Hazen

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City of Clarksville Distribution System Water Master Plan

Prepared for the City of Clarksville Gas and Water Department

Final Report
October 2017

Hazen Project 32118-010

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October 31, 2017

Garth Branch, P.E.
Chief Utility Engineer
City of Clarksville Gas and Water Department (CGW)
2215 Madison Street
Clarksville, TN 37043

Re: Water Master Plan

Dear Garth:

CGW's Water Master Plan (WMP) is now complete. The development of the WMP was divided into several tasks to comprehensively develop/evaluate the following items:

- Task 1 -Regulatory, Operational & Reliability Goals
- Task 2 - Modeling of Existing Conditions
- Task 3 - Stage 2 D/DBP Rule Compliance
- Task 4 - Population and Demand Projections
- Task 5 - Barge Point WTP / Raw Water Pump Station Facilities Conceptual Planning
- Tasks 6 and 7 - Modeling of Future Conditions and Capital Improvement Plan

Please see attached relevant technical memorandums and presentation slides for each specific task.

Hazen would like to thank CGW for their input and feedback throughout the many workshops conducted as part of the WMP. We sincerely hope this effort has been viewed as a positive investment by CGW and one that will benefit the City of Clarksville as capital improvement decisions are made in the future.

As always, Hazen appreciates the opportunity to work with CGW in the support of its water and wastewater systems. Please do not hesitate to contact us if you have any questions about the master plan, need any additional support, and/or need help updating the master plan in the future.

Sincerely,

Caleb Sanders, PE
Senior Principal Engineer

Executive Summary

This report presents a distribution system hydraulic analysis of CGW's water system that will guide future capital planning efforts to accommodate growth. Additionally, work performed for the conceptual planning at the proposed new Barge Point Water Treatment Plant (WTP) is presented.

The hydraulic analysis used a computer model that simulated how the distribution system will respond to increasing demand. It also tested improvements to eliminate predicted deficiencies. We verified the accuracy of the model by checking simulations of existing conditions against flow and pressure measurements and operational records. This calibration process established confidence in model predictions for future conditions and the effectiveness of proposed improvements.

Projected demands were based on available data from regional planning documents including traffic analysis zones and statewide population projections provided by the University of Tennessee. CGW's water system is projected to reach a maximum day demand of 39.3 mgd by year 2040. We checked pump capacity, storage capacity, and pipe capacity in each pressure zone. The model tested improvement alternatives to eliminate deficiencies, taking full advantage of the existing system and thus minimizing costs.

Capital improvements were based on demands and event triggers (e.g. maximum day demands in system exceeding 80% of treatment plant capacity, large industrial users coming online, etc.). Figure 1 shows an overview of the capital improvement projects identified.

The first phase of recommended projects includes construction of the first phase of a new WTP at Barge Point Road and a second elevated storage tank in the Rossview Pressure Zone. Also included are transmission improvements in the Main Pressure Zone required for the New Trane Tank, Sango PS improvements, and Secondary Rossview Booster Station.

The second phase of improvements will include additional transmission improvements in the Rossview Pressure Zone along with construction of the new Rossview Booster Station, Trane Tank, Acme Tank, and upsized Sango PS.

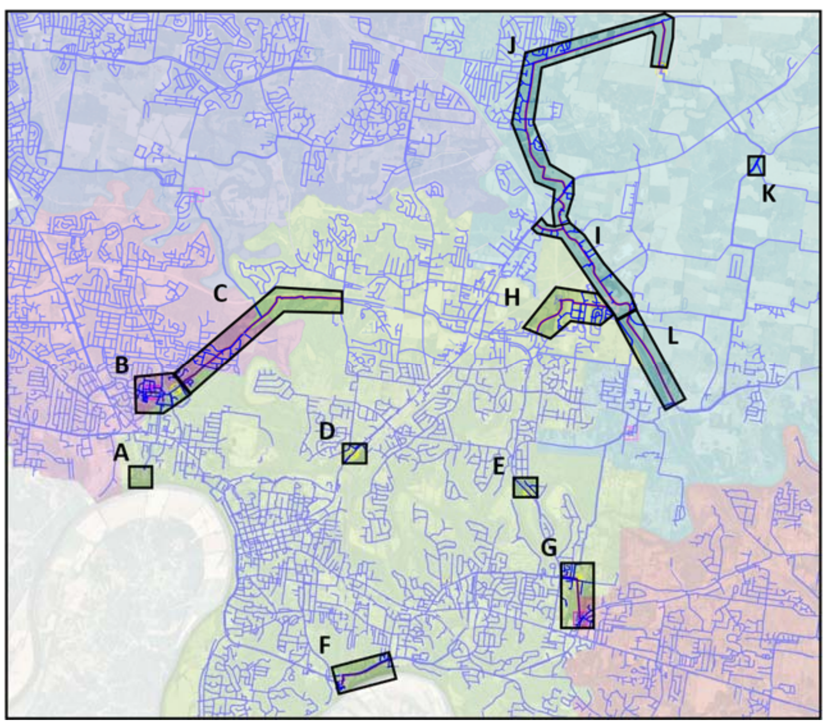

Figure 1: Capital Improvement Project Overview

Farther out on the planning horizon, the new Barge Point WTP will be expanded in subsequent phases as demand grows. Ultimately, it is envisioned the capacity at this plant will match the 30 mgd capacity of the existing Clarksville WTP.

The resulting projects identified in the master plan with associated planning cost estimates are shown in Table 1 in Year 2017 dollars.

Table 1: Capital Improvement Project List

Project Group / ID	Project Description	Planning Cost Estimate
A-1	Barge Point WTP Phase 1	$58,035,000
A-2	Barge Point WTP Phase 2	$31,760,000
B-1	Upsize lines to Kenwood Elementary	$54,000
B-2	Valving Improvements	$280,000
C-1	Increase Transmission Capacity	$4,405,000
D-1	Delineation of North/South Main	$175,000
E-1	Delineation of North/South Main	$175,000
F-1	Increase Transmission Capacity	$1,210,000
F-2	Create South Main Pressure Zone	$300,000
G-1	Sango PS Redundant Supply Line Improvements	$795,000
G-2	Construct Acme #3 Tank	$2,140,000
G-3	Replace Sango PS	$3,775,000
H-1	Increase Transmission Capacity to New Trane Tank	$1,810,000
H-2	Construct New Trane Tank	$8,045,000
I-1	Construct RVPS2	$8,145,000
I-2	Increase Transmission Capacity to Dunlop Lane	$2,910,000
J-1	Increase Transmission Capacity to Oakland Rd / HSC Tank	$7,890,000
K-1	Construct Rossview #2 Tank	$8,075,000
L-1	Increase Transmission Capacity to Rossview Road	$3,430,000
	Total	**$143,409,000**

Task 1 - Regulatory, Operational & Reliability Goals

Memorandum

HAZEN AND SAWYER
Environmental Engineers & Scientists

Date: February 2, 2015

To: Clarksville Gas and Water

From: Hazen and Sawyer Project Team

Project No.: 32118-010

545 Mainstream Drive
Suite 320
Nashville, TN 37228

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Re: **Technical Memorandum 1 – Regulatory Overview; Operational and Reliability Goals**
Water System Master Plan – Phase 1
Clarksville Gas and Water

The purpose of this Technical Memorandum (TM) is to summarize current and potential future regulations, compliance concerns, and to establish water quality goals that will enable Clarksville Gas and Water to continue reliably producing high quality water and while meeting current and future demands and regulations. Included in the contents of this TM are current federal and state drinking water regulations, and future and proposed regulations. TM 1 also includes a brief discussion of historical water quality information in order to establish primary and secondary water quality goals. An operational/capacity assessment of the existing WTP was not required based on the recent expansion to 28 MGD capacity.

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1. Introduction

The City of Clarksville owns and operates its water treatment plant and distribution system which serves 120,000 people in the area. Plant staff report that the recent plant expansion provides a reliable capacity of 28 mgd, with peak hourly rate capacity at 30 mgd. Clarksville Gas and Water commissioned Hazen and Sawyer to develop a Water System Master Plan that identifies probable capital improvements required at the water treatment plant over the next 20 years.

Raw water is pumped to the plant from the Cumberland River. A positively-charged coagulant, Aluminum Chlorohydrate is added to the water to cause the negatively-charged particles in the raw water to attract and form ionic bonds (coagulation). Sodium permanganate is added to oxidize inorganic and some organic materials making them easier to coagulate, flocculate and settle with the particles. The flocculation process increases the coagulated particles to a size and weight that will settle in the sedimentation basins. Settled water is then filtered, removing the smallest particles that remain. The microfiltration process provides a physical barrier and filters all particulates greater than 0.1 micron in size and provides a direct barrier against bacteria, protozoa, and some viruses.

The chlorination process following filtration effectively disinfects all pathogens that may still be present. A corrosion inhibitor is added after filtration in response to the lead, copper, corrosion control regulation. In addition, fluoride is added to the water post-filtration. As part of master planning efforts, Hazen and Sawyer will identify and evaluate potential improvements for its service area that can provide additional reliability to meet future demands and regulatory requirements.

2. Regulatory Requirements

In 1974, the United States Congress passed the Safe Drinking Water Act (SDWA) to regulate the nation's public drinking water supplies and protect public health. The SDWA protects drinking water as well as drinking water sources in the form of rivers, lakes, reservoirs, springs, and groundwater wells. The SDWA was amended in 1986 and 1996 and ensures safe drinking water by regulating source water protection, water treatment, finished water distribution, and public information.

The SWDA authorized the United States Environmental Protection Agency (USEPA) to establish national health-based standards for the protection of drinking water from both natural and manmade contaminants which are enforceable by local, state, and federal agencies. The resulting standards were in the form of the National Interim Primary Drinking Water Regulations promulgated in 1975. These regulations established health-based maximum contaminant levels (MCLs) for specific drinking water contaminants. These standards also stipulated contaminant testing methods to ensure that the standards were met. Additional information on the SDWA can be found at www.epa.gov/safewater/sdwa.

A state may be granted "primacy" by the USEPA if the state can demonstrate that it will adopt drinking water standards at least as stringent as the USEPA standards and can ensure that water systems within the state meet these standards. "Primacy" is the authority for a state to implement the SDWA within the state's jurisdiction. Meeting drinking water standards is a joint effort involving the USEPA, primacy state drinking water programs, and public water systems.

2.1 Federal Drinking Water Regulations

The following sections describe existing and proposed federal drinking water regulations that are applicable to the Clarksville Water Treatment Plant (WTP). Finalized rules are designated as either primary or secondary standards. Primary standards (National Primary Drinking Water Regulations, or NPDWRs) are enforceable as they are associated with public health protection and apply to all public water systems. The USEPA website (www.epa.gov/safewater/contaminants/index.html) lists all the regulated drinking water contaminants and their respective MCLs. The regulated contaminants are classified as follows:

- Microorganisms
- Disinfectants
- Disinfection By-Products
- Inorganic Chemicals
- Organic Chemicals, and
- Radionuclides

National Secondary Drinking Water Regulations (NSDWRs) correspond to aesthetic qualities such as color, taste, and odor. Secondary standards are not enforceable. The USEPA recommends secondary standards to water systems but does not require water systems to comply. However, States may choose to adopt them as enforceable standards.

Under the SDWA, the USEPA has created a number of drinking water regulations applicable to public water systems, including Clarksville Gas and Water:

- Amendments to the SDWA (National Primary Drinking Water Regulations), 1986
- Surface Water Treatment Rule, 1989
- Total Coliform Rule, 1989
- Lead and Copper Rule, 1991
- Interim Enhanced Surface Water Treatment Rule, 1998
- Stage 1 Disinfectants and Disinfection By-Products Rule, 1998
- Radionuclides Rule, 2000
- Arsenic Rule, 2001

- Filter Backwash Recycling Rule, 2001
- Stage 2 Disinfectants and Disinfection By-Products Rule, 2006
- Long Term 2 Enhanced Surface Water Treatment Rule, 2006

With the passing of the SDWA in 1974 came the regulation of approximately 20 contaminants between 1974 and 1986 by the USEPA. In 1979, a total trihalomethanes (TTHMs) standard of 0.1 mg/L was set for public water systems serving greater than 10,000 people. The SDWA was amended in 1986, resulting in the National Primary Drinking Water Regulations (NPDWR). The 1986 modifications to the SDWA resulted in the regulation of 83 contaminants, designated best available technologies, established filtration criteria and disinfection requirements, and banned lead solder. Between 1987 and 1992, the USEPA issued four rules (Phase I, II, IIb, and V Rules) for the regulation of 69 contaminants. Each contaminant had a health goal (maximum contaminant level goal, MCLG) and a legal limit (maximum contaminant level, MCL). The Phase I Rule included the regulation of 8 Volatile Organic Compound (VOC) contaminants, the Phase II and IIb Rules set standards for 38 contaminants, and the Phase V Rule regulated 23 contaminants.

In 1989, the Surface Water Treatment Rule (SWTR) was published to protect against waterborne diseases caused by viruses, *Giardia lamblia,* and *Legionella*. The SWTR required the disinfection of surface waters and a residual disinfectant in the distribution system, as well as a 3-log (99.9%) removal/inactivation of *Giardia* and 4-log (99.99%) removal/inactivation of viruses. The SWTR also required filtered water turbidity monitoring to determine the adequacy of the filtration process unless avoidance criteria were met. The SDWA was amended in 1996 to enhance source water protection, consumer education, and water system management. The Clarksville WTP is not exempt from this rule and are therefore required to remove/inactivate 99.9% of *Giardia lamblia* cysts and 99.99% of viruses, maintain a residual disinfectant concentration in the distribution system, monitor filtered turbidity a minimum of every four hours and residual disinfectant concentration continuously and report turbidity, disinfection information, and waterborne disease outbreaks to the state on a monthly basis. The microfiltration process used by Clarksville was granted 4-log Giardia removal and 2-log virus removal. Therefore, disinfection in the clearwell is used to obtain an additional 2-log virus inactivation. As such, Clarksville Gas and Water complies with this rule through a combination of the use of complete treatment and microfiltration, use of chlorine as a primary disinfectant, turbidity and chlorine residual monitoring, and monthly reporting to the state primacy agency.

The Total Coliform Rule (TCR), published in 1989, regulated the amount of total coliforms in drinking water. The non-enforceable MCLG was set as zero and the MCL allowed the presence of coliforms in 5 percent or less of the total number of samples, where number of required samples depends on the number of people served. The TCR also requires that a positive test for total coliforms be followed by a repeat testing of samples within 24 hours, as well as testing the positive sample for fecal coliforms and *Escherichia coli (E. coli).* A sample that tests positive for fecal coliforms or *E. coli* results in an acute MCL violation. Clarksville Gas and Water has a distribution system bacteriological monitoring plan approved by the Tennessee Department of Environment and Conservation (TDEC).

In June 1991, the USEPA published the Lead and Copper Rule (LCR) to protect public health by minimizing lead and copper levels in drinking water. The rule specified action levels of 0.015 mg/L for lead and 1.3 mg/L for copper. If the 90^{th} percentile value of all samples exceeded the action level, specific actions were required. Potential actions required include water quality parameter monitoring, implementation of recommended corrosion control treatment, source water monitoring, public education, and/or lead service line replacement. The LCR was revised in October 2007 to enhance effectiveness in terms of monitoring, treatment, customer awareness, lead service line replacement, and compliance with public education requirements. Clarksville Gas and Water has completed all required monitoring and reporting to date for this rule and is in compliance. The next round of monitoring for this rule will commence in 2015.

The Interim Enhanced Surface Water Treatment Rule (IESWTR) was published in 1998 with the intention of improving the control of microbial pathogens such as *Cryptosporidium* and to guard against the risk of microbial infection. The IESWTR added protection from *Cryptosporidium* through strengthened combined filter effluent turbidity performance standards and individual filter turbidity provisions for filtered systems. The IESWTR applies to public water systems serving 10,000 or more people and requires a 2-log reduction in *Cryptosporidium*. The rule also requires that the average filtered water turbidity for any month be less than 0.3 NTU in 95% of samples and never exceed 1 NTU. For unfiltered systems, *Cryptosporidium* was included in the watershed control requirements. The IESWTR also requires covers for all new finished water storage facilities and includes disinfection benchmark provisions to ensure continued levels of microbial protection while taking the necessary steps to comply with the DBP standards.

The Stage 1 Disinfectants and Disinfection By-Products Rule (Stage 1 DBPR) was published at the same time as the IESWTR to address risks associated with disinfectants such as disinfection by-products (DBPs) formed when chlorine reacts with organics. The rule applies to all community water systems and nontransient noncommunity water systems that add a chemical disinfectant for either primary or secondary treatment. The Stage 1 DBPR also requires monitoring of total organic carbon (TOC), alkalinity, TTHM, five haloacetic acids (HAA5), and several other chemicals dependent on the disinfectant used. The Stage 1 DBPR updated and superseded the 1979 TTHM standard by lowering the MCL for TTHMs and creating new MCLs for five haloacetic acids (HAA5), chorite, and bromate. Table 2.1 shows the MCLs for the DBPs and the maximum residual disinfectant levels (MRDLs) for the disinfectant residuals specified by the Stage 1 DBPR.

Table 2.1 Stage 1 DBPR MCLs for Disinfection By-Products and MRDLs for Disinfectant Residuals

Stage 1 DBPR MCLs and MRDLs	
Disinfection By-Products (DBPs)	**MCL (mg/L)**
Total Trihalomethanes (TTHMs)	0.080
Five Haloacetic Acids (HAA5)	0.060
Chlorite	1.0
Bromate	0.010
Disinfectant Residual	**MRDL (mg/L)**
Chlorine	4.0 (as Cl_2)
Chloramines	4.0 (as Cl_2)
Chlorine Dioxide	0.8 (as ClO_2)

The Stage 1 DBPR also establishes regulations for the removal of DBP precursors. Conventional filtration systems were required to remove specified percentages of organic matter depending on raw water TOC and alkalinity, as shown in Table 2.2. With respect to the Clarksville WTP, source water TOC concentrations are historically between 2 mg/L and 3- mg/L. With raw water alkalinities of 70-100 mg/L, the raw TOC concentrations require 25% reduction through treatment to maintain compliance.

Table 2.2 Stage 1 DBPR TOC Reduction Requirements

TOC Reduction Requirements			
Raw Water TOC (mg/L)	**Raw Water Alkalinity (mg/L)**		
	0-60	**60-120**	**>120**
2 - 4	35%	25%	15%
4 - 8	45%	35%	25%
> 8	50%	40%	30%

In December 2000, the Radionuclides Rule was published as a revision of the 1977 regulation. The standards included a combined radium 226/228 of 5 picocuries (pCi)/L, a gross alpha standard for all alphas of 15 pCi/L (not including radon and uranium), a combined standard of 4 millirems/year for beta emitters, and a new MCL of 30 µg/L for uranium. Shortly after, in January 2001, the Arsenic Rule was published to reduce the arsenic drinking water MCL from 50 µg/L to 10 µg/L. Monitoring conducted to date indicates that the Clarksville WTP is in compliance with both the Radionuclides and the Arsenic Rules.

The Filter Backwash Recycling Rule (FBRR) was published in June 2001 and requires recycled filter backwash water, thickener supernatant, and liquids from dewatering processes be routed to allow treatment by all of the system's conventional processes or direct filtration. The EPA established this rule to reduce the probability of recycling processes allowing pathogenic microorganisms to be present in finished drinking water. The FBRR applies to all systems that use surface water or ground water under the direct influence of surface water (GWUDI), practice conventional or direct filtration, and recycled spent filter backwash, thickener supernatant, or liquids from dewatering process. Currently the Clarksville WTP sometimes recycles waste reverse filtration back to the head of the plant prior to chemical addition.

The Stage 2 Disinfectants and Disinfection By-Products Rule (Stage 2 DBPR) was proposed in 2003 and promulgated in 2006 in conjunction with the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) to reduce the health risks associated with DBP formation in drinking water. Criteria required by the Stage 2 DBPR to enhance regulations on DBPs included instituting a maximum contaminant limit goal for several individual DBPs (chloroform, monochloroacetic acid, and trichloroacetic acid) and requiring DBPs to be monitored in the distribution system based on locational running annual averages (RAAs).

The Stage 2 DBPR also required utilities to establish a baseline for DBPs by conducting an Initial Distribution System Evaluation (IDSE). The IDSE and Stage 2 DBPR compliance dates are summarized in Table 2.3, which is adapted from page 415 of the Federal Register (Vol. 71, No. 2, Jan 4, 2006).

Table 2.3 IDSE and Stage 2 DBPR Compliance Dates

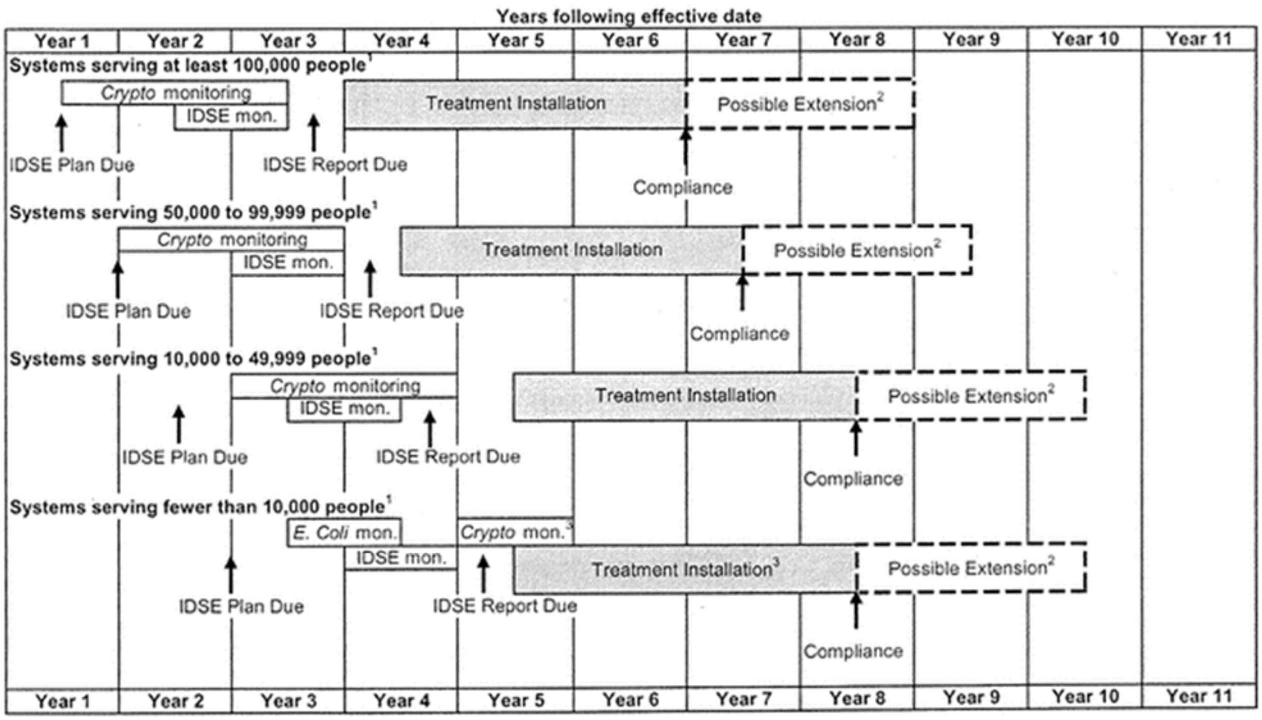
	Compliance dates by PWS size (retail population served) [1]				
Requirement	**CWSs and NTNCWSs serving at least 100,000**	**CWSs and NTNCWSs serving 50,000 - 99,999**	**CWSs and NTNCWSs serving 10,000 - 49,999**	**CWSs serving < 10,000**	**NTNCWSs serving < 10,000**
Submit IDSE monitoring plan OR. Submit IDSE system specific study plan OR. Submit 40/40 certification OR. Receive very small system waiver from State.	October 1, 2006	April 1, 2007	October 1, 2007	April 1, 2008	Not applicable.
Complete standard monitoring or system specific study.	September 30, 2008	March 31, 2009	September 30, 2009	March 31, 2010	Not applicable.
Submit IDSE Report ………	January 1, 2009	July 1, 2009	January 1, 2010	July 1, 2010	Not applicable.
Begin subpart V (Stage 2) compliance monitoring [2].	April 1, 2012	October 1, 2012	October 1, 2013	October 1, 2013 (October 1, 2014 if Cryptosporidium monitoring is required under Subpart W)	

[1] Wholesale and consecutive systems that are part of a combined distribution system must comply based on the schedule required of the largest system in the combined distribution system

[2] States may grant up to an additional 2 years for systems making capital improvements.

The Stage 2 DBPR also published a final Stage 2 DBPR and LT2ESWTR implementation schedule. This is presented as **Figure 2.1**, and is adapted from page 416 of the Federal Register (Vol. 71, No. 2, Jan 4, 2006).

Figure 2.1 Stage 2 DBPR and LT2ESWTR Implementation Schedule



[1] Includes all systems that are part of a combined distribution system that has a largest system with this population.
[2] A State may grant up to a two year extension for systems to comply if the State determines that additional time is necessary for capital improvements needed for compliance.
[3] Subpart H systems serving fewer than 10,000 that must conduct *Crypto* monitoring have an additional 12 months to comply with Stage 2 DBPR MCLs.

The Stage 2 DBPR improves the stringency of the Stage 1 DBPR by requiring water systems to meet DBP MCLs at each monitoring site in the distribution system to enhance the safety of public health. The Stage 2 DBPR includes four provisions:

1. **Initial Distribution System Evaluation (IDSE)** – The purpose of the IDSE is to identify Stage 2 DBPR compliance monitoring sites that represent the system's highest DBP levels. Since compliance will be determined at these new monitoring sites, the IDSE will offer assurance that MCLs are being met across the distribution system. The IDSE was designed to offer flexibility to water systems. There are four IDSE compliance options:

a. *Standard Monitoring Plan (SMP)*: Systems can monitor for TTHM and HAA5 levels for one year on a regular schedule, based on system size and source water type. Table 2.4 identifies the IDSE monitoring frequencies and locations and is adapted from page 4644 of the Federal Register (Vol. 17, No. 18, Jan 27, 2006).

b. *System Specific Study (SSS)*: Systems can perform a site-specific study based on historical data, water distribution system models, or other data.

c. *40/30 Certification*: If the locational running annual average (LRAA) is less than 0.040 mg/L for TTHM and less than 0.030 mg/L for HAA5 at each location, a 40/30 certification may be obtained.

d. *Very Small System (VSS) Waiver*: This applies to systems that serve fewer than 500 people and is therefore not applicable to Clarksville WTP.

Table 2.4 Standard IDSE Monitoring Requirements

Source Water Type	Population Size Category	Monitoring Frequency	Distribution System Monitoring Locations [1]				
			Total per monitoring period	Near Entry Points [2]	Average Residence Time	High TTHM Locations	High HAA5 Locations
Subpart H (surface water or ground water under the direct influence of surface water)	< 500 consecutive systems	one (during peak historical month)	2	1	-	1	-
	> 500 non-consecutive systems		2		-	1	1
	500 - 3,300 consecutive systems	four (every 90 days)	2	1	-	1	-
	500 - 3,300 non-consecutive systems		2	-	-	1	1
	3,301 - 9,999		4	-	1	2	1
	10,000 - 49,999	six (every 60 days)	8	1	2	3	2
	50,000 - 249,999		16	3	4	5	4
	250,000 - 999,999		24	4	6	8	6
	1,000,000 - 4,999,999		32	6	8	10	8
	>= 5,000,000		40	8	10	12	10
Ground	< 500 consecutive	one (during peak historical month)	2	1	-	1	-
	> 500 non-consecutive		2	-	-	1	1
	500 - 9,999	Four (every 90 days)	2	-	-	1	1
	10,000 - 99,999		6	1	1	2	2
	100,000 - 499,999		8	1	1	3	3
	>= 500,000		12	2	2	4	4

[1] When choosing sites consider TTHM and HAA5 Levels, Residence Time, Water Age, Disinfectant Residual, Geographic Coverage of Distribution System, and Hydraulic Representation.

[2] Near Entry Points: If you have more sites than required: choose entry points with the highest flows. If you have fewer sites than required, replace additional sites with TTHM and HAA5 sites.

2. **Compliance and Monitoring Requirements** – The second provision of the Stage 2 DBPR serves to ensure that spatial variations in DBP exposure do not allow consumers to be at risk. This provision provides a new compliance calculation (referred to as locational running annual average,

LRAA) for TTHM and HAA5. The MCL values remain equal to the Stage 1 DBPR levels of 0.080 mg/L and 0.060 mg/L for TTHM and HAA5, but the LRAA approach determines compliance by using the annual average at each individual sampling location. This approach will reduce exposure to high DBP concentrations by ensuring that each monitoring site is in compliance.

3. **Operational Evaluation Levels** – Using the IDSE and LRAA calculations for compliance determination will lead to lower DBP concentrations overall. However, it will still be possible for individual DBP samples to exceed the MCL even if the system is in compliance. The Stage 2 DBPR therefore requires systems that exceed operational evaluation levels to analyze operational practices within the system and seek opportunities for DBP concentration reductions within the distribution system. The operational evaluation levels for each monitoring location are determined by the following equation, where Q_3 is the current quarter measurement, Q_2 is the previous quarter measurement, Q_1 is the quarter prior to the Q_2 measurement, and MCL refers to the Stage 2 MCL for TTHM or HAA5.

   If $(Q_1 + Q_2 + 2Q_3) / 4 > MCL$, then the system must conduct an operational evaluation.

   The operational evaluation should include an examination of system treatment and distribution operational practices, including changes in sources or source water quality, storage tank operations, and excess storage capacity, which may contribute to high TTHM and HAA5 formation. Systems must also identify what steps could be considered to minimize future operational evaluation level exceedences. If factors such as water quality data, plant performance data, and distribution system configuration can be utilized to identify the cause of the increased DBP levels, the State may allow isolating the evaluation to the identified cause. System operational evaluation reports must be submitted to the State for review within 90 days after notification that operational evaluation is required.

4. **Consecutive Systems** – The fourth provision of the Stage 2 DBPR regulates consecutive systems, which are defined as public water systems that receive some of their finished water from another public water system. This provision will ensure that all consecutive systems provide drinking water that meets applicable DBP standards. Discussions related to the state of Tennessee's Consecutive Systems rule can be found below under Section 2.3, State Drinking Water Regulations.

Clarksville Gas and Water completed their IDSE monitoring, selected DBP monitoring sites and have been collecting the required DBP samples quarterly as required by the rule.

Under the Stage 2 DBPR, USEPA has identified the best available technology (BAT) for complying with TTHM and HAA5 MCLs. USEPA has specified a different BAT for systems that treat their source water than for consecutive systems as shown in Table 2.5.

Table 2.5 Identified Best Available Technologies (BAT) for TTHM and HAA5 Compliance

System Type	Identified Best Available Technologies
Systems that treat their own source water	a. GAC10 - Granular activated carbon filter beds with an empty-bed contact time of 10 minutes based on average daily flow and a carbon reactivation frequency of every 120 days
	b. GAC20 - Granular activated carbon filter beds with an empty-bed contact time of 20 minutes based on average daily flow and a carbon reactivation frequency of every 240 days.
	c. Nanofiltration (NF) using a membrane with a molecular weight cutoff of 1000 Daltons or less.
Consecutive Systems	a. Chloramination with management of hydraulic flow and storage to minimize residence time in the distribution system for systems serving at least 10,000 people.
	b. Management of hydraulic flow and storage to minimize residence time in the distribution system for systems serving fewer than 10,000 people.

Table 2.6 shows the Stage 2 TTHM and HAA5 routine compliance monitoring requirements for all systems, as adapted from page 427 of the Federal Register (Vol. 71, No. 2, Jan 4, 2006). If system LRAA values for TTHM and HAA5 at each location are ≤ 0.040 mg/L and ≤ 0.030 mg/L, respectively, based on a minimum of one year of monitoring at routine compliance locations, the system can qualify for reduced monitoring. The reduced monitoring frequencies and locations are listed on page 427/428 of the Federal Register (Vol. 71, No. 2, Jan 4, 2006).

Table 2.6 Stage 2 DBPR Routine Compliance Monitoring Frequencies and Locations

Source Water Type	Population Size Category	Monitoring Frequency[1]	Distribution System Monitoring Locations			
			Total per monitoring period[2]	Highest TTHM locations	Highest HAA5 locations	Existing Subpart L compliance locations
Subpart H (surface water or ground water under the direct influence of surface water)	< 500	per year	2	1	1	-
	500 - 3,300	per quarter	2	1	1	-
	3,301 - 9,999		2	1	1	-
	10,000 - 49,999		4	2	1	1
	50,000 - 249,999		8	3	3	2
	250,000 - 999,999		12	5	4	3
	1,000,000 - 4,999,999		16	6	6	4
	>= 5,000,000		20	8	7	5
Ground	< 500	per year	2	1	1	-
	500 - 9,999		2	1	1	-
	10,000 - 99,999	per quarter	4	2	1	1
	100,000 - 499,999		6	3	2	1
	>= 500,000		8	3	3	2

[1] All systems must monitor during month of highest DBP concentrations

[2] Systems on quarterly monitoring must take dual sample sets every 90 days at each monitoring location, except for subpart H systems serving 500 - 3,300. Systems on annual monitoring and subpart H systems serving 500 - 3,300 are required to take individual TTHM and HAA5 samples (instead of a dual sample set) at the locations with the highest TTHM and HAA5 concentrations, respectively. Only one location with a dual sample set per monitoring period is needed if highest TTHM and HAA5 concentrations occur at the same location, and month, if monitored annually.

The LT2ESWTR was promulgated to enhance public protection against illness caused by microbial pathogens including *Cryptosporidium* in drinking water as well as assess the tradeoffs associated with the control of disinfection byproducts. Prior to the LT2ESWTR, *Cryptosporidium* was not regulated in unfiltered systems with surface water sources, which was found to be an issue due to evidence from survey data showing that *Cryptosporidium* levels in these systems were higher than in filtered water systems. With the enactment of the LT2ESWTR, *Cryptosporidium* treatment for unfiltered water systems was required and therefore allowed the systems to achieve comparable public health protection. After treatment studies illustrated multiple disinfectants that could be used for *Cryptosporidium* inactivation, the USEPA established LT2ESWTR requirements for unfiltered water systems to provide *Cryptosporidium* treatment based on the level of source water contamination. The LT2ESWTR also addressed risks from uncovered finished water storage facilities by requiring cover or treatment for discharge from uncovered finished water storage facilities.

The LT2ESWTR requires source water monitoring, additional treatment for *Cryptosporidium*, and modifications to uncovered finished water storage facilities as described below.

1. **Source Water Monitoring** – The LT2ESWTR required source water monitoring by all Public Water Systems (PWSs) using surface water or ground water under the direct influence of surface water (GWUDI) to determine treatment requirements for *Cryptosporidium*. PWSs serving at least 10,000 people monitored for *Cryptosporidium* (plus *E. coli* and turbidity in filtered PWSs) for a period of two years. Under the LT2ESWTR, specific criteria were set for sampling frequency and schedule, sampling location, and monitoring of new plants and sources. The date for PWSs to begin monitoring was staggered by PWS size, with larger PWSs starting earlier.

2. **Additional Treatment for Cryptosporidium** – Source water monitoring results allow filtered systems to be classified into one of four treatment bins specifying required treatment measures. To supplement existing *Cryptosporidium* treatment requirements, the LT2ESWTR established risk-targeted *Cryptosporidium* treatment for surface waters and GWUDI. Table 2.7 describes the bin classification for filtered PWSs as well as the treatment requirements for the various bin classifications and was adapted from page 674 and page 675 of the Federal Register (Vol. 71, No. 3, Jan 5, 2006). Filtered PWSs classified in Bins 2, 3, or 4 can use one or more treatment or control processes from a ‘‘microbial toolbox’’ of options.

   The LT2ESWTR requires all unfiltered PWSs to provide at least 2-log (99 percent) *Cryptosporidium* inactivation. If the average source water *Cryptosporidium* level exceeds 0.01 oocysts/L based on the monitoring, the unfiltered PWS must provide at least 3-log (99.9 percent) *Cryptosporidium* inactivation. Further, unfiltered PWSs must achieve their overall inactivation requirements (including *Giardia lamblia* and virus inactivation) using a minimum of two disinfectants. If there is a low occurrence of *Cryptosporidium* and the plant is given a Bin 1 classification, as is the case with Clarksville WTP during first round source water testing in 2009, then the plant will only have to meet the SWTR and IESWTR requirements. If the classification falls in one of the higher bins then one or several of the additional treatment alternatives from the LT2ESWTR’s toolbox will have to be considered in the design. The toolbox options are presented in Table 2.8. The Clarksville WTP uses low pressure membrane microfiltration with a nominal pore size of 0.1 micron which has been granted a 4-log removal credit for *Cryptosporidium* because microfiltration is a direct barrier and effectively filters particles in the cryptosporidium size range.

Table 2.7 Bin Classifications and Additional Treatment Requirements for Filtered Systems

For systems	Mean Cryptosporidium Concentration	Bin Classification	Additional Cryptosporidium treatment requirements assuming system uses specified filtration treatment in full compliance with existing requirements			
			Conventional filtration treatment (including softening)	Direct filtration	Slow sand or diatomaceous earth filtration	Alternative filtration technologies
…required to monitor for Cryptosporidium	**< 0.075 oocysts/L**	**Bin 1**	**No additional treatment**	**No additional treatment**	**No additional treatment**	**No additional treatment**
	from 0.075 to < 1.0 oocysts/L	Bin 2	1-log treatment	1.5-log treatment	1-log treatment	(1)
	from 1.0 to < 3.0 oocysts/L	Bin 3	2-log treatment	2.5-log treatment	2-log treatment	(2)
	>= 3.0 oocysts/L	Bin 4	2.5-log treatment	3-log treatment	2.5-log treatment	(3)

1 As determined by the state such that the total Cryptosporidium removal and inactivation is at least 4.0-log

2 As determined by the state such that the total Cryptosporidium removal and inactivation is at least 5.0-log

3 As determined by the state such that the total Cryptosporidium removal and inactivation is at least 5.5-log

3. **Uncovered Finished Water Storage Facilities** – Existing regulations require PWSs to cover all new finished water storage facilities. However, they did not address existing uncovered finished water storage facilities. Under the LT2ESWTR, PWSs using uncovered finished water storage facilities must either cover the storage facility or treat the storage facility discharge to achieve inactivation and/or removal of 4-log virus, 3-log *Giardia lamblia*, and 2-log *Cryptosporidium* on a State-approved schedule.

Based on past studies, USEPA estimated that plants using conventional treatment techniques (defined as coagulation, flocculation, sedimentation, and filtration) that are in compliance with the IESWTR or LT1ESWTR typically achieve a *Cryptosporidium* removal efficiency of approximately 3-log. Cryptosporidium treatment credits towards LT2ESWTR.

The LT2ESWTR included a variety of treatment and control options, collectively termed the "Microbial

Toolbox," that PWSs can implement to comply with additional *Cryptosporidium* treatment requirements. Options in the microbial toolbox include source protection and management programs, pre-filtration processes, treatment performance programs, additional filtration components, and inactivation technologies. The Stage 2 Microbial/Disinfection Byproducts (M–DBP) Advisory Committee recommended the microbial toolbox to provide PWSs with broad flexibility in selecting cost-effective LT2ESWTR compliance strategies. Most options in the microbial toolbox carry prescribed credits toward *Cryptosporidium* treatment requirements. PWSs receive these credits by demonstrating compliance with required design and operational criteria. In addition, States may award treatment credits other than the prescribed credit through a "demonstration of performance," which involves site-specific testing by the PWS with a State-approved protocol. Table 2.8 describes the Microbial Toolbox and is adapted from pages 684/685 of the Federal Register (Vol. 71, No. 3, Jan 5, 2006). In order to receive removal credit for *Cryptosporidium* under the LT2SWTR, a membrane filtration system must meet the following three criteria:

1. The process must comply with the definition of membrane filtration as stipulated by the rule.

2. The removal efficiency of a membrane filtration process must be established through a product-specific challenge test and ongoing, site-specific direct integrity testing during system operation.

3. The membrane filtration system must undergo periodic direct integrity testing and continuous indirect integrity monitoring during operation.

The rule does not prescribe a specific removal credit for membrane filtration processes. Instead, removal credit is based on system performance as determined by challenge testing and verified by direct integrity testing. According to the Preliminary Engineering Report for the Clarksville WTP Expansion to 28 MGD prepared by JJG in 2009, the microfiltration process used at Clarksville has been granted a 4-log removal credit for *Cryptosporidium* based on manufacturer-certified challenge testing performed in California.

Challenge testing demonstrates the ability of an integral membrane process to remove the target organism. Integrity breaches can develop in the membrane during routine operation that could allow the passage of microorganisms. In order to verify the removal efficiency of a membrane process during operation, direct integrity testing is required for all membrane filtration processes. A direct integrity test is defined as a physical test applied to a membrane unit in order to identify and isolate integrity breaches. The rule does not mandate the use of a specific type of direct integrity test, but rather performance criteria that any direct integrity test must meet. These criteria include requirements for resolution, sensitivity, and frequency:

- Resolution: The direct integrity test must be applied in a manner such that a 3 micrometer breach contributes to the response from the test.
- Sensitivity: The direct integrity test must be capable of verifying the ability of a membrane filtration system to achieve the log removal value awarded to the process by the state.

Frequency: The direct integrity test must be applied at a frequency of at least once per day, although less frequent testing may be permitted by the state at its discretion if appropriate safety factors are incorporated.

A control limit must also be established for a direct integrity test, representing a threshold response which, if exceeded, indicates a potential integrity problem and triggers subsequent corrective action. For the purposes of LT2ESWTR compliance, this threshold response must be indicative of an integral membrane unit capable of achieving the Cryptosporidium removal credit awarded by the state.

The LT2ESWTR also specifies that PWSs should start a second round of source water monitoring six years after the end of the first round of monitoring. For PWSs serving more than 100,000 people, the monitoring should start no later than April 2015, while systems serving between 50,000 and 99,999 people should start by October 2015, and systems serving between 10,000 and 49,999 people should start the second round of monitoring by October 2016. Systems serving less than 10,000 people that monitor for *E. coli* must begin the second round by October 2017 while systems serving less than 10,000 people and monitor for *Cryptosporidium* should start the second round by April 2019. PWSs are required to perform the second round of monitoring in accordance with the initial source water monitoring requirements. Subsequently, PWSs will receive new bin classifications based on the results of the second round of monitoring. Clarksville Gas and Water should be receiving notice soon, if they have not already received notice, informing them of their requirement for the next round of source water monitoring for the LT2ESWTR.

Table 2.8 Microbial Toolbox: Options, Credits and Criteria

Toolbox option	Cryptosporidium treatment credit with design and operational criteria [1]
Source Protection and Management Toolbox Options	
Watershed control program	0.5-log credit for State-approved program comprising required elements, annual program status report to State, and regular watershed survey. Unfiltered PWSs are not eligible for credit.
Alternative source/intake management.	No prescribed credit. PWSs may conduct simultaneous monitoring for treatment bin classification at alternative intake locations or under alternative intake management strategies.
Prefiltration Toolbox Options	
Presedimentation basin with coagulation.	0.5-log credit during any month that presedimentation basins achieve a monthly mean reduction of 0.5-log or greater in turbidity or alternative State-approved performance criteria. To be eligible, basins must be operated continuously with coagulant addition and all plant flow must pass through basins.
Two-stage lime softening	0.5-log credit for two-stage softening where chemical addition and hardness precipitation occur in both stages. All plant flow must pass through both stages. Single-stage softening is credited as equivalent to conventional treatment.
Bank filtration	0.5-log credit for 25-foot setback; 1.0-log credit for 50-foot setback; horizontal and vertical wells only; aquifer must be unconsolidated sand containing at least 10 percent fines (as defined in rule); average turbidity in wells must be less than 1 NTU. PWSs using existing wells followed by filtration must monitor the well effluent to determine bin classification and are not eligible for additional credit.
Treatment Performance Toolbox Options	
Combined filter performance	0.5-log credit for combined filter effluent turbidity less than or equal to 0.15 NTU in at least 95 percent of measurements each month.
Individual filter performance	0.5-log credit (in addition to 0.5-log combined filter performance credit) if individual filter effluent turbidity is less than or equal to 0.15 NTU in at least 95 percent of samples each month in each filter and is never greater than 0.3 NTU in two consecutive measurements in any filter.
Demonstration of performance	Credit awarded to unit process or treatment train based on a demonstration to the State with a State-approved protocol.
Additional Filtration Toolbox Options	
Bag and cartridge filters	Up to 2-log credit with demonstration of at least 1-log greater removal in a challenge test when used singly. Up to 2.5-log credit with demonstration of at least 0.5-log greater removal in a challenge test when used in series.
Membrane filtration	Log credit equivalent to removal efficiency demonstrated in challenge test for device if supported by direct integrity testing.
Second stage filtration	0.5-log credit for second separate granular media filtration stage if treatment train includes coagulation prior to first filter.
Slow sand filters	2.5-log credit as a secondary filtration step; 3.0-log credit as a primary filtration process. No prior chlorination.
Inactivation Toolbox Options	
Chlorine dioxide	Log credit based on measured CT in relation to CT table.
Ozone	Log credit based on measured CT in relation to CT table.
UV	Log credit based on validated UV dose in relation to UV dose table; reactor validation testing required to establish UV dose and associated operating conditions.

[1] Table provides summary information only; refer to following preamble and regulatory language for detailed requirements.

After the attacks on September 11, 2001, a greater emphasis was placed on the safety of critical government infrastructure, including the safety of water and wastewater treatment plant infrastructure. The government has subsequently produced legislation and instructions based on the need to protect the public water supply from the threat of terrorist attacks. These include The Homeland Security Presidential Directives (HSPDs) and the Public Health Security and Bioterrorism Preparedness and Response Act (Bioterrorism Act) of 2002. Other existing legislation related to water supply security include the 1996 amendment of the Safe Drinking Water Act (SDWA) that increased regulations on source water protection and prevention activities and the Federal Water Pollution Control Act (Clean Water Act).

In 2002, the Bioterrorism Act was promulgated. Title IV of the Bioterrorism Act deals with the safety and security of drinking water. The Title requires drinking water systems with over 3,300 consumers to conduct vulnerability assessments in order to develop response measures to terrorist or other intentional acts that may affect public health. In accordance with the Bioterrorism Act, the USEPA must provide water systems with information on potential threats, incident response strategies, vulnerability assessment protocols, and water security research studies.

The sections of the HSPDs that are particularly relevant to water security matters are HSPD 7: Critical Infrastructure Identification, Prioritization, and Protection, HSPD 8: National Preparedness, HSPD 9: Defense of United States Agriculture and Food, and HSPD 10: Biodefense for the 21st Century. HSPD 7 stipulated that the Water Security Division develop a water sector specific plan as input to the National Infrastructure Protection Plan. The resulting Water-Sector Specific Plan (2007) provides a strategy for the protection of critical infrastructure for drinking water and wastewater utilities, water and wastewater regulatory agencies, and other partners of the Water Sector. HSPD 8 provides policies to improve readiness for prevention and response to terrorist attacks and other emergencies. HSPD 9 stipulated that the USEPA develop a monitoring program to supply a means of advanced warning in the event of a terrorist attack. In response, the USEPA developed the Water Security Initiative and the Water Laboratory Alliance. The Water Security Initiative is a program that addresses the risk of drinking water contamination through three phases. Phase I of the program involves the development of a detection and response system for drinking water contamination incidents. Phase II involves a testing period in which the contamination warning systems (CWS) are to be piloted at drinking water treatment plants in order to improve the system design. As part of Phase II, USEPA installed a CWS pilot at the Greater Cincinnati Water Works, with pre-design activities started in 2005 and data collection completed in 2010. The USEPA has also been funded for the installation of CWS pilots in New York City, San Francisco, Philadelphia, and Dallas, with pilot studies expected to reach completion in 2012. Phase III includes providing guidance and outreach to water utilities to enhance the utilization of effective drinking water contamination warning systems. The Water Laboratory Alliance provides drinking water utilities with a national system of laboratories capable of analyzing water samples in the event of contamination. If utilities become members of the WLA, critical support will be provided during a contamination incident to improve emergency response readiness.

2.2 Future and Proposed Regulations

The USEPA has several programs to evaluate the public health impact and potential regulation of the many known compounds and microorganisms that are not currently subject to proposed or promulgated NPDWR. These contaminants, however, are known to or anticipated to occur in drinking water. Many of these unregulated contaminants are listed in the Drinking Water Contaminant Candidate List (CCL) or in the Unregulated Contaminant Monitoring Rule (UCMR) program. The more well-known contaminants that may be the subject of future regulations or an increase in regulation stringency include strontium, perchlorate, chlorate, additional non-regulated VOCs, chromium VI, nitrosamines, and emerging contaminants, as discussed below. Note that strontium was the ONLY contaminant to get a positive regulatory determination.

The USEPA has decided to regulate perchlorate under the SDWA with a NPDWR MCL to be proposed in the next 24 months. Several states have already established a perchlorate MCL including California (6 µg/L) and Massachusetts (2 µg/L). Nevada has an action level of 18 µg/L. Sources of perchlorate include munitions, rocket fuel, industrial sites, and hypochlorite. The use of an on-site sodium hypochlorite generation system (OSG) at the Clarksville WTP indicates this rule may apply to Clarksville Gas and Water.

In addition to perchlorate, chlorate is another impurity commonly occurring in drinking water facilities that use bulk hypochlorite or OSG hypochlorite. In hypochlorite solutions, chlorate may form during manufacture, transport, or storage, and increases in concentration correlate with the increase of time and/or temperature (Stanford et al., 2011). Chlorate has been placed on the third USEPA Contaminant Candidate list and the USEPA has announced a chlorate health reference level of 210 µg/L. Therefore, chlorate is likely to be regulated in the future.

USEPA will be looking closely at chlorate and nitrosamines in the context of the review of the M/DBP Cluster in the third six-year review in 2016. While no immediate determination has been made. if the USEPA incorporates rule making during their Six-Year review, the approval and implementation process may be shorter than sending them via a positive regulatory determination and an entirely new rule. (With six year review, they just revise the existing rules, thus we could easily envision a Stage3DBPRule or possibly a “Long Term DBPRule”, depending on how USEPA is feeling about naming conventions.) Thus, we may still be on the 2022 horizon for regulatory compliance for chlorate and nitrosamines.

Two states, Massachusetts and Minnesota, have nominated manganese for inclusion in the agency's contaminated candidate list (CCL4), the list of substances eligible for regulation under the Safe Drinking Water Act. Manganese was included in CCL3 and it was deemed unnecessary to regulate it in drinking water. But an agency source says that more recent toxicity studies suggest that ingestion of manganese may lead to "troubling" neurological effects in children. "It looks like the effects [in the studies] are in the range of [USEPA's] existing [reference dose (RfD)] or lower," the source says.

The source's comments are backed up by the states' nominations of manganese for the CCL4 list. Both note that the element occurs in drinking water at levels exceeding USEPA's health advisory level, and that research published since USEPA's 1993 IRIS assessment indicate the possibility of subtle neurological effects in schoolchildren. "Manganese is commonly detected in groundwater in the United States at concentrations greater than the lifetime Health Advisory (HA) value of 300 ug/L," according to Minnesota Department of Health's 2012 nomination. "Twelve percent of 4,976 groundwater samples taken throughout the United States by the US Geological Survey from 1992 -- 2003 exceeded the HA for manganese."

Both states also cite the newer neurological data. Massachusetts Department of Environmental Protection writes in its 2012 nomination, "There has been an accumulating body of work since USEPA's last review of manganese suggesting an association between drinking water exposure in school age children and a variety of subtle neurological effects .Effects in one of the more recent studies have been seen at manganese water concentrations below the current USEPA lifetime Health Advisory value, suggesting that the validity of that research finding be critically examined and that possibly the basis for the current HA be revisited.

Clarksville 2014 MOR data indicate average raw water manganese concentration of 0.07 mg/L and an average finished water concentration of 0.01 mg/L. Both the raw and finished water concentrations fall significantly below the Health Advisory value. However, monitoring of the future research findings and the regulatory climate for a potential revision to the HA is recommended.

Budget constraints and limited resources continue to delay most of the major drinking water regulations that are anticipated to be released by USEPA's Office of Groundwater and Drinking Water (OGWDW). Regulatory actions that may impact the Clarksville water systems were released in 2014:

Proposed definition of Waters of the U.S.; Proposed ambient water quality criteria for the protection of human health; Advance notice of proposed rulemaking for hydraulic fracturing chemicals and mixtures; Evaluation of chemical safety and USEPA Report on Risk Management Plans (RMPs); and Proposed Clean Power Plan (CPP).

On July 31st, USEPA, in response to Executive Order 13650, requested information on potential revisions to its Risk Management Program (RMP) regulations and related programs. In this Request for Information (RFI), the Agency asked for information and data on specific regulatory elements and process safety management approaches, the public and environmental health and safety risks they address, and the costs and burdens they may entail. USEPA will use the information received in response to this RFI to inform what action, if any, the Agency may take in the future. This may ultimately impact systems using certain chemicals such as gaseous chlorine.

The drinking water community will see published in the *Federal Register* in 2014 will be focused on two must-do regulatory actions from the five-year cycles set in the SDWA for identifying new contaminants for potential regulation. As previously discussed, Table 2.9 below shows how these actions, as well as other drinking water regulations, have been significantly delayed over the past couple of years. This table shows the delays with final regulations by comparing expected proposal and final dates from November 2012 to October 2014.

Table 2.9 Regulatory Delays

Regulatory Delays/Regulatory Action	Proposal (11/12)	Final (11/12)	Proposal (10/14)	Final (10/14)	Potential Delays
Perchlorate	2/13	8/14	2015 or 2016	2017 or 2018	3-4 years
Third Regulatory Determination (RegDet 3)	2013	2014 or 2015	2014	2015 or 2016	1 year

Regulatory Delays/Regulatory Action	Proposal (11/12)	Final (11/12)	Proposal (10/14)	Final (10/14)	Potential Delays
Long-Term Lead and Copper Rule (LT-LCR) Revisions	2013	2015	2016 or 2017	2018 or 2019	3-4 years
Carcinogenic VOCs (cVOCs)	2013	2015	2015 or 2016	2017 or 2018	2-3 years
Third Six-Year Review		2015		2016	
Any Regulations from RegDet 3	2016 or 2017	2018 or 2019	2017 or 2018	2019 or 2020	1 year
Hexavalent Chromium	2017 or 2018		2019 or 2020		N/A
Fourth Contaminant Candidate List (CCL4)	2014		2015 or 2016		N/A
Fourth Unregulated Contaminant Monitoring Rule (UCMR4)	2015		2016		N/A

Volatile organic compounds (VOCs) are a group of contaminants for which the USEPA has recently decided to increase regulation stringency. There are currently 8 regulated VOCs, and the USEPA plans to regulate 8 additional compounds as well as revise the regulations for the currently regulated VOCs. In particular, the currently regulated compounds trichloroethylene (TCE) and tetrachloroethylene (PCE) will receive stricter regulations due to scientific advances allowing for a lowered MCL.

An Environmental Working Group report has sparked renewed interest from the USEPA in chromium VI, which is toxic and may cause people exposed at high levels over a long period of time to experience allergic dermatitis. Chromium is a naturally occurring metal in rocks, plants, humans, soil and volcanic dust, and animals. It is mostly present as chromium III, chromium VI, and the metal form of chromium, the latter two of which are produced in industrial processes. Major sources of chromium include steel and pulp mills and natural deposit erosion. Instead of regulating chromium VI as a single contaminant, the USEPA currently regulates the total concentration of chromium in drinking water, with an MCL of 0.1 mg/L. California regulates the total chromium concentration at 0.05 mg/L. Due to emerging research, the USEPA has proposed in the September 2010 draft human health assessment that chronic chromium VI exposure be classified as a probable carcinogen. When the draft human health assessment is finalized, a comprehensive review will be completed to determine if a new chromium standard should be set. (USEPA, 2010)

Another group of contaminants that may be increasingly regulated in the future is emerging contaminants, also known as microconstituents, micropollutants, or trace organics. These contaminants include pharmaceutically-active compounds (PhACs), personal care products (PCPs), endocrine-disrupting compounds (EDCs), and other organic compounds. There has been a recent increase in scientific and public interest in these compounds as they are being discovered in surface waters, groundwater, wastewater treatment plant effluents, and drinking water. Sources of endocrine-disrupting compounds as well as other emerging contaminants include domestic sources such as human excretion and flushing of expired drugs, agricultural runoff, industrial sources, and solid waste. There are currently no set of federal or state regulations that specifically address PhACs, PCPs or EDCs, although there are national primary drinking water standards for many synthetic organic chemicals. The USEPA is currently very active in research and analysis of these compounds and is developing strategies to protect the health of both the public and the environment. Also, some states and local communities are becoming more involved in helping consumers properly dispose of pharmaceuticals and personal care products.

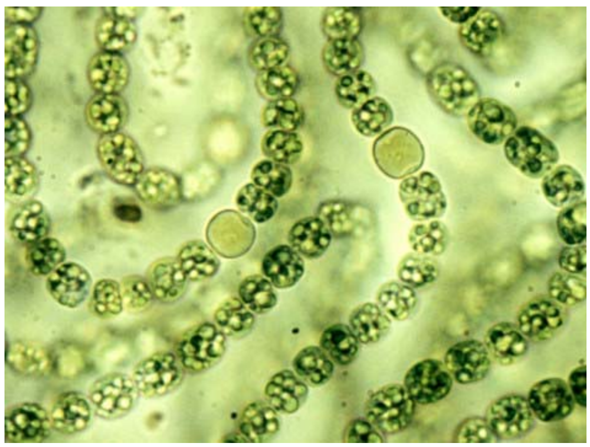
2.3 State Drinking Water Regulations

The Tennessee Department of Environment and Conservation (TDEC) is responsible for the protection of Tennessee's natural resources, specifically land, air, water and recreational resources. Under TDEC, the Division of Water Supply is the main administrative manager for drinking water related rules and regulations, including the Safe Drinking Water Supply Rules and Water Pollution Control Rules. Chapter 1200-05-01 of the Rules of the Tennessee Department of Health and TDEC provides drinking water quality regulations for all public water supply systems that provide drinking water for human consumption through pipes or other drinking water conveyance structures. Community Public Water Systems Design Criteria from the TDEC Division of Water Supply provides general design criteria as well as criteria for treatment processes, chemical application, pumping facilities, finished water storage, and distribution systems. Table 2.10 shows unit process goals based on TDEC Public Water Systems Design Criteria. Current State of Tennessee regulations require conformance with current Federal regulations. It is anticipated that as new Federal regulations are promulgated, Tennessee's regulations will be revised to correspond to all Federal criteria.

Rule 0400-45-01-.36 states that if DBP monitoring in a consecutive system demonstrates exceedance of the MCL or the operational evaluation level trend, for the parent system to avoid having to perform an operational evaluation of their system processes for DBP reduction, the results for DBP concentrations from the master meter or nearest compliance monitoring location must be 60% or less of the MCL for the constituent in question. To maintain DBP concentrations equal to or less than 60% of the MCLwould mandate Clarksville Gas and Water to provide TTHM levels $\leq$ 48 ug/L and HAA5 $\leq$ 36 ug/L.

2.4 Cyanobacteria and Toxins

Cyanobacteria, also known as blue-green algae, are a concern for water utilities worldwide as their persistence in water supplies causes numerous problems for water treatment plants. They are not true algae, but rather gram-negative bacteria which contain chlorophyll and perform photosynthesis. The major concern associated with the presence of cyanobacteria is the metabolites they produce, including taste and odor (T&O) compounds (particularly 2-methyl isoborneol (MIB) and geosmin) and a range of toxic compounds known collectively as algal toxins, or cyanotoxins. Presently, about 30 species of cyanobacteria are known; however, not all produce T&O or toxins. Most of the toxic action produced by cyanotoxins can be classified as either (1) hepatoxins (taken up by the liver causing weakness and anorexia); (2) neurotoxins (effecting the nervous system); and (3) dermatoxins (causing skin and mucous irritations upon contact).



Cyanobacteria (Blue-Green Algae)

Algal toxins are not currently regulated by the USEPA. The World Health Organization (WHO) has a chronic exposure guideline value of 1 ug/L for microcystinand a maximum tolerable daily intake of 6 ug/L for an adult (WHO 2011). The WHO's guideline value assumes that the presence and concentration of microcystin is an adequate surrogate for any other algal toxins that may also be present.

Currently, several algal toxins have been included on the third USEPA contaminant candidate list (CCL3), but have yet to be included in the unregulated contaminant monitoring rule (UCMR) program. This lack of inclusion in UCMR to date was partly due to inconsistencies among analytical methods and partly due to inflexibility in the structure of the UCMR. In the original rule, utilities were asked to collect quarterly samples over a 2-year period. In the case of algal toxins, their occurrence is typically seasonal, variable from year to year, and associated with blooms which may or may not coincide with pre-determined sampling dates.

However, analytical method improvement and current efforts to encourage the USEPA to consider an alternative sampling schedule for algal toxins, may mean that algal toxins will be included in the fourth iteration, UCMR4. Even if included on UCMR4, challenges will still remain in determining appropriate sampling locations and interpreting the monitoring data, given the short-term, seasonal, and inconsistent nature of algal blooms.

Pro-active utilities are not waiting for legislation to confront the issue of HAB's in water supplies. Mitigation using conventional water treatment (flocculation, coagulation, sedimentation and filtration) is effective in removing algal cells, but not for any extracellular algal toxins or dissolved T&O in the water column. Additionally, weak oxidants like permanganate or free chlorine can be used to control algae in-plant, but can actually lyse cells causing release of toxins and T&O compounds. Although regarded as a weak oxidant hydrogen peroxide has been shown for hydrogen sulfide and a decent algaecide when used in the storage basin, similar to copper sulfate.

Table 2.10 Unit Process Goals from the TDEC Community Public Water Systems Design Criteria

Process	Goal / Requirement
New Raw Water Source	• Sanitary survey and study required to assess biological, physical, chemical, and radiological characteristics of water
Flash Mix	• Detention time ≤ 30 seconds • Velocity gradient ≥ 300 s^{-1}
Flocculation	• Detention time ≥ 30 minutes; 45 minutes (recommended)
Sedimentation	• Detention time ≥ 4 hours (conventional); ≥ 1 hour (tube settlers) • Tube settler loading rate ≤ 2.5 gpm/ft^2 • Surface overflow rate = 0.25-0.38 gpm/ft^2 (conventional) • Weir loading rate = 8-10 gpm/ft for low turbidity raw water; 10-15 gpm/ft for high turbidity raw water
Filtration	• Filtration rate ≤ 2.0 gpm/ft^2 (nominal), ≤4 gpm/ft^2 (dual/mixed media and coag/floc/sed requirements met) • Influent pipe velocity = 2 ft/s • Filter depth ≥ 8.5 ft
Disinfection	• Chlorine preferred. • Capacity for free chlorine residual = 2.0 mg/L after 30 minutes when maximum flow coincides with maximum chlorine demand.
Waste Streams	• Recycle allowed if returned to head of plant following clarification.
Chemical Storage	• 30 days of storage required
TOC Removal	• As stated in DBPR.
Raw and Finished Water Pumping	• N+1 Firm Capacity for Peak Demand • Elevated to minimum 1-ft above 100-yr flood elevation.

3. Water Quality Goals

One of the objectives of this study is to develop a set of water quality goals to be utilized as part of the analysis of alternatives for reliably meeting capacity requirements. Water quality goals were developed for the City of Clarksville with the primary purpose of meeting or exceeding all primary water quality standards enforced by TDEC and the USEPA. Secondary standards were also utilized to develop additional water quality goals to guarantee aesthetically-pleasing characteristics of the water. Along with regulatory requirements, the goals were developed through review of historical plant water quality information and with staff input. These water quality goals can also be used as criteria for long-term treatment targets.

Raw water stability at the treatment plant was assessed by looking at raw water alkalinity, pH, TOC, and turbidity. The raw water alkalinity generally remained between 60 mg/L and 100 mg/L as $CaCO_3$, while the raw water pH remained consistently between 7.3 and 8.3 pH units. Raw water turbidities are shown in Figures 3.1. For the 2014 data received the turbidities generally stayed below 25 NTU, with sporadic peaks up to 100 NTU and a minimum around 2 NTU.

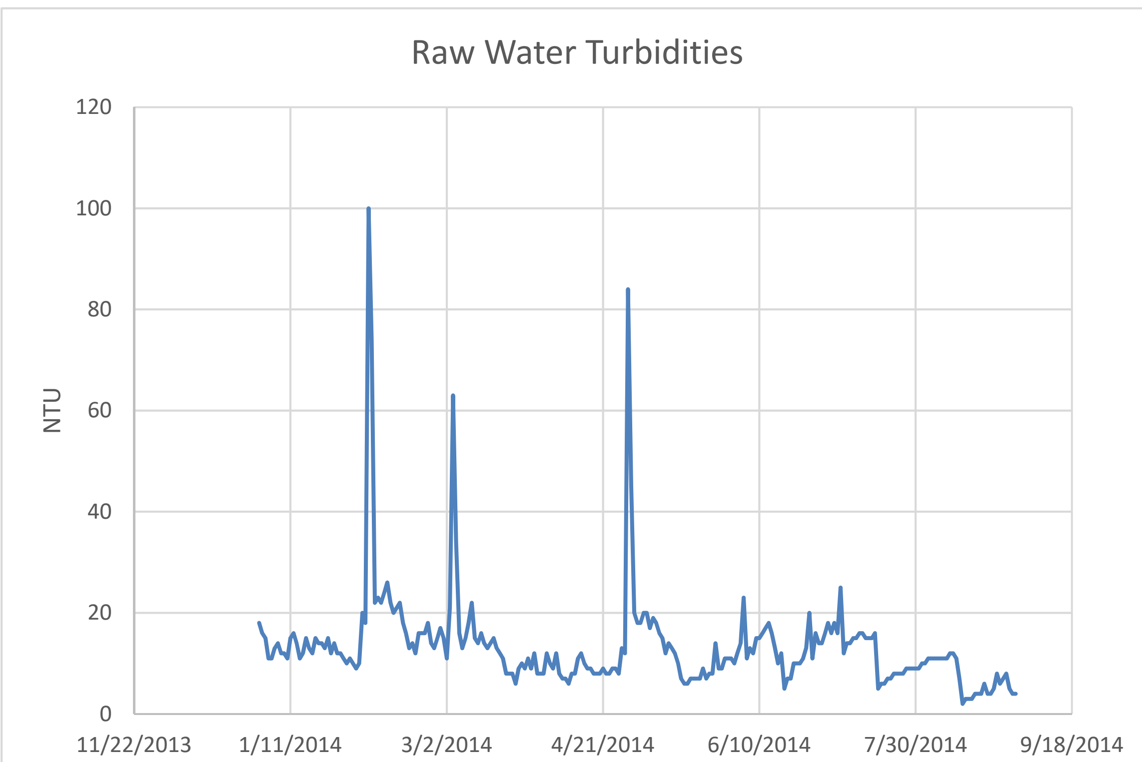


Figure 3.1 Raw Water Turbidity at the Clarksville WTP

As TOC has a major impact on DBPs in the effluent drinking water, the raw, settled and finished TOC values were analyzed. Figure 3.2 shows total organic carbon as reported from Clarksville's in-house laboratory. The system's treated water averages 1.9 mg/L, with excursions up to 3.0 mg/L.

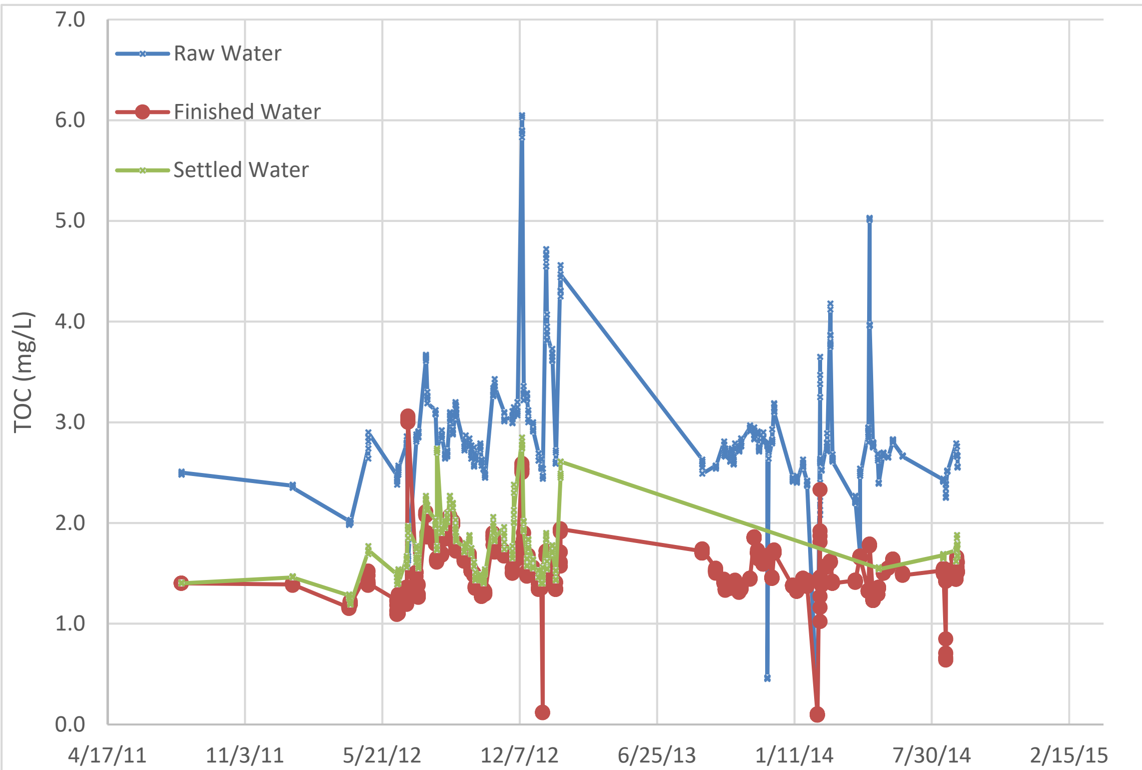


Figure 3.2 Total Organic Carbon

It appears that TOC is being efficiently removed, with average removals of 57% Raw water TOC averages approximately 2.8 mg/L (Figure 3.3). Based on raw water alkalinity averages that remain between 70 and 100 mg/L as $CaCO_3$, the Stage 1 DBPR requires a TOC removal equal to or greater than 25%. The plant consistently meets this requirement.

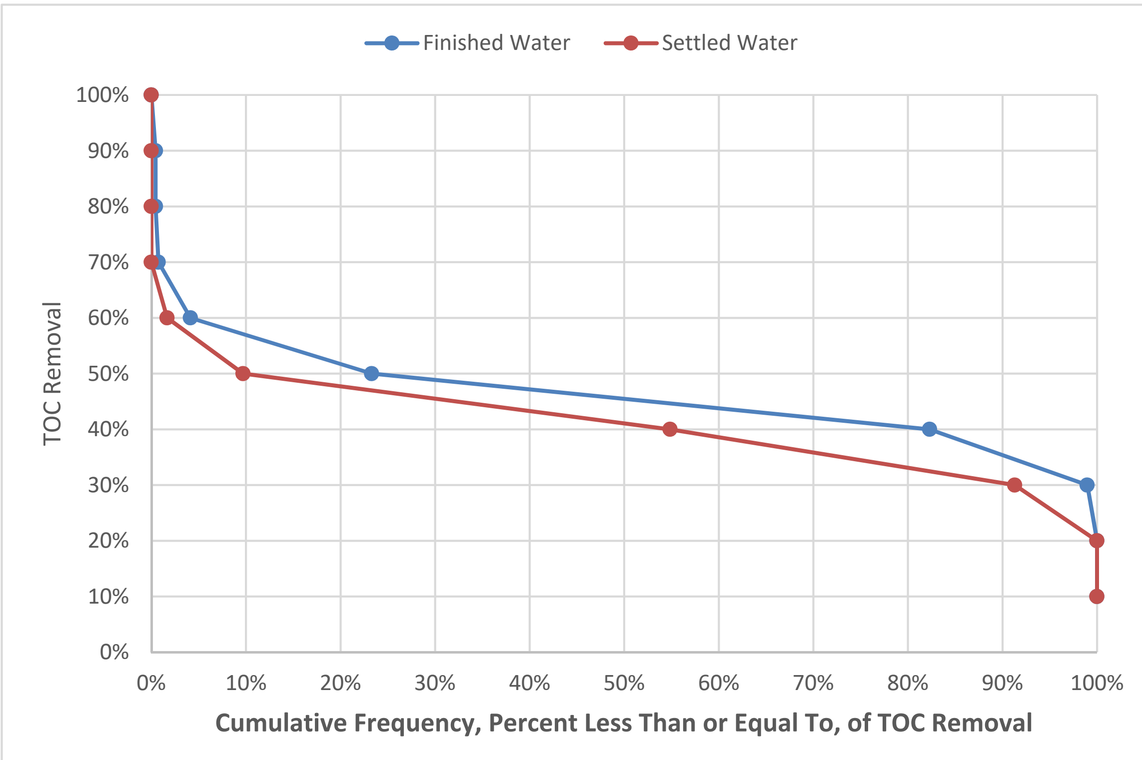


Figure 3.3 Total Organic Carbon Percent Removal (Aug. 2011- Sept. 2014)

TTHM and HAA5 sampling data from 2012 and 2013 indicated high levels of DBP's in the summer months, or 3rd quarter. Clarksville modified its disinfection strategies and discontinued the practice of pre-chlorination. One option is a goal of no single reading above the MCL, such that OELs are avoided. Figure 3.4 illustrates that since 2013 only the Pinewoods Rd. sampling location exceeds the TTHM MCL and that occurs only in the summer months, or 3rd quarter. Clarksville Gas and Water has expressed interest in establishing a DBP water quality goal equal at 60% of the MCLs for TTHM and HAA5. Since the change in disinfection strategies, Pineywoods compliance site LRAA has dropped from 90.1 mg/L in September, 2013 to 72.8 mg/L in September, 2014. Some utilities view a water age goal as part of its DBP strategy, as DBP formation may be minimized in the distribution system by reducing water age at specific average DBP "problem" sites and disinfection optimization. Clarksville TTHM species are 70-85% chloroform.

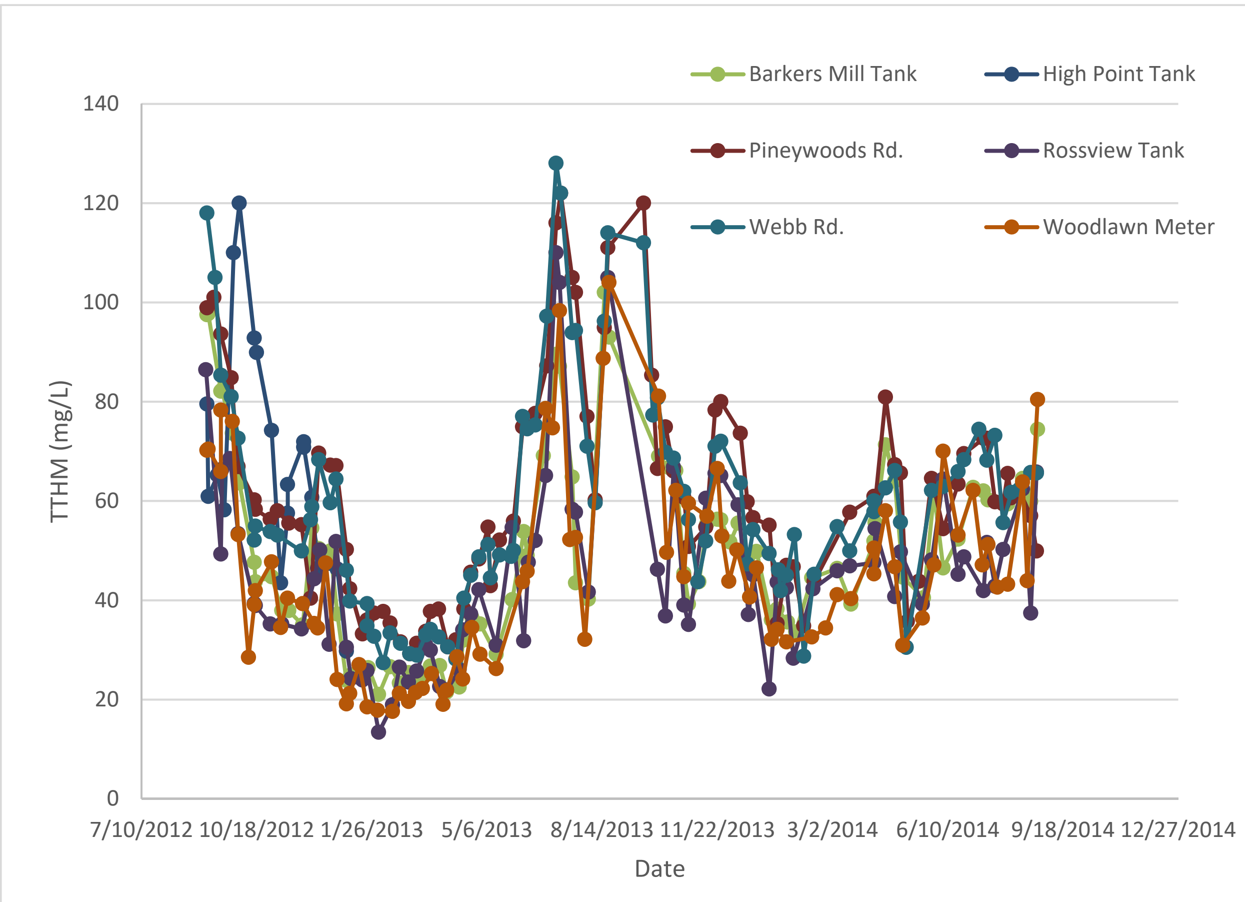


Figure 3.4 TTHM Concentrations at Monitoring Points

Based on data reviews, regulatory requirements, and a workshop with Clarksville staff, a set of water quality goals was developed. The primary and secondary water quality goals are provided in Tables 3.1 and 3.2.

Table 3.1 Primary Water Quality Goals

Parameter	Goal	Reference Comment
Individual Sedimentation Basin Settled Water Turbidity	< 1 NTU 95% of the time when raw < 10 NTU < 2 NTU 85% of the time when raw > 10 NTU < 5 NTU (max)	• Partnership for Safe Drinking Water Individual Sedimentation Basin Performance Goals
Individual Filtered Water Turbidity	≤ 0.1 NTU 95% of the time	• Partnership for Safe Drinking Water Individual Filter Performance Goal • Goal for filter run termination and return to service following backwash
Combined Filtered Water Turbidity	< 0.1 NTU 95% of the time	• Partnership for Safe Drinking Water Combined Filter Performance Goal
UV 254 Absorbance	None	• Surrogate for monitoring organic content only.
pH & Corrosion Control	None	• Phosphate added for corrosion control.
Giardia lamblia	3.0-log removal / inactivation	• SWTR Requirement
Cryptosporidium	4.0-log removal / inactivation	• LT2ESWTR Bin = 1 • 4- log inactivation credit for membrane
Viruses	4-log inactivation	• SWTR Requirement
Membrane Integrity Test	0.3 psi over 5 minutes on each	• Daily test on each membrane rack • Verify membrane integrity as a physical barrier
TOC Removal Percentage	25%	• DBPR requirement: 25% at current raw water TOC and alkalinity levels (re-evaluate if raw water TOC increases above 4 mg/L)
DBP LRAA Concentrations for consecutive system	60% of MCL	• 48 ug/L TTHM • 36 ug/L HAA
TTHM, Individual Samples	LRAA <80% of MCL No individual samples above MCL	• To avoid operational evaluation trigger.
HAA5, Individual Samples	LRAA <80% of MCL No individual samples above MCL	• To avoid operational evaluation trigger.
Chlorine Residual	< 4.0 mg/L 0.2 mg/L min	• DBPR Requirement.

Table 3.2 Secondary Water Quality Goals

Parameter	Goal	Comment
Aluminum	≤ 0.20 mg/L	• Secondary standard
Color	< 15 CU	• Secondary standard
Manganese	< 0.05 mg/L	• Secondary standard = 0.05 mg/L
Iron	< 0.1 mg/L	• Secondary standard = 0.30 mg/L; lower goal minimizes consumer complaints about color
Fluoride	0.7-1.0 mg/L	• Finished water level for optimal dental benefits. Secondary standard = 2.0 mg/L
Geosmin	5 ppt	• To minimize consumer complaints about taste and odor.
MIB	10 ppt	• To minimize consumer complaints about taste and odor.

As regulations are constantly changing, the City of Clarksville should be prepared for existing as well as future regulations. Additional goals should also be considered for future regulations based on the following contaminants:

- Emerging Contaminants – Annual monitoring of select representative sample of PhACs, PCPs, and EDCs in raw water supply.
- Perchlorate – Monitor on an annual basis - OSG system.
- Chlorate – Goal of 210 ug/L (USEPA announced HRL)
- Chromium VI – Monitor on an annual basis.

In general, the Clarksville WTP has performed well in producing high quality drinking water and remaining in compliance with all regulations. Establishing water quality goals to serve as a baseline for future improvements and improving reliability of the existing processes will ensure that a high level of water service continues long into the future.

4. References

United States Environmental Protection Agency (USEPA). December 2010. Chromium-6 in Drinking Water. USEPA 815-F-10-005. Office of Water, Washington, DC.

Stanford, B. D., Pisarenko, A. N., Snyder, S. A., & Gordon, G. (2011). Perchlorate, bromate, and chlorate in hypochlorite solutions: Guidelines for utilities. *Journal AWWA*, *103*(6), 71-83.

Task 2 - Modeling of Existing Conditions

Hazen

December 15, 2015

To: Clarksville Gas & Water (CGW)

From: Hazen and Sawyer (Hazen)

Re: Water Master Plan Study – Phase 1
Hydraulic Analysis of Existing System

Introduction

This technical memorandum (TM) provides a summary of the existing distribution system evaluation conducted as part of the ongoing comprehensive Water Master Plan Study for CGW. A calibrated hydraulic model was developed for CGW to determine areas within each pressure zone of the existing water distribution system areas of deficiency in terms of three (3) parameters: pressure, fire flow, and water age. The results from these parameter model runs were then mapped and deficiencies in the existing system were noted. However, no improvements were included within this TM related to these 3 parameters because the future model conditions also need to be completed in order to determine the best fit for the system improvements. Those recommended improvements will be identified in Phase 2 of this Water Master Plan study.

Also included within this TM is an analysis of existing system reliability and finished water storage. Within in the system reliability section of this TM, deficiencies were identified to address known areas of vulnerability and also some conceptual solutions were provided. Future alternative evaluation and development will be also be included in Phase 2.

Steady State Simulations

Model simulations were run as steady state to evaluate pressure and fire flow foe the existing distribution system. A steady state run is a snapshot of the model at a single point in time with operating conditions specified such as tank levels and number of pumps running. The conditions for the runs used in the evaluations were set according to standard guidance from AWWA. For pressure, demand was set equal to the peak hour of the maximum day. For fire flow, demand was set equal to maximum day. Both evaluations assumed tanks at the bottom of operating ranges, booster pump stations running with a single duty pump, and the water plant only producing enough water to meet maximum day demands.

Demands in the model were originally input from billing records covering the 12-month period from July 1, 2010 to June 30, 2011. Since that time it is believed minimal changes have occurred to overall system demand. However, since the time of the model's development, CGW's SCADA system has added capabilities for CGW staff to observe total demand in each zone. Based on these observations and conversations with the CGW staff, slight adjustments were made in terms of demands in the model to proportionately increase the demand seen in Rossview Pressure Zone while decreasing demands in Sango and Jackson Road. **Table 1** shows the updated demand totals in the existing model.

