TECHNICAL MEMORANDUM

TO: Tim Fisher, P.E., City of Denton

FROM: Scott Cole, P.E., Freese and Nichols, Inc.
Stephanie Neises, E.I.T., Freese and Nichols. Inc.

SUBJECT: Southwest Water System Analysis

DATE: December 10, 2008

STATE OF TEXAS
SCOTT A. COLE
98813
LICENSED
PROFESSIONAL ENGINEER
12/10/08

1.0 Introduction

Freese and Nichols, Inc. was retained in 2007 by the City of Denton to conduct a water system analysis on the southwest portion of the City's distribution system. Rapid growth in the area south of Roselawn Drive and west of Country Club Road (herein referred to as the Southwest) has led to a significantly increased demand for water. A thorough evaluation of the capacity of the existing system was conducted utilizing the calibrated extended period simulation (EPS) model developed as part of the ongoing Water Distribution System Master Plan. The model was also used to identify short-term capital improvements over the next 5-year planning period required to support immediate developments.

2.0 Population and Water Demands

Water demands depend on the residential population and commercial developments served by the distribution system. Existing and proposed developments in the Southwest were analyzed to calculate projected water demands in the area. **Figure 1** shows the study area for the Southwest. Specific developments that were evaluated include:

- Country Club Village – an existing residential development east of Fort Worth Drive and south of Brush Creek Road.
- Country Lakes – an existing residential development located just east of I-35W, near John Paine Road.

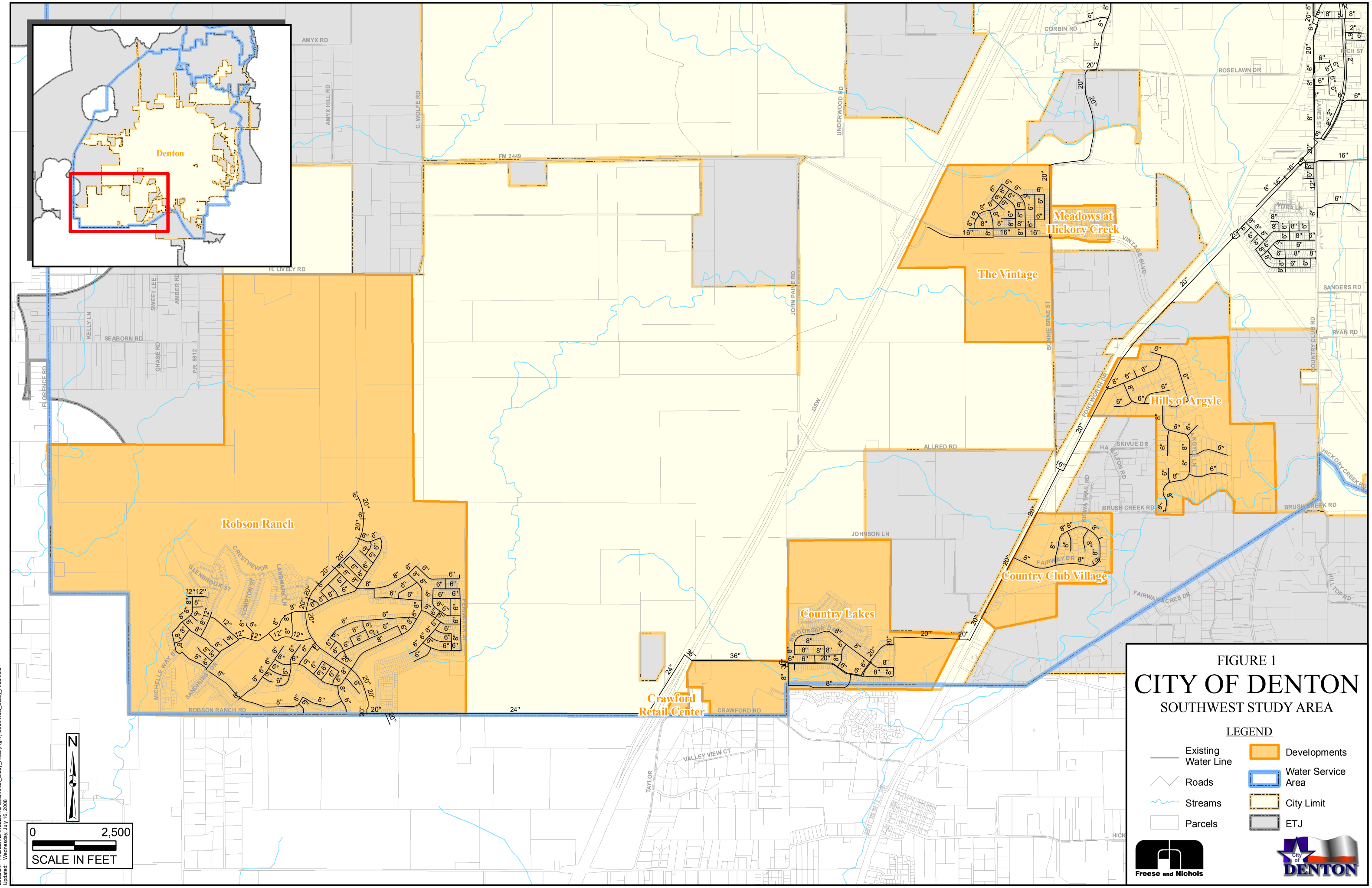

FIGURE 1

CITY OF DENTON

SOUTHWEST STUDY AREA

LEGEND

- Existing Water Line
- Roads
- Streams
- Parcels
- Developments
- Water Service Area
- City Limit
- ETJ

