Albany Water Model Update

Prepared for
City of Albany Public Works
Albany, OR
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Section 1

Introduction

1.1 Background

Brown and Caldwell (BC) assisted the City of Albany (City) in developing an updated computer hydraulic model of its municipal water system, facilities, and network. The purpose of this report is to summarize the update of the City water distribution system model and an evaluation of the water system.

The City's previous water model was simplified and skeletonized relative to the water system's actual infrastructure as contained in the City GIS. Based on early discussions between the City and BC and recommendations from BC, it was decided to develop a new/updated model that more accurately reflected actual system configurations and layouts, was consistent with current GIS data, and could be updated in the future based on GIS updates. This effort was intended to provide a representative and functional water system model that could be used to support ongoing and future system analyses and design work.

Additionally, the City's previous water model was developed to perform a steady state (SS) analysis which essentially only simulated a "snapshot in time" that is subject to prescribed conditions. This new/updated model includes an extended period simulation (EPS), which simulates continuous system performance over a period of time and runs for 24 hours or more. For example, if one goal is to model system performance under existing maximum day demand (MDD) and peak hour demand (PHD) conditions, it can be accomplished via either two individual SS scenarios, or one EPS scenario. EPS scenarios take more time to develop but provide greater simulation and analysis flexibility, allow for water age modeling, and simulate the changing demands and the operation of pumps and tanks.

Figure 1-1 shows a map of the water system facilities and **Figure 1-2** shows a hydraulic schematic of the system, which illustrates the relationship between the supply, pumping, and storage facilities.

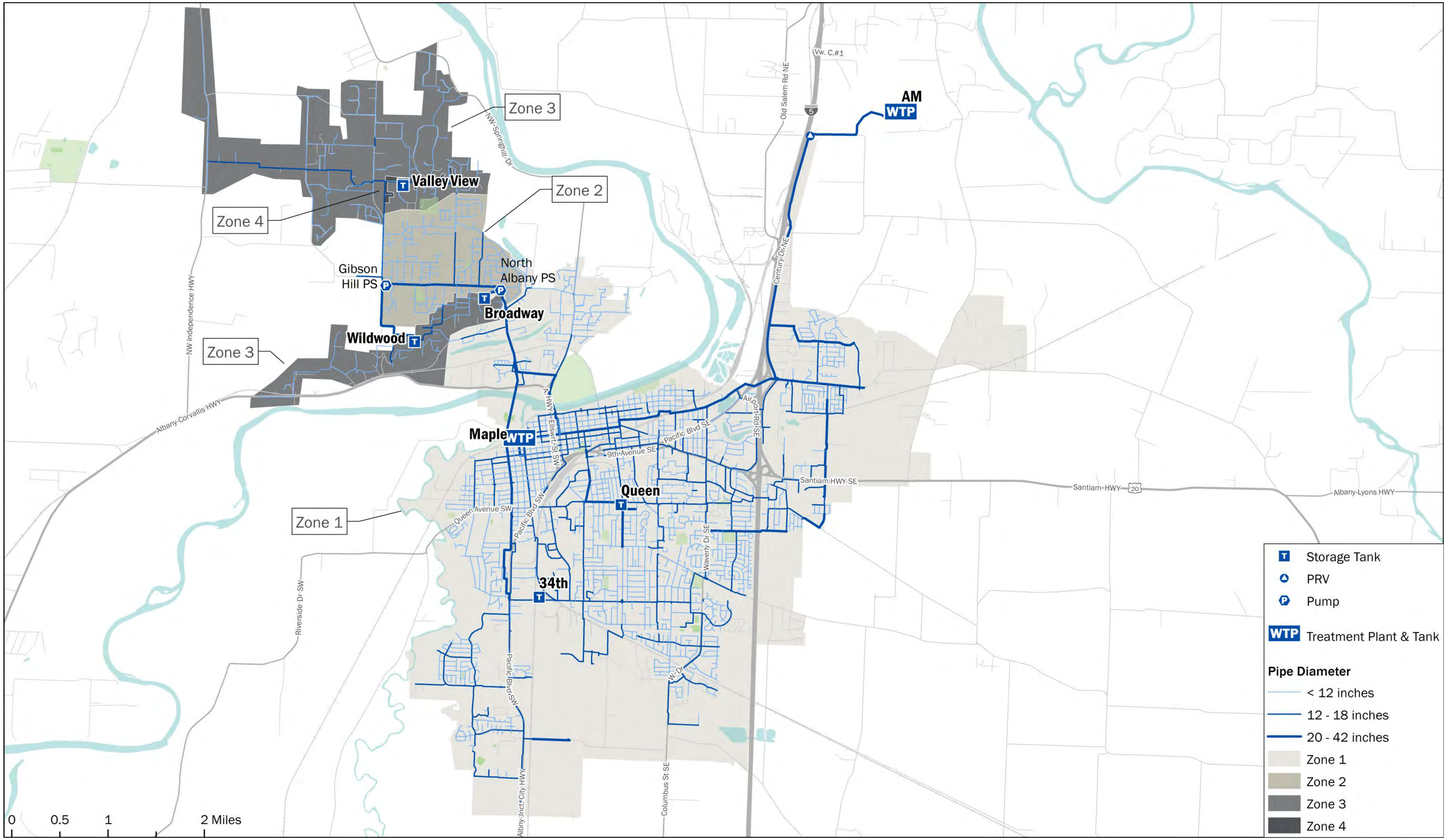


Figure 1-1. Albany Water System Map

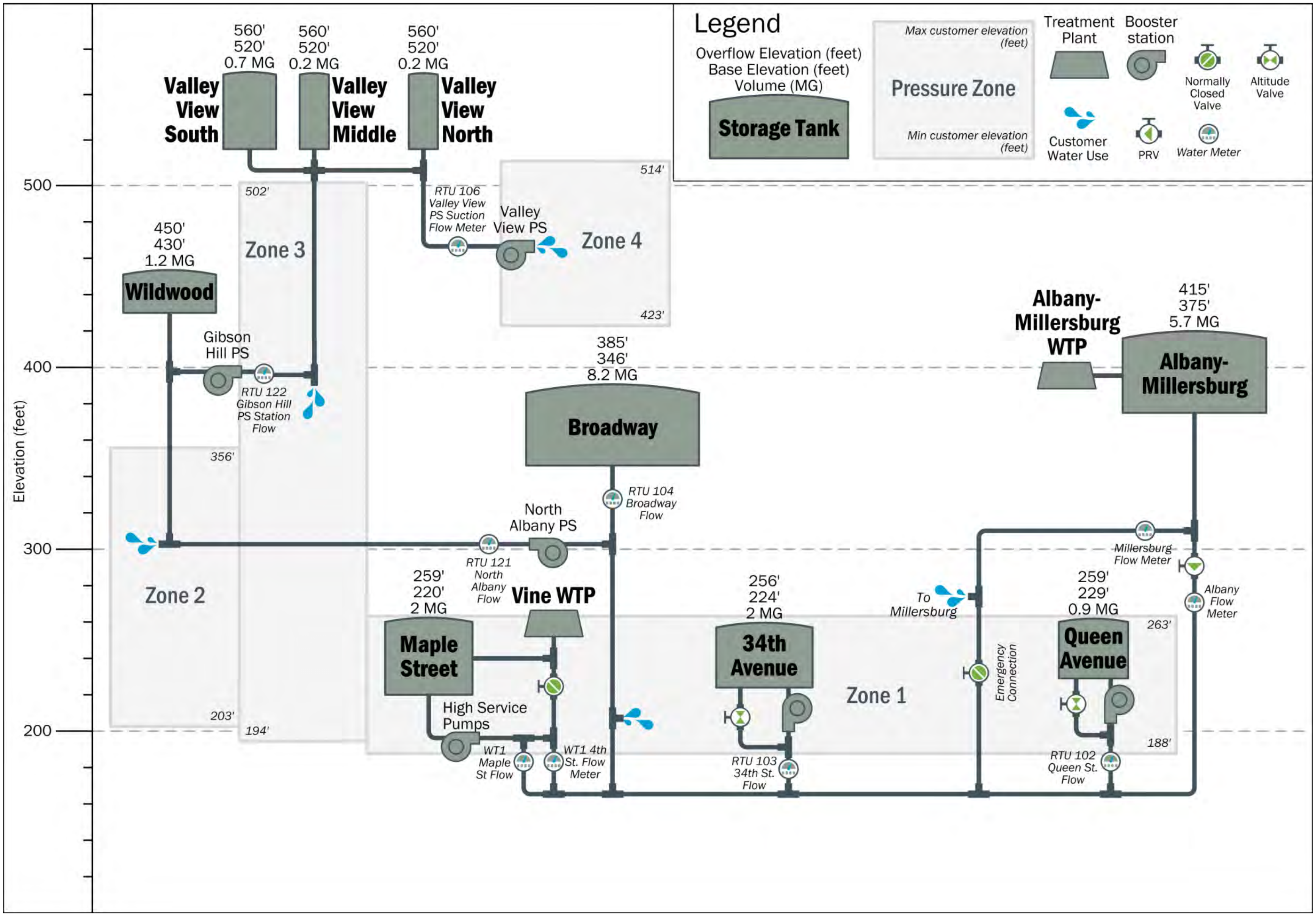


Figure 1-2. Existing System Hydraulic Schematic

1.2 Scope of Work

The model update process was divided in the following project tasks:

Task 100. Model Update - Rebuild the water model pipe network and system elements using City water system GIS and other City water system data sources. Provide a high-level overview of the model elements in a brief technical memorandum.

Task 200. Demand Update - Update existing and build-out water model demand datasets. Provide a high-level overview of model demand development and updates in a brief technical memorandum.

Task 300. Calibration - Calibrate model inputs and system characteristics to demonstrate model accuracy relative to actual system performance. Provide a high-level overview of model calibration results in a brief technical memorandum.

Task 400. Hydraulic Analysis - Complete preliminary/basic water model hydraulic analyses representative of expected water system performance relative to previously established system performance and evaluation criteria. No technical memorandum associated with this task.

Task 500. Development Documentation - Consolidate technical memorandums from tasks 100 through 300 and analysis from Task 400 into a single common document. This report is the result of Task 500.

Section 2

Model Facilities Update

This section describes the development of the updated all-pipes computer model for the City. The model was created using Bentley System Inc.'s WaterGEMS software. WaterGEMS is a widely used water distribution system modeling tool based on the US Environmental Protection Agency's EPANET. The model was created by incorporating the most current GIS data of the system piping, data from the existing water model, and data provided by City staff as described below.

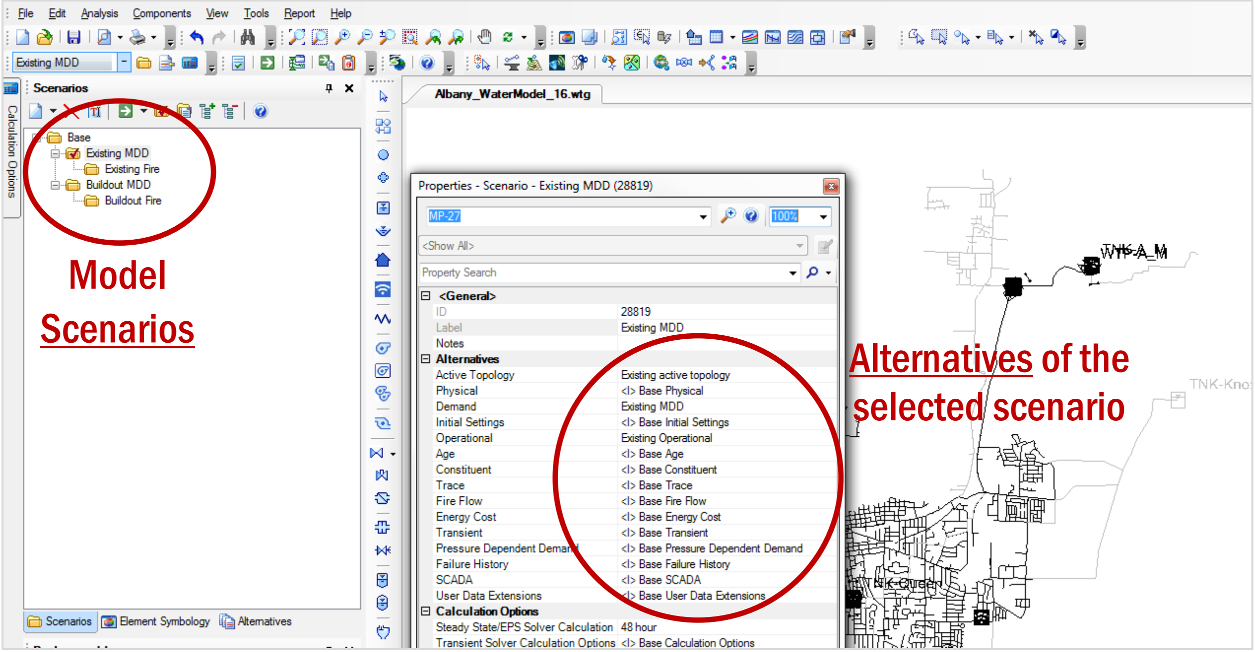
2.1 Scenarios, Alternatives

This section describes the development of the model scenarios and alternatives. Understanding the relationships between attributes, alternatives, and scenarios is necessary in understanding model development and function. The WaterGEMS help file (Bentley 2015) provides the following descriptions:

> **Attribute** — An attribute is a fundamental property of an object and is often a single numeric quantity. For example, the attributes of a pipe include diameter, length, and roughness.
>
> **Alternative** — An alternative holds a family of related attributes so pieces of data that you are most likely to change together are grouped for easy referencing and editing. For example, a physical properties alternative groups physical data for the network's objects, such as elevations, sizes, and roughness coefficients.
>
> **Scenario** — A scenario has a list of referenced alternatives (which hold the attributes) and combines these alternatives to form an overall set of system conditions that can be analyzed. This referencing of alternatives enables you to easily generate system conditions that mix and match groups of data that have been previously created. Scenarios do not actually hold any attribute data—the referenced alternatives do.

The scenarios developed for the final model deliverable include; Existing 2015 MDD, Existing 2015 Fire, Existing 2015 Average Day Demand (ADD), Buildout MDD, and Buildout Fire.

Figure 2-1 shows a model scenario and the alternatives it references.



Model Scenarios

Alternatives of the selected scenario

Properties - Scenario - Existing MDD (28819)

<General>	
ID	28819
Label	Existing MDD
Notes	
Alternatives	
Active Topology	Existing active topology
Physical	<I> Base Physical
Demand	Existing MDD
Initial Settings	<I> Base Initial Settings
Operational	Existing Operational
Age	<I> Base Age
Constituent	<I> Base Constituent
Trace	<I> Base Trace
Fire Flow	<I> Base Fire Flow
Energy Cost	<I> Base Energy Cost
Transient	<I> Base Transient
Pressure Dependent Demand	<I> Base Pressure Dependent Demand
Failure History	<I> Base Failure History
SCADA	<I> Base SCADA
User Data Extensions	<I> Base User Data Extensions
Calculation Options	
Steady State/EPS Solver Calculation	48 hour
Transient Solver Calculation Options	<I> Base Calculation Options

Figure 2-1. Model Scenarios and Alternatives

2.2 Model Object Attributes

This section describes how the model objects were updated from the GIS data and information provided by the City. Object information that is used in the computer calculations, or that can be useful to the model user, is stored as attributes of the respective objects in the database files of the model. The pipes in the new model were imported directly from the GIS database through WaterGEMS tools, while the other model objects were input manually or imported from the previous model.

Table 2-1 describes the model attributes that apply to all objects. Sections 2.2.1 through 2.2.6 describe the data processing and model attributes specific to each object type.

<table>
<tr><th colspan="5">Table 2-1. Common Attributes</th></tr>
<tr><th>Attribute</th><th colspan="4">Value</th></tr>
<tr><td>ID</td><td colspan="4">IDs are integers generated by WaterGEMS and cannot be edited by the modeler.</td></tr>
<tr><td rowspan="8">Label</td><td colspan="4">This field represents a user-friendly identification (ID) for each object. The numbering is alphanumeric, with a prefix and a unique identifier. The prefix indicates object type and the unique identifier includes text describing the object or a unique number.</td></tr>
<tr><td>Object Type</td><td>Prefix</td><td>Unique Identifier</td><td>Sample ID</td></tr>
<tr><td>Junction</td><td>J</td><td>A unique number</td><td>J-10000</td></tr>
<tr><td>Pipe</td><td>(none)
MP (pipes only in the model)
BOP (build out pipes)</td><td>ID field from the topoMains feature class
A unique number
A unique number</td><td>123456
MP-1
BOP-1</td></tr>
<tr><td>Valve</td><td>PRV, PSV, FCV</td><td>Unique description of the valve</td><td>PRV-NorthAlbanyBypass</td></tr>
<tr><td>Tank</td><td>TNK</td><td>Unique description of the tank</td><td>TNK-Broadway</td></tr>
<tr><td>Water Treatment Plant</td><td>WTP</td><td>Unique description</td><td>WTP-Vine</td></tr>
<tr><td>Booster Pump</td><td>PMP</td><td>Unique description of the pump station and the pump number</td><td>PMP-NorthAlbany_1</td></tr>
<tr><td>Zone</td><td colspan="4">The pressure zone that the object is within (Zone 1, Zone 2, Zone 3, Zone 4).</td></tr>
<tr><td>Year Install</td><td colspan="4" rowspan="2">Used to indicate for which scenarios the object should be active. The user will still need to activate/deactivate objects using queries based on these fields.</td></tr>
<tr><td>Year Retire</td></tr>
<tr><td>Elevation</td><td colspan="4">Elevations are assigned to model nodes (junctions, valves, pumps, tanks). Elevations for pumps and tanks were provided by the City. Elevations for junctions and valves were interpolated from 2015 LIDAR data provided by the City (LIDAR29).</td></tr>
<tr><td>Is Active?</td><td colspan="4">Specifies whether or not the object is active for the current scenario.</td></tr>
</table>

2.2.1 Junctions

Junction nodes are automatically created in the model at the endpoints of each pipe. Demands are applied to junctions in the model (see Section 3 for more detail on how the demands were allocated to each of the junctions). **Table 2-2** lists the model's junction attributes.