Table 1: Pressure Zones Current System Demands

Pressure Zone	Avg. Day Demand (mgd)	Max. Day Demand (mgd)	Max. Hour Demand (mgd)
Rossview	3.0	4.2	7.1
Allen Griffey	2.3	3.1	5.4
Sango	0.9	1.2	2.1
Jackson Road	3.2	4.4	7.6
Main	6.2	8.6	14.8
Total	**15.6**	**21.6**	**37.1**

Through discussion with CGW staff, it was determined the need to include two large developments that require large water demands within the existing evaluation of the Rossview Pressure Zone. These two developments are called Hankook Tire Facility and Project X. These developments are either currently being built are to be constructed in the very near future. For that reason, these demands were modeled as part of existing system. Exact water demand has yet to be set for Project X; therefore, a range of different demands were evaluated. **Table 2** shows Rossview demands with these included. It was assumed that the current water treatment plant (WTP) production was increased to match these potential demands.

Table 2: Rossview Demands with Hancook and Project X Various Demand Scenarios

Scenario ID	Scenario Description	Avg. Day Demand (mgd)	Max. Day Demand (mgd)	Max. Hour Demand (mgd)
A	Current	3.0	4.2	7.1
B	Hankook 1.0	4.0	5.2	8.1
C	Hankook 1.0 & Project X 4.5	8.5	9.7	12.6
D	Hankook 1.0 & Project X 8.5	12.5	13.7	16.6
E	Hankook 1.0 & Project X 12.5	16.5	17.7	20.6

Peak Hour Pressures

The peak hour simulation represents the highest annual demand in a system by taking the maximum day demand and applying the peak hourly factor from the diurnal pattern. Based on the Tennessee Department of Environment and Conservation (TDEC) Community Public Water System Design Criteria, pressure deficiencies were identified by areas within the existing system having a pressure lower than 20 pounds per square inch (psi). Areas within the distribution system that were above 100 psi were also identified, but the concern over improvements with these higher pressures are not as of great concern as the lower pressure areas. This is due to the fact that the higher pressure areas that were identified can be mitigated by installing pressure reducing valves (PRVs) to lower pressures with much less effort than supplying higher pressures to low pressure areas.

Rossview Pressure Zone – Pressures

Existing System

The Rossview Pressure Zone under the current maximum hour condition has low pressure in the Oakland Road area if the HSC Tank is too low. This condition occurs even if a large pump is run at Rossview Booster Station (RBS), which produces over 10 mgd of flow. Running the smaller pump results in lower pressures in the Oakland Road area. Model runs indicate the most significant driver for maintaining pressure in this area is keeping the HSC Tank level maintained. **Figure 1** shows the areas with low pressure if the HSC Tank level drops near 50%.

Running a single large pump at RBS produces a discharge pressure at the station of 74 psi. However, pressures at lower ground elevations near the Red River at the end of Powell Road are over 150 psi with the one large pump running (see **Figure 1**). Running the smaller pump reduces discharge pressure by over 20 psi at RBS.

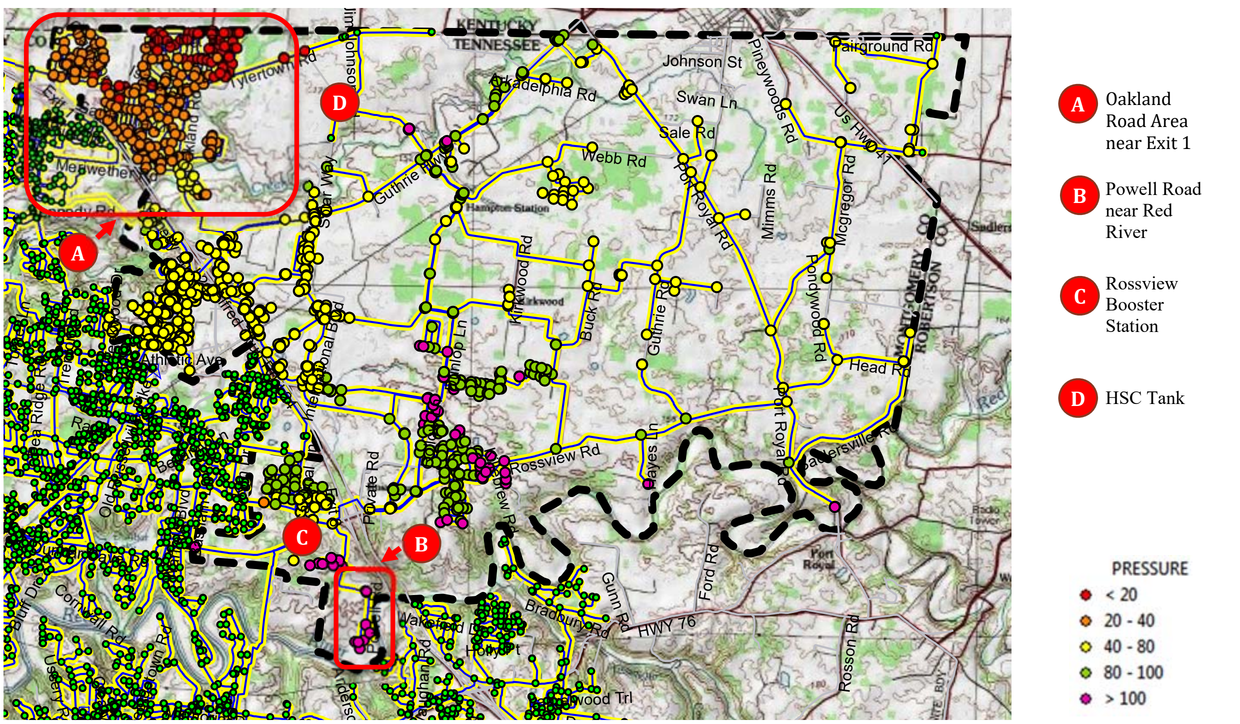


Figure 1: Rossview Pressure Zone Pressures

Hankook Tire and Project X Developments

As shown in **Table 2**, Hazen projected future demands for these two locations based on discussion with CGW staff. Of the two locations, Project X presents the biggest challenge since it is the larger demand and located farther from RBS. When modeling Scenario C, the results of the model indicates that adding Hankook demand at 1 mgd and Project X demand at 4.5 mgd (total pressure area demand of 12.6 mgd) can be delivered as long as the water level in HSC Tank can be maintained. HSC Tank provides over 60%

of the Project X demand of 4.5 mgd with only one large pump running at RBS. Providing demand from one pump and 60% of the HSC tank is a more ideal local system operation rather than running both pumps at the same time due to higher pressures. The model shows one large pump running produces just over 10 mgd while two large pumps can produce 15 mgd of flow.

When Project X demand is increased to 8.5 mgd, both large pumps will the need to run at the same time because if only a single large pump ran at RBS, the HSC Tank would need to provide 80% of Project X demands. This local operation is difficult to maintain and not optimal. However while even running a second large pump, it still results in HSC Tank draining at approximately 2 mgd, and the pressures closer to RBS being 30 psi higher.

Main Pressure Zone – Pressures

Existing System

The Main Pressure Zone under the current maximum hour condition has adequate pressure in most areas. As shown in Figure 2, the areas with the lowest pressure are at the northern side along 101st Airborne Division Parkway and also in the high elevation area along Memorial Boulevard. Higher pressures can be found in low-lying areas near Wall Branch, Red River, and the Cumberland River.

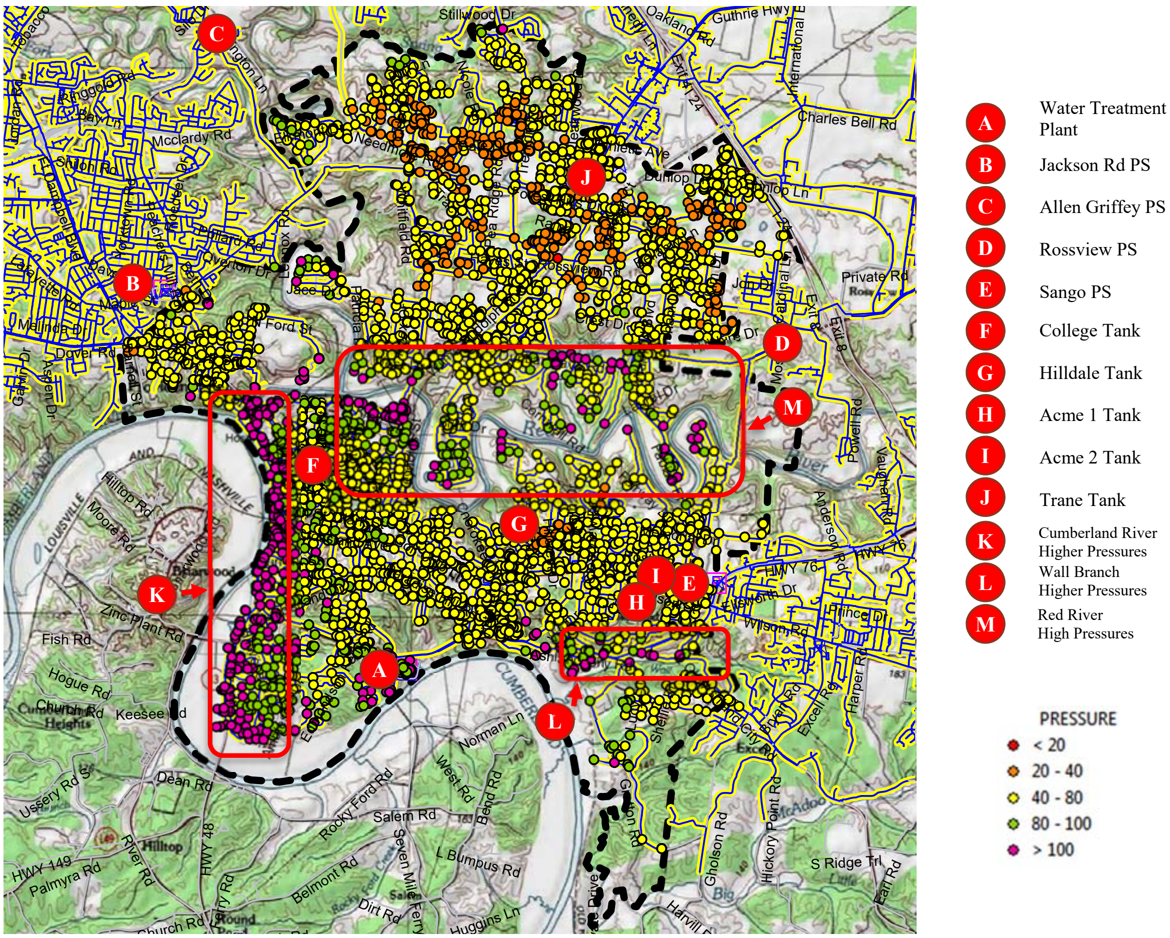


Figure 2: Main Pressure Zone Pressures

Sango Pressure Zone – Pressures

Existing System

The Sango Pressure Zone under the current maximum hour condition has adequate pressure in most areas. As shown in **Figure 3**, the area with the lowest pressure is near the area surrounding Sango Tank. Higher pressures can be found in low-lying areas near McAdoo Creek on the south and the Cumberland River to the north.

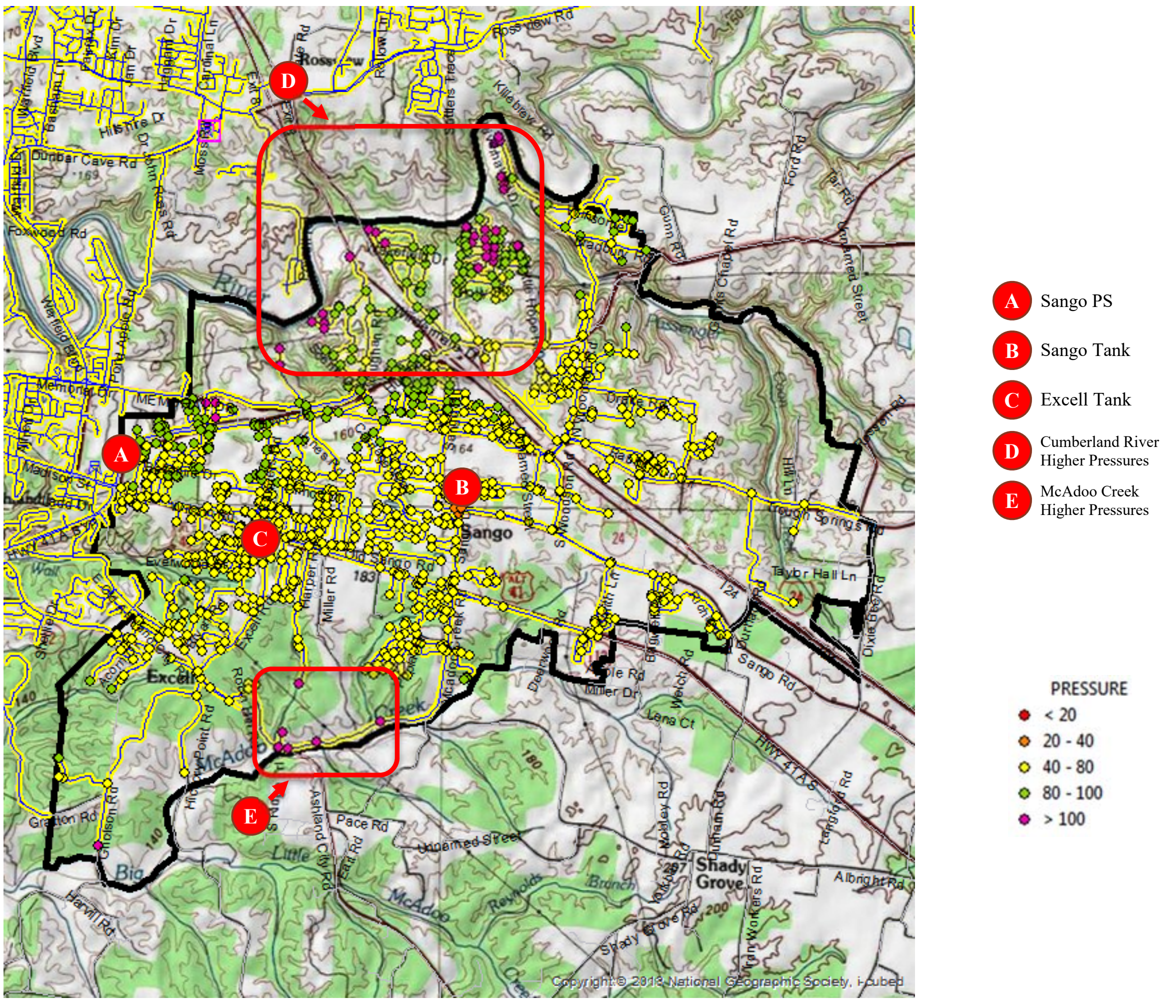


Figure 3: Sango Pressure Zone Pressures

Jackson Road Pressure Zone – Pressures

Existing System

The Jackson Road Pressure Zone under the current maximum hour condition has adequate pressure in most areas. As shown in **Figure 4**, the areas with the lowest pressure are near High Point Water Tank. Higher pressures can be found in low-lying areas near Little West Fork Creek.

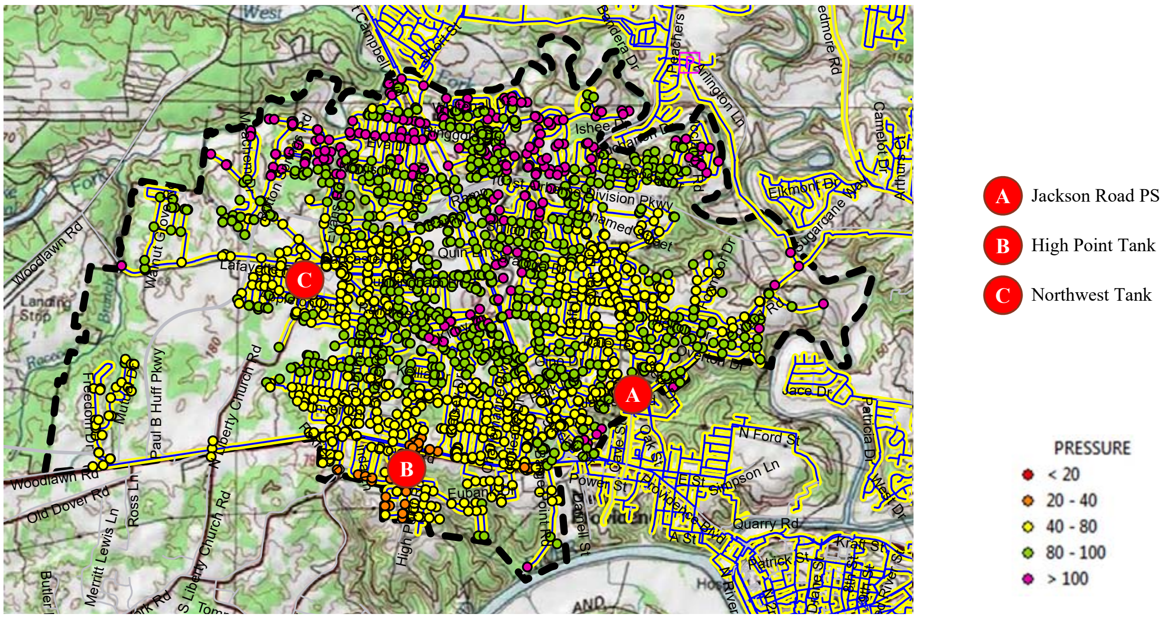


Figure 4: Jackson Road Pressure Zone Pressures

Allen Griffey Pressure Zone – Pressures

Existing System

The Allen Griffey Pressure Zone under the current maximum hour condition has good pressure in most areas. As shown in **Figure 5**, higher pressures can be found in low-lying areas near Little West Fork Creek and Red River West.

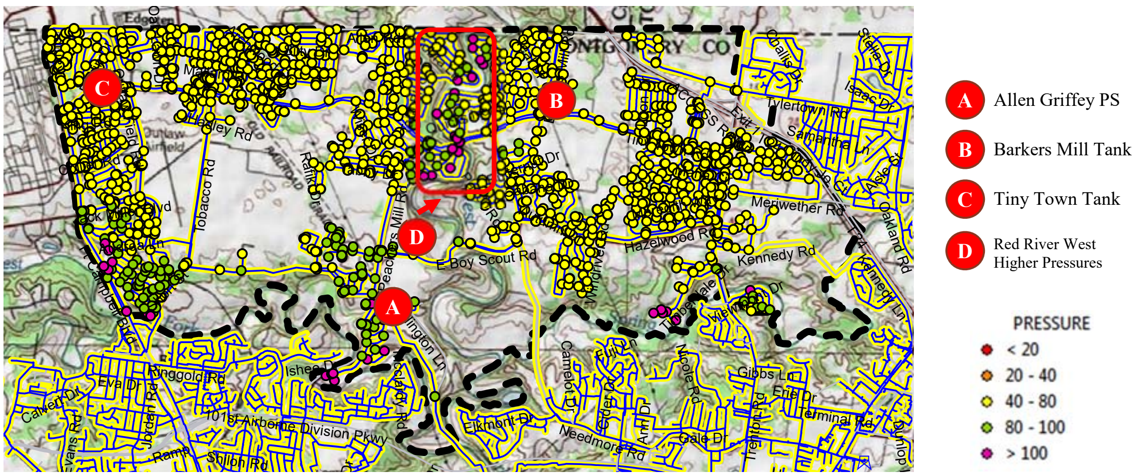


Figure 5: Allen Griffey Pressure Zone Pressures

Fire Flow

The available fire flow simulation represents the maximum day demand in a system and assumes tanks are near the bottom of their operating ranges with maximum day demands and only a single duty pump running. Nodes were considered to be deficient if they could not deliver 500 gpm at 20 psi (as recommended within the TDEC Community Public Water Systems Design Criteria) while maintaining 10 feet per second in surrounding pipes.

Rossview Pressure Zone – Available Fire Flow

Existing System

The Rossview Pressure Zone under the current maximum day fire flow condition has available fire flow below 500 gpm at 20 psi in some locations in the Oakland Road Area. However, most of these are only slightly below 500 gpm. As shown in **Figure 6**, the limiting constraint is the single 10-inch supply line (A). Also, several areas outside the city limits were found to have less than 500 gpm at 20 psi due to long runs of 6-inch line or smaller.

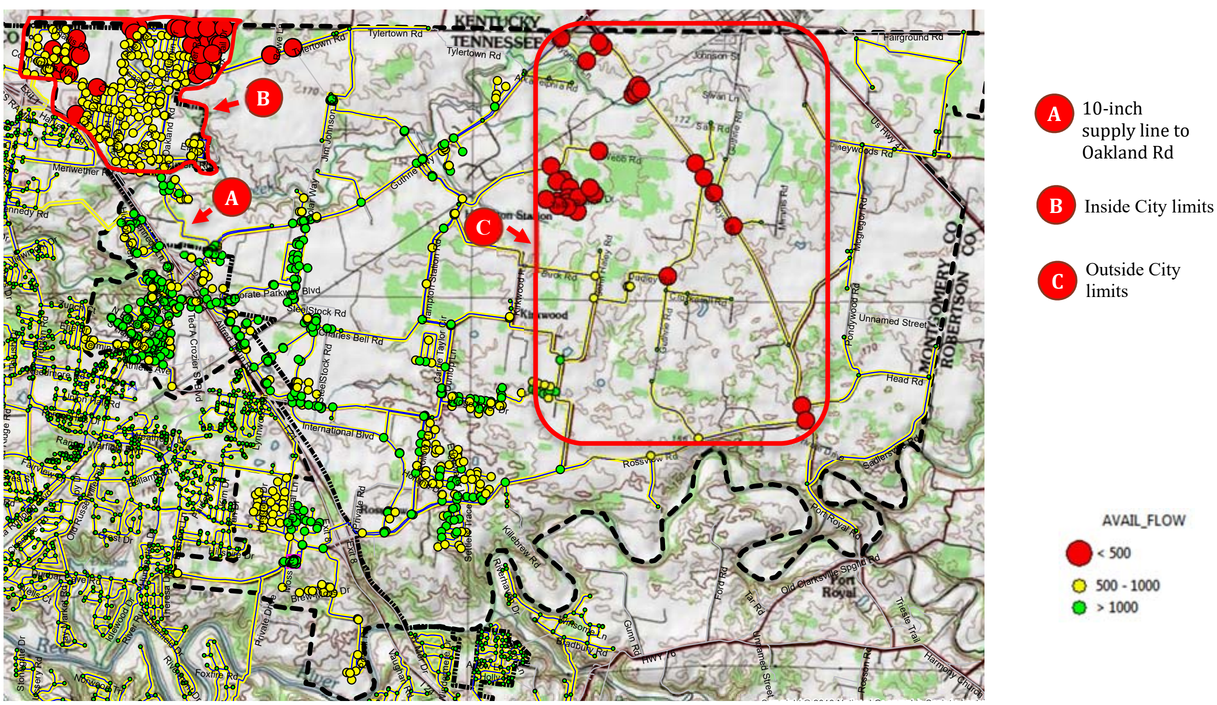


Figure 6: Rossview Pressure Zone Fire Flow Availability

Hankook Tire and Project X Developments

With the addition of these developments in the near future, fire flows are obviously affected with increased demands and pump output for the existing conditions. However, comparing the differences is not straightforward since operation of RBS would likely be different. Running a single large pump, which produces over 10 mgd, can effectively raise the available fire flow at Project X when compared to running the smaller 4 mgd pump with no demand at the Project X site. **Figure 7** shows the results of the fire flow simulation when running a single large pump at RBS with 4.5 mgd of demand at Project X and 1.5 mgd of demand at Hankook Tire. Comparison with the results of the model run without the developments shows similar areas with deficient fire flows.

It was assumed the WTP production would be increased to match the inclusion of these demands. Although the 8-mg ground storage reservoir at Rossview is shown to drain at a significant flow rate when the large pump at RBS runs, model runs show that as long as the WTP can produce enough water RBS can operate successfully. In fact, temporarily disconnecting the reservoir from the system does not prohibit RBS from running with a single large pump.

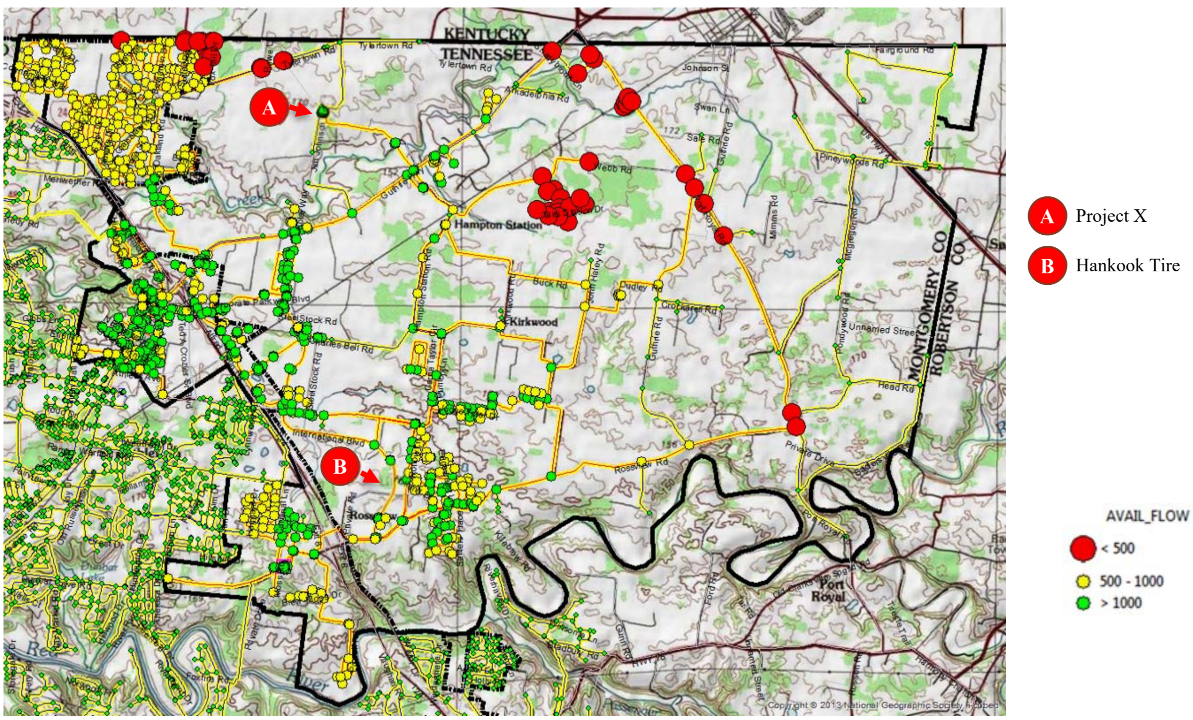


Figure 7: Project X and Hankook Tire Fire Flow Availability

Main Pressure Zone – Available Fire Flow

Existing System

The Main Pressure Zone, under the current maximum day fire flow condition, has available fire flows below 500 gpm at 20 psi in some areas. Most of these areas not meeting the fire flow condition are dead ends on 6-inch lines or areas of higher ground elevations. All areas with less than 500 gpm in **Figure 8** are inside City limits.

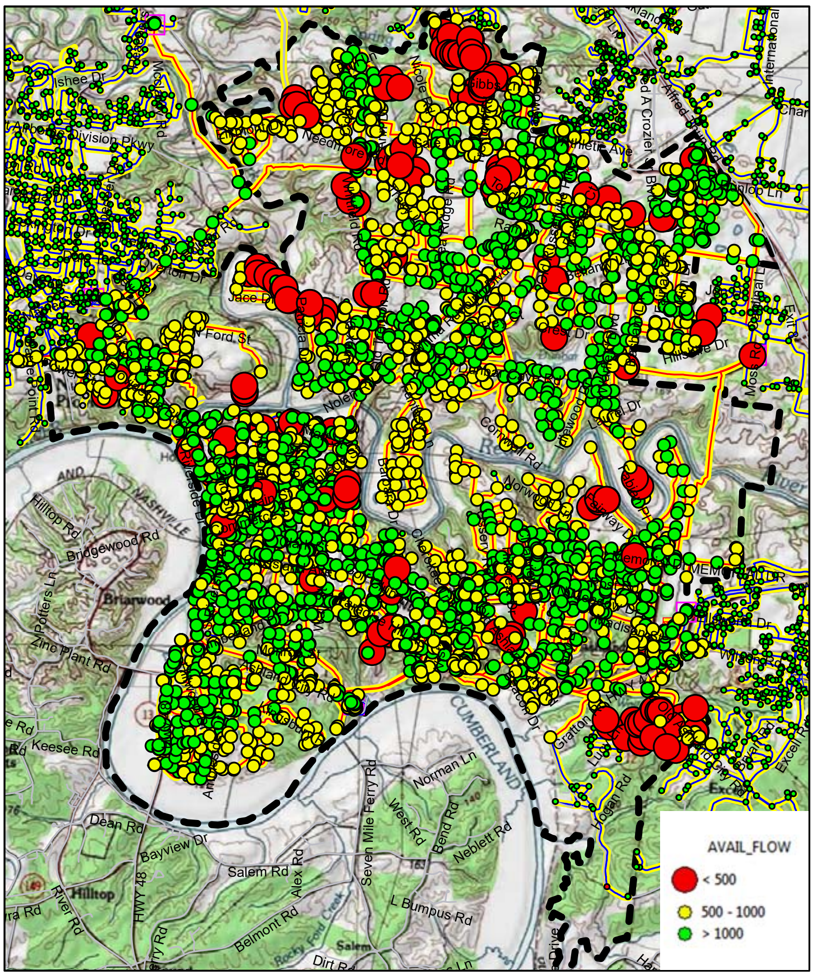


Figure 8: Main Pressure Zone Fire Flow Availability

Sango Pressure Zone – Available Fire Flow

Existing System

The Sango Pressure Zone under the current maximum day fire flow condition has available fire flows below 500 gpm at 20 psi in some areas Most of these areas not meeting the fire flow condition are dead ends on 6-inch lines or areas of higher ground elevations. All areas less than 500 gpm in **Figure 9** are inside City limits.

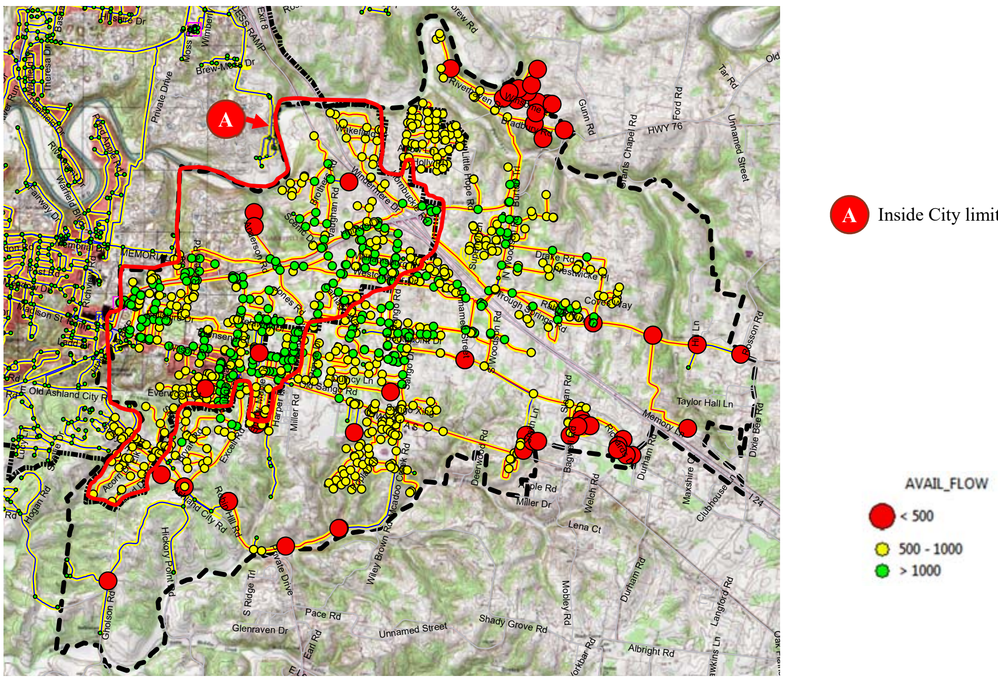


Figure 9: Sango Pressure Zone Fire Flow Availability

Jackson Road Pressure Zone – Available Fire Flow

Existing System

The Jackson Road Pressure Zone under the current maximum day fire flow condition has available fire flows below 500 gpm at 20 psi in some areas. Most of these areas not meeting the fire flow condition are dead ends on 6-inch lines or areas of higher ground elevations. Two areas less than 500 gpm in **Figure 10** are outside City limits.

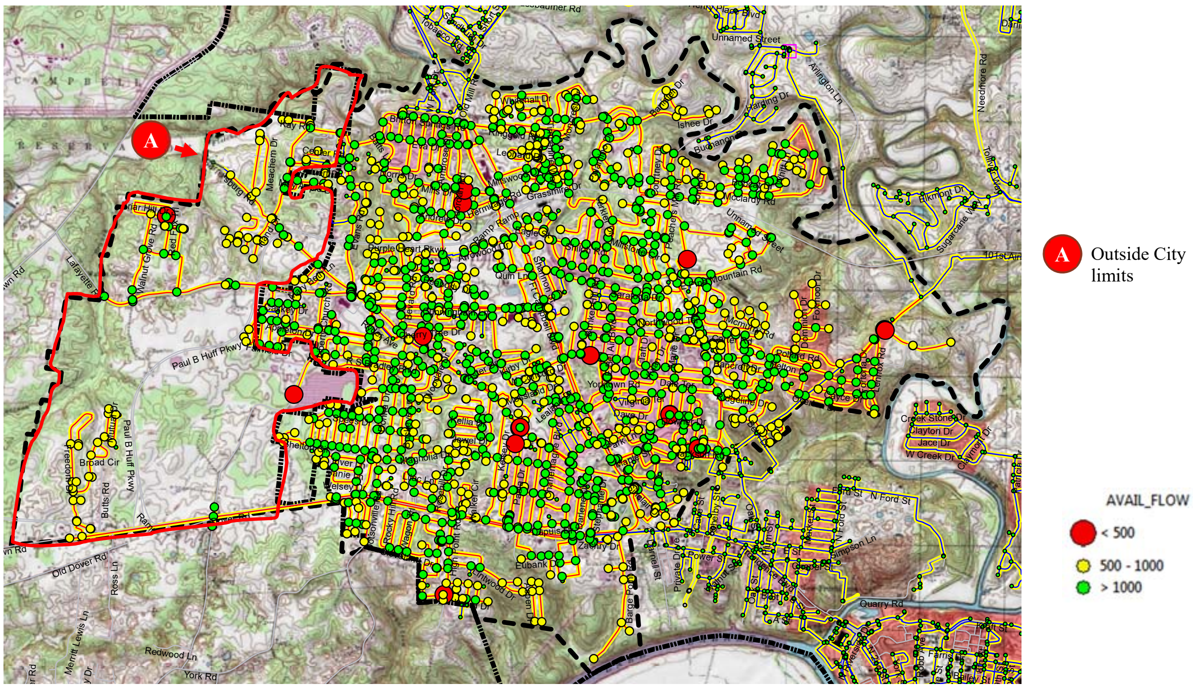


Figure 10: Jackson Road Pressure Zone Fire Flow Availability

Allen Griffey Pressure Zone – Available Fire Flow

Existing System

The Allen Griffey Pressure Zone under the current maximum day fire flow condition has available fire flows below 500 gpm at 20 psi in some areas. As shown in **Figure 11**, most of these areas not meeting the fire flow condition are dead ends on 6-inch lines or areas of higher ground elevations. All areas in this pressure zone are inside City limits.

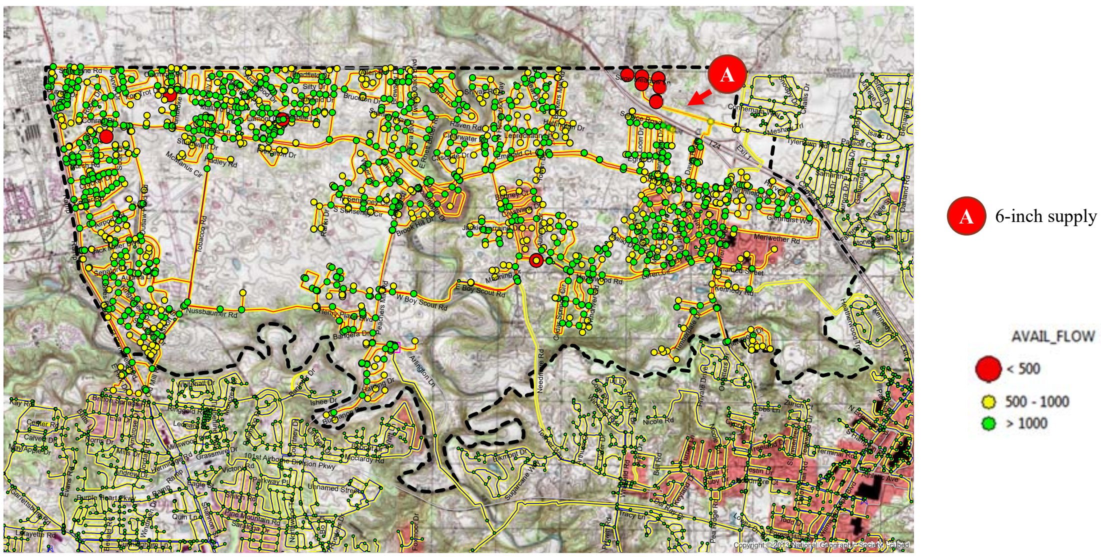


Figure 11: Allen Griffey Pressure Zone Fire Flow Availability

Extended Period Simulations

Model simulations were run as extended period to evaluate water age. An extended period run occurs over a period of time with controls in place that determine pump and valve operation. The conditions for the extended period simulation were set to represent average day demands with normal operation as described by CGW staff. The model simulation duration was set at 30 days.

Water Age

Water age is a key indicator of water quality. Low chlorine residual occurs most often due to biodegradation of organic material inside the water line due to the chemical reaction with chlorine. In theory, the longer water is allowed to stay in the system, more time is allowed for this chemical reaction to occur, which lowers chlorine residual. Generally water under a week old is considered to be optimal. However, factors such as temperature and organic composition of raw water must be considered as well. Regardless, this simulation gives a relative indicator of where water age is higher in the distribution system.

CGW System – Water Age

The entire system at the end of the 30-day simulation is shown in **Figure 12**. Dead end lines and areas on the perimeter of the system farthest from the Water Plant resulted in the highest age.

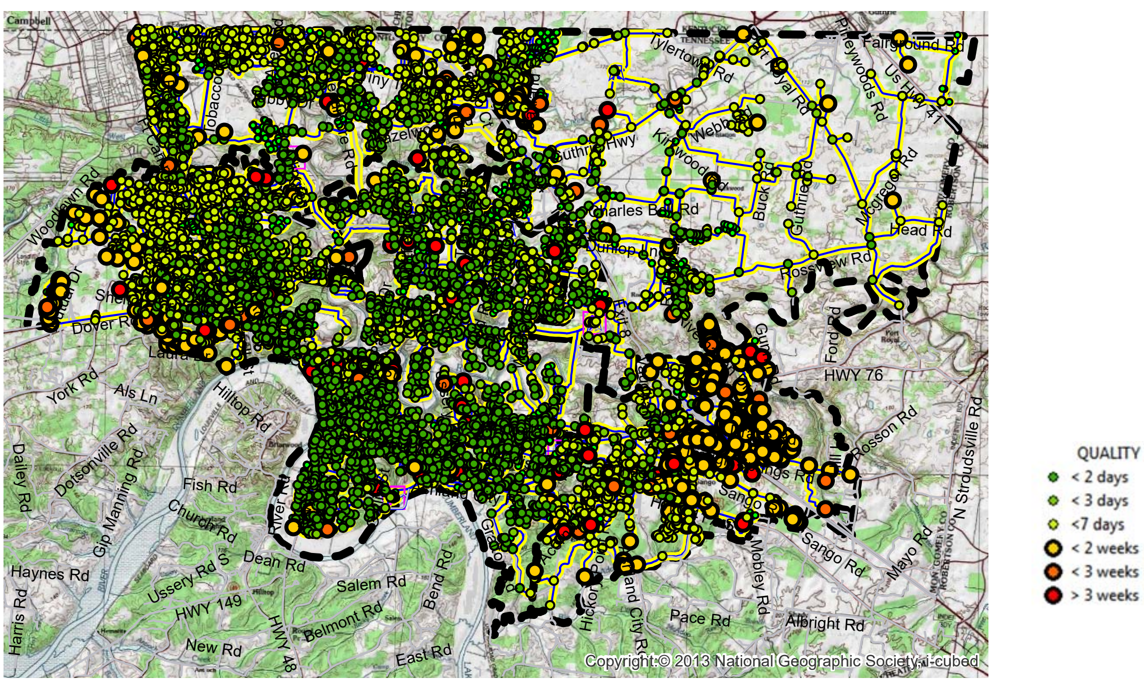


Figure 12: Water Age of CGW's Distribution System

Hazen

Rossview Pressure Zone – Water Age

Figure 13 shows the areas with water age in excess of one week. Primarily these areas were either on dead end lines or in areas farthest away from RBS. The Oakland Road area has higher water age since it only has one supply line.

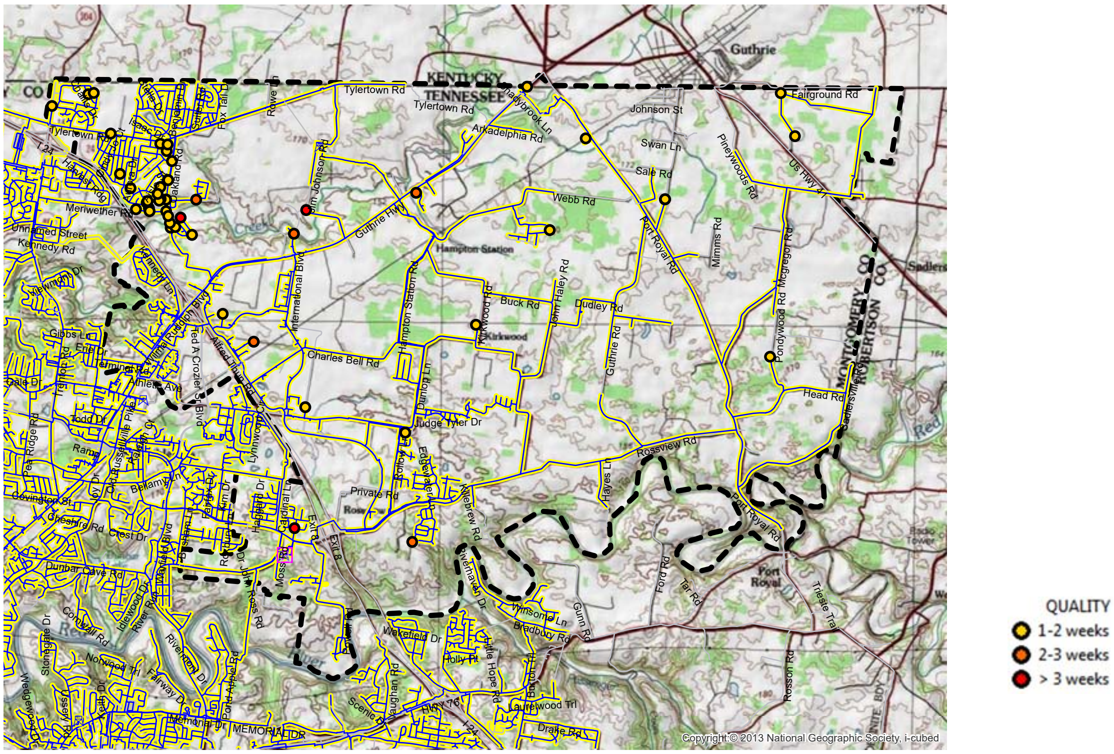


Figure 13: Water Age in Rossview Pressure Zone

Main Pressure Zone – Water Age

Figure 14 shows the areas with water age in excess of one week. Nodes with water age greater than two weeks are primarily located on dead end lines.

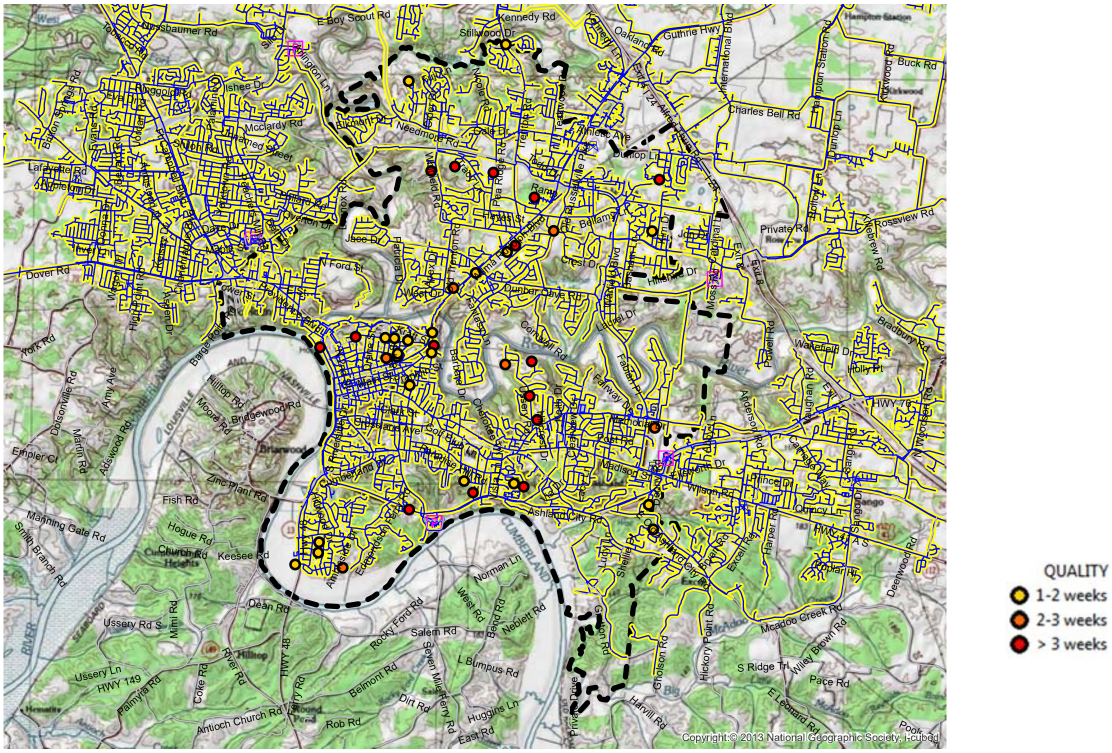


Figure 14: Water Age in Main Pressure Zone

Sango Pressure Zone – Water Age

Figure 15 shows the areas with water age in excess of one week. Nodes with water age greater than two weeks are primarily located on dead end lines. Several locations in this pressure zone are between one and two weeks.

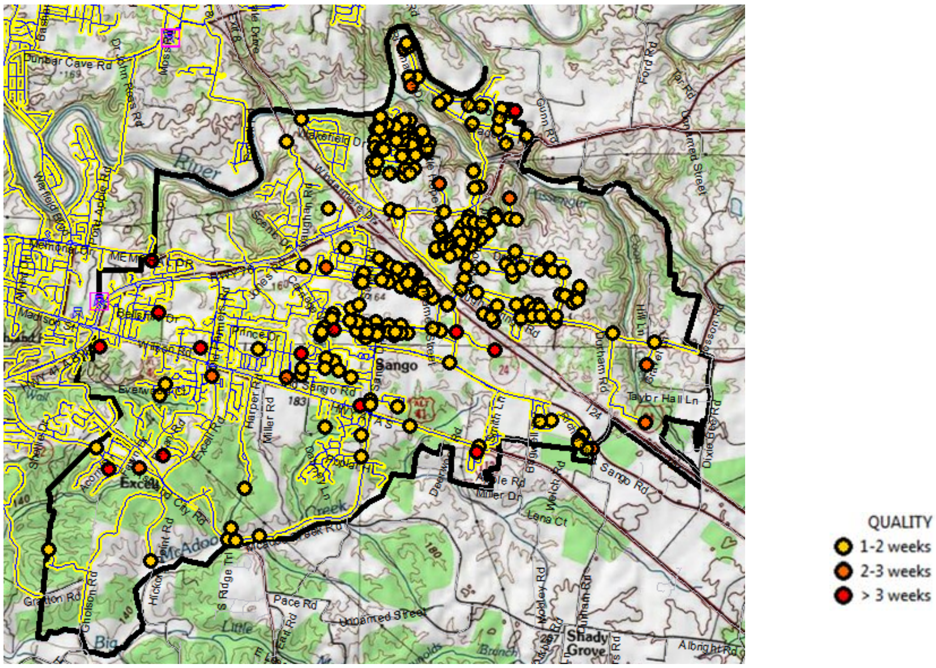


Figure 15: Water Age in Sango Pressure Zone

Jackson Road Pressure Zone – Water Age

Figure 16 shows the areas with water age in excess of one week. Nodes with water age greater than two weeks are primarily located on dead end lines.

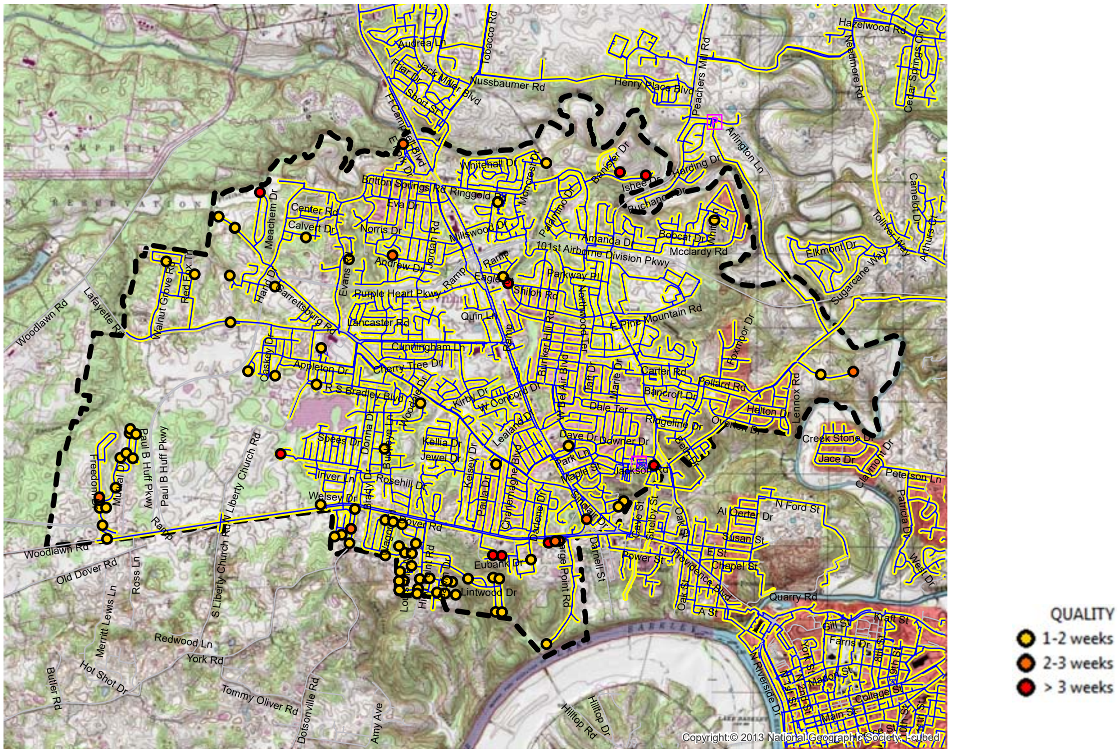


Figure 16: Water Age in Jackson Road Pressure Zone

Allen Griffey Pressure Zone – Water Age

Figure 17 shows the areas with water age in excess of one week. Nodes with water age greater than two weeks are primarily located on dead end lines.

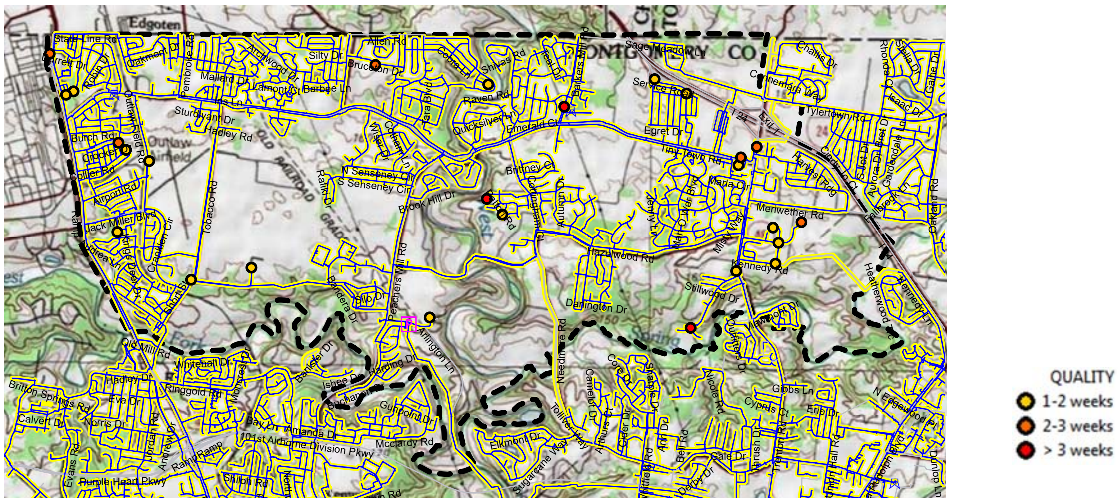


Figure 17: Water Age in Allen Griffey Pressure Zone

System Reliability

Transmission Redundancy

CGW relies solely on its Water Plant production and existing storage capacity to meet the demands of its customers. Disruption to transmission lines in the Main Pressure Zone outside of the WTP would be the most detrimental to the supply of finished water to the entire system. **Figure 18** shows how Main Pressure Zone is the supply for each of the other pressure zones.

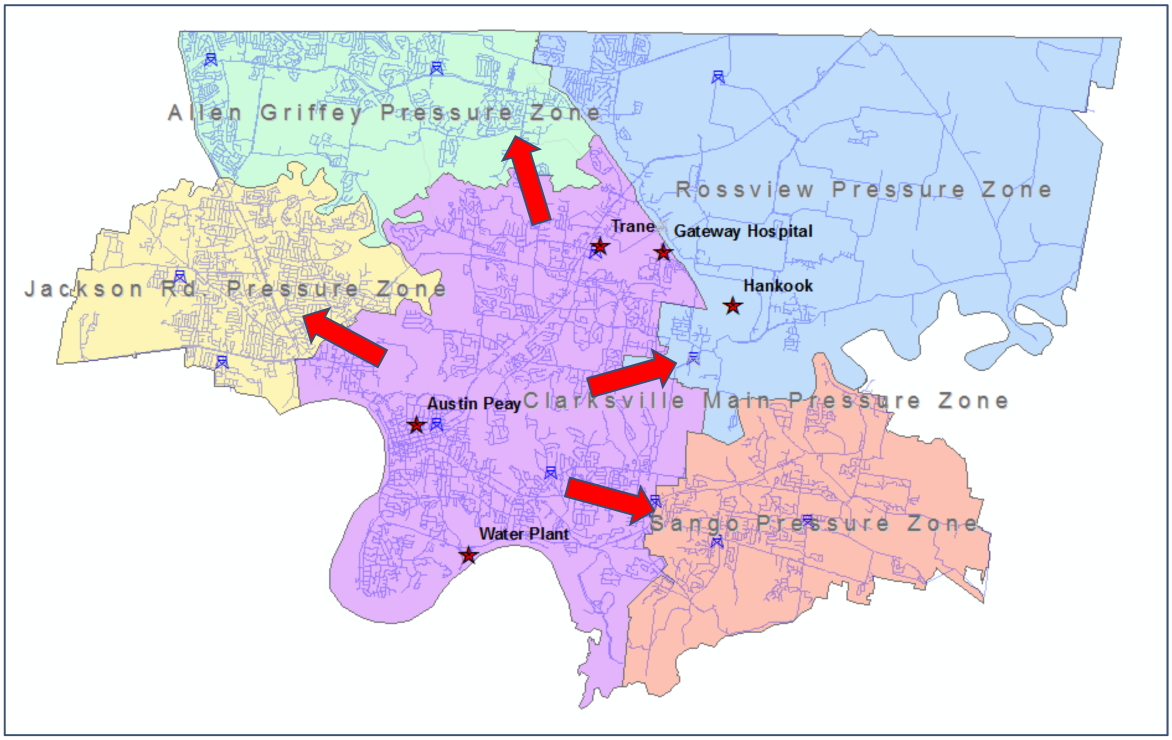


Figure 18: CGW Distribution System

Rossview Pressure Zone – Reliability

Existing and potential customers in the Rossview Pressure Zone were identified in discussions with CGW as being critical. RBS is the only pump station and HSC Tank is the only available storage tank within this zone. In addition to HSC Tank being the only storage tank, it can only be filled with a single, dedicated 24-inch line. Various engineering studies have been conducted in this area to determine needed improvements for reliability. The primary concepts for improvement that have been identified are:

- Adding a redundant pump station from the Main Pressure Zone into Rossview Pressure Zone
- Adding a secondary pipeline to feed the HSC Tank and/or adding a second tank to Rossview Pressure Zone

Allen Griffey Pressure Zone – Reliability

Allen Griffey Pump Station, which is the only pump station serving the Allen Griffey Pressure Zone, has only one supply line. If this line were to break, the area would have to rely on storage in Barker's Mill and Tiny Town Tanks. The primary concepts for improvement that have been identified are:

- Adding a redundant line to the Allen Griffey Pump Station
- Adding valves to allow water supply from Jackson Road Pressure Zone and Rossview Pressure Zone, which are adjacent at higher service hydraulic grade lines

Finished Water Storage

The purpose of system storage is to have sufficient water available to provide adequate flow and pressure at peak demand as well as to provide for fire flows when needed. Per TDEC Guidance, a satisfactory rule-of-thumb is to provide at least the average 24-hour demand in finished water storage. **Table 3** shows system storage by pressure zone. Main Pressure Zone has the largest surplus. Rossview Pressure Zone has a deficit before Project X or Hankook demands are considered.

Table 3: Demand and Storage by Pressure Zone

Pressure Zone	Avg. Day Demand (MG)	System Storage (MG)	Variance
Rossview	3.0	2	(1.0)
Allen Griffey	2.3	1.5	(0.8)
Sango	0.9	2.25	1.35
Jackson Road	3.2	3.5	0.3
Main	6.2	14.7	8.5
Total	**15.6**	**23.95**	**8.35**

Summary

Hazen has completed an evaluation of the existing system conditions for CGW's water distribution system. The calibrated hydraulic model was used to analyze system pressure, fire flow availability, and water age. Moving forward, the data from model runs summarized in this report will be used as a baseline to identify specific improvement alternatives and develop cost estimates.

Task 3 - Stage 2 D/DBP Rule Compliance

Clarksville Water Treatment Plant Jar Test Memo

To: **Clarksville Gas and Water (CGW)**

From: **Hazen and Sawyer** – Scott Woodard, Bret Casey and Nichole Sajdak

Date: January 21, 2015

Introduction

The Clarksville WTP practices conventional flocculation, high-rate sedimentation using tube settlers and membrane filtration. Clarksville Gas and Water (CGW) evaluates their coagulant dose daily through jar testing. The staff use jar tests to confirm the current coagulant dose at the plant maximizes TOC removal efficiency for current raw water quality. The Jar Test Standard Operating Procedure dated July, 2010 used by the plant is provided in this memo along with results from several treatment scenarios of varying pH and coagulant dose.

Currently, coagulation at the plant is done with a highly charged polymeric inorganic coagulant (PACL). PACLs are highly charged aluminum-based species that do not require alkalinity to form floc. Aluminum Chlorohydrate (ACH) is a form of PACL with high basicity (~83%) that has minimal effect on the overall pH of the water when treated. The floc tends to be tight and dense for good settlability and is often used upstream of membrane filtration. Coagulation with ACH is performed at the plant's ambient raw water pH (~7.5) which is at the high end of optimum pH for TOC removal using the ACH (pH 6.5-7.5). This report compares the full-scale and jar test results provided by CGW staff, investigates baseline conditions and makes recommendations for future jar testing including testing hydrogen peroxide as a pre-oxidant in lieu of permanganate and the use of acidified alum. Results from the following jar tests are also included in this memo :

- One set of ACH optimal dose jars run using Standard Operating Procedure
- One set of ACH optimal dose jars run at proposed mixing energies and durations
- One set of jar tests run to compare H_2O_2 and permanganate as described in this memo.

Full-Scale Plant Flow Rates

The Clarksville WTP capacity is 28 MGD with a peak flow rate of 30 MGD. Typical average day operations are at 15 MGD.

Chemicals, Dosages and Application Points

Raw water is pumped to the plant from the Cumberland River. Sodium permanganate is added to oxidize inorganic and some organic materials coating the particles and making them easier to coagulate, flocculate and settle. ACH is added to the water, typically at a dose of 16-18 mg/L to cause the negatively-charged particles in the raw water to attract and form ionic bonds (coagulation). The flocculation process increases the coagulated particles to a size and weight that will settle in large sedimentation basins. Settled water is then filtered, removing the smallest particles that remain. The microfiltration process filters all particulates greater than 0.1

micron in size and provides a direct barrier against bacteria, protozoa, and some viruses. The chlorination process following filtration effectively disinfects all pathogens that may be still present. A corrosion inhibitor is added after filtration to help protect water lines in the system. In addition, fluoride is added to the water post-filtration.

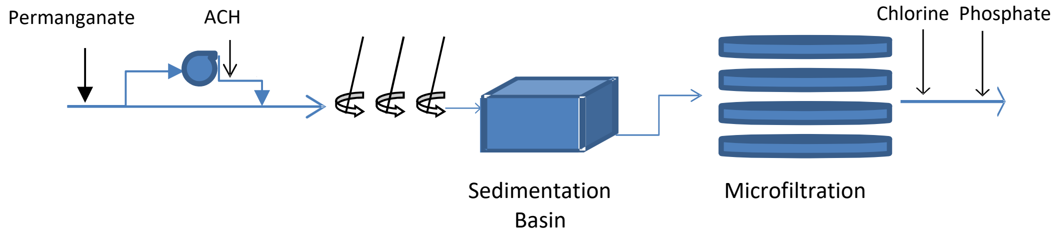


Figure 1: Clarksville WTP Chemical Application Points

Jar Testing Calibration

The standard Jar Test operating procedure used by CGW uses a pre-programmed sequence with the mixing energies and durations noted in Table 1 below.

Table 1: Clarksville Lab Test SOP Mixing Energies and Durations

	Rapid Mix	1st	2nd	Settling
Jar Speed (rpm)	300	60	10	N/A
Duration (min)	0.5	15	15	30

The first step of this set of bench scale test procedures is to establish relationships between the full-scale plant and the bench scale testing protocols and confirm that the program reflects the best match of mixing and energies. Examination of jar test TOC data and comparison with full-scale plant data collected at the same time indicates that the plant tends to be more efficient at TOC removal.

This section relates full-scale plant dimensions, geometries and retention times to jar testing parameters. Data collected from and about the full- scale plant to properly calibrate the jar test procedures included:

- Plant flow rates.
- Mixing Energy and Durations
- Basin dimensions and volumes.
- Settled water samples from the full-scale plant.

Mixing Energy and Durations

Full-scale plant operation uses diffusion pumps to introduce and mix permanganate and coagulant into raw water pipe upstream of the flocculation basins. Common industry design parameters for pumped diffusion is to provide a mixing jet velocity 20-25fps at the orifice and a mixing energy (GT) between 400-1600.

Calculations were performed to compare the available jar testing mechanical rapid mix to the full scale rapid mix at maximum flow rate as shown in Table 2. The maximum rapid mix speed possible by the Phipps and Bird jar testing machine is 300 rpm which would require the rapid mix to be two minutes long to provide a Gt value similar to full scale plant conditions. However, in order to prevent floc shearing, turning the mixers on to maximum speed for a shorter duration is recommended to provide the best possible replication of the mixing energy provided by diffusion pumps. An initial rapid mix of 45 seconds was used with the first stage of flocculation serving the remainder of the rapid mix.

Table 2: Rapid Mix Calibration

Raw Water Pipe Diameter	36”
Full Scale Flow Rate (MGD)	28
Side Stream Diameter	14”
Diffusion Jet Velocity (fps)	20.5
Rapid Mix Time (min)	0.75
Full Scale G Value	830
Gt	610
Jar Speed required (rpm)	420
Jar Speed Available (rpm)	300
Jar Test Rapid Mix Time (min)	2.0
Actual Jar Test Rapid Mix Time (min)	0.75

Once particle destabilization occurs, collisions between the particles are promoted through slow, gentle mixing, or flocculation. Smaller charged particles combine into larger, heavier particles which helps in the settling process. The full scale plant has four tapered steps of “slow mixing”. The flocculators are rated for 15 rpm and provide a G value of 20-70 s^{-1}. The plant’s flow rate and calculated volume through each flocculation stage determined the duration of each stage. Each stage of flocculation lasts for 7.5 minutes.

In order to determine the proper mixing speed and time for jar testing, the dimensions of the plant design and type of mechanical mixing are used and correlated to the geometry and volume of the jars. A jar test was run on December 11, 2014 using manually adjusted speed settings rather than the pre-programmed settings to test the optimal coagulant dose. The first attempt at modifying the mixing speeds from the pre-programmed SOP used information from the Clarksville PER (2008) to predict the jar mixing speeds. Visual inspection of the jars noted that floc formation occurred earlier using the modified procedure but that the larger floc tended to shear during the later flocculation stages and not settle well. The settled water turbidities and TOCs were higher than the SOP which suggested the speeds were too high.

On December 10, 2014 plant SCADA indicated the full scale mixer speeds were set as shown in Table 3 below. The jar tests G values and speeds corresponding to these full scale mixing speeds were recalculated. Results from an additional jar test to determine optimal dose using these modified jar mixing speeds are described in the Jar Test Data Review section below.

Table 3: Flocculation Calibration

Stage	1st	2nd	3rd	4th
Flow Rate (MGD)	28			
Floc Time (min)	30			
Full Scale (% Speed)	68%	49%	26%	17%
Full Scale G Value (sec^{-1})	48	29	11	6
Full Scale Speed (rpm)	10.2	7.5	3.9	3.0
Jar Speed	56	40	22	14

Basin surface areas and volumes

After flocculation, the mixing units were raised and removed from each jar to allow for settling. Simulation of plant conditions requires calculation of the plant's sedimentation basin settling time based on surface area loading rate and tube settler geometry in each of the six sedimentation basins. The plant flow rate divided by the sedimentation basin surface area, including the projected tube settler area, is the full scale basin loading rate. To establish similitude between the plant and jars, the full scale loading rate is converted into a settling rate for the 2000 mL jars as shown in Table 4. Calculations are based on 10 cm sample depth in jars.

Table 4: Sedimentation Calibration

Conventional Basin with Tube Settlers	
Tube or Plate Opening (inch)	**2**
Tube or Plate Angle (degrees)	**60**
Tube Depth (inch)	36
Flow Rate per basin(MGD)	4.7
Surface Area (ft^2)	**1,291**
Settling Velocity (cm/min)	1.1
Sample Time (min)	**9.8**

Coagulant Demand Jar Test Procedure (Microliter Method)

Equipment:

Phipps & Bird Six Paddle Stirrer with jars
10-100 microliter pipet in 0.2 microliter increments and tips
Coagulant (full strength) from day tank

Procedure:

1. Using 2000 mL graduated cylinder, fill each beaker to 2 liter mark with raw water from lab spigot.

2. Select a range of concentrations that will bracket the actual concentration of coagulant being added to raw water e.g. If coagulant is being fed at 18ppm then use range of 14ppm — 24ppm in 2ppm increments.

3. Determine specific gravity of full strength coagulant by measuring it with a hydrometer.

4. By using coagulant chart on the wall, determine the amount of coagulant needed to dose individual jars e.g.

    - Specific gravity-- 1.35
    - Dose in ppm --18ppm
    - Amount in microliter-- 26.6 microliter

5. Dose each jar by placing a septum at the corner of each jar. Adjust pipeter to desired setting and use a new tip each time. Fully depress pipeter plunger then slowly release with thumb. To dose each septum partially press plunger back in until the stop in reached.

6. Once all septas have been dosed select #2 for "run sequential" on soft key pad, press START. Immediately flip all dosed septas into jar simultaneously.

7. Alarm will sound when process is complete.

8. Pipet sample two inches below water level in each beaker and measure turbidity on 2100N.

9. The ideal feed rate should coincide with the lowest turbidity measurement however, some operator judgment is still necessary.

Jar Test Data Review:

Turbidity particles such as clay, microbial biomass and organic colloids found in natural water systems tend to adsorb NOM molecules. The attachment of NOM to these particles increases their negative charge, rendering them more stable and more resistant to aggregation. To destabilize the particles the plant currently uses a polyaluminum chloride polymer, namely ACH, at a dose of 16 mg/L. PACl has a polymeric structure and is totally soluble in water. On hydrolysis, various mono- and polymeric species are formed that neutralize negatively charged particles and reduce the inherent repulsion between them. Once the chemical coagulant destabilizes flow enters tapered flocculation where the opportunity for particle collisions and aggregation increases and floc formation occurs.

Determination of the optimal dose is critical to producing floc of adequate size and toughness to resist shearing and be amenable to settling in the sedimentation basins. Under-dosing of chemical leads to poor floc formation. However, in addition to increased chemical costs overdosing coagulant can also lead to premature settling in the flocculation basins. This can be especially true of the high density floc typically formed using ACH.

The Cumberland River serves as a raw water source for the plant and its water is characterized by low TOC concentrations, average 2.7 mg/L, and mid-range alkalinity, averaging 83.4 mg/L as CaCO3. As defined by the Stage 1 D/DBP Rule the Enhanced Coagulation goal is 25% TOC removal prior to applying chlorine. This removal efficiency is attained in full scale plant operations and during jar testing.

Optimal Coagulant Dose and pH

Jar testing results indicate a modest TOC removal improvement when decreasing coagulation pH. Examining results from a representative jar test conducted by CGW on May 27 in Figure 2 below shows a 2% increase in removal efficiency between jars dosed at 16 ppm at pH 7.0 instead of ambient pH of 7.7. When the coagulant dose was increased to 26 ppm in addition to lowering the pH 7.0 then the removal efficiency increased 7% to 48%. Plant staff have indicated that due to the modest gains in TOC removal that further testing of decreased coagulation pH are not desired at this time.

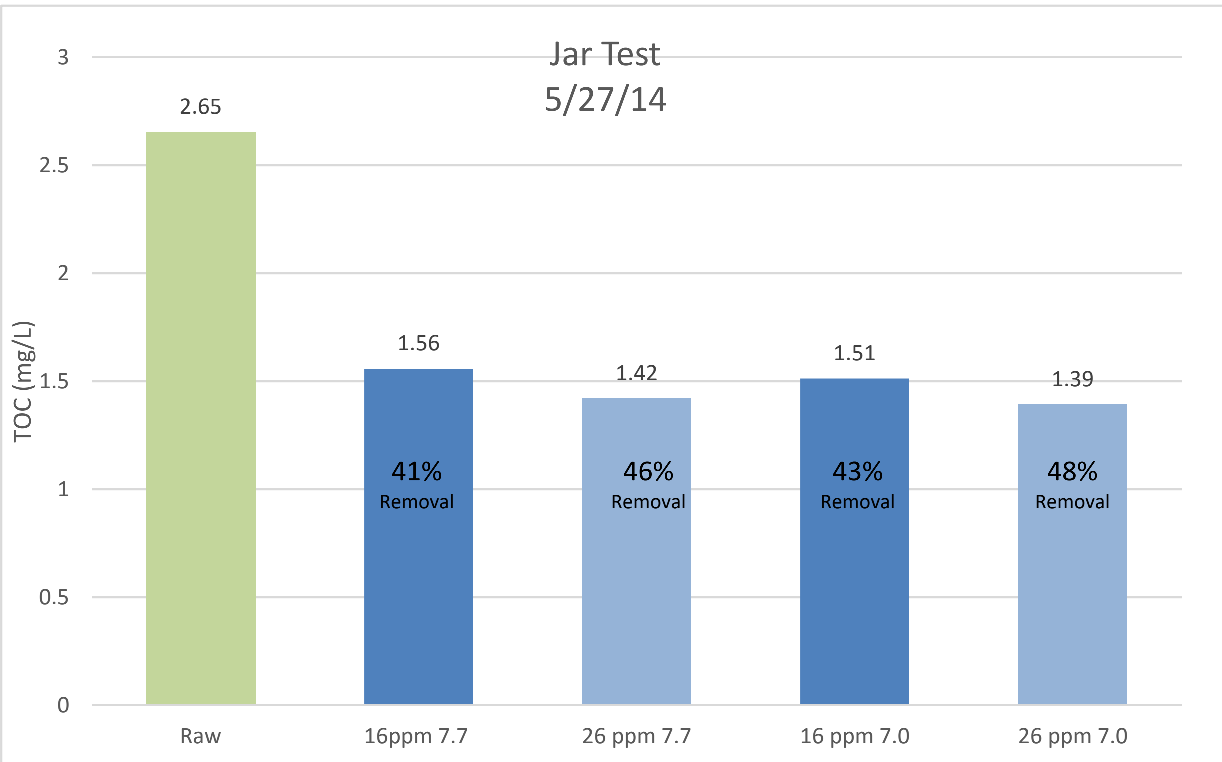


Figure 2: TOC removal, varying dose and pH

Modified Mixing Energies

The modified mixing procedure previously described in Table 3 was tested on December 12, 2014. TOC results from this jar test are shown in Figure 3 below. From this graph we note that providing four stages of tapered flocculation in lieu of the two stages provided by the pre-programmed unit provides greater TOC removal efficiencies at the lower coagulant doses (16 and 18 mg/L) suggesting better mixing in the jars. The plant typically uses 16-18 mg/L as the target dose. During the modified mixing #2 test on December 12, the settled water TOC of the full scale plant was 1.77 mg/L.

Figure 3: Jar Test Mixing Energy Protocols

Benefits of NaMnO4 as a Pre-Oxidant

Clarksville uses permanganate to oxidize iron and manganese in the raw water. Permanganate can also oxidize the NOM in the water making it more amenable to removable by coagulation and sedimentation. Two sets of jar tests, on September 3 and September 5, 2014 illustrate the effects of permanganate usage on settled water TOC. Figure 4 shows jar test results from September 3. The green bars are represent data from the full-scale plant and the blue bars represent data from the jar tests. The full-scale plant data exceeded the jar test's predicted TOC removal, even when a higher dose of coagulant (26 ppm) was used.

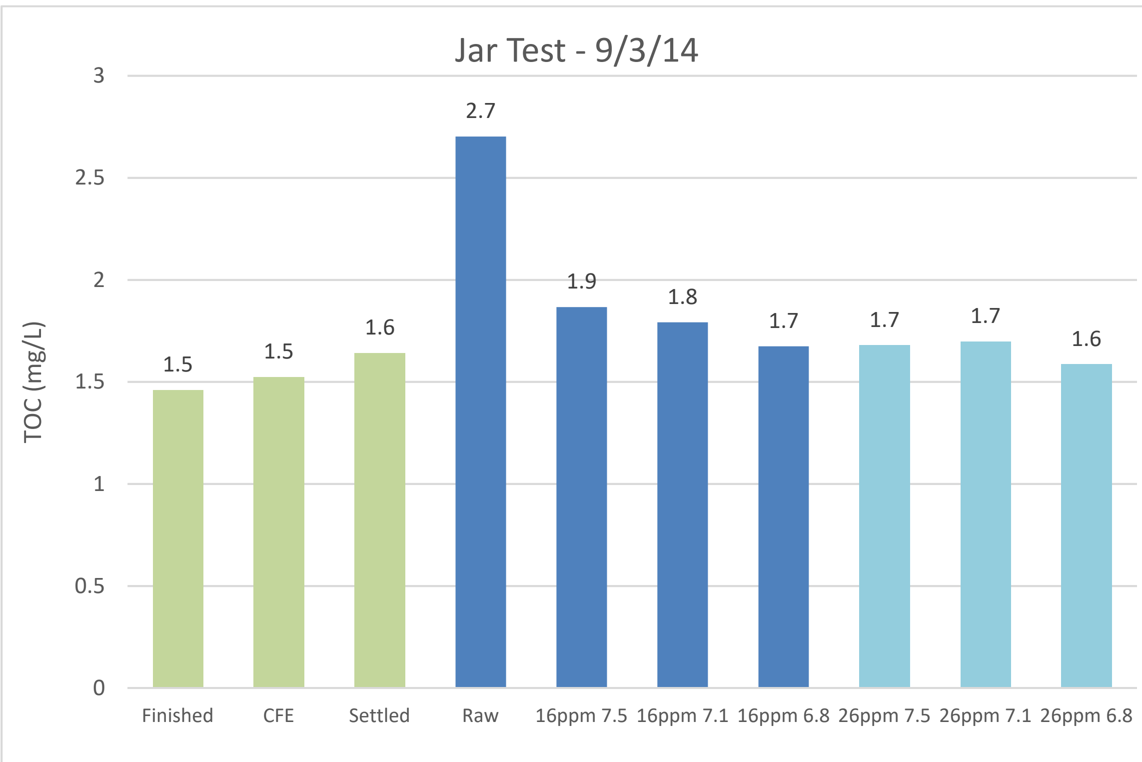


Figure 4: Full Scale Vs. Jar Test TOC - no permanganate

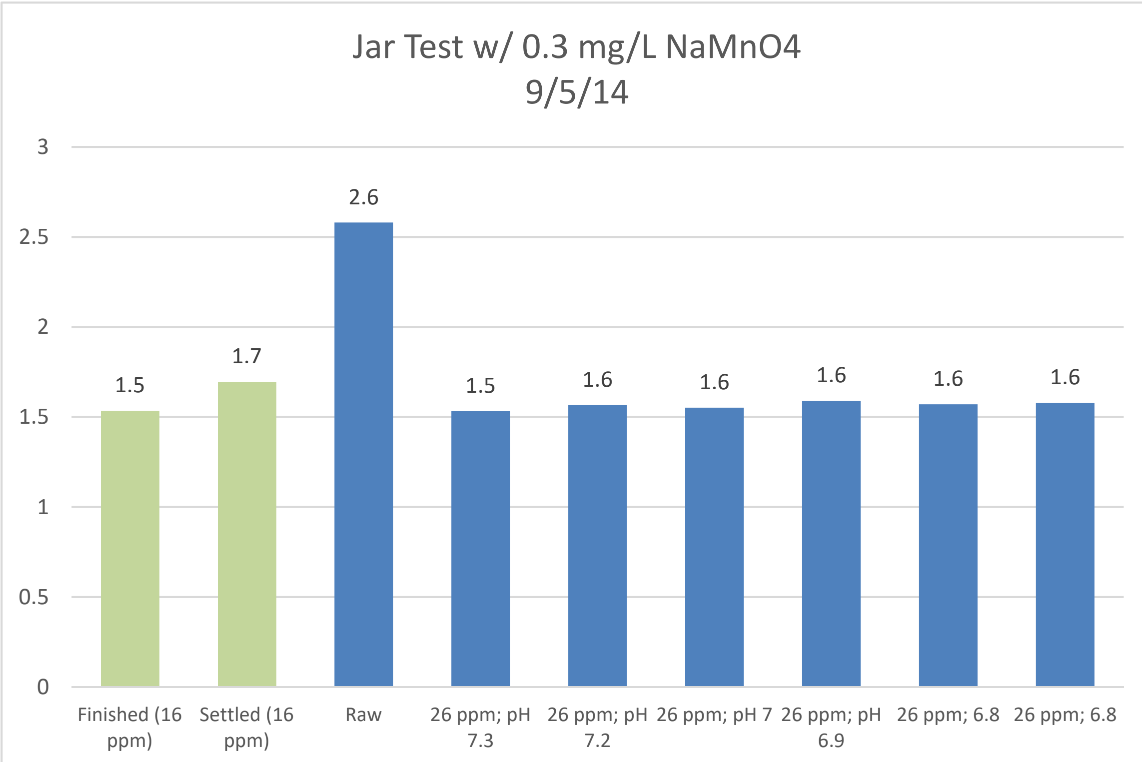


Figure 5: Full Scale Vs. Jar Test TOC - Permanganate Addition

Jar test results in Figure 5 also uses green bars to represent full scale plant TOC data. The blue bars indicate jar test results when 0.3 mg/L of permanganate was added. TOC concentrations for all jars are approximately equal, regardless of pH and coagulant dose. The jar tests showed greater TOC removal as compared to the full scale settled water TOC concentration.

Although modest, each of the jars from the test on 9/5/14 using 26 ppm of coagulant with permanganate exhibited lower TOC than the 26 ppm jars on 9/3/14.

Protocol for Testing H_2O_2 as a Pre-Oxidant

Permanganate can be an effective pre-oxidant for organics. Some utilities, including Murfeesboro, TN and Cookeville, TN are using hydrogen peroxide instead of or in addition to permanganate. Cookeville feeds 2.0 mg/L of peroxide at the raw water intake (similar to Jar 2) Murfeesboro feeds0.3 mg/L $NaMnO_4$ and 0.5-0.65 mg/L of peroxide (similar to Jar 5). Plant personnel in both locations report a drop in distribution system THM formation. Clarksville would like to investigate using hydrogen peroxide to oxidize organics. The following protocol suggests a method for comparison.

Dilute 3% store bought hydrogen peroxide to 3 mg/L hydrogen peroxide by taking a 10% dilution of H_2O_2 in a separate container (i.e. 10 mL of 3% peroxide into 100 mL solution) and then pipetting the appropriate dose based on the table below. (ie. 2 mL of this working solution into a 2 L jar test to achieve 3 mg/L of 100% H_2O_2).

All jars are dosed with 16 mg/L ACH coagulant and run on the SOP protocol.

Table 5: Pre-Oxidant Jar Test H202 Doses

Jar		Vol 10% H_2O_2	Settled Water TOC (mg/L)
	Raw		**2.97**
1	**H_2O_2 @ 1.0 mg/L**	**0.7 mL**	**1.87**
2	**H_2O_2 @ 1.5 mg/L**	**1 mL**	**1.58**
3	**H_2O_2 @ 3.0 mg/L**	**2 mL**	**1.48**
4	**$NaMnO_4$ @ 0.3 mg/L**	**None**	**1.56**
5	**$NaMnO_4$ @ 0.3mg/L with H_2O_2 @ 1.0 mg/L**	**0.7 mL**	**1.62**
6	**No preoxidant – raw water**	**None**	**1.61**

The jars with increasing concentrations of hydrogen peroxide (Jars 1, 2 and 3) show decreasing settled water TOC. A reduction in TOC occurs with increasing peroxide dose.

There is a small increase in TOC concentration between Jar 4 with only permanganate and the jar with both permanganate and hydrogen peroxide. Jar 4 which included only permanganate had a slightly pink color during coagulation. In Jar 5 the hydrogen peroxide reduced the permanganate to a colorless product perhaps reducing its effectiveness.

$$5\ H_2O_2 + 2MnO_4- + 6H+ = 5O_2 + 2Mn_2+ + 8H_2O$$

It should be noted that using hydrogen peroxide prior to disinfecting with chlorine can increase the chlorine consumption. Hydrogen peroxide and free chlorine are both strong oxidants. Hydrogen peroxide is a stronger oxidant and oxidizes free chlorine to a chloride ion while the hydrogen peroxide reduces to water and oxygen. Since the hydrogen peroxide oxidizes the free chlorine and the chemical reaction yields the chloride ion, useless in disinfection, additional chlorine use should be accounted for during economic analysis of the hydrogen peroxide option. The half-life of hydrogen peroxide ranges from 8 hours to 20 days depending on the microbiological activity and metal contamination of the water [FMC Corporation, 2008]. Theoretically 2.1mg Cl_2 is required to quench 1 mg H_2O_2

Three separate portions of the settled and filtered water from each jar were dosed with chlorine at 3 mg/L, 5 mg/L and 7 mg/L of. The handheld HACH chlorine meter was checked to ensure the reading of free chlorine. Chlorine residual readings are shown in Table 6 below:

Jar	1	2	3	4	5	6
H_2O_2 (mg/L)	1.0	1.5	3.0	0	1.0	0
MnO_4(mg/L)	0	0	0	0.3	0.3	0
	Chlorine Residual					
Cl Dose						
3 mg/L	**0.2**	**0.2**	**0.3**	**0.2**	**0.2**	**0.1**
5mg/L	**0.4**	**0.1**	**0.2**	**0.1**	**0.6**	**0.1**
7 mg/L	**2.7**	**2.0**	**0.4**	**4.9**	**4.6**	**4.9**

Jar 6 indicates the settled water's chlorine demand to be approximately 2 mg/L (7.0-4.9 mg/). The greater the hydrogen peroxide concentration, the lower the chlorine residual levels in jars with hydrogen peroxide only.

