Final Report

Lake Havasu City Water Master Plan Update

October 2007

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Project No. WT3060

Lake Havasu City

WATER MASTER PLAN UPDATE

FINAL

October 2007

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Lake Havasu City

WATER MASTER PLAN UPDATE

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Table of Acronyms and Abbreviations

AAC	Arizona Administrative Code
AACE	Association for the Advancement of Cost Engineering
AAD	average day
AADF	average annual day flow
ADEQ	Arizona Department of Environmental Quality
ADES	Arizona Department of Economic Security
ADWR	Arizona Department of Water Resources
BPS	booster pump station
CIP	capital improvement program
ENR CCI	Engineering News-Record Construction Cost Index
EPA	Environmental Protection Agency
EPS	extended period simulation
fps	feet per second
ft	foot
gal/ac/day	gallon per acre per day
GIS	Geographic Information System
gpad	gallons per acre per day
gpcd	gallons per capita per day
gpm	gallon per minute
HCW	Horizontal Collector Well
HL	Head Loss
hr	hour
IDSE	Initial Distribution System Evaluation
ISO	Insurance Services Office
kPa	kilopascal
L/m	liter per minute
LHC	Lake Havasu City
MD	maximum day
MG	million gallons
mgd	million gallons per day
PH	peak hour
PRV	pressure regulating valves
psi	per square inch
SCADA	Supervisory Control And Data Acquisition
UWL	unaccounted water loss
WTP	water treatment plant

OVERVIEW

Lake Havasu City is a growing community located along the Colorado River and adjacent to Lake Havasu. The lake was created as a result of the Parker Dam that was constructed on the river. The City has a unique setting with the lake, arid desert, and pleasant environment that makes it an ideal area for recreation and for retired residents. In addition, the City has been developing an employment base that provides good jobs for city residents. The City's 2002 General Plan states that one of the major challenges faced by the City is to "constructively cope with the impacts of growth." The City recognizes that successful communities must plan and prepare for growth so that the community benefits from the quality of life that is a result of the City's planning efforts. This water master plan is one element of the City's overall planning process. It is based on information in the General Plan, and serves to guide the City in planning for the water infrastructure that will effectively serve existing and future customers.

The City completed a water system master plan in 1992. This current master plan is an update to that master plan. There have been many changes to the water system and the direction that the City is going to supply water. The 1992 master plan was based on a buildout population of 70,000 people by year 2015. The current master plan is based on a buildout population of 96,000 people with a buildout year sometime beyond 2050. One of the biggest changes in water supply since the last master plan is that the City now obtains raw water via a horizontal collector well (HCW) and this water is pumped to a new water treatment plant (WTP). This new water supply and treatment facility removes the manganese, arsenic and other water quality problems that the City has dealt with in the past. The last master plan also included recommendations for increased pumping and storage in the distribution system.

The City's current water distribution system consists of 14 pump stations, 25 reservoirs, 9 wells, 1 collector well, and approximately 474 miles of pipe, ranging in diameter from 4 inches to 48 inches. The water system has served the City well in the past. Looking to the future, many of the pump stations are old and need replacement. In addition, the City has been growing and some of the existing infrastructure is no longer sized appropriately for current or future demands. City staff have expressed a desire to improve operational flexibility to the water system by increasing storage, and by providing greater flexibility in operating the pump stations. Recommendations in the master plan have been developed to address these issues.

In the future, the City will have several challenges to overcome in delivering water to City residents. These challenges include water supply, aging infrastructure, and projected growth. Water supplies are limited, so the City is looking for ways to conserve water and to effectively use reclaimed water as it becomes available. The City is also looking for opportunities to expand its water resources portfolio as well as stretch utilization of the existing portfolio. The City has a number of pump stations and wells that are near the end of their useful life. The wells will need to be rehabilitated and equipped to provide potential additional supplies to serve growth. The booster stations will need to be replaced and in many cases expanded so that the stations have sufficient capacity to supply projected growth north and east of the City. This plan includes a conceptual infrastructure plan to supply currently undeveloped portions to the north and east within the water service area. Planned growth along the highway and lake will also require significant amounts of water.

The foundation of this master plan consists of a definition of the service area, population growth projections, and the type of growth upon which water demand projections have been developed. Demand projections then determine the location, size, and timing of new infrastructure. Demand projections were also compared with water resource availability to determine if the planned service area can then be fully developed. Infrastructure that is to be recommended to supply water was sized based on an established standard of acceptability. This standard is called performance criteria and it defines the limits of acceptability for water distribution infrastructure. Chapter 2 contains the definition of the service area, demand projections, and performance criteria that is collectively called the planning framework.

The master plan requires extensive information on the water system infrastructure, historical water production and consumption information, SCADA and other operational data, as well as institutional knowledge. This information is used to create a hydraulic model of the water distribution system to evaluate the distribution system, identify deficiencies, and to plan for future growth. This information and the model development process are documented in Chapter 3.

Chapter 4 explains the evaluation of the existing water system. Using the model, the distribution system was compared with the performance criteria to identify areas where current water demands may require that the existing infrastructure perform at a level beyond the original intended design. Infrastructure needed for future growth is also presented, along with model results to demonstrate that the proposed infrastructure performs as intended.

Chapter 5 contains a capital improvement program with costs and an implementation time frame so that the City can prepare a capital improvement budget.

PLANNING FRAMEWORK

The planning framework for the Master Plan Update includes:

- A definition of the water service area to be included in the study
- A description of the water resources available to the City
- A land use plan that was used to project demands
- Unit demands and peaking factors
- Water distribution system performance criteria

2.1 WATER SERVICE AREA

Lake Havasu City's City boundary covers approximately 42 square miles and the water service area is estimated to be 56 square miles.

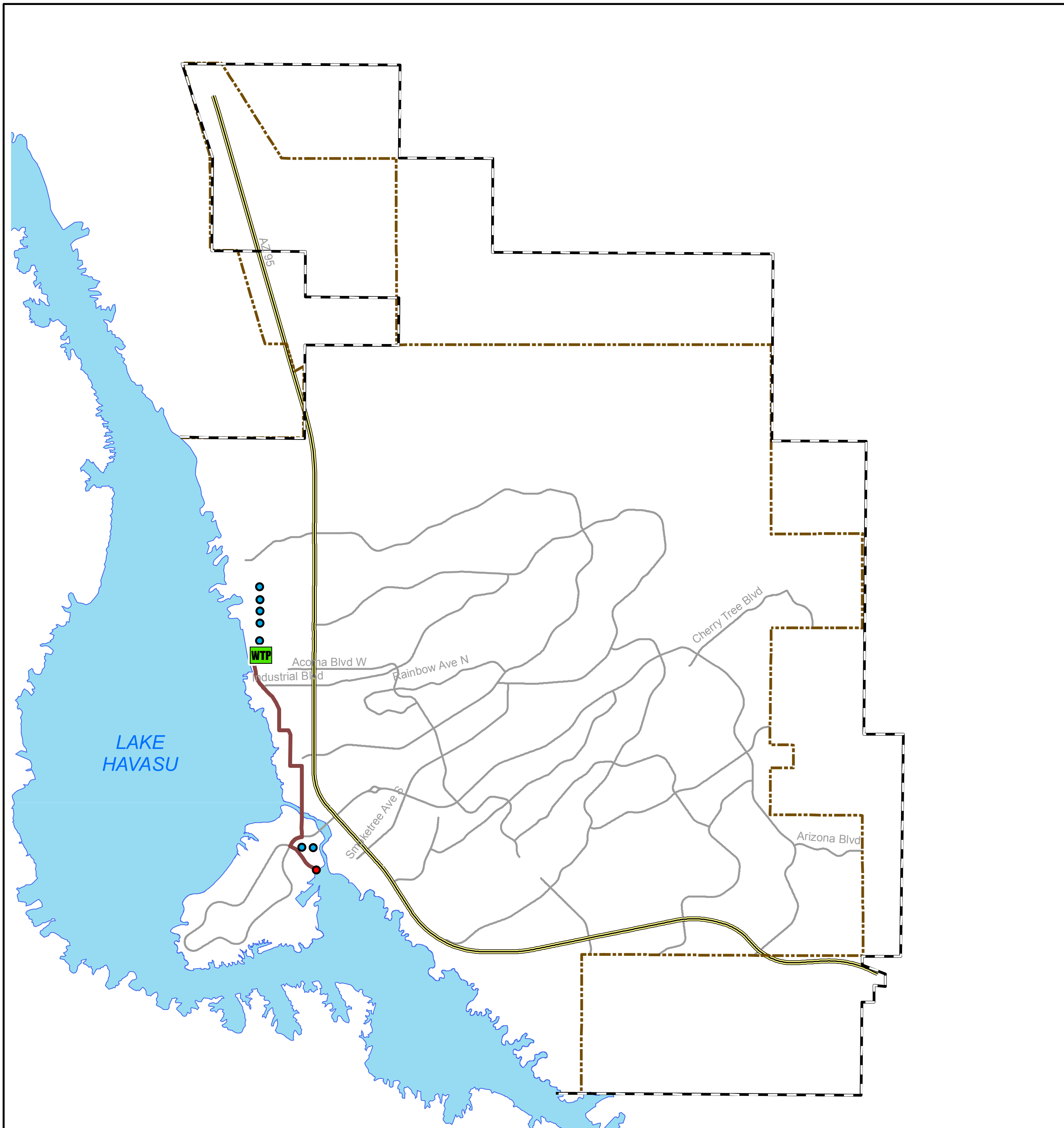
Figure 2.1 shows the City's current water service area and the City boundary. The legally defined water service area is also shown. The water service area includes most of the City as well as significant undeveloped areas to the north, east, and south of the City boundary.

2.2 WATER RESOURCES

The City currently has a water right of 25,180 acre-feet. An additional 2,098 acre-feet is being purchased and the City plans to have this additional water right in the near future. This additional water right will be available to the City only after the 25,180 acre-feet are being fully utilized.

The City's current water is supplied via a specific type of a groundwater well called a horizontal collector well (HCW). Water from the HCW is conveyed through a 48-inch raw water main along the Lake to the City's Water Treatment Plant (WTP). Figure 2.1 includes the location of the City's raw water well fields, water service area, and City boundary. After treatment, two large pump stations distribute the water into a network of eight pressure zones. A majority of these zones float on a series of tanks that are supplied from a pump station at the next lower zone.

The City can also use the nine wells that supplied potable water before the WTP was constructed. These wells all connect to the 48-inch transmission main that supplies the WTP and can be used when needed.



Horizontal Collector Well

Wells

Water Treatment Plant

48" Raw Water Transmission Pipe

Water Service Boundary

Lake Havasu City Limits

Major Streets

N

Miles

0 1 2

LAKE HAVASU CITY BOUNDARY, WATER SERVICE AREA, AND WATER SUPPLY LOCATIONS

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Figure 2.1

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 2_1 Boundary and Wells.mxd

The wastewater treatment plants produce effluent that could be used as part of the City's water resources portfolio. In addition to using this reclaimed effluent for irrigation and other types of outside water use, the City plans to subsurface inject the effluent to develop a groundwater reservoir. If successful, this reservoir would be above the existing water table and portions could then be pumped to the WTP to augment the potable water supply.

The City has implemented some water conservation measures in recent years to reduce overall per capita consumption. Additional conservation measures are planned that could further reduce water consumption. If successful, water conservation measures could help the City maximize utilization of its water resources.

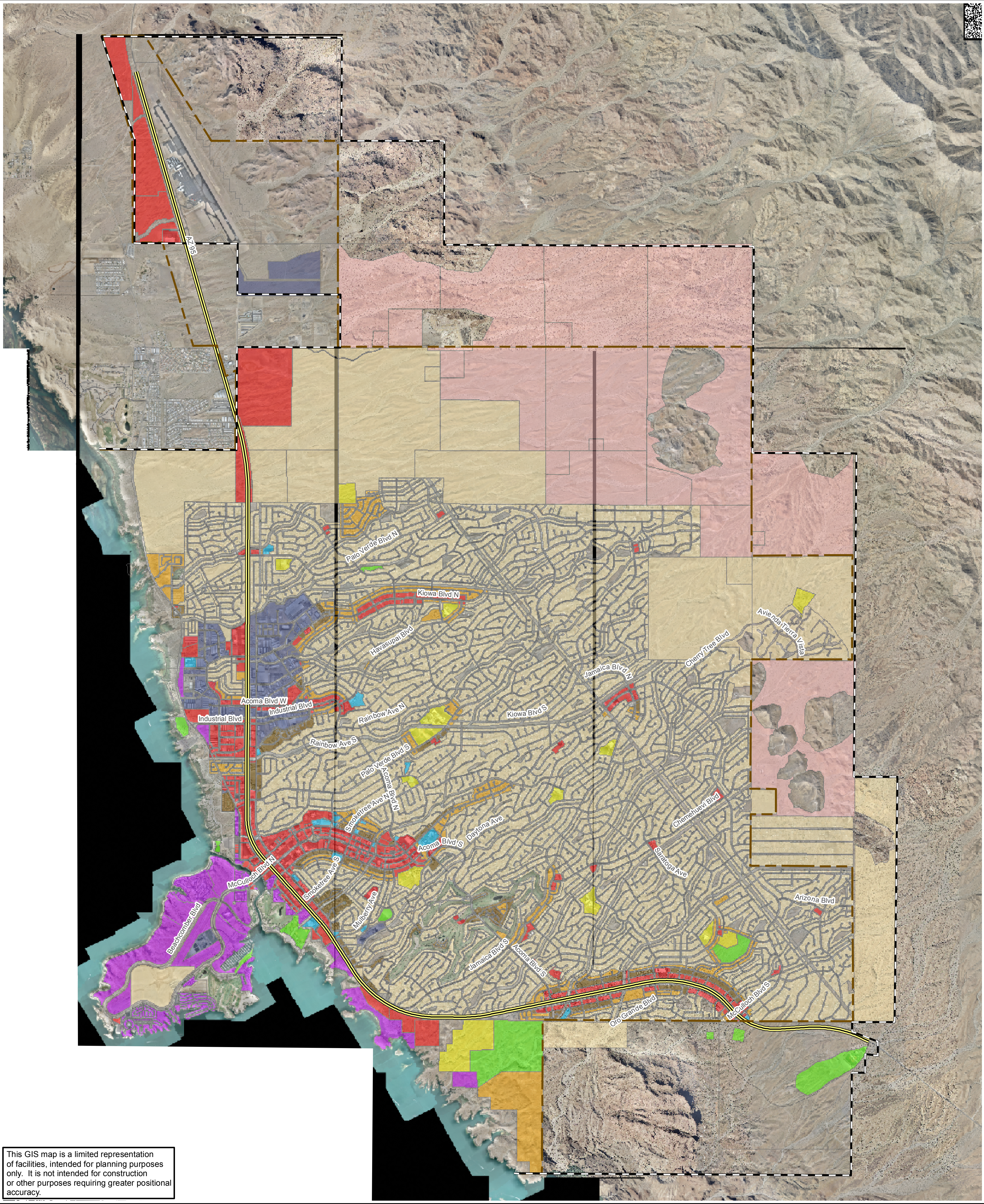
2.3 WATER DEMAND DEVELOPMENT

2.3.1 Water Consumption

The first step in estimating future demands is to have a thorough understanding of current demands. The City provided customer billing data for one year. The customer meters in this database were geo-located using Geographic Information System (GIS) tools to the specific property parcel where each water meter is located. The water consumption data was then assigned to the nearest location in the model. Ninety-nine percent of the meters in the customer billing database were matched to the specific property parcel where the meter is located.

2.3.2 Land Use Plan

A land use plan was then developed that described the type of customers in each area throughout the City. This land use consists of a GIS data layer that classifies land usage into ten categories that correspond to different types of land use. This land use plan was originally based on the land use information in the City's General Plan. However, some changes needed to be made to the land use as described in the General Plan so that the land use plan would correctly represent different types of water usage patterns. Categories of land usage in the General Plan were consolidated into the ten categories of land usage for the land use plan. Figure 2.2 shows a representation of the land use plan. A large scale map of the land use plan is in Appendix A. Each colored polygon in the figure has information in a database describing the type of customer, number of property parcels, population per house, and the percent developed in each planning year.



Water Service Boundary

Lake Havasu City Limits

Land Use

Category

Rural Residential (0 - 2 DU/AC)	Resort
Low Density Residential (2 - 4 DU/AC)	Business / Government
Medium Density Residential (4 - 10 DU/AC)	Commercial
High Density Residential (5 - 20 DU/AC)	School
	Irrigation
	Industrial
	No Potable Water Use Or Effluent Irrigation

LAKE HAVASU CITY, ARIZONA INCORPORATED 1978

Miles 0 0.5 1

Note: Sara Park and City Hall are currently irrigated by potable water but will be irrigated by effluent in the future.

