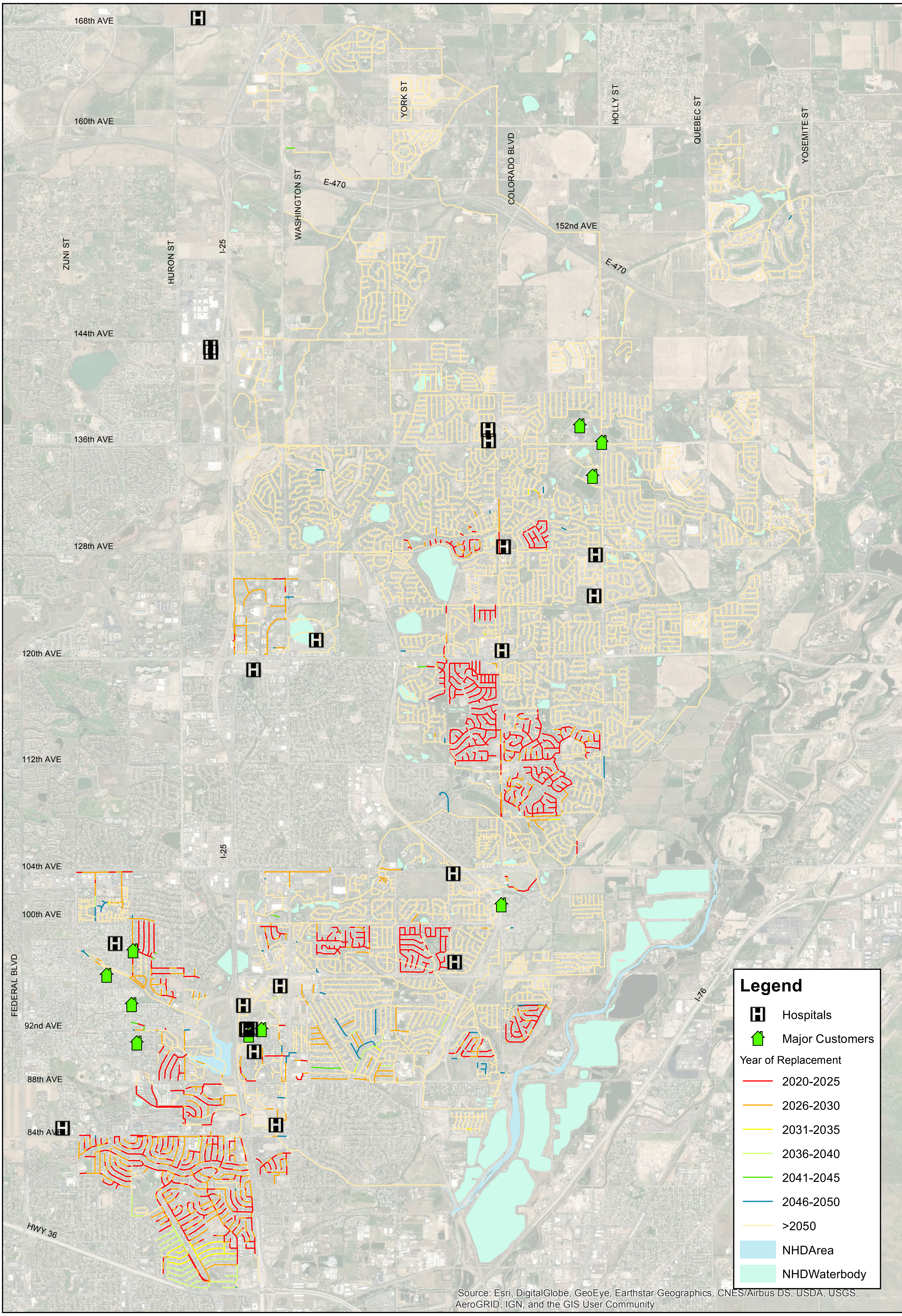

City of Thornton
9500 Civic Center Drive Thornton, Colorado 80229
(303) 538-7295

AECOM 6200 South Quebec Street
Greenwood Village, Colorado 80111

Figure 35
Wastewater Pipelines
Year of Replacement

5/22/2019
1 inch = 4,333 feet

M:\DCS\Projects\WTR\60560104_Thornton M\400-Technical\480-Risk Tool\DOCUMENTATION\Figures\COT_RR_TM_FIG35_WW_YOR.mxd

11. Conclusions and Recommendations

An examination of existing Thornton practices with respect to asset management of water and wastewater main infrastructure was conducted and the following primary observations were made:

- There is a large amount of cementitious water pipeline material in service that is reaching the end of its expected useful life. AC pipe has proven to be failure-prone within the Thornton operating environment.
- There are large investments being made into plastic pipelines, primarily PVC. In the Thornton inventory, PVC is the dominant pipe material used in applications within the last 30 years. As the primary long-term degradation mode for PVC is slow crack growth in response to high applied pressures, its long-term condition should be known with greater certainty in areas of high pressure.
- The current Thornton project prioritization model is based upon a hybrid risk-based model that is consistent with industry best practices; however, this model is centered upon economics and does not address environmental or social impacts to a significant degree.
- The current Thornton condition model is centered upon estimations of useful life and actual failure history. The result is that only very old and/or failure-prone water mains make the list for replacement. This process does not consider highly critical water mains that require proactive condition assessment and possible rehabilitation prior to catastrophic failure.
- Risk mitigation is currently centered upon replacement of failure-prone water mains that are typically small diameter and located in residential areas.
- Per the risk evaluation, most of the water system (86%) and most of the wastewater system (97%) fall in the Monitor and Forecast category; this action level implies that the assets are at a relatively low risk and monitoring can be done on a more opportunistic basis.
- Per the risk evaluation, only three pipes in the water system and none in the wastewater system fall in the Urgent Rehab/Replace category; this action level implies immediate attention to avoid catastrophic system failures and expensive emergency repairs.
- The current annual funding level for water main replacement of $1M is significantly below the estimated required funding level of approximately $7.0M. The estimated required funding level is based on a unit cost of $19/ft-in.
- The estimated annual level of funding will address approximately 1% of the system in a 100-year average, while addressing approximately 2% of the system in the short-term.
- The current annual funding level for wastewater main replacement of $1M is significantly below the estimated required funding level of approximately $4.7M. The estimated required funding level is based on a unit cost of $19/ft-in.
- The estimated annual level of funding will address approximately 1.1% of the system in a 100-year average, while addressing approximately 2.2% of the system in the short-term.
- The investment recommended in the short-term (in the next 10 years) is higher than the investment required in the next 10-year period, for both the water and the wastewater systems, suggesting a current backlog in the current rehab and replacement program.

Based on these conclusions, the following action items are recommended:

1. Implement procedures to maintain GIS data quality. An approximation of missing information can be made with an interpolation of neighboring infrastructure with known installation dates but the confidence in the results of this analysis is fully dependent on the quality of the GIS database information.
2. Calibrate the criteria to better match actual objectives of the stakeholders. This could be achieved by making adjustment of the scores and importance weightings and then re-calculate and display the results.
3. Perform further calibration of the Preliminary Probability of Failure model criteria to better match real-world situations once further condition assessment data is made available.

4. Develop a more comprehensive database of relevant soil chemistry and electrochemistry properties as well as introducing a formal opportunistic sampling program for CI/DI failures. The objective of this program would be to develop a unique, spatially referenced pitting model database that would facilitate a better understanding of risk exposure due to corrosion for all ferrous metals in inventory.
5. Revise the Long-Term Funding Model based on deterioration patterns within the advanced condition data, once it is available. This will allow a better estimate of the future financial requirements such that assets can be maintained at a sustainable level that is commensurate with the level of risk tolerance identified within the asset management approach.

Appendices

Appendix A- Deterioration Drivers

Appendix B – Prioritization Tool Results – Asset List - Water

Appendix C – Prioritization Tool Results – Asset List - Wastewater

Appendix A- Deterioration Drivers

To understanding why pipelines fail, it is important to consider the primary factors that are responsible for pipe deterioration. This will be impacted by many factors including the type of surrounding soil, the operating pressures within the pipelines, the method of construction, groundwater conditions, surface or overburden loading and the interactions of these upon the deterioration of the pipe material fabric. These factors should all be considered in order to carry out a complete assessment of pipeline probability of failure.

The deterioration drivers for Cast Iron, Ductile Iron, Steel, and Asbestos Cement are linked to exposure to several different environmental factors. Conversely, PVC is not affected by most environmental factors but can be significantly affected by the magnitude of applied internal and external stresses.

Most pressure pipe design is typically based on hoop (circumferential) stress analysis although the ultimate failure mode is often due to flexural stress or simple perforation of the pipe wall due to corrosion. The factor of safety against failure for hoop stress is generally constant through different diameters. The flexural factor of safety against failure increases with increasing diameter as does the time to fully perforate a pipe wall as hoop stress design uses a common dimension ratio. By utilizing knowledge of the typical modes of failure for the pipes within the inventory, an initial condition assessment program can be developed that will maximize the use of data to infer a pipe's condition based on its exposure environment which is far more readily characterized than the pipe condition itself.

The level of detail invested in this program will depend on the value within the context of the condition assessment and the probability model. By knowing the potential failure modes, it becomes possible to define whether or not the potential for that problem exists in the given inventory and its given environment. It also allows the potential to know which pipes are susceptible and whether or not these are localized or global environmental factors.

The following sections identify typical deterioration factors for each water main pipe material type currently in service within the Thornton inventory.

Ferrous Metal Pipes (CI/DI/Steel)

The primary contributing mechanism for failure of CI/DI/Steel (i.e. ferrous materials) is overwhelmingly related to corrosion. Corrosion can occur in many different forms in terms of either generalized or localized corrosion processes, with more localized corrosion being far more prevalent in water distribution systems than generalized corrosion processes. Corrosion is not a diameter sensitive issue; it is a material loss issue and eventually affects all pipes, regardless of size. In CI and DI pipes, the ultimate failure mode is often flexure or purely related to wall thickness, therefore, failures appear earlier in a pipe's life in smaller diameters.

The corrosion process may stop over time or shift within a system due to the impact of more global corrosion processes. In heavily graphitized pipe, the most common failure initiator is ground movement on a weakened pipe, which usually generates a flexural rather than hoop stress failure. The design life of ferrous pipes is well documented to increase with increasing diameter, primarily due to the thicker pipe walls associated with the larger diameters being less sensitive to material loss through corrosion or the much increased factor of safety associated with the pipe in flexure in larger diameters. Methods of assessing condition on ferrous pipes typically involve an examination of corrosion and the associated environmental factors.

Cathodic protection can have a profound impact on future corrosion rates in CI and DI systems, an effect observed by many researchers and well developed in analytical models. Where coatings and cathodic protection systems are used in a comprehensive maintenance work program, as is commonly the case with steel mains, the effect of external environment is less pronounced in a mains failure history.

PVC

PVC is a thermoplastic material; typically driven to failure due to applied stresses and not due to material loss or degradation. PVC has three (3) reasonably well understood, yet independent life funds:

- Resistance to slow crack growth in response to long term sustained pressure
- Resistance to bursting in response to short term overpressure, and
- Resistance to fatigue in response to exposure to large cyclic pressure variations.

The first of the above life funds can be examined through a balance of desk top analysis and opportunistic sampling and assessment. The second would become apparent in examination of failure records; while the third, fatigue, is rare in distribution system applications as large cyclic pressure variation are not common.

When PVC does fail, it is subject to rapid crack growth as a failure mode which creates failure that can be subjected to very large losses of water.

Asbestos Cement (AC)

Material deterioration is the most common driving process for AC pipe failure. Failures will occur more commonly due to flexural (longitudinal beam) as opposed to the hoop (circumferential) stress. The effective design life increases with increasing diameter. Previous studies have identified several common soil and water conditions that can cause concrete products to deteriorate as indicated below.

- Soft waters, which leach calcium (lime and soluble silicates) from cement;
- Soluble sulphates; and
- Acidic conditions;
  - Organic acids, as occur in marshlands, bogs and peaty soils;
  - Inorganic acids, as occur in mine waters, or are generated in cinder fills or through the oxidation of sulphides;
  - Dissolved carbon dioxide;
  - Soils having hydrogen ion exchange ability, which act to remove the calcium from the Portland cement structure and replace it with the hydrogen acid radical.

Methods of assessing condition on AC pipes typically involve an examination of the most predominate of the previous environmental factors. Thornton has indicated a large number of AC pipe failures within their water distribution system, however, rapid pressure fluctuations were not found in literature to be a known cause of failure.

Appendix B- Prioritization Tool Results – Asset List - Water

THORNTON - REHAB AND REPLACEMENT PROGRAM

WATER DISTRIBUTION AND TRANSMISSION SYSTEM

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
4684	Urgent Rehab/Replace	770	Ductile Iron	24	20-40yr	1991	29	2020	$ 351,120
4687	Urgent Rehab/Replace	30	Ductile Iron	24	20-40yr	1991	29	2020	$ 13,680
6404	Urgent Rehab/Replace	740	Ductile Iron	36	<20yr	2006	14	2020	$ 506,160
8072	Repair/Replace on Failure	20	Ductile Iron	8	40-60yr	1979	41	2020	$ 3,040
21560	Repair/Replace on Failure	280	Ductile Iron	6	20-40yr	1983	37	2020	$ 31,920
20200	Repair/Replace on Failure	360	Ductile Iron	8	20-40yr	1980	40	2020	$ 54,720
17559	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2020	$ 4,560
15767	Repair/Replace on Failure	280	Ductile Iron	8	20-40yr	1984	36	2020	$ 42,560
19854	Repair/Replace on Failure	60	Asbestos Cement	8	40-60yr	1970	50	2020	$ 9,120
7254	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1979	41	2020	$ 4,560
11997	Repair/Replace on Failure	30	Ductile Iron	6	40-60yr	1978	42	2020	$ 3,420
3197	Repair/Replace on Failure	20	Ductile Iron	8	40-60yr	1979	41	2020	$ 3,040
8956	Repair/Replace on Failure	10	Ductile Iron	8	40-60yr	1979	41	2020	$ 1,520
17562	Repair/Replace on Failure	230	Ductile Iron	8	20-40yr	1984	36	2020	$ 34,960
23107	Repair/Replace on Failure	40	Ductile Iron	10	>60yr	1955	65	2020	$ 7,600
24245	Repair/Replace on Failure	50	Ductile Iron	8	>60yr	1955	65	2020	$ 7,600
22865	Repair/Replace on Failure	330	Ductile Iron	6	>60yr	1957	63	2020	$ 37,620
22866	Repair/Replace on Failure	80	Ductile Iron	6	>60yr	1957	63	2020	$ 9,120
13257	Repair/Replace on Failure	250	Ductile Iron	8	20-40yr	1980	40	2020	$ 38,000
21540	Repair/Replace on Failure	190	Ductile Iron	8	20-40yr	1983	37	2020	$ 28,880
21573	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2020	$ 4,560
12589	Repair/Replace on Failure	470	Cast iron	8	40-60yr	1976	44	2020	$ 71,440
15845	Repair/Replace on Failure	250	Ductile Iron	8	20-40yr	1984	36	2020	$ 38,000
15862	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2020	$ 4,560
17138	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1978	42	2020	$ 4,560
9578	Repair/Replace on Failure	240	Ductile Iron	6	40-60yr	1979	41	2020	$ 27,360
6936	Repair/Replace on Failure	50	Ductile Iron	8	40-60yr	1979	41	2020	$ 7,600
18767	Repair/Replace on Failure	60	Ductile Iron	8	20-40yr	1984	36	2020	$ 9,120
21310	Repair/Replace on Failure	340	Ductile Iron	8	20-40yr	1985	35	2020	$ 51,680
8706	Repair/Replace on Failure	920	Ductile Iron	10	40-60yr	1979	41	2020	$ 174,800
16102	Repair/Replace on Failure	50	Ductile Iron	8	40-60yr	1974	46	2020	$ 7,600
9620	Repair/Replace on Failure	260	Ductile Iron	8	40-60yr	1975	45	2020	$ 39,520
12077	Repair/Replace on Failure	80	Ductile Iron	8	40-60yr	1975	45	2020	$ 12,160
16417	Repair/Replace on Failure	380	Ductile Iron	8	40-60yr	1979	41	2020	$ 57,760
16420	Repair/Replace on Failure	270	Ductile Iron	8	40-60yr	1979	41	2020	$ 41,040
18850	Repair/Replace on Failure	170	Ductile Iron	8	40-60yr	1979	41	2020	$ 25,840
6886	Repair/Replace on Failure	20	Ductile Iron	8	40-60yr	1979	41	2020	$ 3,040
20194	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1980	40	2020	$ 6,080
20195	Repair/Replace on Failure	190	Ductile Iron	8	20-40yr	1980	40	2020	$ 28,880
21548	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1983	37	2020	$ 7,600
15854	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2020	$ 4,560
15860	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2020	$ 3,040
16129	Repair/Replace on Failure	610	Ductile Iron	6	20-40yr	1984	36	2020	$ 69,540

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
21824	Repair/Replace on Failure	510	Ductile Iron	8	20-40yr	1984	36	2020	$ 77,520
21856	Repair/Replace on Failure	190	Ductile Iron	8	20-40yr	1984	36	2020	$ 28,880
21814	Repair/Replace on Failure	250	Ductile Iron	8	20-40yr	1984	36	2020	$ 38,000
21821	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2020	$ 4,560
21830	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1984	36	2020	$ 7,600
18794	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2020	$ 6,080
18796	Repair/Replace on Failure	190	Ductile Iron	8	20-40yr	1984	36	2020	$ 28,880
21309	Repair/Replace on Failure	80	Ductile Iron	8	20-40yr	1985	35	2020	$ 12,160
21312	Repair/Replace on Failure	280	Ductile Iron	8	20-40yr	1985	35	2020	$ 42,560
8035	Programmed Rehab/Replace	70	Ductile Iron	16	40-60yr	1979	41	2020	$ 21,280
7523	Programmed Rehab/Replace	80	Ductile Iron	16	40-60yr	1979	41	2020	$ 24,320
8108	Programmed Rehab/Replace	200	Ductile Iron	12	40-60yr	1979	41	2020	$ 45,600
18882	Programmed Rehab/Replace	40	Ductile Iron	12	40-60yr	1979	41	2020	$ 9,120
5324	Programmed Rehab/Replace	10	Ductile Iron	12	40-60yr	1979	41	2020	$ 2,280
7518	Programmed Rehab/Replace	290	Ductile Iron	16	40-60yr	1979	41	2020	$ 88,160
5268	Programmed Rehab/Replace	30	Ductile Iron	12	40-60yr	1979	41	2020	$ 6,840
5274	Programmed Rehab/Replace	40	Ductile Iron	12	40-60yr	1979	41	2020	$ 9,120
2530	Programmed Rehab/Replace	70	Ductile Iron	16	40-60yr	1979	41	2020	$ 21,280
2536	Programmed Rehab/Replace	60	Ductile Iron	16	40-60yr	1979	41	2020	$ 18,240
6927	Programmed Rehab/Replace	20	Ductile Iron	16	40-60yr	1979	41	2020	$ 6,080
19843	Programmed Rehab/Replace	100	Ductile Iron	16	40-60yr	1971	49	2020	$ 30,400
7194	Programmed Rehab/Replace	280	Ductile Iron	16	40-60yr	1973	47	2020	$ 85,120
7332	Programmed Rehab/Replace	10	Ductile Iron	16	40-60yr	1979	41	2020	$ 3,040
7967	Programmed Rehab/Replace	20	Ductile Iron	16	40-60yr	1979	41	2020	$ 6,080
9421	Programmed Rehab/Replace	20	Ductile Iron	12	40-60yr	1979	41	2020	$ 4,560
9424	Programmed Rehab/Replace	30	Ductile Iron	12	40-60yr	1979	41	2020	$ 6,840
12047	Programmed Rehab/Replace	20	Ductile Iron	16	40-60yr	1979	41	2020	$ 6,080
25605	Programmed Rehab/Replace	10	Ductile Iron	16	40-60yr	1979	41	2020	$ 3,040
25606	Programmed Rehab/Replace	30	Ductile Iron	16	40-60yr	1979	41	2020	$ 9,120
9208	Programmed Rehab/Replace	340	Ductile Iron	12	40-60yr	1979	41	2020	$ 77,520
9212	Programmed Rehab/Replace	20	Ductile Iron	12	40-60yr	1979	41	2020	$ 4,560
9218	Programmed Rehab/Replace	20	Ductile Iron	12	40-60yr	1979	41	2020	$ 4,560
18927	Programmed Rehab/Replace	220	Ductile Iron	12	40-60yr	1979	41	2020	$ 50,160
8270	Programmed Rehab/Replace	50	Ductile Iron	16	40-60yr	1979	41	2020	$ 15,200
23386	Monitor and Forecast	320	Asbestos Cement	6	40-60yr	1966	54	2020	$ 36,480
8335	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1970	50	2020	$ 7,600
23963	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1970	50	2020	$ 9,120
23109	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1955	65	2020	$ 5,700
11205	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1959	61	2020	$ 3,040
23650	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1959	61	2020	$ 5,700
24287	Monitor and Forecast	260	Asbestos Cement	6	>60yr	1959	61	2020	$ 29,640
24292	Monitor and Forecast	120	Asbestos Cement	6	>60yr	1959	61	2020	$ 13,680
19713	Monitor and Forecast	240	Asbestos Cement	6	40-60yr	1962	58	2020	$ 27,360
10031	Monitor and Forecast	20	Ductile Iron	8	40-60yr	1962	58	2020	$ 3,040
10548	Monitor and Forecast	230	Asbestos Cement	6	>60yr	1959	61	2020	$ 26,220

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
24178	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1970	50	2020	$ 28,880
11874	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1970	50	2020	$ 13,680
23964	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1970	50	2020	$ 6,080
23634	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1954	66	2020	$ 2,280
23635	Monitor and Forecast	200	Asbestos Cement	6	>60yr	1954	66	2020	$ 22,800
26149	Monitor and Forecast	230	Asbestos Cement	8	>60yr	1954	66	2020	$ 34,960
26265	Monitor and Forecast	190	Asbestos Cement	10	>60yr	1954	66	2020	$ 36,100
23493	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1954	66	2020	$ 3,040
23973	Monitor and Forecast	530	Asbestos Cement	8	40-60yr	1970	50	2020	$ 80,560
23522	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1953	67	2020	$ 4,560
19851	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1970	50	2020	$ 12,160
23974	Monitor and Forecast	730	Asbestos Cement	8	40-60yr	1970	50	2020	$ 110,960
23763	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1954	66	2020	$ 4,560
26491	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1954	66	2020	$ 6,840
24230	Monitor and Forecast	50	Asbestos Cement	10	>60yr	1954	66	2020	$ 9,500
23182	Monitor and Forecast	270	Asbestos Cement	10	>60yr	1955	65	2020	$ 51,300
24072	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1956	64	2020	$ 4,560
19850	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1970	50	2020	$ 19,760
23076	Monitor and Forecast	290	Asbestos Cement	6	>60yr	1959	61	2020	$ 33,060
9618	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1960	60	2020	$ 5,700
19856	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1970	50	2020	$ 7,600
24175	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1970	50	2020	$ 3,040
24176	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1970	50	2020	$ 4,560
24177	Monitor and Forecast	450	Asbestos Cement	8	40-60yr	1970	50	2020	$ 68,400
23546	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1959	61	2020	$ 5,700
23584	Monitor and Forecast	2290	Asbestos Cement	6	>60yr	1959	61	2020	$ 261,060
23671	Monitor and Forecast	240	Asbestos Cement	6	>60yr	1959	61	2020	$ 27,360
24223	Monitor and Forecast	540	Asbestos Cement	10	40-60yr	1960	60	2020	$ 102,600
22893	Monitor and Forecast	260	Asbestos Cement	10	>60yr	1954	66	2020	$ 49,400
22899	Monitor and Forecast	260	Asbestos Cement	10	>60yr	1954	66	2020	$ 49,400
23610	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1953	67	2020	$ 4,560
23981	Monitor and Forecast	350	Asbestos Cement	6	>60yr	1956	64	2020	$ 39,900
23175	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1955	65	2020	$ 41,040
24107	Monitor and Forecast	1300	Asbestos Cement	6	>60yr	1959	61	2020	$ 148,200
23558	Monitor and Forecast	480	Asbestos Cement	6	>60yr	1959	61	2020	$ 54,720
23982	Monitor and Forecast	240	Ductile Iron	8	>60yr	1956	64	2020	$ 36,480
23991	Monitor and Forecast	40	Ductile Iron	6	>60yr	1956	64	2020	$ 4,560
24249	Monitor and Forecast	220	Ductile Iron	8	>60yr	1958	62	2020	$ 33,440
23282	Monitor and Forecast	30	Ductile Iron	10	>60yr	1959	61	2020	$ 5,700
23785	Monitor and Forecast	790	Asbestos Cement	6	>60yr	1954	66	2020	$ 90,060
23789	Monitor and Forecast	40	Asbestos Cement	4	>60yr	1954	66	2020	$ 3,040
23760	Monitor and Forecast	30	Asbestos Cement	4	>60yr	1954	66	2020	$ 2,280
23718	Monitor and Forecast	20	Asbestos Cement	4	>60yr	1954	66	2020	$ 1,520
23169	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1955	65	2020	$ 2,280
23619	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1955	65	2020	$ 6,840

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
24077	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1956	64	2020	$ 3,420
24293	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2020	$ 3,420
8485	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1959	61	2020	$ 4,560
24097	Monitor and Forecast	260	Asbestos Cement	6	40-60yr	1960	60	2020	$ 29,640
10860	Monitor and Forecast	260	Asbestos Cement	6	40-60yr	1960	60	2020	$ 29,640
11060	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1960	60	2020	$ 4,560
11244	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1962	58	2020	$ 4,560
8330	Monitor and Forecast	340	Asbestos Cement	8	40-60yr	1970	50	2020	$ 51,680
23429	Monitor and Forecast	490	Asbestos Cement	6	>60yr	1959	61	2020	$ 55,860
23567	Monitor and Forecast	690	Asbestos Cement	6	>60yr	1959	61	2020	$ 78,660
23074	Monitor and Forecast	590	Asbestos Cement	6	>60yr	1959	61	2020	$ 67,260
24034	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1970	50	2020	$ 4,560
24174	Monitor and Forecast	640	Asbestos Cement	8	40-60yr	1970	50	2020	$ 97,280
19483	Monitor and Forecast	1270	Asbestos Cement	6	>60yr	1953	67	2020	$ 144,780
19480	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1953	67	2020	$ 7,980
22886	Monitor and Forecast	1100	Asbestos Cement	10	>60yr	1954	66	2020	$ 209,000
23771	Monitor and Forecast	270	Asbestos Cement	6	>60yr	1954	66	2020	$ 30,780
23501	Monitor and Forecast	200	Asbestos Cement	4	>60yr	1954	66	2020	$ 15,200
23507	Monitor and Forecast	970	Asbestos Cement	8	>60yr	1954	66	2020	$ 147,440
23759	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1954	66	2020	$ 3,040
23498	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1954	66	2020	$ 4,560
23751	Monitor and Forecast	60	Asbestos Cement	4	>60yr	1954	66	2020	$ 4,560
23643	Monitor and Forecast	740	Asbestos Cement	6	>60yr	1954	66	2020	$ 84,360
24237	Monitor and Forecast	270	Asbestos Cement	10	>60yr	1954	66	2020	$ 51,300
24362	Monitor and Forecast	190	Asbestos Cement	8	>60yr	1954	66	2020	$ 28,880
27488	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1954	66	2020	$ 3,040
23143	Monitor and Forecast	30	Asbestos Cement	10	>60yr	1955	65	2020	$ 5,700
23157	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1955	65	2020	$ 6,840
23618	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1955	65	2020	$ 3,420
23736	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1955	65	2020	$ 4,560
23866	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1955	65	2020	$ 4,560
23885	Monitor and Forecast	330	Asbestos Cement	6	>60yr	1955	65	2020	$ 37,620
24075	Monitor and Forecast	620	Asbestos Cement	6	>60yr	1956	64	2020	$ 70,680
23668	Monitor and Forecast	800	Asbestos Cement	6	>60yr	1959	61	2020	$ 91,200
23674	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2020	$ 3,420
23693	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1959	61	2020	$ 2,280
23664	Monitor and Forecast	290	Asbestos Cement	6	>60yr	1959	61	2020	$ 33,060
23840	Monitor and Forecast	240	Asbestos Cement	6	>60yr	1959	61	2020	$ 27,360
23849	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2020	$ 3,420
24299	Monitor and Forecast	560	Asbestos Cement	6	>60yr	1959	61	2020	$ 63,840
24308	Monitor and Forecast	300	Asbestos Cement	6	>60yr	1959	61	2020	$ 34,200
23220	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2020	$ 4,560
23223	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2020	$ 3,420
23225	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1959	61	2020	$ 4,560
24057	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2020	$ 3,420

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
10553	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2020	$ 4,560
10855	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1959	61	2020	$ 6,840
22953	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2020	$ 3,420
24148	Monitor and Forecast	560	Asbestos Cement	6	40-60yr	1960	60	2020	$ 63,840
19637	Monitor and Forecast	730	Asbestos Cement	6	40-60yr	1960	60	2020	$ 83,220
19643	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1960	60	2020	$ 33,440
24099	Monitor and Forecast	370	Asbestos Cement	6	40-60yr	1960	60	2020	$ 42,180
10817	Monitor and Forecast	590	Asbestos Cement	8	40-60yr	1961	59	2020	$ 89,680
11228	Monitor and Forecast	700	Asbestos Cement	6	40-60yr	1961	59	2020	$ 79,800
19867	Monitor and Forecast	10	Asbestos Cement	6	40-60yr	1962	58	2020	$ 1,140
19873	Monitor and Forecast	10	Asbestos Cement	6	40-60yr	1962	58	2020	$ 1,140
11245	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1962	58	2020	$ 5,700
20272	Monitor and Forecast	510	Asbestos Cement	8	40-60yr	1962	58	2020	$ 77,520
23419	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1963	57	2020	$ 3,420
20729	Monitor and Forecast	320	Asbestos Cement	6	40-60yr	1963	57	2020	$ 36,480
23616	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1955	65	2020	$ 41,040
24284	Monitor and Forecast	10	Asbestos Cement	8	40-60yr	1969	51	2020	$ 1,520
23965	Monitor and Forecast	1130	Asbestos Cement	8	40-60yr	1970	50	2020	$ 171,760
5509	Repair/Replace on Failure	190	Ductile Iron	10	20-40yr	1986	34	2021	$ 36,100
11863	Repair/Replace on Failure	40	Ductile Iron	6	20-40yr	1986	34	2021	$ 4,560
3999	Repair/Replace on Failure	220	Ductile Iron	8	40-60yr	1979	41	2021	$ 33,440
5511	Repair/Replace on Failure	580	Ductile Iron	10	20-40yr	1986	34	2021	$ 110,200
5827	Repair/Replace on Failure	90	Asbestos Cement	6	40-60yr	1971	49	2021	$ 10,260
9145	Repair/Replace on Failure	60	Ductile Iron	10	20-40yr	1986	34	2021	$ 11,400
19408	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1986	34	2021	$ 7,600
19409	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1986	34	2021	$ 3,420
19413	Repair/Replace on Failure	120	Ductile Iron	8	20-40yr	1986	34	2021	$ 18,240
19415	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1986	34	2021	$ 3,420
6272	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1979	41	2021	$ 4,560
9285	Repair/Replace on Failure	80	Ductile Iron	6	40-60yr	1979	41	2021	$ 9,120
5506	Repair/Replace on Failure	390	Ductile Iron	10	20-40yr	1986	34	2021	$ 74,100
19527	Repair/Replace on Failure	600	Ductile Iron	6	20-40yr	1986	34	2021	$ 68,400
9144	Repair/Replace on Failure	60	Ductile Iron	10	20-40yr	1986	34	2021	$ 11,400
6924	Repair/Replace on Failure	450	Ductile Iron	8	40-60yr	1979	41	2021	$ 68,400
7007	Repair/Replace on Failure	620	Ductile Iron	8	40-60yr	1979	41	2021	$ 94,240
69	Repair/Replace on Failure	560	Ductile Iron	6	20-40yr	1984	36	2021	$ 63,840
7074	Repair/Replace on Failure	50	Cast iron	6	20-40yr	1986	34	2021	$ 5,700
7076	Repair/Replace on Failure	470	Cast iron	6	20-40yr	1986	34	2021	$ 53,580
9310	Repair/Replace on Failure	40	Cast iron	6	20-40yr	1986	34	2021	$ 4,560
10197	Repair/Replace on Failure	30	Cast iron	6	20-40yr	1986	34	2021	$ 3,420
22883	Repair/Replace on Failure	30	Ductile Iron	6	>60yr	1955	65	2021	$ 3,420
27454	Repair/Replace on Failure	80	Ductile Iron	6	>60yr	1955	65	2021	$ 9,120
7078	Repair/Replace on Failure	280	Cast iron	6	20-40yr	1986	34	2021	$ 31,920
9312	Repair/Replace on Failure	40	Cast iron	6	20-40yr	1986	34	2021	$ 4,560
9384	Repair/Replace on Failure	30	Cast iron	6	20-40yr	1986	34	2021	$ 3,420

