WATER DISTRIBUTION SYSTEM ANALYSIS AND CAPITAL IMPROVEMENTS

for

City of Sanger
(Denton County, Texas)

TCEQ Public Water System No.
TX0610006

KSA Project Number SNG.004

Revision	Description	By	Date
0	Final Report	Danny Hays, P.E. Shriram Manivannan, P.E. Emily Avery, E.I.T.	8/3/2022

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1 Introduction

1.1 Scope of work

The City of Sanger authorized KSA Engineers to update the 2010 Master Plan for the water and sanitary sewer systems. The scope included modeling of the existing systems, projecting future growth, modeling the future systems, identifying the improvements necessary to accommodate future growth, and analysis of water supply capacity. .

To assist in navigation through this report, the following is a brief guide to the information contained within each chapter.

- Chapter 2 provides a summary of City's existing water distribution system infrastructure and facilities.
- Chapter 3 outlines the evaluation of the City's water supply and storage capacity against current Texas Commission on Environmental Quality (TCEQ) regulations under Chapter 30 of the Texas Administrative Code (TAC) section 290.45..
- Chapter 4 provides projected growth for the City of Sanger (5, 10 and 20 year) based on NCTCOG growth data and the evaluation of City's water supply and storage capacity against TCEQ requirements.
- Chapter 5 contains a discussion concerning the findings of the modeling of the existing system.
- Chapter 6 is a summary containing a discussion centering on the recommended capital improvements including estimated costs of the recommended improvements.
- Appendix I contains distribution modeling basis and assumptions as well as a brief information to basic hydraulic terminology and fundamentals. This chapter will provide insight to many of the terms used throughout the report. Appendix II contain several graphical exhibits that are referenced in the report. These exhibits show various maps of the water distribution system and the proposed capital improvements.

1.2 Work Plan

A general work plan for performing the above scope of work, consisted of the following:

A. Conduct a review of existing information related to the City of Sanger's water supply and treatment history including the following:
   1. TCEQ Drinking Water Watch Data;
   2. Customer Meter Reading and Billing Data; and,
   3. Available distribution system mapping.

B. Create a WaterCAD computer module of the distribution system using all line sizes 2-inches and larger. Model is office calibrated, without field verification or calibration.

C. Conduct steady state model simulations for average day, maximum day, peak hour, and TCEQ minimum 1.5 gpm per connection demands for existing conditions as well as for the future 5-, 10- and 20- year future conditions.

D. Identify areas of low pressure within the distribution system on the basis the modeled simulations.

E. Develop new water system infrastructure improvements to address modeled deficiencies; and,

F. Prioritize improvement projects based on city needs and population projections through to year 2040.

1.3 Limitations

References in this report to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the City of Sanger, KSA or other individuals or entities specifically mentioned in this report.

The projected growth rates shown in this report are estimates based upon NCTCOG growth data or from growth patterns in nearby, similar sized cities. Actual growth rates could be higher or lower based upon a number of factors that are beyond the scope of this study.

The design basis for the information presented in this report is preliminary in nature and therefore is subject to change. The facilities and components discussed should be confirmed with more specific data as design development of the capital improvements proceeds.

Any project costs shown are opinions of probable construction cost only and are based upon standard construction practices, materials and installation. Costs are reflective of present day prices and are on the basis of conceptual schematics and alignments. Opinions presented do not include costs arising from property and/or easement acquisition, primary electrical service, etc.

1.4 Acknowledgements

The cooperation and assistance of City of Sanger staff is gratefully acknowledged

2 Existing Water System Facilities and Infrastructure

2.1 Water System Background

The City's water system presently serves approximately 3,386 metered connections (City data), most of whom are residential customers. The distribution system consists of approximately 66 miles of water mains, ranging in diameter from 20-inches to 2-inches. Source water supply for the city's public water system is primarily withdrawn from the Trinity aquifer via six active ground water wells. All information presented is from the TCEQ Drinking Water Watch database and data provided by the City staff. A map of the existing system and pipe diameters is shown on the next page.

2.1.1 Groundwater Facilities

The groundwater system consists of six active groundwater wells, each with groundwater treatment facilities (chlorine dosed), and four high service pumping facility.

The table below represents a tabulation of the various facilities that are contained within the groundwater system production system.

Table 2.1 – Existing Groundwater Wells

Well Number	Location	Year Drilled	Tested Capacity (gpm)	TCEQ Rated Capacity (gpm)
2	1st St and Cherry St (	1955	80	75
5	Acker St	1982	165	200
6	McReynolds	1913	275	320
7	Utility Rd	2002	600	765
8	1st St and Cherry	2016	625	730
9[1]	FM 455 and Keith Dr	2016	725	720
City Total Capacity (GPM)			2,470	2,810
Cowling Rd[2]	Cowling Rd (Contracted capacity)	-	600	600
System Total Capacity (GPM)			**3,070**	**3,410**
System Total Capacity (MGD)			**4.4208**	**4.9104**

[1]Well 9 is currently not in service.
[2]Cowling Rd well is owned and operated by the Upper Trinity Regional Water District with a contracted capacity of 600 GPM.

2.1.2 Distribution System Facilities

The distribution system consists of four high pump service stations, one elevated storage tank, one ground storage tank, and approximately 66 miles of transmission and distribution mains. The City of Sanger water distribution system includes galvanized steel, asbestos cement, and PVC pipes ranging in size from 20-inches to 2-inch in diameter.

Water from the wells is pumped to the groundwater treatment facilities (chlorine dosed) located at each well site. At well sites with ground storage tanks, the water is distributed to the system via a high service pump station. At the elevated storage tank sites, water is chlorinated and then is directly pumped into the elevated storage tank.

The tables below represent a tabulation of the various facilities that are contained within the distribution system.

Table 2.2 – Existing Groundwater Wells

Site Location	Well Number	Ground Storage Facility	Elevated Storage Facility	Pump Station Facility
1st St and Cherry St	2 & 8	2 GST Total	-	1 Pump
Acker St	5	1 GST	1 EST	2 Pumps
McReynolds	6	-	1 EST	

Utility Rd	7	1 GST	1 EST	3 Pumps
FM 455 and Keith Dr	9[1]	-	-	
Cowling Road	Cowling Rd	1 GST	-	2 Pumps

Table 2.3 – Distribution System Pumps

Well Number	Location	Duty Pumps Total Capacity (gpm)[1]
2	1st St and Cherry St	150
5	Acker St (2 Pumps)	600
7	Utility Rd (3 Pumps)	1050
Cowling Rd	Cowling Rd (2 Pumps)	1200
Collective Pump StationCapacity		**3,000**

1: Pump capacity data provided by City staff.

Table 1.4 – Distribution Storage Tanks

Location	Type	Capacity (gallons)[1]
1st St and Cherry St	GST	100,000
1st St and Cherry St	GST	300,000
Acker St	GST	300,000
Acker St	EST	500,000
McReynolds	EST	200,000
Utility Rd	GST	100,000
Walmart District	EST	500,000
Cowling Rd	GST	500,000
Total Capacity		**2,300,000**

1: Storage tank capacity provided by City staff.

Table 2.5 – Summary of Existing Water Distribution Mains

Pipe Diameter (inches)	Approximate Total Length (miles)
2	5.29
4	0.54
6	18.82
12	8.04
16	1.84
20	0.29
Total	**66.04**

The above summary of existing water distribution mains only reflects the length of water mains placed into the water system model. The summary reflects all known water mains 2-inches in diameter and greater.

3 TCEQ Minimum System Capacity Requirements

City of Sanger's water supply and storage capacity evaluation was based on the current Texas Commission on Environmental Quality (TCEQ) regulations under Chapter 30 of the Texas Administrative Code (TAC) section 290.45. Minimum Water System Capacity Requirements listed in 30 TAC 290.45 are directly linked to the number of connections served and the daily demands of the water system. This can have significant impact on the analysis of an existing water system and its abilities to serve not only the connections and demands of the existing facility designs, but also the current and future numbers of connections served, or to be served, along with their respective daily demands.

For the purposes of this master plan, the analysis of minimum system capacity requirements has been limited to the requirements for well capacity, total storage, elevated storage, and high service pumping.

3.1 TCEQ Well Capacity, Storage and Pumping Requirements

The TCEQ rules for minimum system capacity requirements for community water systems are divided in to two categories dependent upon whether the system is served by groundwater or surface water. The groundwater system rules are further divided based upon the number of connections in the water system.

The City of Sanger system is served by a ground water source, therefore the groundwater rules will be applied. A summary of the applicable rules are shown in Table 3.1 below.

Table 3.1 – Applicable Rules From 30 TAC 290, Subchapter D

TCEQ Groundwater System Rule	Rule Text
Well Capacity 290.45(b)(1)(D)(i)	Two or more wells having a total capacity of 0.6 gpm per connection. Where an interconnection is provided with another acceptable water system capable of supplying at least 0.35 gpm for each connection in the combined system under emergency conditions, an additional well will not be required as long as the 0.6 gpm per connection requirement is met for each system on an individual basis. Each water system must still meet the storage and pressure maintenance requirements on an individual basis unless the interconnection is permanently open. In this case, the systems' capacities will be rated as though a single system existed
Total Storage 290.45(b)(1)(D)(ii)	Total storage capacity of 200 gallons per connection.
Pump Capacity 290.45(b)(1)(D)(iii)	Two or more pumps having a total capacity of 2.0 gpm per connection or that have a total capacity of at least 1,000 gpm and the ability to meet peak hourly demands with the largest pump out of service, whichever is less, at each pump station or pressure plane. For systems which provide an elevated storage capacity of 200 gallons per connection, two service pumps with a minimum combined capacity of 0.6 gpm per connection are required. If only wells and elevated storage are provided, service pumps are not required.
Elevated Storage 290.45(b)(1)(D)(iv)	An elevated storage capacity of 100 gallons per connection or a pressure tank capacity of 20 gallons per connection. If pressure tanks are used, a maximum capacity of 30,000

	gallons is sufficient for up to 2,500 connections. An elevated storage capacity of 100 gallons per connection is required for systems with more than 2,500 connections. Alternate methods of pressure maintenance may be proposed and will be approved if the criteria contained in subsection (g)(5) of this section are met.

3.2 Capacity Analysis of Existing Water Facilities

Capacity analysis of existing water system facilities and their ability to meet the TCEQ Minimum System Capacity Requirements were performed using connection and demand data specific to the City's system. This information is presented in the following sections. The comparative analysis is based upon 3,386 active connections (provided by city staff).

3.2.1 Existing Well Production Capacity Analysis

Analysis of existing well production capacity against TCEQ minimum system capacity requirements is presented in Table 3.2 below. Groundwater supplied to the system includes Wells 2, 5, 6, 7, 8, and the well at Cowling Road (owned and operated by the Upper Trinity Regional Water District). It should be noted that Well 9 is currently out of service; however, the tested capacity of Well 9 is included for the purposes of this evaluation. This analysis is conducted on the basis of the 3,386 existing active connections in the system.

Table 3.2 – Required Well Capacity by Number of Connections

Portion of System	Existing Active Number of Connections	Required Well Capacity (gpm)(1)	Existing Tested Well Capacity (gpm)
Entire System	3,386	2,032	**2,345** gpm (tested, without Well #9 in service) **3,070** gpm (tested, with Well #9 in service)

(1) Based upon a minimum capacity requirement of 0.6 gpm per connection.

As evident from Table 3.2 the system meets the minimum requirement for well production capacity based upon the tested capacity of the wells.

3.2.2 Existing Total Storage Capacity Analysis

Analysis of existing total storage capacity against TCEQ minimum system capacity requirements is presented in Table 3.3. This analysis is conducted based upon the number of existing active connections within the system.

Table 3.3 – Required Total Storage by Number of Connections

Portion of System	Approximate Number of Connections	Required Storage Capacity (gallons)(1)	Existing Storage Capacity (gallons)(2)
Entire System	3,386	677,200	2,500,00

(1) Based upon a minimum capacity requirement of 200 gallons per connection.
(2) Includes only ground storage tanks, elevated storage tanks, and standpipes within the current system configuration.

Based upon Table 4.3 the system meets the minimum requirement for total storage.

3.2.3 Existing Elevated Storage Capacity Analysis

Analysis of existing elevated storage capacity against TCEQ minimum system capacity requirements is presented in Table 3.4. This analysis is conducted based upon the approximate number of existing active connections within the system. Table 2 – Required Elevated Storage by Number of Connections

Table 3.4 – Existing Groundwater Wells

Portion of System	Approximate Number of Connections	Required Storage Capacity (gallons)	Existing Storage Capacity (gallons)[3]
Entire System	3,386	338,600	1,200,000

(1) Based upon a minimum capacity requirement of 100 gallons per connection.
(2) Includes only elevated storage tanks, and standpipes within the current system configuration.

Table 3.4 indicates the system exceeds the minimum required for elevated storage based upon the minimum required 100 gallons/connection. Existing High Service Pumping Capacity Analysis

Analysis of existing high service pumping capacity against TCEQ minimum system capacity requirements is presented in Table 3.5. This analysis is conducted based upon the approximate number of existing active connections within the system..

Table 3.5 – Required High Service Pumping Capacity

Portion of System	Approximate Number of Connections	Required Pumping Capacity	Existing Pumping Capacity (gpm)
Entire System	3,386	1000	3,000

Based upon Table 3.5, the system meets the minimum 1000 gpm total pumping capacity with the ability to meet peak hour demands with the largest pump out of service. The system also supplies over 200 gallons of elevated storage per connection, and it does meet the 0.6 gpm pumping capacity per connection requirement.

3.3 TCEQ Adequacy of Service

Another consideration in planning for future growth is based upon a TCEQ regulation concerning adequacy of service. This regulation can be found in 30 TAC 291.93.(3) and reads as follows:

> *"A retail public utility that possesses a certificate of public convenience and necessity that has reached 85% of its capacity as compared to the most restrictive criteria of the commission's minimum capacity requirements in Chapter 290 of this title shall submit to the executive director a planning report that clearly explains how the retail public utility will provide the expected service demands to the remaining areas within the boundaries of its certificated area. A report is not required if the source of supply available to the utility service provider is reduced to below the 85% level due to a court or agency conservation order unless that order is expected to extend for more than 18 months from the date it is entered in which case a report shall be required."*

Based upon this 85% requirement Table 3.6 was created indicating adequacy of service for the City of Sanger water system as currently operated.