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Figure 2.2

LAKE HAVASU CITY LAND USE PLAN

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M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 2_2 LHC Land Use Plan.mxd

Customer's water consumption data was linked to each of the land use polygons in the land use plan to know how much water was being consumed. By relating water consumption to the acreage, a unit demand in gallons/acre/day was obtained. Using the assumption that future water use in each land use category will not change, water demand projections were made for future planning periods. The City's water conservation programs are intended to reduce overall water usage, so the unit demands may decrease in the future. However, for infrastructure planning purposes, it is appropriate to assume that future unit demands are no less than current unit demands so that the City has an adequate water system to deliver water under a variety of demand conditions. Future master plans should revisit these unit demands to determine if a reduction in the calculated unit demand is warranted.

2.3.3 Population Projection

The City supplied population projection numbers generated by the Arizona Department of Economic Security (ADES). These same numbers are referenced in the City’s General Plan. Figure 2.3 shows the population growth curve that was calculated by the ADES. The City also calculates current and future populations, but the populations provided by ADES were recommended for use in this study. Exact population estimates are difficult to obtain due to the City's seasonal and weekend populations.

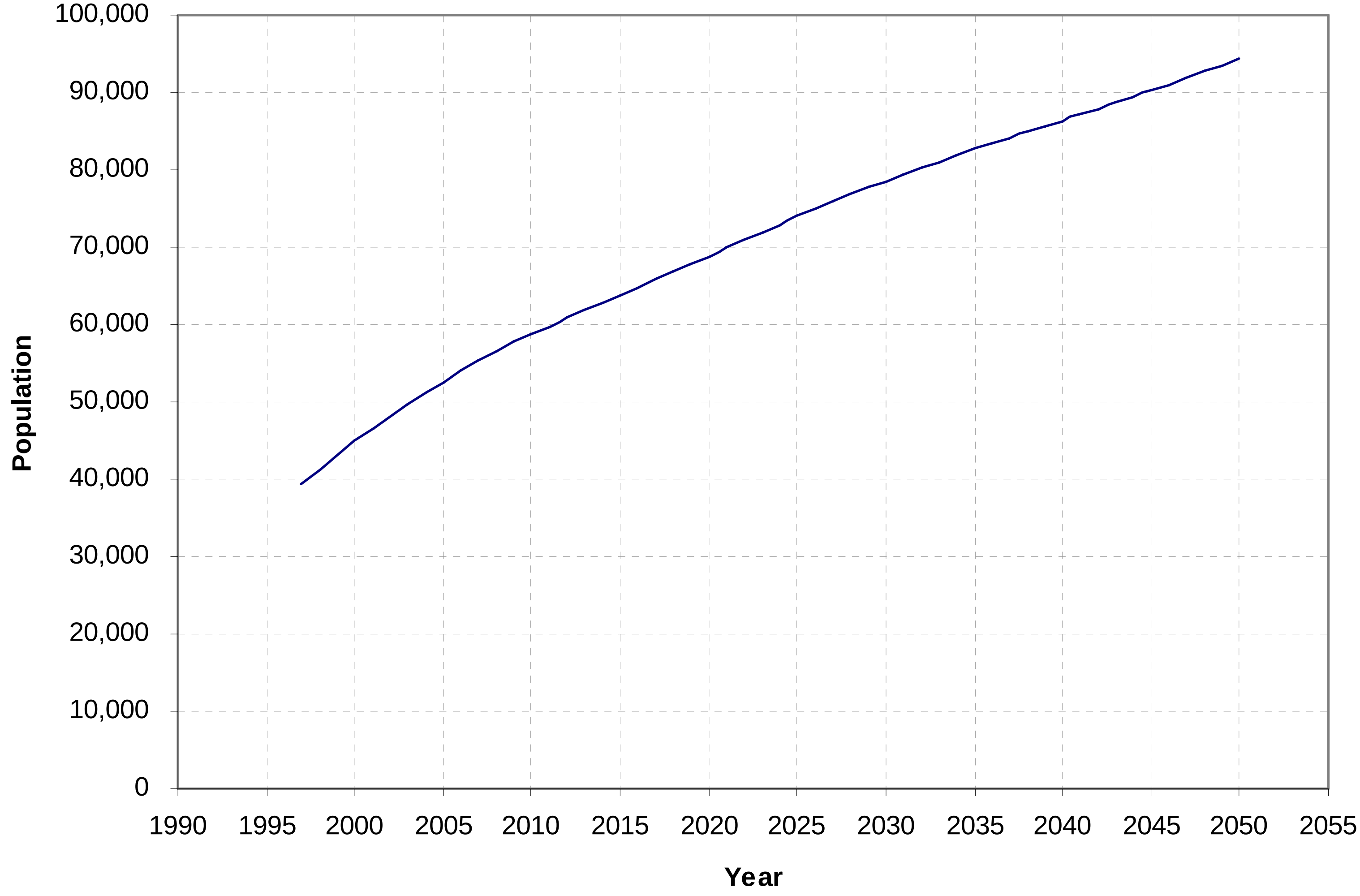
The growth rate in the land use plan was set to correspond with the ADES population growth rate for each of the planning years in this study.

The City has a seasonal and weekend population shift that needs to be considered when estimating per capita water consumption. Housing units may be vacant for significant portions of the year, so to make water production and consumption records match with the estimated population, an occupancy rate of 75.5 percent was used in the demand projection calculations.

Figure 2.4 shows the current and buildout populations differentiated in subzones throughout the City. Also displayed in the figure for each subzone is the percentage of buildout population that currently exists. Some areas will not have any residential land uses.

2.3.4 Unaccounted for Water

Unaccounted water loss (UWL) can be described as leaks, fire flows, under-reporting meters, or any other means of potable water escaping from the distribution system without being metered. Normally, UWL is the difference between water produced and water recorded on customer meters. A precise measurement of UWL was not possible because of meter reading inaccuracies at the treatment plant. A UWL of 10 percent is very typical for Arizona communities, so this is the value used in this study. The City is addressing the metering issues at the WTP, and a resolution is expected in the near future. The City is also working to reduce the amount of UWL to maximize use of its valuable water resource.



LAKE HAVASU CITY POPULATION GROWTH (SOURCE AZ DES)

FIGURE 2.3

LAKE HAVASU CITY
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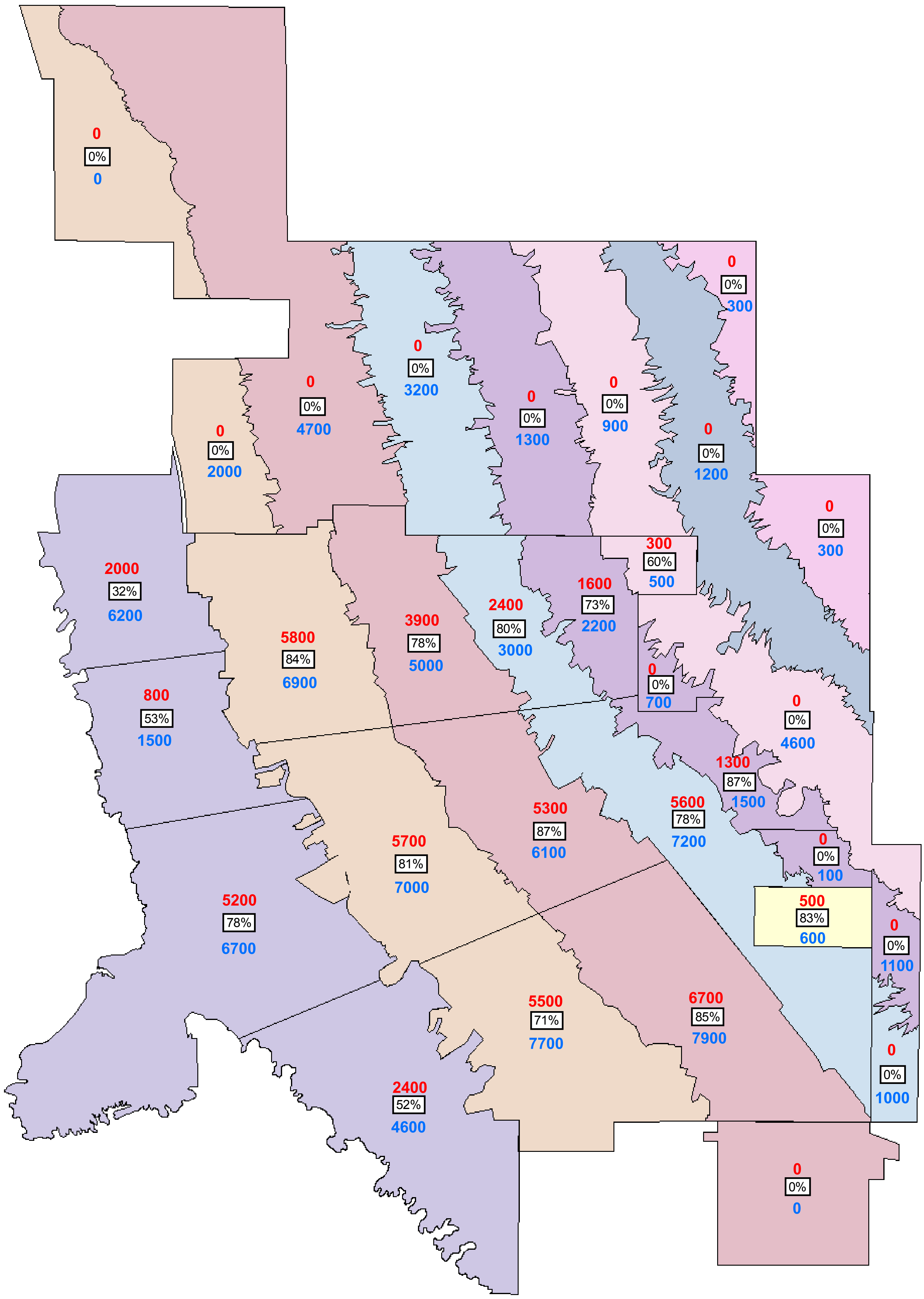

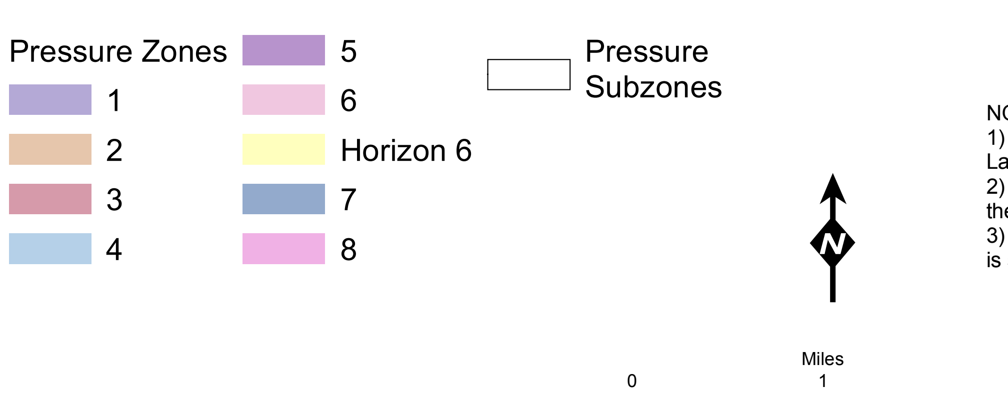

NOTES:
1) Population estimates are derived from the Land Use Plan.
2) The 2006 population is shown in red and the Buildout population is shown in blue.
3) The 2006 population compared to Buildout is shown as a percentage in the white boxes.

2006
Comparison Percent
Buildout

Figure 2.4

EXISTING AND PROJECTED POPULATION, BY SUBZONE

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M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 2_4 Existing and Projected Population by Subzone.mxd

2.3.5 Water Demands

Using information that is built into the land use plan and unit demands derived from customer billing data, the water demands for future years have been estimated.

Table 2.1 shows the unit demands and demand projections for average day and maximum day demands for each planning period to buildout.

Figure 2.5 shows the current and buildout water demand differentiated by subzones. Also displayed in the figure is the estimated percentage of water demand at buildout. Notice that this figure differs from Figure 2.4 as all areas will have increased demand even if there is no change in population because commercial demands are added with no population change in the commercial areas.

The recommendations in this document are based on the assumption that water supplies are available. The City is planning to use reclaimed water to supply irrigated areas wherever possible. However, in the near term, sufficient reclaimed water may not be available, so these irrigated areas must be served by potable water. Therefore, potable water infrastructure needed to serve irrigated areas has been recommended when necessary.

All infrastructure recommendations in this report are based upon these demand projection assumptions.

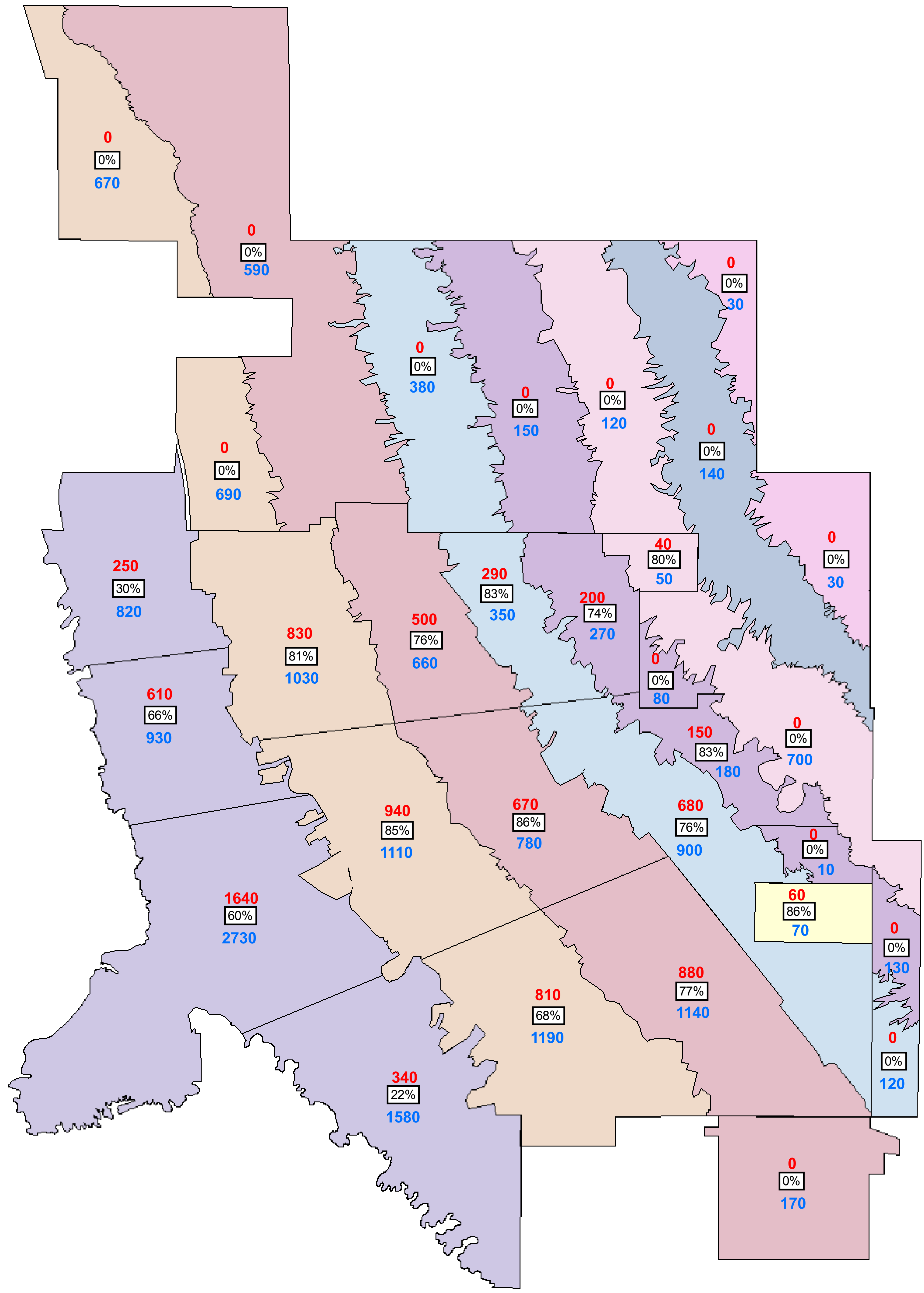
2.3.6 Water Demand Peaking Factors

Demand peaking factors are used to adjust demand estimates from an annual average day demand condition to a maximum day or peak hour demand condition. When the data is available, the maximum day demand is obtained from metered water production. Peak hour demands can be calculated for a water system or zone when all of the inflows and outflows are metered. For Lake Havasu, peaking factors need to be estimated because of incomplete meter data from the plant or at booster station sites. Peaking factors were estimated based on limited Lake Havasu data and peaking factors of similarly sized communities and climates in Arizona.