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
19410	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1986	34	2021	$ 3,040
19673	Repair/Replace on Failure	370	Ductile Iron	8	20-40yr	1986	34	2021	$ 56,240
7257	Repair/Replace on Failure	50	Ductile Iron	8	40-60yr	1979	41	2021	$ 7,600
8070	Repair/Replace on Failure	20	Ductile Iron	8	40-60yr	1979	41	2021	$ 3,040
15883	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2021	$ 3,040
15887	Repair/Replace on Failure	120	Ductile Iron	8	20-40yr	1984	36	2021	$ 18,240
23918	Repair/Replace on Failure	380	Ductile Iron	10	40-60yr	1962	58	2021	$ 72,200
15896	Repair/Replace on Failure	40	Ductile Iron	6	20-40yr	1984	36	2021	$ 4,560
21627	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1984	36	2021	$ 3,420
22591	Repair/Replace on Failure	860	Ductile Iron	8	20-40yr	1986	34	2021	$ 130,720
22374	Repair/Replace on Failure	220	Ductile Iron	8	20-40yr	1986	34	2021	$ 33,440
21563	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1983	37	2021	$ 6,080
22879	Repair/Replace on Failure	250	Ductile Iron	8	>60yr	1955	65	2021	$ 38,000
22873	Repair/Replace on Failure	240	Ductile Iron	8	>60yr	1958	62	2021	$ 36,480
7965	Repair/Replace on Failure	70	Ductile Iron	8	40-60yr	1979	41	2021	$ 10,640
18783	Repair/Replace on Failure	80	Ductile Iron	8	20-40yr	1984	36	2021	$ 12,160
18875	Repair/Replace on Failure	30	Ductile Iron	4	40-60yr	1979	41	2021	$ 2,280
22375	Repair/Replace on Failure	220	Ductile Iron	8	20-40yr	1986	34	2021	$ 33,440
22377	Repair/Replace on Failure	370	Ductile Iron	8	20-40yr	1986	34	2021	$ 56,240
22393	Repair/Replace on Failure	530	Ductile Iron	8	20-40yr	1986	34	2021	$ 80,560
5250	Repair/Replace on Failure	410	Ductile Iron	10	20-40yr	1986	34	2021	$ 77,900
23834	Repair/Replace on Failure	480	Ductile Iron	8	20-40yr	1983	37	2021	$ 72,960
18784	Repair/Replace on Failure	220	Ductile Iron	8	20-40yr	1984	36	2021	$ 33,440
9888	Repair/Replace on Failure	340	Ductile Iron	8	40-60yr	1975	45	2021	$ 51,680
9889	Repair/Replace on Failure	180	Ductile Iron	8	40-60yr	1975	45	2021	$ 27,360
23227	Repair/Replace on Failure	50	Ductile Iron	8	40-60yr	1975	45	2021	$ 7,600
18849	Repair/Replace on Failure	220	Ductile Iron	8	40-60yr	1979	41	2021	$ 33,440
18851	Repair/Replace on Failure	820	Ductile Iron	8	40-60yr	1979	41	2021	$ 124,640
18885	Repair/Replace on Failure	20	Ductile Iron	4	40-60yr	1979	41	2021	$ 1,520
21541	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1983	37	2021	$ 7,600
21550	Repair/Replace on Failure	300	Ductile Iron	8	20-40yr	1983	37	2021	$ 45,600
21559	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1983	37	2021	$ 6,080
21562	Repair/Replace on Failure	180	Ductile Iron	6	20-40yr	1983	37	2021	$ 20,520
21565	Repair/Replace on Failure	120	Ductile Iron	8	20-40yr	1983	37	2021	$ 18,240
21549	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1983	37	2021	$ 4,560
21558	Repair/Replace on Failure	300	Ductile Iron	8	20-40yr	1983	37	2021	$ 45,600
15654	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2021	$ 6,080
15851	Repair/Replace on Failure	370	Ductile Iron	8	20-40yr	1984	36	2021	$ 56,240
15899	Repair/Replace on Failure	120	Ductile Iron	8	20-40yr	1984	36	2021	$ 18,240
21852	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2021	$ 6,080
21855	Repair/Replace on Failure	380	Ductile Iron	8	20-40yr	1984	36	2021	$ 57,760
21862	Repair/Replace on Failure	440	Ductile Iron	8	20-40yr	1984	36	2021	$ 66,880
21632	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2021	$ 6,080
17552	Repair/Replace on Failure	250	Ductile Iron	8	20-40yr	1984	36	2021	$ 38,000
18779	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2021	$ 4,560

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
18787	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2021	$ 3,040
27557	Repair/Replace on Failure	490	Ductile Iron	8	20-40yr	1984	36	2021	$ 74,480
22378	Repair/Replace on Failure	20	Ductile Iron	4	20-40yr	1986	34	2021	$ 1,520
22382	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1986	34	2021	$ 6,080
22386	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1986	34	2021	$ 4,560
22387	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1986	34	2021	$ 4,560
22390	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1986	34	2021	$ 4,560
22394	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1986	34	2021	$ 4,560
22597	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1986	34	2021	$ 7,600
7598	Programmed Rehab/Replace	200	Ductile Iron	16	40-60yr	1973	47	2021	$ 60,800
621	Programmed Rehab/Replace	50	Ductile Iron	16	40-60yr	1972	48	2021	$ 15,200
7319	Programmed Rehab/Replace	30	Ductile Iron	16	40-60yr	1973	47	2021	$ 9,120
2675	Monitor and Forecast	60	Cast iron	8	40-60yr	1971	49	2021	$ 9,120
5373	Monitor and Forecast	70	Ductile Iron	8	40-60yr	1971	49	2021	$ 10,640
23502	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1954	66	2021	$ 3,040
4061	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1971	49	2021	$ 3,420
5383	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1971	49	2021	$ 4,560
4062	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1971	49	2021	$ 4,560
4063	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1971	49	2021	$ 4,560
23747	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1954	66	2021	$ 38,000
23559	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2021	$ 27,360
23843	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1959	61	2021	$ 3,040
23853	Monitor and Forecast	100	Asbestos Cement	6	>60yr	1959	61	2021	$ 11,400
23948	Monitor and Forecast	40	Asbestos Cement	8	>60yr	1959	61	2021	$ 6,080
6083	Monitor and Forecast	70	Asbestos Cement	8	40-60yr	1971	49	2021	$ 10,640
7689	Monitor and Forecast	680	Asbestos Cement	8	40-60yr	1971	49	2021	$ 103,360
23861	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1955	65	2021	$ 4,560
19545	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1965	55	2021	$ 7,600
23403	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1966	54	2021	$ 2,280
3448	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
3449	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1971	49	2021	$ 4,560
3451	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1971	49	2021	$ 7,600
7690	Monitor and Forecast	100	Asbestos Cement	8	40-60yr	1971	49	2021	$ 15,200
11198	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1971	49	2021	$ 3,040
6076	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1971	49	2021	$ 12,160
8483	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1971	49	2021	$ 6,840
23990	Monitor and Forecast	250	Ductile Iron	8	>60yr	1956	64	2021	$ 38,000
5984	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1971	49	2021	$ 7,600
6310	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
6315	Monitor and Forecast	150	Asbestos Cement	8	40-60yr	1971	49	2021	$ 22,800
9314	Monitor and Forecast	50	Asbestos Cement	8	>60yr	1953	67	2021	$ 7,600
23023	Monitor and Forecast	10	Asbestos Cement	8	>60yr	1954	66	2021	$ 1,520
23889	Monitor and Forecast	90	Asbestos Cement	6	>60yr	1954	66	2021	$ 10,260
23890	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1954	66	2021	$ 39,520
26016	Monitor and Forecast	220	Asbestos Cement	6	>60yr	1954	66	2021	$ 25,080

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
22958	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1963	57	2021	$ 4,560
7113	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1971	49	2021	$ 12,160
7116	Monitor and Forecast	150	Asbestos Cement	8	40-60yr	1971	49	2021	$ 22,800
7119	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1971	49	2021	$ 3,040
18373	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1971	49	2021	$ 3,420
5304	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
5370	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
23075	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1959	61	2021	$ 5,700
23411	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1963	57	2021	$ 4,560
23801	Monitor and Forecast	870	Asbestos Cement	6	40-60yr	1964	56	2021	$ 99,180
23750	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1954	66	2021	$ 4,560
22877	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1954	66	2021	$ 5,700
23246	Monitor and Forecast	340	Asbestos Cement	10	>60yr	1955	65	2021	$ 64,600
23274	Monitor and Forecast	20	Asbestos Cement	10	>60yr	1955	65	2021	$ 3,800
24347	Monitor and Forecast	900	Asbestos Cement	10	>60yr	1955	65	2021	$ 171,000
8919	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1959	61	2021	$ 6,840
10274	Monitor and Forecast	60	Asbestos Cement	10	>60yr	1959	61	2021	$ 11,400
23085	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1959	61	2021	$ 5,700
23661	Monitor and Forecast	830	Asbestos Cement	6	>60yr	1959	61	2021	$ 94,620
23797	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1964	56	2021	$ 2,280
6109	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1971	49	2021	$ 9,120
7115	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1971	49	2021	$ 3,040
7117	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1971	49	2021	$ 36,480
7126	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1971	49	2021	$ 13,680
7128	Monitor and Forecast	150	Asbestos Cement	8	40-60yr	1971	49	2021	$ 22,800
18379	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1971	49	2021	$ 4,560
23470	Monitor and Forecast	400	Asbestos Cement	8	40-60yr	1971	49	2021	$ 60,800
6007	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1971	49	2021	$ 7,600
6093	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
6095	Monitor and Forecast	550	Asbestos Cement	8	40-60yr	1971	49	2021	$ 83,600
6304	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1971	49	2021	$ 24,320
6941	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
6947	Monitor and Forecast	370	Asbestos Cement	8	40-60yr	1971	49	2021	$ 56,240
7465	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1971	49	2021	$ 54,720
8183	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
8298	Monitor and Forecast	600	Asbestos Cement	8	40-60yr	1971	49	2021	$ 91,200
8299	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1971	49	2021	$ 13,680
18365	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1971	49	2021	$ 3,420
18366	Monitor and Forecast	90	Asbestos Cement	6	40-60yr	1971	49	2021	$ 10,260
18374	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1971	49	2021	$ 4,560
6072	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1971	49	2021	$ 12,160
6074	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1971	49	2021	$ 24,320
6094	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1971	49	2021	$ 4,560
6582	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1971	49	2021	$ 54,720
6587	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1971	49	2021	$ 9,120

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
7456	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1971	49	2021	$ 24,320
7462	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1971	49	2021	$ 4,560
7464	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1971	49	2021	$ 9,120
7788	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1971	49	2021	$ 28,880
8251	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1971	49	2021	$ 7,600
8555	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1971	49	2021	$ 2,280
5372	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1971	49	2021	$ 9,120
6201	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1971	49	2021	$ 38,000
23471	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1971	49	2021	$ 45,600
7717	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1954	66	2021	$ 3,040
2677	Monitor and Forecast	360	Cast iron	8	40-60yr	1971	49	2021	$ 54,720
24224	Monitor and Forecast	700	Asbestos Cement	6	>60yr	1959	61	2021	$ 79,800
23574	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2021	$ 4,560
10806	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2021	$ 3,420
19640	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1960	60	2021	$ 3,040
18148	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1971	49	2021	$ 41,040
18149	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1971	49	2021	$ 54,720
18150	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1971	49	2021	$ 2,280
18352	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1971	49	2021	$ 38,000
18354	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1971	49	2021	$ 4,560
18355	Monitor and Forecast	570	Asbestos Cement	6	40-60yr	1971	49	2021	$ 64,980
18381	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1971	49	2021	$ 4,560
23266	Monitor and Forecast	800	Ductile Iron	6	>60yr	1955	65	2021	$ 91,200
23597	Monitor and Forecast	100	Asbestos Cement	4	>60yr	1953	67	2021	$ 7,600
23004	Monitor and Forecast	470	Asbestos Cement	6	>60yr	1954	66	2021	$ 53,580
23018	Monitor and Forecast	210	Asbestos Cement	3	>60yr	1954	66	2021	$ 11,970
23811	Monitor and Forecast	610	Ductile Iron	6	40-60yr	1964	56	2021	$ 69,540
19487	Monitor and Forecast	1250	Asbestos Cement	6	>60yr	1953	67	2021	$ 142,500
22888	Monitor and Forecast	230	Asbestos Cement	8	>60yr	1954	66	2021	$ 34,960
23238	Monitor and Forecast	590	Asbestos Cement	6	>60yr	1955	65	2021	$ 67,260
23247	Monitor and Forecast	360	Asbestos Cement	10	>60yr	1955	65	2021	$ 68,400
23601	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1955	65	2021	$ 3,040
23240	Monitor and Forecast	1000	Asbestos Cement	6	>60yr	1955	65	2021	$ 114,000
23848	Monitor and Forecast	900	Asbestos Cement	6	>60yr	1959	61	2021	$ 102,600
24162	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1959	61	2021	$ 2,280
10545	Monitor and Forecast	10	Asbestos Cement	8	>60yr	1959	61	2021	$ 1,520
24101	Monitor and Forecast	290	Asbestos Cement	6	40-60yr	1960	60	2021	$ 33,060
24147	Monitor and Forecast	520	Asbestos Cement	6	40-60yr	1960	60	2021	$ 59,280
19696	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1962	58	2021	$ 4,560
23413	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1963	57	2021	$ 3,420
7372	Monitor and Forecast	440	Asbestos Cement	8	40-60yr	1971	49	2021	$ 66,880
23679	Monitor and Forecast	410	Asbestos Cement	6	>60yr	1959	61	2021	$ 46,740
22932	Monitor and Forecast	1120	Asbestos Cement	8	>60yr	1959	61	2021	$ 170,240
10862	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1960	60	2021	$ 4,560
23412	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1963	57	2021	$ 3,420

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
4042	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1971	49	2021	$ 13,680
23767	Monitor and Forecast	190	Asbestos Cement	6	>60yr	1954	66	2021	$ 21,660
23740	Monitor and Forecast	880	Asbestos Cement	6	>60yr	1954	66	2021	$ 100,320
23752	Monitor and Forecast	780	Asbestos Cement	6	>60yr	1954	66	2021	$ 88,920
22906	Monitor and Forecast	50	Asbestos Cement	8	>60yr	1954	66	2021	$ 7,600
24257	Monitor and Forecast	1240	Asbestos Cement	6	>60yr	1954	66	2021	$ 141,360
24342	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1954	66	2021	$ 3,420
24376	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1954	66	2021	$ 2,280
27484	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1954	66	2021	$ 4,560
23151	Monitor and Forecast	50	Asbestos Cement	3	>60yr	1955	65	2021	$ 2,850
23178	Monitor and Forecast	240	Asbestos Cement	8	>60yr	1955	65	2021	$ 36,480
23181	Monitor and Forecast	160	Asbestos Cement	10	>60yr	1955	65	2021	$ 30,400
23265	Monitor and Forecast	60	Asbestos Cement	10	>60yr	1955	65	2021	$ 11,400
23609	Monitor and Forecast	260	Asbestos Cement	6	>60yr	1955	65	2021	$ 29,640
24343	Monitor and Forecast	560	Asbestos Cement	6	>60yr	1955	65	2021	$ 63,840
23883	Monitor and Forecast	300	Asbestos Cement	6	>60yr	1955	65	2021	$ 34,200
24087	Monitor and Forecast	950	Asbestos Cement	6	>60yr	1956	64	2021	$ 108,300
24106	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1959	61	2021	$ 4,560
23586	Monitor and Forecast	900	Asbestos Cement	6	>60yr	1959	61	2021	$ 102,600
23552	Monitor and Forecast	200	Asbestos Cement	8	>60yr	1959	61	2021	$ 30,400
23646	Monitor and Forecast	970	Asbestos Cement	6	>60yr	1959	61	2021	$ 110,580
23941	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2021	$ 4,560
22995	Monitor and Forecast	250	Asbestos Cement	6	>60yr	1959	61	2021	$ 28,500
23119	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2021	$ 3,420
23192	Monitor and Forecast	670	Asbestos Cement	6	>60yr	1959	61	2021	$ 76,380
24035	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2021	$ 3,420
11251	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2021	$ 41,040
23847	Monitor and Forecast	260	Asbestos Cement	6	>60yr	1959	61	2021	$ 29,640
23942	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2021	$ 3,420
23544	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2021	$ 3,420
23675	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2021	$ 4,560
23684	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2021	$ 4,560
23689	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1959	61	2021	$ 7,980
11448	Monitor and Forecast	380	Asbestos Cement	6	40-60yr	1960	60	2021	$ 43,320
9891	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1960	60	2021	$ 4,560
9367	Monitor and Forecast	260	Asbestos Cement	6	40-60yr	1960	60	2021	$ 29,640
24153	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2021	$ 3,420
19631	Monitor and Forecast	310	Asbestos Cement	6	40-60yr	1960	60	2021	$ 35,340
11236	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2021	$ 3,420
10833	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1961	59	2021	$ 36,480
11409	Monitor and Forecast	270	Asbestos Cement	6	40-60yr	1961	59	2021	$ 30,780
11401	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1961	59	2021	$ 3,420
19688	Monitor and Forecast	80	Asbestos Cement	6	40-60yr	1962	58	2021	$ 9,120
19707	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1962	58	2021	$ 4,560
20736	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1963	57	2021	$ 3,040

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
2676	Monitor and Forecast	740	Asbestos Cement	8	40-60yr	1971	49	2021	$ 112,480
7692	Monitor and Forecast	320	Asbestos Cement	8	40-60yr	1971	49	2021	$ 48,640
18151	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1971	49	2021	$ 4,560
18353	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1971	49	2021	$ 39,520
18356	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1971	49	2021	$ 4,560
18357	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1971	49	2021	$ 3,040
18358	Monitor and Forecast	500	Asbestos Cement	8	40-60yr	1971	49	2021	$ 76,000
18369	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
18372	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1971	49	2021	$ 25,840
18377	Monitor and Forecast	130	Asbestos Cement	6	40-60yr	1971	49	2021	$ 14,820
18380	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1971	49	2021	$ 3,040
18385	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1971	49	2021	$ 4,560
18386	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1971	49	2021	$ 4,560
18387	Monitor and Forecast	460	Asbestos Cement	8	40-60yr	1971	49	2021	$ 69,920
18388	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1971	49	2021	$ 30,400
18391	Monitor and Forecast	880	Asbestos Cement	6	40-60yr	1971	49	2021	$ 100,320
18392	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1971	49	2021	$ 4,560
18393	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
18395	Monitor and Forecast	970	Asbestos Cement	8	40-60yr	1971	49	2021	$ 147,440
18396	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
6313	Monitor and Forecast	830	Asbestos Cement	8	40-60yr	1971	49	2021	$ 126,160
18368	Monitor and Forecast	620	Asbestos Cement	6	40-60yr	1971	49	2021	$ 70,680
18371	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1971	49	2021	$ 38,000
18378	Monitor and Forecast	670	Asbestos Cement	6	40-60yr	1971	49	2021	$ 76,380
18384	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1971	49	2021	$ 4,560
18389	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1971	49	2021	$ 3,420
6605	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1971	49	2021	$ 3,040
7463	Monitor and Forecast	510	Asbestos Cement	8	40-60yr	1971	49	2021	$ 77,520
9629	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1971	49	2021	$ 6,080
16413	Repair/Replace on Failure	160	Ductile Iron	8	40-60yr	1979	41	2022	$ 24,320
20199	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1980	40	2022	$ 4,560
8881	Repair/Replace on Failure	240	Ductile Iron	6	40-60yr	1979	41	2022	$ 27,360
4515	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1987	33	2022	$ 7,600
23037	Repair/Replace on Failure	60	Ductile Iron	8	20-40yr	1987	33	2022	$ 9,120
23039	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1987	33	2022	$ 7,600
8558	Repair/Replace on Failure	30	Cast iron	6	40-60yr	1979	41	2022	$ 3,420
23228	Repair/Replace on Failure	250	Ductile Iron	8	40-60yr	1975	45	2022	$ 38,000
10113	Repair/Replace on Failure	290	Ductile Iron	8	40-60yr	1979	41	2022	$ 44,080
8548	Repair/Replace on Failure	480	Ductile Iron	10	40-60yr	1962	58	2022	$ 91,200
9752	Repair/Replace on Failure	60	Ductile Iron	8	40-60yr	1974	46	2022	$ 9,120
8967	Repair/Replace on Failure	700	Cast iron	6	40-60yr	1979	41	2022	$ 79,800
9085	Repair/Replace on Failure	20	Ductile Iron	8	40-60yr	1979	41	2022	$ 3,040
25904	Repair/Replace on Failure	300	Ductile Iron	8	40-60yr	1979	41	2022	$ 45,600
25906	Repair/Replace on Failure	10	Ductile Iron	8	40-60yr	1979	41	2022	$ 1,520
26906	Repair/Replace on Failure	20	Ductile Iron	6	40-60yr	1979	41	2022	$ 2,280

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
9210	Repair/Replace on Failure	290	Ductile Iron	6	40-60yr	1979	41	2022	$ 33,060
17561	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1984	36	2022	$ 7,600
23983	Repair/Replace on Failure	20	Ductile Iron	6	>60yr	1956	64	2022	$ 2,280
17555	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2022	$ 6,080
21566	Repair/Replace on Failure	120	Ductile Iron	8	20-40yr	1983	37	2022	$ 18,240
21567	Repair/Replace on Failure	40	Ductile Iron	6	20-40yr	1983	37	2022	$ 4,560
9663	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1979	41	2022	$ 4,560
8705	Repair/Replace on Failure	60	Ductile Iron	10	40-60yr	1979	41	2022	$ 11,400
15838	Repair/Replace on Failure	300	Ductile Iron	8	20-40yr	1984	36	2022	$ 45,600
21818	Repair/Replace on Failure	390	Ductile Iron	8	20-40yr	1984	36	2022	$ 59,280
13239	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1980	40	2022	$ 3,420
13242	Repair/Replace on Failure	200	Ductile Iron	6	20-40yr	1980	40	2022	$ 22,800
18782	Repair/Replace on Failure	380	Ductile Iron	8	20-40yr	1984	36	2022	$ 57,760
16298	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1974	46	2022	$ 4,560
20197	Repair/Replace on Failure	320	Ductile Iron	4	20-40yr	1980	40	2022	$ 24,320
21553	Repair/Replace on Failure	200	Ductile Iron	8	20-40yr	1983	37	2022	$ 30,400
15831	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1974	46	2022	$ 4,560
15861	Repair/Replace on Failure	320	Ductile Iron	8	20-40yr	1984	36	2022	$ 48,640
13245	Repair/Replace on Failure	40	Ductile Iron	6	20-40yr	1980	40	2022	$ 4,560
13251	Repair/Replace on Failure	250	Ductile Iron	8	20-40yr	1980	40	2022	$ 38,000
15829	Repair/Replace on Failure	20	Ductile Iron	8	40-60yr	1974	46	2022	$ 3,040
9176	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1974	46	2022	$ 4,560
10597	Repair/Replace on Failure	20	Ductile Iron	8	40-60yr	1974	46	2022	$ 3,040
21622	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2022	$ 4,560
18765	Repair/Replace on Failure	200	Ductile Iron	8	20-40yr	1984	36	2022	$ 30,400
18768	Repair/Replace on Failure	140	Ductile Iron	8	20-40yr	1984	36	2022	$ 21,280
16046	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1974	46	2022	$ 6,080
9747	Repair/Replace on Failure	730	Ductile Iron	8	40-60yr	1974	46	2022	$ 110,960
16418	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1979	41	2022	$ 6,080
16427	Repair/Replace on Failure	560	Ductile Iron	8	40-60yr	1979	41	2022	$ 85,120
7990	Repair/Replace on Failure	60	Ductile Iron	8	40-60yr	1979	41	2022	$ 9,120
12037	Repair/Replace on Failure	150	Ductile Iron	10	40-60yr	1979	41	2022	$ 28,500
20207	Repair/Replace on Failure	470	Ductile Iron	8	20-40yr	1980	40	2022	$ 71,440
20189	Repair/Replace on Failure	130	Ductile Iron	8	20-40yr	1980	40	2022	$ 19,760
20206	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1980	40	2022	$ 6,080
21829	Repair/Replace on Failure	520	Ductile Iron	8	20-40yr	1984	36	2022	$ 79,040
15843	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2022	$ 6,080
15850	Repair/Replace on Failure	230	Ductile Iron	8	20-40yr	1984	36	2022	$ 34,960
15898	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2022	$ 3,040
16112	Repair/Replace on Failure	10	Ductile Iron	6	20-40yr	1984	36	2022	$ 1,140
21822	Repair/Replace on Failure	300	Ductile Iron	8	20-40yr	1984	36	2022	$ 45,600
21825	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2022	$ 4,560
21831	Repair/Replace on Failure	270	Ductile Iron	8	20-40yr	1984	36	2022	$ 41,040
21835	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2022	$ 4,560
15863	Repair/Replace on Failure	360	Ductile Iron	8	20-40yr	1984	36	2022	$ 54,720

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
15867	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2022	$ 6,080
21813	Repair/Replace on Failure	40	Ductile Iron	4	20-40yr	1984	36	2022	$ 3,040
21826	Repair/Replace on Failure	230	Ductile Iron	8	20-40yr	1984	36	2022	$ 34,960
21833	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2022	$ 3,040
17566	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2022	$ 4,560
18788	Repair/Replace on Failure	180	Ductile Iron	8	20-40yr	1984	36	2022	$ 27,360
18789	Repair/Replace on Failure	200	Ductile Iron	8	20-40yr	1984	36	2022	$ 30,400
18795	Repair/Replace on Failure	200	Ductile Iron	8	20-40yr	1984	36	2022	$ 30,400
23264	Repair/Replace on Failure	70	Ductile Iron	6	>60yr	1955	65	2022	$ 7,980
9628	Programmed Rehab/Replace	30	Ductile Iron	18	40-60yr	1962	58	2022	$ 10,260
5502	Programmed Rehab/Replace	450	Ductile Iron	10	20-40yr	1986	34	2022	$ 85,500
5668	Programmed Rehab/Replace	50	Ductile Iron	16	40-60yr	1971	49	2022	$ 15,200
7597	Programmed Rehab/Replace	360	Ductile Iron	16	40-60yr	1973	47	2022	$ 109,440
8949	Monitor and Forecast	100	Ductile Iron	8	40-60yr	1972	48	2022	$ 15,200
24413	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2022	$ 3,420
8442	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
23113	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1955	65	2022	$ 6,840
11210	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1959	61	2022	$ 3,040
23702	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2022	$ 4,560
24285	Monitor and Forecast	100	Asbestos Cement	6	>60yr	1959	61	2022	$ 11,400
22952	Monitor and Forecast	110	Asbestos Cement	8	40-60yr	1960	60	2022	$ 16,720
22969	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1960	60	2022	$ 6,840
20015	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1962	58	2022	$ 9,120
20493	Monitor and Forecast	90	Asbestos Cement	6	40-60yr	1963	57	2022	$ 10,260
8795	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1972	48	2022	$ 54,720
18615	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
9291	Monitor and Forecast	350	Asbestos Cement	8	40-60yr	1972	48	2022	$ 53,200
11602	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1972	48	2022	$ 2,280
17658	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1972	48	2022	$ 7,600
18124	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1972	48	2022	$ 5,700
9528	Monitor and Forecast	30	Ductile Iron	6	>60yr	1955	65	2022	$ 3,420
11252	Monitor and Forecast	80	Asbestos Cement	8	>60yr	1954	66	2022	$ 12,160
23013	Monitor and Forecast	640	Asbestos Cement	8	>60yr	1954	66	2022	$ 97,280
23027	Monitor and Forecast	40	Asbestos Cement	8	>60yr	1954	66	2022	$ 6,080
23607	Monitor and Forecast	110	Asbestos Cement	8	>60yr	1953	67	2022	$ 16,720
9456	Monitor and Forecast	510	Asbestos Cement	8	40-60yr	1972	48	2022	$ 77,520
23516	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1953	67	2022	$ 3,420
23486	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1954	66	2022	$ 7,980
23212	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2022	$ 3,420
8071	Monitor and Forecast	70	Asbestos Cement	8	40-60yr	1972	48	2022	$ 10,640
8792	Monitor and Forecast	680	Asbestos Cement	8	40-60yr	1972	48	2022	$ 103,360
8786	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1972	48	2022	$ 19,760
23513	Monitor and Forecast	720	Asbestos Cement	6	>60yr	1953	67	2022	$ 82,080
22982	Monitor and Forecast	200	Asbestos Cement	3	>60yr	1954	66	2022	$ 11,400
23624	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1953	67	2022	$ 7,980

