City of Minot Water Distribution System Modeling and Master Plan

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July 22, 2014

City of Minot

Houston Engineering Inc.

Water Distribution System Modeling and Master Plan

City of Minot

Executive Summary

HoustonEngineering Inc.

Introduction

The City of Minot's Public Works Department is responsible for managing, storing, treating, monitoring and delivering safe, potable water to the citizens of Minot as well as to the Northwest Area Water Supply (NAWS) transmission system, Minot Air Force Base (MAFB), and the North Prairie Rural Water District (NPRWD). The Minot Public Works Department's responsibility to provide potable water starts with obtaining source water from two aquifers and ends with meeting water quality standards and regulations at the customer's tap. To execute this responsibility the Public Works Department operates and maintains pipeline distribution systems, storage facilities, pumping facilities, treatment facilities, and testing programs necessary to ensure the citizens of Minot and bulk customers are provided with a sufficient supply of potable water. The City of Minot's staff has recognized that, to provide this sufficient water system capacity, a plan must be developed to ensure the Public Works Department's needs for maintenance and future capital projects are being met in a fiscally responsible manner.

The objective of this study is to update the City's overall water distribution system model and provide master planning to assist in recovery from impacts of the 2011 Mouse River flood.

Water System Overview

Generally, the City's water system consists of source water supply, water treatment, and distribution system components described below.

The City of Minot's water system is supplied by two ground water sources, the Sundre Aquifer has 5 active wells, and the Minot Aquifer has 7 active wells. The eighteen MGD-capacity Water Treatment Plant transfers treated water to the High Service Pump Station (HSPS), from there it is pumped into the distribution system and storage reservoir tanks.

The distribution system is divided into three pressure zones, the Valley Pressure Zone (nominal hydraulic grade 1715 ft. MSL), the North Hill Pressure Zone (nominal hydraulic grade 1770 ft. MSL), and the South Hill Pressure Zone (nominal hydraulic grade 1790 ft. MSL). Pressure zones are created to maintain acceptable system pressures within established limits across wide elevation ranges. The pressure zone boundaries are, for the most part, dictated by elevation. These boundaries are created by physical separation, closed pipes, and/or pressure regulating valves (PRVs). A map showing these different pressure zones can be located on Figure 2-8 of Technical Memorandum #2.

There are currently 8 operational tanks in the distribution system:

- 4 ground storage tanks and one elevated tank are located in the Valley Pressure Zone
- 2 elevated tanks in the South Hill pressure Zone
- 1 elevated tank in the North Hill Pressure Zone.

8 Pump Stations are used to send water to the operational tanks, and also located in strategic areas to supplement system pressure during peak usage times. A more detailed list of tanks and pump stations can be located in Tables 2-6 and 2-7 of Technical Memorandum #2.

The distribution system is comprised of over 255 miles of pipeline ranging from 2 inch to 36 inch diameter pipes. Most of the piping in the existing system is the original piping. In the older parts of the City the piping is primarily cast iron, comprising approximately 37% of the entire pipe network. Another 62% of the City's pipe network consists of polyvinyl chloride (PVC).

The remaining pipe is High Density Polyethylene, Asbestos Cement (AC), Copper, Ductile Iron (DI), or Steel. A complete breakdown of pipe sizes and material type can be found in Tables 2-2 and 2-3 of Technical Memorandum #2.

Criteria Devlopment and Demand Projections

Typically, a master plan would be on a pre-determined time based outlook (i.e. 25 years, etc.), but with the City of Minot currently growing at a rapid pace, a phased population-based growth approach was used for this analysis. The basis for the analysis is the Comprehensive Growth Plan (Figure 1-2 of Technical Memorandum #1) completed by Stantec for the City of Minot, which is divided into 5 future growth development phases. The 2010 Census estimated that 42,000 (± 5,000) people lived in the City of Minot. For this analysis, it was assumed that about 50,000 people lived in the City of Minot in 2012. Stantec projected that at build-out, the City of Minot would have a population of 80,000. This would be an addition of 30,000 people to the distribution system.

For this analysis, a two stage approach was used to develop demand projections and Capital Improvement Plan projects. Phase 1, 2 and 3 of the Comprehensive Growth Plan were incorporated for Stage 1 (which estimates a population of 68,000), and Phase 4 and 5 of the Comprehensive Growth Plan were incorporated for Stage 2 (estimates a population of 79,000).

This approach was used to determine the projected future water demand on the system. Accurate demand forecasting is critical for the development of a useful model and an accurate master plan.
A unit-use rate demand per acre, was developed for each land use type by evaluating the existing demand on the system within each land use. The existing demand within each land use was divided by the acreage of each land use to develop gallons per minute (gpm) per acre unit-use rate for each land use. These unit-use rates were then compared to other unit-use rates developed for similar water systems. They were also adjusted to match the City of Minot's future population projection. Due to the abnormally high amount of precipitation Minot received during 2013,

historic water use records, Water Treatment Plant (WTP) production records, and population estimates from 2012 were used to perform this analysis and develop Peaking Factors. Estimated 2012 population and WTP production information can be located in Tables 1-1 and 1-2 of Technical Memorandum #1.

Model Development

The Innovyze Infowater® hydraulic model that was developed and calibrated for the prior East Side Valley Zone projects was used for the basis of this city-wide hydraulic model and master plan. The East Side Valley Zone hydraulic model was developed in 2006, so additional information was required. This additional information included new facilities added since 2006 (High Service Pump Station, Southwest Booster Pump Station, etc.) as well as a considerable amount of pipe in newly developed areas of town. This information was provided by City staff in the form of GIS shape files and as-built drawing files. After the existing distribution system components and demands were entered into the model, the hydraulic model was calibrated to confirm its accuracy. Calibration consisted of adjusting the model to match real-time field-collected data. The calibration consisted of two components: steady-state and dynamic calibration.

Steady-state calibration was accomplished by placing pressure recorders (collecting pressure data at 1 minute increments) at various locations throughout the City from August 16, 2013 to August 23, 2013. On August 20, 2013, 11 fire flow tests were performed throughout the City to stress the distribution system by imposing a large demand at a particular location and then collecting instantaneous flow and pressure data at various locations throughout the distribution system. After completion of the field hydrant tests, the tests were simulated in the hydraulic model. This required the creation of a steady-state calibration scenario where each measured test flow was added to the corresponding hydrant in the model as a water demand over and above the demands existing in the system at the time the test was performed. The model was run to observe the resulting flows and residual pressures. The pressures measured by the pressure loggers were also compared to the pressures at the corresponding model hydrants. The model was adjusted to more closely reproduce the residual pressures and flow rates observed in the field.

Dynamic calibration consists of comparing actual tank levels, system pressures and booster pump flows with corresponding model levels, pressures, and flows over a 24-hour period. All available recorded data for the tanks, booster pump stations, and wells were compiled for August 21, 2013. The demands in the model were adjusted to match the actual demands for that day. The model was then run for 24 hours and was adjusted to better match the field data. More detailed calibration results can be located in Technical Memorandum #5.

Once the hydraulic model was successfully calibrated it was modified to include a layout for future system piping and other facilities based on the populations projections listed in Section E.3 of this Executive Summary.

Water System Analysis

The calibrated hydraulic model was then used to evaluate the performance of the water distribution system in its existing, Future Stage 1 and Future Stage 2 scenarios (the latter 2 with recommended Capital Improvement Plan projects completed). The criteria used to evaluate the system included capacity, operation, and reliability requirements for piping, pumping and storage facilities.

Piping

Pipe criteria include diameter, flow rate, pressure, velocity, head loss, and reliability. Pipes must have sufficient capacity to convey flows under each of the two demand conditions defined as:

- Peak Hour - the hour of peak demand usage on the Maximum Day.
- Fire Suppression - the average Maximum Day plus various fire flow requirements for fire suppression.

Diameter

The criteria for pipe diameter is based on peak domestic flow, fire flow and pressure requirements of hydraulic analysis as well as other hydraulic criteria. In addition, minimum diameter requirements have been established by the Ten-State Standards which incorporate Insurance Services Office (ISO) standards. The City of Minot has adopted a minimum diameter of eight (8) inches for new construction or replacement. Currently, all pipes with a diameter 6 inches or less requiring replacement or repair are replaced with 8-inch diameter pipe.

Flow Rate

The criteria for pipe flow rate is that pipes must have sufficient capacity to convey flows under peak hour water demand conditions. This requirement also applies to sizing of proposed pipe and other distribution system improvements. Current peak hour demand conditions were determined from recent water system operation records.

Pipe capacity was also evaluated under fire flow demand. Because needed fire flow for each customer in the distribution system varies based on a number of individual circumstances and are not readily available, typical fire flow values – based on ISO requirements for each land use – were used for evaluation. Categories include residential, commercial, industrial, and institutional. Fire flow duration was also based on Fire Suppression Rating Schedule requirements.

Pressure

Pipe pressure criteria include maximum, minimum and fire flow requirements. Under normal operation, pressures should range between 60 and 80 psi at ground level. It should be noted that all pressures indicated are at ground elevation, and not at the elevation of the pipe.

Maximum distribution system pressure is dictated by the pressure class of pipe and other appurtenances in the distribution system. Static pressure above 100 psi is not advisable because of the increased leakage rate, an increased risk of pipe failure and the required installation of pressure reducing valves on distribution mains or on service connections.

A minimum distribution system pressure is required to avoid customer complaints and prevent contamination from backflow. The Ten-State Standards require that a minimum pressure of 20 psi, measured at ground level, be maintained at all points in the distribution system under all conditions of flow. The minimum pressure of 20 psi occurs only during fire flow conditions (i.e. residual pressure). However, a minimum of 35 psi is required during peak hour operations to avoid customer complaints.

Fire Flow

The fire flow is the critical part of the analysis and results in the recommendation of replacement of many of the pipes that are 6 inches and smaller, especially in areas that are zoned something other than residential. The system is required to maintain a minimum of 20 psi at each fire hydrant with the average of maximum day demand plus required fire flow. The majority of the distribution system is residential and is required to maintain a fire flow of 1,000 gpm for 2 hours. The existing maximum day model shows there are 462 fire flow nodes out of 2,340 total fire flow nodes that do not meet the required 20 psi residual pressure. There are 185 nodes that are not able to provide 1,000 gpm with a 20 psi residual. Even after all the Capital Improvement Plan (CIP) projects are completed, there are still 361 fire flow nodes that do not meet the required 20 psi residual pressure and 160 nodes that are not able to provide 1,000 gpm. Most of the deficiencies are due to 40% of the system as 6 inch and smaller cast iron pipe that was installed before 1960. As construction projects are completed where cast iron pipe is in place, these pipes should be replaced with minimum 8 inch PVC pipe.

Velocity

There are no regulations governing the maximum velocity of flow in pipes (other than a minimum target velocity of 2.5 feet per second (fps) when flushing is performed). Criteria for evaluation and design are provided by way of recommendation rather than requirement. For evaluation of existing pipes, a maximum velocity of 10 fps under peak hour flow conditions is recommended. For design or sizing of recommended pipe improvements, a maximum velocity of 5 fps under peak hour flow conditions is suggested.

Head Loss

As with velocity, head loss criteria are suggested as indicators of sufficient capacity and energy efficiency. It is recommended that a maximum design head loss rate of 10 ft./1,000 ft. under peak hour flow conditions be used for pipes less than 16 inches in diameter. For pipes 16 inches and greater diameter, a head loss rate of 3 ft./1,000 ft. is recommended.

Reliability

To increase reliability of service in the distribution system, dead end pipes should be minimized by looping whenever practical. It is also recommended that hydraulically isolated areas be provided with two feed sources. There are at least two feed sources to each of the three Pressure Zones in the area. The North Hill Pressure Zone has water being supplied by the North Hill 3 MG Reservoir pump station to the North Hill Tower, with the 1 MG Reservoir pump station supplementing the pressure in this Zone. The South Hill Pressure Zone has two elevated tanks, the South Hill Tower and the Dakota Square Tower. Each of these towers has two supply lines. The Jim Hill Booster Pump Station and the South Hill Reservoir supply water to the South Hill Pump Station. The Southwest Booster Pump Station and the Dakota Square Pump Station provide water to the Dakota Square Tower. The newly constructed 72nd St Tower is only fed by the Railway Ave BPS.

As part of the CIP projects, the 72nd St Tower will also be able to be fed from the North Hill Zone through a new PRV located at 46th Ave NE and 13th Street NE. There would also be an additional Tower constructed in the North Hill Zone and an additional Tower constructed in the South Hill Zone. These improvements will add to the redundancy and reliability of the system.

The majority of the system is looped except at pressure zone boundaries and cul-de-sacs. One way to improve reliability is to make sure the PRVs are operational and to adjust pressure settings so that they operate during emergency conditions (if pressure falls below a certain pressure).

Pumping

Capacity
The evaluation criteria for pumping capacity is that all pump stations should have sufficient capacity to supply peak water demands without dangerous overloading (within safe operating range of the pump). The pump stations are capable of supplying sufficient capacity for maximum day water demand. It is assumed that the peak hour demand and fire flow will be supplied by the storage facilities. Since there is currently only one feed line to the 72nd St Tower, the Railway Avenue BPS is equipped with a fire pump that will operate during fire conditions as necessary (such as if water storage in the 72nd Street Tower has been depleted).

It should be noted that if all the projected demand in Future Stage 2 (79,000 people) is experienced the WTP City High Service Pumps and the Southwest Booster Pump Station will be pumping at maximum capacity.

Reliability
Evaluation criteria for pump reliability is that all pump stations must be equipped with at least two pumps. The pump station must be able to provide a firm capacity, or the maximum pumping demand with the largest of the pumps out of service. All pump stations are equipped with at least two pumps. Most pump stations also have power redundancy in the form of a fixed stand-by generator to provide electrical

power during a line-loss event. The exceptions to this being the South Hill Pump Station, Dakota Square Pump station, and the North Hill Pump Station (which is supplied by the North Hill 1 MG Ground Reservoir).

Storage

Capacity

Storage capacity evaluation criteria includes provisions for operations, fire and emergencies.

Fire

Fire storage capacity must, at a minimum, be equal to the water volume required to serve the largest needed fire flow for the required fire flow duration. For the City of Minot, this is equal to 5,000 gpm for a duration of 4 hours, or 1,200,000 gallons. Fire storage capacity should be evaluated at the minimum storage level under average daily demand conditions. Fire storage capacity can only be counted for hydrants or points of delivery where it is hydraulically available at the minimum pressure for the required fire flow duration. Where ground level storage is to be used as fire storage, only the volume that can be delivered by the pumps during the fire flow duration can be counted.

Operational

Operational storage requirements are calculated based on the diurnal (daily cycle) water use records of the maximum day. As planning or design criteria for future storage capacity requirements, the same current maximum day diurnal curve should be applied to the projected maximum day water use of the planning horizon. Elevated storage, which is not hydraulically available to the distribution system under normal operating conditions, cannot be counted as operational storage. The operational storage analysis does not include storage required for the NAWS system, the MAFB system, or the NPRWD system. These entities are required to provide their own water storage facilities.

Emergency

The emergency storage requirement was established as the average daily demand for a duration of 4 hours. Emergency storage did not include storage required for the NAWS system, the MAFB system, or the NPRWD system. These entities are required to provide their own water storage facilities.

Following this evaluation criteria for storage capacity, the North Hill Zone and South Hill Zone are required to have new elevated tanks constructed to meet the storage essential to meet operational storage, emergency storage, and fire flow storage. A one million gallon storage tank should be constructed in each Zone in order to provide adequate storage for existing and build-out demand on the system. A detailed Storage Analysis can be found in Table 4 in Technical Memorandum #4.

Recommended Capital Improvement Plan Program (CIP)

After evaluating the results of the Existing, Future Stage 1 and Future Stage 2 Scenarios, Capital Improvements Plan program projects were developed to address velocity and pressure issues and some of the general fire flow issues for Existing and Future development.

Summary of issues identified in the existing distribution system:

1. As identified in section E.5.3 of this Executive Summary and shown in Table 4 of Technical Memorandum #4, the available storage in the North Hill Pressure Zone and South Hill Pressure Zone is undersized and needs additional capacity installed to meet the Insurance Services Office (ISO) Required Storage Capacity criteria for operational storage, emergency storage, and fire flow storage. A 1 million gallon elevated tank in each should be constructed in each Zone to provide adequate storage for the existing distribution system (These are listed as Projects 5 and 7 in Table 4 of Technical Memorandum #3). The addition of these tanks will also provide adequate storage for the Future Stage 1 and Future Stage 2 build outs.

2. All fire flow issues cannot be resolved without replacing or upsizing replacing a large portion of the existing 6-inch cast iron pipe. As construction projects occur where existing 6-inch water lines are located, these should be replaced with 8 inch pipe, but overall 6 inch pipe replacement is not shown in the CIP.

3. Installation of a redundant source of power (i.e. generator) should be considered at the South Hill Pump Station, Dakota Square Pump Station, and the North Hill Pump Station to provide power during a line-loss event.

4. During meetings with City of Minot staff and subsequent conversations, it was discovered that there are a number of control valves (pressure reducing valves, altitude valves, etc.) in the distribution system that do not function properly. An Operational Plan should be developed for proper operation and maintenance of all valves in the distribution system, including gate valves.

The detailed list of recommended CIP projects for Future Stage 1 and Future State 2 are located in Tables 3-1 and 3-2 of Technical Memorandum #3, Table ES-1 lists the estimated costs for each of those projects:

Table ES-1

Project No.	Project	Estimated Cost
	Phase 1 build out (68,000 population)	
Project 1	*Pipe Replacement - Downtown Project * - Water main only, does not include street paving	$2,700,000
Project 2	Northeast Side Phase 1	$2,320,000
Project 3	Northeast Side Phase 2	$3,200,000
Project 4	46th Ave NE - N Broadway to 13th Street NE	$1,900,000
Project 5	Future North Hill Elevated Tank	$3,000,000
Project 6	6" Pipe Replacement - 16th Ave SE- to Vie Street	$400,000
Project 7	Future South Hill Elevated Tank	$3,000,000
Project 8	*37th Ave SE/2nd Street SE to 13th St SE * - Water main only, does not include street paving	$800,000
Project 9	Northwest Project	$2,180,000
Project 10	6" Pipe Replacement - 21st Ave NW/6th Street NW to Skyline Dr., 5th Street NW to 3rd Street NW	$800,000
Project 11	6" Pipe Replacement - University Ave/1st NE to 3rd Street NE	$260,000
Project 12	6" Pipe Replacement - 11th Ave NW/N Broadway to Main St	$300,000
Project 13	6" Pipe Replacement - 8th Street SE/Railway Ave to Burdick Expy.	$990,000
Project 14	72nd Street SE to 88th Street SE	$1,600,000
	Phase 2 build out (79,000 population)	
Project 20	South Project	$1,900,000
Project 21	Valley Street/27th Street SE to Hwy 2/52	$1,400,000
Project 22	Valley Street/14th Ave SE to 20th Ave SE	$2,000,000

Water Distribution System Modeling and Master Plan

City of Minot

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MWH
MONTGOMERY WATSON HARZA

To:	Dave Schwengler Houston Engineering	**Date:**	March 24, 2014
Subject:	Demand Analysis and Projections		
From:	Gracelyn NeVille	**Job No:**	10503376

PURPOSE

This technical memorandum presents the demand analysis results for the City of Minot's future growth. The purpose of this analysis was to determine the projected future water demand on the system. Accurate demand forecasting is critical for the development of a useful model and an accurate master plan. Unit-use rates were developed utilizing the existing demand and existing land use plan. Then the demand factors were applied to the future land use plan to develop future demand on the system.

UNIT-USE RATES

A unit-use rate, demand per acre, was developed for each land use type by evaluating the existing demand on the system within each land use. **Figure 1-1** shows the existing land use map provided by the City of Minot. The existing demand within each land use was divided by the acreage of each land use to develop gpm per acre unit-use rate for each land-use.

These unit-use rates were then compared to other unit-use rates developed for similar water systems. They were also adjusted to match the City of Minot's future population projection. Stantec completed a comprehensive growth plan for the City of Minot. They divided the future growth into five development phases. The Stantec Comprehensive Growth Plan is shown in **Figure 1-2**. The 2010 Census estimated that 42,000 (± 5000) people lived in the City of Minot. For the demand analysis, it was assumed that about 50,000 (± 5000) people lived in the City of Minot in 2012. Stantec projected that at buildout, the City of Minot would have a population of 80,000 people. This would be an addition of 30,000 people to the System.

Table 1-1 shows the estimated demand and estimated population in 2012. The maximum water demand occurred in the month of July. The average maximum day demand was around 6,300 gpm. If we estimate a per capita use of 200 gpd, that would be about 46,000 people. This estimate correlates to the 2010 Census and the 2012 estimate (± 5000). So this per capita use was used to check the future demand unit-use rates.

Table 1-1. Estimated Population Based on 2012 Maximum Day Demand

	2012 Max. Production		
	Average Maximum Day	Est. Use	Est. Population
	gpm	gpd/capita	people
WTP Production	7,200		
City Demand	6,300	200	46,000
NAWS Demand	900		

Peaking Factors were also developed looking at the WTP production records for 2012 as shown in **Table 1-2.** This table shows that the peaking factor from average day production to maximum day production was 1.5 and the reducing factor from average day use to minimum day production was 0.75.

Table 1-2. 2012 WTP Production

	MG	gpm	Factor of Average
Jan.	161.15	3610	0.78
Feb.	147.18	3524	0.77
March	163.50	3663	0.80
April	156.72	3628	0.79
May	193.87	4343	0.94
June	217.85	5043	1.10
July	320.67	7183	**1.56**
Aug.	306.49	6866	**1.49**
Sept.	268.93	6225	1.35
Oct.	181.48	4065	0.88
Nov.	147.49	3414	**0.74**
Dec.	162.98	3651	0.79
Average	205.89	4601	

After evaluating the demand per land use and comparing it to the per capita use for the projected population, **Table 1-3** was developed for the unit use rates for each land use.

Table 1-3. Unit-Use Rates for Each Land Use Type

Land Use Type	**Average Day Unit-Use Rate**	**Max Day Unit-Use Rate**	**Min Day Unit-Use Rate**
	gpm/ acre	**gpm/acre**	**gpm/ acre**
Parks and Open Space	**0.00**	**0.00**	**0.00**
Public/Semi-Public	**0.02**	**0.03**	**0.02**
Rural/Agricultural	**0.02**	**0.03**	**0.02**
Very Low Density Residential	**0.03**	**0.05**	**0.02**
Low Density Residential	**0.18**	**0.27**	**0.14**
Medium Density Residential	**0.23**	**0.35**	**0.17**
Manufactured Home Park	**0.23**	**0.35**	**0.17**
High Density Residential	**0.8**	**1.20**	**0.60**
Commercial	**0.2**	**0.30**	**0.15**
Neighborhood Commercial	**0.73**	**1.10**	**0.55**
Office Business Park	**0.4**	**0.60**	**0.30**
General Mixed Use	**0.2**	**0.30**	**0.15**
Industrial	**0.08**	**0.12**	**0.06**

The unit-use rates shown in **Table 1-3** for each land use type were applied to the City of Minot's future land use plan (**Figure 1-3**) and added to the existing model to simulate future demand on the system.

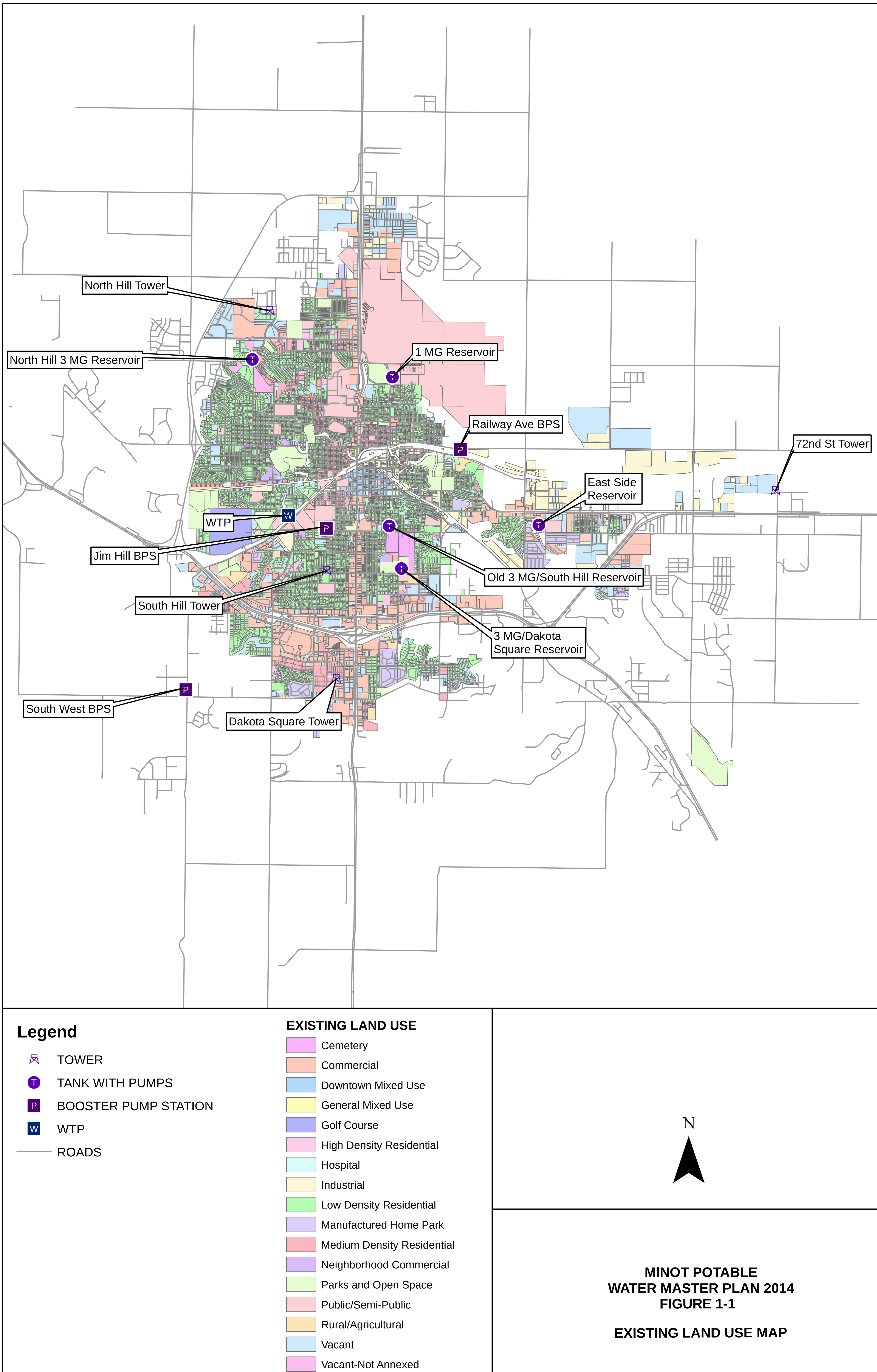
PROJECTED DEMAND

Two additional future scenarios were created to evaluate the existing system's ability to handle the future growth and to recommend future facilities. The first future model is with a projected population of 70,000 people. This included Phase 1, 2, and 3 of the Stantec Comprehensive Growth Plan. The second future model is the build out model which would have a projected population of 80,000 people. This included all 5 phases of the Growth Plan. These scenarios also included the projected demand for the Minot Air Force Base (MAFB) and the NAWS demand. **Table 1-4** shows the additional demand on the system for each of these stages.

Table 1-4. System Demand

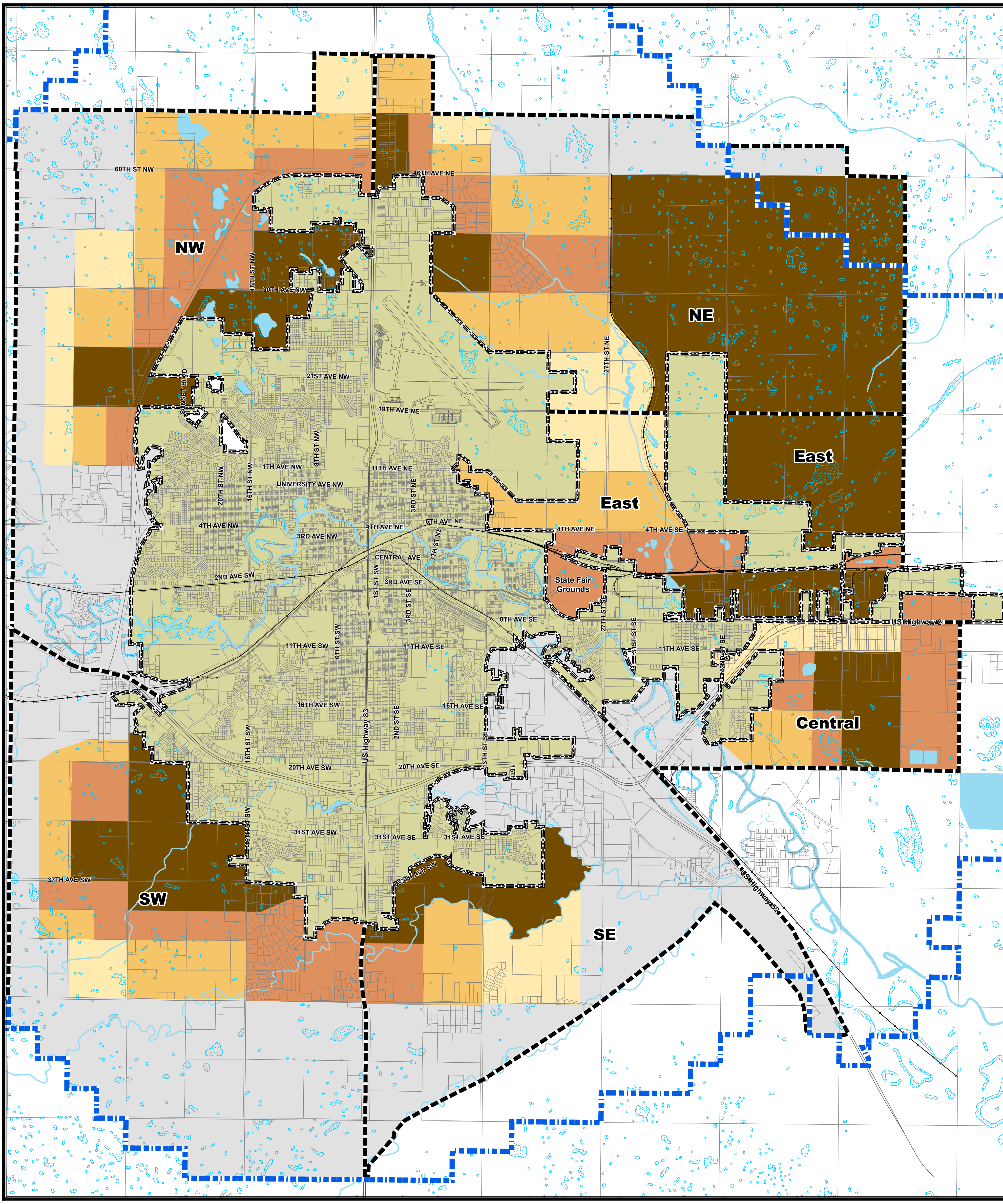
	Existing Demand	Future Stage 1	Future Stage 2
	gpm	**gpm**	**gpm**
North Hill	1,083	1,003	1,542
South Hill	2,190	976	1,658
Valley	2,634	1,129	1,407
Total City	**5,907**	**3,108**	**4,608**
NPRW	412		
Total City & NPRW	**6,319**	**3,108**	**4,608**
MAFB	**1,750**	**1,050**	**1,050**
North NAWS	**125**	**2,675**	**2,675**
South NAWS	**880**	**620**	**620**
Total Demand Added At Each Stage	**9,074**	**7,453**	**8,953**
Total Demand on City & NPRW	**6,319**	**9,427**	**10,927**
200 gpd/capita	**46,000**	**68,000**	**79,000**
Total Demand on System	**9,074**	**16,527**	**18,027**

Table 1-4 shows that by applying the unit-use rates per land use type shown in **Table 1-3** to the land use map shown in **Figure 1-3** that the approximate population projection is achieved. The Future Stage 1 and Future Stage 2 results are used to analyze the existing and future facilities.



MINOT POTABLE
WATER MASTER PLAN 2014
FIGURE 1-1

EXISTING LAND USE MAP



Development Phases in Growth Areas

City of Minot

2012 Comprehensive Plan

- 2-Mile Jurisdictional Boundary
- Growth Area Boundaries
- Phase 1
- Phase 2
- Phase 3
- Phase 4
- Phase 5
- City of Minot (2011)
- Railroad
- AIRPORT
- Streams
- Open Water
- Wetlands

N S E W

0.8 0 0.8 Miles

Figure 1-2

May 11, 2012

Stantec

Note: The growth area phases represent the progression of development based on the location of available infrastructure; and the location of planned infrastructure expansions are anticipated to occur.

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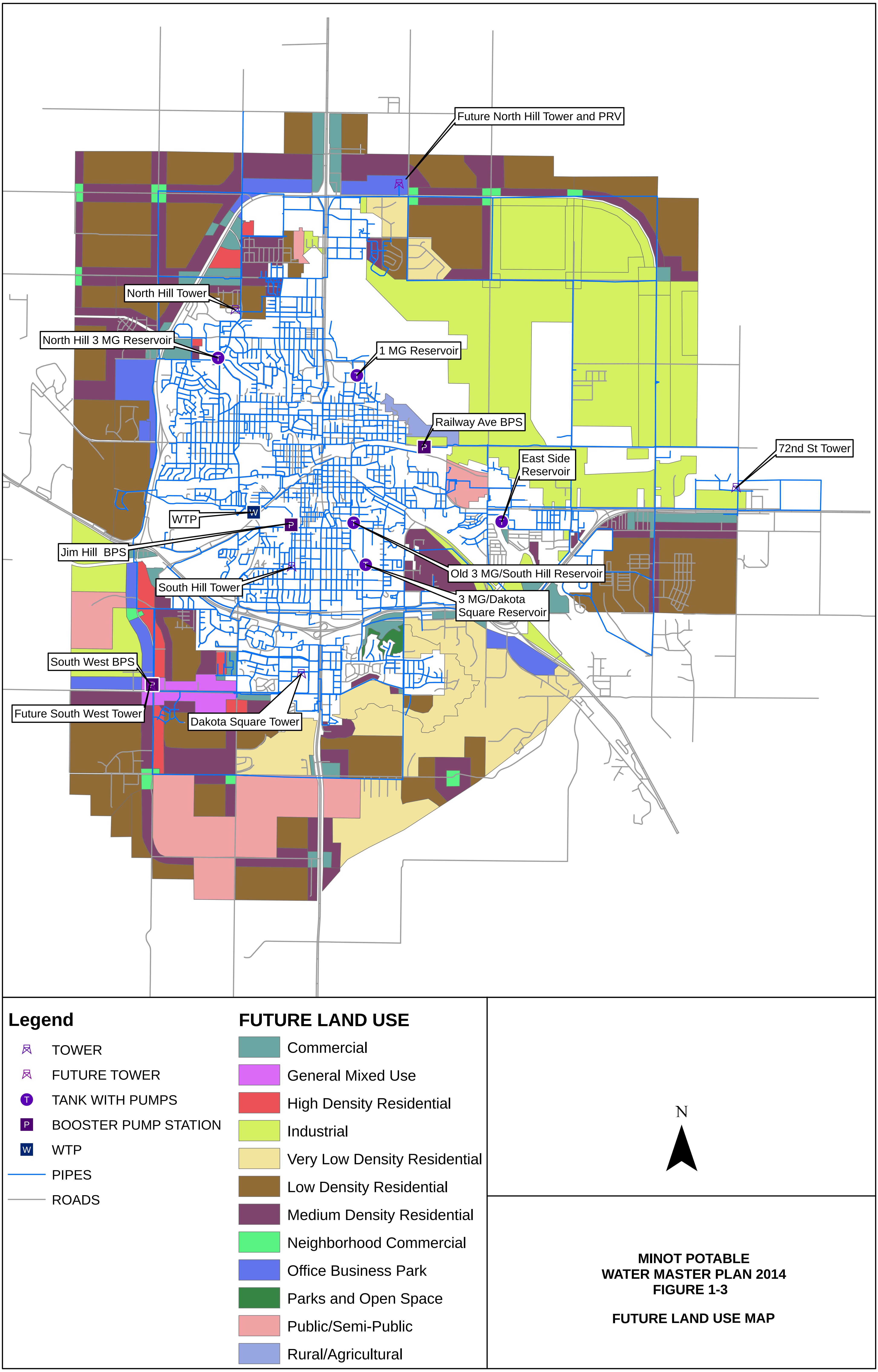


MINOT POTABLE
WATER MASTER PLAN 2014
FIGURE 1-3

FUTURE LAND USE MAP

MWH
MONTGOMERY WATSON HARZA

To:	Dave Schwengler Houston Engineering	**Date:**	March 24, 2014
Subject:	Description of Existing Facilities and Operations		
From:	Gracelyn NeVille	**Job No:**	10503376

PURPOSE

The City of Minot's existing water distribution system is comprised of a pipe network, water storage facilities, and pumping stations. This memorandum contains a summary of the City of Minot's water distribution system facilities and other important information about the system's current operation.

The City of Minot provides potable water to all consumers within city limits, to North Prairie Rural Water District (NPRWD), to Northwest Area Water Supply (NAWS), and to the Minot Air Force Base (MAFB).

MODEL UPDATE

The 2004 model piping is shown in **Figure 2-1**. This model was updated with the piping for areas shown in **Figure 2-2** and **Figure 2-3,** associated demands, and with updated demand for NPRWD, NAWS and MAFB. The existing model location did not match the coordinate system of the new GIS data. One example of the discrepancy is shown in **Figure 2-4**. All model pipes were moved to the spatial location that overlapped the street and parcel maps and imagery.

Besides additional piping to accommodate new growth, there were some major facility changes to the model. These major facility changes are listed below:

- WTP reconfigured.
- NAWS HSPS Pumps installed
- City HSPS Pumps replaced.
- 5 MG tank replaced with 3 MG North Hill Tank and New Pumps
- Southwest Booster Pump Station
- Railway Ave Booster Pump Station
- New 72nd Street Elevated Tank Operational after Calibration
- East Side Ground Storage Tank and BPS taken offline after Calibration

The existing water distribution system is illustrated in **Figure 2-5**. **Figure 2-5** shows the distribution piping layout, the WTP, the storage tank locations, the pump stations, the PRV's, and the closed pipes in the system. The hydraulic schematic of the existing system is shown in **Figure 2-6**.

EXISTING FACILITIES

JUNCTIONS

Demand

The meters were geocoded in the 2004 model and the demand was allocated based on billing records in the 2004 model. These demands remained the same. New demands were only added to the model in the new areas shown in **Figure 2-3**, NPRWD, NAWS and MAFB. The demands allocated to the existing model are shown in **Table 2-1**.

Table 2-1. Existing Model Demand (GPM)

	Demand 1	Demand 2	Demand 3	Total
North Hill	778		305	1,083
South Hill	1,581	316	293	2,190
Valley	1,999	452	183	2,634
NPRW		412		
MAFB		1,750		
North NAWS		125		
South NAWS		880		
Total Demand	**4,358**	**3,935**	**7,81**	**9,074**

The following demand fields were used during the allocation process. All the large users are allocated in Demand 2.