Table 2.1 Lake Havasu City Water Demand Projections Table Based on Land Use
Lake Havasu City Water Master Plan Update

Land Use Category	2006 Unit Demands	2006			2010			2015			2020			2025			Buildout		
		Acres	Population	Demand (mgd)	Acres	Population	Demand (mgd)	Acres	Population	Demand (mgd)	Acres	Population	Demand (mgd)	Acres	Population	Demand (mgd)	Acres	Population	Demand (mgd)
Rural Residential	172 gpcd	0	0	0.0	0	0	0.0	0	0	0.0	462	198	0.0	693	400	0.1	5,605	4,500	0.8
Low Density Residential	172 gpcd	7,671	48,800	8.4	8,312	52,600	9.1	9,098	57,000	9.8	9,980	61,400	10.6	11,167	66,100	11.4	13,761	80,700	13.9
Medium Density Residential	175 gpcd	357	2,800	0.5	400	3,000	0.5	439	3,300	0.6	500	3,600	0.6	554	3,900	0.7	793	5,600	1.0
High Density Residential	230 gpcd	175	2,900	0.7	181	3,000	0.7	188	3,200	0.7	218	3,700	0.9	236	4,000	0.9	321	5,100	1.2
Resort	2,468 gal/ac/day	220		0.5	221		0.5	222		0.5	308		0.8	350		0.9	750		1.8
Commercial	2,409 gal/ac/day	534		1.3	677		1.6	811		2.0	942		2.3	942		2.3	1,542		3.7
Industrial	1,347 gal/ac/day	401		0.5	480		0.6	585		0.8	624		0.8	624		0.8	624		0.8
Business/Government	3,876 gal/ac/day	70		0.3	76		0.3	77		0.3	78		0.3	78		0.3	78		0.3
School	2,752 gal/ac/day	151		0.4	207		0.6	236		0.7	269		0.7	279		0.8	314		0.9
Irrigation	3,515 gal/ac/day	41		0.1	44		0.2	44		0.2	44		0.2	44		0.2	298		1.0
Developed Land, Acres		9,621			10,598			11,700			13,423			14,965			24,086		
Developed Land, Square Miles		15			17			18			21			23			38		
Projected Population (estimated)			**55,000**			**59,000**			**64,000**			**69,000**			**74,000**			**96,000**	
Total Demand, mgd				**12.8**			**14.1**			**15.5**			**17.2**			**18.3**			**25.5**
Unaccounted-for-Water (UFW), mgd				**1.3**			**1.4**			**1.6**			**1.7**			**1.8**			**2.5**
Total Water Production (Average Day), mgd				**14.1**			**15.5**			**17.1**			**18.9**			**20.1**			**28.0**
Maximum Day, mgd				**22.5**			**24.9**			**27.3**			**30.2**			**32.2**			**44.8**

Notes: Infrastructure planned for 10% added to projected demands.
Maximum Day Peaking Factor: 1.6
Unaccounted Water Loss: 10%
Occupancy Ratio: 75.5%



Pressure Zones

- 1
- 2
- 3
- 4
- 5
- 6
- Horizon 6
- 7
- 8

Pressure Subzones

NOTES:
1) Demand estimates are derived from the Land Use Plan and are in units of gallons per minute.
2) The 2006 demand is shown in red and the Buildout demand is shown in blue.
3) The 2006 demand compared to Buildout is shown as a percentage in the white boxes.

N

Miles
0 1 2

2006
Comparison
Buildout

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Figure 2.5

EXISTING AND PROJECTED AVERAGE DAILY DEMAND, BY SUBZONE

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M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 2_5 Existing and Projected Average Daily Demand by Subzone.mxd

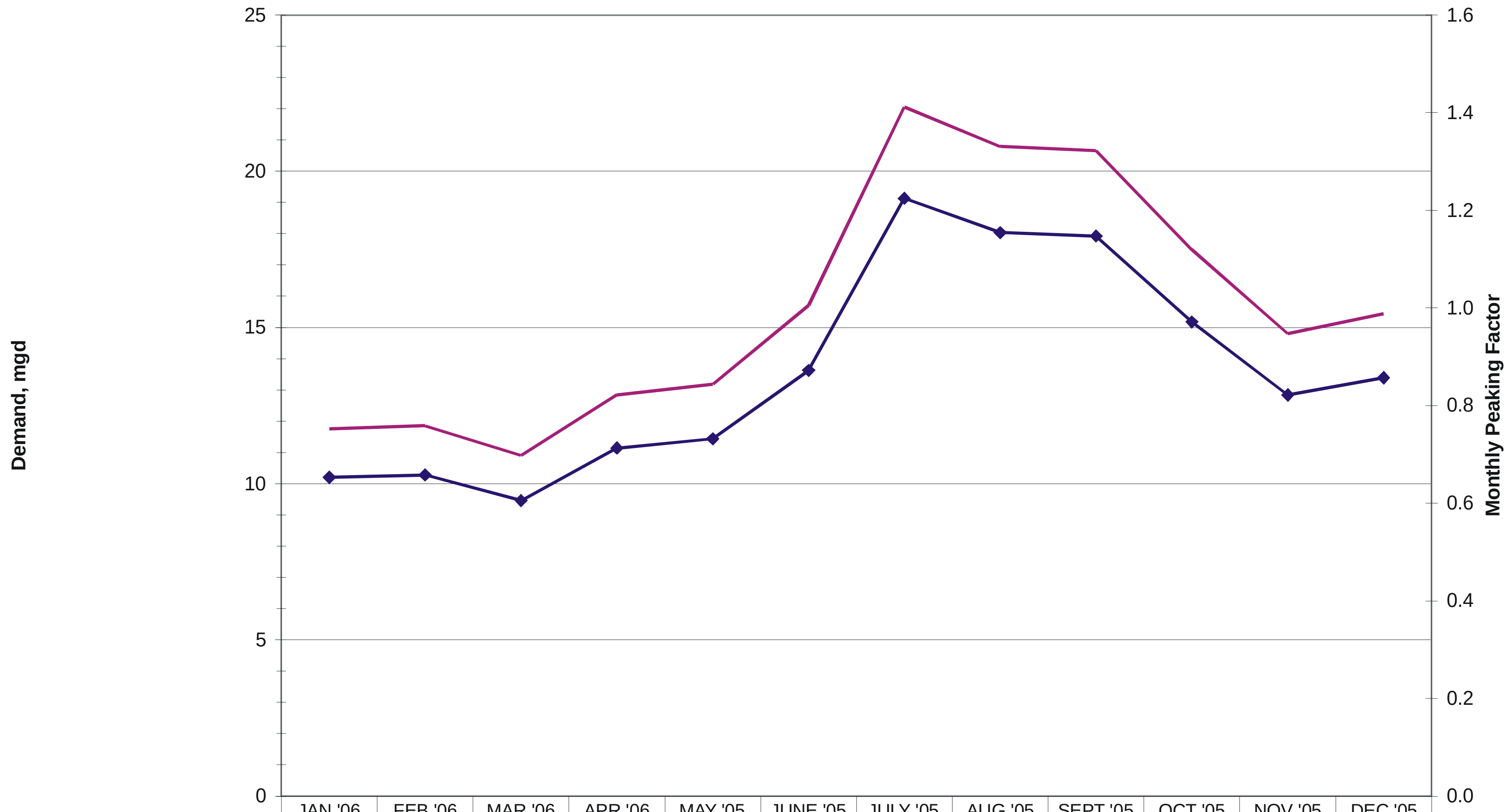
The average day (AAD) to maximum day (MD) water demand peaking factor is assumed to be 1.6. This value is slightly more conservative than the peaking factor for 2006 (1.4), but this more conservative factor has been adopted for planning purposes since good metered flow data from the water treatment plant is not currently available. The maximum day to peak hour (PH) peaking factor that has been selected for planning purposes is estimated to be 2.5 based on the mass balance calculations that were performed for Zone 4. The peak hour factor is expected to be lower in Zones 1 and 2, which have greater diversity in the types of water usage. Higher zones are expected to have a similar peaking factor. However, a peaking factor of 2.5 is used as an overall average.

Table 2.2 shows the peaking factors as derived previously.

Table 2.2 Peaking Factors
Lake Havasu City Water Master Plan Update

Demand Condition	Peaking Factor
Average Day (AAD)	1
Maximum Day (MD/AAD)	1.6
Peak Hour (PH/MD)	2.5

Figure 2.6 shows the monthly water demand peaking factors. The peak months begin in June and extend to September. The months of lowest water demands are generally December through February. Peaking factors are usually highest in high demand months.



	JAN '06	FEB '06	MAR '06	APR '06	MAY '05	JUNE '05	JULY '05	AUG '05	SEPT '05	OCT '05	NOV '05	DEC '05
Demand, mgd	10.20	10.28	9.46	11.14	11.44	13.63	19.13	18.04	17.93	15.18	12.84	13.39
Monthly Peaking Factor	0.75	0.76	0.70	0.82	0.84	1.01	1.41	1.33	1.32	1.12	0.95	0.99

MONTHLY PEAKING FACTORS

FIGURE 2.6

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2.4 PERFORMANCE CRITERIA

The infrastructure that will be recommended in this master plan is intended to provide acceptable levels of performance and reliability, while being sensitive to cost. As new infrastructure is being planned and analyzed with the use of a new hydraulic model, agreed upon "standards of measurement" are necessary to evaluate the adequacy of the infrastructure. The "standards of measurement" are the performance criteria that are utilized by LHC and upon which this master plan is based.

Performance criteria address the following categories related to water system infrastructure.

- Water Supply Redundancy: Addresses the ability for water supplies from the City's water resources portfolio to be delivered into the distribution system under a variety of conditions.
- Water System Reliability: Addresses strategies for the distribution system collectively to deliver water even when some facilities are not in service.
- System Operational Requirements: Addresses infrastructure sizing so that water can be delivered reliably under fire flow, high demand, or other extreme or unusual operating conditions.

Water supply redundancy refers to the degree to which water can still be supplied to the City in the event that one or more of the water supply sources is unavailable. Decisions concerning the extent of redundancy in a water system are often policy decisions influenced by the price a utility is willing to pay for the redundancy compared with the risk of having to implement water use restrictions or provide a lower level of service to the customer. Under some conditions, it may be more economical for the City to implement water conservation measures than to build infrastructure that will be used only on infrequent occasions when a particular water source may be unavailable. Although no firm guidelines exist, most communities in central Arizona seek to provide redundant or backup water supplies for average day demand conditions.

The level of reliability provided is usually based on historic operational experience and judgment, which results in confidence that the system can deliver water under a variety of normal and emergency conditions. Consequently, professional judgment must be used when specifying system components and the number and location of components needed to meet reliability criteria.

The level of reliability provided by the system is a function of the reliability of the major system components:

- Raw Water Sources.
- Water Treatment.

- Major Transmission Mains.
- Power Sources.
- Booster Stations.
- Storage Tanks.
- Pressure Reducing Valves (PRVs).

Reliability of the City's water system is provided by a combination of the following factors:

- Sufficient water sources and treatment capability to meet maximum-day demand.
- Reserve system storage to meet emergency conditions, in addition to fire and normal operational needs.
- Transmission capability to deliver water to the distribution system.
- Looped distribution system network.
- Sufficient booster pumping capabilities with a pump station or the largest pump in a station out of service.

System operational requirements refer to the level of service provided by a utility to the customer. Levels of service include many parameters, such as maximum and minimum pressures, maximum flow velocities, storage, redundancy, and provisions for emergency conditions. Adequate pressure is usually defined in terms of a minimum pressure under certain demand conditions, such as peak hour or fire flow. Adequate fire protection refers to providing adequate storage volume and flow to meet firefighting demands. The water system is considered to be adequate when system demand conditions are satisfied while meeting system performance criteria, such as system pressure, velocity, and head loss.

2.4.1 Water Production Facilities

Production facilities for the water system should have sufficient capacity to meet the demands of the maximum day of the year. Existing production facilities consist of wells and the HCW that supply the water treatment plant (WTP).

State regulations regarding emergency operation plans require that emergency conditions, such as loss of source of water supply, be addressed by the municipality.

Backup water supplies should be available for when the WTP is shut down for scheduled maintenance, repairs, mechanical failure, or contaminants during average day demand conditions.

2.4.2 Fire Flow

The City's Fire Department has adopted the standard for fire flow. Table 2.3 shows the fire flow volume and duration for various building sizes and types.

Table 2.3 Fire Flow Requirements for Different Building Types
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Minimum Required Fire Flow and Flow Duration for Buildings[a]						
Fire Flow Calculation Area (square feet)					Fire Flow (gpm)[c]	Flow Duration (hours)
Type IA and IB[b]	Type IIA and IIIA[b]	Type IV and V-A[b]	Type IIB and IIIB[b]	Type V-B[b]		
0-22,700	0-12,700	0-8,200	0-5,900	0-3,600	1,500	2
22,701-30,200	12,701-17,000	8,201-10,900	5,901-7,900	3,601-4,800	1,750	
30,201-38,700	17,001-21,800	10,901-12,901	7,901-9,800	4,801-6,200	2,000	
38,701-48,300	21,801-24,200	12,901-17,400	9,801-12,600	62,01-7,700	2,250	
48,301-59,000	24,201-33,200	17,401-21,300	12,601-15,400	7,701-9,400	2,500	
59,001-70,900	33,201-39,700	21,301-25,500	15,401-18,400	9,401-11,300	2,750	
70,901-83,700	39,701-47,100	25-501-30,100	18,401-21,800	11,301-13,400	3,000	3
83,701-97,700	47,101-54,900	30,101-35,200	21,801-25,900	13,401-15,600	3,250	
97,701-112,700	54,901-63,400	35,201-40,600	25,901-29,300	15,601-18,000	3,500	
112,701-128,700	63,401-72,400	40,601-46,400	29,301-33,500	18,001-20,600	3,750	
128,701-145,900	72,401-82,100	46,401-52,500	33,501-37,900	12,601-23,300	4,000	4
145,901-164,200	82,101-92,400	52,501-59,100	37,901-42,700	23,301-26,300	4,250	
164,201-183,400	92,401-103,100	59,101-66,000	42,701-47,700	26,301-29,300	4,500	
183,401-203,700	103,101-114,600	66,001-73,300	47,701-53,300	29,301-32,600	4,750	
203,701-225,200	114,601-126,700	73,301-81,100	53,301-58,600	32,601-36,000	5,000	
225,201-247,700	126,701-139,400	81,101-89,200	58,601-65,400	36,001-39,600	5,250	
247,701-271,200	139,401-152,600	89,201-97,700	65,401-70,600	39,601-43,400	5,500	
271,201-295,900	152,601-166-500	97,701-106,500	70,601-77,000	43,401-47,400	5,750	
295,901-Greater	166-501-Greater	106,501-115,800	77,001-83,700	47,401-51,500	6,000	
-	-	115,801-125,500	83,701-90,600	51,501-55,700	6,250	
-	-	125,501-135,500	90,601-97,900	55,701-60,200	6,500	
-	-	135,501-145,800	97,901-106,800	60,201-64,800	6,750	
-	-	145,801-156,700	106,801-113,200	64,801-69,600	7,000	
-	-	156,701-167,900	113,201-121,300	69,601-74,600	7,250	
-	-	167,901-179,400	121,301-129,600	74,601-79,800	7,500	
-	-	179,401-191,400	129,601-138,300	79,801-85,100	7,750	
-	-	191,401- Greater	138,301-Greater	85,101-Greater	8,000	

For SI: 1 square foot = 0.0929 m^2, 1 gallon per minute = 3.785 L/m, 1 pound per square inch = 6.895 kPa.

a. The minimum required fire flow shall be permitted to be reduced by 25 percent for Group R.

b. Table provided by Lake Havasu City, from the *International Building Code.*

c. Measured at 20 psi.

The type of buildings in each zoning category as defined by the City's Planning and Zoning Department can be categorized based on fire flow requirements. Table 2.4 shows the fire flow requirements in each zone.

Table 2.4 Fire Flow Requirements by Zoning Category
Lake Havasu City Water Master Plan Update

Category		Flow (gpm)	Duration (hours)
R-1	Single Family	1,500	2
R-2	Duplex Family	1,500	2
R-3	Multiple Family	2,500	2
R-4	Multiple Family	2,500	2
R-1C	Multiple Family Condo	2,500	2
C-1	Commercial	3,500	3
C-2	Commercial	3,500	3
C-O	Commercial Office	3,500	3
C-R	Commercial/Residential	5,000	4
H-1	Hotel-Depends on Height	6,000-10,000	4
M-1-P	Manufacturing Light	5,000	4
M-2-P	Manufacturing Heavy	5,000-8,000	4

It is assumed that a major fire will not occur during the peak hour demand condition since the chance of this happening is minimal. But rather, it is more likely that a fire could occur under maximum day demand conditions.