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
27686	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1953	67	2022	$ 7,980
23742	Monitor and Forecast	80	Asbestos Cement	6	>60yr	1954	66	2022	$ 9,120
23716	Monitor and Forecast	250	Asbestos Cement	6	>60yr	1954	66	2022	$ 28,500
24352	Monitor and Forecast	60	Asbestos Cement	10	>60yr	1954	66	2022	$ 11,400
23153	Monitor and Forecast	280	Asbestos Cement	10	>60yr	1955	65	2022	$ 53,200
23174	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1955	65	2022	$ 3,420
23734	Monitor and Forecast	1330	Asbestos Cement	8	>60yr	1955	65	2022	$ 202,160
24365	Monitor and Forecast	30	Asbestos Cement	10	>60yr	1955	65	2022	$ 5,700
24366	Monitor and Forecast	280	Asbestos Cement	10	>60yr	1955	65	2022	$ 53,200
23090	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1959	61	2022	$ 6,840
19697	Monitor and Forecast	100	Asbestos Cement	6	40-60yr	1962	58	2022	$ 11,400
19700	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1962	58	2022	$ 6,840
8763	Monitor and Forecast	190	Asbestos Cement	6	40-60yr	1964	56	2022	$ 21,660
8111	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1972	48	2022	$ 42,560
9481	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1972	48	2022	$ 7,600
7638	Monitor and Forecast	150	Asbestos Cement	8	40-60yr	1972	48	2022	$ 22,800
8115	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
8116	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1972	48	2022	$ 7,600
9413	Monitor and Forecast	460	Asbestos Cement	8	40-60yr	1972	48	2022	$ 69,920
9439	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1972	48	2022	$ 19,760
16857	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
18605	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1972	48	2022	$ 7,600
19256	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1972	48	2022	$ 33,440
8469	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
8475	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
8542	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1972	48	2022	$ 54,720
18121	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1972	48	2022	$ 19,760
18599	Monitor and Forecast	110	Asbestos Cement	6	40-60yr	1972	48	2022	$ 12,540
18602	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1972	48	2022	$ 7,600
18608	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1972	48	2022	$ 7,600
7000	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
9473	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1972	48	2022	$ 47,120
23057	Monitor and Forecast	670	Asbestos Cement	8	40-60yr	1972	48	2022	$ 101,840
19435	Monitor and Forecast	810	Asbestos Cement	8	40-60yr	1972	48	2022	$ 123,120
22979	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1954	66	2022	$ 4,560
22876	Monitor and Forecast	280	Asbestos Cement	6	>60yr	1954	66	2022	$ 31,920
24233	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1954	66	2022	$ 5,700
22887	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1955	65	2022	$ 4,560
23978	Monitor and Forecast	240	Asbestos Cement	6	>60yr	1956	64	2022	$ 27,360
23021	Monitor and Forecast	30	Asbestos Cement	3	>60yr	1954	66	2022	$ 1,710
23778	Monitor and Forecast	330	Asbestos Cement	8	>60yr	1954	66	2022	$ 50,160
22904	Monitor and Forecast	60	Asbestos Cement	8	>60yr	1958	62	2022	$ 9,120
23565	Monitor and Forecast	1040	Asbestos Cement	6	>60yr	1959	61	2022	$ 118,560
23564	Monitor and Forecast	280	Asbestos Cement	6	>60yr	1959	61	2022	$ 31,920
23141	Monitor and Forecast	840	Asbestos Cement	6	>60yr	1955	65	2022	$ 95,760

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
19641	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1960	60	2022	$ 19,760
9999	Monitor and Forecast	250	Asbestos Cement	6	40-60yr	1963	57	2022	$ 28,500
23800	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1964	56	2022	$ 3,420
18111	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1972	48	2022	$ 42,560
18123	Monitor and Forecast	180	Asbestos Cement	6	40-60yr	1972	48	2022	$ 20,520
18126	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1972	48	2022	$ 2,280
18613	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
18619	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1972	48	2022	$ 2,280
18627	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1972	48	2022	$ 44,080
18628	Monitor and Forecast	590	Asbestos Cement	8	40-60yr	1972	48	2022	$ 89,680
19427	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
8503	Monitor and Forecast	30	Ductile Iron	8	40-60yr	1972	48	2022	$ 4,560
15553	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1972	48	2022	$ 2,280
15554	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1972	48	2022	$ 5,700
16886	Monitor and Forecast	900	Asbestos Cement	6	40-60yr	1972	48	2022	$ 102,600
16888	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
17636	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1972	48	2022	$ 57,760
17646	Monitor and Forecast	990	Asbestos Cement	8	40-60yr	1972	48	2022	$ 150,480
18106	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1972	48	2022	$ 24,320
18103	Monitor and Forecast	180	Asbestos Cement	6	40-60yr	1972	48	2022	$ 20,520
18107	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
18125	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1972	48	2022	$ 45,600
18621	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
19426	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
19428	Monitor and Forecast	790	Asbestos Cement	6	40-60yr	1972	48	2022	$ 90,060
22846	Monitor and Forecast	190	Ductile Iron	8	40-60yr	1972	48	2022	$ 28,880
23526	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2022	$ 3,420
23095	Monitor and Forecast	600	Asbestos Cement	6	>60yr	1959	61	2022	$ 68,400
23043	Monitor and Forecast	990	Asbestos Cement	6	40-60yr	1963	57	2022	$ 112,860
23717	Monitor and Forecast	320	Asbestos Cement	6	>60yr	1954	66	2022	$ 36,480
23117	Monitor and Forecast	240	Asbestos Cement	10	>60yr	1955	65	2022	$ 45,600
23841	Monitor and Forecast	260	Asbestos Cement	6	>60yr	1959	61	2022	$ 29,640
23070	Monitor and Forecast	10	Asbestos Cement	8	>60yr	1959	61	2022	$ 1,520
23079	Monitor and Forecast	340	Asbestos Cement	6	>60yr	1959	61	2022	$ 38,760
23845	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1959	61	2022	$ 2,280
10557	Monitor and Forecast	210	Asbestos Cement	6	>60yr	1959	61	2022	$ 23,940
9006	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1960	60	2022	$ 4,560
9881	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1960	60	2022	$ 7,600
19690	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1962	58	2022	$ 3,420
23418	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1963	57	2022	$ 4,560
23096	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2022	$ 4,560
23196	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2022	$ 3,420
16895	Monitor and Forecast	610	Asbestos Cement	6	40-60yr	1972	48	2022	$ 69,540
17394	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1972	48	2022	$ 4,560
17396	Monitor and Forecast	1420	Asbestos Cement	6	40-60yr	1972	48	2022	$ 161,880

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
19251	Monitor and Forecast	580	Asbestos Cement	6	40-60yr	1972	48	2022	$ 66,120
19252	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
19255	Monitor and Forecast	700	Asbestos Cement	8	40-60yr	1972	48	2022	$ 106,400
19260	Monitor and Forecast	270	Asbestos Cement	6	40-60yr	1972	48	2022	$ 30,780
19261	Monitor and Forecast	960	Asbestos Cement	8	40-60yr	1972	48	2022	$ 145,920
19271	Monitor and Forecast	580	Asbestos Cement	6	40-60yr	1972	48	2022	$ 66,120
16897	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
16899	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
6999	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
19761	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
19776	Monitor and Forecast	180	Asbestos Cement	8	40-60yr	1972	48	2022	$ 27,360
19259	Monitor and Forecast	240	Asbestos Cement	6	40-60yr	1972	48	2022	$ 27,360
19265	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
8710	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
17397	Monitor and Forecast	630	Asbestos Cement	6	40-60yr	1972	48	2022	$ 71,820
17401	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1972	48	2022	$ 5,700
19272	Monitor and Forecast	260	Asbestos Cement	6	40-60yr	1972	48	2022	$ 29,640
19432	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1972	48	2022	$ 42,560
19263	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
19266	Monitor and Forecast	710	Asbestos Cement	6	40-60yr	1972	48	2022	$ 80,940
19267	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1972	48	2022	$ 26,220
19269	Monitor and Forecast	500	Asbestos Cement	6	40-60yr	1972	48	2022	$ 57,000
19429	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
19431	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1972	48	2022	$ 42,560
19433	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1972	48	2022	$ 5,700
19436	Monitor and Forecast	690	Asbestos Cement	6	40-60yr	1972	48	2022	$ 78,660
23628	Monitor and Forecast	30	Asbestos Cement	4	>60yr	1953	67	2022	$ 2,280
23492	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1954	66	2022	$ 41,040
23762	Monitor and Forecast	60	Asbestos Cement	8	>60yr	1954	66	2022	$ 9,120
23765	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1954	66	2022	$ 5,700
23772	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1954	66	2022	$ 6,840
23497	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1954	66	2022	$ 39,520
23757	Monitor and Forecast	50	Asbestos Cement	4	>60yr	1954	66	2022	$ 3,800
23780	Monitor and Forecast	60	Asbestos Cement	4	>60yr	1954	66	2022	$ 4,560
23781	Monitor and Forecast	250	Asbestos Cement	4	>60yr	1954	66	2022	$ 19,000
24227	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1954	66	2022	$ 5,700
24331	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1954	66	2022	$ 5,700
24336	Monitor and Forecast	270	Asbestos Cement	6	>60yr	1954	66	2022	$ 30,780
23611	Monitor and Forecast	1430	Asbestos Cement	8	>60yr	1955	65	2022	$ 217,360
23732	Monitor and Forecast	300	Asbestos Cement	8	>60yr	1955	65	2022	$ 45,600
23886	Monitor and Forecast	660	Asbestos Cement	6	>60yr	1955	65	2022	$ 75,240
23876	Monitor and Forecast	330	Asbestos Cement	6	>60yr	1955	65	2022	$ 37,620
23881	Monitor and Forecast	310	Asbestos Cement	6	>60yr	1955	65	2022	$ 35,340
24071	Monitor and Forecast	200	Asbestos Cement	6	>60yr	1956	64	2022	$ 22,800
24074	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1956	64	2022	$ 3,420

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
24382	Monitor and Forecast	40	Asbestos Cement	8	>60yr	1958	62	2022	$ 6,080
23657	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2022	$ 4,560
23854	Monitor and Forecast	80	Asbestos Cement	6	>60yr	1959	61	2022	$ 9,120
24164	Monitor and Forecast	260	Asbestos Cement	6	>60yr	1959	61	2022	$ 29,640
24294	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1959	61	2022	$ 7,980
24297	Monitor and Forecast	760	Asbestos Cement	6	>60yr	1959	61	2022	$ 86,640
24307	Monitor and Forecast	290	Asbestos Cement	6	>60yr	1959	61	2022	$ 33,060
24309	Monitor and Forecast	280	Asbestos Cement	6	>60yr	1959	61	2022	$ 31,920
24310	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2022	$ 3,420
23084	Monitor and Forecast	330	Asbestos Cement	6	>60yr	1959	61	2022	$ 37,620
23089	Monitor and Forecast	1200	Asbestos Cement	6	>60yr	1959	61	2022	$ 136,800
23193	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2022	$ 3,420
23219	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2022	$ 4,560
23221	Monitor and Forecast	230	Asbestos Cement	8	>60yr	1959	61	2022	$ 34,960
23943	Monitor and Forecast	600	Asbestos Cement	6	>60yr	1959	61	2022	$ 68,400
23541	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2022	$ 4,560
23667	Monitor and Forecast	350	Asbestos Cement	6	>60yr	1959	61	2022	$ 39,900
23672	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2022	$ 4,560
23687	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2022	$ 3,420
22940	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1960	60	2022	$ 4,560
2481	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2022	$ 3,420
11454	Monitor and Forecast	580	Asbestos Cement	6	40-60yr	1960	60	2022	$ 66,120
11458	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1960	60	2022	$ 42,560
11235	Monitor and Forecast	450	Asbestos Cement	6	40-60yr	1960	60	2022	$ 51,300
11452	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1960	60	2022	$ 3,040
11459	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1960	60	2022	$ 6,840
11393	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1961	59	2022	$ 3,420
25657	Monitor and Forecast	280	Asbestos Cement	10	40-60yr	1962	58	2022	$ 53,200
19876	Monitor and Forecast	10	Asbestos Cement	6	40-60yr	1962	58	2022	$ 1,140
19861	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1962	58	2022	$ 3,420
20279	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1962	58	2022	$ 6,080
23810	Monitor and Forecast	260	Asbestos Cement	6	40-60yr	1964	56	2022	$ 29,640
23029	Monitor and Forecast	750	Asbestos Cement	6	40-60yr	1966	54	2022	$ 85,500
24049	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1959	61	2022	$ 5,700
9436	Monitor and Forecast	10	Asbestos Cement	8	40-60yr	1972	48	2022	$ 1,520
9444	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
9462	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
16889	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
16891	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
16896	Monitor and Forecast	410	Asbestos Cement	6	40-60yr	1972	48	2022	$ 46,740
17387	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1972	48	2022	$ 36,480
17391	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1972	48	2022	$ 33,440
17393	Monitor and Forecast	1180	Asbestos Cement	6	40-60yr	1972	48	2022	$ 134,520
16839	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
17626	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1972	48	2022	$ 7,600

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
17630	Monitor and Forecast	220	Asbestos Cement	6	40-60yr	1972	48	2022	$ 25,080
17638	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1972	48	2022	$ 39,520
17656	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
17664	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
17848	Monitor and Forecast	340	Asbestos Cement	6	40-60yr	1972	48	2022	$ 38,760
17849	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1972	48	2022	$ 4,560
18110	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
18112	Monitor and Forecast	620	Asbestos Cement	8	40-60yr	1972	48	2022	$ 94,240
18117	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1972	48	2022	$ 5,700
18127	Monitor and Forecast	1240	Asbestos Cement	8	40-60yr	1972	48	2022	$ 188,480
19253	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
19254	Monitor and Forecast	250	Asbestos Cement	6	40-60yr	1972	48	2022	$ 28,500
19257	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
19258	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1972	48	2022	$ 4,560
19270	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1972	48	2022	$ 4,560
8474	Monitor and Forecast	430	Asbestos Cement	8	40-60yr	1972	48	2022	$ 65,360
18105	Monitor and Forecast	490	Asbestos Cement	8	40-60yr	1972	48	2022	$ 74,480
18116	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
18119	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
18598	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1972	48	2022	$ 2,280
18600	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1972	48	2022	$ 4,560
18601	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
18606	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
18607	Monitor and Forecast	140	Asbestos Cement	6	40-60yr	1972	48	2022	$ 15,960
18609	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1972	48	2022	$ 31,920
18612	Monitor and Forecast	180	Asbestos Cement	8	40-60yr	1972	48	2022	$ 27,360
18614	Monitor and Forecast	750	Asbestos Cement	8	40-60yr	1972	48	2022	$ 114,000
18616	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
18617	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1972	48	2022	$ 54,720
18618	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
18622	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
18623	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
18624	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1972	48	2022	$ 54,720
18625	Monitor and Forecast	470	Asbestos Cement	8	40-60yr	1972	48	2022	$ 71,440
18626	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
18630	Monitor and Forecast	410	Asbestos Cement	8	40-60yr	1972	48	2022	$ 62,320
18631	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
18635	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
18636	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
18637	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
18638	Monitor and Forecast	180	Asbestos Cement	8	40-60yr	1972	48	2022	$ 27,360
16902	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1972	48	2022	$ 2,280
17389	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1972	48	2022	$ 2,280
17392	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1972	48	2022	$ 34,960
17402	Monitor and Forecast	180	Asbestos Cement	6	40-60yr	1972	48	2022	$ 20,520

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
15837	Monitor and Forecast	900	Asbestos Cement	8	40-60yr	1972	48	2022	$ 136,800
16890	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
16901	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
19758	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
19775	Monitor and Forecast	120	Asbestos Cement	6	40-60yr	1972	48	2022	$ 13,680
19782	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1972	48	2022	$ 36,480
19786	Monitor and Forecast	390	Asbestos Cement	8	40-60yr	1972	48	2022	$ 59,280
19787	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1972	48	2022	$ 28,880
19798	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
19973	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
19974	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1972	48	2022	$ 38,000
19978	Monitor and Forecast	200	Asbestos Cement	6	40-60yr	1972	48	2022	$ 22,800
19981	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
19987	Monitor and Forecast	470	Asbestos Cement	8	40-60yr	1972	48	2022	$ 71,440
19989	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1972	48	2022	$ 9,120
19990	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
19992	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1972	48	2022	$ 36,480
19262	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1972	48	2022	$ 24,320
19264	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1972	48	2022	$ 4,560
19268	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1972	48	2022	$ 6,080
19425	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
19430	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1972	48	2022	$ 5,700
27880	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1972	48	2022	$ 4,560
23120	Monitor and Forecast	540	Asbestos Cement	8	40-60yr	1972	48	2022	$ 82,080
23125	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1972	48	2022	$ 3,420
23126	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1972	48	2022	$ 7,600
23127	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1972	48	2022	$ 7,600
8472	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1972	48	2022	$ 21,280
18118	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1972	48	2022	$ 3,040
18639	Monitor and Forecast	150	Asbestos Cement	6	40-60yr	1972	48	2022	$ 17,100
18647	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1972	48	2022	$ 2,280
21552	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1983	37	2023	$ 3,420
9148	Repair/Replace on Failure	70	Ductile Iron	10	40-60yr	1979	41	2023	$ 13,300
20198	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1980	40	2023	$ 6,080
15694	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1988	32	2023	$ 7,600
15705	Repair/Replace on Failure	330	Ductile Iron	8	20-40yr	1988	32	2023	$ 50,160
15706	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1988	32	2023	$ 4,560
15906	Repair/Replace on Failure	40	Ductile Iron	4	20-40yr	1988	32	2023	$ 3,040
15921	Repair/Replace on Failure	70	Ductile Iron	8	20-40yr	1988	32	2023	$ 10,640
15923	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1988	32	2023	$ 4,560
16481	Repair/Replace on Failure	310	Ductile Iron	8	20-40yr	1988	32	2023	$ 47,120
9883	Repair/Replace on Failure	10	Ductile Iron	10	40-60yr	1979	41	2023	$ 1,900
27664	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1979	41	2023	$ 6,080
25892	Repair/Replace on Failure	220	Ductile Iron	8	40-60yr	1979	41	2023	$ 33,440
25893	Repair/Replace on Failure	220	Ductile Iron	8	40-60yr	1979	41	2023	$ 33,440

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
10128	Repair/Replace on Failure	640	Ductile Iron	8	40-60yr	1979	41	2023	$ 97,280
9216	Repair/Replace on Failure	30	Ductile Iron	6	40-60yr	1979	41	2023	$ 3,420
21864	Repair/Replace on Failure	180	Ductile Iron	8	20-40yr	1984	36	2023	$ 27,360
15886	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2023	$ 6,080
17554	Repair/Replace on Failure	410	Ductile Iron	8	20-40yr	1984	36	2023	$ 62,320
17565	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1984	36	2023	$ 7,600
22890	Repair/Replace on Failure	230	Ductile Iron	6	>60yr	1957	63	2023	$ 26,220
21544	Repair/Replace on Failure	100	Ductile Iron	8	20-40yr	1983	37	2023	$ 15,200
5171	Repair/Replace on Failure	30	Ductile Iron	6	40-60yr	1979	41	2023	$ 3,420
13244	Repair/Replace on Failure	60	Ductile Iron	6	20-40yr	1980	40	2023	$ 6,840
16416	Repair/Replace on Failure	690	Ductile Iron	8	40-60yr	1979	41	2023	$ 104,880
6270	Repair/Replace on Failure	10	Ductile Iron	10	40-60yr	1979	41	2023	$ 1,900
20192	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1980	40	2023	$ 4,560
15848	Repair/Replace on Failure	760	Ductile Iron	8	20-40yr	1984	36	2023	$ 115,520
21623	Repair/Replace on Failure	70	Ductile Iron	8	20-40yr	1984	36	2023	$ 10,640
21848	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2023	$ 4,560
19134	Repair/Replace on Failure	90	Ductile Iron	4	40-60yr	1979	41	2023	$ 6,840
21630	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2023	$ 4,560
19446	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1988	32	2023	$ 3,040
19458	Repair/Replace on Failure	320	Ductile Iron	8	20-40yr	1988	32	2023	$ 48,640
21556	Repair/Replace on Failure	380	Ductile Iron	6	20-40yr	1983	37	2023	$ 43,320
22845	Repair/Replace on Failure	1320	Ductile Iron	8	40-60yr	1972	48	2023	$ 200,640
21624	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2023	$ 4,560
18775	Repair/Replace on Failure	20	Ductile Iron	4	20-40yr	1984	36	2023	$ 1,520
13240	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1980	40	2023	$ 3,420
18880	Repair/Replace on Failure	160	Ductile Iron	4	40-60yr	1979	41	2023	$ 12,160
15685	Repair/Replace on Failure	320	Ductile Iron	6	20-40yr	1988	32	2023	$ 36,480
15687	Repair/Replace on Failure	170	Ductile Iron	6	20-40yr	1988	32	2023	$ 19,380
15688	Repair/Replace on Failure	250	Ductile Iron	6	20-40yr	1988	32	2023	$ 28,500
15696	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1988	32	2023	$ 6,080
15697	Repair/Replace on Failure	90	Ductile Iron	8	20-40yr	1988	32	2023	$ 13,680
15698	Repair/Replace on Failure	290	Ductile Iron	8	20-40yr	1988	32	2023	$ 44,080
15699	Repair/Replace on Failure	60	Ductile Iron	8	20-40yr	1988	32	2023	$ 9,120
15700	Repair/Replace on Failure	270	Ductile Iron	8	20-40yr	1988	32	2023	$ 41,040
15703	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1988	32	2023	$ 7,600
15909	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1988	32	2023	$ 7,600
15911	Repair/Replace on Failure	60	Ductile Iron	8	20-40yr	1988	32	2023	$ 9,120
15912	Repair/Replace on Failure	320	Ductile Iron	8	20-40yr	1988	32	2023	$ 48,640
15913	Repair/Replace on Failure	210	Ductile Iron	8	20-40yr	1988	32	2023	$ 31,920
16482	Repair/Replace on Failure	610	Ductile Iron	8	20-40yr	1988	32	2023	$ 92,720
9887	Repair/Replace on Failure	440	Asbestos Cement	6	40-60yr	1960	60	2023	$ 50,160
7981	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1972	48	2023	$ 6,080
16103	Repair/Replace on Failure	220	Ductile Iron	8	40-60yr	1974	46	2023	$ 33,440
16304	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1974	46	2023	$ 6,080
20006	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1974	46	2023	$ 4,560

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
19142	Repair/Replace on Failure	30	Ductile Iron	4	40-60yr	1979	41	2023	$ 2,280
18928	Repair/Replace on Failure	270	Ductile Iron	4	40-60yr	1979	41	2023	$ 20,520
18847	Repair/Replace on Failure	230	Ductile Iron	8	40-60yr	1979	41	2023	$ 34,960
16430	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1979	41	2023	$ 6,080
7099	Repair/Replace on Failure	70	Ductile Iron	8	40-60yr	1979	41	2023	$ 10,640
20202	Repair/Replace on Failure	460	Ductile Iron	8	20-40yr	1980	40	2023	$ 69,920
20193	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1980	40	2023	$ 6,080
20205	Repair/Replace on Failure	230	Ductile Iron	6	20-40yr	1980	40	2023	$ 26,220
15844	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2023	$ 6,080
15900	Repair/Replace on Failure	130	Ductile Iron	6	20-40yr	1984	36	2023	$ 14,820
16123	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2023	$ 4,560
16125	Repair/Replace on Failure	460	Ductile Iron	6	20-40yr	1984	36	2023	$ 52,440
21844	Repair/Replace on Failure	400	Ductile Iron	8	20-40yr	1984	36	2023	$ 60,800
21851	Repair/Replace on Failure	320	Ductile Iron	8	20-40yr	1984	36	2023	$ 48,640
21816	Repair/Replace on Failure	260	Ductile Iron	8	20-40yr	1984	36	2023	$ 39,520
21817	Repair/Replace on Failure	60	Ductile Iron	8	20-40yr	1984	36	2023	$ 9,120
17550	Repair/Replace on Failure	890	Ductile Iron	8	20-40yr	1984	36	2023	$ 135,280
18780	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1984	36	2023	$ 7,600
18785	Repair/Replace on Failure	130	Ductile Iron	8	20-40yr	1984	36	2023	$ 19,760
18786	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2023	$ 3,040
18791	Repair/Replace on Failure	230	Ductile Iron	8	20-40yr	1984	36	2023	$ 34,960
18793	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2023	$ 4,560
19447	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1988	32	2023	$ 4,560
19459	Repair/Replace on Failure	320	Ductile Iron	8	20-40yr	1988	32	2023	$ 48,640
19460	Repair/Replace on Failure	210	Ductile Iron	8	20-40yr	1988	32	2023	$ 31,920
11057	Repair/Replace on Failure	40	Ductile Iron	6	20-40yr	1983	37	2023	$ 4,560
8409	Programmed Rehab/Replace	100	Ductile Iron	36	40-60yr	1973	47	2023	$ 68,400
9044	Programmed Rehab/Replace	20	Ductile Iron	36	40-60yr	1973	47	2023	$ 13,680
10870	Programmed Rehab/Replace	60	Ductile Iron	36	40-60yr	1973	47	2023	$ 41,040
3194	Programmed Rehab/Replace	140	Steel	42	40-60yr	1979	41	2023	$ 111,720
3195	Programmed Rehab/Replace	250	Steel	18	40-60yr	1979	41	2023	$ 85,500
28990	Programmed Rehab/Replace	530	Steel	42	40-60yr	1979	41	2023	$ 422,940
28991	Programmed Rehab/Replace	160	Steel	42	40-60yr	1979	41	2023	$ 127,680
28992	Programmed Rehab/Replace	130	Steel	42	40-60yr	1979	41	2023	$ 103,740
7721	Programmed Rehab/Replace	1140	Ductile Iron	30	40-60yr	1973	47	2023	$ 649,800
29956	Programmed Rehab/Replace	460	Steel	42	40-60yr	1979	41	2023	$ 367,080
29957	Programmed Rehab/Replace	460	Steel	48	40-60yr	1979	41	2023	$ 419,520
11212	Programmed Rehab/Replace	20	Ductile Iron	16	40-60yr	1971	49	2023	$ 6,080
8037	Programmed Rehab/Replace	20	Ductile Iron	16	40-60yr	1971	49	2023	$ 6,080
7049	Programmed Rehab/Replace	20	Ductile Iron	16	40-60yr	1973	47	2023	$ 6,080
5185	Programmed Rehab/Replace	70	Ductile Iron	16	40-60yr	1973	47	2023	$ 21,280
9811	Programmed Rehab/Replace	80	Ductile Iron	16	40-60yr	1978	42	2023	$ 24,320
18048	Proactive Assessment	200	Ductile Iron	16	>60yr	1959	61	2023	$ 60,800
18049	Proactive Assessment	60	Ductile Iron	16	>60yr	1959	61	2023	$ 18,240
18050	Proactive Assessment	1250	Ductile Iron	16	>60yr	1959	61	2023	$ 380,000

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
20267	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1962	58	2023	$ 9,120
9011	Monitor and Forecast	40	Ductile Iron	8	40-60yr	1973	47	2023	$ 6,080
9016	Monitor and Forecast	30	Ductile Iron	8	40-60yr	1973	47	2023	$ 4,560
23180	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1955	65	2023	$ 4,560
11059	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
28421	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
28422	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
235	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1973	47	2023	$ 57,760
23540	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1959	61	2023	$ 6,840
23842	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2023	$ 4,560
24409	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1959	61	2023	$ 6,840
24197	Monitor and Forecast	100	Asbestos Cement	8	>60yr	1959	61	2023	$ 15,200
22943	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1960	60	2023	$ 47,120
22948	Monitor and Forecast	60	Asbestos Cement	10	40-60yr	1962	58	2023	$ 11,400
20498	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1963	57	2023	$ 7,600
24083	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1956	64	2023	$ 3,420
10552	Monitor and Forecast	320	Asbestos Cement	6	>60yr	1959	61	2023	$ 36,480
27459	Monitor and Forecast	50	Ductile Iron	8	>60yr	1955	65	2023	$ 7,600
11411	Monitor and Forecast	1070	Asbestos Cement	8	40-60yr	1973	47	2023	$ 162,640
11418	Monitor and Forecast	500	Asbestos Cement	8	40-60yr	1973	47	2023	$ 76,000
8790	Monitor and Forecast	190	Asbestos Cement	6	40-60yr	1973	47	2023	$ 21,660
11462	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1973	47	2023	$ 34,960
11466	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
11468	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1973	47	2023	$ 57,760
15587	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1973	47	2023	$ 45,600
15791	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
15584	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1973	47	2023	$ 5,700
26736	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1973	47	2023	$ 12,160
10424	Monitor and Forecast	20	Ductile Iron	6	40-60yr	1973	47	2023	$ 2,280
21105	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
22964	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1963	57	2023	$ 6,840
23006	Monitor and Forecast	30	Asbestos Cement	3	>60yr	1954	66	2023	$ 1,710
19759	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
20927	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1973	47	2023	$ 57,760
8377	Monitor and Forecast	320	Asbestos Cement	10	>60yr	1955	65	2023	$ 60,800
20968	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1973	47	2023	$ 47,120
22871	Monitor and Forecast	400	Asbestos Cement	6	>60yr	1958	62	2023	$ 45,600
21091	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
8701	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1959	61	2023	$ 2,280
10149	Monitor and Forecast	330	Asbestos Cement	6	40-60yr	1963	57	2023	$ 37,620
21767	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
23213	Monitor and Forecast	320	Asbestos Cement	8	>60yr	1959	61	2023	$ 48,640
10355	Monitor and Forecast	110	Asbestos Cement	8	40-60yr	1973	47	2023	$ 16,720
10443	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
22980	Monitor and Forecast	500	Asbestos Cement	8	>60yr	1954	66	2023	$ 76,000

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
21084	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
20917	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1973	47	2023	$ 7,600
21130	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1973	47	2023	$ 5,700
21137	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
21139	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
20919	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1973	47	2023	$ 24,320
20920	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
20921	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1973	47	2023	$ 50,160
9010	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1973	47	2023	$ 47,120
23621	Monitor and Forecast	300	Asbestos Cement	8	>60yr	1953	67	2023	$ 45,600
23761	Monitor and Forecast	220	Asbestos Cement	8	>60yr	1954	66	2023	$ 33,440
26150	Monitor and Forecast	10	Asbestos Cement	8	>60yr	1954	66	2023	$ 1,520
23745	Monitor and Forecast	80	Asbestos Cement	6	>60yr	1954	66	2023	$ 9,120
23748	Monitor and Forecast	80	Asbestos Cement	6	>60yr	1954	66	2023	$ 9,120
22896	Monitor and Forecast	60	Asbestos Cement	10	>60yr	1955	65	2023	$ 11,400
20916	Monitor and Forecast	500	Asbestos Cement	6	40-60yr	1973	47	2023	$ 57,000
21094	Monitor and Forecast	140	Asbestos Cement	6	40-60yr	1973	47	2023	$ 15,960
23593	Monitor and Forecast	960	Asbestos Cement	4	>60yr	1953	67	2023	$ 72,960
24179	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1965	55	2023	$ 4,560
10144	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1968	52	2023	$ 4,560
9159	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
16596	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10421	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10425	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1973	47	2023	$ 9,120
10454	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1973	47	2023	$ 34,960
10456	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1973	47	2023	$ 33,440
10433	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1973	47	2023	$ 38,000
10441	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1973	47	2023	$ 33,440
10461	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
15169	Monitor and Forecast	310	Asbestos Cement	6	40-60yr	1973	47	2023	$ 35,340
15591	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
18821	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1973	47	2023	$ 25,840
18840	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
9161	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
9290	Monitor and Forecast	330	Asbestos Cement	6	40-60yr	1973	47	2023	$ 37,620
26737	Monitor and Forecast	70	Asbestos Cement	8	40-60yr	1973	47	2023	$ 10,640
8336	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1973	47	2023	$ 9,120
8338	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
11417	Monitor and Forecast	180	Asbestos Cement	8	40-60yr	1973	47	2023	$ 27,360
8453	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
8461	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
8640	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1973	47	2023	$ 7,600
9020	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
19765	Monitor and Forecast	110	Asbestos Cement	8	40-60yr	1973	47	2023	$ 16,720
19767	Monitor and Forecast	100	Asbestos Cement	8	40-60yr	1973	47	2023	$ 15,200