Table 3.6 – Adequacy of Service Requirements

Minimum System Capacity Criteria	System Capacity	TCEQ Required Capacity(1)	Percentage of Capacity	Meets TCEQ minimum capacity requirements?
Well Capacity	2,345 gpm (tested, without Well #9 in service) 3,070 gpm (tested, with Well #9 in service)	2,032 gpm	87% (tested, without Well #9 in service) 66% (tested, with Well #9 in service)	Yes, however without Well #9 in service, system has surpassed 85% limit. It is recommended to bring Well #9 back in service.
Total Storage	2,500,000 gallons	677,200 gallons	27%	Yes
Elevated Storage(2)	1,200,000 gallons	338,600 gallons	28%	Yes
Pumping Capacity(3)	3,000 gpm	2,031 gpm	60%	Yes

(1) Based upon the number of connections within the pressure zone served.
(2) Criteria shown is based upon an elevated storage capacity of 100 gallons/connection.
(3) Criteria shown is based upon a minimum of 2 gpm/connection or that have a capacity of 1000 gpm and can meet peak hourly demands with the largest pump out of service. With the system supplying more than 200 gallons of elevated storage per connection, the pumping capacity must provide 0.6 gpm per connection.

4 Projected Population and System Requirements

4.1 Projected Population

The City of Sanger service area consists of the incorporated area of Sanger, Texas in Denton County. In order to develop future population growth for the city, the NCTCOG population projection growth rate of 3.2% CAGR was used to estimate the future population.

This data can be seen in Table 4.1.

Table 4.1 –Population Projections

Year	Sanger, Texas Population (Est.)
2019	8,800
2020	9,080
2025	10,629
2030	12,442
2040	17,048

Using the projected population for the City of Sanger, shown above in Table 4.1, a projected number of water system connections can be developed for the system.

In order to establish the number of future connections the ratio of persons per connection must be calculated. For the purposes of this study the projected population values have been divided by 2.68 the estimated number of person per household per the City's 2020 population and number of customer meters.

Table 4.2 –Connection Projections

Year	Estimated Population	Estimated Total Connections (Calculated per Ratio)
2020 (current)	9,080	3,386
2025	10,629	3,966
2030	12,442	4,643
2040	17,048	6,361

4.2 Projected System Requirements

Capacity analysis of future system requirements (2025, 2030 and 2040) and their ability to meet the TCEQ Minimum System Capacity Requirements were performed using project population, connection and demand data specific to the City's system.

Table 4.3 –Connection Projections

Projected System Needs	2020 (Current)	2025	2030	2040
Population	9,080	10,629	12,442	17,048
Active Connections	3,386	3,966	4,643	6,361
Well Capacity Assessment				
Existing Facilities System Capacity	3,070 gpm (tested, with Well #9 in service) 2,345 gpm (tested, without Well #9 in service)			
TCEQ Required Capacity	2,032 gpm	2,380 gpm	2,786 gpm	3,817 gpm
Additional Capacity Needed	None required	None required	Planning for new Well required	Additional 750 gpm required
Notes	Bring Well #9 back into service	Bring Well #9 back into service	85% limit reached, start planning for new well capacity	Required capacity exceeded, install new well(s)
Total Storage Capacity Assessment				
Current System Capacity	2,500,000 gal			
TCEQ Required Capacity	677,200 gal	793,200 gal	928,600 gal	1,272,200 gal
Additional Capacity Needed	None required	None required	None required	None required

Elevated Storage Capacity Assessment				
Current System Capacity	1,200,000 gal			
TCEQ Required Capacity	338,600 gal	396,600 gal	464,300 gal	636,100 gal
Additional Capacity Needed	None required	None required	None required	None required
Notes	Meets both 100 gal and 200 gal per connection requirement for EST capacity.	Meets both 100 gal per connection and 200 gal per connection requirement for EST capacity.	Meets both 100 gal and 200 gal per connection requirement for EST capacity.	Meets 100 gal per connection, however does not meet 200 gal per connection (TAC Ch. 290.45 b.D.iii).
Pumping Capacity Assessment				
Current System Capacity	3,000 gpm			
TCEQ Required Capacity	1,000 gpm	1,000 gpm	1,000 gpm	1000 gpm
Additional Capacity Needed	None required	None required	None required	None required
Notes				Per TAC Ch. 290.45 b.D.iii, does not meet 200 gal per connection. Must supply 1000 gpm per connection with largest pumps out of service.

A summary of the number of connections the system can support before each capacity criteria requires design is shown in Table 4.4 below. The system has already passed the number of connections supported at 85% capacity for the wells and will need to either install a new well or bring Well #9 into service again. The next criteria that will require design is elevated storage. However, the amount of total storage is adequate through the next 30 years, per the population and corresponding total number of connections estimations.

Table 4.4 – Estimated Number of Connections System Can Support Before Reaching 85% Capacity of TCEQ Requirements

Minimum System Capacity Criteria	85% System Capacity – Design Required (gpm)	No. of Connections Supported at 85% Cap
Well Capacity(1)	2,610	4,350
Total Storage(2)	2,125,000	10,625
Elevated Storage(3)	1,020,000	10,200
Pumping Capacity(4)	2,550	

(1) Criteria shown is based on 0.6 gpm per connection.
(2) Criteria shown is based on 200 gallons/connection.
(3) Criteria shown is based upon an elevated storage capacity of 100 gallons/connection.
(4) Criteria shown is based upon a minimum of 2 gpm/connection. However, a system that has a capacity of 1000 gpm and can meet peak hourly demands with the largest pump out of service is also adequate per the TCEQ.

5 Modeling Results

5.1 System Demands

The City of Sanger provides water service to approximately 3,386 metered connections. The magnitude and distribution of water demands were determined from analysis of city water records and used in development of the WaterCAD computer model of the distribution system. The following water demands are of particular interest in analysis of a water distribution system.

- Average Daily Demand: The average amount of water used each day during a calendar year, i.e., annual water usage / 365 days (provided by City staff).
- Maximum Daily Demand: Maximum daily demand is 2.4 times the average daily demand of the system per TAC CH 290.38.46.
- Peak Hourly Demand: In the absence of specific system data the peak hourly demand is calculated using the maximum daily demand multiplied by a peak hour factor defined by the TCEQ. For systems that meet the minimum capacity requirement for elevated storage this factor is 1.25, and for systems that do not meet the minimum capacity requirement for elevated storage, or use hydro-pneumatic tanks, this factor is 1.82.
- 1.5 gpm per Connection Demand: The required minimum demand established by the TCEQ for which a public water system must maintain a minimum system pressure of 35 psi.

5.1.1 Demand Allocation

Table 5.1 – Connection Projections

	Number of Connections	Average Day Flow GPM	Maximum Day Flow GPM	Peak Flow Rate GPM
Demand per Connection		0.16	0.384	0.48
2020	3,386	542	1300	1625
2025	3,966	635	1523	1904
2030	4,643	743	1783	2229
2040	6,361	1018	2443	3053

5.2 Existing Conditions

Static condition modeling simulations were conducted for the existing average day demand, existing maximum day demand, existing peak hour demand, and TCEQ 1.5 gpm per connection demand.

5.2.1 Average Day Demand

Under the average daily demand scenario, no pressures below 35 psi were discovered other than those located within the pump station piping between the ground storage tank and the suction side of the high service pumps (1st &Cherry, Acker Rd, Utility Rd, and Cowling Rd pump stations). Pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios. This is an indication that the current system facilities meet the TCEQ criteria for minimum pressure requirements under average day demand conditions (mention rule number). A pressure contour map of the results of this scenario is shown below.

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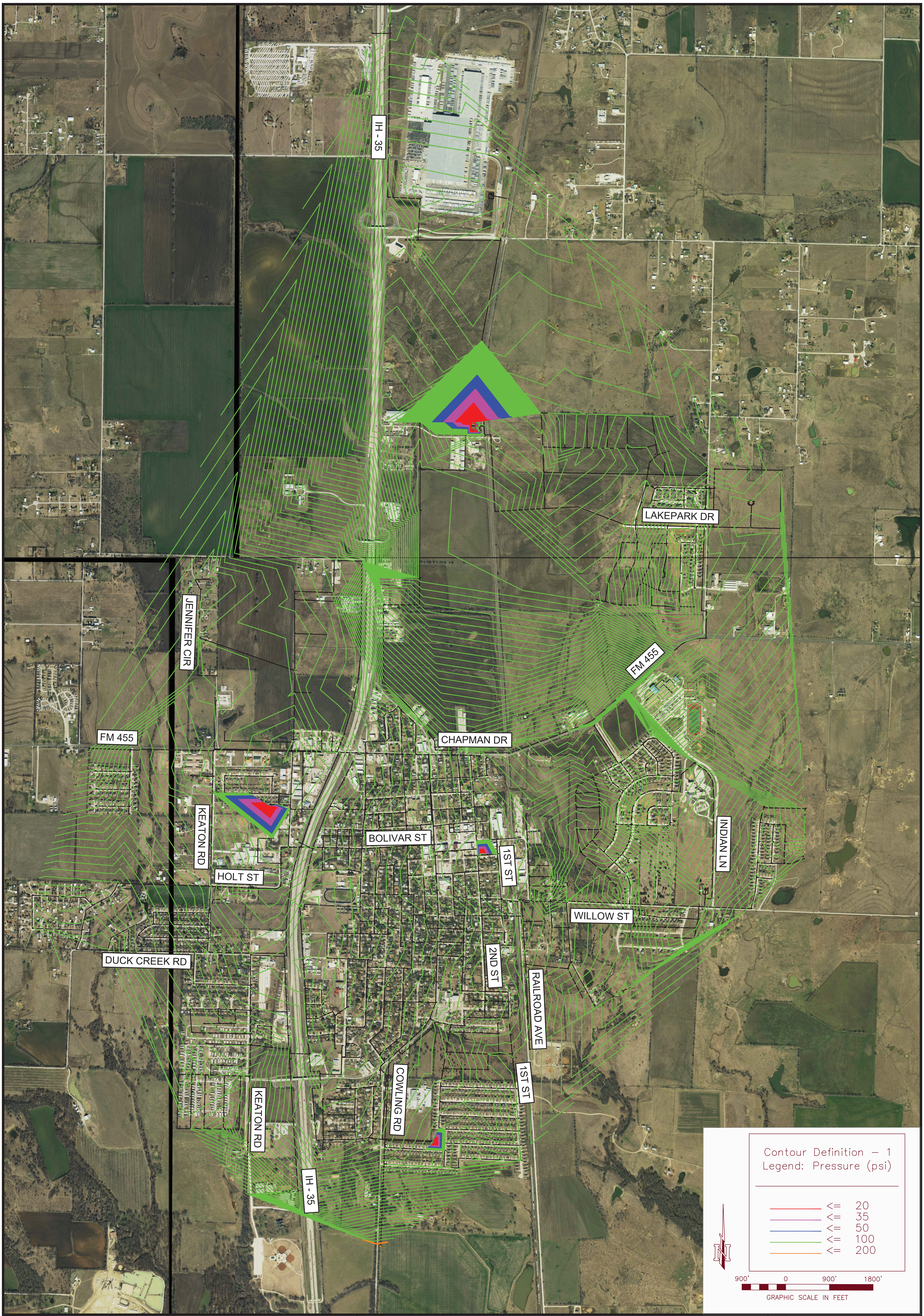

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EXISTING WATER DISTRIBUTION SYSTEM
SANGER, TEXAS

PROJECT NAME:

EXISTING SYSTEM AVERAGE DAY DEMAND

SHEET NAME:

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5.2.2 Maximum Day Demand

The maximum daily demand scenario is based upon the average daily demand multiplied by a factor of 2.4 per the TAC CH 290.38.46. This modeling scenario revealed no pressures below 35. This is an indication that the current system facilities meet the TCEQ criteria for minimum pressure requirements under maximum day demand conditions (TAC 290.44.d). A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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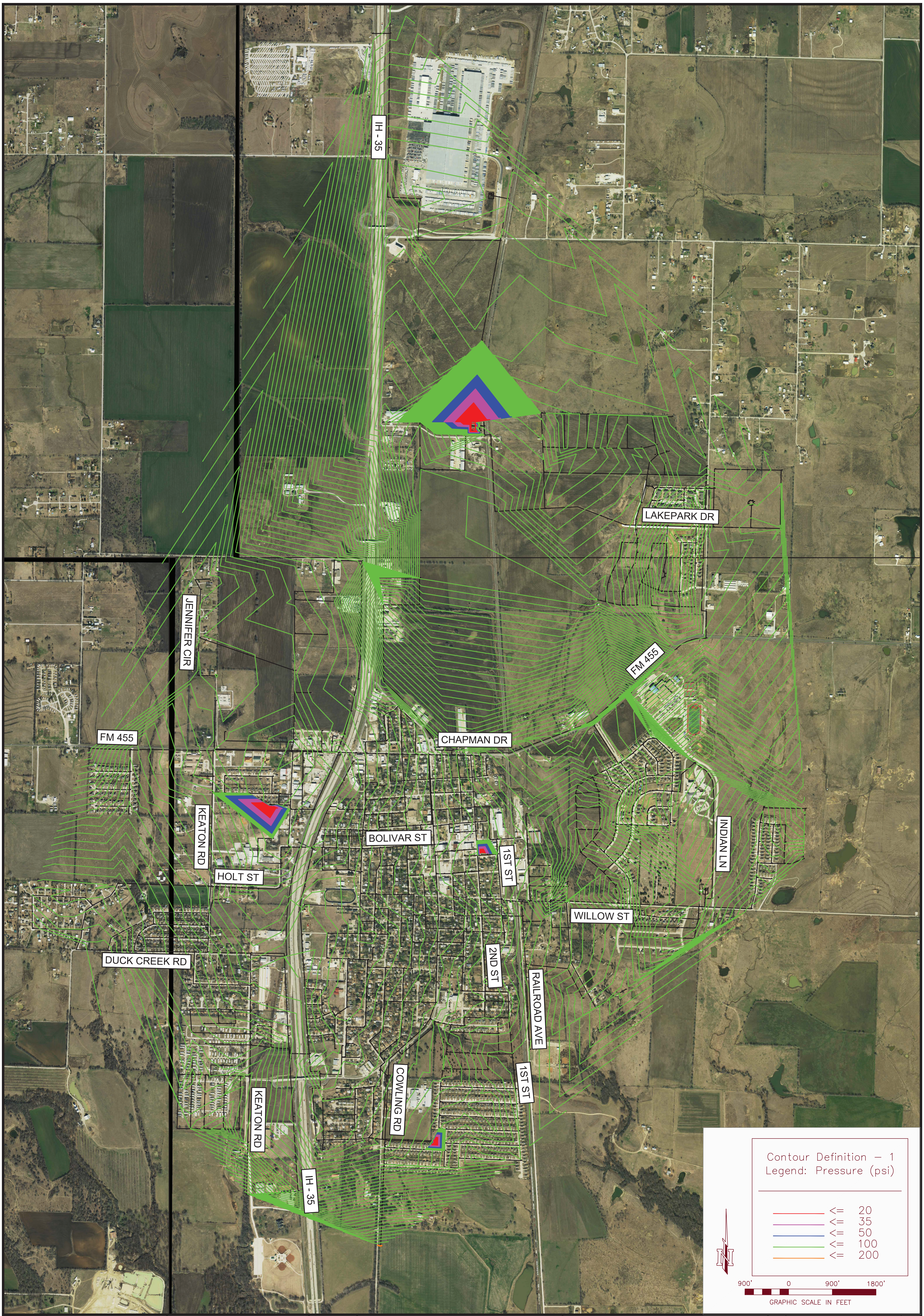