- Demand 1 = General Consumption
- Demand 2 = Large consumer demand
- Demand 3 = Unverified demand allocated by meter route
- Demand 5 = Future demand

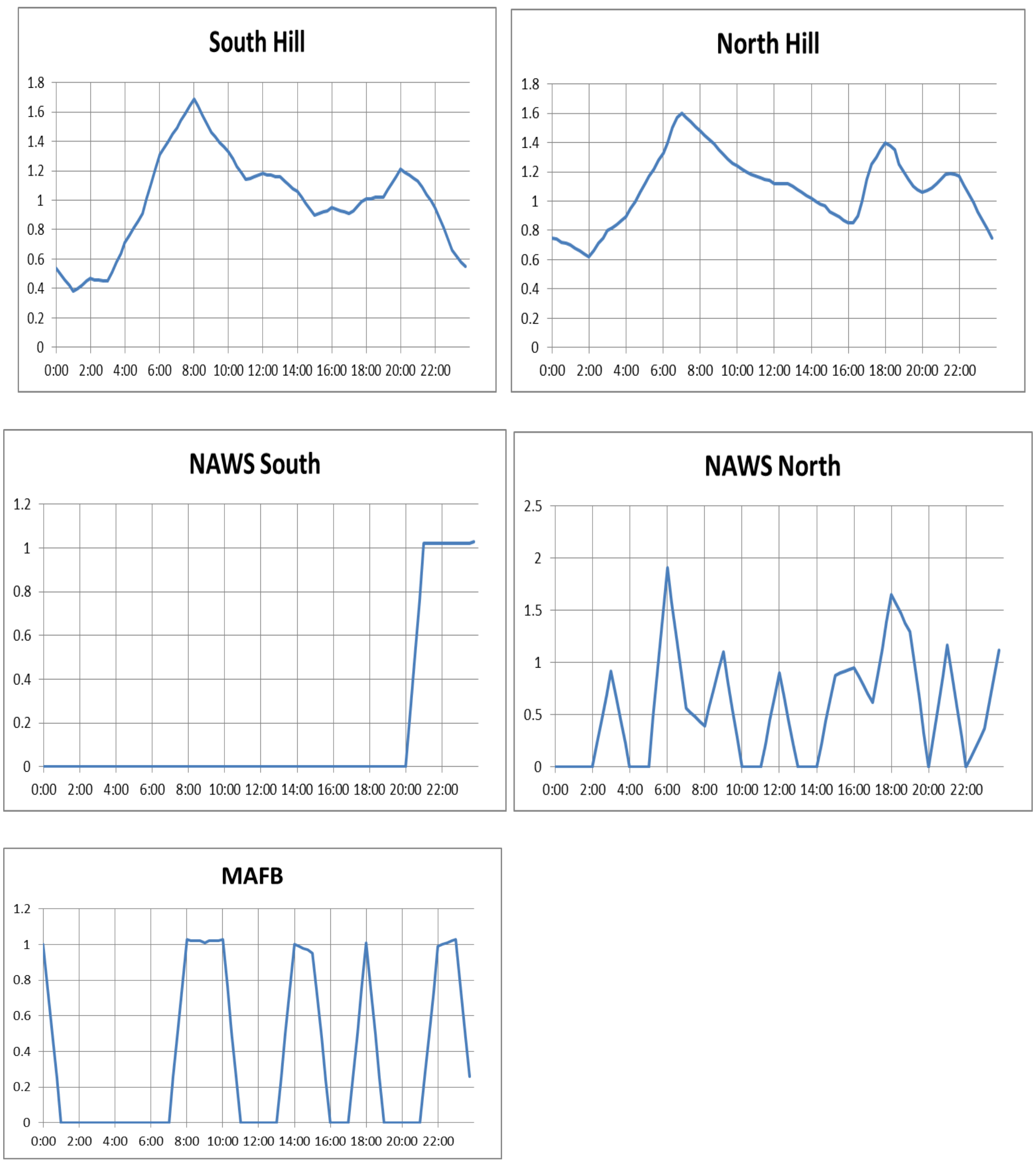
Diurnal Pattern

The existing system model was created as an extended period simulation (EPS) model. An EPS model is one which simulates various demands during different hours of the day, with greater demands during peak hours based on a diurnal pattern. Two 24-hour diurnal patterns were created (one for the North Hill and one for the South Hill-Valley Zone). Separate diurnal curves were developed for the two NAWS demand points as well as the two MAFB demand points. The NPRWD demands were assigned the same diurnal pattern as the zone they are connected to (North Hill, South Hill or Valley).

Maximum day diurnal patterns for the model were derived from hourly flow and tank level data collected as part of the calibration testing and as provided from the City of Minot's SCADA data. Using this data, a consumption diurnal curve was created with factors (ratios) for each hour representing the demand for that hour compared to the average for the entire day.

For Maximum Day Analysis and for Calibration, the SCADA, 2013 data from August 21, 2013 was used to develop the diurnal curve. **Figure 2-A** shows the existing maximum day diurnal utilized in the model for all maximum day scenarios. The diurnals for the NAWS and MAFB were taken from the August 21, 2013 SCADA data, but it should be noted that the demand pattern varied substantially from day to day. The NAWS demand and half of the MAFB is isolated from the rest of the City system so it has no effect on the rest of the system, but the North MAFB demand pattern (diurnal curve) does have an effect on the North Hill operations.

Figure 2-A. Maximum Day Diurnals



PIPE NETWORK

The existing Minot potable water system is comprised of pipelines ranging in diameter from 2 to 36-inches, with most pipes in the system being 6 to 8 inches in diameter. It should be noted that pipe dead ends less than 100 feet and most of the smaller pipes (2 to 4 inches) that do not affect the hydraulics of the model are not included in the model to minimize the links in the system. **Table 2-2** shows the pipe diameters that are included in the model. The existing pipe sizes are shown in **Figure 2-5**.

Table 2-2. Existing Model Diameters

Diameter	Length	Percent
in	ft	%
2	919	0.07%
3	2,819	0.21%
4	11,555	0.86%
5	651	0.05%
6	584,972	43.32%
8	410,204	30.38%
10	66,174	4.90%
12	104,050	7.71%
14	27,476	2.03%
16	80,524	5.96%
18	27,896	2.07%
20	347	0.03%
24	15,882	1.18%
30	8,659	0.64%
36	8,106	0.60%
Total	1,350,237	

Table 2-3 shows the material of the existing system.

Table 2-3. Existing Model Pipe Material

AC	4,080	0.30%
CI	493,674	36.56%
COPPER	1,492	0.11%
DI	6,757	0.50%
PVC	843,667	62.48%
STEEL	250	0.02%
14" DR9 POLY	317	0.02%
Total	**1,350,237**	

Most of the piping in the existing system is the original piping. In the older parts of the City of Minot the piping is primarily cast iron, comprising approximately 37% of the entire pipe network. Another 62% of the City of Minot's pipe network consists of polyvinyl chloride (PVC). The remaining pipe is High Density Polyethylene (HDPE or DR9 Poly), Asbestos Cement (AC), Copper, Ductile Iron (DI), or Steel. The pipe material of the existing water system is shown in **Figure 2-7**.

PRESSURE ZONES

The City of Minot's system is currently divided into 3 pressure zones. These pressure zones are the North Hill, South Hill, and the Valley Zones. Other zones served by the WTP are the Northwest Area Water Supply (NAWS) line, the Minot Air Force Base (MAFB), and the North Prairie Rural Water District (NPRWD). The pipes in each of these pressure zones are shown in **Figure 2-8**.

Pressure zones are created to keep pressures within established limits across wide elevation ranges. The pressure zone boundaries are, for the most part, dictated by elevation. These boundaries are created by physical separation, closed pipes, and/or pressure regulating valves (PRVs). The closed pipes are shown in **Figure 2-8**. The pressure (or hydraulic grade) within each zone is governed by boundary conditions such as tanks, pumps and/or the PRVs. A list of the PRVs in the system with their associated elevation and setting is shown in **Table 2-4**.

Table 2-4. Existing PRV

ID	Description	Type	Elev	Dia	Setting	Operations
9001	Existing PRV-Between Frontage Rd & Broadway Just North of 2nd St NW	PRVs	1,687.51	6	60	Closed
9003	Existing PRV-27th St NW & 5th Ave NW	PRVs	1,597.06	6	62	Operational
9005	Existing PRV-27th St NW	PRVs	1,659.28	6	60	Operational
9007	Existing PRV-1st St SW	PRVs	1,670.97	6	45	Not Operational
9009	Existing PRV-Old East Side PS	PRVs	1,557.40	8	81	Operational during Calibration, but not Operational during other Scenarios.
9015	Existing PRV-Dakota PS	PRVs	1,735.42	8	77	Operational
9021	Existing PRV-HW2 & 52 BYP	PRVs	1,709.75	6	52	Operational

There are 7 PRVs in the City of Minot's system; of them, 4 are currently in use. There is very little flow coming through the valve on Highway 2. The PRV between the frontage road and Broadway, just north of 2nd Street SW, is closed. The PRV on 1st Street Southwest was not closed, but the City of Minot believes all pipes downstream feeding into the Valley Zone are closed. The model does operate better during peak hour and fire flow conditions if this PRV is operational, but at a very low setting (between 40-45 psi).

VALVES

Besides the 7 PRVs, there are five (5) control valves in the system. These valves are shown in **Table 2-5**. There are few control valves in the system that are not operable, so they are not listed in **Table 2-5** below.

Table 2-5. Existing Valves

ID	Description	Type	Elevation	Dia.	Setting	Operation
8000	Throttle Valve South of Burdick Expressway feeding Jim Hill BPS	Throttle	1,579.86	16	0.55	Throttle Gate Valve
V8002	NAWS N Master Meter-19th Ave NW	FCV	1,724.11	18	1,800	FCV for NAWS flow into North Hill
V8008	North Hill PSV	PSV/ FCV	1,745.50	12	60	PSV at 60 psi
V8010	FCV to Old East Side Tank	FCV	1,558.00	8	Pattern	Used as FCV with pattern based on Calibration data. Not Operational in Maximum Day or Future Models
V8012	FCV into SH Booster	FCV	1,726.00	12	1,500	Controls flow into Old 3 MG Tank/ SH Booster Station

STORAGE RESERVOIRS AND TANKS

There are eight (8) operational tanks in the Minot Model. **Table 2-6** shows tank information and capacity for the existing tanks in the system.

Table 2-6. Existing Reservoirs and Towers

Tank Site	Model ID No.	Type	Model Type	Elev. ft	Min. ft	Max. ft	Initial ft	Dia. ft	Capacity (gal)
South Hill Res (Old 3 MG Res)	7002	Ground	Cylindrical	1,722.3	9.0	24.0	16.5	150	3,000,000
Dakota Square Res (3 MG Reservoir)	7004	Ground	Cylindrical	1,721.3	10.0	23.0	19.1	150	3,000,000
Dakota Square Tower	7006	Elevated	Variable Area	1,866.5	0.0	37.5	33.5	50	500,000
South Hill Tower	7008	Elevated	Variable Area	1,866.6	0.0	37.5	31.5	50	500,000
North Hill Tower	7010	Elevated	Variable Area	1,857.0	20.0	37.5	26.7	50	500,000
North Hill 3 MG Reservoir	7012	Ground	Variable Area	1,725.1	15.0	21.4	17.8	156	3,000,000
North Hill 1 MG Reservoir	7014	Ground	Cylindrical	1,717.3	10.0	30.0	22.1	75	1,000,000
East Side Reservoir	7018	Ground-Offline After Calibration	Variable Area	1,546.0	12.0	16.3	16.2	72	500,000
72nd St Tower	7020	Elevated-Online After Calibration	Cylindrical	1,741.0	5.0	40.0	35.0	70	1,000,000
Total Without East Side Ground & With East Side Elevated									**12,500,000**

During calibration the East Side Tank and Booster Pump Station was operational, but it was decommissioned after the 72nd Street Elevated Tank came online in the fall of 2013. The total storage capacity is 12.5 million gallons with the New East Side Tower and without the existing East Side Ground Storage Tank.

The tank levels of the ground storage tanks are controlled by the hydraulic grade line of the system (HGL). The tank levels of the elevated storage tanks are controlled by the pump feeding into the tanks.

PUMPING STATIONS

Pump hydraulics in the model are represented by a curve that defines the pump's head versus flow relationship. Pump curves in the model were derived from the actual certified pump curves or pump test data during the 2004 model update, if available, and confirmed by field-testing. **Table 2-7** lists the pumps along with the model ID, whether it is controlled by a curve or design point, if it is a variable speed pump, if there are additional parallel pumps, what controls the pump operation, and any comments about the pump itself.

Table 2-7. Existing Pump Station

		Design Flow	Additional Parallel	On-Off Control	Comments
Description	**Model ID No.**	**gpm**	**Pumps**	**Curve/ gpm/psi**	
Water Treatment Plant					
WTP City HSPS	HSP110	VSP-Curve	3	Flow Curve	New Pump
WTP NAWS HSPS	HSP210	VSP-Curve	3	142 psi	New Pump
South Hill Pumps (Old 3 MG Reservoir)					
South Hill PS 1	5001	Curve		SH Tower	2004 Pump
South Hill PS 2	5003	Curve		SH Tower	2004 Pump
Jim Hill Booster					
Jim Hill BPS 1	5043	Curve		SH Tower	2004 Pump
Jim Hill BPS 2	5045	Curve		SH Tower	2004 Pump
North Hill 3 MG Reservoir					
North Hill BPS 1	5005	Curve		NH Tower	New Pump
North Hill BPS 2	5007	Curve		NH Tower	New Pump
North Hill BPS 3	5009	Curve		NH Tower	New Pump
1 MG Reservoir					
1 MG PS 1	5017	Curve		Time	2004 Pump
1 MG PS 2	5019	Curve		Time	2004 Pump
Dakota Square Reservoir (New 3 MG Reservoir)					
Dakota Square PS 1	5037	1200		DS Tower	2004 Pump
Dakota Square PS 2	5039	1200		DS Tower	2004 Pump
Dakota Square PS 3	5041	1200		DS Tower	2004 Pump
Southwest BPS					
Southwest BPS	SWBPS	VSP-Curve	0	DS Tower	New Pump
East Side Tank					
East Side PS 1	5047	Curve		Time	Offline After Calibration
East Side PS 2	5049	Curve		Time	Offline
East Side PS 3	5051	Curve		Time	Offline
Railway Ave BPS					
Railway Ave BPS 1	RWBP1	VSP-Curve	1	72nd St. Tower	Online After Calibration
Railway Ave Fire Pump	5062	Curve			Online After Calibration

The existing model has 27 pumps. There are 4 pump stations with Variable Speed Pumps (VSP) operational in the system. These pumps allow the flow to fluctuate at a greater range with more efficiency. The Railway Pump Station and 72nd Street Elevated Tank came on line after calibration. When these facilities came online, the East Side ground tank and pump stations were decommissioned. The East Side ground tank and pump stations were not operational in the Maximum Day analysis. The Railway Pump Station and 72nd Street Elevated Tank were operational during the Maximum Day analysis.

OPERATIONS

Operational controls were added to reflect actual control settings or the intent of manual operational practices or procedures. Initially the controls were set using the Facility Controls found in **Appendix A**, but during calibration these controls were modified to reflect the actual operations of the system.

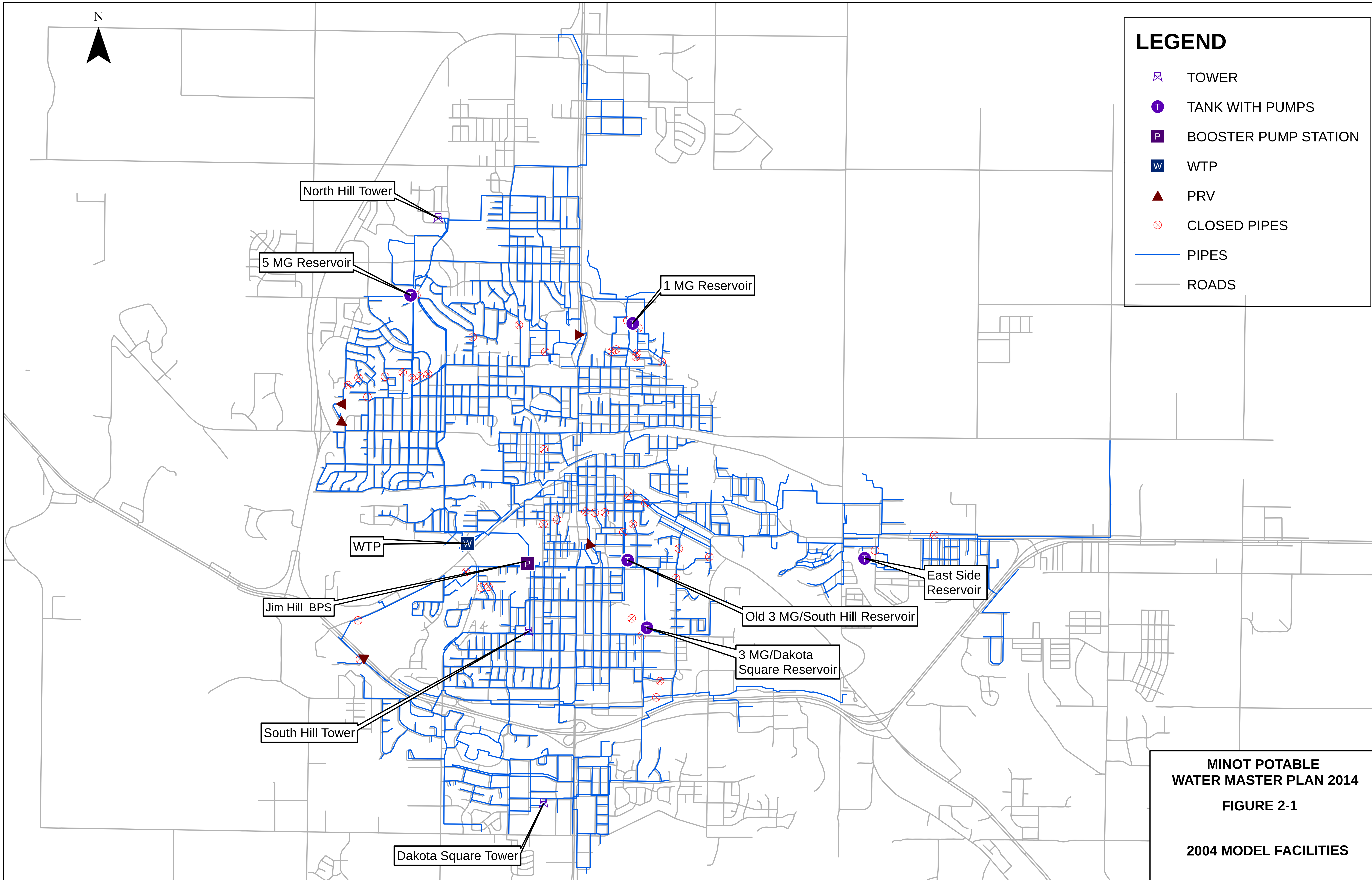
Most of the pumps are controlled by the elevated tank levels. However, the City of Minot currently operates some of the facilities manually. The controls actually used in the model for Calibration and Maximum Day Scenario can be found in **Table 2-8**.

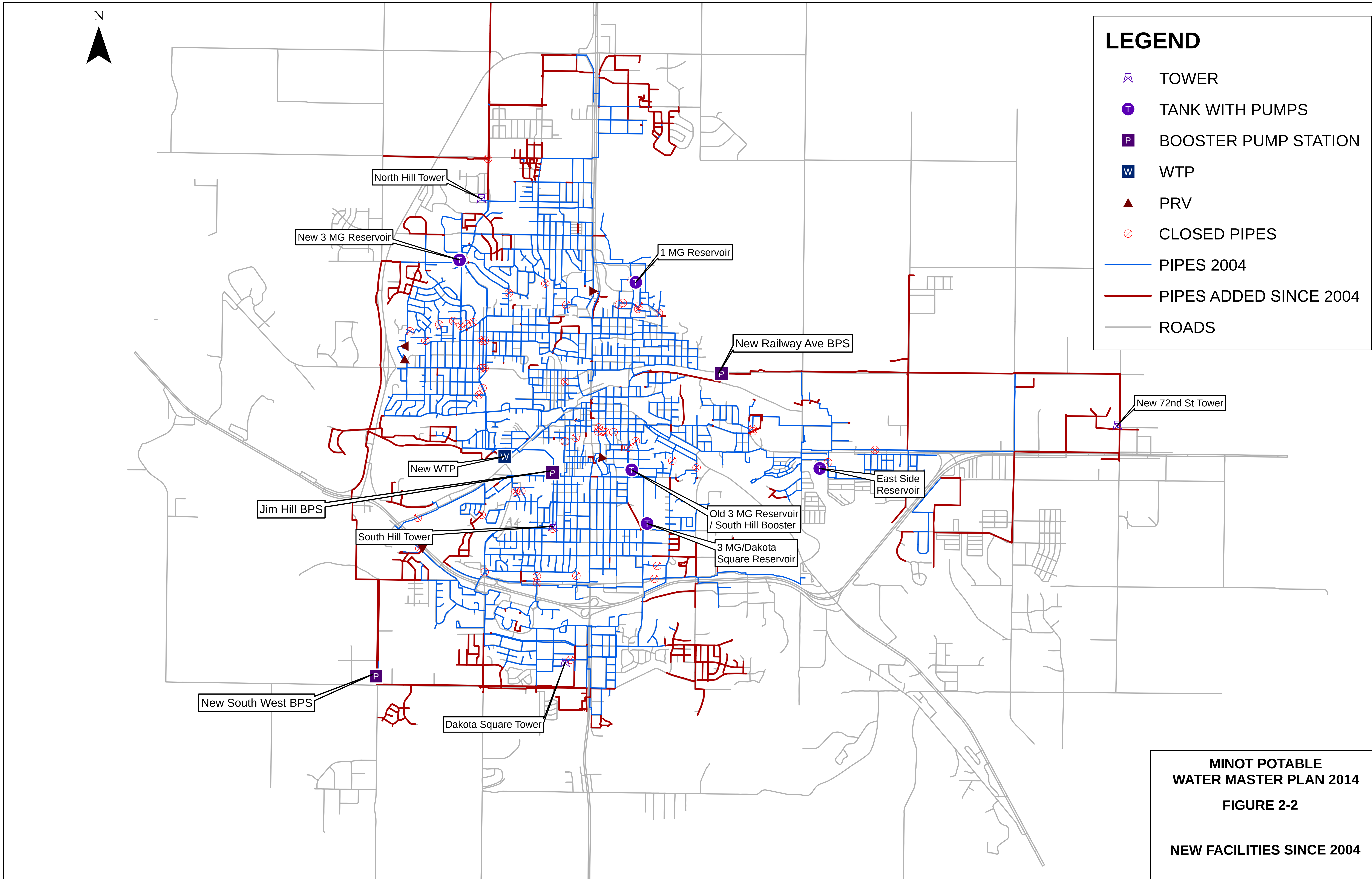
Table 2-8. Calibration and Maximum Day Controls

	Facility	Type	Control	Control	Fill or Pump	Calibration		Maximum Day	
Water Treatment Plant	ID			ID		On	Off	On	Off
WTP NAWS HSP	HSP210	VSP	Pressure			142		142	
WTP City HSP	HSP140	VSP	Flow			Flow Curve		Flow Curve	
South Hill Res (Old 3 MG Reservoir)	T7002	FCV/ Time	1500 gpm	V8012	Fill	22	7	22	7
South Hill PS 1	5001	Level	SH Tower	T7008	Pump	31	36	31	36
South Hill PS 2	5003	Level	SH Tower	T7008	Pump	28	34	28	34
Jim Hill Booster									
Jim Hill BPS 1	5043	Level	SH Tower	T7008	Pump	30	36	30	36
Jim Hill BPS 2	5045	Level	SH Tower	T7008	Pump	27	36	27	36
Dakota Square Re (3 MG Reservoir)	T7004			477	Fill	Gravity/Check Valve			
Dakota Square PS 1	5037	Level	DS Tower	T7006	Pump	29	36	29	36
Dakota Square PS 2	5039	Level	DS Tower	T7006	Pump	20	35	20	35
Dakota Square PS 3	5041	Level	Closed						
Southwest BPS									
Southwest BPS	SWBPS	VSP /Level	1200 gpm (DS Tower)	T7006	Pump	28	35	28	35
North Hill 3 MG Reservoir	T7012	PSV	60 psi	V8008	Fill	17	19	15	20
North Hill BPS 1	5005	Level	NH Tower	T7010	Pump	29	37	29	37
North Hill BPS 2	5007	Level	NH Tower	T7010	Pump	20	32	20	32
North Hill BPS 3	5009	Level	NH Tower	T7010	Pump	16	24	16	24
North Hill Bypass	P8709		Open if V8008 is closed/ Closed if V8008 is Open						
North Hill 1 MG Res	T7014								
1 MG PS 1	5017	Time			Pump	6	13	6	13
1 MG PS 2	5019	Time	Closed						
East Side Tank	T7018	Flow/ Time	100 gpm/ 400 gpm	V8010	Fill	0/16	6	Offline	
East Side PS 1	5047	Time	Closed					Offline	
East Side PS 2	5049	Time			Pump	7	18	Offline	
East Side PS 3	5051	Time	Closed					Offline	
Railway Ave BPS									
Railway Ave BPS 1	RWBP1	VSP/ Level	1800 gpm ES Tower	T7020		Offline		26	36
Railway Ave Fire Pump	5062	Level				Offline		15	18

During Calibration the WTP was manually controlled, so a flow curve was developed to operate the pumps. The NAWS VSP was set to operate at 142 psi based on the SCADA data. The 1 MG and the East Side pump station were both set up to run on time based on SCADA data. Calibration results will be discussed in more detail in Technical Memorandum 5. It should be noted that if there is no control on the 1 MG fill line, the tank is not being pulled down as fast as shown in the calibration data. There are times during the day that the tank is filling and the model keeps the elevation in the tank higher than shown in the SCADA data.

The major change between the Calibration Scenario and the Maximum Day Scenario is that the East Side Tower and Railway Ave Pump Station came on line this fall after calibration. When the facilities became operational, the East Side reservoir and pump station were taken off-line.


N
LEGEND
TOWER
TANK WITH PUMPS
BOOSTER PUMP STATION
WTP
PRV
CLOSED PIPES
PIPES
ROADS
North Hill Tower
5 MG Reservoir
1 MG Reservoir
WTP
Jim Hill BPS
Old 3 MG/South Hill Reservoir
East Side Reservoir
3 MG/Dakota Square Reservoir
South Hill Tower
Dakota Square Tower
MINOT POTABLE
WATER MASTER PLAN 2014
FIGURE 2-1
2004 MODEL FACILITIES



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 2-2

NEW FACILITIES SINCE 2004

FIGURE 2-3
NEW AREAS SINCE 2004 MODEL

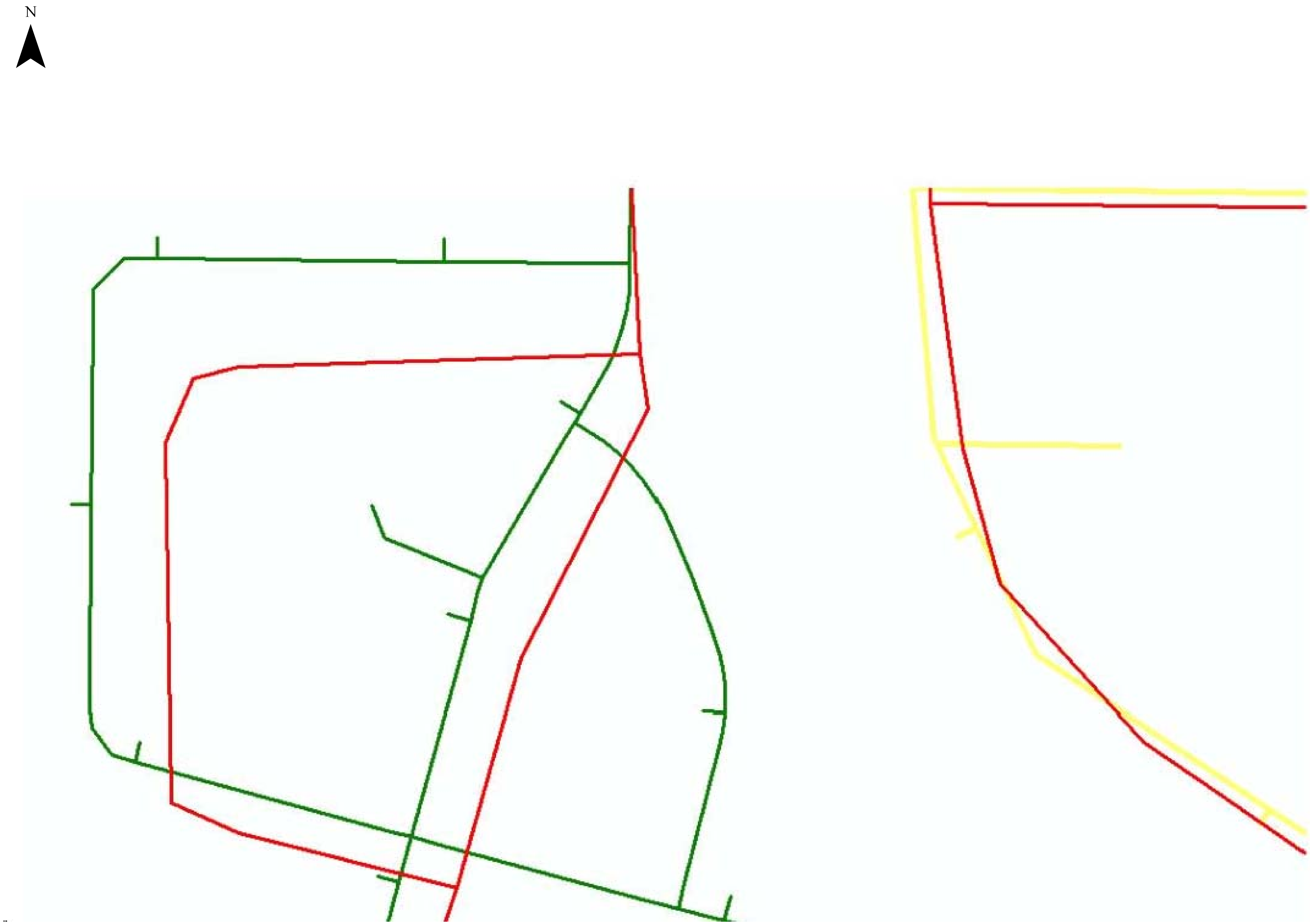
Scale:	Drawn By:	Checked By:	Project No.	Date:
AS SHOWN	DDS	DDS	6824-006	3/10/2014

Houston Engineering Inc.

Minot

P: 701.852.7931
F: 701.858.5655

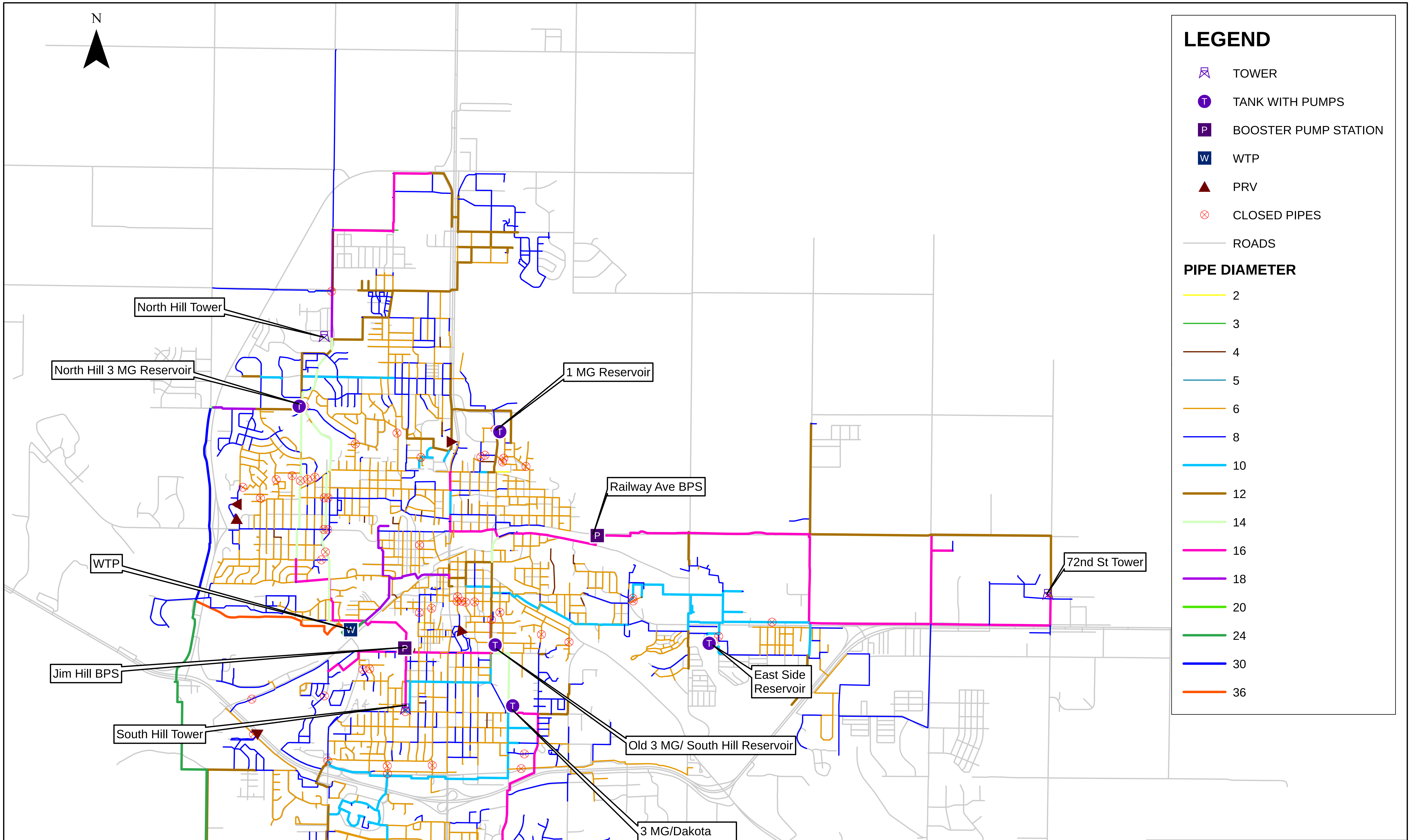
Path: H:\Projects\6027-XXX City of Minot\6027-026 Water Distribution System Modeling and Master Plan\New Areas since 2004 model.mxd



MINOT POTABLE
WATER MASTER PLAN 2014

FIGURE 2-4

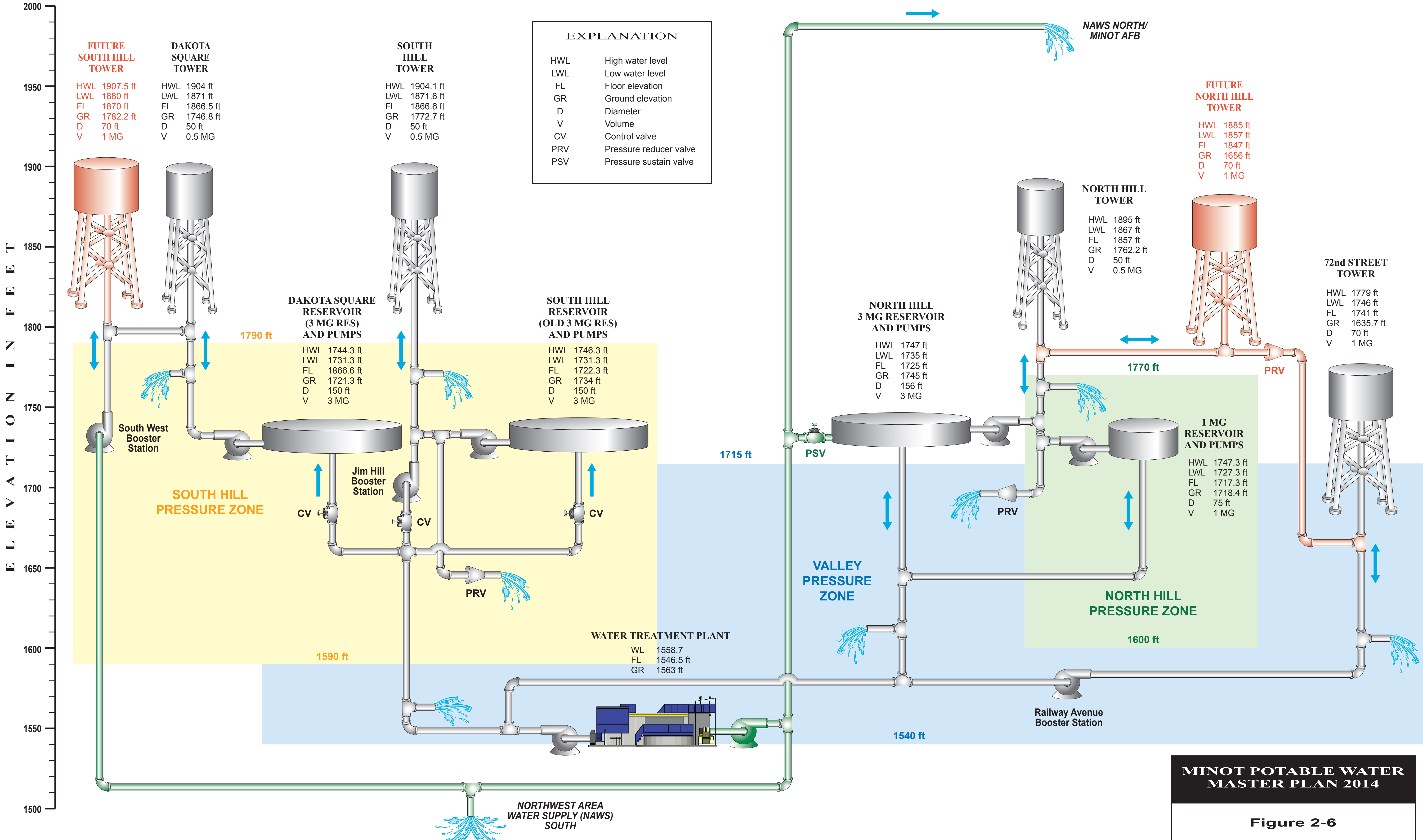
PIPE SHIFT EXAMPLE



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 2-5

EXISTING WATER SYSTEM



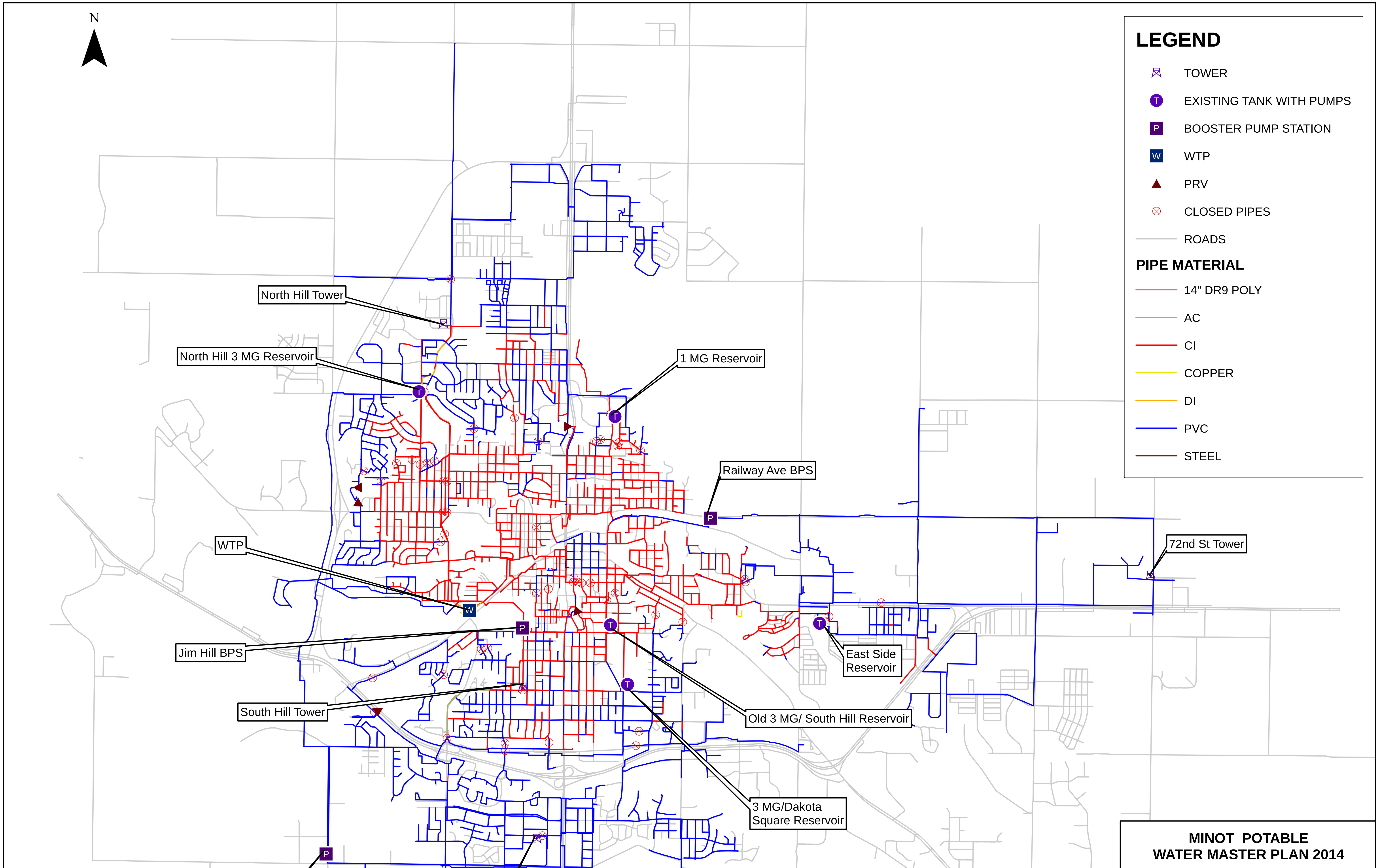
MINOT POTABLE WATER MASTER PLAN 2014

Figure 2-6

HYDRAULIC SCHEMATIC

FILE: Fig 2-5_Minot_Hydraulic Schematic_17Mar2014.ai

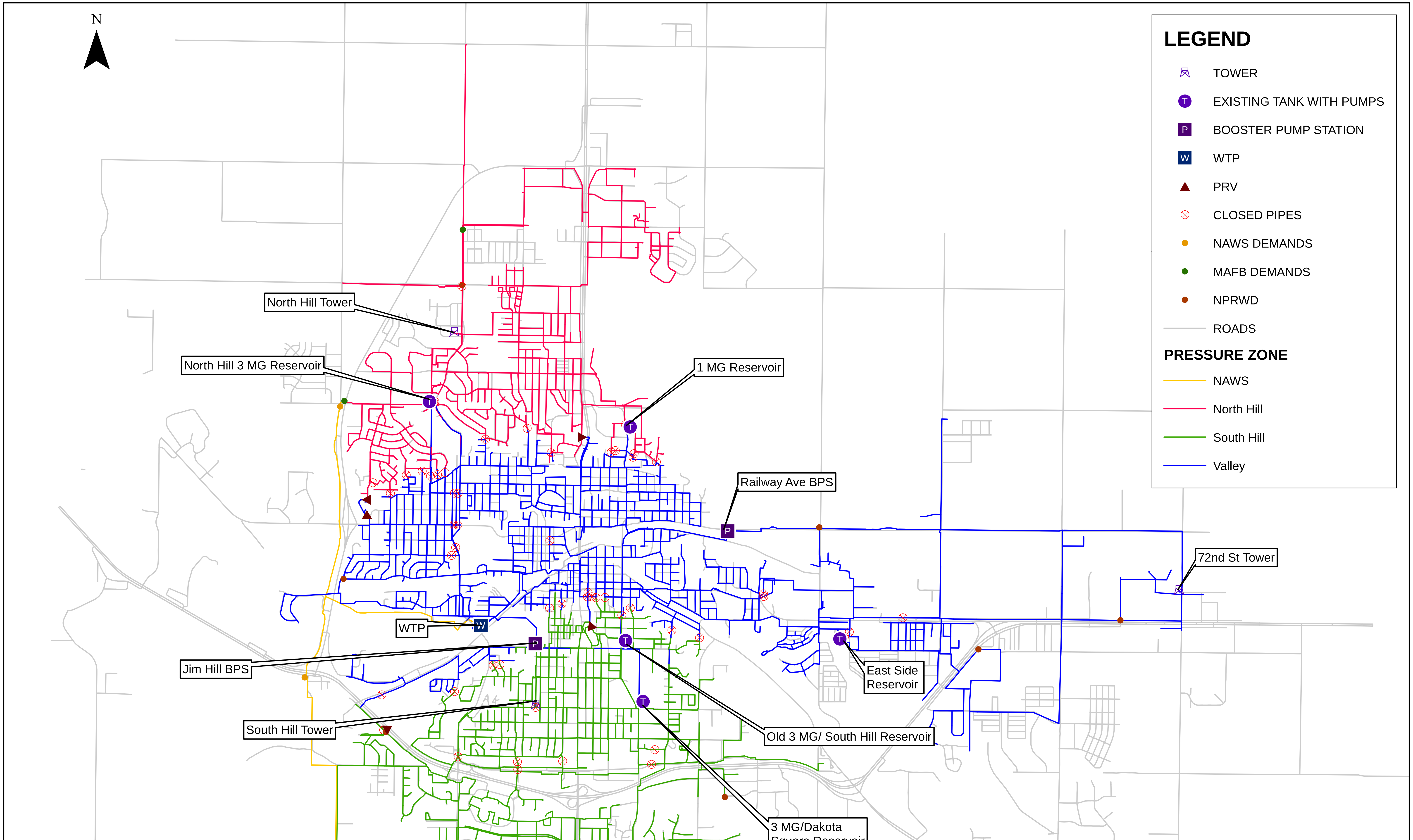
DATE: 17 Mar 2014



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 2-7

EXISTING WATER SYSTEM MATERIAL



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 2-8

PRESSURE ZONE MAP

MWH
MONTGOMERY WATSON HARZA

To:	Dave Schwengler Houston Engineering	**Date:**	March 24, 2014
Subject:	Description of Future Facilities and Operations		
From:	Gracelyn NeVille	**Job No:**	10503376

PURPOSE

This memorandum contains a summary of the proposed Capital Improvement Projects (CIP) along with a description of future water distribution system facilities and other information about the City of Minot's future operations of the system. The City of Minot will continue to provide potable water to all consumers within city limits, to North Prairie Rural Water District (NPRWD), to Northwest Area Water Supply (NAWS), and to the Minot Air Force Base (MAFB). **Figure 3-1** shows the Future Water System at build-out conditions (79,000 people).