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
14957	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
21101	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1973	47	2023	$ 34,960
21110	Monitor and Forecast	370	Asbestos Cement	6	40-60yr	1973	47	2023	$ 42,180
21129	Monitor and Forecast	730	Asbestos Cement	8	40-60yr	1973	47	2023	$ 110,960
21142	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
21145	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
8481	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
19772	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
19780	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
19794	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1973	47	2023	$ 26,220
19799	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
20925	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
20926	Monitor and Forecast	480	Asbestos Cement	6	40-60yr	1973	47	2023	$ 54,720
20928	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
20929	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
21086	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
21098	Monitor and Forecast	70	Asbestos Cement	6	40-60yr	1973	47	2023	$ 7,980
21100	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
21118	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1973	47	2023	$ 26,220
21147	Monitor and Forecast	840	Asbestos Cement	6	40-60yr	1973	47	2023	$ 95,760
21345	Monitor and Forecast	550	Asbestos Cement	6	40-60yr	1973	47	2023	$ 62,700
23686	Monitor and Forecast	740	Asbestos Cement	6	>60yr	1959	61	2023	$ 84,360
20923	Monitor and Forecast	150	Asbestos Cement	6	40-60yr	1973	47	2023	$ 17,100
21085	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
21117	Monitor and Forecast	1860	Asbestos Cement	8	40-60yr	1973	47	2023	$ 282,720
22868	Monitor and Forecast	1210	Asbestos Cement	6	>60yr	1954	66	2023	$ 137,940
8680	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1955	65	2023	$ 3,420
24076	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1956	64	2023	$ 3,420
22983	Monitor and Forecast	30	Asbestos Cement	3	>60yr	1954	66	2023	$ 1,710
23010	Monitor and Forecast	310	Asbestos Cement	8	>60yr	1954	66	2023	$ 47,120
3028	Monitor and Forecast	30	Cast iron	8	40-60yr	1973	47	2023	$ 4,560
12766	Monitor and Forecast	90	Cast iron	8	40-60yr	1973	47	2023	$ 13,680
12762	Monitor and Forecast	70	Cast iron	8	40-60yr	1973	47	2023	$ 10,640
24104	Monitor and Forecast	10	Asbestos Cement	6	>60yr	1959	61	2023	$ 1,140
23140	Monitor and Forecast	680	Asbestos Cement	6	>60yr	1955	65	2023	$ 77,520
20969	Monitor and Forecast	470	Asbestos Cement	8	40-60yr	1973	47	2023	$ 71,440
12757	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
15459	Monitor and Forecast	520	Asbestos Cement	6	40-60yr	1973	47	2023	$ 59,280
15473	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1973	47	2023	$ 19,760
19762	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
20963	Monitor and Forecast	930	Asbestos Cement	8	40-60yr	1973	47	2023	$ 141,360
16601	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
16608	Monitor and Forecast	680	Asbestos Cement	6	40-60yr	1973	47	2023	$ 77,520
16617	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1973	47	2023	$ 5,700
14932	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1973	47	2023	$ 54,720

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
14952	Monitor and Forecast	80	Asbestos Cement	6	40-60yr	1973	47	2023	$ 9,120
14953	Monitor and Forecast	730	Asbestos Cement	8	40-60yr	1973	47	2023	$ 110,960
14958	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
14963	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1973	47	2023	$ 26,220
14965	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1973	47	2023	$ 18,240
15123	Monitor and Forecast	240	Asbestos Cement	6	40-60yr	1973	47	2023	$ 27,360
15462	Monitor and Forecast	70	Asbestos Cement	6	40-60yr	1973	47	2023	$ 7,980
15585	Monitor and Forecast	160	Asbestos Cement	6	40-60yr	1973	47	2023	$ 18,240
15595	Monitor and Forecast	480	Asbestos Cement	8	40-60yr	1973	47	2023	$ 72,960
15596	Monitor and Forecast	390	Asbestos Cement	6	40-60yr	1973	47	2023	$ 44,460
15598	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1973	47	2023	$ 28,880
15601	Monitor and Forecast	600	Asbestos Cement	8	40-60yr	1973	47	2023	$ 91,200
15776	Monitor and Forecast	110	Asbestos Cement	6	40-60yr	1973	47	2023	$ 12,540
15790	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
18596	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
18808	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
18812	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1973	47	2023	$ 36,480
14962	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
15460	Monitor and Forecast	470	Asbestos Cement	8	40-60yr	1973	47	2023	$ 71,440
15461	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
15464	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
15465	Monitor and Forecast	570	Asbestos Cement	8	40-60yr	1973	47	2023	$ 86,640
15468	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1973	47	2023	$ 41,040
15469	Monitor and Forecast	250	Asbestos Cement	6	40-60yr	1973	47	2023	$ 28,500
15476	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
18436	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
20957	Monitor and Forecast	430	Asbestos Cement	6	40-60yr	1973	47	2023	$ 49,020
20970	Monitor and Forecast	400	Asbestos Cement	6	40-60yr	1973	47	2023	$ 45,600
20972	Monitor and Forecast	400	Asbestos Cement	8	40-60yr	1973	47	2023	$ 60,800
20975	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
14951	Monitor and Forecast	150	Asbestos Cement	6	40-60yr	1973	47	2023	$ 17,100
14954	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
14955	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
18833	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
22897	Monitor and Forecast	30	Ductile Iron	8	>60yr	1958	62	2023	$ 4,560
23291	Monitor and Forecast	1560	Ductile Iron	10	>60yr	1959	61	2023	$ 296,400
19760	Monitor and Forecast	800	Asbestos Cement	8	40-60yr	1973	47	2023	$ 121,600
19764	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1973	47	2023	$ 36,480
19991	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1973	47	2023	$ 18,240
21768	Monitor and Forecast	470	Asbestos Cement	6	40-60yr	1973	47	2023	$ 53,580
21769	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1973	47	2023	$ 5,700
23517	Monitor and Forecast	550	Asbestos Cement	6	>60yr	1953	67	2023	$ 62,700
16622	Monitor and Forecast	260	Ductile Iron	8	40-60yr	1973	47	2023	$ 39,520
23422	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2023	$ 3,420
23427	Monitor and Forecast	280	Asbestos Cement	6	>60yr	1959	61	2023	$ 31,920

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
21087	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
21092	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
21093	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1973	47	2023	$ 38,000
21097	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
21099	Monitor and Forecast	180	Asbestos Cement	6	40-60yr	1973	47	2023	$ 20,520
21103	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
21109	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1973	47	2023	$ 39,520
21111	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
21112	Monitor and Forecast	220	Asbestos Cement	6	40-60yr	1973	47	2023	$ 25,080
21115	Monitor and Forecast	440	Asbestos Cement	8	40-60yr	1973	47	2023	$ 66,880
21108	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1973	47	2023	$ 38,000
21124	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
21335	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
21341	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
19489	Monitor and Forecast	1260	Asbestos Cement	6	>60yr	1953	67	2023	$ 143,640
22905	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1954	66	2023	$ 2,280
22885	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1954	66	2023	$ 2,280
22913	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1954	66	2023	$ 5,700
24243	Monitor and Forecast	740	Asbestos Cement	8	>60yr	1958	62	2023	$ 112,480
24219	Monitor and Forecast	1160	Asbestos Cement	6	>60yr	1959	61	2023	$ 132,240
24195	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2023	$ 41,040
10856	Monitor and Forecast	1010	Asbestos Cement	6	>60yr	1959	61	2023	$ 115,140
23188	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2023	$ 4,560
24050	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2023	$ 3,420
9007	Monitor and Forecast	280	Asbestos Cement	6	40-60yr	1960	60	2023	$ 31,920
21089	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
21096	Monitor and Forecast	120	Asbestos Cement	6	40-60yr	1973	47	2023	$ 13,680
21106	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
21114	Monitor and Forecast	100	Asbestos Cement	6	40-60yr	1973	47	2023	$ 11,400
21770	Monitor and Forecast	150	Asbestos Cement	6	40-60yr	1973	47	2023	$ 17,100
21771	Monitor and Forecast	360	Asbestos Cement	6	40-60yr	1973	47	2023	$ 41,040
23578	Monitor and Forecast	280	Asbestos Cement	6	>60yr	1959	61	2023	$ 31,920
23071	Monitor and Forecast	590	Asbestos Cement	6	>60yr	1959	61	2023	$ 67,260
19791	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
7027	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
7942	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
10350	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10422	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1973	47	2023	$ 33,440
10432	Monitor and Forecast	470	Asbestos Cement	8	40-60yr	1973	47	2023	$ 71,440
16602	Monitor and Forecast	200	Asbestos Cement	6	40-60yr	1973	47	2023	$ 22,800
16604	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10426	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10436	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
14966	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
23414	Monitor and Forecast	290	Asbestos Cement	6	40-60yr	1963	57	2023	$ 33,060

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
28428	Monitor and Forecast	1350	Asbestos Cement	6	40-60yr	1964	56	2023	$ 153,900
20918	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
21116	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
21123	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1973	47	2023	$ 26,220
21132	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1973	47	2023	$ 34,960
21133	Monitor and Forecast	420	Asbestos Cement	8	40-60yr	1973	47	2023	$ 63,840
21135	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
21146	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
21324	Monitor and Forecast	740	Asbestos Cement	8	40-60yr	1973	47	2023	$ 112,480
21325	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
21331	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
21333	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
21337	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
21340	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1973	47	2023	$ 36,480
21342	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1973	47	2023	$ 38,000
21343	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
19766	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
19801	Monitor and Forecast	140	Asbestos Cement	6	40-60yr	1973	47	2023	$ 15,960
19980	Monitor and Forecast	70	Asbestos Cement	6	40-60yr	1973	47	2023	$ 7,980
19983	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1973	47	2023	$ 36,480
14961	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1973	47	2023	$ 36,480
27314	Monitor and Forecast	590	Asbestos Cement	8	40-60yr	1973	47	2023	$ 89,680
23629	Monitor and Forecast	50	Asbestos Cement	4	>60yr	1953	67	2023	$ 3,800
23638	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1954	66	2023	$ 5,700
24421	Monitor and Forecast	1490	Asbestos Cement	6	>60yr	1954	66	2023	$ 169,860
24428	Monitor and Forecast	700	Asbestos Cement	4	>60yr	1954	66	2023	$ 53,200
26268	Monitor and Forecast	270	Asbestos Cement	10	>60yr	1954	66	2023	$ 51,300
23753	Monitor and Forecast	880	Asbestos Cement	8	>60yr	1954	66	2023	$ 133,760
22985	Monitor and Forecast	50	Asbestos Cement	8	>60yr	1954	66	2023	$ 7,600
24337	Monitor and Forecast	30	Asbestos Cement	10	>60yr	1954	66	2023	$ 5,700
24356	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1954	66	2023	$ 5,700
24371	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1954	66	2023	$ 3,420
23116	Monitor and Forecast	30	Asbestos Cement	10	>60yr	1955	65	2023	$ 5,700
23727	Monitor and Forecast	40	Asbestos Cement	8	>60yr	1955	65	2023	$ 6,080
23877	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1955	65	2023	$ 3,420
23882	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1955	65	2023	$ 4,560
24088	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1956	64	2023	$ 3,420
24085	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1956	64	2023	$ 3,420
22900	Monitor and Forecast	770	Asbestos Cement	6	>60yr	1957	63	2023	$ 87,780
24335	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1958	62	2023	$ 4,560
23534	Monitor and Forecast	850	Asbestos Cement	6	>60yr	1959	61	2023	$ 96,900
23944	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2023	$ 4,560
24166	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1959	61	2023	$ 2,280
24300	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2023	$ 3,420
24199	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1959	61	2023	$ 4,560

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
10752	Monitor and Forecast	260	Asbestos Cement	6	>60yr	1959	61	2023	$ 29,640
23554	Monitor and Forecast	220	Asbestos Cement	6	>60yr	1959	61	2023	$ 25,080
23659	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1959	61	2023	$ 2,280
23700	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2023	$ 4,560
22947	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1960	60	2023	$ 3,040
22966	Monitor and Forecast	180	Asbestos Cement	8	40-60yr	1960	60	2023	$ 27,360
24149	Monitor and Forecast	490	Asbestos Cement	6	40-60yr	1960	60	2023	$ 55,860
9885	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1960	60	2023	$ 4,560
9890	Monitor and Forecast	480	Asbestos Cement	6	40-60yr	1960	60	2023	$ 54,720
11435	Monitor and Forecast	710	Asbestos Cement	6	40-60yr	1960	60	2023	$ 80,940
22945	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2023	$ 3,420
24100	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1960	60	2023	$ 4,560
11450	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1960	60	2023	$ 38,000
11394	Monitor and Forecast	520	Asbestos Cement	6	40-60yr	1961	59	2023	$ 59,280
11398	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1961	59	2023	$ 2,280
11403	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1961	59	2023	$ 3,420
19868	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1962	58	2023	$ 2,280
20278	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1962	58	2023	$ 30,400
20273	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1962	58	2023	$ 4,560
22996	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1963	57	2023	$ 3,420
23823	Monitor and Forecast	880	Asbestos Cement	6	40-60yr	1964	56	2023	$ 100,320
23804	Monitor and Forecast	160	Asbestos Cement	6	40-60yr	1964	56	2023	$ 18,240
22973	Monitor and Forecast	750	Asbestos Cement	6	40-60yr	1966	54	2023	$ 85,500
23938	Monitor and Forecast	710	Asbestos Cement	6	>60yr	1959	61	2023	$ 80,940
19788	Monitor and Forecast	150	Asbestos Cement	6	40-60yr	1973	47	2023	$ 17,100
19802	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1973	47	2023	$ 30,400
19979	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
19982	Monitor and Forecast	730	Asbestos Cement	8	40-60yr	1973	47	2023	$ 110,960
19986	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
20953	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
20954	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
20955	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1973	47	2023	$ 18,240
20956	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1973	47	2023	$ 31,920
20959	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1973	47	2023	$ 57,760
20961	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
20973	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1973	47	2023	$ 50,160
20977	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1973	47	2023	$ 30,400
20983	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
20984	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
21334	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
21336	Monitor and Forecast	1130	Asbestos Cement	8	40-60yr	1973	47	2023	$ 171,760
21338	Monitor and Forecast	370	Asbestos Cement	8	40-60yr	1973	47	2023	$ 56,240
10352	Monitor and Forecast	80	Asbestos Cement	6	40-60yr	1973	47	2023	$ 9,120
10354	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
10357	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1973	47	2023	$ 21,280

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
10423	Monitor and Forecast	570	Asbestos Cement	8	40-60yr	1973	47	2023	$ 86,640
10430	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10431	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
10434	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
10435	Monitor and Forecast	450	Asbestos Cement	8	40-60yr	1973	47	2023	$ 68,400
10440	Monitor and Forecast	790	Asbestos Cement	8	40-60yr	1973	47	2023	$ 120,080
10442	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
10444	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
10451	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1973	47	2023	$ 34,960
12758	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
12759	Monitor and Forecast	830	Asbestos Cement	6	40-60yr	1973	47	2023	$ 94,620
12760	Monitor and Forecast	250	Asbestos Cement	6	40-60yr	1973	47	2023	$ 28,500
12761	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1973	47	2023	$ 28,880
12763	Monitor and Forecast	800	Asbestos Cement	6	40-60yr	1973	47	2023	$ 91,200
12764	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
12765	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
12767	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
16603	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
16605	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
16606	Monitor and Forecast	190	Asbestos Cement	6	40-60yr	1973	47	2023	$ 21,660
16607	Monitor and Forecast	210	Asbestos Cement	6	40-60yr	1973	47	2023	$ 23,940
16610	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1973	47	2023	$ 13,680
16611	Monitor and Forecast	440	Asbestos Cement	8	40-60yr	1973	47	2023	$ 66,880
16612	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
16613	Monitor and Forecast	70	Asbestos Cement	6	40-60yr	1973	47	2023	$ 7,980
16614	Monitor and Forecast	890	Asbestos Cement	8	40-60yr	1973	47	2023	$ 135,280
16615	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
16616	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
16618	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1973	47	2023	$ 7,600
16619	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1973	47	2023	$ 39,520
16621	Monitor and Forecast	440	Asbestos Cement	8	40-60yr	1973	47	2023	$ 66,880
16623	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1973	47	2023	$ 18,240
16625	Monitor and Forecast	1100	Asbestos Cement	8	40-60yr	1973	47	2023	$ 167,200
10437	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1973	47	2023	$ 34,960
10439	Monitor and Forecast	280	Asbestos Cement	6	40-60yr	1973	47	2023	$ 31,920
10445	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10455	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
10459	Monitor and Forecast	690	Asbestos Cement	8	40-60yr	1973	47	2023	$ 104,880
10460	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1973	47	2023	$ 12,160
10462	Monitor and Forecast	450	Asbestos Cement	8	40-60yr	1973	47	2023	$ 68,400
10465	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10466	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
10570	Monitor and Forecast	70	Asbestos Cement	8	40-60yr	1973	47	2023	$ 10,640
10571	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10036	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
14933	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
15156	Monitor and Forecast	570	Asbestos Cement	8	40-60yr	1973	47	2023	$ 86,640
27322	Monitor and Forecast	270	Asbestos Cement	6	40-60yr	1973	47	2023	$ 30,780
10438	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
10449	Monitor and Forecast	270	Asbestos Cement	6	40-60yr	1973	47	2023	$ 30,780
10452	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
10457	Monitor and Forecast	120	Asbestos Cement	6	40-60yr	1973	47	2023	$ 13,680
10458	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
10463	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1973	47	2023	$ 39,520
15120	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15126	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
15128	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1973	47	2023	$ 33,440
15129	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15130	Monitor and Forecast	660	Asbestos Cement	6	40-60yr	1973	47	2023	$ 75,240
15145	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15172	Monitor and Forecast	100	Asbestos Cement	6	40-60yr	1973	47	2023	$ 11,400
15463	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1973	47	2023	$ 42,560
15597	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
15599	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
15769	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15770	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15771	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1973	47	2023	$ 45,600
15772	Monitor and Forecast	70	Asbestos Cement	8	40-60yr	1973	47	2023	$ 10,640
15773	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15774	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1973	47	2023	$ 36,480
15777	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
15778	Monitor and Forecast	450	Asbestos Cement	8	40-60yr	1973	47	2023	$ 68,400
15779	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
15780	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
15781	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15783	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1973	47	2023	$ 47,120
15784	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1973	47	2023	$ 38,000
15785	Monitor and Forecast	640	Asbestos Cement	8	40-60yr	1973	47	2023	$ 97,280
15789	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15793	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
18438	Monitor and Forecast	420	Asbestos Cement	8	40-60yr	1973	47	2023	$ 63,840
18809	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
18813	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
18814	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
18816	Monitor and Forecast	140	Asbestos Cement	6	40-60yr	1973	47	2023	$ 15,960
18817	Monitor and Forecast	780	Asbestos Cement	8	40-60yr	1973	47	2023	$ 118,560
18818	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
18819	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1973	47	2023	$ 30,400
18820	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
18822	Monitor and Forecast	310	Asbestos Cement	6	40-60yr	1973	47	2023	$ 35,340

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
18823	Monitor and Forecast	350	Asbestos Cement	6	40-60yr	1973	47	2023	$ 39,900
18824	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
18825	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
18827	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1973	47	2023	$ 34,960
18834	Monitor and Forecast	1140	Asbestos Cement	8	40-60yr	1973	47	2023	$ 173,280
18835	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1973	47	2023	$ 34,960
18836	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
18837	Monitor and Forecast	150	Asbestos Cement	8	40-60yr	1973	47	2023	$ 22,800
18838	Monitor and Forecast	240	Asbestos Cement	6	40-60yr	1973	47	2023	$ 27,360
14968	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1973	47	2023	$ 26,220
11230	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
14960	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1973	47	2023	$ 38,000
15152	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
15467	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15470	Monitor and Forecast	180	Asbestos Cement	8	40-60yr	1973	47	2023	$ 27,360
15471	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1973	47	2023	$ 33,440
15475	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1973	47	2023	$ 5,700
15477	Monitor and Forecast	370	Asbestos Cement	6	40-60yr	1973	47	2023	$ 42,180
15483	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
17252	Monitor and Forecast	790	Asbestos Cement	8	40-60yr	1973	47	2023	$ 120,080
17253	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
17254	Monitor and Forecast	380	Asbestos Cement	6	40-60yr	1973	47	2023	$ 43,320
18437	Monitor and Forecast	490	Asbestos Cement	6	40-60yr	1973	47	2023	$ 55,860
18439	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
18484	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
18486	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
15474	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
15478	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
15480	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1973	47	2023	$ 28,880
15485	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
20962	Monitor and Forecast	10	Asbestos Cement	8	40-60yr	1973	47	2023	$ 1,520
20965	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
20966	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1973	47	2023	$ 21,280
20967	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1973	47	2023	$ 4,560
20971	Monitor and Forecast	550	Asbestos Cement	8	40-60yr	1973	47	2023	$ 83,600
20976	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1973	47	2023	$ 2,280
20978	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1973	47	2023	$ 33,440
20980	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1973	47	2023	$ 28,880
20981	Monitor and Forecast	90	Asbestos Cement	6	40-60yr	1973	47	2023	$ 10,260
20982	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
14959	Monitor and Forecast	90	Asbestos Cement	6	40-60yr	1973	47	2023	$ 10,260
14964	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1973	47	2023	$ 39,520
14967	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1973	47	2023	$ 7,600
15131	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1973	47	2023	$ 25,840
15132	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1973	47	2023	$ 41,040

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
15164	Monitor and Forecast	70	Asbestos Cement	6	40-60yr	1973	47	2023	$ 7,980
15167	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
15168	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1973	47	2023	$ 3,420
15479	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
15481	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1973	47	2023	$ 4,560
15482	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
15484	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
15486	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1973	47	2023	$ 26,220
15488	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1973	47	2023	$ 6,080
17251	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1973	47	2023	$ 38,000
18839	Monitor and Forecast	270	Asbestos Cement	6	40-60yr	1973	47	2023	$ 30,780
15782	Monitor and Forecast	170	Asbestos Cement	6	40-60yr	1973	47	2023	$ 19,380
10448	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1973	47	2023	$ 26,220
234	Monitor and Forecast	620	Asbestos Cement	8	40-60yr	1973	47	2023	$ 94,240
8635	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1973	47	2023	$ 3,040
3434	Repair/Replace on Failure	10	Cast iron	8	40-60yr	1971	49	2024	$ 1,520
23421	Repair/Replace on Failure	40	Asbestos Cement	6	>60yr	1959	61	2024	$ 4,560
23425	Repair/Replace on Failure	120	Asbestos Cement	8	>60yr	1959	61	2024	$ 18,240
25900	Repair/Replace on Failure	50	Ductile Iron	8	40-60yr	1979	41	2024	$ 7,600
7441	Repair/Replace on Failure	20	Ductile Iron	6	40-60yr	1979	41	2024	$ 2,280
5277	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2024	$ 6,080
17560	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2024	$ 6,080
23164	Repair/Replace on Failure	210	Ductile Iron	10	>60yr	1955	65	2024	$ 39,900
12083	Repair/Replace on Failure	340	Ductile Iron	6	>60yr	1959	61	2024	$ 38,760
8982	Repair/Replace on Failure	40	Cast iron	6	40-60yr	1979	41	2024	$ 4,560
22992	Repair/Replace on Failure	60	Ductile Iron	16	40-60yr	1971	49	2024	$ 18,240
22990	Repair/Replace on Failure	310	Ductile Iron	16	40-60yr	1971	49	2024	$ 94,240
5626	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1979	41	2024	$ 4,560
23073	Repair/Replace on Failure	330	Asbestos Cement	6	>60yr	1959	61	2024	$ 37,620
25884	Repair/Replace on Failure	50	Ductile Iron	8	40-60yr	1979	41	2024	$ 7,600
15884	Repair/Replace on Failure	220	Ductile Iron	8	20-40yr	1984	36	2024	$ 33,440
15891	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2024	$ 3,040
21547	Repair/Replace on Failure	50	Ductile Iron	8	20-40yr	1983	37	2024	$ 7,600
21930	Repair/Replace on Failure	50	Ductile Iron	8	40-60yr	1972	48	2024	$ 7,600
21836	Repair/Replace on Failure	520	Ductile Iron	8	20-40yr	1984	36	2024	$ 79,040
15847	Repair/Replace on Failure	60	Ductile Iron	8	20-40yr	1984	36	2024	$ 9,120
20201	Repair/Replace on Failure	270	Ductile Iron	6	20-40yr	1980	40	2024	$ 30,780
15647	Repair/Replace on Failure	240	Ductile Iron	8	20-40yr	1984	36	2024	$ 36,480
18766	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2024	$ 4,560
2962	Repair/Replace on Failure	20	Ductile Iron	6	40-60yr	1974	46	2024	$ 2,280
15855	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2024	$ 4,560
5299	Repair/Replace on Failure	120	Ductile Iron	4	40-60yr	1979	41	2024	$ 9,120
16127	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1984	36	2024	$ 3,420
15652	Repair/Replace on Failure	150	Ductile Iron	8	20-40yr	1984	36	2024	$ 22,800
9178	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1979	41	2024	$ 6,080

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
11062	Repair/Replace on Failure	510	Ductile Iron	8	20-40yr	1983	37	2024	$ 77,520
18773	Repair/Replace on Failure	220	Ductile Iron	8	20-40yr	1984	36	2024	$ 33,440
18781	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2024	$ 3,040
16108	Repair/Replace on Failure	20	Ductile Iron	8	40-60yr	1974	46	2024	$ 3,040
20004	Repair/Replace on Failure	300	Ductile Iron	8	40-60yr	1974	46	2024	$ 45,600
20007	Repair/Replace on Failure	20	Ductile Iron	10	40-60yr	1974	46	2024	$ 3,800
18845	Repair/Replace on Failure	260	Ductile Iron	8	40-60yr	1979	41	2024	$ 39,520
6881	Repair/Replace on Failure	20	Ductile Iron	8	40-60yr	1979	41	2024	$ 3,040
16429	Repair/Replace on Failure	120	Ductile Iron	8	40-60yr	1979	41	2024	$ 18,240
12042	Repair/Replace on Failure	20	Ductile Iron	10	40-60yr	1979	41	2024	$ 3,800
18890	Repair/Replace on Failure	40	Ductile Iron	6	40-60yr	1979	41	2024	$ 4,560
15852	Repair/Replace on Failure	200	Ductile Iron	8	20-40yr	1984	36	2024	$ 30,400
15853	Repair/Replace on Failure	260	Ductile Iron	8	20-40yr	1984	36	2024	$ 39,520
15893	Repair/Replace on Failure	40	Ductile Iron	6	20-40yr	1984	36	2024	$ 4,560
15895	Repair/Replace on Failure	150	Ductile Iron	6	20-40yr	1984	36	2024	$ 17,100
16126	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1984	36	2024	$ 3,420
21631	Repair/Replace on Failure	350	Ductile Iron	6	20-40yr	1984	36	2024	$ 39,900
15859	Repair/Replace on Failure	40	Ductile Iron	6	20-40yr	1984	36	2024	$ 4,560
21819	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2024	$ 3,040
21839	Repair/Replace on Failure	90	Ductile Iron	8	20-40yr	1984	36	2024	$ 13,680
17551	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2024	$ 4,560
17567	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1984	36	2024	$ 3,420
18769	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2024	$ 3,040
18776	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2024	$ 3,040
18792	Repair/Replace on Failure	200	Ductile Iron	8	20-40yr	1984	36	2024	$ 30,400
18797	Repair/Replace on Failure	180	Ductile Iron	8	20-40yr	1984	36	2024	$ 27,360
22875	Repair/Replace on Failure	320	Ductile Iron	6	>60yr	1957	63	2024	$ 36,480
7195	Programmed Rehab/Replace	60	Ductile Iron	16	20-40yr	1983	37	2024	$ 18,240
22984	Monitor and Forecast	40	Asbestos Cement	3	>60yr	1954	66	2024	$ 2,280
23551	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2024	$ 4,560
21997	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1974	46	2024	$ 4,560
23538	Monitor and Forecast	50	Asbestos Cement	8	>60yr	1959	61	2024	$ 7,600
23662	Monitor and Forecast	60	Asbestos Cement	8	>60yr	1959	61	2024	$ 9,120
24291	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1959	61	2024	$ 7,980
23171	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1955	65	2024	$ 3,420
10134	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1968	52	2024	$ 3,040
23987	Monitor and Forecast	410	Ductile Iron	8	>60yr	1956	64	2024	$ 62,320
23959	Monitor and Forecast	40	Ductile Iron	6	>60yr	1956	64	2024	$ 4,560
24340	Monitor and Forecast	40	Ductile Iron	8	>60yr	1958	62	2024	$ 6,080
16963	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
17221	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1974	46	2024	$ 28,880
16959	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1974	46	2024	$ 7,600
21999	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
17203	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
15828	Monitor and Forecast	170	Ductile Iron	8	40-60yr	1974	46	2024	$ 25,840