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City of DENTON

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Job No.: [DTN071724]
Location: H:\GIS\ARCMAPFILES\12_Southwest_Study_Area\(Fig.1)-Southwest_Study_Area.mxd
Updated: Wednesday, July 16, 2008

- Crawford Retail Center – a proposed development consisting of three restaurants, two service stations and a hotel located at I-35W and Crawford Road.
- Hills of Argyle – an existing residential development east of Fort Worth Drive, between Ryan Road and Brush Creek Road.
- Meadows at Hickory Creek – a new residential development located east of Bonnie Brae Street and north of Vintage Boulevard.
- Robson Ranch – an existing adult community west of I-35W and north of Robson Ranch Road.
- The Vintage – an existing residential development located west of Bonnie Brae Street and north of Vintage Boulevard.

In addition to these identified developments, FNI also projected a small amount of growth in other areas within the Southwest as shown in Table 2-2 and on the TSZ map included in **Appendix A.**

2.1 Water Demand Projection Design Criteria

The City of Denton provided metered water utility billing data from January 2004 to January 2008. The meter counts and water usage for each of the residential developments was determined by intersecting the geocoded meter account locations with the development area polygons. The data was analyzed to determine appropriate criteria for estimating water demands in the Southwest. Historical meter data and detailed water demand calculations are included in **Appendix A**. **Table 2-1** summarizes the design criteria used to develop water demands for each development.

Table 2-1 Water Demand Design Criteria

Development	People/Unit	Average Day Per-capita Consumption (gpcd)	MD:AD Peaking Factor	PH:MD Peaking Factor
Country Club Village	3.2	200	2.0	2.0
Country Lakes	3.2	100	2.0	2.0
Hills of Argyle	3.2	300	2.0	2.0
Meadows at Hickory Creek	3.2	105	2.0	2.0
Robson Ranch	1.8	270	2.0	2.8
The Vintage	3.2	105	2.0	2.0

2.2 Projected Population and Water Demands

Projected population and water demands were developed for each development based on the design criteria presented in Table 2-1. Water demands for the Crawford Retail Center were provided by the City. **Table 2-2** shows the maximum day water demands for the specified Southwest developments and the total projected demands for the entire Southwest area. Projected total system demands and allocation were consistent with the modeling efforts from the ongoing Water Distribution System Master Plan. A map showing population by traffic survey zone can be found in **Appendix A**.

Table 2-2 Southwest Maximum Day Water Demands

Development	2008		2009		2010		2011		2012	
	Population	Demand (mgd)	Population	Demand (mgd)	Population	Demand (mgd)	Population	Demand (mgd)	Population	Demand (mgd)
Country Club Village	163	0.06	227	0.09	291	0.12	355	0.14	419	0.17
Country Lakes	1,155	0.23	1,475	0.30	1,795	0.36	2,115	0.42	2,435	0.49
Hills of Argyle	480	0.29	544	0.33	608	0.36	672	0.40	704	0.42
Meadows at Hickory Creek	48	0.01	224	0.05	400	0.08	576	0.12	752	0.16
Robson Ranch	1,960	1.06	2,410	1.30	2,860	1.55	3,310	1.79	3,760	2.03
The Vintage	835	0.18	1,011	0.21	1,187	0.25	1,363	0.29	1,539	0.32
Crawford Retail Center	-	0.00	-	0.00	-	0.12	-	0.12	-	0.12
Sub-Total	**4,641**	**1.83**	**5,891**	**2.27**	**7,141**	**2.84**	**8,238**	**3.28**	**9,280**	**3.71**
Existing SW Demand	-	0.43	-	0.43	-	0.43	-	0.43	-	0.43
Additional SW Demand	-	0.00	-	0.35	-	0.28	-	0.99	-	2.14
Total	**-**	**2.26**	**-**	**3.05**	**-**	**3.55**	**-**	**4.70**	**-**	**6.28**

3.0 EPS Calibration Refinement

An EPS calibration was conducted as part of the ongoing Water Distribution System Master Plan using SCADA data supplemented by field pressure testing data from July 2007. The demand allocation consisted of utilizing metered billing data from July 2006. The SCADA data allowed for two diurnal curves that represented the hourly variations in water demands throughout the 24-hour calibration period for the Northwest and Central pressure planes, respectively. The Central pressure plane accounts for over 90% of the system demand; therefore it is nearly impossible to account for the localized variations in hourly demands with a single curve. To ensure a more accurate analysis of the Southwest, a calibration refinement was performed taking into account the individual demand characteristics of each development and recorded field data.