SCENARIOS

The maximum day system was analyzed under three Scenarios.

- Existing Maximum Day (Peak Hour and Fire Flow on Average of Maximum Day)
- Future Stage 1 (68,000 population) Maximum Day (Peak Hour and Fire Flow on Average of Maximum Day)
- Future Stage 2 (79,000 population) Maximum Day (Peak Hour and Fire Flow on Average of Maximum Day)

These Scenarios were used to develop CIP projects.

CIP PROJECTS

After evaluating the results of these Scenarios, CIP were developed to address velocity and pressure issues and some of the general fire flow issues. All fire flow issues cannot be resolved without replacing or upsizing replacing a large portion of the existing 6-inch Cast Iron Pipe. As construction projects occur where existing 6-inch water lines are located, these should be replaced, but overall 6 inch pipe replacement is not shown in the CIP.

Table 3-1 and **Figure 3-2** show the proposed projects required for most of Future Stage 1 Growth. As new development takes place in future areas, local distribution pipe lines will need to be added and looped as much as possible to provide the best fire flow protection.

Table 3-1. Future Stage 1 CIP Projects

Project No.	Project	Description	Unit	Quantity
Project 1	Pipe Replacement-Down Town Project	8-inch pipeline	LF	7,100
		12-inch pipeline	LF	3,000
		16-inch pipeline	LF	1,500
		18-inch pipeline	LF	1,200
Project 2	North East Side Phase 1	16-inch pipeline	LF	23,800
		Interim Booster Pump Station	EA	1
		Interim Keep Closed Valve	EA	1
Project 3	North East Side Phase 2	16-inch pipeline	LF	37,200
Project 4	46th Ave NE -N Broadway to 13th St NE	8-inch pipeline	LF	100
		16-inch pipeline	LF	5,800
		12-inch PRV	EA	1
Project 5	Future North Hill Elevated Tank	1 MG Elev Tank	EA	1
		16-inch pipeline	LF	780
Project 6	6" Pipe Replacement- 16th Ave SE-From 8" to VIE St	8-inch pipeline	LF	1,100
Project 7	Future South Hill Elevated Tank	1 MG Elev Tank	EA	1
		16-inch pipeline	LF	100
Project 8	37th Ave SE-2nd St SE to 13th St SE	12-inch pipeline	LF	4,100
Project 9	North West Project	12-inch pipeline	LF	18,600
Project 10	6" Pipe Replacement- 21st Ave NW-6th St NW to Skyline Dr / 5th St NW to 3rd St NW	8-inch pipeline	LF	1,100
Project 11	6" Pipe Replacement- University Ave- 1st NE to 3rd St NE	8-inch pipeline	LF	800
Project 12	6" Pipe Replacement- 11th Ave NW-N Broadway to Main St	8-inch pipeline	LF	900
Project 13	6" Pipe Replacement- 8th St SE-Railway Ave to Burdick Expy	8-inch pipeline	LF	3,300
Project 14	72nd St SE to 88th St SE	10-inch pipeline	LF	14,400
Project 15	Rivers Edge Dr to 55th St SE	8-inch pipeline	LF	1,600
		10-inch pipeline	LF	10,400

The additional transmission mains required to accommodate build-out conditions (79,000 people) are shown in **Table 3-2** and **Figure 3-3**.

Table 3-2. Future Stage 2 Projects

Project No.	Project	Description	Unit	Quantity
Project 20	South Project	8-inch pipeline	LF	100
		12-inch pipeline	LF	22,800
		16-inch pipeline	LF	7,000
Project 21	Valley St 27th St SE to Hwy 2	12-inch pipeline	LF	9,400
Project 22	Valley St 14th Ave SE to 20th Ave SE	12-inch pipeline	LF	16,600

FUTURE FACILITIES

JUNCTIONS

Demand

Two additional future scenarios were created to evaluate the existing system's ability to handle future growth and to recommend future facilities. The first future model is with a projected population of 68,000 people. This included Phase 1, 2, and 3 of the Stantec Comprehensive Growth Plan. The second future model is the build-out model which would have a projected population of 79,000 people, this included all 5 phases of the Stantec Comprehensive Growth Plan. These scenarios also included the projected demand for the Minot Air Force Base (MAFB) and the NAWS demand. **Table 3-3** shows the additional demand on the system for each of these stages.

Table 3-3. System Demand

	Existing Demand	Future Stage 1	Future Stage 2
	gpm	gpm	gpm
North Hill	1,083	1,003	1,542
South Hill	2,190	976	1,658
Valley	2,634	1,129	1,407
Total City of Minot	**5,907**	**3,108**	**4,608**
NPRW	412		
Total City of Minot & NPRWD	**6,319**	**3,108**	**4,608**
MAFB	**1,750**	**1,050**	**1,050**
North NAWS	**125**	**2,675**	**2,675**
South NAWS	**880**	**620**	**620**
Total Demand Added At Each Stage	**9,074**	**7,453**	**8,953**
Total Demand on City of Minot & NPRWd	**6,319**	**9,427**	**10,927**
Total Demand on System	**9,074**	**16,527**	**18,027**

* All future demand was allocated in the Demand 5 field in the model.

Diurnal Pattern

The same diurnal patterns used for the existing system were used for the North Hill, South-Hill Valley, and MAFB. The NAWS South diurnal was adjusted slightly to allow them to pull more frequently in the future, but this does not really affect the City's system.

PIPE NETWORK

The CIP projects added approximately 175,000 linear feet of pipe to the system**. Table 3-4** shows the length of pipe included in the model for each pipe size. **Figure 3-1** shows the pipe sizes in the future system.

Table 3-4. Future Model Diameters

Diameter	Length	Percent
in	ft	%
2	919	0.06%
3	2,819	0.18%
4	11,555	0.76%
5	651	0.04%
6	572,753	37.55%
8	428,300	28.08%
10	89,714	5.88%
12	171,425	11.24%
14	27,467	1.80%
16	157,728	10.34%
18	29,039	1.90%
20	285	0.02%
24	16,117	1.06%
30	8,715	0.57%
36	7,871	0.52%
Total	1,525,360	

PRESSURE ZONES

The City of Minot's system will still be divided into 3 pressure zones. The pressure zones are the North Hill, South Hill, and the Valley Zones. Other zones served by the WTP are the NAWS line, the Minot Air Force Base (MAFB), and the North Prairie Rural Water District (NPRWD). The future system pipes in each of these pressure zones are shown in **Figure 3-4**.

The physical separation and closed pipes were not changed in the future scenarios. There was one PRV installed in the future model. This PRV was installed to feed the Northeast side of the Valley Zone from the North Hill Zone. The information about the future PRV is shown in **Table 3-5**.

Table 3-5. Future Model PRV

ID	Description	Type	Elevation	Dia	Setting	Comment
V8006	Future PRV 46th Ave NE & 13th St NE	PRV	1,647.08	12	55	Feeds to the Northeast side of the Valley Zone from North Hill Zone

VALVES

An interim keep closed valve will be added on the east side of the Valley Zone to prevent the water from the interim booster pump station flowing back into the Valley Zone. This valve will only be required to be closed until the Future North Hill Tower and PRV is constructed. For more information about Project 2 refer to the East Side –Valley Zone 2013 Distribution System Improvement Analysis Technical Memorandum, the only other valve change is to the NAWS N Master Meter. In the Future Stage 2 Scenario, the North Hill Tank is not able to keep up with the demand without having more flow from the NAWS line. The flow through the master meter would have to be increased from 1,800 gpm to 2,500 gpm if all of the projected demand comes online. These valves changes are shown in **Table 3-6**.

Table 3-6. Valve Changes to CIP and Future Model Scenarios

ID	Description	Type	Exist	CIP	Future Stage 1	Future Stage 2
V8002	NAWS N Master Meter-19th Ave NW	FCV	1,800	1,800	1,800	2,500

STORAGE RESERVOIRS AND TANKS

Two additional elevated tanks (towers) are recommended to be constructed to accommodate future demand. The Future North Hill Tower was modeled to be constructed near 46th Ave NE & 13th St NE. The Future Southwest Tower will be constructed near County Road 14 and 30th Street SW. **Table 3-7** shows the information for the future towers being added to the system.

Table 3-7. Future Towers

Tank Site	Model ID Number	Type	Model	Ground Elev.	Elev.	Min.	Max.	Initial	Dia.	Capacity
			Type	ft	ft	ft	ft	ft	ft	(gal)
North Hill Tower	T5002	Elevated	Cylindrical	1656	1,847	20	40	32	70	1,000,000
Southwest Tower	T5004	Elevated	Cylindrical	1782	1,870	20	40	33.5	70	1,000,000
Total Additional Storage										2,000,000

The tank levels are controlled by the pumps feeding the towers. The Future North Hill Tower will be supplied with water from the existing North Hill Elevated Tank which is supplied by the North Hill 3 MG Ground Reservoir. The Southwest Tower is supplied with water from the Southwest Booster Station.

PUMPING STATIONS

There was one interim pump station recommended as part of Project 2. This will operate to provide adequate pressure during peak hour and fire flow to the Northeast side of the Valley Zone. This pump will only be required until the Future North Hill Tower and PRV is constructed. For more information about Project 2 refer to the East Side –Valley Zone 2013 Distribution System Improvement Analysis Technical Memorandum. No other pumps were added to the future system. However, many of the controls were altered to accommodate the future demand on the system.

OPERATIONS

Operational control for each scenario are shown in **Table 3-8**.

	Facility	Type	Control	Control	Fill or Pump	Maximum Day		Maximum Day CIP		Future Stage 1		Future Stage 2	
Water Treatment Plant	ID			ID		On	Off	On	Off	On	Off	On	Off
WTP NAWS HSPS	HSP210	VSP	Pressure			142		142		143		145	
WTP City HSPS	HSP140	VSP	Pressure			Flow Curve		85		90		92	
South Hill Res (Old 3 MG Reservoir)	T7002	FCV/ Time	1500 gpm	V8012	Fill	22	7	22	7	22	7	22	7
South Hill PS 1	5001	Level	SH Tower	T7008	Pump	31	36	31	36	31	36	31	36
South Hill PS 2	5003	Level	SH Tower	T7008	Pump	28	34	28	34	28	34	28	34
Jim Hill Booster													
Jim Hill BPS 1	5043	Level	SH Tower	T7008	Pump	30	36	30	36	30	36	30	36
Jim Hill BPS 2	5045	Level	SH Tower	T7008	Pump	27	36	27	36	27	36	27	36
Dakota Square Res (3 MG Reservoir)	T7004			477	Fill	Gravity/Check Valve							
Dakota Square PS 1	5037	Level	DS Tower	T7006	Pump	29	36	29	35	29	35	28	34
Dakota Square PS 2	5039	Level	DS Tower	T7006	Pump	20	35	20	34	19	32	19	32
Dakota Square PS 3	5041	Level	Closed										
Southwest BPS													
Southwest BPS	SWBPS	VSP /Level	1200 gpm* DS Elev	T7006	Pump	28	35	28	35	29	35	29	35

	Facility	Type	Control	Control	Fill or Pump	Maximum Day		Maximum Day CIP		Future Stage 1		Future Stage 2	
	ID			ID		On	Off	On	Off	On	Off	On	Off
North Hill 3 MG Res	T7012	Level		V8008	Fill	15	20	15	20	15	20	15	20
North Hill BPS 1	5005	Level	NH Tower	T7010	Pump	29	37	29	37	29	37	29	37
North Hill BPS 2	5007	Level	NH Tower	T7010	Pump	20	32	20	32	25	32	23	32
North Hill BPS 3	5009	Level	NH Tower	T7010	Pump	16	24	16	24	20	24	20	24
North Hill Bypass	P8709					Open if V8008 is closed/ Closed if V8008 is Open							
North Hill 1 MG Res	T7014	Time		1517	Fill	Gravity							
1 MG PS 1	5017	Time			Pump	6	13	6	13	(1)	(1)	(1)	(1)
1 MG PS 2	5019	Time	Closed										
East Side Tank	T7018			V8010	Fill	Offline							
East Side PS 1	5047	Time				Offline							
East Side PS 2	5049	Time			Pump	Offline							
East Side PS 3	5051	Time				Offline							
Railway Ave BPS													
Railway Ave BPS 1	RWBP1	VSP/ Level	1800 gpm* ES Elev	T7020	Offline	26	36	30	36	26	36	26	36
Railway Ave Fire Pump	5062	Level			Offline	15	18	15	18	15	18	15	18

* Southwest Booster Pump Station flows are as follows: 1200 at Maximum Day, 1400 gpm at Maximum Day CIP, 2000 gpm at Future Stage 1, and 2400 gpm at Future Stage 2.

* Railway Ave Pump Station Flows are as follows: 1800 gpm at Maximum Day, 1800 gpm at Maximum Day CIP, 2200 gpm at Future Stage 1, and 2800 at Future Stage 2.

(1) 1 MG tank to be operational based on pressure in the North Hill Pressure Zone

There are a few changes in operations for each scenario that should be noted.

1. The NAWS High Service Pump (HSP) control pressure was set at 142 psi based on the SCADA data available in 2013 from August 16 to August 23. This was the average pressure setting during this time frame. This control pressure was used for Maximum Day and Maximum Day CIP scenarios. It was increased from 143 psi in Future Stage 1 and to 147 psi in Future Stage 2. The ultimate design control pressure of the NAWS HSP is 150 psi. There is difficulty operating the Southwest Booster Pump Station when the pressure at the NAWS HSP is over 145 psi. If NAWS is pulling from both the North and South Meters the Southwest Booster Pump Station will operate with the NAWS HSP set at 147 psi. If NAWS is not pulling, the Southwest Booster Pump Station will only operate with NAWS HSP set at 145 psi. This is because the Southwest Booster Pump Station becomes unnecessary if the pressures are set at 150 psi. This issue will need to be readdressed when NAWS buildout is complete. At Future Stage 1, the maximum pumping rate is 9,200 gpm. During Future Stage 2, the maximum pumping rate is 10,300 gpm.

2. The City of Minot's High Service Pump (HSP) control pressure was set at 85 psi based on the SCADA data available in 2013 from August 16 to August 23. The control pressure ranged from 73 to 97 psi during this time frame. The average pressure during the time frame was 85 psi. This control pressure was used for Maximum Day and Maximum Day CIP scenarios. To maintain tank levels and pressure in the system, the control pressure had to be increased to 90 psi in Future Stage 1 and 92 psi in Future Stage 2. At Future Stage 1, the maximum pumping rate is 8,000 gpm. During Future Stage 2, the maximum pumping rate is 8,950 gpm. If all this projected demand comes online in Future Stage 2, the City HSP will be at maximum capacity.

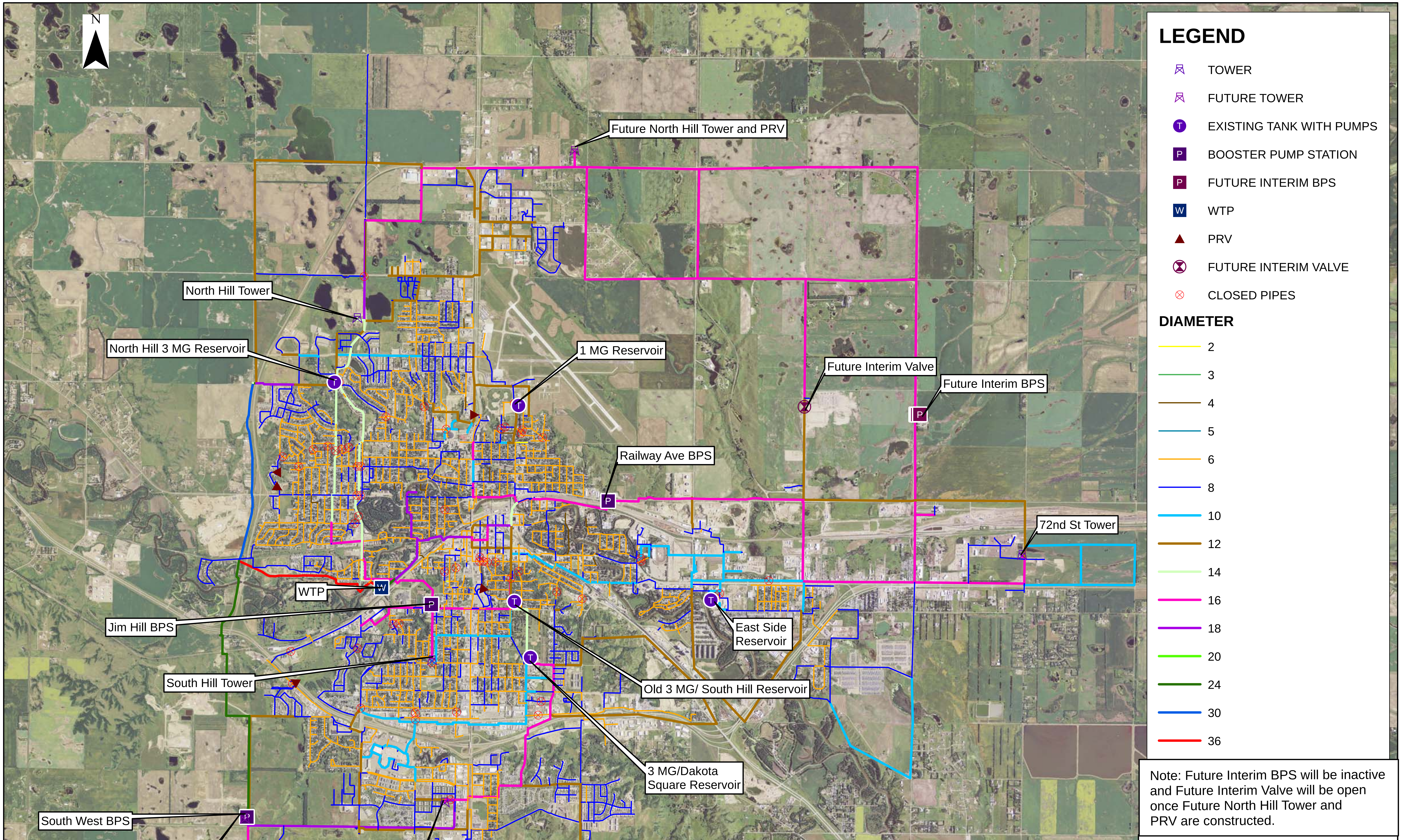
3. The Southwest Booster Pump Station (BPS) is controlled by flow and the tank level of the Dakota Square Tower. Based on SCADA data available, the average pumping rate was around 1200 gpm. This flow control was used for Maximum Day and Maximum Day CIP Scenarios. It was increased to 2,000 gpm to handle Future Stage 1 demand and 2,400 gpm for Future Stage 2 demand. The design point for this pump is only 2,000 gpm, so this may be an issue if all of the projected demand in Future Stage 2 comes on line. The level controls were also altered to ensure that the Dakota Square Tank recovered properly.

4. Dakota Square Pump operational controls were altered along with the Southwest BPS controls. During calibration and maximum day scenario, this tank was not recovering. The controls were adjusted to have the Southwest BPS operate more frequently to allow the Dakota Square Tank to recover properly.

5. The Railway BPS is controlled by flow and the tank level of the New 72nd St Tower. This pump station was not operational during calibration. The initial pumping rate for Maximum Day and Maximum Day CIP Scenarios is 1,800 gpm. This pumping rate was increased to 2,200 gpm in Future Stage 1 and 2,800 gpm in Future Stage 2.

6. The 1 MG reservoir on North Hill is currently manually operated. It fills over night, but there is really no control valve. To calibrate the system, controls had to be set based on time for this fill line. The control basically has the fill line open from 11 at night to 6 in the morning. It does not allow the ground storage to feed back into the system during the day. These controls were taken off for the Maximum Day CIP and Future Scenarios. The function of this fill line out in the field needs to be evaluated in more detail. The pumps were also turned on and off based on the SCADA data time. The pumps came on at 6:30 a.m. and turned off at 1:30 p.m. In the future models it is changed to operate off the pressure in the system.

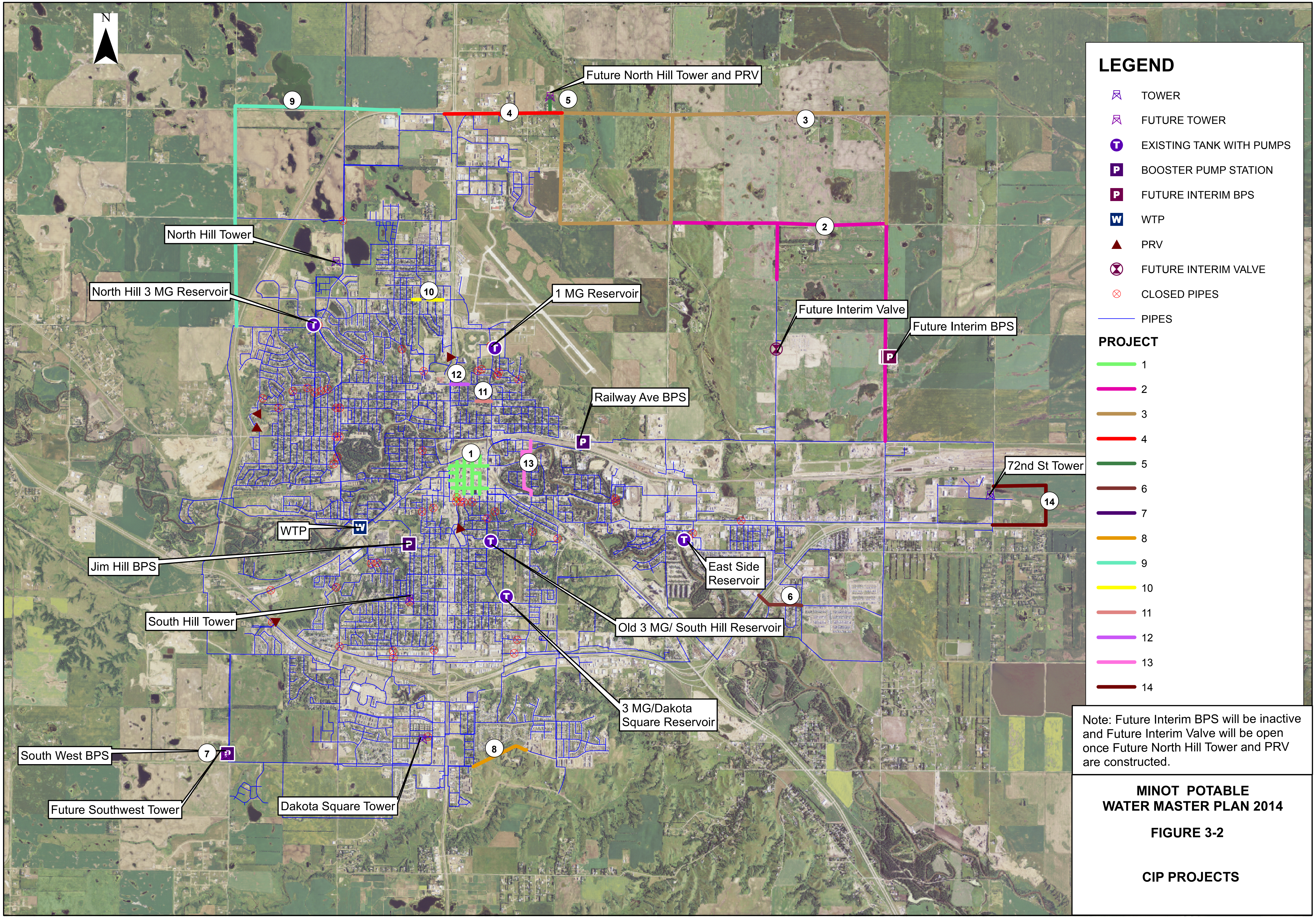
7. The final major change is the NAWS North Meter (V8008). Its current flow control setting is 1800 gpm. This is sufficient to handle up to Future Stage 1 demand, but it will need to be increased to 2,500 gpm to provide for Future Stage 2 demand.



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 3-1

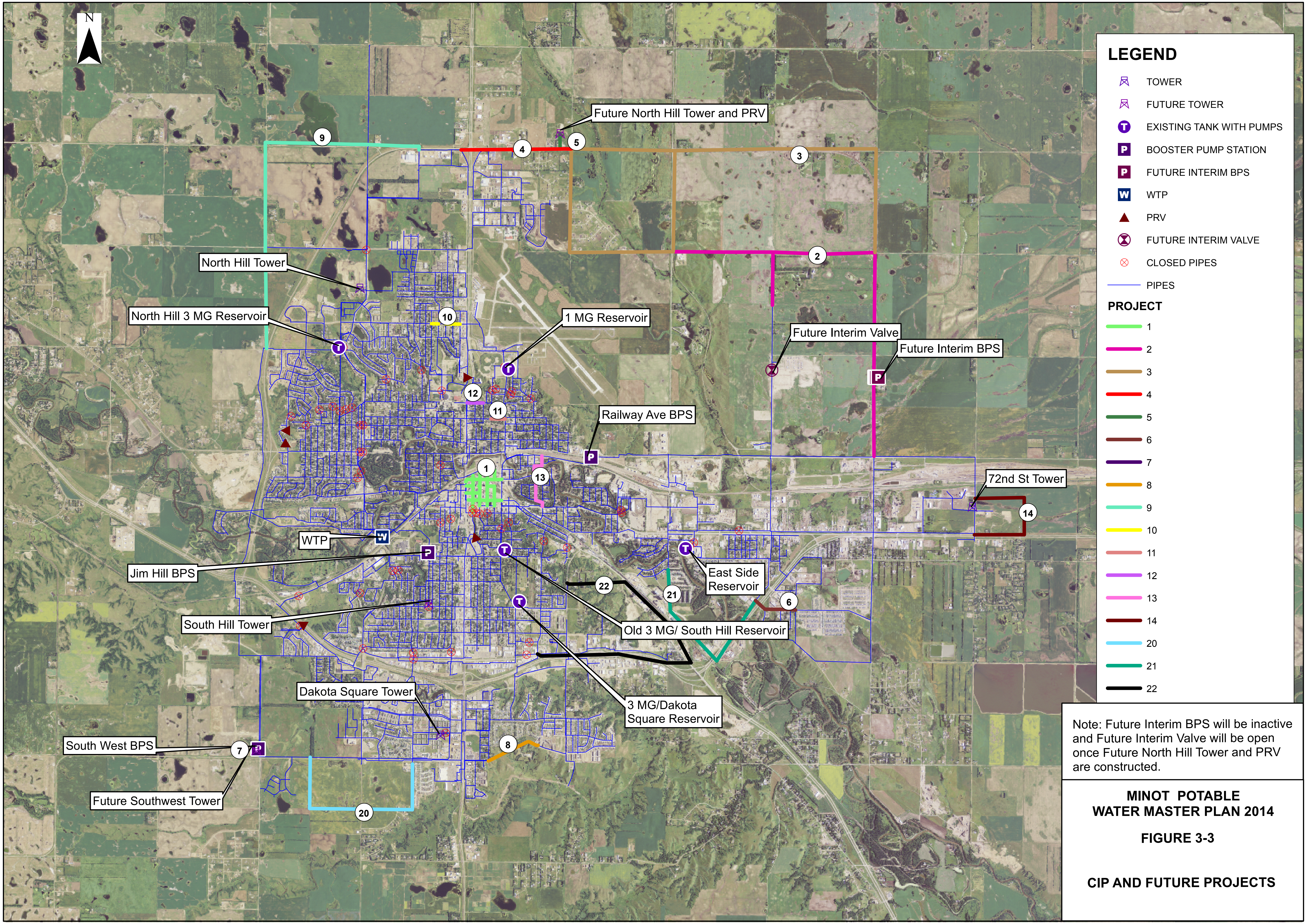
FUTURE WATER SYSTEM



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 3-2

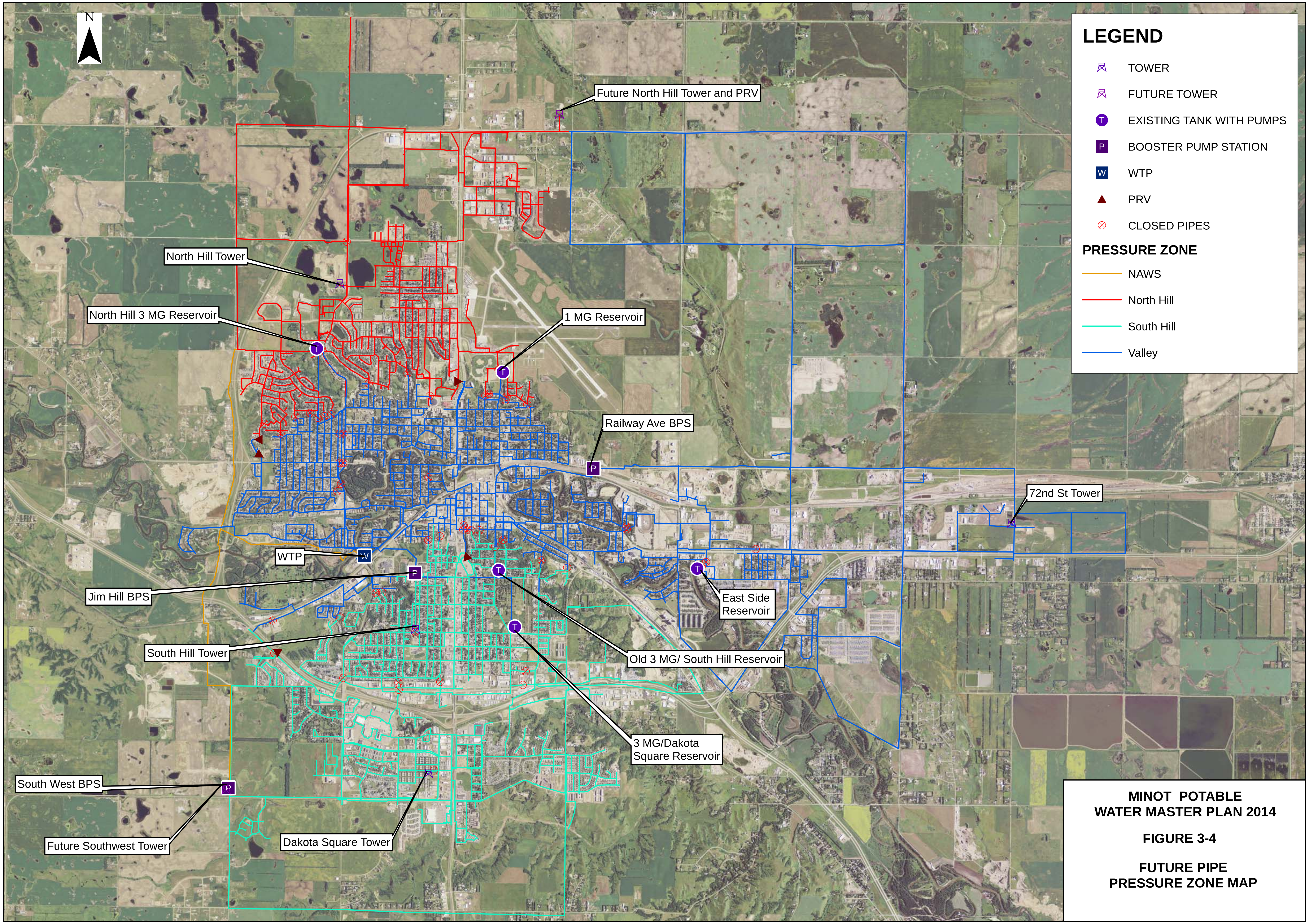
CIP PROJECTS



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 3-3

CIP AND FUTURE PROJECTS



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 3-4

FUTURE PIPE PRESSURE ZONE MAP

MWH
MONTGOMERY WATSON HARZA

To:	Dave Schwengler Houston Engineering	**Date:**	March 24, 2014
Subject:	Potable Water System Analysis		
From:	Gracelyn NeVille	**Job No:**	10503376

PURPOSE

This memorandum discusses the evaluation criteria used in analyzing the capacity and performance of the City of Minot's water distribution system facilities. This memorandum also discusses the results of the different scenarios run to analyze the system. The evaluation process identified deficiencies in the system (defined as those components that do not meet the performance criteria). The City of Minot's hydraulic model was utilized as the primary tool in performing the analysis.

CRITERIA DEVELOPMENT

The criteria covers capacity, operation, and reliability requirements for piping, pumping, and storage facilities. A summary of the criteria and associated references are provided in **Table 4-1**. The criteria herein are based on adopted State and local regulations, and industry standards. Where not otherwise established, criteria are based on best practices.

In the State of North Dakota, the design and construction of public drinking water systems is regulated by the North Dakota Department of Health (NDDH). The NDDH has adopted the "Ten-State Standards" to use as guidelines, with some modification [1]. In the discussions that follow, the performance criteria have been grouped by facility type:

- Pipe criteria – distribution network.
- Pumping criteria – supply and booster facilities.
- Storage criteria – ground and elevated facilities.

Pipes must have sufficient capacity to convey flows under each of the two demand conditions defined as:

- Peak Hour - the hour of peak demand usage on the Maximum Day.
- Fire Suppression - the average Maximum Day plus various fire flow requirements for fire suppression.

These two criteria were evaluated for Existing Maximum Day Demand Conditions, Existing Maximum Day Demand Conditions with CIP projects completed, Future Stage 1 Demand (68,000 people) with CIP projects completed, and Future Stage 2 (79,000 people) with CIP projects completed.

Table 4-1.
Design and Evaluation Criteria

Criteria	Value/Description	Reference
Diameter		
Required size	As calculated to serve the greater of: peak hourly flow or average of MDD + fire flow	[1] Articles 8.1.1, 8.1.2
Minimum size		
Serving hydrants	6 inches	[1] Articles 8.1.2
W/o hydrants	3 inches	[1] Articles 8.1.4
Fire Flow		
Residential		
1 and 2 family dwellings, two stories or less (for spacing between buildings of 11-30 ft.)	1000 gpm, 2 hours duration	[3] Section 340, 604
Residential (Multi-family)	2500 gpm, 2 hrs. duration	[3] Sections 300, 604
Commercial	3000 gpm, 3 hrs. duration	[3] Sections 300, 604
Industrial	4000 gpm, 4 hrs. duration	[3] Sections 300, 1100
Institutional	5000 gpm, 4 hrs. duration	[3] Sections 300, 1100
Pressure [at ground level]		
Normal operation	60 to 80 psi	[1] Articles 8.1.1
Maximum pressure	100 psi	[1] Articles 7.3.1
Minimum pressure		
Working pressure (peak hour)	35 psi	[1] Articles 8.1.1
All flow conditions (including fire flow)	20 psi	[1] Articles 8.1.1
Velocity		
Maximum operational		
Existing pipe	10 fps	[2] pp.39
Design pipe	5 fps	[2] pp.39
Minimum flushing	2.5 fps	[1] Article 8.1.6b
Headloss		
Maximum design rate, at peak hour flow conditions		
Pipe diameter < 16-inch	10 ft/ 1000 ft	[2] pp.39
Pipe diameter ≥ 16-inch	3 ft/ 1000 ft	[2] pp.39

Table 4-1. (Continued)
Design and Evaluation Criteria

Criteria	Value/Description	Reference
Reliability		
Distribution	Looping of dead-ends wherever practical	[1] Article 8.1.6a
Transmission	Two source feeds to all hydraulically isolated areas	
Valve Spacing		[1] Article 8.2
Commercial districts	Maximum of 500 feet	
Other districts	Maximum of 800 feet	
Widely scattered	Maximum of 1 mile	
Pumping Criteria	**Value/Description**	**Reference**
Capacity		
Required Flow	Equal to maximum pumping demand of the following 2 criteria. Pump to storage tanks (average of maximum day demand). If pump directly to distribution (greater of peak hourly flow or average of MDD + fire flow).	[1] Article 6.3
Reliability		
Equipment	Firm capacity (sufficient to deliver minimum capacity with largest pump out of service). Minimum of 2 pumps.	[1] Article 6.3
Power	Electric pumps must have at least two different power sources or emergency generator	[1] Article 6.6.6
Operation		
Minimum pressures (booster pumps)		
Pump intake	20 psi	[1] Article 6.4
Suction line	10 psi	[1] Article 6.4
Storage Criteria	**Value/Description**	**Reference**
Capacity		
Fire protection storage	1,200,000 gallons (5000 gpm x 4 hour duration)	[3] Section 611A
Operational storage (minimum)	Volume of Maximum Day Diurnal Curve above Average Maximum Day Demand	
Emergency storage	Average Day Demand For Four Hours	
Total Required	Sum of Operational, Emergency, and Fire Protection Requirements	
Operation		
Maximum level range (elevated storage)	30 feet	[1] Article 7.3.1

PIPE NETWORK

Pipe criteria include diameter, flow rate, pressure, velocity, headloss, and reliability.