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EXISTING SYSTEM
MAXIMUM DAY DEMAND

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5.2.3 Peak Hour Demand

This demand scenario is based upon the maximum daily system demand multiplied by a factor of 1.25. This factor is based upon the definition of peak hourly demand in 30 TAC 290.38(60). This modeling scenario revealed no pressures below 35 psi. This is an indication that the current system facilities meet the TCEQ criteria for minimum pressure requirements under peak hour demand conditions. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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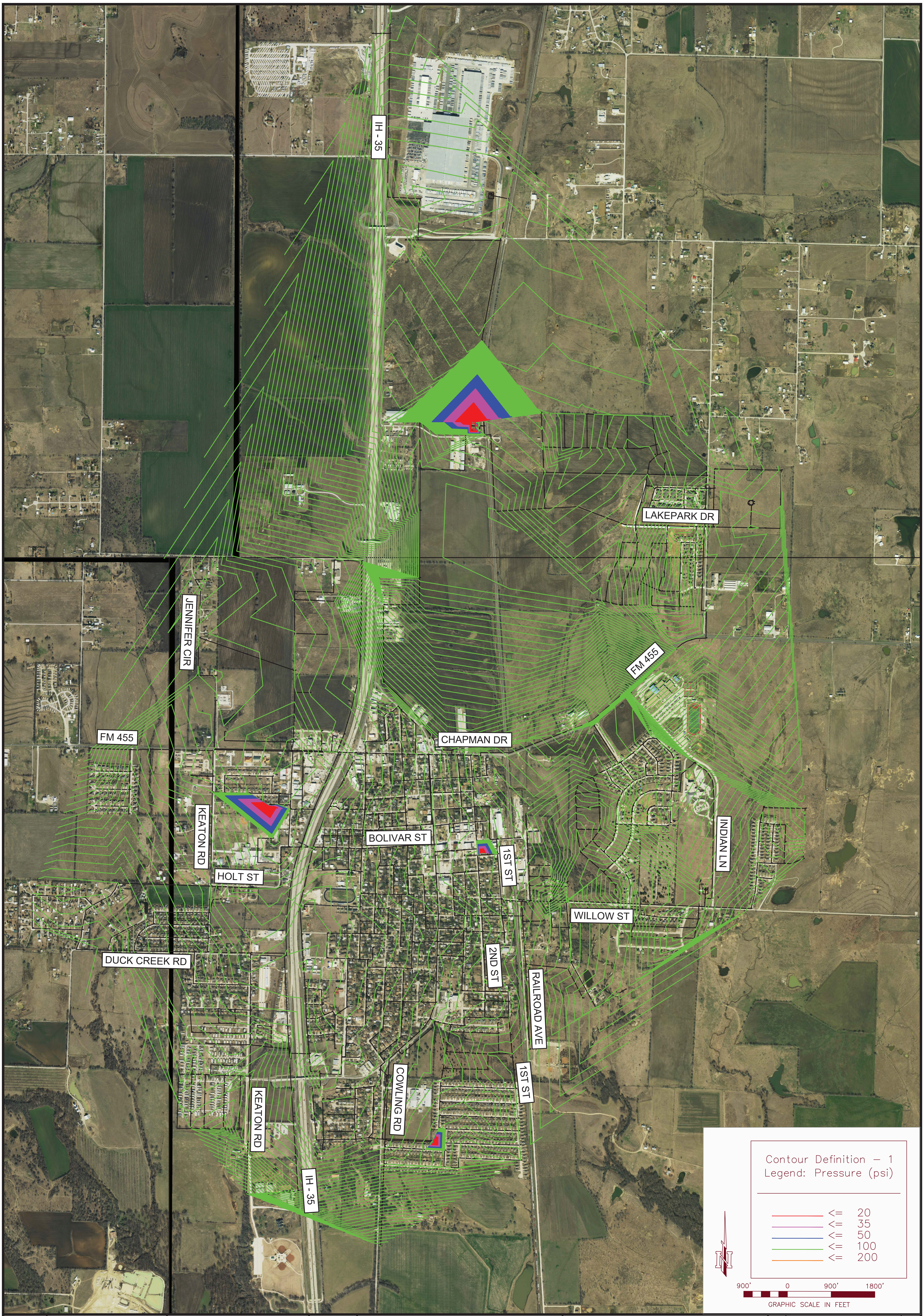

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5.2.4 TCEQ 1.5 gpm per Connection Demand

This demand scenario is based upon the TCEQ requirement of maintaining a minimum of 35 psi with demands set at 1.5 gpm per connection (30 TAC 290.38(60). This demand is the highest demand for which the system will be modeled. This demand is a very conservative demand when compared to the average daily demand of 0.16 gpm per connection discussed in Section 3.2.1 of this report. This demand can also provide an indication of system performance under extreme demand events such as fire-flows. This modeling scenario revealed no pressures below 35 psi. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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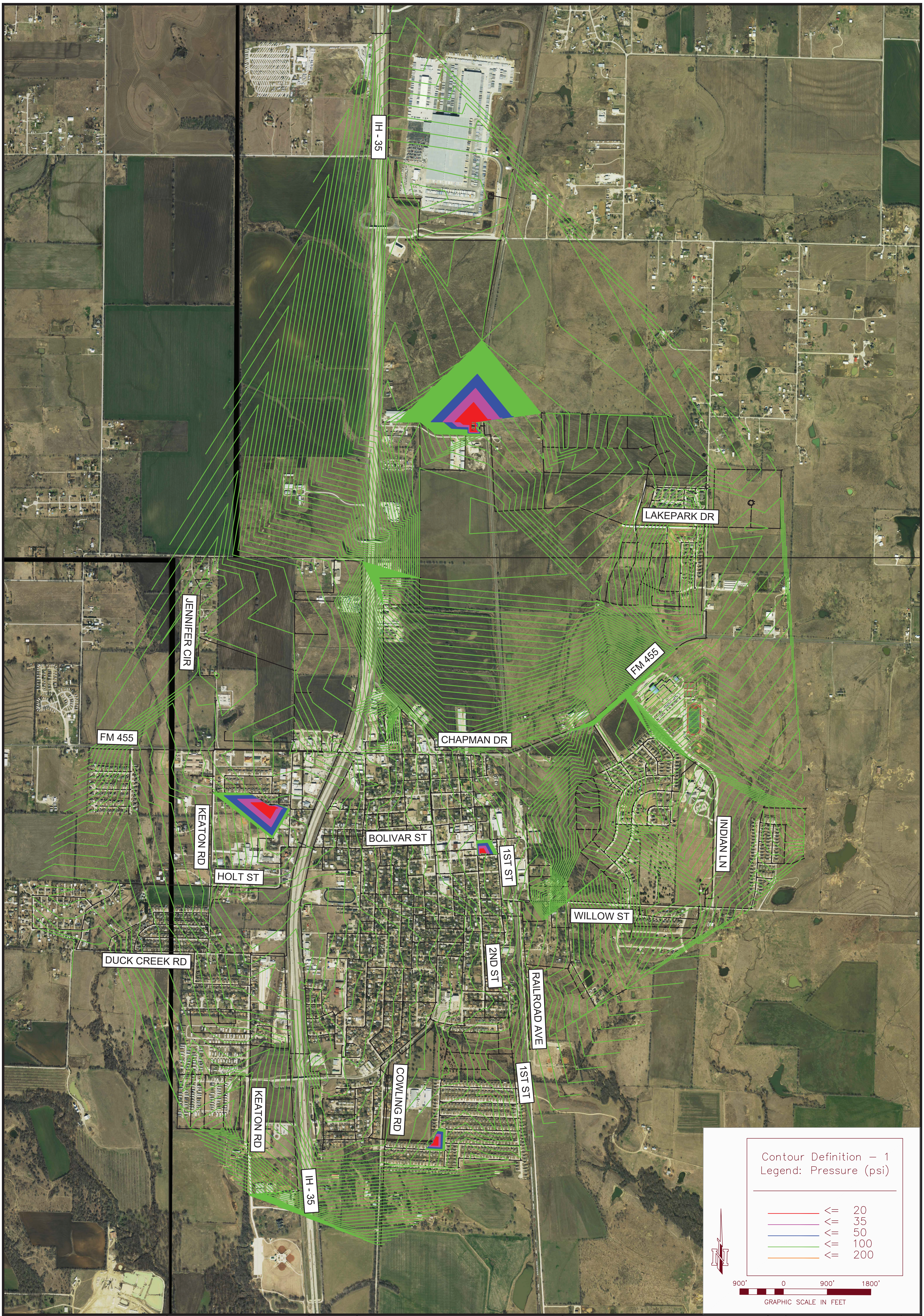

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PROJECT NAME:

EXISTING SYSTEM 1.5 GPM PER CONNECTION DEMAND

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5.3 Future Conditions

Static condition modeling simulations were conducted for the future 5-year, 10-year, and 20-year average day demand, maximum day demand, peak hour demand, and TCEQ 1.5 gpm per connection demand scenarios.

5.3.1 Development of Future Water Demands and Growth Areas

Water demand projections for future conditions (ie. 5-year, 10-year and 20-year projections) were developed using detailed comprehensive plan (supplied by City staff) and historical water demand information. Figure xx shows the location of the future developments per city comprehensive plan.

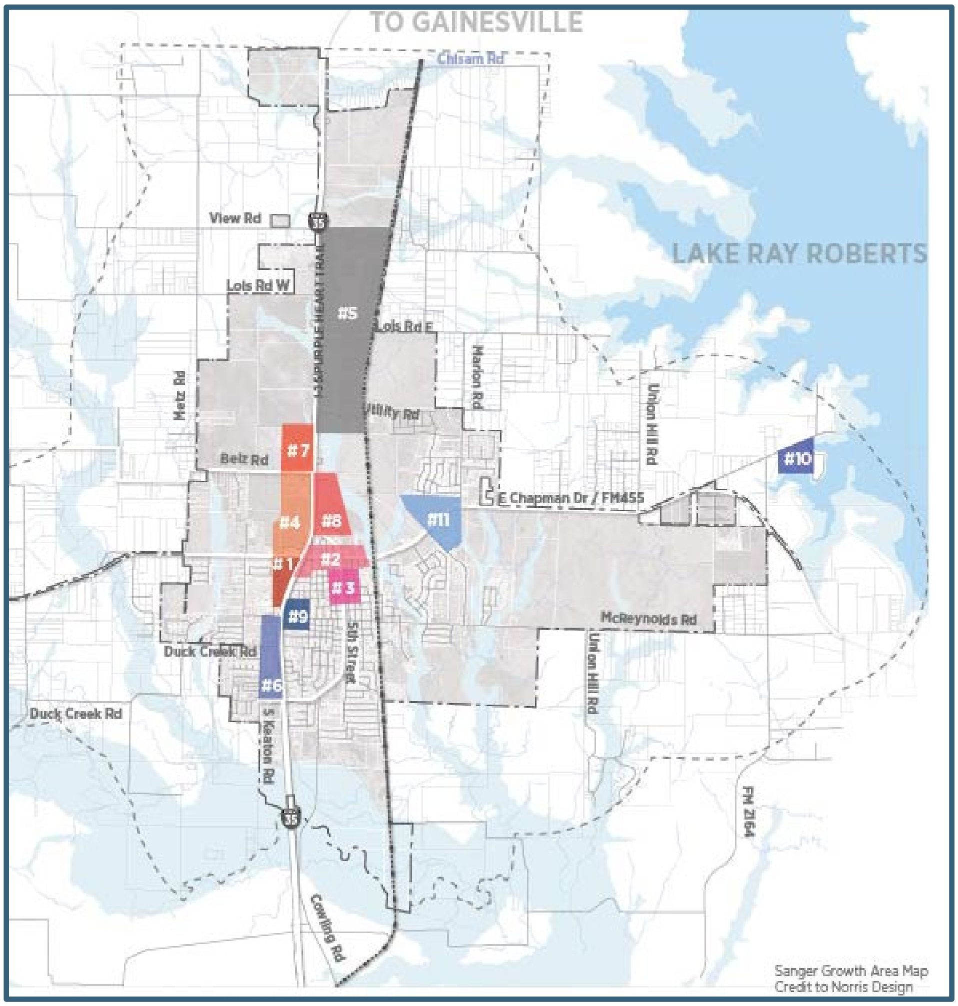

Figure 5.1: Future development areas per comprehensive plan.

Growth Areas identified in the comprehensive plan includes:

#1 – FM 455 & I-35/Southwest Corner

#2 – FM 455 Corridor (East of I-35)

#3 – Downtown Sanger

#4 – FM 455 & I-35/Northwest Corner

#5 – Light Industrial near Walmart Distribution Center

#6 – I-35 Corridor (west of I-35 in Core of Sanger)

#7 – Belz Road & I-35 (Northwest Corner)

#8 – 5th Street Corridor (North of FM 455)

#9 – Linda Tutt Learning Center/SISD Site

#10 – Lake Ray Roberts

#11 – FM 455 & Future Indian Lane Extension

Based on discussions with the city staff with respect to growth projected for the city in the 5-year, 10-year and 20-year scenarios, the following water demands were projected for the future development areas, which were further used in the water distribution modeling analysis.