Table 2-2. Junction Attributes

Attribute		Value
Demand Collection	Demand	The model demands at a junction.
	Pattern	The diurnal (daily water use) pattern for the corresponding demand.

2.2.2 Pipes

For the existing system scenarios, all pipes that were included in the live City GIS Water Main feature class with a "Type" of "W" were included in the model. Pipes identified as service lines in the GIS were excluded. An extensive effort by the City was made to clean up the existing GIS data and make it suitable for hydraulic modeling. This included fixing pipe connectivity problems (nodes in close proximity, pipe splits, crossings), missing pipe diameters, etc. Buildout scenario waterlines were also provided by the City in a separate shapefile.

The model was set up to facilitate on-going model updates as changes are made to the GIS. The GIS “ID” and model “GIS ID” fields provide the relationship between the GIS and model pipes. Additional pipes were needed for the model to operate correctly, such as pump station piping. These pipes are not included in the City GIS database and are labeled with the “MP-”prefix (see **Table 2-1**). These pipes can be viewed in the model using a model query.

WaterGEMS uses the Hazen-Williams equation to determine friction-related headloss. The roughness coefficient, also known as the “C-factor”, used in the equation is assumed for each pipe based on industry research for typical factors associated with a given pipe material, lining and/or age (if known). Lower C-factors equate to higher headloss. Pipes in the model were assigned C-factors taken from industry standards.

Table 2-3 summarizes the model pipe attributes.

<table>
<tr><th colspan="4">Table 2-3. Pipe Attributes</th></tr>
<tr><th>Attribute</th><th colspan="3">Value</th></tr>
<tr><td>GIS-ID</td><td colspan="3">This attribute contains the ID field from the City GIS data and is used to facilitate on-going model updates as changes are made to GIS. Pipes present only in the model do not have a GIS-ID.</td></tr>
<tr><td>Length</td><td colspan="3">Calculated in the model. Matches GIS-calculated pipe length.</td></tr>
<tr><td>Diameter</td><td colspan="3">Inner pipe diameter taken from “inDia” field in GIS pipe attributes.</td></tr>
<tr><td>Install Date</td><td colspan="3">From the GIS “DateInstal” field. Used to compute age of the pipe and for adjustments to the C-factor.</td></tr>
<tr><td>Material</td><td colspan="3">Pipe material from GIS</td></tr>
<tr><td rowspan="12">Hazen-Williams C</td><th>Material</th><th>C-factor</th><th>Source</th></tr>
<tr><td>Default/Blank/Other</td><td>130</td><td>Assumed because Ductile Iron is the most common material used in the systm.</td></tr>
<tr><td>Asbestos Cement</td><td>140</td><td>Linsley, Lindeburg</td></tr>
<tr><td>Cast Iron</td><td>130 (New)
120 (5 years old)
100 (20 years old)</td><td>Linsley, Lindeburg</td></tr>
<tr><td>Copper</td><td>135</td><td>WaterGEMS</td></tr>
<tr><td>Ductile Iron</td><td>130</td><td>Linsley, WaterGEMS</td></tr>
<tr><td>Galvanized Iron</td><td>120</td><td>InfoWater, WaterGEMS</td></tr>
<tr><td>High-Density Polyethylene (HDPE)</td><td>140</td><td>AWWA, InfoWater</td></tr>
<tr><td>Polyvinyl Chloride (PVC)</td><td>140</td><td>AWWA, InfoWater</td></tr>
<tr><td>ODDW</td><td>120</td><td>Outside diameter dipped and wrapped. (Steel pipe with a protective coating)</td></tr>
<tr><td>Steel</td><td>120</td><td>Linsley</td></tr>
<tr><td>Yelo (Plastic)</td><td>140</td><td>InfoWater</td></tr>
<tr><td>Check Valve</td><td colspan="3">Set to “Yes” if there is a check valve on a pipe. See also Section 2.2.6.</td></tr>
</table>

2.2.3 Storage Tanks

Storage tank locations and piping connectivity at the tanks was based on the previous model and verified by the City. Ground elevations and dimensions for storage tanks were provided by the City. **Table 2-4** lists the model's tank attributes.

Table 2-4. Tank Attributes

Attribute	Value
Operating Range Type	The user can choose either Elevation or Level as the Operating Range Type. The water level in a tank can be described based on either the hydraulic grade line elevation (Elevation) or the water level above the base elevation (Level).
Section	Specifies how the tank volume is defined. Options are Circular, Non-Circular, and Variable Area.
Elevation (Base)	The elevation of the bottom of the tank.
Elevation/Level (Minimum)	The lowest allowable water surface elevation/level in the tank. Minimum water levels controlled by a pump or valve will be set by adding controls to the pump or valve.
Elevation/Level (Maximum)	The overflow water surface elevation/level in the tank.
Elevation/Level (Initial)	Starting water surface elevation/level in the tank.
Diameter / Area (Average) / Cross Section Curve	Tank diameter for circular tanks, average area for rectangular tanks, volume/depth curve for other tank shapes.
Volume	Calculated automatically from the tank dimensions.

2.2.4 Pumps

All pumps (including lead, lag and stand-by) at the booster stations and the finished water pumps at the treatment plants are included in the model. The pumps are controlled in the model with start and stop controls that simulate actual pump operations based on tank levels or the time of day as described in Section 2.1.7. **Table 2-5** lists the model's pump attributes.

Table 2-5. Pump Attributes

Attribute	Value
Pump Definition	A pump definition must be supplied for every pump in the model. A multiple point definition based on the manufacturers pump curve was created for each pump. Manufacturer pump curve data was provided by the City.
Elevation	The pump elevation based on the previous model data and verified by the City.
Pump Type	The type of pump (variable or constant speed) based on the previous model data and verified by the City.

2.2.5 Water Treatment Plants

The two water treatment plants (WTPs) are each modeled as reservoir nodes discharging to the Maple and Albany-Millersburg (AM) tanks, which then feed the rest of the system. **Table 2-6** lists the model's reservoir attributes.

Table 2-6. Reservoir Attributes

Attribute	Value
Hydraulic Grade Pattern	Set to "Fixed".
Elevation	The elevation of the reservoir free water surface.

2.2.6 Valves

Only valves that impact the system operations were added to the model. The following valve types were used in the model:

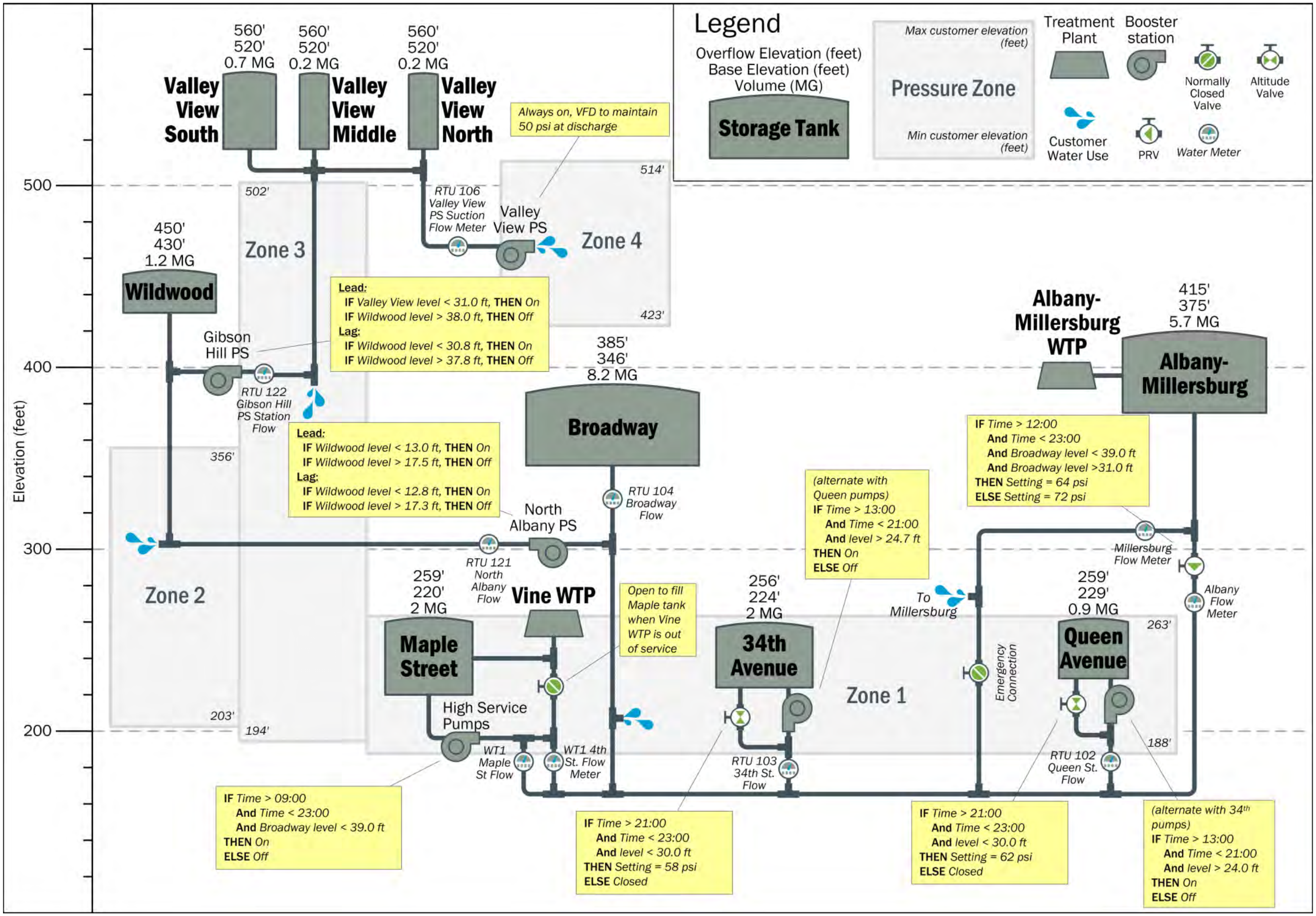
- **Isolation Valves** – The only isolation valves added to the model are associated with actual closed valves or associated with the uni-directional flushing pilot program that was performed as part of this project. Other isolation valves were not included in the model because adding all the isolation valves from the City GIS database to the model adds multiple steps to the on-going model update process, and does not increase the accuracy of the model. City staff determined that the value of linking the model valves to GIS did not justify the added effort.
- **Check valves** – Modeled by turning on the check valve option for a pipe.
- **Tank Fill Valves** – Modeled as pressure sustaining valves (PSVs) with controls to open or close based on the level in the tank. The upstream pressure to maintain was based on the City Supervisory Control and Data Acquisition (SCADA) records.
- **Pressure Regulating/Reducing Valves (PRVs)** – Settings were supplied by the City and verified with SCADA records.

2.2.7 Control Logic

A summary of the control logic for each pump and valve was provided by the City on June 5, 2015 and is shown in **Figure 2-2**. The controls were verified using the SCADA data and entered into the model.

2.2.8 Background data

All background layers came from GIS data provided by the City.



Always on, VFD to maintain 50 psi at discharge

Lead:
IF Valley View level < 31.0 ft, **THEN** On
IF Wildwood level > 38.0 ft, **THEN** Off
Lag:
IF Wildwood level < 30.8 ft, **THEN** On
IF Wildwood level > 37.8 ft, **THEN** Off

Lead:
IF Wildwood level < 13.0 ft, **THEN** On
IF Wildwood level > 17.5 ft, **THEN** Off
Lag:
IF Wildwood level < 12.8 ft, **THEN** On
IF Wildwood level > 17.3 ft, **THEN** Off

IF Time > 12:00
And Time < 23:00
And Broadway level < 39.0 ft
And Broadway level >31.0 ft
THEN Setting = 64 psi
ELSE Setting = 72 psi

(alternate with Queen pumps)
IF Time > 13:00
And Time < 21:00
And level > 24.7 ft
THEN On
ELSE Off

Open to fill Maple tank when Vine WTP is out of service

IF Time > 09:00
And Time < 23:00
And Broadway level < 39.0 ft
THEN On
ELSE Off

IF Time > 21:00
And Time < 23:00
And level < 30.0 ft
THEN Setting = 58 psi
ELSE Closed

IF Time > 21:00
And Time < 23:00
And level < 30.0 ft
THEN Setting = 62 psi
ELSE Closed

(alternate with 34th pumps)
IF Time > 13:00
And Time < 21:00
And level > 24.0 ft
THEN On
ELSE Off

Figure 2-2. Typical Operational Control Strategy

Section 3

Model Demand Development

This section describes the development of demands for the City water system model update. Average daily, maximum day, and fire flow demands were developed for the existing and buildout system scenarios. The methods used for calculating and allocating those demands to the model junctions are described below.

3.1 Updated Water Demands

Total existing system demands were calculated from the production records. Customer billing data was then used to allocate those demands in the model.

3.1.1 System Demand Calculations

The City provided SCADA records for January 2008 through June 2014. The SCADA records included water treatment plant production and tank level records and metered use for Millersburg, a large wholesale customer. These records were used to calculate average daily demand (ADD), average monthly demands, and maximum day demand (MDD). The ADD and MDD are shown in **Table 3-1**.The average monthly demands calculated from the SCADA records are shown in **Figure 3-1.**

Table 3-1. ADD and MDD Summary

Year	Demand (MGD)		MDD Date
	ADD	MDD	
2008	7.22	10.8	7/11/2008
2009	7.87	15.5*	7/29/2009
2010	7.17	12.7	7/26/2010
2011	6.81	11.7	8/25/2011
2012	6.77	12.2	8/15/2012
2013	6.89	12.4	7/24/2013
Average	7.12		

**MDD used in the model*

For an extended period model, the Peak Hour Demand (PHD) is modeled as the time during the MDD run when the diurnal multiplication factor is the largest. The typical Minimum Hour Demand (MHD) is calculated as the time during ADD when the diurnal multiplication factor is the smallest.

Table 3-2. Existing Demand Ratios

Ratio	Existing
MDD/ADD	2.2
PHD/MDD	1.7

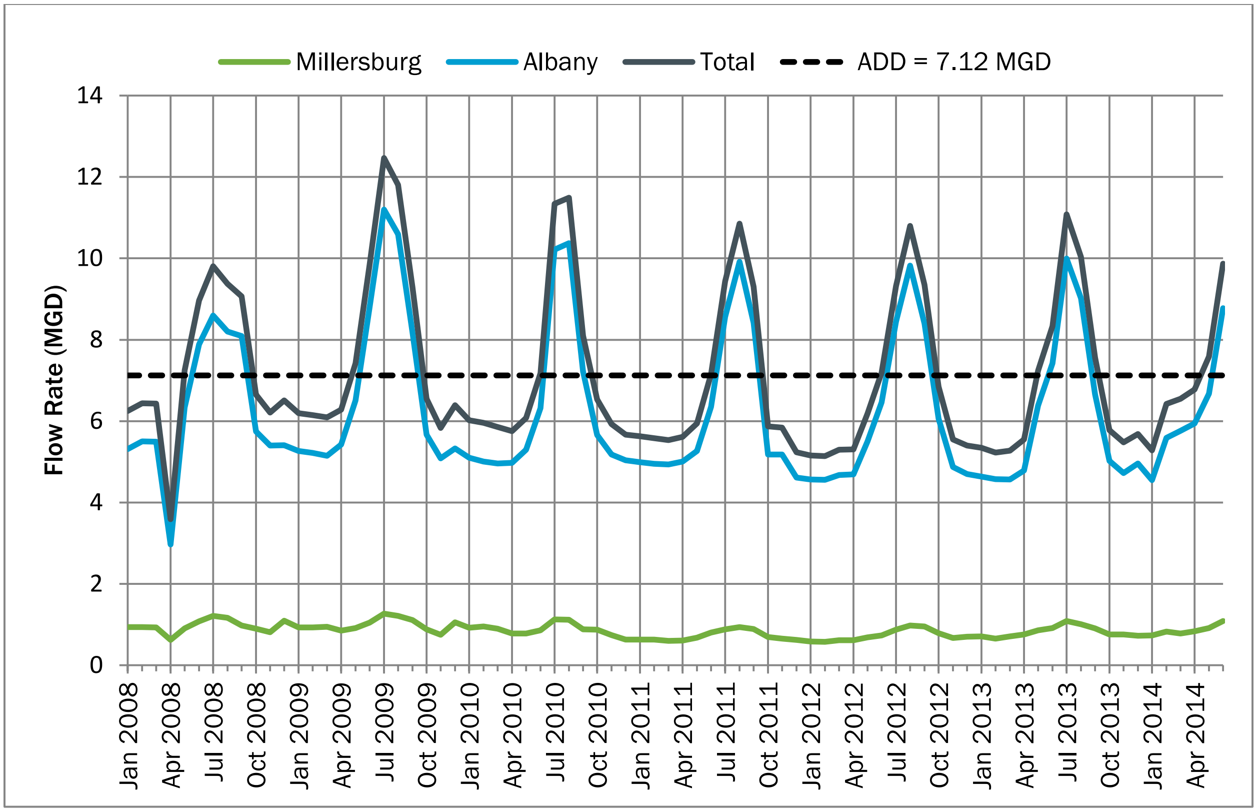


Figure 3-1. Average Monthly Demand Data, January 2008 through June 2014

3.1.2 Customer Billed Usage

The City provided monthly billed water usage for 17,538 Albany customers for July 2013 to June 2014. This data was used to calculate the average annual demand for each customer served by the water system. The total customer water usage for a water system is typically less than the amount produced for the same period of time. The difference between production and billed usage is called non-revenue water. The average monthly production, consumption and non-revenue water are summarized in **Table 3-2**. These values were calculated for modeling purposes and are not intended to be used as a non-revenue water audit.