Utility billing data from 2007 and 2008 was reviewed to ensure that the most recent demand data was utilized for modeling each of the Southwest developments. City of Denton water utility staff provided fire hydrant testing data from the Southwest for various dates in 2006 and 2007. Upon review of the data, three fire flow testing periods were selected for analysis:

1. October 12, 2007 – before the 24/16-inch lines in Vintage Boulevard and Bonnie Brae Street were in service.
2. October 18, 2007 – after the 24/16-inch lines in Vintage Boulevard and Bonnie Brae Street were in service.
3. March 28, 2006 – fire flow tests in Country Lakes subdivision.

SCADA data for each of these time periods was provided by City water utility staff. The data was utilized to simulate the boundary conditions (i.e. tank levels, WTP flows) that occurred during the fire flow tests. Diurnal demands curves were generated from the SCADA data to estimate the system-wide demand that occurred during the fire flow tests. The fire flow locations were identified using the test hydrant and flow hydrant IDs referenced in the hydrant testing data sheets.

A model run was conducted for each of the three fire flow testing periods. The results of the model calibration refinement are presented in **Table 3-1**, **Table 3-2**, and **Table 3-3**. The locations of the fire hydrants are shown on **Figure 2**.

Table 3-1 Calibration Refinement Results - Scenario #1 (October 12, 2007)

	Recorded	Modeled
Static Pressure (psi)	66	66.3
LLWTP Flow (mgd)	14.7	14.5
LLWTP Pressure (psi)	87.9	88.9
RRWTP Flow (mgd)	7.7	7.3
RRWTP Pressure (psi)	95.9	96.7
Fire Flow (gpm)	2122.4	2122.4
Fire Flow Pressure (psi)	48.0	44.7
Available Fire Flow @ 20 psi	3522.7	3315.8
Test Hydrant: F1646-F02	Test Model ID: 9338	
Flow Hydrant: F1588-F04	Flow Model ID: 9330	

Table 3-2 Calibration Refinement Results - Scenario #2 (October 18, 2007)

	Recorded	Modeled
Static Pressure (psi)	65.0	65.8
LLWTP Flow (mgd)	4.6	4.9
LLWTP Pressure (psi)	87.0	86.7
RRWTP Flow (mgd)	9.8	9.8
RRWTP Pressure (psi)	97.3	98.6
Fire Flow (gpm)	2122.4	2122.4
Fire Flow Pressure (psi)	47.0	50.3
Available Fire Flow @ 20 psi	3481.2	3953.3
Test Hydrant: F1646-F02	Test Model ID: 9338	
Flow Hydrant: F1588-F04	Flow Model ID: 9330	

Table 3-3 Calibration Refinement Results - Scenario #3 (March 28, 2006)

	Recorded	Modeled
Static Pressure (psi)	60	63.8
LLWTP Flow (mgd)	7.2	7.3
LLWTP Pressure (psi)	86.3	87.3
RRWTP Flow (mgd)	10.4	10.4
RRWTP Pressure (psi)	96.7	98.5
Fire Flow (gpm)	2251.2	2251.2
Fire Flow Pressure (psi)	38.0	41.7
Available Fire Flow @ 20 psi	3109.0	3254.3
Test Hydrant: F1646-F02	Test Model ID: 9338	
Flow Hydrant: F1647-F03	Flow Model ID: 9314	

Each of the three model runs shows a strong correlation between recorded and modeled conditions. The modeled available fire flow at 20 psi was within 6% of the recorded flow for two of the three scenarios (#1 and #3). City of Denton utility staff indicated that two closed valves were discovered on the 24/16-inch lines in Vintage Boulevard and Bonnie Brae Street when the lines were in service for Scenario #2. The closed valves are likely the reason that the modeled fire flow was greater than the recorded value. The accuracy of the calibration refinement runs indicates that the model reflects real-world conditions in the field.