Table 5.1 –Connection Projections

Growth Area	2025		2030		2040	
	Number of Additional Connections	**Additional Average Day Flow GPM**	**Number of Additional Connections**	**Additional Average Day Flow GPM**	**Number of Additional Connections**	**Additional Average Day Flow GPM**
#1	29	4.64				
#2	29	4.64				
#3	29	4.64				
#4	29	4.64				
#5	174	27.84	118	18.93	301	48.13
#6	29	4.64				
#7	232	37.12	136	21.6	258	41.26
#8	29	4.64				
#9	29	4.64				
#10			304	48.67	860	137.52
#11			118	18.93	301	48.13
Total	**580**	**93**	**679**	**108**	**1719**	**275**

5.3.2 5-Year Average Day Demand

Under the proposed 5-year average daily demand scenario, no pressures below 35 psi were discovered. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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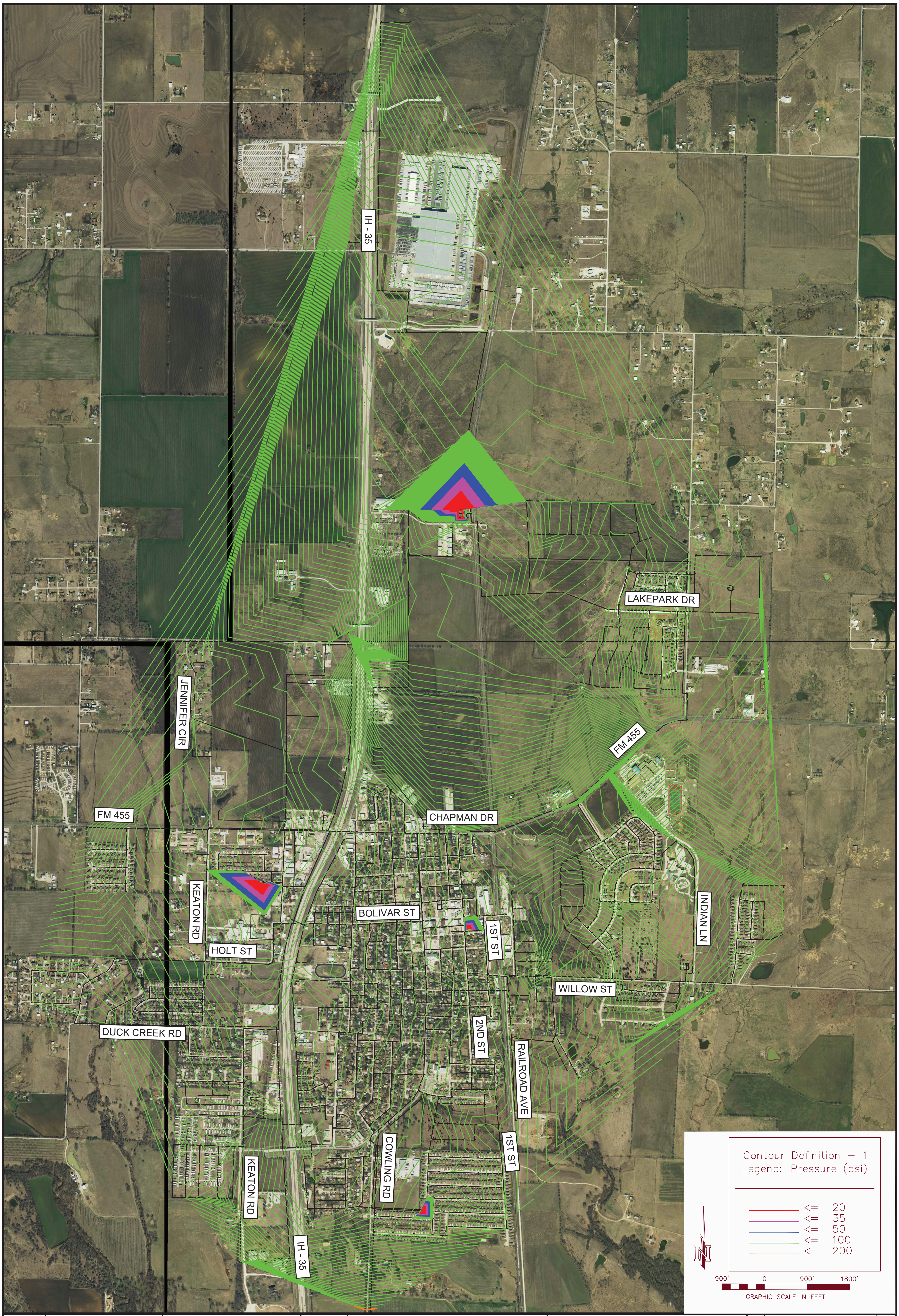

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PROJECT NAME:
PROPOSED WATER DISTRIBUTION SYSTEM
SANGER, TEXAS

SHEET NAME:
5 YEAR PROPOSED SYSTEM AVERAGE DAY DEMAND

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5.3.3 5-Year Maximum Day Demand

The proposed 5-year maximum daily demand scenario is based upon the average daily demand multiplied by a factor of 2.4 per the TAC CH 290.38.46. This modeling scenario revealed no pressures below 35. This is an indication that the current system facilities meet the TCEQ criteria for minimum pressure requirements under maximum day demand conditions (TAC 290.44.d). A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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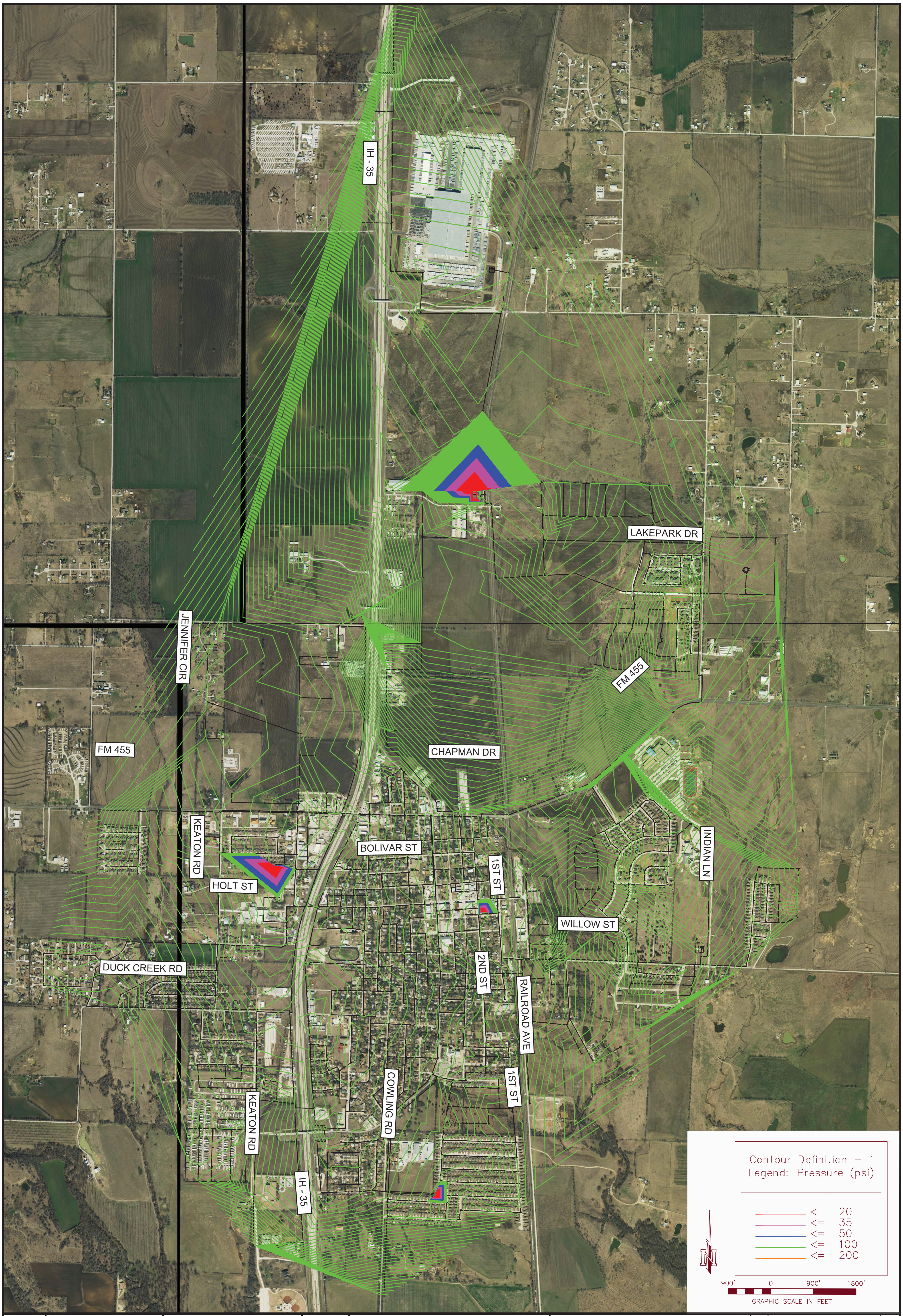

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SANGER, TEXAS

SHEET NAME:
5 YEAR PROPOSED SYSTEM MAXIMUM DAY DEMAND

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5.3.4 5-Year Peak Hour Demand

The proposed 5-year peak hour demand scenario is based upon the maximum daily system demand multiplied by a factor of 1.25. This factor is based upon the definition of peak hourly demand in 30 TAC 290.38(60). This modeling scenario revealed no pressures below 35 psi. This is an indication that the current system facilities meet the TCEQ criteria for minimum pressure requirements under peak hour demand conditions. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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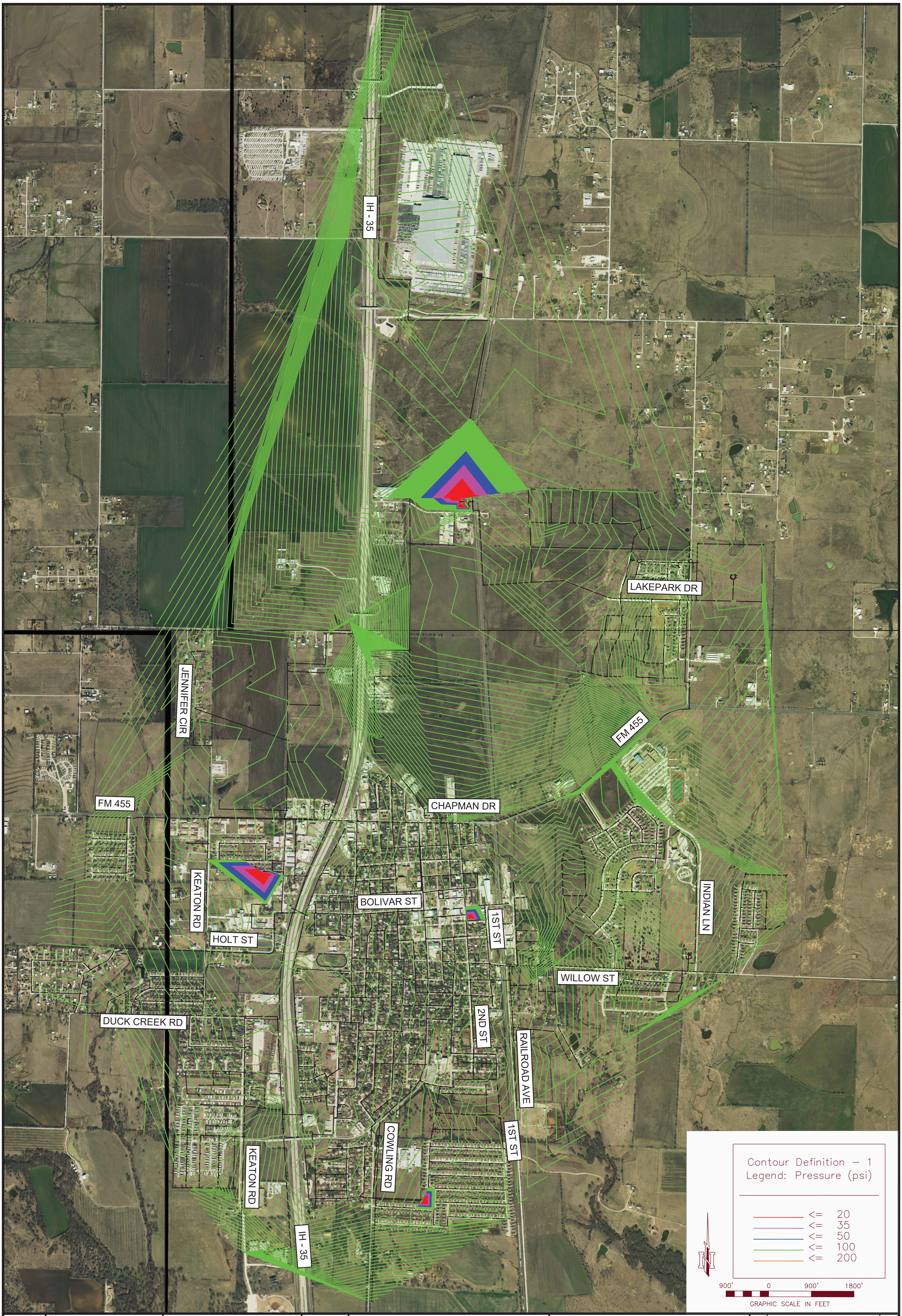

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PROPOSED WATER DISTRIBUTION SYSTEM
SANGER, TEXAS

SHEET NAME:
5 YEAR PROPOSED SYSTEM PEAK HOUR DEMAND

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5.3.5 5-Year 1.5 GPM per Connection Demand