Diameter

The criteria for pipe diameter is based on peak domestic flow, fire flow and pressure requirements of hydraulic analysis as well as other hydraulic criteria. In addition, minimum diameter requirements have been established by the Ten-State Standards. Article 8.2.2 states: “The minimum size of water main for providing fire protection and serving fire hydrants shall be six inches in diameter”. The minimum size of water main in the distribution system where fire protection is not to be provided should be a minimum of three (3) inches in diameter” [1].

The City of Minot has adopted a minimum diameter of eight (8) inches for new construction or replacement. Currently, all pipes with a diameter 6 inches or less requiring replacement or repair are replaced with 8-inch diameter pipe.

Flowrate

Pipes must have sufficient capacity to convey flows under peak hour water demand conditions. This requirement also applies to sizing of proposed pipe and other distribution system improvements. Current peak hour demand conditions were determined from recent water system operation records.

Pipe capacity was also evaluated under fire flow demand. The Ten-State Standards refer to the Insurance Service Office (ISO), Fire Suppression Rating Schedule for determination of fire flow requirements [1]. According to the Fire Suppression Rating Schedule, fire flow conditions include average of maximum day domestic demands plus “Needed Fire Flow” [3]. Maximum Day Demand was calculated from recent water production records. Because needed fire flow for each customer in the distribution system is not available, typical fire flow values for each of land use will be used for evaluation. These values were established based on ISO requirements. Categories include residential, commercial, industrial, and institutional. Fire flow duration will also be based on Fire Suppression Rating Schedule requirements. Fire flow and duration assigned to each land-use category are summarized in **Table 4-1**.

Pressure

Pressure criteria include maximum, minimum and fire flow requirements. Under normal operation, pressures should range between 60 and 80 psi at ground level. It should be noted that all pressures indicated are at ground elevation, and not at the elevation of the pipe.

Maximum distribution system pressure is dictated by the pressure class of pipe and other appurtenances in the distribution system. Static pressure above 100 psi is not advisable because of the increased leakage rate, an increased risk of pipe failure and the required installation of pressure reducing valves on distribution mains or on service connections. [1]

A minimum distribution system pressure is required to avoid customer complaints and prevent contamination from backflow. The Ten-State Standards require that a minimum pressure of 20 psi, measured at ground level, be maintained at all points in the distribution system under all conditions of flow [1]. The minimum pressure of 20 psi occurs only during fire flow conditions (i.e. residual pressure). However, a minimum of 35 psi is required during peak hour operations to avoid customer complaints. [1]

The minimum pressure during maximum day conditions are shown on **Figures 4-2, 4-6, 4-10, and 4-14** show the maximum velocity for the Existing Maximum Day Demand Conditions, Existing Maximum Day Demand Conditions with CIP projects completed, Future Stage 1 Demand (68,000 people) with CIP projects completed, and Future Stage 2 (79,000 people) with CIP projects completed. The junctions that do not meet the required 35 psi during peak hour conditions in the existing maximum day scenario are shown in **Table 4-2.** The pressures at these junctions are also shown for the three scenarios after the CIP projects are completed.

Table 4-2. Minimum System Pressures During Peak Hour Conditions

			Max Day	Max Day CIP	Future Stage 1	Future Stage 2
Model	Description	Elev	Min Press	Min Press	Min Press	Min Press
ID		ft	psi	psi	psi	psi
J7684	PZ Boundary 2nd St NW & Broadway	1671	19	29	30	28
3026	PZ Boundary 1st NE & 13th Ave NE	1660	24	36	35	34
1754	Dead End 2nd St SE & 5th Ave SE	1666	24	34	36	34
2498	Dead End 7th St NW & 13th Ave NW	1660	26	34	35	33
2464	Dead End 7th St NW & 13th Ave NW	1659	26	34	35	34
3008	PZ Boundary 6th St NE & Hill Crest Dr	1651	27	38	38	36
2024	PZ Boundary 2nd St NW & Broadway	1652	27	38	39	37
766	PZ Boundary 18th St SW & Trailer Park Rd	1657	28	37	40	41
1500	PZ Boundary 6th St SW & 6th Ave SW	1662	28	36	38	37
3012	PZ Boundary 6th St NE & Hill Crest Dr	1645	30	42	42	40
4002	PZ Boundary 1st NE & 13th Ave NE	1645	30	42	42	40
J7286	PZ Boundary 2nd St NW & Broadway	1646	30	40	41	39
778	PZ Boundary 18th St SW & Trailer Park Rd	1653	30	39	42	43
J7682	PZ Boundary 2nd St NW & Broadway	1645	30	41	42	40
J7282	PZ Boundary 2nd St NW & Broadway	1644	31	41	42	40
J7280	PZ Boundary 2nd St NW & Broadway	1644	31	41	42	40
1772	PZ Boundary 6th St SW & 6th Ave SW	1650	31	40	42	40
1770	PZ Boundary 6th St SW & 6th Ave SW	1649	31	40	42	41
2806	PZ Boundary 15th Ave NW & 13th ST NW	1650	31	38	39	38
3010	PZ Boundary 6th St NE & Hill Crest Dr	1641	32	42	43	41
1440	PZ Boundary Main St & 5th Ave SW	1648	32	42	43	42
3046	PZ Boundary 6th St NE & Hill Crest Dr	1639	32	43	44	42
J7284	PZ Boundary 2nd St NW & Broadway	1640	32	43	44	42
2804	PZ Boundary 15th Ave NW & 13th ST NW	1646	33	40	41	40
772	PZ Boundary 18th St SW & Trailer Park Rd	1645	33	42	45	46
J7274	PZ Boundary 2nd St NW & Broadway	1638	33	44	45	43
1522	Dead End 6th St SW & 6th Ave SW	1649	34	42	44	43
1710	PZ Boundary 4th St SE	1643	34	43	45	43
1762	Dead End 7th Ave SE	1642	34	43	45	44
3048	PZ Boundary 6th St NE & Hill Crest Dr	1634	34	45	46	44

The **Figures** and **Table 4-2** show that the CIP projects eliminate most of the low pressure areas**.** J7684 is only one junction that never meets a minimum pressure of 35 psi or greater in any of the scenarios. This is a dead end at a pressure zone boundary at 2nd

Street NW & Broadway. There are four other junctions that are just below the minimum pressure of 35 psi depending on the scenario and changing operations and the actual demand on the system.

Fire Flow

The system is required to maintain 20 psi at each fire hydrant with the average of maximum day demand plus required fire flow. **Table 4-1** shows the fire flow placed on the system for each use type. The majority of the system is residential and is required to maintain a fire flow of 1,000 gpm for 2 hours. The fire flow is the critical part of the analysis and would result in the recommendation of replacement of many of the pipes 6 inches and smaller, especially in areas that are zoned other than residential. Although some general changes were made to correct fire flow, 6 inch pipe replacement or upgrade throughout the system was not recommended as part of the CIP. Therefore, there are still fire flow issues throughout the system. The residual pressure are shown on **Figures 4-3, 4-7, 4-11, and 4-15** for the Existing Maximum Day Demand Conditions, Existing Maximum Day Demand Conditions with CIP projects completed, Future Stage 1 Demand (68,000 people) with CIP projects completed, and Future Stage 2 (79,000 people) with CIP projects completed.

Many of the areas are capable of providing the minimum 1,000 gpm for 2 hours requirement, but not the required higher flow based on land-use. **Figures 4-4, 4-8, 4-12, and 4-16** show the available flow for each fire flow junction for each scenario. The junctions that do not meet the required 20 psi residual pressure at the target fire flow are included in **Appendix B.** The existing maximum day model shows there are 462 fire flow nodes out of 2,340 fire flow nodes that do not meet the required 20 psi residual pressure. There are 185 nodes that are not able to provide 1,000 gpm with a 20 psi residual. Even after all the CIP projects are completed, there are still 361 fire flow nodes that do not meet the required 20 psi residual pressure and 160 nodes that are not able to provide 1000 gpm.

Most of the deficiencies are due to having 40% of the system as 6 inches and smaller cast iron pipe that was installed before 1960. As construction projects are completed where cast iron pipe is in place, these pipes should be replaced with minimum 8 inch PVC pipe.

Velocity

There are no regulations governing the maximum velocity of flow in pipes (other than a minimum target velocity of 2.5 fps when flushing is performed). Criteria for evaluation and design are provided by way of recommendation rather than requirement. For evaluation of existing pipes, a maximum velocity of 10 fps under peak hour flow conditions is recommended. For design or sizing of recommended pipe improvements, a maximum velocity of 5 fps under peak hour flow conditions is suggested. By maintaining pipe velocities below 5 fps, the system can in most cases avoid the necessity of surge protection devices [2].

Figures 4-1, 4-5, 4-9, and 4-13 show the maximum velocity for the Existing Maximum Day Demand Conditions, Existing Maximum Day Demand Conditions with CIP projects completed, Future Stage 1 Demand (68,000 people) with CIP projects completed, and Future Stage 2 (79,000 people) with CIP projects completed. **Table 4-3** shows areas that have velocities greater than 5 fps in any of the four scenarios analyzed.

Table 4-3. Maximum Velocity During Peak Hour Conditions

		Max Day	Max Day CIP	Future Stage 1	Future Stage 2
Model	Description	Max Vel	Max Vel	Max Vel	Max Vel
ID		fps	fps	fps	fps
3093	6" Along 27th St NW from 10th Ave NW to 27th Ct NW	6.66	0.24	0.24	0.24
9003D	PRV-27th St NW & 5th Ave NW (62 psi)	6.49	0	0	0
5055	14" Supply line to Dakota Square Tank	6.14	3.05	2.81	2.84
1895	12" Downtown on 2nd Ave SW	6.08	1.94	2.15	2.54
1125	10" South Hill Tower	5.45	5.96	4.11	3.78
P328	8" from 27th St SE to 4th Ave SE South of Railway Ave	5.35	4.64	3.54	4.09
4601	14" North Hill Tower	2.7	5.97	5.97	6.02
4653	12" North Hill BPS Discharge	2.98	5.56	5.92	5.93

Table 4-3 shows that there are really only 8 areas that see velocities over 5 fps. All the higher velocities in the distribution piping were corrected with the proposed CIP projects.

Headloss

As with velocity, headloss criteria are suggested as indicators of sufficient capacity and energy efficiency. It is recommended that a maximum design headloss rate of 10 ft./1,000 ft. under peak hour flow conditions be used for pipes less than 16 inches in diameter. For pipes 16 inches and greater diameter, a headloss rate of 3 ft./1,000 ft. is recommended [2].

Reliability

[1]. The Ten-State Standards suggests that all hydraulically isolated areas should be provided with two or more feed sources [1].

There are at least two feed sources to each of the three Pressure Zones in the area. The North Hill Pressure Zone has water being supplied by the North Hill 3 MG Reservoir pump station to the North Hill Tower with the 1 MG Reservoir pump station supplementing the pressure in this Zone. The South Hill Pressure Zone has two elevated tanks, the South Hill Tower and the Dakota Square Tower. Each of these towers has two supply lines. The Jim Hill Booster Pump Station and the South Hill Reservoir supply water to the South Hill Pump Station. The Southwest Booster Pump Station and the Dakota Square Pump Station provide water to the Dakota Square Tower. The newly constructed 72nd St Tower is only fed by the Railway Ave BPS.

As part of the CIP projects, the 72nd St Tower will also be able to be fed from the North Hill Zone through a new PRV located at 46th Ave NE and 13th Street NE. There would also be an additional Tower constructed in the North Hill Zone and an additional Tower constructed in the South Hill Zone. These improvements will add to the redundancy and reliability of the system.

Valve spacing will not be analyzed as part of this project. However, valve spacing requirements are provided herein for reference. In general, sufficient valves should be provided on water mains to minimize inconvenience and sanitary hazard during repairs. Ten States Standards requires valves to be spaced at no more than 500 foot intervals in commercial districts and at not more than one block or 800 foot intervals in other districts. Where systems serve widely scattered customers, valve spacing should not exceed one mile. Auxiliary valves must also be installed on all hydrant leads [1].

The majority of the system is looped except at pressure zone boundaries and cul-de-sacs. One way to improve reliability is to make sure the PRV's are operational and to adjust pressure settings so that they operate during emergency conditions (if pressure falls below a certain pressure).

PUMPING CRITERIA

Capacity

All pump stations should have sufficient capacity to supply peak water demands without dangerous overloading (within safe operating range of the pump) [1]. This is usually the average of maximum day water demand for supply pumps delivering to storage facilities. For pumps delivering to the distribution system this is either peak domestic flow or the average of maximum day flow plus fire flow, whichever is greater.

The pump stations are capable of supplying sufficient capacity for maximum day water demand. It is assumed that the peak hour demand and fire flow will be supplied by the storage facilities. Since there is currently only one feed line to the 72nd St Tower, the Railway Avenue BPS is equipped with a fire pump that will operate during fire conditions as necessary.

It should be noted if all the projected demand in Future Stage 2 (79,000 people) is experienced, that the WTP City High Service Pumps and the Southwest Booster Pump Station will be pumping at maximum capacity.

Reliability

All pump stations must be equipped with at least two pumps. The pump station must be able to provide a firm capacity, or the maximum pumping demand with the largest of the pumps out of service [1].

Power for each electrically driven pump station shall be supplied from at least two independent sources. As recommended by Ten State Standards, one power source may be from a standby or an auxiliary source such as an emergency generator [1].

All Pump Stations are equipped with at least two pumps. Most pump stations also have power redundancy in the form of a generator to provide power in during a line-loss event, the exceptions to this being the South Hill Pump Station, Dakota Square Pump station and the North Hill Pump Station supplied by the North Hill 1MG Ground Reservoir.

Operation

In-line booster pumps shall be located or controlled so that they do not produce an intake pressure of less than 20 psi under normal operating conditions, nor suction line pressures of less than 10 psi [1].

The inline booster pump stations all have suction line pressure greater than 20 psi.

STORAGE CRITERIA

Capacity

Storage capacity requirements include provisions for operations, fire and emergencies. Only those portions of clearwells at water treatment facilities not required to achieve the necessary disinfection contact time may be considered in calculating storage capacity [1]. The capacity of storage tanks not required for backwash or process water at the treatment facilities will also be considered for fire, operational, and emergency capacity.

Fire

Fire storage capacity must, at a minimum, be equal to the water volume required to serve the largest needed fire flow for the required fire flow duration. For the City of Minot, this is equal to 5,000 gpm for a duration of 4 hours, or 1,200,000 gallons. Fire storage capacity should be evaluated at the minimum storage level under average daily demand conditions. Fire storage capacity can only be counted for hydrants or points of delivery where it is hydraulically available at the minimum pressure for the required fire flow duration. Where ground level storage is to be used as fire storage, only the volume that can be delivered by the pumps during the fire flow duration can be counted [3].

Operational

Operational storage requirements are calculated based on the diurnal water use records of the maximum day. As planning or design criteria for future storage capacity requirements, the same current maximum day diurnal curve should be applied to the projected maximum day water use of the planning horizon. Elevated storage, which is not hydraulically available to the distribution system under normal operating conditions, cannot be counted as operational storage [1].

The maximum day diurnal curve was plotted along with a line equal to the average of maximum day demand. The operational storage requirement for each Zone was then calculated by determining the area between the diurnal curve and the average demand line. This area is equivalent to the storage volume required to supply peak demands without emptying the storage tanks.

Operational Storage did not include storage required for the NAWS system, the MAFB system, or the NPRWD system. These entities are required to provide their own water storage facilities.

Emergency
The emergency storage requirement was established as the average daily demand for duration of 4 hours. Emergency storage did not include storage required for the NAWS system, the MAFB system, or the NPRWD system. These entities are required to provide their own water storage facilities.

Table 4-4 shows the required storage and the available storage for each zone and then as a total system. The available storage from the reservoirs in the Valley Zone up to the North Hill Zone or the South Hill Zone was based on the pump station capacity at each reservoir assuming that one pump was standby and would not be operational at each facility. These pumps were assumed to operate for the four hour duration of the fire flow.

Table 4-4. Storage Analysis

	North Hill	South Hill	Valley	Total
	(gal)	(gal)	(gal)	(gal)
Existing Required Storage				
Fire Storage (4 hours at 5,000 gpm)	1,200,000	1,200,000	1,200,000	1,200,000
Operational Storage	212,662	422,451	508,099	1,143,212
Emergency Storage (4 hours at average day demand)	199,885	404,308	486,277	1,090,470
Total	**1,612,547**	**2,026,759**	**2,194,376**	**3,433,681**
Future Stage 1 Required Storage				
Fire Storage (4 hours at 5,000 gpm)	1,200,000	1,200,000	1,200,000	1,200,000
Operational Storage	397,358	606,863	725,883	1,730,104
Emergency Storage (4 hours at average day demand)	376,246	580,800	694,708	1,651,754
Total	**1,973,604**	**2,387,663**	**2,620,590**	**4,581,858**
Future Stage 2 Required Storage				
Fire Storage (4 hours at 5,000 gpm)	1,200,000	1,200,000	1,200,000	1,200,000
Operational Storage	493,357	738,614	779,509	2,011,480
Emergency Storage (4 hours at average day demand)	475,754	706,892	746,031	1,928,677
Total	**2,169,111**	**2,645,506**	**2,725,540**	**5,140,157**

Available Storage per Zone				
	North Hill	**South Hill**	**Valley**	**Total**
	Available Storage	Available Storage	Available Storage	Available Storage
Storage Tank	(gallons)	(gallons)	(gallons)	(gallons)
South Hill Pumps (Old 3 MG Reservoir)		100,000	2,900,000	3,000,000
North Hill 3 MG Reservoir	800,000		2,200,000	3,000,000
1 MG Reservoir	100,000		900,000	1,000,000
Dakota Square Reservoir (New 3 MG Reservoir)		600,000	2,400,000	3,000,000
East Side Reservoir			0	0
Dakota Square Tower		500,000	0	500,000
South Hill Tower		500,000	0	500,000
North Hill Tower	500,000		0	500,000
East Side Tower			1,000,000	1,000,000
Total Existing Storage	**1,400,000**	**1,700,000**	**9,400,000**	**12,500,000**
New North Hill Tower	1,000,000			1,000,000
New South Hill Tower		1,000,000		1,000,000
Total Future Storage	**2,400,000**	**2,700,000**	**9,400,000**	**14,500,000**

Table 4-4 shows that the North Hill Zone and South Hill Zone are required to have new elevated tanks constructed to meet the storage required to meet operational storage, emergency storage, and fire flow storage. A one million gallon storage tank should be constructed in each Zone in order to provide adequate storage for existing and build-out demand on the system.

Operation

The maximum operating level range is recommended for elevated storage, and is provided as a planning or design criteria. The maximum variation between high and low levels in elevated tanks should not exceed 30 feet [1].

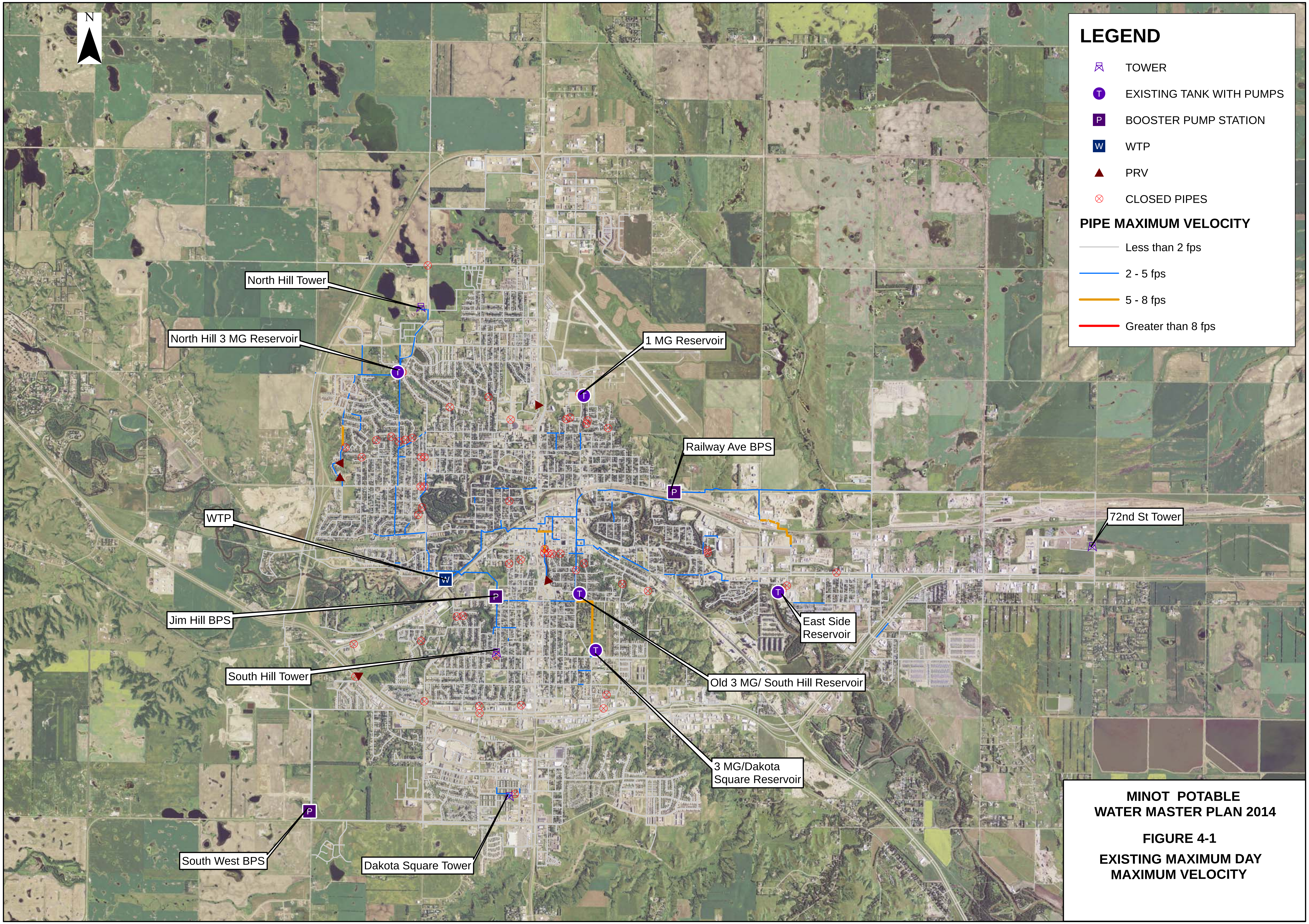
All tanks within the system meet this requirement.

REFERENCES

1. Great Lakes Upper Mississippi River Board of State Public Health & Environmental Managers. Recommended Standards for Water Works, 2002 Edition, pp. 79-117.

2. American Water Works Association. Manual of Water Supply Practices, Distribution Network Analysis for Water Utilities, AWWA Manual M32, First Edition, 1989, pp. 39.

3. Insurance Services Office, Inc. Fire Suppression Rating Schedule, August 1998, pp. 10 & 32.



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 4-1

EXISTING MAXIMUM DAY MAXIMUM VELOCITY

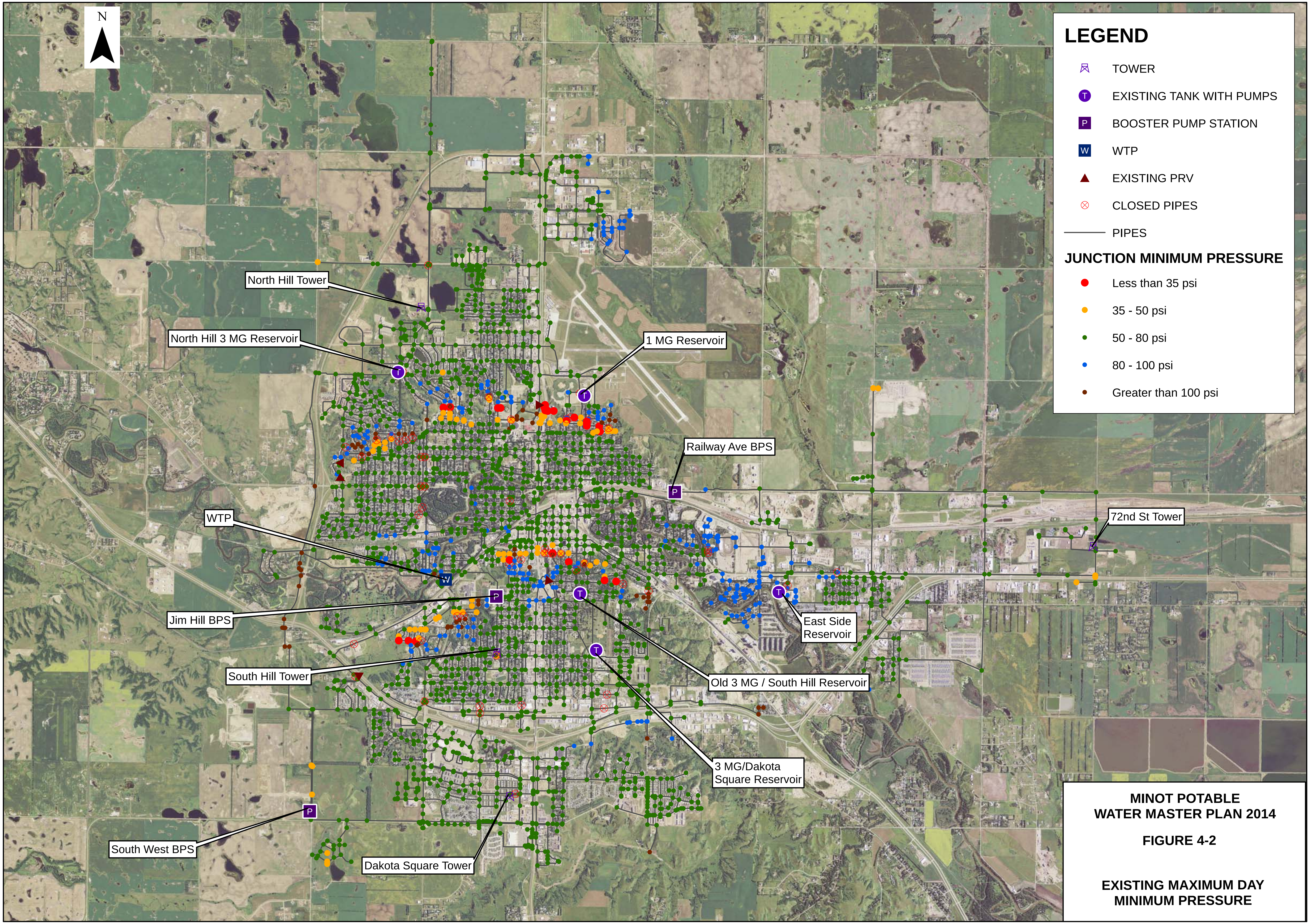


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FIGURE 4-2

EXISTING MAXIMUM DAY MINIMUM PRESSURE

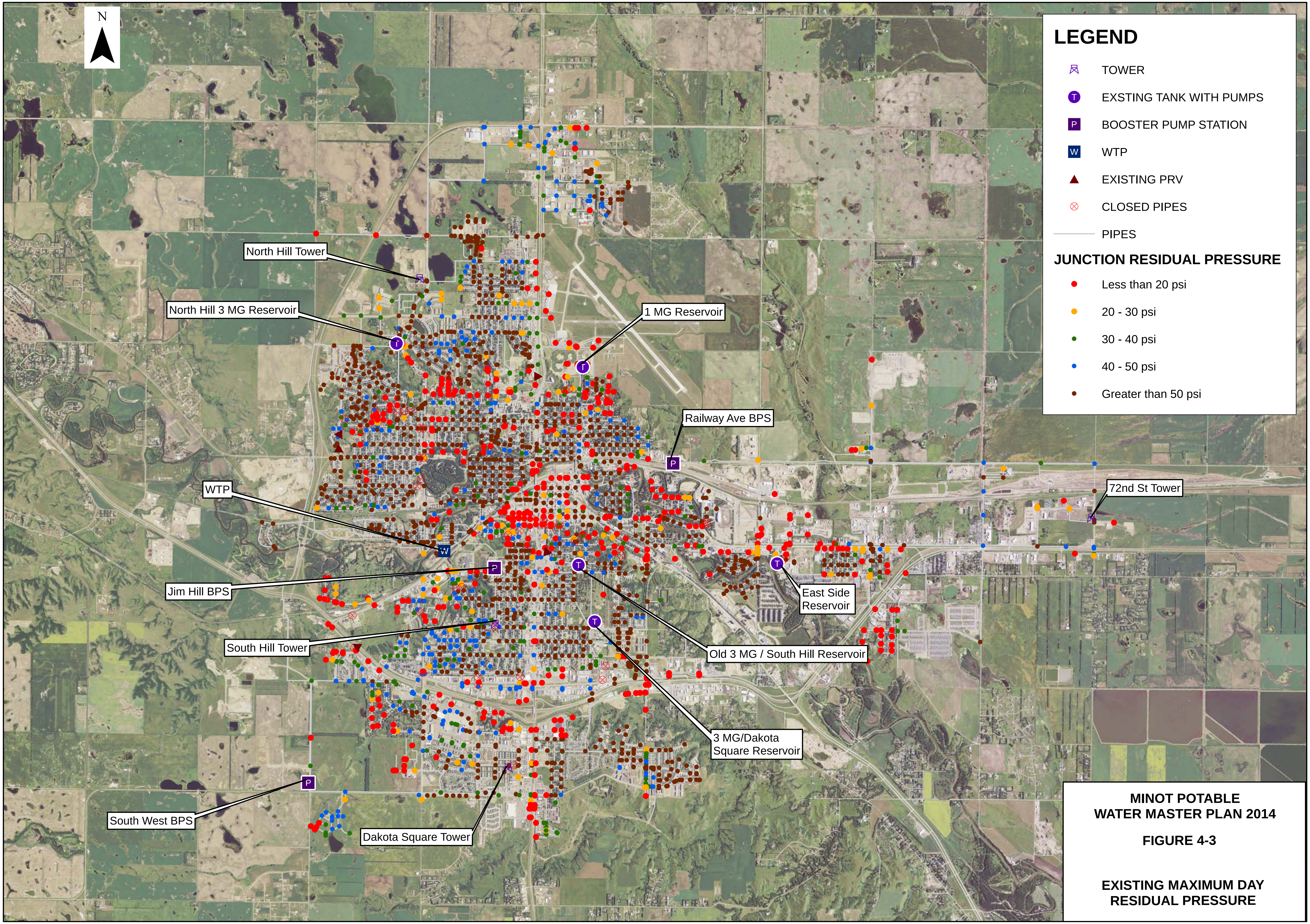

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FIGURE 4-3

EXISTING MAXIMUM DAY RESIDUAL PRESSURE

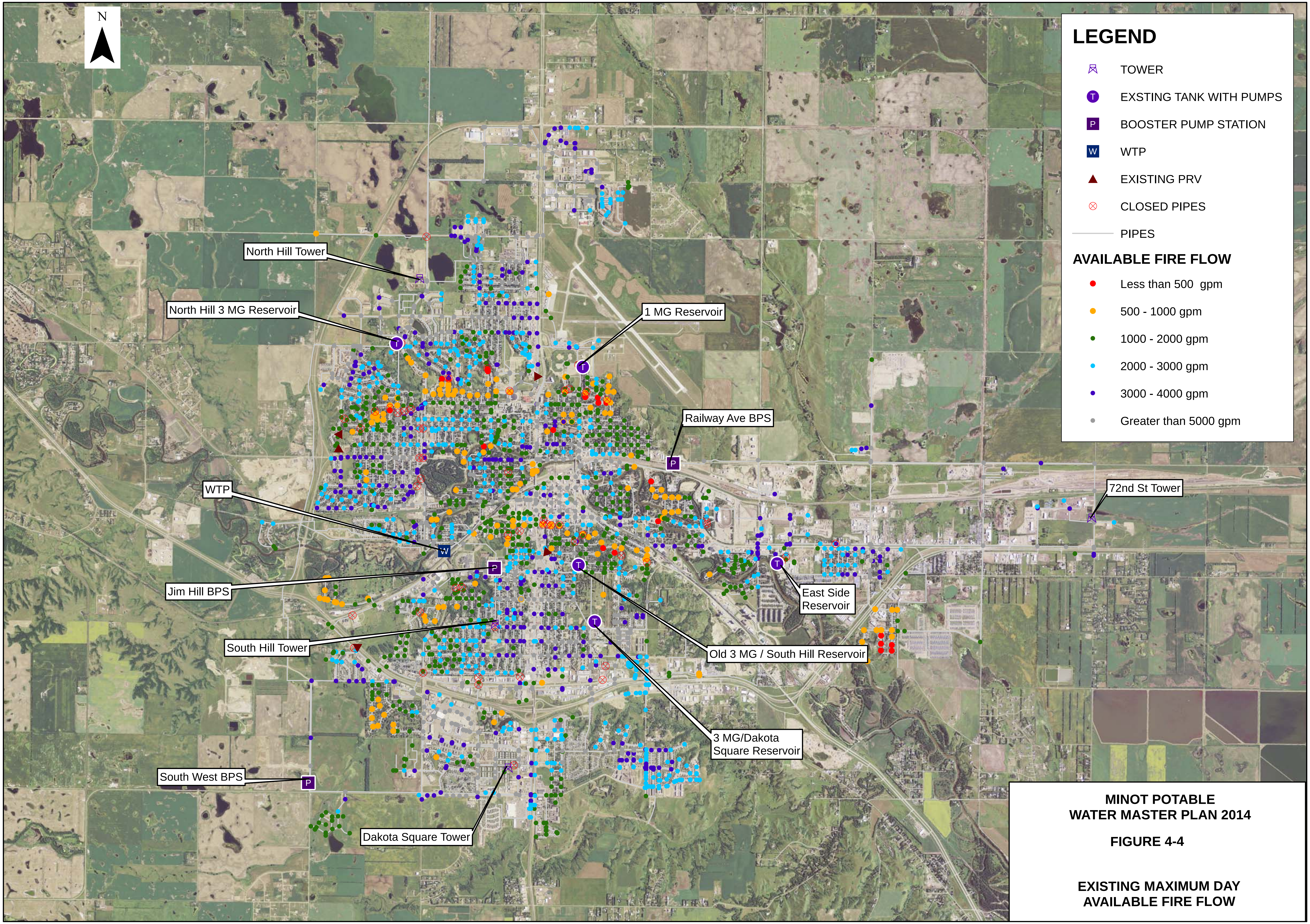

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FIGURE 4-4

EXISTING MAXIMUM DAY AVAILABLE FIRE FLOW

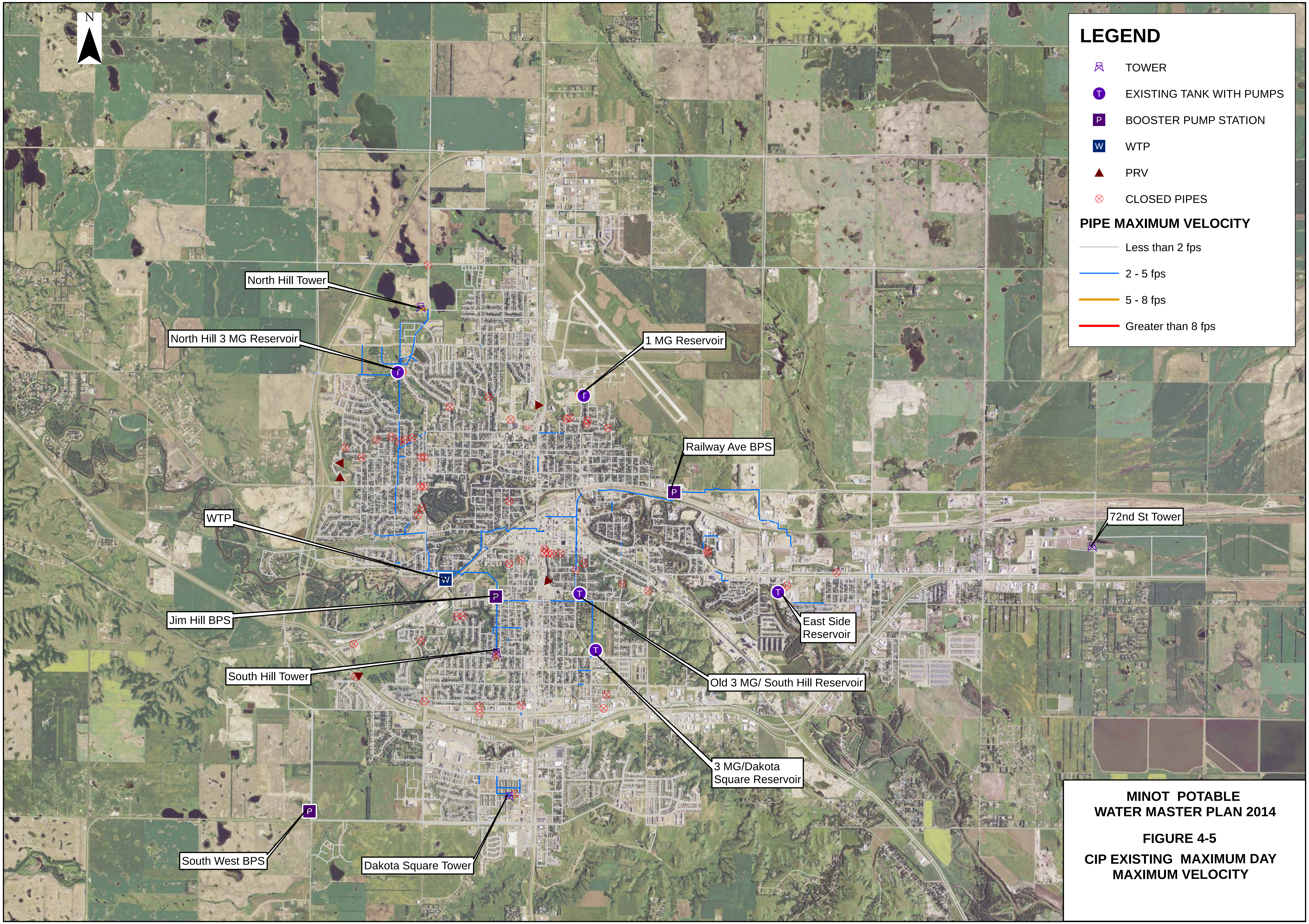

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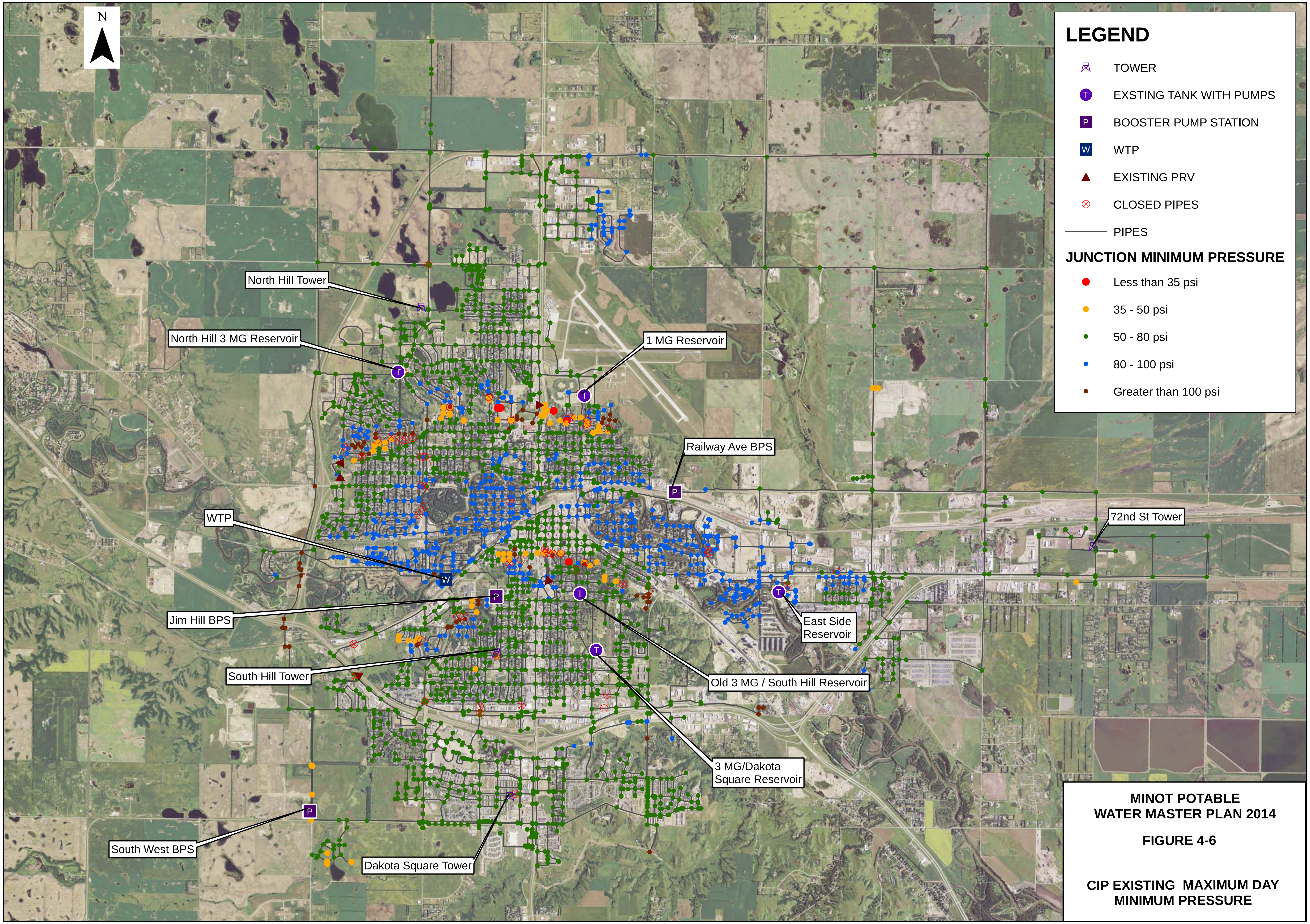
FIGURE 4-5