The City's water audit process uses the American Water Works Association's (AWWA) methodology for estimating unmetered water use. Examples of unmetered uses include firefighting and training, water and sewer main flushing, street cleaning, water line testing, theft, and events like reservoir overflows and large water line breaks. After accounting for meter inaccuracies and these unmetered water uses, the City estimated that the non-revenue water was from 11% to 18% for the same time period.

Table 3-3. Monthly Billed Consumption and Production Comparison

Month		Total Production (MGD)	Millersburg Demand (MGD)	Albany Demand (MGD)[1]	Albany Billed Consumption (MGD)[2]	Non-Revenue Water (MGD)[3]	% Non-Revenue Water[4]
2013	July	11.08	1.09	9.99	7.70	2.29	23%
	August	9.98	1.01	8.97	7.69	1.28	14%
	September	7.57	0.91	6.66	5.41	1.25	19%
	October	5.78	0.76	5.02	3.56	1.46	29%
	November	5.48	0.76	4.72	3.46	1.26	27%
	December	5.68	0.73	4.95	3.44	1.51	31%
2014	January	5.28	0.74	4.54	3.27	1.27	28%
	February	5.44	0.83	4.61	3.42	1.19	26%
	March	5.19	0.78	4.41	3.28	1.13	26%
	April	5.42	0.83	4.59	3.46	1.13	25%
	May	6.19	0.91	5.28	4.40	0.88	17%
	June	8.58	1.09	7.49	6.21	1.28	17%
Average		6.82	0.87	5.95	4.62	1.33	22%

1. *Albany Demand = Total Production – Millersburg Demand*
2. *Includes billed customer, Dumbeck, and auto-flusher consumption*
3. *Non-Revenue Water = Albany Demand – Albany Billed Consumption*
4. *% Non-Revenue Water = Non-Revenue Water/Albany Demand. These values are for modeling purposes and are not intended to be used as a non-revenue water audit.*

Non-revenue water demand was distributed proportionally to customer usage throughout the system. For average day demands, the 1.33 MGD of non-revenue water in **Table 3-2** was spread out proportionally over all the customers so that the total Albany demand in the model equaled 5.95 MGD. The Albany and Millerburg demands were then scaled up until the total system demand equaled 7.12 MGD (**Table 3-1**). This process is described in more detail below.

3.1.3 Customer Demand Allocation

Demand allocation involves calculating the customer demands and then assigning the customer demands to the appropriate junction in the model. The demand for each customer was calculated and allocated using the following process:

1. Obtain billing data and the address for each customer and calculate the average billed demand (ADD or MDD) for each customer.
2. Geocode (locate geographically) each of the customers by matching the customer address to a parcel, street address, or water meter location.
3. Flag each junction in the model as a demand or non-demand junction. A demand junction can have demands assigned and a non-demand junction will not have demands assigned. Non-demand junctions include junctions on transmission pipelines, at tanks, at pump stations, and at water treatment plants.

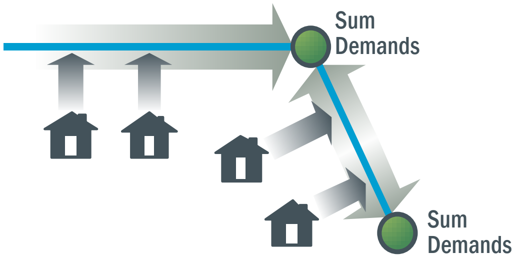


Figure 3-2. Customer Demand Allocation

4. Assign each customer to a demand junction by finding the closest model pipe to each customer and then the closest junction on that pipe as shown in **Figure 3-2**. Calculate the total demand at each demand junction as the sum of the demands for the customers assigned to the junction.
5. Verify the allocation for large demands to ensure they were allocated to the correct junctions.
6. Scale the junction demands so the total model demand equals the total production. This spreads out non-revenue water over the entire system.

3.2 Diurnal Pattern, Fire Flow, and Buildout Demands

This section describes the calculation and allocation of diurnal patterns, fire flow demands, and buildout demands.

3.2.1 Diurnal Demand Pattern

In an extended period model simulation, a diurnal (daily) pattern is applied to the demands in the model to vary the demands throughout the day. During each timestep of the model run, the demand at each junction is multiplied by the diurnal peaking factor for that timestep.

Water demands for residential areas typically follow a diurnal pattern with demand peaking first in the morning as customers are waking and preparing for work, and again in the evening as customers return home. Industrial and commercial zones, which typically use water regularly throughout the day, tend to have flatter peaks.

The following diurnal patterns were calculated for the water system:

- **Zone 1** – Zone 1 contains the majority of the system demand and includes residential, commercial, and industrial customers. This explains why the peak is lower than other patterns.
- **Zone 2** – Zone 2 contains primarily residential customers.
- **Zones 3 & 4** – Zones 3 and 4 contain primarily residential customers at a lower density than Zone 2.
- **System** – The system diurnal pattern represents the water use pattern for the entire system. The system pattern is similar to the pattern for Zone 1 because of the high demand in Zone 1. The system pattern is not used in the model and is only used to calculate the peak hour and minimum hour demands.

The maximum day and average day diurnal patterns for these areas are shown in **Figure 3-3** and **Figure 3-4**. The values for each pattern are shown in **Table 3-3**. These patterns were assigned to the demand junctions residing in the respective pressure zones. A map of the pressure zones is shown in **Figure 1-1**.

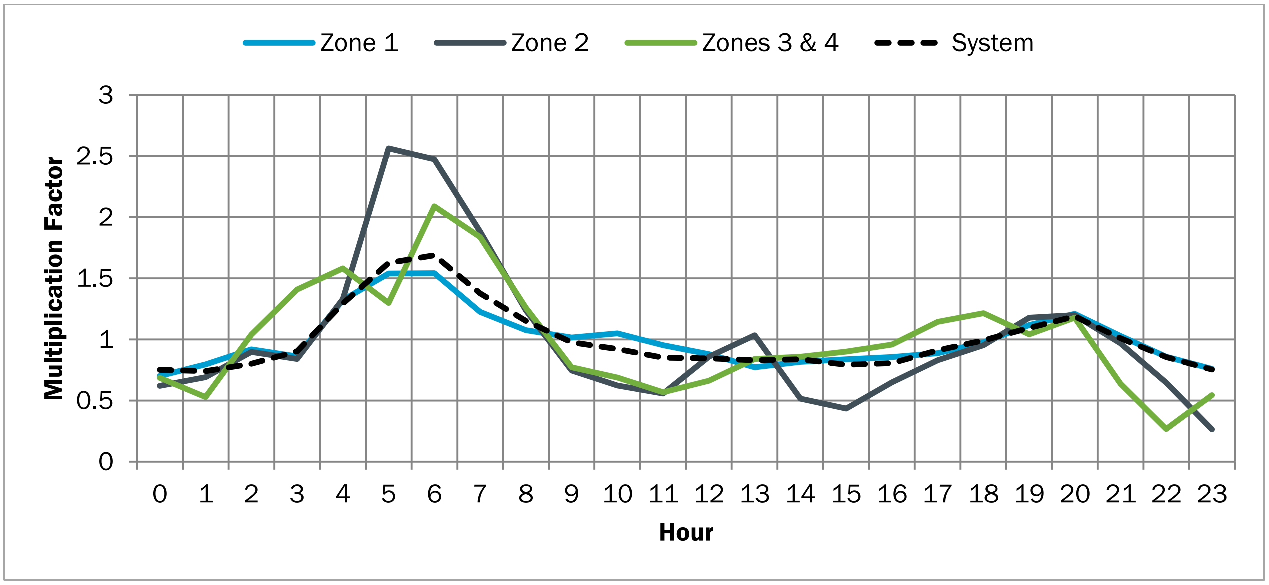


Figure 3-3. System Maximum Day Diurnal Demand Patterns

Patterns from July 24, 2013 (2013-2014 Maximum Day)

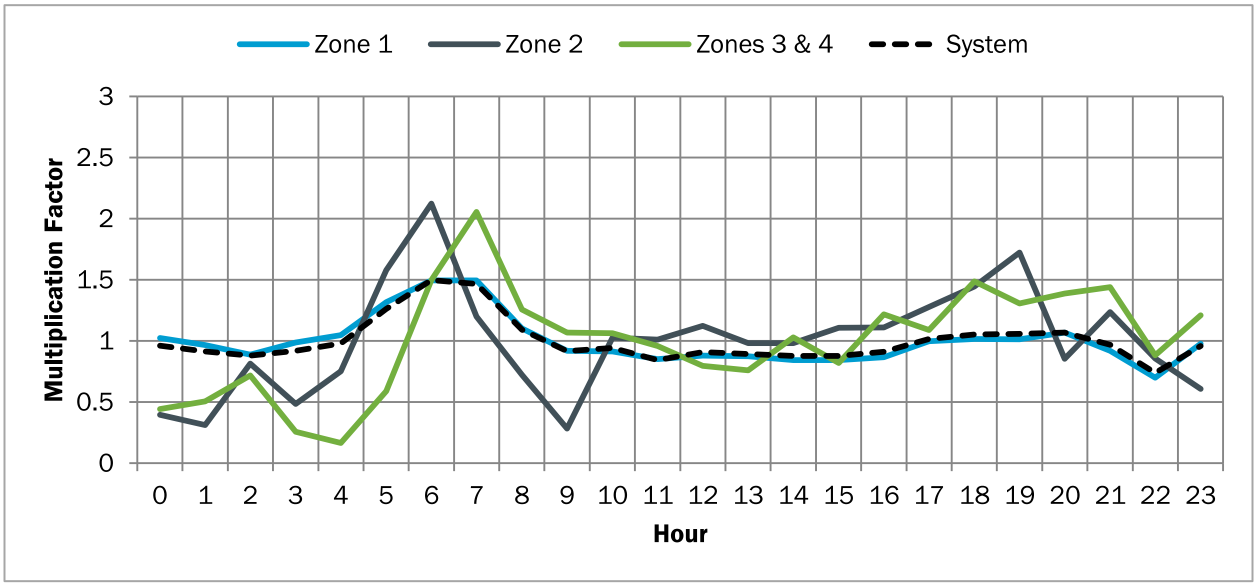


Figure 3-4. System Average Day Diurnal Demand Patterns

Patterns from May 29, 2014, matches 2013-2014 ADD

Table 3-4. Diurnal Demand Patterns

Hour	ADD Multiplication Factor				MDD Multiplication Factor			
	Zone 1	Zone 2	Zones 3 & 4	System	Zone 1	Zone 2	Zones 3 & 4	System
0	1.02	0.40	0.44	0.96	0.70	0.62	0.69	0.75
1	0.96	0.31	0.51	0.91	0.79	0.69	0.53	0.74
2	0.89	0.81	0.72	0.88	0.92	0.90	1.04	0.80
3	0.99	0.48	0.26	0.92	0.86	0.84	1.41	0.90
4	1.05	0.75	0.16	0.98	1.32	1.33	1.58	1.29
5	1.32	1.58	0.59	1.26	1.54	2.56	1.30	1.62
6	1.49	2.12	1.50	1.50	1.54	2.47	2.09	1.69
7	1.49	1.20	2.06	1.47	1.23	1.88	1.84	1.38
8	1.10	0.72	1.26	1.09	1.08	1.24	1.26	1.15
9	0.92	0.28	1.07	0.92	1.02	0.75	0.77	0.98
10	0.91	1.03	1.06	0.94	1.05	0.62	0.69	0.92
11	0.85	1.01	0.96	0.84	0.95	0.56	0.57	0.85
12	0.88	1.12	0.80	0.91	0.88	0.86	0.66	0.85
13	0.88	0.98	0.76	0.89	0.77	1.03	0.84	0.83
14	0.84	0.98	1.03	0.88	0.82	0.52	0.86	0.84
15	0.84	1.11	0.82	0.88	0.84	0.44	0.90	0.79
16	0.87	1.11	1.22	0.91	0.86	0.65	0.96	0.81
17	1.00	1.28	1.09	1.02	0.89	0.83	1.14	0.91
18	1.02	1.44	1.49	1.05	0.98	0.95	1.21	0.99
19	1.01	1.72	1.31	1.06	1.12	1.18	1.04	1.10
20	1.07	0.85	1.39	1.07	1.21	1.20	1.18	1.19
21	0.92	1.23	1.44	0.97	1.03	0.97	0.64	1.01
22	0.70	0.86	0.88	0.74	0.86	0.65	0.27	0.86
23	0.98	0.61	1.21	0.96	0.76	0.26	0.55	0.75
Average	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

3.2.2 Fire Flow Demands

A fire flow demand for each hydrant was calculated and allocated using the following process:

1. Assign a land use and fire demand to each parcel based on land use and fire flow requirements provided by the City (see **Table 5-2**).
2. Assign each hydrant the fire demand based on the closest land use.
3. Assign each hydrant fire demand to a model junction by finding the closest model pipe to each hydrant and then the closest junction on that pipe (using the same method shown in **Figure 3-2**). Calculate the fire demand at each junction as the maximum of the demands for the hydrants assigned to the junction.

3.2.3 Buildout Demands

Buildout demands for 2075 were taken directly from the previous model and were not independently verified. Buildout demand from the previous model junctions were allocated to the closest junction in the new model. Buildout demands are summarized in **Table 3-5**. The existing demands listed in **Table 3-1** are shown as a comparison.

Table 3-5. System Demand Summary

Demand	Total Existing (MGD)[1]	Total Buildout (MGD)
Average Day	7.12	25.4[2]
Maximum Day	15.5	46.1[2]
Peak Hour	26.4	86.1[2]
Typical Minimum Hour[3]	5.27	18.8

1. *From Jan 2008-June 2014 production records (see Figure 3-1 and Table 3-1)*
2. *From CH2MHILL, Water System Hydraulic Modeling Update, Table 2.6, August 2008*
3. *Typical minimum hour demand calculated as the minimum system demand on the average day (Table 3-3)*

Table 3-6 shows the demand ratios for both existing and buildout demands. These values are derived from the demands shown in **Table 3-5** and are given as a reference.

Table 3-6. Buildout Demand Ratios

Ratio	Buildout
MDD/ADD	1.8
PHD/MDD	1.9

Section 4

Model Calibration

This section describes the hydraulic model calibration and results for the City water system model update. Hydraulic models are calibrated to verify that model results are representative of actual system operations. The calibration process for the Albany water system included conducting field tests and making adjustments and corrections to the computer model until the model results matched the data gathered during field testing.

Effort was also expended to define how specific features of the existing physical system are intended to function and to assure that the features were functioning as intended. This included verifying valve positions and locations, pipe size and locations (by checking record drawings), and pump performance curves.

The model calibration effort involved both steady-state calibration and dynamic calibration, which are described in the following sections.

4.1 Steady-State Calibration

For steady-state calibration, hydrant flow tests were performed to simulate high flow conditions and stress the distribution system. This is done to gather field data that reflects the system's reactions to a range of operating conditions. The tests include opening a hydrant and recording pressures at a nearby hydrant. Hydrant flow tests were used to verify elevations, closed/open valves, PRV settings, pipe roughness, and general water system hydraulics.

Thirteen hydrant flow tests were performed on June 4, August 4 and, September 21, 2015. The actual system conditions during the hydrant flow test were replicated in the model and the model and field results were compared. There are no industry standards for the allowable difference between field and model results, but typical practice is +/- 5 pounds per square inch (psi). The test locations are shown in **Figure 4-1**. Detailed maps of the hydrant test locations are shown in **Appendix A.**

Pump test data was collected on June 6, 2015 and used with SCADA to verify the manufacturers pump curve.