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
23779	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1954	66	2024	$ 3,040
15832	Monitor and Forecast	990	Ductile Iron	8	40-60yr	1974	46	2024	$ 150,480
16104	Monitor and Forecast	750	Ductile Iron	8	40-60yr	1974	46	2024	$ 114,000
19488	Monitor and Forecast	80	Asbestos Cement	8	>60yr	1953	67	2024	$ 12,160
22874	Monitor and Forecast	230	Asbestos Cement	10	>60yr	1954	66	2024	$ 43,700
23642	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1954	66	2024	$ 2,280
24093	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1956	64	2024	$ 6,840
23509	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1954	66	2024	$ 6,840
23510	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1954	66	2024	$ 2,280
15331	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16941	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
23594	Monitor and Forecast	130	Asbestos Cement	6	>60yr	1953	67	2024	$ 14,820
23477	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1953	67	2024	$ 3,420
26254	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1954	66	2024	$ 3,040
26488	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1954	66	2024	$ 2,280
23743	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1954	66	2024	$ 27,360
24334	Monitor and Forecast	60	Asbestos Cement	8	>60yr	1954	66	2024	$ 9,120
24379	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1954	66	2024	$ 7,980
23108	Monitor and Forecast	230	Asbestos Cement	8	>60yr	1955	65	2024	$ 34,960
23875	Monitor and Forecast	500	Asbestos Cement	8	>60yr	1955	65	2024	$ 76,000
24348	Monitor and Forecast	60	Asbestos Cement	8	>60yr	1955	65	2024	$ 9,120
23267	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1955	65	2024	$ 7,980
24157	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1956	64	2024	$ 6,840
23088	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1959	61	2024	$ 6,840
20733	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1963	57	2024	$ 6,080
16946	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
20732	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1963	57	2024	$ 2,280
23402	Monitor and Forecast	400	Asbestos Cement	6	40-60yr	1966	54	2024	$ 45,600
15343	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16662	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16701	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1974	46	2024	$ 4,560
16918	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16926	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16929	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1974	46	2024	$ 41,040
16932	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16936	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1974	46	2024	$ 31,920
16943	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1974	46	2024	$ 5,700
16945	Monitor and Forecast	540	Asbestos Cement	8	40-60yr	1974	46	2024	$ 82,080
15361	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16655	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
17213	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1974	46	2024	$ 7,600
17228	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
17232	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
22005	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
17218	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
20009	Monitor and Forecast	140	Ductile Iron	10	>60yr	1959	61	2024	$ 26,600
9617	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1960	60	2024	$ 4,560
10812	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1961	59	2024	$ 7,600
23022	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1954	66	2024	$ 5,700
23506	Monitor and Forecast	50	Asbestos Cement	4	>60yr	1954	66	2024	$ 3,800
22864	Monitor and Forecast	260	Asbestos Cement	10	>60yr	1954	66	2024	$ 49,400
23730	Monitor and Forecast	220	Asbestos Cement	8	>60yr	1955	65	2024	$ 33,440
23007	Monitor and Forecast	310	Asbestos Cement	8	>60yr	1954	66	2024	$ 47,120
22880	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1958	62	2024	$ 4,560
24165	Monitor and Forecast	270	Asbestos Cement	6	>60yr	1959	61	2024	$ 30,780
23550	Monitor and Forecast	400	Asbestos Cement	6	>60yr	1959	61	2024	$ 45,600
7905	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1960	60	2024	$ 2,280
10828	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1961	59	2024	$ 4,560
11387	Monitor and Forecast	150	Asbestos Cement	6	40-60yr	1961	59	2024	$ 17,100
16099	Monitor and Forecast	200	Ductile Iron	6	40-60yr	1974	46	2024	$ 22,800
16297	Monitor and Forecast	40	Ductile Iron	8	40-60yr	1974	46	2024	$ 6,080
15830	Monitor and Forecast	20	Ductile Iron	8	40-60yr	1974	46	2024	$ 3,040
16296	Monitor and Forecast	20	Ductile Iron	8	40-60yr	1974	46	2024	$ 3,040
17187	Monitor and Forecast	70	Asbestos Cement	6	40-60yr	1974	46	2024	$ 7,980
16661	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1974	46	2024	$ 39,520
16692	Monitor and Forecast	90	Asbestos Cement	6	40-60yr	1974	46	2024	$ 10,260
16702	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
16912	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1974	46	2024	$ 38,000
16947	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1974	46	2024	$ 2,280
16948	Monitor and Forecast	200	Asbestos Cement	6	40-60yr	1974	46	2024	$ 22,800
16949	Monitor and Forecast	410	Asbestos Cement	8	40-60yr	1974	46	2024	$ 62,320
17192	Monitor and Forecast	630	Asbestos Cement	8	40-60yr	1974	46	2024	$ 95,760
17225	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
16663	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
16955	Monitor and Forecast	320	Asbestos Cement	8	40-60yr	1974	46	2024	$ 48,640
21992	Monitor and Forecast	300	Asbestos Cement	6	40-60yr	1974	46	2024	$ 34,200
16952	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1974	46	2024	$ 4,560
16954	Monitor and Forecast	140	Asbestos Cement	6	40-60yr	1974	46	2024	$ 15,960
16957	Monitor and Forecast	160	Asbestos Cement	6	40-60yr	1974	46	2024	$ 18,240
16958	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
16964	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
17207	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
23980	Monitor and Forecast	20	Ductile Iron	8	>60yr	1956	64	2024	$ 3,040
22881	Monitor and Forecast	40	Ductile Iron	6	>60yr	1957	63	2024	$ 4,560
24239	Monitor and Forecast	240	Ductile Iron	6	>60yr	1957	63	2024	$ 27,360
15834	Monitor and Forecast	70	Ductile Iron	8	40-60yr	1974	46	2024	$ 10,640
16043	Monitor and Forecast	340	Ductile Iron	8	40-60yr	1974	46	2024	$ 51,680
16045	Monitor and Forecast	20	Ductile Iron	6	40-60yr	1974	46	2024	$ 2,280
16048	Monitor and Forecast	30	Ductile Iron	8	40-60yr	1974	46	2024	$ 4,560
16097	Monitor and Forecast	310	Ductile Iron	8	40-60yr	1974	46	2024	$ 47,120

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
16100	Monitor and Forecast	570	Ductile Iron	8	40-60yr	1974	46	2024	$ 86,640
16101	Monitor and Forecast	260	Ductile Iron	8	40-60yr	1974	46	2024	$ 39,520
16105	Monitor and Forecast	430	Ductile Iron	8	40-60yr	1974	46	2024	$ 65,360
16107	Monitor and Forecast	30	Ductile Iron	8	40-60yr	1974	46	2024	$ 4,560
16110	Monitor and Forecast	200	Ductile Iron	8	40-60yr	1974	46	2024	$ 30,400
16330	Monitor and Forecast	20	Ductile Iron	8	40-60yr	1974	46	2024	$ 3,040
11022	Monitor and Forecast	30	Ductile Iron	10	>60yr	1959	61	2024	$ 5,700
23819	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1964	56	2024	$ 4,560
23782	Monitor and Forecast	500	Asbestos Cement	8	>60yr	1954	66	2024	$ 76,000
23155	Monitor and Forecast	880	Asbestos Cement	6	>60yr	1955	65	2024	$ 100,320
23489	Monitor and Forecast	280	Asbestos Cement	8	>60yr	1954	66	2024	$ 42,560
26061	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1954	66	2024	$ 3,420
23711	Monitor and Forecast	250	Asbestos Cement	6	>60yr	1954	66	2024	$ 28,500
24363	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1954	66	2024	$ 4,560
23148	Monitor and Forecast	170	Asbestos Cement	3	>60yr	1955	65	2024	$ 9,690
23166	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1955	65	2024	$ 41,040
11211	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1959	61	2024	$ 2,280
23542	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2024	$ 39,520
23940	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2024	$ 3,420
23087	Monitor and Forecast	190	Asbestos Cement	6	>60yr	1959	61	2024	$ 21,660
3930	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2024	$ 4,560
10897	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1962	58	2024	$ 3,420
8502	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1964	56	2024	$ 6,840
23598	Monitor and Forecast	900	Asbestos Cement	4	>60yr	1953	67	2024	$ 68,400
23134	Monitor and Forecast	80	Asbestos Cement	6	40-60yr	1969	51	2024	$ 9,120
23580	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2024	$ 3,420
23663	Monitor and Forecast	280	Asbestos Cement	6	>60yr	1959	61	2024	$ 31,920
23682	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2024	$ 3,420
24221	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1959	61	2024	$ 2,280
15337	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
15338	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
15339	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
15342	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
15351	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
15352	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1974	46	2024	$ 34,960
15355	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
15359	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
15369	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1974	46	2024	$ 2,280
16651	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16653	Monitor and Forecast	370	Asbestos Cement	8	40-60yr	1974	46	2024	$ 56,240
16681	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1974	46	2024	$ 34,960
16682	Monitor and Forecast	90	Asbestos Cement	6	40-60yr	1974	46	2024	$ 10,260
16691	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1974	46	2024	$ 50,160
16915	Monitor and Forecast	200	Asbestos Cement	6	40-60yr	1974	46	2024	$ 22,800
16916	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1974	46	2024	$ 38,000

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
16940	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1974	46	2024	$ 45,600
16671	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16906	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1974	46	2024	$ 41,040
17200	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1974	46	2024	$ 19,760
17224	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1974	46	2024	$ 38,000
17239	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1974	46	2024	$ 26,220
16641	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
16657	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
15345	Monitor and Forecast	110	Asbestos Cement	6	40-60yr	1974	46	2024	$ 12,540
11054	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1964	56	2024	$ 6,840
22962	Monitor and Forecast	180	Asbestos Cement	6	40-60yr	1963	57	2024	$ 20,520
26051	Monitor and Forecast	220	Asbestos Cement	8	>60yr	1954	66	2024	$ 33,440
23754	Monitor and Forecast	930	Asbestos Cement	6	>60yr	1954	66	2024	$ 106,020
23756	Monitor and Forecast	200	Asbestos Cement	4	>60yr	1954	66	2024	$ 15,200
22915	Monitor and Forecast	290	Asbestos Cement	6	>60yr	1954	66	2024	$ 33,060
23721	Monitor and Forecast	200	Asbestos Cement	6	>60yr	1954	66	2024	$ 22,800
24252	Monitor and Forecast	260	Asbestos Cement	6	>60yr	1954	66	2024	$ 29,640
24339	Monitor and Forecast	720	Asbestos Cement	6	>60yr	1954	66	2024	$ 82,080
24346	Monitor and Forecast	530	Asbestos Cement	6	>60yr	1954	66	2024	$ 60,420
24424	Monitor and Forecast	880	Asbestos Cement	6	>60yr	1954	66	2024	$ 100,320
23137	Monitor and Forecast	250	Asbestos Cement	10	>60yr	1955	65	2024	$ 47,500
23158	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1955	65	2024	$ 4,560
23242	Monitor and Forecast	250	Asbestos Cement	6	>60yr	1955	65	2024	$ 28,500
24067	Monitor and Forecast	180	Asbestos Cement	6	>60yr	1956	64	2024	$ 20,520
24070	Monitor and Forecast	240	Asbestos Cement	6	>60yr	1956	64	2024	$ 27,360
24090	Monitor and Forecast	310	Asbestos Cement	6	>60yr	1956	64	2024	$ 35,340
24238	Monitor and Forecast	250	Asbestos Cement	10	>60yr	1958	62	2024	$ 47,500
23658	Monitor and Forecast	240	Asbestos Cement	8	>60yr	1959	61	2024	$ 36,480
23562	Monitor and Forecast	300	Asbestos Cement	8	>60yr	1959	61	2024	$ 45,600
23937	Monitor and Forecast	490	Asbestos Cement	6	>60yr	1959	61	2024	$ 55,860
24170	Monitor and Forecast	580	Asbestos Cement	6	>60yr	1959	61	2024	$ 66,120
24302	Monitor and Forecast	210	Asbestos Cement	6	>60yr	1959	61	2024	$ 23,940
23118	Monitor and Forecast	250	Asbestos Cement	6	>60yr	1959	61	2024	$ 28,500
9882	Monitor and Forecast	330	Asbestos Cement	6	>60yr	1959	61	2024	$ 37,620
23072	Monitor and Forecast	80	Asbestos Cement	4	>60yr	1959	61	2024	$ 6,080
24303	Monitor and Forecast	230	Asbestos Cement	6	>60yr	1959	61	2024	$ 26,220
23563	Monitor and Forecast	330	Asbestos Cement	6	>60yr	1959	61	2024	$ 37,620
23579	Monitor and Forecast	990	Asbestos Cement	6	>60yr	1959	61	2024	$ 112,860
23696	Monitor and Forecast	390	Asbestos Cement	6	>60yr	1959	61	2024	$ 44,460
22970	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2024	$ 3,420
23269	Monitor and Forecast	370	Asbestos Cement	6	40-60yr	1960	60	2024	$ 42,180
19649	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1960	60	2024	$ 45,600
19633	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2024	$ 3,420
19651	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1960	60	2024	$ 39,520
11449	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1960	60	2024	$ 31,920

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
11404	Monitor and Forecast	250	Asbestos Cement	6	40-60yr	1961	59	2024	$ 28,500
19710	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1962	58	2024	$ 4,560
20742	Monitor and Forecast	950	Asbestos Cement	6	40-60yr	1963	57	2024	$ 108,300
22999	Monitor and Forecast	620	Asbestos Cement	6	40-60yr	1963	57	2024	$ 70,680
23415	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1963	57	2024	$ 4,560
23710	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1954	66	2024	$ 3,420
22974	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1966	54	2024	$ 3,420
15341	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1974	46	2024	$ 4,560
15344	Monitor and Forecast	90	Asbestos Cement	6	40-60yr	1974	46	2024	$ 10,260
15346	Monitor and Forecast	100	Asbestos Cement	6	40-60yr	1974	46	2024	$ 11,400
15347	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1974	46	2024	$ 34,960
15348	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1974	46	2024	$ 31,920
15350	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1974	46	2024	$ 47,120
15356	Monitor and Forecast	590	Asbestos Cement	8	40-60yr	1974	46	2024	$ 89,680
15357	Monitor and Forecast	550	Asbestos Cement	8	40-60yr	1974	46	2024	$ 83,600
15362	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1974	46	2024	$ 44,080
15363	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
15365	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
15368	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1974	46	2024	$ 4,560
16639	Monitor and Forecast	260	Asbestos Cement	6	40-60yr	1974	46	2024	$ 29,640
16640	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1974	46	2024	$ 2,280
16644	Monitor and Forecast	390	Asbestos Cement	8	40-60yr	1974	46	2024	$ 59,280
16645	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1974	46	2024	$ 7,600
16646	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16649	Monitor and Forecast	290	Asbestos Cement	6	40-60yr	1974	46	2024	$ 33,060
16650	Monitor and Forecast	440	Asbestos Cement	8	40-60yr	1974	46	2024	$ 66,880
16658	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1974	46	2024	$ 36,480
16672	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16673	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16675	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1974	46	2024	$ 41,040
16676	Monitor and Forecast	120	Asbestos Cement	6	40-60yr	1974	46	2024	$ 13,680
16677	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1974	46	2024	$ 41,040
16678	Monitor and Forecast	370	Asbestos Cement	8	40-60yr	1974	46	2024	$ 56,240
16680	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1974	46	2024	$ 4,560
16683	Monitor and Forecast	140	Asbestos Cement	6	40-60yr	1974	46	2024	$ 15,960
16687	Monitor and Forecast	440	Asbestos Cement	8	40-60yr	1974	46	2024	$ 66,880
16688	Monitor and Forecast	590	Asbestos Cement	8	40-60yr	1974	46	2024	$ 89,680
16689	Monitor and Forecast	100	Asbestos Cement	6	40-60yr	1974	46	2024	$ 11,400
16696	Monitor and Forecast	540	Asbestos Cement	8	40-60yr	1974	46	2024	$ 82,080
16697	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1974	46	2024	$ 4,560
16703	Monitor and Forecast	220	Asbestos Cement	6	40-60yr	1974	46	2024	$ 25,080
16704	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16917	Monitor and Forecast	590	Asbestos Cement	8	40-60yr	1974	46	2024	$ 89,680
16919	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16922	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1974	46	2024	$ 6,840

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
16930	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
16934	Monitor and Forecast	680	Asbestos Cement	8	40-60yr	1974	46	2024	$ 103,360
16937	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1974	46	2024	$ 4,560
16679	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16690	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
16699	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
16904	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
16942	Monitor and Forecast	1020	Asbestos Cement	8	40-60yr	1974	46	2024	$ 155,040
17179	Monitor and Forecast	310	Asbestos Cement	6	40-60yr	1974	46	2024	$ 35,340
17191	Monitor and Forecast	450	Asbestos Cement	8	40-60yr	1974	46	2024	$ 68,400
17193	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
17198	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1974	46	2024	$ 7,600
17212	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1974	46	2024	$ 45,600
16674	Monitor and Forecast	680	Asbestos Cement	8	40-60yr	1974	46	2024	$ 103,360
16685	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16686	Monitor and Forecast	980	Asbestos Cement	8	40-60yr	1974	46	2024	$ 148,960
16693	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16700	Monitor and Forecast	450	Asbestos Cement	8	40-60yr	1974	46	2024	$ 68,400
16705	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1974	46	2024	$ 41,040
16903	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16908	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16909	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1974	46	2024	$ 45,600
16913	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
16920	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16921	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
16923	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
16928	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16951	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1974	46	2024	$ 44,080
16966	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1974	46	2024	$ 41,040
17190	Monitor and Forecast	340	Asbestos Cement	8	40-60yr	1974	46	2024	$ 51,680
17199	Monitor and Forecast	240	Asbestos Cement	6	40-60yr	1974	46	2024	$ 27,360
17201	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1974	46	2024	$ 7,600
17206	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1974	46	2024	$ 7,600
17211	Monitor and Forecast	740	Asbestos Cement	8	40-60yr	1974	46	2024	$ 112,480
17214	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
17215	Monitor and Forecast	430	Asbestos Cement	8	40-60yr	1974	46	2024	$ 65,360
17223	Monitor and Forecast	370	Asbestos Cement	8	40-60yr	1974	46	2024	$ 56,240
17226	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
17231	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1974	46	2024	$ 34,960
17233	Monitor and Forecast	350	Asbestos Cement	8	40-60yr	1974	46	2024	$ 53,200
17235	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1974	46	2024	$ 34,960
17236	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
17238	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1974	46	2024	$ 42,560
17240	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1974	46	2024	$ 42,560
17241	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
17242	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
17243	Monitor and Forecast	120	Asbestos Cement	6	40-60yr	1974	46	2024	$ 13,680
17245	Monitor and Forecast	330	Asbestos Cement	6	40-60yr	1974	46	2024	$ 37,620
17419	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
17420	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
17421	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
17422	Monitor and Forecast	160	Asbestos Cement	6	40-60yr	1974	46	2024	$ 18,240
15340	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1974	46	2024	$ 44,080
16643	Monitor and Forecast	350	Asbestos Cement	8	40-60yr	1974	46	2024	$ 53,200
16647	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16666	Monitor and Forecast	900	Asbestos Cement	8	40-60yr	1974	46	2024	$ 136,800
16968	Monitor and Forecast	270	Asbestos Cement	6	40-60yr	1974	46	2024	$ 30,780
17222	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16652	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1974	46	2024	$ 4,560
16656	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
21989	Monitor and Forecast	510	Asbestos Cement	6	40-60yr	1974	46	2024	$ 58,140
21998	Monitor and Forecast	590	Asbestos Cement	6	40-60yr	1974	46	2024	$ 67,260
22000	Monitor and Forecast	310	Asbestos Cement	6	40-60yr	1974	46	2024	$ 35,340
22001	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
22004	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1974	46	2024	$ 2,280
22006	Monitor and Forecast	730	Asbestos Cement	6	40-60yr	1974	46	2024	$ 83,220
22007	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1974	46	2024	$ 42,560
22009	Monitor and Forecast	870	Asbestos Cement	6	40-60yr	1974	46	2024	$ 99,180
22011	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1974	46	2024	$ 3,420
16956	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1974	46	2024	$ 4,560
16960	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1974	46	2024	$ 39,520
16967	Monitor and Forecast	400	Asbestos Cement	8	40-60yr	1974	46	2024	$ 60,800
16969	Monitor and Forecast	110	Asbestos Cement	6	40-60yr	1974	46	2024	$ 12,540
16970	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
17178	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1974	46	2024	$ 6,080
17180	Monitor and Forecast	110	Asbestos Cement	6	40-60yr	1974	46	2024	$ 12,540
17181	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1974	46	2024	$ 3,040
17184	Monitor and Forecast	440	Asbestos Cement	6	40-60yr	1974	46	2024	$ 50,160
17185	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1974	46	2024	$ 2,280
17188	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1974	46	2024	$ 2,280
17195	Monitor and Forecast	320	Asbestos Cement	8	40-60yr	1974	46	2024	$ 48,640
17197	Monitor and Forecast	210	Asbestos Cement	6	40-60yr	1974	46	2024	$ 23,940
17217	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1974	46	2024	$ 24,320
17219	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1974	46	2024	$ 2,280
17220	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1974	46	2024	$ 13,680
16670	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1974	46	2024	$ 5,700
21546	Repair/Replace on Failure	30	Ductile Iron	6	20-40yr	1983	37	2025	$ 3,420
8476	Repair/Replace on Failure	30	Asbestos Cement	8	40-60yr	1971	49	2025	$ 4,560
25891	Repair/Replace on Failure	90	Ductile Iron	8	40-60yr	1979	41	2025	$ 13,680
11996	Repair/Replace on Failure	60	Ductile Iron	6	40-60yr	1978	42	2025	$ 6,840

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
23361	Repair/Replace on Failure	50	Ductile Iron	8	40-60yr	1975	45	2025	$ 7,600
17563	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2025	$ 4,560
17556	Repair/Replace on Failure	260	Ductile Iron	8	20-40yr	1984	36	2025	$ 39,520
21543	Repair/Replace on Failure	60	Ductile Iron	8	20-40yr	1983	37	2025	$ 9,120
2670	Repair/Replace on Failure	680	Cast iron	8	40-60yr	1971	49	2025	$ 103,360
16414	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1979	41	2025	$ 6,080
16415	Repair/Replace on Failure	30	Ductile Iron	8	40-60yr	1979	41	2025	$ 4,560
20191	Repair/Replace on Failure	170	Ductile Iron	8	20-40yr	1980	40	2025	$ 25,840
15645	Repair/Replace on Failure	190	Ductile Iron	8	20-40yr	1984	36	2025	$ 28,880
13250	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1980	40	2025	$ 6,080
9181	Repair/Replace on Failure	60	Ductile Iron	8	40-60yr	1974	46	2025	$ 9,120
8695	Repair/Replace on Failure	350	Ductile Iron	10	40-60yr	1979	41	2025	$ 66,500
21626	Repair/Replace on Failure	230	Ductile Iron	8	20-40yr	1984	36	2025	$ 34,960
13264	Repair/Replace on Failure	40	Ductile Iron	4	20-40yr	1980	40	2025	$ 3,040
15882	Repair/Replace on Failure	170	Ductile Iron	6	20-40yr	1984	36	2025	$ 19,380
9186	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1979	41	2025	$ 6,080
18772	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2025	$ 4,560
9892	Repair/Replace on Failure	1170	Asbestos Cement	8	40-60yr	1960	60	2025	$ 177,840
8920	Repair/Replace on Failure	700	Ductile Iron	10	40-60yr	1979	41	2025	$ 133,000
16428	Repair/Replace on Failure	50	Ductile Iron	8	40-60yr	1979	41	2025	$ 7,600
18846	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1979	41	2025	$ 6,080
18852	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1979	41	2025	$ 6,080
6874	Repair/Replace on Failure	40	Ductile Iron	8	40-60yr	1979	41	2025	$ 6,080
7080	Repair/Replace on Failure	60	Ductile Iron	8	40-60yr	1979	41	2025	$ 9,120
20190	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1980	40	2025	$ 6,080
20203	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1980	40	2025	$ 6,080
23833	Repair/Replace on Failure	490	Ductile Iron	8	20-40yr	1983	37	2025	$ 74,480
21542	Repair/Replace on Failure	250	Ductile Iron	8	20-40yr	1983	37	2025	$ 38,000
21555	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1983	37	2025	$ 3,040
27700	Repair/Replace on Failure	250	Ductile Iron	8	20-40yr	1984	36	2025	$ 38,000
67	Repair/Replace on Failure	380	Ductile Iron	6	20-40yr	1984	36	2025	$ 43,320
15894	Repair/Replace on Failure	120	Ductile Iron	6	20-40yr	1984	36	2025	$ 13,680
15902	Repair/Replace on Failure	40	Ductile Iron	6	20-40yr	1984	36	2025	$ 4,560
21827	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2025	$ 4,560
21837	Repair/Replace on Failure	490	Ductile Iron	8	20-40yr	1984	36	2025	$ 74,480
21846	Repair/Replace on Failure	300	Ductile Iron	8	20-40yr	1984	36	2025	$ 45,600
15866	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2025	$ 3,040
21629	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2025	$ 6,080
21838	Repair/Replace on Failure	250	Ductile Iron	8	20-40yr	1984	36	2025	$ 38,000
21849	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2025	$ 6,080
18771	Repair/Replace on Failure	30	Ductile Iron	8	20-40yr	1984	36	2025	$ 4,560
18774	Repair/Replace on Failure	20	Ductile Iron	8	20-40yr	1984	36	2025	$ 3,040
18778	Repair/Replace on Failure	40	Ductile Iron	8	20-40yr	1984	36	2025	$ 6,080
23568	Monitor and Forecast	30	Asbestos Cement	8	>60yr	1959	61	2025	$ 4,560
11042	Monitor and Forecast	10	Asbestos Cement	6	>60yr	1959	61	2025	$ 1,140

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
23649	Monitor and Forecast	140	Asbestos Cement	8	>60yr	1959	61	2025	$ 21,280
23694	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2025	$ 4,560
23697	Monitor and Forecast	40	Asbestos Cement	8	>60yr	1959	61	2025	$ 6,080
22955	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1960	60	2025	$ 25,840
25661	Monitor and Forecast	30	Asbestos Cement	10	40-60yr	1962	58	2025	$ 5,700
27482	Monitor and Forecast	280	Asbestos Cement	8	>60yr	1954	66	2025	$ 42,560
10116	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1963	57	2025	$ 36,480
10135	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1968	52	2025	$ 50,160
27461	Monitor and Forecast	390	Ductile Iron	8	>60yr	1955	65	2025	$ 59,280
23960	Monitor and Forecast	40	Ductile Iron	6	>60yr	1956	64	2025	$ 4,560
23353	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1975	45	2025	$ 4,560
8564	Monitor and Forecast	20	Ductile Iron	10	40-60yr	1962	58	2025	$ 3,800
24315	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1975	45	2025	$ 6,840
24313	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1975	45	2025	$ 18,240
23614	Monitor and Forecast	40	Asbestos Cement	8	>60yr	1953	67	2025	$ 6,080
23011	Monitor and Forecast	40	Asbestos Cement	8	>60yr	1954	66	2025	$ 6,080
23783	Monitor and Forecast	50	Asbestos Cement	8	>60yr	1954	66	2025	$ 7,600
23142	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1955	65	2025	$ 5,700
10835	Monitor and Forecast	650	Asbestos Cement	8	40-60yr	1963	57	2025	$ 98,800
23032	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1954	66	2025	$ 7,980
23692	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2025	$ 4,560
14522	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1975	45	2025	$ 7,600
19486	Monitor and Forecast	80	Asbestos Cement	8	>60yr	1953	67	2025	$ 12,160
23150	Monitor and Forecast	30	Asbestos Cement	10	>60yr	1955	65	2025	$ 5,700
23879	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1955	65	2025	$ 4,560
27487	Monitor and Forecast	70	Asbestos Cement	6	>60yr	1955	65	2025	$ 7,980
23986	Monitor and Forecast	50	Asbestos Cement	8	>60yr	1956	64	2025	$ 7,600
20005	Monitor and Forecast	60	Ductile Iron	8	>60yr	1959	61	2025	$ 9,120
17601	Monitor and Forecast	490	Asbestos Cement	10	40-60yr	1975	45	2025	$ 93,100
17808	Monitor and Forecast	110	Asbestos Cement	8	40-60yr	1975	45	2025	$ 16,720
10122	Monitor and Forecast	540	Asbestos Cement	8	40-60yr	1968	52	2025	$ 82,080
12538	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
14528	Monitor and Forecast	50	Asbestos Cement	4	40-60yr	1975	45	2025	$ 3,800
24017	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1975	45	2025	$ 50,160
17604	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1975	45	2025	$ 6,080
17804	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1975	45	2025	$ 7,600
12525	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1975	45	2025	$ 7,600
22902	Monitor and Forecast	310	Asbestos Cement	10	>60yr	1954	66	2025	$ 58,900
24332	Monitor and Forecast	1200	Asbestos Cement	6	>60yr	1954	66	2025	$ 136,800
8676	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1955	65	2025	$ 3,420
23865	Monitor and Forecast	310	Asbestos Cement	6	>60yr	1955	65	2025	$ 35,340
23870	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1955	65	2025	$ 3,420
23547	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2025	$ 3,420
10011	Monitor and Forecast	340	Asbestos Cement	8	40-60yr	1975	45	2025	$ 51,680
23364	Monitor and Forecast	210	Asbestos Cement	6	40-60yr	1975	45	2025	$ 23,940

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
23257	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1975	45	2025	$ 3,420
24320	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1975	45	2025	$ 2,280
24369	Monitor and Forecast	250	Ductile Iron	8	>60yr	1954	66	2025	$ 38,000
27635	Monitor and Forecast	220	Ductile Iron	8	>60yr	1956	64	2025	$ 33,440
24375	Monitor and Forecast	140	Ductile Iron	8	>60yr	1958	62	2025	$ 21,280
23519	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1953	67	2025	$ 4,560
23520	Monitor and Forecast	490	Asbestos Cement	8	>60yr	1953	67	2025	$ 74,480
23786	Monitor and Forecast	920	Asbestos Cement	4	>60yr	1954	66	2025	$ 69,920
13429	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1975	45	2025	$ 41,040
23490	Monitor and Forecast	40	Asbestos Cement	8	>60yr	1954	66	2025	$ 6,080
23766	Monitor and Forecast	30	Asbestos Cement	4	>60yr	1954	66	2025	$ 2,280
22891	Monitor and Forecast	850	Asbestos Cement	6	>60yr	1954	66	2025	$ 96,900
22920	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1954	66	2025	$ 4,560
23145	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1955	65	2025	$ 6,840
24068	Monitor and Forecast	310	Asbestos Cement	6	>60yr	1956	64	2025	$ 35,340
10278	Monitor and Forecast	200	Asbestos Cement	6	>60yr	1959	61	2025	$ 22,800
23851	Monitor and Forecast	190	Asbestos Cement	6	>60yr	1959	61	2025	$ 21,660
4226	Monitor and Forecast	130	Asbestos Cement	6	40-60yr	1960	60	2025	$ 14,820
2480	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1960	60	2025	$ 4,560
23808	Monitor and Forecast	410	Asbestos Cement	6	40-60yr	1964	56	2025	$ 46,740
23217	Monitor and Forecast	540	Asbestos Cement	8	>60yr	1959	61	2025	$ 82,080
24211	Monitor and Forecast	740	Asbestos Cement	6	>60yr	1959	61	2025	$ 84,360
22957	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1963	57	2025	$ 7,600
23417	Monitor and Forecast	820	Asbestos Cement	6	40-60yr	1963	57	2025	$ 93,480
13413	Monitor and Forecast	90	Asbestos Cement	4	40-60yr	1975	45	2025	$ 6,840
13420	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
13421	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
14521	Monitor and Forecast	40	Asbestos Cement	4	40-60yr	1975	45	2025	$ 3,040
14526	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1975	45	2025	$ 6,080
23822	Monitor and Forecast	590	Asbestos Cement	6	40-60yr	1964	56	2025	$ 67,260
17602	Monitor and Forecast	440	Asbestos Cement	8	40-60yr	1975	45	2025	$ 66,880
17807	Monitor and Forecast	30	Asbestos Cement	4	40-60yr	1975	45	2025	$ 2,280
17810	Monitor and Forecast	110	Asbestos Cement	4	40-60yr	1975	45	2025	$ 8,360
23496	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1954	66	2025	$ 41,040
24368	Monitor and Forecast	250	Asbestos Cement	6	>60yr	1954	66	2025	$ 28,500
23784	Monitor and Forecast	40	Asbestos Cement	4	>60yr	1954	66	2025	$ 3,040
23720	Monitor and Forecast	60	Asbestos Cement	6	>60yr	1954	66	2025	$ 6,840
24241	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1954	66	2025	$ 38,000
24367	Monitor and Forecast	260	Asbestos Cement	6	>60yr	1954	66	2025	$ 29,640
27485	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1954	66	2025	$ 3,420
23138	Monitor and Forecast	180	Asbestos Cement	6	>60yr	1955	65	2025	$ 20,520
23869	Monitor and Forecast	690	Asbestos Cement	6	>60yr	1955	65	2025	$ 78,660
23168	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1955	65	2025	$ 3,040
23170	Monitor and Forecast	20	Asbestos Cement	6	>60yr	1955	65	2025	$ 2,280
24079	Monitor and Forecast	920	Asbestos Cement	6	>60yr	1956	64	2025	$ 104,880