H_2O_2 as a Pre-Oxidant

Jar tests using hydrogen peroxide did not yield a substantial decrease in TOC concentration. Subsequent conversations with the City of Murfeesboro, TN indicate that they did not witness drops in TOC concentration. They performed a plant trial with the hydrogen peroxide as follows:

- Permanganate is fed at the raw water intake based on the inorganic demand in the raw water. The utility will turn it off during summer months and then will monitor membrane TMP. Too rapid of an increase in pressure requires the permanganate to be turned back on. Daily demand tests must be performed to determine dose.

- Hydrogen Peroxide is fed April – October at the effluent end of the sedimentation basin. Doses range 0.5-0.65 ppm. Peristaltic hose pumps from Watson Marlowe are used to dose. (H_2O_2 is fed 6 days a week and NaOCl is fed the 7th day to control algal growth in the basins)

Although Murfeesboro did not see a drop in TOC concentrations at the plant, a drop of more than 50% in THM formation (from 110 ppb to 65 ppb) occurred at their worst compliance site in the distribution system.

For a pilot study similar to Murfeesboro, the following feed rates and chemical storage would be assumed:

	Plant Flow
Max Rated Flow, mgd	28.0
Avg Flow, mgd	15.0
Product Feed Method	Peristaltic Metering Pumps
Specific Gravity	1.1
Chemical Strength, %	25%
Effective Density, lb/gal	2.29

Chemical Feed

Max Feed Rate (Max Q x Max C x 8.34 / Pr Dens / 24), gph	2.8
Avg Feed Rate (Avg Q x Avg C x 8.34 / Pr. Dens. / 24), gph	1.2

Metering pumps capable of 1-3 gph are also appropriately sized for the permanganate feed following the pilot if the hydrogen peroxide feed is not adopted.

Task 4 - Population and Demand Projections

Hazen *Technical Memorandum*

August 18, 2016

To: Clarksville Gas & Water (CGW)

From: Hazen and Sawyer (Hazen)

Re: Population and Demand Projections Technical Memorandum
Water System Master Plan – Phase 2

Introduction

This technical memorandum (TM) provides a summary of the data, research, and projections conducted as part of the ongoing comprehensive water system master plan for CGW. To determine the short-term and long-term needs of CGW's water supply, population and flow estimates were developed for the 2015 baseline water demand and projected for the years 2020 to 2040 in 5 year increments. Future delineation of the service area was also evaluated. The objectives of this TM are to describe the population and flow projection methodology and to define the future demands and service area that will be used going forward for the planning tasks within this project.

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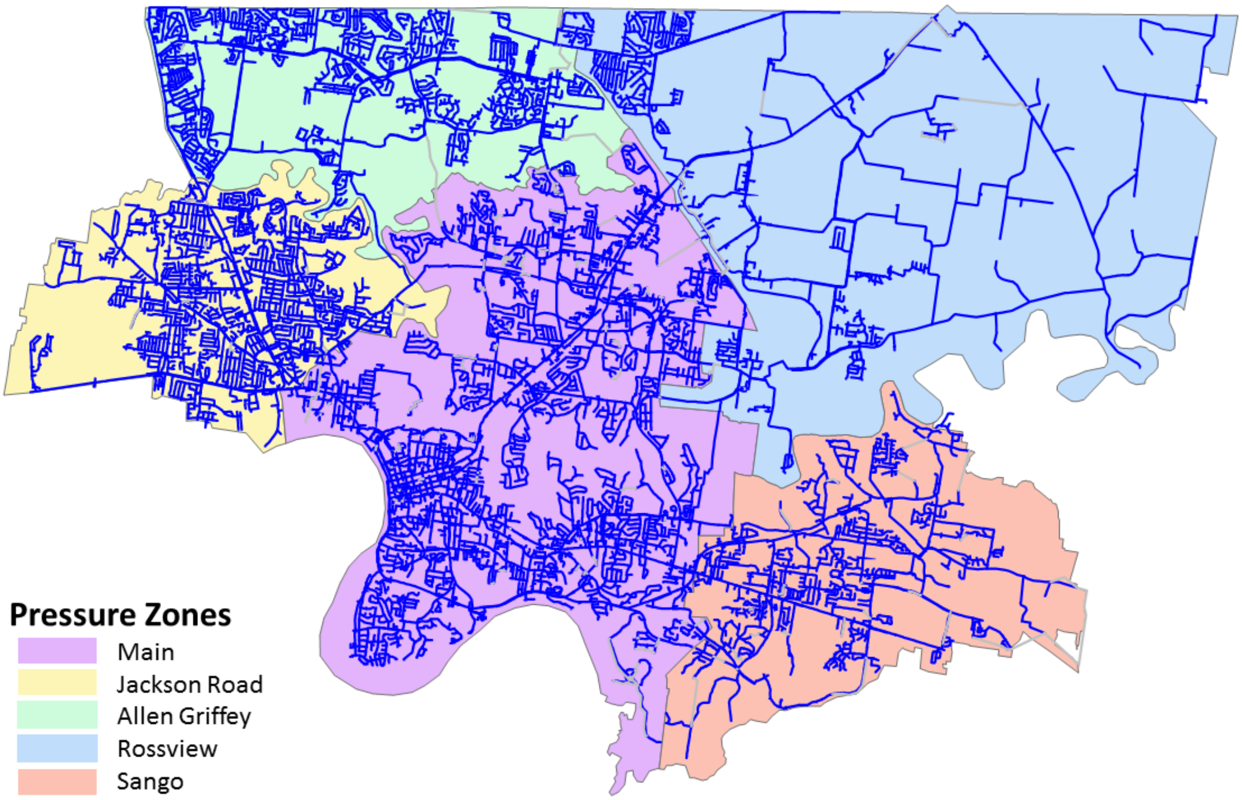
1. Service Area Delineation

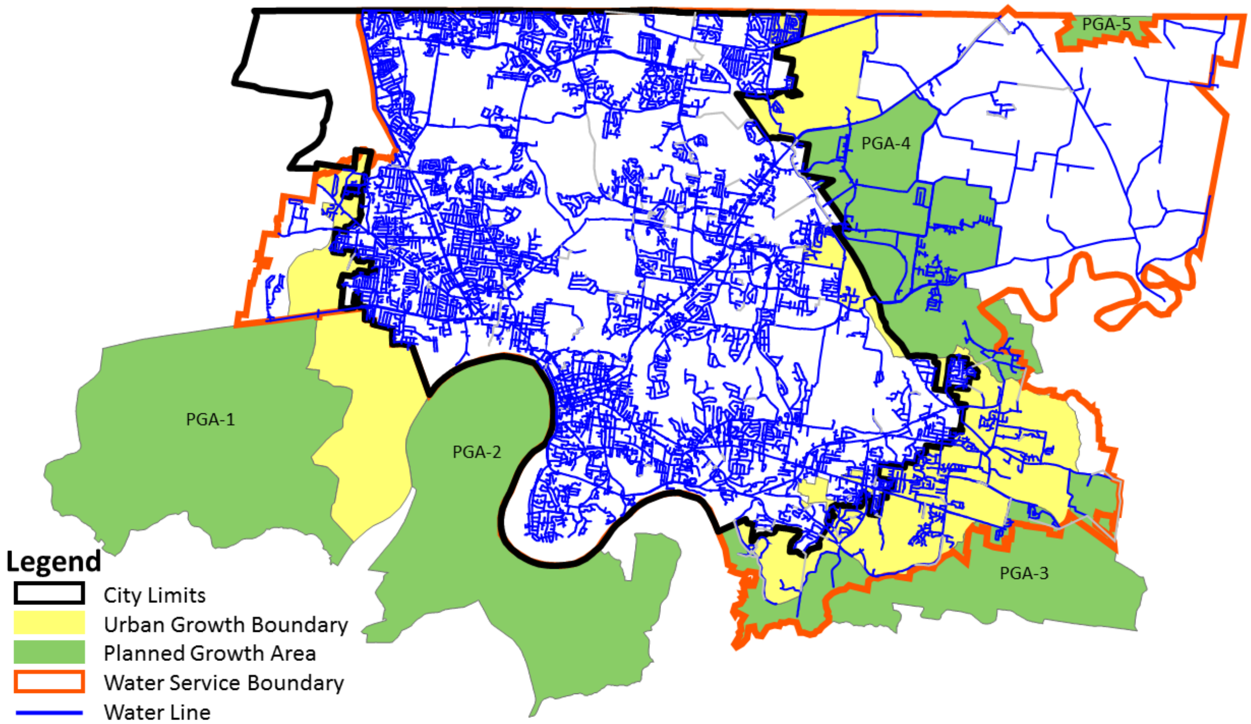
CGW currently provides water service within Clarksville city limits as well as adjacent areas within Montgomery County. CGW's water system is separated into five pressure zones (PZ): the main or high service, Sango, Rossview, Allen Griffey, and Jackson Road.

Figure 1: Clarksville Water Distribution System



In order to determine the potential future service area of CGW's water distribution system, Hazen reviewed GIS data and planning documents from several sources, including the Clarksville-Montgomery County Regional Planning Commission (CMC-RPC) and the Clarksville Urbanized Area Metropolitan Planning Organization (CUAMPO). The CMC-RPC Growth Plan document, amended in 2012, outlined five specific growth areas that were further explored. These planned growth areas (PGA), shown in **Figure 2**, were presented and discussed in a workshop with CGW. In addition to these planned growth areas, the city limits and urban growth boundary (UGB) were updated in the model to reflect minor changes made over the past few years. The possibility of any annexation or planned expansion beyond the current service area and into surrounding utility districts was also discussed in the workshop and is described in the following section.

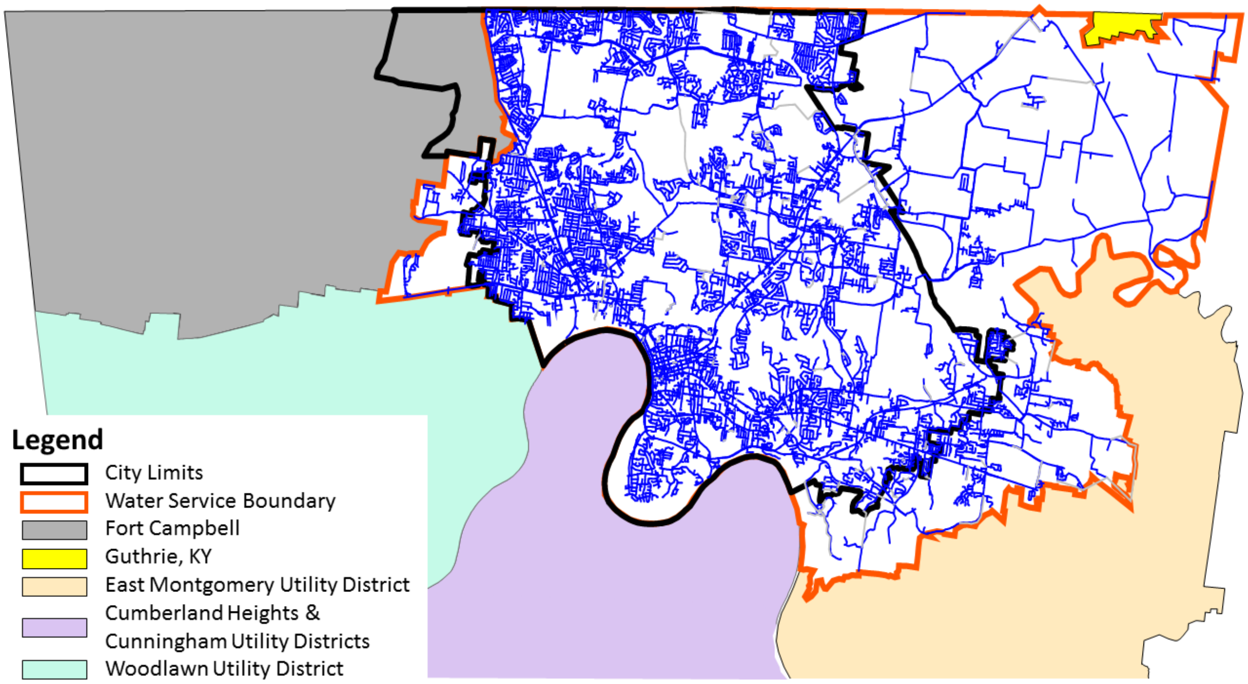
Figure 2: Clarksville Planned Growth Areas



1.1 Future Service Area

Based on research and feedback from CGW, there is no anticipation that the current water service area boundary will expand into any adjacent utility districts. Although there were five PGAs highlighted in the CMC-RPC Growth Plan, PGAs 1, 2, 3, and 5 are currently served by adjacent utility districts as shown in **Figure 3**, and they are unlikely to join the current water service area. PGA 4 is already being served by CGW and is contained in the Rossview PZ of CGW's service area. Fort Campbell, to the west, has its own water treatment plant (WTP) and therefore is not viewed as a possible future expansion of service area. Woodlawn Utility District (UD), to the southwest, has about 3500 customers and currently pays sewer fees to CGW for the portion of the district that has sewer available. A planned 600 – 900 more residential units are planned for the district but with the construction of a new WTP within the next 5 years, this area will also be excluded from any CGW water service area expansion. Cumberland Heights, Cunningham, and East Montgomery UD's, located to the south and east of CGW's service area, share a small WTP and are also not forecasted to be annexed within the 24 year planning period. CGW's Rossview PZ shares a border with the eastern edge of the Montgomery County border. Across the county border east into neighboring Robertson County, water service is provided by Adams-Cedar Hill which has its own WTP as well as future plans to tie into the Logan-Todd Regional Water Commission (RWC) water service that currently feeds Springfield, TN. Logan-Todd RWC also serves all of the Kentucky portion bordering CGW's water service area including the cities of Guthrie, Trenton, and Oak Grove. Because of this and the Kentucky-Tennessee border, no expansion of CGW's water service area is expected here, either.

Figure 3: Northern Montgomery County Utilities



Therefore, the boundary of the water service area is not projected to have any major changes in the planning period. It will continue to be bounded by the KY-TN state border to the north, Fort Campbell and Woodlawn UD to the west, the Cumberland River to the south, and East Montgomery UD and the Robertson-Montgomery county border to the east and southeast.

1.2 Future Growth Areas

For planning purposes, Hazen reviewed a number of sources previously mentioned as well as traffic analysis zone (TAZ) data and CUAMPO's 2040 Metropolitan Transportation Plan (MTP) in order to identify future growth areas within the expected service area. According to the MTP, the majority of the region's new population is projected to locate either within the UGB or in PGA-4, within the city/county industrial park, both of which are already served by CGW. Considerable new residential growth is expected to occur on the east side of Interstate 24 in areas accessible to the interchanges at Trenton Road (SR-48) and Guthrie Highway (US-79/SR-13). Additional growth is anticipated south and east of the downtown Clarksville area, along the Rossview Road (SR-237) corridor and along Madison Street (US-41A). Growth is also poised to occur within the city limits in the area bounded by Tiny Town Road (SR-236), downtown Clarksville, Fort Campbell Boulevard (US-41A) and Trenton Road (SR-48). This area, highlighted in **Figure 4**, is expected to gain more than 25,000 additional people over the next 25 years. With the relocation of Gateway Medical Center and early success of the Clarksville/Montgomery County Industrial Park, it is anticipated that many new jobs will be located on either side of the I-24 corridor between Guthrie Highway (US-79/SR-13) and Rossview Road (SR-237). Another projected area of high job growth is focused around the Trenton Road (SR-48) interchange, shown in **Figure 5**.

Figure 4: Projected Change in Population (2010 - 2040)

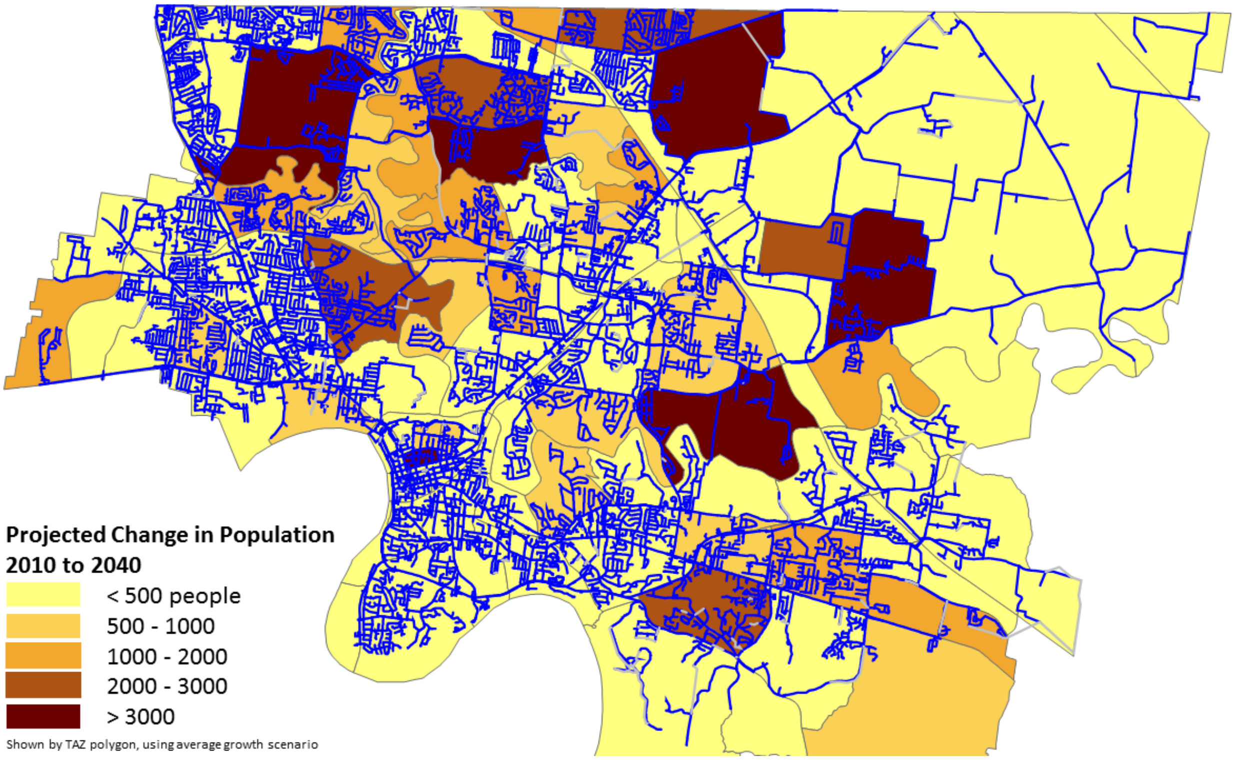
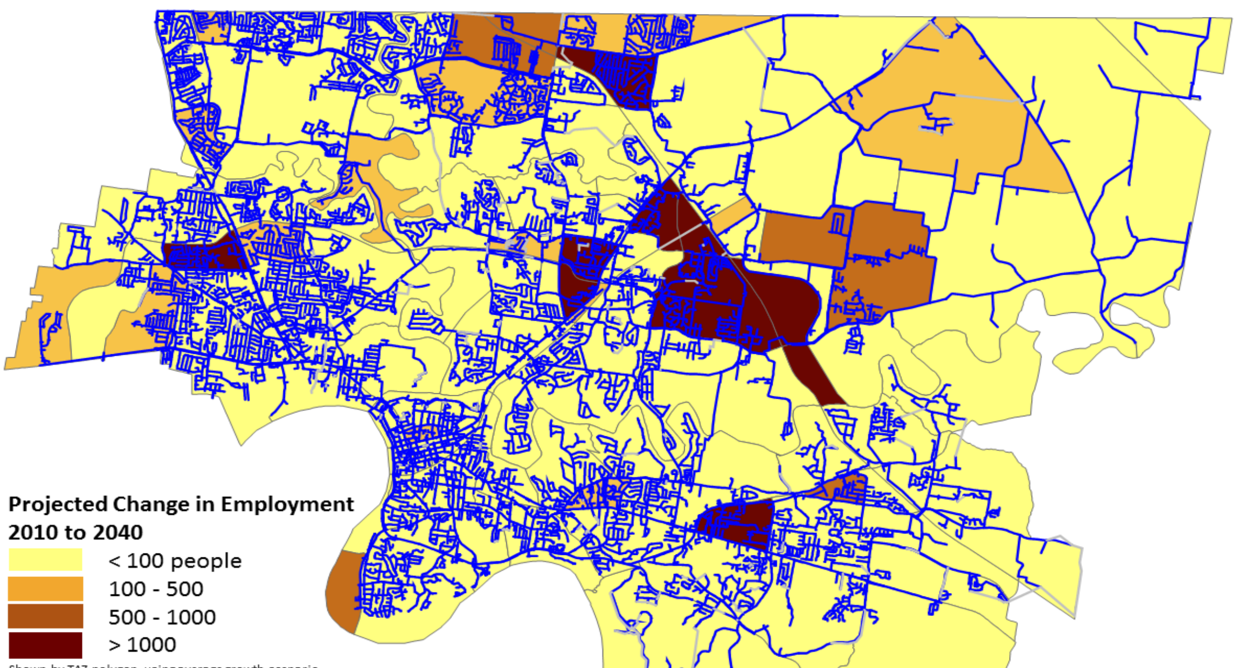


Figure 5: Projected Change in Employment (2010 - 2040)



2. Population Projections

In order to identify local population and socioeconomic trends, Hazen was able to obtain population data and projections from several state and federal sources including the US Census, the University of Tennessee Boyd Center for Business and Economic Research (CBER), the Tennessee Department of Transportation's (TDOT) Traffic Analysis Zones (TAZ), as well as, other regional planning agencies. Population projections were prepared in five-year increments between 2015 and 2040, for the system as a whole and for each pressure zone, and were used to develop water demands.

2.1 Data Sources

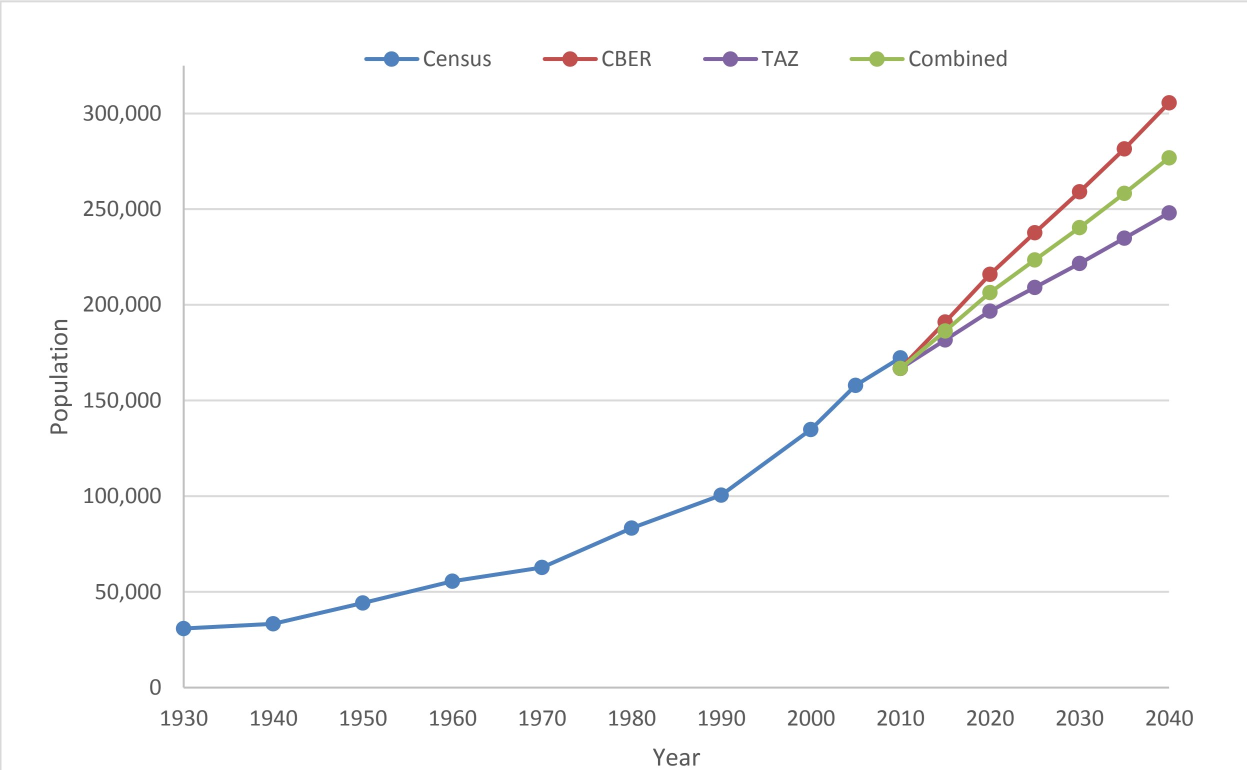
A review of available population forecast data produced two highly reliable sources in the CBER and the TAZ. The CBER serves as the lead agency of the U.S. Census Bureau's State Data Center program for Tennessee and acts as a federal-state cooperative program for population estimates. It produces single year projections from the latest 2015 projections to year 2064 based on the 2010 census. While CBER only produces Tennessee resident population data at a county-wide level, the TAZ provide a more detailed look with more than 250 zones within Montgomery County containing population data. This resolution is vital in identifying specific growth areas of future demand to the water service area. With the CBER population projections being much more aggressive than the TAZ, the most distant population projections for the year 2040 showed a difference in population of more than 50,000 (shown below in **Table 1** and **Figure 6**).

Table 1: Montgomery County Population Data

Year	*Data Source*		
	US Census	**CBER**	**TAZ**
1940	33,346	-	-
1950	44,186	-	-
1960	55,645	-	-
1970	62,721	-	-
1980	83,342	-	-
1990	100,498	-	-
2000	134,768	-	-
2005	157,955	-	-
2010	172,331	166,719*	166,719*
2015	-	190,993*	181,716*
2020	-	216,008*	196,713*
2025	-	237,758*	209,136*
2030	-	259,068*	221,558*
2035	-	281,493*	234,845*
2040	-	305,627*	248,132*

*population projection does not include Fort Campbell

Figure 6: Montgomery County Population



2.2 Growth Scenarios

Following coordination with CGW regarding the differences in population projections between TAZ and CBER, it was agreed to provide projections for both growth rates that acted as a representation of the high and low ends of population projections, as well as, a combined projection that fell between the two. In order to match the resolution that the TAZ data provided, the CBER data was distributed proportionally to calculate an adjusted TAZ that represented the higher CBER rate. The outcome of these adjusted projections mirrored the more aggressive growth rate of the CBER projections but allowed them to be spatially represented across Montgomery County in the same manner as the TAZ projections. In the same way, a combined scenario was also produced to represent a more moderate growth rate between the TAZ and CBER projections. Therefore, an average growth scenario (TAZ), an aggressive growth scenario (CBER), and a moderate growth scenario (COMBINED) were presented with the same resolution and adapted for CGW’s water service area.

All 3 projections excluded Fort Campbell, and the TAZ data does not include spatial coverage or statistics for any of the Fort Campbell area. Furthermore, Fort Campbell is not expected to grow in the future, and CGW does not currently serve or expect to serve Fort Campbell in the future.

3. Demand Projections

Current baseline demand conditions were determined and used as the basis for future demand projections. These baseline demands, shown below in **Table 2**, were established from a combination of current water billing data, treatment plant flow records, and through discussions with CGW.

Table 2: Baseline System Demand (2015)

Pressure Zone	Avg. Day Demand (MGD)	Max. Day Demand (MGD)	Max. Hour Demand (MGD)
Rossview	3.0	4.2	7.1
Allen Griffey	2.3	3.1	5.4
Sango	0.9	1.2	2.1
Jackson Road	3.2	4.4	7.6
Main	6.2	8.6	14.8
Total	**15.6**	**21.5**	**37.0**

Beyond population projections, overall system water demand was assumed to be a function of per capita consumption, industrial and commercial usage, irrigation usage, wholesale customers, and peaking factors. Future site and subdivision plans, and other available development plans not included in the TAZ data were reviewed and updated based on coordination with CGW. Evaluation of critical service areas and proposed industrial regions were also evaluated.

3.1 Residential Based Projections

In order to obtain demand projections for each pressure zone, the TAZ shapefile, containing population projection data, was utilized. Each water demand node, with its average day demands, was linked with the respective TAZ polygon (see **Figure 7** below). The average day demands were scaled accordingly to the respective growth rate scenario for each projection year in order to produce demand projections for each node, which were then totaled for each pressure zone as shown in **Table 3** and graphically summarized for the whole system in **Figure 8**.

Figure 7: Merging of TAZ Polygons and Demand Nodes

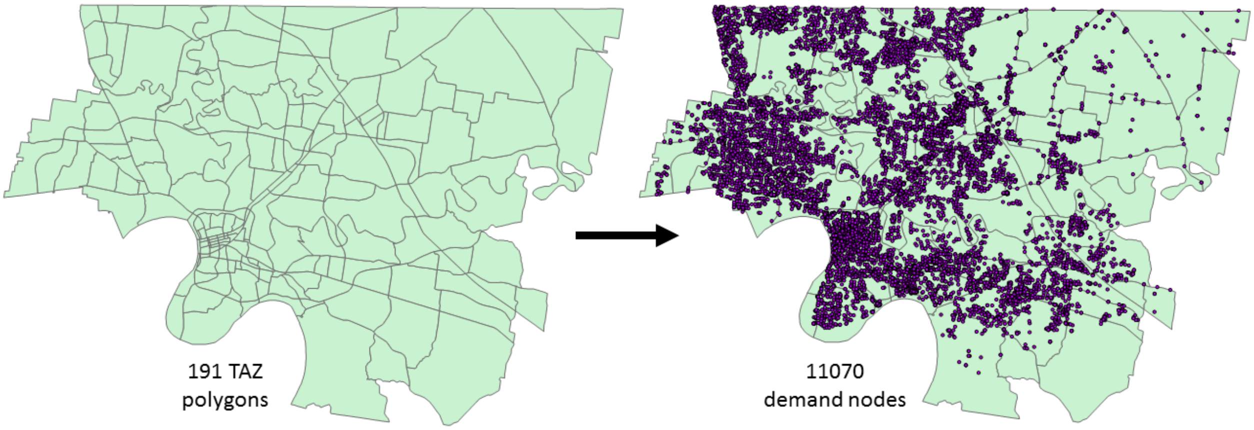
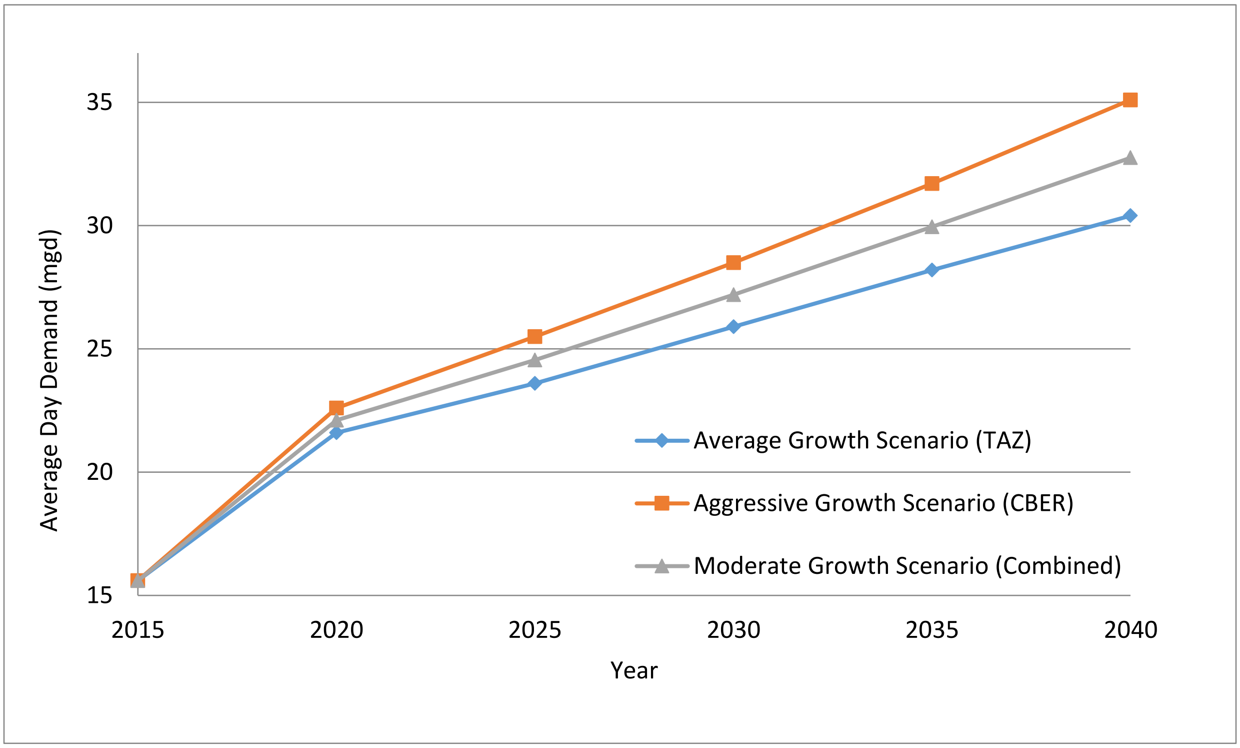


Table 3: Average Day Demand Projections (mgd)

Pressure Zone	2020		2025		2030		2035		2040	
	TAZ	*CBER*	*TAZ*	*CBER*	*TAZ*	*CBER*	*TAZ*	*CBER*	*TAZ*	*CBER*
Rossview	8.8	9.3	10.1	10.8	11.4	12.4	12.9	14.2	14.3	16.1
Allen Griffey	2.5	2.8	2.6	3.0	2.7	3.2	3.1	3.8	3.5	4.5
Sango	1.0	1.1	1.0	1.2	1.1	1.3	1.2	1.4	1.2	1.5
Jackson Road	3.2	3.2	3.3	3.4	3.5	3.6	3.5	3.7	3.6	3.8
Main	6.1	6.2	6.6	7.1	7.2	8.0	7.5	8.6	7.8	9.2
Total	**21.6**	**22.6**	**23.6**	**25.5**	**25.9**	**28.5**	**28.2**	**31.7**	**30.4**	**35.1**
Combined	**22.1**		**24.6**		**27.2**		**30.0**		**32.8**	

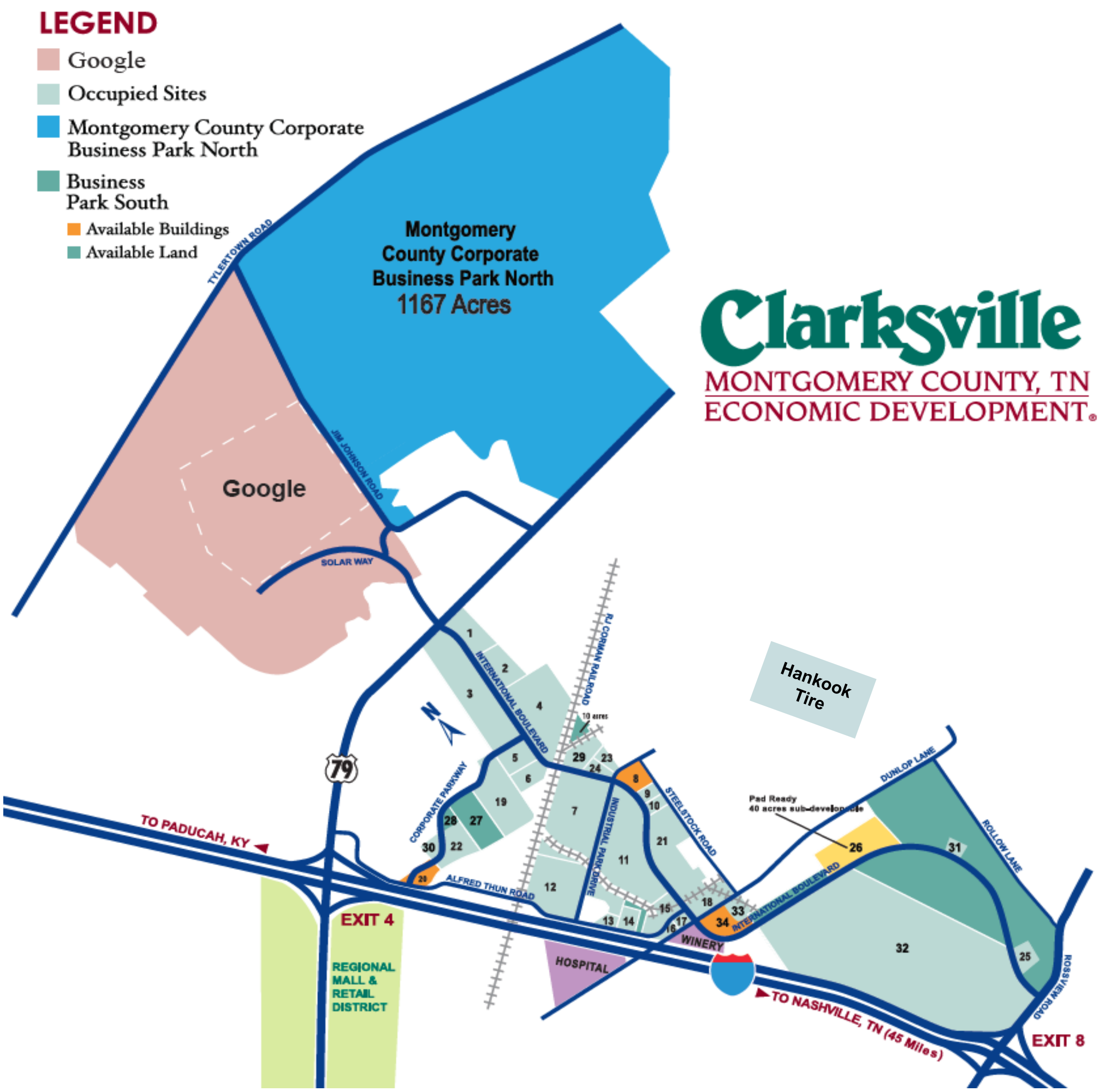
Figure 8: Average Day Demand Projections (mgd)



3.2 Non-Residential Based Projections

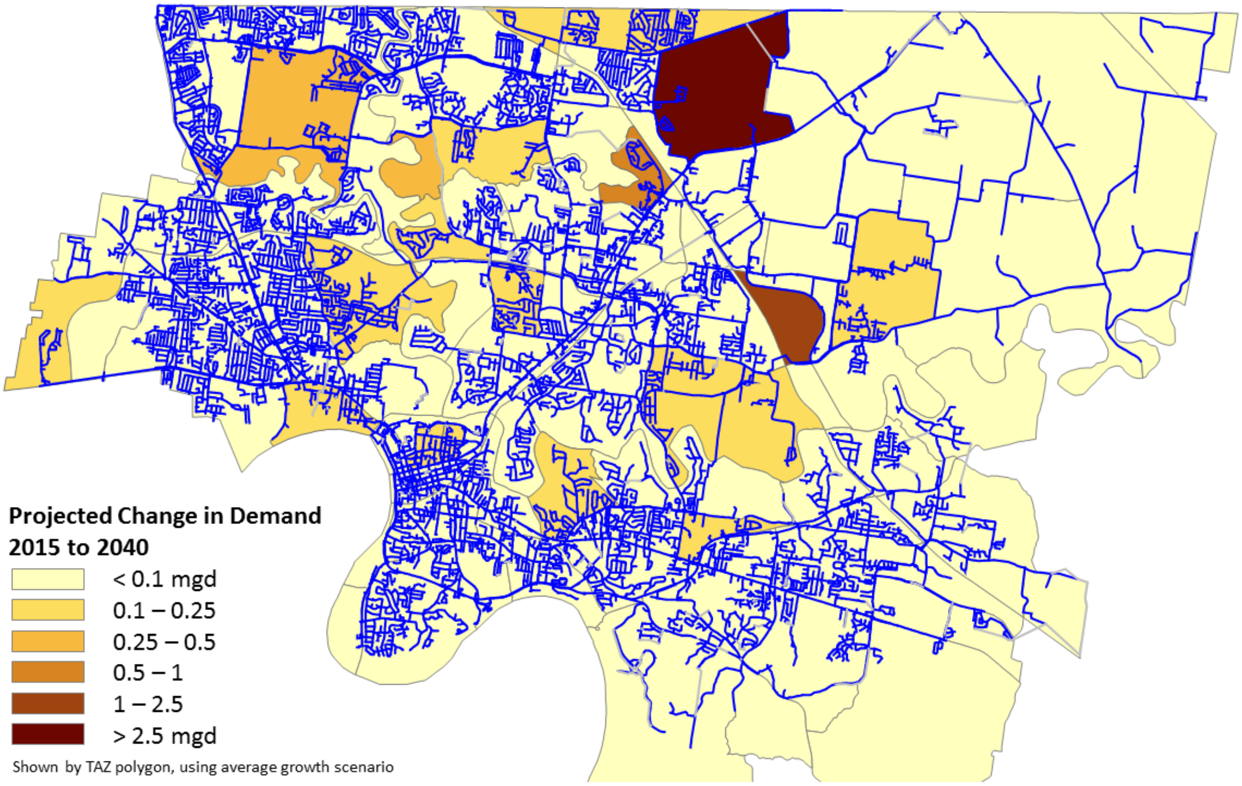
For certain TAZ polygons with a majority of area zoned for commercial or industrial, employee data was used to calculate growth rates instead of residential. This employee data was used for the majority of the business park demand projections, with the exception of Google and Hankook Tire industries that were manually entered given their known projected demands. The projections show significant population and demand growth in the Rossview PZ where a large portion of industrial growth is possible. Hankook Tire and Google amount for a significant increase alone by 2020. Furthermore, 1200-1400 new residential lots are to be developed along Powell Road just west of interstate-24, which also lie within Rossview PZ. However, it should be noted that the 1167 acres of available land labeled as the Montgomery County Corporate Business Park North (shown below in **Figure 9**) was only applied a moderate growth rate to the demands as no major industry development is known at this time.

Figure 9: Clarksville-Montgomery County Corporate Business Park



According to the Clarksville-Montgomery County Industrial Development Board (IDB), more than 1500 acres are available for industrial development. These areas that are zoned for heavy industrial are advertised with railroad service, as well as water, gas, sewer, and electric, have a potential for significant water demand increase. In the future if a large industry is to build or relocate within CGW's service area, the projections should be updated to show an increase in the established demands and projections similar to the way that Google and Hankook Tire demands were integrated into the current demand projects.

Figure 10: Projected Change in Demand (2015 – 2040)



3.3 Peaking Factors

Water production records were previously analyzed for a 12-month period to determine average and maximum day production. The results were average day production at 15.6 mgd while maximum day production was 21.5 mgd, or 1.38 times that of the average. For hourly peaking factors, system-wide diurnal patterns were developed from SCADA values for finished water and tank flows during field tests conducted as part of model calibration. The maximum hourly peaking factor was calculated as 1.72 times daily demand which was applied to the maximum day demand multiplier of 1.38, resulting in a total peaking factor of 2.37 times average day demand.

4. Conclusion

Following consultation with CGW, there is no anticipation that the current water service area boundary will expand due to the TN-KY state border to the north, Fort Campbell to the west, and several other surrounding utility districts. Population growth within the service area is projected to be the greatest in the northern portions of the service area within Main, Allen Griffey, and Rossview pressure zones while employment growth will be the greatest around interstate-24 in those same pressure zones.

The future water demand projections will be based on the combined growth scenario that falls between the average (TAZ) and aggressive (CBER) growth scenarios. As a result of using the combined growth scenario, the projected system wide average day demand are shown in **Table 4**.

Table 4: Projected Average Day Demand

Year	2020	2025	2030	2035	2040
Combined (mgd)	22.1	24.6	27.2	30.0	32.8

Future model simulations will utilize the projections at each 5-year planning horizon in order to create overviews of the entire system and how it is affected at each new demand projection. These future model simulations will help identify areas where predicted pressures do not meet design criteria as well as evaluate water age, pump capacity, and tank capacity needed to supply future projected demands within the system. If additional storage is required, the model will also be used to explore possible sites for more locations of storage. These evaluations will be included within the Capital Improvement Plan (CIP) that will establish the future needs for the addition of new water lines, upsizing existing water lines, sizing of transmission mains, distribution pump station capacity needs, and the addition of a new WTP.

Task 5 - Barge Point WTP Conceptual Planning

October 24, 2017

To: Clarksville Gas & Water

From: Hazen and Sawyer

Re: Barge Road Water Treatment Plant Conceptual Planning Technical Memorandum (TM)
Water System Master Plan – Phase 2

Introduction

This TM summarizes the criteria used to develop a conceptual design for a new water treatment plant (WTP) to be located at a previously-identified site off of Barge Point Road. The overarching design philosophy was to develop a process train that is similar to the existing WTP, while incorporating the technological preferences and expansion increments identified in previous phases of this project. The objective of this memorandum is to develop a conceptual site layout for the new Barge Point WTP. To do this, pertinent results of the population and demand projections and technology evaluation conducted previously were reviewed, factors influencing siting of structures within the plant site were evaluated, major unit processes were sized, and a preliminary site layout was developed. The proposed facility provides multiple treatment barriers against both regulated contaminants and other microconstituents.

Job no 32118-010

Table of Contents

1. Summary of Previous Work

1.1 Population and Demand Projections

To determine the short-term and long-term needs of CGW's water supply, population and flow estimates were developed for the 2015 baseline water demand and projected for the years 2020 to 2040 in 5 year increments during a previous task of the Phase 2 Master Plan effort. Future delineation of the service area was also evaluated. The results of these activities were documented in the "Population and Demand Projections Technical Memorandum," dated August 18, 2016.

Population projections were developed in 5-year increments from 2015 to 2040 based on data from the University of Tennessee Center for Business and Economic Research (CBER) and the Tennessee Department of Transportation's (TDOT) Traffic Analysis Zone projections. An analysis of each pressure zone was carried out to identify future residential and industrial growth areas that could impact water demand. Based on this effort, population growth within the service area is projected to be the greatest in the northern portions of the service area within Main, Allen Griffey, and Rossview pressure zones while employment growth will be the greatest around Interstate-24 in those same pressure zones. The future water demand projections was based on the combined growth scenario that falls between the average (TAZ) and aggressive (CBER) growth scenarios.

Existing water demands were characterized based on baseline water demands for each pressure zone. These demands were established from a combination of current water billing data, treatment plant flow records, and other information provided by CGW. Beyond population projections, overall system water demand was assumed to be a function of per capita consumption, industrial and commercial usage, irrigation usage, wholesale customers, and peaking factors. Future site and subdivision plans, and other available development plans not included in the TAZ data were reviewed and updated based on coordination with CGW. Evaluation of critical service areas and proposed industrial regions were also conducted. Water demand characteristics were also used to develop maximum-day (1.38) and peak hour (2.37) peaking factors. Table 1-1 summarizes projected average day, maximum day, and peak hour projected demands from 2015-2040.

Table 1-1: Projected Water System Demands, 2015-2040

Year	2020	2025	2030	2035	2040
Average Day Flow (ADF), MGD	22.1	24.6	27.2	30.0	32.8
Maximum Day Flow (MDF), MGD [1]	30.5	33.9	37.5	41.4	45.3
Peak Hour Flow (PHF), MGD [2]	52.4	58.3	64.5	71.1	77.7

1: MDF = ADF * Peaking Factor of 1.38
2: PHF = ADF * Peaking Factor of 2.37

Industrial development within the CGW service area is expected to be a major driver of future water system growth. Since the requirements of larger users are often in the millions of gallons per day range, plant expansion will likely be triggered by discrete requirements of major new users, rather than organic population and small industrial and commercial user growth over time.

1.2 Raw Water Pump Station

Raw water pump station locations, configurations and pump technologies were evaluated as part of the "Raw Water Pump Station, Facilities Conceptual Planning Workshop" held on February 16, 2016. Two potential locations were considered: the one originally proposed in the previous Barge Point WTP design on a site owned by others, and an alternate location on CGW property, but at a higher elevation and farther from the river. The original site is lower elevation and closer to the river, which reduces the required wetwell depth and length of intake tunnel structures, but CGW would need to enter into a lease agreement with the Army Corps of Engineers (USACE) to be able to site the station at that location if USACE is not willing to sell it outright. The disadvantage of this is that CGW would not ultimately own the site on which the pump station is built. The alternate location may be more costly to develop, but is already owned by CGW.

For the wetwell, rectangular and circular caisson configurations were considered. A circular caisson wetwell was selected since it is a proven technology, has inherent structural strength, and is expected to be less expensive than a rectangular wetwell, as well as faster to construct. Vertical turbine and submersible pump technologies were evaluated, and vertical turbines were selected since they are consistent with what is at the current plant, are typically more energy-efficient, and are more customizable. Three potential operating floor levels were discussed: the 100-year floodplain (390.4 ft.), the flood crest elevation of the 2010 Cumberland River flood (393.5 ft.) and the 500-year flood elevation (397.2 ft.). The 500-year flood elevation was selected as the preferred basis of setting the operating floor elevation.

1.3 Technology Evaluation

The need to implement advanced treatment technologies is driven by a variety of factors. New analytical technologies have allowed for detection of pharmaceutically active compounds and other constituents down to the nanogram per liter level. Recent algal toxin outbreaks have had serious impacts on several communities. As water demand increases, utilities are forced to consider "less pristine" sources of water, while at the same time public awareness of, and concern over, emerging contaminants in their water supply increases. Due to the vast amount of chemicals present in the environment and the limited knowledge available of their effects at very low levels, there is a considerable amount of uncertainty regarding what may be regulated and at what level. This has driven a desire to select a suite of treatment technologies for the new water treatment plant that are effective against a wide range of known and unknown contaminants.

A series of advanced water treatment technologies that could allow CGW to meet current regulations while providing flexibility to remove emerging contaminants now and in the future were evaluated. Technologies considered included ozone, membrane filtration, reverse osmosis, activated carbon, and hydroxyl radical-based advanced oxidation processes (AOPs). Membrane filtration was selected to provide enhanced removal of particulates, including *Cryptosporidium* and *Giardia.* It was also decided to leave space at the beginning and end of the water plant hydraulic profile to accommodate future advanced treatment processes.

On the raw water side, ozone could be applied to treat a wide variety of currently-regulated and emerging contaminants. Prior to implementing ozone, it is recommended that a pilot study be conducted to confirm that biologically stable water would be produced without having a dedicated biologically active filtration (BAF) step. Use of ozone without BAF has been successfully implemented at a limited number of membrane plants, including Emmons County WTP and North Burleigh WTP, both in North Dakota. Three large water treatment facilities in North America – Boston's (MWRA) Carroll WTP (405 MGD), Seattle's Cedar River WTP (180 MGD), and Vancouver's Coquitlam Water Supply (317 MGD) – all successfully apply ozone without a downstream BAF process.

As an alternative to ozone, a flexible pretreatment basin could be constructed that could be used for preoxidation or adsorption processes on an as-needed basis. For example, permanganate and PAC feed capabilities could be provided and used intermittently to address specific challenges that arise. PAC could be used to address a taste and odor event, chemical spill, or other contaminant issue, and permanganate could be applied to address dissolved metal issues or potentially to help control disinfection byproduct formation (DBP) during the summer months. Sufficient head will be provided within the plant hydraulic profile to incorporate this strategy, ozone, or an alternative advanced treatment process.

A UV-based Advanced Oxidation Process (UV-AOP) could also be considered for a future advanced treatment process at the new WTP. The key advantage of a UV-AOP system are that it can be run at a low dose year-round to provide a redundant pathogen barrier and can be put into AOP mode (high UV dose with peroxide addition) as-needed to address intermittent issues such as taste and odor, contaminant releases into the Cumberland River, hazardous algal blooms, or others. UV-AOP systems can be brought online within minutes to address rapidly changing water quality. Sufficient head will be left in the hydraulic profile to allow for this technology to be integrated in the future.

2. Site Constraints

Development of the site layout for the new WTP requires taking into account overall site surface and subsurface conditions, grading, flooding potential, local environmental and cultural resources, transportation access, and other factors. This section summarizes key site constraints taken into account when developing the Barge Point WTP layout.

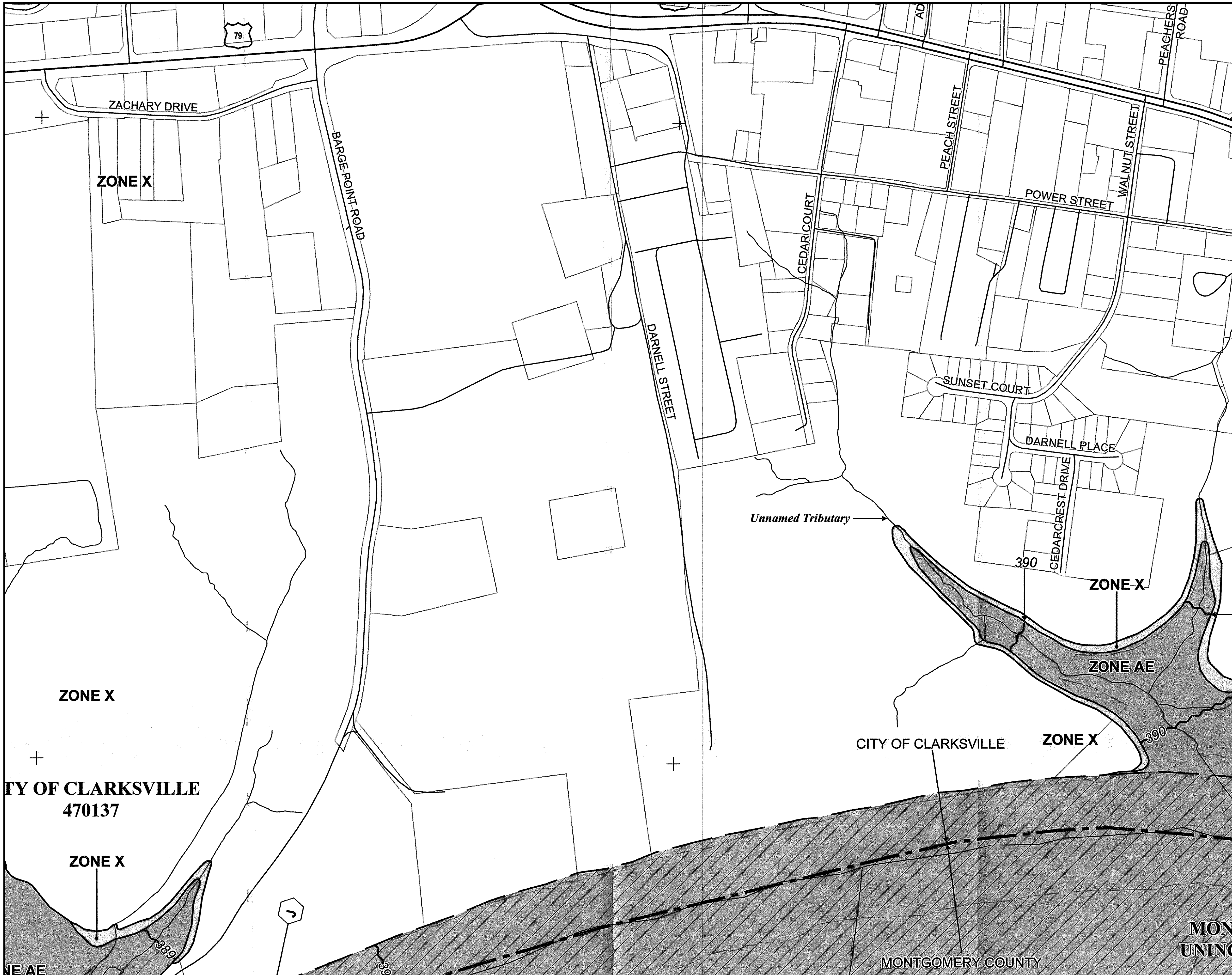
2.1 Flood Protection

Flood protection requirements for the plant site were evaluated using the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM). Map Number 47125C0217D covers the proposed plant and raw water pump station sites; Figure 2-1 shows the portion of this map panel that covers the intake pump station and plant sites. According to this map, the proposed plant site is in Zone X (unshaded), which means it above the 100-year and 500-year floodplains. The proposed location on USACE property for the raw water pump station is within the 100-year flood zone (Zone AE), with an established base flood elevation of 390.4 feet. In 2010, water levels in the Cumberland River reached 393.5 feet, and 500-year flood levels are projected to be 397.2 feet. Therefore, it was recommended that the pump station floor operating level be located between 395-400 feet, with all electrical equipment to be placed above the 500-year flood elevation.

2.2 Environmental and Cultural Sensitivity

Environmental factors taken into account include identifying the potential presence of wetlands on the site and minimizing the impact to existing woodlands on the site. The majority of the proposed layout is located on areas that had been previously cleared. In order to determine if wetlands exist on the site, the National Wetlands Inventory Wetlands Mapper tool was used. It appears that there is a freshwater pond located just to the west of the northern portion of the cleared area. The proposed plant layout avoids this area. Figure 2-2 shows the wetlands mapper output for the WTP site.

An archaeological survey of the proposed water treatment plant site was conducted in 2005 by TRC, Inc. as part of a previous design effort. This report is attached as Appendix A. This survey identified two new archaeological sites, one covering the area on which the water plant will be sited (40MT979), and one located where the raw water pump station will be located (40MT978). Based on the results of a Phase I study, the 40MT979 site was determined not to be eligible for registration in the National Register of Historic Places (NRHP), and the 40MT978 site was carried forward for a Phase II study. Based on the results of the study, the 40MT978 site was determined to be also ineligible for NRHP listing. Both sites generally had low density of prehistoric and historic artifacts that generally consisted of stone tool fragments and debitage (debris from the stone tool making process), white refined earthenware (i.e. ceramic shards), bottle glass, and cut nails. There was evidence of a potential brick manufacturing enterprise at the 40MT978 site that, while interesting, was not deemed to be eligible for NRHP listing. The archaeologist concluded that no further archaeological work is needed at either site prior to construction of the WTP.



IAP SCALE 1" = 500'

500 1000 FEET

150 300 METERS

PANEL 0217D

Figure 2-1

FIRM

FLOOD INSURANCE RATE MAP

MONTGOMERY COUNTY TENNESSEE

AND INCORPORATED AREAS

PANEL 217 OF 491

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
CLARKSVILLE, CITY OF	470137	0217	D
MONTGOMERY COUNTY	470136	0217	D

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
47125C0217D

EFFECTIVE DATE
MARCH 18, 2008

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

U.S. Fish and Wildlife Service

National Wetlands Inventory

Figure 2-2
Barge Point Site Wetland Map

August 12, 2016

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

2.3 Subsurface Conditions

Geotechnical reports were prepared by PSI, Inc. as part of the previous facility design at the Barge Point site. Reports dated January 18, 2005 and August 2, 2005 were used as the basis of the conceptual subsurface condition evaluation; additional geotechnical work may be required as part of the new water treatment plant design. 37 total boring were drilled to depths ranging from 15 to 80 feet, and select laboratory testing was done to determine soil characteristics. It does not appear that borings were done at the intake pump station site; therefore, this could be done as part of the new WTP design.

In general, the PSI report indicated that the site is susceptible to solution weathering and sinkhole development, and that some remedial measures will be necessary due to the presence of plastic (i.e. clays), wet, and soft soils on the site. In general, certain areas of the site were suitable for conventional shallow spread footing foundations, while other areas will require deep foundation systems. Micropiles were recommended for the deep foundations due to the nature of the underlying bedrock.

2.4 Transportation Access

The planned entrance to the new WTP site will be off of Barge Road. This road already accommodates traffic from a nearby rock quarry and logging operation; therefore, it appears that it will likely be adequate for construction equipment and chemical delivery trucks to access the site. Barge Point Road connects to US Route 71 (Dover Road), which is a multilane divided highway. It does not appear that there is any significant access limitation for the types of vehicles that will be required to service the new WTP. However, the roadway should be evaluated in detail as part of the design process to identify if any potential improvements or upgrades are warranted.

3. Major Process and Facility Sizing

This section of the TM describes the selected major unit process layout, expansion scheme, and basis for sizing of the major unit processes. This information was used to develop an overall process flow diagram, site layout, and hydraulic profile that can accommodate expansion from 10 MGD to an ultimate buildout capacity of 30 MGD. These expansion increments can be adjusted as required based on the particular requirements of major industrial projects and population growth over time.

3.1 Overall Plant Configuration

The treatment train will be similar to the existing WTP and will incorporate technology preferences for emerging contaminant removal identified in the Water Treatment Technologies Workshop held on June 9, 2016. The conceptual process layout was arranged to allow for modular expansion from the initial 10 MGD capacity to the ultimate planned buildout capacity of 30 MGD. The following unit processes will be included:

- Space for future advanced treatment process (raw water)
- Preoxidation (chlorine or permanganate)
- Pumped diffusion rapid mix

- Flocculation
- Sedimentation (high-rate plate settlers)
- Membrane Microfiltration (MF)
- Space for future advanced treatment process (filtered water)
- Disinfection (OSG hypochlorite and chlorine contact tanks)
- Residuals storage and pumping

Other major facilities to be included at the plant include:

- Raw water pumping with two wedge-wire screened intakes
- Clearwells
- High service pumping
- Chemical storage tanks, metering pumps, and other conveyance, storage, and handling equipment
- Administration and laboratory space

The process layout will be further developed as part of the preliminary design phase. Options to reduce or eliminate unit processes are available that could reduce the overall cost of the facility; these include aggressively sizing the lamella clarifier units, using a direct filtration MF process (i.e. eliminate flocculation and sedimentation), selection of chlorine disinfection system (OSG vs. bulk sodium hypochlorite) based on lifecycle cost, combining the finished water clearwells and disinfection CT contact chamber into one structure, and others. These options can be further explored during detailed design of the plant.

3.2 Process Expansion Intervals

Basins (flocculation, sedimentation, and disinfection) will be built in 10 MGD increments to limit the amount of independent structures and associated piping, valves, and other appurtenances located onsite; process equipment can either be added all at once as the basins are built, or added in 5 MGD increments. For example, the physical flocculation and sedimentation basin structures would be expanded in 10 MGD increments, but the process equipment (flocculator drive motors and turbines, plate settler units, collection weirs/troughs, etc.) can be added in 5 MGD increments to spread out costs, if desired. The rapid mix system will be sized to treat flow at buildout; mixing intensity can be adjusted as needed to match incoming flows by adjusting the speed on the sidestream water pump. The membrane filtration building, piping, and appurtenant systems will be built to accommodate flows at buildout, and microfiltration membrane skids will be added as required for each expansion interval. Chemical containment, storage, and metering pump structures will be sized to accommodate all equipment anticipated at buildout, with tanks and pumps being added as needed as the plant is expanded.

3.3 Raw Water Pump Station

The raw water pump station structure and piping will be built to full capacity at the initial expansion increment. Initially, three 6 MGD pumps will be installed to give a firm capacity of 12 MGD and a total capacity of 18 MGD. As the plant is expanded, three additional pumps will be added up to a firm raw water production capacity of 30 MGD and a total production capacity of 36 MGD. As was discussed in Section 1.2, the operating floor elevation will be set above the 500-year floodplain, and the station will be constructed with a circular caisson wetwell and vertical turbine pumps. A detailed hydraulic analysis should be conducted during the plant's design to select and size the raw water pumps. A summary of raw water pump station design criteria is presented in Table 3-1.

Table 3-1: Raw Water Pump Station Design Criteria

Type	Vertical Turbine Raw Water Pump Station
Initial Capacity, MGD (Total/Firm)	Structure: 36/30 Pumps :16/12
Expansion Increment, MGD	N/A
Buildout Capacity, MGD (Total/Firm)	36/30
Minimum Operating Floor Elevation	Above 500-year Floodplain
Process Configuration	Vertical turbine pumps in a circular caisson wetwell
Major Equipment	Building, pumps, VFDs

3.4 Rapid Mix

The coagulation process begins when coagulant is dispersed into the raw water supply. Fast and efficient mixing is required to properly mix the coagulant, which ultimately helps to build a readily-settleable floc that can be removed in the downstream sedimentation and filtration processes. A preoxidant (such as potassium permanganate) or Powdered Activated Carbon (PAC) can also be added in the rapid mix. A pumped-injection type rapid mix similar to the one at the existing WTP will be used at the Barge Point WTP. This type of mixer uses a water jet to disperse coagulant chemical(s) into the raw water. A sidestream booster pump is used to pump approximately 2-5 percent of the total raw water flow through the jet nozzle, which points upstream into the raw water pipe. Coagulant chemicals are added into the sidestream just upstream of the nozzle. The turbulence generated by the jet rapidly mixes chemical into the raw water stream.

One rapid mix structure will be built to handle flows through buildout. One duty and one standby sidestream pump will be included in the design to provide for redundant operation. The pumps will be VFD-controlled to allow for optimization of the rapid mix process under varying conditions. The nozzle will be inserted into the pipe through a box structure to allow for maintenance access. The box structure can be designed to accommodate a future mechanical mixer unit that could be used as another layer of redundancy to the pumped injection system or as a second-stage rapid mix. Table 3-3 summarizes the design criteria for the rapid mix system.

Table 3-3: Rapid Mix Process Design Criteria

Type	Pumped Diffusion Mixer
Initial Capacity, MGD (Total/Firm)	30/30
Expansion Increment, MGD	N/A
Buildout Capacity, MGD (Total/Firm)	30/30
Sizing Criteria	G*t=1,000 Sidestream flow: 2-5% of raw water flow at buildout
Process Configuration	Single unit, variable-speed sidestream pump, 1,000 gpm Nozzle inserted into raw water pipe via access box Box sized to accommodate future mechanical mixer
Major Equipment	Sidestream piping, pump, nozzle, coagulant feed system

3.5 Flocculation

The flocculation process builds floc formed in the coagulation process into larger, more readily settleable particles. A three-stage tapered flocculation process using hydrofoil ("fan blade") type mixers was selected for the new WTP. Tapered flocculation allows for mixing energy to be gradually reduced in each stage, which can help form larger floc that settle better. Hydrofoil-type units were selected over horizontal paddle wheel-type units because they keep all motors, gearboxes, and bearings above the water surface and accessible for maintenance. The flocculation tanks will be in the same basin structure as the sedimentation process, which helps to reduce the number of independent structures onsite and may also help to limit the amount of site space occupied.

The flocculation tanks will be sized to provide a minimum retention time of 30 minutes, consistent with Tennessee Department of Environment and Conservation (TDEC) standards which recommend 30-45 minutes. Mixers in the basin will be adjustable-speed and capable of providing G values (a measure of mixing energy applied) of 70 to 10 s^{-1}. Baffles will be provided between each flocculation stage to limit short-circuiting through the process. The first expansion increment will include two 5 MGD flocculation/sedimentation basins in one structure. This will provide a rated capacity of 10 MGD, since all basins are counted in the flocculation process firm capacity calculations. The second expansion interval will include two 5 MGD flocculation/sedimentation basins (20 MGD total capacity), and the third expansion will add a third set of two additional 5 MGD basins, for a total buildout capacity of 30 MGD. If desired, mixers, electrical equipment, and instrumentation can be added in 5 MGD expansion increments with the not-yet-needed basins remaining idle to save coat, if desired. A summary of conceptual flocculation design criteria are presented in Table 3-4.

Table 3-4: Flocculation Process Design Criteria

Type	Vertical Hydrofoil Mixers in Baffled Compartments
Initial Capacity, MGD (Total/Firm)	10/10
Expansion Increment, MGD	2 x 5 MGD basins per expansion
Buildout Capacity, MGD (Total/Firm)	30/30[1]
Sizing Criteria	30 minute total detention time per three-stage basin Mixer G values: 70 S^{-1} to 10^{-1}
Process Configuration	Three-stage tapered flocculation, variable speed hydrofoil mixers, baffle wall separation between stages
Major Equipment	Mixers

1: If required, the retention times in the basins can be further reduced on a temporary basis if conditions require one basin to be taken out of service temporarily.

3.6 Sedimentation

The sedimentation process removes floc formed during the upstream coagulation and filtration process. Typical process configurations include conventional open basins, tube settler units, and lamella plate settler units. Tube and plate settler units increase the surface area available for settling, thereby allowing for similar performance to a conventional basin in a significantly reduced footprint. Tube settler units typically use plastic tube bundles, while lamella plate settlers typically use stainless steel plates inclined at an angle of approximately 55 degrees. Based on a conceptual-level lifecycle cost evaluation, the lamella plate settlers are expected to be either similarly or more cost-effective over time assuming a useful life of 10-15 years for the tube settlers, 35-50 years for the plate settlers, and discount rates of approximately 0-5 percent. Lamella plate settlers were selected for the conceptual design due to their small footprint compared to conventional basins, longer service life compared to tube settlers, and favorable economics.

TDEC's community public water systems design criteria indicate that plate settlers shall be designed based on manufacturers' recommendations. The sedimentation basin were initially sized based on a basin overflow rate of approximately 1.5 gpm/sq. ft., which is conservative for high-rate settling processes. This design was further refined by a vendor based on a surface loading rate for each plate of 0.3 gpm/sq. ft.; with their plate configuration, this equates to a basin surface loading rate of approximately 2.1 gpm/sq. ft. This reduced the basin size with respect to the initial conceptual design. The basin area may be able to be further reduced by more aggressively sizing the basins. The initial capacity and the expansion increments will be the same as the flocculation process. Like with flocculation equipment, the sedimentation basin internals (plate packs, sludge collection mechanisms, electrical equipment, and instrumentation) can be installed in 5 MGD increments, if desired, and the basins built in 10 MGD increments. Sedimentation process conceptual design criteria are summarized in Table 3-5.

As another alternative to fully eliminating the flocculation/sedimentation process, ballasted flocculation (Actiflo or similar) was considered. The primary advantage of using such a process would be further reduction in the footprint required for flocculation/sedimentation; however, the polymers typically used for these types of processes can irreversibly foul MF membranes and they are significantly more operationally complex than high-rate lamella clarifiers. Use of a ballasted sedimentation process can be further evaluated as part of the WTP design, if desired, along with other strategies that may be used to reduce the footprint required for pretreatment.

Table 3-5: Sedimentation Process Design Criteria

Type	Lamella Plate Settlers
Initial Capacity, MGD (Total/Firm)	10/10
Expansion Increment, MGD	2 x 5 MGD basins per expansion
Buildout Capacity, MGD (Total/Firm)	30/30[1]
Sizing Criteria	Vendor's recommendations (0.3 gpm/ft^2 of projected plate area)
Process Configuration	Inclined plate settlers with stainless steel plates, baffled inlet, mechanical sludge collection mechanism
Major Equipment	Plates, collection troughs/weirs, sludge removal equipment

1: Sufficient conservatism can be built in to the design of the basins to allow them to run above their nominal capacities, should one need to be taken out of service for an extended period of time.

3.7 Filtration

Membrane filtration was selected as the filtration technology for the new Barge Point WTP. This is consistent with the process currently used at the existing water treatment plant. Microfiltration (MF) and ultrafiltration (UF) are the two types of membrane filtration used in drinking water treatment, with MF having larger pore sizes and UF having smaller ones. MF and UF are low-pressure size-exclusion processes that remove particles, including protozoa and bacteria, but are generally not effective against dissolved constituents. In other words, MF and UF can be thought of as sheets of material with small holes, where the size of the holes controls the size of particles that can pass. Compared to conventional granular media filters, MF and UF provide more of an absolute barrier against pathogens larger than the membrane's pore size.

Since the overall treatment train for the Barge Point WTP will be similar to the existing WTP, is treating the same source water, and has similar capacity (28 MGD vs 30 MGD), the footprint of the existing membrane building was used as the basis for the new building, less space for some of the bulk chemical storage that will be stored outside the building at the new plant. The design flux rate will be 85 gfd, consistent with the existing facility. The building, piping, and other shared equipment will be built to accommodate all trains needed at buildout, with 2.5 MGD membrane skids being added to increase capacity as the WTP is expanded. Five 2.5 MGD skids, 4 duty and 1 standby, will be initially installed at the WTP, and four new skids will be added at each 10 MGD expansion increment. In lieu of adding capacity in 10 MGD chunks, individual skids can be added if the full 10 MGD of expansion capacity is not needed all at once. This would allow expansion costs to be spread out over a longer period of time. Design criteria for the membrane filtration system are provided in Table 3-6.

If ozone is used upstream of the membrane filtration system, it will change the nature of the organic matter in the water that will be treated by the membrane filtration system. This could potentially either reduce or increase the fouling rate of the membranes, which could affect the overall system size and operation. It is recommended that piloting of the membrane system downstream of ozone be conducted to better characterize the impacts of upstream ozone treatment on membrane filtration if ozone is selected for future use at the WTP.

Table 3-6: Filtration Process Design Criteria

Type	Membrane Filtration
Initial Capacity, MGD (Total/Firm)	12.5/10 (Building will be constructed to accommodate all skids needed at buildout)
Expansion Increment, MGD	4 x 2.5 MGD trains per 10 MGD increment
Buildout Capacity, MGD (Total/Firm)	32.5/30
Sizing Criteria	85 gfd flux rate (same as existing plant)
Process Configuration	Parallel 2.5 MGD Pall MF skids
Major Equipment	MF trains, compressed air system, backwash pumps, CEB/CIP chemical systems

3.8 Disinfection

The new WTP will be required to remove or inactivate 4-logs (99.99%) of viruses, three logs (99.9%) of *Giardia*, and two logs (99%) of *Cryptosporidium*. *Cryptosporidium* and *Giardia* log removal requirements will be met via the filtration process, since they are larger than the pore size of the membrane that will be used. On the other hand, membrane filtration is relatively ineffective at removing viruses. Of the three microorganism categories, viruses are readily inactivated by free chlorine, *Giardia* is an order of magnitude more resistant to chlorine than viruses, and *Cryptosporidium* is relatively inert to chlorine. Chemical disinfection via free chlorine will be used to achieve virus inactivation. Although it is anticipated that the full 3.0 log requirement for *Giardia* removal will be met via membrane filtration, the free chlorine disinfection process will be sized to achieve 0.5 log of Giardia inactivation to provide a redundant treatment barrier.

Free chlorine in the form of onsite-generated 0.8% sodium hypochlorite will be used for disinfection at the new water treatment plant. Sodium hypochlorite was selected because it is inherently safer than gas chlorine. The design of the onsite generation (OSG) system will be similar to the one at the existing water treatment facility, with one 1,200 lb./day generator unit and associated DC rectifier, hydrogen offgas blowers, and water softener systems being installed initially, and the second at the expansion interval from 10 to 20 MGD.

As an alternative to OSG, a commercial-strength bulk sodium hypochlorite system could be used. Compared to onsite-generated hypochlorite, it is less maintenance-intensive, as well as cost-competitive (and often cheaper). The primary disadvantages of commercial-strength hypochlorite is that it is more hazardous than the lower-strength OSG solution and there is a greater potential for metering pumps to vapor lock due to offgassing. An ion-exchange softened dilution water system would be provided to reduce commercial-strength 12% hypochlorite solution to around 6% strength, if desired. 6% sodium hypochlorite has a lower degradation rate, and tends to form chlorate (a byproduct of the decomposition process) more slowly. Chlorate is not currently regulated, but may be in the future.

The amount of disinfection achieved is a function of the disinfectant residual present, the amount of disinfection contact time, water pH, temperature, and the hydraulic characteristics of the basin or pipe in which disinfection is occurring. With free chlorine, disinfection tends to be less efficient at lower temperatures and higher pH levels. The amount of disinfection required is defined as a CT value, which is calculated as follows:

$$CT = \text{disinfectant concentration} * \text{contact time} * \text{baffle factor}$$

To calculate CT, disinfectant residual is measured at the end of a contact segment, contact time is the hydraulic residence time of water in the segment, and the baffle factor is used to account for short-circuiting that may occur in the contact basin. The closer the flow is to perfect plug flow, the higher the baffle factor.

The TDEC Design Criteria for Community Water Systems recommends two hours of free chlorine contact time for surface water systems, but Rule 0400-45-01-17(28) only requires that sufficient CT be provided to meet CT requirements. Meeting the CT criterion would result in a significantly smaller basin than would meeting the 2-hour recommendation, which would save space on site. The TDEC Design Criteria are written around a conventional filtration process, and it is expected that the membrane filtration units will provide a more effective barrier against *Giardia* than a conventional process would. Because of this, it is reasonable to reduce the amount of contact time below the 2-hour recommendation. Since the 4-log virus reduction requirement would result in a very short contact time (on the order of 9 minutes or less), 0.5 log reduction of Giardia was selected as the basis for sizing the chlorine contact basins. Sizing criteria, shown in Table 3-7, were selected to be conservative based on expected operating conditions.

Table 3-7: Disinfection Process Sizing Criteria

Type	Free Chlorine Contact
Minimum Water Temperature	0.5 °C
Maximum pH	8.0
Minimum Residual	2.0 mg/L as Cl_2
Baffle Factor	0.7, assumes serpentine baffle tank with multiple passes
CT Required, 4-Log Virus[1]	12 mg*min/L
CT Required, 0.5 Log Giardia[1]	58 mg*min/L

1: CT values taken from USEPA's "Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems using Surface Water Sources," 1991.

Under the selected design conditions, this criteria results in a contact time of approximately 45 minutes. This provides a significant size reduction when compared to the 2-hour design recommendation, while still providing adequate contact time to meet all required virus inactivation targets, provide a secondary barrier against giardia and other microorganisms, and help to provide a biologically stable water for the distribution system. Initially, one structure with two serpentine-baffled contact basins will be provided, each designed to accommodate 5 MGD maximum-day flow (10 MGD total). The basins will be connected such that they can either be operated as two parallel 5 MGD basins or as one single basin able to treat up to 10 MGD. Similar to other process basins, a redundant basin is desirable, but not required. Therefore, the overall conceptual design allows for isolation of individual 5 MGD basin segments, and will ultimately allow for one of those segments to be taken out of service without impacting the plant's ability to produce to its rated capacity.

Basins will be expanded in 10 MGD increments (2 x 5 MGD parallel basins as one structure), to an ultimate buildout capacity of 30 MGD total. Appurtenant equipment (chemical storage tanks, metering pumps, etc.) may be expanded in 5 MGD increments to save cost, if desired. Overall design criteria for the disinfection system are provided in Table 3-8.

Table 3-8: Disinfection Process Design Criteria

Type	Free Chlorine Contact
Initial Capacity, MGD (Total/Firm)	10/10
Expansion Increment, MGD	10
Buildout Capacity, MGD (Total/Firm)	30/30[1]
Sizing Criteria	45 minute contact time based on 0.5-log Giardia inactivation at 0.5°C, pH 8.0 or less, free chlorine residual of 2.0 mg/L, baffle factor of 0.7.
Process Configuration	10 MGD basins with 2 independent chambers that can be operated in parallel or in series
Major Equipment	Basins, OSG equipment, chemical storage tanks, ion exchange dilution water system, metering pumps, online residual monitors

1: Since the design basis is well in excess of what is required to meet regulatory requirements for virus inactivation, taking one basin out of service would not affect the plant's ability to meet its virus removal/inactivation requirements.

3.9 Storage and Pumping

Onsite clearwell storage will be provided downstream of the disinfection contact chambers to provide a buffer for demands during peak hour flows. The amount of storage provided in the initial expansion was based on supplying the difference between projected peak hour flows and maximum daily WTP capacity for a four-hour period. The actual amount of storage required can be refined based on systemwide hydraulic modeling that takes into account utility-specific demand patterns, available distribution storage, and balancing flows with the existing plant. Initially, two 750,000 gallon circular clearwells constructed of prestressed concrete will be provided. Future storage expansions will be identified based on system demand growth and hydraulics. A summary of the amount of storage that will be provided at the WTP is presented in Table 3-9.

Table 3-9: Clearwell Storage Design Criteria

Type	Prestressed Concrete tanks
Initial Capacity	2 x 750,000 gal tanks (1.5 MG total)
Expansion Increment, MG	TBD based on system demand growth
Buildout Capacity, MG (Total/Firm)	TBD
Sizing Criteria	Provide a quantity equal to the difference between plant firm capacity and peak hour flows on a peak day.
Process Configuration	Two parallel tanks
Major Equipment	Tanks, Level Indicators

To reduce overall facility costs, volume required for CT could be integrated into the finished water clearwells in lieu of providing a separate storage structure. If this was done, a minimum clearwell level would be set such that the required CT would be achieved at all flows, with the remainder of the tank volume allowed to float based on system demands. This concept can be further explored during the design process.

High service pumps will be designed to meet peak hour demands, with any difference between peak hour and instantaneous demands being met by distribution system storage. The high service pump station building and piping will be designed to accommodate all pumps required at buildout. Pumps will be installed and upgraded with each expansion interval to meet projected demands. The pump station will initially be built with four pumps and three expansion slots. A conceptual layout and expansion plan was developed based on required flows; specific pump selection will be done as part of the detailed design effort. The initial setup will include 6 duty and 1 redundant high service pump, with each pump rated at 3.4 MGD. Two of the three pumps will be constant speed, and one will be driven by a VFD. The constant speed pumps can be used to meet baseline demand, and the VFD can be used to trim flows and pressures based on demands. As the plant is expanded, pumps will be added and replaced to meet projected peak-hour demands. Conceptually, the high service pump station will be built out as shown in Table 3-10, and the overall design criteria for the high service pump station is shown in Table 3-11.

Table 3-10: High Service Pump Station Buildout Increments

Expansion Increment	Plant Max Day Capacity (MGD)	Peak Hour Flow (MGD)	Constant Speed Pumps	VFD Pumps
1	10.0	20.1	• 5 x 3.4 MGD (duty) • 1 x 3.4 MGD (standby)	• 1 x 3.4 MGD (duty)
2[1]	20.0	40.2	• 2 x 10.3 MGD (duty) • 3 x 3.4 MGD (duty) • 1 x 10.3 MGD (standby)	• 1 x 10.3 MGD (duty)
4[2]	30.0	60.3	• 3 x 10.3 MGD (duty) • 2 x 5.2 MGD (duty) • 1 x 10.3 MGD (standby)	• 1 x 10.3 MGD (duty)

1: Remove 4 x 3.4 MGD pumps and replace with 3 x 10.3 MGD pumps
2: Remove 3 x 3.4 MGD pumps and replace with 1 x 10.3 MGD and 2 x 5.2 MGD pumps

Table 3-11: High Service Pump Station Design Criteria

Type	Prestressed Concrete tanks
Initial Capacity, MGD (Total/Firm)	14/10.3 w/ 3 duty, 1 standby (Station layout and piping will be designed to accommodate upsized pumps for future demand)
Expansion Increment, MGD	See Table 3-10
Buildout Capacity, MGD (Total/Firm)	60.2/51.6 w/ 6 duty, 1 standby
Sizing Criteria	Projected peak hour flows
Process Configuration	Parallel pumps, constant speed and VFD-driven
Major Equipment	Pumps, motors

3.10 Residuals Management

Residuals handling at the new WTP will be similar to the existing facility. Sludge from the sedimentation basins, membrane backwash waste, and membrane clean-in-place waste will be collected in a solids holding tank with a floating decanter. Decant from the tank with be discharged to the Cumberland River (as previously permitted by TDEC), and solids remaining in the tank will be disposed of via the sanitary sewer system, similar to the current facility. Alternately, solids could be trucked offsite for disposal.