This demand scenario is based upon the TCEQ requirement of maintaining a minimum of 35 psi with demands set at 1.5 gpm per connection (30 TAC 290.38(60). This demand is the highest demand for which the system will be modeled. This demand is a very conservative demand when compared to the average daily demand of 0.16 gpm per connection discussed in Section 3.2.1 of this report. This demand can also provide an indication of system performance under extreme demand events such as fire-flows. This modeling scenario revealed no pressures below 35 psi. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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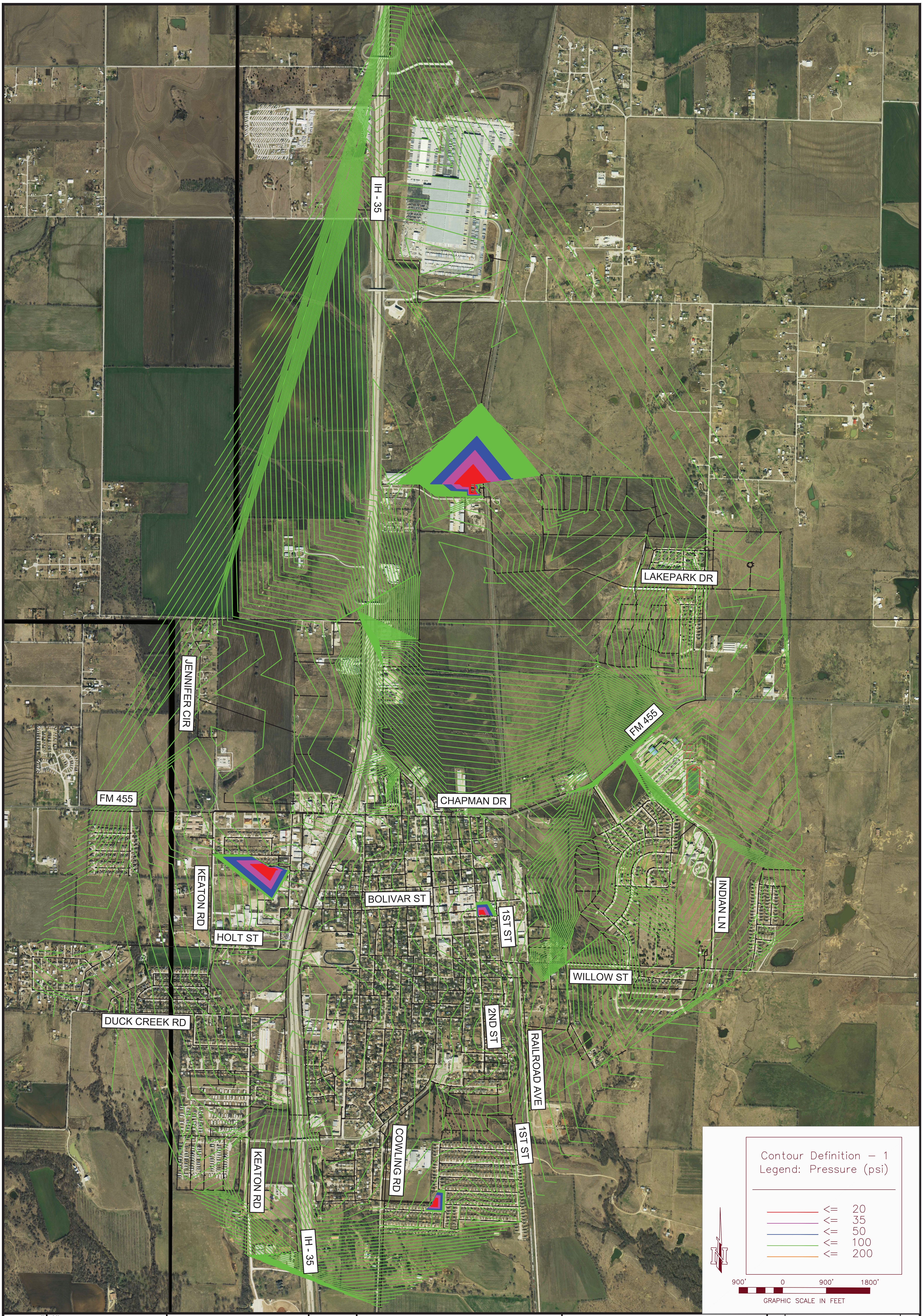

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SHEET NAME:
5 YEAR
PROPOSED SYSTEM
1.5 GPM PER CONNECTION
DEMAND

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5.3.6 10-Year Average Day Demand

Under the proposed 10-year average daily demand scenario, pressures above 100 psi were discovered east along FM 455 toward Lake Ray Roberts. This is due to a lower elevation in that area and relatively low demands. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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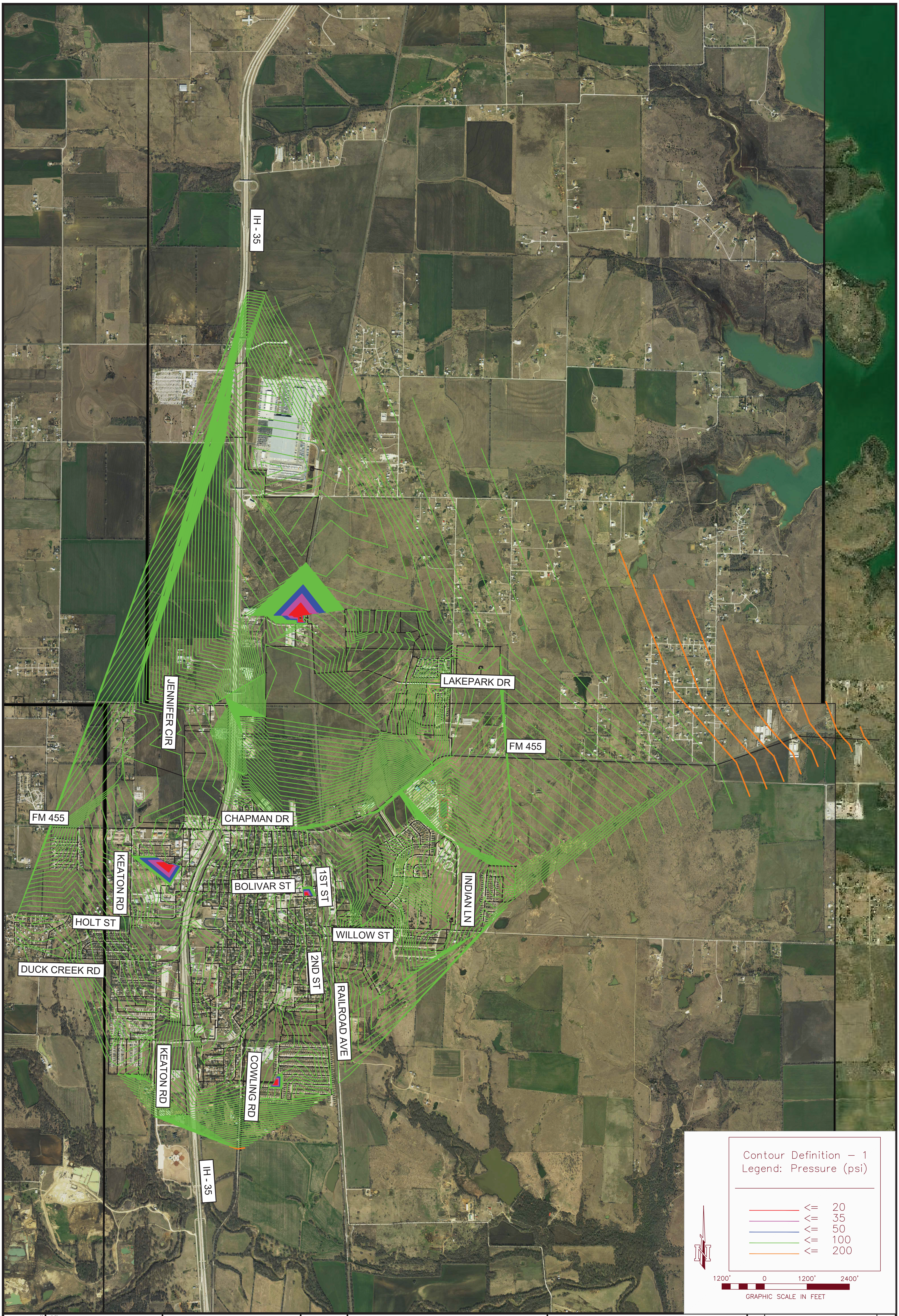

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PROPOSED WATER DISTRIBUTION SYSTEM
SANGER, TEXAS

PROJECT NAME:

10 YEAR PROPOSED SYSTEM AVERAGE DAY DEMAND

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5.3.7 10-Year Maximum Day Demand

The proposed 10-year maximum daily demand scenario is based upon the average daily demand multiplied by a factor of 2.4 per the TAC CH 290.38.46. This modeling scenario revealed pressures above 100 psi discovered east along FM 455 toward Lake Ray Roberts. This is due to a lower elevation in that area and relatively low demands. This is an indication that the current system facilities meet the TCEQ criteria for minimum pressure requirements under maximum day demand conditions (TAC 290.44.d). A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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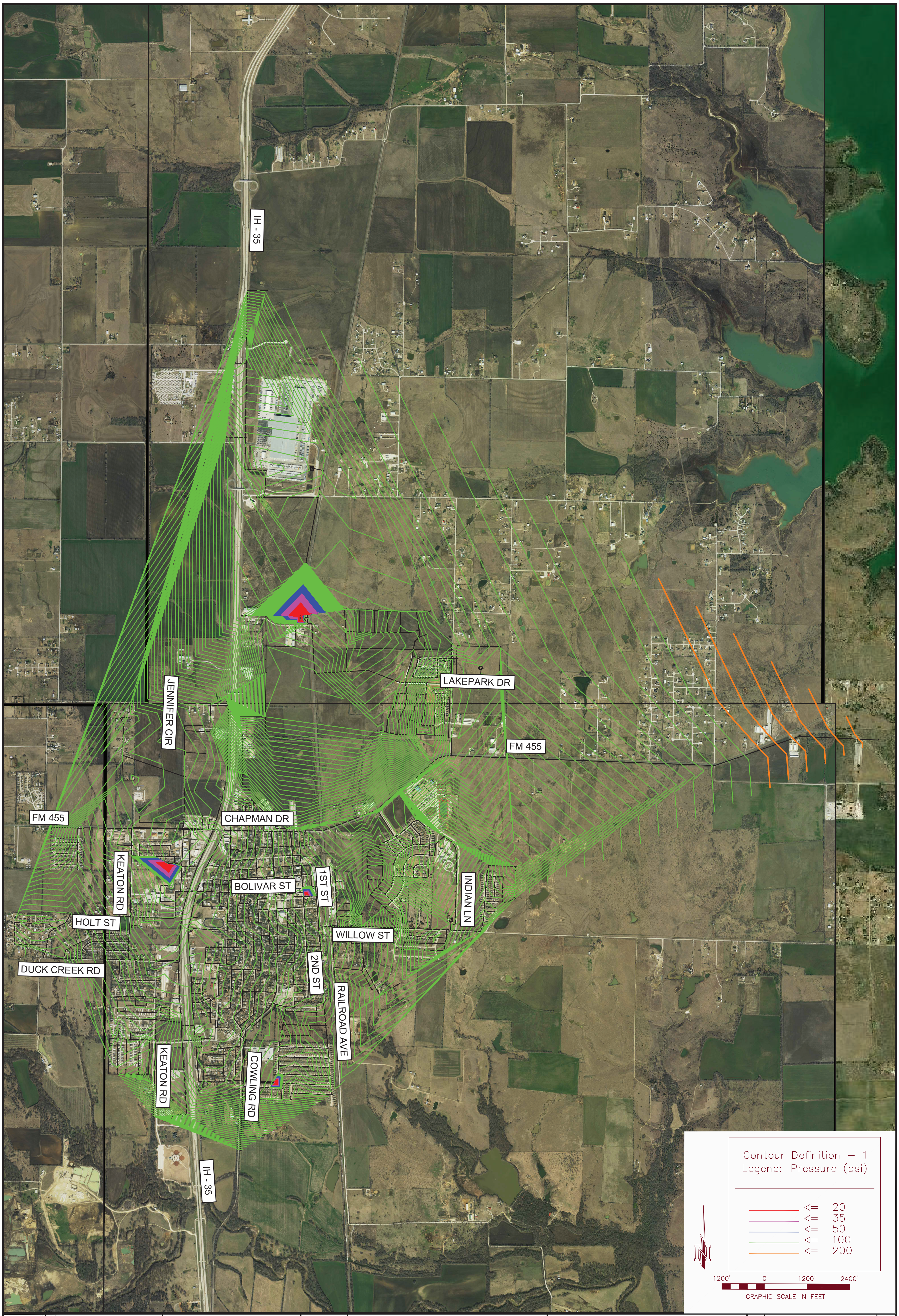

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10 YEAR PROPOSED SYSTEM MAXIMUM DAY DEMAND
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5.3.8 10-Year Peak Hour Demand