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
24091	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1956	64	2025	$ 4,560
23535	Monitor and Forecast	640	Asbestos Cement	8	>60yr	1959	61	2025	$ 97,280
23660	Monitor and Forecast	20	Asbestos Cement	8	>60yr	1959	61	2025	$ 3,040
23569	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1959	61	2025	$ 38,000
23680	Monitor and Forecast	290	Asbestos Cement	8	>60yr	1959	61	2025	$ 44,080
23214	Monitor and Forecast	220	Asbestos Cement	8	>60yr	1959	61	2025	$ 33,440
24160	Monitor and Forecast	230	Asbestos Cement	6	>60yr	1959	61	2025	$ 26,220
10853	Monitor and Forecast	40	Asbestos Cement	6	>60yr	1959	61	2025	$ 4,560
4803	Monitor and Forecast	30	Asbestos Cement	6	>60yr	1959	61	2025	$ 3,420
23582	Monitor and Forecast	50	Asbestos Cement	6	>60yr	1959	61	2025	$ 5,700
23583	Monitor and Forecast	560	Asbestos Cement	6	>60yr	1959	61	2025	$ 63,840
23690	Monitor and Forecast	240	Asbestos Cement	6	>60yr	1959	61	2025	$ 27,360
24096	Monitor and Forecast	390	Asbestos Cement	6	40-60yr	1960	60	2025	$ 44,460
11442	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2025	$ 3,420
12080	Monitor and Forecast	370	Asbestos Cement	6	40-60yr	1960	60	2025	$ 42,180
19645	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1960	60	2025	$ 3,420
10829	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1961	59	2025	$ 3,420
11224	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1961	59	2025	$ 4,560
11390	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1961	59	2025	$ 26,220
11406	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1961	59	2025	$ 2,280
19703	Monitor and Forecast	50	Asbestos Cement	6	40-60yr	1962	58	2025	$ 5,700
19708	Monitor and Forecast	280	Asbestos Cement	6	40-60yr	1962	58	2025	$ 31,920
20274	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1962	58	2025	$ 47,120
17801	Monitor and Forecast	400	Asbestos Cement	8	40-60yr	1975	45	2025	$ 60,800
23003	Monitor and Forecast	310	Asbestos Cement	6	40-60yr	1963	57	2025	$ 35,340
23637	Monitor and Forecast	200	Asbestos Cement	8	>60yr	1954	66	2025	$ 30,400
23806	Monitor and Forecast	600	Asbestos Cement	6	40-60yr	1964	56	2025	$ 68,400
23817	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1964	56	2025	$ 3,420
12526	Monitor and Forecast	150	Asbestos Cement	8	40-60yr	1975	45	2025	$ 22,800
12530	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
12534	Monitor and Forecast	530	Asbestos Cement	8	40-60yr	1975	45	2025	$ 80,560
12536	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
12539	Monitor and Forecast	400	Asbestos Cement	8	40-60yr	1975	45	2025	$ 60,800
12541	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
12546	Monitor and Forecast	670	Asbestos Cement	8	40-60yr	1975	45	2025	$ 101,840
12548	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1975	45	2025	$ 36,480
12549	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
12556	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
13414	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
13417	Monitor and Forecast	370	Asbestos Cement	8	40-60yr	1975	45	2025	$ 56,240
13418	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1975	45	2025	$ 44,080
13419	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1975	45	2025	$ 30,400
13424	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
13425	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
13426	Monitor and Forecast	480	Asbestos Cement	8	40-60yr	1975	45	2025	$ 72,960

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
13428	Monitor and Forecast	30	Asbestos Cement	4	40-60yr	1975	45	2025	$ 2,280
14517	Monitor and Forecast	60	Asbestos Cement	6	40-60yr	1975	45	2025	$ 6,840
14520	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1975	45	2025	$ 44,080
14523	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
14524	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1975	45	2025	$ 2,280
14525	Monitor and Forecast	170	Asbestos Cement	6	40-60yr	1975	45	2025	$ 19,380
14527	Monitor and Forecast	570	Asbestos Cement	8	40-60yr	1975	45	2025	$ 86,640
14529	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
14532	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1975	45	2025	$ 21,280
14534	Monitor and Forecast	710	Asbestos Cement	8	40-60yr	1975	45	2025	$ 107,920
14535	Monitor and Forecast	530	Asbestos Cement	8	40-60yr	1975	45	2025	$ 80,560
14536	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1975	45	2025	$ 6,080
14539	Monitor and Forecast	510	Asbestos Cement	8	40-60yr	1975	45	2025	$ 77,520
14563	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1975	45	2025	$ 45,600
14564	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
14565	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
14566	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1975	45	2025	$ 25,840
14567	Monitor and Forecast	540	Asbestos Cement	8	40-60yr	1975	45	2025	$ 82,080
14568	Monitor and Forecast	40	Asbestos Cement	4	40-60yr	1975	45	2025	$ 3,040
14569	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1975	45	2025	$ 39,520
17590	Monitor and Forecast	520	Asbestos Cement	8	40-60yr	1975	45	2025	$ 79,040
17592	Monitor and Forecast	350	Asbestos Cement	8	40-60yr	1975	45	2025	$ 53,200
17593	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1975	45	2025	$ 50,160
17606	Monitor and Forecast	560	Asbestos Cement	8	40-60yr	1975	45	2025	$ 85,120
24316	Monitor and Forecast	210	Asbestos Cement	6	40-60yr	1975	45	2025	$ 23,940
24317	Monitor and Forecast	640	Asbestos Cement	6	40-60yr	1975	45	2025	$ 72,960
24318	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1975	45	2025	$ 3,420
24322	Monitor and Forecast	1150	Asbestos Cement	8	40-60yr	1975	45	2025	$ 174,800
10013	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1975	45	2025	$ 2,280
10015	Monitor and Forecast	670	Asbestos Cement	6	40-60yr	1975	45	2025	$ 76,380
12041	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1975	45	2025	$ 45,600
23383	Monitor and Forecast	20	Asbestos Cement	6	40-60yr	1975	45	2025	$ 2,280
23406	Monitor and Forecast	110	Asbestos Cement	6	40-60yr	1975	45	2025	$ 12,540
9623	Monitor and Forecast	40	Asbestos Cement	6	40-60yr	1975	45	2025	$ 4,560
23263	Monitor and Forecast	250	Asbestos Cement	6	40-60yr	1975	45	2025	$ 28,500
23363	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1975	45	2025	$ 6,080
23404	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1975	45	2025	$ 3,420
12547	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
12550	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1975	45	2025	$ 31,920
12557	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1975	45	2025	$ 6,080
13416	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
13422	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1975	45	2025	$ 9,120
13427	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
17591	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
17594	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1975	45	2025	$ 34,960

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
17595	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
17598	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1975	45	2025	$ 41,040
17608	Monitor and Forecast	220	Asbestos Cement	6	40-60yr	1975	45	2025	$ 25,080
17795	Monitor and Forecast	130	Asbestos Cement	4	40-60yr	1975	45	2025	$ 9,880
17796	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1975	45	2025	$ 6,080
17797	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
17800	Monitor and Forecast	580	Asbestos Cement	8	40-60yr	1975	45	2025	$ 88,160
17802	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
17803	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1975	45	2025	$ 6,080
17805	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1975	45	2025	$ 36,480
12528	Monitor and Forecast	940	Asbestos Cement	8	40-60yr	1975	45	2025	$ 142,880
12531	Monitor and Forecast	20	Asbestos Cement	8	40-60yr	1975	45	2025	$ 3,040
12532	Monitor and Forecast	50	Asbestos Cement	8	40-60yr	1975	45	2025	$ 7,600
12533	Monitor and Forecast	40	Asbestos Cement	8	40-60yr	1975	45	2025	$ 6,080
12543	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1975	45	2025	$ 36,480
12542	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1975	45	2025	$ 4,560
12544	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1975	45	2025	$ 30,400
12545	Monitor and Forecast	30	Asbestos Cement	6	40-60yr	1975	45	2025	$ 3,420
12555	Monitor and Forecast	100	Asbestos Cement	8	40-60yr	1975	45	2025	$ 15,200
13415	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1975	45	2025	$ 12,160
17603	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1975	45	2025	$ 54,720
17605	Monitor and Forecast	690	Asbestos Cement	8	40-60yr	1975	45	2025	$ 104,880
17607	Monitor and Forecast	30	Asbestos Cement	4	40-60yr	1975	45	2025	$ 2,280

Appendix C- Prioritization Tool Results – Asset List - Wastewater

THORNTON - REHAB AND REPLACEMENT PROGRAM

WASTEWATER COLLECTION SYSTEM

GIS ID	Recommendation	Length (ft)	Material	Diameter (in)	Age Range	Installation Year	Age (yr)	Year of Replacement	Cost
5246	Repair/Replace on Failure	40	Ductile iron	8	40-60yr	1979	41	2020	$ 6,080
5073	Repair/Replace on Failure	240	Ductile iron	8	40-60yr	1979	41	2020	$ 36,480
9788	Repair/Replace on Failure	150	Ductile iron	8	40-60yr	1979	41	2020	$ 22,800
9793	Repair/Replace on Failure	250	Ductile iron	8	40-60yr	1979	41	2020	$ 38,000
9875	Repair/Replace on Failure	110	Ductile iron	8	40-60yr	1979	41	2020	$ 16,720
13806	Proactive Assessment	130	Concrete NonReinf	18	40-60yr	1979	41	2020	$ 44,460
969	Monitor and Forecast	410	Concrete NonReinf	15	40-60yr	1979	41	2020	$ 116,850
922	Monitor and Forecast	390	Concrete NonReinf	12	40-60yr	1979	41	2020	$ 88,920
497	Monitor and Forecast	40	Concrete NonReinf	8	40-60yr	1979	41	2020	$ 6,080
4880	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1970	50	2020	$ 45,600
123	Monitor and Forecast	260	Concrete NonReinf	8	40-60yr	1979	41	2020	$ 39,520
8642	Monitor and Forecast	300	Concrete NonReinf	8	40-60yr	1973	47	2020	$ 45,600
6864	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2020	$ 41,040
7107	Monitor and Forecast	360	Asbestos Cement	8	>60yr	1959	61	2020	$ 54,720
7124	Monitor and Forecast	440	Asbestos Cement	8	>60yr	1959	61	2020	$ 66,880
9941	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2020	$ 41,040
9957	Monitor and Forecast	210	Asbestos Cement	8	>60yr	1959	61	2020	$ 31,920
388	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1960	60	2020	$ 21,280
4935	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1963	57	2020	$ 38,000
7238	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1963	57	2020	$ 47,120
7257	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1963	57	2020	$ 24,320
6254	Monitor and Forecast	350	Asbestos Cement	8	40-60yr	1964	56	2020	$ 53,200
6360	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1964	56	2020	$ 31,920
6372	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1964	56	2020	$ 38,000
4877	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1970	50	2020	$ 45,600
2068	Monitor and Forecast	530	Asbestos Cement	8	40-60yr	1968	52	2020	$ 80,560
4879	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1970	50	2020	$ 60,800
339	Monitor and Forecast	140	Concrete NonReinf	8	40-60yr	1979	41	2020	$ 21,280
116	Monitor and Forecast	90	Concrete NonReinf	8	40-60yr	1979	41	2020	$ 13,680
786	Monitor and Forecast	330	Concrete NonReinf	8	40-60yr	1979	41	2020	$ 50,160
3042	Monitor and Forecast	230	Concrete NonReinf	8	40-60yr	1977	43	2020	$ 34,960
1263	Monitor and Forecast	300	Concrete NonReinf	8	40-60yr	1979	41	2020	$ 45,600
4875	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1970	50	2020	$ 51,680
4876	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1970	50	2020	$ 47,120
4881	Monitor and Forecast	320	Asbestos Cement	8	40-60yr	1970	50	2020	$ 48,640
4893	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1970	50	2020	$ 57,760
4894	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1970	50	2020	$ 30,400
4898	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1970	50	2020	$ 30,400
4899	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1970	50	2020	$ 34,960
4902	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1970	50	2020	$ 57,760
4904	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1970	50	2020	$ 62,320
6711	Monitor and Forecast	60	Concrete Reinf	6	>60yr	1955	65	2020	$ 6,840
6714	Monitor and Forecast	130	Concrete Reinf	6	>60yr	1955	65	2020	$ 14,820

7131	Monitor and Forecast	320	Concrete Reinf	8	>60yr	1955	65	2020	$ 48,640
7129	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2020	$ 41,040
4947	Monitor and Forecast	210	Asbestos Cement	8	>60yr	1959	61	2020	$ 31,920
5002	Monitor and Forecast	130	Asbestos Cement	8	>60yr	1959	61	2020	$ 19,760
8371	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2020	$ 39,520
9322	Monitor and Forecast	100	Asbestos Cement	8	>60yr	1959	61	2020	$ 15,200
9341	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2020	$ 41,040
9343	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2020	$ 39,520
9401	Monitor and Forecast	320	Asbestos Cement	8	>60yr	1959	61	2020	$ 48,640
7236	Monitor and Forecast	160	Asbestos Cement	8	>60yr	1959	61	2020	$ 24,320
9944	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1959	61	2020	$ 38,000
7141	Monitor and Forecast	320	Asbestos Cement	10	>60yr	1959	61	2020	$ 60,800
7226	Monitor and Forecast	140	Asbestos Cement	8	>60yr	1959	61	2020	$ 21,280
7228	Monitor and Forecast	160	Asbestos Cement	8	>60yr	1959	61	2020	$ 24,320
7834	Monitor and Forecast	290	Asbestos Cement	8	>60yr	1959	61	2020	$ 44,080
8987	Monitor and Forecast	200	Asbestos Cement	8	>60yr	1959	61	2020	$ 30,400
9937	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2020	$ 41,040
8367	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2020	$ 39,520
2209	Monitor and Forecast	380	Asbestos Cement	8	>60yr	1959	61	2020	$ 57,760
4430	Monitor and Forecast	330	Asbestos Cement	8	>60yr	1959	61	2020	$ 50,160
4919	Monitor and Forecast	410	Concrete NonReinf	8	40-60yr	1971	49	2020	$ 62,320
4954	Monitor and Forecast	190	Asbestos Cement	8	>60yr	1959	61	2020	$ 28,880
3936	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1960	60	2020	$ 62,320
8069	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1960	60	2020	$ 12,160
3929	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1960	60	2020	$ 47,120
8068	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1960	60	2020	$ 21,280
8074	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1960	60	2020	$ 42,560
3312	Monitor and Forecast	150	Asbestos Cement	8	40-60yr	1960	60	2020	$ 22,800
302	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1961	59	2020	$ 34,960
2204	Monitor and Forecast	180	Asbestos Cement	8	40-60yr	1961	59	2020	$ 27,360
3005	Monitor and Forecast	150	Concrete NonReinf	8	40-60yr	1973	47	2020	$ 22,800
9234	Monitor and Forecast	240	Concrete NonReinf	8	40-60yr	1973	47	2020	$ 36,480
10416	Monitor and Forecast	90	Concrete NonReinf	8	40-60yr	1973	47	2020	$ 13,680
6702	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1962	58	2020	$ 45,600
8741	Monitor and Forecast	320	Asbestos Cement	8	40-60yr	1962	58	2020	$ 48,640
8747	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1962	58	2020	$ 39,520
10575	Monitor and Forecast	60	Concrete NonReinf	8	40-60yr	1974	46	2020	$ 9,120
10569	Monitor and Forecast	380	Concrete NonReinf	8	40-60yr	1974	46	2020	$ 57,760
10570	Monitor and Forecast	120	Concrete NonReinf	8	40-60yr	1974	46	2020	$ 18,240
10573	Monitor and Forecast	340	Concrete NonReinf	8	40-60yr	1974	46	2020	$ 51,680
10665	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1974	46	2020	$ 19,760
10677	Monitor and Forecast	390	Concrete NonReinf	8	40-60yr	1974	46	2020	$ 59,280
2536	Monitor and Forecast	270	Concrete NonReinf	8	40-60yr	1974	46	2020	$ 41,040
10222	Monitor and Forecast	370	Concrete NonReinf	8	40-60yr	1974	46	2020	$ 56,240
7254	Monitor and Forecast	350	Asbestos Cement	8	40-60yr	1963	57	2020	$ 53,200
4775	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1963	57	2020	$ 39,520
6361	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1964	56	2020	$ 39,520

6365	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1964	56	2020	$	50,160
6574	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1964	56	2020	$	13,680
6565	Monitor and Forecast	320	Asbestos Cement	8	40-60yr	1964	56	2020	$	48,640
1083	Monitor and Forecast	30	Asbestos Cement	8	40-60yr	1964	56	2020	$	4,560
3082	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1976	44	2020	$	19,760
3015	Monitor and Forecast	180	Concrete NonReinf	8	40-60yr	1977	43	2020	$	27,360
4395	Monitor and Forecast	190	Concrete NonReinf	8	40-60yr	1977	43	2020	$	28,880
4850	Monitor and Forecast	80	Concrete NonReinf	8	40-60yr	1977	43	2020	$	12,160
11574	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1967	53	2020	$	38,000
934	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1968	52	2020	$	33,440
12513	Monitor and Forecast	120	Concrete NonReinf	8	40-60yr	1979	41	2020	$	18,240
1988	Monitor and Forecast	120	Concrete NonReinf	8	40-60yr	1979	41	2020	$	18,240
2154	Monitor and Forecast	270	Concrete NonReinf	8	40-60yr	1979	41	2020	$	41,040
4878	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1970	50	2020	$	59,280
4896	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1970	50	2020	$	38,000
4897	Monitor and Forecast	110	Asbestos Cement	8	40-60yr	1970	50	2020	$	16,720
4903	Monitor and Forecast	290	Asbestos Cement	10	40-60yr	1970	50	2020	$	55,100
4895	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1970	50	2020	$	28,880
4900	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1970	50	2020	$	12,160
4901	Monitor and Forecast	270	Asbestos Cement	10	40-60yr	1970	50	2020	$	51,300
111	Repair/Replace on Failure	390	Concrete NonReinf	8	40-60yr	1979	41	2021	$	59,280
5123	Repair/Replace on Failure	250	Ductile iron	8	40-60yr	1979	41	2021	$	38,000
5245	Repair/Replace on Failure	90	Ductile iron	8	40-60yr	1979	41	2021	$	13,680
9858	Repair/Replace on Failure	200	Ductile iron	8	40-60yr	1979	41	2021	$	30,400
5064	Repair/Replace on Failure	140	Ductile iron	8	40-60yr	1979	41	2021	$	21,280
5243	Repair/Replace on Failure	150	Ductile iron	8	40-60yr	1979	41	2021	$	22,800
1943	Repair/Replace on Failure	300	Steel	8	40-60yr	1979	41	2021	$	45,600
1714	Monitor and Forecast	400	Concrete NonReinf	12	40-60yr	1974	46	2021	$	91,200
6270	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1971	49	2021	$	39,520
194	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1971	49	2021	$	60,800
6350	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1971	49	2021	$	34,960
6654	Monitor and Forecast	90	Asbestos Cement	10	40-60yr	1971	49	2021	$	17,100
6655	Monitor and Forecast	310	Asbestos Cement	10	40-60yr	1971	49	2021	$	58,900
6656	Monitor and Forecast	190	Asbestos Cement	10	40-60yr	1971	49	2021	$	36,100
6659	Monitor and Forecast	190	Asbestos Cement	10	40-60yr	1971	49	2021	$	36,100
12462	Monitor and Forecast	230	Asbestos Cement	10	40-60yr	1971	49	2021	$	43,700
6349	Monitor and Forecast	350	Asbestos Cement	8	40-60yr	1971	49	2021	$	53,200
6352	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1971	49	2021	$	57,760
9237	Monitor and Forecast	200	Concrete NonReinf	8	40-60yr	1973	47	2021	$	30,400
7126	Monitor and Forecast	330	Asbestos Cement	8	>60yr	1959	61	2021	$	50,160
7836	Monitor and Forecast	360	Asbestos Cement	8	>60yr	1959	61	2021	$	54,720
759	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2021	$	27,360
987	Monitor and Forecast	410	Asbestos Cement	8	40-60yr	1960	60	2021	$	62,320
1076	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1960	60	2021	$	39,520
4928	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1963	57	2021	$	19,760
7255	Monitor and Forecast	100	Asbestos Cement	8	40-60yr	1963	57	2021	$	15,200
8194	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1963	57	2021	$	39,520

8207	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1963	57	2021	$ 31,920
8982	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1963	57	2021	$ 24,320
8983	Monitor and Forecast	100	Asbestos Cement	8	40-60yr	1963	57	2021	$ 15,200
6368	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1964	56	2021	$ 19,760
162	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1964	56	2021	$ 57,760
6651	Monitor and Forecast	260	Asbestos Cement	10	40-60yr	1971	49	2021	$ 49,400
1204	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1968	52	2021	$ 39,520
1223	Monitor and Forecast	380	Concrete NonReinf	8	40-60yr	1979	41	2021	$ 57,760
461	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1971	49	2021	$ 57,760
9265	Monitor and Forecast	220	Concrete NonReinf	8	40-60yr	1973	47	2021	$ 33,440
3941	Monitor and Forecast	330	Concrete NonReinf	8	40-60yr	1960	60	2021	$ 50,160
6658	Monitor and Forecast	410	Asbestos Cement	10	40-60yr	1971	49	2021	$ 77,900
6351	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1971	49	2021	$ 19,760
6650	Monitor and Forecast	250	Asbestos Cement	10	40-60yr	1971	49	2021	$ 47,500
12464	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1954	66	2021	$ 41,040
12466	Monitor and Forecast	140	Asbestos Cement	8	>60yr	1954	66	2021	$ 21,280
4959	Monitor and Forecast	110	Asbestos Cement	8	>60yr	1959	61	2021	$ 16,720
4967	Monitor and Forecast	400	Asbestos Cement	8	>60yr	1959	61	2021	$ 60,800
4990	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1959	61	2021	$ 38,000
4998	Monitor and Forecast	160	Asbestos Cement	8	>60yr	1959	61	2021	$ 24,320
7824	Monitor and Forecast	320	Asbestos Cement	8	>60yr	1959	61	2021	$ 48,640
4982	Monitor and Forecast	410	Asbestos Cement	8	>60yr	1959	61	2021	$ 62,320
4994	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2021	$ 39,520
4996	Monitor and Forecast	60	Asbestos Cement	8	>60yr	1959	61	2021	$ 9,120
9317	Monitor and Forecast	80	Asbestos Cement	8	>60yr	1959	61	2021	$ 12,160
9328	Monitor and Forecast	350	Asbestos Cement	8	>60yr	1959	61	2021	$ 53,200
9390	Monitor and Forecast	120	Asbestos Cement	8	>60yr	1959	61	2021	$ 18,240
9407	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2021	$ 39,520
9414	Monitor and Forecast	200	Asbestos Cement	8	>60yr	1959	61	2021	$ 30,400
11270	Monitor and Forecast	280	Asbestos Cement	8	>60yr	1959	61	2021	$ 42,560
7248	Monitor and Forecast	340	Asbestos Cement	8	>60yr	1959	61	2021	$ 51,680
8381	Monitor and Forecast	240	Asbestos Cement	8	>60yr	1959	61	2021	$ 36,480
9350	Monitor and Forecast	140	Asbestos Cement	8	>60yr	1959	61	2021	$ 21,280
6869	Monitor and Forecast	400	Asbestos Cement	8	>60yr	1959	61	2021	$ 60,800
7127	Monitor and Forecast	110	Asbestos Cement	8	>60yr	1959	61	2021	$ 16,720
9945	Monitor and Forecast	240	Asbestos Cement	8	>60yr	1959	61	2021	$ 36,480
4435	Monitor and Forecast	330	Asbestos Cement	8	>60yr	1959	61	2021	$ 50,160
4436	Monitor and Forecast	330	Asbestos Cement	8	>60yr	1959	61	2021	$ 50,160
4972	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2021	$ 39,520
5127	Monitor and Forecast	310	Asbestos Cement	8	>60yr	1959	61	2021	$ 47,120
3940	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1960	60	2021	$ 41,040
3379	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1960	60	2021	$ 39,520
8221	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1960	60	2021	$ 41,040
5511	Monitor and Forecast	110	Concrete NonReinf	8	40-60yr	1972	48	2021	$ 16,720
2020	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1961	59	2021	$ 24,320
6833	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1961	59	2021	$ 33,440
3107	Monitor and Forecast	30	Concrete NonReinf	8	40-60yr	1973	47	2021	$ 4,560

9241	Monitor and Forecast	220	Concrete NonReinf	8	40-60yr	1973	47	2021	$ 33,440
9266	Monitor and Forecast	290	Concrete NonReinf	8	40-60yr	1973	47	2021	$ 44,080
9248	Monitor and Forecast	170	Concrete NonReinf	8	40-60yr	1973	47	2021	$ 25,840
9271	Monitor and Forecast	300	Concrete NonReinf	8	40-60yr	1973	47	2021	$ 45,600
6725	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1962	58	2021	$ 47,120
10539	Monitor and Forecast	170	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 25,840
10562	Monitor and Forecast	350	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 53,200
10565	Monitor and Forecast	280	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 42,560
10673	Monitor and Forecast	50	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 7,600
2516	Monitor and Forecast	230	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 34,960
2519	Monitor and Forecast	390	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 59,280
2546	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 19,760
10192	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 19,760
10545	Monitor and Forecast	270	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 41,040
10561	Monitor and Forecast	160	Concrete NonReinf	8	40-60yr	1974	46	2021	$ 24,320
13805	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1963	57	2021	$ 45,600
6278	Monitor and Forecast	160	Asbestos Cement	10	40-60yr	1964	56	2021	$ 30,400
6535	Monitor and Forecast	160	Asbestos Cement	10	40-60yr	1964	56	2021	$ 30,400
6357	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1964	56	2021	$ 28,880
3069	Monitor and Forecast	300	Concrete NonReinf	8	40-60yr	1976	44	2021	$ 45,600
8079	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1966	54	2021	$ 44,080
8080	Monitor and Forecast	410	Asbestos Cement	8	40-60yr	1966	54	2021	$ 62,320
8081	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1966	54	2021	$ 57,760
4842	Monitor and Forecast	160	Concrete NonReinf	8	40-60yr	1977	43	2021	$ 24,320
6236	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1969	51	2021	$ 30,400
1480	Monitor and Forecast	120	Concrete NonReinf	8	40-60yr	1979	41	2021	$ 18,240
2191	Monitor and Forecast	240	Concrete NonReinf	8	40-60yr	1979	41	2021	$ 36,480
1934	Monitor and Forecast	180	Concrete NonReinf	8	40-60yr	1979	41	2021	$ 27,360
1906	Monitor and Forecast	360	Concrete Reinf	8	40-60yr	1971	49	2021	$ 54,720
3308	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1971	49	2021	$ 44,080
3309	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1971	49	2021	$ 38,000
4268	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1971	49	2021	$ 44,080
4269	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1971	49	2021	$ 39,520
4270	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1971	49	2021	$ 33,440
4271	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1971	49	2021	$ 34,960
4272	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1971	49	2021	$ 45,600
4273	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1971	49	2021	$ 51,680
4274	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1971	49	2021	$ 41,040
4275	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1971	49	2021	$ 16,720
4279	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1971	49	2021	$ 21,280
4280	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1971	49	2021	$ 56,240
4281	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1971	49	2021	$ 59,280
4285	Monitor and Forecast	360	Concrete Reinf	8	40-60yr	1971	49	2021	$ 54,720
4286	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1971	49	2021	$ 18,240
4287	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1971	49	2021	$ 19,760
4288	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1971	49	2021	$ 28,880
4289	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1971	49	2021	$ 18,240

4290	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1971	49	2021	$ 16,720
4291	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1971	49	2021	$ 45,600
4292	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1971	49	2021	$ 38,000
4293	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1971	49	2021	$ 15,200
4295	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1971	49	2021	$ 38,000
4296	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1971	49	2021	$ 57,760
4297	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1971	49	2021	$ 39,520
4329	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1971	49	2021	$ 38,000
5979	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1971	49	2021	$ 15,200
5985	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1971	49	2021	$ 44,080
6159	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1971	49	2021	$ 60,800
6165	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1971	49	2021	$ 18,240
6190	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1971	49	2021	$ 21,280
6214	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1971	49	2021	$ 60,800
6246	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1971	49	2021	$ 25,840
6247	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1971	49	2021	$ 62,320
6248	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1971	49	2021	$ 39,520
6249	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1971	49	2021	$ 21,280
6250	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1971	49	2021	$ 31,920
6251	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1971	49	2021	$ 48,640
6252	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1971	49	2021	$ 48,640
6265	Monitor and Forecast	440	Concrete Reinf	8	40-60yr	1971	49	2021	$ 66,880
6266	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1971	49	2021	$ 28,880
6267	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1971	49	2021	$ 51,680
6268	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1971	49	2021	$ 60,800
6269	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1971	49	2021	$ 62,320
6271	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1971	49	2021	$ 30,400
6273	Monitor and Forecast	450	Concrete Reinf	8	40-60yr	1971	49	2021	$ 68,400
6274	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1971	49	2021	$ 21,280
6280	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1971	49	2021	$ 57,760
6211	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1971	49	2021	$ 19,760
4278	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1971	49	2021	$ 19,760
4282	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1971	49	2021	$ 15,200
4283	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1971	49	2021	$ 59,280
4294	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1971	49	2021	$ 22,800
4298	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1971	49	2021	$ 41,040
4328	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1971	49	2021	$ 28,880
510	Monitor and Forecast	810	Asbestos Cement	10	40-60yr	1971	49	2021	$ 153,900
1510	Monitor and Forecast	490	Asbestos Cement	10	40-60yr	1971	49	2021	$ 93,100
2263	Monitor and Forecast	530	Asbestos Cement	10	40-60yr	1971	49	2021	$ 100,700
4913	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1971	49	2021	$ 56,240
4918	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1971	49	2021	$ 13,680
6380	Monitor and Forecast	200	Asbestos Cement	10	40-60yr	1971	49	2021	$ 38,000
6253	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1971	49	2021	$ 44,080
6262	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1971	49	2021	$ 45,600
6263	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1971	49	2021	$ 36,480
6272	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1971	49	2021	$ 24,320