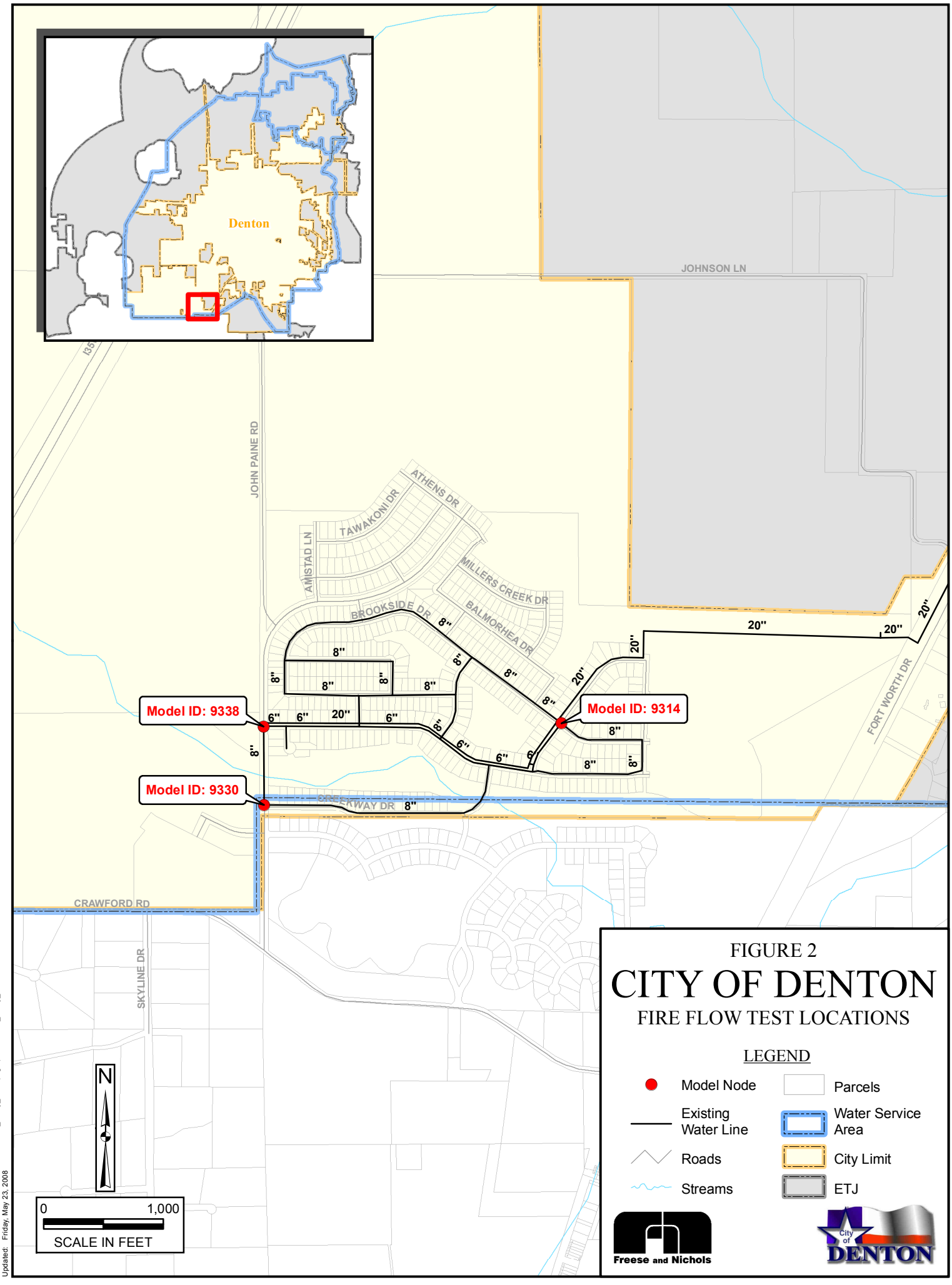

FIGURE 2

CITY OF DENTON

FIRE FLOW TEST LOCATIONS

LEGEND

- Model Node
- Existing Water Line
- Roads
- Streams
- Parcels
- Water Service Area
- City Limit
- ETJ

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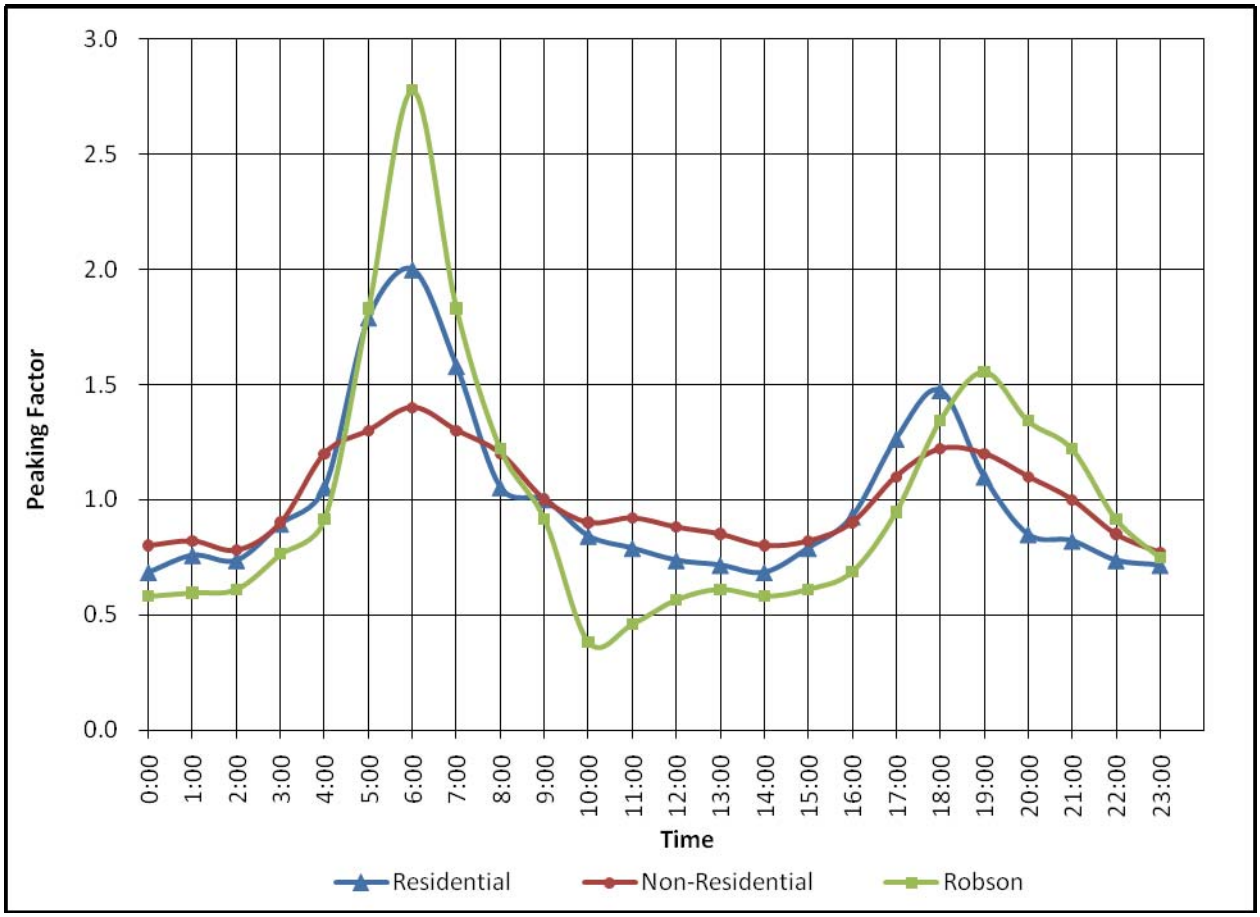
Job No.: [DTN07124]
Location: H:\DELIVERABLES\12-Southwest_Study_Area\(Fig.1)-Southwest_Study_Area.mxd
Updated: Friday, May 23, 2008