2.4.3 Pump Stations

Usually pumping stations are the most critical components in a distribution system with respect to meeting reliability/redundancy criteria, because these facilities are subject to disruption by the following conditions:

- Power outage.
- Mechanical failure.
- Line breaks.

Table 2.5 summarizes these conditions and the criteria to be employed for reliability in this master plan.

Table 2.5 Booster Station Reliability Criteria
Lake Havasu City Water Master Plan Update

Condition	Result	Mitigating Criteria
Power Outage	Creates loss of pumping capacity at one or more pumping facilities.	Provide emergency backup power supply generation or dual power feed to critical facilities.
Mechanical Failure	Creates loss of pumping capacity due to one or more pumps at a facility being out of service.	Provide sufficient pumping capacity at each booster pumping station to meet maximum day demands with any one pump or the largest pump out of service (referred to as "firm capacity" of the station). This allows for pumps to be out of service due to mechanical failure or unscheduled maintenance. For pressure zones with 3 or more booster stations, have sufficient pumping capacity to supply the zone under average day conditions with one pump station out of service.
Line Break	Occurs at or near the booster station, creating a loss of all or a portion of the pumping capacity at the facility.	A line break at or near a booster station disrupting supply is usually mitigated through multiple pumping facilities, storage, and PRV facilities. A water main transmission capability between pump stations within a zone shall be provided so that water can be delivered throughout the zone if one pump station is out of service on an average demand day. A PRV shall be provided at pump stations so that if the pump station is out of service in an emergency, water supplies could be provided on a temporary basis from storage in a higher zone.

For line breaks affecting critical pumping facilities, reliability/redundancy criteria are established so that average day demand conditions can be met on a zone-by-zone basis.

A pump station pumping to a closed system, with no other water sources or elevated storage, should be sized for the larger of either peak hour demand or maximum day plus fire flow demand. An additional 10 percent is to account for uncertainties in demand estimates. Diurnal demands (peak hour) and fire demands will be met from ground set storage, and the booster stations will need to be able to pump this flow from the reservoirs. Pump stations should be designed based on the firm capacity that can be consistently provided with the largest pump out of service. In addition, pump stations that deliver water into higher zones must be sized to meet the demands of all zones that are directly or indirectly served by the pump station.

The following summarizes pump station criteria:

- When pumping to a closed system, the capacity should equal the larger of either peak hour demand or maximum day plus fire flow demand.
- The allowance for reliability and uncertainties in demand projections equals 10 percent of the station's firm capacity.
- Pump stations should be sized to meet demands with the largest pump out of service (firm capacity).
- When multiple booster stations supply a zone, average annual water demands should be supplied with the largest booster station out of service.
- Pump stations should have a back-up power supply sufficient to allow the station to pump the firm capacity of the station.
- The firm capacity of booster stations that pump from reservoirs is often set so that half of the reservoir can be emptied or refilled in a six-hour period.

2.4.4 Transmission/Distribution Mains

Water system piping serves three basic purposes:

- To transfer water from the source of production to storage.
- To distribute water from the source or storage to the consumer.
- To provide a conduit to supply firefighting water.

Transmission and distribution mains are sized for the greater of the following two demand conditions:

- Maximum day demand plus fire flow, or
- Peak hour demand.

Peak hour demands are usually the controlling demand condition for pressure zones of the size found in LHC. The following pressure criteria are recommended to assess the adequacy of the water transmission/distribution system under the two demand conditions:

- Peak Hour Demand: Pressures should be greater than 50 pounds per square inch (psi). Pressures higher than 80 psi require a PRV on each service line. Criteria are established to account for distribution system and backflow prevention facility head loss in order to achieve a minimum service pressure of 40 psi.
- Maximum Day Demand plus Fire-Flow Condition: A minimum of 20 psi at the point of maximum fire draft.

The recommended water velocity criteria under maximum day demand conditions are as follows:

- Velocity ≤ 5 feet per second (fps) for pipes < 36 inches diameter
(Head loss, HL = 2 to 7 feet/1,000 feet).
- Velocity ≤ 6 fps for pipes ≥ 36 inches diameter
(Head loss, HL = 1 to 2.5 feet/1,000 feet).

Velocity criteria under peak hour demand conditions is as follows:

- Velocity ≤ 7 fps (HL < 10 feet/1,000 feet).

Velocity criteria under fire demand conditions is as follows:

- Velocity ≤ 10 fps.

Transmission mains should be placed and sized so that water can be supplied under peak hour demands, fire flow, and critical emergency conditions.

2.4.5 Storage Facilities

Water production facilities are usually designed to operate at a steady rate over an extended period of time, so storage reservoirs are planned to accommodate fluctuating demands. The factors included in designing reservoir capacity are diurnal demand fluctuations, fire demand, and emergency reserve storage. In some situations, it may be prudent to have additional storage volume to provide operational storage. Storage facilities should be designed and operated to meet these conditions, while achieving storage turnover to minimize water quality degradation.

2.4.5.1 Storage for Diurnal Demand Fluctuations

Storage capacity to meet diurnal demand fluctuation is determined as the volume of water required to meet the peak hour demands exceeding the maximum day demand rate (the difference between maximum day and peak hour). For storage volume planning, a conservative value of 20 percent of maximum day demand is typically used.

$$\text{Diurnal fluctuation} = 20 \text{ percent of maximum day demand}$$

2.4.5.2 Storage for Fire Demand

Fire flow duration for determining zone storage requirements is determined by the local fire department, but generally ranges from 4 to 10 hours for multiple fire occurrences within a pressure zone. Given these guidelines, required storage capacities can be calculated for different fire conditions. The variables in establishing fire storage volume include determining the type of fire and the number of multiple occurrences.

For planning purposes, population can be used to calculate the required fire storage for specific pressure zones. Fire demand rates and storage volumes are determined using criteria established by the American Insurance Association according to the following equation:

$$G = 1{,}020\ \sqrt{P}\left(1 - 0.01\sqrt{P}\right)$$

Where

G = fire demand rate, gpm

P = population in thousands

Table 2.6 summarizes these calculations.

Table 2.6 Required Fire Flow and Fire Reserve Storage
Lake Havasu City Water Master Plan Update

Pressure Zone Population	Fire Flow		Duration (hr)	Fire Reserve[1] Storage (MG)
	gpm	mgd		
1,000	1,000	1.4	4	0.3
2,000	1,500	2.2	6	0.6
4,000	2,000	2.9	8	1.0
10,000	3,000	4.3	10	1.8
17,000	4,000	5.8	10	2.4
28,000	5,000	7.2	10	3.0
40,000	6,000	8.6	10	3.6
56,000	7,000	10.0	10	4.2
80,000	8,000	11.5	10	4.8
96,000	9,000	13.0	10	5.4
125,000	10,000	14.4	10	6.0

Note: (1) American Insurance Association

Using these guidelines, fire storage can be determined for each pressure zone, and an assessment made regarding multiple fire capability within a pressure zone or service area.

2.4.5.3 Storage for Emergency Reserve

Emergency or reserve storage capacity is an additional volume of water that is held in the reservoir to meet various emergency conditions, such as a facility outage. The amount of emergency storage that a utility should plan for is largely based on professional judgment, and is influenced by a number of factors such as power outage history, line break frequency, and overall supply redundancy. A customary rule of thumb for emergency storage is 10 percent of maximum day demand. Emergency reserve storage is also available to provide reliability/redundancy to adjacent zones through booster stations or PRVs.

2.4.5.4 Operational Storage

Operational storage shall be provided to give the flexibility needed to operate the distribution system. The storage required at each site shall be considered on a case-by-case basis to satisfy the operational requirements of each site and pressure zone.

2.5 PERFORMANCE CRITERIA SUMMARY

Table 2.7 summarizes the recommended system performance criteria to be utilized to determine the adequacy of the water system, and planning for infrastructure improvements.

Table 2.7 Recommended Water System Performance Criteria Summary
Lake Havasu City Water Master Plan Update

Description	Criteria
Production	Maximum Day plus 10% Reserve
Storage Criteria:	
Equalizing	20% of Maximum Day Demand
Fire	Volume according to Table 2.6
Emergency	10% of Maximum Day Demand
Operational	Specific needs of each site and zone
Transmission/Distribution – Velocity/Head Loss (HL) Criteria:	
Maximum Day (MD)	
Pipe <36"	<5 feet per second (fps)
Pipe ≥36"	<6 fps
Peak Hour (PH)	≤7 fps (HL <10 feet/1,000 feet)
Fire Flow Condition	<10 fps, ≥20 psi
System Pressure Criteria	≥50 psi
Location Criteria	Transmission capability between booster stations in a zone
Booster Pump Station Criteria:	
Without Elevated Storage	Capacity equal to larger of peak hour or Maximum Day Demand plus fire; plus 10%
With Adequate Elevated Storage	Capacity equal to maximum day demand; plus 10%
Firm Capacity	Capacity with a single pump or the largest pump out of service
Pressure Zone Supplies	Zones with 3 or more booster stations supply average day demands with one station out of service
Booster Station	Minimum of 3 equally sized pumps. Back-up generator supplies sufficient power for firm capacity
Fire Demand Criteria:	
Fire demand requires a determination of both the rate of flow and the total amount of water that must be applied.	
Fire flow demand to be superimposed on the peak day demand (Insurance Services Office [ISO] requirements):	
1. Residential = 2 hours at 1,500 gpm	
2. Low risk commercial/industrial = 4 hours at 3,500 gpm	

HYDRAULIC MODEL DEVELOPMENT

3.1 MODEL DEVELOPMENT

A hydraulic model of the City's water system was created for use on the master plan. This model is a fully detailed model that includes all the pipes in the City's GIS. A detailed demand allocation was undertaken for the model that used customer billing data for 2006 demands and land use plan demand estimates for future planning years. All pumps, reservoirs, and pressure reducing valves were also included in the model. The model contains scenarios that represent varying demand and operating conditions. The model was used in a steady state mode for all simulations completed as a part of this master plan. As a part of a separate Initial Distribution System Evaluation (IDSE), the model was enhanced to include extended period simulation (EPS) capabilities. The model is a deliverable to the City as part of this project. The model should be periodically updated so that it remains a viable tool to evaluate a wide variety of planning, design, operational, and water quality events to assist the City in operating the water system.

The following sections describe the model building process, model data, and model calibration.

3.1.1 GIS Data

The model was developed from GIS data provided to Carollo by the City at the start of the project and updated with GIS data received on December 11, 2006. This GIS data contained pipe diameters and locations. Elevation data in the model came from contour information that the City provided from the most recent aerial survey, as well as site drawings and as-built drawings. Figure 3.1 shows the Lake Havasu water infrastructure that was entered into the model. Appendix A has a larger and more detailed map of the existing water distribution system.

3.1.2 Pump Stations

The City provided pump station data from reports, manufacturers' pump curves, and site visits. Table 3.1 shows the pump design points from the pump curves that were entered into the model. This table also shows measured flows and pressures provided by the City. In a number of cases, the pumps do not operate at the design points. Explanatory notes are provided in the table where appropriate. Table 3.2 shows the pump on/off setpoints. The pumps are controlled based on the water level in the reservoirs that float on the zone that the pumps serve.

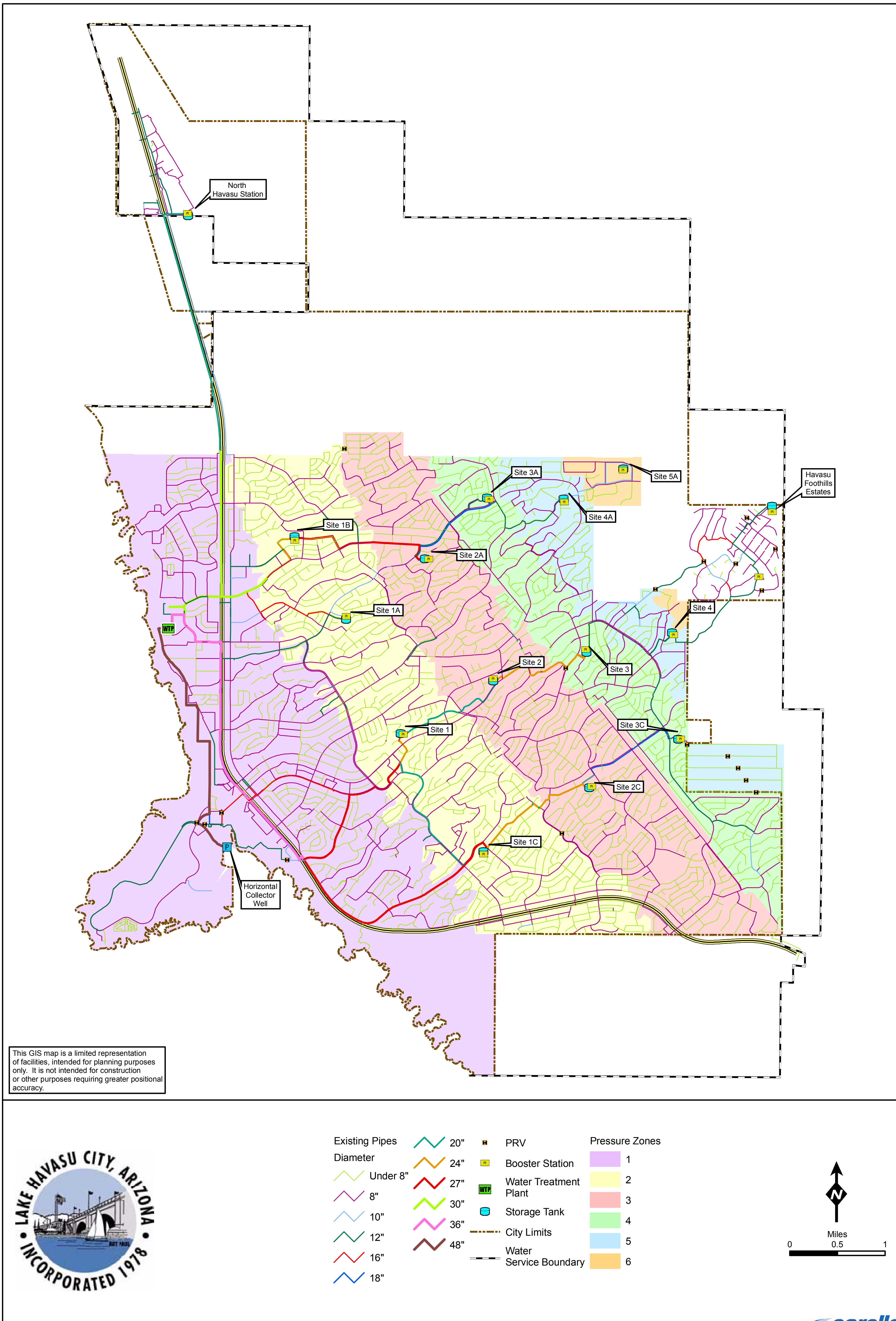


Figure 3.1

WATER DISTRIBUTION SYSTEM - 2006

Lake Havasu City Water Master Plan Update
Final - October 2007

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 3_1 Water Distribution System 2006.mxd

Table 3.1 Pump Station Information
Lake Havasu City Water Master Plan Update

Booster Site Name	Booster Pump Number	Zone Serviced	System	Type – Electric/ Gas	Pump Curve Design Flow (gpm)	Pump Curve Design Head (ft)	Meter Flow Rate (gpm)	Gauge Pressure (psi)	Comments
WTP High Service Pump Station (North Bank)	1	1	North	Electric	3,500 VFD	400	4,400	130	All WTP High Service pumps operate at the far right of the curves.
	2	1		Electric	3,500 VFD	400	4,400		
	3	1		Electric	3,500 VFD	400	4,400		
	4	1		Electric	3,500	400	4,400		
	5	1		Electric	3,500	400	4,400		
	6	1		Electric	3,500	400	4,400		
WTP High Service Pump Station (South Bank)	1	1	South	Electric	3,500 VFD	400	4,400	130	All WTP High Service pumps operate at the far right of the curves.
	2	1		Electric	3,500 VFD	400	4,400		
	3	1		Electric	3,500 VFD	400	4,400		
	4	1		Electric	3,500	400	4,400		
	5	1		Electric	3,500	400	4,400		
	6	1		Electric	3,500	400	4,400		
Station 1A	1	2	North	Gas engine	1,000	320	700	110	Gas engine probably runs at a lower speed.
Station 1B	1	2	North	Electric	2,600	272	3,000	120	Pumps operate to the right of the design point.
	2	2		Electric	2,600	272	3,000		Pumps operate to the right of the design point.
	3	2		Gas engine	1,000	348	750		Gas engine probably runs at a lower speed.
Station 1	1	2	Central	Electric	1,400	250	1,100	110	Pump design head is similar to gauge pressure head, so meter or pump curve is suspect. Pump control valves may be restrictive.
	2			Electric w/ gas engine backup	1,400	250	1,100		
	3			Electric	1,400	250	1,100		