3.11 Chemical Storage and Handling

Storage tanks will be provided for the following chemicals:

- Potassium permanganate or alternate preoxidant
- Coagulant (alum)
- Onsite generated sodium hypochlorite (note – these tanks will be built to allow for delivery and storage of 12-15% commercial strength sodium hypochlorite to allow for its use in the future or for a situation where the OSG system is offline for an extended time)
- Hydrofluorosilicic acid (fluoride)
- Corrosion inhibitor
- Membrane clean-in-place (CIP) and neutralization chemicals (subject to change based on manufacturer's recommendations)

  - Citric acid
  - Sulfuric acid
  - Sodium hydroxide
  - Sodium bisulfite
  - Neutralization tank will also be provided for clean-in-place waste

Chemical bulk storage tanks, as well as the CIP neutralization tank, will be located in an outdoor tank farm. Sodium hypochlorite tanks will be shaded, since heating of the tanks will increase its decomposition rate. Other storage tanks will be insulated and/or heat traced as required. Day tanks and metering pumps will be located inside the MF building.

3.12 Administration and Treatment Building

The unit process and major equipment sizing were used to develop a conceptual plant layout and hydraulic profile for the new WTP. In addition to the major unit process structures, space was allocated for various support functions. It was assumed that the membrane filtration and chemical feed areas would be built as a 1-story structure with ceiling clearance as needed to facilitate future addition of treatment equipment, maintenance, etc. A two-story area will be used for the support areas. The membrane filtration building and other functions will be designed as a single structure to economize on space. Approximate square footage allocated for various functions is summarized in Table 3-12.

Table 3-12: WTP Building Space Allotments

Area	Allocated Space (ft^2)
Membrane Filtration[1]	12,000
Chemical Feed Room[2]	2,500
Subtotal, Treatment Areas	*14,500*
Control Room[2]	300
Laboratory[2]	1,500
Machine Shop[2]	750
Offices (5) [2]	1,000
Lobby, conference room, lunch room, locker room/restroom[2]	1,300
Building mechanicals[2]	250
Subtotal, Support Areas	*5,100*
Total Footprint, Treatment Areas (1 Story)	**14,500**
Total Footprint, Support Areas (2 Story)	**2,500**

1: Estimated based on Clarksville WTP Expansion to 28 MGD drawings, revised March 2014

2: Estimated based on Kawamura, S. "Integrated Design of Water Treatment Facilities." 2000, pg. 419

A preliminary evaluation of building materials suggests that metal building structures and steel-framed masonry structures are cost-competitive, with low-end metal structures having the lower life cycle cost compared to both steel-framed masonry and higher-end metal buildings. Key assumptions included a 25 year service life for metal buildings, 50-year service life for masonry buildings, and 3 percent discount rate. Under these conditions, the life cycle cost for steel-framed masonry as about 14 percent higher, and the higher-end (concealed fastener) metal building about 17 percent more expensive. Results were sensitive to discount rate, with discount rates below about 1.4% favoring masonry buildings and above that favoring low-end metal buildings. When looking at higher-end metal buildings and masonry, the break-even discount rate was about 3.6 percent, with lower rates favoring masonry and higher favoring metal.

4. Site Layout and Hydraulic Profile

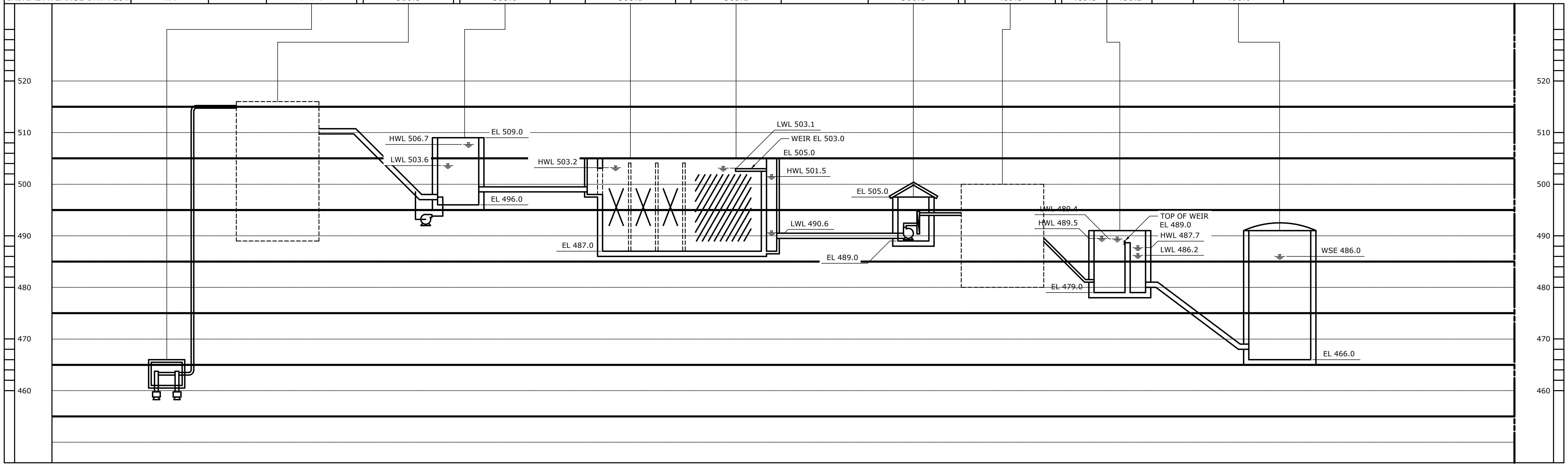
The overall site layout for the new WTP is presented in Figure 4-1. The plant will be built out from east to west and will use the natural grade onsite to move water by gravity through the process. An area of relatively level land to the northwest of the plant has been preserved as open space and can be used for future development on the WTP site, if needed. A conceptual hydraulic profile is provided in Figure 4-2.

FIGURE 4-1
BARGE POINT WTP SITE LAYOUT

NOTES:

1. ALL ELEVATIONS PRELIMINARY PENDING FINAL PROCESS SIZING, PIPE SIZING, AND SITE LAYOUT.

CONDITION	PLANT RAW WATER FLOW (MGD)	RAW WATER PUMP STATION	FUTURE ADVANCED TREATMENT PROCESS	RAPID MIX	FLOCCULATION	SEDIMENTATION	MF BUILDING (PUMPED FLOW)	FUTURE ADVANCED TREATMENT PROCESS	CHLORINE CONTACT TANK		STORAGE
BUILDOUT MAX DAY FLOW	30.0	515.5	510.5	506.7	503.2	503.1	500.0	489.5	489.5	487.7	486.0
INITIAL MAX DAY FLOW	10.0	515.5	510.5	505.6	503.1	503.1	500.0	489.5	489.5	487.1	486.0
INITIAL AVERAGE DAY FLOW	4.4	515.5	510.5	503.6	503.1	503.1	500.0	489.5	489.5	486.2	486.0



Hazen

HAZEN AND SAWYER
545 MAINSTREAM DRIVE, SUITE 320
NASHVILLE, TENNESSEE 37228

CLARKSVILLE, TENNESSEE
WATER TREATMENT PLANT

FIGURE 4-2
HYDRAULIC PROFILE
PRELIMINARY-NOT FOR CONSTRUCTION

5. Permitting

Both state and federal permits are required for constructing a new WTP. This process was previously completed during the design of the North Clarksville WTP in 2005, 2006, and 2007. For the most part, the same permits obtained then will need to be obtained now throughout the design and construction process. To permit this project in a timely fashion, it is recommended that CGW communicate and gain feedback from the regulatory bodies early in the process (e.g. PER phase) for a smoother and possibly faster reviewing period than the typical ones noted below for each permit or process. At a minimum, the timeframes below can be anticipated for when submitting and gaining permitted approval.

From the state regulatory level, TDEC, there are two permits that will need to be obtained, and the final design submittal will need to be reviewed and approved. Recent changes to TDEC's design review process require more coordination to occur in the early stages of the design process. Specific permits/reviews include:

- Aquatic Resources Alternations Permit (ARAP) – application should be submitted with construction plans during design phase that normally takes 90 days to approve:
  - Withdraw water from the Cumberland River; and
  - Construction of intake (401 Water Quality Certification)
- National Pollutant Discharge Elimination System (NPDES) Permit – application should be submitted during design phase for discharging of filter backwash back in to the Cumberland River. Review period of application is 180 days before discharging.
- TDEC Preliminary Engineering Report (PER) Coordination Meetings – TDEC has requested meetings with the designer and utility during the preliminary design phase. Meetings will be required after completion of the PER and potentially earlier in the design development process as well.
- Plans Review and Approval for Public Water Systems – application should be submitted during design phase for approval of constructing the new WTP. It is anticipated that 30 days will be required for completing the review and approval of the construction plans of the WTP.

At the federal level, a United States Army Corps of Engineers (USACE) Individual Section 404 Permit was previously obtained to build the new WTP in 2005 (File No. LRN 2005-00099). This permit has expired and a new ENG Form 4345 would need to be submitted along with the updated WTP design plans. Although the pump station will not be located on USACE property, an easement will be needed to access the river through the floodway. This would need to be completed during design phase as well. Since an individual permit is anticipated to be acquired, the review and comment period would mostly likely be in the range of 75 to 90 days or longer for final approval. Also, the TDEC ARAP would first need to be approved prior to this permit being approved.

Permitting efforts for this facility should be initiated soon. In particular, application for the USACE permit should be prioritized because it impacts the raw water pump station siting.

Appendix A: Archaeological Survey

WR ✓ DL __ Tae E. __ SR __
File Barge Pt. Rd. WTP

GRESHAM
SMITH AND
PARTNERS

October 28, 2005

Chris Hammer, City Engineer
City of Clarksville
P.O. Box 387
2215 Madison Street
Clarksville, Tennessee 37041-0387

Re: **Final Archaeological Reports**
North Clarksville Water Treatment Plant
Clarksville, Tennessee
Project No. 23492.00

Dear Chris:

Please find enclosed for your records an approved copy of the subject archaeological report. According to the archaeologist, we should be hearing from the state within a week or two and from the CORP thirty to sixty days after that regarding the status of the intake site.

If you have any questions, please call.

Sincerely,

John R. Markham, Jr., P.E.
Principal

cc Dwight Luton – City of Clarksville
Wade Rudolph – City of Clarksville
Kenny Vaughan - City of Clarksville
Bill Corlew - City of Clarksville
File 23492.00

TRC

Customer-Focused Solutions

PHASE I ARCHAEOLOGICAL SURVEY OF A PROPOSED WATER TREATMENT FACILITY AND PHASE II ARCHAEOLOGICAL TESTING AT SITE 40MT978, CLARKSVILLE, MONTGOMERY COUNTY, TENNESSEE

October 2005

TRC

Customer-Focused Solutions

PHASE I ARCHAEOLOGICAL SURVEY OF A PROPOSED WATER TREATMENT FACILITY AND PHASE II ARCHAEOLOGICAL TESTING AT SITE 40MT978, CLARKSVILLE, MONTGOMERY COUNTY, TENNESSEE

DRAFT REPORT

Submitted to:
Gresham Smith and Partners
1400 Nashville City Center
511 Union St.
Nashville TN 37219

Submitted by:
TRC, Inc.
1865 Air Lane Drive, Suite 9
Nashville, TN 37210

Larry McKee, PhD, Principal Investigator

Authored by Larry McKee, Marc E. Wampler, and Ted Karpynec

October 2005

MANAGEMENT SUMMARY

In July of 2005, Gresham Smith and Partners (GSP) contracted with TRC, Inc. (TRC) to carry out a Phase I archaeological survey of a parcel proposed as the site of a water treatment facility on the northwestern outskirts of Clarksville, TN. Specifically, the parcel investigated consists of approximately 30 acres to the west of Barge Point Road, bounded on the south by the Cumberland River. The Phase I study undertaken by TRC consisted of a literature search and archaeological field survey designed to document and assess archaeological resources located within the project area according to their National Register of Historic Places (NRHP) eligibility status.

No previously recorded archaeological sites or historic properties are listed with the State of Tennessee on the development parcel. A variety of prehistoric and historic period sites have been recorded within one mile of the project area. Most are associated with the river shoreline and the early settlement of New Providence, to the east of the project area.

Two newly identified archaeological sites, 40MT978 and 40MT979, were recorded during TRC's Phase I investigation. Site 40MT978, located at the east end of the project area, contains Prehistoric, Archaic period components and late 19th century historic-period components. The site is situated on three narrow benches stepping down to the confluence of an unnamed stream and the Cumberland River, west of Trice's Landing Park. Substantial subsurface deposits of brick rubble were discovered on the lowest bench. A low density of prehistoric artifacts, which included an Archaic period projectile point/knife (PP/K), was also found at site 40MT978. In initial consultation with the state of Tennessee Historic Preservation Office (TN-SHPO) TRC recommended that the historic component of 40MT978 is potentially eligible for the NRHP based on its potential to yield information on late 19th century life and commerce in the project region. Phase II archaeological testing was recommended to further evaluate the site's NRHP eligibility status.

Site 40MT979, consisting of a low-density scatter of prehistoric and historic materials, is located across the northern two-thirds of a large field at the proposed location of the water treatment plant. No artifact concentrations, diagnostic prehistoric artifacts, or intact archaeological deposits were discovered at the site. TRC recommends that site 40MT979 is ineligible for the NRHP.

In September 2005, GSP contracted with TRC to carry out Phase II archaeological testing at site 40MT978. TRC's Phase II study at site 40MT978 included more thorough historical research of immediate areas within and around the site boundaries and archaeological test excavations designed to delineate the vertical and horizontal extent and content of deposits.

More thorough historical and archival research of the project area was conducted at the Tennessee State Library and Archives in Nashville. The research did not reveal information specific regarding the location of past structures located within project area or site 40MT978 site boundaries. The proposed location of the Water Treatment Plant is partially located within an area that once comprised a 640-acre land grant issued to a man named George Cook in 1788. Valentine Sevier, a prominent historical figure in the area, later purchased the land and established Sevier Station. Later in 1819, a large portion of the tract was divided into lots, which later became the town of New Providence. The research further indicated that the project area was largely historically used for farming purposes, although its southeastern portion, within site 40MT978, may have once contained buildings associated with Trice's and Planters Landings. These landings were located immediately east of site 40MT978 boundaries.

Archaeological test excavations at site 40MT978 involved the excavation of eight 1 x 1 meter test units. The units were strategically placed according to the Phase I survey shovel test results and landform configuration at the site. Prehistoric and historic components were discovered within the units. Artifacts were low in density and shallow. Prehistorically the site likely represents a temporary encampment possible used for raw material procurement activities. No diagnostic prehistoric artifacts were recovered at 40MT978 during Phase II investigations, however one PP/K fragment was recovered that retained most of its hafting element and appears to represent a Late Archaic stemmed variant. No midden or intact prehistoric cultural deposits were discovered at 40MT978 during Phase II investigations.

Historically, 40MT978 represents an area used from likely the middle nineteenth to early twentieth century. A relatively high amount of cut nails recovered from the site during test unit excavation points to nineteenth century activity at the site. The possible remains of a brick kiln were discovered on a low terrace at the site. Ash and burnt soil layers were noted in the profile of two test units excavated in this area and a variety of glazed and unglazed brick fragments were also recovered. The kiln may represent a small enterprise of brick making at this location along the Cumberland River. No historic artifact midden or subsurface historic structural remains were noted during TRC's Phase II excavations at 40MT978.

It is the opinion of TRC that prehistoric and historic components at 40MT978 are ineligible for the NRHP. Prehistoric deposits are relatively shallow and low in artifact density. Long-term prehistoric habitation at the site is unlikely. Historic deposits are also shallow and low in artifact density. Although the evidence of brick making activity at the site is interesting it is considered ineligible for NRHP inclusion. TRC recommends no further archaeological work at 40MT978 in relation to proposed construction of the water treatment facility.

ACKNOWLEDGEMENTS

TRC would like to thank Mark Markham and Teresa Estes of Gresham Smith and Partners for working closely with us on project administration and maps of the project area. Seth Rye, an engineer with the City of Clarksville, helped in facilitating access to the site and also visited us from time to time during the work. Rob Karwedsky, archaeologist with the US Army Corps of Engineers also provided timely answers and advise on administrative matters in regard to the portion of the property on Corps land.

At TRC, Larry McKee served as Principal Investigator in general charge of the project and co-authored the technical draft. Marc Wampler served as the field director and archaeologist in direct charge of the project and co-authored the report. Field crew for the testing project included Matt Logan (Crew Chief), Ross Fraser, Isaac Deter-Wolf, and Grady Lowery. Logan and Fraser conducted lab processing and analysis under the supervision of McKee and Wampler. Ted Karpynec, Preservation Planner in the TRC Nashville office, carried out historical research on the property presented in this report. Wampler produced the report with graphical assistance from Logan.

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I. INTRODUCTION

In July of 2005, Gresham Smith and Partners (GSP) contracted with TRC, Inc. (TRC) to carry out a Phase I archaeological survey of a parcel proposed as the site of a water treatment facility on the northwestern outskirts of Clarksville, TN. Specifically, the parcel investigated consists of approximately 30 acres to the west of Barge Point Road, bounded on the south by the Cumberland River (Figures 1 and 2). The initial study undertaken by TRC consisted of a literature search and archaeological field survey designed to document and assess archaeological resources located within the project area according to their National Register of Historic Places (NRHP) eligibility status.

The literature search, conducted prior to the Phase I survey at the Tennessee Department of Archaeology (TDOA) and the Tennessee Historical Commission (THC), revealed that no previously recorded archaeological sites or historic properties are listed with the State of Tennessee on the development parcel. A variety of prehistoric and historic period sites have been recorded within one mile of the project area. Most are associated with the river shoreline and the early settlement of New Providence, to the east of the project area.

TRC personnel conducted a Phase I archaeological survey of the development parcel on July 14, 19, and 20, 2005. The central portion of the project area is an open unused pasture or farm field over relatively level terrain. Wooded areas to the east and northeast, where the project area extends on the high bluffs along the Cumberland River and wooded ravine slopes leading down to the unnamed stream drainage, border the central portion.

TRC staff discovered and recorded two archaeological sites, 40MT978 and 40MT979 during the investigation. 40MT978 consists of remains of a historic-period site at the east end of the project area, including the entire footprint of the proposed raw water intake facility. The area is at the toe of the ridge running east from the center of the tract down to the confluence of Tanyard Branch bordering the northeast edge of the parcel and the Cumberland River, west of Trice's Landing Park. The site is spread across a set of three narrow benches stepping down to the confluence. Shovel testing found substantial subsurface deposits of brick rubble on the lowest of the three benches. Shovel testing on the other benches failed to find a continuation of this rubble deposit, and also failed to find artifact concentrations or other signs of undisturbed archaeological deposits. Several prehistoric artifacts were also found during this work, but at a low density that suggests no significant prehistoric deposits are located here. In initial consultation with the state of Tennessee Historic Preservation Office (TN-SHPO) TRC recommended that 40MT978 is potentially eligible for the NRHP based on its potential to yield information on late nineteenth century life and commerce in this region of Tennessee.

A second site, 40MT979, discovered during the Phase I survey of the project area, is a large but low-density scatter of prehistoric and historic materials covering the northern two-thirds of a large open field at the center of the tract. The work found no artifact concentrations, diagnostic prehistoric artifacts, or evidence of intact buried archaeological deposits here. TRC recommends that this site is not eligible for the NRHP.

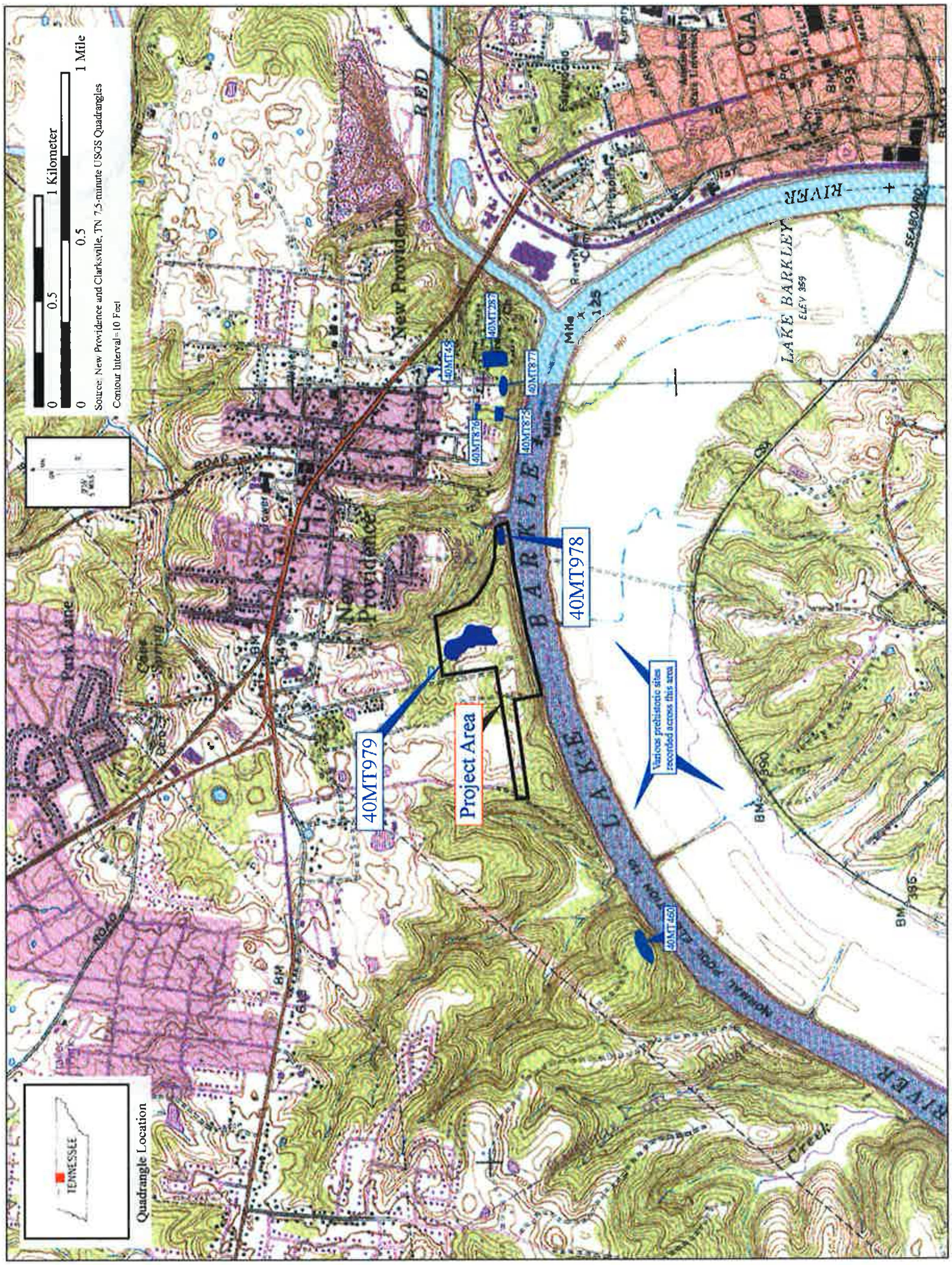

Figure 1. Location of project area, newly recorded archaeological sites within the project area, and previously recorded archaeological sites within a one mile radius of the project area.

Figure 2. Aerial photograph of project area vicinity.

In September 2005, GSP contracted with TRC to carry out Phase II archaeological testing at site 40MT978. TRC's Phase II study at site 40MT978 included more thorough historical research of immediate areas within and around the site boundaries and archaeological test excavations designed to delineate the vertical and horizontal extent and content of deposits.

More thorough historical and archival research of the project area was conducted at the Tennessee State Library and Archives in Nashville. The research did not reveal information specific regarding the location of past structures located within project area or site 40MT978 site boundaries. The proposed location of the Water Treatment Plant is partially located within an area that once comprised a 640-acre land grant issued to a man named George Cook in 1788. Valentine Sevier, a prominent historical figure in the area, later purchased the land and established Sevier Station. Later in 1819, a large portion of the tract was divided into lots, which later became the town of New Providence. The research further indicated that the project area was largely historically used for farming purposes, although its southeastern portion, within site 40MT978, may have once contained buildings associated with Trice's and Planters Landings. These landings were located immediately east of site 40MT978 boundaries. More exact information, such as the extent and location, regarding structures associated with the landings was unable to be determined as a result of the archival research.

Archaeological test excavations at site 40MT978 involved the excavation of eight 1 x 1 meter test units. The units were placed according to the Phase I survey shovel test results and landform configuration at the site. Prehistoric and historic components were discovered within the units. Artifacts were low in density and shallow. Prehistorically the site likely represents a temporary encampment possibly used for raw material procurement activities. No diagnostic prehistoric artifacts were recovered at 40MT978 during Phase II investigations, however one possible Late Archaic PP/K fragment was recovered. No midden or intact prehistoric cultural deposits were discovered at 40MT978 during Phase II investigations.

Historically, 40MT978 represents an area used from likely the middle nineteenth to early twentieth century. A relatively high amount of cut nails recovered from the site during test unit excavation points to nineteenth century activity. The possible remains of a brick kiln were discovered on a low terrace at the site. Ash and burnt soil layers were noted in the profile of two units excavated in this area and a variety of glazed and low-fired brick fragments were also recovered. The kiln may represent a small enterprise of brick making at this location along the Cumberland River. No historic artifact midden or subsurface historic structural remains were noted during TRC's Phase II excavations at 40MT978.

It is the opinion of TRC that prehistoric and historic components at 40MT978 are ineligible for the NRHP. Prehistoric deposits are relatively shallow and low in artifact density. Long-term prehistoric habitation at the site is unlikely. Historic deposits are also shallow and low in artifact density. Although the evidence of brick making activity at the site is interesting it is considered ineligible for NRHP inclusion. TRC recommends no further archaeological work at 40MT978 in relation to proposed construction of the water treatment facility.

II. ENVIRONMENT

NATURAL SETTING

The project area is in central Montgomery County, TN, on the northwestern outskirts of the city of Clarksville. The surveyed tract covers approximately 30 acres east of Barge Point Road, bordered on the south by high bluffs along the Cumberland River and the northeast by Tanyard Branch. The central portion of the property, the proposed site of the main water treatment facilities, is currently an open unused farm pasture covering approximately 20 acres (Figure 3). The bulk of the remaining property includes a ridgeline running east to the confluence of the Cumberland and Tanyard Branch (Figure 4). The ridge terminates in a series of narrow terraces or benches stepping down toward the confluence, and one of these benches will be the site of the raw water intake facility for the treatment plant.

PHYSIOGRAPHY AND GEOLOGY

The project area is contained in the Western Highland Rim physiographic division of Tennessee (Figure 5). The Highland Rim is a subdivision of the larger and inclusive Interior Lowland Plateau, which extends west of the Appalachian Plateau and surrounds the Central or Nashville Basin (Fenneman 1938). The region of the Highland Rim surrounding the project area generally features lightly rolling to steep terrain. Riverine action by the Cumberland River and its tributaries has heavily dissected the landscape in certain areas, creating steep uplands characterized by narrow winding ridges and steep ridge slopes that alternate with nearly level stream valleys (Miller 1974). Elevations on these ridges can extend as high as 1,000 feet above mean sea level (AMSL). Other physiographic features of the region include sinkholes, caves, rock overhangs, and underground drainages resulting from the karst limestone topography.

The Western Highland Rim's geologic bedrock is primarily made up of Mississippian age limestone formations deposited 320–360 million years ago (MYA). Major geologic formations exposed in the project region include the St. Louis and Warsaw formations (Miller 1974). Other geologic strata present in this portion of the Western Highland Rim include Maury Shale and the Ft. Payne Formation (Miller 1974). Post-Mississippian geologic deposition in the region was minimal until the Cretaceous period (66–144 MYA). At that time, rivers flowing from the highlands northwest of Tennessee transported and deposited loads of cobbles, pebbles, and sand consisting of chert and quartz. These resources are still present throughout much of the Western Highland Rim.

SOILS

The soils within the project area are included in the Baxter-Mountview association, characterized by rolling to hilly well-drained soils with cherty hillsides and chert-free hill tops (Lampley et al. 1975).

Figure 3. North view of open field in the central portion of the project area.

Figure 4. West view of wooded area along the Cumberland River in the eastern portion of the project area.

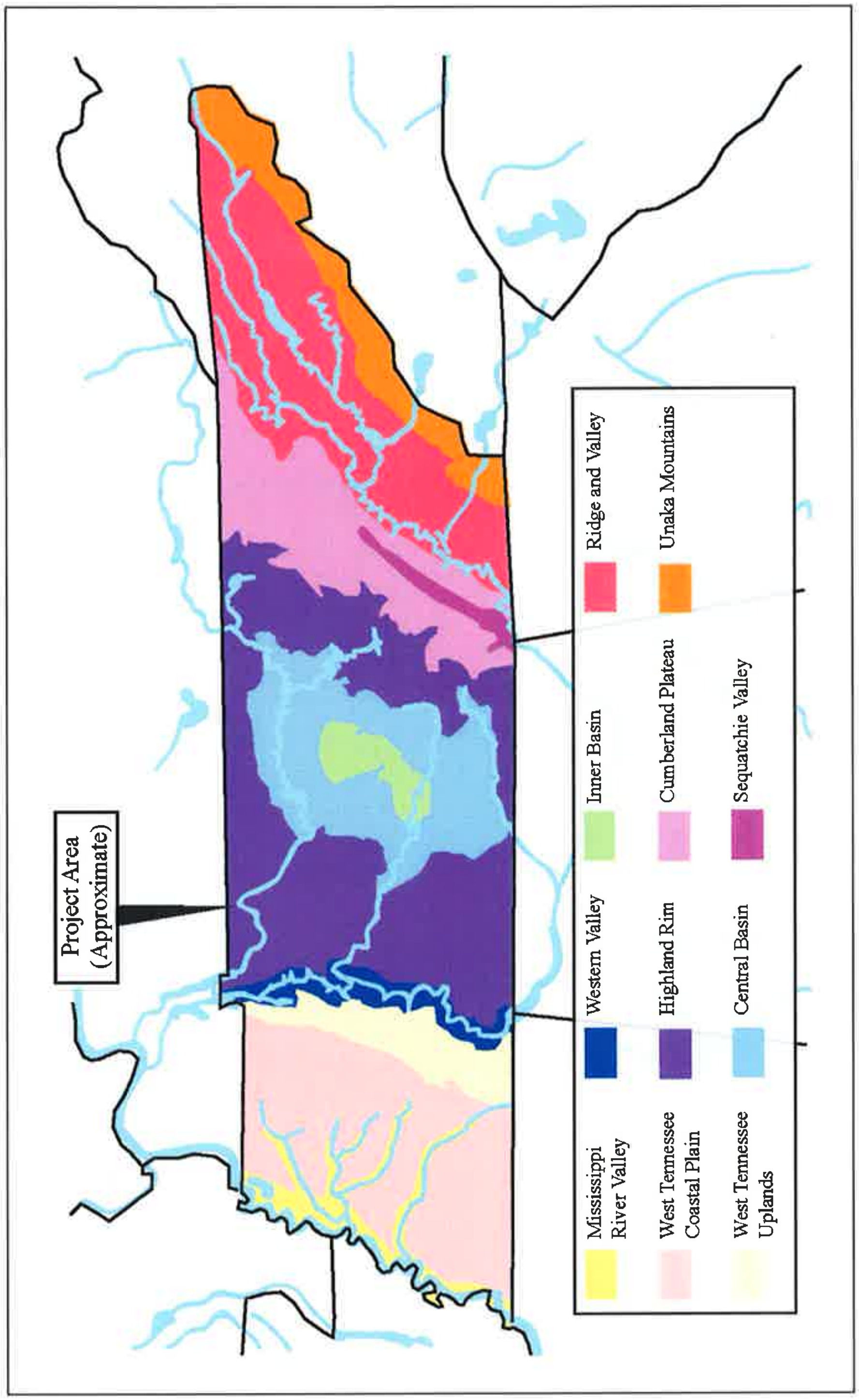

Figure 5. Project area location within the physiographic provinces of Tennessee.

MODERN CLIMATE

Climate in Montgomery County is mild in the winter and warm during the summer. At Clarksville, Lampley et al. (1975) have documented an average of 47.9 inches of precipitation per year. The average daily temperature ranges between 48–71 degrees, and the average annual temperature is 60 degrees. Long periods of temperature extremes are unusual for the area.

PALEOCLIMATE

The environmental setting of the project area has changed dramatically in the approximately 12,000 years since humans first occupied Tennessee. Humans first arrived in the American Southeast between about 10,000 and 12,000 years before present (B.P.), during the final stages of the Pleistocene epoch (ca. 1.8 MYA to 10,000 years B.P.). At that time the environment of the region was characterized by repeated glacial stages, punctuated by warmer interglacial periods. Full glacial conditions resulted in less seasonal variations and average temperatures 21–27 degrees Fahrenheit cooler than today (Bense 1994).

Sea level had dropped dramatically during the Pleistocene, reaching levels 100–119 m (330–390 feet) lower than today and exposing much of the continental shelf, including the Bering land bridge between Alaska and Siberia. During the Wisconsonian glaciation (ca. 28,000–18,000 B.P.), the great Laurentide ice sheet spread across much of North America above the Ohio Valley, covering portions of northern Iowa, northern and central Illinois, all of Michigan, approximately two-thirds of Indiana, northern Pennsylvania, and nearly all of New England and Long Island (Frison and Walker 1990).

Plant and animal species inhabiting the American Southeast during the late Pleistocene were in many ways close to modern species; many Pleistocene flora and fauna, including some conifers, mosses, flowering plants, insects, birds, and mammals survive to this day. In addition, a number of now extinct megafauna including mammoth, mastodon, bison, saber-toothed cats, giant ground sloth, horse, and bear roamed the Pleistocene Southeast. Pleistocene megafauna provided an important source of food for early inhabitants of the region.

The transition between the Pleistocene epoch and the ensuing Holocene (ca. 10,000 B.P. to present) is marked by fluctuations in global temperatures resulting in a gradual transition to interglacial conditions. As temperatures increased, the glaciers and ice sheets that covered much of North America began to retreat northward (Dawson 1994). Pine and spruce dominated boreal forests were established in the project area by about 14,000 B.P. (Delcourt and Delcourt 1981). As temperatures and precipitation continued to increase, these boreal forests were replaced by deciduous growth, including northern hardwoods such as oak, hickory, beech, birch, and elm (Webb et al. 1993).

The Holocene can be divided into three periods; Early, Middle, and Late. The Early Holocene (ca. 10,000–8,500 B.P.) is characterized by continuation of the warming trends established towards the end of the Pleistocene. Sea level continued to rise rapidly, and deciduous forests flourished throughout the region (Bense 1994). These provided an abundance of small game and plant species for use by the region's earliest inhabitants. Changing environmental conditions during the Early Holocene also contributed to massive extinctions of megafauna species. By about 8,000 B.P., these large animals were largely extinct, and vegetation in the project area closely resembled that of present conditions (Bense 1994; Delcourt 1979).

The Middle Holocene (ca. 8,500–4,000 B.P.), also known as the Altithermal or Hypsithermal Interval, marked the peak of interglacial conditions. The rise in sea level slowed, precipitation decreased, and temperatures increased as weather patterns changed (Bense 1994). Plant, animal, and human populations were forced to adapt to these altered conditions. By the Late Holocene (ca. 4,000 B.P. to present), the weather had again cooled, sea level had stabilized, and environmental conditions in the Southeast were comparable to today (Bense 1994). Since the beginning of the Late Holocene, coniferous species have steadily intermixed with the predominately deciduous forests of the region.

FLORA AND FAUNA

The Western Highland Rim also lies in the Mississippian Plateau section of the Western Mesophytic Forest Region. Vegetation in the project area includes mainly open pasture and forest. Mesophytic, deciduous hardwood tree varieties are found throughout the region and are represented by bodoc (Osage Orange), oaks, hickory, walnut, white oak, and persimmon. Coniferous species such as cedars and pines also are present in moderate numbers, as well.

The Western Highland Rim also is part of the Carolinian Biotic Province (Dice 1943). Fauna in the study area is typical of that found in the Western Valley and on the Coastal Plain. White-tailed deer, turkey, raccoon, opossum, skunk, squirrel, rabbit, and gray fox comprise the majority of modern-day mammals. Species that are no longer present but would have been hunted during initial European colonization and prehistoric inhabitation included black bear, elk, bison, and cougar. Waterways are inhabited by several varieties of fish (e.g., crappie, bass, catfish, and drum). Buzzard, red-tailed hawk, crow, quail, dove, killdeer, and several varieties of ducks and geese represent typical avian species in the area.

III. CULTURAL HISTORY

Human occupation of Tennessee and the project area is likely to have occurred continuously since at least 12,000 B.P. Over the course of this vast period both major and minor changes have taken place in various aspects of human behavior including technology, settlement patterns, subsistence strategies, population density, and social organization. Understanding the broad patterns of these changes and their specific regional trends helps investigators analyze the recovered information. Through comparison with local and regional data, it is possible to assign dates to certain artifacts and features, and to evaluate the nature and significance of site deposits.

The following discussion provides a general overview of the currently accepted trajectory of human development in the region, as documented in the archaeological record of Tennessee and the American Southeast. For organizational purposes, these 12,000 years are divided into two primary categories, Prehistoric and Historic Occupations. The discussion of the Prehistoric Period includes four generally recognized divisions: Paleoindian, Archaic, Woodland, and Mississippian. The description of these cultural sequences and their sub-periods is based largely on changes in temporally diagnostic artifacts, subsistence, and settlement. The chapter concludes with a discussion of historic occupations in Montgomery Counties, beginning in the sixteenth century.

PREHISTORIC OVERVIEW

Paleoindian Period (12,000–10,000 B.P.)

The earliest humans populations entered the Western Hemisphere sometime during the final glacial episodes of the late Pleistocene. The specifics of this migration, including the exact dates and routes of travel, are subject to ongoing research and widespread speculation. However, scholars generally agree that early populations moved into North America via the Bering land bridge and began to spread southwards by at least 12,000 B.P. It is likely that the earliest inhabitants of Tennessee arrived at least 11,500 years ago. A calibrated radiocarbon date of 11,700 +/- 980 B.P. has been obtained from charcoal associated with Paleoindian artifacts at the Johnson site (40DV400), located along the Cumberland River just east of Nashville (Broster and Norton 1996).

Paleoindian groups were efficient hunters and carried a variety of tools. The hallmark diagnostic artifacts of the Paleoindian period are fluted lanceolate projectile points (pp/ks). These large points exhibit parallel sides and feature shallow channels that have been removed from each face. Research on Paleoindian diagnostics suggests that in the southeastern United States this period can be somewhat arbitrarily subdivided into smaller subperiods, based primarily on changes in the morphology and distribution of fluted bifaces (Anderson 1990, 1995a, 1995b; Anderson et al. 1996; Morrow 1996). In Tennessee, large fluted forms including Clovis and Cumberland belong to the Early Paleoindian period (ca. 12,000–11,000 B.P.). Quad, Beaver Lake, and other smaller, generally unfluted forms have been assigned to the Middle Paleoindian period (ca.

11,500–10,500 B.P.). The Dalton point, the first pp/k to show evidence of extensive reuse and resharpening, has been placed in the Late or Transitional Paleoindian period (ca. 10,500–10,000 B.P.) (Bense 1994; Broster 1982; Walthall 1980). In addition to the highly efficient PP/K types mentioned above, Paleoindian peoples employed a variety of less distinctive stone and bone implements used for butchering and hide processing.

Paleoindian adaptation in Middle Tennessee, as well as across North America, was likely characterized by small, highly mobile bands that moved from place to place as preferred resources were depleted and new supplies were sought (Kelly and Todd 1988). The Middle and Late Paleoindian periods saw increases in the frequency of diagnostic point types, as compared with the earlier Clovis and Cumberland forms. This increase, which is especially dramatic along the Tennessee River in Tennessee and Alabama, suggests that Paleoindian populations increased dramatically as the Pleistocene drew to a close.

A number of Paleoindian occupations have been identified in the region surrounding the current project area, including the Puckett (40SW228) (Norton and Broster 1993), Adams (15CH90) (Sanders and Maynard 1979), and Knuckolls sites (Lewis and Kneberg 1958). University of Kentucky archaeological investigations at Fort Campbell identified five sites featuring Paleoindian components. These components were generally mixed and disturbed, or defined through surface collection (O'Malley et al. 1983).

Archaic Period (10,000–3,000 B.P.)

The Archaic period is distinguished within the archaeological record by technological changes from the Paleoindian period. Most notably, the onset of the Archaic period is distinguished by the cessation of fluted point manufacture, and the advent of numerous regional projectile forms, as well as a variety of specialized artifact types. In general, the Archaic tradition is associated with environmental changes that occurred at the terminal Pleistocene / Early Holocene transition, and the corresponding shift in adaptive strategies employed by human populations.

Early Archaic (10,000–8,000 B.P.) populations of the Western Highland Rim continued to subsist in ways closely resembling those of earlier Paleoindian hunters and foragers. However, in contrast to Paleoindian adaptations, the Early Archaic appears to represent a shift to a more localized subsistence pool based on the seasonal harvest of plant and animal resources. With the extinction of Pleistocene megafauna, small highly mobile bands hunted modern fauna such as white-tailed deer and wild turkey. Early Archaic sites, like earlier Paleoindian occupations, tend to consist of light lithic scatters usually found in multi-component contexts.

Throughout the Southeast, pp/ks produced during the Early Archaic were noticeably different from earlier Paleoindian forms. Beginning about 10,000 B.P., these artifacts became smaller in size, took on triangular shapes as opposed to earlier lanceolate forms, and begin to exhibit notched bases. It is generally believed that this shift in technology is related to the invention of the atlatl spear thrower. This tool greatly increased the force, accuracy, and distance with which projectiles could be launched, and allowed Early Archaic peoples to successfully hunt the smaller, faster game animals of the Early

Holocene. Early Archaic diagnostic artifacts include triangular chipped stone bifaces or pp/ks with side- and corner notched hafting elements including Big Sandy and Kirk Corner Notched forms. Two radiocarbon dates from the Puckett site (40SW228) on the lower Cumberland indicate Kirk and related components in the region by approximately 9,500–8,500 B.P. (Norton and Broster 1993; Walthall 1980).

The Middle Archaic (8,000–5,500 B.P.) is generally seen as a difficult time for prehistoric populations, coinciding with the warmer and drier Hypsithermal Interval (Pielou 1991). Local inhabitants may have experienced occasional long droughts during this period. It has been postulated that population density increased from the Early to Middle Archaic in most regions of the Southeast (e.g. Amick and Carr 1996; Anderson 1989; McNutt and Weaver 1985). This broad regional pattern is not so apparent in the upland sections of the Highland Rim, but appears to be rather dramatic in the Nashville Basin along both the Cumberland and Duck river drainages (Childress and Buchner 1992).

Diagnostic hafted bifaces indicating the onset of the Middle Archaic include various basally notched and stemmed forms, such as Eva, Morrow Mountain (ca. 7,000–6,500 B.P.), Sykes/White Springs (ca. 7,000–6,000 B.P.), and Benton (ca. 5,600–5,000 B.P.) types. The Middle Archaic material culture can also be distinguished from the Early Archaic by the advent of a more diverse stone tool kit. Middle Archaic lithic assemblages are characterized by supplemental use of shale, slate, quartz, and quartzite, in addition to non-local cherts. Personal ornamentations, including cut and polished shell, bone, and stone also appear with increasing frequency in the archaeological record during this time.

During the Late Archaic (5,500–3,000 B.P.), climatic conditions throughout North America were shifting to resemble the modern environment. This change resulted in increasingly moist conditions throughout the American Southeast, and a corresponding boom in local plant and animal life. Prehistoric peoples took advantage of the new, lush conditions by living along major streams where water, plants, and animals were plentiful.

Some Late Archaic groups lived for long periods of time in single, strategically placed locations that laid the foundation for later, fully sedentary villages (Wauchope 1966). The Robinson (40SM3) and Penitentiary Branch (40JK25) sites along the Cumberland River contain extensive prehistoric midden deposits with substantial amounts of Late Archaic material. Inhabitants of both sites exploited shellfish found in the shoals of the Cumberland River from ca. 3,600–2,450 B.P. (Cridlebaugh 1983; Morse 1967). Structural data from the Robinson and Bailey (40GL26) sites suggests the construction of oval or semi-rectangular houses with single wall posts (Bentz 1988). Seasonal base camps situated in protected coves may have served as hubs for the exploitation of upper tributary resources (Childress and Buchner 1992).

Numerous Archaic sites have been identified and investigated in the vicinity of the project area. During survey of Fort Campbell, O'Malley et al. (1983) identified 50 sites with components spanning all three sub-periods of the Archaic. Archaic components also appear at larger sites throughout the region including Nuckolls, Roach Village (15TR10) (Rollingson and Schwartz 1966), Dunbar Cave (40MT43) (Butler 1977), and Lawrence

(15TR33) (Jefferies 1990). Radiocarbon dates obtained from Late Archaic deposits at the Lawrence site cluster around 7,400 B.P.

Woodland Period (3,000–1,100 B.P.)

The Woodland period in Tennessee is also divided into three sub-periods: Early (3,000–2,200 B.P.), Middle (2,200–1,650 B.P.), and Late (1,650–1,100 B.P.). This period has been traditionally linked to decreasing mobility, population growth, and organizational complexity as manifested in the intensive cultivation of crops, establishment of well-defined village settlements, the construction of ceremonial mounds, and the appearance of pottery. However, recent research has proven that all these traditionally Woodland cultural markers have more ancient roots dating back to the Early and Middle Archaic (Fritz 1997; Sassaman 1993; Saunders et al. 1994). In this respect, the beginnings of the Woodland period in Tennessee mark only a gradual transition from subsistence and settlement patterns of the Archaic. However, technological refinement and ideological changes clearly distinguish the Woodland period from its predecessor.

The onset of the Early Woodland period (3,000–2,200 B.P.) corresponds with the widespread appearance of pottery. Distinct series of ceramic traditions, distinguished by stylistic and technological variations, are identifiable across the Southeast at this time (Bense 1994). South of the Cumberland valley in the Normandy region, the earliest ceramics belong to the Watts Bar series. The Watts Bar phase (ca. 2,700–2,400 B.P.) is characterized by quartz-tempered fabric marked wares and rounded base Adena projectile points. The subsequent Long Branch phase (ca. 2,400–2,150 B.P.) is characterized by limestone-tempered fabric marked wares of the Long Branch series and triangular McFarland-like projectile points (Faulkner 1992). In the vicinity of the project area, the earliest reported ceramics consist of limestone, chert, and quartz-tempered varieties recorded at the Lawrence site, dating to ca. 2,320 B.P. (Mocas 1991).

Early Woodland settlement throughout much of the lower Southeast appears to have been exemplified by fairly small sites exhibiting limited long-distance interaction and trade. Anderson and Mainfort (2002) suggest that Early Woodland village settlements in much of the region consisted of only a few structures, housing between fifty and sixty people per site. Notable exceptions to the theory of small, isolationist settlements include the Adena culture of central and eastern Kentucky and the Colbert culture of northern Alabama. Both these Early Woodland cultures exhibit a variety of non-local materials used in the manufacture of both mortuary and everyday artifacts (Clay 1998; Walthall 1980; Webb and Snow 1945).

While a variety of indigenous cultigens had been exploited prior to 3,000 B.P., the Early Woodland period saw the beginnings of intensive agriculture or horticulture (Watson 1989). Various plants, including goosefoot, maygrass, knotweed, sumpweed, little barley, and sunflower began to be systematically exploited, and in some cases show morphological variations suggesting the beginnings of domestication (Gremillion 1998, 2002; B. Smith 1992).

The most widely recognized markers of the Middle Woodland period (2,200–1,650 B.P.) are the appearance of exotic artifacts, burial mound construction, and iconography associated with an extensive, pan-Eastern Hopewellian culture, termed the *Hopewell Interaction Sphere* (Caldwell 1964; Seeman 1979). Artifacts associated with this exchange network, including greenstone celts, sandstone pipes, and insect effigy gorgets have been found in Middle Woodland burials throughout Middle Tennessee. These items reflect the ritual and symbolic disposal of non-subsistence goods as part of mortuary ceremonialism.

Starchy seed plants that began to be intensively exploited during the Early Woodland continued to be the focus of an expanding system of horticulture by Middle Woodland people, and cemented the cultural fluorescence that began during the Early Woodland period. In addition to carbonized plant remains, the manufacture of ceramic cooking and storage vessels, construction of storage facilities, and evidence of land clearing point to widespread agriculture during the Middle Woodland (Delcourt et al. 1998; Gremillion 1998, 2002). Although not found at sites in the western third of the state, maize (corn) remains recovered from sites along the Little Tennessee River in East Tennessee have yielded calibrated dates of ca. 1,800 B.P. (Chapman and Crites 1987). Corn is thought to have played only a minor role in prehistoric diets until about 1,200 B.P. (B. Smith 1992).

The Early Woodland Watts Bar and Long Branch phases in the Normandy region are followed by the Middle Woodland McFarland phase (ca. 2,200–1,800 B.P.). The triangular, unnotched projectile points that define this phase typically occur with plain, simple stamped, and check stamped, limestone-tempered pottery (Faulkner 1988). As originally defined, the McFarland phase includes the Elk and Duck River valleys on the Eastern Highland Rim and possibly areas along the upper Caney Fork River (Faulkner 1988; Jolley 1979). However, assemblages similar to McFarland phase occupations have been identified in Middle Woodland occupations in Trousdale and Perry Counties (Peterson 1973; Weaver and McNutt 1981).

The Late Woodland period (1,650–1,100 B.P.) is less well defined in the region than earlier Woodland subperiods. Traditionally, the Late Woodland has been seen as a time of turmoil, conflict, and cultural decline throughout the Midwest and Southeast (Kneberg 1952; Dragoo 1976). However, recent research has indicated that Woodland cultural markers (i.e. ceramic production, mound building, intensive agriculture) show no sign of retreat during the Late Woodland (Jefferies 1994; Nassaney and Cobb 1991; Wood and Bowen 1995). Shell-tempered pottery, which first appeared during earlier portions of the Woodland period, becomes the standard during this time.

Perhaps the most significant technological advance of the Late Woodland period was the introduction of the bow and arrow. This technology was introduced from the West or Northwest around 1,400 B.P., and quickly spread throughout the Southeast. PP/K styles changed dramatically to suit the needs of the new technology (Bense 1994; Blitz 1988). Smaller, lighter Madison and Hamilton types diagnostic of the Late Woodland reflect this adaptation.

Mississippian Period (1,100–300 B.P.)

The Mississippian period has been the subject of much research throughout the Southeast. Its cultural manifestations began along the middle course of the Mississippi River between present-day St. Louis, Missouri and Vicksburg, Mississippi. Mississippian culture underwent major development at the site of Cahokia in the American Bottom, and spread primarily along major river systems to all parts of the Southeast (Hudson 1976).

From 1,000 B.P. until initial European contact about 400 years ago, Mississippian societies controlled local and regional territories along most of the large rivers in the interior Southeast, including the middle section of the Cumberland River and adjacent portions of the Nashville Basin. Mississippian populations were substantial, and centered in permanent villages that far exceeded those of the Woodland period in size. These villages were primarily supported by floodplain agriculture centered on intensive maize cultivation. Remains of this cultigen have been recovered from archaeological contexts at sites in Middle Tennessee including Spencer (40DV191), and Mound Bottom (40CH8). In addition to maize, Mississippian populations relied on other domesticants including beans and squash. Domesticated crops were further supplemented with wild foods that had contributed to aboriginal diets in the southeast for previous millennia, including wild plants and animals such as nuts, berries, greens, deer, turkey, and aquatic animals.

The focus on maize as a primary food crop and the generally increased commitment to agriculture had significant impacts on the organizational complexity of aboriginal societies in Middle Tennessee. The relatively egalitarian Woodland societies of the region were apparently transformed into more hierarchical constructs with new emphases on hereditary leadership and the emergence of managerial organizations. Compared to work on the Mississippian emergence in the eastern portion of the state (e.g. Schroedl et al. 1990), much research remains to be done on this phenomenon in the Nashville Basin and the Western Highland Rim.

In our current understanding of Mississippian settlement patterns, isolated villages and farmsteads were linked to regional ceremonial centers that were the focus of important religious and social activities. Larger Mississippian towns were often planned around a central plaza and included one or more flat-topped, truncated substructural mounds. Mississippian mounds served as foundations for religious structures and the locations for residences of high-status individuals. Social stratification was reinforced through differential access to non-subsistence items such as conch shell jewelry, native copper, and non-utilitarian chipped stone items, as well as esoteric knowledge.

The Mississippian period saw a resurgence of shared regional religious icons similar to those manifested under Hopewellian influence during the Middle Woodland period. This ideological assemblage is commonly referred to as the *Southeastern Ceremonial Complex* and is defined by a shared body of symbolism, artistic motifs, and artifact types (Waring and Holder 1945). Common motifs include the forked or weeping eye, the hand-eye, the bi-lobed arrow, the cross with a sunburst circle, and representations of anthropomorphic beings. This iconography often appeared on shell gorgets, embossed copper and stone plates, pottery, stone maces, and a variety of other elaborate and specialized artifacts.

While the structure of the Southeastern Ceremonial Complex centered on religious iconography and prestige goods, the complex seems to have also served the centralization of political authority in Mississippian cultures.

Status distinctions were also reflected in variations among Mississippian burials. Burials of higher status individuals usually occurred in conical mound earthworks. Distinctive stone box graves of the "middle Cumberland culture" are considered regional markers of Mississippian mortuary activity (K. Smith 1992). These graves, lined with slabs of limestone, often include elaborate non-utilitarian funerary furniture and one or multiple human burials. Stone box graves also appear in earth mounds. These were apparently erected by arranging numerous stone box coffins in tiers or layers before piling up dirt to create a mound. Low status individuals were interred in family cemetery plots near their residences.

Lithic assemblages during the Mississippian period are much less complex than those of the previous cultural periods. This may result from an increased use of more perishable items such as bone, antler, and shell, which typically do not survive well in the archaeological record. However, triangular points such as Madison, Fort Ancient, and Hamilton are present, as well as hoes manufactured out of both local and non-local chert. Mill Creek chert, native to central Illinois, was used in production of hoes that were apparently traded across wide regional boundaries. Other artifacts typical of the Mississippian period in Tennessee include ground stone items, engraved shell items, mica, and galena. Around 1,000 B.P., plain and surface-decorated, shell-tempered ceramics became the dominant types in Mississippian assemblages. Small sandstone discoidals are diagnostic for upland Mississippian occupations on the Highland Rim (Jolley 1979).

It appears that there was a rapid and rather substantial population decline or abandonment during the late Mississippian period (ca. 550–450 B.P.) in an area that encompassed from the mouth of the Ohio River to Cahokia at East St. Louis, to the Arkansas/Missouri border, up the Ohio to near Evansville, Indiana, and finally up the Cumberland River to the Nashville Basin (Williams 1980, 1983, 1990). The region does not appear to have been entirely abandoned, but rather the large Mississippian mound centers and fortified villages were left virtually unattended in comparison to earlier high population levels. It appears that this hypothesis has some merit, due to the lack of sites in the Nashville Basin with aboriginal components post dating this era.

HISTORIC OVERVIEW

Little is known about the protohistoric populations of the Western Highland Rim, as the sixteenth century de Soto and Pardo expeditions were confined to the eastern portions of Tennessee. Permanent Shawnee settlements were reported in the Cumberland River valley in 1681 A.D., where they had apparently migrated from the Ohio River area (Swanton 1979). The Shawnee are usually recognized as the last Native American group to have occupied the Cumberland River valley in permanent settlements (Maggert and Sutton 1986). The Cherokee and Chickasaw expelled the remaining Shawnee prior to

1710 (Clayton 1880). During the period following 1710, both the Chickasaw and Cherokee subsequently claimed the region as hunting territory, neither tribe permanently settled in the area. The Overhill Cherokee settlements in the Appalachian region were the only sizable Native American settlements in the state from the early eighteenth century onwards.

European explorers first made their way into the Cumberland Valley beginning in the early eighteenth century. Sometime around 1710, French traders established a store and fort at French Lick, which would later become Nashboro and eventually Nashville. The first American settlers arrived at French Lick in December 1779, lead by Captain James Robertson (Clayton 1880). In 1768 the first known map of the Cumberland area was produced by the Thomas Hutchins survey (Beach 1964). This map included the location of Red Paint Hill, a site below the mouth of Red River that was employed in later times as an important riverboat landmark along the Cumberland.

Montgomery County

Montgomery County is one of Tennessee's oldest counties, and was created in 1796, the same year the state was organized from land formerly associated with North Carolina. Prior to Tennessee's recognition as a state, the region was known as "Tennessee County," and included the area presently associated with Robertson County (Montgomery County Historical Society 2000). Euro-American settlement was well established by the mid-1770s (Goodspeed 1886).

The county was named for John Montgomery, a native Virginian who arrived in Middle Tennessee in 1780 as a member of John Donelson's expedition party. In 1785, Montgomery was appointed commissioner of Clarksville and later served as a justice of the peace for the county and a militia colonel (Goodspeed 1886). White settlement in the region provoked numerous attacks by Native Americans, and in particular by the Cherokee. One of the most aggressive series of attacks occurred during the early 1790s, when Valentine Sevier, brother of the state's first governor John Sevier, settled on the Cumberland River near present-day New Providence. Sevier constructed a blockhouse known as "Sevier Station," which the Cherokee attacked in 1791, killing his three sons (Waters 1983). In 1794, the station was again attacked. Sevier moved to Clarksville in 1796 where he remained until his death in 1800.

The town of Clarksville was established in 1784 on 640 acres of land along the east bank of the Cumberland River owned by John Montgomery and Martin Armstrong. The town was named in honor of General George Rogers Clark, "a distinguished officer known to all early pioneers" (Goodspeed 1886:809). The town was little more than a trading post during its early years, prior to the arrival of the steamboat and railroad. In 1796, Tennessee County became Montgomery County, at which time Clarksville was designated the county seat. At that time, a log courthouse, jail, and stocks were commissioned (Waters 1983). A brick building constructed in 1811 served as the courthouse until 1843, when a new building was erected. In 1878, this building burned and was replaced by another brick structure on the site of the current county courthouse

(Goodspeed 1886). The present courthouse was virtually destroyed by a tornado in 1999 and, as a result, has been renovated to its current appearance.

Montgomery County's early schools were typical of those found in most Tennessee counties. Initially, schools were privately funded due to lack of federal, state, or local monies. Private academies established in 1814 (Sparta Academy) and 1818 (Spring Creek) are the earliest known schools in the county. The Clarksville Female Academy opened in 1846 and became one of Clarksville's most successful educational facilities. Although the state funded public education as early as 1806, most schools were privately owned and operated by religious institutions and local organizations. After the Civil War, the state again provided public funds for school construction, at which time two brick schools were constructed in Clarksville, one for whites and one for blacks. A county high school was constructed in 1906–1907. Austin Peay University, located near downtown Clarksville, grew out of an early college established in 1806. The school transformed itself many times, including a period of time in which it was owned and operated by the Presbyterian Church. The state acquired the school property in 1925, at which time it became Austin Peay Normal School (Beach and Williams 1989).

Religion played an integral but limited role in early county development. Baptists settled in the area as early as 1791, when they formed the Red River Baptist Church. A more formal Baptist organization arrived in 1808, when a church was constructed near Spring Creek. Methodists also arrived during the early years of Montgomery County. Prior to 1800, Methodist circuit riders incorporated the region into their routes. In 1870, Clarksville supported eleven churches, including one Baptist, two Methodist, two Episcopalian, two Presbyterian, one Christian, one Catholic, and two "African" (Killebrew 1870:6).

Early transportation relied upon the Cumberland and Red rivers. Flatboats constructed at Port Royal in Montgomery County were utilized for transporting goods in and out of the county until the steamboat arrived in 1820. Clarksville's trade remained limited with these early modes of transport, although trade was established as far away as New Orleans. Steamboats assisted in the exportation of tobacco, which became an important cash crop during the nineteenth century (Killebrew 1874; Waters 1983; Winn 1998).

County roads originated from footpaths utilized by Native Americans and early explorers. As settlement increased and mills began operating along the rivers, residents petitioned the county to develop improved roadways. The earliest attempts to improve roads included the development of turnpikes, in which tolls were charged to build, improve, and maintain the roads. The county's earliest toll roads included the Clarksville and Russellville Turnpike (completed in 1830) and the Clarksville and Hopkinsville Turnpike (completed in 1838). The federal government funded construction of "post roads," in which routes were developed for mail delivery (Beach and Williams 1989:39–40).

Montgomery, Stewart, and Robertson counties (as well as counties in southeastern Kentucky) comprised what came to be known as the "Clarksville District" (Goodspeed 1886:750). During the late nineteenth century, this area transported tobacco to markets internationally. Between 1900 and 1904, large tobacco interests created a trust and gained control of Clarksville's world markets. This, coupled with increasing federal taxation, led to a sharp decline in tobacco production and resulted in several incidents of violence among local farmers (Waters 1983).

In addition to tobacco, the Clarksville area also produced staple crops including wheat, hay, potatoes, clover, and corn. Local caves provided cool storage areas for produce, which promoted fruit production (Killebrew 1874). In 1870, the county formed its first grange, the "Farmers Club," which led to the rapid development of several agricultural organizations throughout the region (Waters 1983:82–83).

Industry also played an integral role during the early development of Montgomery County. Prior to the Civil War, the county's primary industry was iron production. Timber was used to produce charcoal to heat furnaces and forges for iron processing (Goodspeed 1886). Montgomery County reached its peak of iron production in 1856, although it continued to transport iron out of the region until the mid-1930s (Beach and Williams 1989; Killebrew 1870). Because of the county's numerous waterways, milling was also important during the nineteenth century. A mill established in the Ringgold community in 1810 is located within the current project area. By 1870, the county supported 13 flour mills, which produced 70,000 barrels of flour annually. Dairy farming became important during the late nineteenth century (Killebrew 1870).

The arrival of the railroad dates to the mid-nineteenth century. In 1852, the Memphis, Clarksville and Louisville Railroad was incorporated. By 1860, the line extended to Clarksville (Beach and Williams 1989). The route stretched diagonally across the county and intersected with the Nashville and Henderson line at Guthrie City, Kentucky. The latter train line provided service to New York, Philadelphia, Cincinnati, Louisville, Memphis, and New Orleans (Killebrew 1870). Service continued until 1862, when the Confederate Army burned the bridge across the Cumberland River to restrict Union occupation (Beach and Williams 1989). In 1881, the county sought service through the Indiana, Alabama and Texas Railroad to exploit its iron-ore beds (Goodspeed 1886). The line was consolidated with the Mobile, Clarksville and Evansville Railroad, which extended to join the Louisville and Nashville (L&N) Railroad north of Clarksville. L&N acquired the entire route in 1887 and continued service until 1933. The northern railroad routes served agricultural export needs, while the southern lines transported iron out of the county until 1936 (Beach and Williams 1989).

Historic Settlement Before the Civil War

The first permanent American settlers to the Cumberland region arrived at French Lick in December 1779, led overland by Captain James Robertson (Beach 1964; Clayton 1880). On February 27, 1780, Colonel John Donelson, along with a flotilla of about 40 boats, left the Holston settlements and floated and poled down the Tennessee and brought more settlers to Fort Nashborough. Of the original 260 persons in this expedition, a little of over 200 remained. The earliest permanent settler in what was to become Montgomery County was Moses Renfroe. He and his companions parted from the main body of the Donelson expedition on March 22, 1780, and struck out on their own up the Red River to Person's Creek. In the early summer months a Choctaw-Chickasaw war party attacked

Renfroe's Station and killed and wounded several settlers including Nathan Turpin (Beach 1964).

From 1780 to 1783 the Cumberland Association, in what would become Davidson County, established eight frontier stations (forts) in the Cumberland valley. In addition to serving as protection from hostile Indians, these stations were local seats of government (West 1998). Apart from the settlements along the Cumberland River near Nashborough, the stations along the Red River and its tributaries formed their own compact. In late January 1785, a majority of the settlers of Clarksville met and formed their own "confederation," asserting their right to local government and vowing to not enact regulations contrary to the shortly anticipated U.S. Constitution. They established the Clarksville Compact that created a tribunal of four magistrates and a sheriff that lasted until November 1787 (Beach 1964). From 1780 to 1795, Prince's, Nevill's, and Clark's (now Clarksville) stations, with others, successfully defended the vicinity from hostile incursions by Native Americans challenging American settlement in the region (although casualties were common and numerous). In 1784, John Montgomery and Martin Armstrong received a 640-acre land grant, surveyed it, constructed a blockhouse, and began selling lots for settlement. Two hundred of these acres were set aside for the town and its public buildings (Beach 1964). On December 29, 1785 the North Carolina Legislature officially established the Town of Clarksville as the county seat of the newly created Tennessee County (West 1998).

Recent interpretations of the early settlement and formative periods of Middle Tennessee history describe it as a distinct and influential sub-domain of the South, definable in terms of physiography, climate, economy, settlement pattern, and society. Geographer Sam Hilliard has described this area succinctly as "an island of agricultural productivity surrounded by marginal plateau lands" (Hilliard 1984:10). This "island" of prosperity also encouraged a certain social distinctiveness for settlers of the area, with one assessment noting that it was a region whose geography, demography, and social patterns suggested conflict and separation from the lower South. Historian Stephen Ash sees Middle Tennessee during its formative period in the late eighteenth and early nineteenth century as a "third South," suspended between "the egalitarian, non-slaveholding South of the yeoman farmer and . . . the plutocratic, plantation South of the cotton nabobs" (Ash 1988:xi, 9).

In 1820, steamboats began to appear along the Cumberland River at Clarksville, opening that waterway up to ship traffic that could transport goods faster and cheaper than traditional overland routes. The social distinctiveness of Middle Tennessee during the early nineteenth century arose in part because of its prosperity, which was based on generalized agricultural production rather than on a monocrop economy. The farmers of the region produced surpluses of grain and meat for which "other Southerners elsewhere were hungry" (Ash 1988:16). These farmers did not participate in the cotton boom of the later antebellum years in part because of climatic restrictions, but also because of a conscious choice of a production strategy focusing on the strong returns available from producing corn, wheat, and livestock. Cotton did produce more money for Middle Tennessee farmers than any other single crop, but the amounts of cotton grown in the region decreased steadily during the decades leading up to the Civil War (Ash 1988:17–

18). However, Clarksville was primarily known as a tobacco center. In 1850, Clarksville was thriving and had a population of nearly 2,600. In 1858, over $2.3 million of dark fired tobacco was exported from the small town to markets overseas (West 1998). In 1859–1860, the railroad came to Clarksville. The Memphis, Clarksville, and Louisville Railroad coupled the growing city to a vast regional transportation network and greatly increased its economic importance.

Enslaved African Americans were present in Middle Tennessee from the earliest years of American exploration and settlement, and the institution of slavery had a strong influence on social and economic development in the region. The demographics of slavery in Middle Tennessee were another factor setting it apart from the rest of the South. In 1850, 46.2 percent of all white families in two key Middle Tennessee counties (Davidson and Maury) owned slaves, with an average holding of 11.5 people (Mooney 1957:190). In 1860, there were between 10,000 and 13,000 slaves in Montgomery County (West 1998). The common figure cited for the proportion of white families owning slaves in the South is 1 in 4, and the average holding was 12.7 in the Deep South and 7.7 slaves in the Upper South (Stampp 1956:30–31, based on the 1860 federal census). Although over half the white families in Middle Tennessee did not own slaves, all saw slavery as part of the accepted social order, as the necessary means for producing wealth, and as a marker of social achievement. Ash points out that in Middle Tennessee, "it was necessary to own slaves" in order to become part of the social and economic elite. "The idea of hiring labor, or of being rich without Negroes, was apparently incomprehensible" (Ash 1988:44).

One of the more interesting but often overlooked facets of the historical development on the Western Highland Rim in Tennessee is that the iron ore industry that thrived from as early as ca. 1795–1796 (Burchard 1934; Daniel 1970). In order to encourage iron production in Tennessee while it was part of the Territory South of the Ohio River (1790–1796), the Federal government offered 3,000-acre land grants to individuals who produced a certain quantity of iron within three years. An early ironworks, known as the Cumberland Furnace, was operated in the last decade of the eighteenth century in Dickson County. In Montgomery County, a furnace located at Palmyra was reported in a 1799 journal (Williams 1928). Several additional ironworks were operating on the Highland Rim in Montgomery, Dickson, and Hickman counties during the first few decades after Tennessee achieved statehood (Coxe 1814:141; Goodspeed 1886:773; Henry 1968:39). In 1809, the Tennessee Legislature formally adopted a law that encouraged the building and operating of ironworks within two years by offering 3,000-acre land grants with 99-year property tax exemptions (Nave 1953). Beginning during the 1830s, the iron industry grew rapidly, peaking around 1854.

By 1860, the number of ironworks had sharply declined to 16, a reflection of the general nationwide economic downturn, rather than as a result of Civil War deprivations. One causal factor (real or perceived) of this decline in the regional iron production was the "Slave Insurrection Panic of 1856" (Wish 1939). In December of that year, a large number of slaves "employed" at iron facilities in Stewart and Montgomery counties allegedly were organized and conspired in a plot to overthrow their overseers and escape to the North. Many slaves subsequently were arrested by the local constabulary and were whipped or executed for their role in such a plot (if it ever existed). The general uneasiness and fear felt by the small ironworks' owners may have prompted closure of some these facilities (Stephens 1934). However, the steadily increasing costs of slave labor, higher rising overhead costs, and the general economic depression during 1856–1857 surely played a more important role in closing the doors on some of the less profitable operations in the region.

After the Civil War, the Western Highland Rim iron industry never regained the prominence that it once enjoyed during the antebellum days. During the late 1880s, a period of railroad building injected the anemic industry with some new life. In 1888, numerous rail spurs were built to service these ironworks and their mining operations (Sulzer 1975). This facilitated the development of large company towns along these routes and allowed coke from East Tennessee to be effectively transported into the region at a cheaper price. By the mid-1890s, most of the Highland Rim ironworks were owned by the Southern Iron Company, headquartered in Nashville. The Southern Iron Company attempted to facilitate the production of steel at its Chattanooga facility utilizing Western Highland Rim pig iron, but this attempt was abandoned in favor of other more profitable investments (Killibrew 1897). After the turn of the century, few new iron furnaces opened and those pre-existing operations steadily closed. Only one new furnace was opened on the Highland Rim after 1907, and production in the region again dropped dramatically in the early years of the twentieth century. Profitably operating an ironwork in Tennessee became next to impossible in light of the decline of Tennessee contributions to the national iron supply. By the 1930s, the last ironwork on the Western Highland Rim had failed and closed.

The Civil War, Clarksville, and the Cumberland

Montgomery County and the surrounding countryside have produced a number of distinct Civil War components within and around the city of Clarksville (see Ezell and McKee 2001:Figure 4). Recent historical research and archaeological excavations by TRC at Fort Defiance (40MT287) overlooking the mouth of the Red River at Clarksville/New Providence has provided a clearer insight into the large role that Montgomery County played during this time in Tennessee history (Ezell and McKee 2001).

On June 8, 1861, Tennesseans voted to secede from the Union and joined the Confederate States of America. Tennessee was to supply 55,000 men for the Southern cause (Beach 1964). Nashville served as an important supply center and was a major target for the northern army from the beginning of the conflict. Fort Donelson, a Confederate fortress guarding the approach to Nashville along the Cumberland River, surrendered to forces commanded by General U.S. Grant on February 16, 1862 (McRaven 1949). Nashville was then quickly abandoned by General Albert S. Johnson and became the first major southern city to fall to the Federal Army.

Clarksville voted 561 to 1 in favor of joining the Confederacy and cutting ties to the Federal union. Fortunately, the town did not see any major military engagements during the war but it played a vital part in the logistical support of the Federal Army in Tennessee, especially at occupied Nashville. Although not a focus of severe military aggression, Montgomery County was home to numerous training grounds and staging areas for newly raised Confederate regiments.

After the quick fall of Forts Henry and Donelson on the Tennessee and Cumberland Rivers in February 1862, Federal gunboats turned their attention toward destroying the important railroad bridge at Clarksville (*O.R.,* 1, VII). On February 20th, Admiral A.H. Foote sailed to Clarksville with the Union gunboats, the *Conestoga* and the *Cairo*. Upon reaching the city, he found Fort Sevier (a.k.a. Fort Defiance) abandoned. Foote reported finding three mounted cannon at Fort Sevier, three at the fort "near the city" (Fort Clark) and two cannon in a small fort a short way up the Red River (Beach 1964). The City formally surrendered to Adm. Foote, and Colonel Joseph Webster was left in command of Clarksville.

Following the fall of Atlanta in September 1864, General Hood attempted to recapture Middle Tennessee. The largest military engagement fought during the war in the vicinity was the battle of Nashville on December 15 and 16, 1864. General Hood with a force of 20,000 men, engaged General Thomas commanding a force of 55,000 men. The Federal forces drove out the out-manned and under-supplied Confederates to Mississippi. This left almost the entire State under Union control (West 1998). For the remainder of the war no major Confederate offensives were launched against the Union army at Clarksville or in Middle Tennessee. Confederate military actions were limited to small skirmishes and guerrilla raids against the firmly entrenched Federal army. On May 31, 1865, orders were given for the 83rd Illinois Infantry to muster out of Clarksville (Loughry 1986). General Robert E. Lee had surrendered his army of Virginia at Appomattox Courthouse in April. The war was finally finished.

Clarksville After the Civil War

Normalcy was slow to return to Clarksville and Montgomery County after the Civil War. The depredations experienced by the local populace were difficult to erase. The Freedman's Bureau became active in the education and social advancement of ex-slaves. By the late 1870s blacks in the community recognized they held a powerful political weapon. In 1878 they elected numerous blacks to local and state government to equalize the political and economic playing field. By the turn of the twentieth century planters around Clarksville had again become a major producer of dark-fired tobacco, and they formed the Eastern Dark-Fired Tobacco Growers Association to serve as a focal point for pressing their interests in competition with the American Tobacco Company (West 1998).

Throughout the early twentieth century, the Clarksville area remained focused on agriculture and industrial growth was slow. In 1941, Camp Campbell was established as an army base just northwest of the city. In 1942, Fort Campbell as we know it today was created and has been a driving force in the local economic scene into present times. Urbanization and Interstate 24 have combined to radically alter the social and economic landscape of the surrounding area.

IV. METHODS

BACKGROUND RESEARCH

Prior to initiating the Phase I fieldwork, TRC personnel conducted a background literature and records search in order to identify known historical and archaeological sites in the project area and to develop the historic context for the study area. The background search included research on the state archaeological site files at the TDOA, the NRHP listings and pending files, and historic structures and buildings files located at the THC in Nashville, TN. Additional and more thorough documentary research of the project area was conducted at the Tennessee State Library and Archives prior to conducting Phase II archaeological investigations at site 40MR978.

FIELD METHODS

Phase I Survey

The Phase I archaeological survey combined systematic pedestrian examination of all exposed ground surfaces and shovel testing of land having poor surface visibility. Those areas with greater than 50 percent ground visibility and/or greater than 20 percent slope were visually inspected for cultural materials along transects spaced 15-m apart within the APE. Areas that were relatively level and contain less than 50 percent ground surface visibility required systematic shovel testing at 30-m intervals. Shovel tests consisted of 30 x 30-cm excavations into subsoil. Soil was screened through ¼-inch mesh hardware cloth to insure uniform artifact recovery. Notes were maintained on each shovel test excavated.

Once an archaeological site was identified, shovel testing was conducted in a cruciform pattern (north-south, east-west) across the site within the APE at 10-m intervals to define the site boundaries and gather data on the horizontal and vertical artifact distributions at the site. All excavated dirt from those tests was screened through ¼-inch mesh hardware cloth, and all artifacts were segregated by provenience. All identified sites were photographed, and standardized notes were taken on the site and landscape. Sites were mapped using hand-held GPS equipment, and all site boundaries were flagged and labeled in a way that will be visible and understandable to construction crews. TDOA Site Survey Forms were completed for all sites identified during the survey.

Phase II Test Excavations

Two overall goals were paramount for the Phase II archaeological investigations: 1) to evaluate the integrity and eligibility of archaeological deposits at site 40MT978 for the NRHP pursuant to 36CFR60.4; and 2) to obtain data sufficient for producing a research design for data recovery in the event that the site cannot be avoided. In order to achieve these goals, it was necessary to pursue several specific objectives. These objectives are as follows:

- Determine the presence of undisturbed subsurface features or stratified deposits.
- Determine the density and distribution of intact archaeological deposits within the APE.
- Determine the classes of archaeological remains retrievable.
- Determine the chronological and cultural affiliations for the components represented.

To achieve these goals the Phase II testing at site 40MT978 involved the hand excavation of eight 1 x 1-m test units to determine the overall nature of the archaeological deposits. Test units were placed according to analysis of landforms and artifact concentrations recorded at the site during the Phase I survey. All soil excavated from the 1 x 1-m test units was passed through ¼-inch mesh hardware cloth. Test units were dug in standard 10 cm increments. All artifacts recovered from within each level were placed in plastic bags labeled with their associated provenience. An excavation unit/level summary form was used to record critical information such as elevations, soil/artifact descriptions, and names of excavators, as well as to summarize the results of excavation. At least one profile was drawn for each unit at the site to maintain a complete stratigraphic record. Profiles included Munsell designations for soil types recognized within the natural strata and intact cultural features. Temporally diagnostic artifacts, such as projectile points and ceramics, found *in situ* within each level, were piece plotted and mapped, assigned a unique specimen number, and placed within their associated level bag.

The field director maintained a daily journal detailing each day's activities, findings, and other aspects pertaining to archaeological testing at the site. A complete master plan map was created for the site. A complete photographic record of all testing procedures was kept. This includes the taking of both black-and-white negatives, color slides, and color digital images of field techniques, test units, natural and cultural strata, exposed subplowzone transects, artifacts, and encountered features and intact cultural deposits.

LABORATORY METHODS

All artifacts, notes, forms, film, etc. were transported to the TRC office in Nashville for processing and analysis. Artifacts were then washed with brush and water and air-dried. Next, the artifacts were sorted based on the sorting criteria described below. The focus of the laboratory analysis was geared to determine the occupation span, possible function, and degree of artifact preservation at each site, as well as gather the data necessary to make evaluations regarding National Register eligibility. Laboratory analysis included the comprehensive description of recovered artifacts using well-established, temporally diagnostic types. After the analysis, all artifacts were placed into reclosable plastic bags labeled with the pertinent descriptive and provenience data. During the analysis all artifacts were segregated by type and morphological attributes (if discernable).

Prehistoric Lithic Analysis

The lithic artifact sample initially was divided according to the presence or absence of positive percussion features. Those exhibiting only negative flake scars were included in the "core" category (i.e., all types of cores and formal bifaces). Cores were further sorted by morphological attributes into more descriptive categories (e.g., PP/K, bifaces, unifaces, etc.). Those items with positive percussion features (interior or ventral surfaces) were segregated by the presence or absence of retouch. The resulting retouched artifacts were further subdivided according to morphological characteristics. Evidence of heat treatment exhibited on all lithic artifacts was also noted during the analysis. The signs of heat-treatment are many and variable. Surfaces of heat-treated lithic debitage or tools may appear cracked or exhibit numerous pot-lid fractures. Also, a fine luster generally develops across the surface. After the initial sort was completed, chipping debris, flake fragments, and broken flakes were segregated from the remainder of the assemblage. Basic lithic typological groups used during this stage of the analysis are provided below.

Core Debitage

Tested Cobble. Cobble with one or more striking platforms, exhibiting a minimal number of flakes removed to test raw material quality.

Exhausted Cores. Cobble with most or all of the cortex removed, one or more striking platforms, and evidence of primary-flake production from two or more flake faces; usually less than 5 cm in size.

Core Fragments. Broken fragments of cores with one or more striking platforms or some evidence of flake production.

Flake Debitage

Primary Flake. Flake with more than 50 percent of the dorsal surface covered by cortex; contains all or a portion of striking platform; no presence of flake scars on dorsal surface; represents initial decortification.

Secondary Flake. Flake with less than 50 percent of the dorsal surface covered by cortex; contains all or a portion of striking platform; negative scars are present on dorsal surface; represents secondary decortification.

Tertiary Flake. Flake with no cortex on dorsal surface or platform; contains all or a portion of striking platform; negative flake scars are present on dorsal surface; represents final reduction of decorticated core by either pressure or percussion flaking.

Flake Fragment. A broken flake lacking a striking platform. By amount of cortex present can be subdivided into primary, secondary, and tertiary flake fragment.

Formal Tools

Side Scraper. Uniface exhibiting primary flaking on dorsal surface of flake blank and secondary flaking primarily on the lateral edges.

End Scraper. Uniface exhibiting primary flaking on dorsal surface of flake blank and secondary flaking primarily along the distal end.

Primary Biface (whole or fragment). Shaping consists of only primary flaking; biface edge is sinuous and biface cross-section is thick and irregular; usually retains a portion of cortex; usually represents an unfinished tool.

Secondary Biface (whole or fragment). Shaping consists of primary and secondary flaking; most or all cortex has been removed; flaking is more systematic; biface edges are less sinuous and biface cross-section is relatively thin and lenticular; represents a late-stage production failure or preform.

Tertiary Biface (whole or fragment). Shaping consists of secondary and tertiary flaking; cortex is virtually absent and flaking is systematic; biface edges are straight and cross-section is thin; usually represents an unidentifiable finished-tool fragment (e.g., PP/K mid-section or distal tip).

Projectile Point/Knife. Shaping usually consists of primary, secondary, and tertiary flaking; systematic flaking and removal of cortical surfaces; longitudinal asymmetrical with a haft element at proximal end and pointed at distal end.

Other Artifacts

Flake Tool. A flake that exhibits retouch or fine pressure flaking, generally a dorsal or ventral surface edge signifying use as a tool on one or more edges.

Fire-Cracked Rock (FCR). Thermally altered stone either naturally or intentional; characterized by crenated fractures, irregular edges, crazing, pot-lid fractures and discoloration.

Shatter. Includes angular, blocky specimens that do not exhibit evidence of striking platforms or bulbs of percussion and cannot be placed into any of the previous categories; overall form is irregular in shape, and heat alteration may be present.

Historic Artifact Analysis

The focus of the historic artifact analysis is to determine date of manufacture and probable site functions. Historic artifacts were described, where possible, by material (e.g., solarized glass, nail, brick fragment, ceramic sherd, etc.) and by form (e.g., machine made bottle, decorated rim sherd, etc). Dates of production, as well as style and technology were addressed for certain artifacts where appropriate. Possible historic site function is evaluated in terms of the density and types of artifacts present. General discussion of historic artifacts encountered during the survey is provided below.

White Refined Earthenwares (WRE). White Refined Earthenwares have porous bodies, a function of relatively low firing temperature, although this porosity varies greatly among subtypes. As the name implies, the clay used in making WRE underwent various refinement processes, driven by the desire for a "cleaner," more consistent raw material which would respond to firing in a very consistent way and produce a very light colored body. Body color for WRE can vary from very pale yellowish off-white to "pure" bright white to light dull gray. All types of WRE have a clear or slightly tinted glossy glaze, keeping the body from absorbing moisture and allowing the general whiteness of the body to show through.

Decoration on WRE is common and important, and varies from unpainted molding to elaborate hand painting (sometimes with gold) to transfer prints and decaling. Transfer printing allowed for very standardized motifs repeated on all vessels within a set. These motifs vary widely, from simple bands of leaves and flowers to well known landscape and historic scenes. Decorations on WRE can be very useful dating tools, given that the motifs and techniques underwent documented cycles of use.

Bottle Glass. One of the most significant impacts of the Industrial Revolution on nineteenth-century material culture was the increase in the forms and functions of bottle and table glass. By the late nineteenth century, glass containers had mostly replaced ceramic vessels for food storage, tableware, and other functions. Bottle fragments are one of the most diagnostic classes of artifacts removed from historic era archaeological sites. It is possible to assign more or less specific periods of manufacture based on unique morphological traits or manufacturing techniques. Such traits may include color, seam scars, finishes, and basal attributes.