The proposed 10-year peak hour demand scenario is based upon the maximum daily system demand multiplied by a factor of 1.25. This factor is based upon the definition of peak hourly demand in 30 TAC 290.38(60). This modeling scenario revealed no pressures below 35 psi. This is an indication that the current system facilities meet the TCEQ criteria for minimum pressure requirements under peak hour demand conditions. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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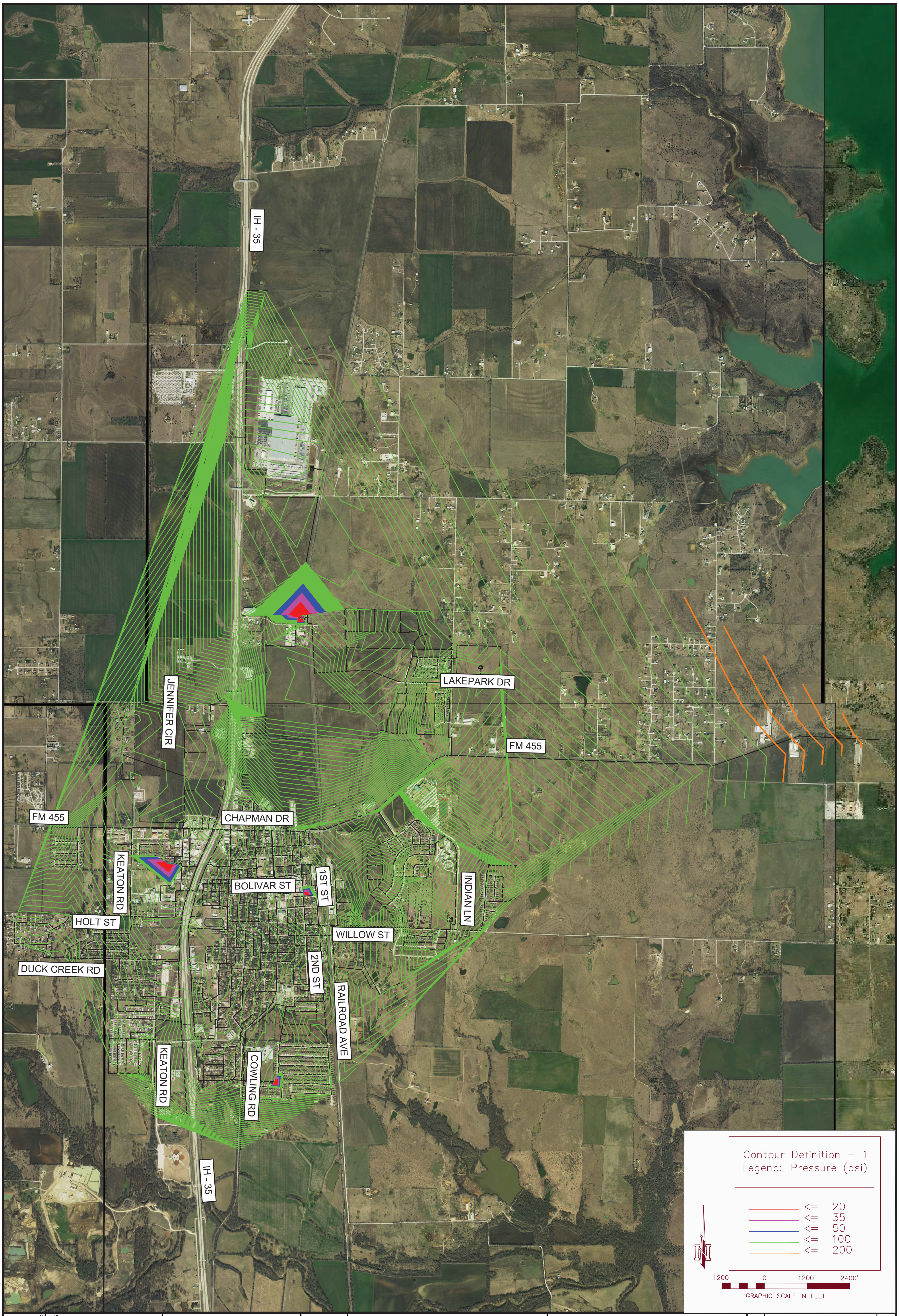

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PROPOSED WATER DISTRIBUTION SYSTEM
SANGER, TEXAS

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10 YEAR PROPOSED SYSTEM PEAK HOUR DEMAND

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5.3.9 10-Year 1.5 GPM per Connection Demand

This demand scenario is based upon the TCEQ requirement of maintaining a minimum of 35 psi with demands set at 1.5 gpm per connection (30 TAC 290.38(60). This demand is the highest demand for which the system will be modeled. This demand is a very conservative demand when compared to the average daily demand of 0.16 gpm per connection discussed in Section 3.2.1 of this report. This demand can also provide an indication of system performance under extreme demand events such as fire-flows. This modeling scenario revealed no pressures below 35 psi. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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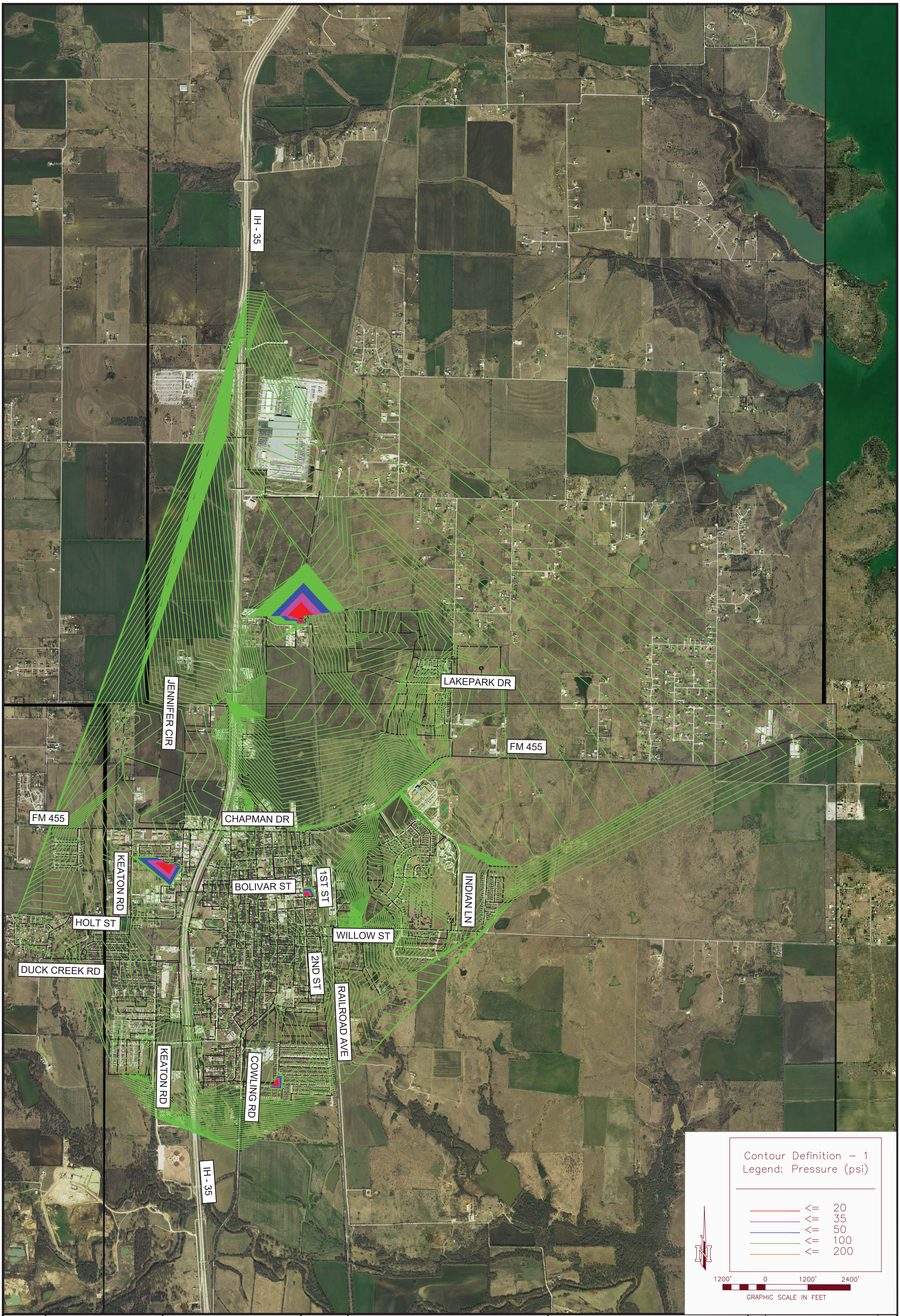

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SHEET NAME:

10 YEAR PROPOSED SYSTEM 1.5.GPM PER CONNECTION DEMAND

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5.3.10 20-Year Average Day Demand

Under the proposed 20-year average daily demand scenario, pressures above 100 psi were discovered east along FM 455 toward Lake Ray Roberts. This is due to a lower elevation in that area and relatively low demands. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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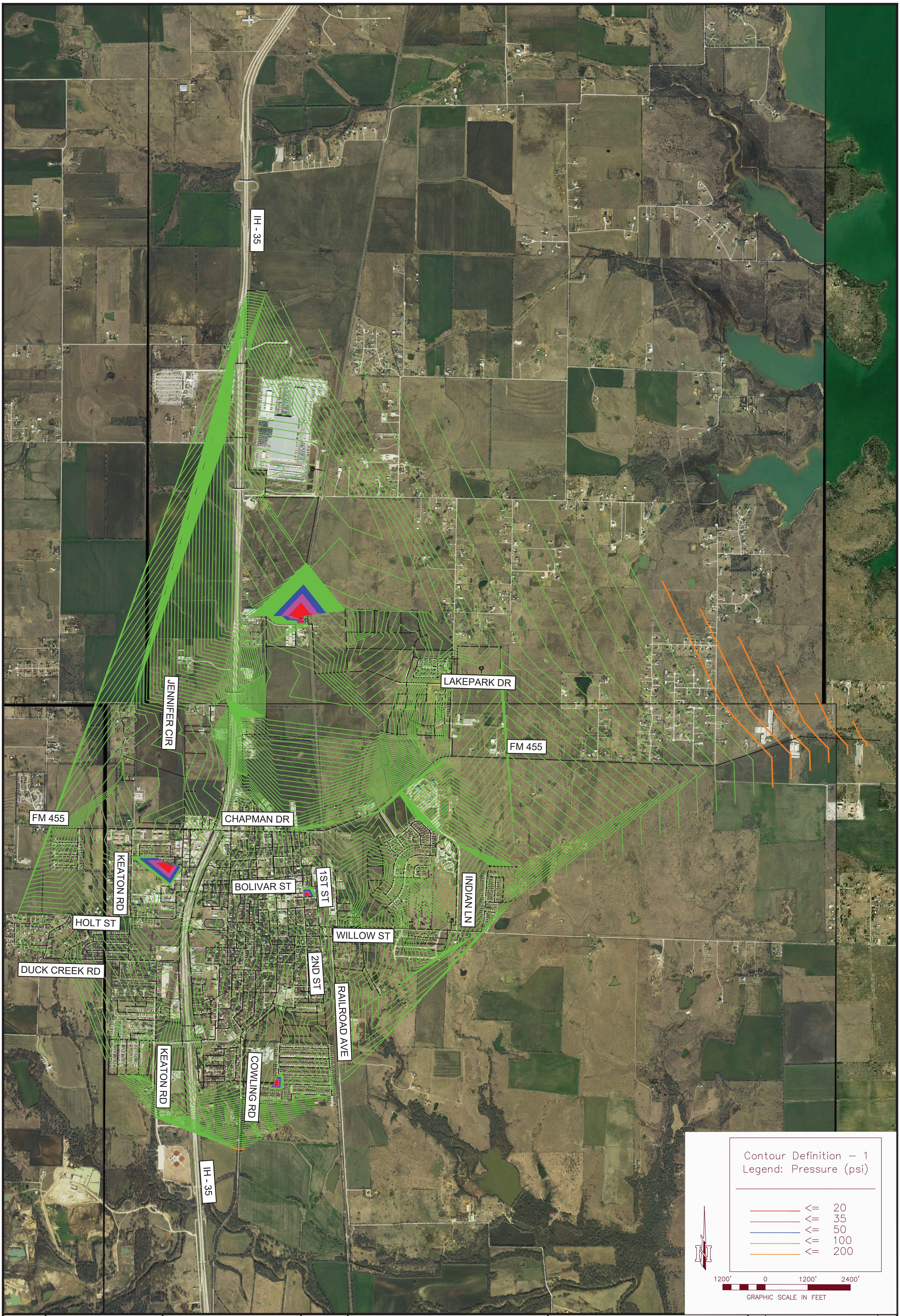

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PROPOSED WATER DISTRIBUTION SYSTEM
SANGER, TEXAS

PROJECT NAME:

20 YEAR PROPOSED SYSTEM AVERAGE DAY DEMAND

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5.3.11 20-Year Maximum Day Demand

The proposed 20-year maximum daily demand scenario is based upon the average daily demand multiplied by a factor of 2.4 per the TAC CH 290.38.46. This modeling scenario revealed no pressures below 35 psi. This is an indication that the current system facilities meet the TCEQ criteria for minimum pressure requirements under maximum day demand conditions (TAC 290.44.d). A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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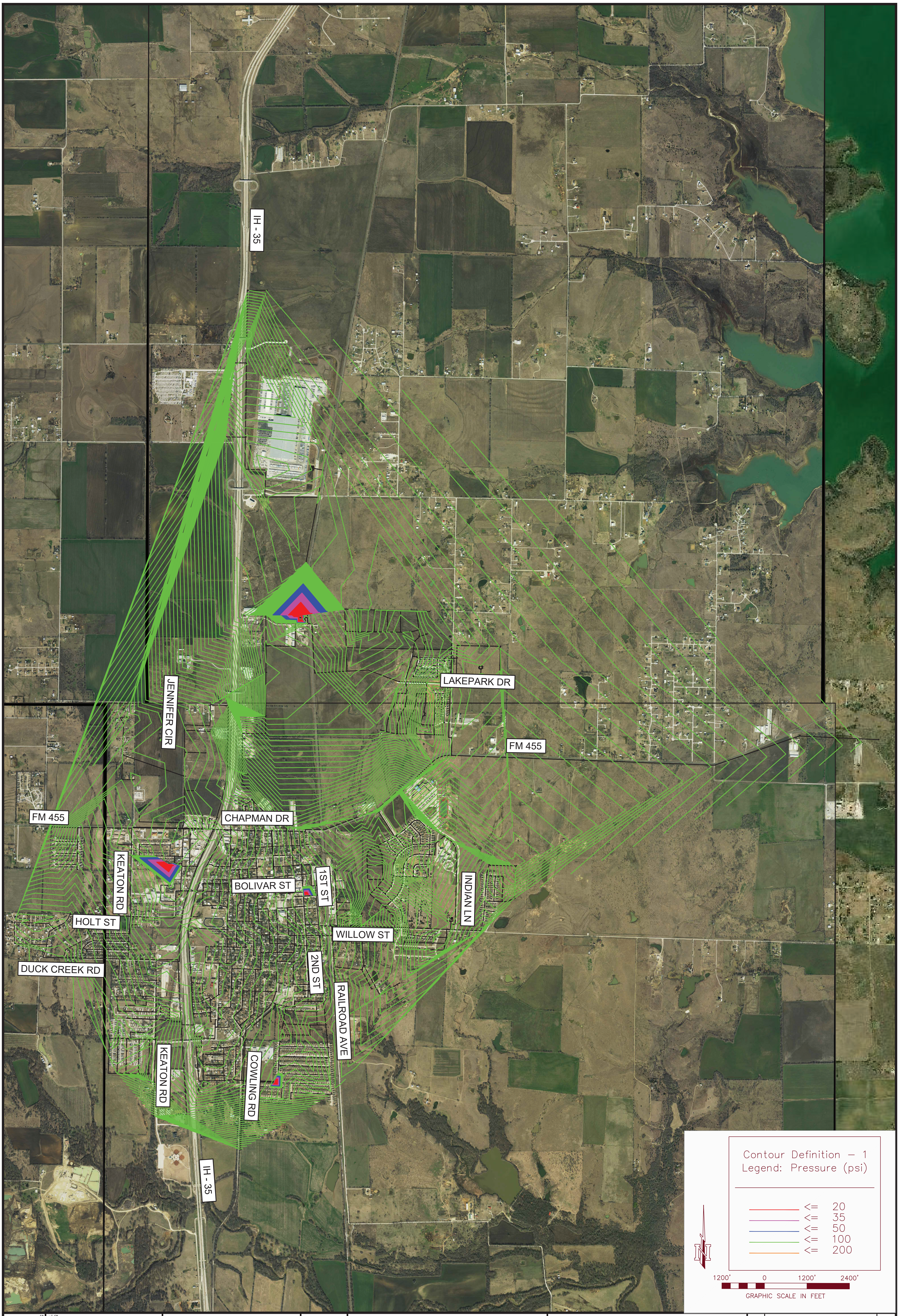