Table 3.1 Pump Station Information
Lake Havasu City Water Master Plan Update

Booster Site Name	Booster Pump Number	Zone Serviced	System	Type – Electric/ Gas	Pump Curve Design Flow (gpm)	Pump Curve Design Head (ft)	Meter Flow Rate (gpm)	Gauge Pressure (psi)	Comments
Station 1C	1	2	South	Electric	2,750	300	2,800	110	Missing pump curve
	2			Electric	2,750	300	2,800		Missing pump curve
	3			Electric w/ gas engine backup	1,250	350	1,000		Engine speed may be lower than pump curve speed
North Havasu Pump Station	1	2	North	Jockey	170	250		130	
	2			Electric	1,500 VFD	305			
	3			Electric	1,500 VFD	305			
	4			Electric	2,000	305			
	5			Electric	2,000	305			
	6			Electric	2,000	305			
Station 2A	1	3	North	Electric	1,435	315	1,750	110	Pump operates out on the curve
	2			Electric	1,435	315	1,750		Pump operates out on the curve
	3			Gas engine	1,050	272	1,000		Pump operates out on the curve
Station 2	1	3	Central	Electric	1,200	265	1,400	105	Pumps operate to the right of the design point.
	2			Electric	1,200	265	1,400		Pumps operate to the right of the design point.
	3			Electric	1,590	260	1,400		Pumps operate to the right of the design point.
	4			Gas	740	240	700		Gas engine probably runs at a lower speed.
Station 2C	1	3	South	Electric	1,550	300	1,800	100	Pump operates out on the curve
	2			Electric	1,550	300	1,800		Pump operates out on the curve
	3			Gas engine	1,000	290	750		Gas engine probably runs at a lower speed
Station 3A	1	4	North	Electric	1,100	380	1,200	90	The gauge pressure at this site does not correlate with the head on pump curve. Possible causes may be throttled discharge valves, or the pumps may have 4 stages instead of 7.
	2			Electric	1,100	380	1,200		
	3			Electric	1,100	380	1,200		

Table 3.1 Pump Station Information
Lake Havasu City Water Master Plan Update

Booster Site Name	Booster Pump Number	Zone Serviced	System	Type – Electric/ Gas	Pump Curve Design Flow (gpm)	Pump Curve Design Head (ft)	Meter Flow Rate (gpm)	Gauge Pressure (psi)	Comments
Station 3	1	4	Central	Electric	1,400	256	1,400	110	This pump operates at the far right of the curve.
	2			Electric w/ gas engine backup	1,000	354	1,400		
Station 3C	1	Horizon Six	South	Electric	290	307		120-140	
	2			Electric	290	307			
Station 4A	1	5	North	Electric	650	210	650	90	
	2			Electric	650	210	650		
	3			Gas	500	202	500		
Station 4	1	5	Central	Electric w/ gas engine backup	350	304	350-500	120-140	
	2			Electric	350	324	350-500		
Station 5A	1	6	North	Electric w/ gas engine backup	440	204	300-500	86-96	
	2			Electric w/ gas engine backup	440	204	300-500		

Note: VFD = Variable Speed Drive

Table 3.2 shows the pump controls, where known, for the pump stations.

Table 3.2 Pump Station Control Data
Lake Havasu City Water Master Plan Update

Booster Site Name	Zone Serviced	High Alarm	Start Lead	Start Lag	Start Lag Lag	Stop Lag Lag	Stop Lag	Stop Lead	Low Alarm
Station 1	2	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 2	3	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 3	4	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 4	5	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 1A	2	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	9
Station 1B	2	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 2A	3	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 3A	4	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 4A	5	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 5A	6	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
WTP High Service Pump Station (North Bank)	2	205 psi							100 psi
WTP High Service Pump Station (South Bank)	2	230 psi							100 psi
Station 1C	2	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 2C	3	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
Station 3C	4	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	13
North Havasu Station	2	21 ft	18 ft	17 ft	16.5 ft	17.5 ft	18.5 ft	19.5 ft	9

3.1.3 Reservoirs

Table 3.3 lists the reservoir size and elevation for reservoirs in the distribution system.

Table 3.3 Water Reservoir Information
Lake Havasu City Water Master Plan Update

Facility Name	Address	Service Zone[1]	Service Area	No. of Tanks	Height[2] (ft)	Capacity (MG)	Base Elevation (ft)
WTP Clearwell North	1525 Copper Lane	1	North	1	24	1.3	460
WTP Clearwell South	1525 Copper Lane	1	South	1	24	1.3	460
Station 1A	2430 Alpine Lane	1	North	1	24	1	770
Station 1B	2300 Anancapa Place	1	North	2	24	2	770
Station 1	2503 Mariner Lane	1	Central	2	24	1.25	770
Station 1C	701 Scout Drive	1	South	2	24	2	770
North Havasu Station	5000 North Hwy 95	2	North	1	24	2	733
Station 2A	2938 Havasupai Blvd	2	North	2	24	2	996
Station 2	3099 McCulloch Blvd	2	Central	2	24	1.25	996
Station 2C	3636 Silver Arrow Drive	2	South	2	24	2	996
Station 3A	3381 Oasis Drive	3	North	2	24	1.25	1,203
Station 3	3641 Swordfish Drive	3	Central	2	24	0.75	1,203
Station 3C[3]	3946 Chickasaw Drive	3	South	2	24	2	1,203
Station 4A	3764 Yucca Drive	4	North	2	24	1.25	1,379
Station 4[4]	336 Pacific Drive	4	Central	2	24	1.25	1,381
Station 5A[5]	4166 Colt Drive	5	North	1	24	0.5	1,555
Havasu Foothills Estates		7	Central	2	24	0.75	1,812

Notes: (1) Defined as the pressure zone where the reservoir floats; however, the WTP Clearwell also serves Zone 1.
(2) Overflow level for all reservoirs vary between 22 and 22.5 feet.
(3) Two 5,000 gallon hydro-pneumatic tanks service Horizon Six.
(4) One 5,000 gallon hydro-pneumatic tank services Zone 6.
(5) One 5,000 gallon hydro-pneumatic tank services Zone 6A.

Table 3.4 lists the water level ranges for reservoirs with altitude valves. The altitude valves open in an attempt to maintain water levels within this range.

Table 3.4 Altitude Valve Information
Lake Havasu City Water Master Plan Update

No.	Location	Lower Range, ft	Upper Range, ft
1	Station 1	15.5	17.5
2	Station 1A	16.5	17.5
3	North Havasu Station	14.5	15.5

3.1.4 Pressure Regulating Valves

The Lake Havasu water system has several pressure reducing valves that have been added to improve pressures in selected areas. Table 3.5 lists these valves.

Table 3.5 Pressure Regulating Valve Information
Lake Havasu City Water Master Plan Update

No.	Description / Address	PRV Size(s)	Main Connected To	Zone	
				Upstream	Downstream
1	Well 2 and Old Station "A"	8"	12"	1	1
2	North Front Corner of the Isleside Condos	4"	12"	1	1
3	2791 Anita Avenue (at Alibi Drive)	6"	6"	3	2
4	Rolling Hills and Thunderbolt Drives	4"	4"	3	2
5	Near Booster "C"	10" & 6"	12"	1	1
6	900 Lakeside Drive	6"	6"	4	West Horizon Six
7	4027 Lake View Road	6"	6"	East Horizon Six	West Horizon Six
8	4035 Gold Springs Road	6"	6"	East Horizon Six	West Horizon Six
9	4041 Blue Canyon Road	6"	6"	East Horizon Six	West Horizon Six
10	4049 Little Finger Road	6"	6"	East Horizon Six	West Horizon Six

3.2 FIELD TEST

Several field tests were undertaken to measure pressures throughout the distribution system, along with SCADA data to compare actual field measurements with the model to determine if the model corresponds well with field measurements. The purpose of field testing is to obtain a thorough understanding of the water system and its operation so that the model can be configured to provide a reasonable representation of water system operation.

3.2.1 Field Test Plan

Six separate field tests were identified to collect pressures throughout the City in June and July 2006. The City purchased eight Dixon pressure transducers, and Carollo provided five additional pressure transducers that were used in the test, so each test could have up to 13 pressure recordings, if needed.

The field test data was supplemented with SCADA data consisting of reservoir levels, pump station flows, and pump station pressures. Each test lasted approximately one week, and the pressure loggers for a test were dispersed throughout a zone, and along the borders in adjacent zones in an attempt to detect any open boundary between zones. Figure 3.2 is a map of the City water system showing pressure monitoring locations and locations where SCADA data was collected.

3.2.2 Field Test Results

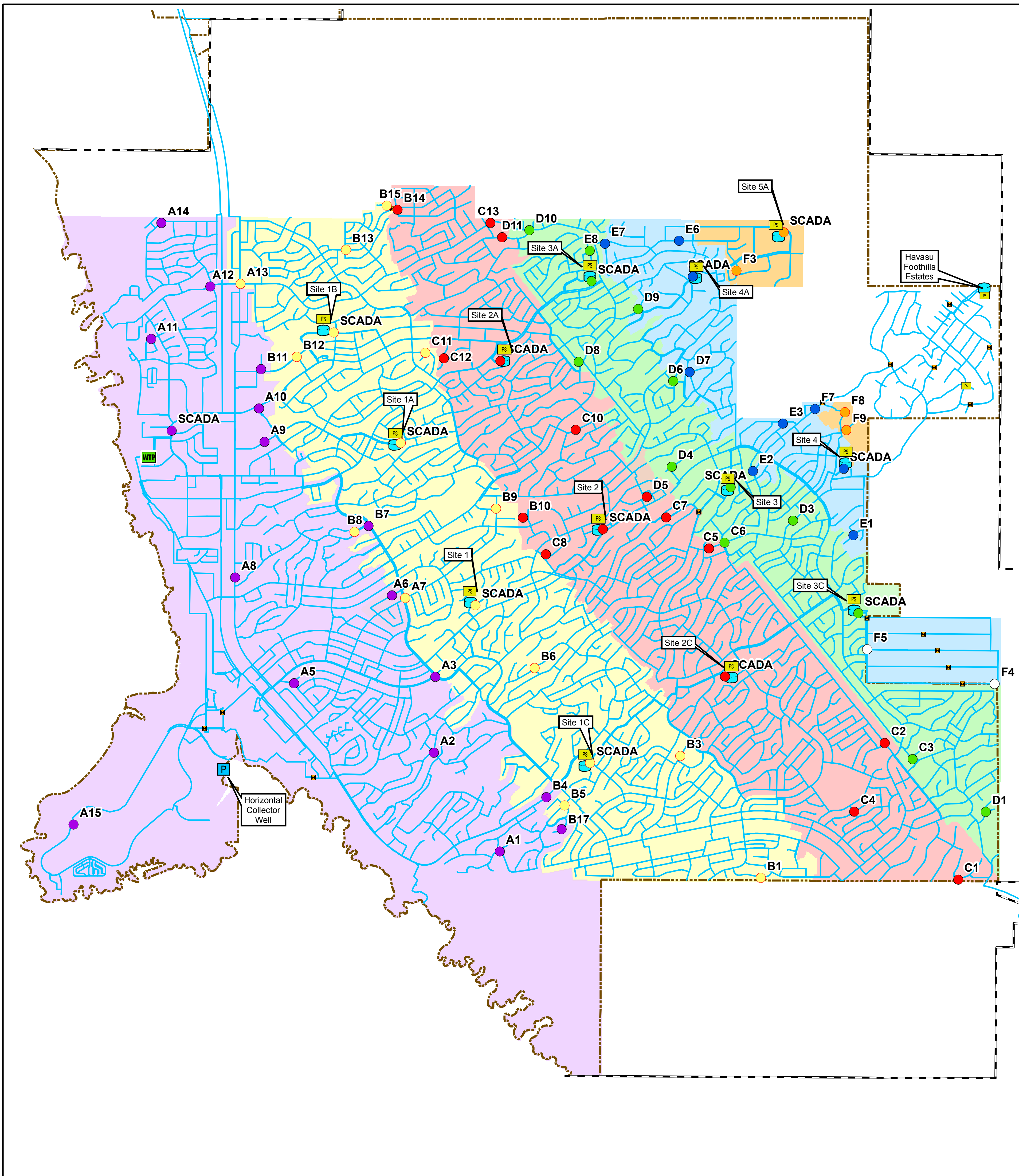
Once collected, the field test data was reviewed to evaluate data quality and to identify anomalies in the distribution system operation. The figures in this section show the field data, organized with the data for each zone on one graph. In general, the data shows significant pressure drops during peak demand times.

Figure 3.3 shows the field test data for Zone 1. At times, the hydraulic grade lines are above the reservoir, and this is caused by the pumps at the water treatment plant pumping water into the reservoirs, so the grade line near the pump stations needs to be higher than the reservoir level. During peak hours of the day, the grade line at locations far from the pump stations drops about 25 feet. An operational anomaly appears to be the cause of the extreme high and low readings at approximately hour 70 into the field tests. Figure 3.4 shows the field data for Zone 2. During peak hours of the day, the hydraulic grade line drops up to 45 feet below the reservoir level. Figure 3.5 shows the data for Zone 3. The hydraulic grade line drops up to 55 feet in this zone. Figure 3.6 shows the field data for Zone 4, where the grade line drops approximately 50 feet during peak hour demands. Figure 3.7 shows the field data for Zone 5, where the grade line drops as much as 90 feet during peak hour demands.

High pressure drops in the distribution system during peak demands is an indication of high head losses in the distribution system that are caused by small diameter pipes, high pipe internal wall roughness, closed valves, or connectivity problems. Due to the disparity in hydraulic grade lines in Zone 4, closed valves are suspected in that zone.

Figures 3.8 and 3.9 show the field test data for Zones 6, 6A and the Horizon Six subdivision.

Appendix B contains graphs of the new field data and model calibration results. The model was calibrated to provide a good representation of Lake Havasu water system behavior.



This GIS map is a limited representation of facilities, intended for planning purposes only. It is not intended for construction or other purposes requiring greater positional accuracy.