9779	Repair/Replace on Failure	160	Ductile iron	8	40-60yr	1979	41	2022	$	24,320
5076	Repair/Replace on Failure	100	Ductile iron	8	40-60yr	1979	41	2022	$	15,200
5105	Repair/Replace on Failure	320	Ductile iron	8	40-60yr	1979	41	2022	$	48,640
5110	Repair/Replace on Failure	100	Ductile iron	8	40-60yr	1979	41	2022	$	15,200
5116	Repair/Replace on Failure	90	Ductile iron	8	40-60yr	1979	41	2022	$	13,680
9777	Repair/Replace on Failure	150	Ductile iron	8	40-60yr	1979	41	2022	$	22,800
9778	Repair/Replace on Failure	140	Ductile iron	8	40-60yr	1979	41	2022	$	21,280
9803	Repair/Replace on Failure	400	Ductile iron	8	40-60yr	1979	41	2022	$	60,800
9877	Repair/Replace on Failure	170	Ductile iron	8	40-60yr	1979	41	2022	$	25,840
9881	Repair/Replace on Failure	190	Ductile iron	8	40-60yr	1979	41	2022	$	28,880
1690	Repair/Replace on Failure	110	Ductile iron	8	40-60yr	1979	41	2022	$	16,720
5109	Repair/Replace on Failure	350	Ductile iron	8	40-60yr	1979	41	2022	$	53,200
114	Monitor and Forecast	240	Concrete NonReinf	12	40-60yr	1979	41	2022	$	54,720
8798	Monitor and Forecast	140	Concrete NonReinf	12	40-60yr	1973	47	2022	$	31,920
8810	Monitor and Forecast	140	Concrete NonReinf	12	40-60yr	1973	47	2022	$	31,920
498	Monitor and Forecast	360	Concrete NonReinf	8	40-60yr	1979	41	2022	$	54,720
8581	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$	39,520
7098	Monitor and Forecast	350	Concrete Reinf	8	40-60yr	1972	48	2022	$	53,200
6872	Monitor and Forecast	190	Asbestos Cement	8	>60yr	1959	61	2022	$	28,880
7148	Monitor and Forecast	150	Asbestos Cement	8	>60yr	1959	61	2022	$	22,800
7150	Monitor and Forecast	80	Asbestos Cement	8	>60yr	1959	61	2022	$	12,160
7206	Monitor and Forecast	220	Asbestos Cement	8	>60yr	1959	61	2022	$	33,440
9953	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2022	$	27,360
586	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2022	$	39,520
587	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2022	$	39,520
521	Monitor and Forecast	70	Concrete NonReinf	8	40-60yr	1979	41	2022	$	10,640
6284	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1964	56	2022	$	36,480
6367	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1964	56	2022	$	24,320
6561	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1964	56	2022	$	30,400
6578	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1964	56	2022	$	41,040
2566	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1972	48	2022	$	18,240
2109	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1972	48	2022	$	16,720
161	Monitor and Forecast	350	Concrete NonReinf	10	40-60yr	1979	41	2022	$	66,500
1210	Monitor and Forecast	70	Concrete NonReinf	8	40-60yr	1979	41	2022	$	10,640
9446	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1972	48	2022	$	45,600
9571	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1972	48	2022	$	42,560
9586	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1972	48	2022	$	12,160
9724	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1972	48	2022	$	13,680
8725	Monitor and Forecast	150	Asbestos Cement	8	40-60yr	1962	58	2022	$	22,800
4768	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1963	57	2022	$	60,800
3041	Monitor and Forecast	250	Concrete NonReinf	8	40-60yr	1977	43	2022	$	38,000
124	Monitor and Forecast	380	Concrete NonReinf	8	40-60yr	1979	41	2022	$	57,760
2324	Monitor and Forecast	150	Concrete NonReinf	8	40-60yr	1979	41	2022	$	22,800
3937	Monitor and Forecast	330	Concrete NonReinf	8	40-60yr	1960	60	2022	$	50,160
2570	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1972	48	2022	$	15,200
8575	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$	39,520
8579	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1972	48	2022	$	62,320

8582	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$ 39,520
8669	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1972	48	2022	$ 56,240
2971	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1972	48	2022	$ 50,160
4905	Monitor and Forecast	280	Asbestos Cement	8	>60yr	1954	66	2022	$ 42,560
4906	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1954	66	2022	$ 41,040
4907	Monitor and Forecast	190	Asbestos Cement	10	>60yr	1954	66	2022	$ 36,100
6710	Monitor and Forecast	180	Concrete Reinf	6	>60yr	1955	65	2022	$ 20,520
6712	Monitor and Forecast	140	Concrete Reinf	6	>60yr	1955	65	2022	$ 15,960
829	Monitor and Forecast	110	Asbestos Cement	8	>60yr	1959	61	2022	$ 16,720
7823	Monitor and Forecast	400	Asbestos Cement	8	>60yr	1959	61	2022	$ 60,800
4978	Monitor and Forecast	410	Asbestos Cement	8	>60yr	1959	61	2022	$ 62,320
4980	Monitor and Forecast	230	Asbestos Cement	8	>60yr	1959	61	2022	$ 34,960
4995	Monitor and Forecast	410	Asbestos Cement	8	>60yr	1959	61	2022	$ 62,320
8365	Monitor and Forecast	120	Asbestos Cement	8	>60yr	1959	61	2022	$ 18,240
9290	Monitor and Forecast	160	Asbestos Cement	8	>60yr	1959	61	2022	$ 24,320
9319	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2022	$ 27,360
9320	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2022	$ 27,360
11174	Monitor and Forecast	320	Asbestos Cement	8	>60yr	1959	61	2022	$ 48,640
7108	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1959	61	2022	$ 38,000
7125	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2022	$ 39,520
4932	Monitor and Forecast	220	Asbestos Cement	8	>60yr	1959	61	2022	$ 33,440
6867	Monitor and Forecast	230	Asbestos Cement	8	>60yr	1959	61	2022	$ 34,960
7227	Monitor and Forecast	110	Asbestos Cement	8	>60yr	1959	61	2022	$ 16,720
7232	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2022	$ 39,520
7837	Monitor and Forecast	360	Asbestos Cement	8	>60yr	1959	61	2022	$ 54,720
4915	Monitor and Forecast	390	Concrete NonReinf	8	40-60yr	1971	49	2022	$ 59,280
9410	Monitor and Forecast	50	Asbestos Cement	8	>60yr	1959	61	2022	$ 7,600
1835	Monitor and Forecast	350	Asbestos Cement	8	>60yr	1959	61	2022	$ 53,200
4976	Monitor and Forecast	360	Asbestos Cement	8	>60yr	1959	61	2022	$ 54,720
11220	Monitor and Forecast	120	Asbestos Cement	6	>60yr	1959	61	2022	$ 13,680
3944	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1960	60	2022	$ 38,000
8073	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1960	60	2022	$ 39,520
8225	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1960	60	2022	$ 39,520
3935	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1960	60	2022	$ 51,680
3381	Monitor and Forecast	360	Asbestos Cement	8	40-60yr	1960	60	2022	$ 54,720
3386	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1960	60	2022	$ 33,440
8224	Monitor and Forecast	390	Asbestos Cement	8	40-60yr	1960	60	2022	$ 59,280
800	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1961	59	2022	$ 33,440
2206	Monitor and Forecast	160	Asbestos Cement	8	40-60yr	1961	59	2022	$ 24,320
2207	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1961	59	2022	$ 44,080
3032	Monitor and Forecast	120	Concrete NonReinf	8	40-60yr	1973	47	2022	$ 18,240
9243	Monitor and Forecast	170	Concrete NonReinf	8	40-60yr	1973	47	2022	$ 25,840
6715	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1962	58	2022	$ 44,080
6728	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1962	58	2022	$ 28,880
6706	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1962	58	2022	$ 33,440
6724	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1962	58	2022	$ 51,680
10292	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1962	58	2022	$ 44,080

10300	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1962	58	2022	$	13,680
8723	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1962	58	2022	$	38,000
8742	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1962	58	2022	$	38,000
2528	Monitor and Forecast	360	Concrete NonReinf	8	40-60yr	1974	46	2022	$	54,720
10537	Monitor and Forecast	60	Concrete NonReinf	8	40-60yr	1974	46	2022	$	9,120
2498	Monitor and Forecast	360	Concrete NonReinf	8	40-60yr	1974	46	2022	$	54,720
2514	Monitor and Forecast	270	Concrete NonReinf	8	40-60yr	1974	46	2022	$	41,040
2525	Monitor and Forecast	290	Concrete NonReinf	8	40-60yr	1974	46	2022	$	44,080
10220	Monitor and Forecast	220	Concrete NonReinf	8	40-60yr	1974	46	2022	$	33,440
10571	Monitor and Forecast	280	Concrete NonReinf	8	40-60yr	1974	46	2022	$	42,560
10572	Monitor and Forecast	160	Concrete NonReinf	8	40-60yr	1974	46	2022	$	24,320
9915	Monitor and Forecast	370	Concrete NonReinf	8	40-60yr	1974	46	2022	$	56,240
2510	Monitor and Forecast	180	Concrete NonReinf	8	40-60yr	1974	46	2022	$	27,360
2553	Monitor and Forecast	350	Concrete NonReinf	8	40-60yr	1974	46	2022	$	53,200
10559	Monitor and Forecast	90	Concrete NonReinf	8	40-60yr	1974	46	2022	$	13,680
7243	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1963	57	2022	$	38,000
4773	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1963	57	2022	$	9,120
4779	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1963	57	2022	$	60,800
4783	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1963	57	2022	$	42,560
6563	Monitor and Forecast	260	Asbestos Cement	10	40-60yr	1964	56	2022	$	49,400
6358	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1964	56	2022	$	41,040
3072	Monitor and Forecast	100	Concrete NonReinf	8	40-60yr	1976	44	2022	$	15,200
8082	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1966	54	2022	$	36,480
4170	Monitor and Forecast	80	Concrete NonReinf	8	40-60yr	1977	43	2022	$	12,160
11573	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1967	53	2022	$	36,480
11575	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1967	53	2022	$	44,080
12056	Monitor and Forecast	100	Asbestos Cement	10	40-60yr	1968	52	2022	$	19,000
1389	Monitor and Forecast	260	Concrete NonReinf	8	40-60yr	1979	41	2022	$	39,520
1915	Monitor and Forecast	190	Concrete NonReinf	10	40-60yr	1979	41	2022	$	36,100
1117	Monitor and Forecast	400	Concrete NonReinf	8	40-60yr	1979	41	2022	$	60,800
377	Monitor and Forecast	310	Concrete NonReinf	8	40-60yr	1979	41	2022	$	47,120
1986	Monitor and Forecast	260	Concrete NonReinf	8	40-60yr	1979	41	2022	$	39,520
2572	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1972	48	2022	$	15,200
2574	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1972	48	2022	$	51,680
2578	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1972	48	2022	$	13,680
2590	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$	38,000
9388	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1972	48	2022	$	22,800
9396	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
9450	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$	39,520
9452	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$	38,000
9563	Monitor and Forecast	350	Concrete Reinf	8	40-60yr	1972	48	2022	$	53,200
9573	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$	39,520
9587	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1972	48	2022	$	24,320
9588	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1972	48	2022	$	19,760
9598	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1972	48	2022	$	51,680
9601	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1972	48	2022	$	34,960
9604	Monitor and Forecast	350	Concrete Reinf	8	40-60yr	1972	48	2022	$	53,200

9606	Monitor and Forecast	360	Concrete Reinf	8	40-60yr	1972	48	2022	$	54,720
9656	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$	39,520
9659	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1972	48	2022	$	19,760
9665	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1972	48	2022	$	34,960
9669	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1972	48	2022	$	34,960
9673	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1972	48	2022	$	33,440
9676	Monitor and Forecast	360	Concrete Reinf	8	40-60yr	1972	48	2022	$	54,720
9679	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$	39,520
9682	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1972	48	2022	$	34,960
10038	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1972	48	2022	$	31,920
10039	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
10189	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1972	48	2022	$	51,680
10223	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1972	48	2022	$	44,080
10228	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1972	48	2022	$	42,560
10513	Monitor and Forecast	240	Concrete Reinf	10	40-60yr	1972	48	2022	$	45,600
3219	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
3230	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1972	48	2022	$	25,840
3235	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1972	48	2022	$	45,600
3742	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1972	48	2022	$	15,200
3743	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1972	48	2022	$	33,440
3744	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$	38,000
3745	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1972	48	2022	$	42,560
3746	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1972	48	2022	$	47,120
3747	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1972	48	2022	$	21,280
3748	Monitor and Forecast	60	Concrete Reinf	8	40-60yr	1972	48	2022	$	9,120
4284	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$	38,000
4330	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1972	48	2022	$	30,400
4331	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1972	48	2022	$	25,840
4332	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
4333	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1972	48	2022	$	15,200
4334	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1972	48	2022	$	13,680
4335	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1972	48	2022	$	18,240
4336	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1972	48	2022	$	16,720
4337	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1972	48	2022	$	50,160
4345	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1972	48	2022	$	57,760
4346	Monitor and Forecast	360	Concrete Reinf	8	40-60yr	1972	48	2022	$	54,720
4347	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1972	48	2022	$	13,680
4348	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1972	48	2022	$	33,440
4349	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1972	48	2022	$	34,960
4350	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1972	48	2022	$	56,240
4352	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1972	48	2022	$	24,320
4353	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1972	48	2022	$	13,680
4354	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1972	48	2022	$	48,640
4355	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1972	48	2022	$	16,720
4357	Monitor and Forecast	360	Concrete Reinf	8	40-60yr	1972	48	2022	$	54,720
4358	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1972	48	2022	$	48,640
4359	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1972	48	2022	$	12,160

4361	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$	39,520
4362	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1972	48	2022	$	62,320
4363	Monitor and Forecast	70	Concrete Reinf	8	40-60yr	1972	48	2022	$	10,640
4364	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1972	48	2022	$	28,880
4365	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1972	48	2022	$	47,120
4366	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$	38,000
4367	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1972	48	2022	$	59,280
4368	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1972	48	2022	$	25,840
4369	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$	39,520
4370	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1972	48	2022	$	44,080
4371	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1972	48	2022	$	59,280
4372	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1972	48	2022	$	60,800
4374	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1972	48	2022	$	18,240
4375	Monitor and Forecast	60	Concrete Reinf	8	40-60yr	1972	48	2022	$	9,120
4742	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1972	48	2022	$	57,760
4743	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1972	48	2022	$	59,280
4744	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1972	48	2022	$	59,280
4745	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1972	48	2022	$	28,880
4746	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1972	48	2022	$	28,880
4747	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1972	48	2022	$	47,120
4748	Monitor and Forecast	480	Concrete Reinf	8	40-60yr	1972	48	2022	$	72,960
4749	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1972	48	2022	$	12,160
4750	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
4751	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1972	48	2022	$	25,840
4753	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1972	48	2022	$	48,640
4754	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1972	48	2022	$	12,160
4755	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1972	48	2022	$	12,160
4756	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1972	48	2022	$	15,200
8567	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
8573	Monitor and Forecast	450	Concrete Reinf	8	40-60yr	1972	48	2022	$	68,400
8583	Monitor and Forecast	450	Concrete Reinf	8	40-60yr	1972	48	2022	$	68,400
8584	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1972	48	2022	$	60,800
8585	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1972	48	2022	$	62,320
9515	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1972	48	2022	$	42,560
9516	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
10029	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1972	48	2022	$	47,120
10030	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1972	48	2022	$	25,840
10031	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$	38,000
10033	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1972	48	2022	$	12,160
10034	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1972	48	2022	$	50,160
10035	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
10036	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
10037	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
10113	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1972	48	2022	$	16,720
10114	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1972	48	2022	$	36,480
10115	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$	38,000
10116	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1972	48	2022	$	19,760

10117	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$	39,520
10118	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1972	48	2022	$	56,240
10119	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1972	48	2022	$	59,280
10190	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1972	48	2022	$	13,680
10191	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1972	48	2022	$	22,800
10224	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
10225	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1972	48	2022	$	25,840
10226	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
10227	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$	41,040
10229	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1972	48	2022	$	33,440
10230	Monitor and Forecast	70	Concrete Reinf	8	40-60yr	1972	48	2022	$	10,640
10231	Monitor and Forecast	60	Concrete Reinf	8	40-60yr	1972	48	2022	$	9,120
10232	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1972	48	2022	$	34,960
10233	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1972	48	2022	$	57,760
10234	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1972	48	2022	$	31,920
10510	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1972	48	2022	$	31,920
10511	Monitor and Forecast	40	Concrete Reinf	8	40-60yr	1972	48	2022	$	6,080
10512	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1972	48	2022	$	51,680
10515	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1972	48	2022	$	50,160
10516	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1972	48	2022	$	30,400
10517	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1972	48	2022	$	42,560
10518	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1972	48	2022	$	31,920
10519	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1972	48	2022	$	44,080
10520	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1972	48	2022	$	51,680
10521	Monitor and Forecast	350	Concrete Reinf	8	40-60yr	1972	48	2022	$	53,200
10522	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1972	48	2022	$	13,680
10523	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1972	48	2022	$	19,760
10525	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1972	48	2022	$	25,840
10526	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1972	48	2022	$	56,240
10528	Monitor and Forecast	70	Concrete Reinf	8	40-60yr	1972	48	2022	$	10,640
10529	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1972	48	2022	$	60,800
10530	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1972	48	2022	$	45,600
10534	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1972	48	2022	$	62,320
1661	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1972	48	2022	$	60,800
1662	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1972	48	2022	$	50,160
2966	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1972	48	2022	$	19,760
3193	Monitor and Forecast	360	Concrete Reinf	8	40-60yr	1972	48	2022	$	54,720
3194	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1972	48	2022	$	62,320
3195	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1972	48	2022	$	12,160
3196	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$	38,000
3197	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1972	48	2022	$	59,280
3198	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1972	48	2022	$	62,320
3199	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1972	48	2022	$	36,480
3200	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1972	48	2022	$	44,080
3202	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1972	48	2022	$	36,480
3217	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1972	48	2022	$	27,360
3218	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1972	48	2022	$	34,960

3220	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1972	48	2022	$ 45,600
3222	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1972	48	2022	$ 47,120
3223	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1972	48	2022	$ 24,320
3224	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1972	48	2022	$ 33,440
3225	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1972	48	2022	$ 24,320
3226	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1972	48	2022	$ 16,720
3227	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1972	48	2022	$ 33,440
3228	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1972	48	2022	$ 18,240
3231	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1972	48	2022	$ 60,800
3232	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1972	48	2022	$ 28,880
3233	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1972	48	2022	$ 15,200
3234	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1972	48	2022	$ 59,280
3236	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1972	48	2022	$ 59,280
4757	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1972	48	2022	$ 31,920
10524	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1972	48	2022	$ 44,080
10531	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1972	48	2022	$ 34,960
10532	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$ 38,000
10533	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1972	48	2022	$ 60,800
10535	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1972	48	2022	$ 48,640
10598	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1972	48	2022	$ 28,880
10599	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$ 38,000
9449	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$ 38,000
10032	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1972	48	2022	$ 34,960
10514	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1972	48	2022	$ 25,840
2559	Monitor and Forecast	360	Concrete Reinf	8	40-60yr	1972	48	2022	$ 54,720
9662	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$ 38,000
4338	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1972	48	2022	$ 42,560
4344	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1972	48	2022	$ 28,880
4351	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$ 41,040
4356	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1972	48	2022	$ 47,120
4360	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1972	48	2022	$ 30,400
9088	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1972	48	2022	$ 41,040
9089	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1972	48	2022	$ 19,760
9091	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1972	48	2022	$ 16,720
9092	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1972	48	2022	$ 31,920
9291	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1972	48	2022	$ 62,320
9387	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1972	48	2022	$ 22,800
9391	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1972	48	2022	$ 39,520
9393	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1972	48	2022	$ 59,280
9394	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1972	48	2022	$ 27,360
9395	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1972	48	2022	$ 38,000
9398	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1972	48	2022	$ 24,320
9404	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1972	48	2022	$ 60,800
8576	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1972	48	2022	$ 16,720
8672	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1972	48	2022	$ 16,720
2970	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1972	48	2022	$ 51,680
2972	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1972	48	2022	$ 31,920

2976	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1972	48	2022	$ 50,160
3165	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1972	48	2022	$ 50,160
3192	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1972	48	2022	$ 28,880
5092	Repair/Replace on Failure	90	Ductile iron	8	40-60yr	1979	41	2023	$ 13,680
5095	Repair/Replace on Failure	90	Ductile iron	8	40-60yr	1979	41	2023	$ 13,680
9795	Repair/Replace on Failure	400	Ductile iron	8	40-60yr	1979	41	2023	$ 60,800
9866	Repair/Replace on Failure	150	Ductile iron	8	40-60yr	1979	41	2023	$ 22,800
5120	Repair/Replace on Failure	310	Ductile iron	8	40-60yr	1979	41	2023	$ 47,120
5264	Repair/Replace on Failure	160	Ductile iron	8	40-60yr	1979	41	2023	$ 24,320
5273	Repair/Replace on Failure	390	Ductile iron	8	40-60yr	1979	41	2023	$ 59,280
781	Proactive Assessment	230	Concrete NonReinf	18	40-60yr	1979	41	2023	$ 78,660
612	Monitor and Forecast	390	Concrete NonReinf	12	40-60yr	1979	41	2023	$ 88,920
8313	Monitor and Forecast	370	Concrete NonReinf	12	40-60yr	1973	47	2023	$ 84,360
2556	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1973	47	2023	$ 42,560
2569	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$ 41,040
2579	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$ 38,000
2589	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1973	47	2023	$ 15,200
9307	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$ 38,000
9312	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$ 38,000
9313	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$ 33,440
9599	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1973	47	2023	$ 48,640
122	Monitor and Forecast	290	Concrete NonReinf	8	40-60yr	1979	41	2023	$ 44,080
988	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1960	60	2023	$ 34,960
2557	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1973	47	2023	$ 19,760
2567	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$ 25,840
2581	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1973	47	2023	$ 36,480
9603	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1973	47	2023	$ 36,480
9607	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$ 31,920
9614	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$ 41,040
9301	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1973	47	2023	$ 44,080
9308	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$ 30,400
9309	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$ 25,840
10397	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$ 25,840
10419	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1973	47	2023	$ 19,760
4518	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$ 31,920
2576	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$ 30,400
9565	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1973	47	2023	$ 21,280
9568	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$ 39,520
9667	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$ 30,400
9680	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1973	47	2023	$ 47,120
4429	Monitor and Forecast	160	Asbestos Cement	8	>60yr	1959	61	2023	$ 24,320
9940	Monitor and Forecast	320	Asbestos Cement	8	>60yr	1959	61	2023	$ 48,640
588	Monitor and Forecast	210	Asbestos Cement	8	>60yr	1959	61	2023	$ 31,920
387	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1960	60	2023	$ 41,040
991	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1960	60	2023	$ 34,960
4938	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1963	57	2023	$ 21,280
6260	Monitor and Forecast	400	Asbestos Cement	8	40-60yr	1964	56	2023	$ 60,800

6564	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1964	56	2023	$	44,080
11656	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1964	56	2023	$	42,560
4567	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1973	47	2023	$	42,560
4574	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1973	47	2023	$	59,280
2568	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$	38,000
2571	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$	41,040
2575	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$	33,440
2577	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1973	47	2023	$	15,200
2580	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1973	47	2023	$	45,600
2582	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1973	47	2023	$	34,960
2583	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1973	47	2023	$	16,720
2585	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$	25,840
2588	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1973	47	2023	$	47,120
9445	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$	41,040
9447	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$	33,440
9566	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1973	47	2023	$	50,160
9572	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1973	47	2023	$	19,760
9589	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$	39,520
9590	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1973	47	2023	$	27,360
9594	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1973	47	2023	$	45,600
9595	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$	33,440
9596	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$	30,400
9602	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1973	47	2023	$	60,800
9610	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1973	47	2023	$	62,320
9651	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$	39,520
9652	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1973	47	2023	$	34,960
9655	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$	31,920
9658	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1973	47	2023	$	18,240
9661	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1973	47	2023	$	50,160
9663	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1973	47	2023	$	56,240
9666	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1973	47	2023	$	51,680
9668	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1973	47	2023	$	59,280
9674	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1973	47	2023	$	36,480
9675	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$	33,440
9677	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$	39,520
9678	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1973	47	2023	$	28,880
9681	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1973	47	2023	$	42,560
9684	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$	30,400
9721	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1973	47	2023	$	45,600
9276	Monitor and Forecast	230	Concrete NonReinf	8	40-60yr	1973	47	2023	$	34,960
8726	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1962	58	2023	$	36,480
1194	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1973	47	2023	$	13,680
1195	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1973	47	2023	$	19,760
3043	Monitor and Forecast	200	Concrete NonReinf	8	40-60yr	1977	43	2023	$	30,400
9295	Monitor and Forecast	70	Concrete Reinf	8	40-60yr	1973	47	2023	$	10,640
9296	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$	38,000
9298	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$	31,920

9299	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$ 39,520
9300	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1973	47	2023	$ 19,760
10415	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$ 38,000
10417	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$ 38,000
10418	Monitor and Forecast	70	Concrete Reinf	8	40-60yr	1973	47	2023	$ 10,640
4501	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$ 25,840
4981	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1959	61	2023	$ 38,000
5001	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1959	61	2023	$ 38,000
8188	Monitor and Forecast	390	Asbestos Cement	8	>60yr	1959	61	2023	$ 59,280
4966	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1959	61	2023	$ 38,000
7818	Monitor and Forecast	120	Asbestos Cement	8	>60yr	1959	61	2023	$ 18,240
8370	Monitor and Forecast	410	Asbestos Cement	8	>60yr	1959	61	2023	$ 62,320
8378	Monitor and Forecast	220	Asbestos Cement	8	>60yr	1959	61	2023	$ 33,440
9323	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2023	$ 27,360
9326	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2023	$ 39,520
9327	Monitor and Forecast	400	Asbestos Cement	8	>60yr	1959	61	2023	$ 60,800
9330	Monitor and Forecast	140	Asbestos Cement	8	>60yr	1959	61	2023	$ 21,280
9397	Monitor and Forecast	330	Asbestos Cement	8	>60yr	1959	61	2023	$ 50,160
9403	Monitor and Forecast	150	Asbestos Cement	8	>60yr	1959	61	2023	$ 22,800
1833	Monitor and Forecast	200	Asbestos Cement	8	>60yr	1959	61	2023	$ 30,400
8368	Monitor and Forecast	190	Asbestos Cement	8	>60yr	1959	61	2023	$ 28,880
8373	Monitor and Forecast	230	Asbestos Cement	8	>60yr	1959	61	2023	$ 34,960
9399	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2023	$ 27,360
7142	Monitor and Forecast	130	Asbestos Cement	8	>60yr	1959	61	2023	$ 19,760
7832	Monitor and Forecast	160	Asbestos Cement	8	>60yr	1959	61	2023	$ 24,320
7835	Monitor and Forecast	280	Asbestos Cement	8	>60yr	1959	61	2023	$ 42,560
7869	Monitor and Forecast	150	Asbestos Cement	8	>60yr	1959	61	2023	$ 22,800
9959	Monitor and Forecast	300	Asbestos Cement	8	>60yr	1959	61	2023	$ 45,600
70	Monitor and Forecast	80	Asbestos Cement	8	>60yr	1959	61	2023	$ 12,160
9405	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2023	$ 39,520
385	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1959	61	2023	$ 38,000
8226	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1960	60	2023	$ 44,080
8075	Monitor and Forecast	230	Asbestos Cement	8	40-60yr	1960	60	2023	$ 34,960
3930	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1960	60	2023	$ 12,160
2059	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1960	60	2023	$ 25,840
8760	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1960	60	2023	$ 36,480
3388	Monitor and Forecast	70	Asbestos Cement	8	40-60yr	1960	60	2023	$ 10,640
10050	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1960	60	2023	$ 47,120
10061	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1960	60	2023	$ 18,240
8067	Monitor and Forecast	400	Asbestos Cement	8	40-60yr	1960	60	2023	$ 60,800
303	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1961	59	2023	$ 30,400
381	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1961	59	2023	$ 39,520
799	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1961	59	2023	$ 47,120
1830	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1961	59	2023	$ 30,400
1831	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1961	59	2023	$ 18,240
2019	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1961	59	2023	$ 18,240
2208	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1961	59	2023	$ 42,560

3004	Monitor and Forecast	180	Concrete NonReinf	8	40-60yr	1973	47	2023	$ 27,360
3010	Monitor and Forecast	340	Concrete NonReinf	8	40-60yr	1973	47	2023	$ 51,680
3021	Monitor and Forecast	80	Concrete NonReinf	8	40-60yr	1973	47	2023	$ 12,160
9249	Monitor and Forecast	260	Concrete NonReinf	8	40-60yr	1973	47	2023	$ 39,520
6718	Monitor and Forecast	60	Concrete Reinf	8	40-60yr	1962	58	2023	$ 9,120
6723	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1962	58	2023	$ 56,240
6727	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1962	58	2023	$ 39,520
10298	Monitor and Forecast	340	Asbestos Cement	8	40-60yr	1962	58	2023	$ 51,680
8744	Monitor and Forecast	350	Concrete Reinf	8	40-60yr	1962	58	2023	$ 53,200
10596	Monitor and Forecast	340	Concrete NonReinf	8	40-60yr	1974	46	2023	$ 51,680
9914	Monitor and Forecast	240	Concrete NonReinf	8	40-60yr	1974	46	2023	$ 36,480
10593	Monitor and Forecast	340	Concrete NonReinf	8	40-60yr	1974	46	2023	$ 51,680
10536	Monitor and Forecast	290	Concrete NonReinf	8	40-60yr	1974	46	2023	$ 44,080
7244	Monitor and Forecast	100	Asbestos Cement	8	40-60yr	1963	57	2023	$ 15,200
9335	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1963	57	2023	$ 45,600
9334	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1963	57	2023	$ 25,840
9336	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1963	57	2023	$ 45,600
2017	Monitor and Forecast	410	Asbestos Cement	10	40-60yr	1964	56	2023	$ 77,900
6259	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1964	56	2023	$ 30,400
6261	Monitor and Forecast	340	Asbestos Cement	8	40-60yr	1964	56	2023	$ 51,680
6255	Monitor and Forecast	60	Asbestos Cement	8	40-60yr	1964	56	2023	$ 9,120
6566	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1964	56	2023	$ 39,520
3081	Monitor and Forecast	70	Concrete NonReinf	8	40-60yr	1976	44	2023	$ 10,640
3085	Monitor and Forecast	180	Concrete NonReinf	8	40-60yr	1976	44	2023	$ 27,360
3087	Monitor and Forecast	150	Concrete NonReinf	8	40-60yr	1976	44	2023	$ 22,800
3869	Monitor and Forecast	270	Concrete NonReinf	8	40-60yr	1977	43	2023	$ 41,040
6234	Monitor and Forecast	230	Asbestos Cement	6	40-60yr	1969	51	2023	$ 26,220
518	Monitor and Forecast	410	Concrete NonReinf	8	40-60yr	1979	41	2023	$ 62,320
2347	Monitor and Forecast	390	Concrete NonReinf	8	40-60yr	1979	41	2023	$ 59,280
2627	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1973	47	2023	$ 15,200
5035	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$ 25,840
9302	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$ 30,400
9303	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$ 30,400
9304	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1973	47	2023	$ 15,200
9305	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1973	47	2023	$ 15,200
9306	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1973	47	2023	$ 24,320
9310	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1973	47	2023	$ 19,760
9314	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1973	47	2023	$ 24,320
9315	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1973	47	2023	$ 59,280
9441	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$ 39,520
9448	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$ 30,400
9564	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$ 38,000
9597	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1973	47	2023	$ 47,120
9605	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$ 33,440
9608	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$ 31,920
9609	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$ 31,920
9613	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$ 31,920