Black glass and olive green glass were common until the eighteenth and early nineteenth centuries. Early-nineteenth-century glass not treated to remove impurities usually had an aqua color; probably glass of this color mostly dates to before the twentieth century. Red was obtained by adding copper, selenium, and gold; green and yellow glass was manufactured by using iron; milkglass was produced by using tin or zinc (Munsey 1970) and is still manufactured today. Clear glass containers were manufactured after 1860 by adding soda lime to the glass formula. Colorless bottle glass dates to the era after ca. 1916–1917.

Nails. Hand-wrought nails were popular throughout the eighteenth century but were on the decline by the 1820s (Nelson 1968). Cut nails, first produced in 1786, were popular by the 1820s. Cut nails were cut from sheets of metal and can be distinguished by the presence of two tapering and two parallel edges. Wire nails, which are round and manufactured from metal cylinders, began to be produced in 1850. By the late 1880s to early 1890s, wire nails were the most popular nail type.

NRHP ELIGIBILITY CRITERIA

Sufficient data were compiled to make recommendations regarding eligibility for listing on the NRHP for each archaeological and architectural resource addressed during this study. According to 36 CFR 60.4 (CFR 2004; NRHP 2002), cultural resources eligible for listing on the NRHP are defined as buildings, structures, objects, sites, and districts that have "integrity," and that meet one or more of the criteria outlined below.

- Criterion A (Event). Association with one or more events that have made a significant contribution to the broad patterns of national, state, or local history.
- Criterion B (Person). Association with the lives of persons significant in the past.
- Criterion C (Design/Construction). Embodiment of distinctive characteristics of a type, period, or method of construction; or representation of the work of a master; or possession of high artistic values; or representation of a significant and distinguishable entity whose components may lack individual distinction.
- Criterion D (Information Potential). Properties that yield, or are likely to yield, information important in prehistory or history. Criterion D is most often (but not exclusively) associated with archaeological resources. To be considered eligible under Criterion D, sites must be associated with specific or general patterns in the development of the region. Therefore, sites become significant when they are seen within the larger framework of local or regional development.

"Integrity" is perhaps the paramount qualification of NRHP eligibility, and can be related to any or all of the following (NRHP 2002):

- Location: the place where the historic property (or properties) was/were constructed or where the historic event(s) occurred;
- Design: the combination of elements that create the form, plan, space, structure, and style of a property (or properties);
- Setting: the physical environment of the historic property (or properties);
- Materials: the physical elements that were combined to create the property (or properties) during the associated period of significance;
- Workmanship: the physical evidence of the crafts of a particular culture or people during any given period in history or prehistory;
- Feeling: the property's (or properties') expression of the aesthetic or historic sense of the period of significance; and
- Association: the direct link between the important historic event(s) or person(s) and the historic property (or properties).

For the purposes of archaeology, assessment of site integrity depends largely on the level of disturbance exhibited by archaeological deposits. The nature of deposits (intact, partially disturbed, obliterated, etc.) has direct bearing on the potential to view a site within the context of its past, and on the degree to which it can provide data based on the material record (NRHP 2002). In short, the integrity of a site (and thereby its potential for NRHP eligibility) is directly tied to its capacity to address research questions.

V. RESULTS

PREVIOUSLY RECORDED ARCHAEOLOGICAL SITES

Although the background research found no sites previously recorded within the project area, a number are located in the general vicinity. Nearly all are associated with the alluvial terraces, natural levees, and bluff tops along the Cumberland River. Figure 1 shows the location of nearby previously recorded sites.

One prehistoric site, 40MT460, was recorded in 1997 on a bluff above the north shoreline of the Cumberland River approximately one mile west of the project area. The site recorders characterized the site as a lithic scatter associated with a temporary base camp, and reported the presence of one diagnostic artifact, a Late Archaic/Early Woodland stemmed projectile point base. The site has been eroded and deflated due to logging activity across the area.

New Providence, an early historic period settlement and current residential district of Clarksville, is located east of the project area, on the bluffs along the Cumberland River. Several archaeological sites have been recorded in this area. Two of these sites, Fort Defiance (40MT287) and Sevier's Station (40MT45), were the subject of archaeological testing carried out by TRC (Ezell and McKee 2001). Fort Defiance, also known as Fort Bruce, is a Civil War earthen fortification with a commanding view of the Cumberland River. Sevier's Station is a stone building dating to the early to mid nineteenth century that probably originally served as a kitchen/cookhouse for a small plantation located in this area.

In 2002, archaeologists with the Center for Transportation Research at the University of Tennessee-Knoxville conducted a reconnaissance survey of a proposed city park expansion in the New Providence district. Their work found three additional sites in this area: 40MT875, an early to mid-nineteenth century cemetery; 40MT876, a late nineteenth to mid-twentieth century house site; and 40MT877, remains of a structure of undetermined date and function (Meyers 2002).

Across the Cumberland River from the project area, a variety of prehistoric sites have been recorded on the floodplain and bluff area along the river shoreline.

ARCHAEOLOGICAL SURVEY RESULTS

The following sections describe the location, context, and material remains of each newly recorded archaeological resource investigated as a part of this project. Recommendations for NRHP eligibility regarding each site are provided using a consistent set of criteria (see Chapter IV). A listing by minimal provenience of the artifacts recovered from each site is provided with each site description as well. For clarity and convenience, illustrations of each site are provided with the discussions.

40MT978 – Results of Phase I Investigation

USGS Quadrangle: New Providence	**Cultural Affiliation:** Late 19^{th} century, Late Archaic period
UTM Coordinate: Z16; E0465748 N4043808	**Total Site Area (m^2):** 7200
Topographic Setting: Bluff/ridge toe	**Positive Shovel Tests:** 13
Elevation (feet AMSL): 370-410	**Prehistoric Artifacts:** 12
	Historic Artifacts: 43
Site Type: Industrial/warehouse?, Prehistoric open habitation	**NRHP Recommendation:** Potentially Eligible

Site 40MT978 was discovered during a visual inspection of the raw water intake facility area for the proposed water treatment plant, in the southeastern corner of the project area just above the confluence of the Cumberland River and Tanyard Branch (see Figures 1, 4, 6, 7, and 8). The bluff-top/ridge landform here forms a series of narrow benches or terraces as it steps down to this confluence, and 40MT978 occupies at least three of these relatively level terrace-like areas. Surface indications of cultural activity on these benches include a light scatter of hand made brick fragments and rusted metal, an artificial cut through the bluffs providing access down to the river shore, and one concentrated scatter of domestic artifacts, mostly ceramics datable to the late nineteenth and early twentieth centuries (Figure 9, a–b). One base fragment from a prehistoric PP/K was also collected within this small artifact scatter. The point exhibits an expanding stem (see Figure 9, f) and is diagnostic of the Late Archaic period. Of 21 shovel tests excavated across the area during Phase I investigation, 13 encountered subsurface artifacts. Most of these tests did not find heavy concentrations of artifacts or clearly undisturbed archaeological deposits and features. However, substantial subsurface deposits of brick rubble were encountered on the lowest of the terraces within the site, precisely at the flagged location of the water intake facility footprint. The testing also consistently produced chert debitage flakes associated with prehistoric tool manufacturing, but at a low density that suggests no significant prehistoric deposits are located here.

The typical soil profile at 40MT978, as revealed in the shovel tests, consists of a topsoil layer of loose silty loam (Munsell color reading 10YR 4/3, brown) ranging in depth from 9 to 15 cm over a compacted silty clay subsoil (10YR 4/6, dark yellowish brown). Some of the shovel tests, especially on the upper benches of the site area, hit bedrock at 22 to 29 cm.

Results of the Phase I Survey at 40MT978 suggested it was the location of a commercial enterprise associated with some kind of a river landing and cargo transport operation. During the Phase I work TRC staff carried out a cursory examination of historical maps and records on Montgomery County, with findings backing up this interpretation. An 1877 map (Beers 1877) shows that J.H. Tandy owned 440 acres in the vicinity, probably including the entire proposed water treatment tract. A local history source describes Tandy as a "pretty big farmer" specializing in tobacco, "among the most substantial men in the place … [and] … a leading spirit in the Baptist church" (Montgomery County Historical Society 2000:15) This same source mentions "immense brick warehouses" in association with various wharves and landings along the Cumberland east of the Red

River, upstream from 40MT978. These warehouses were used to store "great quantities" of tobacco while awaiting transport to market.

Following the Phase I investigation TRC recommended that 40MT978 is potentially eligible for the NRHP based on its potential to yield information on late nineteenth century life and commerce in this region of Tennessee. Further archival research was recommended to provide more definite information on J.H. Tandy and his use of this part of his property, and on details on river landing and cargo transport activities here. Phase II archaeological investigation was recommended to help define architectural remains at the site, which along with artifacts and other features should provide details on commercial and possibly domestic activities here.

Figure 6. View of 40MT978, lower terrace, looking south.

Figure 7. View of 40MT978, upper terrace and road cut through bluffs, looking southeast.

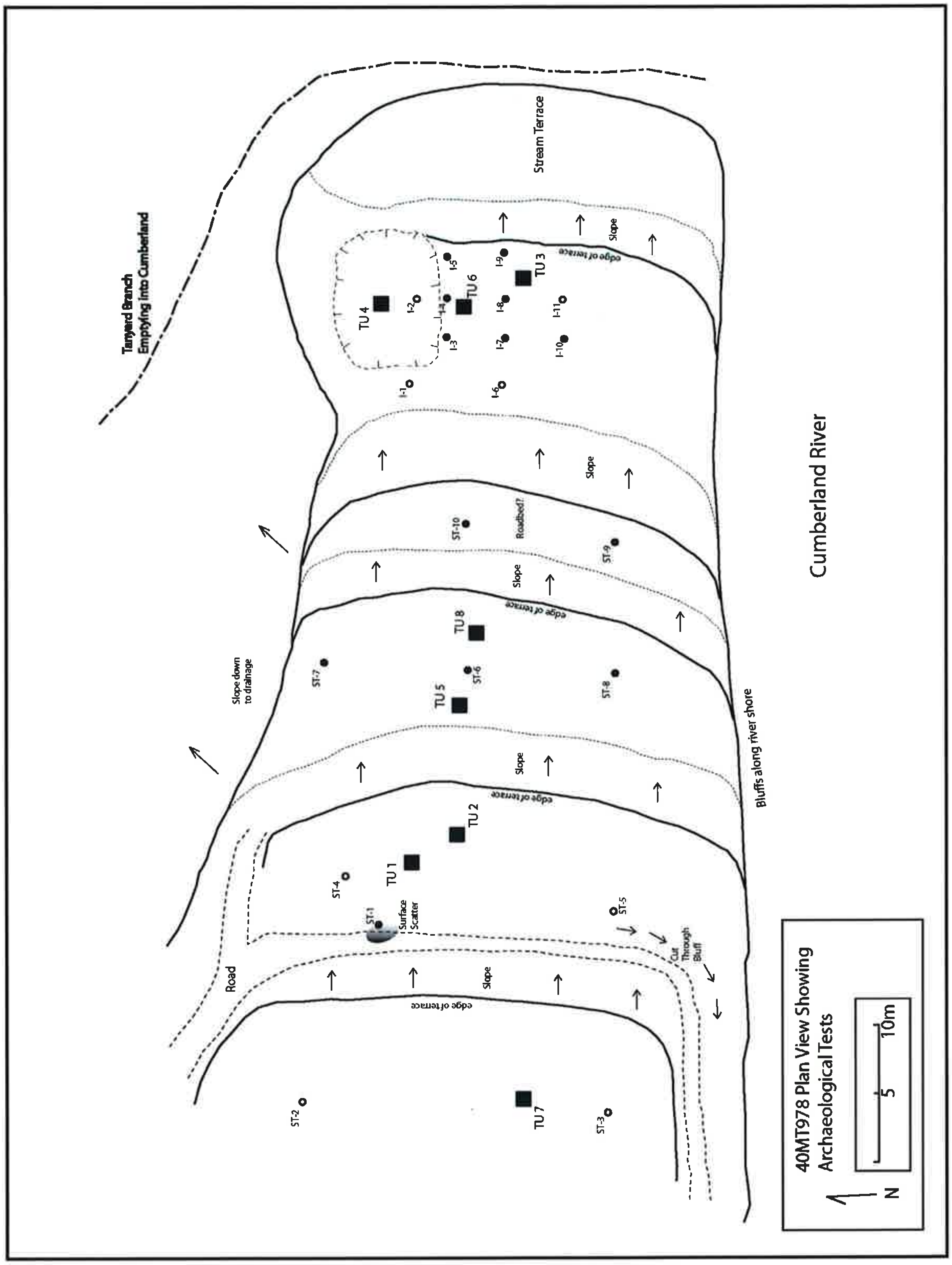

Figure 8. Plan view of site 40MT978 showing TRC's Phase I and II archaeological investigations.

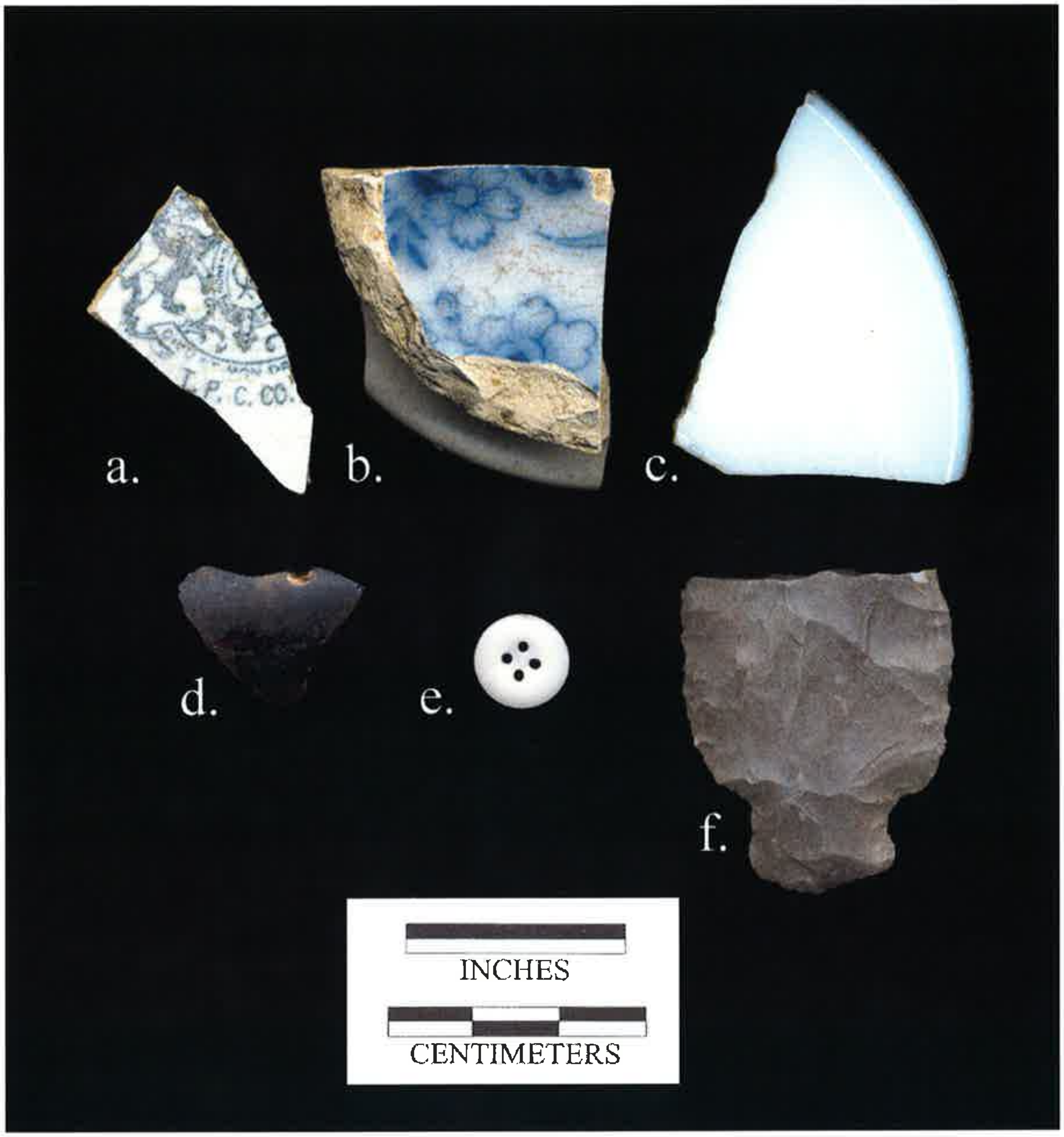

Figure 9. Selection of artifacts recovered from surface scatter at 40MT978.

Table 1. Artifacts Recovered During Phase I Investigations at Site 40MT978.

GSC Road Scatter	1 base fragment, PPK, expanding stemmed, Late Archaic; 1 fragment, dark beverage bottle glass; 1 fragment, milk glass table vessel rim w/impressed floral design; 1 fragment, handmade brick; 1 shirt button, white porcelain, 4 hole; Refined Earthenware: 1 fragment w/decal decoration; 1 fragment, heavy bowl footed base w/flow-blue transfer print (late) and partial makers mark (unreadable); 4 undecorated body fragments 1 undecorated rim fragment, shallow bowl/saucer 1 undecorated rim fragment, cup/mug 1 undecorated footed base fragment 2 undecorated base fragments, w/partial makers mark, "T.[?] P. C. Co." w/royal coat of arms Porcelain: 1 white undecorated body fragment, European/Domestic
ST 1	Iron hinge fragment
ST 6	Mussel shell fragment
ST 7	2 flake fragments, chert 1 Refined Earthenware fragment, undecorated rim
ST 8	2 flake fragments, chert 1 Refined Earthenware fragment, undecorated pitcher spout
ST 9	1 Refined Earthenware fragment, undecorated rim
ST 10	1 Refined Earthenware undecorated body fragment, burned
ST Intake Area (I)-3	1 handmade brick fragment
ST I-4	2 flake fragments, chert 1 handmade brick fragment, glazed 2 handmade brick fragments 1 corroded nail fragment, cut?
ST I-5	2 handmade brick fragments, glazed 7 handmade brick fragments
ST I-7	1 handmade brick fragment, glazed 1 handmade brick fragment
ST I-8	1 flake fragment, chert 1 handmade brick fragment
ST I-9	1 handmade brick fragment, glazed
ST I-10	4 flake fragments, chert 1 handmade brick fragment 1 glass vessel body fragment, clear frosted 1 Refined Earthenware undecorated body fragment

40MT979

USGS Quadrangle: New Providence	**Cultural Affiliation:** Undetermined prehistoric; Historic
UTM Coordinate: Z16; E0465209 N4044028	**Total Site Area (m^2):** 14400
Topographic Setting: Ridge top	**Positive Shovel Tests:** 92
Elevation (feet AMSL): 490	**Prehistoric Artifacts:** 268
	Historic Artifacts: 34
Site Type: Rural farmstead, Prehistoric open habitation	**NRHP Recommendation:** Ineligible

This is an extensive but low density scatter of prehistoric and historic materials covering most of the northern two-thirds of the large open field at the center of the proposed water treatment plant tract (see Figures 1, 10, and 11). Extensive shovel testing across the field discovered no artifact concentrations, diagnostic prehistoric artifacts, or evidence of intact buried archaeological deposits or features. The location, a fairly level ridge or bluff top, offered easy access to unnamed drainages to the east and west. The drainage to the west, Tanyard Branch, provided a route through the bluffs to the Cumberland River. Prehistoric groups apparently made use of this area over a long period of time, but at a low level of intensity. The lack of ceramics in the assemblage from the site suggests the period of occupation predated the Woodland period, when this artifact category came to be common and widespread throughout the region.

The typical soil profile encountered in tests at 40MT979 consists of 20 to 25 cm of heavy silt clay loam topsoil/plowzone (Munsell reading 7.5 YR 4/4, brown) over a stiff clay subsoil, 10YR5/6, yellowish brown.

Historic artifacts from the site came mostly from the east-central area. The collection includes a light scatter of ceramics, glass, and architectural materials such as window glass and nails, suggesting that this was once the location of a small farmstead. A pushpile of stone and brick in the wooded area along the eastern boundary of the site suggests whatever structure or structures that once stood at the site may have been bulldozed away to clear the field (Figure 12). The historic period artifacts do not include tightly datable items, but the presence of handmade bricks and cut nails in the collection suggest the site was built and occupied during the mid to late nineteenth century. The absence of earlier nineteenth century material, such as decorated ceramics from the period, or modern/twentieth century artifacts, such as machine-made bottles or synthetic items, points to an occupation restricted to the second half of the nineteenth century.

Although 40MT979 is relatively large and produced numerous prehistoric and historic artifacts, the collection lacks distinctive diagnostic items unambiguously tying the occupation here to specific periods or representing distinctive activities. Ploughing and clearing activities have disturbed and mixed whatever intact archaeological deposits and features that might have been at the site, limiting its ability to provide clear information on human activity in the past. For these reasons, TRC recommends that this site is not eligible for the NRHP.

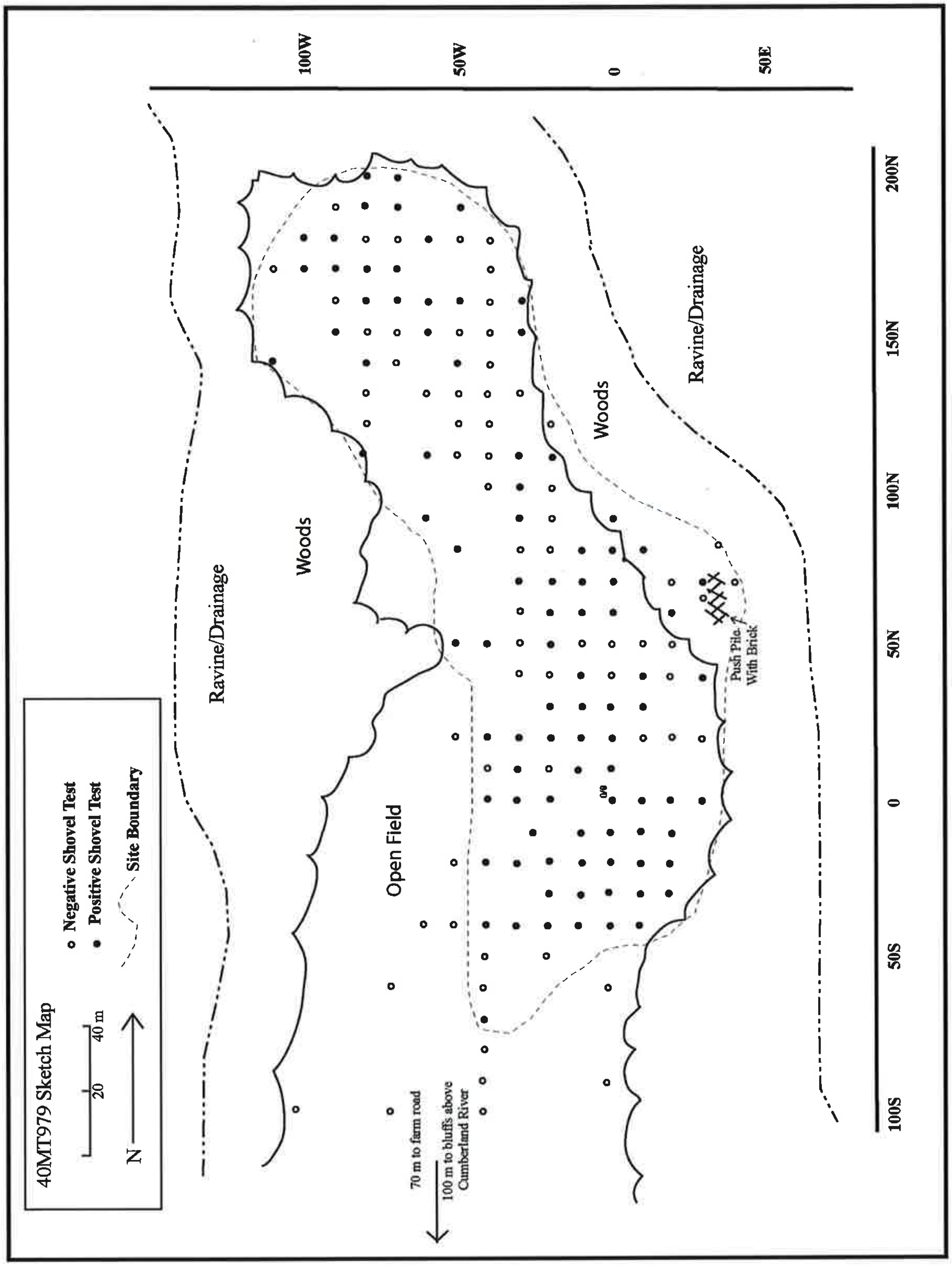

Figure 10. Plan view of TRC's Phase I archaeological investigations at site 40MT979.

Figure 11. View of 40MT979 from south edge, looking north-northeast.

Figure 12. Pushpile of architectural material at 40MT979, looking southwest.

Table 2. Prehistoric and Historic Artifacts Recovered from Site 40MT979.

Provenience		Prehistoric						Historic				Total
	Depth (cmbs)	*Primary Flake*	*Secondary Flake*	*Tertiary Flake*	*Flake Fragment*	*Shatter*	*Biface Fragment*	*White Refined Earthenware*	*Glass*	*Nails*	*Brick*	
0N/10E	0-22			1	2							**3**
0N/20E	0-35			2		2						**4**
0N/30E	0-22				1							**1**
0N/0W	0-10				2							**2**
0N/20W	10-26				1							**1**
0N/30W	0-30				1							**1**
0N/40W	0-25					2						**2**
10N/0E	0-30			1	4	2						**7**
10N/10W	0-10				2							**2**
10N/30W	10-20				1							**1**
20N/0W	0-30				5	2						**7**
20N/10W	0-30		1	2	5	3						**11**
20N/20W	0-30			1	1							**2**
20N/30W	0-30		1	2	1							**4**
20N/40W	0-30				1	1						**2**
30N/0E	0-23				8	1				1		**10**
30N/10E	0-28					5						**5**
30N/0W	0-35		1	1								**2**
30N/10W	0-35				1							**1**
30N/20W	0-30				2							**2**
40N/10E	0-35				1	1						**2**
40N/30E	0-29				1							**1**
40N/10W	0-28				3							**3**
40N/20W	0-30	1	1									**2**
50N/40W	0-25	1										**1**
50N/50W	0-18				1							**1**
60N/0E	0-30				4	1						**5**
60N/20E	0-25	1			4	2						**7**
60N/10W	0-28								2			**2**
60N/20W	0-30	1			1	2						**4**
70N/0E	0-15								1			**1**
70N/30E	0-15							2				**2**
70N/10W	0-28				1				4	1	5	**11**
70N/20W	0-25							1				**1**
70N/30W	0-22									1		**1**
80N/0E	0-25								1			**1**
80N/10E	0-15				1							**1**
80N/10W	0-22				2				1		1	**4**

Table 2, continued.

80N/20W	10-25				2						**2**
90N/30W	0-20				2						**2**
100N/30W	0-25				1	1					**2**
110N/30W	0-20				2						**2**
110N/80W	0-20				2	1					**3**
140N/50W	0-16									2	**2**
140N/80W	0-23				3						**3**
140N/110W	0-25	1		3	5						**9**
150N/30W	0-20				1						**1**
150N/60W	0-28			1	1						**2**
150N/80W	0-20				1						**1**
160N/30W	0-20				1						**1**
160N/50W	0-20				5						**5**
160N/70W	0-20				1	1					**2**
170N/70W	0-15				2	4					**6**
170N/80W	0-23			1	9	2					**12**
170N/90W	0-15				3	1		1			**5**
170N/100W	0-32			1	7	6					**14**
180N/60W	0-15				4						**4**
180N/90W	0-15				1	2					**3**
180N/100W	0-32				6						**6**
190N/50W	0-15				13	4					**17**
190N/70W	0-7			1							**1**
200N/70W	0-7				1						**1**
200N/80W	0-30			1	3	3					**7**
200N/110W	0-16							1			**1**
10S/0E	10-25			1	1	1					**3**
10S/10E	0-20			1							**1**
10S/20E	0-20				1	1					**2**
10S/10W	0-10				1						**1**
10S/25W	0-25		1		1						**2**
20S/0E	0-22					2			1		**3**
20S/10E	0-20				2			5			**7**
20S/20E	0-15								2		**2**
20S/10W	0-22				2	2					**4**
20S/20W	0-22				1						**1**
20S/30W	0-14					1					**1**
20S/40W	20-40				1	1	1				**3**
30S/10E	0-20				2			1	1	1	**5**
30S/20E	0-25			4	5	1					**10**
30S/0W	0-15			1	2						**3**

Table 2, continued.

30S/10W	10-20			1								1
30S/20W	15-20				1							1
40S/10E	0-36				2							2
40S/0W	0-30				1	1						2
40S/10W	0-33				2							2
40S/20W	0-30				1							1
40S/30W	0-33				2							2
40S/40W	0-45					2						2
70S/40W	0-25		1									1
70S/50W	0-15				3	1						4
150S/90W	0-25				1	1						2
	Total:	**5**	**6**	**26**	**165**	**63**	**1**	**11**	**13**	**6**	**6**	**302**

RESULTS OF ARCHIVAL RESEARCH OF PROJECT AREA AND 40MT978

More thorough documentary research of the area within and surrounding than described above within the discussion above of the Phase I survey results at 40MT978 revealed that the proposed location for the Clarksville Water Treatment Plant is partially situated within an area that once comprised a 640-acre land grant issued by the State of North Carolina to George Cook in 1788 (North Carolina Secretary of State Office 1788) (Figure 13). This tract, along with additional lands to the west, was eventually purchased by Valentine Sevier where he established Sevier Station (Beach 1964; Montgomery County Register's Office 1792). In 1819, a large portion of this tract was laid off with a public square, a street grid, and divided into lots that were sold at public auction for the establishment of the town of Cumberland, later named New Providence (Beach 1988).

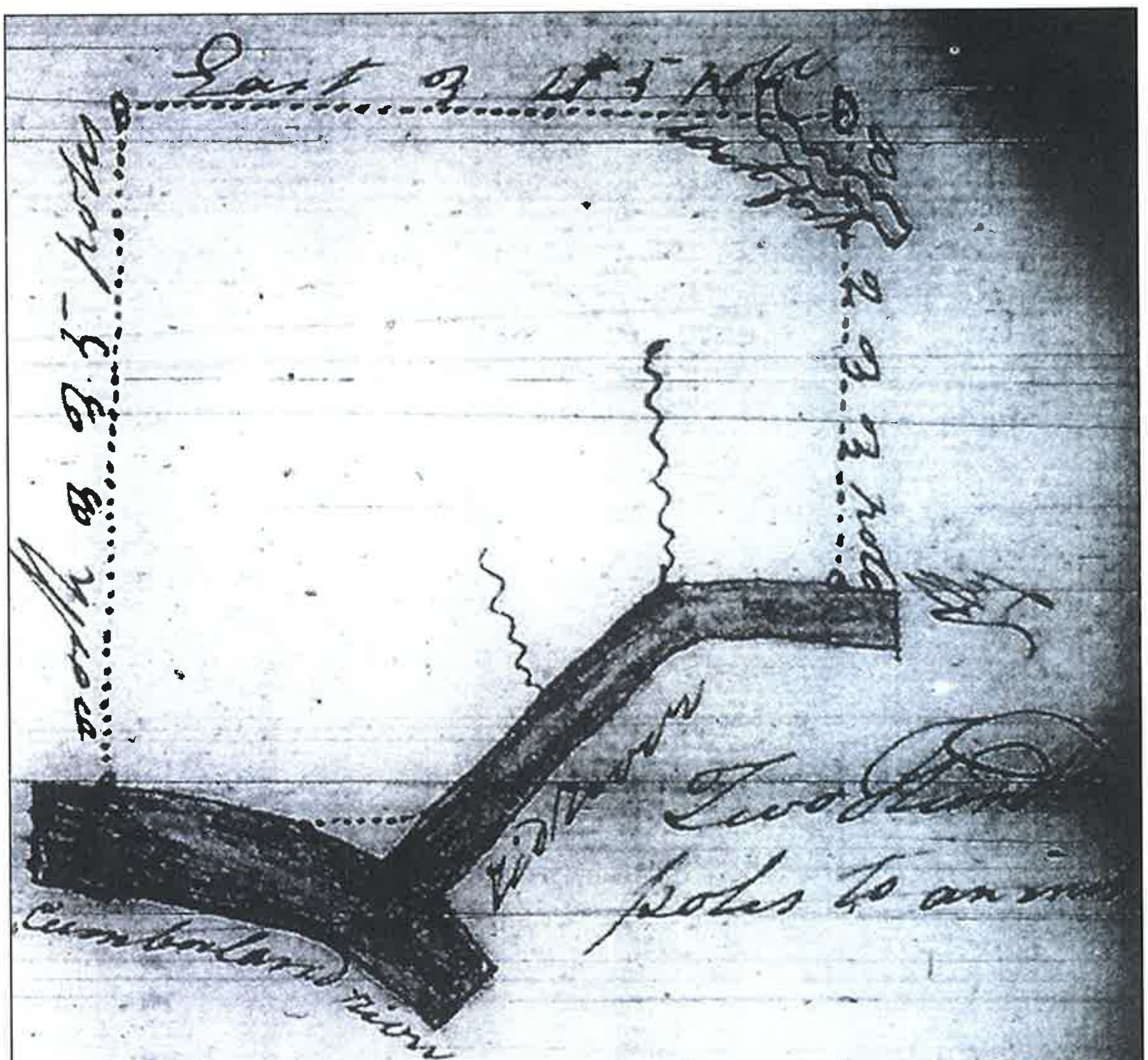

Figure 13. The original survey map of George Cook's land located at the confluence of the Red and Cumberland Rivers.

Nestled between the Red and Cumberland Rivers, New Providence quickly developed into a significant shipping hub. With easy access to the Clarksville and Hopkinsville Pike, merchants established a series of wharfs or landings capable of loading and receiving goods from the burgeoning steamboat trade. Helping to foster the increase in wharf construction was a decree from the city officials in Clarksville in ca. 1839, which deemed its wharf inadequate to handle the increase in steamboat commerce. As a result, the city of Clarksville encouraged the creation of new wharf companies (Beach 1964).

According to local histories and deed records, New Providence featured at least four landings, which were located along the north bank of the Cumberland River. From west to east these included Linwood, Trice's, Planters, and the Red River landings, which were established between ca. 1832 and ca. 1857 (Montgomery County Historical Society 2000; Montgomery County Register's Office 1865; Beach 1964). The general location of these landings are illustrated in a 1862 *New York Times* map of Clarksville (New York Times 1862) (Figure 14). Although the landings at Linwood and Red River are clearly identified, the wharf labeled "Landing and Warehouses" west of Fort Sevier (Defiance) likely represents Trice's and Planters Landing. Deed research indicates these two wharfs were located adjacent to one another and as such, were often bought and sold together (Montgomery County Register of Deeds 1865, 1873). The location of Trice's Landing is more clearly identified in an 1877 map of New Providence (Figure 15), however, the absence of the other three landings suggests that they were no longer in operation by this time (D.G. Beers Co. 1877).

The historic research further indicates that although the majority of the project area is located on land that was historically used for farming, its southeastern portion may fall within an area that once contained buildings associated with Trice's and Planters Landing. A deed transfer dating to 1850 indicates that Planters Landing consisted of five acres that included the landing and warehouses (Montgomery County Register's Office 1850). Trice's Landing has been described as containing a "well paved" wharf, multiple lots, buildings, immense brick warehouses, and even a hotel (Montgomery County Register's Office 1865; Montgomery County Historical Society 2000).

According to local historical accounts, Trice's Landing was established by a consortium of prominent merchants and landowners from New Providence who formed a wharf company called the Garrett, Bell & Co. This group of business men included Isaac Garrett, John F. Bell, William Hester, James Jenkins, S.G. Barker and several members of the Trice family, hence the origin of the landing's name (Beach 1964). Although the general location of Trice's Landing is known, deed references and plat maps of the area failed to reveal the exact location of buildings associated with either Trice's and Planters landing. It is clear, however, that by the late nineteenth century deed references to the landings are omitted suggesting that the property was no longer being used as a wharf. In addition, early twentieth century highway and topographical maps fail to indicate the presence of any buildings located near Trice's Landing. As with many of the small river wharfs throughout Tennessee, it appears that the decline in river shipping due to the growth of the railroads in the latter half of the nineteenth century led to the demise of the landing. Soon after ceasing operations, the buildings associated with the wharves, were likely torn down and the area reverted back to its natural state as a wooded riverbank.

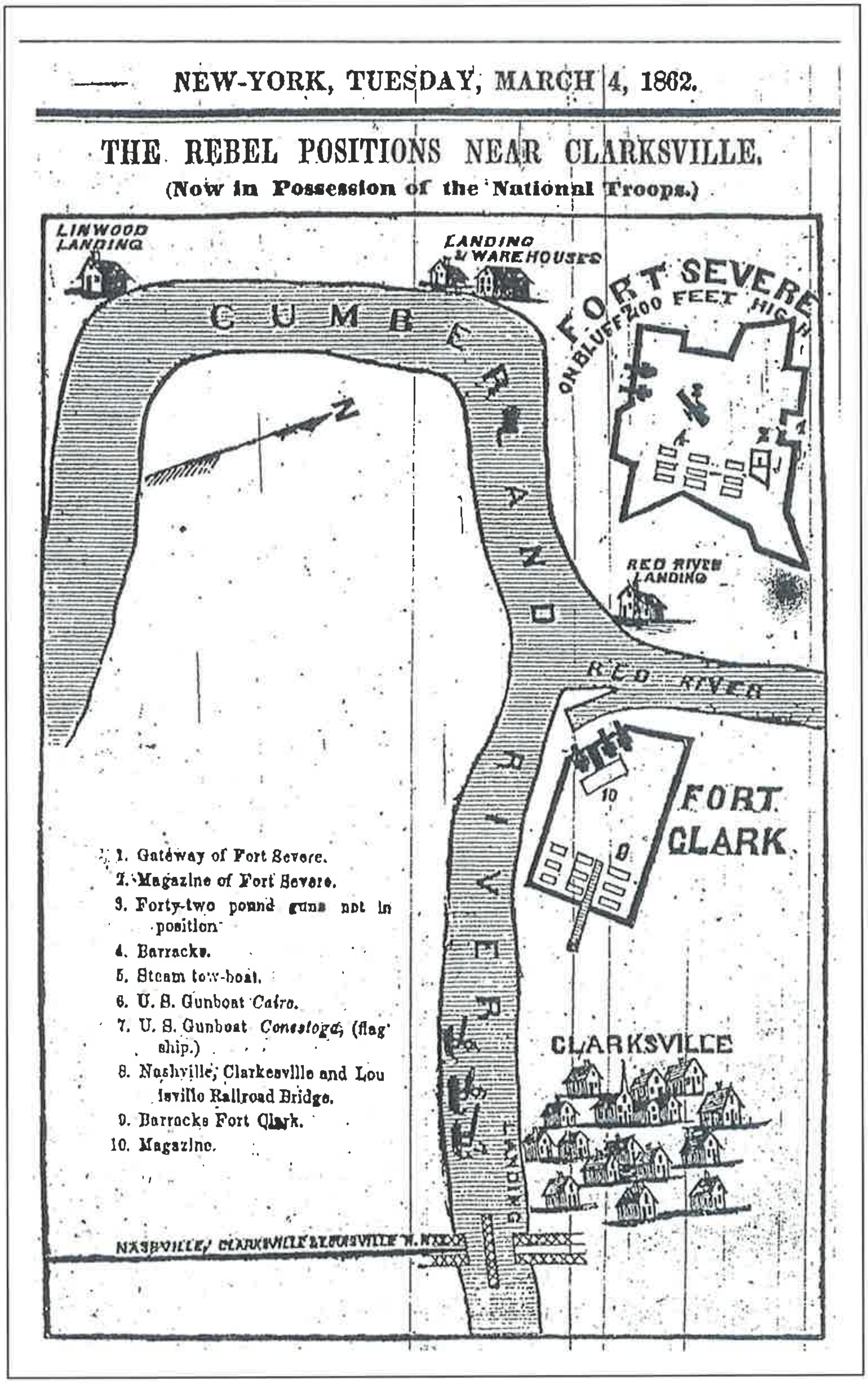

Figure 14. 1862 New York Times Map illustrating the location of New Providence wharfs (adapted from Ezell and McKee 2001).

Figure 15. 1877 Beers Map illustrating the location of Trice's Landing.

RESULTS OF PHASE II ARCHAEOLOGICAL TESTING AT 40MT978

As described above, site 40MT979 represents a prehistoric Late Archaic period and historic 19th century occupation. The site is situated on a bluff line/ridge toe along the north bank of the Cumberland River just west of Trice's Landing (see Figures 1, 2, 4, and 16). Its position along and relatively high elevation above the river as well as its close proximity to the confluence of a small drainage would have provided a dry and strategic location for prehistoric inhabitants. Likewise, historic occupation at the site is likely linked to the site's close river association as well as its close proximity to the early 19th century Trice's Landing immediately to the east.

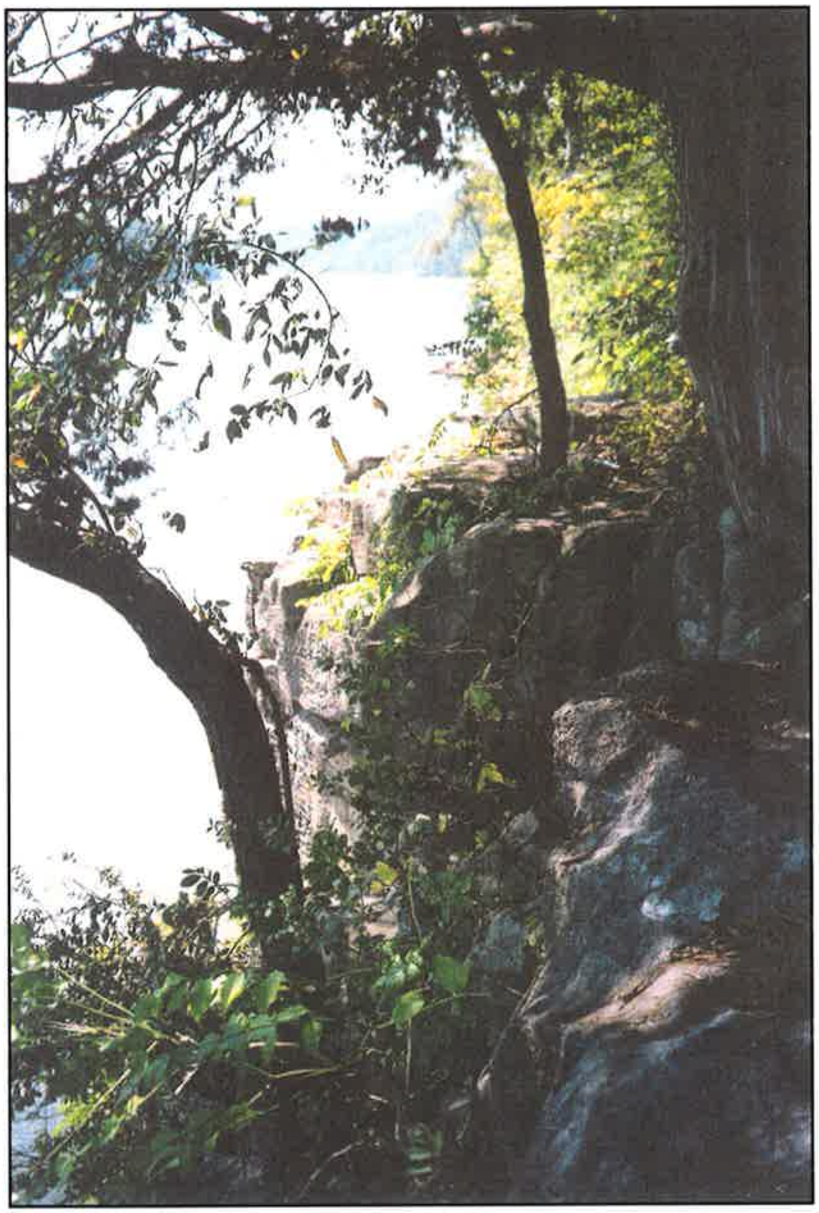

Figure 16. West view of exposed bluff line at site 40MT978.

More detailed inspection of the bluff line/ridge toe landform on which site 40MT978 is situated concluded that it forms a series of six narrow benches or terraces as it steps down to an unnamed confluence. A profile schematic of the stepped landform is provided in Figure 17. Each of these nearly level areas, except for the lowest and often flooded stream terrace, would have presented possible areas of prehistoric and historic occupation at the site. The third lowest terrace appears to represent a possible old roadbed, possibly facilitating easier access to the river. Prehistoric and historic artifacts were recovered from shovel tests on the roadbed as well as from the terraces above and below it (see Figure 10). Dense and often impenetrable brick rubble was encountered on the lowest terrace. No artifacts were recovered from Phase I shovel tests excavated on the highest two terraces.

Phase II archaeological test excavation conducted at Site 40MT978 sought to vertically and horizontally delineate and historic and prehistoric archaeological deposits along each terrace. This was accomplished through the excavation of eight 1 x 1 meter test units (see Figure 10).

STRATIGRAPHY

Wall profiles of Test Units 1, 2, 5, 7, and 8 are presented in Figure 18. Test Unit 7 was placed on the highest terrace, and Test Units 1 and 2 and Test Units 5 and 8 were excavated on the next two succeeding lower terraces respectively. Archaeological deposits encountered in the five units are contained within natural stratigraphic units. Although soil color did vary considerably across the units, in general texture of soil layers encountered consisted of silt loam upper layers and a clay loam lower subsoil layer. Natural deposition encountered within the units is likely the result of both growth and decay of organic material and colluvial action. Soils located within forested environments, such as those encountered at site 40MT978, slowly accumulate decomposed organic material. The sloped and stepped landform characteristics within the site boundaries are the result of weathering or erosion of accumulated soils caused by rain and wind. This in turn has resulted in the collection of colluvium within each terrace at the site. Cultural deposits within units 1, 2, 5, 7, and 8 averaged approximately 40 centimeters in thickness. Exposed limestone bedrock was noted throughout the site boundaries.

Manmade deposits were encountered in Test Units 3 and 6, located on the second lowest terrace. Test Unit 4, also placed on the second lowest terrace, turned up no sign of cultural materials. A wall profile was not drawn for this unit. Deposits in Test Units 3 and 6 consisted of a variety of compact burned layers, sandy loam layers, and an ash deposit. Stratigraphy in the units is likely the result of brick manufacturing activity at this location within site 40MT978 boundaries.

Test Unit 3 presented the most interesting or complex stratigraphy of all units excavated at site 40MT978 (Figures 19 and 20). Five distinct strata were recognized in profile. The top layer (Stratum I) consisted of a 10YR 4/3 brown silt loam that in general contained a high amount of brick fragments and forest organic material. This top layer

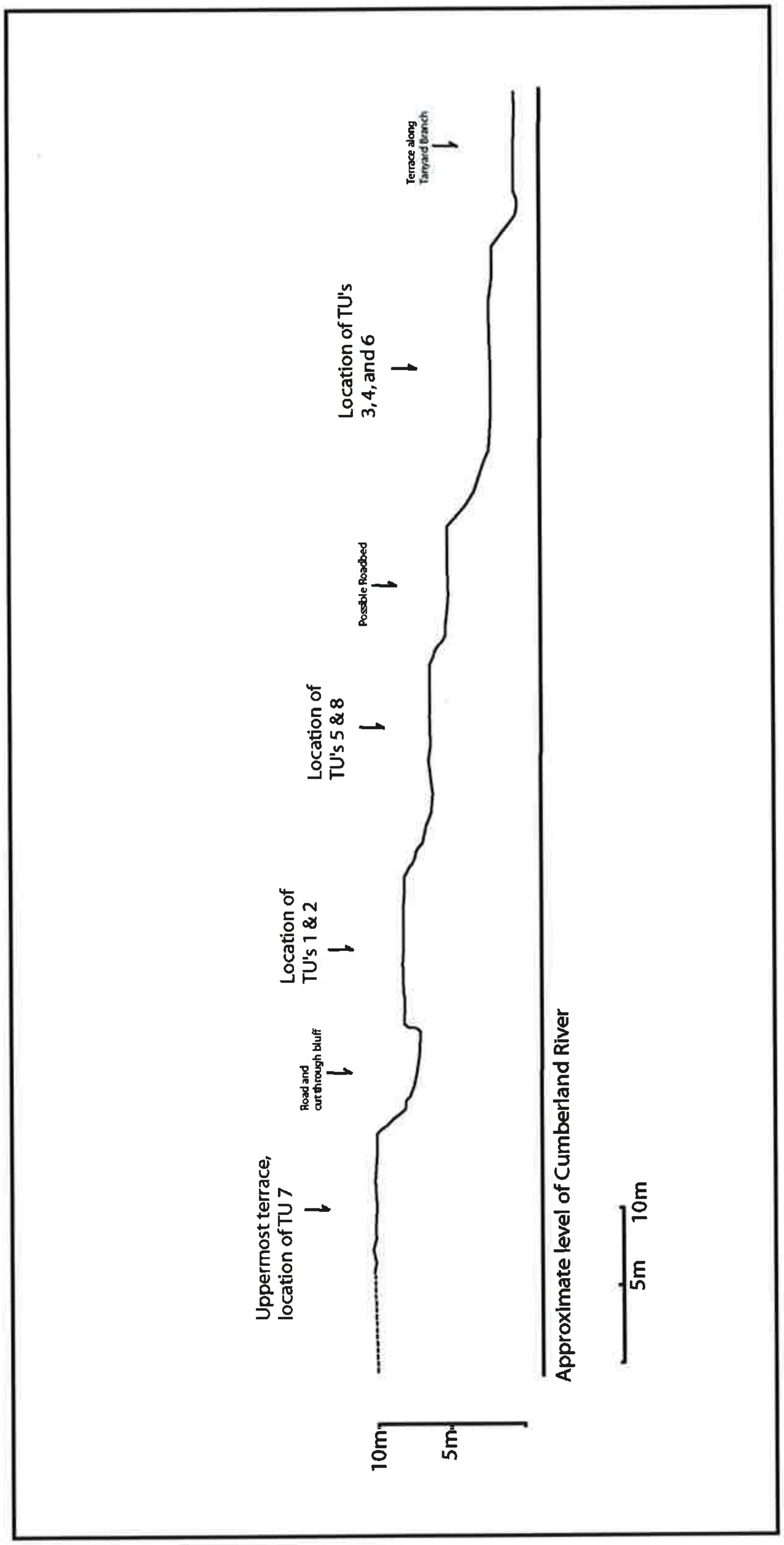

Figure 17. Surface profile of site 40MT978.

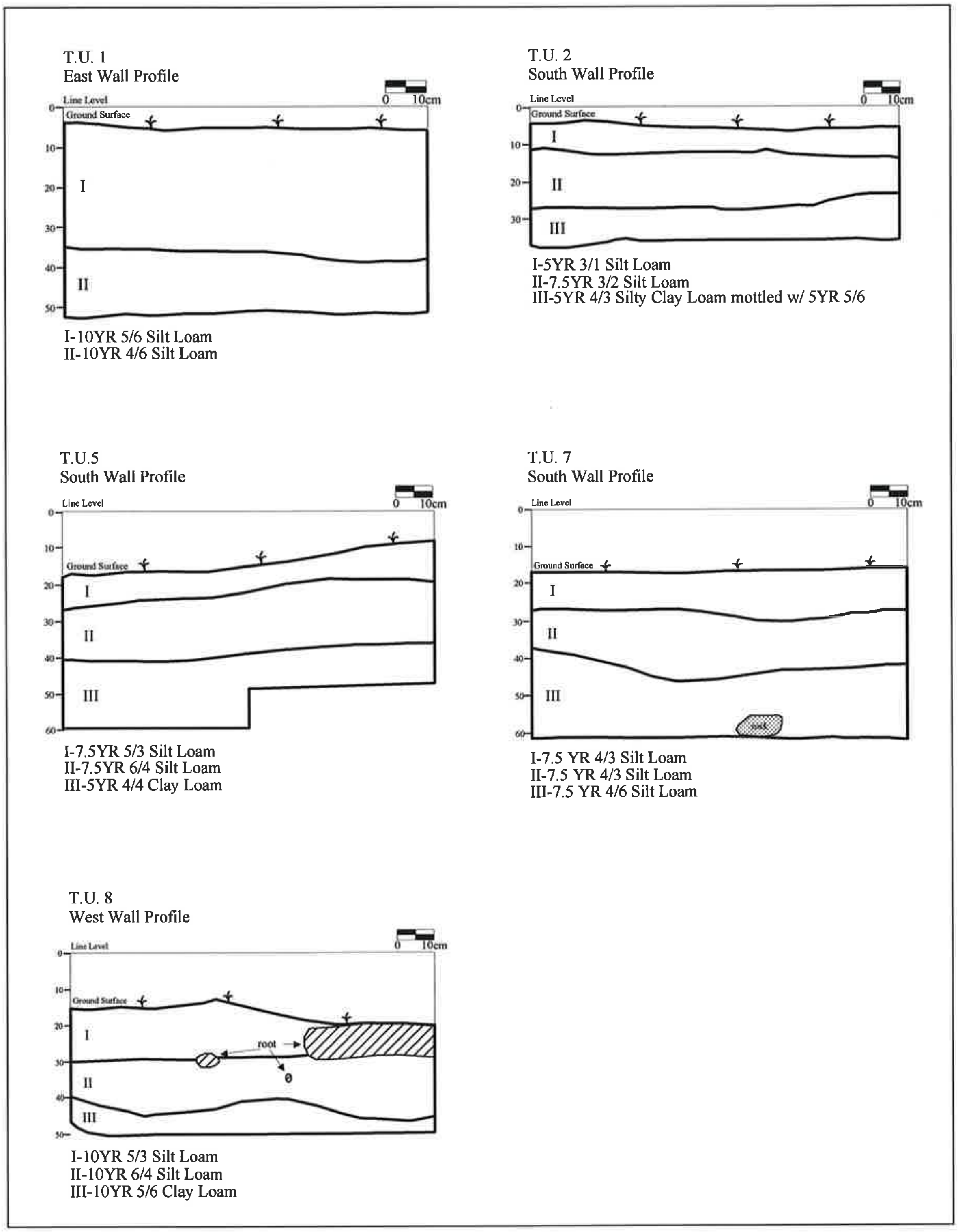

Figure 18. Test Units 1, 2, 5, 7, and 8 wall profile drawings.

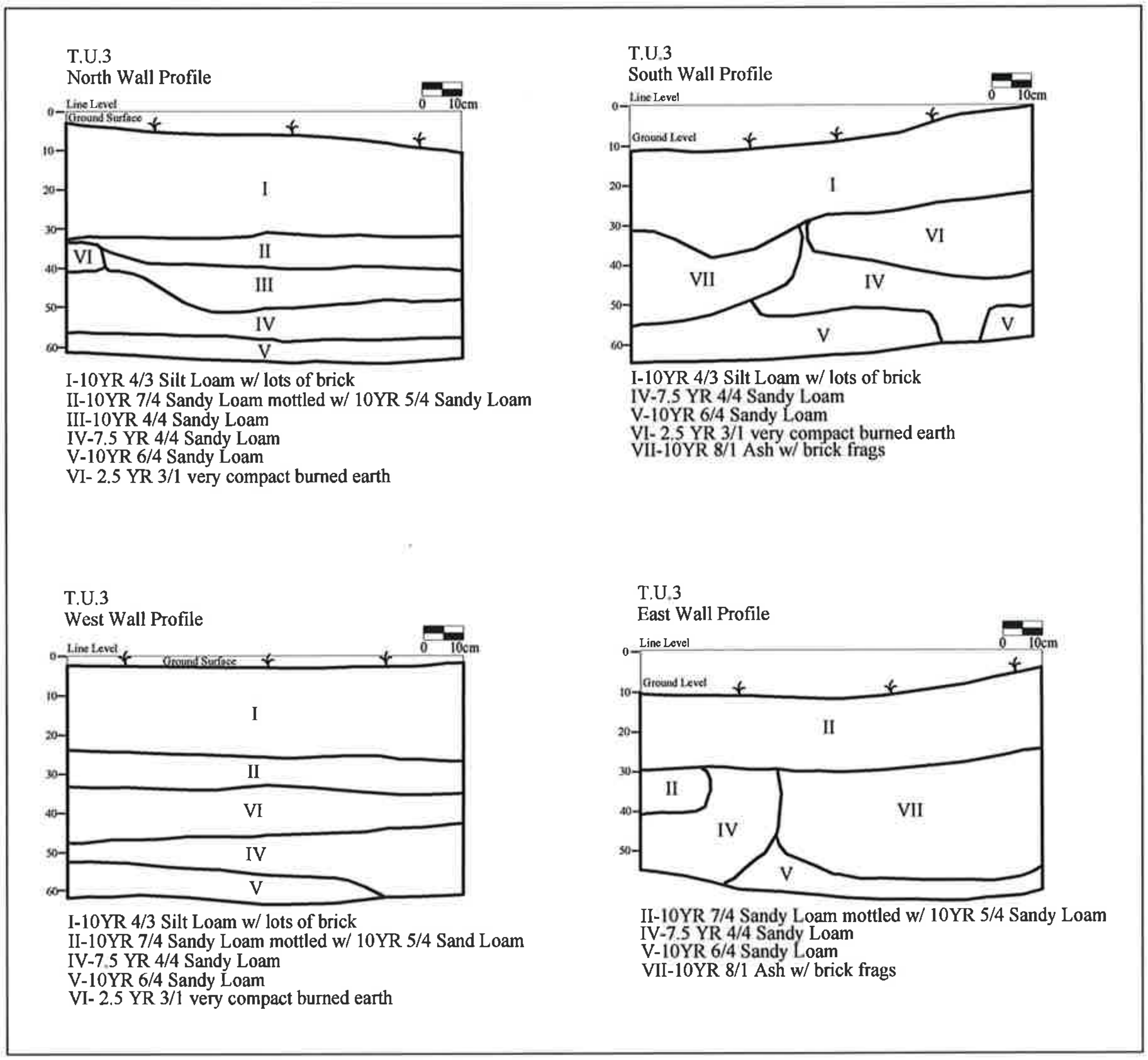

Figure 19. Test Unit 3 wall profile drawings.

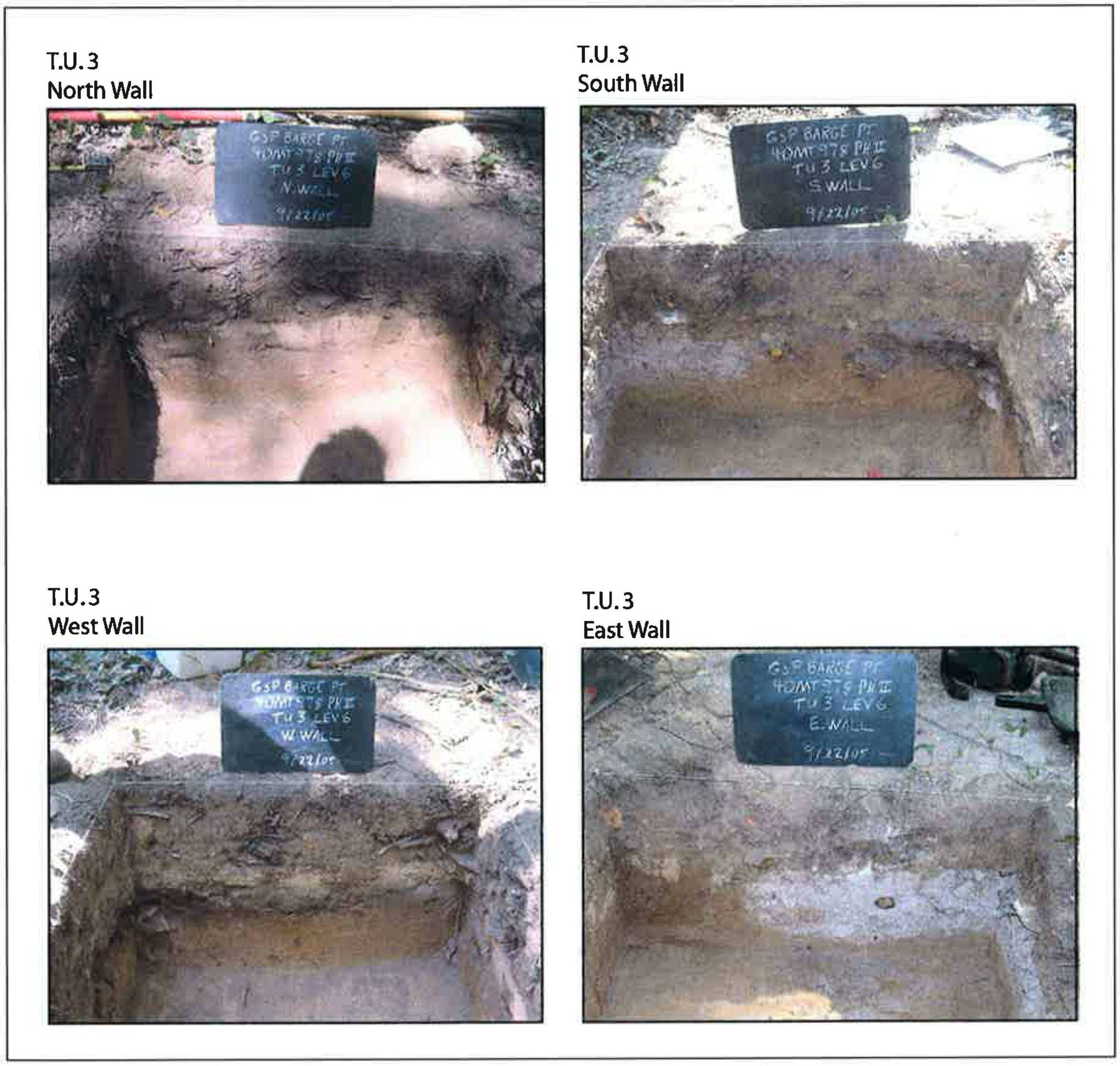

Figure 20. Test Unit 3 wall profile photographs.

averaged 20 cm in thickness, was recognized in the north, south, and west walls of the units, and is considered a natural layer likely the result of decomposed organic material accumulating over time over lower mainly unnatural, manmade layers. Stratum II was described as 10YR 7/4 very pale brown sandy loam with occasional mottles or pockets of 10YR 5/4 yellowish brown sandy loam. It was seen in all wall profiles except the east wall and averaged approximately 10 cm in thickness. Stratums III and IV were of a similar texture and were described as a 10YR 4/4 dark yellowish brown and a 7.5YR 4/4 brown sandy loam respectively. These strata were highly compact likely the result of some sort of burning activity and ranged in thickness from 10 to 20 cm. Stratum III was recognized only in the north wall of Test Unit 3 and Stratum IV was seen in profile within all four walls of the unit. Stratum V averaged 10 cm in thickness, was seen in the profiles of all four walls of the unit, and was described as a 10 YR6/4 light yellowish brown sandy loam. Stratum VI appeared in the south and west walls of the unit and was described as 2.5 YR3/1 dark reddish gray very compact burned earth layer. It ranged in thickness from 10 to 20 cm. Stratum VII was seen only in the south and east walls, was up to 30 cm thick, and consisted of a 10 YR 8/1 white ash layer contained a moderate amount of brick fragments. Stratums VI and VII were noticed in planview at approximately 20 cmbs. Plan views drawn and photographs taken at 20 and 30 cmbs during excavation of Test Unit 3 are provided in Figure 21. The dark burned earth layer, described in Figure 19 as Deposit II, appeared as a stain contained within the southwest quadrant of the unit at 20 cmbs and developed into a linear stain in the units western portion at 30 cmbs. The ash deposit (see Figure 19, Stratum III) appeared in circular form in the unit's southeastern quadrant.

East and west wall profile drawings and photographs for Test Unit 6 are provided in Figure 22. The unit was excavated a few meters northwest of Test Unit 3 at the crest of a small rise predicted to be a possible brick and/or trash pile. Four strata (I–IV) were recognized in profile. The surface layer (Stratum I) consisted of a 10 YR5/4 yellowish brown silt loam up to 23 cm thick and similar to the top layer of Test Unit 3. Underlying it was a similar but darker 7.5 YR4/4 brown silt loam (Stratum II). A dense, solid brick and limestone layer (Stratum III) was encountered 10 cm below surface and extended 50 cm below surface. The concentration covered the entire unit in plan view. Stratum IV was described as a 10 YR5/4 sandy loam. Burned layers were absent in Test Unit 6.

ARTIFACTS

Artifacts recovered during test unit excavations at 40MT978 are presented by provenience in Tables 3–6. Historic (n=344) and prehistoric (n=544) make up the assemblage, considered a low density. Historic artifacts include ceramics, glass, nails, and handmade bricks that date historic activity at the site from the middle nineteenth century to the early twentieth century. Prehistoric lithic artifacts recovered from test units included non-temporally diagnostic debitage and tools. One probable Late Archaic projectile point was recovered. Artifact counts were fairly evenly distributed across test units excavated on the higher terraces at the site. Artifacts, except handmade brick, were not as dense within units excavated within the lowest inhabitable terrace at 40MT978. Depth of artifacts extended about 40 cmbs on average, but they were recovered as deep as 60 cmbs. More detailed summary of the assemblage is provided below.

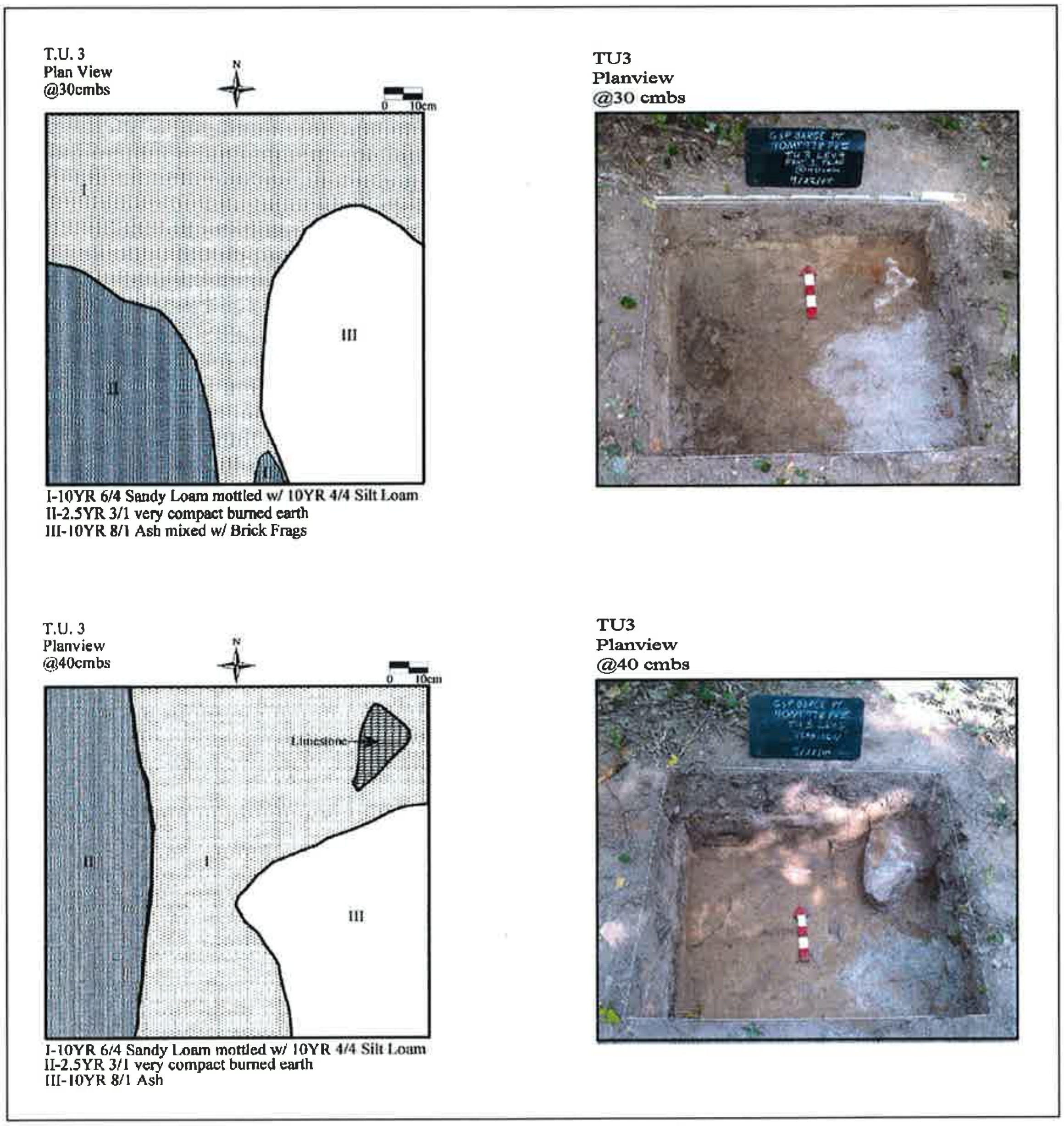

Figure 21. Test Unit 3 plan view drawings and photographs.

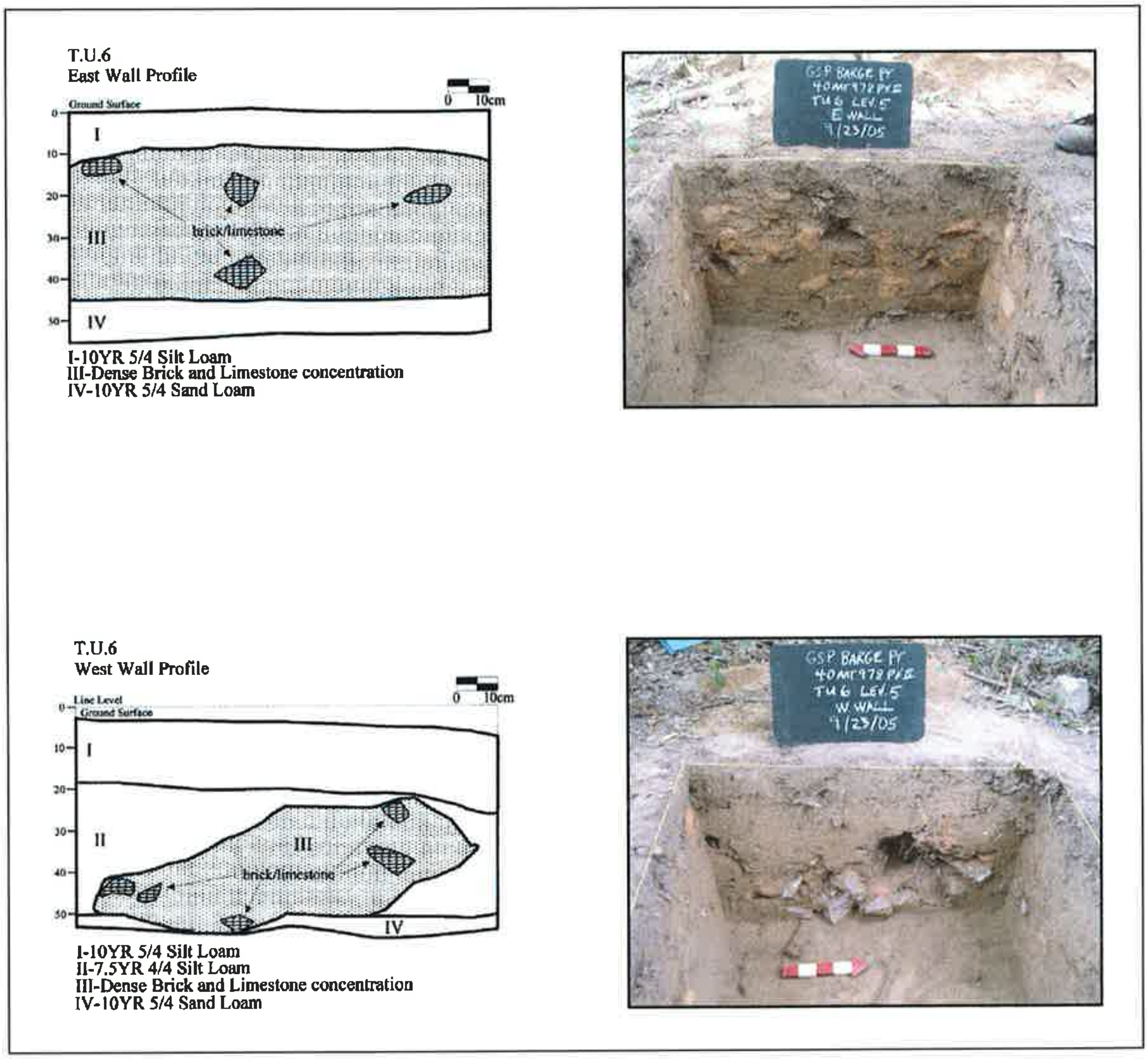

Figure 22. Test Unit 6 wall profile drawings and photographs.

Table 3. Historic Ceramic Artifacts Recovered from 40MT978.

Provenience	*Depth (cmbs)*	*White Refined Earthenware*				*Yellowware*	*Stoneware*	*Undecorated Porcelain*	*Total*
		Undecorated	*Annular Decoration*	*Decal Decoration*	*Hand Painted Decoration*				
TU1	0-10	2							**2**
	10-20	1							**1**
TU2	0-10	1			1				**2**
	10-20	3			1				**4**
TU4	10-20		1						**1**
TU5	0-10	2			2			1	**5**
	10-20	9					1		**10**
	20-30	3		3	1	1			**8**
TU6	20-30	1							**1**
TU7	20-30	1							**1**
TU8	0-20	8			3			1	**12**
	Total:	**31**	**1**	**3**	**8**	**1**	**1**	**2**	**47**

Table 4. Glass Artifacts Recovered from 40MT978

Provenience	*Depth (cmbs)*	*Clear Curved*	*Clear Flat*	*Amber Curved*	*Amethyst Curved*	*Green Curved*	*Solarized*	*Milk*	*Pressed*	*Total*
GSC									1	**1**
GSC Top Terrace		1								**1**
TU1	0-10	20	1				9	1		**31**
	10-20	4	1							**5**
TU2	0-10	1	1					1		**3**
TU3	10-20					3				**3**
TU5	0-10	4	2				1		3	**10**
	10-20	12	3	1	1			1		**18**
	20-30	3	5							**8**
	30-40		1							**1**
TU8	0-20		10							**10**
	20-30		1							**1**
	Total:	**45**	**25**	**1**	**1**	**3**	**10**	**3**	**4**	**92**

Table 5. Additional Historic Artifacts Recovered from 40MT978.

Provenience	*Depth (cmbs)*	*Metal*					*Other*							*Total*
		Cut Nail	*Wire nail*	*Construction Hardware*	*Identifiable*	*Misc.*	*Handmade Brick*	*Leather/Shoe Parts*	*Bone/Teeth*	*Coal/Clinker*	*Porcelain Button*	*Writing Stylus*	*Modern Misc.*	
TU1	0-10	5		1	1-.22 shell casing	1								**8**
	10-20	7	1					2	2					**12**
	20-30	1												**1**
TU2	0-10	4	1	2		2			1		1			**11**
	10-20	20		1			2		1	1				**25**
	20-30									1				**1**
TU3	0-10						9		1					**10**
	10-20						2						3-plastic	**5**
	20-30						3							**3**
	30-40	2					3		5					**10**
	40-50	1			1-flatware handle				15					**17**
	50-60												1-cellophane	**1**
TU4	0-10				1-shotgun shell cap		5							**6**
	10-20						1							**1**
TU5	0-10	1					1	6	1					**9**
	10-20	7	1				2	3						**13**
TU6	0-10						2							**2**
	10-20						7							**7**
	20-30	5			1-knife blade		6							**12**
	30-40	1					5							**6**
TU7	0-10	27										1		**28**
	10-20	7					1							**8**
TU8	0-20	9												**9**
	Total:	**97**	**3**	**4**	**4**	**3**	**49**	**11**	**26**	**2**	**1**	**1**	**4**	**205**

Table 6. Prehistoric Lithic Artifacts Recovered from 40MT978.

Provenience	*Depth (cmbs)*	*Primary Flake*	*Secondary Flake*	*Tertiary Flake*	*Flake Fragment*	*Shatter*	*Flake Tool*	*Biface*	*Biface Fragment*	*Scraper*	*PP/K*	*Total*
TU1	0-10		2	6	6							**14**
	10-20	3	3	15	12	3	4		1			**41**
	20-30	5	12	13	35	6						**71**
	30-40		1	6	16							**23**
TU2	0-10		2	5		8						**15**
	10-20	2	4		4	3						**13**
	20-30			1	3		1					**5**
TU3	0-10		1									**1**
	10-20			1								**1**
	20-30			1								**1**
	30-40			1	3							**4**
	40-50	1		1	2							**4**
	50-60	1		4	5	2						**12**
TU5	0-10		3	1								**4**
	10-20	1	2	9	11	7			1		1	**32**
	20-30	2	5	16	12	25			1	1		**62**
	30-40	2	7	17	30	10						**66**
	40-50		1	5	6	4	1		1			**18**
	50-60		3									**3**
TU6	0-10		2	2	2							**6**
	30-40		1	1	4							**6**
TU7	0-10	1	1	3	1							**6**
	10-20		1	9	5	1						**16**
	20-30		8	14	13	8			1			**44**
	30-40		4			1						**5**
TU8	0-20	6	3	7	16	4	1	2				**39**
	20-30	3		12	10	7						**32**
	Total:	**27**	**66**	**150**	**196**	**89**	**7**	**2**	**5**	**1**	**1**	**544**

Historic Artifacts

Forty-seven historic ceramic artifacts were recovered from test units at 40MT978 (see Table 3). They consisted of fragments of undecorated (n=31) and decorated (n=12) white refined earthenware, yelloware (n=1), stoneware (n=1), and undecorated porcelain (n=2). Nearly half (n=23) of the historic ceramics were recovered from Test Unit 5. Selected examples of the ceramic fragments are shown in Figure 23. They include an annular decorated fragment (a), a salt glazed stoneware fragment (b), and four hand painted examples (c–f). The paucity of material and the lack of clearly datable early nineteenth century ceramics leads to the conclusion that the historic ceramic assemblage recovered from 40MT978 is associated to historic activity at the site from the middle nineteenth century to the early twentieth century.

Ninety-two glass fragments were recovered from 40MT978 suring Phase II investigations (see Table 4). Clear curved (n=45) and flat (n=25) dominate the assemblage. Colored (n=15) glass, milk glass (n=3), and pressed glass (n=4) fragments were recovered in smaller amounts. Glass artifacts were clustered in Test Units 1 (n=36) and 5 (n=37), both of which were excavated on higher terraces at the site. Many of the glass fragments are modern and likely attributable to recreation activity along the River at this location. One complete salt shaker (Figure 24, a) and a bottle top with an automatic bottle machine finish (Figure 24, b) were recovered from the site. The bottle top can be broadly dated from 1903 to the present. Solarized fragments recovered from the site (n=10) were manufactured likely around the turn of the nineteenth and twentieth centuries and are related to earlier activity at the site.

One hundred eleven metal artifacts were recovered from test units excavated at 40MT978 (see Table 5). Ninety-seven of these were cut nails (Figure 24, g). Other metal recovered included wire nails (n=3), fence post staples or construction hardware (n=4), 1 .22 caliber shell casing, 1 flatware handle, 1 shotgun shell cap, and 1 knife blade fragment (Figure 24, f). The metal artifacts were recovered in fairly even distributions from test units. The high amount of cut nails recovered from the site points to nineteenth century activity. Cut nails became popular by the 1820s (Nelson 1968). They continued in popularity until the late nineteenth century when wire nails became the most popular nail type used. Although structural remains were not found during Phase II archaeological investigations at 40MT978, the prevalence of cut nails recovered does suggest building or construction activity within the site boundaries in some fashion.

Forty-nine handmade brick fragments were recovered from test units at 40MT978. In general the brick fragments were evenly distributed across the units, except Test Units 3 and 6 where high amounts of brick were encountered. Collection of brick from these units was of representative examples only. Three examples of brick fragments recovered from these units are depicted in Figure 25. Example (a) in Figure 25 represents a brick with a glazed exterior surface, example (b) is a brick fragment fired at a very low temperature, of the type known as a “salmon brick”. The recovery of these three types of bricks provide evidence, along with the ash and burned earth deposits seen in lower terrace test units, of some scale of brick making activities on the low terrace above the stream floodplain. During the brick making process bricks closest to the fire generally are

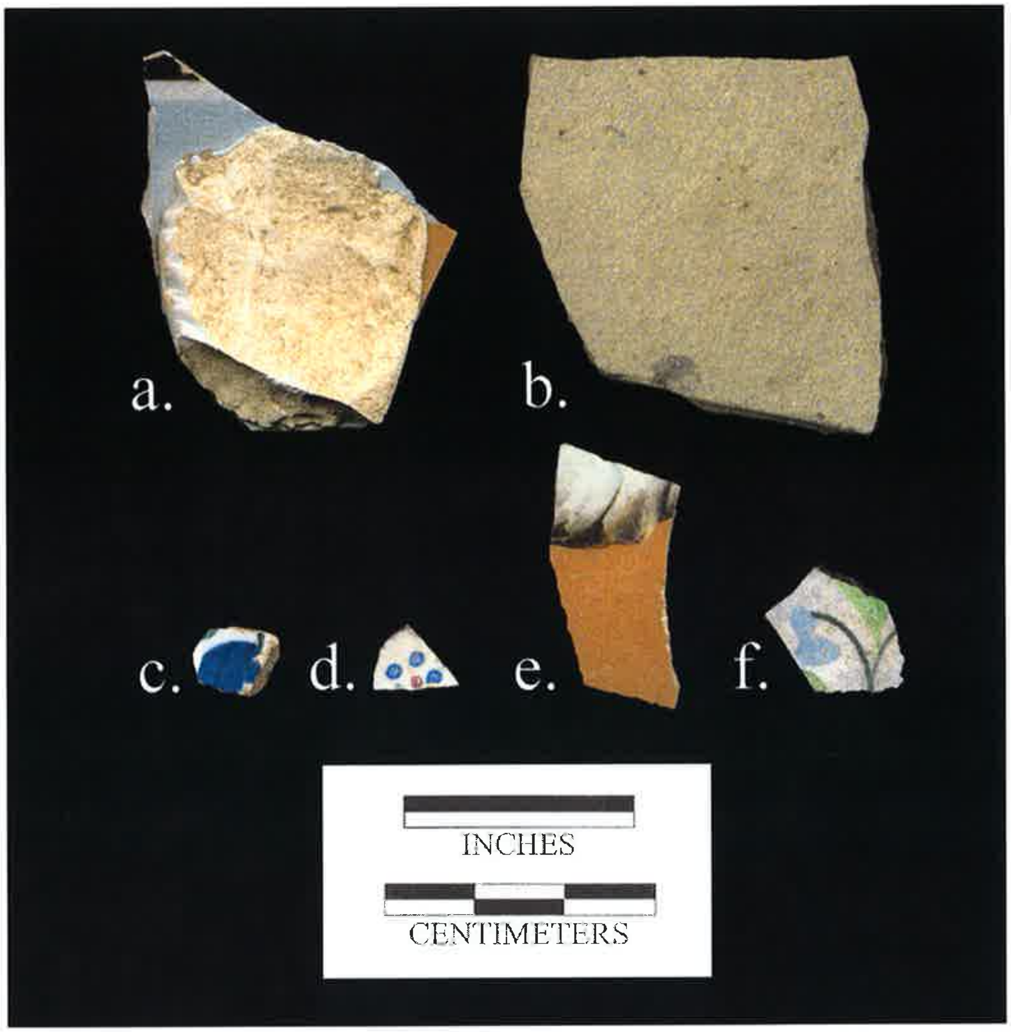

Figure 23. Selected examples of historic ceramic fragments recovered from 40MT978.