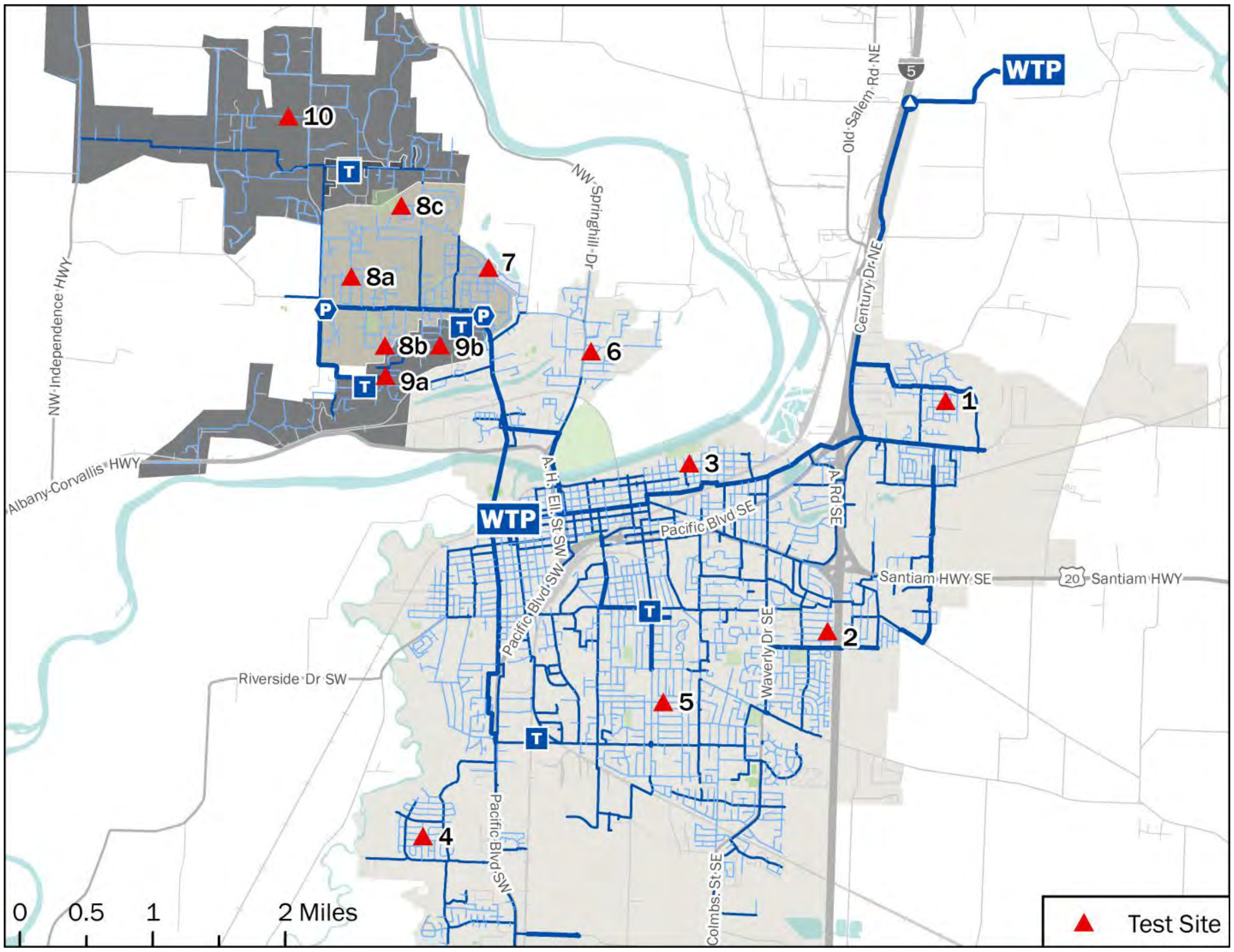


Figure 4-1. Hydrant Flow Test Sites

SCADA records were used to verify the model boundary conditions (i.e. tank levels, pump on/off status, control valve settings, and demands) at the time of each hydrant flow test. Overall, the steady-state calibration effort was successful. Model pressures matched field pressures within approximately 5 psi. **Table 4-1** presents the calibration results, including any special considerations for each test.

Table 4-1. Steady-State Calibration Results

Zone	Test	Static Pressure (Before Flowing Hydrant, psi)			Residual Pressure (While Flowing Hydrant, psi)			Comment
		Field	Model	Difference	Field	Model	Difference	
Zone 1	1	66	67	1	59	63	4	
	2	62	63	1	57	59	2	
	3	70	72	2	65	69	4	
	4	70	71	1	65	65	0	
	5	65	66	1	56	62	6	Slightly higher than normal. Could find no evidence of closed valves in the system in this area.
	6	75	79	4	62	64	2	
Zone 2	7	95	93	-2	86	88	2	
	8a	70	70	0	65	67	2	
	8b	45	44	-1	40	42	2	
	8c	60	60	0	52	55	3	
Zone 3	9a	62	62	0	53	49	-4	
	9b	60	62	2	43	48	5	
	10	92	94	2	25	23	-2	

4.2 Dynamic Calibration

Dynamic calibration involves comparing model simulation results with field measurements over a period of time, and is used to verify valve settings, flow rates, operational controls, pressures, and system demands. Similar to steady-state calibration, high demands are desired to stress the system and provide a better comparison between modeled results and recorded data. June 24-25, 2015 was a recent high demand period and was selected for dynamic calibration.

For dynamic calibration, a 24-hour scenario was created in the model. The pump and valve control settings, initial tank levels, total demands, and diurnal demand patterns for the calibration day were set to match values extracted from SCADA records. Model results were then compared with SCADA values and adjustments were made to the model until the model data matched the SCADA values. These adjustments included refinement of the tank fill valve settings and the pump curves to match metered flow rates and tank levels.

Graphs of the dynamic calibration results are shown in **Appendix B**. These figures show that a good match between model and field results was achieved. This gives a high level of confidence that the model will be a good predictor of the actual water system performance over a wide range of operating conditions.

Section 5

Model Evaluation

Model evaluation was limited to simple presentation of the model results and no analysis of the results was performed. Separate analysis and evaluations for water age and unidirectional flushing (UDF) were performed under a contract addendum and are included in separate individual technical memorandums.

5.1 Hydraulic Evaluation

Distribution system hydraulic evaluation criteria were provided by the City and are shown below in **Table 5-1** and **Table 5-2**. The results presented below will be further investigated and utilized in near term efforts to help identify potential improvements to the water distribution system.

Table 5-1. Evaluation Criteria

Criterion		Value
Pressure	Minimum Operating	40 psi
	Maximum Operating	80 psi
	Minimum During MDD plus Fire Demands[1]	20 psi
Maximum Velocity	Distribution[2]	10 feet/second
	Transmission[3]	5 feet/second
Maximum Headloss	Distribution	10 feet / 1000 feet
	Transmission	3 feet / 1000 feet

1. *Fire demands from section 5-2*
2. *Defined as pipes >=8 inches, < 16 inches*
3. *Defined as pipes >= 16 inches*

Table 5-2. Fire Flow Demand Criteria

Land Use Type	Fire Flow Demand (gallons per minute, gpm)	Duration (hours)
Residential - Low Density	1,500	2
Residential - Medium Density	2,500	
Residential - High Density	3,500	3
Commercial		
Mixed Use		
Institutional (hospital/jail)		
Industrial	5,000	4
Schools		

The existing system water model results for elements violating evaluation criteria are shown in **Figure 5-1** through **5-3**. These results are also accessible in final delivered model.

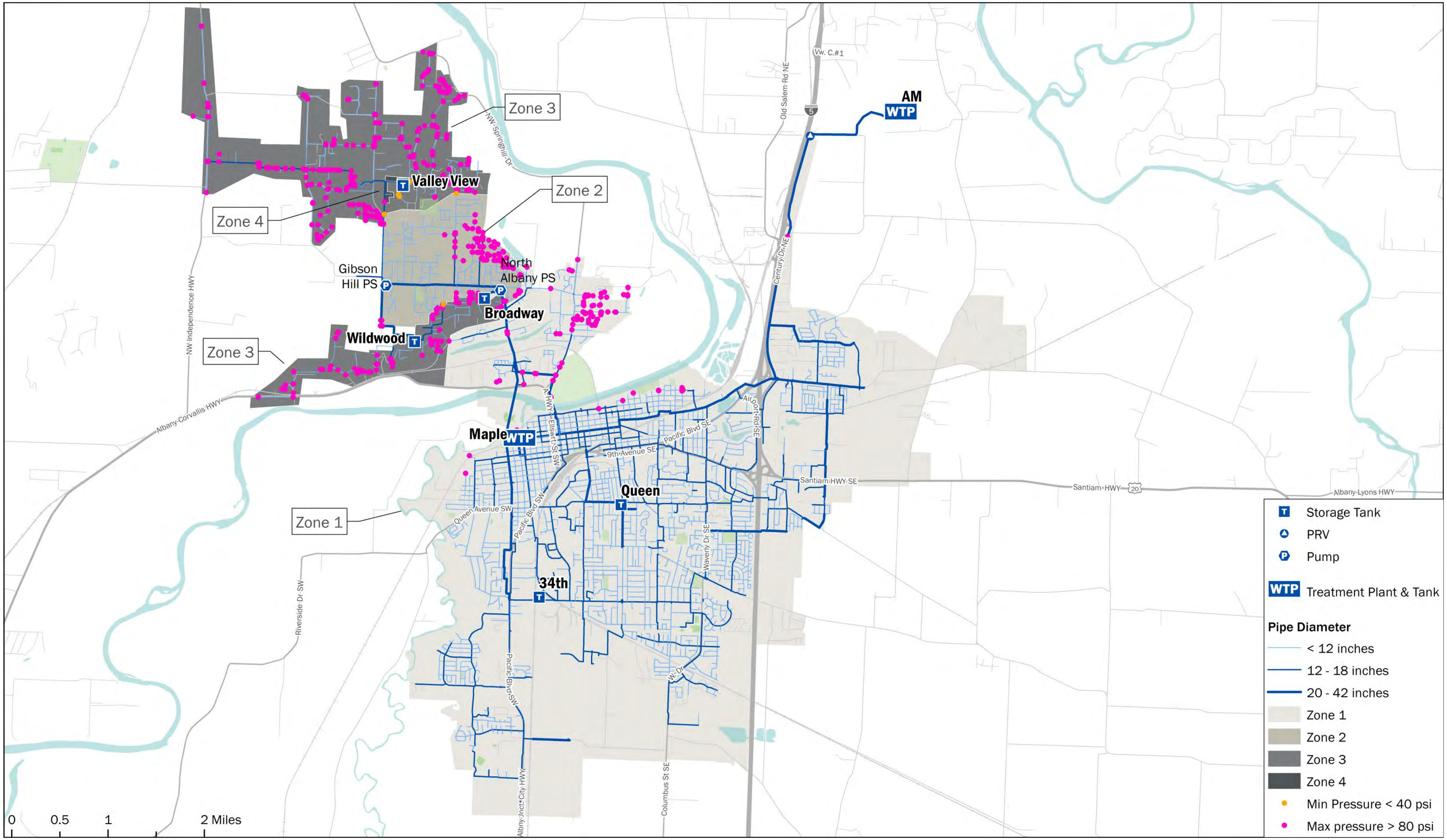


Figure 5-1. Existing System MDD, Minimum and Maximum Pressure Results

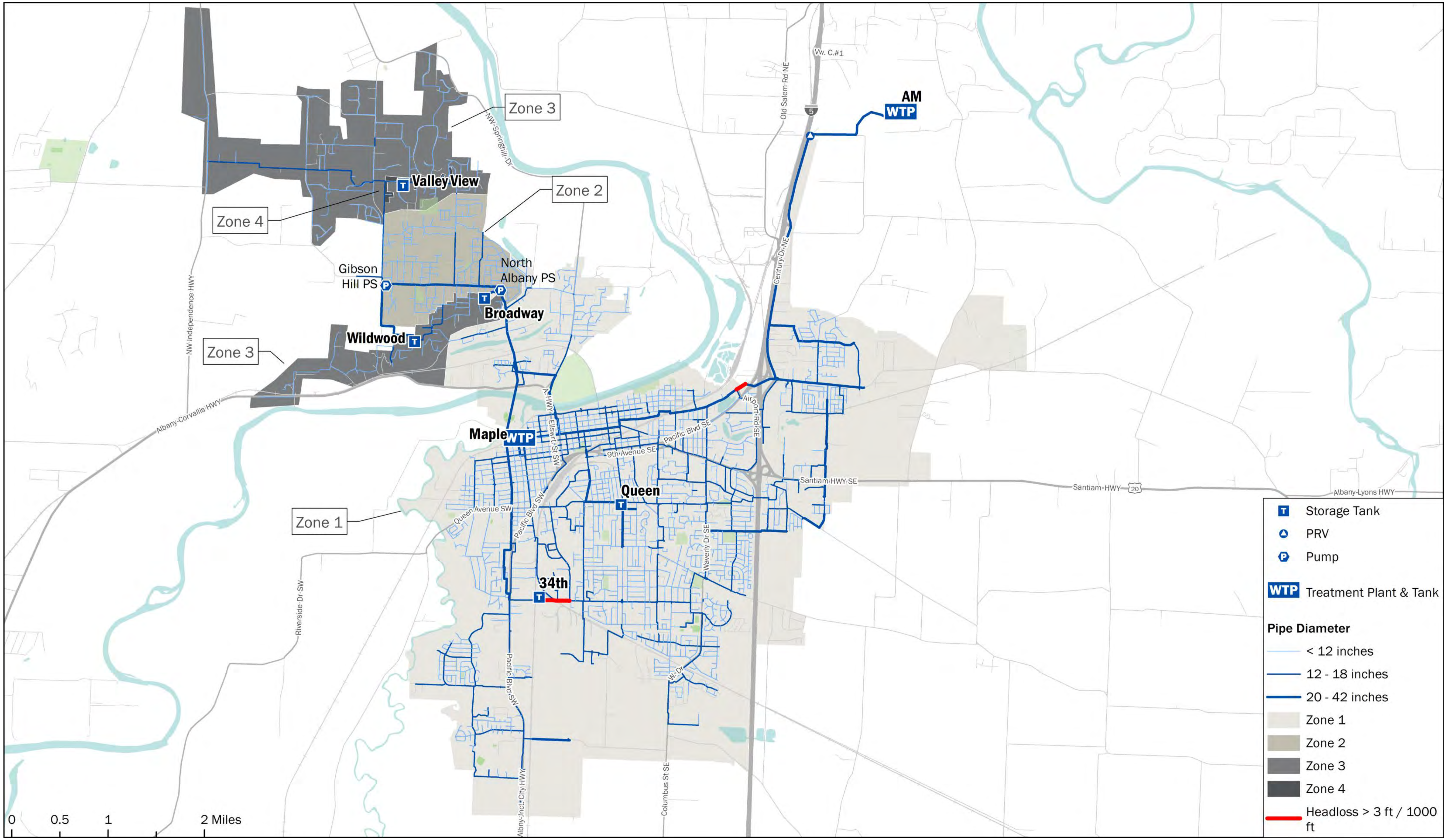


Figure 5-2. Existing System MDD, Transmission Pipe Headloss Results

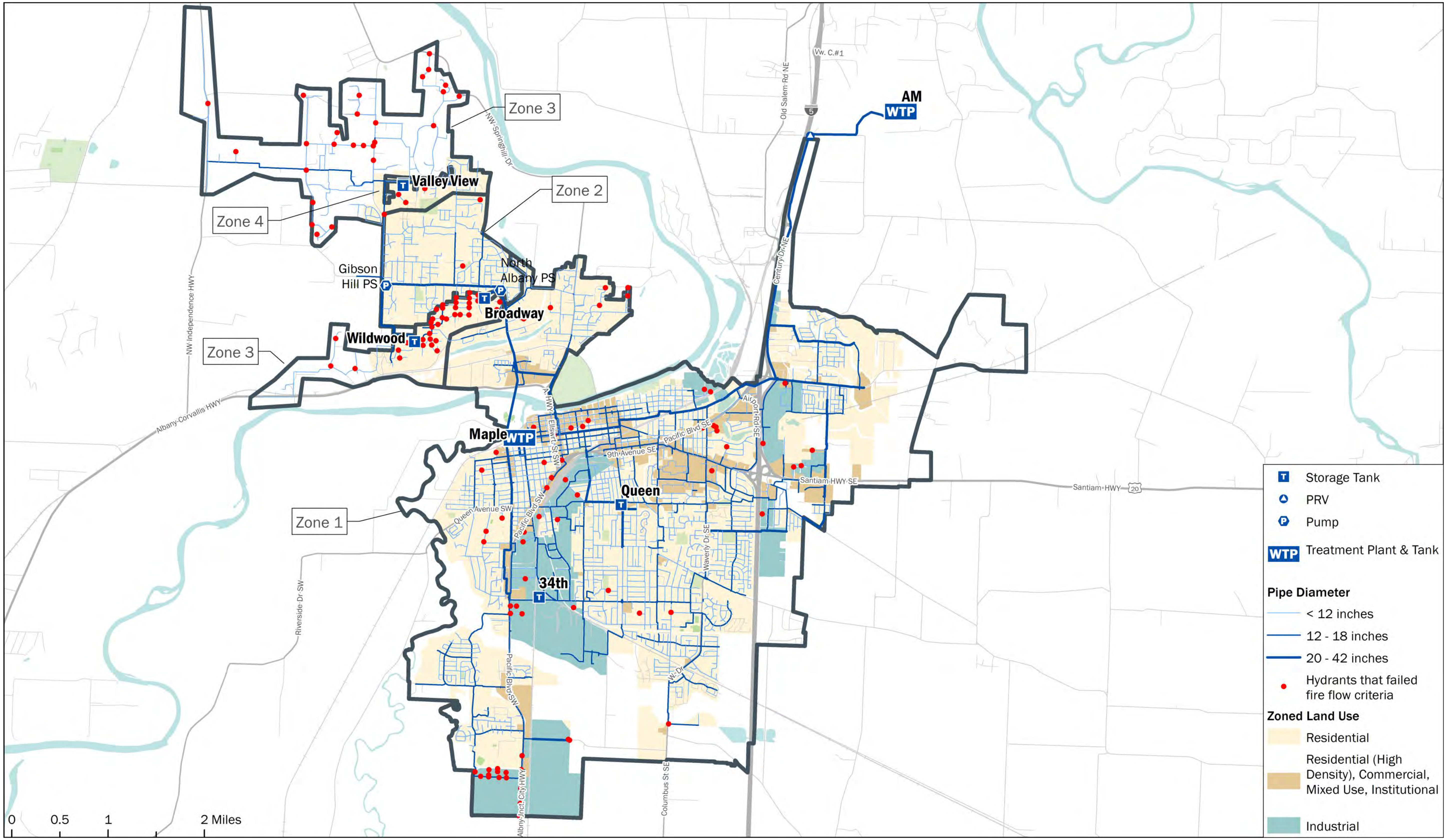


Figure 5-3. Existing MDD, Hydrants that Failed Fire Flow Requirements

5.1.1 Fire Flow Evaluation Results

The fire flow demands listed in **Table 5-2** were applied to parcels based on the type of land use assigned to the parcel. Detailed fire flow calculations were not made for individual buildings. Therefore, no reductions to the fire flow demands were made to account for building construction class, on-site fire suppression systems, proximity of supplemental flow hydrants, or other factors. Future near term effort will be spent to identify the magnitude of the failures and identify the necessary improvements. **Table 5-3** below shows a summary of the fire flow evaluation results.