CIP EXISTING MAXIMUM DAY MAXIMUM VELOCITY



MINOT POTABLE
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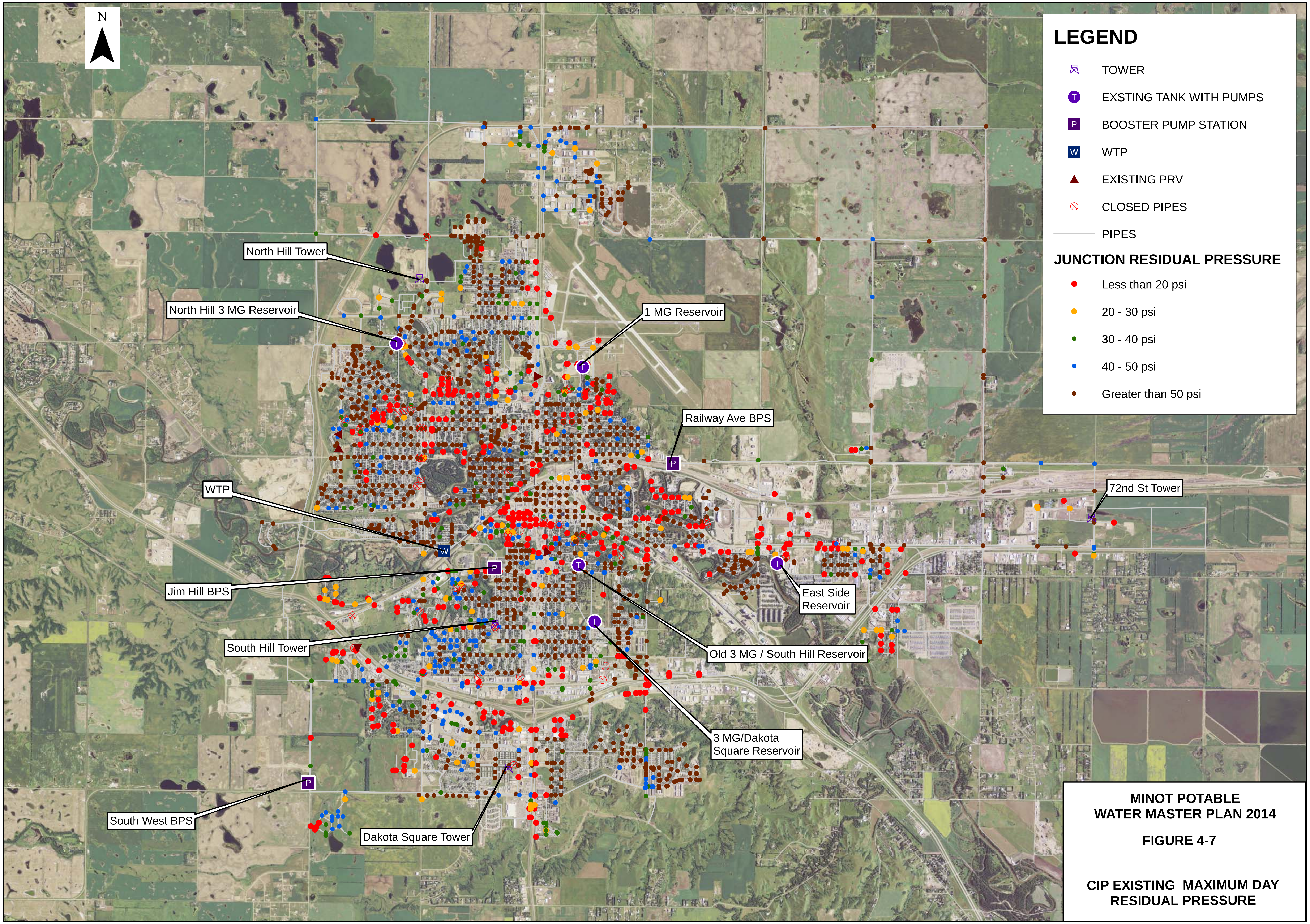
FIGURE 4-6

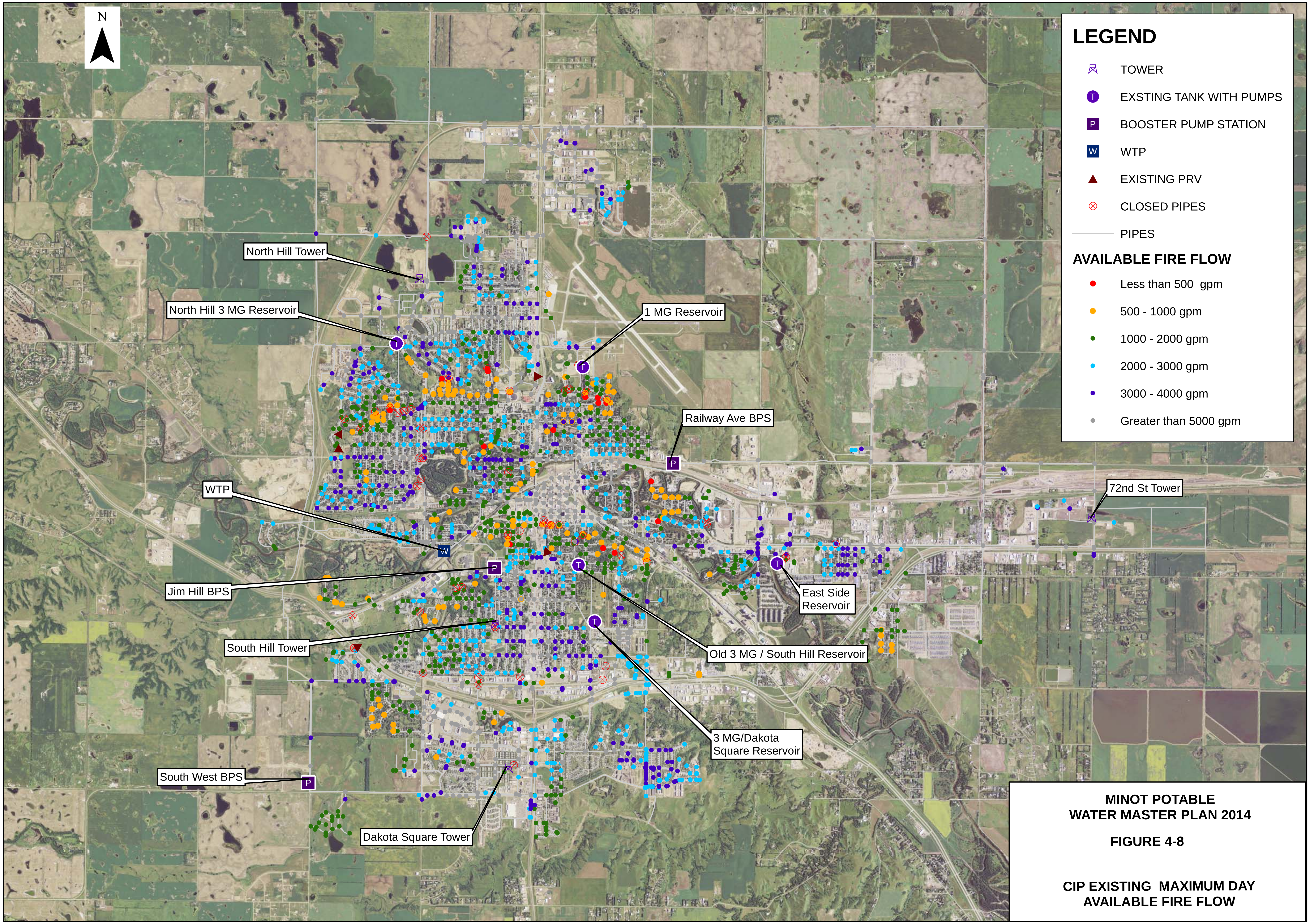
CIP EXISTING MAXIMUM DAY
MINIMUM PRESSURE



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 4-7

CIP EXISTING MAXIMUM DAY RESIDUAL PRESSURE


N
LEGEND
TOWER
EXSTING TANK WITH PUMPS
BOOSTER PUMP STATION
WTP
EXISTING PRV
CLOSED PIPES
PIPES
AVAILABLE FIRE FLOW
Less than 500 gpm
500 - 1000 gpm
1000 - 2000 gpm
2000 - 3000 gpm
3000 - 4000 gpm
Greater than 5000 gpm
North Hill Tower
North Hill 3 MG Reservoir
1 MG Reservoir
Railway Ave BPS
72nd St Tower
WTP
Jim Hill BPS
East Side Reservoir
South Hill Tower
Old 3 MG / South Hill Reservoir
3 MG/Dakota Square Reservoir
South West BPS
Dakota Square Tower
MINOT POTABLE WATER MASTER PLAN 2014
FIGURE 4-8
CIP EXISTING MAXIMUM DAY AVAILABLE FIRE FLOW

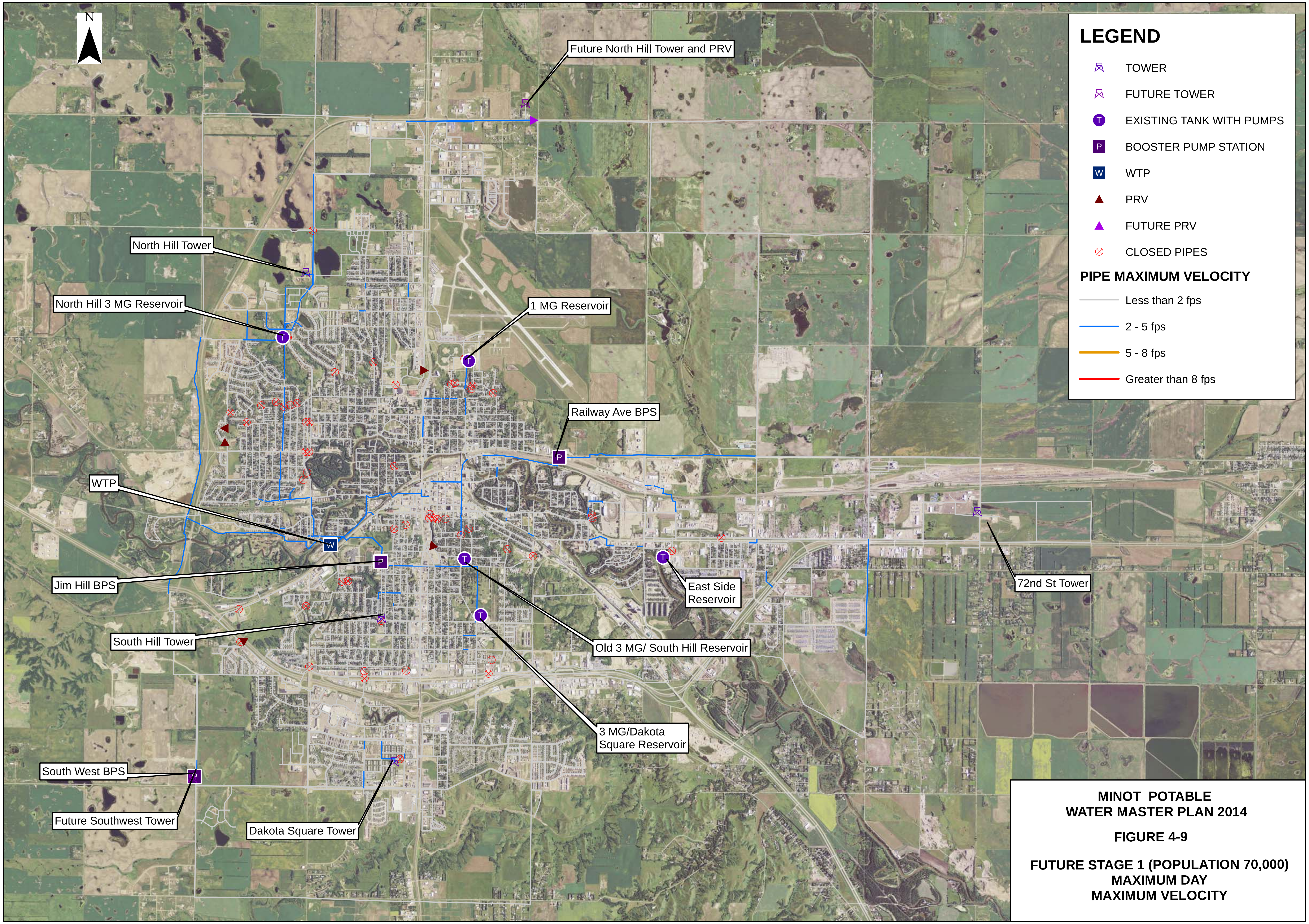


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FIGURE 4-9

FUTURE STAGE 1 (POPULATION 70,000)
MAXIMUM DAY
MAXIMUM VELOCITY

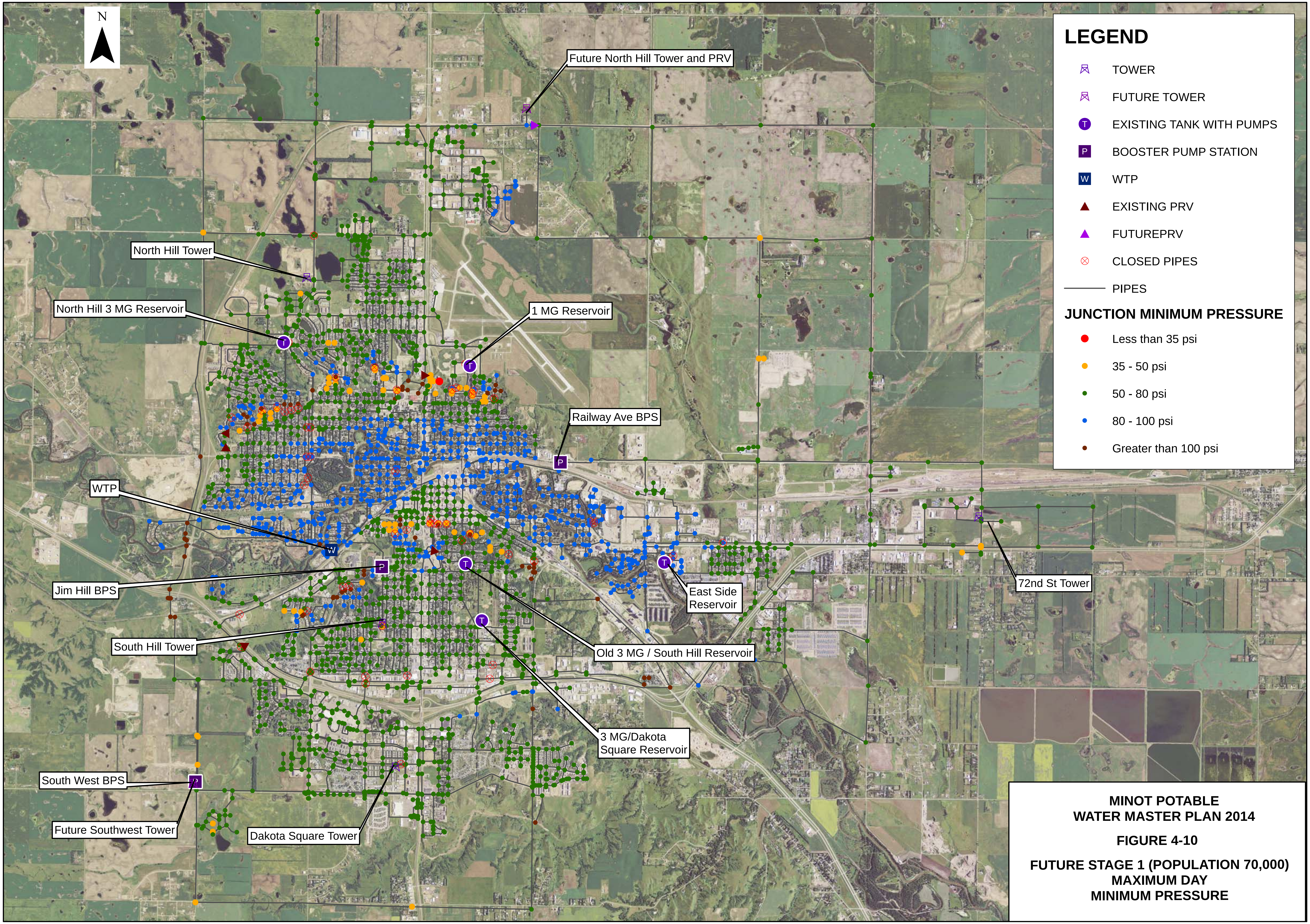

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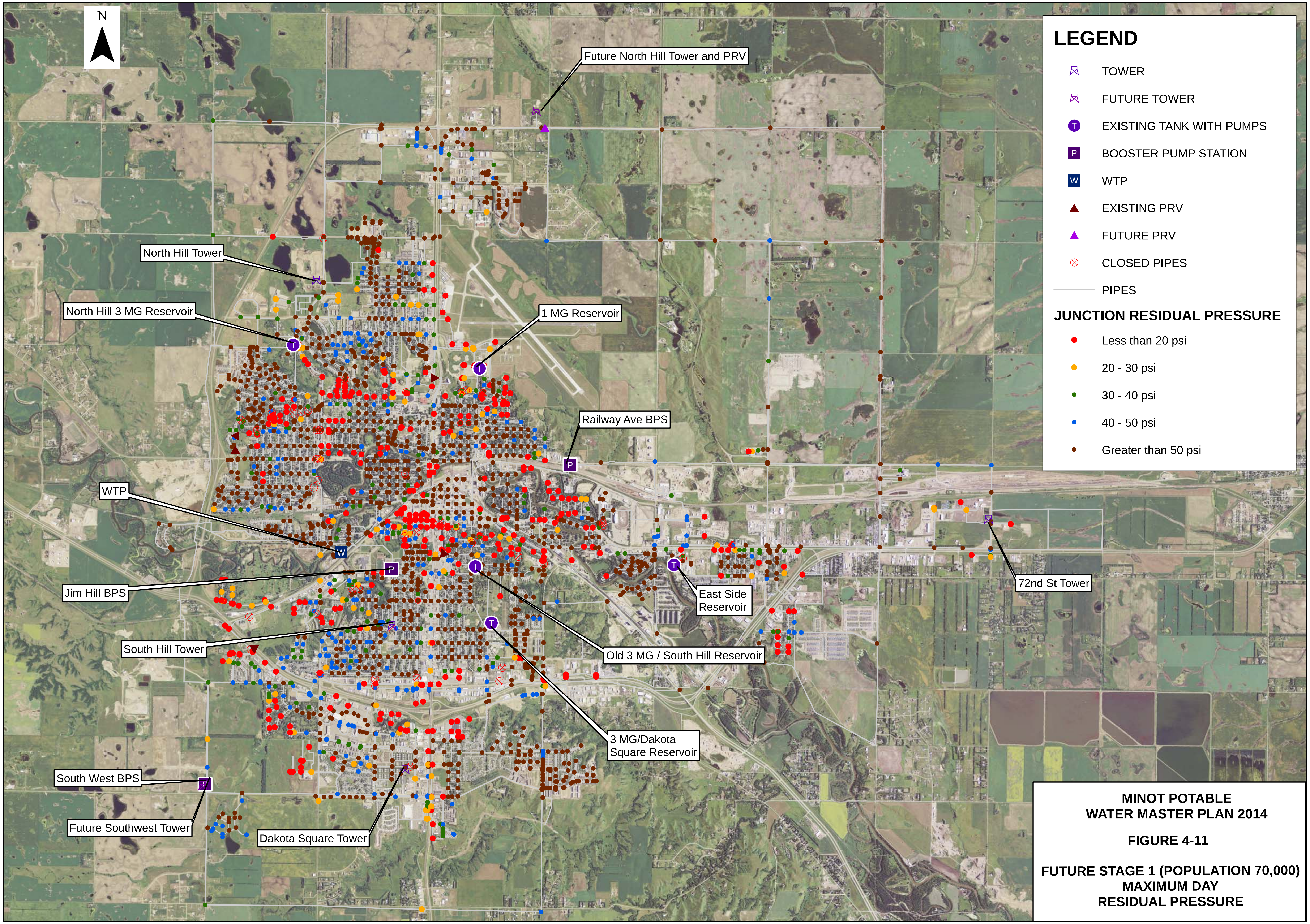
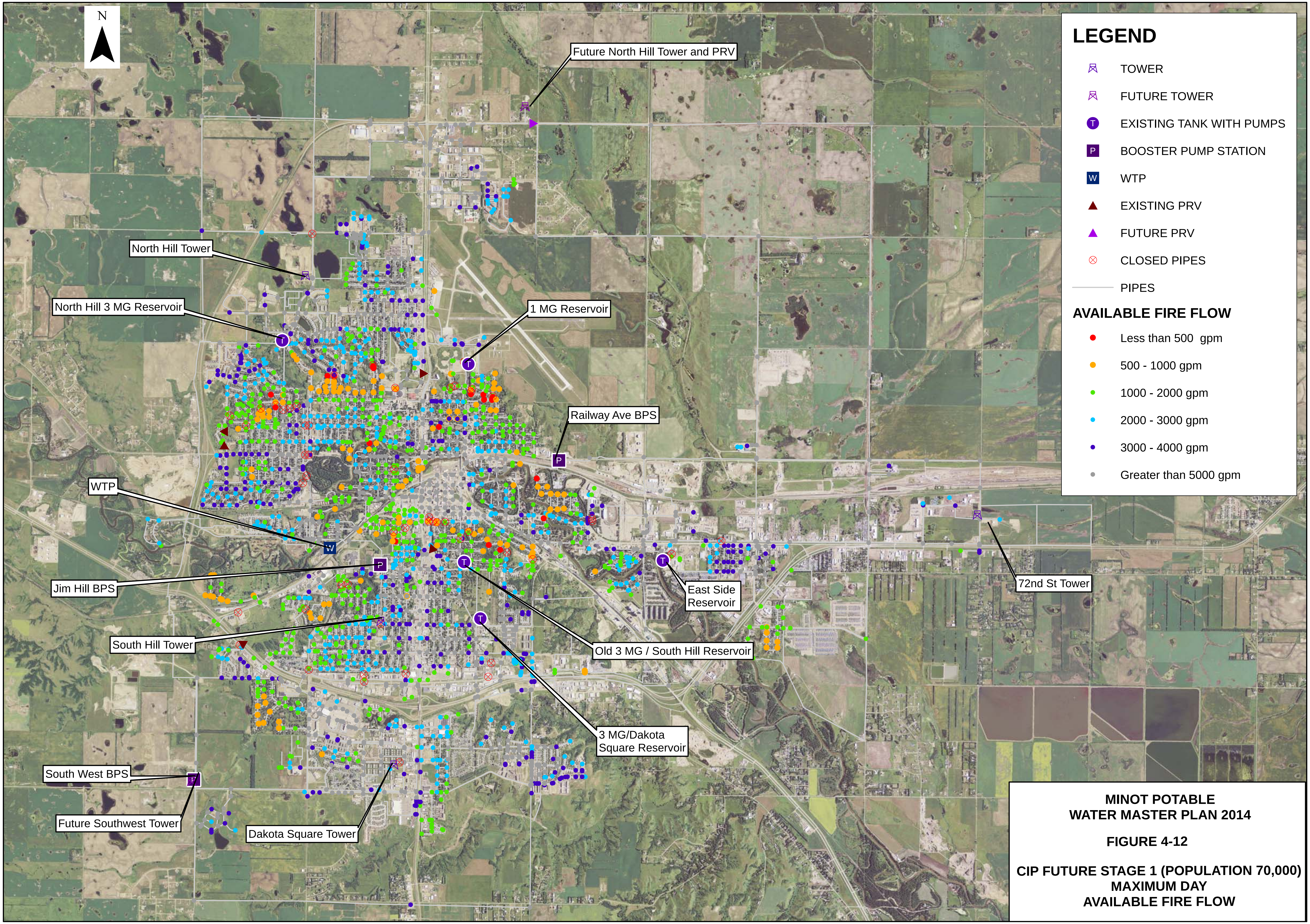
FIGURE 4-10

FUTURE STAGE 1 (POPULATION 70,000) MAXIMUM DAY MINIMUM PRESSURE

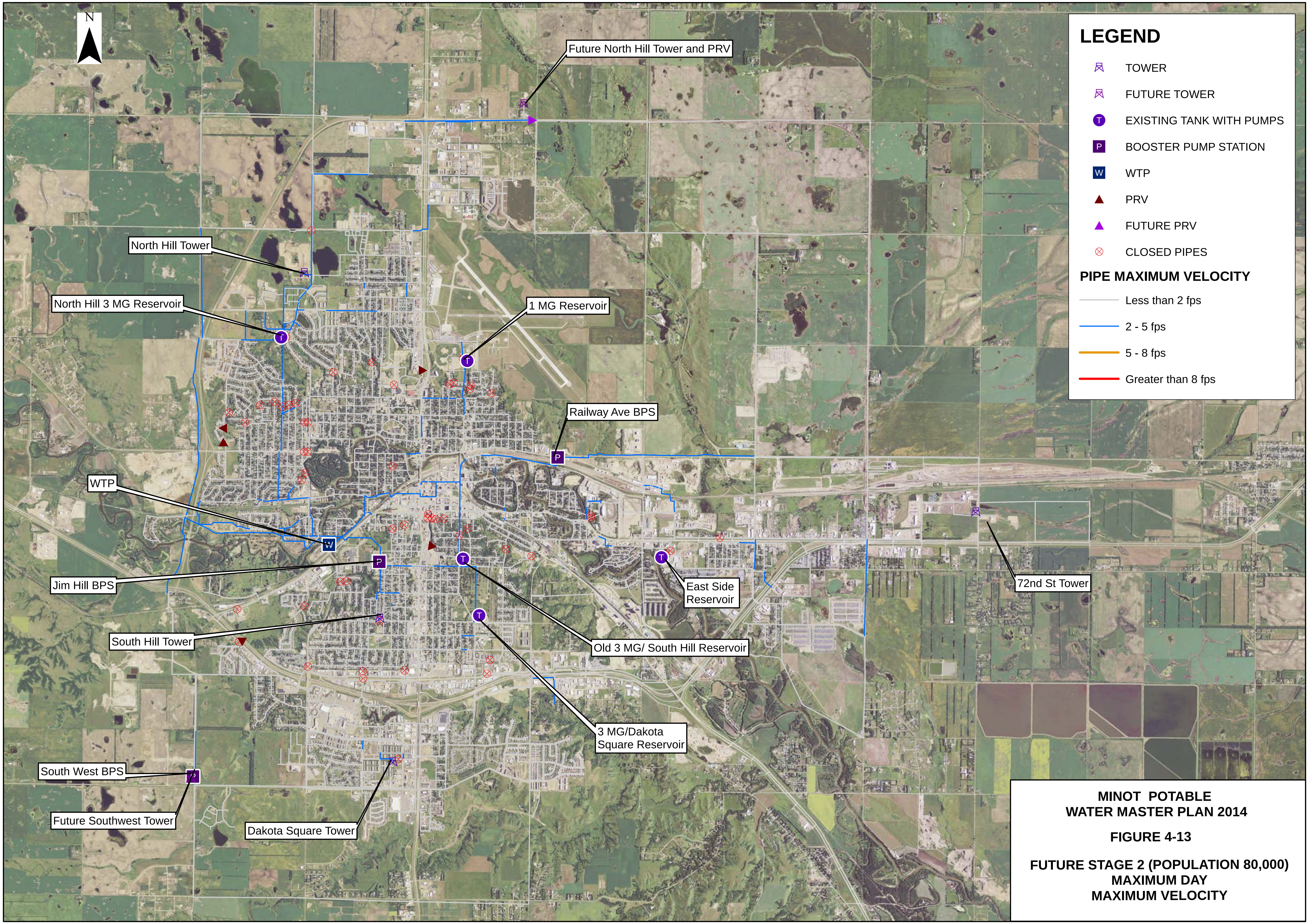

N
Future North Hill Tower and PRV
North Hill Tower
North Hill 3 MG Reservoir
1 MG Reservoir
Railway Ave BPS
WTP
Jim Hill BPS
South Hill Tower
Old 3 MG / South Hill Reservoir
East Side Reservoir
72nd St Tower
3 MG/Dakota Square Reservoir
South West BPS
Future Southwest Tower
Dakota Square Tower
LEGEND
TOWER
FUTURE TOWER
EXISTING TANK WITH PUMPS
BOOSTER PUMP STATION
WTP
EXISTING PRV
FUTURE PRV
CLOSED PIPES
PIPES
JUNCTION RESIDUAL PRESSURE
Less than 20 psi
20 - 30 psi
30 - 40 psi
40 - 50 psi
Greater than 50 psi
MINOT POTABLE
WATER MASTER PLAN 2014
FIGURE 4-11
FUTURE STAGE 1 (POPULATION 70,000)
MAXIMUM DAY
RESIDUAL PRESSURE



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 4-12

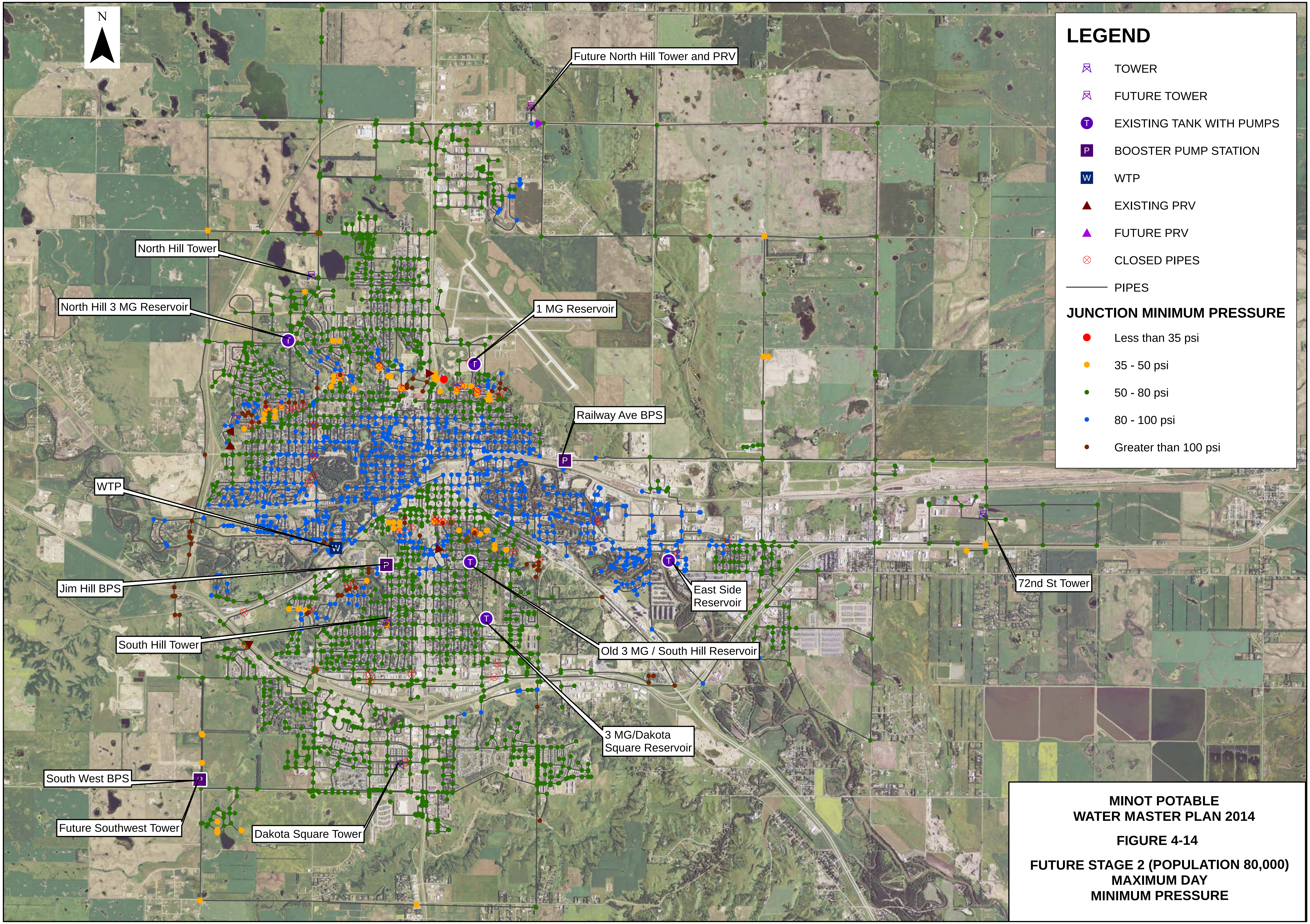
CIP FUTURE STAGE 1 (POPULATION 70,000) MAXIMUM DAY AVAILABLE FIRE FLOW



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 4-13

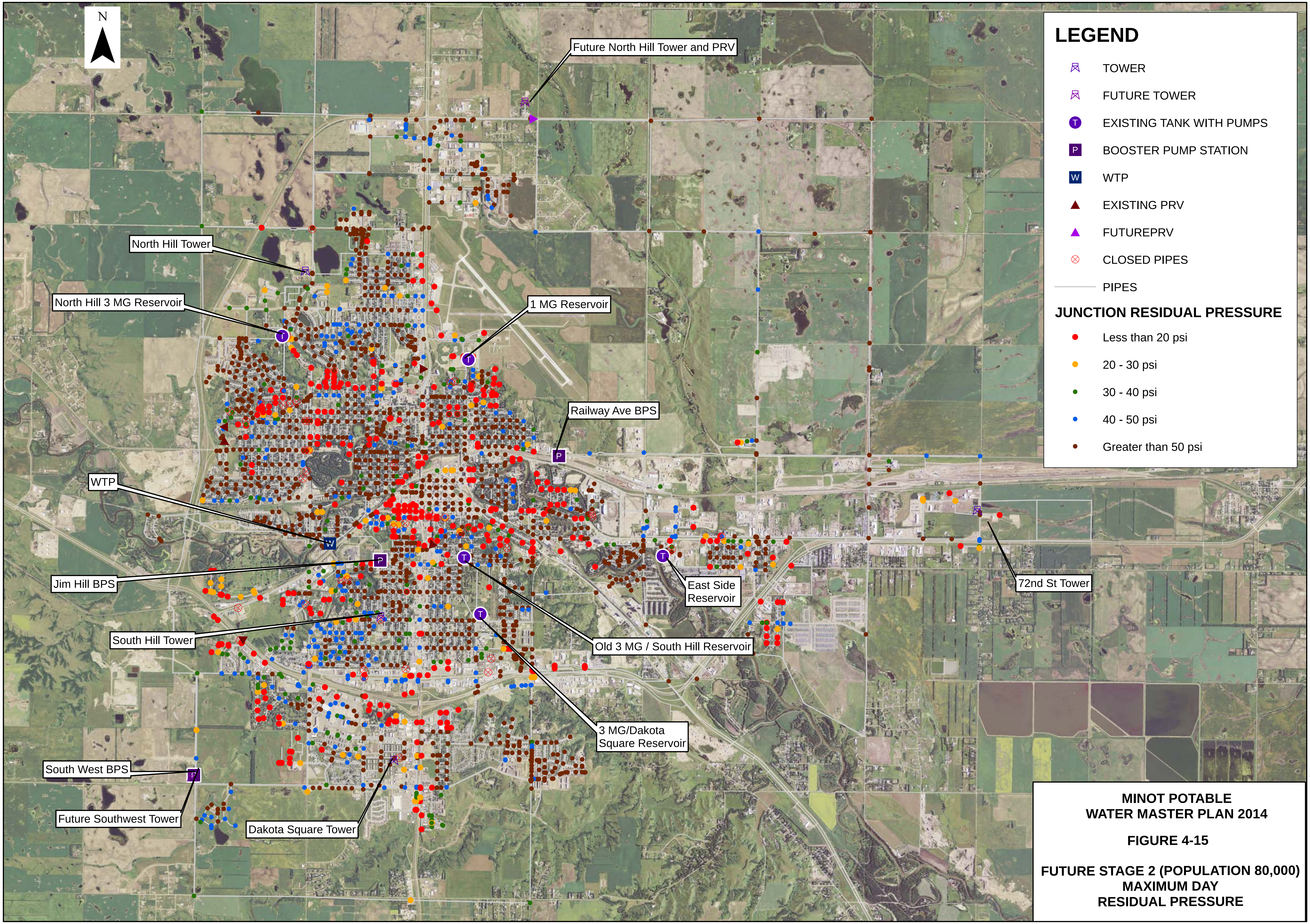
FUTURE STAGE 2 (POPULATION 80,000)
MAXIMUM DAY
MAXIMUM VELOCITY



MINOT POTABLE
WATER MASTER PLAN 2014

FIGURE 4-14

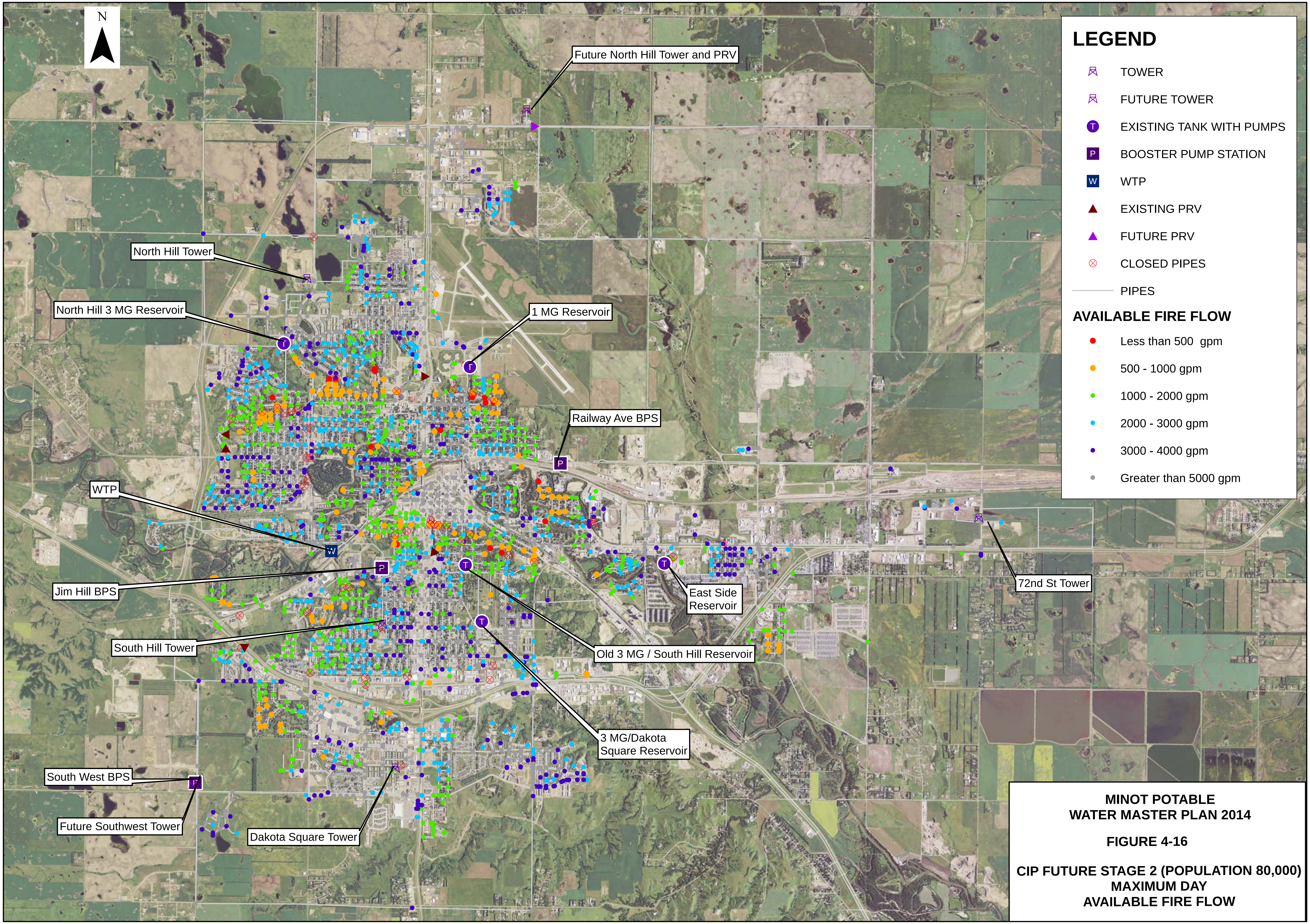
FUTURE STAGE 2 (POPULATION 80,000)
MAXIMUM DAY
MINIMUM PRESSURE



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 4-15

FUTURE STAGE 2 (POPULATION 80,000) MAXIMUM DAY RESIDUAL PRESSURE



MINOT POTABLE WATER MASTER PLAN 2014

FIGURE 4-16

CIP FUTURE STAGE 2 (POPULATION 80,000) MAXIMUM DAY AVAILABLE FIRE FLOW

MWH
MONTGOMERY WATSON HARZA

To:	Dave Schwengler Houston Engineering	**Date:**	March 24, 2014
Subject:	Model Calibration Results		
From:	Gracelyn NeVille	**Job No:**	10503376

PURPOSE

This memorandum outlines the hydraulic model calibration process and results. The calibration process included field testing, calibration scenario development, review of results and model adjustments. The purpose of the calibration testing was to discover the actual operating conditions that occur in the City of Minot's water distribution system. The operating conditions recorded out in the field were compared with the computer model output to confirm that the model would provide accurate results when executed.