Field Test Locations
- Zone 1
- Zone 2
- Zone 3
- Zone 4
- Zone 5
- Zone 6
- Horizon Six

- Pipes
- PRV
- Booster Station
- Water Treatment Plant
- Storage Tank
- City Limits
- Water Service Boundary

Pressure Zones
- 1
- 2
- 3
- 4
- 5
- 6

Miles
0 0.5 1

LAKE HAVASU CITY, ARIZONA • INCORPORATED 1978 •

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Figure 3.2

FIELD TEST LOCATIONS

Lake Havasu City Water Master Plan Update
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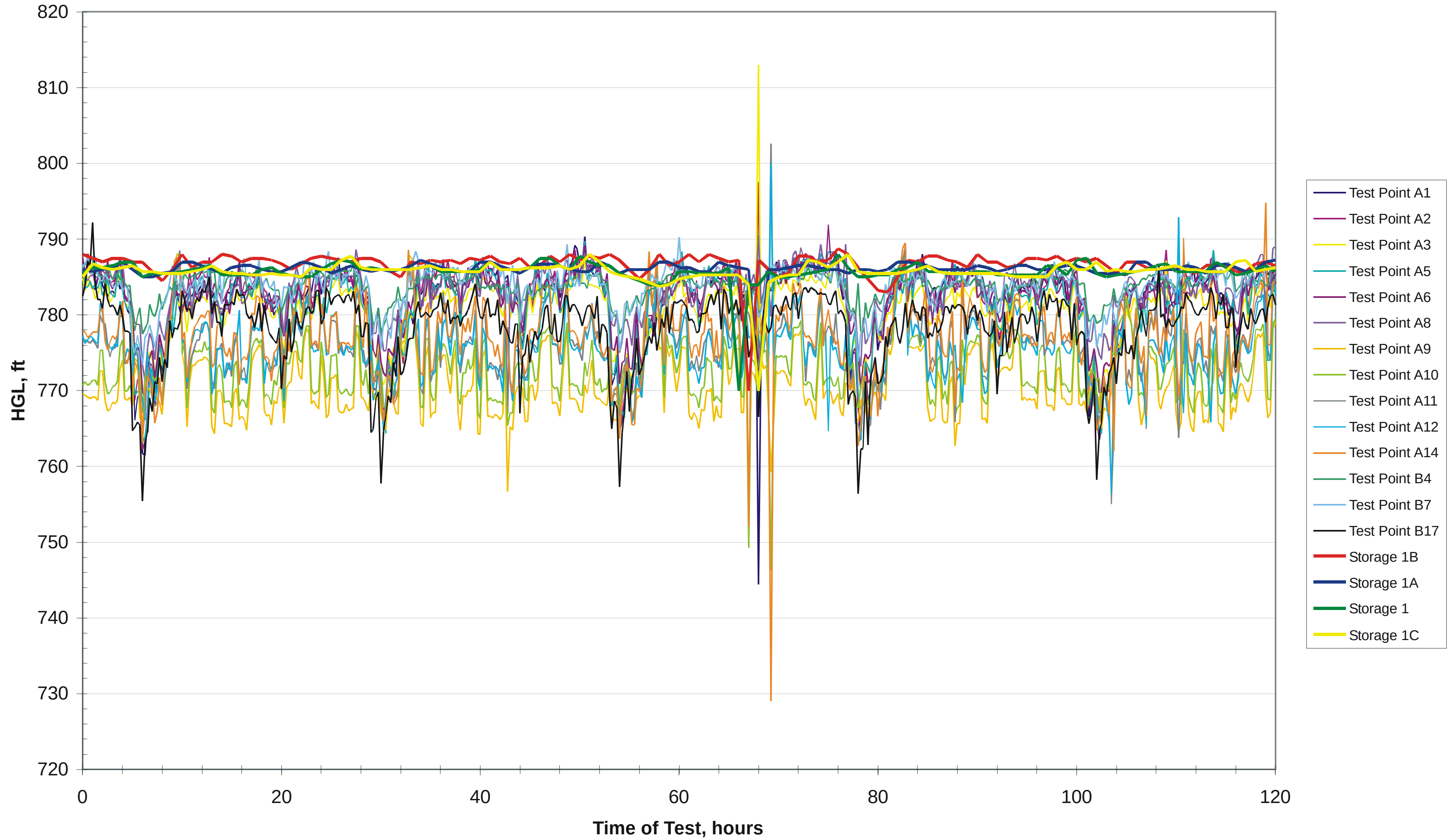

HYDRAULIC GRADELINE OF ZONE 1 - DISTRIBUTION SYSTEM POINTS AND STORAGE SITES

FIGURE 3.3

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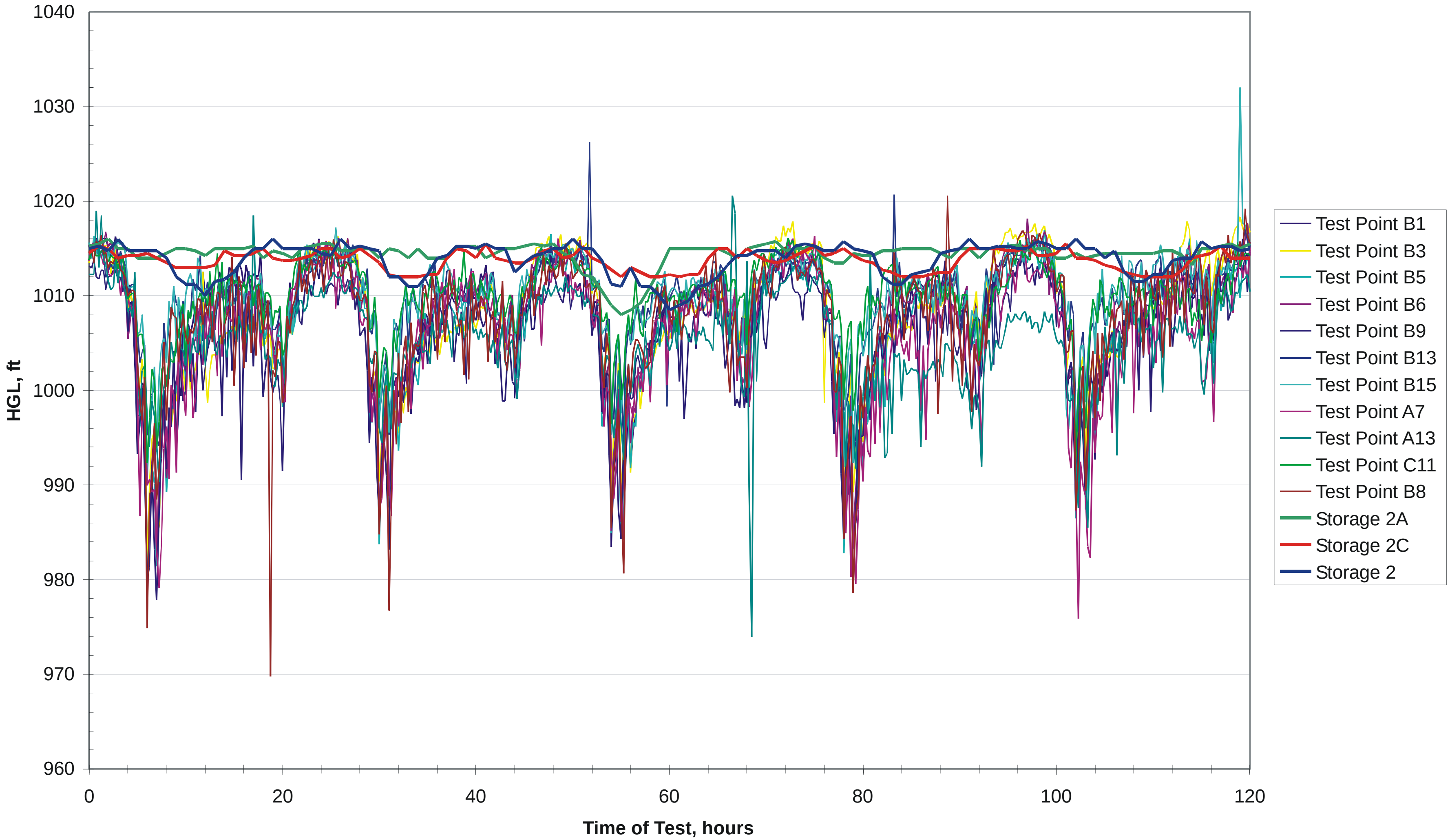

HYDRAULIC GRADELINE OF ZONE 2 - DISTRIBUTION SYSTEM POINTS AND STORAGE SITES

FIGURE 3.4

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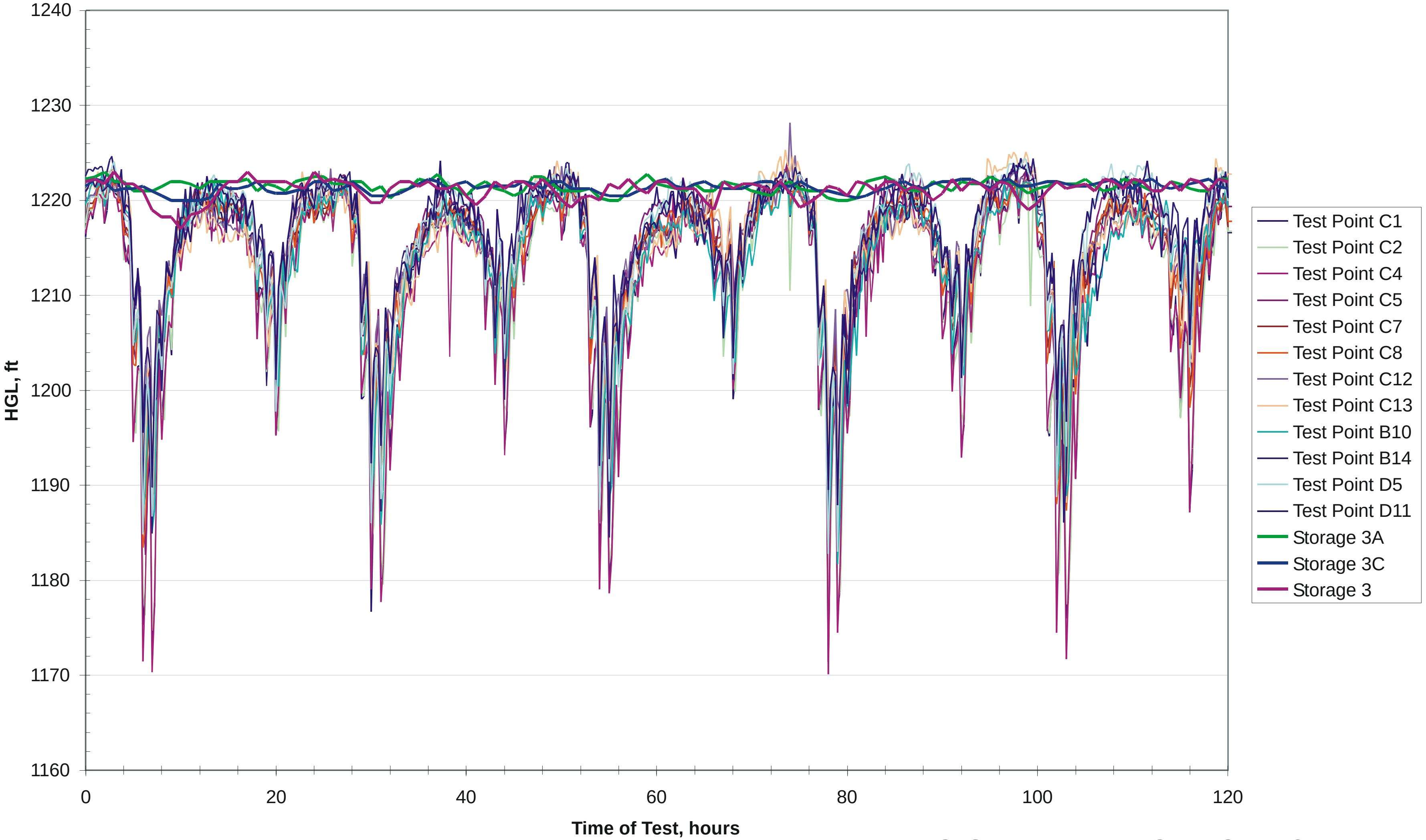

HYDRAULIC GRADELINE OF ZONE 3 - DISTRIBUTION SYSTEM POINTS AND STORAGE SITES

FIGURE 3.5

LAKE HAVASU CITY
WATER MASTER PLAN UPDATE

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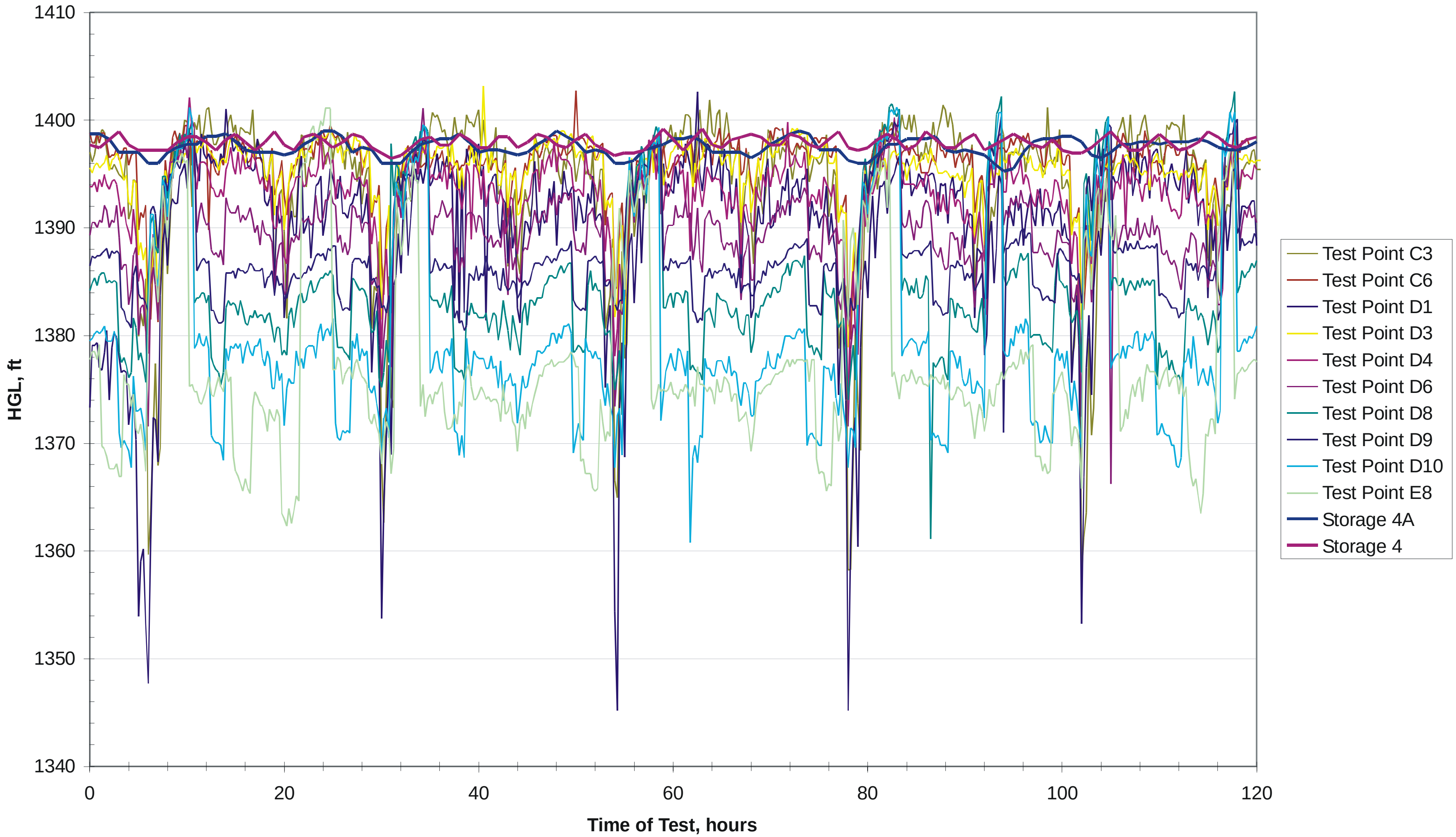

HYDRAULIC GRADELINE OF ZONE 4 -
DISTRIBUTION SYSTEM POINTS AND STORAGE SITES

FIGURE 3.6

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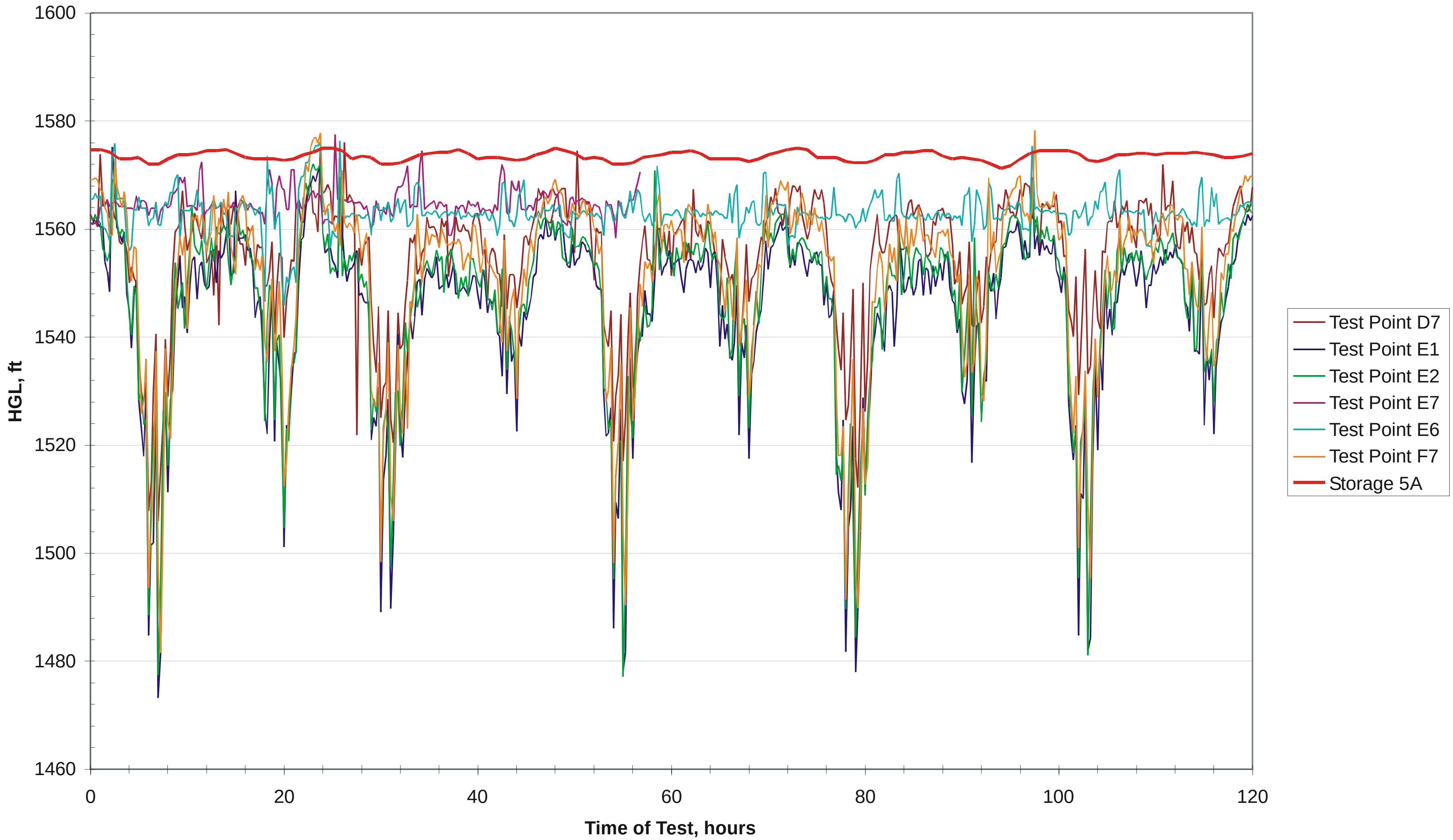