4.0 Hydraulic Modeling

The hydraulic model was used to evaluate the City of Denton's water distribution system yearly over the next 5 years. Diurnal demand patterns were developed for residential and non-residential demands based on the City's overall diurnal pattern. The diurnal pattern used for the Robson Ranch development was consistent with the diurnal curve presented in a Technical Memorandum regarding the "Robson Ranch transmission line and elevated tank analysis" dated July 27, 2006 prepared by Kimley-Horn and Associates, Inc. for the City of Denton. **Figure 3** presents the diurnal demand patterns used in the hydraulic model.

Figure 3 Diurnal Demand Curves



Five separate extended period simulations were conducted for a 24-hour modeled duration under maximum day demand conditions for 2008, 2009, 2010, 2011, and 2012. It is important to note that the ability to convey water to the Southwest influences other portions of the distribution system; therefore it is necessary to analyze the system as a whole. Projects constructed in areas other than the Southwest may improve or impair the system's ability to meet demands in the Southwest. Tank

replenishment, pumping capacity, pressure maintenance (minimum 35 psi), and fire flow were factors in determining the system's ability to meet demands.

4.1 2008 Analysis

The system-wide maximum day demand estimated for the 2008 analysis was approximately 39 mgd. Existing facilities (including the Southwest booster pump station and transmission line), without improvements, were evaluated in this scenario. The status of the high service pump station at LLWTP was controlled by the level of the McKenna Park standpipe and the McKenna Park booster pumps were controlled by the level in the Northwest elevated storage tank. When tank levels surpass high and low set points, pumps turn on or off to maintain the appropriate head range. The modeled flow from RRWTP was adjusted based on discharge pressure. A pump variable speed pattern was developed to maintain a discharge pressure of approximately 105 psi. The inlet valve to the Southwest ground storage tank was modeled as a pressure sustaining valve with a set point of 50 psi. The existing well in the Robson Ranch development was used during the peak demand periods to supplement the water being pumped from the Southwest ground storage tank.

The results of the analysis indicated that the system was not capable of meeting the estimated 2008 maximum day demands. The level in McKenna standpipe dropped below an acceptable level during the morning peak demand period and the system was unable to fully replenish the volume of water used during the 24-hour simulation. While the McKenna standpipe was difficult to fill, the High School elevated storage tank remains full throughout the simulation. Residential demands were decreased in the model until McKenna standpipe was operating within acceptable ranges. The demands were lowered by approximately 3 mgd (36 mgd system-wide demand) to keep the level in McKenna standpipe no more than 25 feet below the overflow elevation. When McKenna standpipe is more than 25 feet down, some areas within the Central pressure plane experience pressures lower than 35 psi and the ability to convey water to the Southwest is hindered. Therefore, if the system-wide demand exceeds 36 mgd, undesired operational issues may be experienced. Some potential approaches to limit increased demands include managing plat approvals and public education on water conservation.