STATIC CALIBRATION

After the existing distribution system components and demands were entered into the model, the hydraulic model was calibrated to confirm its accuracy. Calibration consists of adjusting the model to match field collected data. The calibration consisted of two components: steady-state and dynamic calibration.

Steady-State Calibration

Steady-state calibration is accomplished by performing fire flow tests in the field and then comparing the field results with model results under the same conditions in the model. On August 20, 2013, Houston Engineering performed 11 fire flow tests throughout the City. Pressure loggers were also placed on various hydrants throughout the system during the testing. Appendix TM-5A contains the Model Calibration Testing with figures showing the test and pressure logger locations.

The objective of fire flow testing is to stress the distribution system by imposing a large demand at a particular location and then collecting instantaneous flow and pressure data at various locations throughout the distribution system. For each test, a large demand was achieved by flowing one or more hydrants. The flow from the hydrants was measured using pitot gages. The residual and rebound pressures were measured at a hydrant nearby the flow hydrants.

After completion of the field hydrant tests, the tests were simulated in the hydraulic model. This required the creation of a steady state calibration scenario where each measured test flow was added to the corresponding hydrant in the model as a water demand over and above the demands existing in the system at the time the test was performed. The model was run to observe the resulting flows and residual pressures. The pressures measured by the pressure loggers were also compared to the pressures at the corresponding model hydrants. The model was adjusted to more closely reproduce the residual pressures and flow rates observed in the field. The primary model adjustments included the following:

- The Hazen-Williams resistance coefficients were lowered in the old cast iron pipes.
- Pipe diameters, closed pipes, and connectivity problems were corrected at various locations.

A comparison of the field data and the model results revealed that under steady state conditions, the model was hydraulically well calibrated. **Table 5-1** compares the field measurements with the modeled results. This table shows the initial pressure, the residual pressure, the difference between the field data and model data for initial pressure, and the difference in the change of pressure when the test occurs. It also shows the pressure at each of the three pressure loggers.

Table 5-1. Steady State Calibration Results

Residual Jns	Test No	Test	Field Test Time	Initial Pressure (Psi)		Residual Pressure (Psi)		Diff In Initial Press (psi)	Diff in Change in Press (Psi)		PL1			PL2		PL3	
		Jns		Field	Model	Field	Model		Field	Model	Field	Adj.	**3362**	Field	**2906**	Field	**498**
3206	1	3204	13:45	76	76.1	72	72.5	-0.1	4	3.6	110.5	90.5	87.2	74.8	72.9	68.1	70.4
2978	2	2982	13:30	67	70.7	61	66.8	-3.7	6	3.8	109.4	89.4	86.9	69.6	72.9	68.1	70.3
1962	3	3508	10:15	77	79.7	63	68.2	-2.7	14	11.5	107.8	87.8	90.4	73.4	72.6	66.8	70.8
4018	4	3496	13:00	77	74.7	55	67.2	2.3	22	7.5	109.9	89.9	89.2	75.8	72.3	67.9	70.1
1908	5	1904	10:30	74	75.4	61	67.4	-1.4	13	8.0	107.3	87.3	88.1	73.7	72.8	67.1	70.9
3582	6	1438	11:00	58	58.5	52	54.7	-0.5	6	3.9	107.0	87.0	87.1	74.4	73.0	68.1	71.2
284	7	282	11:15	77	80.9	67	70.6	-3.9	10	10.3	106.3	86.3	87.2	73.8	73.6	67.9	71.1
4040	8	4000	11:45	66	69.2	56	59.3	-3.2	10	9.9	108.7	88.7	87.4	74.1	74.1	67.4	71.2
1534	9	458	12:45	76	77.7	54	72.2	-1.7	22	5.6	110.5	90.5	87.6	75.2	74.7	62.5	69.4
488	10	486	12:30	64	68.5	59	63.6	-4.1	5	4.9	109.4	89.4	87.7	77.0	75.3	66.1	68.3
540	11	542	12:00	59	63.0	55	58.5	-4.0	4	4.5	108.0	88.0	87.5	75.9	75.9	66.2	69.1

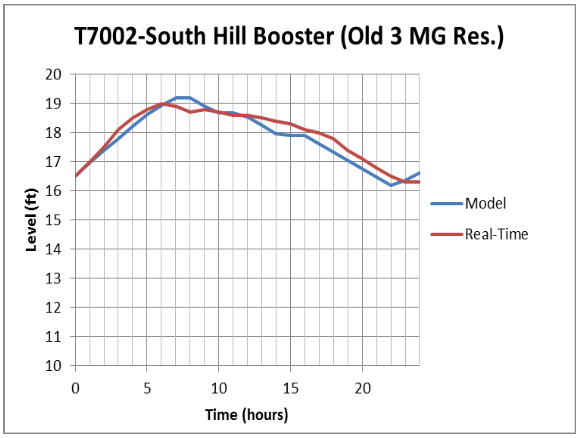
The system calibrated fairly well. All initial pressures are within 4 psi. There are two areas that do not see the pressure drop as shown in the field, this is probably due some closed pipes in the areas. Test number 4 is located at 5th Avenue NW and 21st St. NW. The other pressure test that does not show the same pressure drop as in the field is test 9, this is located at 9th Avenue SW and 4th Street SW. Both of these tests are located near zone boundaries and there are several closed pipes in the area. The initial pressures calibrate, but the model is not seeing the pressure drop due to the test. Additional closed pipes should be field verified in these two areas.

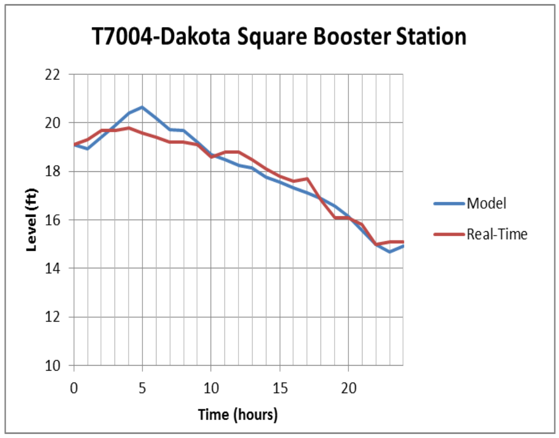
Dynamic Calibration

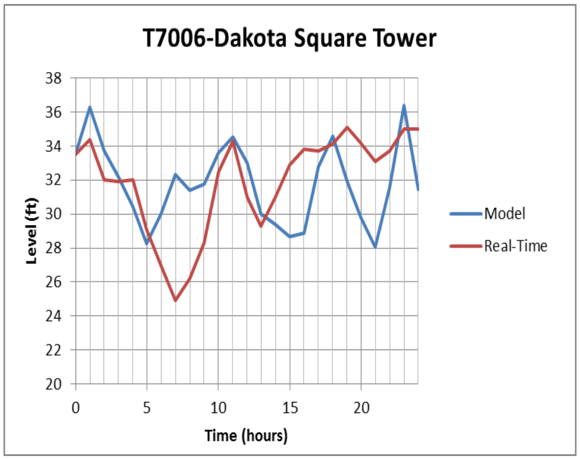
Dynamic calibration consists of comparing actual tank levels, system pressures, booster pump flows, and well flows with corresponding model levels, pressures, and flows over a 24-hour period. All available recorded data for the tanks, booster pump stations, and wells were compiled for August 21, 2013. The demands in the model were adjusted to match the actual demands for that day. The model was then run for 24 hours and was adjusted to better match the field data. The primary model adjustments included the following:

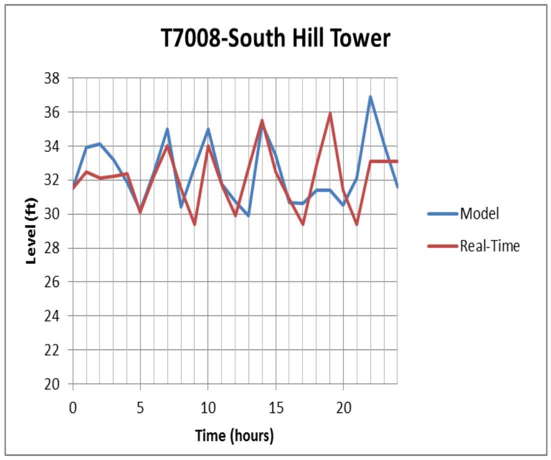
- Pipe diameters, closed pipes, and connectivity problems were corrected at various locations
- Pump controls were adjusted
- 1 MG reservoir pumps operates on time rather than pressure. The SCADA showed the pumps ran between 6:30 and 15:30. The pump was throttled back with a setting of 0.9.
- The Southwest booster pump station flow control was set at 1,200 gpm.
- The South Hill Reservoir fill line has a flow control valve set at 1,500 gpm. It is closed at 7 am and opened at 10 p.m.
- Flow restriction put on fill line to 1 MG tank so it doesn't fill too fast.
- The Old East Side Tank automatic controls were disabled, and manual controls were set for both the supply line and the discharge pumps.
- During the calibration, the Railway Booster Pump Station and New 72nd St Tank were offline.
- The automatic controls for the NAWS feed into the North Hill Reservoir were disabled, and a manual flow pattern was created based on the SCADA data.
- It should be noted that the NAWS patterns and MAFB patterns are very different from day to day. The patterns used were those for August 21, 2013.

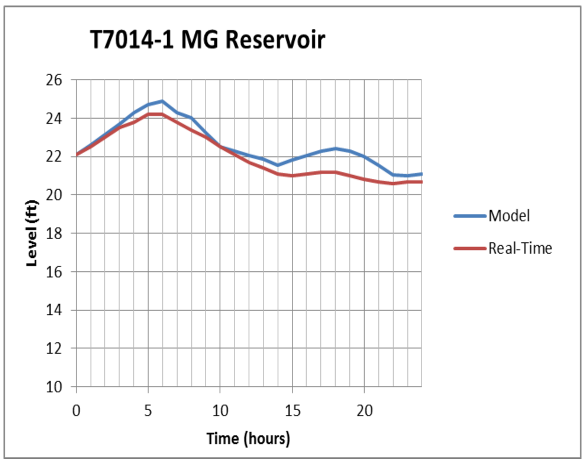
The tank graphs for each tank are shown below.

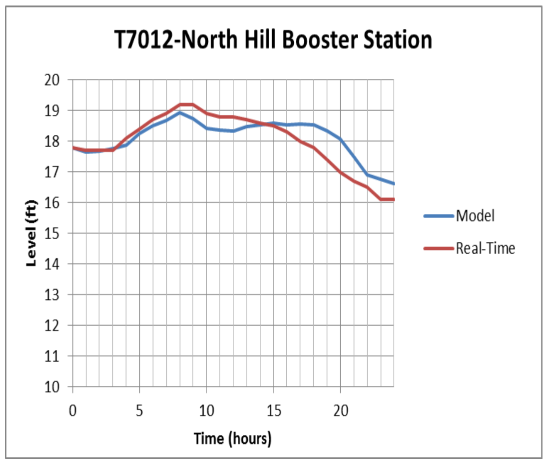

T7002-South Hill Booster (Old 3 MG Res.)
Level (ft)
Time (hours)
Model
Real-Time

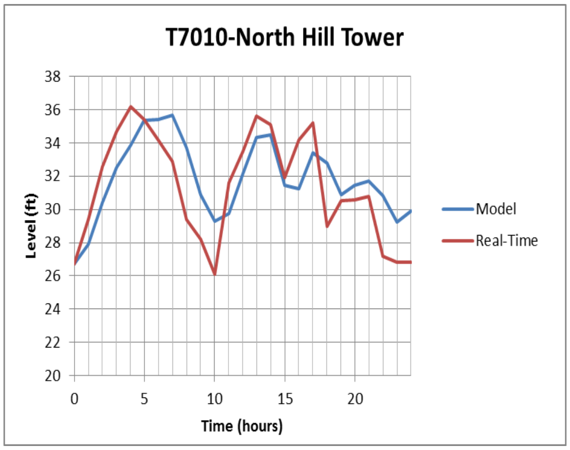

T7004-Dakota Square Booster Station
Level (ft)
Time (hours)
Model
Real-Time

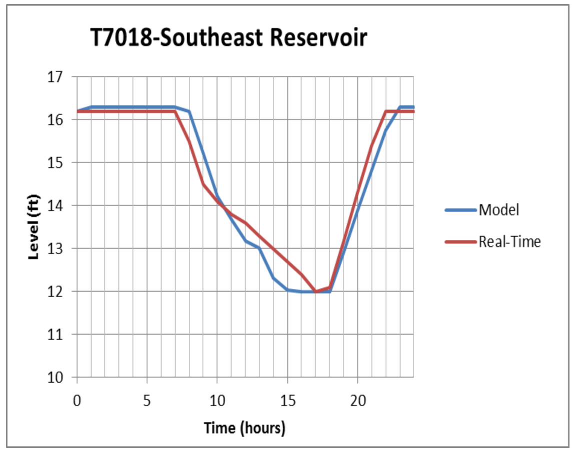

T7006-Dakota Square Tower
Level (ft)
Time (hours)
Model
Real-Time


T7008-South Hill Tower
Level (ft)
Time (hours)
Model
Real-Time


T7014-1 MG Reservoir
Level (ft)
Time (hours)
Model
Real-Time


T7012-North Hill Booster Station
Level (ft)
Time (hours)
Model
Real-Time





SUMMARY

MWH was successful in developing an accurate model of the City of Minot's water distribution system. The model is hydraulically well calibrated, and can be used for analysis of the system. The results of the analysis can be compared to the standards summarized in Technical Memorandum #4. In this way, system deficiencies can be identified and improvements can be developed to fix the deficiencies.

APPENDIX A

EXISTING FACILITY CONTROLS

Facility Controls

High Service Pump Station (HSPS)

The HSPS was put in service in 2009 and replaced the high service pumps in the Water Treatment Plant (WTP). The HSPS consists of 8 pumps (HSP110, HSP120, HSP130, HSP140, HSP210, HSP220, HSP230 and HSP240) and a 2 MG reservoir that is fed from the WTP.

The HSPS has 2 discharge points, HSP110 – HSP140 discharge into the city's "Valley" zone and are considered the "City" pumps. HSP210-HSP240 discharge to the Northwest Area Water Supply (NAWS) which is owned by the North Dakota State Water Commission, the NAWS system serves a large area of western North Dakota but also has 2 meter vaults that feed back into the city system at V8002 (NAWS N Master Meter) and another that is not in the model but should be installed between nodes J26 and J28, also feeds the NAWS system to the north at J84 and to the west at J26.

HSP110-140 feed the valley zone and either ground storage reservoirs or booster stations in the north hill and south hill zones. Pumps 110 or 140 are VFD's, 120 and 120 are RVSS's and there are 2 control options for these pumps: WE ARE USING OPTION 1 FOR THE MODEL.

1. Option 1 – Pressure (Cities preferred method) - See Figure 1 below for SCADA screenshot
    a. The operator sets a Pressure Setpoint (normally 75 psi)
    b. When the system pressure drops 0.5 psi below the setpoint, either 110 or 140 start (Alternate every 500 hours for lead) to maintain pressure setpoint.
    c. If the lead pump cannot maintain pressure 120 or 130 start (Alternate every 500 hours for Lag 1 and Lag 2) and the lead pump varies speed to maintain pressure setpoint.
    d. If the lead pump and Lag 1 cannot maintain pressure, Lag 2 starts also and the lead varies speed to maintain pressure setpoint.
    e. If the lead pump, Lag 1 and Lag 2 cannot maintain pressure, the remaining VFD starts as the Lag 3 pump and the lead pump varies speed to maintain pressure setpoint.
    f. The pumps shut down in reverse order if not longer required to maintain pressure setpoint and the lead pump shuts off if the discharge pressure is 0.5 psi over the pressure setpoint.

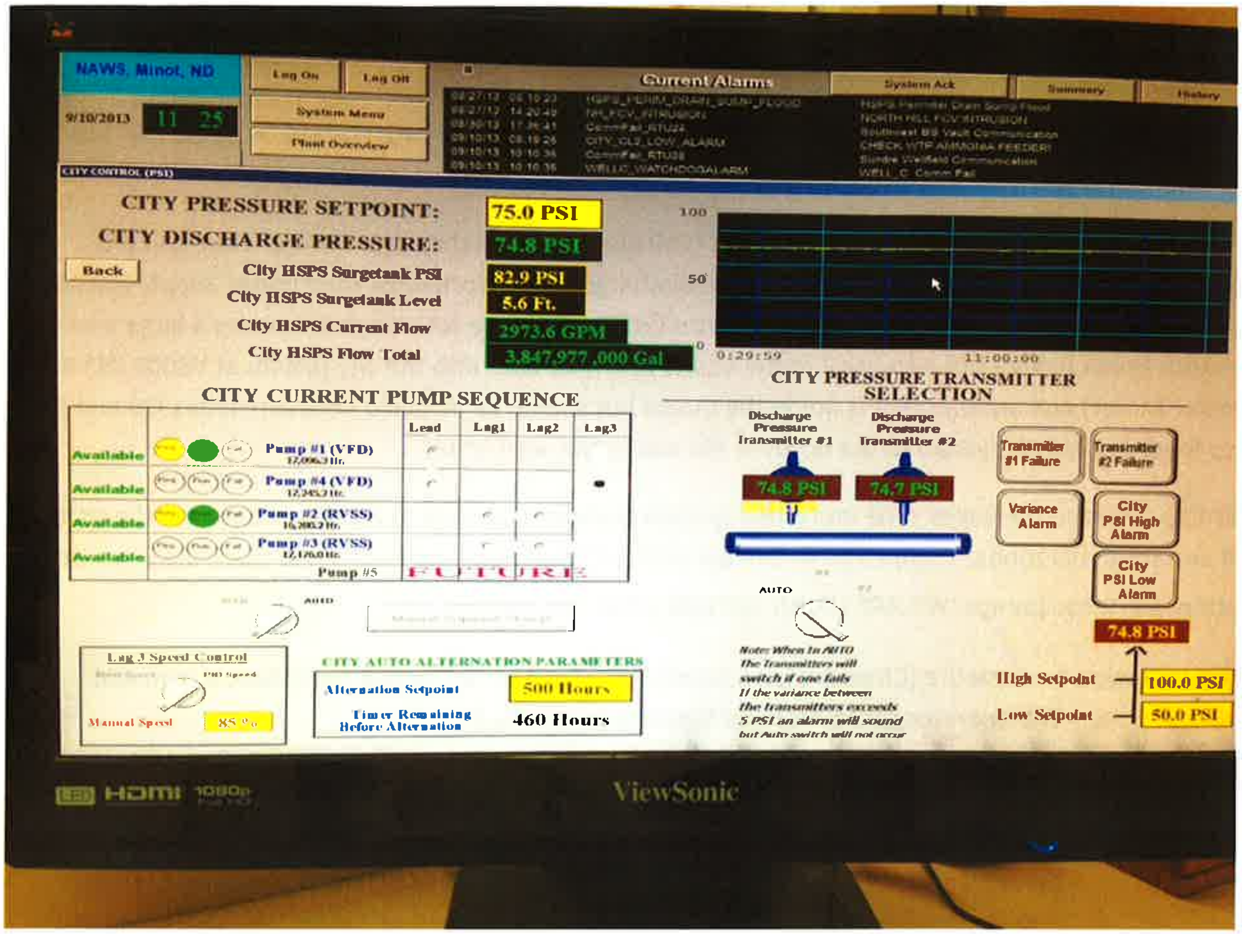


Figure 1 – City Pressure Control Option 1

2. Option 2 – Flow – See Figure 2 below
    a. Operation is similar to Option 1 but instead of starting and stopping pumps trying to maintain a Pressure Setpoint the pumps are trying to maintain a Flow Setpoint.

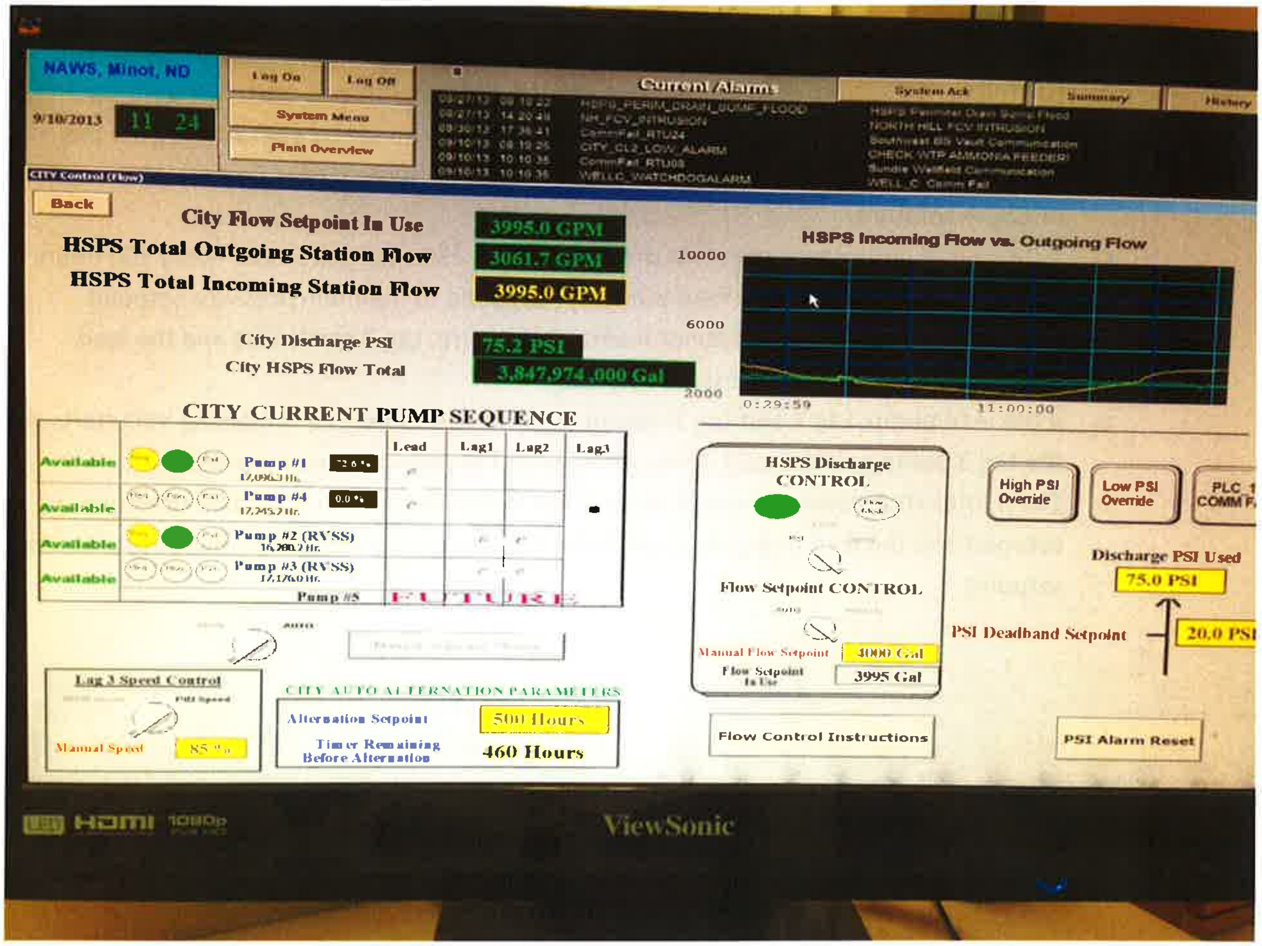


Figure 2 – City Flow Control Option 2

HSP210-240 operations:

HSP210 – HSP240 feed the NAWS system, North Hill zone and South Hill zone. 210 & 240 are VFD's and 220 & 230 are RVSS's. The pumps are controlled similar to the City Pressure Control Option 1 above.

a. The operator sets a Pressure Setpoint (system was designed to operate at 150psi with the full NAWS system in place, running around 140 psi with only partial system installed)
b. When the system pressure drops 1 psi (deadband can be set by operator) below the setpoint, either 210 or 240 start (Alternate every 100 hours for lead) to maintain pressure setpoint.
c. If the lead pump cannot maintain pressure 220 or 230 start (Alternate every 100 hours for Lag 1 and Lag 2) and the lead pump varies speed to maintain pressure setpoint.
d. If the lead pump and Lag 1 cannot maintain pressure, Lag 2 starts also and the lead varies speed to maintain pressure setpoint.
e. If the lead pump, Lag 1 and Lag 2 cannot maintain pressure, the remaining VFD starts as the Lag 3 pump and the lead pump varies speed to maintain pressure setpoint.
f. The pumps shut down in reverse order if not longer required to maintain pressure setpoint and the lead pump shuts off if the discharge pressure is 1 psi over the pressure setpoint.

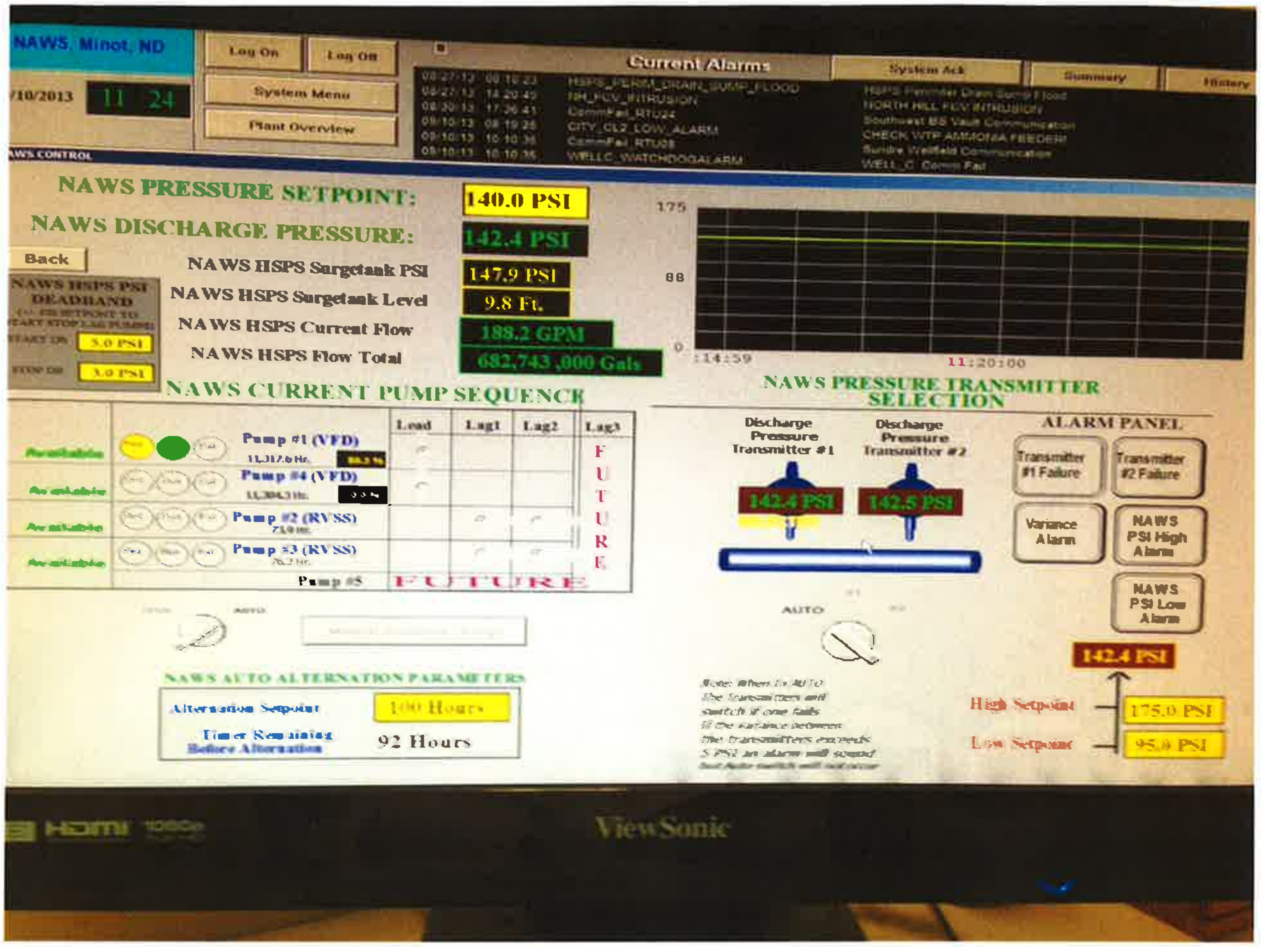


Figure 3 NAWS Control

Jim Hill Booster Station – Nodes 5073 & 5045

This station is an in-line booster pump that boosts pressure from the Valley Zone to fill the South Hill Elevated Tank, this pump station is in the original model and control setpoints are shown in Figure 4 below.

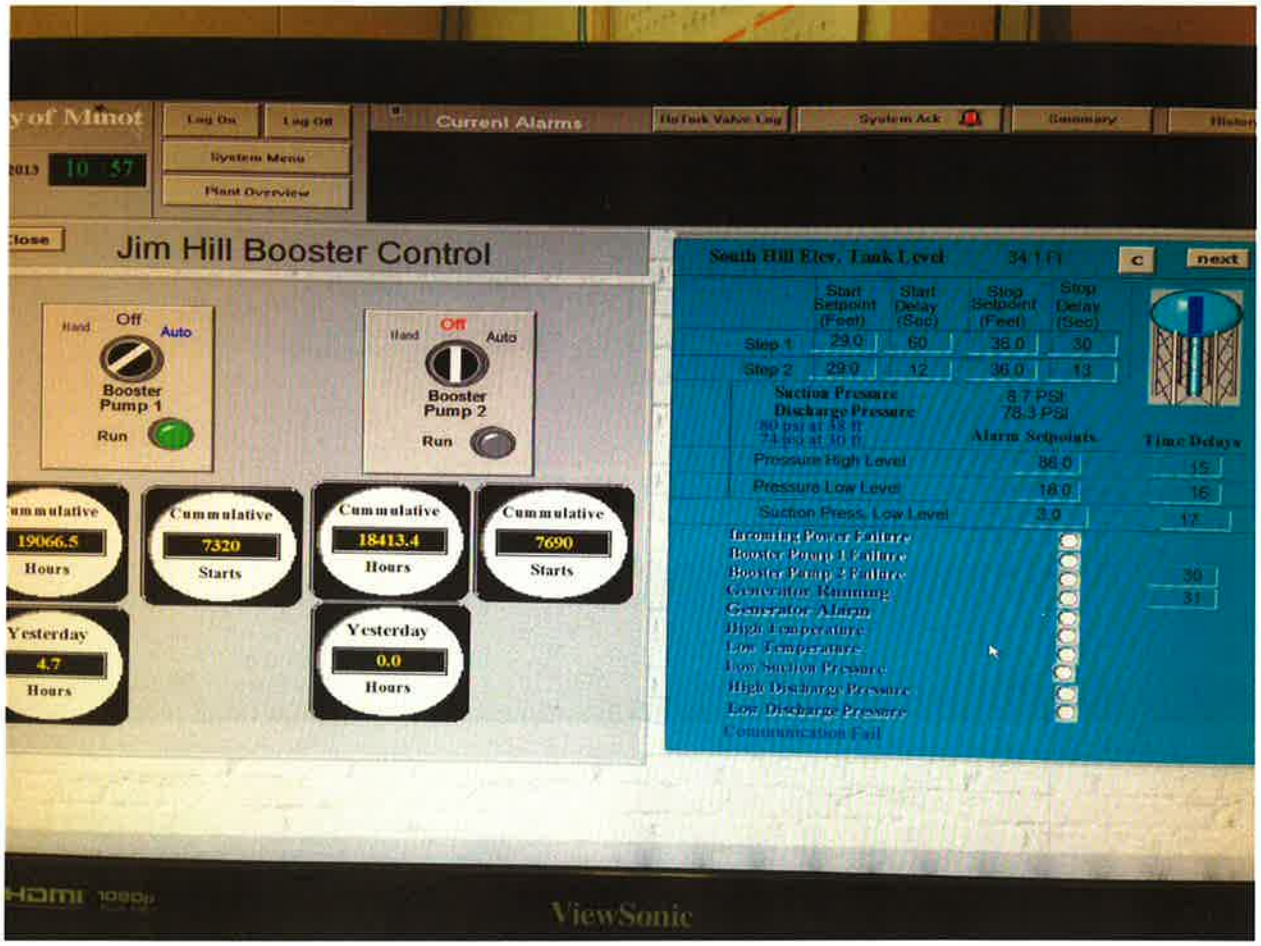


Figure 4 - Jim Hill Booster Station

Dakota Square Booster Station (New 3 MG Reservoir) and 3MG Ground Storage Reservoir

3 MG Ground Storage Reservoir Node T7004– supplied from the HSPS. There is a valve to control the filling of the reservoir but it has not worked in years and the city just operates the pump station when the reservoir is full to draw it back down, feeding water to the Dakota Square Elevated Tank (Valve needs to be fixed).

Booster Pumps – nodes 5037, 5039 and 5041 feed the Dakota Square Elevated Tank T7006. 3 pumps are available but only 2 are usually used in 2 step process. Lead pump turns on when T7006 is below 29' and Lag pump turns on if T7006 drops below 20'. Lag pump turns off when T7006 reaches 35' and Lead pump turns off when T7006 reaches 36'. See Figure 5 below.

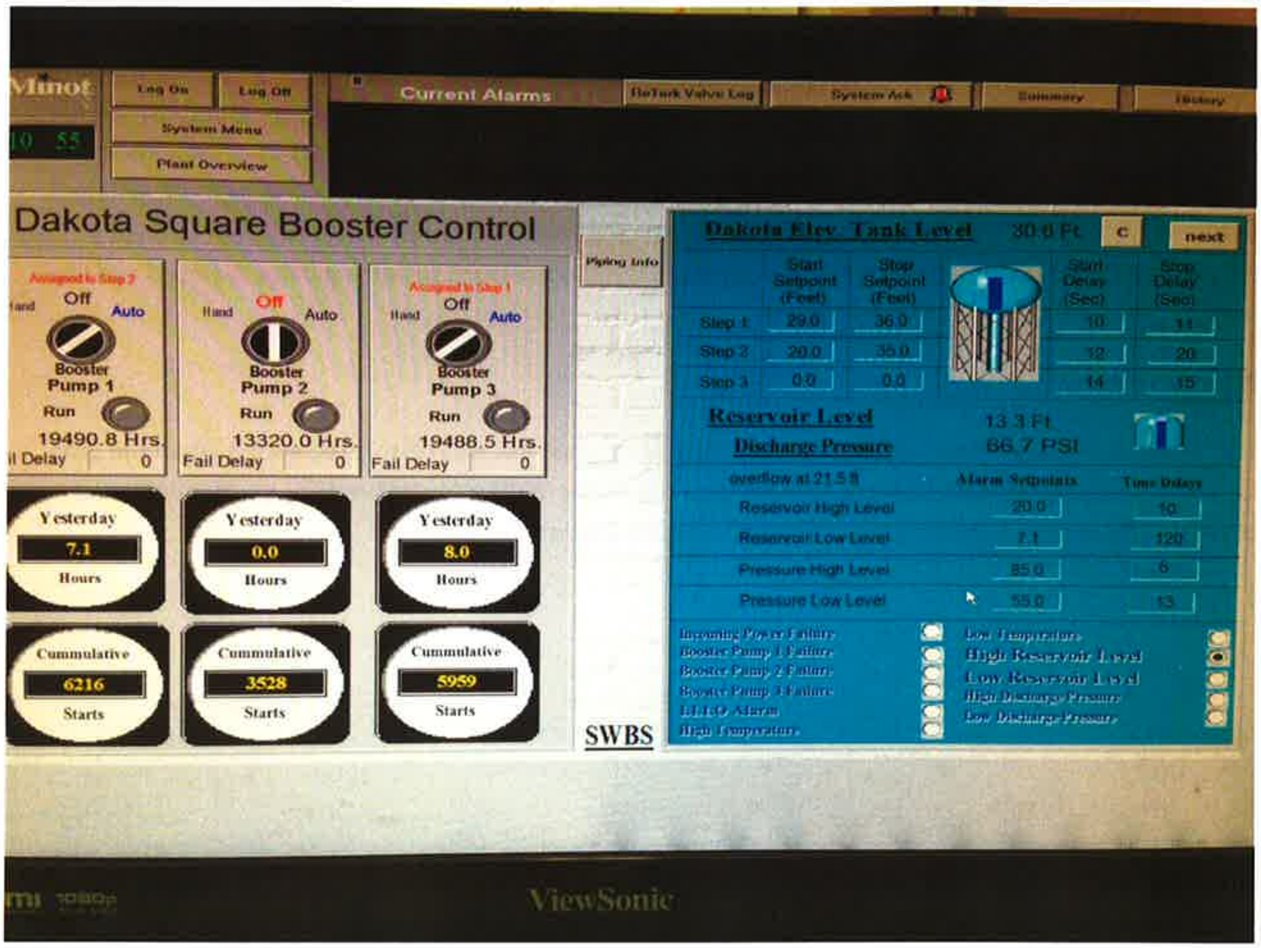


Figure 5 - Dakota Square Booster Control

Facility Controls

North Hill Booster Station and 3 MG Ground Storage Reservoir

3MG Ground Storage Reservoir, Node – T7012 – This tank was a 5MG reservoir as our model depicts but it leaked so badly that the city removed the structure and had a round 3MG reservoir installed inside the old foundation in 2005. It is supplied from the City Pumps at the HSPS (there is a control valve to control the filling of the reservoir but the city doesn't use it (Figure 7 below)) and the NAWS pumps at the HSPS. A pressure sustaining valve that supplies the reservoir from the NAWS pumps needs to be installed between Node 2704 and T7012 the valve should be set at 60 psi. A control valve needs to be installed between nodes 2704 and 2754. The pressure sustaining valve has controls installed that open and close it based on T7012 level. The control valve opens when the pressure sustaining valve is closed and vice versa.