HYDRAULIC GRADELINE OF ZONE 5 - DISTRIBUTION SYSTEM POINTS AND STORAGE SITES

FIGURE 3.7

LAKE HAVASU CITY
WATER MASTER PLAN UPDATE

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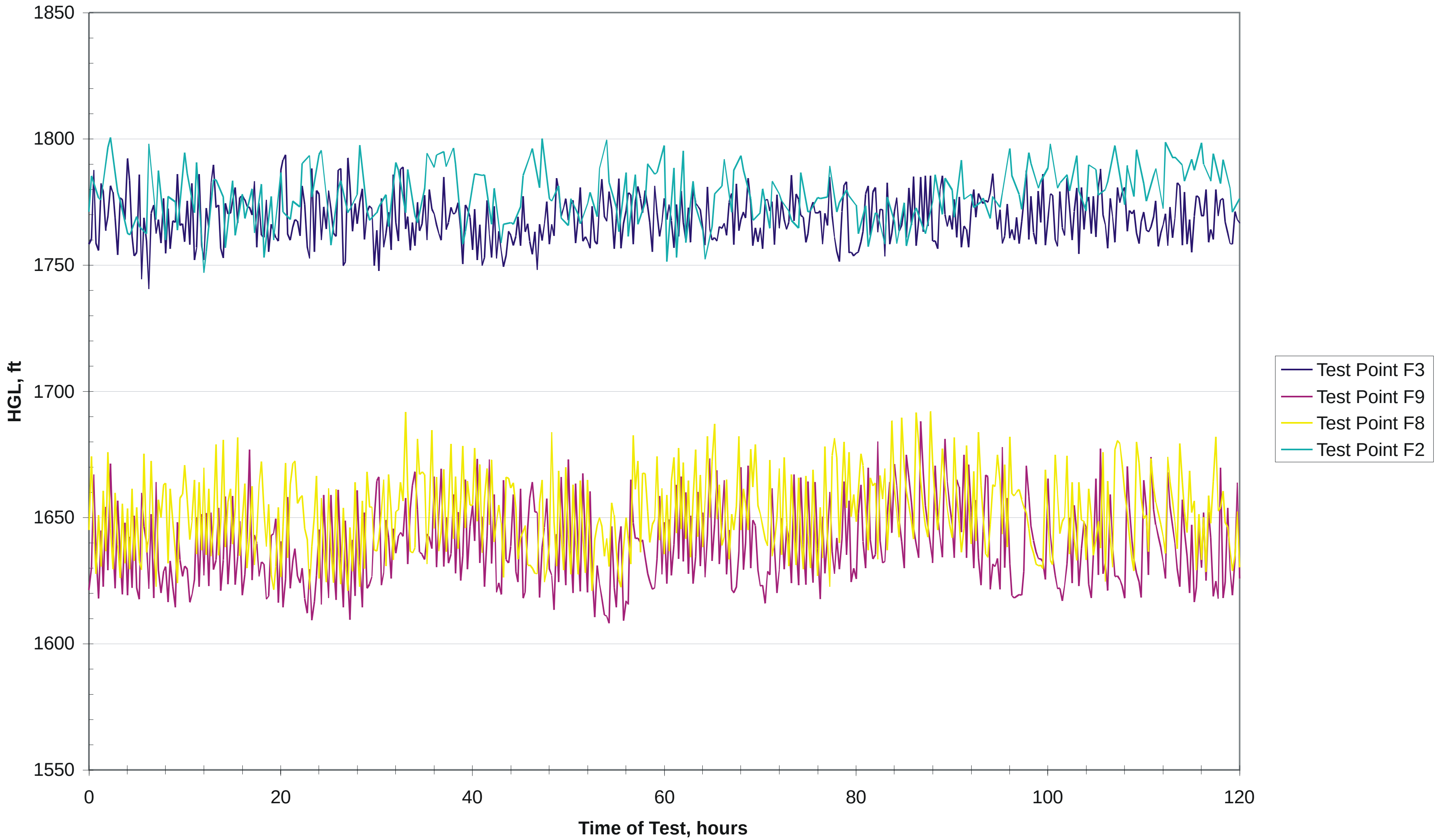

HYDRAULIC GRADELINE OF ZONES 6 AND 6A - DISTRIBUTION SYSTEM POINTS

FIGURE 3.8

LAKE HAVASU CITY
WATER MASTER PLAN UPDATE

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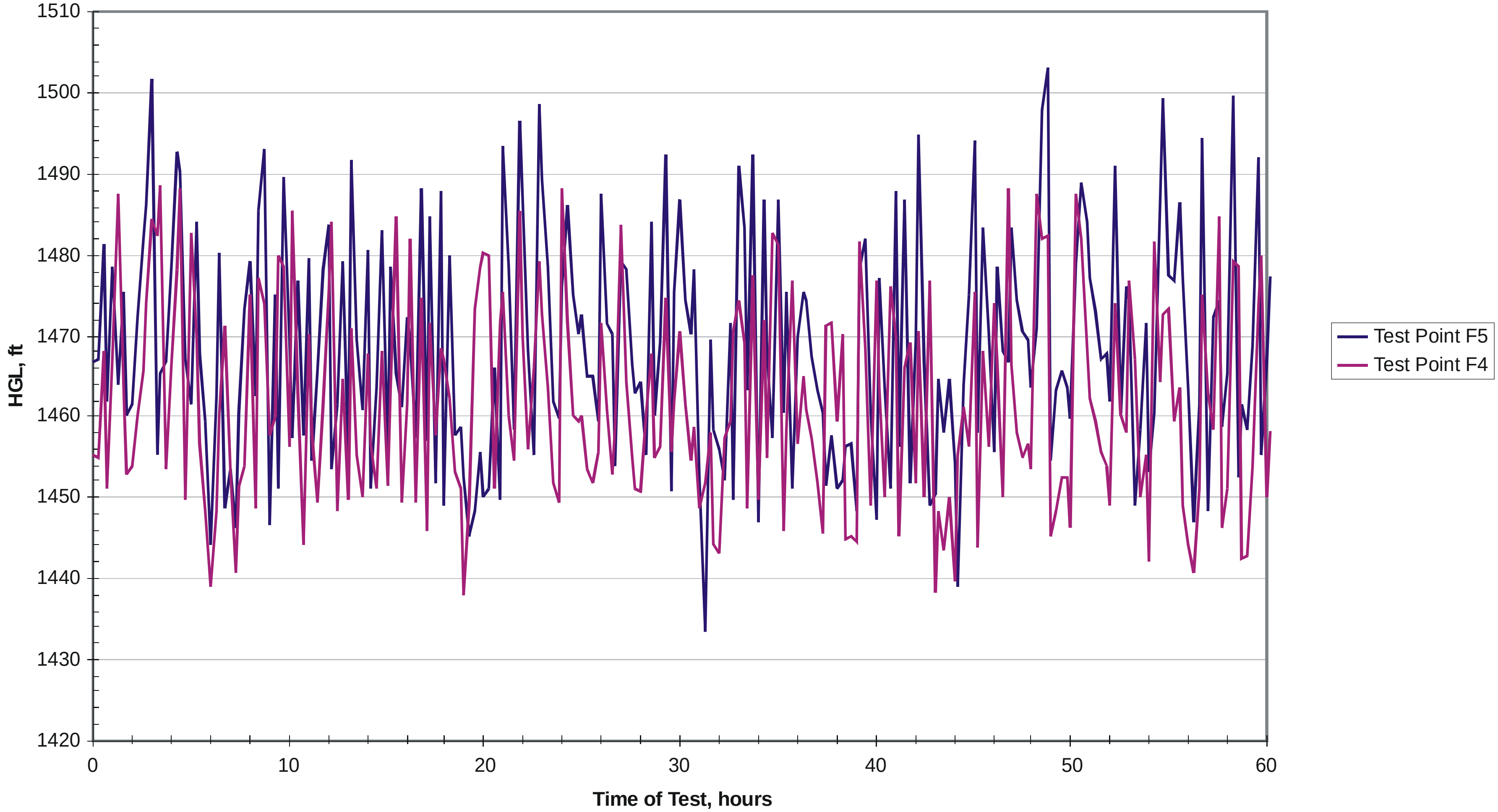

HYDRAULIC GRADELINE OF HORIZON SIX - DISTRIBUTION SYSTEM POINTS

FIGURE 3.9

LAKE HAVASU CITY
WATER MASTER PLAN UPDATE

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WATER SYSTEM EVALUATION

This chapter describes the results of the water system evaluations using the City's model. The purpose of these evaluations was to identify additions and improvements to the water distribution system. Additions are recommended to supply projected growth within the City. Improvements to the water infrastructure have been identified in areas that do not meet the City's performance criteria. Each of the following sections contains information on both the additions and improvements. The City's hydraulic model was used to identify deficiencies, and verify that the recommended infrastructure satisfies the performance criteria.

Figure 4.1 is a map of the City that shows the water distribution components that are recommended by buildout, and are described throughout this chapter. On this map, the mains that are highlighted are recommended to serve the current water system. The other proposed pipes show a conceptual layout of mains to serve future growth.

The actual infrastructure that would be constructed in undeveloped areas may be different from the layout in this master plan, depending on the timing and layout of specific developments. However, the infrastructure that is designed and constructed for each new development should fit within the overall framework laid out in this master plan. When each zone is fully developed, the infrastructure constructed in each development should be tied to other infrastructure in a zone where practical, and will work together with the rest of the infrastructure in the zone to provide an increased level of reliability.

4.1 WATER SUPPLY AND TREATMENT

Table 4.1 lists the raw water sources that are currently available to the City.

Table 4.1 Lake Havasu Raw Water Sources
Lake Havasu City Water Master Plan Update

Name	Design Flow (gpm)	Design Flow (mgd)
Horizontal Collector Well	17,322	24.9
Well 2	2,300	3.3
Well 9	3,000	4.3
Well 10	1,500	2.2
Well 11	700	1.0
Well 12	750	1.1
Well 13	1,200	1.7
Well 14	1,500	2.2
Well 15	1,400	2.0
Well 18	1,770	2.5
Total Water Supply without HWC, mgd		20.3
Total Water Supply with HWC, mgd		45.3

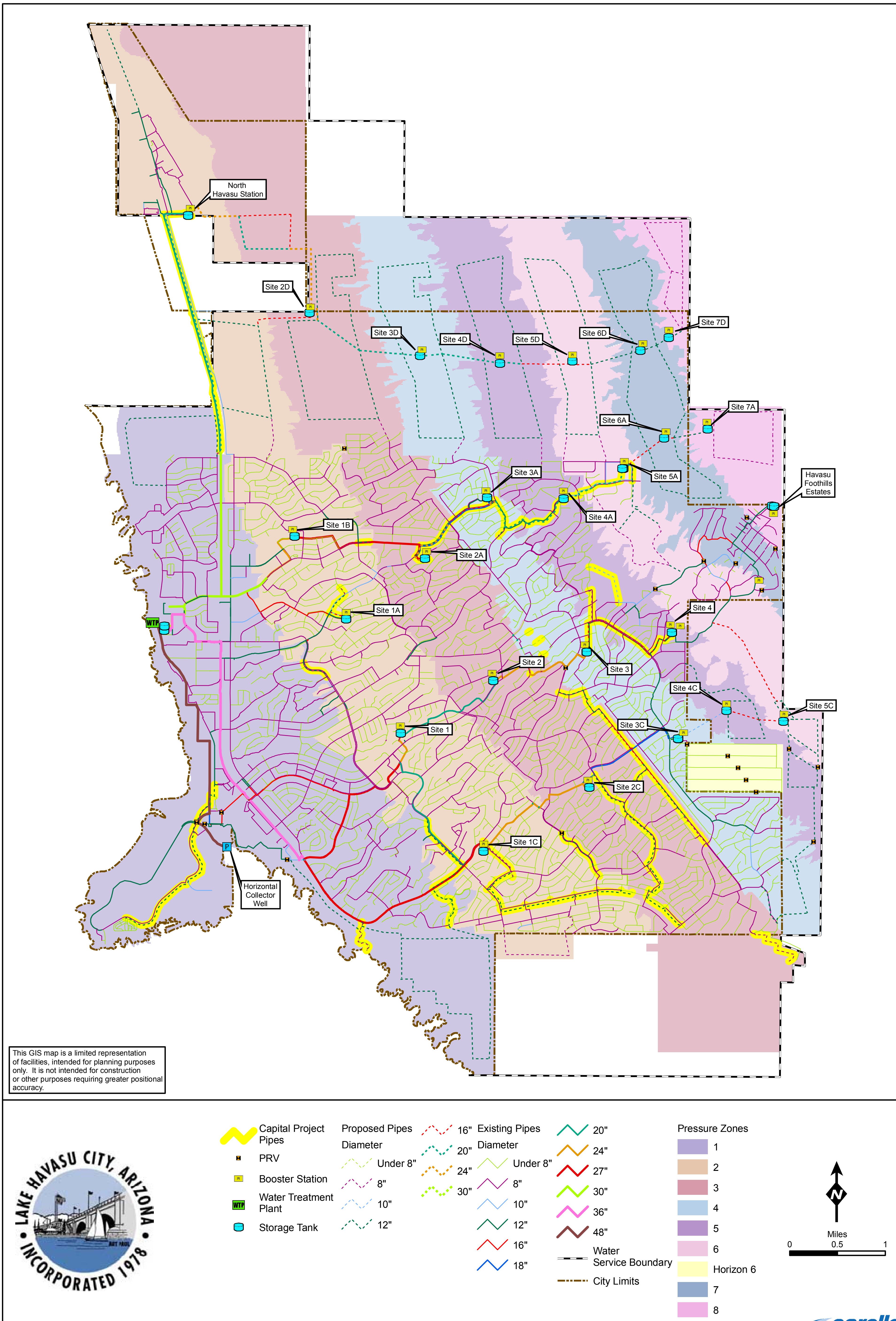


Figure 4.1

WATER DISTRIBUTION SYSTEM -
PROPOSED PIPE LAYOUT FOR BUILDOUT

Lake Havasu City Water Master Plan Update

Final - October 2007

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 4_1 Water Distribution System Buildout.mxd

The HCW is the primary source for the water treatment plant (WTP). The City's other wells have been rehabilitated, and are all connected to the 48-inch transmission main leading to the WTP. These wells are exercised and maintained regularly to keep them in operating condition, and to provide a backup water supply. All well water is treated to meet water quality standards. The total water supply in each planning period should be equal to or greater than the total demand.

The WTP can currently produce up to 26 mgd, and the next expansion is planned to provide 32 mgd. The average day demand in 2006 was about 14.1 mgd, and maximum day demands are approximately 22 mgd. More than 80 percent of the current plant capacity is therefore needed to supply maximum day demands, so the City should begin planning for the next expansion. An expansion of the WTP to 32 mgd within the next 5 years is recommended. The City should begin planning to obtain an additional capability beyond 32 mgd to treat water to supply demands that are identified in Table 3.2 for future planning period. The City needs a water treatment capability of at least 45 mgd at buildout to supply maximum day demands. This water treatment capability could be constructed at the existing plant as long as there is sufficient space for expansion. The pump station at the WTP and the transmission mains leaving the WTP are capable of supplying the maximum daily demand that is projected at buildout.