Figure 24. Selected additional artifacts recovered from 40MT978.

Figure 25. Selected examples of brick recovered from 40MT978.

glazed on an exterior surface (example a). Glazing will not occur on brick away from the fire (example b), and brick that break apart during the firing process often will glaze on one or more interior surfaces depending on how close they end up to the fire.

Additional artifacts recovered from 40MT978 include 11 leather/shoe parts (see Figure 24, c), 26 animal bone and tooth fragments, 2 coal fragments, 1 writing stylus (see Figure 24, d), 1 porcelain button (see Figure 24, e), as well as plastic and cellophane fragments.

Prehistoric Artifacts

Five hundred forty four prehistoric stone or lithic artifacts were recovered from test units at 40MT978. The bulk of the assemblage included debitage (n=528) or the waste created from chipping stone to make a stone tool. Seven flake tools were recovered. These represent flake debitage that has been retouched or sharpened along one or more edges to be used as a cutting implement. Nine lithic tools were recovered from the site and include 2 complete bifaces, 5 biface fragments, 1 scraper, and 1 PP/K. Selected examples of the tools are shown in Figure 26. Examples (a–b) are the two complete bifaces and represent preforms or bifaces in the early stage of manufacture. Examples (c–d) are early stage biface fragments. Examples (e–g) represent late stage PP/K biface fragments. Specimens (e) and (f) are distal portions and specimen g is a middle portion. Example (h) is a PP/K fragment that retains most of its hafting element. Too much of the element is missing to definitively type the point to a prehistoric period, however it appears to represent a Late Archaic expanding stemmed variant. The prehistoric artifacts recovered from 40MT978 suggest that tool making may have been an important activity at the site.

NRHP ELIGIBILITY DETERMINATIONS

Overall, artifact density is low at 40MT978 and deposits are relatively shallow and mainly colluvial in nature. Prehistorically, the site likely represents a small perhaps short-term encampment. The site location within sloped terrain with exposed bedrock throughout coupled with evidence of tool making activity suggest that the area may have been used as a raw material procurement locale. Of course the site's close vicinity to the Cumberland River also would have made it ideal for hunting, fishing, as well as access to the waterway. No prehistoric features (i.e. midden, trash pits, house floors) were discovered during Phase II investigations at 40MT978. Also, no discernable intact archaeological prehistoric deposits were apparent. It is the opinion of TRC that the prehistoric component at 40MT978 is not eligible for NRHP inclusion.

Archival research did not reveal specific information regarding location or extent of past structures that may have been located within 40MT978 boundaries. The site represents an area likely used for various purposes throughout historic times or from the middle nineteenth century to the early twentieth century as well as to the present. This includes nineteenth century landing activities. The relatively high amounts of cut nails recovered from the site does suggest nineteenth century building activities, however no surface or subsurface structural remains were encountered during the Phase II investigations. No intact historic midden or artifact concentrations were noted at 40MT978.

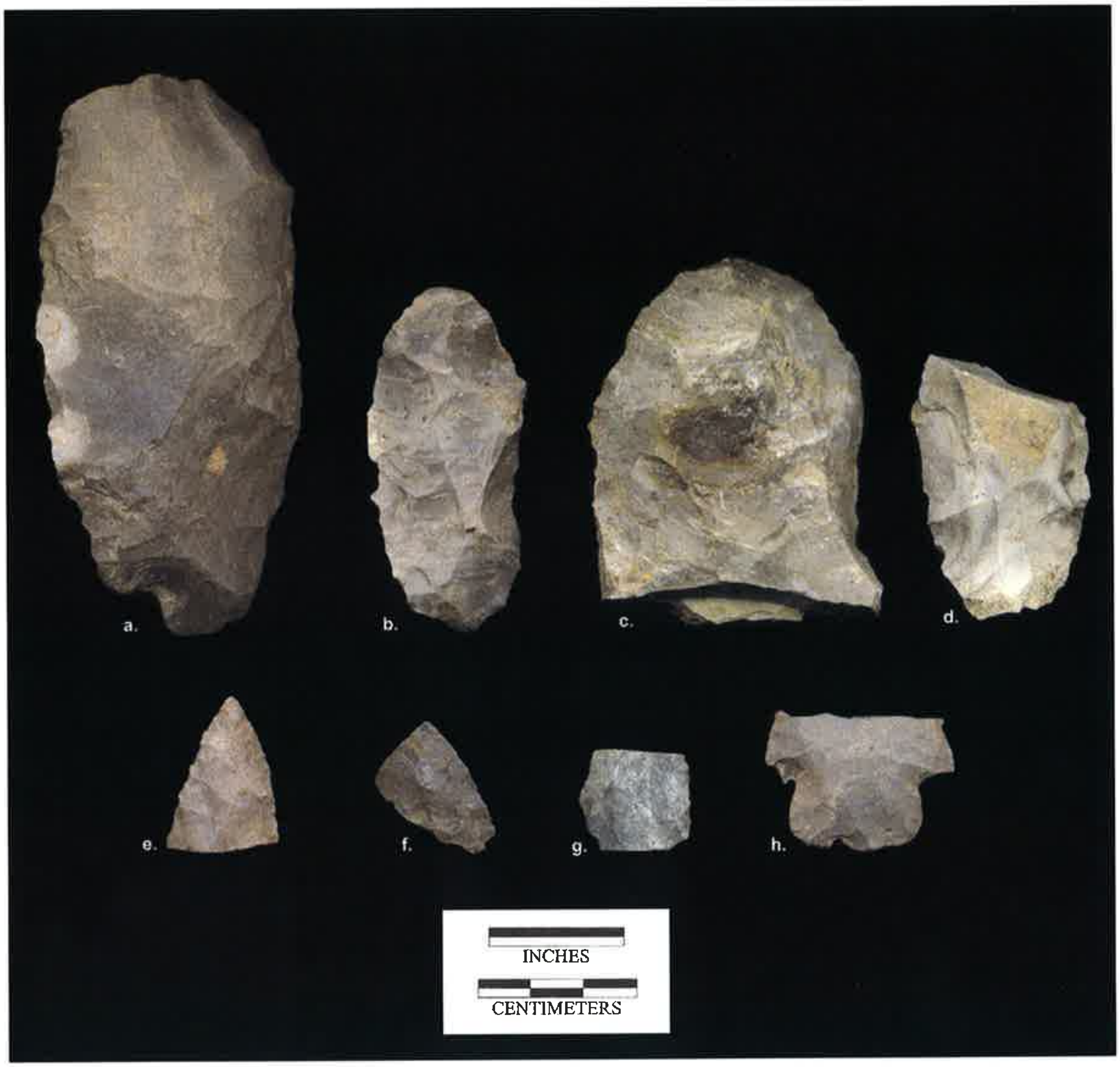

Figure 26. Selected examples of prehistoric lithic tools recovered from 40MT978.

The most significant finding during Phase II investigations at 40MT978 was evidence of brick making activity or a possible brick kiln within Test Units 3 and 6 on a low terrace at the site. This was presented in the discovery of ash and burnt layers in profile and the recovery of a high amount of glazed and underfired or "salmon" bricks (Figures 27 and 28). Brick kilns are common throughout middle Tennessee, but are often large in size sometime spanning at least 50 x 50 feet. Recently, TRC excavated the remains of a portion of a well-preserved brick kiln during Phase II excavations in the vicinity of Tennessee Woolen Mills (TWM) in Lebanon, Tennessee (McKee et al. 2004). The remains included intact kiln brick stacks accompanied with very dark burnt soil, and variety of fired and unfired brick fragments. The TWM kiln represented an "on site" method of brick making, but was recommended as ineligible for the NRHP because it exhibited no unusual characteristics setting it apart from many other comparable kilns in the region. The possible brick kiln discovered a 40MT978 appears to not be particularly well preserved and is small. It may represent entrepreneurial activity at this location along the river. The site's close proximity to Trice's Landing may have provided an ideal spot to make bricks and load them on passing barges for future sale. Nonetheless, it is TRC's opinion that the possible brick kiln at 40MT978 is ineligible for NRHP listing. Furthermore, as a whole, the historic component at 40MT978 is also recommended as ineligible for the NRHP.

Figure 27. Ash deposits from Test Unit 3 at 40MT978.

Figure 28. Bricks recovered from Test Unit 6 at 40MT978.

VI. SUMMARY AND RECOMMENDATIONS

In July of 2005, GSP contracted with TRC to carry out a Phase I archaeological survey of a parcel proposed as the site of a water treatment facility on the northwestern outskirts of Clarksville, TN. Specifically, the parcel investigated consists of approximately 30 acres to the west of Barge Point Road, bounded on the south by the Cumberland River. The Phase I study undertaken by TRC consisted of a literature search and archaeological field survey designed to document and assess archaeological resources located within the project area according to their NRHP eligibility status.

No previously recorded archaeological sites or historic properties are listed with the State of Tennessee on the development parcel. A variety of prehistoric and historic period sites have been recorded within one mile of the project area. Most are associated with the river shoreline and the early settlement of New Providence, to the east of the project area.

Two newly identified archaeological sites, 40MT978 and 40MT979, were recorded during TRC's Phase I investigation. Site 40MT978, located at the east end of the project area, contains Prehistoric, Archaic period components and late 19th century historic-period components. The site is situated on three narrow benches stepping down to the confluence of an unnamed stream and the Cumberland River, west of Trice's Landing Park. Substantial subsurface deposits of brick rubble were discovered on the lowest bench. A low density of prehistoric artifacts, which included an Archaic period PP/K, was also found at site 40MT978. During initial consultation with the TN-SHPO TRC recommended that the historic component of 40MT978 is potentially eligible for the NRHP based on its potential to yield information on late 19th century life and commerce in the project region. Phase II archaeological testing is recommended to further evaluate the site's NRHP eligibility status. Site 40MT979, consisting of a low-density scatter of prehistoric and historic materials, is located across the northern two-thirds of a large field at the center of the tract. No artifact concentrations, diagnostic prehistoric artifacts, or intact archaeological deposits were discovered at the site. TRC recommends that site 40MT979 is ineligible for the NRHP.

In September 2005, GSP contracted with TRC to carry out Phase II archaeological testing at site 40MT978. TRC's Phase II study at site 40MT978 included more thorough historical research of immediate areas within and around the site boundaries and archaeological test excavations designed to delineate the vertical and horizontal extent and content of deposits.

More thorough historical and archival research did not reveal information specific regarding the location of past structures located within project area or site 40MT978 site boundaries. The proposed location of the Water Treatment Plant is partially located within an area that once comprised a 640-acre land grant issued to a man named George Cook in 1788. Valentine Sevier, a prominent historical figure in the area, later purchased the land and established Sevier Station. Later in 1819, a large portion of the tract was divided into lots, which later became the town of New Providence. The research further indicated that the project area was largely historically used for farming purposes, although its southeastern portion, within site 40MT978, may have once contained buildings associated with Trice's and Planters Landings. These landings were located immediately east of site 40MT978 boundaries. More exact information, such as the extent and location, regarding structures associated with the landings was unable to be determined as a result of the archival research.

Archaeological test excavations at site 40MT978 involved the excavation of eight 1 x 1 meter test units. The units were strategically placed according to the Phase I survey shovel test results and landform configuration at the site. Prehistoric and historic components were discovered within the units. Artifacts were low in density and shallow. Prehistorically the site likely represents a temporary encampment possibly used for raw material procurement activities. No diagnostic prehistoric artifacts were recovered at 40MT978 during Phase II investigations, however one PP/K fragment that retained most of its hafting element appears was recovered and appears to represent a Late Archaic stemmed variant. No midden or intact prehistoric cultural deposits were discovered at 40MT978 during Phase II investigations.

Historically, 40MT978 represents an area used from likely the middle nineteenth to early twentieth century. A relatively high amount of cut nails recovered from the site during test unit excavation points to nineteenth century activity at the site. The possible remains of a brick kiln were discovered on a low terrace at the site. Ash and burnt soil layers were noted in the profile of two test units excavated in this area and a variety of glazed and unglazed brick fragments were also recovered. The kiln may represent a small enterprise of brick making at this location along the Cumberland River. No historic artifact midden or subsurface historic structural remains were noted during TRC's Phase II excavations at 40MT978.

It is the opinion of TRC that prehistoric and historic components at 40MT978 are ineligible for the NRHP. Prehistoric deposits are relatively shallow and low in artifact density. Long-term prehistoric habitation at the site is unlikely. Historic depostis are also shallow and low in artifact density. Although the evidence of brick making activity at the site is interesting it is considered ineligible for NRHP inclusion. TRC recommends no further archaeological work at 40MT978 in relation to proposed construction of the water treatment facility.

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Task 5 - Raw Water Pump Station Facilities Conceptual Planning

Hazen

Water Master Plan
Raw Water Pump Station
Facilities Conceptual Planning

CLARKSVILLE GAS & WATER

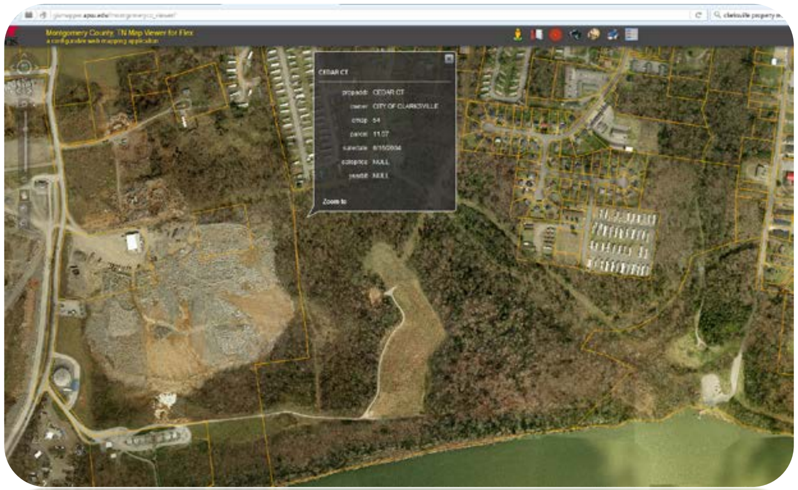
February 16, 2015

Today's Discussion

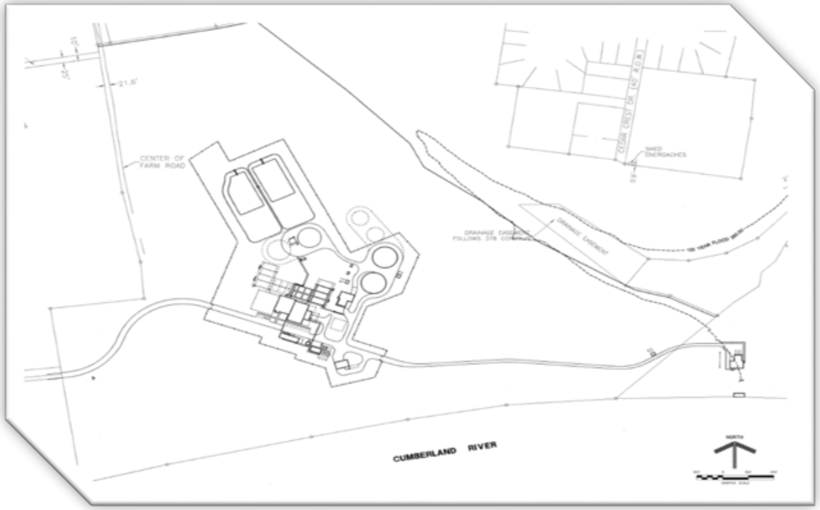
- Barge Point WTP Site Constraints
- Applicable Raw Water Pump Technologies
- Phasing of WTP
- Next Steps

Barge Point WTP Site

Current Site



Montgomery County Property Map



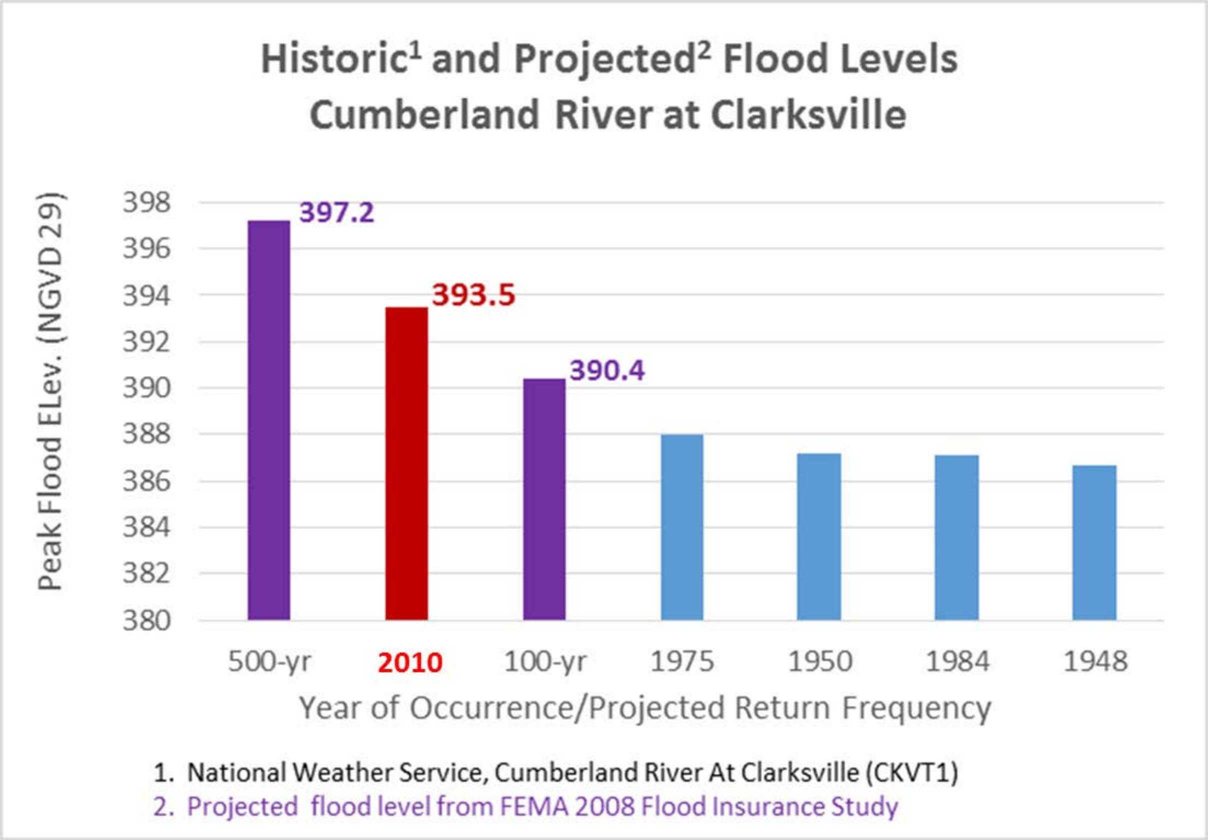
2006 Proposed Site Layout

Site Layout and Constraints

FEMA Mapping

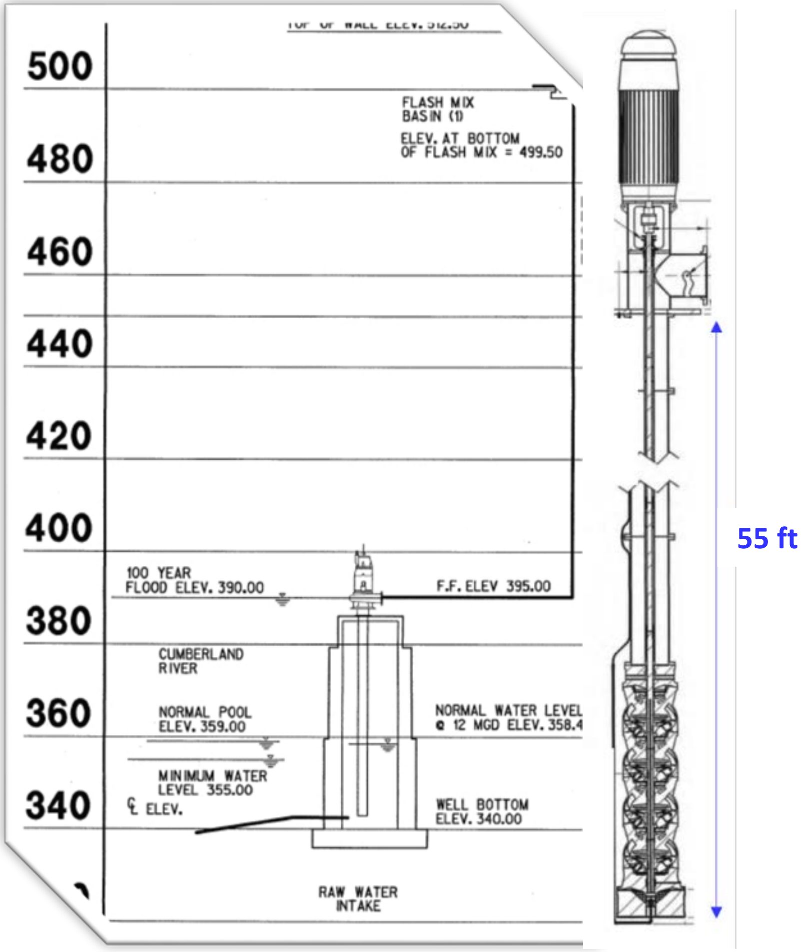
Updated Levels: 2010 Flood

- "Official" 100-yr and 500-yr flood levels being updated
- Recommended operations floor EL 395 – 400



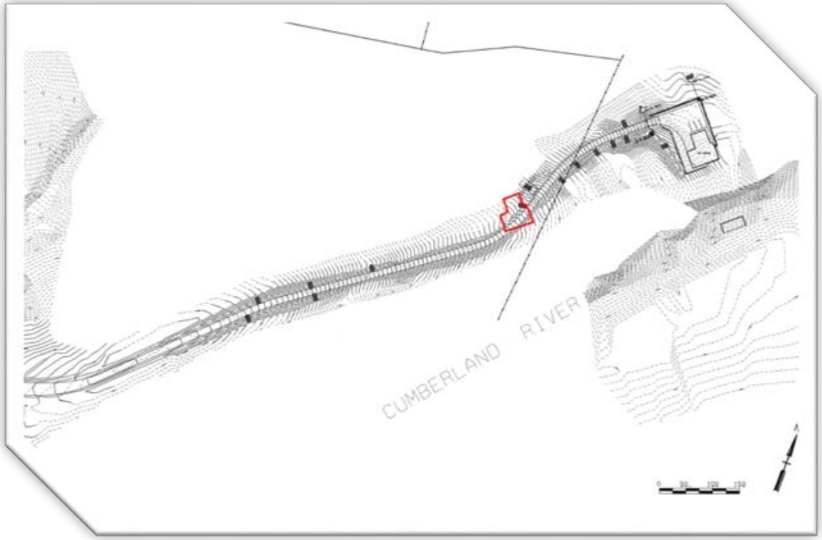
Assumed River and Pump Station Elevations

- Projected 100-Year = 395'+
  - All electrical equipment will need to be above this elevation
- Normal Pool = 359'
- Minimum Water Level = 355'
- Intake = 340'



Moving RWPS to CGW Property

- New Ground Elevation = 445’
- Intake Elevation = 340’
- Moving location doubles depth of intake from ground surface
    - Previous Depth = 55’-60’
    - Depth at CGW Location = 110’-115’



Applicable Pump Technologies

Design Constraints

- Deep Drawdown
- High Static Head
- High Flow Rate

Applicable Pumps for Site

- Vertical Turbine
  - Wet Well
  - Can
- Submersible
  - Wet Well
  - Dry Pit

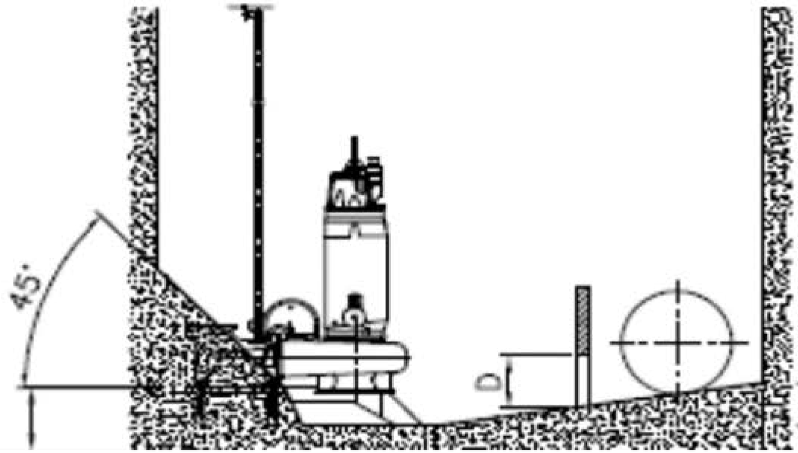
Vertical Turbine Pumps

Wet Well Configuration

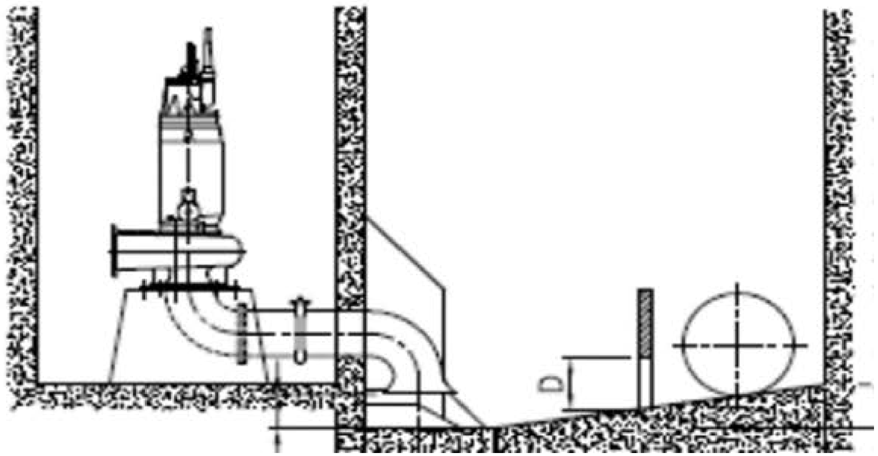
Can Configuration

Submersible Pumps

Wet



Dry



Vertical Turbines vs Submersibles

- Typically Higher Efficiency
- More Customizable Pump Selection
- Same Type as Existing WTP Raw Water PS

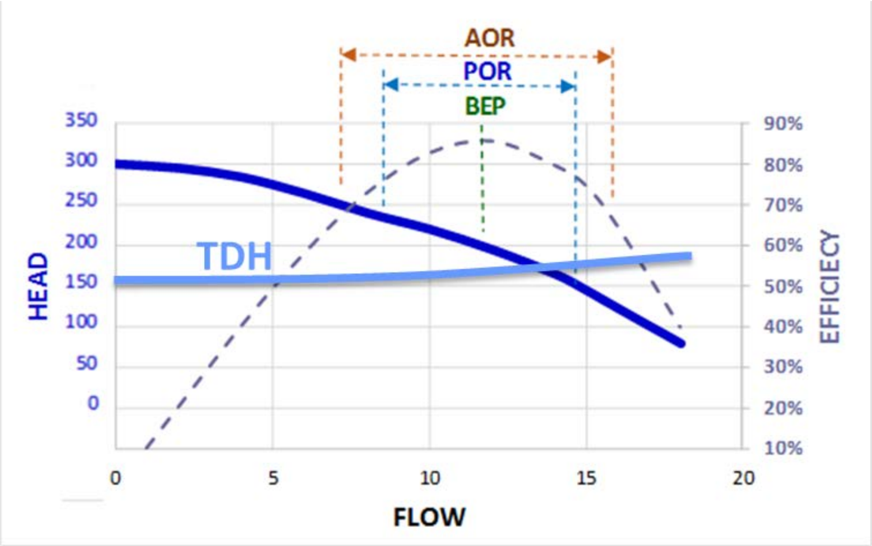
- Solids Handling
- High Head and Horsepower Limitations
- Typically easier to access and perform maintenance on pumps

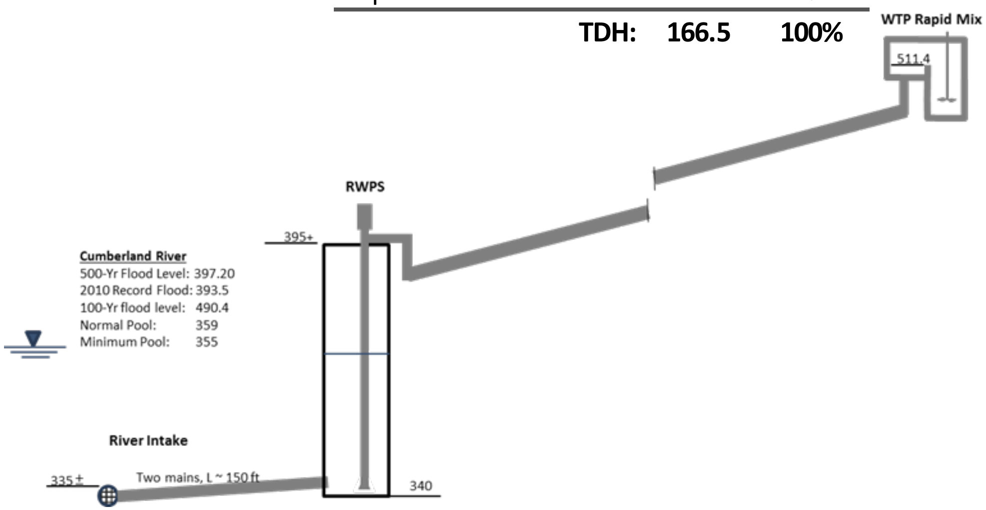
Phasing of WTP

Project Phasing & Other Factors Affecting Pump Lineup

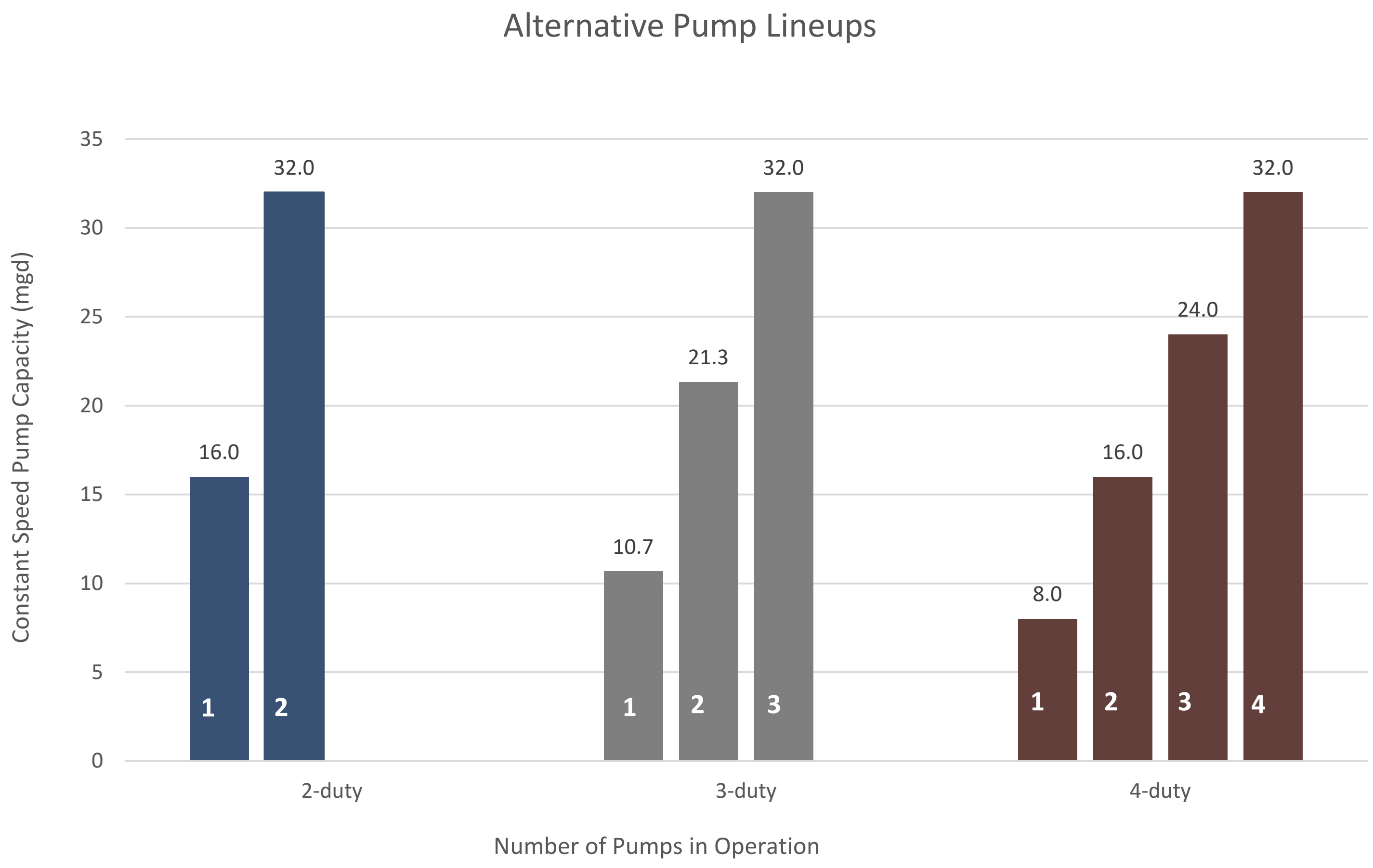
- High static head, low friction losses = flat system curve (TDH)
  - Will limit pump turndown on VFD
  - Points to more pumps for operational flexibility

Raw Water Transmission	Feet	%
Static Head/Vertical Lift:	156.5	94%
Pipeline Friction Losses	10.0	6%
TDH:	**166.5**	**100%**



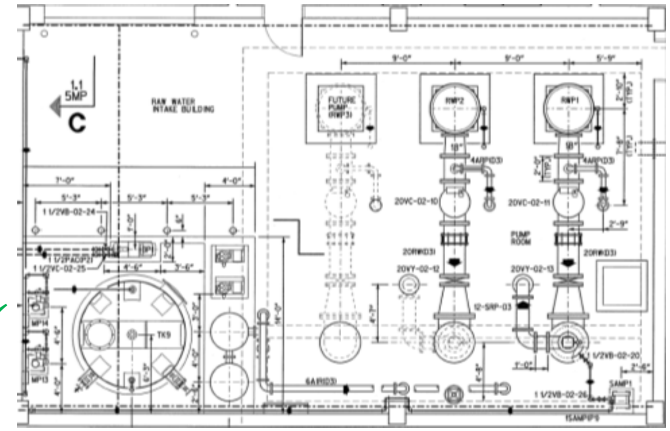


Project Phasing & Other Factors Affecting Pump Lineup



RWPS Wet Well

- Square/rectangular wet well
  - Pump layout
- Circular caisson
  - Lower construction cost and time ✓
  - Inherent structural strength ✓
  - Proven technology ✓
    - HI approved designs
    - Dry/wet well alternatives



Hydraulic Institute © ✓

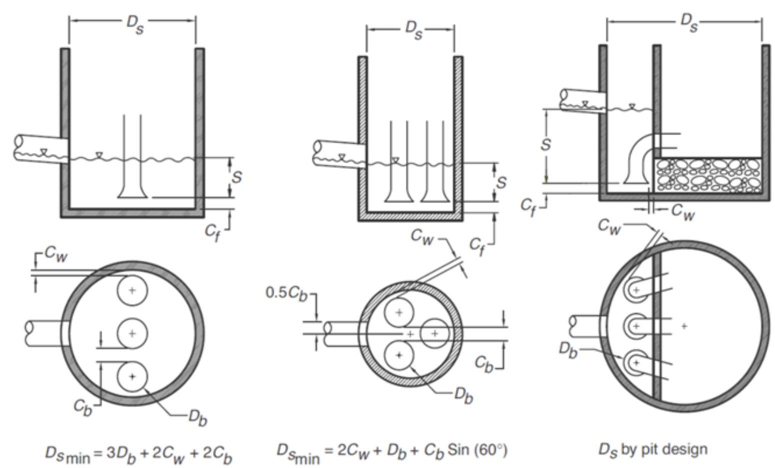


Figure 9.8.2.3.1d — Wet-pit triplex sump, pumps in line

Figure 9.8.2.3.1e — Wet-pit triplex sump, compact

Figure 9.8.2.3.1f — Dry-pit/wet-pit triplex sump

Questions?

Hazen

October 13, 2017

Tasks 6 and 7 - Modeling of Future Conditions and Capital Improvement Plan

Hazen *Technical Memorandum*

October 30, 2017

To: Clarksville Gas & Water (CGW)

From: Hazen and Sawyer (Hazen)

Re: Modeling of Future Conditions & Capital Improvements Plan Technical Memorandum (TM)
Water System Master Plan – Phase 2

Modeling of Future Conditions & Capital Improvements Plan

This TM addresses CGW's water distribution system for future demand conditions and associated capital improvement requirements. Projected demands, which were previously developed by Hazen, were used to model system performance in terms of having adequate pressure, fire flows, and storage volume. Where potential issues were identified, proposed improvements were identified and evaluated to determine a comprehensive list of solutions for CGW's system. Figure 1 shows CGW's system and current pressure zone delineation.

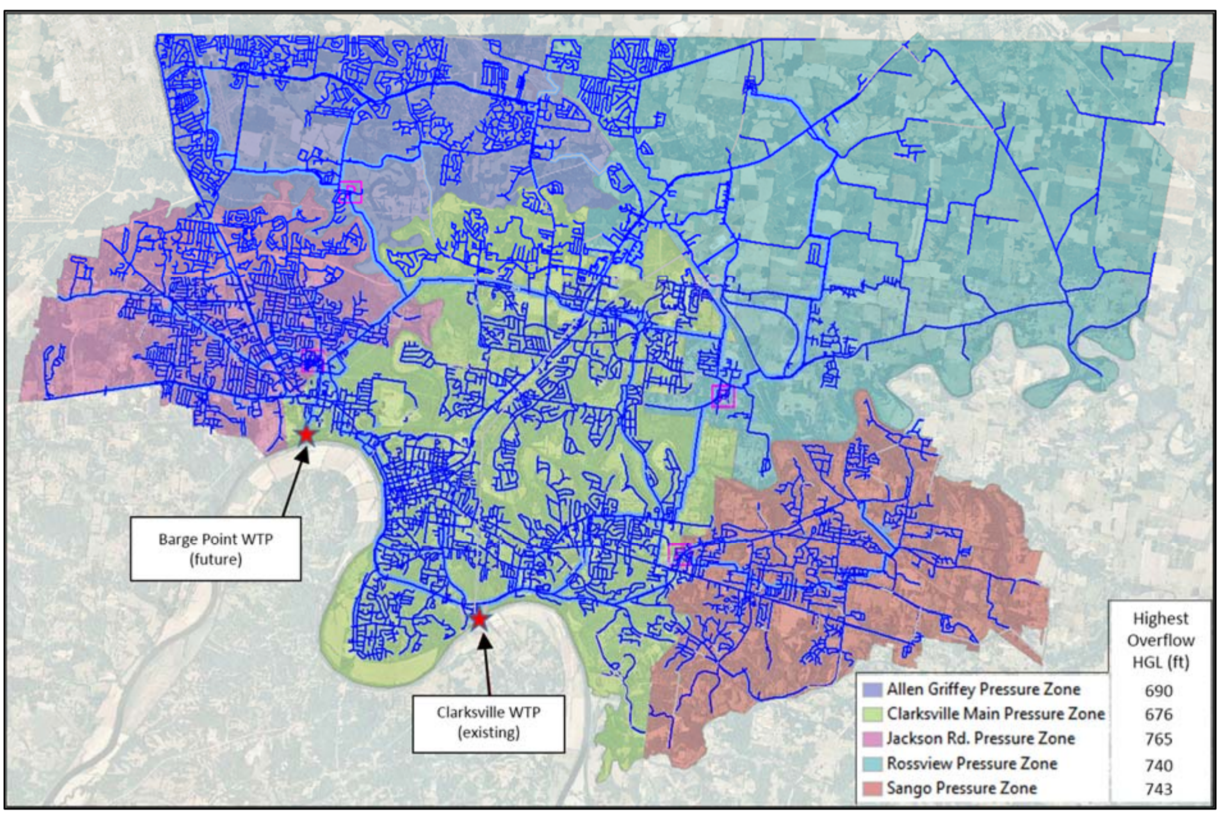


Figure 1: CGW Water Distribution System Overview

The Clarksville Water Treatment Plant (CWTP), which is currently CGW's only water treatment facility, is a state-of-the-art microfiltration membrane facility that is rated at 28 million gallons/day (mgd) and can peak at 30 mgd for a short period of time.

A summary of the latest demand projections for CGW's system are shown in Table 1. The demands in the Rossview Pressure Zone are expected to grow significantly starting in Year 2020 in large part due to the addition of a large industrial customer at the old Hemlock Semiconductor (HSC) site.

Table 1: CGW Demand Projections

Pressure Zone	Demand Projections (mgd)				
	2020 Avg Day Demand	2025 Avg Day Demand	2030 Avg Day Demand	2035 Avg Day Demand	2040 Avg Day Demand
Rossview	10.0	10.7	11.7	12.6	13.5
Allen Griffey	2.7	2.8	3.0	3.5	4.0
Sango	1.0	1.1	1.2	1.3	1.4
Jackson Road	3.2	3.4	3.5	3.6	3.7
Clarksville Main	6.2	6.9	7.6	8.1	8.5
Total Avg Day (mgd)	**23.0**	**24.9**	**26.9**	**29.0**	**31.1**
Max Day (mgd)	**29.1**	**31.4**	**33.9**	**36.6**	**39.3**
Max Hour (mgd)	**45.3**	**49.1**	**53.1**	**57.5**	**61.9**

Maximum day and maximum hour demands were previously developed for CGW's model based on review of historical data at CWTP and development of diurnal patterns from reported tank levels. These factors were carried forward into the demand projections.

Although the balance between water production and demand in CGW's system is currently sufficient (i.e. CWTP capacity is greater than maximum day demands), future growth will eventually require increasing the system production capacity. This TM provides the results of an evaluation of CGW's system with future growth in the Year 2040.

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1. Future Conditions Analysis

1.1 Assumptions for Future Conditions

1.1.1 Existing Clarksville WTP

The existing CWTP, which was recently expanded to a capacity of 28 mgd, is responsible for meeting current demands for the entire CGW system. However, more capacity is projected to be required as future growth occurs. In order to meet future production requirements, CGW will either need to continue to expand water production capacity at the existing CWTP or construct a new WTP. However, due to discussion with CGW staff in various workshops throughout the master planning process, it is now assumed the existing CWTP will not be expanded any further and that additional water production capacity needed will come from the construction of a second WTP. This is in large part due to a desire to increase system reliability and to reduce dependence on a single WTP.

1.1.2 Barge Point WTP

The Barge Point Road location has been identified as the most likely site for a new WTP because the land has already been purchased by CGW as part of prior planning efforts (see the Barge Point Road WTP Conceptual Design Technical Memorandum). Also, as referenced in the previous section, additional capacity is projected to be needed at this location based on future demand projections. Therefore, this evaluation assumes that the future Barge Point WTP (BPWTP) will be brought online incrementally to increase water production capacity as required by future system demands.

Although the operation of the system with two WTPs will be adjusted in the future, it was assumed for future conditions that both plants would produce water simultaneously and ultimately be similar in terms of water production capacity. Table 2 shows the water production schedules assumed for this evaluation. As discussed with CGW, a likely scenario is that BPWTP would be brought online at 12 mgd instead of 10 based on standard membrane equipment configurations. Although this scenario would be possible and would decrease the needed output from CWTP, the capital improvements outlined in this report would still be the same.

Table 2: Assumed Water Production Schedule for Barge Point and Clarksville Water Plants

	Maximum Day Production (mgd)				
	2020	**2025**	**2030**	**2035**	**2040**
Clarksville WTP	29.1[1]	21.4	23.9	26.6	19.3
Barge Point WTP	0.0	10.0	10.0	10.0	20.0
Total	**29.1**	**31.4**	**33.9**	**36.6**	**39.3**

[1] It should be noted that although production at CWTP exceeds the rated capacity of 28 mgd in Year 2020, CWTP is capable of 30 mgd for short periods and this would be a maximum day scenario. Bringing BPWTP online by Year 2020 was not assumed to be realistic due to required time for permitting, design, and construction.

1.1.3 Identification of Improvements

An essential part of any water master planning effort is to identify the overall goals of what is to be achieved by the proposed improvements. For CGW, the planning goals were identified as the following:

- Ensuring adequate production capacity is available to meet future demands
- Providing redundancy to customers where cost/benefit makes sense
- Ensuring headloss is kept to a minimum for transmission mains (i.e. pipes 16 inches or greater in diameter by keeping peak velocities under 5 feet per second (fps)).
- Ensuring water age does not exceed ten days under normal operating conditions

1.2 Evaluation

The primary focus of the future conditions evaluation section in this report was to determine the necessary infrastructure improvements required to achieve the goals outlined in Section 1.1.3 with the demand projections developed for Year 2040. The list of needed capital improvements and associated cost estimates are included in Section 2 of this report.

The modeling evaluation for pressure, headloss, and fire flow availability was performed for each pressure zone individually while extended period simulations were run to look at tank turnover, pump operation, and water age.

For all evaluations of pressure and headloss, maximum-hour demand conditions were assumed with tanks near the bottom of the normal operating range. Fire flow availability was assumed to have maximum-day demand conditions with tanks at the bottom of the normal operating range. Finally, all extended period runs were assumed to have average-day demands with normal operation and start with tanks full.

1.2.1 Rossview Pressure Zone Improvements

Since Rossview Pressure Zone (Rossview) is projected to have the most water demand growth of any area within CGW's system, special consideration was given to implementing improvements that would provide sufficient reliability and capacity to satisfy future demands. Several workshops with CGW resulted in proposed changes to the system, which are described in the following subsections, and included in the model setup used in the evaluation of future conditions.

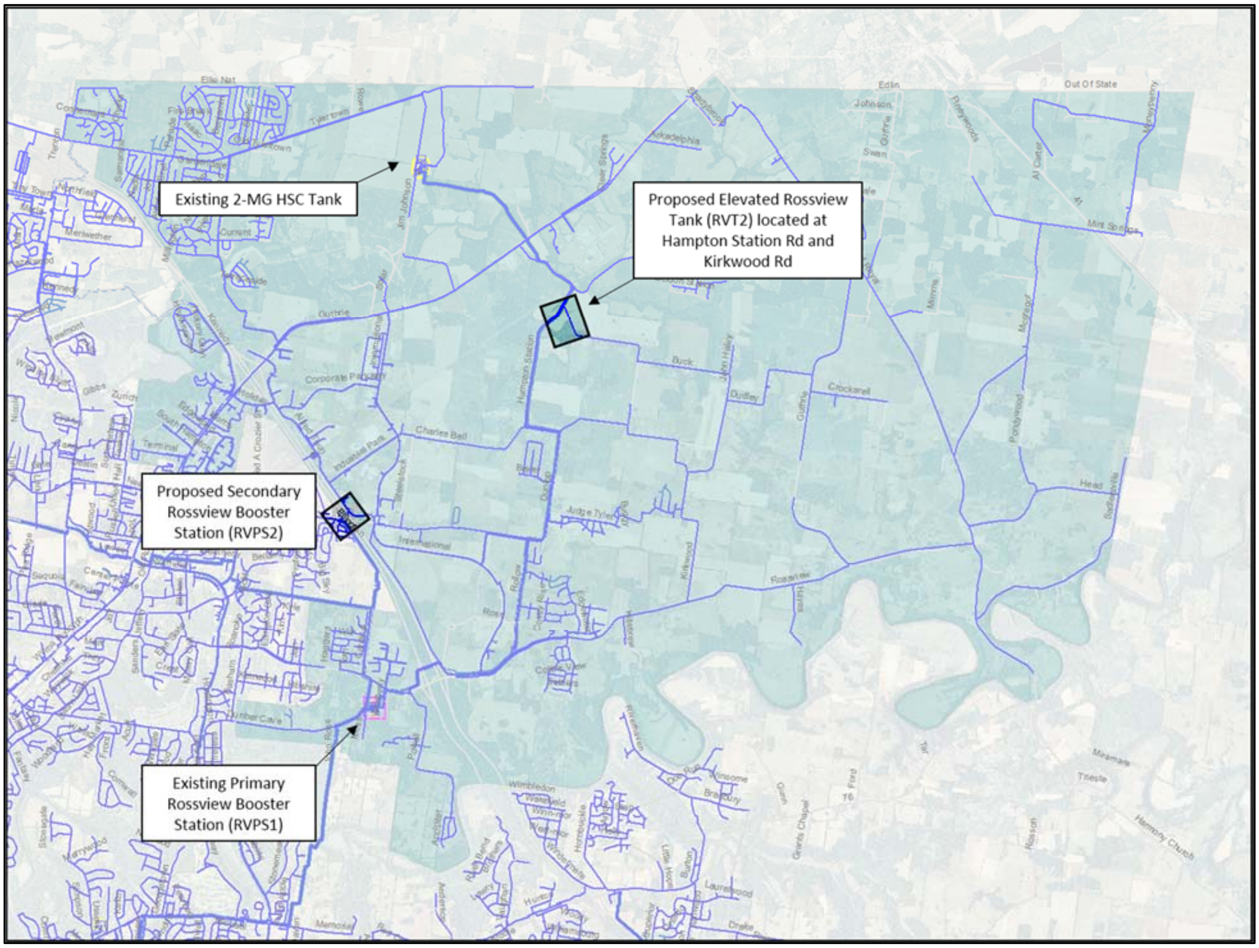


Figure 2: Rossview Existing and Proposed Facilities

1.2.1.1 Secondary Rossview Booster Station

Although Rossview Pump Station (RVPS1) currently has a backup generator, an interruption of service at this facility could result in rapid depletion of storage in Rossview and ultimately a water outage. Therefore, a second pump station (RVPS2) was identified as a critical need for water supply. RVPS2 was conceptualized in the vicinity of the RJ Cormin railroad near Dunlop Lane (See Figure 2). A booster station here would allow a second supply point from Main into Rossview.

As a result of workshops with CGW, it was determined that RVPS2 should be capable of supplying the entire Rossview demand in case RVPS1 should be taken out of service. For this reason, line sizes were evaluated under both operational scenarios to verify either station could meet demand and storage requirements for future conditions.

1.2.1.2 New Elevated Rossview Tank

Based on future demand projections in Rossview and the need for redundancy, more storage was determined to be necessary in Rossview. From discussion with CGW staff, a preliminary review of the topography in Rossview was evaluated to narrow down potential tank sites. The conclusion was that a new tank (RVT2) must either be located very near the HSC Tank or south of Guthrie Highway near Hampton Station and Kirkwood Roads. It was ultimately determined that storage at Hampton Station and Kirkwood would be preferable based on available land and proximity to industrial customers in the southern part of Rossview (See Figure 2).

Since RVT2 will need to be elevated due to existing ground elevation, the size will be constrained by constructability issues to a maximum of 4 million gallons (MG) based on experience with other tank design projects. However, for the purposes of this evaluation, RVT2 was assumed to be just 2 MG, which is the same size as the existing HSC Tank.

1.2.1.3 Transmission Line Improvements

The concept of a secondary booster station and new elevated tank will also require transmission line improvements. A transmission loop was determined to be the best way to deliver reliable and redundant water supply. The proposed loop, conceptualized in a workshop with CGW, will include upsizing some of the existing mains and construction of new segments to create a "backbone" for the pressure zone.

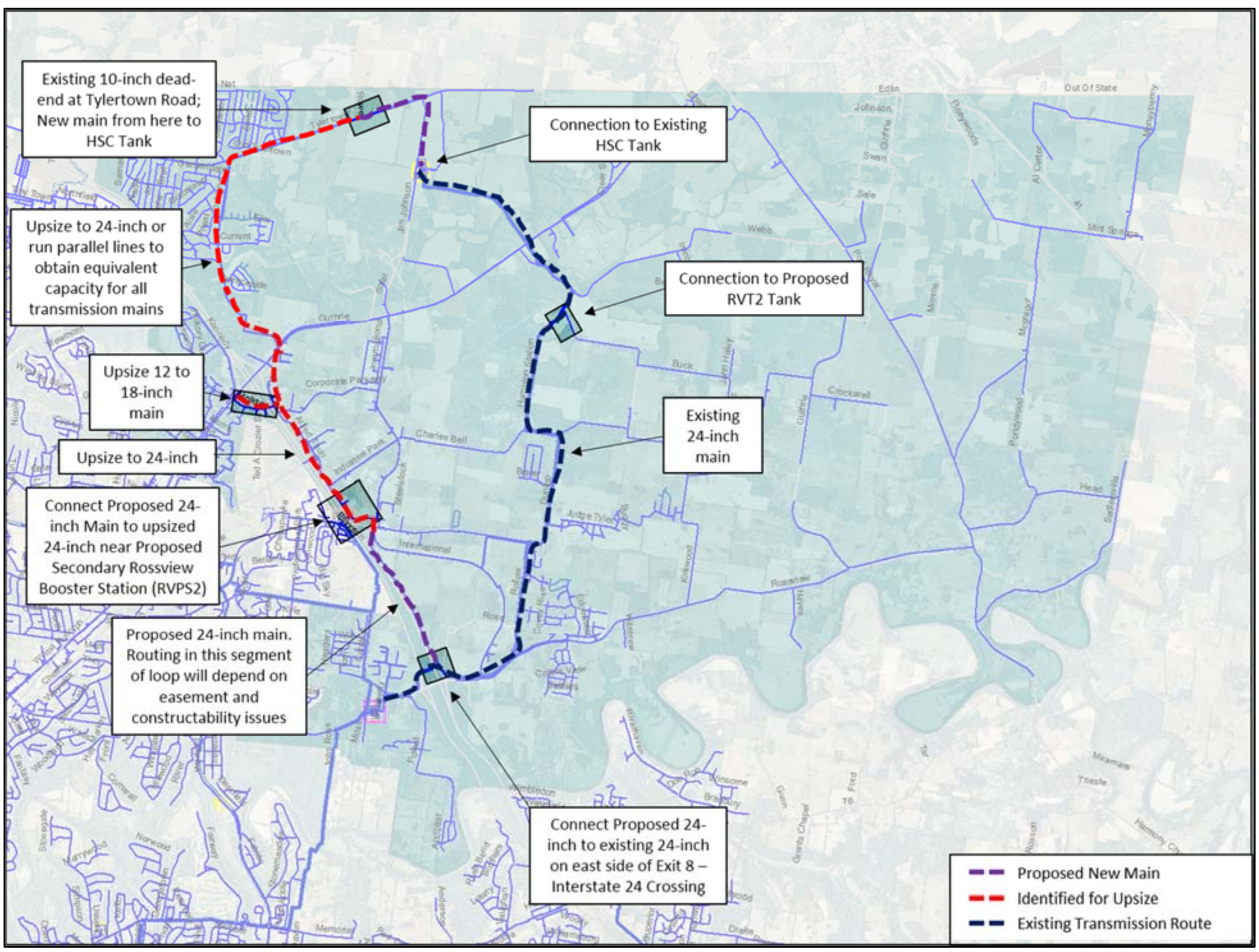


Figure 3: Proposed Transmission Loop Improvements

A loop of this configuration will allow versatility in operations and provide the capability to take a single tank or a single booster station offline temporarily for maintenance. It would also increase the transmission capability from the booster stations to the tanks in Rossview since each station could share the role of water production thereby lowering flow at each booster station's discharge and overall headloss throughout the loop.

As shown in Figure 3, the proposed loop would consist of the existing 24-inch main to HSC Tank, a new 24-inch main segment alongside Interstate 24 to connect RVPS1 and RVPS2, an upsized segment between RVPS2 and Tylertown Road, and a new main between the existing 10-inch dead-end on Tylertown Road and the site of HSC and RVT2 Tanks.

For the Interstate crossings at both Exit 8, and for RVPS2, a 24-inch main already exists. However, these mains will be a capacity bottleneck based on the goal of staying under 5 fps (see Section 1.1.3) and the rationale that each station shall by itself have the ability to meet maximum-day demands in Year 2040 for Rossview demands, which are projected to be 15 mgd (i.e. peak velocity for a 24-inch main is limited to 10 mgd at 5 fps instead of the required 15 mgd).

However, the cost of upsizing the existing crossings or running parallel mains at each location would be significant. Further analysis of the headloss incurred at the crossings under the extreme condition of a single station providing maximum-day demands in Year 2040 show that peak velocity in the 24-inch crossings would be pushed to approximately 7.4 fps. However, model runs indicate that even with the higher headloss, both HSC and RVT2 tanks could still be sustained with acceptable pressures at the discharge of the stations. Therefore, the 24-inch crossings were not upsized in the future conditions evaluation.

1.2.1.4 Large Water Users

Demand in Rossview is projected to increase in large part due to the addition of known industrial customers in the next five years. For these customers, assumptions were made on the daily pattern of water usage based on the type of industry. For example, Hankook Tire Facility was assumed to operate on a 16-hour pattern, which increases its steady-state demand by a factor of 1.5 compared to the entire day consumption (i.e. 24 hours of demand in 16 hours = 24/16 or 1.5).

1.2.1.5 Required Pump Capacity

As established in the master plan goals for redundancy, either RVPS1 or RVPS2 should have the capability to supply Rossview demands independently. Pump stations are typically sized to deliver no less than maximum-day demands for the projected design life cycle. Therefore, each station would need to be sized to deliver at least 15 mgd based on demand projections for Year 2040.

1.2.1.6 Pressures and Fire Flows

Rossview will experience some variation in pressures and available fire flow due to the operation of RVPS1 and RVPS2. Model results for Year 2040 are shown below with facility and line improvements as outlined in previous sections.

In general, pressure is sufficient throughout Rossview with improvements as modeled. Excessively high pressures occur near some locations with lower ground elevation and may require that customers install pressure reducing valves.

Available fire flow at 20 pounds per square inch (psi) residual pressure is shown to be below 500 gallons per minute (gpm) on the eastern side of Rossview in the vicinity of Webb and Port Royal Roads. The other area shown to have available flow less than 500 gpm is Powell Road. However, fire flows were not far under the 500 gpm threshold in this area. Taking RVPS1 offline was shown to make the deficit more pronounced. Figure 8 shows a close-up of this area.

1.2.1.6.1 RVPS1 Only

Pressures under this condition are shown in Figure 4, and available fire flows are shown in Figure 5.

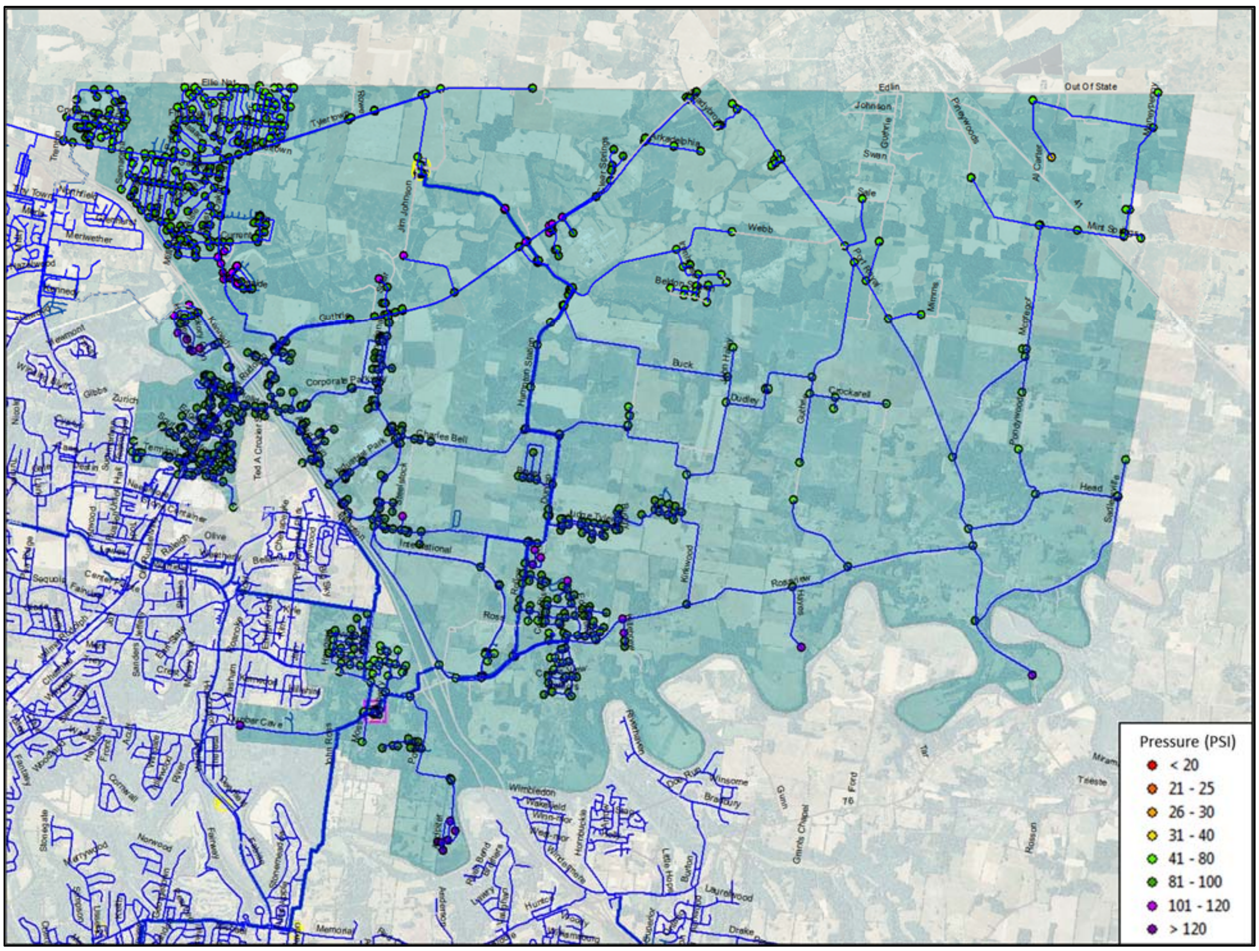


Figure 4: Peak-Hour Pressures in Rossview with RVPS1 Only

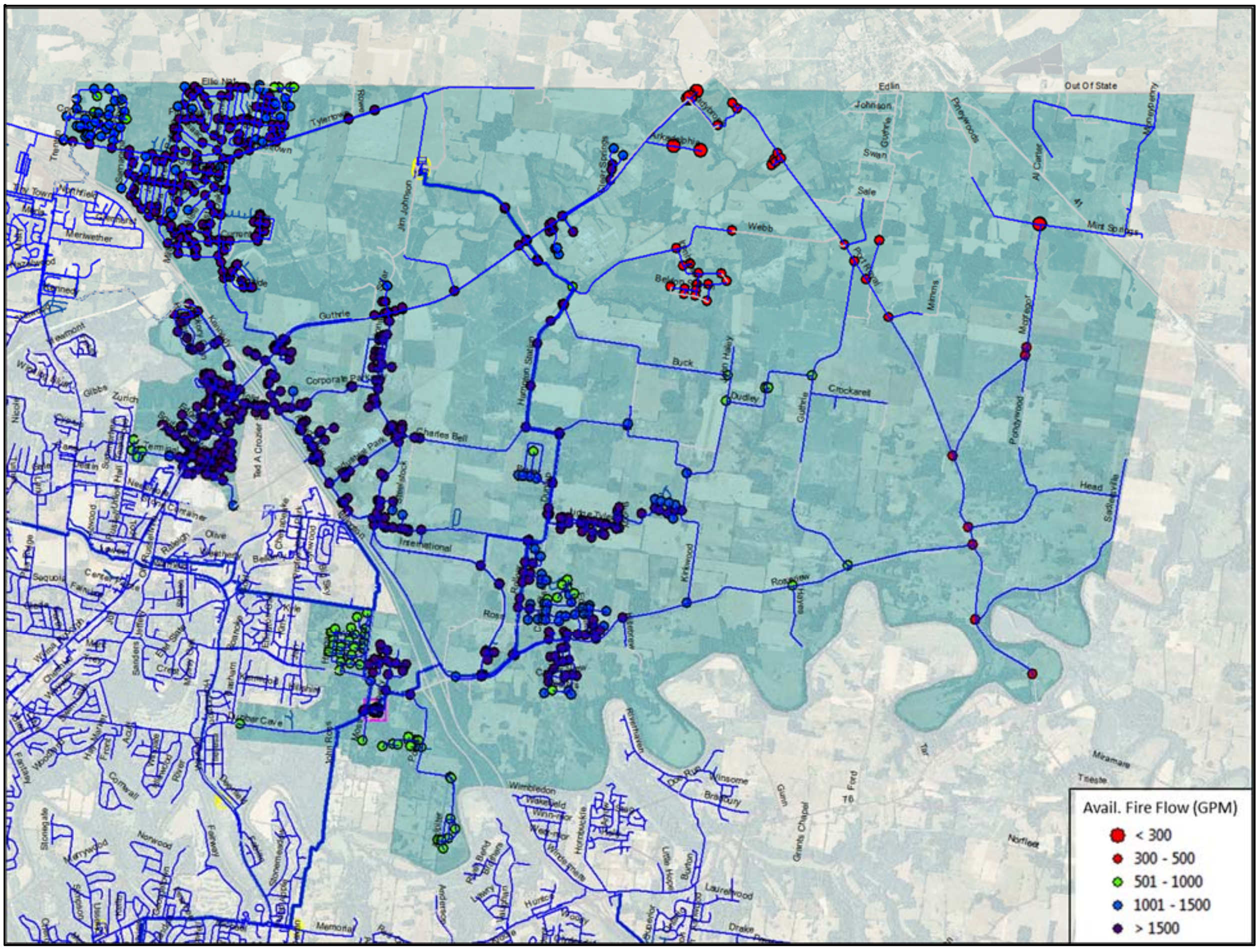


Figure 5: Available Fire Flows in Rossview with RVPS1 Only

1.2.1.6.2 RVPS2 Only

Pressures under this condition are shown in Figure 6, and available fire flows are shown in Figure 7.

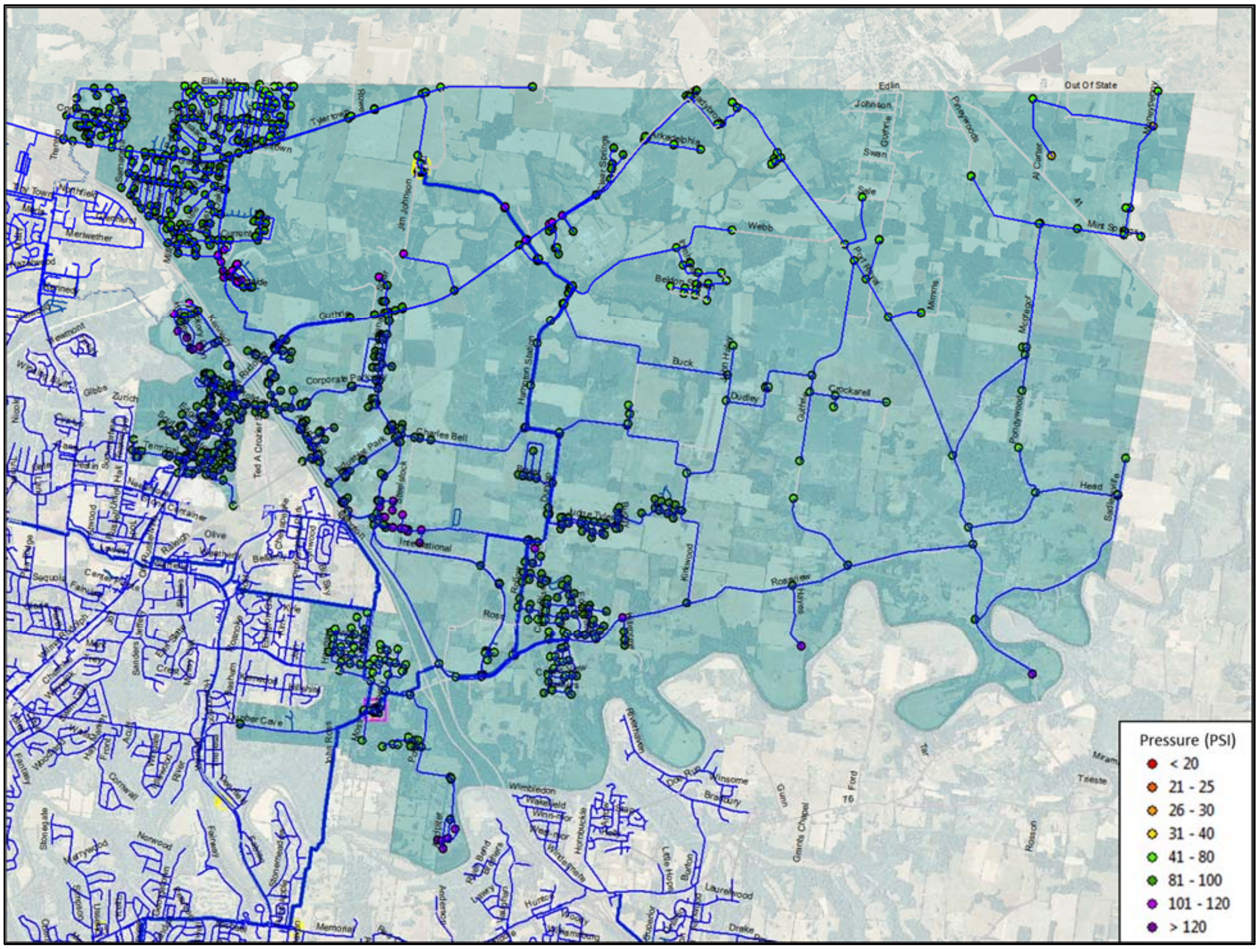


Figure 6: Peak-Hour Pressures in Rossview with RVPS2 Only

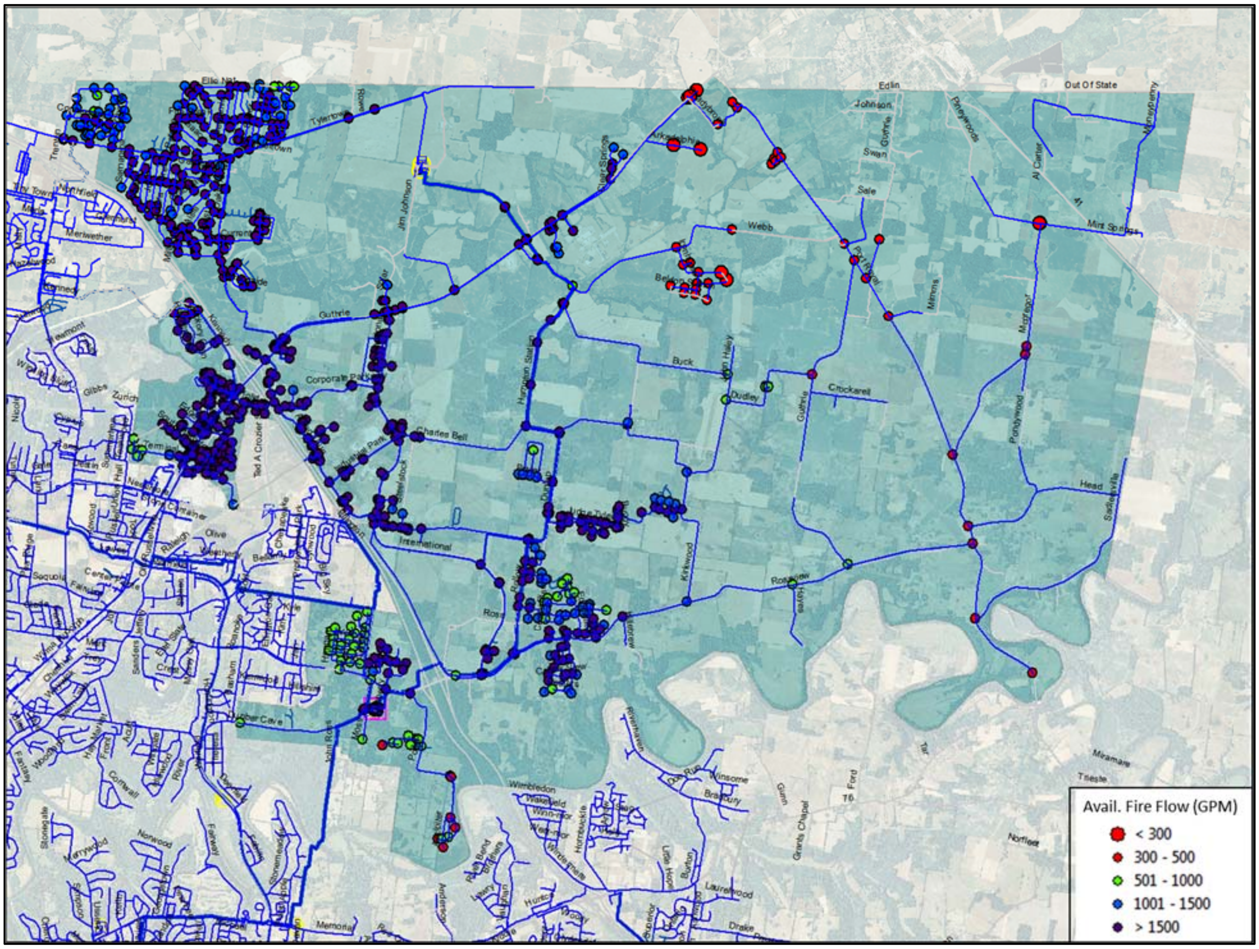


Figure 7: Available Fire Flows in Rossview with RVPS2 Only

Under this scenario, certain areas of Powell Road had less than 500 gpm for available fire flow. As shown in Figure 8, the 6-inch dead-end down Powell Rd resulted in flows just under the 500 gpm threshold.

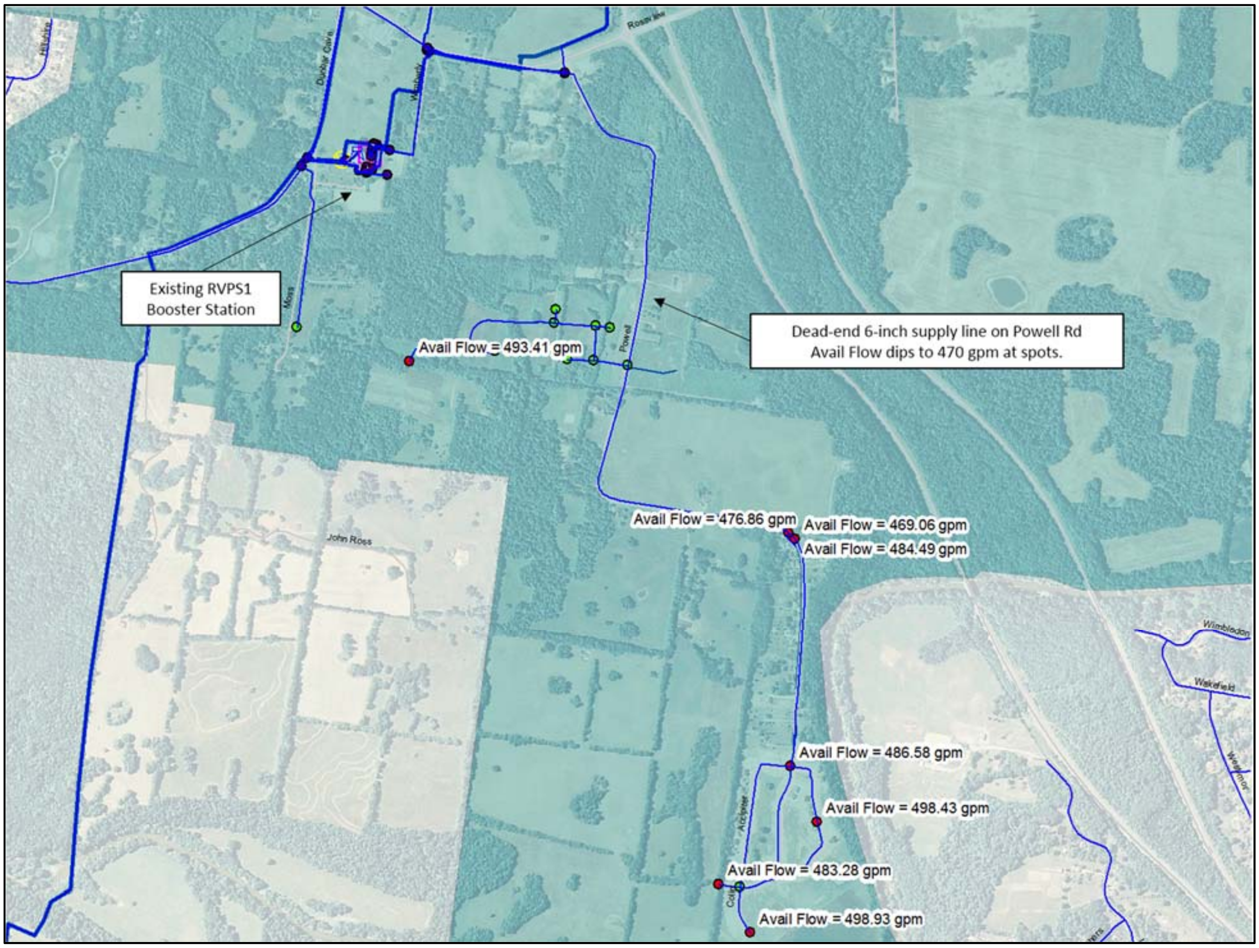


Figure 8: Powell Road Available Fire Flows with RVPS2 Only

1.2.1.6.3 Both RVPS1 and RVPS2

Pressures under this condition are shown in Figure 9, and available fire flows are shown in Figure 10. Flows from both RVPS1 and RVPS2 were set to be the same.

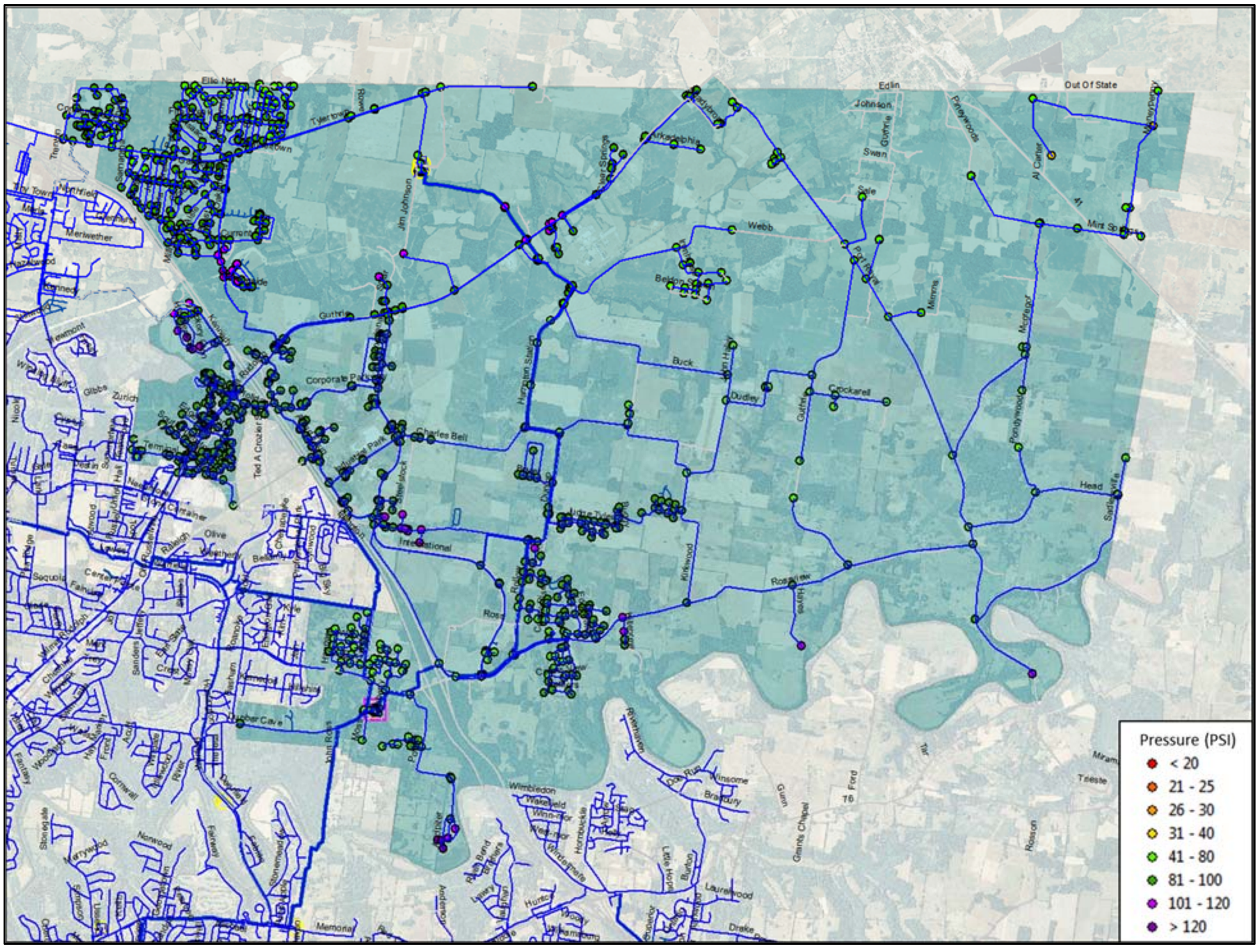


Figure 9: Peak-Hour Pressures in Rossview with Both RVPS1 & 2

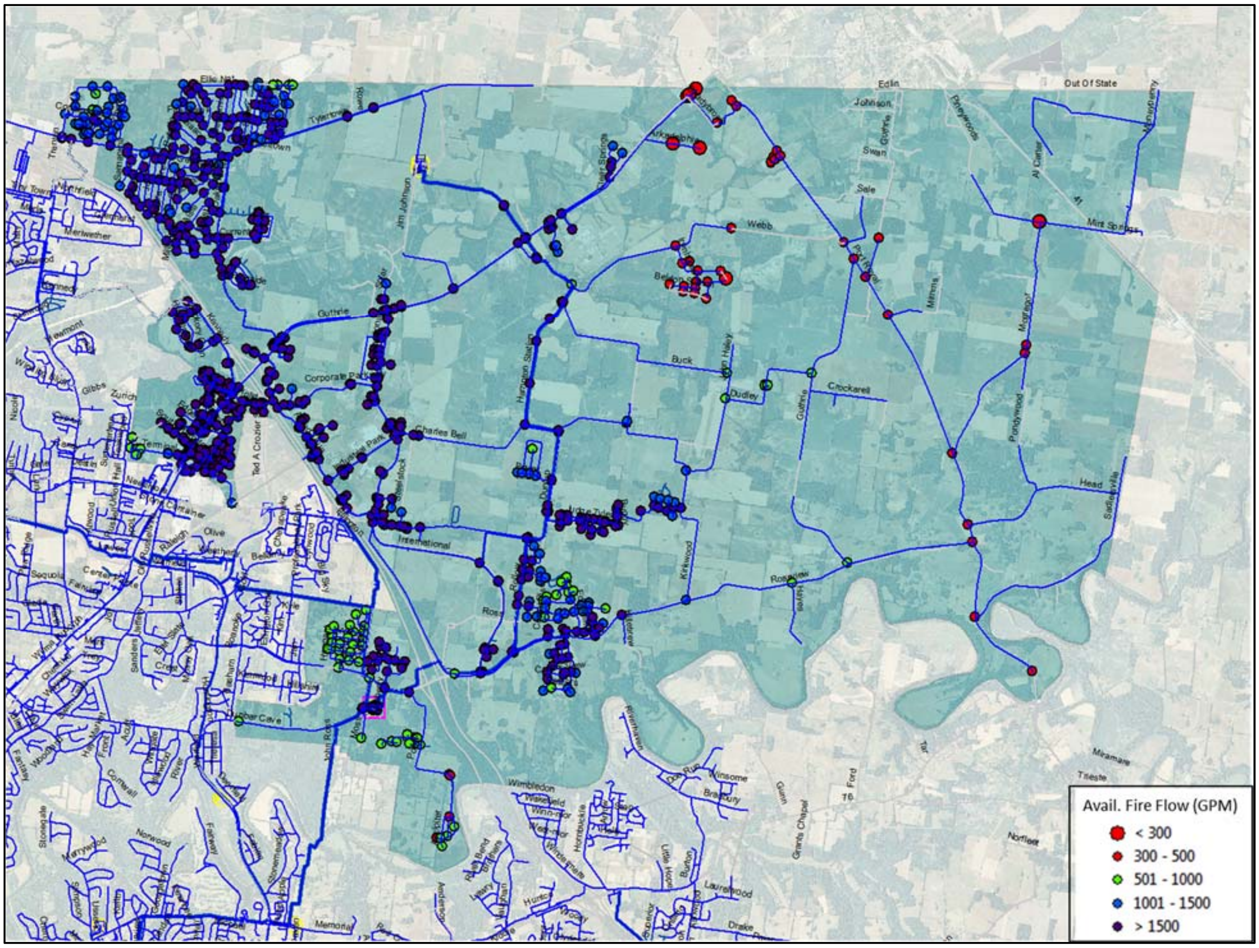


Figure 10: Available Fire Flows in Rossview with Both RVPS 1 & 2

1.2.2 Main Pressure Zone

Main Pressure Zone (Main) will experience a significant change with the addition of BPWTP and increased demands from Rossview. Main is of critical importance to overall distribution since all remaining pressure zones are supplied from it. One of the challenges in the current system operation is forcing the Main water storage tanks near the CWTP to turn over (e.g. College and Hilldale) while maintaining the level in Rossview Ground Tank (RGT), which is not only farther away, but has a higher overflow elevation than all other water storage tanks in Main. As demands in Rossview increase, turning over tanks in Main will become an even greater challenge as the amount of time for RGT to be isolated from Main will shorten, and consequently the amount of time CWTP can run at a reduced rate to produce turnover. Figure 11 illustrates this issue.