Table 5-2. Summary of Fire Flow Evaluation Results

Land Use Type	Fire Flow Demand (gallons per minute, gpm)	Duration (hours)	Number of Failed Junctions
Residential - Low Density	1,500	2	87
Residential - Medium Density	2,500		0
Residential - High Density	3,500	3	19
Commercial			
Mixed Use			
Institutional (hospital/jail)			
Industrial	5,000	4	44
Schools			9

5.1.2 Pressure Evaluation Results

An evaluation of the minimum and maximum pressures in the distribution system piping network was performed during a maximum daily demand (MDD) scenario. **Table 5-1** above lists the City's evaluation criteria. **Table 5-4** below shows the summary of the pressure evaluation results. Only junctions flagged as demand junctions were evaluated against the criteria. This excluded non-demand junctions near tanks, pump stations, or at the water treatment plants.

Table 5-4. Summary of Pressure Evaluation Results

Criterion	Count
Number of demand junctions with pressures less than 20 psi	0
Number of demand junctions with pressures between 20 psi and 40 psi	23
Number of demand junctions with pressures between 40 psi and 80 psi	10,438
Number of demand junctions with pressures over 80 psi	519

5.1.3 Maximum Velocity Evaluation Results

An evaluation of the maximum velocity in the distribution system piping network was performed during a maximum daily demand (MDD) scenario. **Table 5-1** above lists the City's evaluation criteria. **Table 5-5** shows a summary of the velocity evaluation results.

Table 5-5. Summary of Maximum Velocity Evaluation Results

Criterion	Number of Pipes
Distribution Pipes (8 to 16 inch diameter) with Velocity > 10 feet/second	0
Transmission Pipes (>=16 inch diameter) with Velocity > 5 feet/second	0

5.1.4 Headloss Evaluation Results

An evaluation of the pipe headloss in the distribution system piping network was performed during a maximum daily demand (MDD) scenario. **Table 5-1** above lists the City's evaluation criteria. **Table 5-6** below shows a summary of the headloss evaluation results.

Table 5-6. Summary of Headloss Evaluation Results

Criterion	Number of Pipes
Distribution Pipes (8 to 16 inch diameter) with Headloss > 10 feet/1000 feet	0
Transmission Pipes (>=16 inch diameter) with Headloss > 3 feet/1000 feet	10

Section 6

Limitations

This document was prepared solely for the City of Albany in accordance with professional standards at the time the services were performed and in accordance with the contract between the City of Albany and Brown and Caldwell dated April 22, 2015. This document is governed by the specific scope of work authorized by the City of Albany; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by the City of Albany and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Section 7

References

American Water Works Association, *Computer Modeling of Water Distribution Systems, M32*, Third Edition, AWWA, Denver, 2012, pp. 33.

Bentley, *WaterGEMS V8i (Select Series 6) Material Library,* 2015

Innovyze, *InfoWater Help*, 2012.

Lindeburg*, Civil Engineering Reference Manual for the PE Exam*, Eighth Edition, Professional Publications, Inc., Belmont, CA, 2001, pp. A-25.

Linsley, R. K. and Franzini, J. B., *Water Resources and Environmental Engineering*, Third Edition, McGraw-Hill Book Company, 1979, pp. 281.