4.2 2009 Analysis

For the 2009 analysis, the system-wide demand was approximately 41 mgd. All of the model controls model remained the same from the 2008 analysis. The Roselawn water line is the only improvement expected to be in service by the summer of 2009. The results of the analysis indicated that the system was not capable of meeting the projected demands for 2009. Similar to the 2008 analysis, acceptable levels in McKenna standpipe were not maintained throughout the simulation. Residential demands were decreased to a system-wide demand of 37 mgd. While the Roselawn water line increases transmission capacity to the Southwest, the operating conditions of McKenna standpipe limit the amount of water that can be conveyed to the Southwest while maintaining acceptable pressures throughout the distribution system. Therefore, a slight increase in Southwest demands can be met in 2009 but the entire projected growth in demand cannot be served adequately.

4.3 2010 Analysis

The 2010 system-wide demand was approximately 43 mgd. Model controls remained the same from the 2009 analysis with the exception of the use of the Robson Ranch well. The well was not used during this analysis and therefore all of Robson Ranch demand was met through the Southwest booster pump station. The only improvement expected to be constructed in 2010 is the North-South Phase I water line.

The results of the analysis indicated that projected system demands can be met in 2010. The 42-inch North-South water line is a critical project required to support increased demand in the Southwest. This improvement helps to maintain water levels in the McKenna Park standpipe and provides a means for water from the RRWTP to be conveyed further south. The project also allows water from LLWTP to more effectively be conveyed to the Southwest by relieving the burden of maintaining levels in the McKenna standpipe.

4.4 2011 Analysis

The projected system-wide demand for the 2011 analysis was approximately 46 mgd. System operation changed significantly with the addition of the Roselawn and Robson elevated tanks. The high service pump station at LLWTP was controlled by the levels in the Roselawn tank while the pumps at RRWTP continued to be adjusted based on the discharge

pressure. The Southwest booster pump station was controlled by the level in the Robson tank; therefore the pump station would no longer be solely responsible for pumping the instantaneous demands of the Robson development.

With the previously discussed improvements, the water system would be capable of meeting an additional 0.3 mgd maximum day demand beyond the projected demands in the Southwest. Additional demand greater than 0.3 mgd causes the Roselawn tank to drain more than half of its volume to meet peak demands.

4.5 2012 Analysis

The 2012 analysis was conducted with a system-wide demand of 51 mgd, which includes an increase in the wholesale water demands that is consistent with the ongoing Water Distribution System Master Plan. System improvements recommended for 2012 include the High School Booster Pump Station and Phase II of the North-South transmission line. All of the controls in the model remained the same from the 2011 scenario with the exception of the discharge pressure at RRWTP and the operation of McKenna Booster Pump Station. The discharge pressures at RRWTP were allowed to approach 110 psi to increase flows into the system and thus maximize the existing treatment capacity. When the High School Booster Pump Station becomes operational, the existing McKenna pump station will only be used during maintenance or emergency circumstances. Therefore, model controls were established with the new High School pump station being the only supply to the Northwest pressure plane. The High School booster pump station will provide the necessary additional pumping capacity to supply projected demands in the Northwest pressure plane as well as hydraulically decouple the High School elevated storage tank, which improves the system operation and water quality. The 36-inch North-South Phase II line provides transmission capacity southward which helps to maintain the level in the Roselawn elevated storage tank and improves pressures in the Southwest.

The results of the analysis indicated that the water system would be capable of meeting the projected demands for 2012. However, no additional demand can be met while still maintaining tank levels in the Roselawn elevated tank and the Southwest ground storage tank. Additionally, the system wide maximum day demand slightly exceeds the total

treatment capacity (RRWTP = 20 mgd, LLWTP = 30 mgd) so a treatment plant expansion would be required to serve additional demands.

4.6 Summary

Table 4-1 provides a summary of the Southwest maximum day demands that can be met each year and **Figure 4** illustrates the demand versus capacity in the Southwest.

Table 4-1 Summary of Southwest Capacity

Year	Southwest Maximum Day Demand (mgd)	Southwest Capacity (mgd)	Capacity Shortage (-) or Excess (+) (mgd)
2008	2.26	1.96	-0.3
2009	3.05	2.45	-0.6
2010	3.55	3.55	0.0
2011	4.70	5.00	0.3
2012	6.28	6.28	0.0

The City of Denton already has platted commitments for Country Lakes, Hills of Argyle, Meadows at Hickory Creek, Robson Ranch, and The Vintage. The maximum day demand for these commitments is approximately 4.82 mgd, of which 1.83 mgd is currently being served. **Table 4-2** shows the demands associated with the platted commitments for each development while **Figure 5** presents the demand versus capacity for existing and 5-year conditions.

Table 4-2 Water Demands for Platted Commitments

Development	Units	Population	Maximum Day Demand (mgd)
Country Lakes	1,272	4,070	0.81
Hills of Argyle	220	704	0.42
Meadows at Hickory Creek	150	480	0.10
Robson Ranch	2,250	4,050	2.19
The Vintage – Single Family Homes	267	854	0.18
The Vintage – Multi-family Homes	1,920	4,800	1.01
The Vintage – Shopping Center	-	-	0.11
Total	**6,079**	**14,958**	**4.82**

5.0 Phased Capital Improvements Plan

A capital improvements plan (CIP) was developed for the City of Denton as part of the ongoing Water Distribution System Master Plan to ensure high quality water service that promotes residential and commercial development. The 5-year CIP was evaluated on a yearly basis to determine appropriate phasing to accommodate demands in the Southwest. **Figure 6** presents the phased CIP for the Southwest. A detailed description of each project and a cost estimate can be found in **Appendix B**.