9657	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1973	47	2023	$	60,800
10399	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1973	47	2023	$	19,760
10401	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1973	47	2023	$	12,160
10405	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1973	47	2023	$	15,200
10420	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1973	47	2023	$	47,120
3029	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$	33,440
5171	Monitor and Forecast	310	Concrete Reinf	10	40-60yr	1973	47	2023	$	58,900
5253	Monitor and Forecast	300	Concrete Reinf	10	40-60yr	1973	47	2023	$	57,000
5255	Monitor and Forecast	340	Concrete Reinf	8	40-60yr	1973	47	2023	$	51,680
5256	Monitor and Forecast	460	Concrete Reinf	8	40-60yr	1973	47	2023	$	69,920
5258	Monitor and Forecast	250	Concrete Reinf	10	40-60yr	1973	47	2023	$	47,500
5259	Monitor and Forecast	410	Concrete Reinf	10	40-60yr	1973	47	2023	$	77,900
5260	Monitor and Forecast	420	Concrete Reinf	10	40-60yr	1973	47	2023	$	79,800
5269	Monitor and Forecast	250	Concrete Reinf	10	40-60yr	1973	47	2023	$	47,500
5536	Monitor and Forecast	260	Concrete Reinf	10	40-60yr	1973	47	2023	$	49,400
5549	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$	38,000
8314	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$	39,520
8317	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$	30,400
8799	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1973	47	2023	$	44,080
8800	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$	41,040
8801	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1973	47	2023	$	36,480
8803	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1973	47	2023	$	56,240
8804	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$	41,040
8805	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$	39,520
8806	Monitor and Forecast	350	Concrete Reinf	8	40-60yr	1973	47	2023	$	53,200
8807	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1973	47	2023	$	34,960
8809	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$	33,440
8811	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1973	47	2023	$	57,760
5159	Monitor and Forecast	430	Concrete Reinf	8	40-60yr	1973	47	2023	$	65,360
5178	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1973	47	2023	$	16,720
5254	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1973	47	2023	$	42,560
5257	Monitor and Forecast	260	Concrete Reinf	10	40-60yr	1973	47	2023	$	49,400
5262	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1973	47	2023	$	30,400
5265	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1973	47	2023	$	21,280
5267	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$	38,000
5268	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$	38,000
5271	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$	38,000
5527	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1973	47	2023	$	60,800
5531	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1973	47	2023	$	50,160
5551	Monitor and Forecast	280	Concrete Reinf	10	40-60yr	1973	47	2023	$	53,200
5266	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1973	47	2023	$	18,240
5270	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1973	47	2023	$	13,680
5541	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1973	47	2023	$	42,560
5547	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1973	47	2023	$	62,320
9085	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$	33,440
9240	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1973	47	2023	$	28,880
9380	Monitor and Forecast	50	Concrete Reinf	8	40-60yr	1973	47	2023	$	7,600

9381	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1973	47	2023	$ 60,800
10040	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$ 38,000
10041	Monitor and Forecast	40	Concrete Reinf	8	40-60yr	1973	47	2023	$ 6,080
10042	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$ 33,440
10047	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1973	47	2023	$ 16,720
10263	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$ 41,040
10264	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1973	47	2023	$ 15,200
10265	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1973	47	2023	$ 36,480
10266	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$ 39,520
10267	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1973	47	2023	$ 42,560
10268	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1973	47	2023	$ 15,200
10270	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1973	47	2023	$ 27,360
10271	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1973	47	2023	$ 21,280
10272	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$ 31,920
10273	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1973	47	2023	$ 34,960
10274	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1973	47	2023	$ 13,680
10275	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$ 41,040
10276	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1973	47	2023	$ 27,360
10277	Monitor and Forecast	40	Concrete Reinf	8	40-60yr	1973	47	2023	$ 6,080
10278	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$ 25,840
10279	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1973	47	2023	$ 44,080
10280	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1973	47	2023	$ 16,720
10281	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1973	47	2023	$ 60,800
10282	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1973	47	2023	$ 48,640
10283	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$ 38,000
10284	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1973	47	2023	$ 28,880
10303	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$ 31,920
10305	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$ 39,520
10306	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1973	47	2023	$ 47,120
10307	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1973	47	2023	$ 12,160
10308	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1973	47	2023	$ 27,360
10309	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1973	47	2023	$ 42,560
10310	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1973	47	2023	$ 18,240
10311	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1973	47	2023	$ 21,280
10312	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1973	47	2023	$ 16,720
10313	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1973	47	2023	$ 47,120
10314	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1973	47	2023	$ 13,680
10317	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$ 25,840
10318	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1973	47	2023	$ 21,280
10319	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1973	47	2023	$ 24,320
10320	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$ 33,440
10321	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1973	47	2023	$ 24,320
10322	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1973	47	2023	$ 21,280
10323	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1973	47	2023	$ 18,240
10324	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1973	47	2023	$ 48,640
10325	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1973	47	2023	$ 36,480
10326	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1973	47	2023	$ 36,480

10327	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1973	47	2023	$	27,360
1450	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1973	47	2023	$	27,360
2308	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1973	47	2023	$	48,640
8659	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1973	47	2023	$	27,360
8660	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1973	47	2023	$	60,800
8662	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1973	47	2023	$	31,920
8663	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1973	47	2023	$	59,280
8664	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1973	47	2023	$	13,680
8666	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1973	47	2023	$	45,600
8668	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1973	47	2023	$	62,320
9081	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$	41,040
9082	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1973	47	2023	$	42,560
9084	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$	39,520
9374	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1973	47	2023	$	45,600
9377	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$	25,840
9378	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$	39,520
9379	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1973	47	2023	$	59,280
9384	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$	41,040
8661	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1973	47	2023	$	21,280
8667	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1973	47	2023	$	12,160
9083	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1973	47	2023	$	13,680
5031	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1973	47	2023	$	60,800
10398	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$	41,040
10403	Monitor and Forecast	220	Concrete Reinf	8	40-60yr	1973	47	2023	$	33,440
10404	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1973	47	2023	$	27,360
10408	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$	38,000
10412	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1973	47	2023	$	60,800
10414	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1973	47	2023	$	38,000
10424	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1973	47	2023	$	62,320
8665	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1973	47	2023	$	44,080
9242	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1973	47	2023	$	15,200
9373	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1973	47	2023	$	41,040
9375	Monitor and Forecast	120	Concrete Reinf	8	40-60yr	1973	47	2023	$	18,240
9376	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1973	47	2023	$	22,800
9382	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1973	47	2023	$	39,520
9383	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1973	47	2023	$	25,840
4399	Monitor and Forecast	200	Concrete NonReinf	8	20-40yr	1983	37	2023	$	30,400
4400	Monitor and Forecast	280	Concrete NonReinf	8	20-40yr	1983	37	2023	$	42,560
4401	Monitor and Forecast	370	Concrete NonReinf	8	20-40yr	1983	37	2023	$	56,240
5117	Repair/Replace on Failure	310	Ductile iron	8	40-60yr	1979	41	2024	$	47,120
9789	Repair/Replace on Failure	340	Ductile iron	8	40-60yr	1979	41	2024	$	51,680
9799	Repair/Replace on Failure	350	Ductile iron	8	40-60yr	1979	41	2024	$	53,200
5108	Repair/Replace on Failure	150	Ductile iron	8	40-60yr	1979	41	2024	$	22,800
9787	Repair/Replace on Failure	370	Ductile iron	8	40-60yr	1979	41	2024	$	56,240
9870	Repair/Replace on Failure	420	Ductile iron	8	40-60yr	1979	41	2024	$	63,840
5093	Repair/Replace on Failure	320	Ductile iron	8	40-60yr	1979	41	2024	$	48,640
7742	Programmed Rehab/Replace	240	Ductile iron	22	40-60yr	1974	46	2024	$	100,320

1116	Proactive Assessment	400	Concrete NonReinf	18	40-60yr	1971	49	2024	$ 136,800
6902	Proactive Assessment	240	Concrete NonReinf	18	40-60yr	1971	49	2024	$ 82,080
1125	Monitor and Forecast	80	Asbestos Cement	10	40-60yr	1968	52	2024	$ 15,200
12075	Monitor and Forecast	140	Asbestos Cement	8	40-60yr	1974	46	2024	$ 21,280
4973	Monitor and Forecast	160	Asbestos Cement	8	>60yr	1959	61	2024	$ 24,320
4983	Monitor and Forecast	190	Asbestos Cement	8	>60yr	1959	61	2024	$ 28,880
9939	Monitor and Forecast	360	Asbestos Cement	8	>60yr	1959	61	2024	$ 54,720
9951	Monitor and Forecast	210	Asbestos Cement	8	>60yr	1959	61	2024	$ 31,920
9964	Monitor and Forecast	320	Asbestos Cement	8	>60yr	1959	61	2024	$ 48,640
589	Monitor and Forecast	70	Asbestos Cement	8	>60yr	1959	61	2024	$ 10,640
2210	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1960	60	2024	$ 45,600
2205	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1961	59	2024	$ 41,040
4939	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1963	57	2024	$ 36,480
2535	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1974	46	2024	$ 31,920
12074	Monitor and Forecast	110	Asbestos Cement	8	40-60yr	1974	46	2024	$ 16,720
1435	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1968	52	2024	$ 33,440
9235	Monitor and Forecast	300	Concrete NonReinf	8	40-60yr	1973	47	2024	$ 45,600
4782	Monitor and Forecast	260	Asbestos Cement	10	40-60yr	1963	57	2024	$ 49,400
3013	Monitor and Forecast	190	Concrete NonReinf	8	40-60yr	1977	43	2024	$ 28,880
4520	Monitor and Forecast	250	Asbestos Cement	8	40-60yr	1974	46	2024	$ 38,000
12463	Monitor and Forecast	230	Asbestos Cement	8	>60yr	1954	66	2024	$ 34,960
4941	Monitor and Forecast	330	Asbestos Cement	8	>60yr	1959	61	2024	$ 50,160
4957	Monitor and Forecast	150	Asbestos Cement	8	>60yr	1959	61	2024	$ 22,800
4989	Monitor and Forecast	150	Asbestos Cement	8	>60yr	1959	61	2024	$ 22,800
4433	Monitor and Forecast	350	Asbestos Cement	8	>60yr	1959	61	2024	$ 53,200
4945	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2024	$ 39,520
5132	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2024	$ 41,040
9285	Monitor and Forecast	320	Asbestos Cement	8	>60yr	1959	61	2024	$ 48,640
9286	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2024	$ 39,520
9348	Monitor and Forecast	290	Asbestos Cement	8	>60yr	1959	61	2024	$ 44,080
9415	Monitor and Forecast	340	Asbestos Cement	8	>60yr	1959	61	2024	$ 51,680
9517	Monitor and Forecast	230	Asbestos Cement	8	>60yr	1959	61	2024	$ 34,960
1366	Monitor and Forecast	380	Asbestos Cement	8	>60yr	1959	61	2024	$ 57,760
8375	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2024	$ 27,360
7130	Monitor and Forecast	300	Asbestos Cement	8	>60yr	1959	61	2024	$ 45,600
7866	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2024	$ 41,040
8063	Monitor and Forecast	250	Asbestos Cement	8	>60yr	1959	61	2024	$ 38,000
8191	Monitor and Forecast	300	Asbestos Cement	8	>60yr	1959	61	2024	$ 45,600
9948	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2024	$ 27,360
9413	Monitor and Forecast	40	Asbestos Cement	8	>60yr	1959	61	2024	$ 6,080
4914	Monitor and Forecast	400	Concrete NonReinf	8	40-60yr	1971	49	2024	$ 60,800
4970	Monitor and Forecast	200	Asbestos Cement	8	>60yr	1959	61	2024	$ 30,400
4993	Monitor and Forecast	340	Asbestos Cement	8	>60yr	1959	61	2024	$ 51,680
3932	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1960	60	2024	$ 57,760
8070	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1960	60	2024	$ 39,520
8223	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1960	60	2024	$ 39,520
3931	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1960	60	2024	$ 39,520

992	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1960	60	2024	$ 36,480
3384	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1960	60	2024	$ 41,040
8078	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1960	60	2024	$ 42,560
10059	Monitor and Forecast	180	Asbestos Cement	8	40-60yr	1960	60	2024	$ 27,360
9318	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1972	48	2024	$ 19,760
4373	Monitor and Forecast	80	Concrete NonReinf	8	40-60yr	1972	48	2024	$ 12,160
5521	Monitor and Forecast	310	Concrete NonReinf	8	40-60yr	1972	48	2024	$ 47,120
1034	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1961	59	2024	$ 18,240
1827	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1961	59	2024	$ 25,840
1828	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1961	59	2024	$ 28,880
9435	Monitor and Forecast	70	Asbestos Cement	8	40-60yr	1961	59	2024	$ 10,640
10423	Monitor and Forecast	140	Concrete NonReinf	8	40-60yr	1973	47	2024	$ 21,280
9255	Monitor and Forecast	230	Concrete NonReinf	8	40-60yr	1973	47	2024	$ 34,960
10315	Monitor and Forecast	270	Concrete NonReinf	8	40-60yr	1973	47	2024	$ 41,040
9244	Monitor and Forecast	230	Concrete NonReinf	8	40-60yr	1973	47	2024	$ 34,960
9272	Monitor and Forecast	250	Concrete NonReinf	8	40-60yr	1973	47	2024	$ 38,000
6704	Monitor and Forecast	230	Concrete Reinf	8	40-60yr	1962	58	2024	$ 34,960
10296	Monitor and Forecast	380	Asbestos Cement	8	40-60yr	1962	58	2024	$ 57,760
10590	Monitor and Forecast	60	Concrete NonReinf	8	40-60yr	1974	46	2024	$ 9,120
10201	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1974	46	2024	$ 19,760
4780	Monitor and Forecast	90	Concrete Reinf	8	40-60yr	1963	57	2024	$ 13,680
4777	Monitor and Forecast	400	Asbestos Cement	8	40-60yr	1963	57	2024	$ 60,800
6343	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1964	56	2024	$ 25,840
6362	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1964	56	2024	$ 25,840
6375	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1964	56	2024	$ 12,160
6376	Monitor and Forecast	370	Asbestos Cement	8	40-60yr	1964	56	2024	$ 56,240
6573	Monitor and Forecast	80	Asbestos Cement	8	40-60yr	1964	56	2024	$ 12,160
6374	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1964	56	2024	$ 30,400
3088	Monitor and Forecast	290	Concrete NonReinf	8	40-60yr	1976	44	2024	$ 44,080
3096	Monitor and Forecast	180	Concrete NonReinf	8	40-60yr	1976	44	2024	$ 27,360
3080	Monitor and Forecast	220	Concrete NonReinf	8	40-60yr	1976	44	2024	$ 33,440
3083	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1976	44	2024	$ 19,760
3546	Monitor and Forecast	200	Concrete NonReinf	8	40-60yr	1976	44	2024	$ 30,400
3018	Monitor and Forecast	140	Concrete NonReinf	8	40-60yr	1977	43	2024	$ 21,280
3867	Monitor and Forecast	260	Concrete NonReinf	8	40-60yr	1977	43	2024	$ 39,520
4175	Monitor and Forecast	180	Concrete NonReinf	8	40-60yr	1977	43	2024	$ 27,360
1061	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1968	52	2024	$ 50,160
1612	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1968	52	2024	$ 13,680
368	Monitor and Forecast	410	Concrete NonReinf	8	40-60yr	1979	41	2024	$ 62,320
2500	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1974	46	2024	$ 42,560
2524	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1974	46	2024	$ 24,320
2529	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1974	46	2024	$ 44,080
2532	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1974	46	2024	$ 62,320
2538	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1974	46	2024	$ 19,760
2547	Monitor and Forecast	270	Concrete Reinf	8	40-60yr	1974	46	2024	$ 41,040
9906	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1974	46	2024	$ 47,120
9908	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1974	46	2024	$ 36,480

9909	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1974	46	2024	$ 39,520
10200	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1974	46	2024	$ 57,760
10205	Monitor and Forecast	350	Concrete Reinf	8	40-60yr	1974	46	2024	$ 53,200
10206	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1974	46	2024	$ 24,320
10212	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1974	46	2024	$ 42,560
10215	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1974	46	2024	$ 22,800
10540	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1974	46	2024	$ 38,000
10541	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1974	46	2024	$ 36,480
10548	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1974	46	2024	$ 59,280
10549	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1974	46	2024	$ 42,560
10555	Monitor and Forecast	200	Concrete Reinf	8	40-60yr	1974	46	2024	$ 30,400
10566	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1974	46	2024	$ 45,600
10567	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1974	46	2024	$ 31,920
10574	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1974	46	2024	$ 22,800
10577	Monitor and Forecast	310	Concrete Reinf	8	40-60yr	1974	46	2024	$ 47,120
10579	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1974	46	2024	$ 48,640
10582	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1974	46	2024	$ 50,160
10584	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1974	46	2024	$ 15,200
10594	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1974	46	2024	$ 21,280
10595	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1974	46	2024	$ 48,640
10664	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1974	46	2024	$ 44,080
10666	Monitor and Forecast	160	Concrete Reinf	8	40-60yr	1974	46	2024	$ 24,320
10670	Monitor and Forecast	380	Concrete Reinf	8	40-60yr	1974	46	2024	$ 57,760
10675	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1974	46	2024	$ 22,800
2507	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1974	46	2024	$ 21,280
2518	Monitor and Forecast	370	Concrete Reinf	8	40-60yr	1974	46	2024	$ 56,240
2523	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1974	46	2024	$ 45,600
2526	Monitor and Forecast	190	Concrete Reinf	8	40-60yr	1974	46	2024	$ 28,880
2531	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1974	46	2024	$ 22,800
2533	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1974	46	2024	$ 21,280
2548	Monitor and Forecast	210	Concrete Reinf	8	40-60yr	1974	46	2024	$ 31,920
2550	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1974	46	2024	$ 50,160
2555	Monitor and Forecast	180	Concrete Reinf	8	40-60yr	1974	46	2024	$ 27,360
10193	Monitor and Forecast	350	Concrete Reinf	8	40-60yr	1974	46	2024	$ 53,200
10196	Monitor and Forecast	320	Concrete Reinf	8	40-60yr	1974	46	2024	$ 48,640
10197	Monitor and Forecast	130	Concrete Reinf	8	40-60yr	1974	46	2024	$ 19,760
10199	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1974	46	2024	$ 44,080
10203	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1974	46	2024	$ 38,000
10207	Monitor and Forecast	300	Concrete Reinf	8	40-60yr	1974	46	2024	$ 45,600
10547	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1974	46	2024	$ 36,480
10552	Monitor and Forecast	290	Concrete Reinf	8	40-60yr	1974	46	2024	$ 44,080
10553	Monitor and Forecast	330	Concrete Reinf	8	40-60yr	1974	46	2024	$ 50,160
10556	Monitor and Forecast	240	Concrete Reinf	8	40-60yr	1974	46	2024	$ 36,480
10564	Monitor and Forecast	100	Concrete Reinf	8	40-60yr	1974	46	2024	$ 15,200
10576	Monitor and Forecast	140	Concrete Reinf	8	40-60yr	1974	46	2024	$ 21,280
10578	Monitor and Forecast	250	Concrete Reinf	8	40-60yr	1974	46	2024	$ 38,000
10586	Monitor and Forecast	110	Concrete Reinf	8	40-60yr	1974	46	2024	$ 16,720

10680	Monitor and Forecast	260	Concrete Reinf	8	40-60yr	1974	46	2024	$ 39,520
10588	Monitor and Forecast	170	Concrete Reinf	8	40-60yr	1974	46	2024	$ 25,840
4506	Monitor and Forecast	150	Concrete Reinf	8	40-60yr	1974	46	2024	$ 22,800
4509	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1974	46	2024	$ 36,480
4510	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1974	46	2024	$ 60,800
4514	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1974	46	2024	$ 60,800
4526	Monitor and Forecast	400	Concrete Reinf	8	40-60yr	1974	46	2024	$ 60,800
4530	Monitor and Forecast	430	Concrete Reinf	8	40-60yr	1974	46	2024	$ 65,360
4533	Monitor and Forecast	350	Concrete Reinf	8	40-60yr	1974	46	2024	$ 53,200
4547	Monitor and Forecast	390	Concrete Reinf	8	40-60yr	1974	46	2024	$ 59,280
10674	Monitor and Forecast	80	Concrete Reinf	8	40-60yr	1974	46	2024	$ 12,160
5074	Repair/Replace on Failure	400	Ductile iron	8	40-60yr	1979	41	2025	$ 60,800
5086	Repair/Replace on Failure	320	Ductile iron	8	40-60yr	1979	41	2025	$ 48,640
5069	Repair/Replace on Failure	410	Ductile iron	8	40-60yr	1979	41	2025	$ 62,320
5101	Repair/Replace on Failure	170	Ductile iron	8	40-60yr	1979	41	2025	$ 25,840
5251	Repair/Replace on Failure	100	Ductile iron	8	40-60yr	1979	41	2025	$ 15,200
5252	Repair/Replace on Failure	230	Ductile iron	8	40-60yr	1979	41	2025	$ 34,960
9797	Repair/Replace on Failure	130	Ductile iron	8	40-60yr	1979	41	2025	$ 19,760
9868	Repair/Replace on Failure	140	Ductile iron	8	40-60yr	1979	41	2025	$ 21,280
5068	Repair/Replace on Failure	120	Ductile iron	8	40-60yr	1979	41	2025	$ 18,240
5106	Repair/Replace on Failure	390	Ductile iron	8	40-60yr	1979	41	2025	$ 59,280
5121	Repair/Replace on Failure	90	Ductile iron	8	40-60yr	1979	41	2025	$ 13,680
5244	Repair/Replace on Failure	140	Ductile iron	8	40-60yr	1979	41	2025	$ 21,280
9860	Repair/Replace on Failure	210	Ductile iron	8	40-60yr	1979	41	2025	$ 31,920
12232	Proactive Assessment	410	Concrete NonReinf	18	40-60yr	1971	49	2025	$ 140,220
961	Monitor and Forecast	70	Concrete NonReinf	15	40-60yr	1979	41	2025	$ 19,950
109	Monitor and Forecast	340	Concrete NonReinf	8	40-60yr	1979	41	2025	$ 51,680
7207	Monitor and Forecast	310	Asbestos Cement	8	>60yr	1959	61	2025	$ 47,120
9949	Monitor and Forecast	160	Asbestos Cement	8	>60yr	1959	61	2025	$ 24,320
9961	Monitor and Forecast	370	Asbestos Cement	8	>60yr	1959	61	2025	$ 56,240
989	Monitor and Forecast	90	Asbestos Cement	8	40-60yr	1960	60	2025	$ 13,680
4931	Monitor and Forecast	340	Asbestos Cement	8	40-60yr	1963	57	2025	$ 51,680
4940	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1963	57	2025	$ 18,240
6544	Monitor and Forecast	320	Asbestos Cement	8	40-60yr	1964	56	2025	$ 48,640
417	Monitor and Forecast	410	Concrete NonReinf	8	40-60yr	1979	41	2025	$ 62,320
113	Monitor and Forecast	240	Concrete NonReinf	8	40-60yr	1979	41	2025	$ 36,480
671	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1975	45	2025	$ 28,880
6708	Monitor and Forecast	120	Concrete Reinf	8	>60yr	1955	65	2025	$ 18,240
7234	Monitor and Forecast	330	Asbestos Cement	8	>60yr	1959	61	2025	$ 50,160
4955	Monitor and Forecast	240	Asbestos Cement	8	>60yr	1959	61	2025	$ 36,480
4963	Monitor and Forecast	280	Asbestos Cement	8	>60yr	1959	61	2025	$ 42,560
4948	Monitor and Forecast	170	Asbestos Cement	8	>60yr	1959	61	2025	$ 25,840
4949	Monitor and Forecast	270	Asbestos Cement	8	>60yr	1959	61	2025	$ 41,040
4999	Monitor and Forecast	220	Asbestos Cement	8	>60yr	1959	61	2025	$ 33,440
9287	Monitor and Forecast	160	Asbestos Cement	8	>60yr	1959	61	2025	$ 24,320
9294	Monitor and Forecast	170	Asbestos Cement	8	>60yr	1959	61	2025	$ 25,840
9331	Monitor and Forecast	220	Asbestos Cement	8	>60yr	1959	61	2025	$ 33,440

9425	Monitor and Forecast	120	Asbestos Cement	8	>60yr	1959	61	2025	$ 18,240
7237	Monitor and Forecast	360	Asbestos Cement	8	>60yr	1959	61	2025	$ 54,720
9943	Monitor and Forecast	320	Asbestos Cement	8	>60yr	1959	61	2025	$ 48,640
9958	Monitor and Forecast	200	Asbestos Cement	8	>60yr	1959	61	2025	$ 30,400
8376	Monitor and Forecast	140	Asbestos Cement	8	>60yr	1959	61	2025	$ 21,280
7112	Monitor and Forecast	260	Asbestos Cement	8	>60yr	1959	61	2025	$ 39,520
7128	Monitor and Forecast	280	Asbestos Cement	8	>60yr	1959	61	2025	$ 42,560
7251	Monitor and Forecast	150	Asbestos Cement	8	>60yr	1959	61	2025	$ 22,800
8190	Monitor and Forecast	200	Asbestos Cement	8	>60yr	1959	61	2025	$ 30,400
9946	Monitor and Forecast	390	Asbestos Cement	8	>60yr	1959	61	2025	$ 59,280
9329	Monitor and Forecast	380	Asbestos Cement	8	>60yr	1959	61	2025	$ 57,760
4921	Monitor and Forecast	220	Concrete NonReinf	8	40-60yr	1971	49	2025	$ 33,440
4431	Monitor and Forecast	150	Asbestos Cement	8	>60yr	1959	61	2025	$ 22,800
4432	Monitor and Forecast	180	Asbestos Cement	8	>60yr	1959	61	2025	$ 27,360
8210	Monitor and Forecast	310	Asbestos Cement	8	40-60yr	1960	60	2025	$ 47,120
10051	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1960	60	2025	$ 50,160
10060	Monitor and Forecast	240	Asbestos Cement	8	40-60yr	1960	60	2025	$ 36,480
2281	Monitor and Forecast	300	Asbestos Cement	8	40-60yr	1961	59	2025	$ 45,600
10402	Monitor and Forecast	350	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 53,200
3012	Monitor and Forecast	190	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 28,880
9236	Monitor and Forecast	230	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 34,960
9267	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 19,760
9253	Monitor and Forecast	270	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 41,040
9254	Monitor and Forecast	230	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 34,960
9256	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 19,760
10400	Monitor and Forecast	100	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 15,200
10413	Monitor and Forecast	100	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 15,200
9274	Monitor and Forecast	170	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 25,840
10287	Monitor and Forecast	350	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 53,200
10288	Monitor and Forecast	70	Concrete NonReinf	8	40-60yr	1973	47	2025	$ 10,640
8740	Monitor and Forecast	210	Asbestos Cement	8	40-60yr	1962	58	2025	$ 31,920
6705	Monitor and Forecast	280	Concrete Reinf	8	40-60yr	1962	58	2025	$ 42,560
10204	Monitor and Forecast	230	Concrete NonReinf	8	40-60yr	1974	46	2025	$ 34,960
2521	Monitor and Forecast	270	Concrete NonReinf	8	40-60yr	1974	46	2025	$ 41,040
10589	Monitor and Forecast	350	Concrete NonReinf	8	40-60yr	1974	46	2025	$ 53,200
2513	Monitor and Forecast	370	Concrete NonReinf	8	40-60yr	1974	46	2025	$ 56,240
2542	Monitor and Forecast	300	Concrete NonReinf	8	40-60yr	1974	46	2025	$ 45,600
10585	Monitor and Forecast	320	Concrete NonReinf	8	40-60yr	1974	46	2025	$ 48,640
10672	Monitor and Forecast	120	Concrete NonReinf	8	40-60yr	1974	46	2025	$ 18,240
2549	Monitor and Forecast	270	Concrete NonReinf	8	40-60yr	1974	46	2025	$ 41,040
9911	Monitor and Forecast	290	Concrete NonReinf	8	40-60yr	1974	46	2025	$ 44,080
4933	Monitor and Forecast	110	Asbestos Cement	8	40-60yr	1963	57	2025	$ 16,720
4778	Monitor and Forecast	410	Concrete Reinf	8	40-60yr	1963	57	2025	$ 62,320
2015	Monitor and Forecast	400	Asbestos Cement	10	40-60yr	1964	56	2025	$ 76,000
6342	Monitor and Forecast	290	Asbestos Cement	8	40-60yr	1964	56	2025	$ 44,080
6369	Monitor and Forecast	190	Asbestos Cement	8	40-60yr	1964	56	2025	$ 28,880
6281	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1964	56	2025	$ 39,520

9453	Monitor and Forecast	130	Asbestos Cement	8	40-60yr	1964	56	2025	$	19,760
3076	Monitor and Forecast	170	Concrete NonReinf	8	40-60yr	1976	44	2025	$	25,840
3078	Monitor and Forecast	150	Concrete NonReinf	8	40-60yr	1976	44	2025	$	22,800
3094	Monitor and Forecast	140	Concrete NonReinf	8	40-60yr	1976	44	2025	$	21,280
3098	Monitor and Forecast	130	Concrete NonReinf	8	40-60yr	1976	44	2025	$	19,760
4393	Monitor and Forecast	90	Concrete NonReinf	8	40-60yr	1977	43	2025	$	13,680
4846	Monitor and Forecast	260	Concrete NonReinf	8	40-60yr	1977	43	2025	$	39,520
4849	Monitor and Forecast	330	Concrete NonReinf	8	40-60yr	1977	43	2025	$	50,160
1873	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1968	52	2025	$	39,520
760	Monitor and Forecast	280	Asbestos Cement	8	40-60yr	1968	52	2025	$	42,560
1397	Monitor and Forecast	410	Concrete NonReinf	10	40-60yr	1979	41	2025	$	77,900
35	Monitor and Forecast	330	Asbestos Cement	8	40-60yr	1975	45	2025	$	50,160
672	Monitor and Forecast	270	Asbestos Cement	8	40-60yr	1975	45	2025	$	41,040
2287	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1975	45	2025	$	33,440
2288	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1975	45	2025	$	33,440
4177	Monitor and Forecast	170	Asbestos Cement	8	40-60yr	1975	45	2025	$	25,840
4178	Monitor and Forecast	70	Asbestos Cement	8	40-60yr	1975	45	2025	$	10,640
4179	Monitor and Forecast	270	Asbestos Cement	10	40-60yr	1975	45	2025	$	51,300
4890	Monitor and Forecast	280	Asbestos Cement	10	40-60yr	1975	45	2025	$	53,200
4891	Monitor and Forecast	350	Asbestos Cement	8	40-60yr	1975	45	2025	$	53,200
4892	Monitor and Forecast	260	Asbestos Cement	8	40-60yr	1975	45	2025	$	39,520
4929	Monitor and Forecast	270	Asbestos Cement	10	40-60yr	1975	45	2025	$	51,300
4180	Monitor and Forecast	200	Asbestos Cement	8	40-60yr	1975	45	2025	$	30,400
4866	Monitor and Forecast	120	Asbestos Cement	8	40-60yr	1975	45	2025	$	18,240
4867	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1975	45	2025	$	33,440
4868	Monitor and Forecast	220	Asbestos Cement	8	40-60yr	1975	45	2025	$	33,440