Appendix A: Steady State Calibration Maps

Figure A-1. Hydrant Flow Test 1 Map

Figure A-2. Hydrant Flow Test 2 Map

Figure A-3. Hydrant Flow Test 3 Map

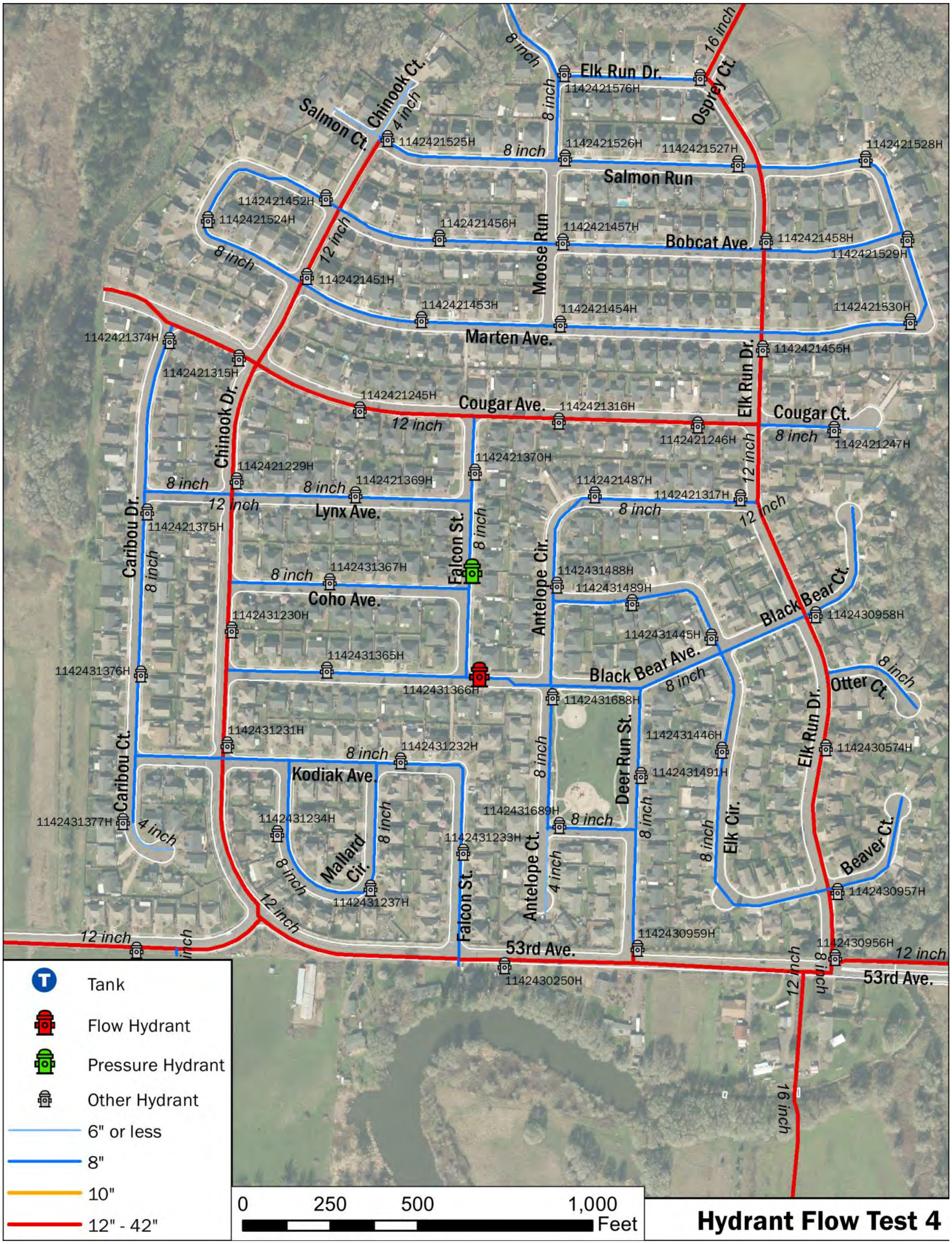


Figure A-4. Hydrant Flow Test 4 Map

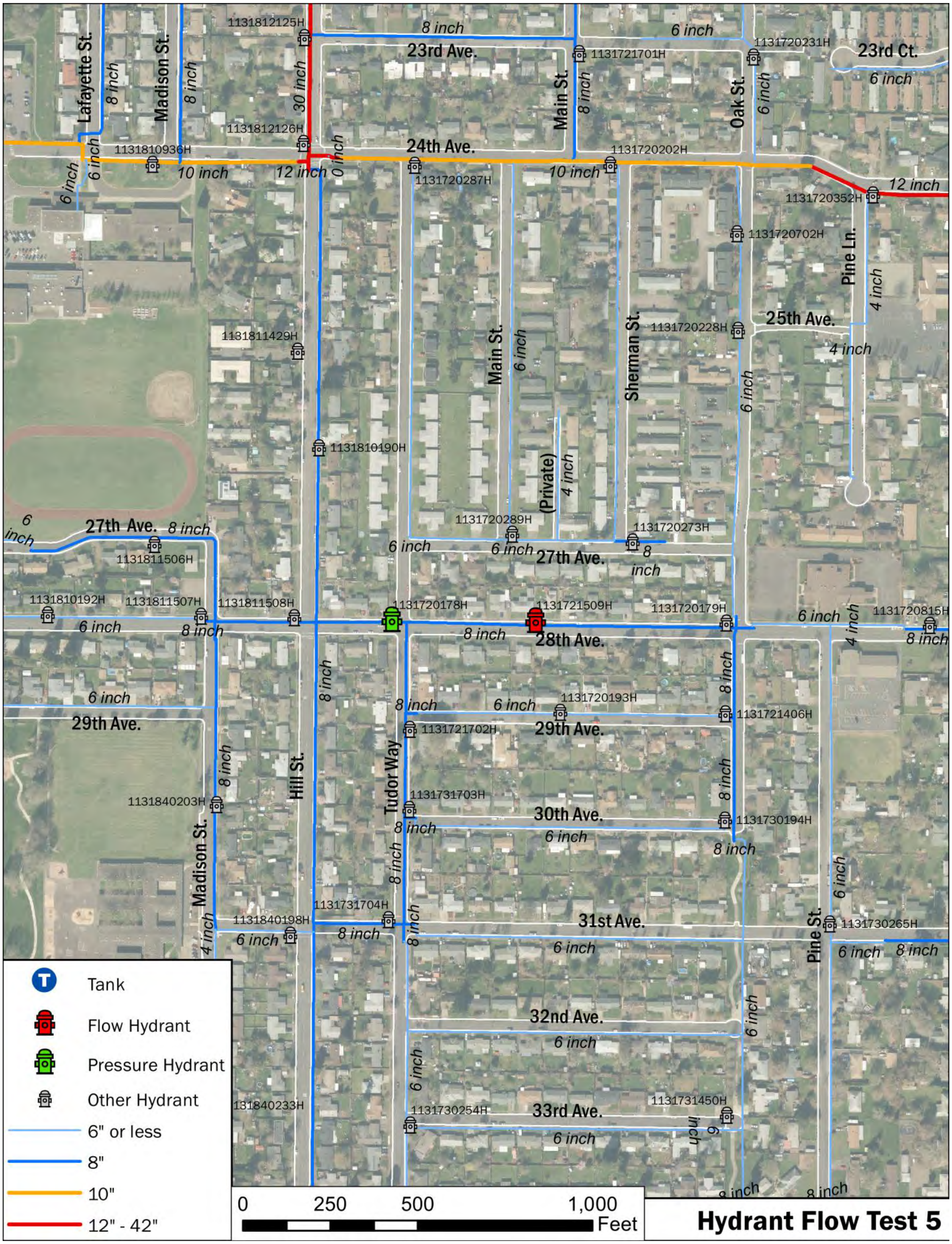


Figure A-5. Hydrant Flow Test 5 Map

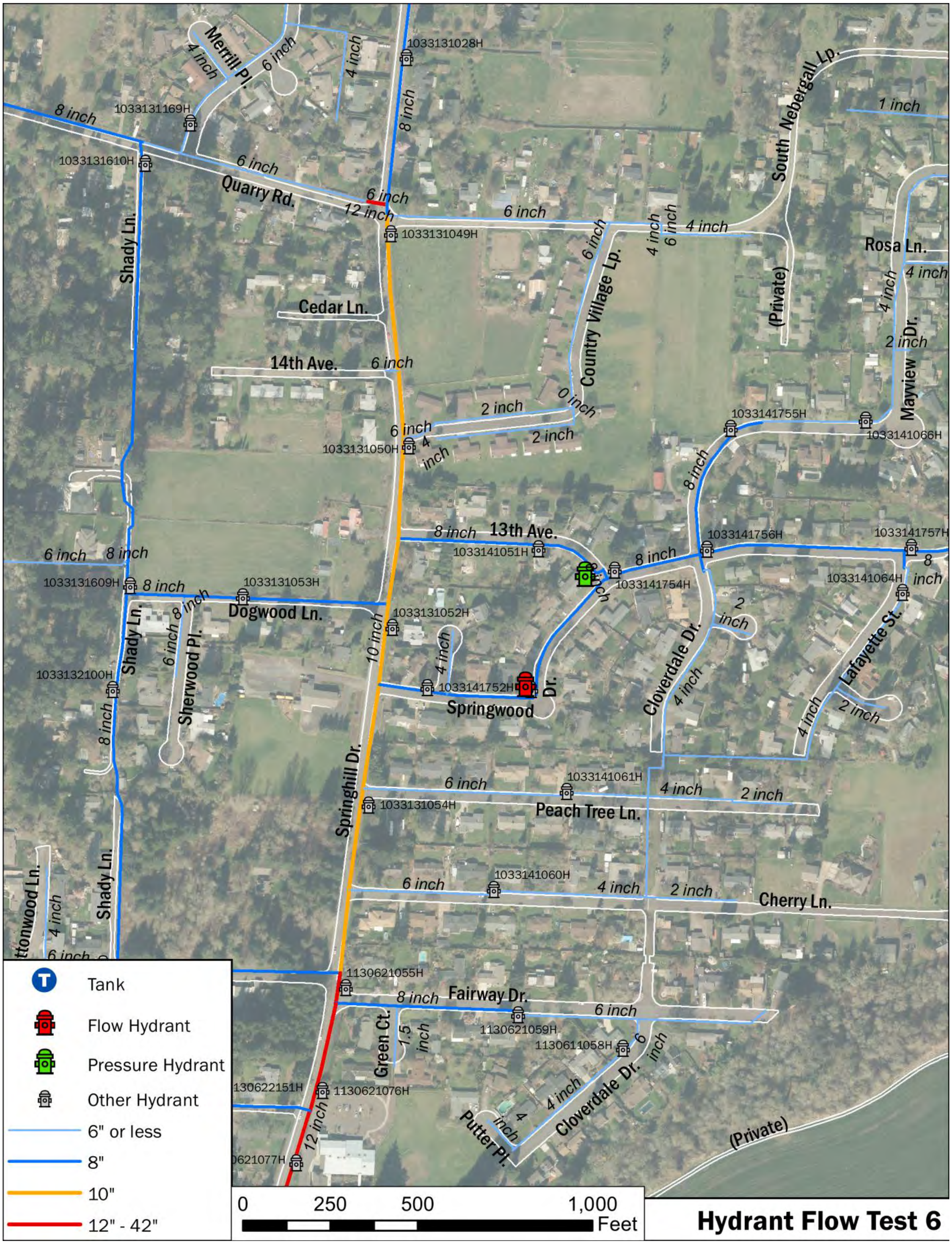


Figure A-6. Hydrant Flow Test 6 Map

Figure A-7. Hydrant Flow Test 7 Map

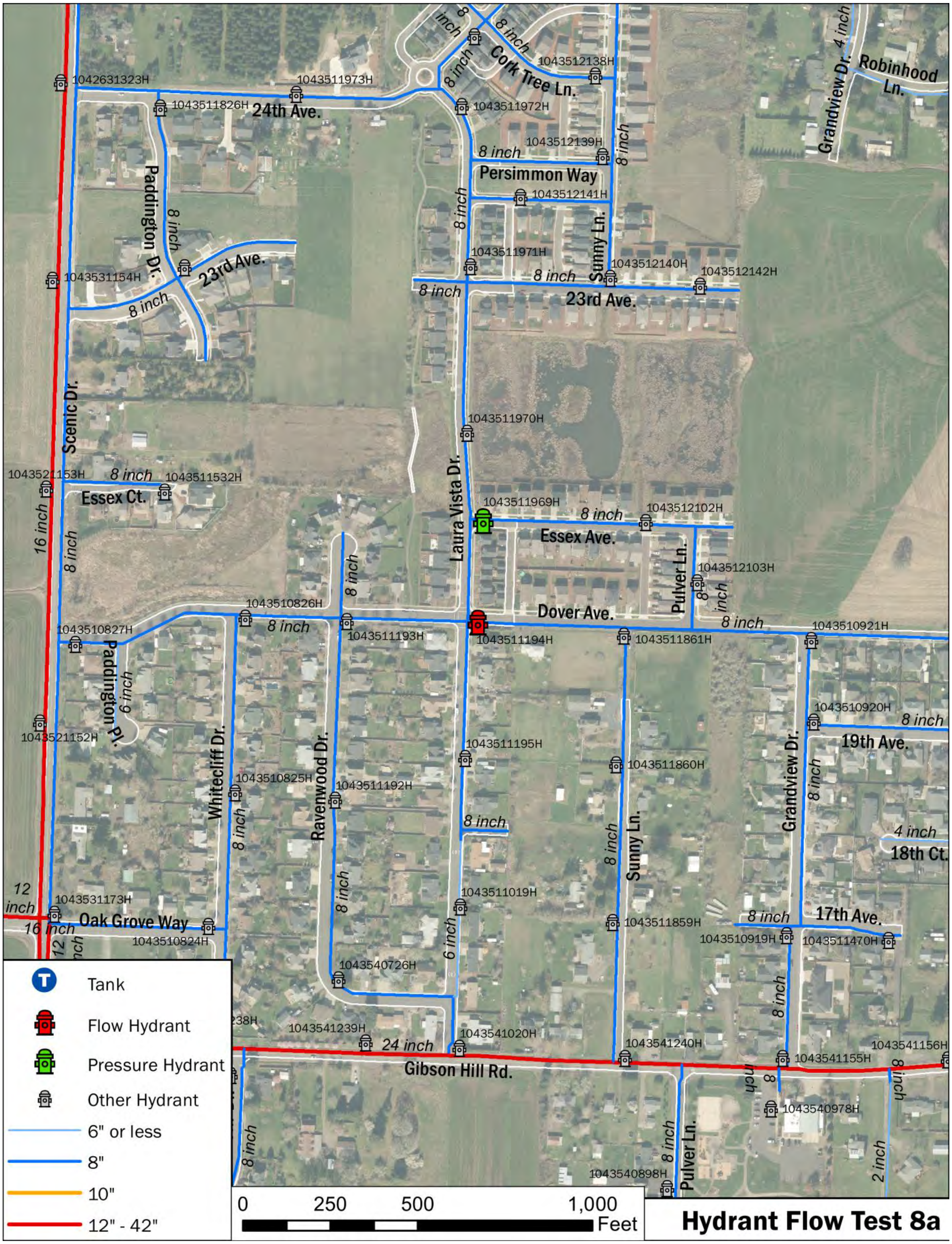


Figure A-8. Hydrant Flow Test 8a Map

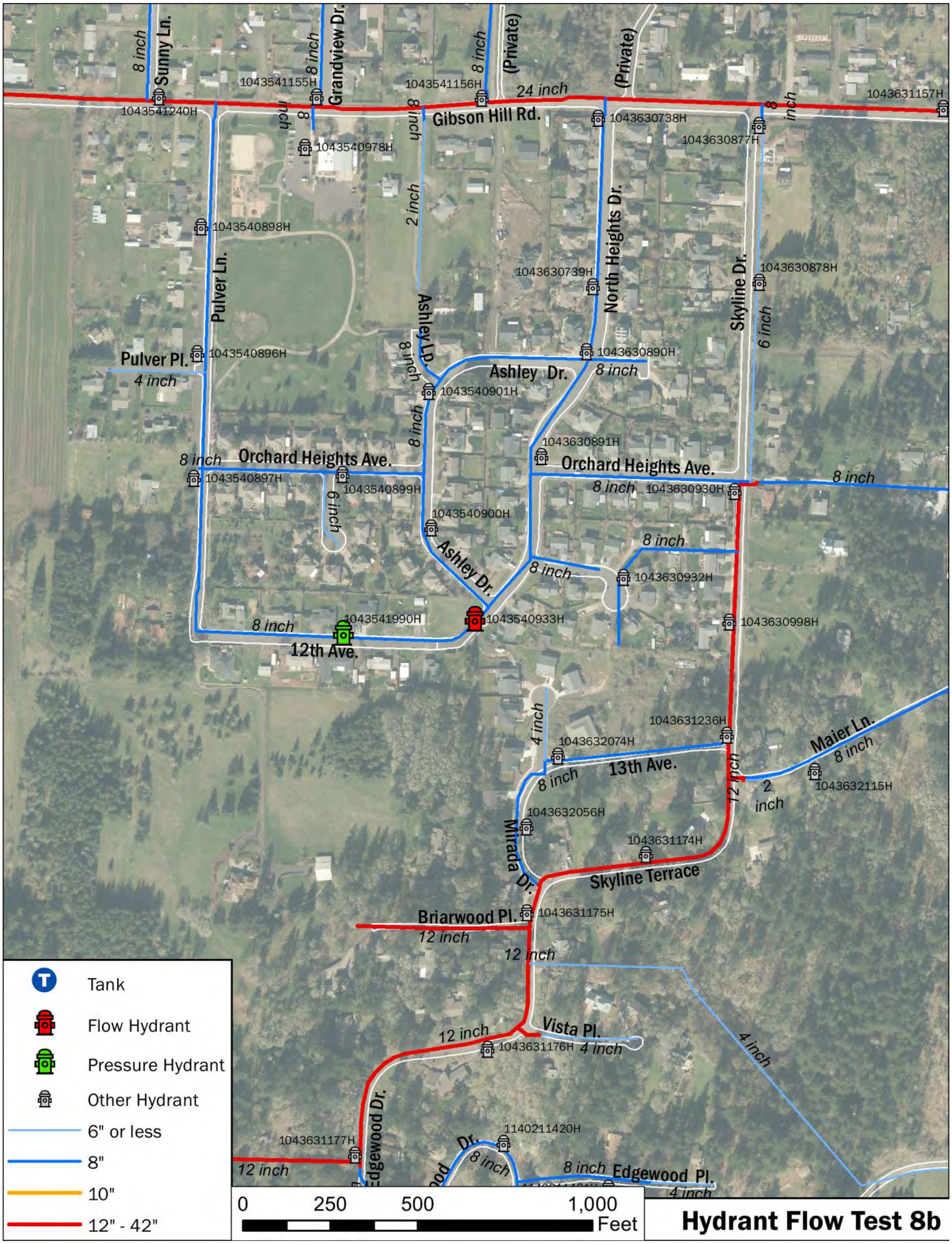


Figure A-9. Hydrant Flow Test 8b Map

Figure A-10. Hydrant Flow Test 8c Map

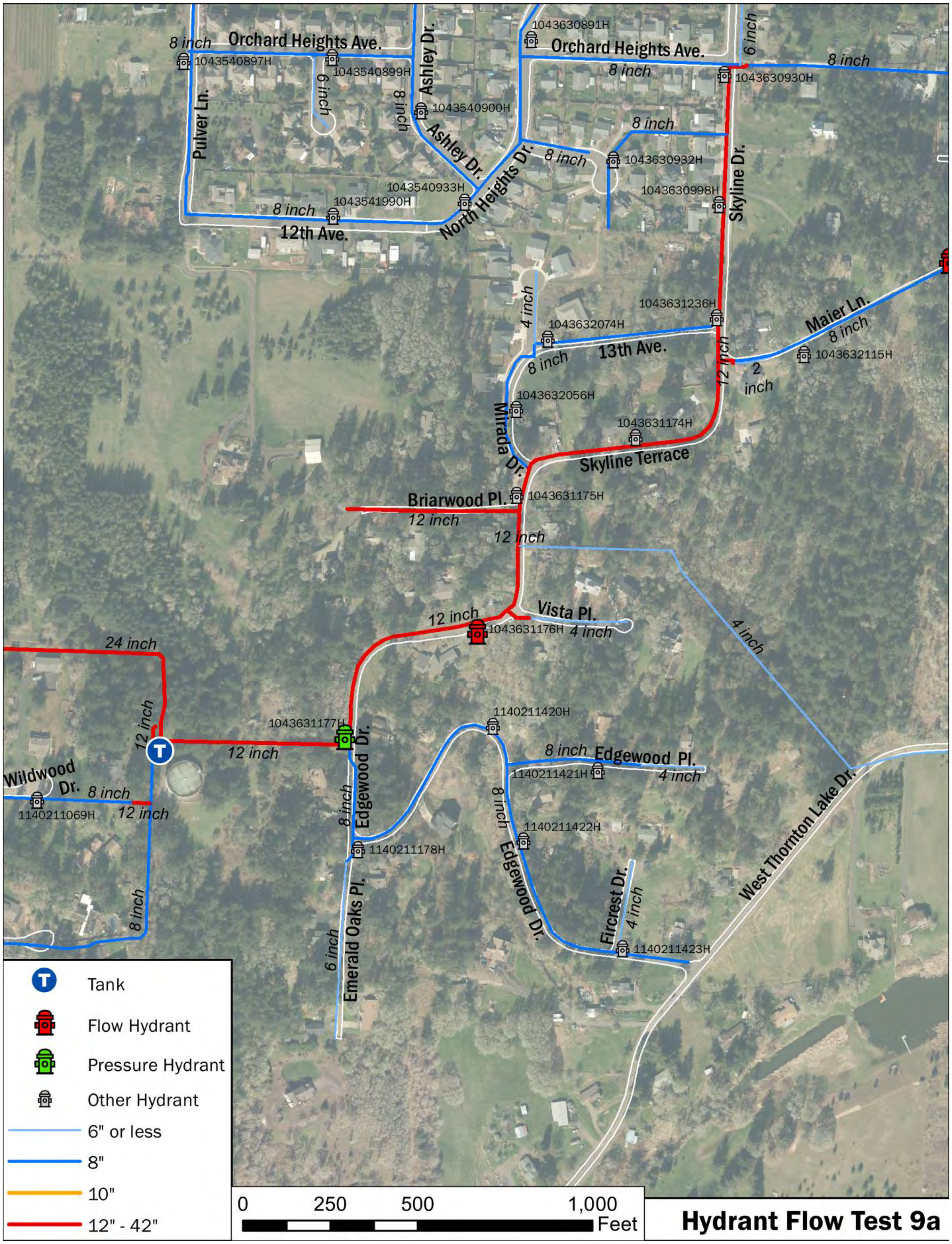


Figure A-11. Hydrant Flow Test 9a Map

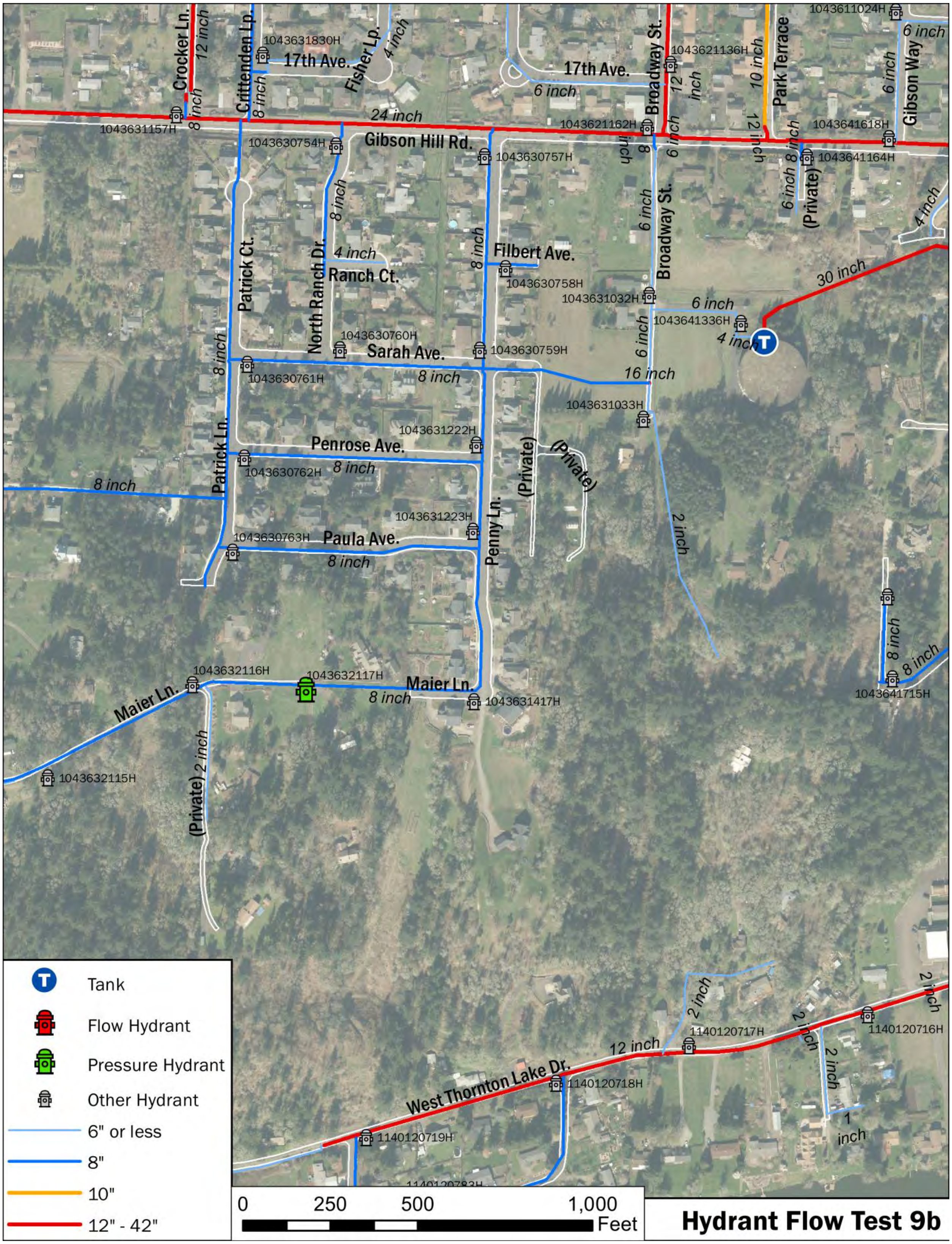