Figure 4 Southwest Capacity

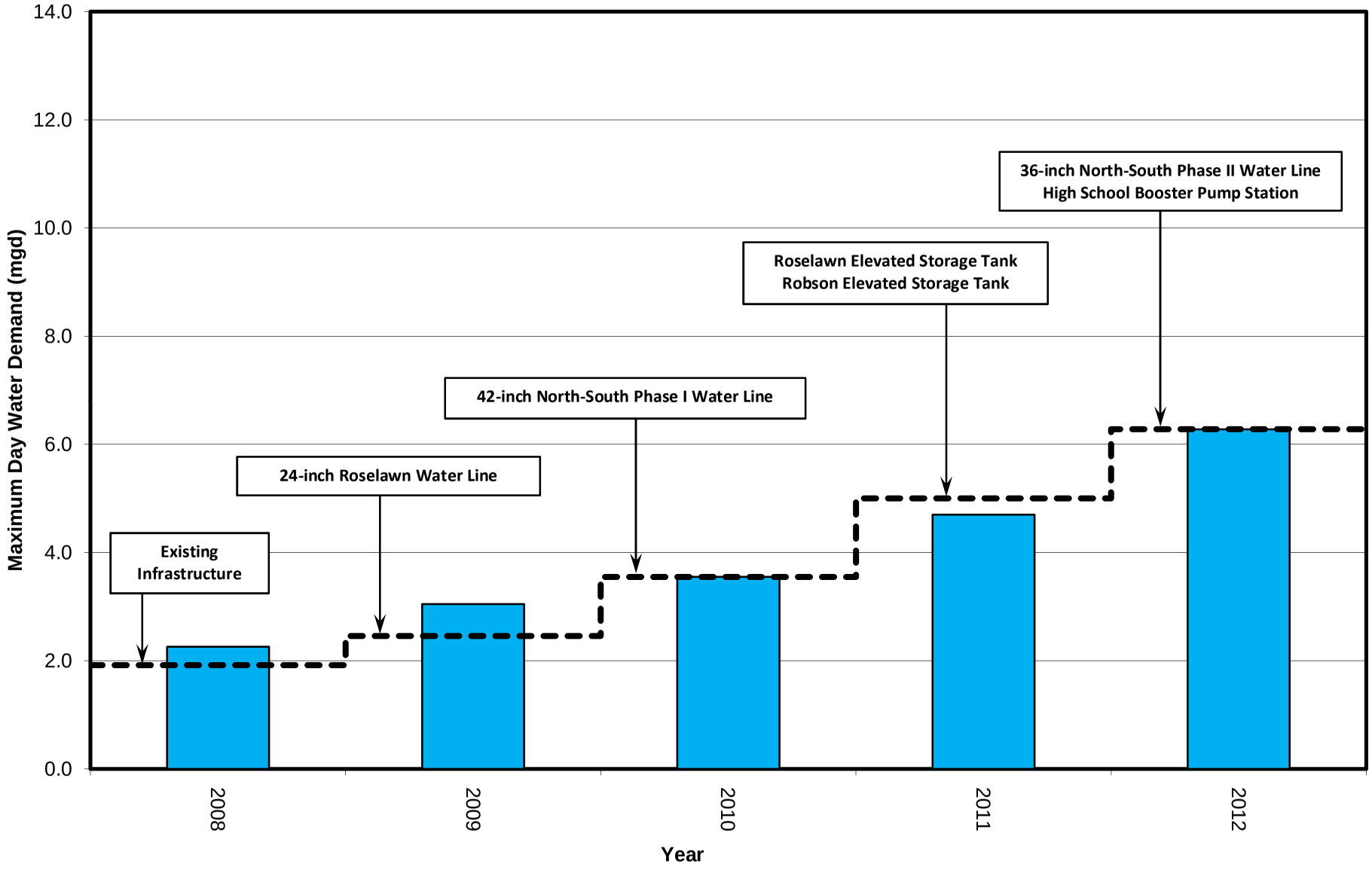


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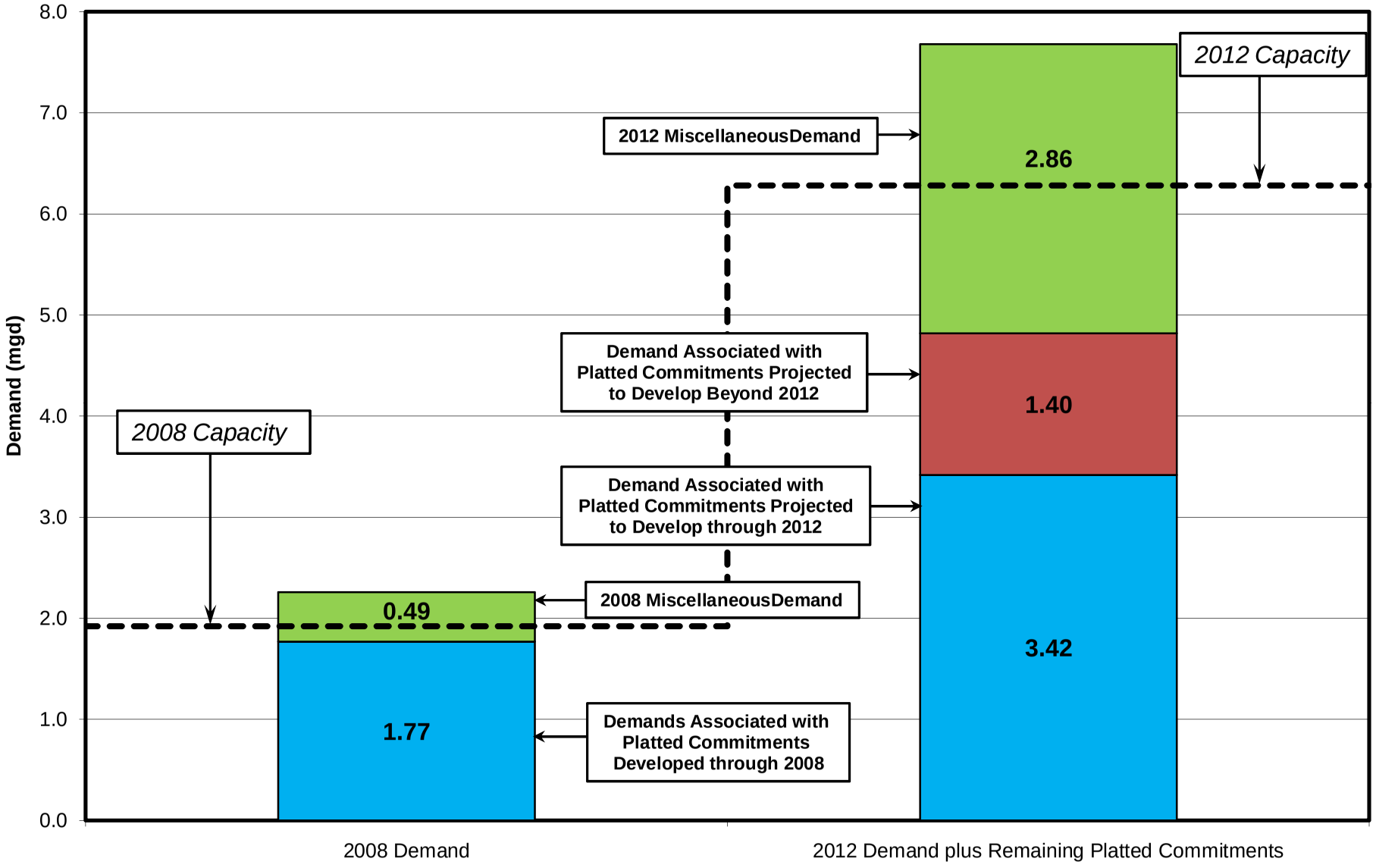
Figure 5 Existing and 5-year Demands Plus Platted Commitments

(Country Lakes, Hills of Argyle, Meadows at Hickory Creek, Robson Ranch, The Vintage)



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Updated: Tuesday, November 4, 2008

Lake Ray Roberts

Ray Roberts
Water Treatment Plant
Capacity = 20.0 MGD

1.0 MG Northwest
Elevated Storage Tank
Overflow Elev. = 900'

2.0 MG High School
Elevated Storage Tank
Overflow Elev. = 826'

Proposed High School
Pump Station
Firm Capacity = 10.0 MGD

McKenna Park
Pump Station

2.0 MG McKenna Park
Standpipe
Overflow Elev. = 827'

Lake Lewisville
Water Treatment Plant
Capacity = 30.0 MGD

Proposed 2.5 MG Roselawn
Elevated Storage Tank
Overflow Elev. = 826'

Proposed 2.0 MG Robson
Elevated Storage Tank
Overflow Elev. = 905'

Southwest
Pump Station

2.0 MG Southwest
Ground Storage Tank

Lake Lewisville

FIGURE 6
CITY OF DENTON
SOUTHWEST ANALYSIS CAPITAL IMPROVEMENTS PLAN

LEGEND

- Existing Elevated Storage Tank
- Proposed 2011 Elevated Storage Tank
- Existing Ground Storage Tank
- Water Treatment Plant
- Proposed 2012 Pump Station
- Existing Pump Station
- Pressure Reducing Valve

Water Lines
- Existing
- 2009 Proposed
- 2010 Proposed
- 2011 Proposed
- 2012 Proposed
- Proposed Beyond 5-year

- Water CCN
- City Limit
- ETJ

Proposed PP Boundary
- Southwest (905')
- Northwest (900')
- Central (826')
- East (745')
- Southeast (745')

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City of DENTON

N

0 7,500
SCALE IN FEET