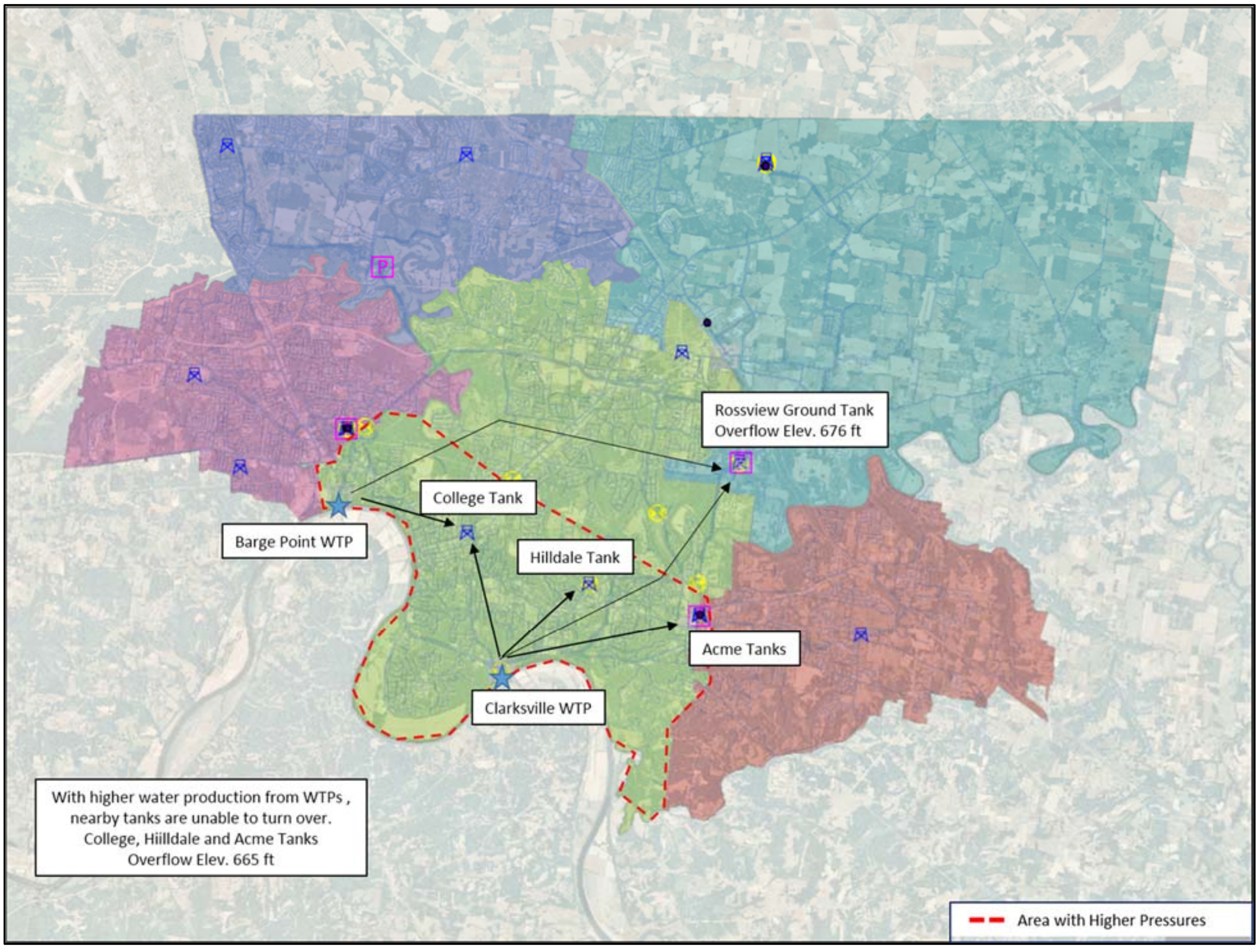


Figure 11: Location of Projected Tank Turnover Issues in Main Pressure Zone

Several workshops with CGW resulted in proposed changes to the current system, which are described in the following subsections, and included in the model setup used in the evaluation of future conditions.

1.2.2.1 Proposed Pressure Zone Delineation within Main

Modeling shows that dividing Main into two pressure zones along the boundary of the Red River can alleviate the tank turnover issue in Main by keeping the areas close to the WTPs protected from high pressures with pressure reducing valves while separating the interconnections with the transmission main loop to Rossview already in place. This transmission loop will provide greater operational flexibility to operate both WTPs and provide some redundancy in case a single WTP goes offline temporarily.

Additionally, the original part of the Main pressure zone south of the Red River (South Main) will still have several interconnections with the newly-created higher pressure zone in Main (North Main), which will provide redundancy to the downtown area and the Acme tanks, which provide water to the Sango Pressure Zone. Creation of South Main will allow greater control of tank turnover (e.g. College, Hilldale, Acme #1 and #2) since pressure reducing valves will now control the flow supplied.

As shown in Figure 12, splitting Main will create two separate zones on either side of the Red River. The South Main zone will still be at the original Main overflow elevation of 665 ft. The North Main Zone will be on the higher RGT overflow elevation of 676 ft.

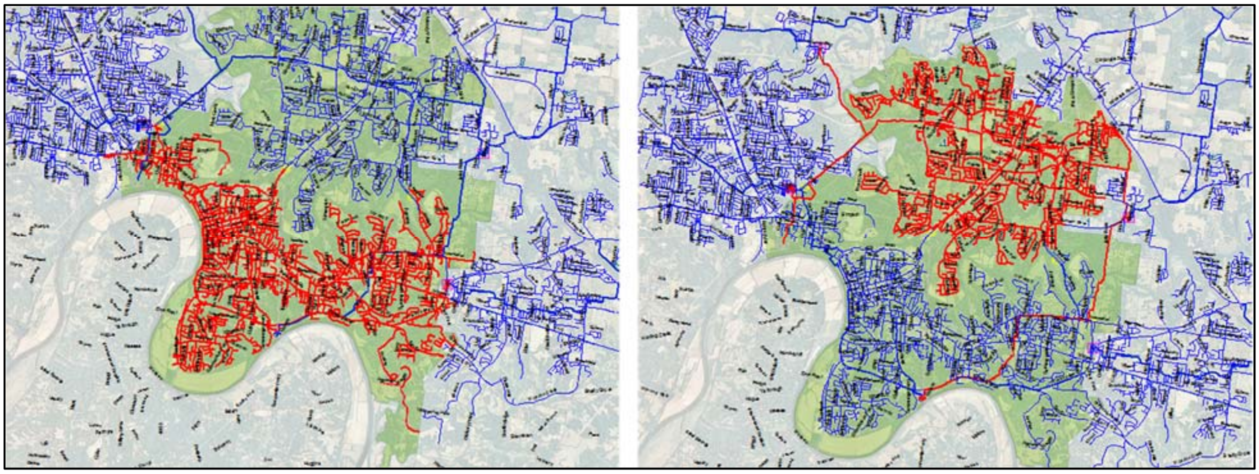


Figure 12: Proposed Division of Main Pressure Zone

This configuration will require installation of pressure reducing valves and to valve off several interconnections between the transmission loop and the distribution grid in South Main as shown in Figure 13.

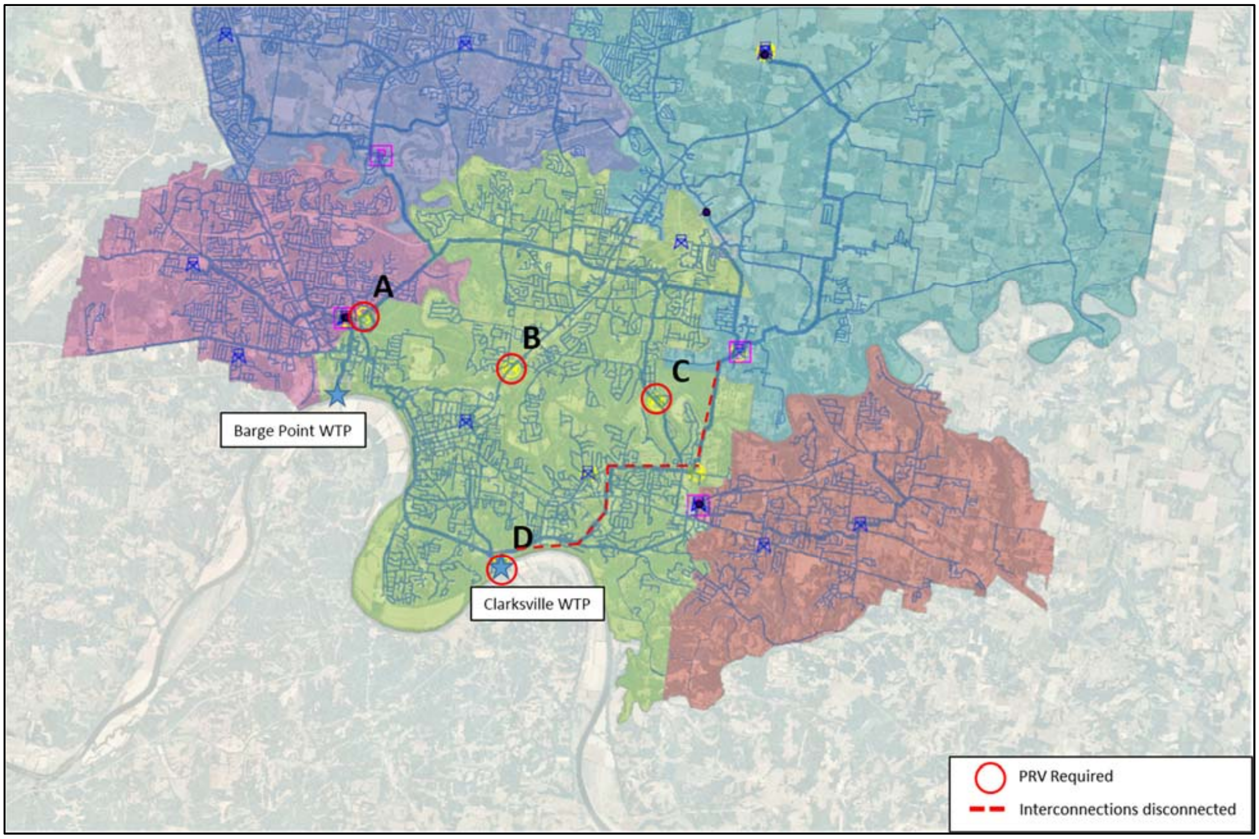


Figure 13: Proposed Requirements for Future Division of Main Pressure Zone

Location A from Figure 13 will have a pressure-reducing valve (PRV) to supply the South Main zone and an electronic butterfly valve (EBV) to control flow to the existing Jackson Tanks as shown in Figure 14.

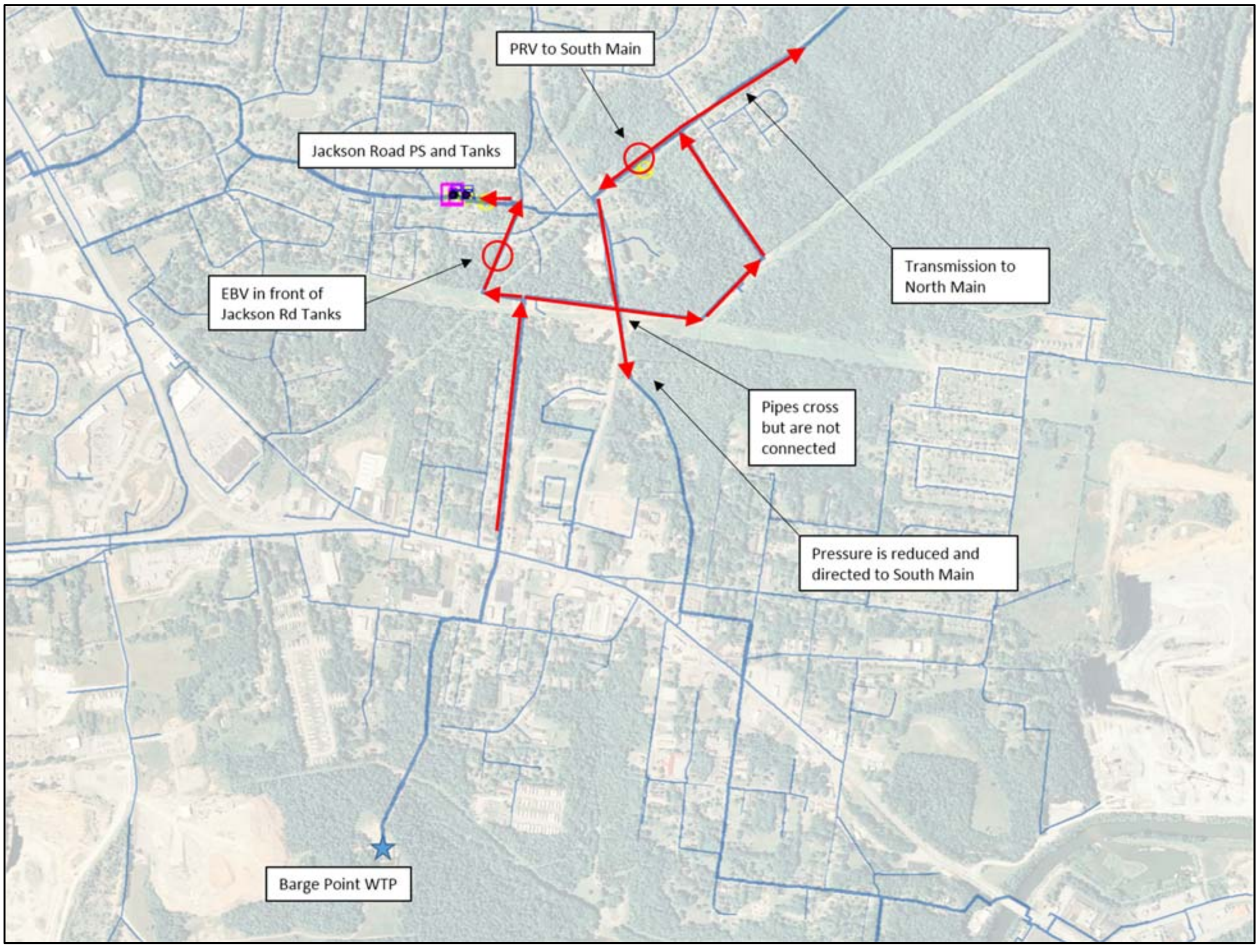


Figure 14: Proposed Controls at Location A (from Figure 13)

Locations B and C are simply located at crossings of the Red River. Location D at the CWTP will have a configuration as shown in Figure 15.

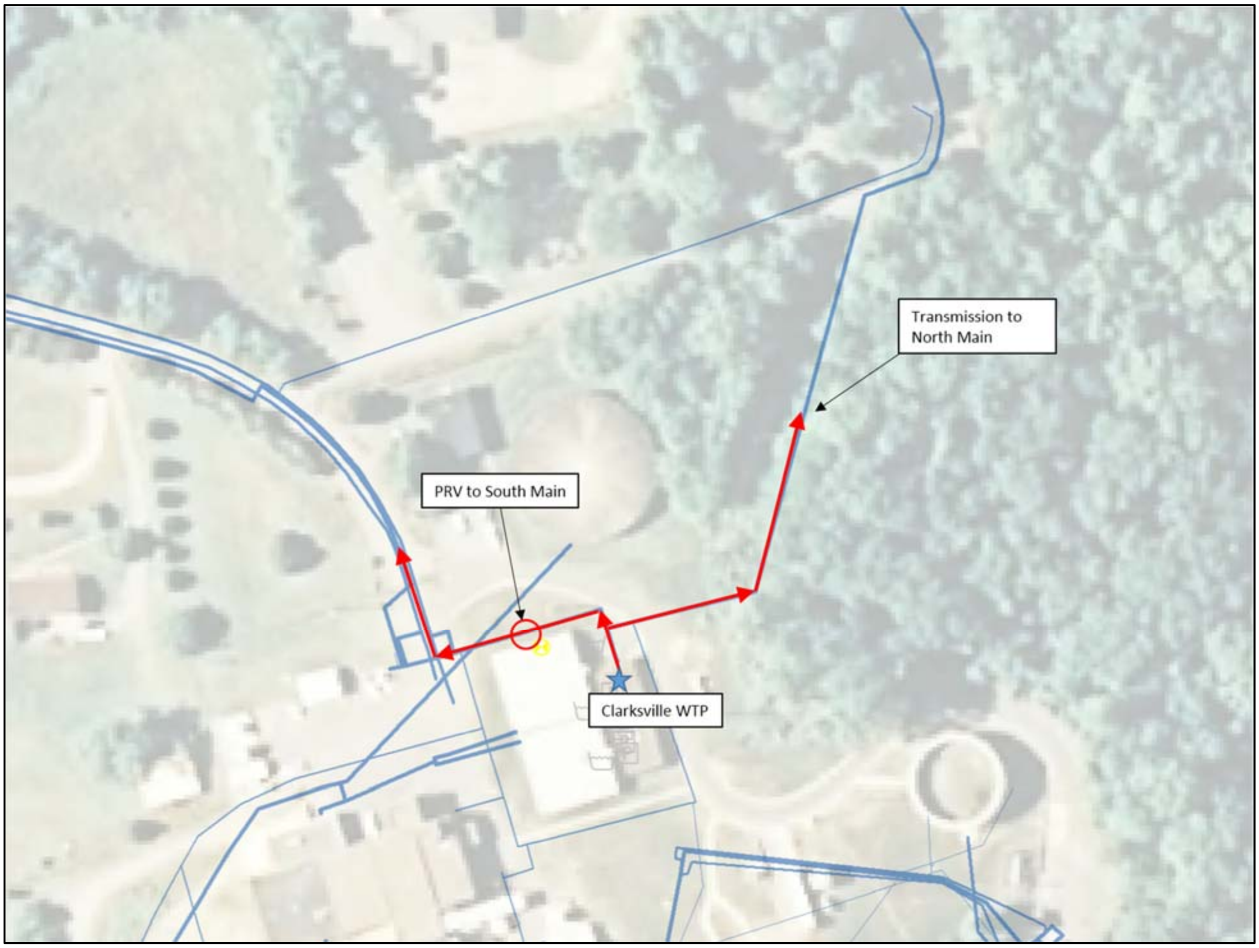


Figure 15: Proposed Controls at Location D (from Figure 13)

1.2.2.2 Storage Tanks in Main Pressure Zone

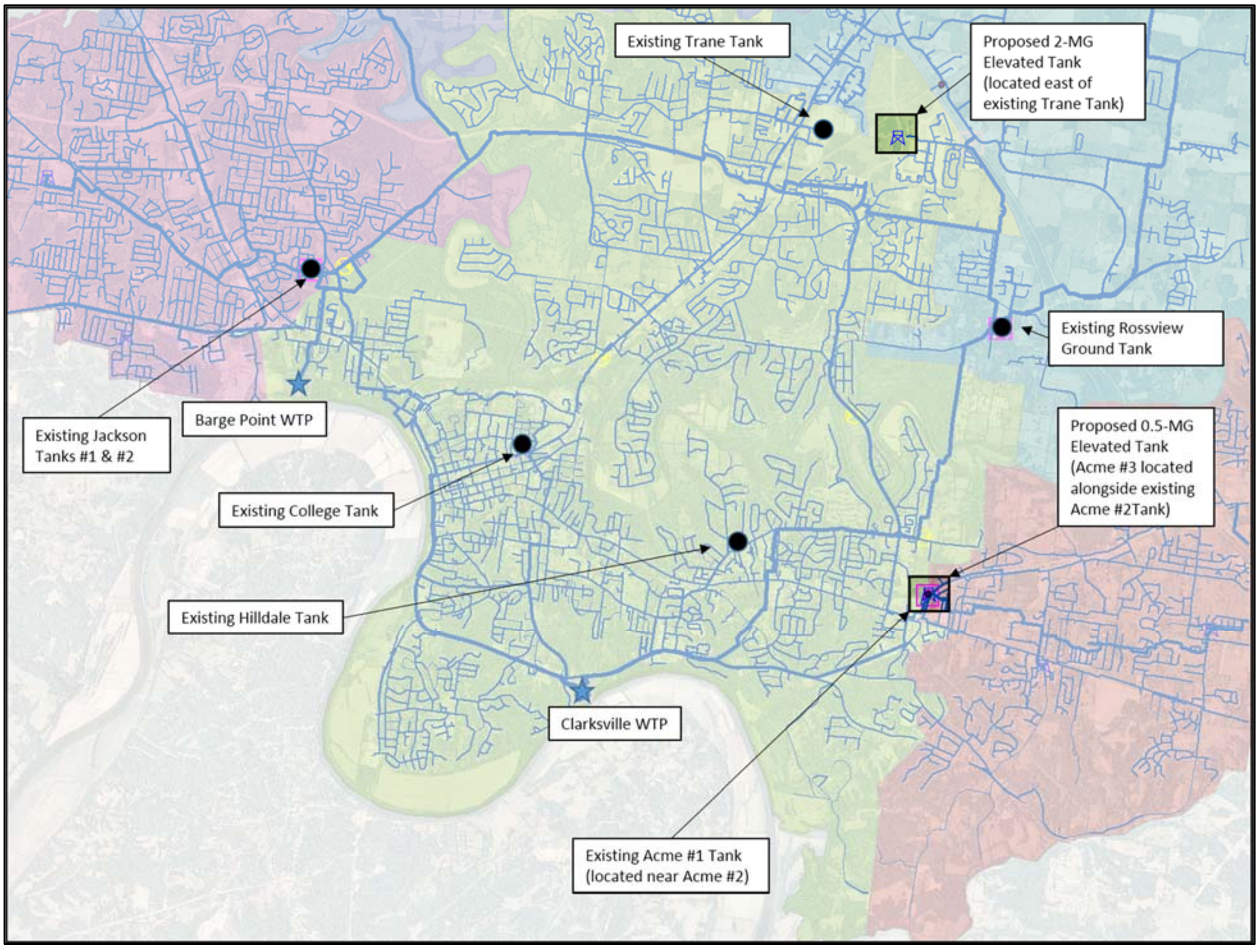


Figure 16: Existing and Proposed Water Storage Tanks in Main Pressure Zone

By splitting Main into two pressure zones, it is possible to leave the overflow elevations of all existing tanks unchanged. However, two additional tanks were determined necessary after several workshops with CGW (see Figure 16). These tanks will provide additional storage for increased demands and provide redundancy to the Rossview and Sango Pressure Zones.

Currently, Main has 14.7 MG of storage as shown in Table 3. While the storage in Main is significantly higher than its current average 24-hour demand, the excess storage provides a necessary buffer for neighboring pressure zones with a deficit, including Rossview and Allen Griffey. Because both Rossview and Allen Griffey are served by booster stations (with backup generator power) that convey water from Main, it was assumed that excess storage in Main could be sufficiently conveyed to these zones under an emergency condition.

Table 3: Water Storage Tank Volume Currently Active in CGW

Pressure Zone	Water Storage Tank Name	Capacity (MG)	Type	Year Erected	Overflow Elevation (ft)
Clarksville Main	ACME #1	0.5	Elevated	1965	665
Clarksville Main	ACME #2	0.5	Elevated	1974	665
Clarksville Main	College	0.5	Elevated	1950	662.2
Clarksville Main	Hilldale	1.5	Standpipe	1959	665
Clarksville Main	Jackson Rd. #1	1.5	Standpipe	1965	659.6
Clarksville Main	Jackson Rd. #2	2.0	Standpipe	1986	665.7
Clarksville Main	Rossview Ground (RGT)	8.0	Reservoir	1996	676
Clarksville Main	Trane	0.2	Elevated	1958	656.8
Clarksville Main Total		**14.7**			
Allen Griffey	Barker's Mill	1	Elevated	2007	690
Allen Griffey	Tiny Town	0.5	Elevated	1974	686.3
Allen Griffey Total		**1.5**			
Jackson Rd.	High Point	1.5	Standpipe	1987	765
Jackson Rd.	Northwest	1.5	Elevated	2007	765
Jackson Rd. Total		**3.0**			
Rossview	HSC	2.0	Elevated	1997	740
Rossview Total		**2.0**			
Sango	Excell Rd	0.75	Elevated	2007	743
Sango	Sango	1.5	Standpipe	1992	738
Sango Total		**2.25**			
Grand Total		**23.45**			

After discussion with CGW and further evaluation of storage needs, the following modifications were assumed in the evaluation of future conditions:

1. All tanks remain in service except for Trane Tank. Although the new pressure zone configuration will make turnover easier, tanks can easily be disconnected from the system if water quality becomes an issue. In the case of Hilldale, a smaller tank could be constructed as was suggested by CGW.
2. Construct a secondary 0.5 MG tank beside Acme #2 to provide redundancy to the Sango Pressure Zone.
3. Construct a new 2 MG elevated tank (TR2) to replace the existing Trane Tank and match overflow elevation of RGT.

Total storage volume in Main would be increased by 2.3 MG to a total of 17.0 MG with the changes described above.

1.2.2.2.1 New Trane Tank

The construction of TR2 will require improvements to strengthen connection with adjacent distribution mains as shown in Figure 17. The proximity of TR2 to RVPS2 should allow water to be conveyed into Rossview with minimal headloss. Also, TR2 will be able to be filled from either direction, which will provided operational flexibility to CGW.

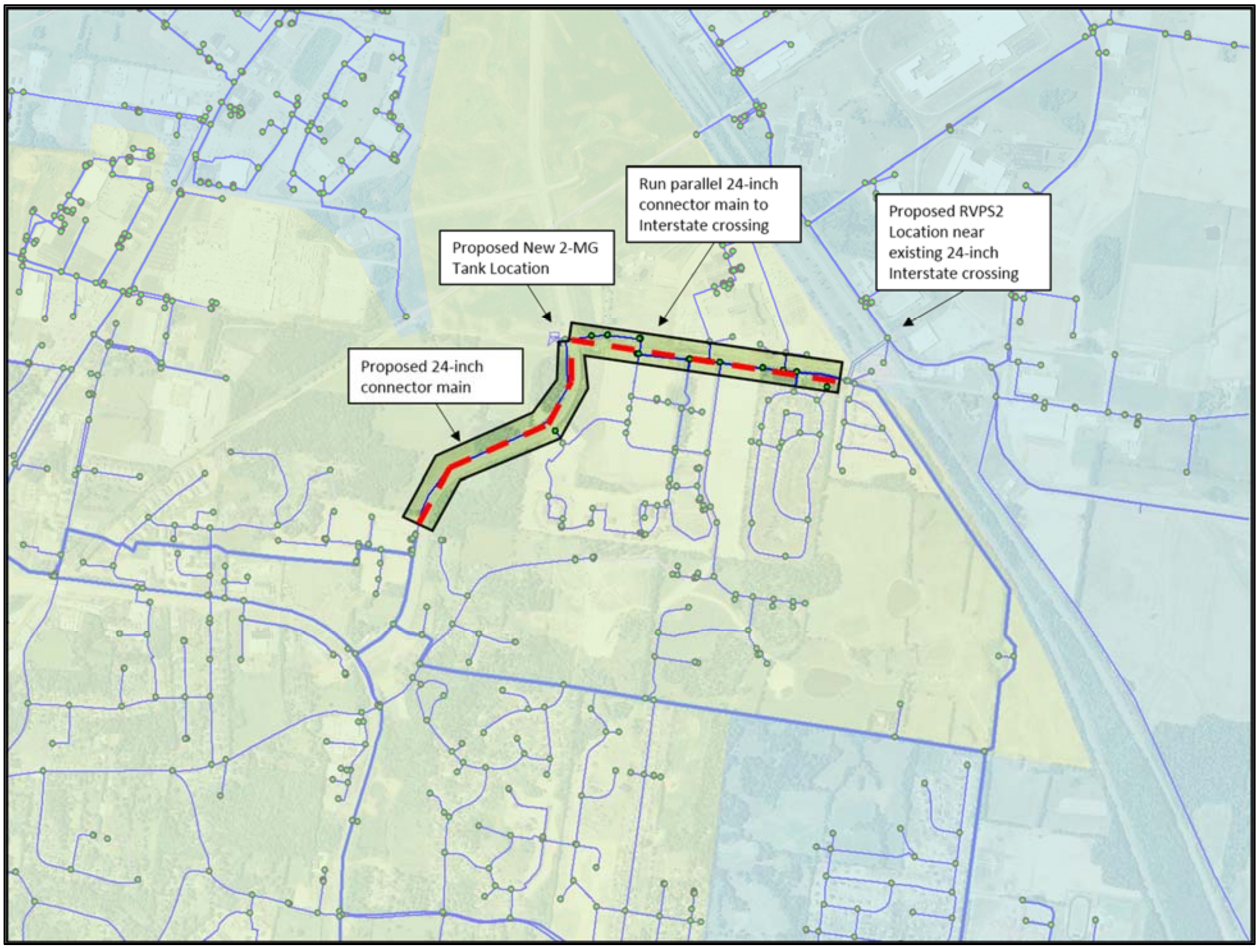


Figure 17: Required Improvements for New Trane Tank Connectivity

1.2.2.2.2 New Acme #3 Tank

One of the main concerns of CGW was the criticality of providing water to the Sango Pressure Zone. Construction of Acme #3 Tank will help address this issue by providing additional storage that can be pumped into Sango. Additionally, it was determined that Acme #3 would provide an easier way to perform maintenance on the existing Acme #2 Tank.

1.2.2.3 Transmission Line Improvements

Evaluation of the system with both WTPs running revealed that a few sections of the transmission loop exceeded the established peak velocity threshold of 5 fps. Figure 18 shows the locations where distribution line segments were either upsized in the model or parallel mains were added to increase capacity and lower headloss. Additionally, a redundant supply line to the Acme Tanks was identified as an improvement after discussion with CGW.

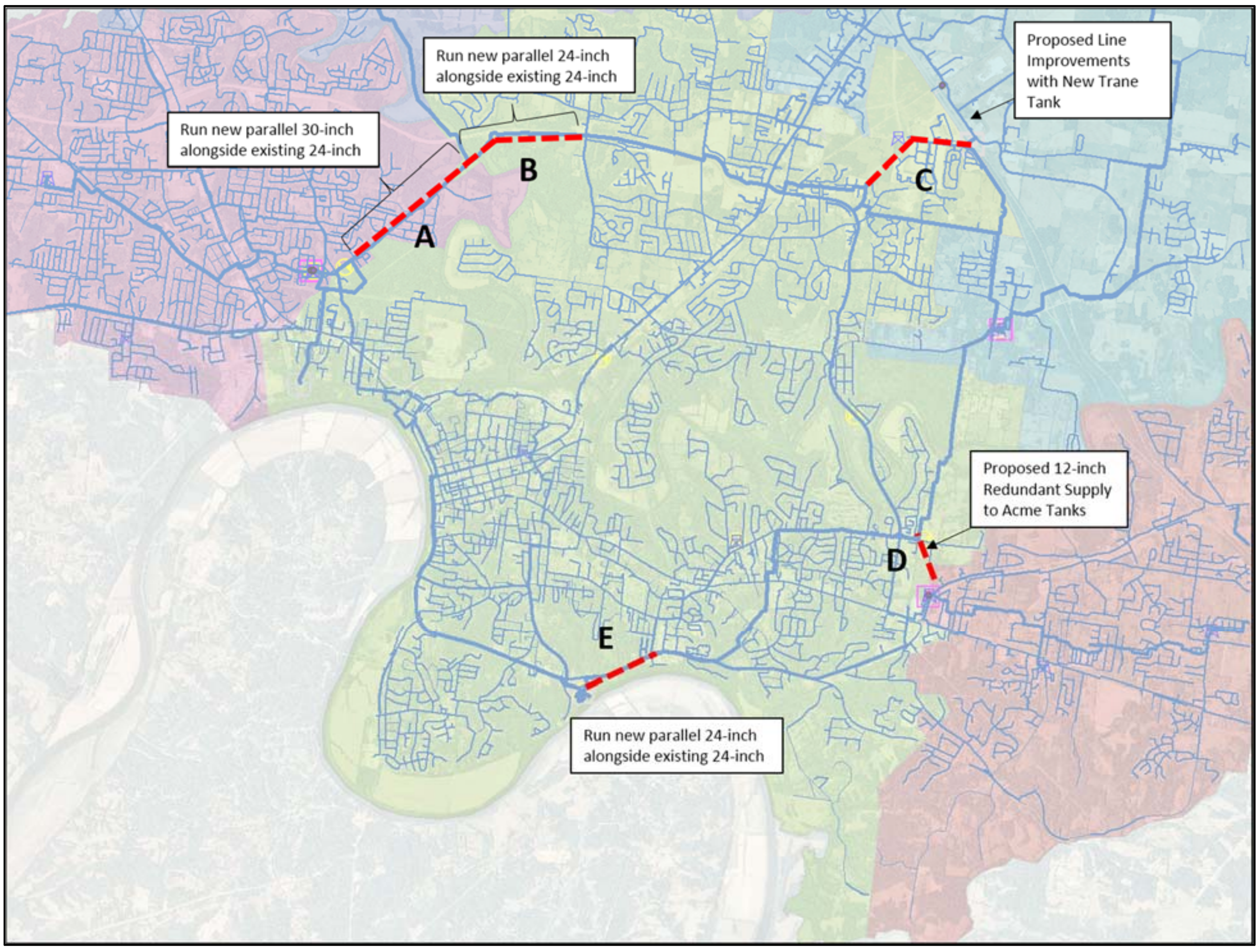


Figure 18: Proposed Line Improvements in Main

Location A is an 8,300 LF section of 24-inch main along Pollard Road, which runs between BPWTP and the supply line to Allen Griffey Pump Station. A 30-inch parallel line was added in model runs for future conditions.

Location B is a 7,200 LF section of 24-inch main along Pollard Road, which runs between the supply to Allen Griffey Pump Station and Whitfield Road. A 24-inch parallel line was added in model runs for future conditions.

Location C, consists of a new 3,400-ft section of 24-inch main running from Weatherly Drive along Ted Crozier Blvd and a new 3,800-ft section of parallel line running east along Dunlop Lane to the Interstate crossing.

Location D is a new 4,500-ft 12-inch line between the transmission loop near the intersection of Memorial Blvd and Richview Road and the existing Acme #2 Tank. As shown in Figure 19, this line will be connected with an electronic butterfly valve to assist with filling the Acme Tanks and provide redundant supply to the Sango Pump Station. An optional electronic butterfly valve was requested in a workshop with CGW between Acme #1 and Acme #2 Tanks. This valve would allow Acme #2 and #3 to be dedicated to the Sango Pressure Zone and give greater operator flexibility in turning over Acme #1, Hilldale and College Tanks.

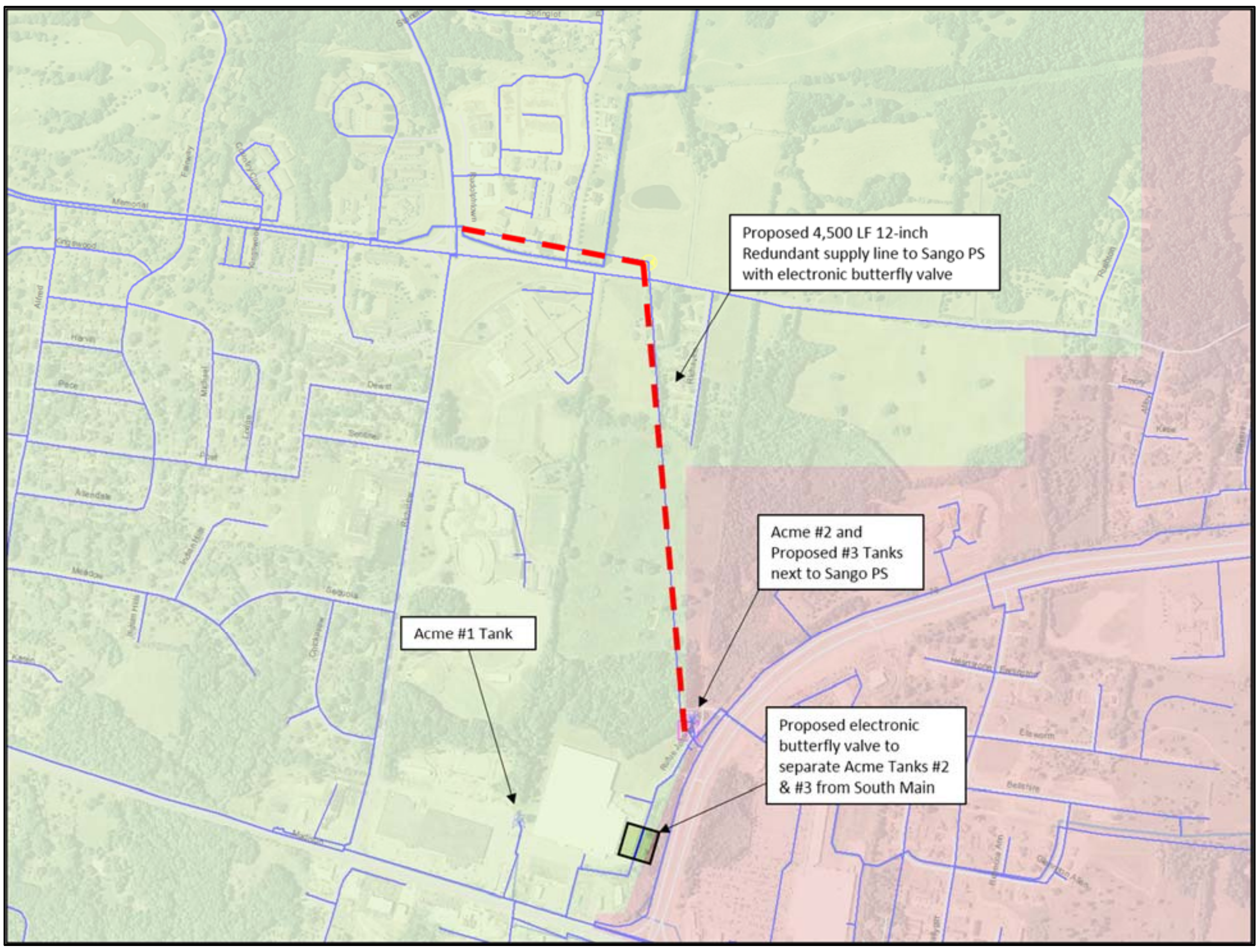


Figure 19: Redundant Supply Line to Sango Pump Station

Location E is a 4,700 LF section of 24-inch main along Ashland City Highway, which runs between the CWTP and Glendale Drive. A 24-inch parallel line was added in model runs for future conditions.

1.2.2.4 Pressures and Fire Flows

Model results for Year 2040 are shown in Figures 20 and 21 with line improvements as detailed in previous section and both RVPS1 and RVPS2 in operation as well as both WTPs in operation.

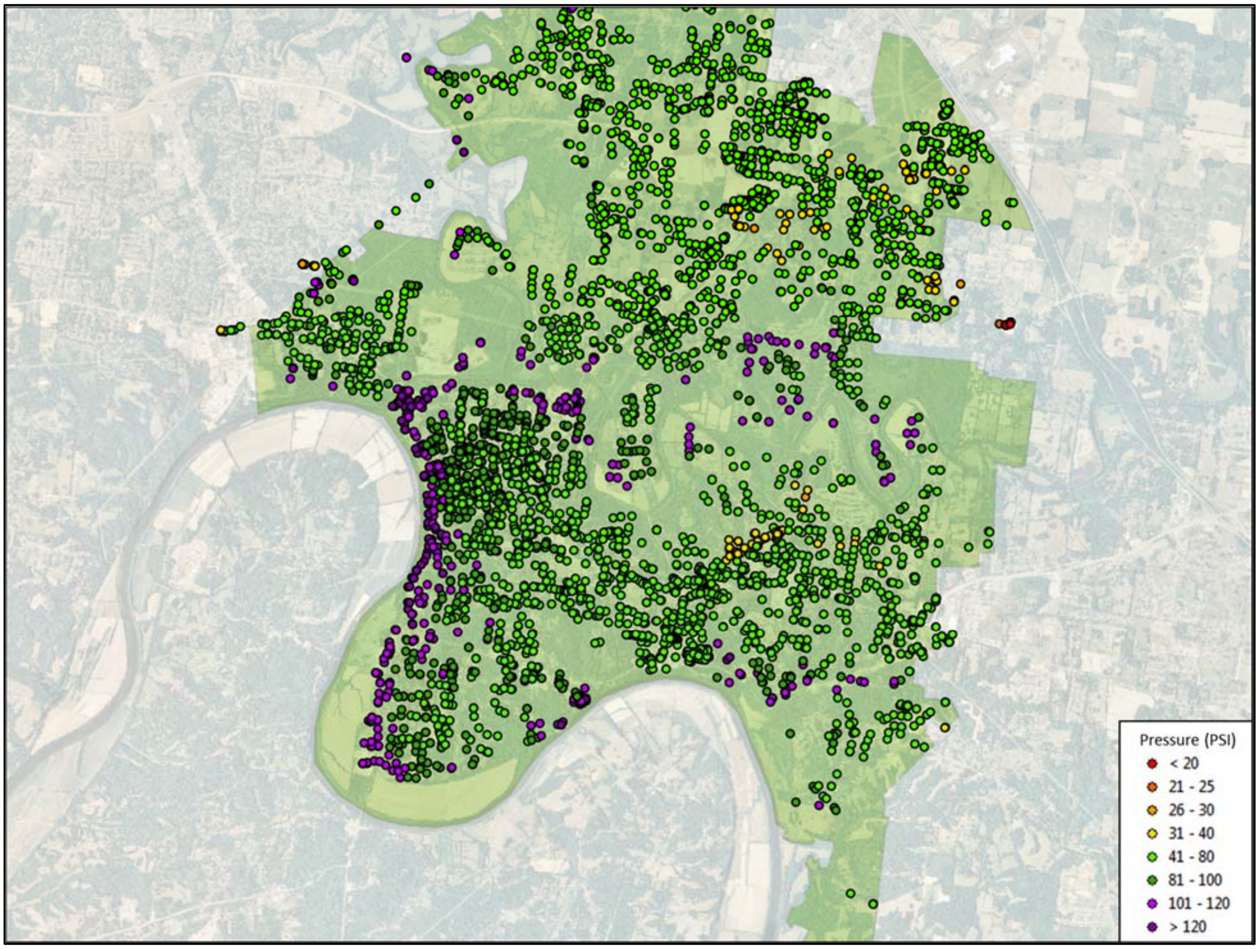


Figure 20: Peak-Hour Pressures in Main

As shown in Figure 20, pressure is sufficient throughout Main with improvements as modeled. High pressures occur near some locations with lower ground elevation (e.g. along the banks of the Cumberland River) and may require that customers install pressure reducing valves.

By splitting the Main pressure zone and implementing the transmission main improvements, the discharge pressures at the WTPs are not expected to be excessive. For example, in the model run above with both CWTP and BPWTP producing 20 mgd, corresponding pressures in the distribution system near the plants are 115 and 110 psi, respectively.

Available fire flow at 20 psi residual pressure is shown in Figure 21.

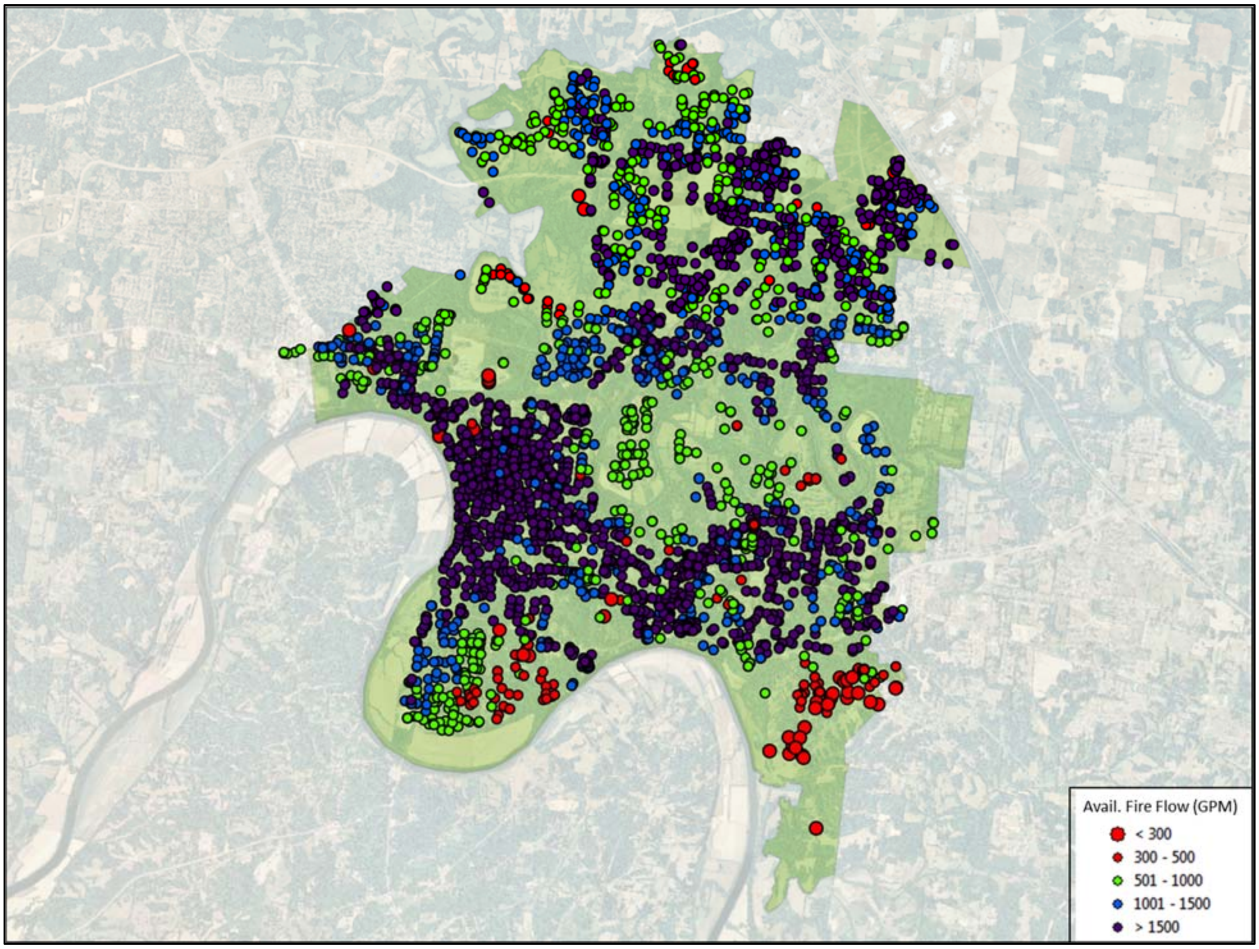


Figure 21: Available Fire Flows in Main

1.2.3 Allen Griffey Pressure Zone

Evaluation of Allen Griffey Pressure Zone (AG) did not result in the identification of any undersized lines with high peak velocities. Therefore, no changes to line size were made in the future evaluation model runs. The existing pump station in AG was sufficient to deliver projected maximum-day demands.

Model results for peak-hour pressures in Year 2040 are shown in Figure 22 and available fire flow at 20 psi residual pressure is shown in Figure 23. Generally speaking, pressure is sufficient throughout AG as modeled. Excessively high pressures occur near some locations with lower ground elevation and may require that customers install pressure reducing valves.

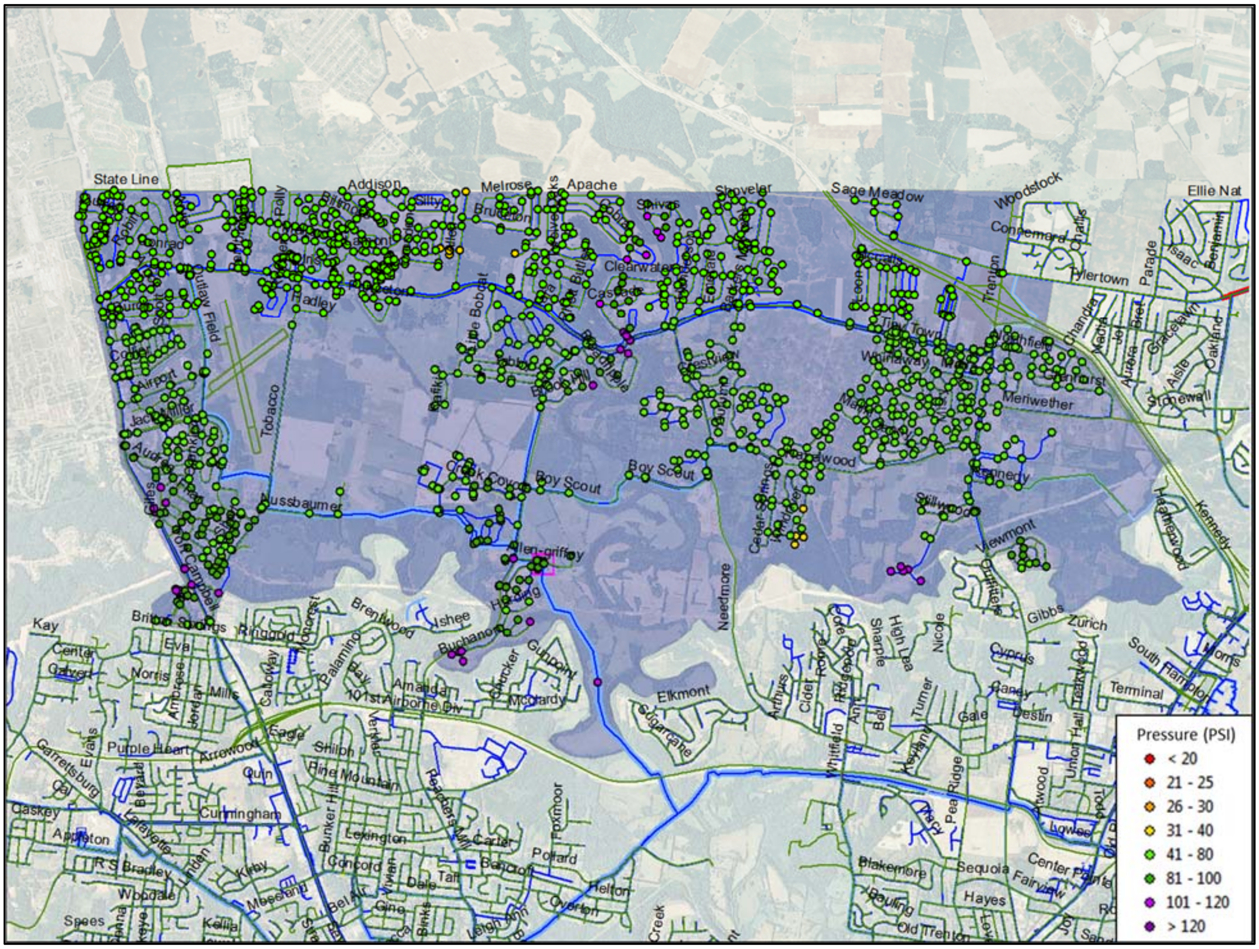


Figure 22: Peak-Hour Pressures in Allen Griffey

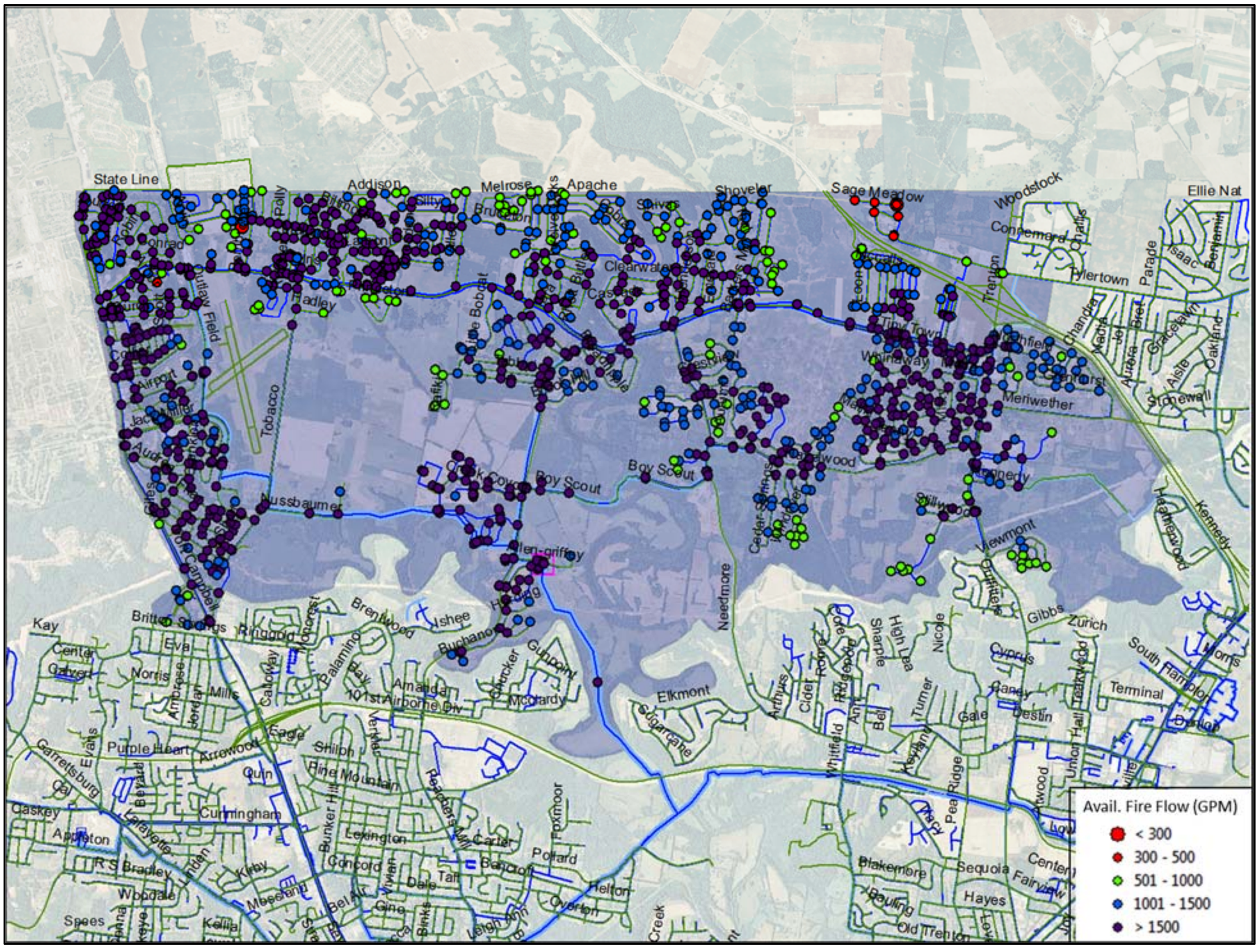


Figure 23: Available Fire Flow in Allen Griffey

1.2.4 Jackson Road Pressure Zone

Evaluation of Jackson Road Pressure Zone (JR) resulted in the identification of undersized lines near the station. These 6-inch lines were upsized as shown in Figure 24 to be within the peak velocity threshold for the future evaluation model runs. The existing pump station in JR was sufficient to deliver projected maximum-day demands.

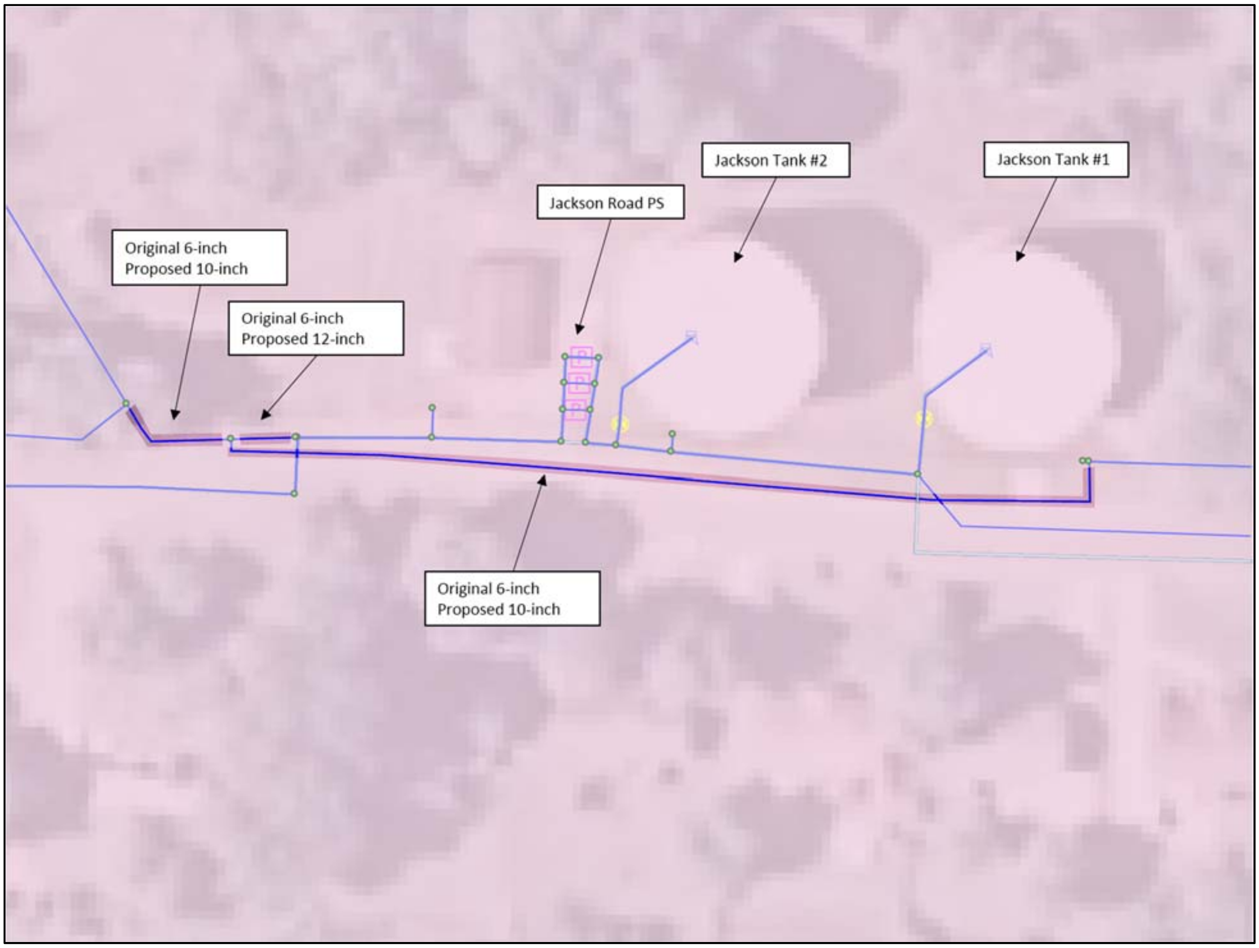


Figure 24: Lines Identified for Upsize near JR Booster Station

Model results for peak-hour pressures in Year 2040 are shown in Figure 25 and available fire flow at 20 psi residual pressure is shown in Figure 26. Pressure is sufficient throughout JR as modeled. Excessively high pressures occur near some locations with lower ground elevation and may require that customers install pressure reducing valves.

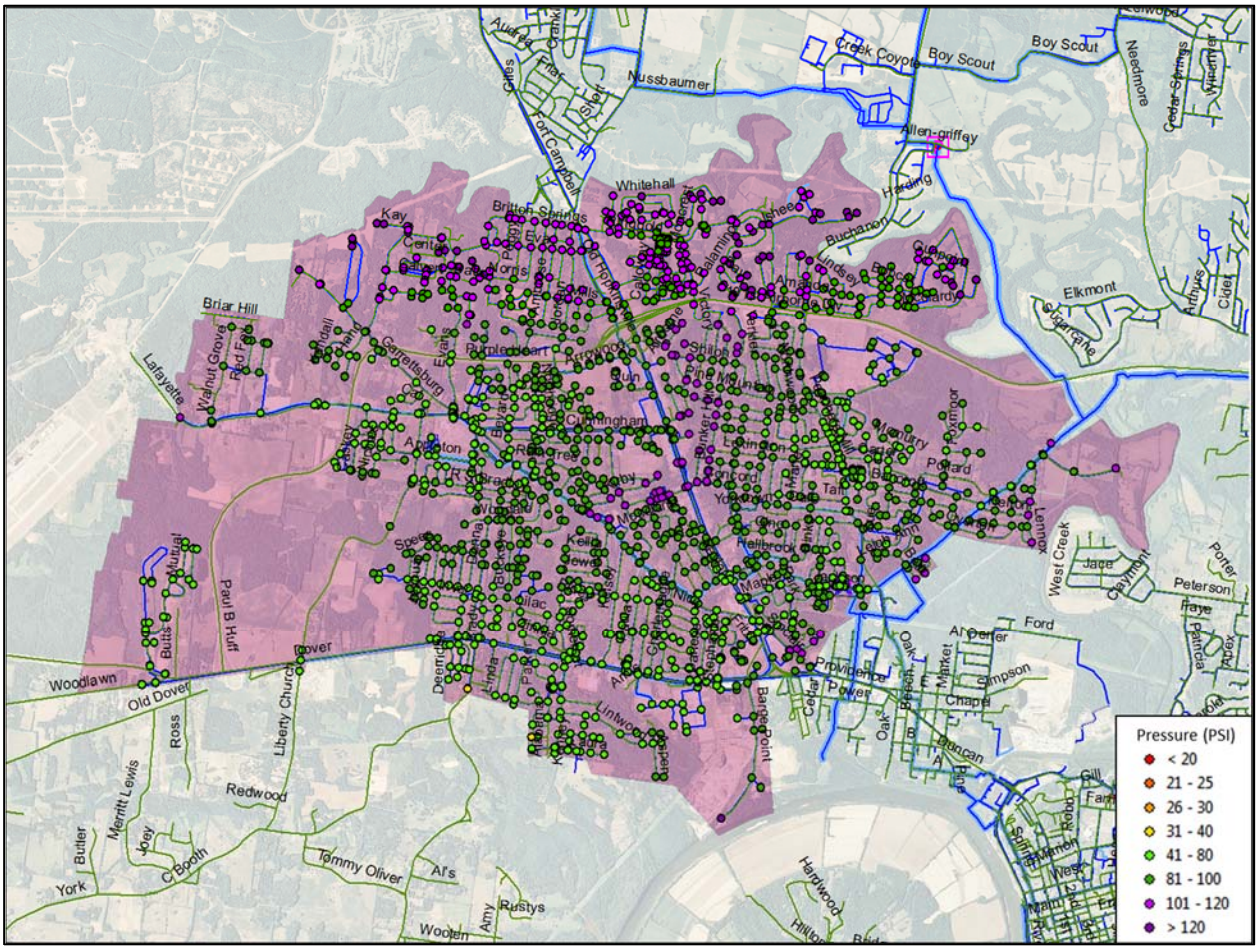


Figure 25: Peak-Hour Pressures in Jackson Road

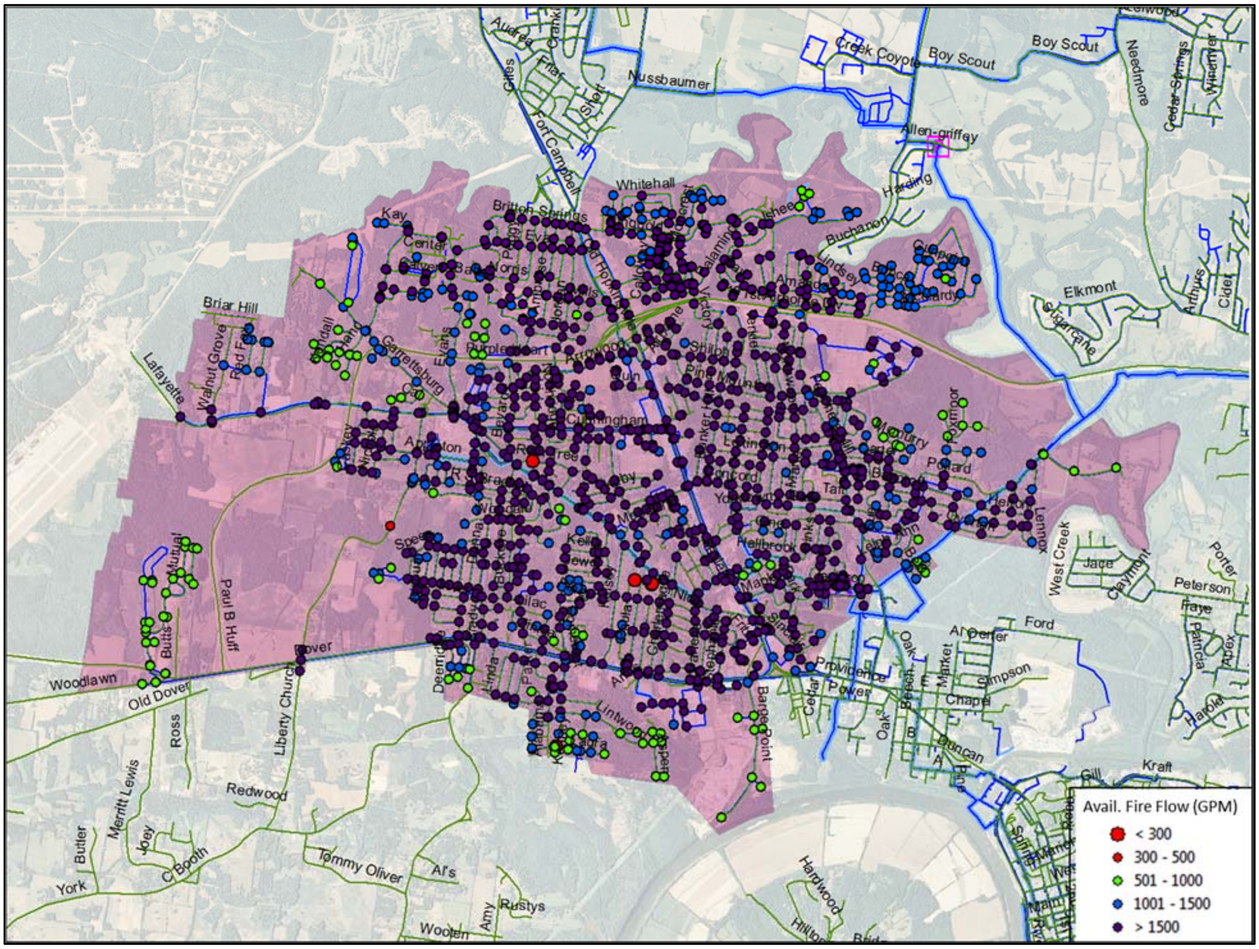


Figure 26: Available Fire Flows in Jackson Road

1.2.5 Sango Pressure Zone

Sango PS has long been observed to require both of its pumps to fill the tanks in Sango Pressure Zone (Sango) during peak demand periods and run for several hours each day to keep tanks full. However, because of investigative work performed by CGW, it was determined that the flow being pumped during the peak demand period measured more than demands in Sango as previously calibrated in model. It is not clear if the measured discharge from Sango PS simply indicates higher demand in Sango or if leakage is occurring either in Sango or if a valve is allowing flow from Sango back into Main.

Therefore, additional investigation is recommended to verify if demand in Sango matches flow pumped by Sango PS with typical water loss. If demands are indeed higher than those previously loaded in model, the model should be updated. Since total demand in model matches measured Clarksville WTP production, it is likely that any increase in Sango demand would be balanced with a decrease in demand for another pressure zone – likely Main.

From a design perspective, it is recommended to have one pump sized to deliver all of Sango's maximum-day flow with a second standby pump for redundancy and better flexibility to take pumps offline for maintenance. It is therefore recommended to replace the existing pumps (or the station entirely) with a traditional duty/standby configuration. Based on the growth in maximum-day demand projections for Sango and current maximum-day demands as measured with the Sango PS flow meter, an ideal target capacity for a single pump would be delivery of something more than 2,500 gpm for tanks to be filled rapidly with shorter pump runtimes. The basis for this recommendation is the fact that current flow with both pumps at Sango PS is 2,500 gpm and is not sufficient to fill tanks rapidly during the peak demand period.

Assuming Sango PS could deliver maximum-day demands, evaluation of Sango did not result in the identification of any undersized lines with high peak velocities. Therefore, no changes to line size were made in the future evaluation model runs.

Model results for peak-hour pressures in Year 2040 are shown in Figure 27 and available fire flow at 20 psi residual pressure is shown in Figure 28. Pressure is sufficient throughout Sango as modeled. Excessively high pressures occur near some locations with lower ground elevation and may require that customers install pressure reducing valves.

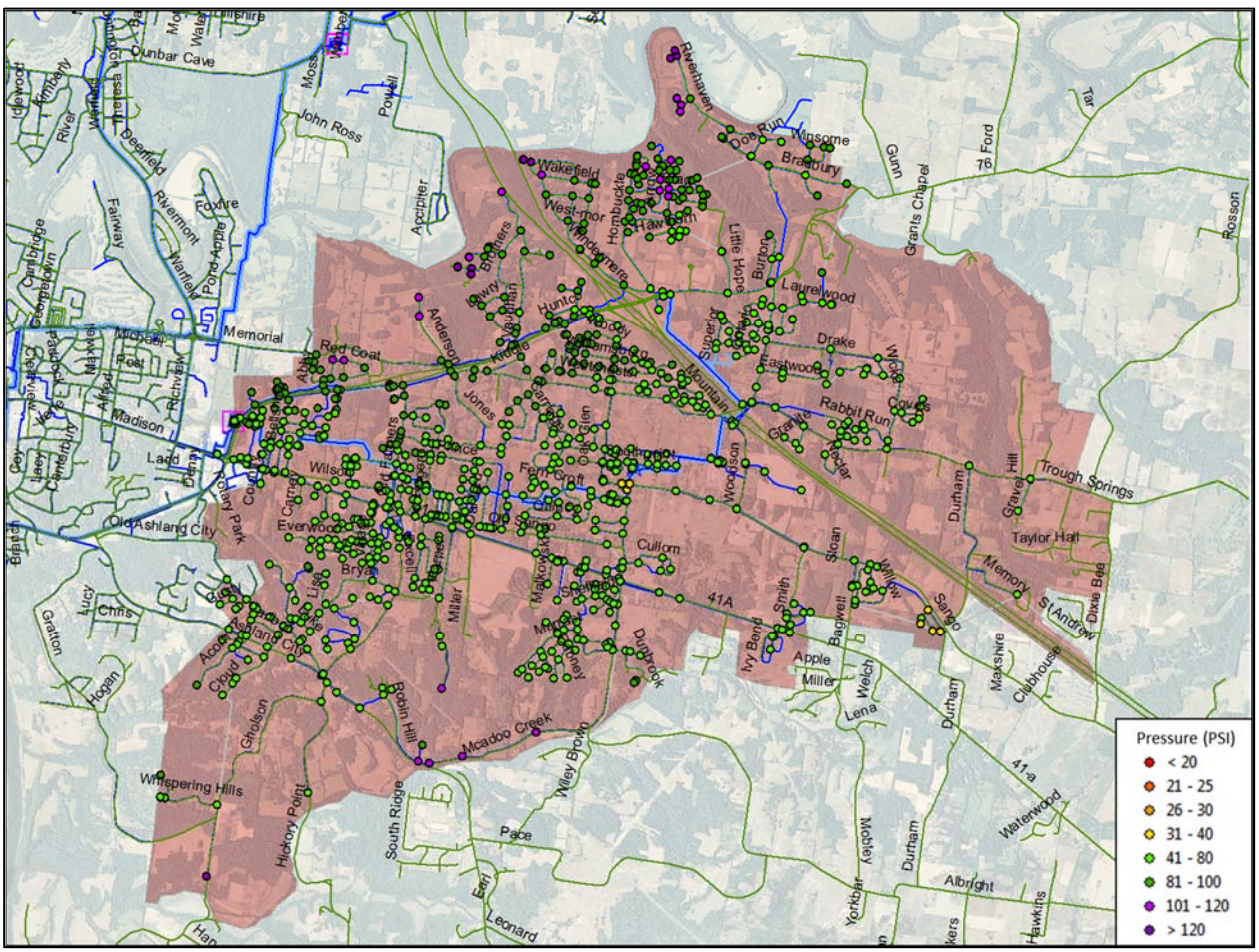


Figure 27: Peak-Hour Pressures in Sango

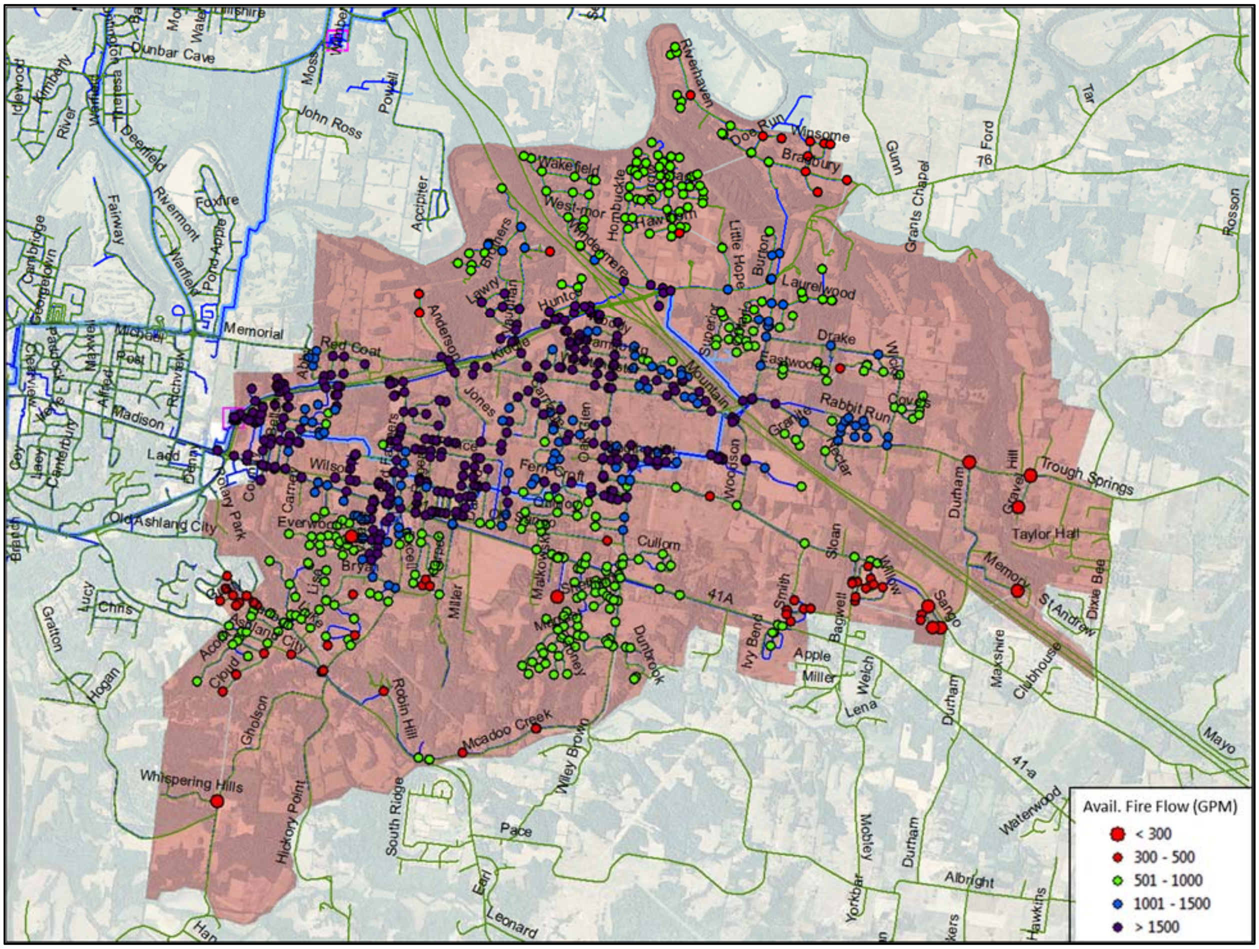


Figure 28: Available Fire Flows in Sango

1.2.6 System-Wide Extended Period Simulation

A system-wide extended period simulation (EPS) was conducted with all improvements in place to determine if issues would exist with tank turnover and/or water age. RVPS1 and RVPS2 were both set to run together for this model run.

Figure 29 shows a summary of how the CGW system was controlled in the future conditions model simulation. With these controls, all tanks were sustained and adequate turnover was achieved.

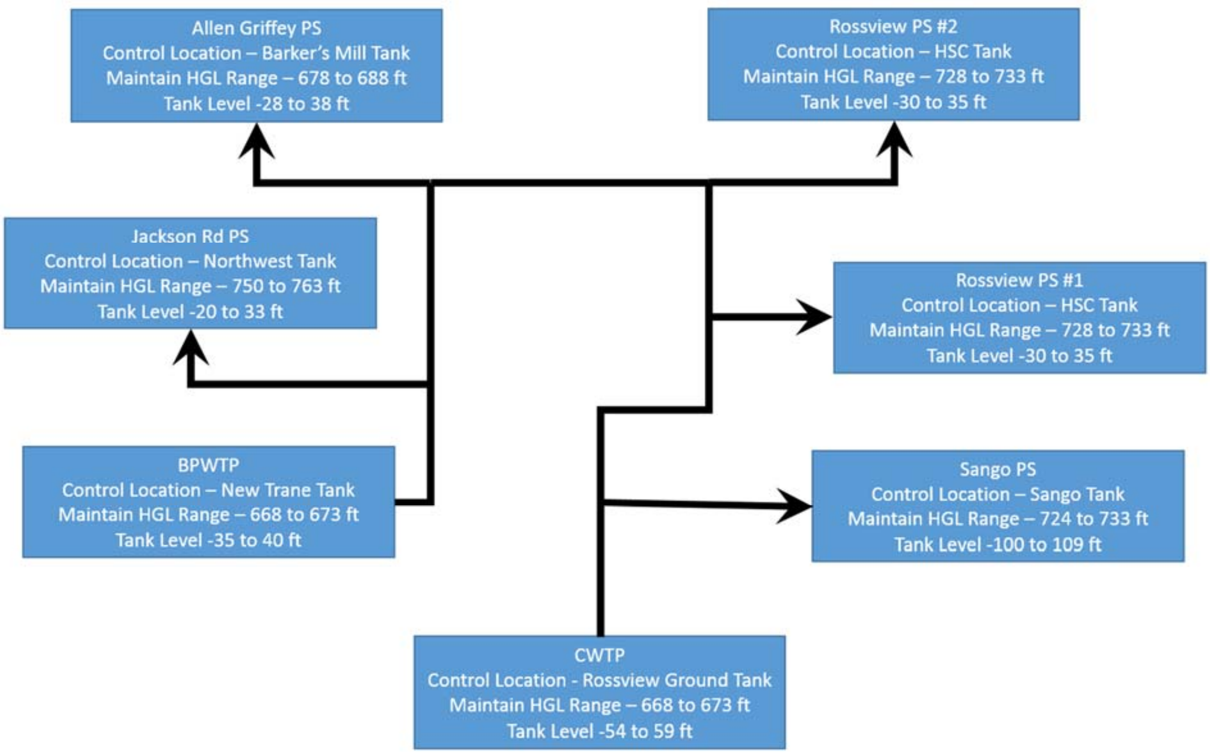


Figure 29: Summary of Controls for Future Conditions

Average water age at the end of 30 days is shown in Figure 30. Water age appears to be the highest in Sango and JR. Although Rossview, Allen Griffey and Main have isolated water age issues associated with small dead-end lines, water age is generally not a problem for these zones.

Water age in JR will be largely controlled by the settings on the EBV that will control turnover in the Jackson Tanks. Although higher water age in JR is less than 10 days in most cases, it looks to be more related to localized dead ends and/or insufficient looping.

The addition of the redundant 12-inch supply line and EBV from the North Main transmission loop to the Acme Tanks will give CGW more control to turn the tanks over as needed. Although higher water age in Sango is less than 10 days in most cases, it looks to be more related to localized dead ends and/or insufficient looping.

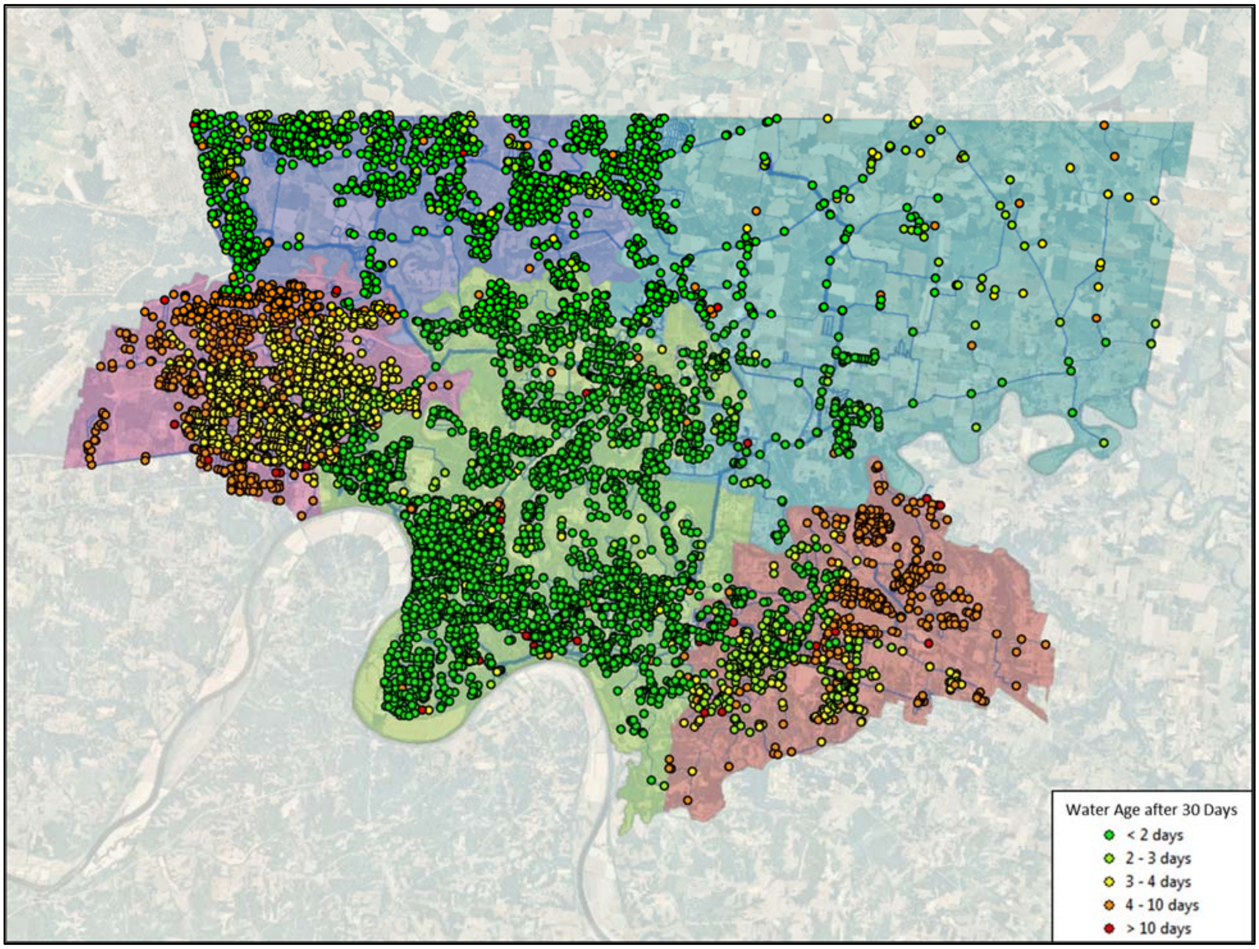


Figure 30: System-Wide Water Age

1.2.7 Observations and Conclusions

After evaluation of the future conditions for CGW's distribution system, the following general observations and conclusions were made:

- Additional water production will be needed based on future demand projections. Although the ultimate operation of the WTPs will be determined by CGW staff based on real-world factors, balanced contribution between the two WTPs will allow CGW to utilize its existing transmission mains in most places without upsize. The discharge pressure from each WTP while running together will not need to be as high as compared to that at each individually if it were to run by itself.