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SANGER, TEXAS

SHEET NAME:
20 YEAR
PROPOSED SYSTEM
MAXIMUM DAY DEMAND

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5.3.12 20-Year Peak Hour Demand

The proposed 20-year peak hour demand scenario is based upon the maximum daily system demand multiplied by a factor of 1.25. This factor is based upon the definition of peak hourly demand in 30 TAC 290.38(60). This modeling scenario revealed no pressures below 35 psi. This is an indication that the current system facilities meet the TCEQ criteria for minimum pressure requirements under peak hour demand conditions. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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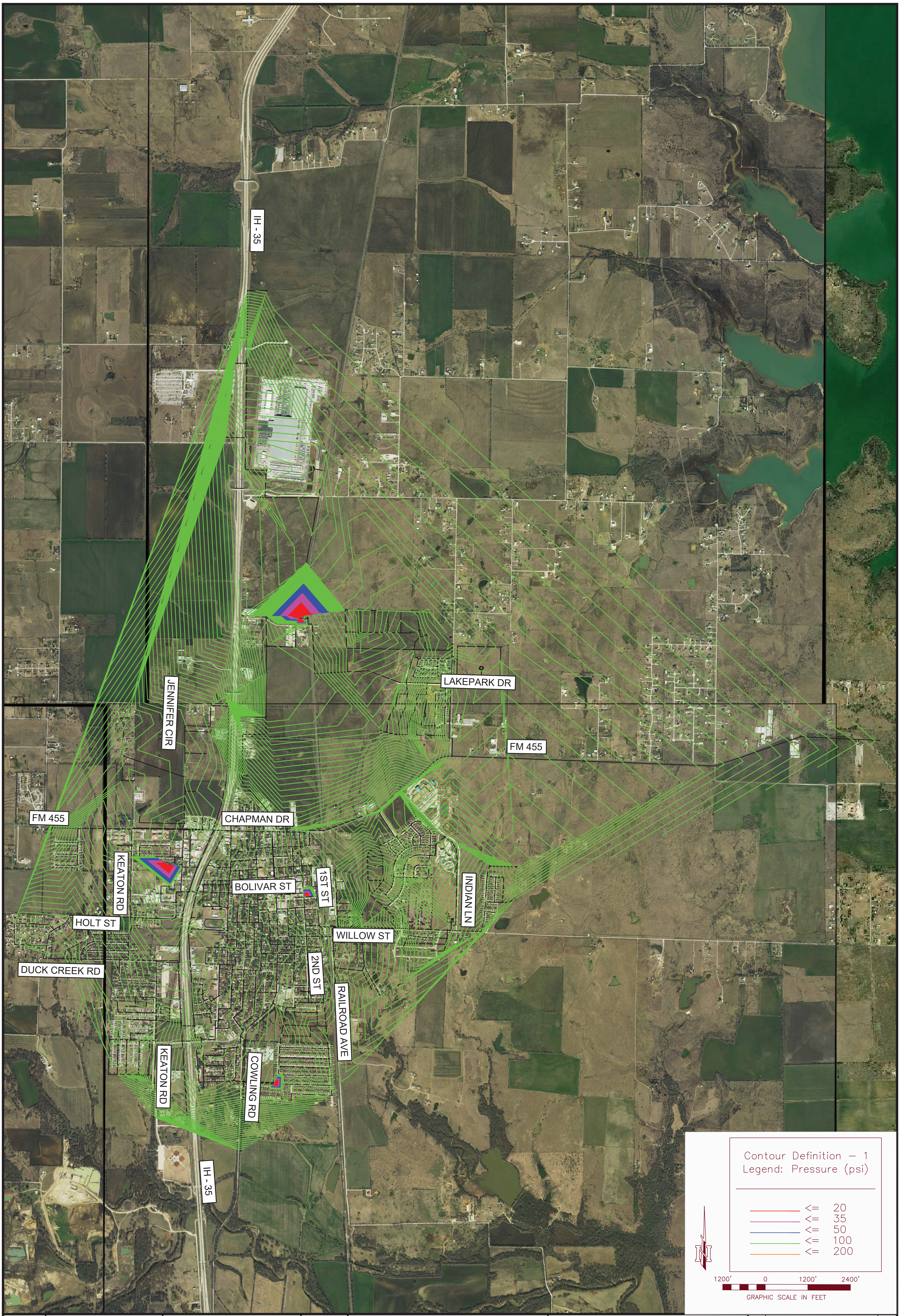

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SHEET NAME:
20 YEAR PROPOSED SYSTEM PEAK HOUR DEMAND

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5.3.13 20-Year 1.5 GPM per Connection Demand

This demand scenario is based upon the TCEQ requirement of maintaining a minimum of 35 psi with demands set at 1.5 gpm per connection (30 TAC 290.38(60). This demand is the highest demand for which the system will be modeled. This demand is a very conservative demand when compared to the average daily demand of 0.16 gpm per connection discussed in Section 3.2.1 of this report. This demand can also provide an indication of system performance under extreme demand events such as fire-flows. This modeling scenario revealed pressures below 35 psi, and therefore indicate a need for new pumping facilities to increase pressures. A pressure contour map of the results of this scenario is below.

As noted previously, pressures below 35 psi on the suction side of pump station piping are common and expected and will be observed in all modeled demand scenarios.

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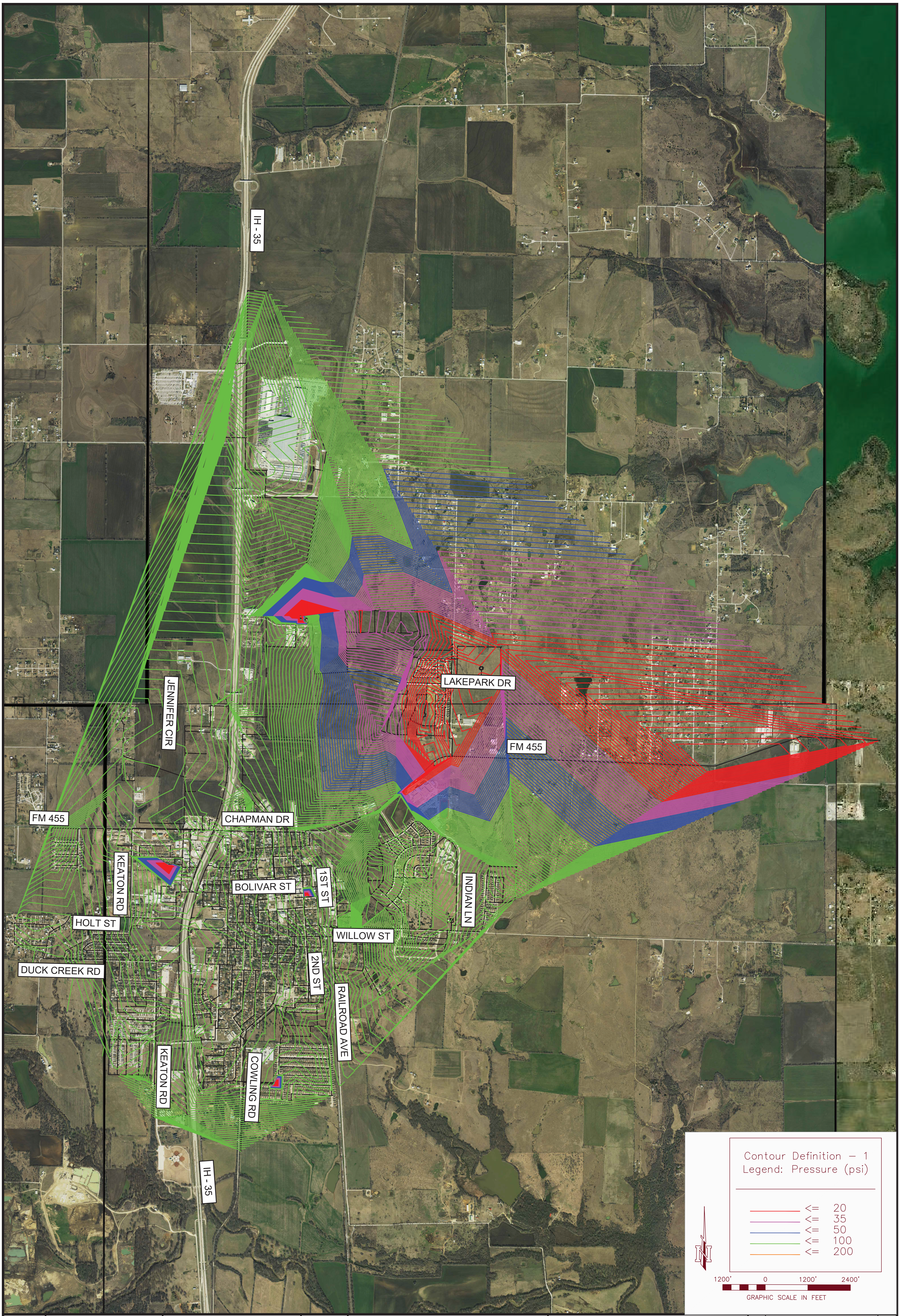

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5.3.14 Modeling Summary

Table 5.2 –Connection Projections

Modeling Findings	Existing System	2025	2030	2040
Population	9,080	10,629	12,442	17,048
Active Connections	3,386	3,966	4,643	6,361
Flow Demand Scenarios and Requirements				
Average Daily Demand	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure
Maximum Daily Demand	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure
Peak Hour Demand	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure
1.5 GPM Per connection Demand	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure	Meets TCEQ criteria for minimum pressure	Does not meet TCEQ criteria for minimum pressure
Notes			Higher pressures up to 105 psi are realized close to Lake Ray Roberts (lower elevation area east of the City), for Average Daily and Max Daily demand.	Higher pressures up to 105 psi are realized close to Lake Ray Roberts (lower elevation area east of the City), for Average Daily demand.

6 Summary of Recommended Facility Improvements

6.1 Well Capacity

Per Table 3.6, the City has reached the 85% of the available well capacity (TCEQ regulation concerning adequacy of service) without Well 9 in service under all conditions (existing and 5-year projection). It is recommended that Well 9 be reinstated to allow the system to continue to meet the TCEQ requirements.

Per table 4.1, given the NCTCOG growth projections, it is expected that by year 2030 the available well capacity will have exceeded the 85% TCEQ regulation concerning adequacy of service and as such new wells will need to be installed for future development.

6.2 Line Replacement Program and Looping of System

It is recommended that the City begin an annual program to replace existing undersized lines. Priority should be given to those lines under 2-inches and known 2-inch lines with more than 10 connections. Additionally, when opportunity presents, dead-end lines should be connected together to form loops within the system.

Upsizing the 2-inch and under, and 4-inch lines with a 6-inch line is preferred, as that will enable the installation and connection of a fire hydrant on the line.

Consideration should be given to the maximum number of connections allowed on any given pipe size. For reference the figure from 30 TAC 290.44(c) can be seen in Table 7.1. A more detailed description of the improvements in each area follows.

Table 6.1 – TCEQ Maximum Connections per Line Size

Maximum Number of Connections	Minimum Line Size (inches)
10	2
25	2.5
50	3
100	4
150	5
250	6
>250	8 and larger

To further help alleviate pressures in the system, it is also recommended to upsized pipes where the velocities are near or above 6 feet per second (fps). This line replacement and looping program should be the priority for the 5 year improvements.

6.3 5-Year Improvements

Please refer to section 5.3 for the locations of the growth areas for the five-year improvements.

Description	Unit	Quantity	Unit Cost	Total Cost
Facility Improvements				
Reinstate Well 9	LS	1	$100,000	$100,000
Line Improvements related to Future Development at Growth Areas				
Area #1 – 6” Line	LF	200	$ 78.00	$ 15,600.00
Area #2 – 8” Line	LF	1200	$ 83.00	$ 99,600.00
Area #3 – 6” Line	LF	500	$ 78.00	$ 39,000.00
Area #4 – 8” Line	LF	1600	$ 83.00	$132,800.00
Area #5 and North– 12” Line	LF	3300	$ 123.00	$405,900.00
Area #6 – 6” Line	LF	1200	$ 78.00	$ 93,600.00
Area #7 – 8” Line	LF	2100	$ 83.00	$174,300.00
Area #8 – 6” Line	LF	1500	$ 78.00	$117,000.00
Area #9 – 6” Line	LF	350	$ 78.00	$ 27,300.00
Line Improvements related to Upsizing of Existing 2”, 3”, and 4” Lines				
E Willow (Railroad to Jones)	LF	660	78	$ 51,480.00
Sims (S of Willow to Jones)	LF	770	78	$ 60,060.00
Elm (4th to 1st)	LF	742	78	$ 57,876.00
Marshall (5th to N of Wood)	LF	890	78	$ 69,420.00
Wood (7th to 5th)	LF	450	78	$ 35,100.00
Wood (Stemmons to 10th)	LF	1190	78	$ 92,820.00
Church (7th to 5th)	LF	460	78	$ 35,880.00
Church (Apartments to 10th)	LF	600	78	$ 46,800.00
FM 455 (Indian Lane looping) – 16”	LF	250	140	$ 35,000.00
Pecan (5th to 3rd)	LF	550	78	$ 42,900.00
Pecan (10th to 7th)	LF	1050	78	$ 81,900.00
Peach (5th to 2nd)	LF	770	78	$ 60,060.00
Peach (10th to 7th)	LF	720	78	$ 56,160.00
Plum (along 10th to 3rd)	LF	1930	78	$150,540.00
Keith (FM 455 to ex. 6”)	LF	1350	78	$105,300.00
5th & 6th (7th, turn to Chapman)	LF	930	78	$ 72,540.00
Southland, Southmanor,	LF	1860	78	$145,080.00

Southpark (West of Southmeadow)				
Hunters Ct (west of Freese)	LF	100	78	$ 7,800.00
11th (Elm to Hughes)	LF	740	78	$ 57,720.00
13th (Bolivar to Hughes)	LF	420	78	$ 32,760.00
3rd (Austin to Jackilue)	LF	330	78	$ 25,740.00
			Total	$2,528,036.00

6.4 10-Year Improvements

Please refer to section 5.3 for the locations of the growth areas for the ten-year improvements.