Booster Pumps –

This BPS had 6 pumps when the 5 MG reservoir was in place but was retrofitted with 3 when the 3MG reservoir was constructed (I have a request in to the Public Works department for pump model and curves). The control parameters are shown in Figure 6 below.

Facility Controls

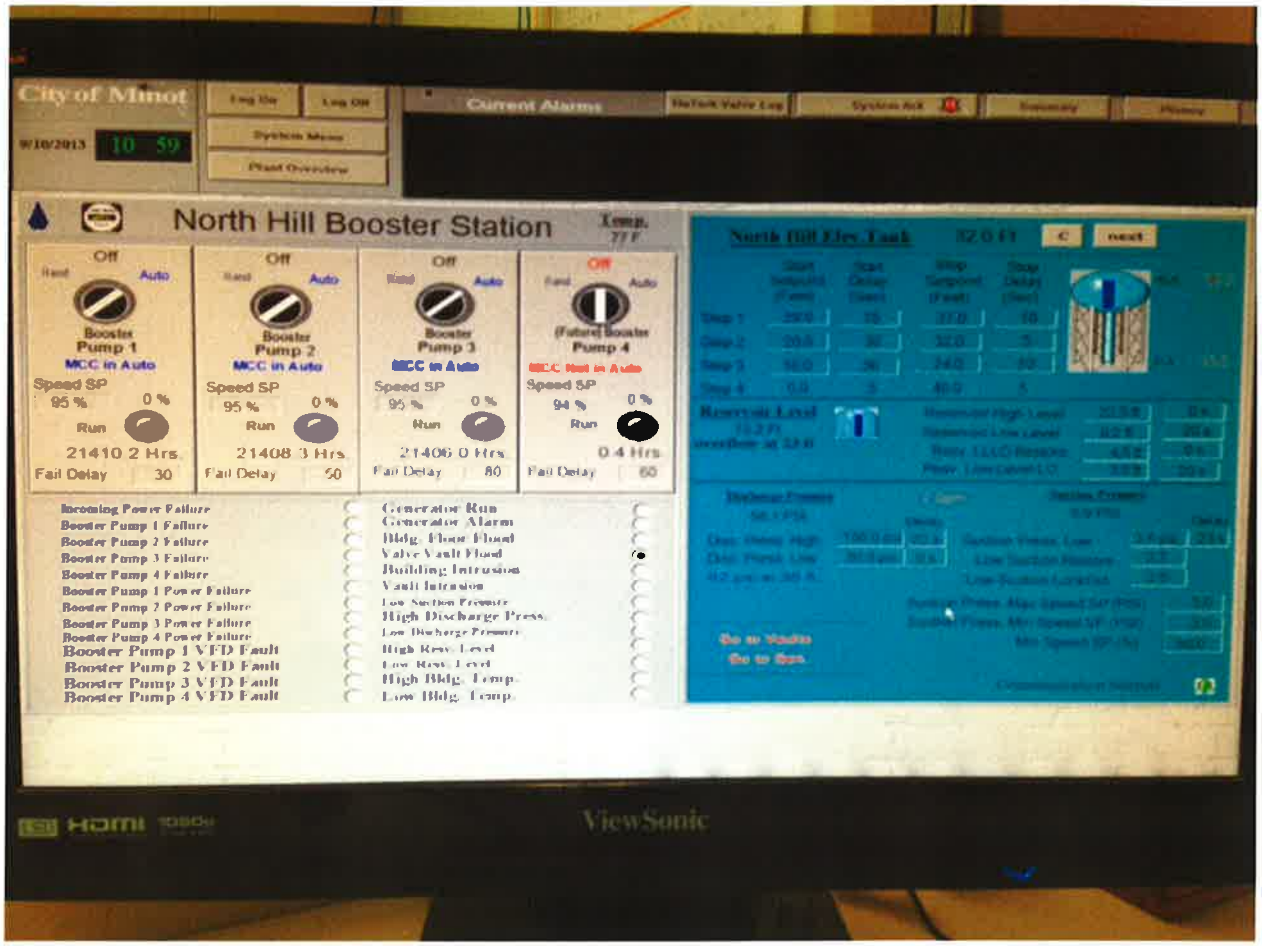


Figure 6 - North Hill Booster Station

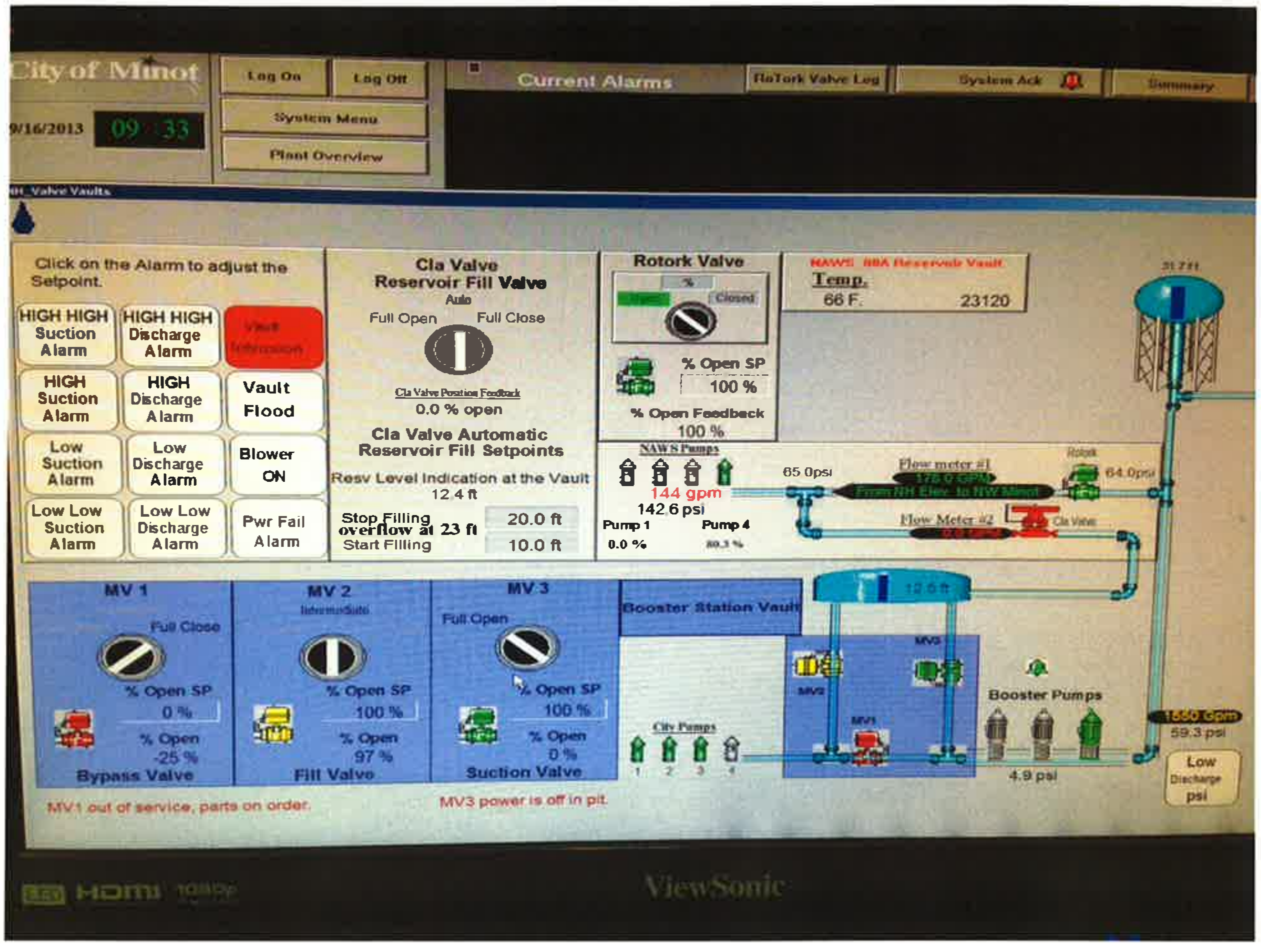


Figure 7 - North Hill Reservoir Fill Valve

1 MG Ground Storage Reservoir and Booster Station

The ground storage Reservoir (T7014) is filled by the City HSPS and fills overnight (there is no control valve to start and stop) and goes out to the system during the day.

The Booster Pumps (5017 and 5019) are just used to supplement pressure in the North Hill Zone during the day. The BPS has the ability to fill the North Hill Elevated Tank but has not been used to do so in years. Controls for the BPS shown in Figure 8 below.

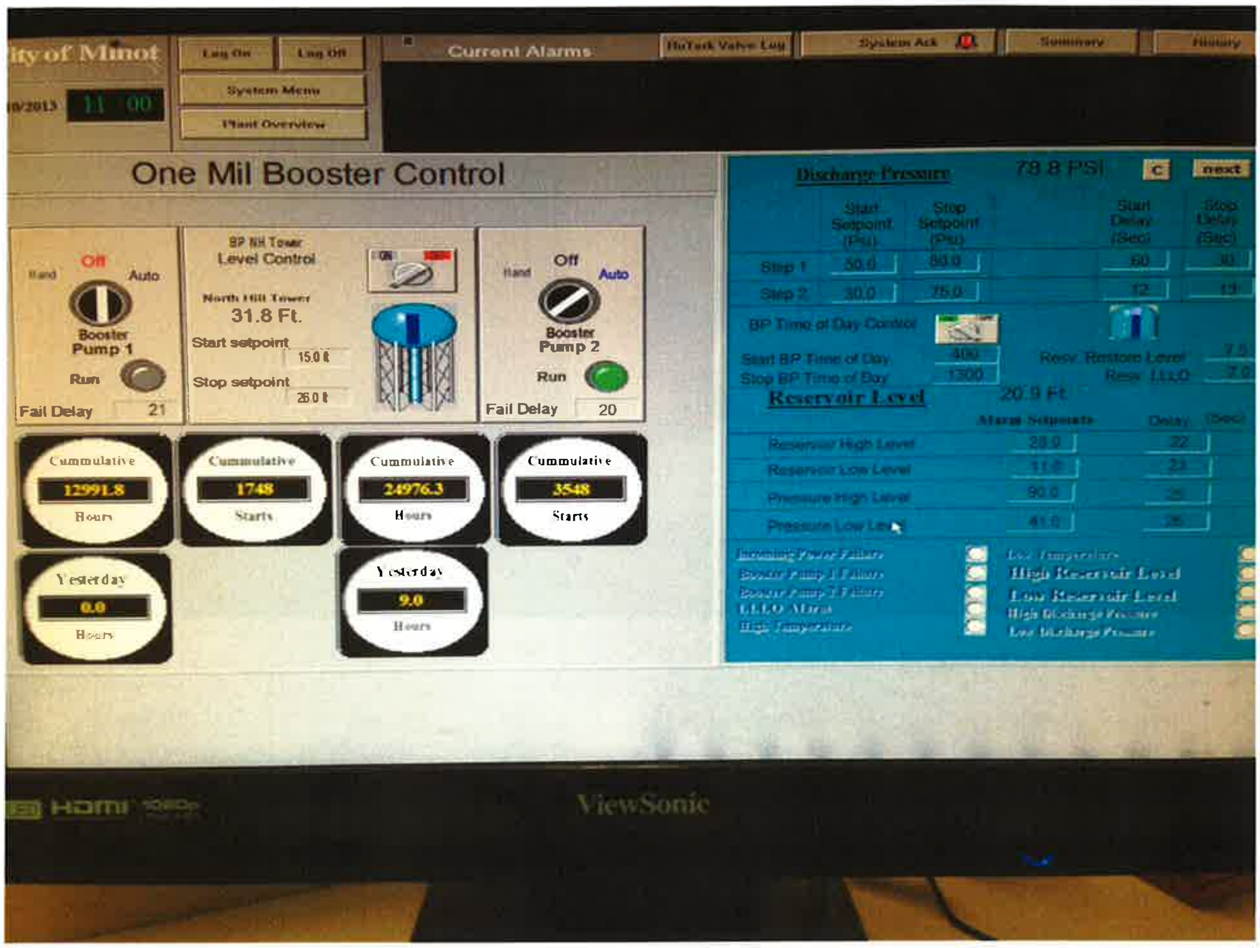


Figure 8 - One Mil Booster Control

Southeast Booster Control and Ground Storage Reservoir

The city fills the reservoir (T7018) from the City HSPS pumps and lets the reservoir fill at night (they use a PRV to throttle the flow into the reservoir) and goes out into the system during the day.

They start Booster Pump (5047, 5049 or 5051) in hand in the morning to supplement pressure to the distribution system and turn off in the evening to let the ground reservoir fill. Control shown in Figure 9 below.

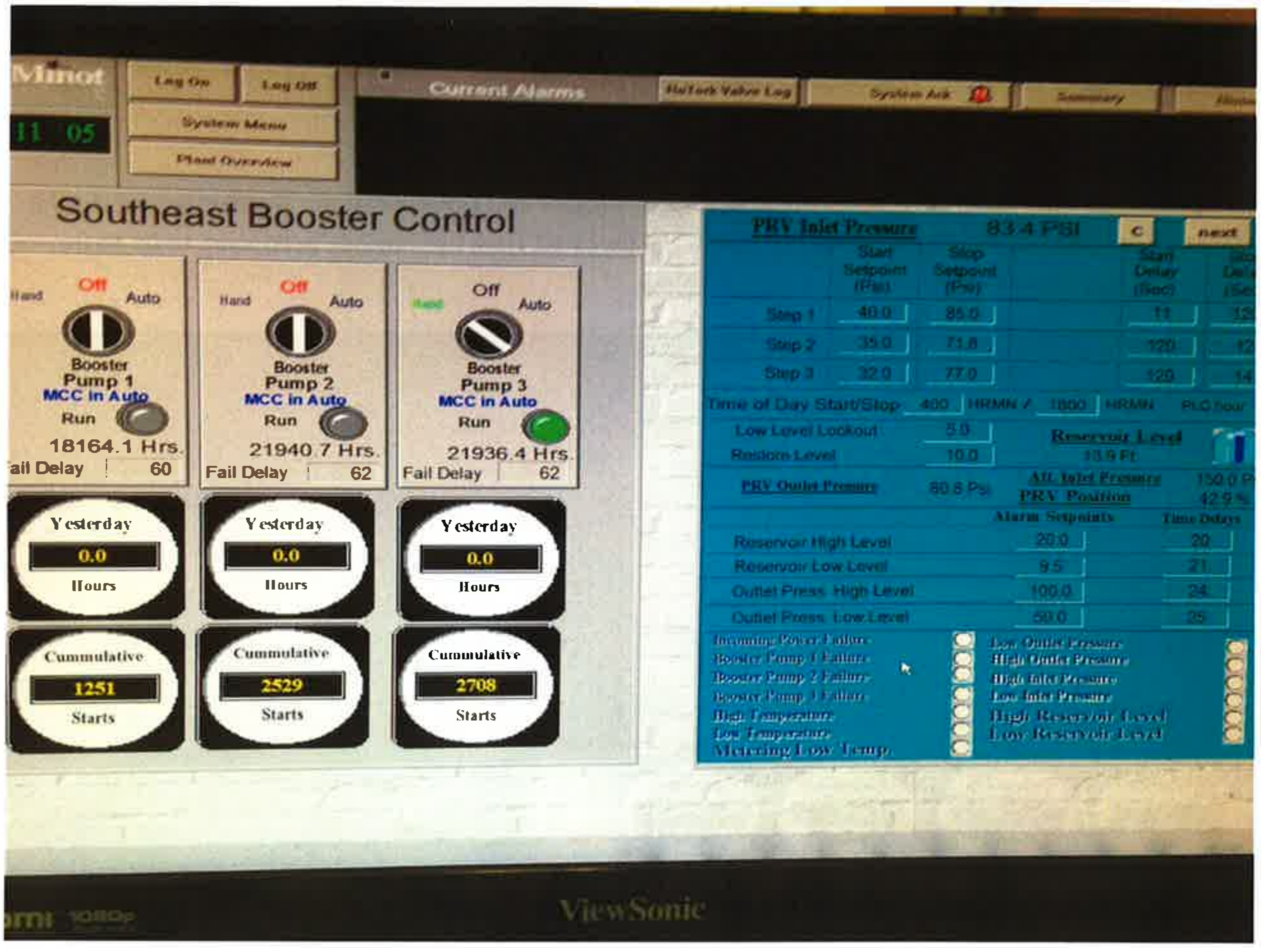


Figure 9 - Southeast Booster Control

South Hill Booster Control and 3MG Ground Storage Reservoir (Old 3 MG Reservoir)

The city fills the reservoir (T7002) from the City HSPS pumps and lets the reservoir fill at night (they use a PRV to throttle the flow into the reservoir) and goes out into the system during the day.

They start Booster Pump (5001 or 5003) in hand in the morning to supplement filling of the South Hill Elevated tank and turn off in the evening to let the ground reservoir fill. Control shown in Figure 10 below.

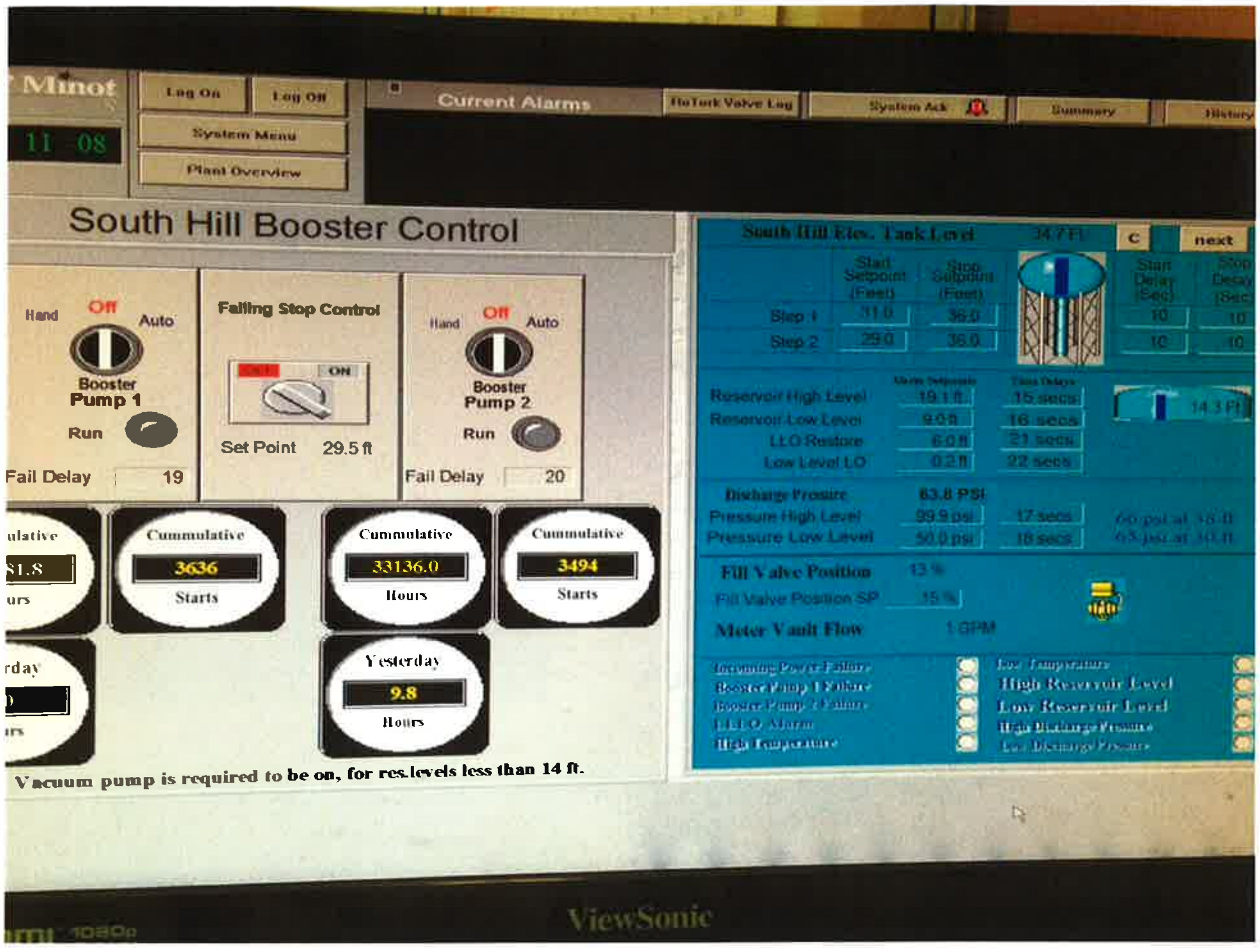


Figure 10 - South Hill Booster Control

Southwest Booster Station

The BPS (U7000) is supplied from the NAWS HSPS pumps and was installed in 2009 (pump curve supplied by the city), it supplies the Dakota Square Elevated tank. There are actually 2 pumps in the station but only 1 runs during operation and they alternate. There is a control valve that opens when the pump is on and closes when the pump is off, this is because the NAWS HSPS pumps can fill the Dakota Square Elevated but there will probably be another Elevated tank SW of the station in the future. Control parameters are shown in Figure 11 below.

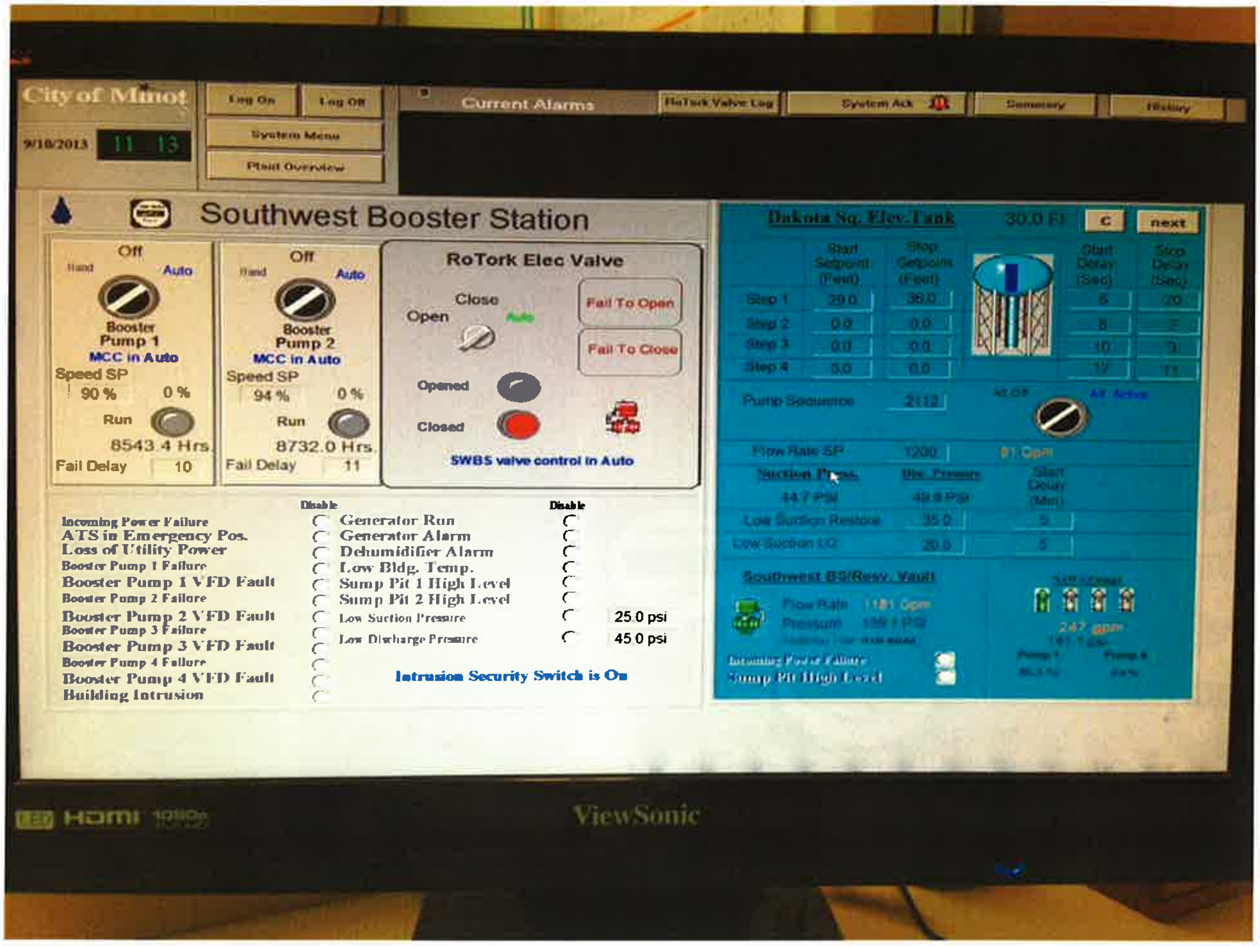


Figure 11 - Southwest Booster Station

Railway Avenue Booster Station

The BPS was installed in in 2009 and consists of 2 high service pumps (RWBP1 and RWBP2) and a Fire flow pump (5062). These are VFD pumps. The high service pumps are used to supply additional pressure to the distribution system east of the BPS (they are in the off position as they are rarely needed) and will be soon used to fill the 72nd Street Elevated Tank (T7020 – "New Eastside Elevated" in the Model) when the tank is commissioned in the near future. The fire flow pump is in the BPS to provide fireflow to the distribution system east of the BPS until the 72nd Street Elevated Tank is in service and will the supplement fireflow if needed. Control parameters are shown in Figures 12 and 13 below but the setpoints for the high service pumps are not accurate as the Elevated Tank has not been commissioned.

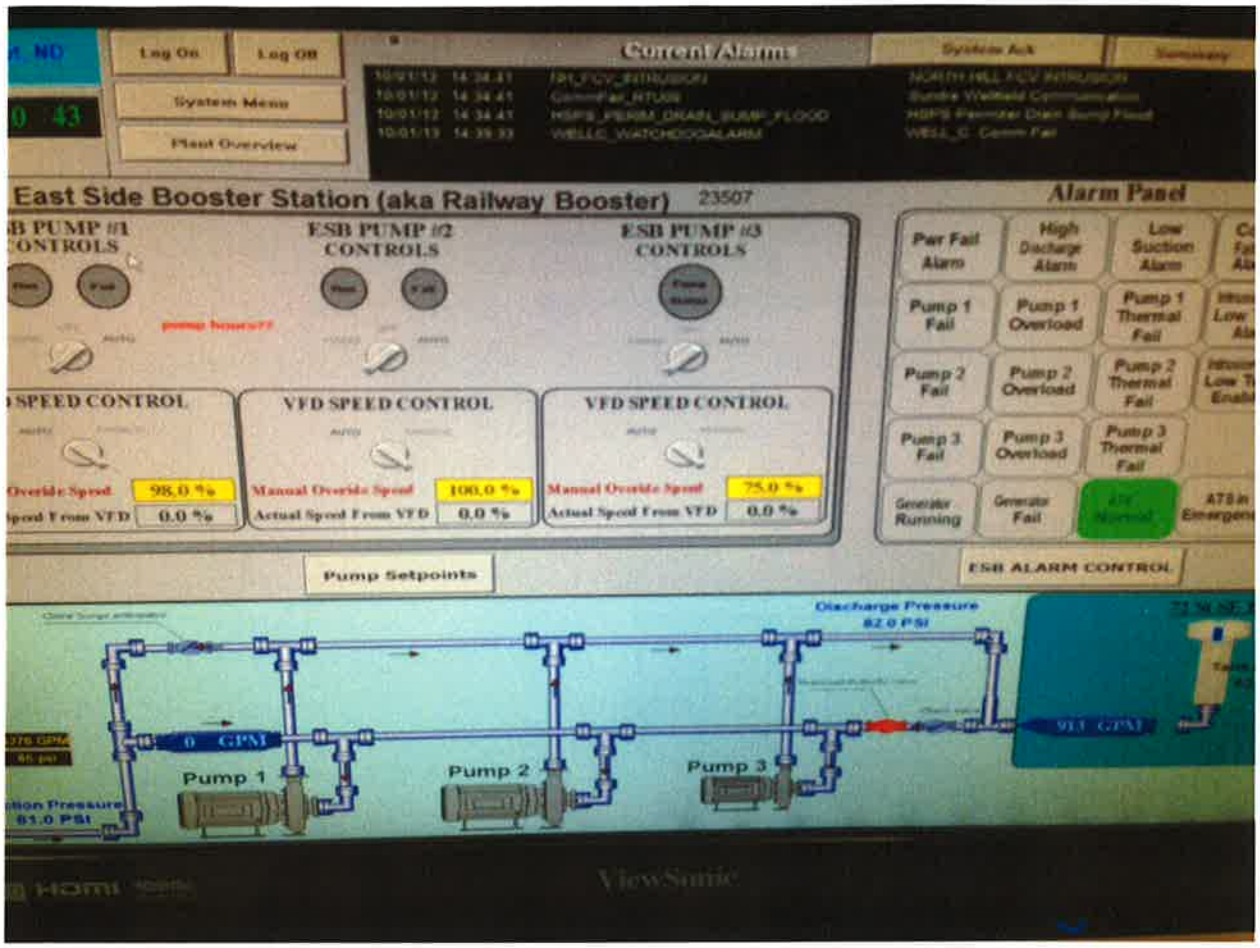


Figure 12 - Eastside Booster Station controls

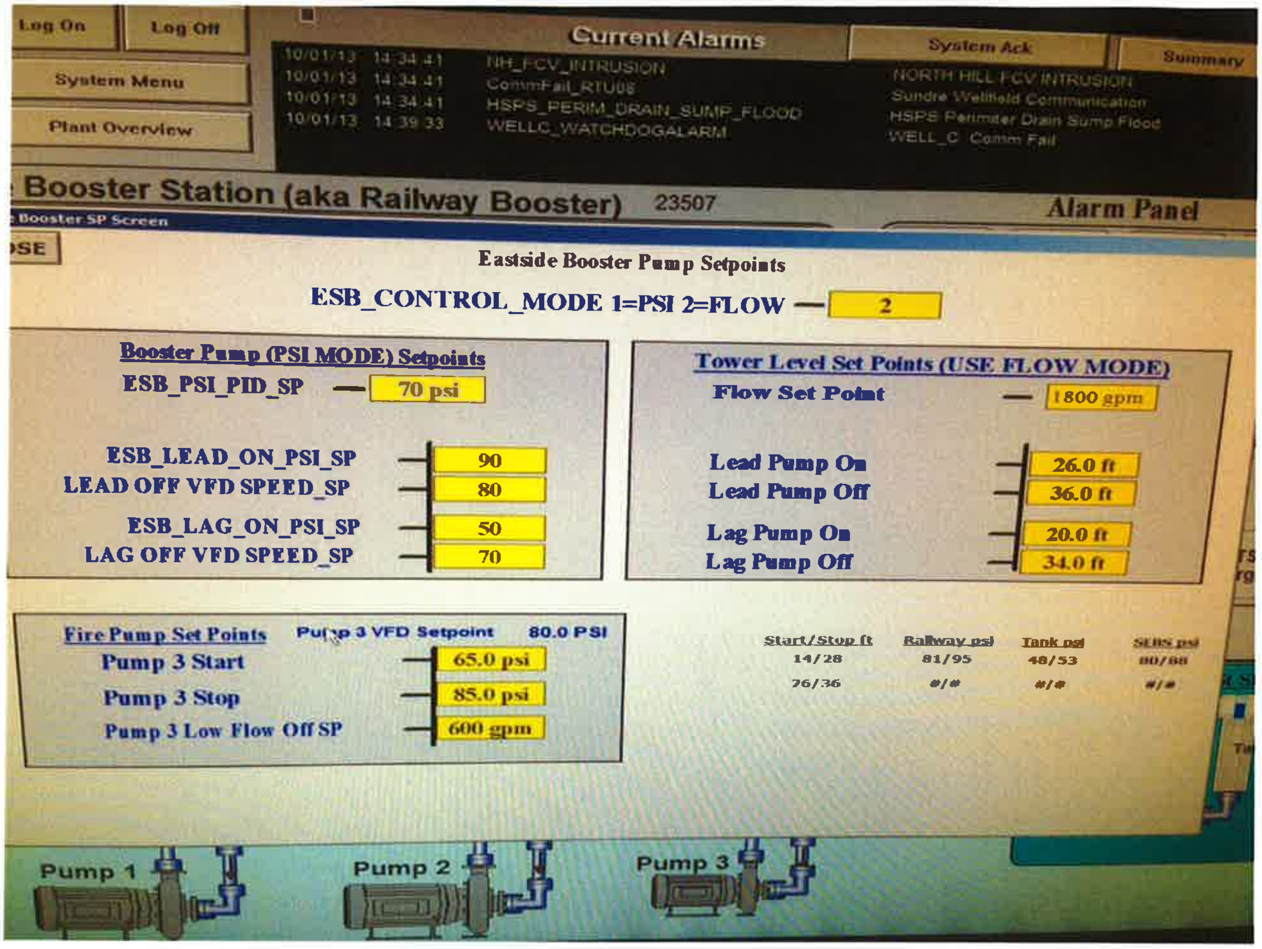


Figure 13 - Eastside Booster Station pump setpoints

APPENDIX B

FIRE FLOW RESULTS

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
1550	1000	-923.35	227.69	-922.02	232.17	-922.98	228.14	-922.35	230.4
1378	4000	-902.33	926.76	-761.74	1008.02	-772.76	968.41	-771.96	942.43
1982	3000	-887.6	697.16	-879.41	700.14	-883.96	685.32	-880.9	673.55
2030	4000	-819.39	658.83	-814.94	660.32	-817.23	644.88	-815	633.77
2890	4000	-784.77	673.04	-780.32	674.83	-782.61	659.11	-780.38	647.87
J8406	4000	-714.15	977.54	-711.14	960.99	-703.96	1004.76	-707.59	985.08
1990	3000	-706.09	783.69	-697.89	788.21	-702.44	772.57	-699.38	759.46
330	4000	-678.34	1047.65	-667.01	1057.9	-653.68	1073.37	-651.46	1064.87
1264	3000	-674.19	745.89	-672.94	746.64	-642.9	770.69	-646.26	759.85
1244	3000	-650.58	766.21	-649.33	766.91	-619.29	792.07	-622.66	781.07
1396	4000	-646.25	1091.16	-505.66	1225.36	-516.68	1175.67	-515.88	1143.64
2464	4000	-594.21	573.22	-589.76	573.02	-592.05	548.76	-589.82	529.99
1980	3000	-592.83	849.63	-584.63	855.63	-589.18	839.16	-586.13	824.81
1888	4000	-521.68	1187.11	-482.01	1238.1	-487.31	1213.26	-484.92	1191.83
1376	4000	-502.51	1213.19	-361.92	1407.25	-372.93	1346.16	-372.13	1307.9
2050	1000	-497.89	312.6	-496.6	311.68	-498.96	304.85	-501.02	299.73
1806	4000	-479.07	1237.78	27.37	4268.8	24.09	4147.64	27.42	4258.62
1802	4000	-474.11	1247.16	29.75	4363.78	26.46	4239.6	29.79	4349.99
1800	4000	-473.74	1239.86	29.07	4341.42	25.95	4221.87	29.33	4336.72
3264	2500	-462.85	657.3	-152.74	1097.36	-135.41	1127.79	-134.89	1133.13
1976	3000	-424.43	980.24	-416.24	989.99	-420.79	971.14	-417.73	953.97
3242	2500	-421.94	677.84	-111.83	1213.93	-94.5	1260.78	-93.98	1266.99
3240	3000	-411.17	910.31	-182.51	1302.84	-158.78	1344.83	-158.3	1351
3584	3000	-394.83	822.2	37.42	4281.84	36	4117.38	39.99	4316.22
430	3000	-383.68	1035.74	-386.24	1035.74	-382.72	1035.74	-384.12	1035.74
342	1000	-353.2	360.29	-352.29	359.38	-348.16	364.61	-348.76	363.11
618	3000	-350.32	998.56	-350.29	996.41	-349.26	1005.69	-350.09	999.69
920	3000	-327.98	986.28	-326.98	995.78	-327.11	991.34	-326.99	993.11
4178	3000	-325.04	1097.3	-327.6	1097.3	-324.09	1097.3	-325.49	1097.3
616	3000	-320.75	999.29	-320.72	996.98	-319.7	1007	-320.53	1000.49
2940	4000	-305.47	1372.48	-300.55	1388.07	-300.83	1370.4	-300.83	1372.46
2218	1000	-299.68	388.62	-298.04	388.73	-298.37	387.64	-299.21	386.41
1242	3000	-298	1079.82	-296.75	1080.38	-266.71	1141.29	-270.08	1122.73
1490	3000	-284.85	1168.43	-280.53	1185.97	-280.85	1187.59	-275.97	1184.07
2370	5000	-279.57	1606.95	-275.75	1612.7	-276.04	1610.92	-273.19	1607.44
4182	3000	-272.66	804.51	-267.96	813.98	-269.02	811.44	-264.71	801.39
J7352	3000	-264.2	845.83	37.34	3965.64	31.96	3689.9	32.57	3819.27
1234	3000	-262.15	1152.05	-260.9	1152.9	-230.86	1223.12	-234.22	1203.07
2432	3000	-252.75	1204.99	-250.84	1212.98	-252.26	1203	-252.82	1198.09
1570	2500	-248.31	1182.77	-246.48	1191.64	-247.77	1185.65	-246.65	1190.02
612	3000	-236.21	1155.56	-236.17	1153.61	-235.15	1164.34	-235.98	1156.79
620	3000	-234.54	1108.04	-233.51	1106.62	-232.18	1121.69	-233.16	1111.37
58	4000	-228.56	1682.18	-216.26	1741.23	-203.97	1782.72	-203.62	1788.71

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
310	1000	-226.17	439.29	-225.04	438.91	-224.12	439.99	-225.18	436.29
908	3000	-221.78	1161.41	-221.33	1166.29	-220.77	1169.38	-221.26	1165.53
1632	3000	-213.19	1193.38	67.96	11389.61	66.53	10966	70.47	10170.79
1716	5000	-209.69	2157.7	-206.58	2181.13	-208.29	2168.19	-207.02	2179.03
1448	4000	-205.79	1741.18	38.1	4809.32	35.26	4675.84	38.82	4796.29
3582	3000	-205.23	1053.9	57.75	10542.56	56.33	10244.43	60.32	9360.84
1144	3000	-198.14	1259.49	-196.79	1271.74	-197.29	1265.74	-196.86	1268.71
1576	5000	-197.79	1870.63	-183.56	1932.65	-178.14	1931.83	-183.41	1915.97
3078	2000	-196.27	832.07	-193.66	839.89	-194.73	828.53	-194.61	829.69
3010	1000	-192.61	305.24	-188.02	301.29	-190.19	288.11	-192.22	274.98
1590	3000	-191.3	1005.93	-186.6	1024.77	-187.66	1021.75	-183.35	1010.47
3016	3000	-187.93	1327.35	-183.26	1345.12	-183.95	1329.91	-183.89	1331.67
1578	3000	-187.01	1188.34	-182.61	1211.56	-183.32	1211.36	-178.74	1203.89
614	3000	-179.58	1328.79	-179.55	1327.22	-178.53	1338.5	-179.36	1330.02
4192	3000	-178.36	1269.04	-171.81	1301.6	-147.91	1350.78	-147.44	1356.92
244	3000	-174.65	1324.42	-168.59	1341.99	-168.47	1342.14	-169.73	1326.09
3014	3000	-173.84	1362.44	-169.17	1381.4	-169.86	1365.75	-169.81	1367.58
2368	5000	-172.69	2223.31	-168.93	2245.84	-169.25	2240.46	-166.43	2234.35
1140	3000	-171.05	1300.29	-169.66	1313.85	-170.22	1307.15	-169.74	1310.59
1488	3000	-168.44	1426.69	-164.12	1454.12	-164.44	1456.04	-159.55	1451.3
3034	3000	-165.87	1303.86	-161.2	1323.8	-161.89	1306.3	-161.83	1308.32
3374	3000	-165.22	1443.85	-157.04	1475.34	-161.61	1443.74	-158.55	1417.8
6052	3000	-157.43	1220.83	-154.24	1227.19	-152.75	1246.22	-153.74	1232.77
1778	4000	-153.09	1981.85	-138.24	2045.48	-138.94	2041.2	-136.06	2014.86
1788	4000	-149.07	1992.72	-135	2053.93	-135.65	2049.97	-132.78	2023.51
1588	2500	-147.77	1027.65	-144.35	1044.34	-144.73	1042.74	-139.66	1034.23
3008	1000	-146.81	315.38	-142.22	310.74	-144.4	294.82	-146.42	278.14
3246	1000	-146.56	416.07	-43.55	617.89	-41.26	619.4	-40.84	622.65
1492	3000	-144.13	1444.18	-139.81	1475.42	-140.14	1477.56	-135.26	1472.14
4176	3000	-142.73	1296.73	-143.05	1272.52	-136.89	1346.65	-139.52	1296.75
3250	1000	-140.1	414.66	-37.09	630.17	-34.8	632.24	-34.38	635.71
1518	3000	-139.82	1508.87	-135.5	1540.29	-135.81	1542.48	-130.92	1537.19
1278	3000	-136.88	1299.07	-133.69	1307.36	-132.21	1326.89	-133.2	1312.92
1836	3000	-133.3	1547.13	-115.25	1633.73	-119.62	1594.36	-121.98	1565.11
906	3000	-133.28	1395.79	-132.84	1402.03	-132.27	1406.21	-132.77	1400.69
1628	3000	-131.2	1529.98	65.66	6502.81	64.13	6414.62	67.98	6118.37
3252	1000	-128.64	424.09	-25.63	669.42	-23.34	673.19	-22.92	676.92
1706	2500	-127.11	1304.83	-125.99	1314.23	-126.38	1310.48	-126.08	1313.09
448	5000	-125.16	2561.13	-120.51	2613.48	-124.16	2572.88	-121.4	2606.93
2214	1000	-124.34	541.84	-122.69	543.59	-123.03	540.76	-123.87	538.37
2622	1000	-123.05	505.65	-121.47	510.6	-124.55	495.03	-124.3	497.25
2438	1000	-122.17	534.55	-121.59	534.27	-122.65	528.95	-123.22	524.99
326	2500	-122.03	1347.79	-117.97	1364.85	-106.48	1417.53	-107.25	1409.39