Figure A-12. Hydrant Flow Test 9b Map

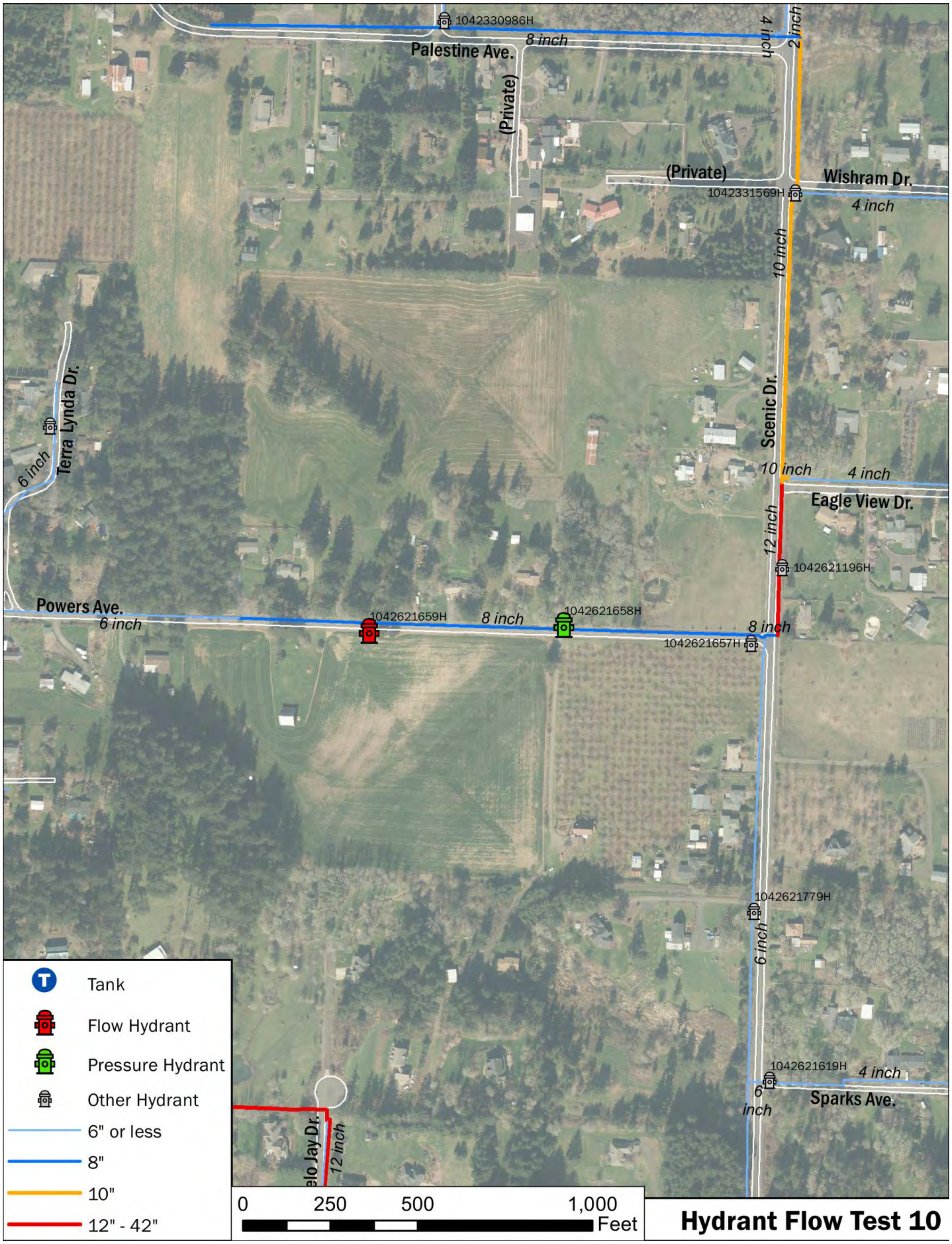


Figure A-13. Hydrant Flow Test 10 Map

Appendix B: Dynamic Calibration Results

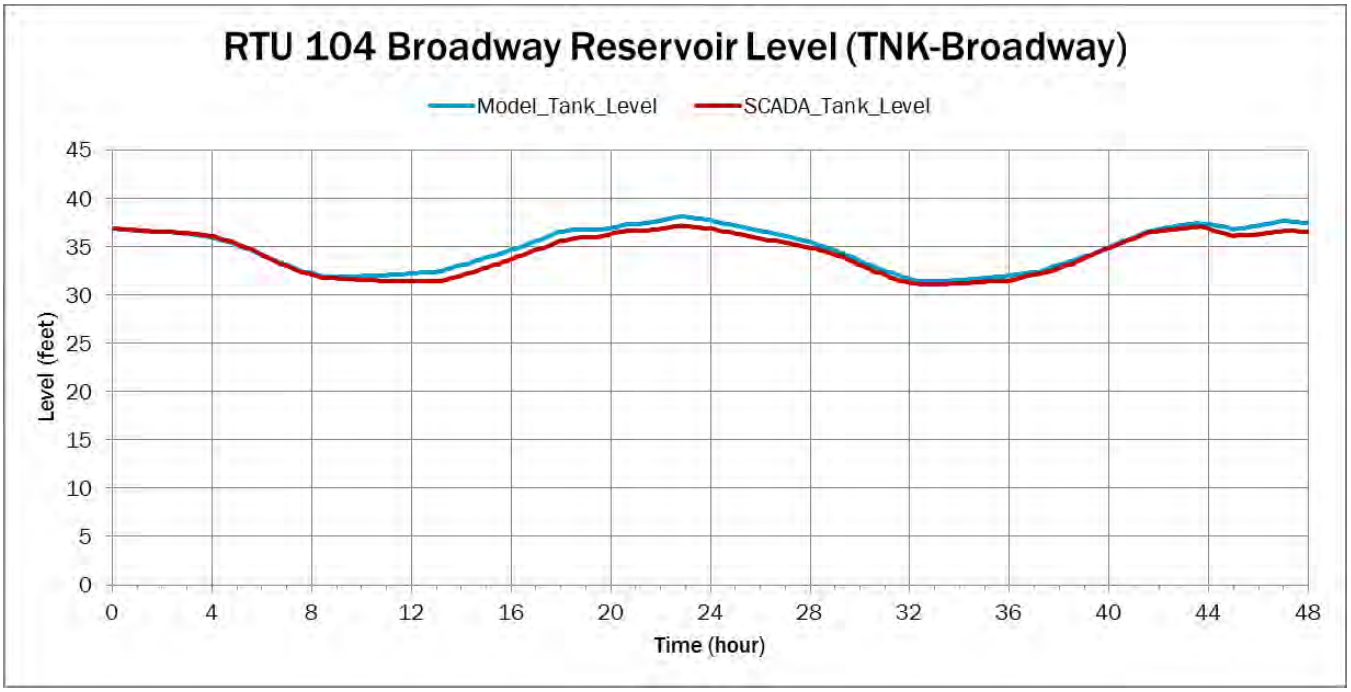


Figure C-1. Broadway Tank Level Results

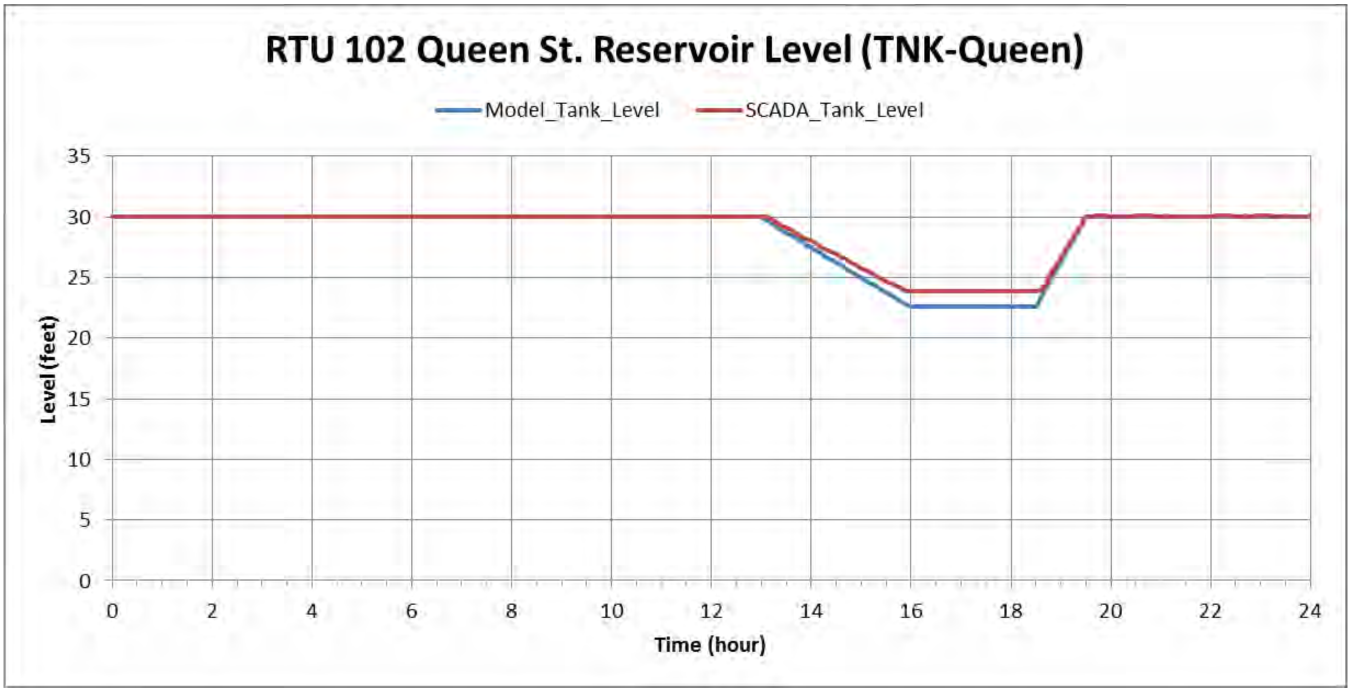


Figure C-2. Queen Street Tank Level Results

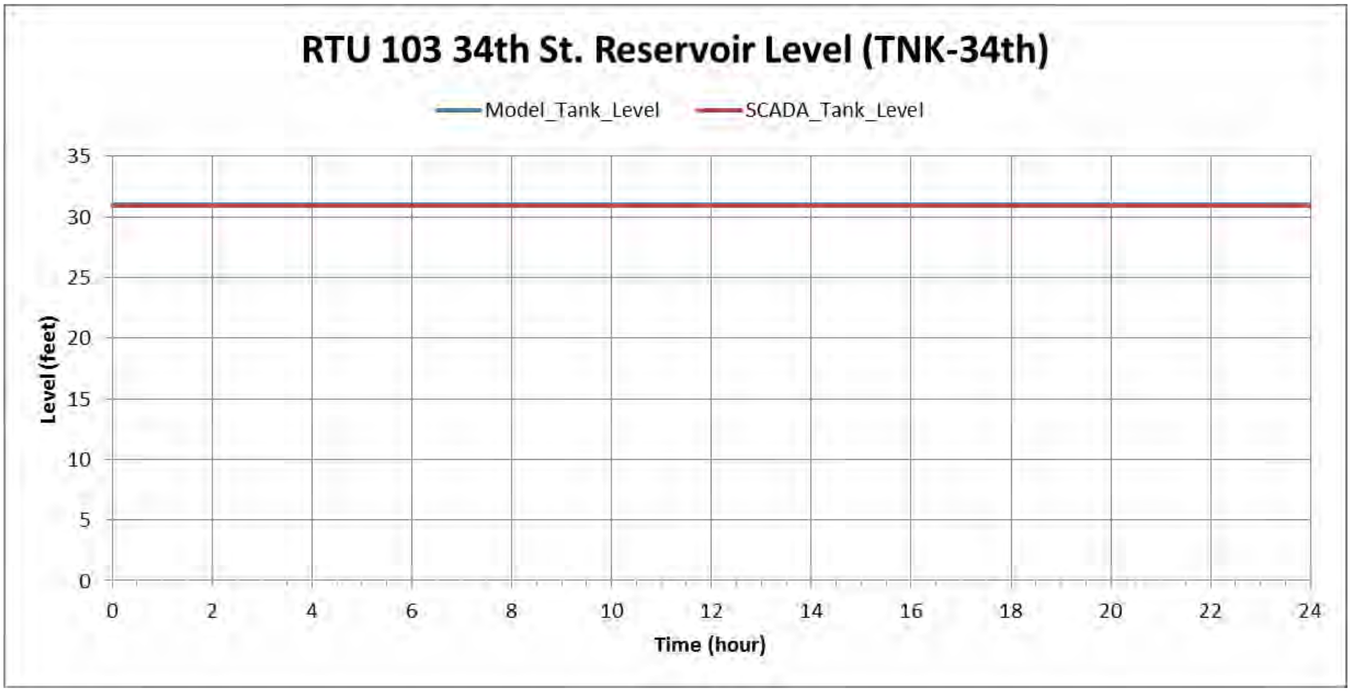


Figure C-3. 34th Street Tank Level Results

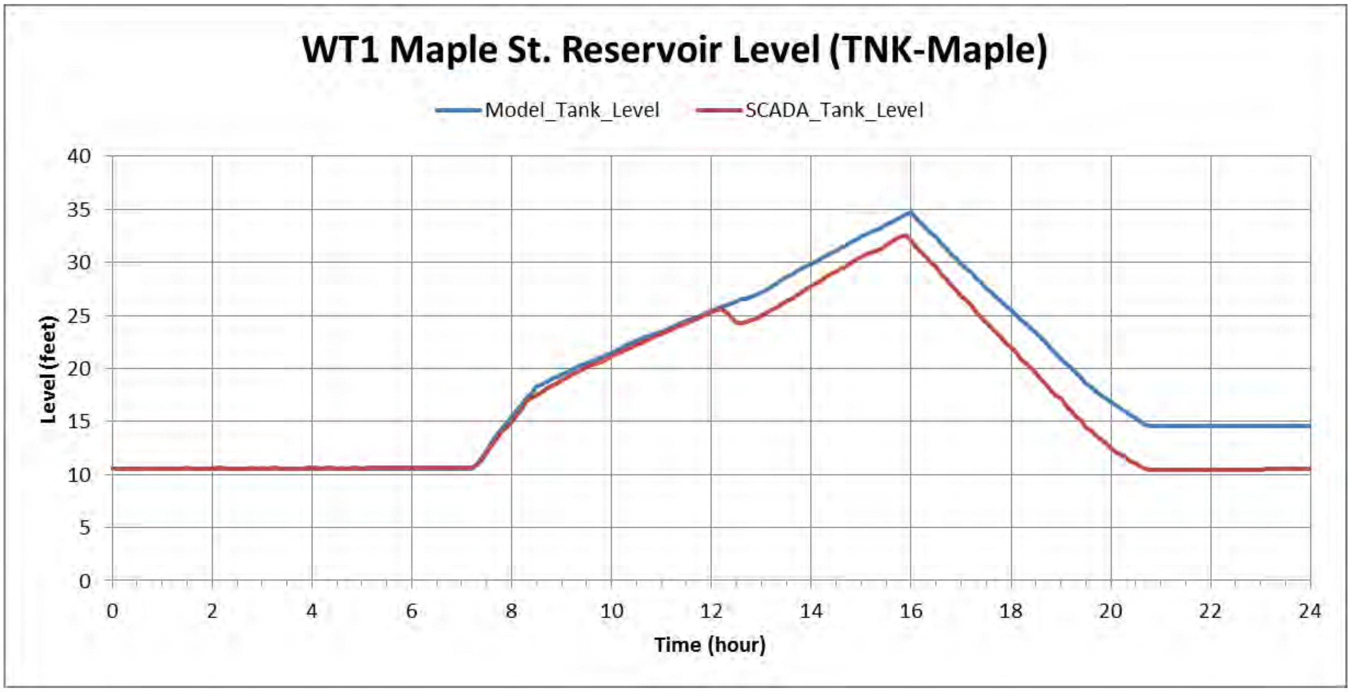


Figure C-4. Maple Street Tank Level Results

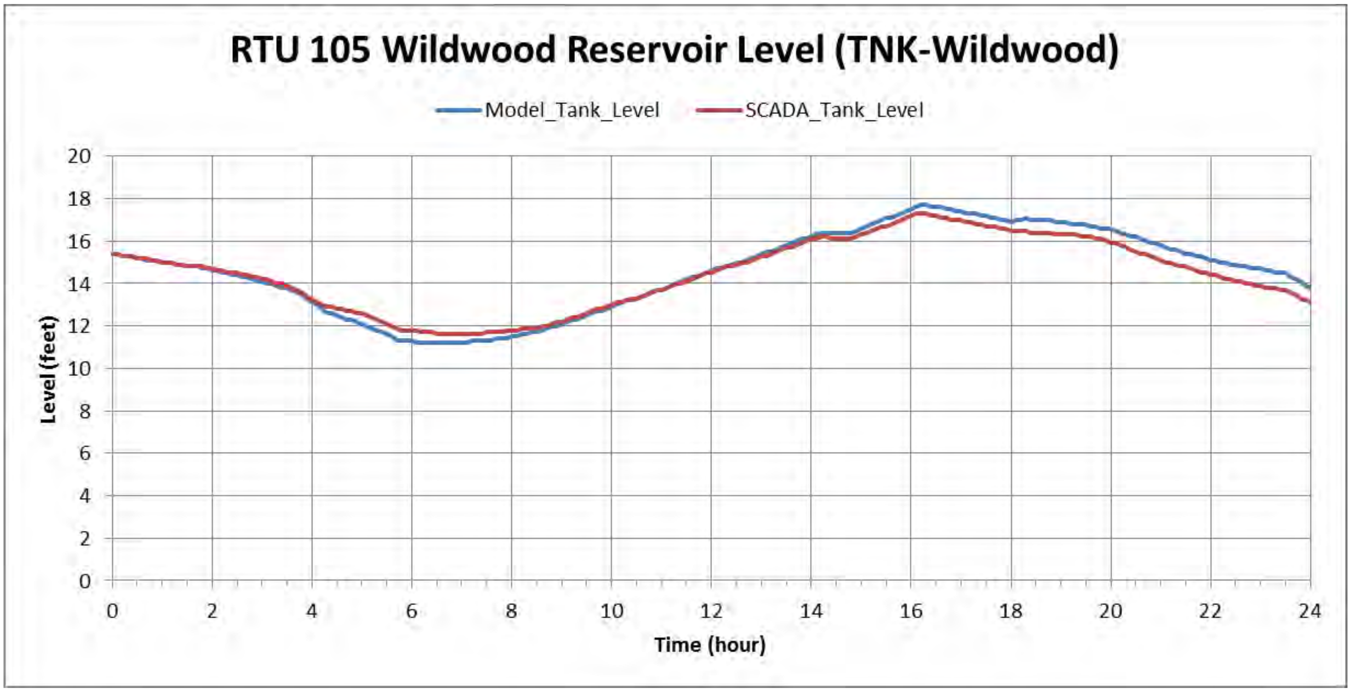


Figure C-5. Wildwood Tank Level Results

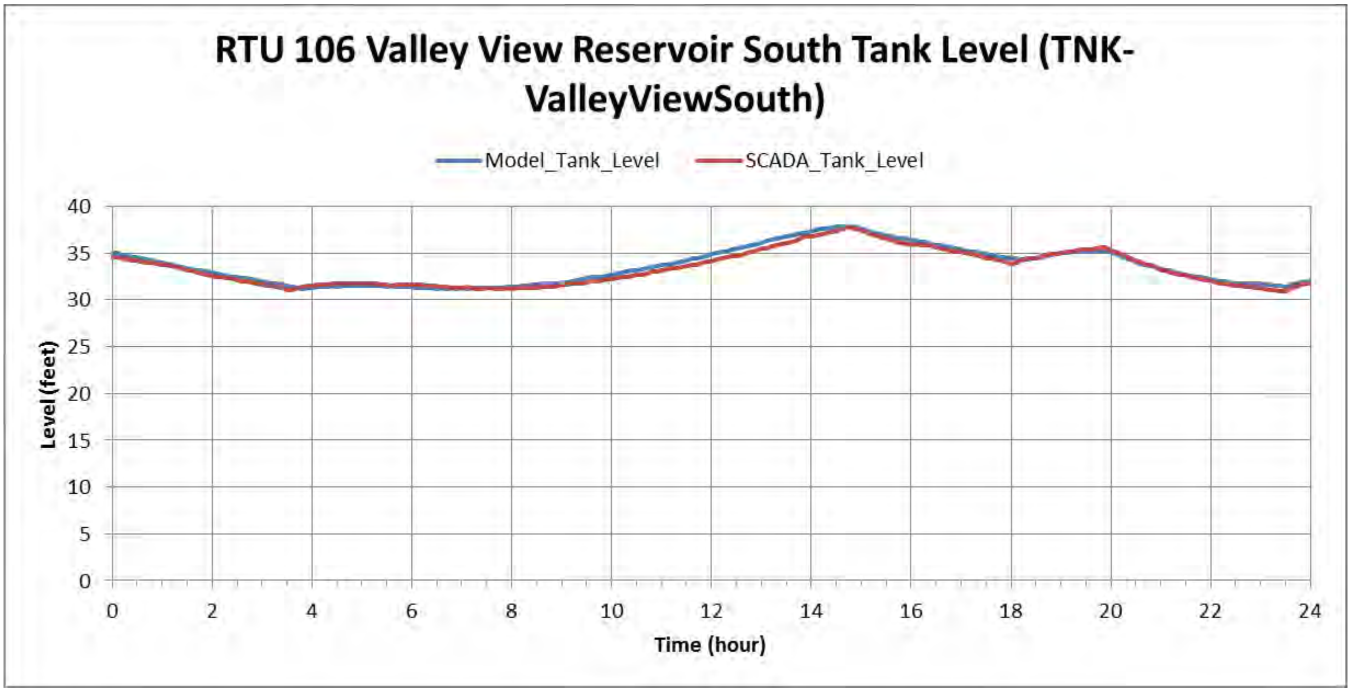


Figure C-6. Valley View Tank Level Results

Only one Valley View tank level shown. Other Valley View tank levels are identical