Description	Unit	Quantity	Unit Cost	Total Cost
Facility Improvements for Lake Ray Roberts				
Proposed New 250 GPM Well(s)	LS	1	$1,800,000	$1,800,000.00
Line Improvements related to Future Development at Growth Areas				
Area #5 and North– 12" Line	LF	3450	123	$ 424,350.00
Area #7 – 8" Line	LF	1800	83	$ 149,400.00
Area #10 – 12" Line	LF	18,300	78	$ 1,427,400.00
Area #11 – 6" Line	LF	1950	78	$ 152,100.00
			Total	$3,953,250.00

6.5 20-Year Improvements

Please refer to section 5.3 for the locations of the growth areas for the twenty-year improvements.

Description	Unit	Quantity	Unit Cost	Total Cost
Facility Improvements for Lake Ray Roberts				
Proposed New 600 GPM Well(s)	LS	1	$3,500,000	$3,500,000.00
Line Improvements related to Future Development at Growth Areas				
Area #5 and North – 12" Line	LF	2400	123	$ 295,200.00
Area #7 – 8" Line	LF	2100	83	$ 174,300.00
Area #10 – 6" Line	LF	5250	78	$ 409,500.00
Area #11 – 6" Line	LF	1500	78	$ 117,000.00
			Total	$4,496,000.00

6.6 Summary of Proposed Improvements for Future Development

The costs estimated for the 5, 10, and 20 year improvements include only construction estimates and does not include engineering fees, administrative costs, funding fees, acquisition costs, construction supervision, etc.

6.6 Summary of Proposed Improvements for Future Development

6.6.1 5-Year Improvements

1) Bring Well 9 back into service.
2) Line replacement program and looping per TCEQ guidelines and to facilitate improved fire protection.
3) Line extensions and distribution system improvements to service future development areas including areas 1, 2, 3, 4, 5, 6, 7, 8, and 9.

6.6.2 10-Year Improvements

1) Installation of new well(s), totaling 250 GPM to accommodate for future growth.
2) Line extensions and distribution system improvements to service future development areas including areas 5, 7, 10, and 11.

6.6.3 20-Year Improvements

1) Installation of new well(s), totaling 600 GPM to accommodate for future growth.
2) Line extensions and distribution system improvements to service future development areas including areas 5, 7, 10, and 11.

6.6.4 Impact Fee Analysis

The impact fee was calculated by estimating the cost of each improvement required to provide water service to the extents of the Proposed Improvements for Future Development. The total costs of these improvements was then divided by the number of additional future connections to be served. This provides an average per connection cost for the improvements. The impact fee analysis is briefly described as follows:

$$Impact\ Fee = \frac{Total\ Cost\ of\ Water\ Improvements}{Total\ Connections\ Served\ (Units\ to\ be\ Added)}$$

The resulting impact fee is $3,690 per connection and 50% of this fee is $1,845.

Appendix I

7 Water Distribution Modeling Fundamentals

7.1 Historical Background

Models are widely used in engineering projects of all types and the term "model" is used in many contexts. The "engineering model"; however, generally conforms to the following definition: *A model is a representation of a physical system that may be used to predict the behavior of the system in some desired respect*.[1] Historically models were physical representations of a system that had been scaled for ease of handling in a laboratory setting. Much has been documented regarding the development of mathematical models and software for use in hydraulic network analysis. The history of water system analysis dates back to the 1930s. In the early years analysis was limited and engineers relied on hydraulic tables and handbooks to solve pipeline problems. These methods often resulted in over designed pipe sizes based upon conservative design. Analyses of entire distribution systems was unheard of during this time, as the methods involved were tedious, time consuming calculation loops.[2]

As advancement in computing technology grew, so did the technology behind hydraulic network analysis. Today, desktop computers running a variety of stand-alone and integrated software, hydraulic network analysis is conducted on many platforms both simple (database only) and complex (CAD/GIS graphics with links to database). This technology allows engineers to integrate system mapping, operations (SCADA), and billings into a single model database thus allowing for real time analysis. The table below shows the historical advances in water-distribution system analysis.

Table 7.1 – Historical Development Summary of Network Modeling.[3]

Period	Important Advances
1930s	Hardy-Cross method
1940s	McElroy analyzer
1950s	In-house programs Mainframe computers
1960s	University and other programs
1970s	Wide program availability Microcomputers
1980s	User-friendly features Emergence of software packages Advanced features and EPS modeling
1990s	Links to other packages Integrated packages Water quality models

7.2 Hydraulic Terminology and Fundamentals

Hydraulics is defined as the "science of the laws governing the motion of water and other liquids and of their practical applications in engineering".[4] Throughout this report several common hydraulic concepts, and their corresponding terminologies, are utilized in the presentation of the study's findings. These common concepts include, but are not limited to, flow, velocity, pressure, hydraulic grade line, head and head loss. In

[1] B.R. Munson, D.F. Young, and T.H. Okiishi, Fundamentals of Fluid Mechanics. 3rd ed. (Wiley, New York, 1998), p. 423.

[2] L. Cesario, Modeling, Analysis, and Design of Water Distribution Systems. (American Water Works Association, Denver, 1995), p. 7.

[3] L. Cesario, Modeling, Analysis, and Design of Water Distribution Systems. (American Water Works Association, Denver, 1995), p. 208

[4] L. Cesario, Modeling, Analysis, and Design of Water Distribution Systems. (American Water Works Association, Denver, 1995), p. 13

the sections to follow these hydraulic concepts are defined and their relationships to one another briefly described.

7.2.1 Flow[5]

Flow is defined as the volume of water moving through a pipeline during a given amount of time. In this report the units of flow used are million gallons per day (MGD) and gallons per minute (gpm). The unit conversion between MGD and gpm is as follows: 1 MGD = 694 gpm. Flow is commonly described, in mathematical equations, by the letter *Q*.

7.2.2 Velocity[6]

Velocity is defined as the distance traveled per unit time. In pipeline hydraulics, velocity is given in terms of feet per second (fps) and is commonly noted, in equations, by the letter *V*. The relationship between flow, velocity and pipe size is given by the equation.

$$Q = AV \tag{2-1}$$

Where:

Q = flow
A = cross-sectional area of pipe
V = velocity.

Care must be taken to ensure that the terms of the equation above be expressed in consistent units.

7.2.3 Pressure[7]

Pressure is defined as the amount of force action on a unit area. In pipe network hydraulics it is commonly given in terms of pounds per square inch (psi). Pressure is a force per area and as such the shape of a container, or tank, holding water does not affect the pressure at the bottom of the tank. Two types of measurable pressures are static and residual. Static pressure is the pressure that occurs when the flow in a pipe is zero or near zero. Residual pressure is the pressure in a pipe under flowing conditions. Flow in a pipe results in a pressure drop, commonly referred to as head loss. Static pressure in a water distribution system is generally created by the weight of water stored in an elevated storage tank or by the pressure added by a pump station.

7.2.4 Head[8]

Head is defined as the measure of the energy of water and is commonly expressed in units of feet. In pipe network hydraulics there are three types of head: pressure, elevation and velocity.

Pressure head reflects the energy resulting from water pressure as described in Section 3.2.3 above. The relationship between pressure and pressure head is as follows; every pound per square inch of pressure corresponds to 2.31 feet of pressure head.

Elevation head reflects the potential energy of water that results from the water's elevation relative to a reference point. In pipe networks this reference point is typically the sea level elevation of the location in question. For example, water 400 feet above sea level has an elevation head of 400 feet.

[5] L. Cesario, Modeling, Analysis, and Design of Water Distribution Systems. (American Water Works Association, Denver, 1995), p. 14
[6] L. Cesario, Modeling, Analysis, and Design of Water Distribution Systems. (American Water Works Association, Denver, 1995), p. 15
[7] L. Cesario, Modeling, Analysis, and Design of Water Distribution Systems. (American Water Works Association, Denver, 1995), pp. 17-18
[8] L. Cesario, Modeling, Analysis, and Design of Water Distribution Systems. (American Water Works Association, Denver, 1995), pp. 19-20

Velocity head reflects water's energy of motion. It is a function of the velocity of the water flowing in the pipe and can be calculated with the following equation.

$$VH = V^2/2g = V^2/64.4 \quad (2\text{-}2)$$

Where:

VH = velocity head, in ft
V = velocity, in fps
g = gravitational constant = 32.2 ft/s^2.

The total head at any given point along a pipeline is the sum of the pressure head, elevation head and velocity head

7.2.5 Head Loss[9]

Head loss is the amount of energy used when water moves between two points along a pipeline and in terms of pressure; head loss simply represents a decrease in pressure. Head loss is typically referred to in terms in feet of head per 1,000 feet of pipe; however other quantities of pipe length may be used. There are two basic types of head loss: friction loss and minor loss.

Friction head loss results from the friction between the water flowing in a pipe and the pipe wall and is dependent upon the geometry of the pipeline (length and diameter), the velocity of water in the pipe and the roughness coefficient of the pipe material. The roughness coefficient is a value, typically between 20 and 150, that describes the roughness of the interior surface of the pipe. Typically, newer, smoother pipes have values in the range of 140 to 150, older pipes in good conditions have values ranging from 100 to 120, while an old pipe in very poor condition could have values as low as perhaps 20 to 60. In the hydraulic network model selected for this project friction head loss is determined by the Hazen-Williams equation.

Minor losses are energy losses that result from sudden changes in flow through a pipe as a result of a change in direction, pipe size or as a result of flow through a valve or other water system appurtenance. Minor losses in hydraulic network modeling are typically insignificant for most models unless the network contains small pipes, long distances between junctions or specific valves that create high head losses.

7.2.6 Hydraulic Grade Line[10]

The hydraulic grade line (HGL), or hydraulic gradient, is probably the most important term used in pipeline and pipe network hydraulics. The hydraulic gradient is used so that all points in a pipe network, regardless of ground elevation, can be related to one another or to any other common point. The HGL is often referred to as simply the grade or grade line and is given in units of feet. Each point on the HGL is related to the head value for the corresponding point in the pipe network and is calculated as the sum of the pressure head and elevation head for that point. Because of the relationship between pressure head and pressure, the HGL is used to calculate the pressure at a point in the pipe network with the following equation.

$$P = (HGL - EH)/2.31 \quad (2\text{-}3)$$

Where:

P = pressure, in psi
HGL = hydraulic grade line, in feet
EH = elevation head, in feet.

[9] L. Cesario, Modeling, Analysis, and Design of Water Distribution Systems. (American Water Works Association, Denver, 1995), pp. 20-22
[10] L. Cesario, Modeling, Analysis, and Design of Water Distribution Systems. (American Water Works Association, Denver, 1995), p. 22

Points in a water distribution system that establish the HGL for any given area or pressure zone include; the high water line of an elevated storage tank or other reservoir, the discharge pressure from a pump station, and the downstream side of any pressure-regulating valves.

7.3 Hydraulic Simulation Model

Hydraulic modeling of water-distribution systems is conducted by iteratively solving a set of mathematical equations that characterize the pipe network of the distribution system. The hydraulic model used by KSA, WaterCAD, is a hydraulic simulator that solves a set of equations for each tank, pipe and node in the water distribution system.

7.4 Applicable Definitions for TCEQ Minimum Capacity Requirements

There are several definitions that are applicable to the analysis of minimum system capacity requirements for storage and pumping requirements, they are as follows.

Connection – A single family residential unit or each commercial or industrial establishment to which drinking water is supplied from the system. As an example, the number of service connections in an apartment complex would be equal to the number of individual apartment units. When enough data is not available to accurately determine the number of connections to be served or being served, the population served divided by three will be used as the number of connections for calculating system capacity requirements. Conversely, if only the number of connections is known, the connection total multiplied by three will be number used for the population served. For the purposes of this definition, a dwelling or business which is connected to a system that delivers water by a constructed conveyance other than a pipe shall not be considered a connection if:

a. the water is used for purposes other than those defined as human consumption;
b. the executive director determines that alternative water to achieve the equivalent level of public health protection provided by the drinking water standards is provided for residential or similar human consumption, including, but not limited to, drinking and cooking; or
c. the executive director determines that the water provided for residential or similar human consumption is centrally treated or is treated at the point of entry by a provider, a pass through entity, or the user to achieve the equivalent level of protection provided by the drinking water standards.[11]

Elevated Storage Capacity – That portion of water which can be stored at least 80 feet above the highest service connection in the pressure plane served by the storage tank.[12]

Maximum Daily Demand – In the absence of verified historical data or in cases where a public water system has imposed mandatory water use restrictions within the past 36 months, maximum daily demand means 2.4 times the average daily demand of the system.[13]

Peak Hourly Demand – In the absence of verified historical data, peak hourly demand means 1.25 times the maximum daily demand (prorated to an hourly rate) if a public water supply meets the commission's minimum requirements for elevated storage capacity and 1.85 times the maximum daily demand (prorated to an hourly rate) if the system uses pressure tanks or fails to meet the commission's minimum elevated storage capacity requirement.[14]

Additional definitions related to public water systems can be found in 30 TAC 290.38

[11] Rules and Regulations for Public Water Systems, Title 30 Texas Admin. Code § 290, Subchapter D.
[12] Rules and Regulations for Public Water Systems, Title 30 Texas Admin. Code § 290, Subchapter D.
[13] Rules and Regulations for Public Water Systems, Title 30 Texas Admin. Code § 290, Subchapter D.
[14] Rules and Regulations for Public Water Systems, Title 30 Texas Admin. Code § 290, Subchapter D.