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
322	2500	-120.28	1363.2	-116.23	1380.42	-104.65	1434.08	-105.42	1426.05
3254	1000	-119.05	431.97	-16.05	709.02	-13.76	714.89	-13.33	718.92
3046	1000	-118.53	375.28	-113.94	373.16	-116.12	357.9	-118.14	341.97
1842	4000	-117.17	2142.03	-90.38	2326.17	-96.13	2253.66	-93.7	2209.34
290	5000	-117.09	2760.93	-96	2915.81	-86.1	3016.44	-83.69	2988.81
3628	2500	-116.49	1452.02	-114.66	1464.69	-115.94	1456.41	-114.83	1463.09
344	1000	-115.01	561.61	-114.11	561.98	-109.97	571.47	-110.57	568.36
520	3000	-113.79	1498.47	-113.76	1497.19	-112.73	1510.73	-113.56	1499.94
1862	4000	-112.83	2171.56	-84.81	2371.16	-90.51	2297.18	-88.09	2252.17
3940	1000	-109.91	398.28	-109.26	395.99	-110.47	384.92	-111.23	375.54
1380	4000	-108.93	2222.59	-88.23	2357.75	-92.64	2313.36	-89.59	2279.31
4044	3000	-108.69	1435.25	-105.46	1447.29	-103.98	1467.68	-104.96	1452.88
2014	3000	-107.35	1653.74	-102.23	1686.91	-104.92	1662.42	-106.36	1643.37
304	5000	-105.55	2836.43	-80.21	3044.01	-74.51	3102.06	-72.13	3070.62
3824	3000	-100.1	1519.88	-95.43	1549.69	-96.12	1528.79	-96.06	1531.28
3826	3000	-100.07	1520.33	-95.4	1550.14	-96.09	1529.25	-96.04	1531.74
J7346	3000	-99.6	1338.7	8.71	2584.09	5.68	2501.77	4.96	2476.4
3256	1000	-99.41	461.29	3.6	833.44	5.89	847.95	6.31	852.88
3822	3000	-99.31	1523.56	-94.64	1553.54	-95.33	1532.6	-95.27	1535.09
3816	3000	-99.31	1523.63	-94.63	1553.61	-95.32	1532.67	-95.27	1535.16
3814	3000	-98.53	1527.11	-93.86	1557.27	-94.55	1536.28	-94.49	1538.78
4028	1000	-98.45	434.54	-97.8	432.75	-99.01	422.08	-99.78	413.32
1516	3000	-94.59	1628.9	-90.28	1671.04	-90.44	1674.79	-85.42	1668.83
3258	1000	-88.41	489.98	14.59	938.54	16.88	962.52	17.31	967.82
2396	5000	-86.34	2884.93	-81.62	2925.83	-83.18	2892.49	-81.28	2880.23
1768	1000	-85.69	435.48	-84.87	433.64	-84.88	434.48	-86.02	425.06
3248	1000	-82.72	505.99	20.29	1004.38	35.12	1273.67	35.54	1280.79
1398	4000	-82.19	2426.81	58.4	6281.92	47.39	5578.5	48.19	5530.21
J8320	1000	-81.04	507.79	21.96	1025.06	35.24	1276.87	35.67	1284.03
3050	1000	-80.15	472.46	-75.57	474.88	-77.74	459.38	-79.77	443.06
1442	3000	-78.78	1501.98	-78.78	1501.98	-78.78	1501.99	-78.78	1501.98
340	1000	-76.99	613.77	-76.09	614.84	-71.96	627.03	-72.56	623.24
7110	1000	-76.96	561.1	26.05	1066.25	45.28	1429.05	45.7	1435.76
3260	1000	-74.37	523.05	28.64	1127.4	30.93	1177.62	31.35	1184.02
3464	1000	-73.55	682.65	-72.38	687.32	-74.14	680.2	-73.9	681.24
1774	3000	-73.01	1755.57	-67.13	1792.63	-67.18	1795.27	-68.42	1772.23
2402	5000	-72.9	3013.42	-68.58	3058.36	-70.03	3023.24	-68.11	3011.82
1916	1000	-72.48	503.56	-67.9	508.1	-70.07	492.45	-72.1	476.51
7120	1000	-72.43	603.98	30.58	1105.86	54.35	1562.21	54.77	1568.74
7125	1000	-72.23	631.27	30.78	1091.18	64.75	1725.22	65.17	1731.83
1756	3000	-72.14	1827.58	-66.31	1867.26	-67.46	1865.49	-63.97	1848.55
88	3000	-71.78	1755.85	-63.52	1836.08	-57.53	1881.45	-57.2	1889.48
1772	1000	-71.18	424.44	-70.35	422.05	-70.37	423.03	-71.51	411.93

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
1950	3000	-70.1	1859.99	-64.91	1906.52	-67.62	1875.06	-69.08	1853.2
2620	1000	-69.72	639.13	-68.14	645.06	-71.22	628.51	-70.97	630.39
334	3000	-67.87	1904.64	-62.25	1947.8	-49.94	2054.18	-50.7	2036.85
898	3000	-66.7	1692.43	-65.7	1709.14	-65.83	1704.56	-65.71	1704.82
74	2500	-63.97	1540.87	-58.04	1593.52	-53.82	1624.14	-53.44	1631.5
3244	1000	-63.73	549.54	39.28	1362.06	41.57	1466.17	41.99	1474.76
J8772	3000	-62.13	1654.97	-62.04	1651.29	-61.57	1665.5	-62.5	1647.76
3596	1000	-61.46	648.25	-60.55	649.74	-56.42	663.38	-57.02	659.63
4012	1000	-60.06	563.64	-55.47	571.51	-57.65	555.92	-59.67	540.58
1574	3000	-59.46	1657.26	-55.05	1710.39	-55.79	1710.87	-51.24	1697.02
868	3000	-59.04	1689.02	-57.53	1714.15	-58.32	1700.76	-57.64	1708.62
1080	3000	-58.63	1948.6	-57	1959.49	-55.62	1978.14	-56.6	1963.95
2806	1000	-58.57	442.97	-58.03	440.83	-59.06	427.99	-59.56	417.21
994	5000	-56.4	3527.6	-41.81	3761.47	-56.02	3534.78	-44.13	3715.77
1414	4000	-56.3	2652.93	-26.75	2988.48	-31.15	2914.63	-28.12	2990.15
J7290	3000	-55.43	1923.23	-50.76	1964.92	-51.45	1945.5	-51.4	1947.65
3030	3000	-55.4	1926.58	-50.73	1968.21	-51.42	1948.89	-51.37	1951.03
J7292	3000	-55.34	1927.67	-50.67	1969.32	-51.36	1950.01	-51.31	1952.14
J7634	3000	-54.1	1968.28	-49.16	2020.02	-51.79	1986.13	-53.2	1963.54
118	3000	-54.01	1979.56	-49.41	2020.7	-12.91	2424.1	-13.14	2420.67
3036	3000	-53.78	1933.29	-49.11	1975.71	-49.8	1956.16	-49.75	1958.31
4046	3000	-53.51	1747.61	-55.45	1721.97	-52.59	1767.28	-53.87	1742.29
1560	3000	-53.04	2122.17	-51.13	2142.05	-52.37	2129.73	-51.36	2140.39
2986	3000	-52.97	1861.87	-47.98	1909.08	-48.66	1887.11	-48.61	1889.6
2994	3000	-52.68	1939.39	-48	1982.34	-48.69	1962.67	-48.64	1964.84
3462	1000	-52.33	657.62	-51.16	664.27	-52.92	654.13	-52.68	655.61
2664	1000	-51.91	516.91	-51.37	516.04	-52.4	505.27	-52.9	497.03
4058	3000	-51.21	1959.58	-49.15	1985.48	-50.56	1968.67	-49.41	1982.97
1584	3000	-51.12	1780.32	-46.71	1833.93	-47.56	1833.51	-43.11	1819.21
3594	3000	-49.46	2026.47	-40.04	2105.77	-40.84	2100.07	-38.1	2072.74
1084	3000	-48.12	1951.02	-46.54	1963.22	-45.17	1984.64	-46.14	1968.32
158	4000	-47.11	2712.32	-39.89	2804.89	13.31	3805.59	13.14	3799.97
3182	3000	-46.72	1918.89	-45.39	1933.58	-45.51	1918.06	-45.48	1919.97
2804	1000	-46.59	489.99	-46.05	488.53	-47.08	475.61	-47.58	465.3
1758	3000	-45.53	1985.41	-39.38	2039.32	-39.18	2045.49	-40.43	2018.11
4048	3000	-45.47	1744.85	-47.13	1719.96	-44.53	1766.46	-45.77	1740.22
2808	1000	-45.22	514.54	-44.68	513.49	-45.7	501.55	-46.21	492.34
4022	1000	-44.29	486.06	-44.13	487.37	-44.28	484.44	-44.39	484.61
162	4000	-43.61	2705.91	-36.41	2803.59	12.2	3763.79	12.1	3759.8
J8758	3000	-42.89	1787.56	-42.8	1784.26	-42.32	1799.38	-43.25	1779.13
1382	4000	-42.85	2799.59	-24.71	3014.46	-29.2	2937.31	-26.12	3016.73
7185	3000	-42.69	1721.17	-42.6	1717.15	-43.37	1713.5	-44.29	1691.75
4026	1000	-42.58	615.69	-41.93	616.12	-43.14	605.31	-43.91	597.42

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
4050	1000	-41.92	621.2	-43.23	610.8	-41.16	626.43	-42.27	618.26
1272	3000	-41.73	1867.38	-38.39	1898.37	-36.89	1925.95	-37.88	1905.67
J8780	3000	-41.32	1789.54	-41.23	1786.17	-41.46	1790.27	-42.38	1769.52
3622	3000	-40.5	1836.96	-36.06	1895.95	-37.06	1893.37	-32.75	1875.9
3066	3000	-40.33	2023.58	-35.66	2073.21	-36.35	2052.36	-36.29	2054.58
1274	3000	-40.13	1901.98	-37.1	1930.41	-35.63	1957.5	-36.62	1937.52
1474	3000	-39.58	1837.6	-35.18	1899.14	-36.04	1898.38	-31.59	1882.35
778	2500	-38.65	1209.56	-40.12	1160.99	-35.04	1303.46	-35.67	1244.07
172	1000	-38.52	722.29	-37.68	724.28	-30.69	753.46	-31.05	752.88
878	3000	-35.05	1926.84	-33.26	1958.65	-34.37	1939.65	-33.44	1954.12
J8834	3000	-34.64	1807.33	-34.55	1803.71	-35.31	1836.02	-36.24	1813.16
918	3000	-34.56	1965.04	-33.73	1981.64	-33.66	1980.72	-33.72	1977.95
J8240	3000	-33.79	1911.27	-36.58	1868.39	-32.81	1931.82	-34.25	1900.46
776	2500	-33.07	1422.93	-34.54	1383.47	-29.46	1502.77	-30.08	1459.09
2092	1000	-32.81	719.59	-16.31	778.29	-17.49	770.8	-19.43	757.75
2090	1000	-32.6	723.72	-16.68	780.13	-17.99	772.2	-19.93	758.76
1586	3000	-31.8	1853.03	-27.1	1923.41	-28.16	1919.37	-23.85	1898.38
2666	1000	-31.39	586.25	-30.85	586.34	-31.87	574.59	-32.38	566.39
4032	3000	-31.09	2102.58	62.5	6810.18	61.06	6681.1	65	6318.68
1082	3000	-30.85	2118.88	-29.26	2135.07	-27.9	2158.51	-28.87	2140.52
J8658	2500	-30.77	1540.15	-35.75	1465.34	52.23	8853.85	50.82	8609.24
1390	4000	-30.5	2958.57	-10.07	3262.38	-14.27	3176.27	-11.16	3265.79
318	1000	-30.2	756	-29.16	759.18	-27.19	767.41	-28.04	762.51
122	4000	-29.93	2871.97	-22.7	2988.99	33.91	4559.38	33.7	4554.41
146	4000	-29.62	2876.33	-22.39	2993.79	34.18	4571.16	33.97	4566.25
3998	3000	-28.83	2137.66	-24.24	2194.87	9.91	2758.7	9.72	2754.94
J8626	3000	-28.33	1757.19	-25.89	1779.55	-25.07	1803.63	-24.72	1815.23
264	1000	-28.3	745.28	-27.39	748.1	-23.26	766.23	-23.86	762.35
J8974	3000	-28.23	2014.47	15.55	2848.81	20.16	3005.67	19.03	2964.88
236	4000	-28.16	2971.2	-20.93	3085.95	33.53	4480.66	33.32	4475.87
1762	1000	-27.77	581.11	-27.02	581.55	-26.92	583.03	-27.97	570.49
2984	3000	-26.52	2094.17	-21.62	2159.05	-22.31	2134.94	-22.25	2137.43
2612	1000	-26.37	791.78	-24.79	799.23	-27.87	782.39	-27.62	784.01
J8670	2500	-25.87	1564.62	-30.85	1483.5	40.01	4048.76	38.67	3956.58
3468	1000	-25.62	630.44	-25.08	631.14	-26.1	619.8	-26.61	612.27
3054	1000	-25.39	761.58	-24.31	766.46	-25.63	758.39	-25.49	759.19
1766	1000	-25.38	672.94	-24.55	675.28	-24.57	675.75	-25.71	665.88
J8954	3000	-24.94	2398.18	-23.63	2412.65	69.45	4654.29	66.78	4551.22
432	3000	-23.95	2066.74	-26.75	2019.49	-22.97	2086.86	-24.41	2054.49
1240	3000	-23.87	2195.32	-22.63	2212.49	4.82	2641.04	1.62	2568.54
2570	1000	-23.86	574.46	-23.71	577.54	-23.85	574.83	-23.95	573.78
1102	3000	-23.71	2205.42	-22.48	2222.38	3.21	2615.14	0.13	2547.29
904	3000	-23.35	2092	-22.55	2109.09	-22.45	2109.49	-22.54	2105.76

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
J8782	3000	-22.4	1998.39	-22.32	1995.91	-22.54	1997.98	-23.47	1974.01
266	1000	-21.87	774.49	-20.96	777.65	-16.83	796.87	-17.43	792.96
1232	3000	-21.75	2227.79	-20.5	2245.52	9.54	2742.42	6.18	2662.24
338	1000	-21.67	771.08	-20.77	774.25	-16.63	793.52	-17.23	789.61
294	1000	-21.57	700.46	-20.74	703.2	-20.75	703.6	-21.9	693.97
1076	2500	-21.14	1812.14	-19.96	1823.1	-18.75	1845.03	-19.66	1828.46
3704	1000	-20.93	701.08	-22.24	689.58	-20.17	707.03	-21.28	697.84
1664	3000	-20.91	2294.14	68.82	7184.67	67.32	7041.18	71.23	6658.16
56	3000	-20.41	2278.69	-12.79	2392.93	-5.33	2500.78	-5.1	2506.58
J8654	2500	-20.39	1628.24	-25.38	1541.15	45.49	5283.01	44.15	5158.48
3184	3000	-20.17	2176.19	-18.85	2196.36	-19.05	2179.88	-19.01	2182.14
272	3000	-20.06	2322.38	-14.58	2393.78	-0.28	2611.46	-0.94	2595.96
3412	3000	-19.96	2216.89	-18.62	2236.43	-18.68	2223	-18.65	2224.97
256	1000	-19.87	776.58	-18.97	779.87	-14.83	799.74	-15.44	795.74
102	4000	-19.75	3063.96	-12.53	3195.22	42.39	4958.06	42.19	4955.92
1750	3000	-19.66	1997.46	40.46	4785.23	39.01	4576.46	42.95	4785.04
406	1000	-19.59	748	-18.87	755.01	-19.02	751.58	-19.08	752.21
512	3000	-19.58	2188.08	-19.61	2185.98	-18.49	2209.78	-19.38	2190.22
774	2500	-19.37	1724.73	-20.84	1689.26	-15.76	1794.42	-16.39	1764.54
J8668	2500	-19.35	1639.82	-24.33	1551.35	41.54	4310.36	40.21	4212.82
48	4000	-19.28	3076.56	-12.05	3208.2	42.71	4967.17	42.52	4965.21
234	4000	-18.96	3105.1	-11.72	3235.21	42.74	4926.15	42.53	4922.87
100	4000	-18.92	3083.29	-11.69	3215.58	43.84	5031.8	43.63	5029.92
2168	1000	-17.95	788.11	-15.64	800.13	-13.95	810.99	-12.75	818.57
258	1000	-17.66	785	-16.75	788.44	-12.62	808.83	-13.22	804.8
78	3000	-17.47	2259.5	-9.96	2383.99	-5.25	2463.79	-4.75	2474.18
2656	3000	-17.25	2258.19	-15.29	2283.26	-16.74	2257.3	-17.33	2243.86
1686	1000	-16.92	783.41	-16.02	790.61	-16.43	786.16	-16.29	787.89
1624	1000	-16.62	791.1	-15.03	797.82	-15.61	793.65	-16.43	788.85
232	4000	-16.16	3147.15	-8.92	3282.99	45.54	5096.29	45.33	5093.99
148	4000	-15.86	3157.79	-8.64	3293.29	44.56	5027.02	44.39	5026.44
J8236	3000	-15.84	2256.55	-18.37	2212.68	-14.89	2275.63	-16.28	2245.54
2654	3000	-15.76	2274.64	-13.91	2298.68	-15.31	2273	-15.84	2260.64
J8238	2000	-15.57	1405.21	-17.22	1380.03	-14.74	1421.34	-15.97	1399.23
228	4000	-15.09	3175.1	-7.86	3311.97	47.12	5172.04	46.91	5170.2
260	1000	-15.09	800.98	-14.18	804.57	-10.05	825.32	-10.65	821.31
2638	1000	-14.54	710.48	-14	712.26	-15.02	701.38	-15.53	694.71
J8242	3000	-14.29	2283.35	-16.83	2238.85	-13.34	2302.46	-14.74	2272.21
110	4000	-14.2	3190.22	-6.96	3329.3	50.27	5390.08	50.05	5389.17
1620	1000	-14.19	799.45	-12.6	806.45	-13.18	802.21	-14	797.3
J8244	3000	-14.02	2287.3	-16.55	2242.64	-13.07	2306.44	-14.46	2276.12
1514	1000	-13.81	779.24	-12.34	785.91	-12.09	787.83	-12.38	785.77
292	1000	-13.81	741.92	-12.98	745.41	-12.99	745.73	-14.14	735.82

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
418	1000	-13.8	730.83	-15.11	718.58	-13.04	737.24	-14.15	727.39
J8892	3000	-13.52	2330.58	-12.22	2351.27	28.69	3278.59	24.67	3147.63
J8894	3000	-13.33	2335.44	-12.04	2356.13	28.78	3280.53	24.75	3149.65
4038	3000	-13.27	2341.82	-8.68	2412.8	25.47	3154.45	25.27	3148.47
1236	3000	-13.18	2340.42	-11.89	2361.09	28.79	3279.82	24.75	3149.07
J96	2900	-12.6	1670.86	32.8	4807.73	34.6	5093.9	35.03	5167.35
810	3000	-12.49	2175.03	-12.81	2128.08	-6.64	2276.37	-6.79	2252.48
160	4000	-12.34	3185.19	-5.13	3331.91	43.48	5038.24	43.38	5040.98
J8890	3000	-12.23	2346.63	-10.94	2367.86	31.56	3390.55	27.76	3258.06
96	4000	-11.53	3207.35	-4.32	3354.98	45.75	5161.28	45.63	5163.46
2576	1000	-11.3	634.35	-11.14	638.92	-11.28	636.15	-11.39	634.04
J8246	3000	-11.03	2342.95	-13.56	2297.16	-10.08	2362.1	-11.47	2331.58
1760	1000	-10.86	691.53	-10.11	694.46	-10.01	695.98	-11.06	683.12
2668	1000	-10.7	683.92	-10.12	685.85	-11.23	670.79	-11.84	660.85
1580	2500	-10.29	1825.98	-6.86	1892.49	-7.05	1893.4	-1.69	1878.01
1754	1000	-9.93	584	-7.17	601.95	-7.46	597.06	-8.4	579.35
2316	1000	-9.33	799.51	-9.2	800.21	-9.31	799.35	-9.38	799.06
638	1000	-8.88	693.6	-10.67	661.38	-5.79	728.53	-8.09	696.36
J8836	3000	-8.86	2207.42	-8.77	2206.03	-8.99	2205.89	-9.92	2178.72
410	3000	-8.81	2397.67	-11.37	2350.26	-7.86	2416.94	-9.26	2385.97
3180	3000	-8.34	2386.13	-7	2408.56	-7.05	2397.39	-7.02	2399.22
J7208	3000	-8.04	2325.43	4.55	2582.2	9.27	2706.78	10.15	2729.2
2574	1000	-7.24	675.4	-7.09	680.52	-7.23	678.07	-7.33	675.36
2504	1000	-6.84	857.26	-5.26	866.7	-8.34	846.66	-8.09	848.47
3296	3000	-6.77	2503.14	-2.16	2575.15	34.33	3386.13	34.1	3379.42
2578	1000	-6.46	678.26	-6.31	683.54	-6.45	681.01	-6.55	678.23
1526	2500	-6.25	1889.48	-2.83	1959.44	-3.03	1959.88	2.31	1943.88
324	3000	-6.17	2507.7	-0.79	2593.11	14.6	2882.54	13.97	2868.02
3012	1000	-6.13	678.56	11.71	847.46	10.68	828.97	8.75	789
1078	3000	-6.11	2432.26	-4.48	2458.93	-3.11	2487.9	-4.08	2465.81
J7730	3000	-5.89	2338.96	-5.6	2339.73	-4.81	2360.57	-4.46	2370.6
J7250	1000	-5.8	740.89	-5.25	743.55	-6.3	730.54	-6.85	722.51
1914	1000	-5.52	803.69	-0.93	829.85	-3.1	810.88	-5.13	792.69
262	1000	-5.47	840.86	-4.56	845.2	-0.43	868.7	-1.03	864.48
7170	3000	-4.78	2356.98	-7.58	2294.69	-3.8	2380.06	-5.24	2341.39
508	3000	-4.48	2456.46	-2.9	2483.29	-1.53	2512.84	-2.5	2490.46
2566	1000	-4.37	714.19	-4.22	717.13	-4.36	714.93	-4.46	712.85
J7430	2500	-4.34	2089.58	67.78	6020.24	75.78	9910.15	75.69	9873.98
768	2500	-4.25	1901.92	-5.72	1859.71	-0.64	1986.63	-1.27	1957.42
716	2500	-4.18	1916.7	-2.25	1960.74	-3.65	1929.7	-2.45	1955.71
2086	1000	-4.09	730.47	8.02	831.23	6.12	804.96	4.14	774.12
1428	3000	-3.93	2472.72	71.97	12237.48	70.44	11662.94	74.29	10863.07
424	1000	-3.7	771.82	-5.01	757.52	-2.94	779.45	-4.05	767.84

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
720	3000	-3.64	2423.25	-3.35	2426.7	-2.1	2457.86	-3.03	2433.98
J7032	1000	-3.18	784.09	-2.53	787.57	-3.74	773.77	-4.49	764.51
J7870	3000	-3.01	2390.61	17.01	2895.71	19.87	2995.15	18.81	2956.98
2658	3000	-2.82	2499.39	-1.07	2528.82	-2.42	2499.48	-2.91	2486.7
J7860	3000	-2.23	2410.16	17.79	2922.68	20.64	3023.31	19.59	2985.01
3702	1000	-2.14	791.95	-3.45	777.98	-1.38	799.45	-2.49	788.14
792	1000	-2.03	849.79	-0.32	862.38	-1.71	851.97	-0.76	858.97
790	1000	-1.85	850.52	-0.14	863.15	-1.53	852.71	-0.58	859.73
3076	2000	-1.62	1651.47	1	1687.75	-0.08	1666.69	0.04	1669.23
1530	2500	-1.58	1964.37	1.83	2039.84	1.61	2039.49	6.93	2194.93
28	4000	-1.37	3350.96	10.95	3686.84	23.96	4159.17	24.29	4173.18
1688	1000	-1.18	842.8	-0.32	850.68	-0.66	846.52	-0.58	847.82
J8982	3000	-1.15	2420.25	24.86	3198.53	28.17	3350.66	27.09	3304.26
302	3000	-0.95	2583.67	5.93	2705.08	11.74	2820.24	10.67	2795.79
2436	3000	-0.84	2564.85	0.59	2587	-0.57	2563.68	-0.88	2556.69
J8980	3000	-0.8	2441.32	25.86	3235.66	29.22	3389.56	28.14	3343.8
2040	3000	-0.7	2524.74	15.3	2877.54	11.63	2780.12	9.42	2719.46
J7878	3000	-0.53	2414.79	19.49	2981.33	22.34	3094.86	21.28	3052.43
794	5000	-0.47	4187.69	10.25	4420.48	24.39	5217.34	22.68	5137.52
1020	1000	-0.44	832.69	1.02	846.71	-0.1	835.42	0.68	842.68
30	3000	-0.27	2525.39	7.36	2686.69	14.82	2859.87	15.05	2866.29
J7890	3000	0.01	2440.66	25.13	3212.76	28.37	3364.53	27.3	3317.62
3336	3000	0.1	2582.12	1.91	2617.08	0.8	2595.94	1.71	2614.15
3960	1000	0.11	907.63	1.44	914.29	0.48	909.34	1.1	912.43
2444	1000	0.19	865.08	0.78	868.1	-0.29	859.99	-0.86	855.3
1922	1000	0.37	842.81	5.84	878.58	3.73	859.69	1.71	841.01
54	3000	0.43	2578.03	8.06	2728.98	15.51	2890.44	15.74	2896.32
3486	1000	0.57	894.69	1.65	900.41	0.33	892.41	0.47	893.24
2568	1000	0.61	764.03	0.76	765.3	0.63	763.34	0.52	762.67
3460	1000	0.89	850.24	2.06	860.91	0.3	844.76	0.55	847.11
992	5000	1.08	4405.28	15.66	4854.76	1.45	4416.81	13.34	4776.59
1710	1000	1.26	751.71	2.13	758.43	2.18	759.48	1.15	743.5
196	3000	1.45	2630.89	6.38	2718.43	31.02	3281.8	30.59	3272.11
3518	1000	1.73	862.51	18.23	985.11	17.05	974.18	15.11	955.47
1440	1000	1.89	748.63	10.57	847.21	10.2	840.35	9.31	824.43
3352	4000	2.11	3427.13	10.62	3672.36	32.26	4528.43	32.85	4569.6
1618	1000	2.43	882.89	4.02	892.12	3.44	887.56	2.62	881.99
3052	1000	2.52	901.48	3.59	907.19	2.28	899.32	2.42	900.14
1572	2500	2.63	2035.81	6.04	2118.27	5.8	2116.82	11.09	2276.77
J8134	3000	2.64	2643.72	3.96	2668.02	51.69	4238.32	48.5	4098.83
J8132	3000	2.8	2644.92	4.11	2669.4	51.05	4206.6	47.88	4081.78
J8234	2000	2.82	1672.72	1.18	1643.92	3.66	1690.36	2.42	1665.99
1522	1000	2.88	755.57	4.16	766.5	4.19	767.32	3.71	759.54

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
2224	1000	3.09	886.42	4.73	896.29	4.4	892.59	3.56	886.32
632	2500	3.12	2151.53	3.23	2152.21	4.37	2176.65	3.47	2157.43
3516	1000	3.65	879.58	19.56	999.55	18.26	987.44	16.32	969.11
240	1000	3.89	860.04	4.72	865.73	4.71	865.82	3.56	855.08
J8130	3000	4.28	2661.57	5.61	2687.46	46.9	4014.36	43.93	3891.58
2648	1000	4.7	845.63	5.21	849.38	4.24	838.39	3.79	832.73
3626	1000	4.87	902.54	6.28	912.69	5.22	904.86	5.93	909.91
J7866	3000	5.11	2573.82	25.13	3200.11	27.98	3323.3	26.92	3280.42
722	3000	5.11	2610.43	5.46	2617.15	6.7	2651.08	5.78	2624.92
208	3000	5.25	2695.46	10.07	2786.94	37.86	3503.09	37.47	3493.11
4024	1000	5.36	869.54	6.01	873.99	4.8	861.64	4.04	853.65
2644	1000	5.42	858.15	5.98	862.22	4.92	850.6	4.38	843.98
J146	3000	5.75	2573.66	5.16	2553.23	5.75	2572.07	6.1	2583.13
3408	1000	5.77	821.85	6.43	827.27	5.21	808.81	4.44	796.28
3306	1000	5.88	899.62	7.29	910.63	6.23	902.16	6.95	907.62
J7204	2900	5.95	2515.99	17.86	2832.75	22.48	2978.7	23.32	3006.24
3470	1000	6.44	866.12	6.98	870.19	5.96	859	5.45	852.89
J8128	3000	7.09	2712.63	8.42	2739.94	45.53	3945.94	42.71	3831.88
374	1000	7.16	875.18	7.99	881.8	7.97	881.87	6.83	869.87
2670	1000	7.42	855.47	8.03	860.57	6.89	845.77	6.26	836.78
3068	3000	7.68	2660.09	12.45	2779.38	11.77	2755.53	11.82	2757.4
3636	1000	8.58	894.51	9.4	901.08	9.39	901.1	8.25	889.77
622	3000	8.89	2727.44	9.91	2750	11.24	2782.58	10.27	2757.94
3322	1000	9.09	928.05	10.8	939.68	9.41	930.12	10.36	936.63
934	2900	9.24	2569.5	10.86	2616.68	9.96	2590.48	10.73	2613.16
1338	3000	9.56	2696.15	11.81	2754.42	13.24	2795.93	12.25	2766.08
1804	1000	9.66	927.96	19.67	997.43	17.65	981.59	15.47	964.16
246	1000	9.82	924.03	10.65	930.31	10.63	930.29	9.49	919.96
2876	5000	9.99	4689.57	18.13	4937.84	18.36	4944.28	18.33	4943.44
2068	1000	10.31	930.42	11.57	938.68	9.25	920.71	7.2	904.87
86	3000	10.37	2743.08	18.64	2960.92	24.62	3144.77	24.96	3155.31
2228	1000	10.5	930.74	12.65	945.77	13.55	952.6	13.83	954.8
506	3000	10.8	2762.86	12.21	2795.94	13.57	2830.72	12.59	2805.01
1708	1000	10.9	946.76	11.9	953.01	11.33	949.31	11.61	951.09
J8206	3000	11.08	2774.46	11.9	2793.75	14.01	2844.37	13.1	2820.44
2580	1000	11.09	878.31	11.24	880.09	11.1	877.98	11	876.9
1894	1000	11.11	914.19	16.73	966.33	14.63	943.6	12.61	921.21
68	3000	11.27	2786.22	18.9	2972.12	26.31	3183.83	26.54	3190.51
4060	1000	11.33	954.3	12.66	961.89	11.71	956.35	12.33	959.93
J7868	3000	11.37	2730.44	31.39	3506.37	34.24	3662.32	33.18	3612.97
1908	2500	11.76	2348.11	34.83	2890.79	31.25	2797.04	29.02	2741.32
422	1000	11.87	913.16	10.57	897.29	12.64	922.09	11.53	908.92
1470	2500	11.88	2263.35	15.3	2358.23	14.92	2350.03	19.99	2500.02

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	Res	Avail	Res	Avail	Res	Avail	Res	Avail
ID	gpm	psi	gpm	psi	gpm	psi	gpm	psi	gpm
1582	1000	11.9	881.64	13.13	896.71	13.1	896.43	12.56	887.93
J7674	4000	12.06	3709.72	23.59	4157.8	32.71	4655.51	32.57	4646.56
788	1000	12.1	949.41	13.81	961.17	12.42	951.53	13.38	958.11
1504	1000	12.38	911.43	13.81	926.46	14.01	928.98	13.68	924.97
J7676	4000	12.43	3722.08	23.85	4169.97	32.96	4671.29	32.82	4662.27
J7496	3000	12.44	2805.34	14.17	2845.38	12.84	2811.69	12.36	2798.72
642	5000	12.68	4538.26	23.4	5570.37	37.54	6545.46	35.9	6226.46
1074	2500	12.71	2326.18	13.89	2351.79	15.11	2381.14	14.19	2358.67
J8908	2000	12.87	1861.99	35.41	2434.44	52.4	3441.94	50.86	3362.98
J7678	4000	12.94	3739.63	24.25	4187.78	33.35	4693.84	33.2	4684.72
2652	1000	13.16	927.72	13.64	932.26	12.71	921.86	12.33	917.28
320	3000	13.34	2851.58	18.57	2970.8	35.76	3457.75	35.2	3443.68
1042	2500	13.47	2373.36	15.29	2408.65	14.02	2384.06	15.12	2405.56
1446	3000	13.51	2732.93	13.51	2732.93	13.51	2732.93	13.51	2732.93
1142	3000	13.59	2824.31	14.95	2860.32	14.44	2846.92	14.88	2858.49
1608	3000	13.97	2831.63	18.39	2953.24	17.28	2923.12	21.45	3039.3
1742	3000	14.35	2823.7	51.36	5674.42	49.99	5987.81	53.93	5639.5
J7514	3000	14.39	2808.99	15.68	2850.11	15.51	2840.46	15.55	2842.34
J8462	1000	14.39	955.26	12.6	939.88	17.48	979.96	12.9	943.24
1556	3000	14.42	2866.75	16.41	2913.73	15.08	2882.5	16.16	2908.32
J8208	3000	14.58	2855.24	15.35	2875.03	17.06	2919.67	16.25	2897.25
2178	1000	14.7	960.38	17.01	977.49	18.7	990.29	19.9	999.28
3504	1000	14.78	962.01	15.36	966.28	14.29	957.59	13.72	952.82
J7434	2400	14.82	2292.82	61.25	4767.13	67.3	6123.19	67.22	6107.78
J7438	2500	14.94	2389.02	58.27	4611.2	64.46	5761.61	64.38	5747.77
J8428	1000	14.96	959.16	13.17	943.61	18.05	984.24	13.47	946.96
1730	1000	14.99	963.66	15.99	971.71	15.43	967.03	15.71	969.3
3042	1000	15.02	970.14	16.1	976.49	14.78	968.43	14.92	969.29
440	1000	15.1	942.12	13.79	924.62	15.86	952.06	14.75	937.41
628	3000	15.1	2855.68	15.3	2860.99	16.56	2897.89	15.6	2869.44
634	3000	15.19	2859.26	15.37	2864.12	16.62	2901.19	15.67	2872.57
1306	3000	15.28	2850.44	20.12	3003.95	21.71	3059.08	20.72	3024.87
3458	1000	15.67	958.54	16.84	971.29	15.08	951.99	15.32	954.72
J8376	1000	15.85	957.12	14.07	937.11	18.94	989.13	14.64	944.28
J8384	1000	15.98	960.18	14.19	941.11	19.07	990.82	14.67	947.01
J7892	3000	15.99	2865.21	33.44	3628.78	36.09	3785.97	35.04	3734.6
2398	3000	16.15	2894.55	17.9	2940.66	16.56	2903.52	16.07	2889.6
J8382	1000	16.16	962.37	14.37	943.57	19.25	992.67	14.83	949.14
7140	4000	16.24	3732.23	15.71	3692.34	27.11	4770.18	25.37	4651.7
786	1000	16.36	978.95	18.07	990.68	16.68	981.1	17.64	987.68
2514	1000	16.52	936.03	16.64	938.2	16.53	936.1	16.46	934.97
3656	3000	16.56	2923.6	21.21	3032.4	56.42	4383.38	56.07	4375.29
3026	1000	16.7	913.76	32.41	1983.47	31.08	1879.22	29.14	1751.24

Appendix B
Fire Flow Results

		Max Day		Max Day CIP		Future Stage 1		Future Stage 2	
	Req'd	**Res**	**Avail**	**Res**	**Avail**	**Res**	**Avail**	**Res**	**Avail**
ID	**gpm**	**psi**	**gpm**	**psi**	**gpm**	**psi**	**gpm**	**psi**	**gpm**
J8196	2000	16.97	1918.59	14.97	1867.45	17.76	1940.29	16.44	1905.12
1882	1000	17.05	977.67	20.6	1006.2	18.32	987.18	16.29	969.93
3070	3000	17.05	2908.88	21.72	3056.76	21.03	3034.61	21.08	3036.29
2180	1000	17.17	978.68	19.48	996.29	21.17	1009.24	22.37	1018.36
3320	1000	17.19	969.3	15.4	946.53	20.28	1005.96	16.38	959.46
668	2500	17.28	2406.92	19.26	2477.85	17.81	2426.18	19.05	2470.45
552	1000	17.31	967.39	16.92	962.24	18.05	976.63	17.32	967.56
3000	1000	17.46	977.76	18.53	987.27	17.22	975.29	17.36	976.56
72	3000	17.5	2933.39	25.12	3146.86	32.44	3396.84	32.68	3404.17
J8126	3000	17.53	2941.69	18.89	2973.44	48.52	4030.28	45.95	3928.54
3018	1000	17.54	978.08	18.61	988.22	17.3	975.45	17.44	976.81
2298	1000	17.89	984.38	18.02	985.6	17.91	984.51	17.83	983.84
554	1000	17.99	976.73	17.6	971.77	18.73	985.68	18	976.89
932	2900	18.17	2838.25	19.82	2897.31	18.87	2863.23	19.68	2892.33
1288	1000	18.19	973.81	17.8	968.05	18.94	984.82	18.22	974.26
2990	3000	18.25	2947.75	22.93	3093.26	22.24	3072.43	22.29	3073.99
518	3000	18.48	2950.91	18.51	2951.97	19.54	2984.96	18.71	2958.06
J78	3000	18.53	2948.62	19.62	2986.78	20.57	3020.53	20.95	3034
66	3000	18.57	2961.82	26.19	3182.31	33.35	3436.21	33.61	3444.1
J8396	1000	18.73	988.31	16.95	971.22	21.82	1016.74	17.29	974.9
J8402	1000	18.81	989.24	17.03	972.5	21.9	1017.13	17.32	975.68
J8404	1000	19.1	992.25	17.31	976.47	22.19	1018.68	17.61	979.42
1892	1000	19.1	992.26	24.72	1049.48	22.62	1027.93	20.6	1007.08
J8398	1000	19.2	992.73	17.41	976.07	22.29	1020.6	17.71	979.21
1558	3000	19.23	2984.2	21.14	3023.57	19.9	2998.03	20.91	3018.73
3064	3000	19.57	2986.06	24.24	3147.85	23.55	3125.92	23.61	3127.56
3500	1000	19.71	1000.17	19.87	1002.2	19.72	1000.3	19.61	998.91
308	1000	19.76	998.46	20.89	1007.5	21.81	1014.97	20.74	1006.4
3224	3000	19.76	2993.61	21.97	3054.32	25.28	3153.84	25.22	3152.03
588	3000	19.8	2997.51	19.95	3002.11	21.2	3040.68	20.25	3011.23
782	1000	19.9	999.25	21.61	1011.87	20.22	1001.59	21.17	1008.68
J8124	3000	19.9	2997.55	21.26	3031.05	48.58	4036.79	46.09	3937.81