- Splitting Main into two separate pressure zones along the Red River will allow CGW to have greater control over tank turnover within Main and avoid costly tank replacements that were previously discussed. This configuration will also avoid over-pressurizing parts of Main with already high pressures (e.g. Riverside Drive).

- Tank turnover may continue to be an issue at College and Hilldale Tanks even with the proposed pressure zone modifications in Main due to the tanks having close proximity to the WTPs. However, these tanks can be easily disconnected from the system in the future if the lack of turnover causes water quality problems.

- Addition of RVPS2 to Rossview will increase reliability to Rossview. However, transmission improvements within Rossview will need to occur to handle the projected peak flows. These improvements will ultimately result in a transmission loop that can supply the storage tanks from different directions, which will increase redundancy in the pressure zone. No new Interstate crossings will be required. The existing 24-inch crossing near Dunlop Lane and the 24-inch crossing recently installed for the HSC project will be adequate.

- Pressures and fire flows will generally be sufficient in most areas of the system. Localized areas with high pressure may need pressure reducing valves. Localized areas with low available fire flow due to insufficient looping or dead-ends may need to be addressed on a case-by-case basis.

- Demand in Sango seems to be higher than previously modeled based on new flow measurement results from Sango PS. Additional investigation into billing records should be conducted to determine if water loss in Sango is suspected or if demand is simply higher than originally thought.

- Water age has the potential to be relatively higher in JR and Sango. However, with the proposed EBVs in front of the Jackson Tanks and the redundant supply line to the Acme Tanks, CGW will have greater control over the turnover in these tanks, which should keep water age in JR and Sango at acceptable levels. Model runs indicated the majority of the nodes in JR and Sango were within the acceptable threshold of 10 days or less.

2. Capital Improvement Plan with Cost Estimates

Recommended improvements from the evaluation for future conditions were incorporated into a capital improvement plan (CIP) that includes planning level cost estimates for each project. Figure 31 shows an overview of the projects grouped geographically.

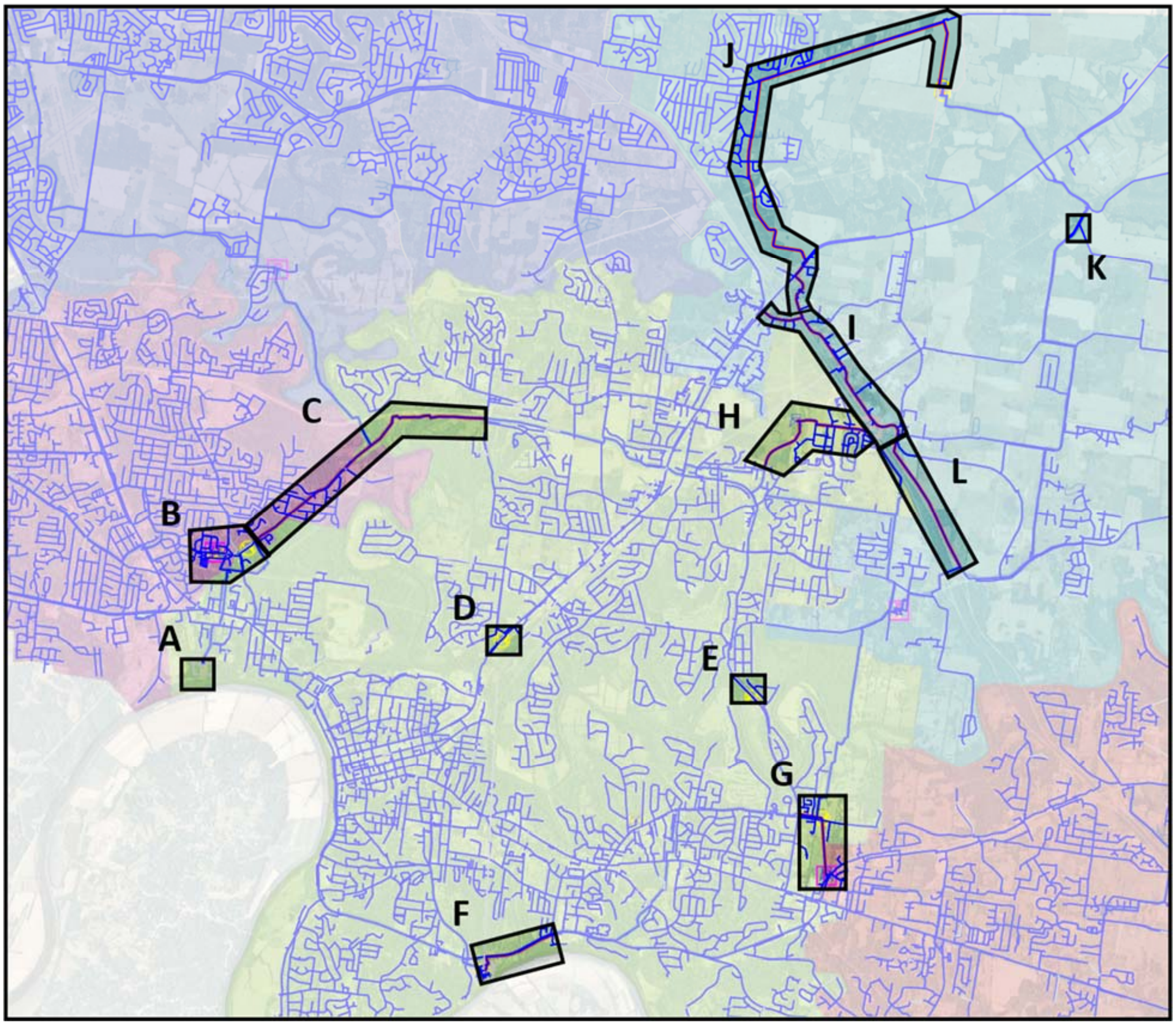


Figure 31: Overview of CIP Projects

Table 4 lists the basis for the project cost estimates. All prices are in 2017 dollars.

Table 4: Unit Prices for CIP Cost Estimation

DI Piping	Unit Cost
10-in	$75 / LF
12-in	$80 / LF
14-in	$90 / LF
16-in	$110 / LF
18-in	$115 / LF
20-in	$122 / LF
24-in	$143 / LF
30-in	$184 / LF
36-in	$200 / LF

Pressure Reducing Valves	Unit Cost
12-in	$16,000 EA
18-in	$35,000 EA
24-in	$47,000 EA

PS and Tank	Unit Cost
Pump Station	$0.30 / Gal to $0.75 / Gal
Tank	$2.50 / Gal

Butterfly Valves with Electric Motor Operation	Unit Cost
12-in	$8,000 EA
36-in	$21,000 EA

On the following pages, the CIP projects are described in greater detail. Each CIP project is shown on an individual sheet and its Project ID references its map location as labeled in Figure 31. Each sheet also includes a localized map, brief description of the recommended improvements, and planning level cost estimate.

2.1 Project Sheets

CIP Project A-1 – Barge Point WTP Phase 1

Brief Project Description

1. Construction of Water Treatment Facility and Raw Water PS with 10 mgd firm capacity

Planning Level Cost Estimate			
Construction WTP Only	42,884,264		
Construction Raw Water PS	15,151,200		
TOTAL	**58,035,000**	*($5.80 / gallon)*	

CIP Project A-2 – Barge Point WTP Phase 2

Brief Project Description

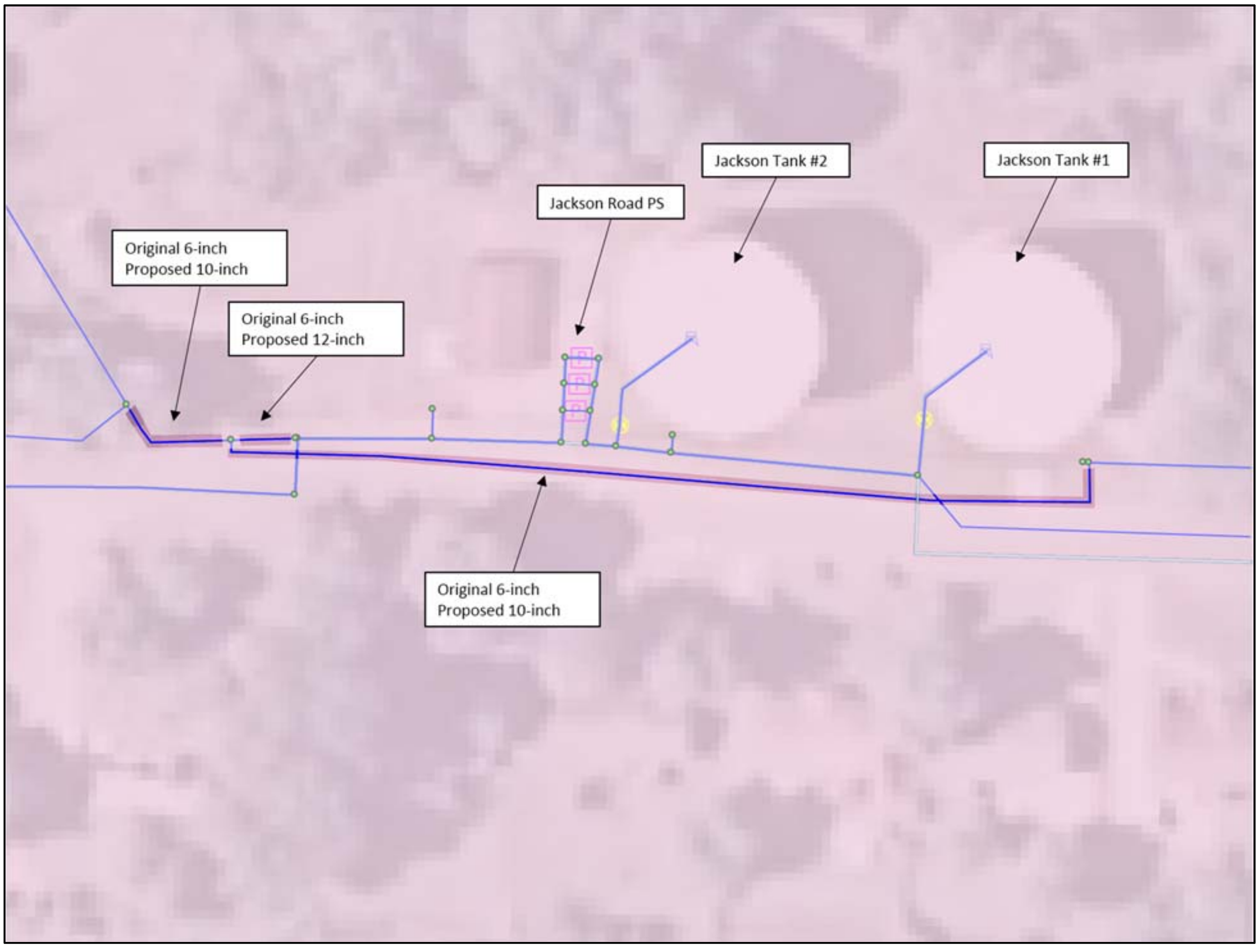
1. Upsize Water Treatment Facility and Raw Water PS to 20 mgd firm capacity

Planning Level Cost Estimate			
Construction WTP Only	29,634,245		
Construction Raw Water PS	2,124,000		
TOTAL	**31,760,000**	*($3.18 / gallon)*	

Note 1: A potential Phase 3 Expansion to 30 mgd would occur beyond Year 2040 at a cost comparable to Phase 2.

Note 2: Average Cost Per Gallon		
	$ / gallon	
Phase 1	5.80	5.80
Phase 2	3.18	3.18
Phase 3		3.18
Average	**4.49**	**4.05**

CIP Project B-1 - Jackson Road PS – Line improvements to Kenwood Elementary School Area



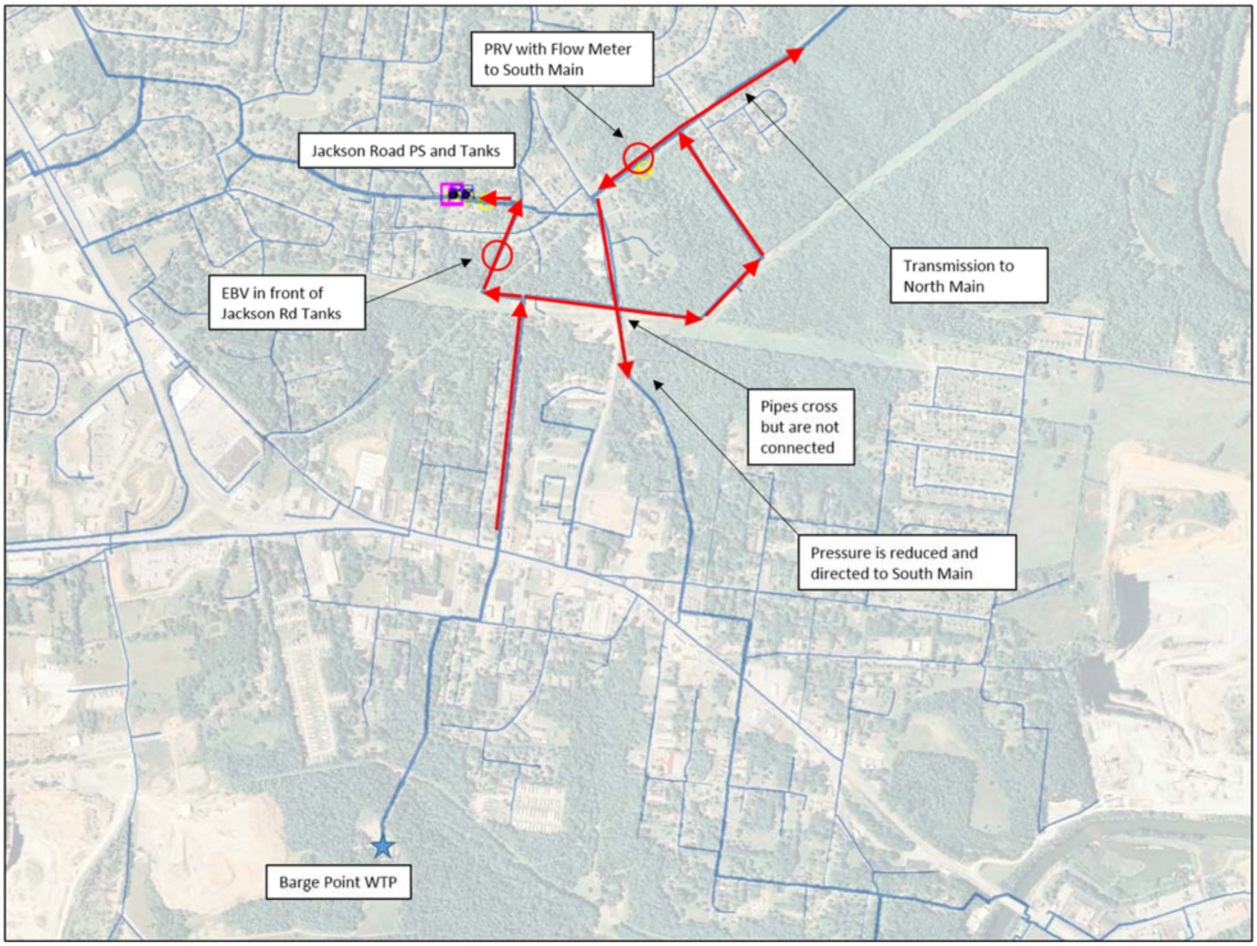
Brief Project Description

1. Upsize of approximately 400 feet of 6 to 10-inch main

2. Upsize of approximately 25 feet of 6 to 12-inch main

Planning Level Cost Estimate	
Mobilization	1,103
Piping	31,500
Restoration/Erosion Control	1,701
Subtotal	34,304
Contractors General Conditions 30%	10,291
Construction Total	44,595
Design @ 15%	6,689
Limited Construction Admin @ 5%	2,230
Engineering Total	8,919
TOTAL	**54,000**

CIP Project B-2 –Installation of Butterfly Valve to separate Barge Point WTP and Jackson Tanks and Pressure Reducing Valve and Flow Meter to South Main



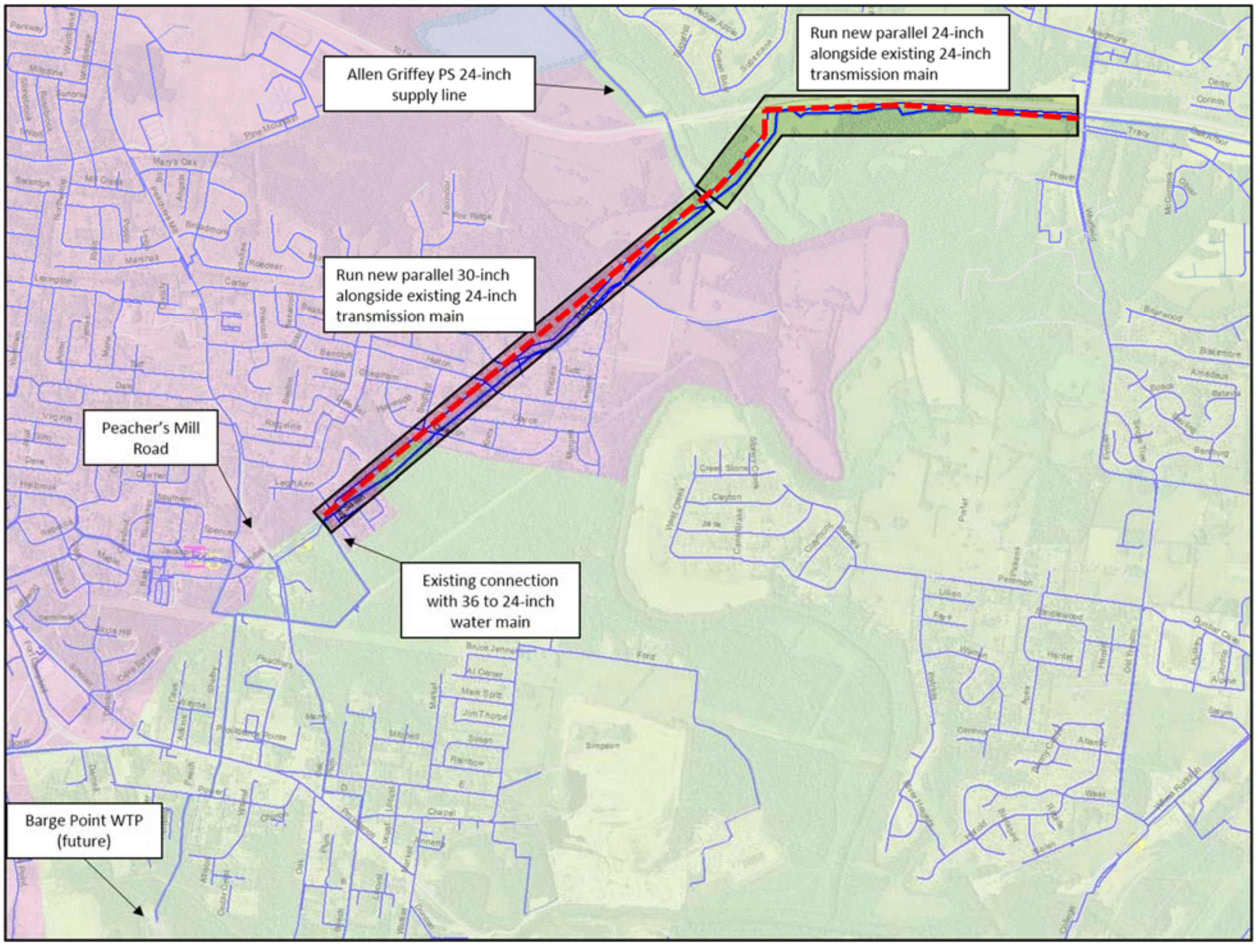
Brief Project Description

1. Installation of a 36-in butterfly valve with electric motor operator and SCADA integration in front of Jackson Tanks to allow CGW to turn them over independently of BPWTP or CWTP operation.

2. Installation of a 24-in pressure-reducing valve with flow meter and SCADA integration to drop pressure and measure flow into the proposed South Main Zone.

Planning Level Cost Estimate	
Mobilization	2,380
Valves	68,000
Vaults	30,000
Power	25,000
SCADA Integration	25,000
Flow Meter	30,000
Subtotal	180,380
Contractors General Conditions 30%	54,114
Construction Total	234,494
Design @ 15%	35,174
Limited Construction Admin @ 5%	11,725
Engineering Total	46,899
TOTAL	**280,000**

CIP Project C-1 – Installation of Parallel Mains to Existing 24-inch Transmission Main



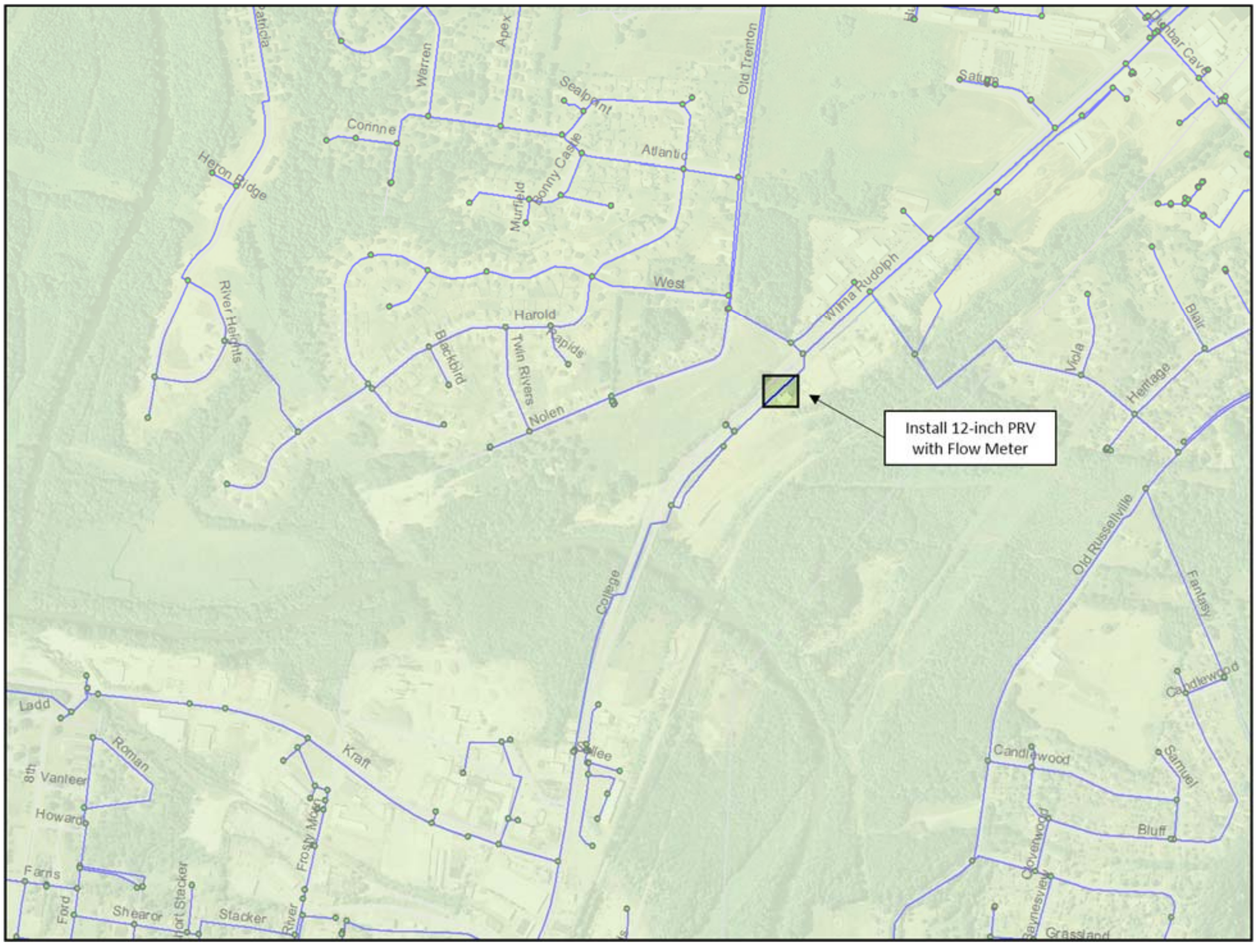
Brief Project Description

1. Installation of approximately 8,400 linear feet of parallel 30-inch water main from connection of existing 36-inch and 24-inch near Peacher's Mill Road to the 24-inch supply line to Allen Griffey PS.

2. Installation of approximately 7,300 linear feet of parallel 24-inch water main from the 24-inch supply line going to Allen Griffey PS to Whitfield Road.

Planning Level Cost Estimate	
Mobilization	89,950
Piping	2,570,000
Tie-ins	25,000
Restoration/Erosion Control	138,780
Subtotal	2,823,730
Contractors General Conditions 30%	847,119
Construction Total	3,670,849
Design @ 15%	550,627
Limited Construction Admin @ 5%	183,542
Engineering Total	734,170
TOTAL	**4,405,000**

CIP Project D-1 – Installation of Pressure Reducing Valve and Flow Meter to South Main

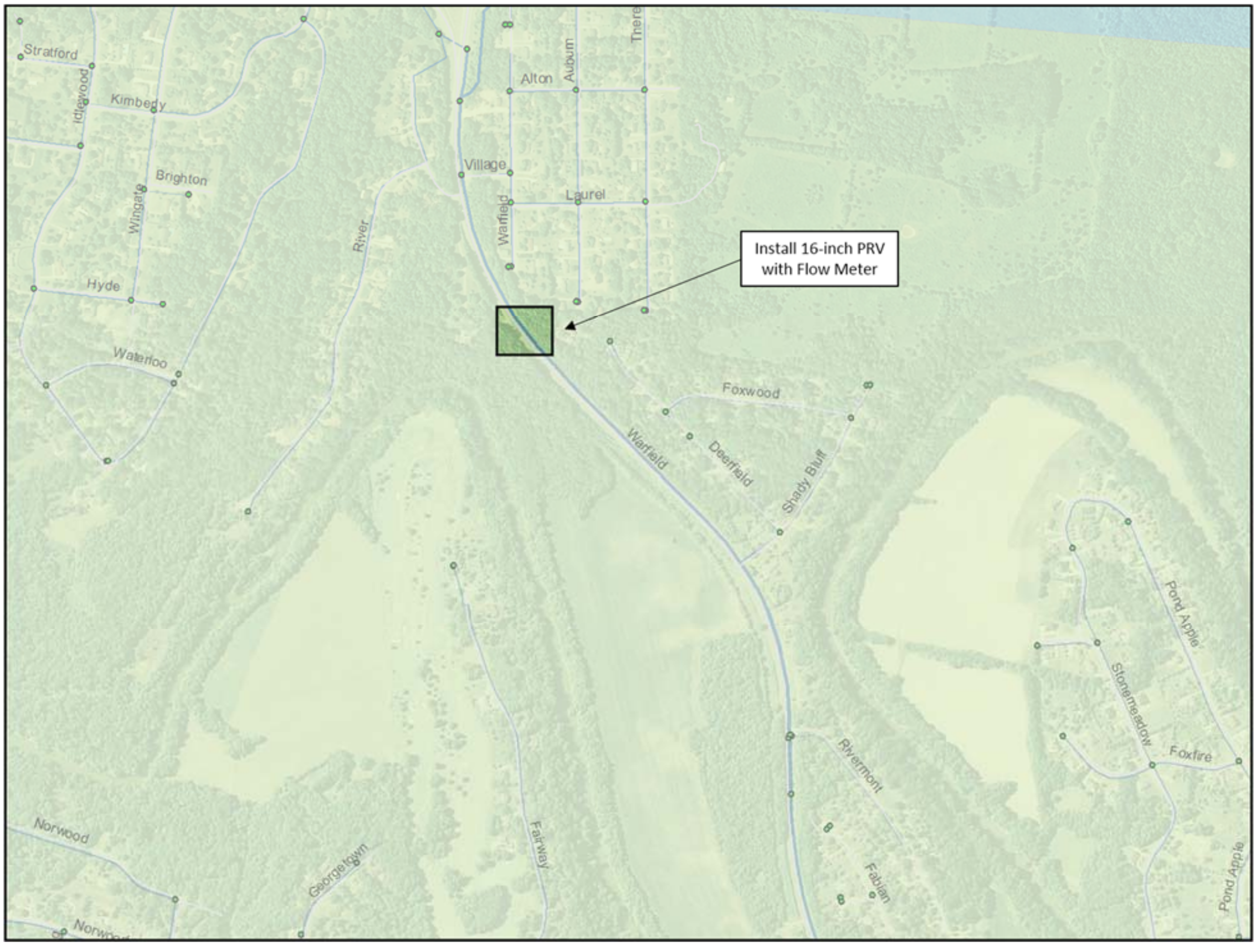


Brief Project Description

1. Installation of a 12-inch pressure reducing valve with a 12-inch magnetic flow meter.

Planning Level Cost Estimate	
Mobilization	560
Valves	16,000
Vault	15,000
Power	25,000
SCADA Integration	25,000
Flow Meter	30,000
Subtotal	111,560
Contractors General Conditions 30%	33,468
Construction Total	145,028
Design @ 15%	21,754
Limited Construction Admin @ 5%	7,251
Engineering Total	29,006
TOTAL	**175,000**

CIP Project E-1 – Installation of Pressure Reducing Valve and Flow Meter to South Main

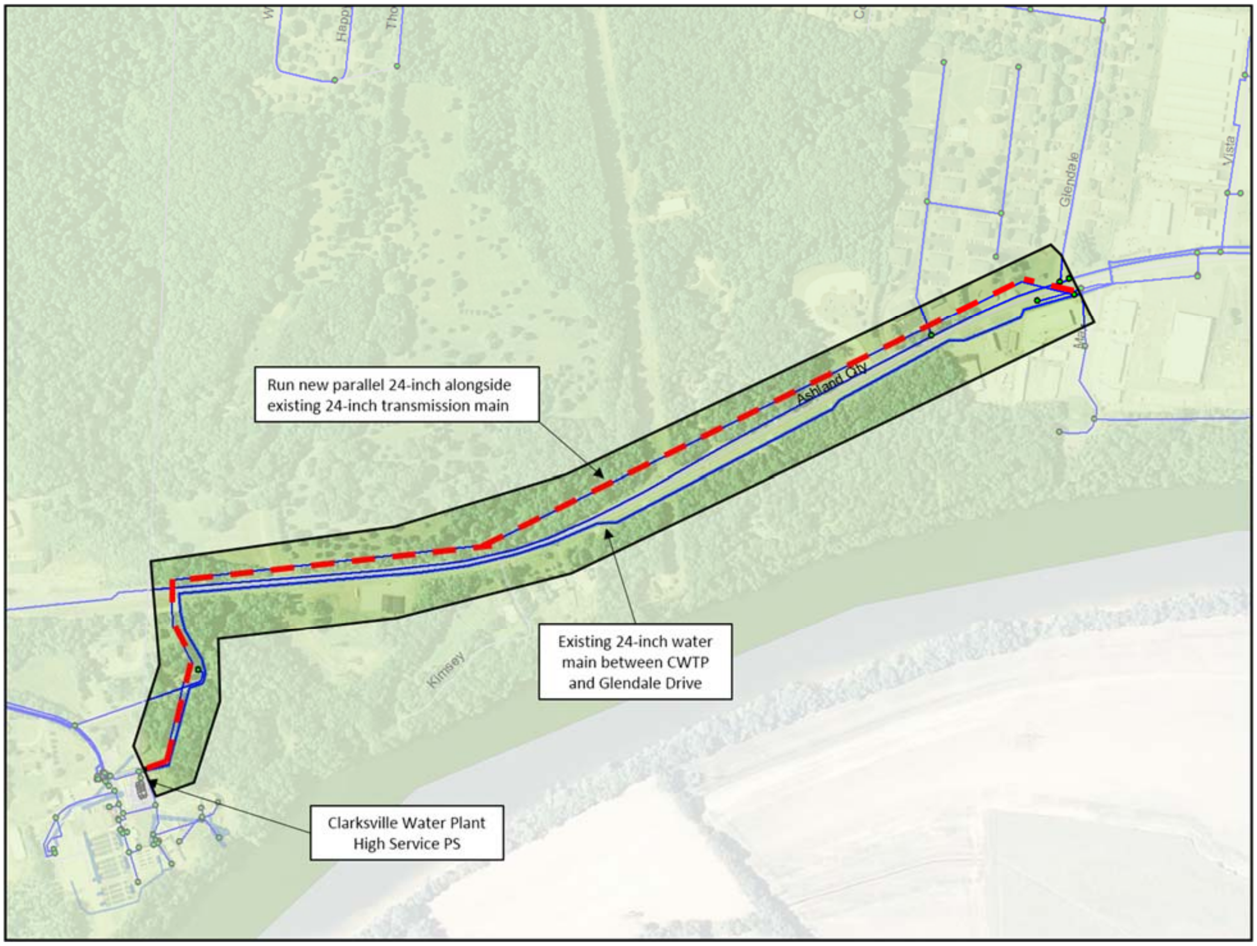


Brief Project Description

1. Installation of a 12-inch pressure reducing valve with a 12-inch magnetic flow meter.

Planning Level Cost Estimate	
Mobilization	560
Valves	16,000
Vault	15,000
Power	25,000
SCADA Integration	25,000
Flow Meter	30,000
Subtotal	111,560
Contractors General Conditions 30%	33,468
Construction Total	145,028
Design @ 15%	21,754
Limited Construction Admin @ 5%	7,251
Engineering Total	29,006
TOTAL	**175,000**

CIP Project F-1 – Installation of Parallel Main to Existing 24-inch Transmission Main

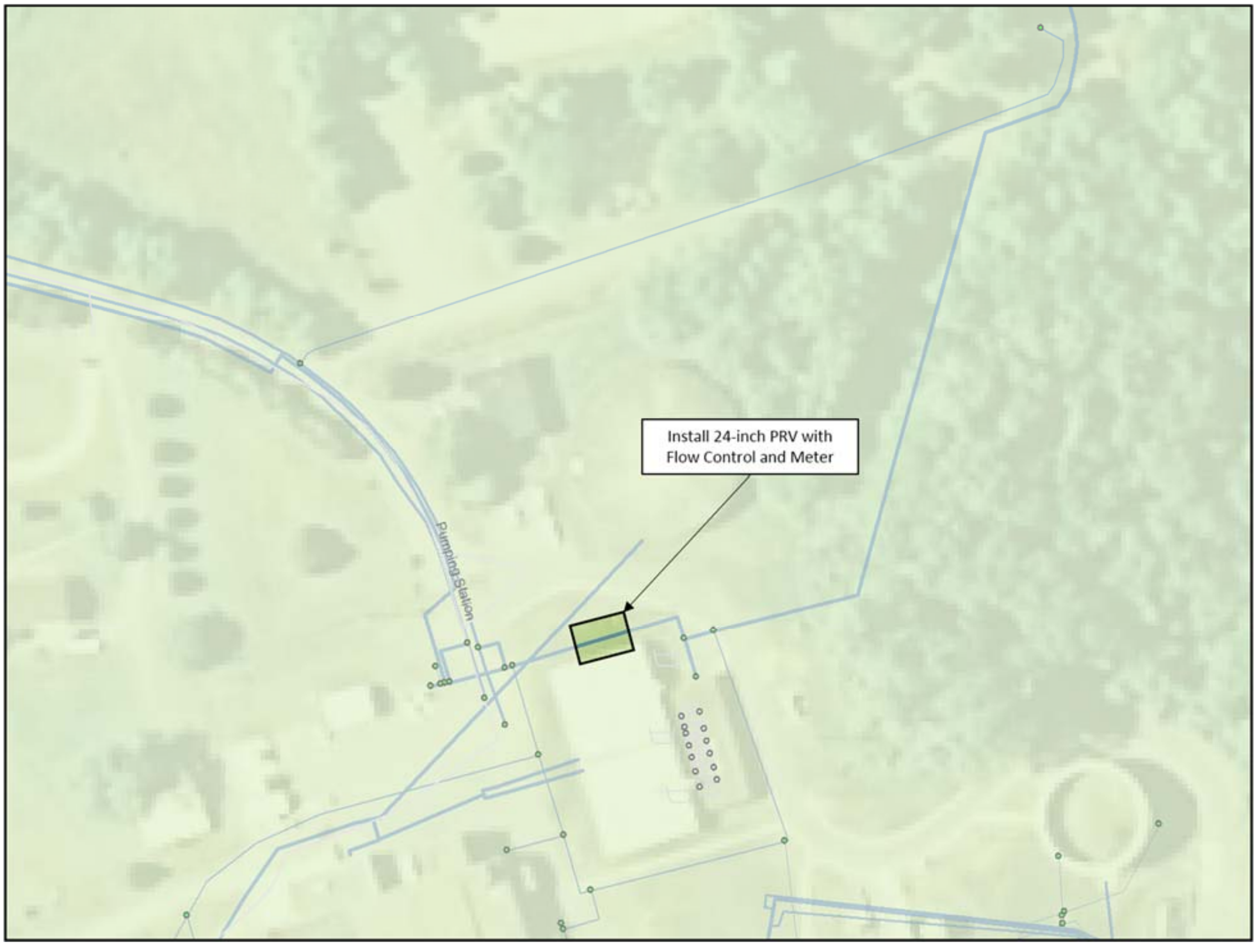


Brief Project Description

1. Installation of approximately 4,750 linear feet of parallel 24-inch water main from CWTP High Service PS to the connection point between the existing 24 and 30-inch transmission main near Glendale Drive.

Planning Level Cost Estimate	
Mobilization	23,625
Piping	675,000
Tie-ins	40,000
Restoration/Erosion Control	36,450
Subtotal	775,075
Contractors General Conditions 30%	232,523
Construction Total	1,007,598
Design @ 15%	151,140
Limited Construction Admin @ 5%	50,380
Engineering Total	201,520
TOTAL	**1,210,000**

CIP Project F-2 – Installation of Pressure Reducing Valve with Flow Control and Flow Meter

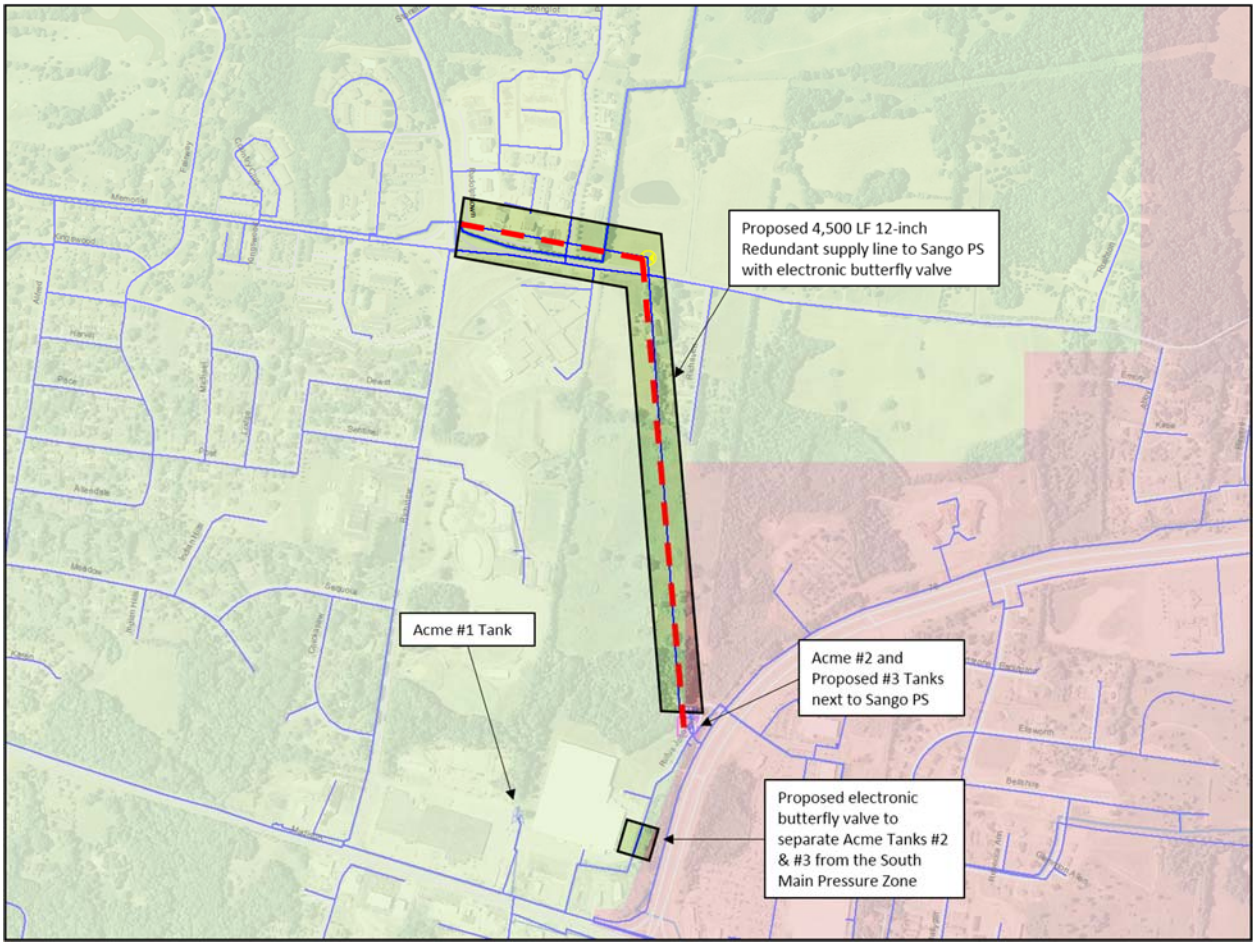


Brief Project Description

1. Installation of a 24-inch pressure reducing valve with flow control

Planning Level Cost Estimate	
Mobilization	1,645
Valves	47,000
Piping Reconfiguration	50,000
Vault	15,000
Power	25,000
SCADA Integration	25,000
Flow Meter	30,000
Subtotal	193,645
Contractors General Conditions 30%	58,094
Construction Total	251,739
Design @ 15%	37,761
Limited Construction Admin @ 5%	12,587
Engineering Total	50,348
TOTAL	**300,000**

CIP Project G-1 – Sango PS Butterfly Valve and Redundant Supply Line Improvements



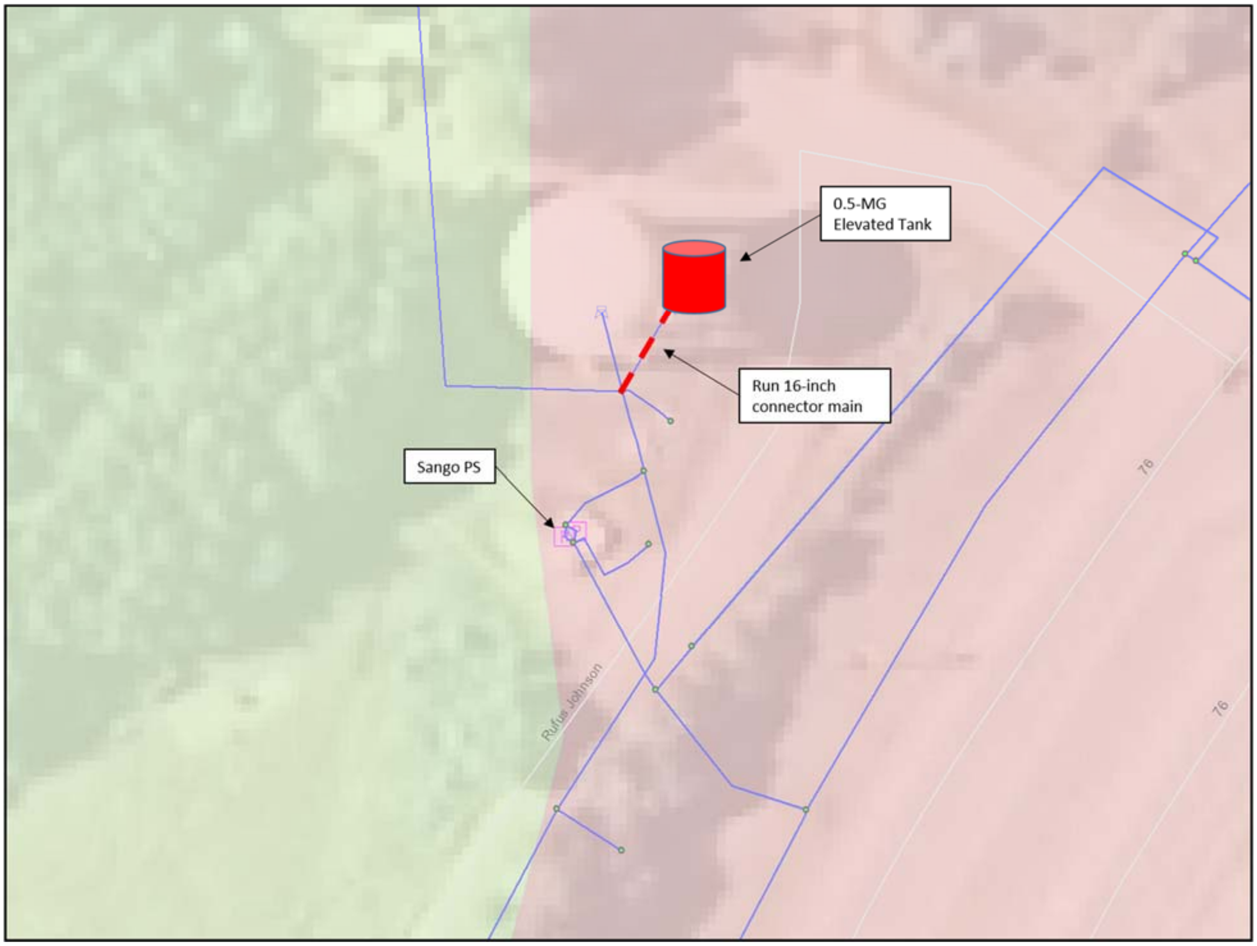
Brief Project Description

1. Installation of approximately 4,500 linear feet of 12-inch water main between the transmission main for the North Main Pressure Zone (near the intersection of Memorial Blvd and Richview Road) and Sango PS.

2. Installation of a 14-in butterfly valve with electric motor operator and SCADA integration in between Acme #1 Tank and Sango PS to allow greater operational flexibility.

Planning Level Cost Estimate	
Mobilization	12,600
Piping	360,000
Tie-ins	20,000
Restoration/Erosion Control	19,440
Valves	18,000
Vaults	30,000
Power	25,000
SCADA Integration	25,000
Subtotal	510,040
Contractors General Conditions 30%	153,012
Construction Total	663,052
Design @ 15%	99,458
Limited Construction Admin @ 5%	33,153
Engineering Total	132,610
TOTAL	**795,000**

CIP Project G-2 – Construction of 0.5-MG Elevated Acme #3 Tank



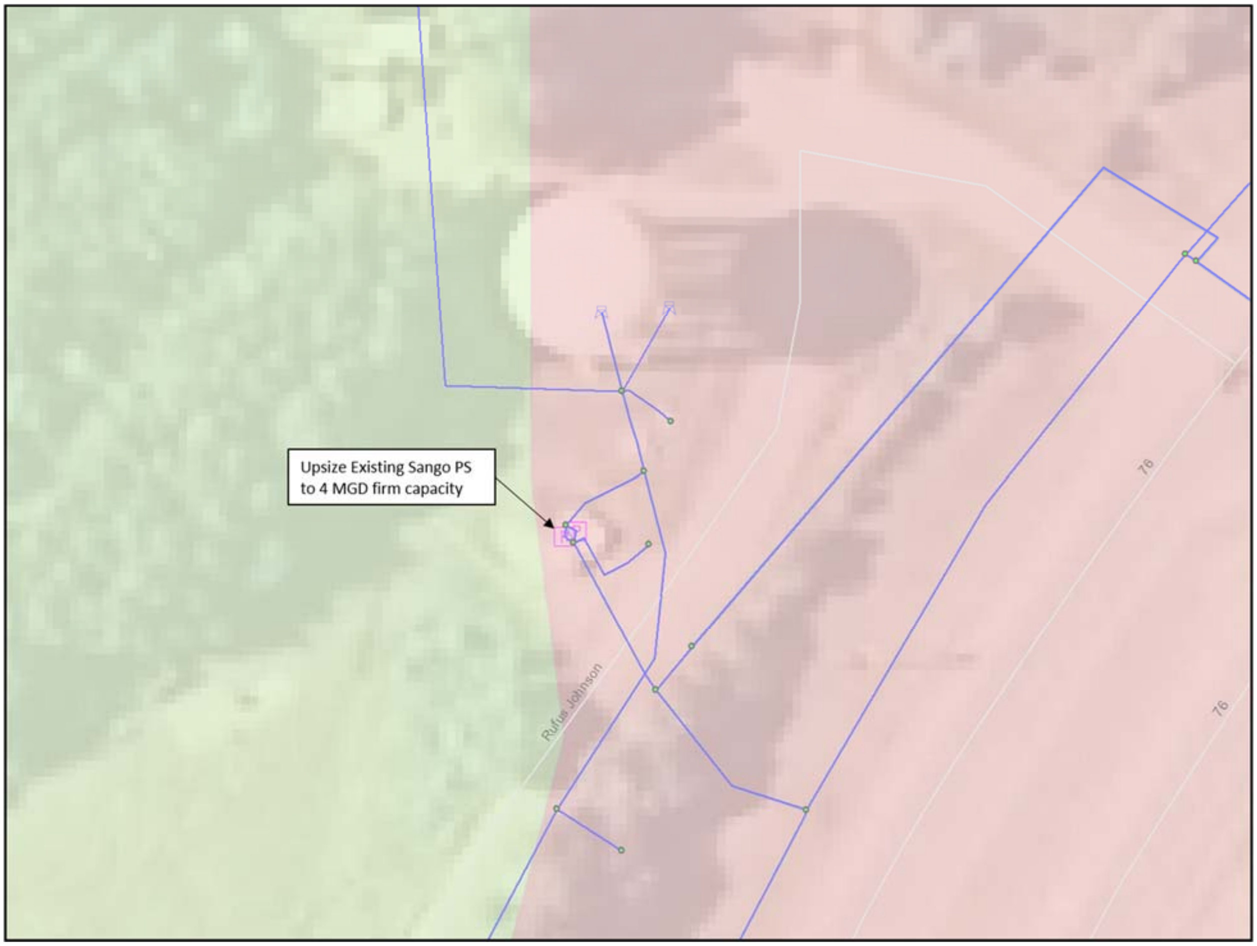
Brief Project Description

1. Construction of a 0.5-MG elevated, cross-braced, multi-column tank to match existing Acme #2 Tank.

2. Installation of approximately 100 linear feet of 16-inch connector main to connect tank with existing system.

Planning Level Cost Estimate	
Mobilization	385
Piping	11,000
Tie-ins	10,000
Restoration/Erosion Control	594
Elevated Storage Tank	1,250,000
Property Acquisition	100,000
Subtotal	1,371,979
Contractors General Conditions 30%	411,594
Construction Total	1,783,573
Design @ 15%	267,536
Limited Construction Admin @ 5%	89,179
Engineering Total	356,715
TOTAL	**2,140,000**

CIP Project G-3 – Upgrade Sango PS Capacity



Brief Project Description

1) Upsize existing Sango Pump Station to 4 MGD firm capacity (2,777 gpm).

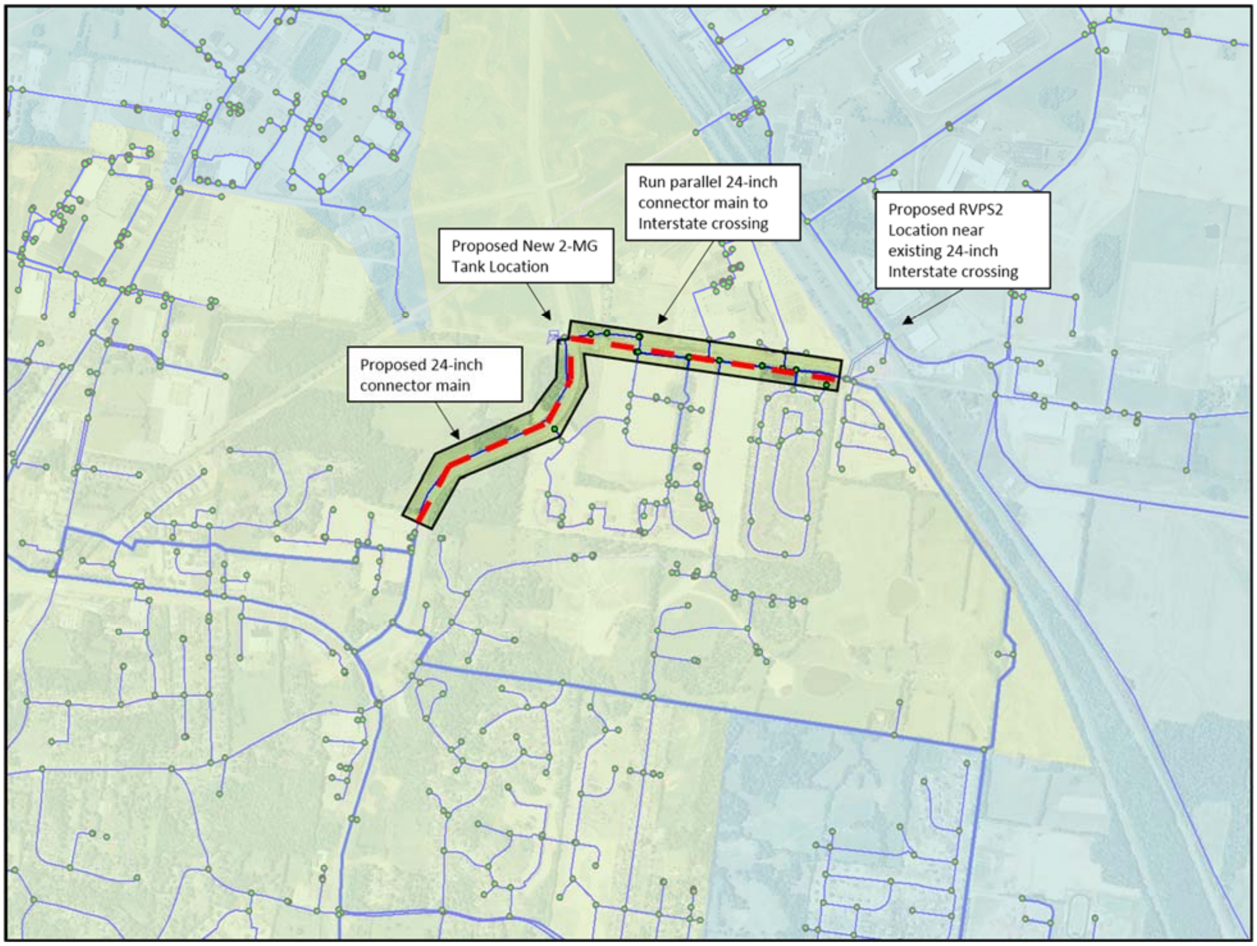
<u>Replacement of equipment only</u>

Planning Level Cost Estimate	
Mobilization	20,000
Upgrade pumps / motors / electrical	400,000
Subtotal	420,000
Contractors General Conditions 30%	126,000
Construction Total	546,000
Design @ 15%	81,900
Limited Construction Admin @ 5%	27,300
Engineering Total	109,200
TOTAL	**655,000**

<u>Total Station Replacement</u>

Planning Level Cost Estimate	
Mobilization	20,000
4 MGD Pump Station	2,400,000
Subtotal	2,420,000
Contractors General Conditions 30%	726,000
Construction Total	3,146,000
Design @ 15%	471,900
Limited Construction Admin @ 5%	157,300
Engineering Total	629,200
TOTAL	**3,775,000**

CIP Project H-1 – 24-inch Transmission Main Improvements for New Trane Tank



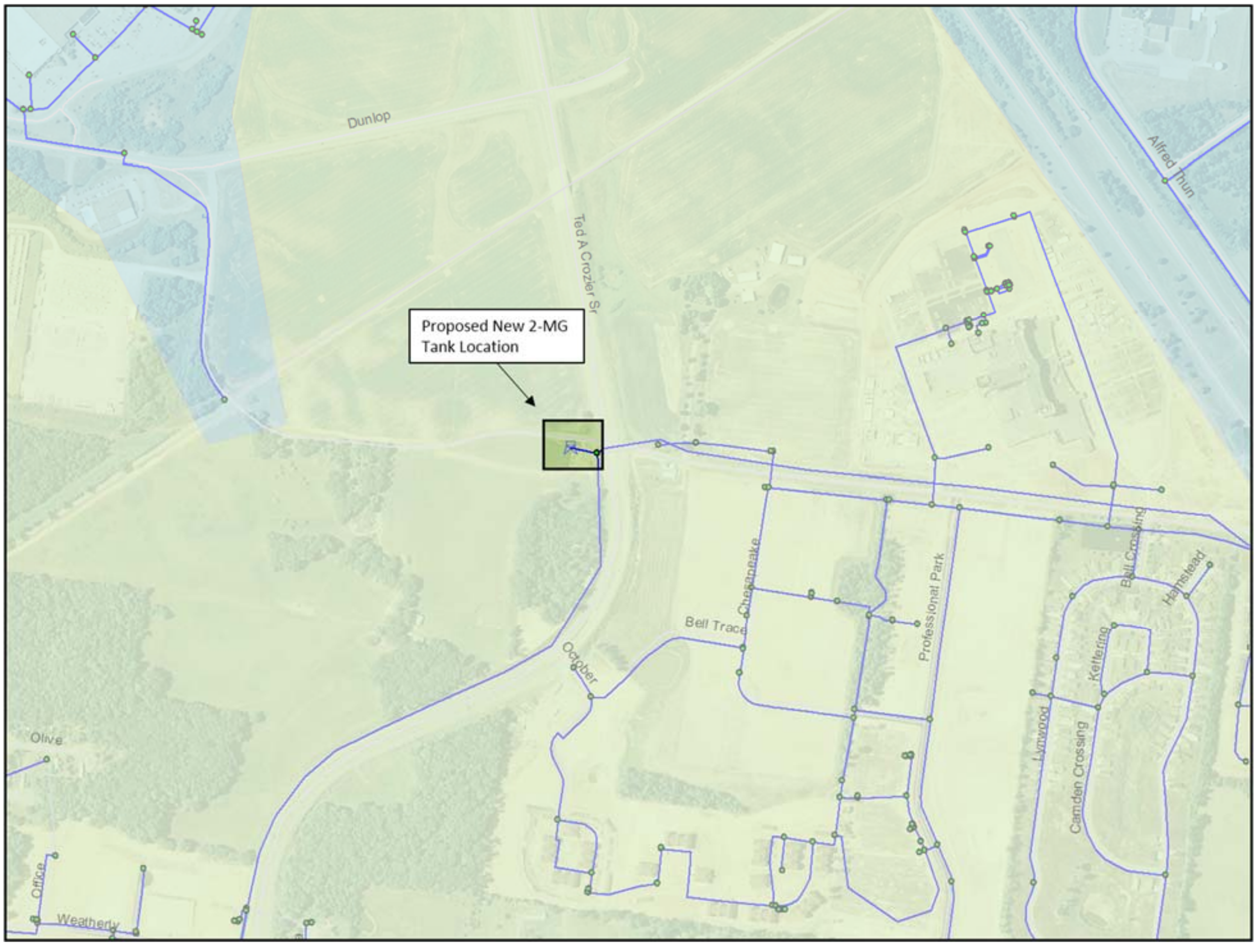
Brief Project Description

1. Installation of approximately 3,400 linear feet of 24-inch water main between the transmission main dead end at Weatherly Drive and Ted Crozier Blvd up to the new 2-MG tank in the North Main Pressure Zone.

2. Installation of approximately 3,800 linear feet of parallel 24-inch water main from to the new 2-MG tank in the North Main Pressure Zone to the existing 24-inch Interstate crossing.

Planning Level Cost Estimate	
Mobilization	35,700
Piping	1,020,000
Tie-ins	50,000
Restoration/Erosion Control	55,080
Subtotal	1,160,780
Contractors General Conditions 30%	348,234
Construction Total	1,509,014
Design @ 15%	226,352
Limited Construction Admin @ 5%	75,451
Engineering Total	301,803
TOTAL	**1,810,000**

CIP Project H-2 - Construction of 2-MG New Trane Tank in North Main Pressure Zone



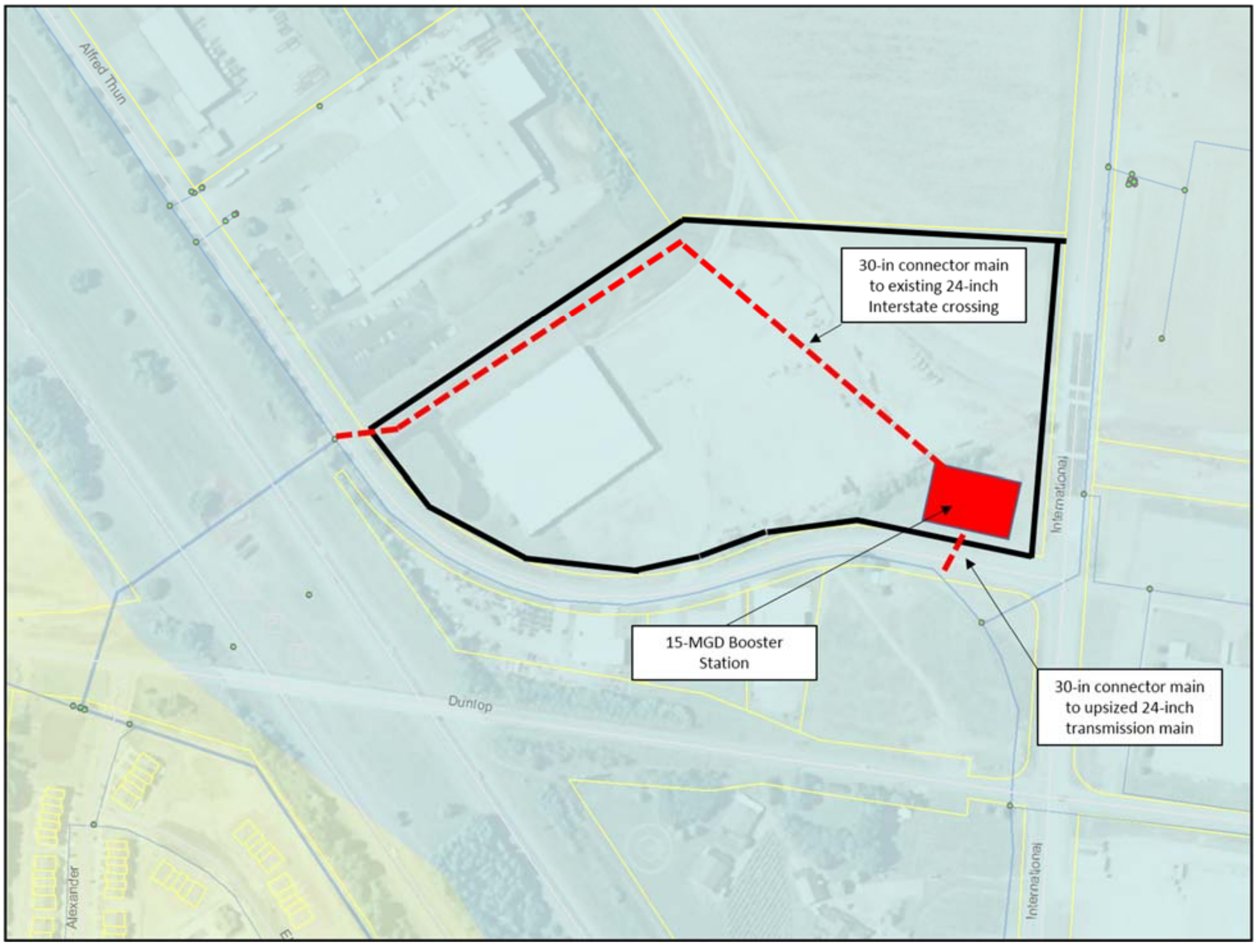
Brief Project Description

1. Construction of a 2-MG elevated, composite tank similar to existing HSC Tank.

2. Installation of 30-inch connector main to connect tank with existing system.

Planning Level Cost Estimate	
Mobilization	20,000
Piping	26,500
Tie-ins	10,000
Restoration/Erosion Control	1,431
Elevated Storage Tank	5,000,000
Property Acquisition	100,000
Subtotal	5,157,931
Contractors General Conditions 30%	1,547,379
Construction Total	6,705,310
Design @ 15%	1,005,797
Limited Construction Admin @ 5%	335,266
Engineering Total	1,341,062
TOTAL	**8,045,000**

CIP Project I-1 – Construction of 15 MGD Rossview Booster Station near Existing 24-inch Interstate Crossing



Brief Project Description

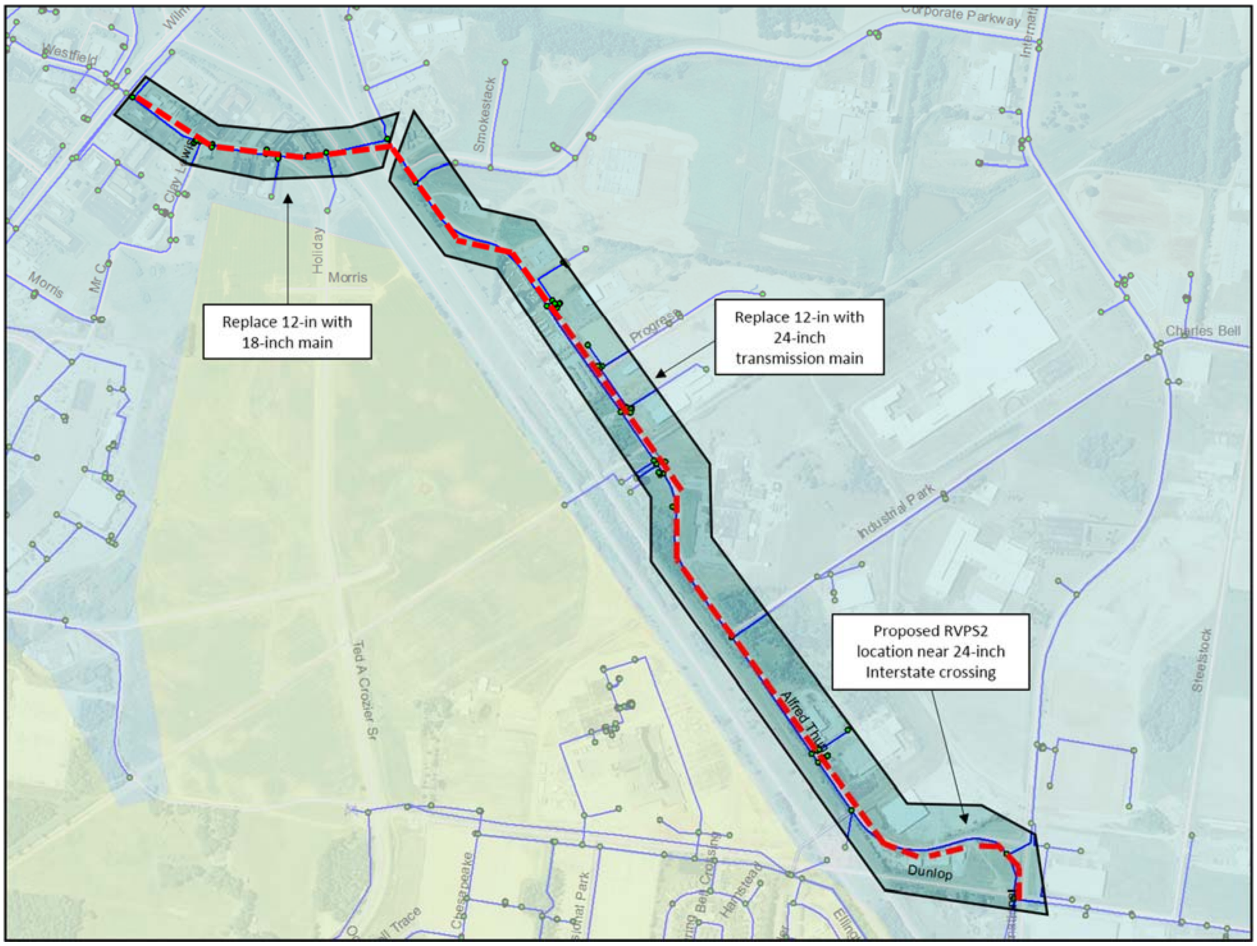
1) Construction of a new pump station with 15 MGD firm capacity using the existing 24-inch Interstate crossing as the supply connection.

2) Installation of approximately 1,400 linear feet of 30-inch water main to connect station to existing system supply.

3) Installation of approximately 250 linear feet of 30-inch water main to connect station to Rossview's upsized transmission main.

Planning Level Cost Estimate	
Mobilization	135,000
15 MGD Pump Station	4,500,000
Property Acquisition	200,000
Piping	300,000
Tie-ins	20,000
Restoration/Erosion Control	16,200
SCADA Integration	50,000
Subtotal	5,221,200
Contractors General Conditions 30%	1,566,360
Construction Total	6,787,560
Design @ 15%	1,018,134
Limited Construction Admin @ 5%	339,378
Engineering Total	1,357,512
TOTAL	**8,145,000**

CIP Project I-2 –Install Upsized Water Mains in Rossview Pressure Zone for Transmission and Distribution Improvements



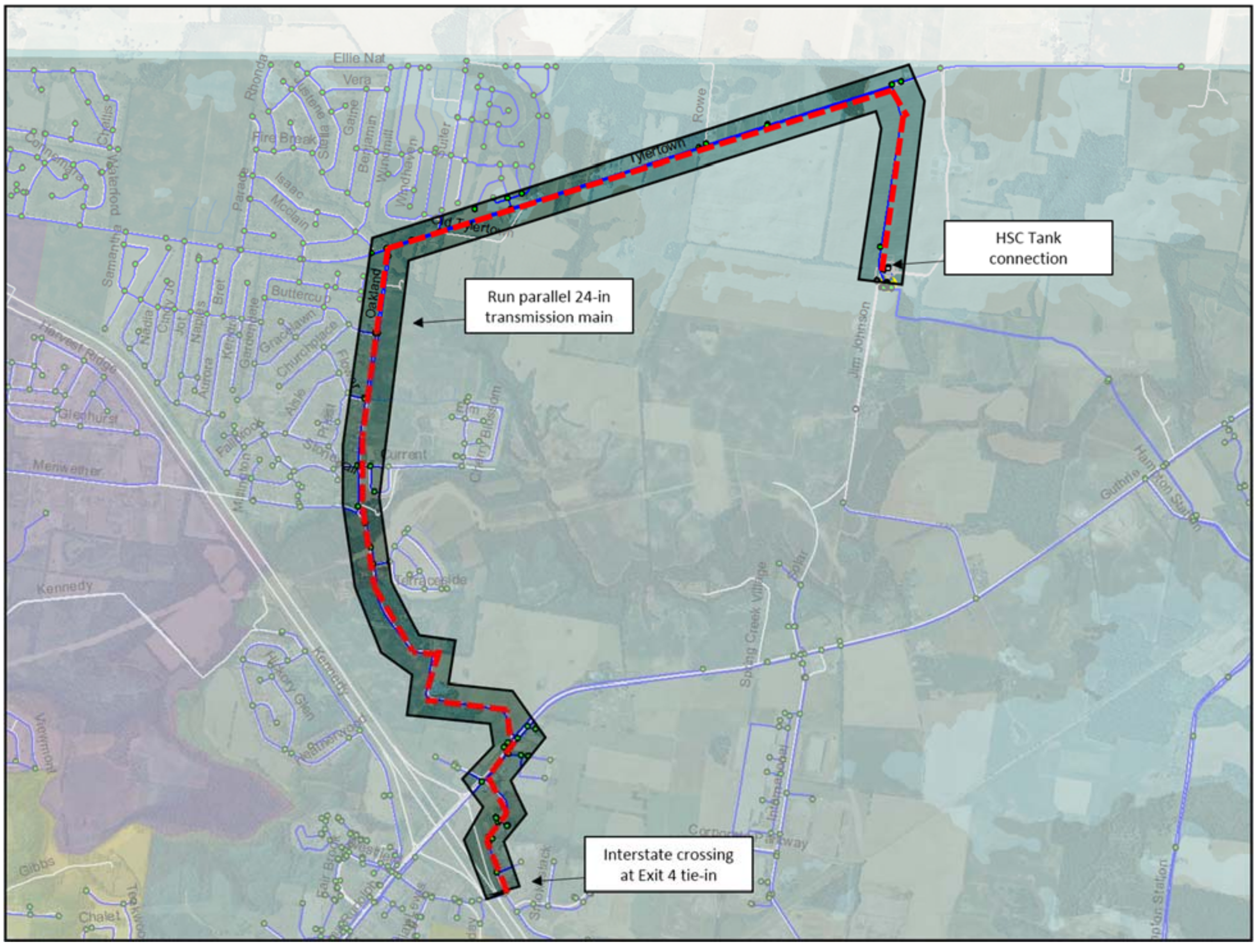
Brief Project Description

1. Upsize of approximately 8,850 linear feet of asbestos-cement pipe to 24-inch water main from the connection with existing 12-inch Interstate crossing at Exit 4 to Dunlop Lane.

2. Upsize of approximately 2,400 linear feet of asbestos-cement pipe to 18-inch water main from Wilma Rudolph Blvd to the connection with the upsized 24-inch Rossview transmission main.

Planning Level Cost Estimate	
Mobilization	53,550
Piping	1,530,000
Tie-ins	150,000
Easements	50,000
Restoration/Erosion Control	82,620
Subtotal	1,866,170
Contractors General Conditions 30%	559,851
Construction Total	2,426,021
Design @ 15%	363,903
Limited Construction Admin @ 5%	121,301
Engineering Total	485,204
TOTAL	**2,910,000**

CIP Project J-1 - Installation of Parallel 24-inch Main along Oakland and Tylertown Road to HSC Tank



Brief Project Description

1. Installation of approximately 30,500 linear feet of parallel 24-inch water main connecting the Rossview transmission main at the tie-in of the existing Interstate crossing at Exit 4 to the existing HSC Tank.

Planning Level Cost Estimate	
Mobilization	152,250
Piping	4,350,000
Tie-ins	20,000
Easements	300,000
Restoration/Erosion Control	234,900
Subtotal	5,057,150
Contractors General Conditions 30%	1,517,145
Construction Total	6,574,295
Design @ 15%	986,144
Limited Construction Admin @ 5%	328,715
Engineering Total	1,314,859
TOTAL	**7,890,000**

CIP Project K-1 - Construction of 2-MG Elevated Rossview #2 Tank

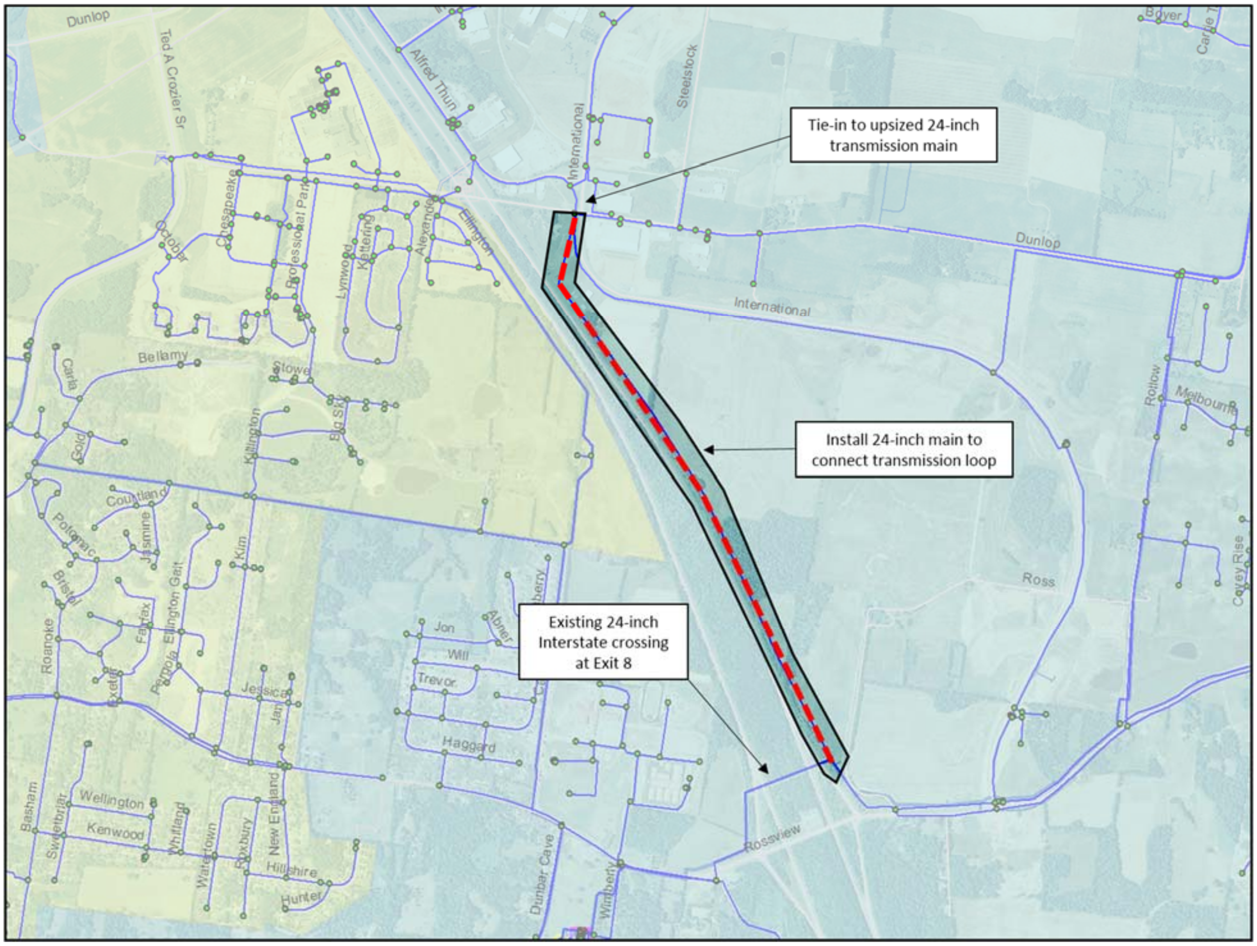
Brief Project Description

1. Construction of a 2-MG elevated, composite tank to match existing HSC Tank.

2. Installation of 30-inch connector main to connect tank with existing system.

Planning Level Cost Estimate	
Mobilization	20,000
Piping	45,000
Tie-ins	10,000
Restoration/Erosion Control	2,430
Elevated Storage Tank	5,000,000
Property Acquisition	100,000
Subtotal	5,177,430
Contractors General Conditions 30%	1,553,229
Construction Total	6,730,659
Design @ 15%	1,009,599
Limited Construction Admin @ 5%	336,533
Engineering Total	1,346,132
TOTAL	**8,075,000**

CIP Project L-1 - Installation of 24-inch Main to Complete Rossview Transmission Main Loop



Brief Project Description

1. Installation of approximately 8,300 linear feet of 24-inch water main to complete Rossview Transmission Loop.

Planning Level Cost Estimate	
Mobilization	42,000
Piping	1,200,000
Tie-ins	100,000
Easements / Permits	500,000
Restoration/Erosion Control	64,800
Subtotal	1,906,800
Contractors General Conditions 50%	953,400
Construction Total	2,860,200
Design @ 15%	429,030
Limited Construction Admin @ 5%	143,010
Engineering Total	572,040
TOTAL	**3,430,000**

2.2 Project Implementation

The projects identified in the previous section should be prioritized based on demand projections and the need for additional capacity to meet those demands. Reliability and redundancy should also be considered to address known vulnerabilities. Table 5 lists all projects with recommended implementation triggers. Cost estimates are provided in 2017 dollars.

Table 5: List of Projects with Costs and Recommended Phasing

Project Group / ID	Project Description	Recommended Trigger	Planning Cost Estimate
Barge Point WTP Phase 1 and 2			
A-1	Barge Point WTP Phase 1	As soon as possible	$58,035,000
A-2	Barge Point WTP Phase 2	Completion of Project A-1 and Max Day Demand > 80% of Total Capacity at both WTPs	$31,760,000
			$89,795,000
North Main Transmission and Storage Improvements			
H-1	Increase Transmission Capacity to New Trane Tank	As soon as possible	$1,810,000
H-2	Construct New Trane Tank	Completion of Project H-1	$8,045,000
C-1	Increase Transmission Capacity	Finish at same time as Project H-2	$4,405,000
F-1	Increase Transmission Capacity	Finish at same time as Project H-2	$1,210,000
			$15,470,000
Splitting Main Pressure Zone			
B-2	Valving Improvements	Finish at same time as Project H-2	$280,000
D-1	Delineation of North/South Main	Finish at same time as Project H-2	$175,000
E-1	Delineation of North/South Main	Finish at same time as Project H-2	$175,000
F-2	Create South Main Pressure Zone	Finish at same time as Project H-2	$300,000
			$930,000
South Main Transmission and Storage Improvements			
G-1	Sango PS Redundant Supply Line Improvements	As soon as possible	$795,000
G-2	Construct Acme #3 Tank	Completion of Project G-1	$2,140,000
G-3	Replace Sango PS	Completion of Project G-2	$3,775,000
			$6,710,000

Table 5 (Cont.): List of Projects with Costs and Recommended Phasing

Project Group / ID	Project Description	Recommended Trigger	Planning Cost Estimate
Rossview 2nd Tank			
K-1	Construct Rossview #2 Tank	As soon as possible	8,075,000
			$8,075,000
Rossview 2nd Booster PS			
I-1	Construct RVPS2	Completion of Project H-2	8,145,000
			$8,145,000
Rossview Transmission Loop			
I-2	Increase Transmission Capacity to Dunlop Lane	Finish at same time as Project I-1	2,910,000
L-1	Increase Transmission Capacity to Rossview Road	Finish at same time as Project I-1	3,430,000
J-1	Increase Transmission Capacity to Oakland Rd / HSC Tank	Completion of Projects I-1 and K-1	7,890,000
			$14,230,000
Jackson Road Line Improvements			
B-1	Upsize lines to Kenwood Elementary	If pressure complaints occur	54,000
			$54,000
		Grand Total	**$143,409,000**