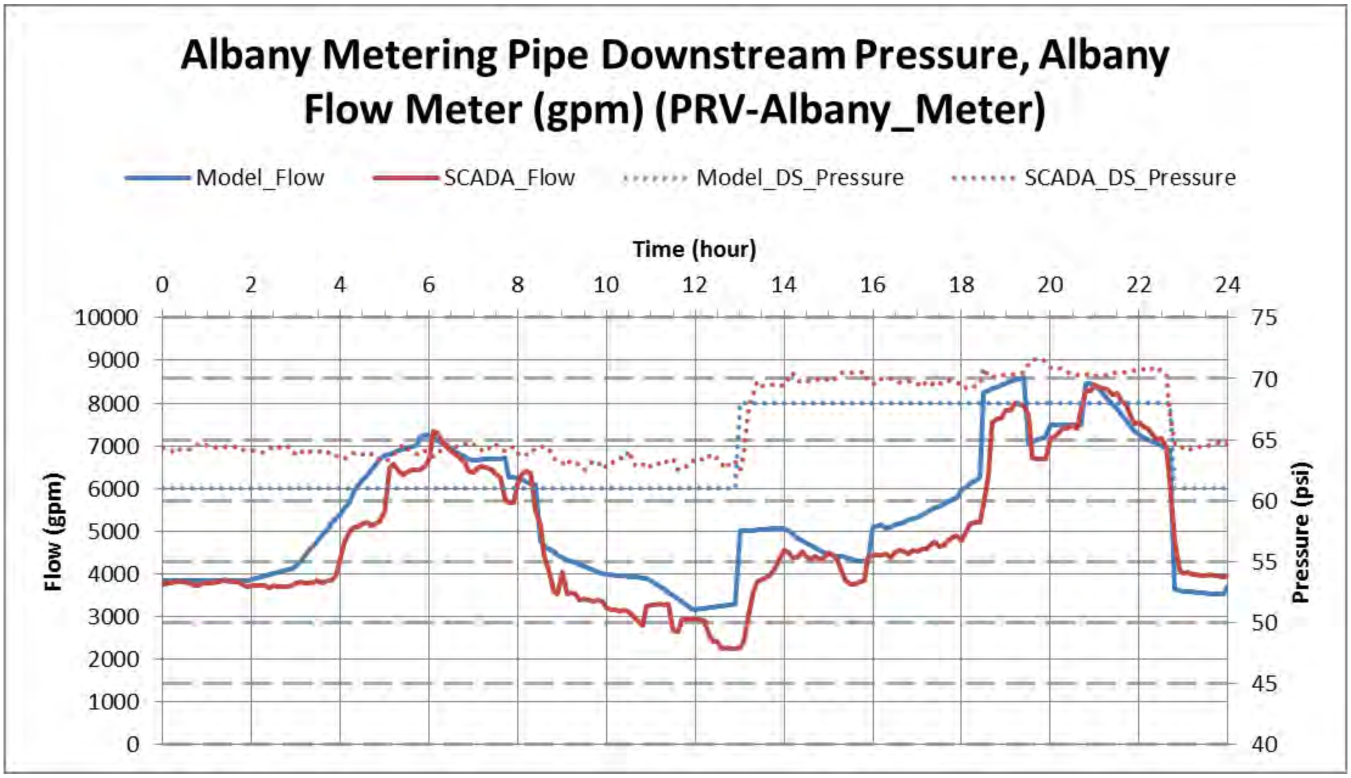


Figure C-7. Albany Meter Flow and Pressure Results

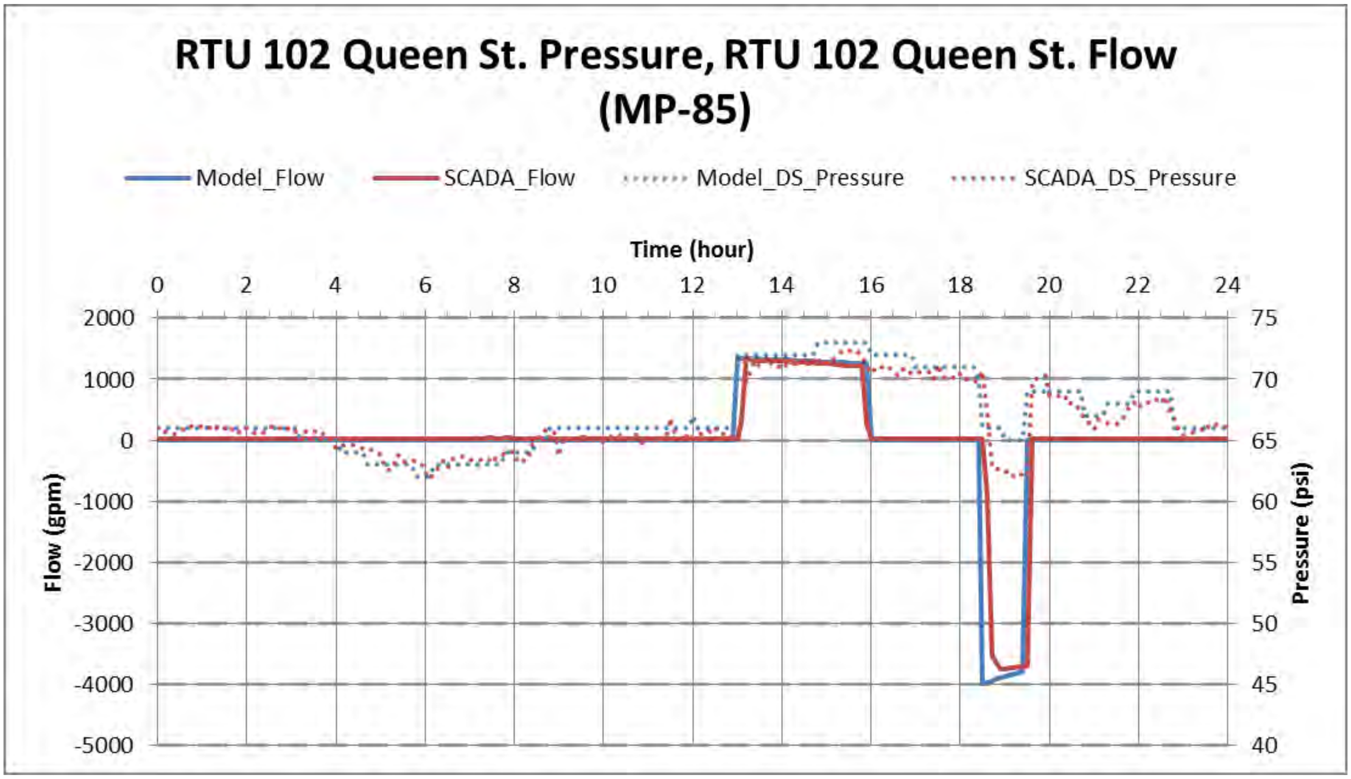


Figure C-8. Queen Street Flow and Pressure Results

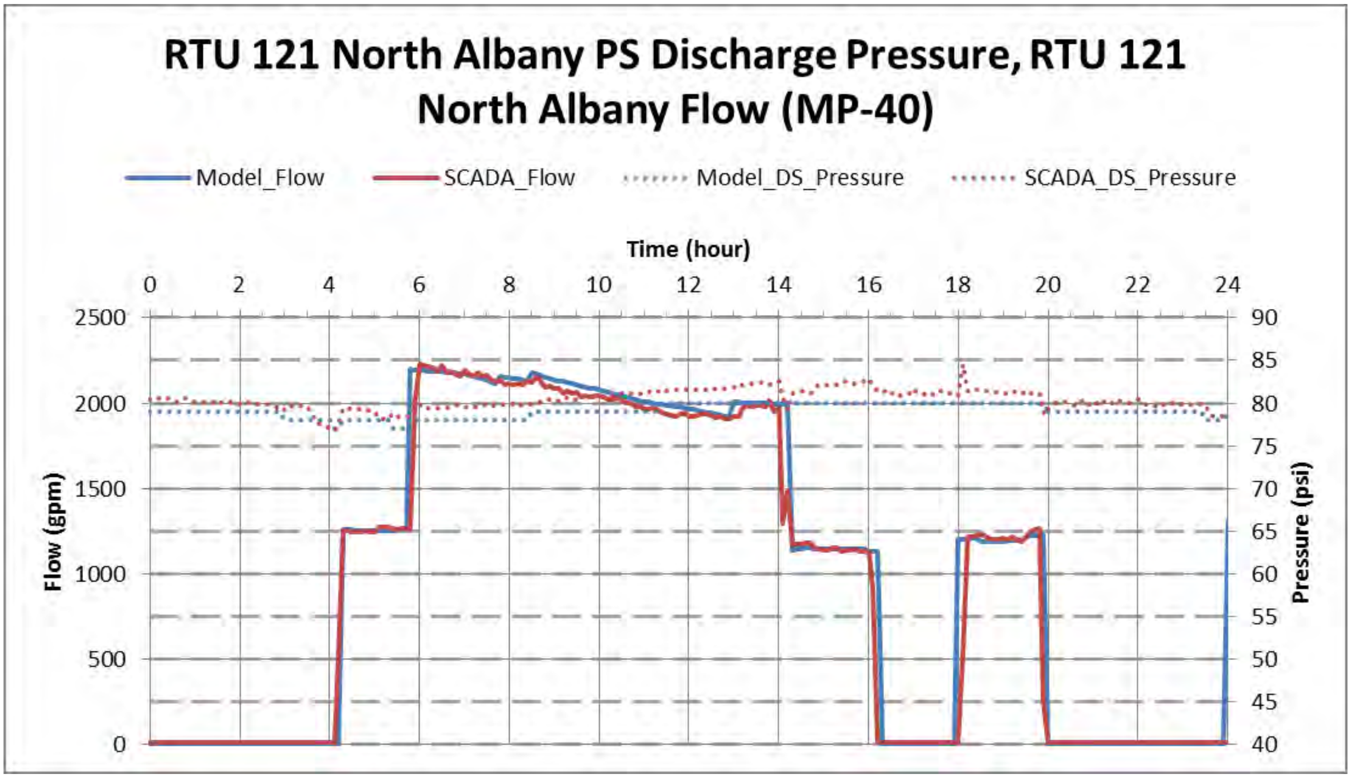


Figure C-9. North Albany Pump Station Flow and Pressure Results

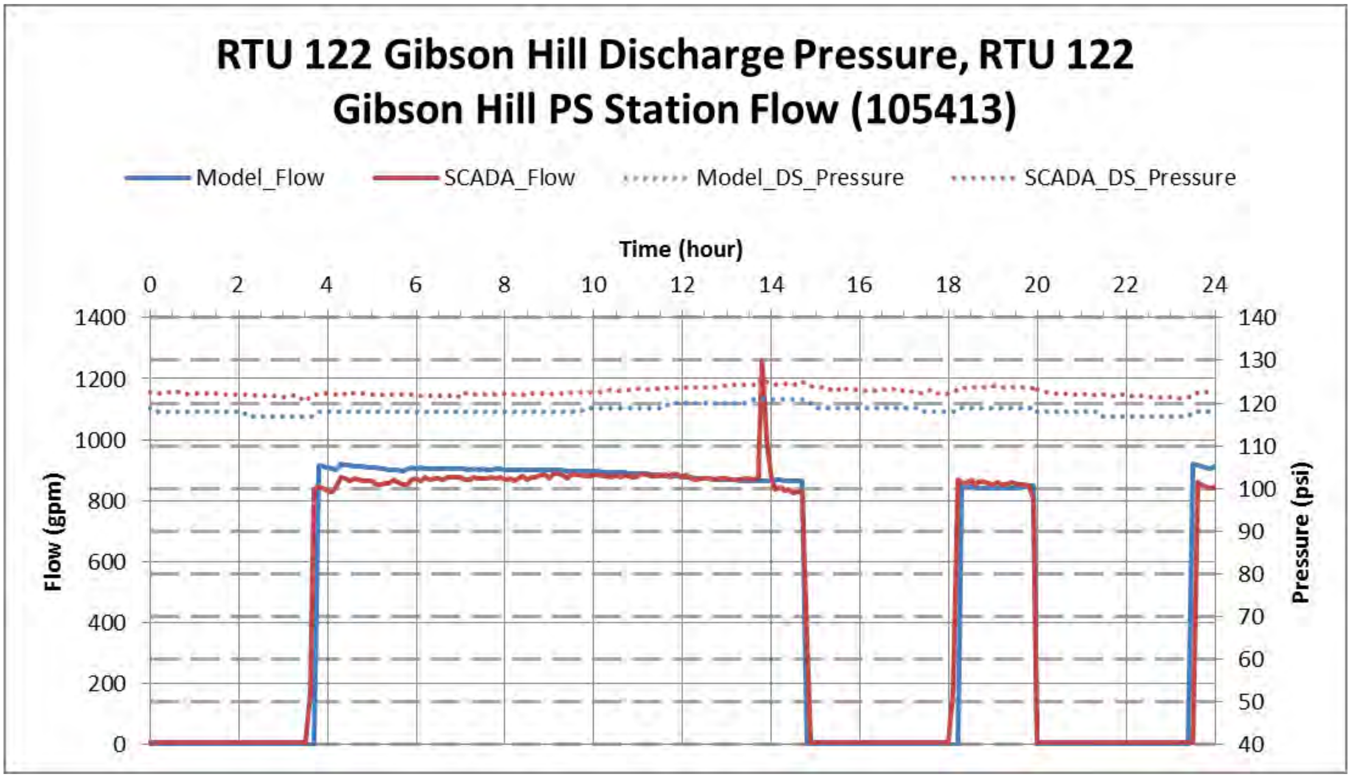


Figure C-10. Gibson Hill Pump Station Flow and Pressure Results

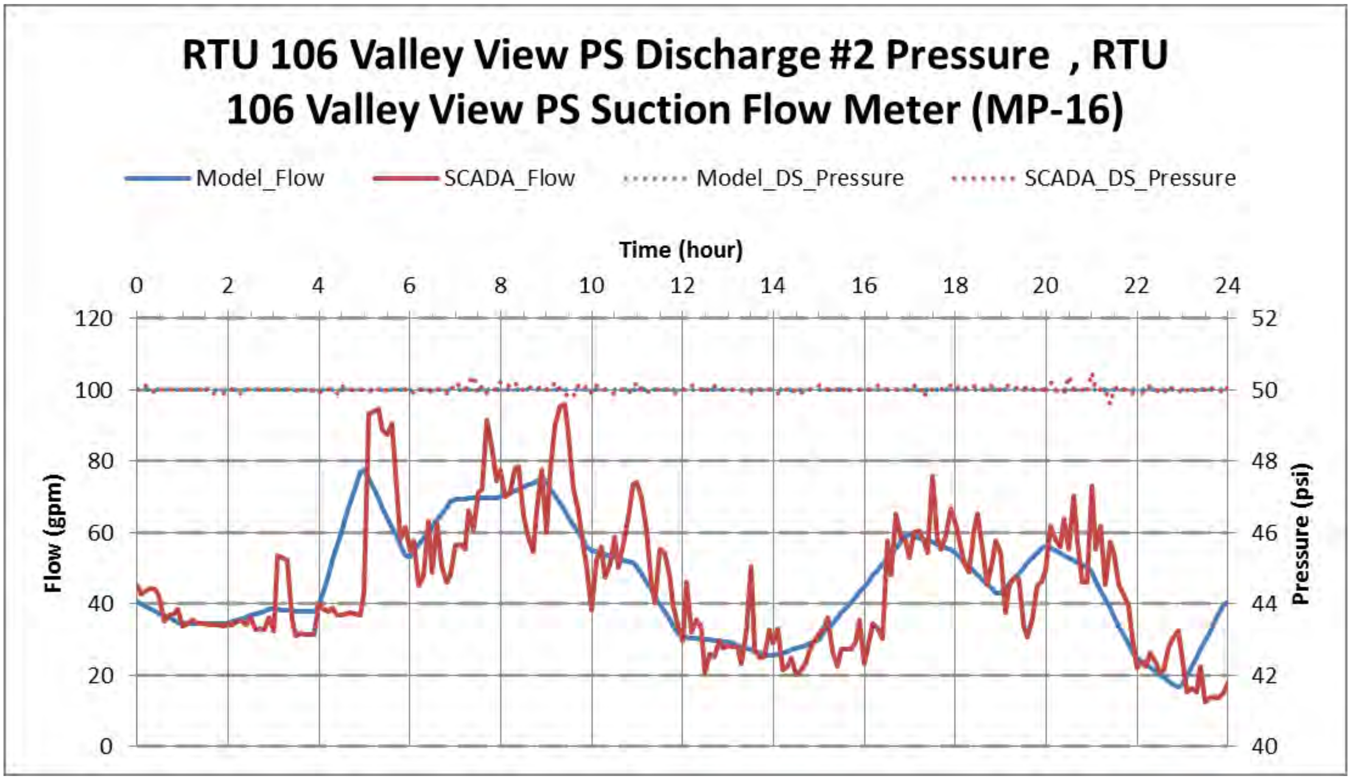


Figure C-11. Valley View Pump Station Flow and Pressure Results