Alternatively, the City may choose to construct a separate WTP in another location that would treat the water from new wells that have not yet been drilled. If a second WTP was constructed, then a transmission system from the wells to the WTP, and from the WTP to the distribution system, would also be required. Possible locations for a second WTP may be adjacent to Port Drive, adjacent to the Mulberry Treatment Plant (Walnut Yard) or the Sweetwater Yard.

The WTP currently has two trains and is designed so that one-half of the plant can be shut down for maintenance. As the plant expands, additional treatment trains will be added. By buildout, the WTP should have sufficient capacity to deliver average daily demands to supply water for sanitation, health, and safety with one treatment train out of service. If the WTP is out of service under demand conditions greater than average day demands, then outside water use would need to be curtailed. The City may need to implement water usage restrictions to curtail outside water use.

The performance criteria that is being used by the City for this water master plan states that water needs to be supplied with the largest well or treatment plant component out of service under average demand conditions. Table 4.2 shows that all of the City's individual wells are barely sufficient to supply maximum daily demands at buildout. An additional well capacity of 8 mgd is recommended by buildout to provide a backup to the existing wells in the event that one or more wells are out of service during the peak demand months of the summer.

Table 4.2 Water Production Capacity Compared to Demands in Each Planning Period
Lake Havasu City Water Master Plan Update

	2006 Flows (mgd)		2007 Flows (mgd)		2008 Flows (mgd)		2009 Flows (mgd)		2010 Flows (mgd)		2015 Flows (mgd)		2020 Flows (mgd)		2025 Flows (mgd)		Buildout Flows (mgd)	
	Maximum Day Demand	Emergency Condition	Maximum Day Demand	Emergency Condition	Maximum Day Demand	Emergency Condition	Maximum Day Demand	Emergency Condition	Maximum Day Demand	Emergency Condition	Maximum Day Demand	Emergency Condition	Maximum Day Demand	Emergency Condition	Maximum Day Demand	Emergency Condition	Maximum Day Demand	Emergency Condition
Existing Wells	8.4	8.4	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
Horizontal Collector Well	24.9	0.0	24.9	0.0	24.9	0.0	24.9	0.0	24.9	0.0	24.9	0.0	24.9	0.0	24.9	0.0	24.9	0.0
New Wells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	8.0
Total	33.3	8.4	45.2	20.3	45.2	20.3	45.2	20.3	45.2	20.3	45.2	20.3	45.2	20.3	45.2	20.3	53.2	28.3
Demand	22.5	14.1	23.1	14.4	23.7	14.8	24.3	15.2	24.9	15.5	27.3	17.1	30.2	18.9	32.2	20.1	44.8	28.0
Surplus (+)/ Deficit (-)	10.8	**-5.7**	22.1	5.9	21.5	5.5	20.9	5.1	20.3	4.8	17.9	3.2	15.0	1.4	13.0	0.2	8.4	0.3

(1) Emergency Condition = Average Day Demand, Horizontal Collector Well unavailable
(2) Available wells in 2006 are assumed to be Wells 13, 14, 15, and 18
(3) Available wells in 2007 are assumed to be Wells 2, 9, 10, 11, 12, 13, 14, 15, and 18

4.1.1 Pressure Zones

Pressure zones in undeveloped areas have been established using similar elevation ranges as the existing distribution system. As the City develops, new infrastructure should be sized and interconnected so that when each zone is fully built out, the pump stations, reservoirs, and transmission system within the zones work efficiently together. This will provide optimal operation and reliability in the event that one pump station or reservoir is out of service.

The undeveloped land areas in the northern and eastern part of the City's planning area should have pressure zones with the same elevation ranges as the developed areas of the City. Constructing the northern areas to have the same pressure zone elevation ranges will allow the City to have an additional level of reliability because adjacent pump stations and reservoirs in the same zone can provide backup water supplies.

Most of the existing pressure zones have a broad elevation range, so there will be a corresponding broad range of pressures in each zone. Table 4.3 shows the static pressure range of each zone including future development areas. The static pressure is the highest pressure that would occur at night when demands are minimal. As the table shows, some areas in Zones 1, 2, and 3 have areas where the elevation is too high to maintain a minimum pressure of 40 psi. In these situations, the only solution to the low pressures is to change the zone boundary. These high elevation areas include the area across Acoma Boulevard between Jamaica Boulevard to Industrial Avenue in Zone 1, the area east of Castaway Drive from Saratoga Avenue to Jamaica Boulevard in Zone 2, and the area east of Bermuda Avenue from Kiowa Boulevard South to McCulloch Boulevard in Zone 3. The far right column in Table 4.3 gives the highest recommended elevation in the zone that would still provide a static pressure of 45 psi. A static pressure of 45 psi was used to calculate this highest elevation so that there can be 5 psi of pressure loss in the pipes supplying the area, and the minimum pressure of 40 psi can still be delivered to the property. Due to the topography of Lake Havasu City, it is not practical to have elevation ranges close to 100 feet, which is typically the desired elevation range for water system pressure zones. Service line PRVs are required as a part of the City's current policy, and need to be used at all locations where the static pressure would exceed 80 psi. The pressure zones in undeveloped areas were established to conform to the elevation ranges in Table 4.3.

Table 4.3 Static Pressure Ranges in Lake Havasu Pressure Zones Lake Havasu City Water Master Plan Update						
Zone	**Reservoir Hydraulic Grade Line (ft)**	**Minimum Elevation (ft)**	**Maximum Elevation (ft)**	**Maximum Static Pressure (psi)**	**Minimum Static Pressure (psi)**	**Recommended Highest Elevation in the Zone (ft)**
1	786	458	730	142	24	682
2	1,016	621	930	171	37	912
3	1,222	855	1,142	159	35	1,118
4	1,396	1,036	1,290	156	46	1,292
5	1,575	1,227	1,467	151	47	1,471
6	1,770	1,400	1,620	160	65	1,620
7	1,935	1,620	1,820	136	50	1,820
8	N/A	1,820	2,040	N/A	N/A	2,040

Note:

1. Minimum and maximum elevations in the existing zones are actual elevation ranges.
2. Zone 8 is assumed to be served with hydrosystems, so a floating reservoir hydraulic grade line has not been established.

4.1.2 Pump Stations

Tables C.1 through C.5 (Appendix C) show the current pumping capacity of each booster station, compared with the water flow rates necessary to supply 2006 demand conditions. The performance criteria that is being used for this master plan states that each pump station should have at least three equally sized pumps. Two of the three pumps should be capable of supplying maximum day demands. When three or more pump stations serve a zone, the average day demand shall be met with one pump station out of service. These tables show the conditions under which this criteria cannot be met in 2006.

In the past, the City used gas engine pumps to supply water when the power company asked to have electric pumps turned off during peak electrical demand times. However, the power company appears to have a decreasing need to interrupt the supply to the City's pumps. Many of these gas engine pumps are not sized appropriately to supply the City's current water demands. As a result, the utility of the engine driven pumps has decreased significantly. By constructing booster pump stations that have a generator backup, electrical power supplies can still be interrupted, but the full pumping capability of the station is not diminished.

The projected growth areas in the north and east of the City's service area require booster stations to serve each zone. These new stations should adequately serve new development and add operational flexibility for circumstances when pump stations to the south are out of service for maintenance or emergency reasons. The pump stations and reservoirs should be set up using a similar strategy as the City's current pump stations, where each booster station takes water from a reservoir and then pumps up to the next higher zone. The land areas that would fall within the Zone 8 elevation range are expected to be served by hydrosystems.

When pump stations are expanded or rebuilt, the station firm capacity should be adequate to supply demands when the service area is fully built out. Therefore, the recommendations contained in this document are based on the required flows at buildout. Tables C.6 - C.12 (Appendix C) show the demands at buildout compared with the recommended pump station sizes for Zones 2 through 6. The pumping capacity at the treatment plant serving Zone 1 is more than sufficient to supply the water demands of the entire City at buildout, so a table was not prepared for Zone 1.

The North Havasu Booster Station currently has one set of pumps that serve the airport area, where the elevation range of the "airport zone" served by the pumps is higher than Zone 1. The second future set of pumps in this station were originally intended to serve a zone that had an elevation range that was not fully consistent with Zone 2. Now that elevation ranges have been defined for the undeveloped areas in Lake Havasu, the second set of pumps in this booster station should be sized to serve Zone 2.

4.1.3 Storage Reservoirs

Table 4.4 shows the water storage analysis based on estimated 2006 population and demands. The criteria for establishing the adequacy of storage is defined by the performance criteria used for this master plan. This table indicates that the existing water system does not have sufficient storage for diurnal, fire flow, and emergency storage requirements in some zones. There is an approximate 2.5 MG deficit across the system. Some sites have space for additional storage to remedy this deficit.

Table 4.5 shows the water storage analysis of the City at buildout. This table shows additional operational storage that would improve daily challenges encountered in operating pump stations to transfer water from one zone to the next higher zone. Due to space requirements, desired additional storage is not possible at all sites. Therefore, storage needs are met by using storage at sites in the distribution system where additional space is available.

Zones 2, 3, 4 and 5 collectively require 5.0 MG of additional storage to address existing deficiencies and to supply infill growth. In the undeveloped areas north and east of the City, up to 15.7 MG is required to serve projected growth.

Table 4.4 2006 Water System Storage Capacity Evaluation
Lake Havasu City Water Master Plan Update

Site(s) Assigned	2006 Storage Volume (MG)	2006 Estimated Population	Diurnal Storage Requirement (MG)	Emergency Reserve Requirement (MG)	Fire Reserve Storage (MG)	Total Storage Required (MG)	Surplus (+) or Deficit (-) (MG)	Space for More Storage?
1B	1.83	1,995	0.15	0.08	0.51	0.74	1.10	No
1A	0.92	797	0.06	0.03	0.24	0.33	0.59	Yes
1	1.15	5,059	0.38	0.19	1.35	1.92	-0.78	No
1C	1.83	2,335	0.18	0.09	0.74	1.00	0.83	Yes
2A	1.83	5,820	0.44	0.22	1.44	2.10	-0.27	Yes
2	1.15	5,718	0.43	0.22	1.43	2.08	-0.93	No
2C	1.83	5,453	0.41	0.21	1.40	2.02	-0.18	Yes
3A	1.15	3,801	0.29	0.14	0.94	1.37	-0.22	No
3	0.69	5,182	0.39	0.20	1.36	1.95	-1.26	Yes
3C	1.83	7,226	0.55	0.27	1.60	2.42	-0.59	Yes
4A	1.15	2,290	0.17	0.09	0.73	0.99	0.16	Yes
4	1.15	5,642	0.43	0.21	1.42	2.06	-0.92	Yes
5A	0.46	3,081	0.23	0.12	0.84	1.19	-0.74	Yes
North Havasu	1.83	N/A	0.32	0.16	0.63	1.11	0.72	N/A
Total	**18.80**	**54,399**	**4.43**	**2.23**	**14.63**	**21.28**	**-2.49**	

Note: The storage volume was calculated based on the assumption that only 22 feet of the reservoir height is available for storage.

Table 4.5 Buildout Water System Storage Capacity Evaluation (Population = 96,000)
Lake Havasu City Water Master Plan Update

Site(s) Assigned	2006 Storage Volume (MG)	Buildout Estimated Population	Diurnal Storage (MG)	Emergency Reserve (MG)	Fire Reserve Storage (MG)	Calculated Storage Required (MG)	Storage to be Added (MG)	Total Storage at Buildout (MG)	Purpose of Additional Storage
1B	1.83	6,235	0.27	0.13	1.49	1.89	0.00	1.83	N/A
1A	0.92	1,505	0.06	0.03	0.44	0.54	0.00	0.92	N/A
1	1.15	6,567	0.28	0.14	1.53	1.95	0.00	1.15	N/A
1C	1.83	4,462	0.19	0.10	1.27	1.55	0.00	1.83	N/A
North Havasu	1.83	N/A	0.32	0.16	0.63	1.11	0.00	1.83	N/A
2A	1.83	6,913	0.30	0.15	1.57	2.01	0.00	1.83	N/A
2	1.15	6,955	0.30	0.15	1.57	2.02	0.00	1.15	N/A
2C	1.83	7,732	0.33	0.17	1.65	2.15	1.00	2.83	To resolve storage deficiency
2D	0.00	1,821	0.08	0.04	0.49	0.61	2.00	2.00	To serve projected growth
3A	1.15	4,933	0.21	0.11	1.33	1.65	0.00	1.15	N/A
3	0.69	6,146	0.26	0.13	1.48	1.88	1.50	2.19	To resolve storage deficiency
3C	1.83	8,417	0.36	0.18	1.72	2.27	0.50	2.33	To resolve storage deficiency
3D	0.00	4,554	0.20	0.10	1.28	1.57	2.00	2.00	To serve projected growth
4A	1.15	2,875	0.12	0.06	0.82	1.00	0.00	1.15	N/A
4	1.15	8,251	0.36	0.18	1.71	2.24	1.00	2.15	To resolve storage deficiency
4C	0.00	1,183	0.05	0.03	0.40	0.47	0.50	0.50	To serve projected growth
4D	0.00	3,122	0.13	0.07	0.85	1.05	1.00	1.00	To serve projected growth
5A	0.46	4,030	0.17	0.09	1.20	1.46	1.00	1.46	To resolve storage deficiency
5C	0.00	671	0.03	0.01	0.24	0.28	0.50	0.50	To serve projected growth
5D	0.00	1,212	0.05	0.03	0.40	0.48	1.00	1.00	To serve projected growth
6D	0.00	922	0.04	0.02	0.24	0.30	0.50	0.50	To serve projected growth
6	0.00	1,725	0.07	0.04	0.48	0.59	1.00	1.00	To serve projected growth
6A	0.00	1,180	0.05	0.03	0.39	0.47	0.50	0.50	To serve projected growth
Foothills Estates	0.00	2,945	0.13	0.06	0.83	0.75	0.70	0.70	To serve projected growth
7A	0.00	274	0.01	0.01	0.24	0.26	0.50	0.50	To serve projected growth
7D	0.00	1,461	0.06	0.03	0.44	0.53	0.50	0.50	To serve projected growth
Total	**18.80**	**96,091**	**4.43**	**2.25**	**24.69**	**31.08**	**15.70**	**34.50**	

Notes: (1) "Calculated Storage Required" is the sum of the diurnal, emergency, and fire reserve storage requirements.
(2) "Total Storage at Buildout" is the sum of the "2006 Storage Volume" and the "Storage to be Added" columns. The "Total Storage at Buildout" sum should be greater than the "Calculated Storage Required" sum.
(3) The storage volume was calculated based on the assumption that only 22 feet of the reservoir height is available for storage.

4.1.4 Water Mains

4.1.4.1 <u>Mains for Projected Growth</u>

Figure 4.1 (page 4-2) shows a conceptual layout of the mains that have been planned to serve projected growth in currently undeveloped areas. These mains are intended to be the "backbone" of the distribution system in these areas. Smaller mains will need to be identified as specific developments are defined.

Water distribution mains that serve new developments should be sized so that two 12-inch mains run across the zone and are interconnected with pump stations and reservoirs that supply each zone. This is necessary to provide fire flows across the zone. A 1,000-gpm fire flow creates a pressure loss in a 12-inch main that is almost an order of magnitude less than the pressure loss in an 8-inch main. Therefore, the flows to a fire event need to travel primarily through 12-inch mains in order to deliver adequate pressure. For this reason, two 12-inch mains have been recommended across the new zones in many areas.

4.1.4.2 <u>Undersized Mains and Main Connections</u>

Existing transmission and water mains in the City may be undersized for one or more of the following reasons:

- Water velocities exceed 7 ft/s for pipes smaller than 36 inches under peak hour demand conditions.
- Head losses exceed 10 ft/1,000 ft for pipes smaller than 36 inches under peak hour demand conditions. High head losses are caused by high velocities and/or high friction losses.
- A transmission main capability does not exist to transport water across the zone if a booster station is out of service.

Figure 4.2 shows the location of pressures, which may occur in the existing distribution system, and are too low as a result of excessive head loss, mains that are too small, or elevations in the top of a zone that are too high. Low pressures occur at the upper end of Zones 1, 2 and 3. Appendix C contains a larger version of Figure 4.2.

Transmission mains can have more connections to the distribution system in order to improve distribution pressures. The connections need to be field verified at the locations listed in Table 4.6. If they do not exist currently, adding these connections will improve pressures.

Table 4.6 also lists the location, diameter, and lengths of additional mains that need to be added to the distribution system to improve pressures and to provide the ability to move water within a zone. The project numbers in Table 4.6 correspond to figures in Appendix C that show a detailed view of each project.

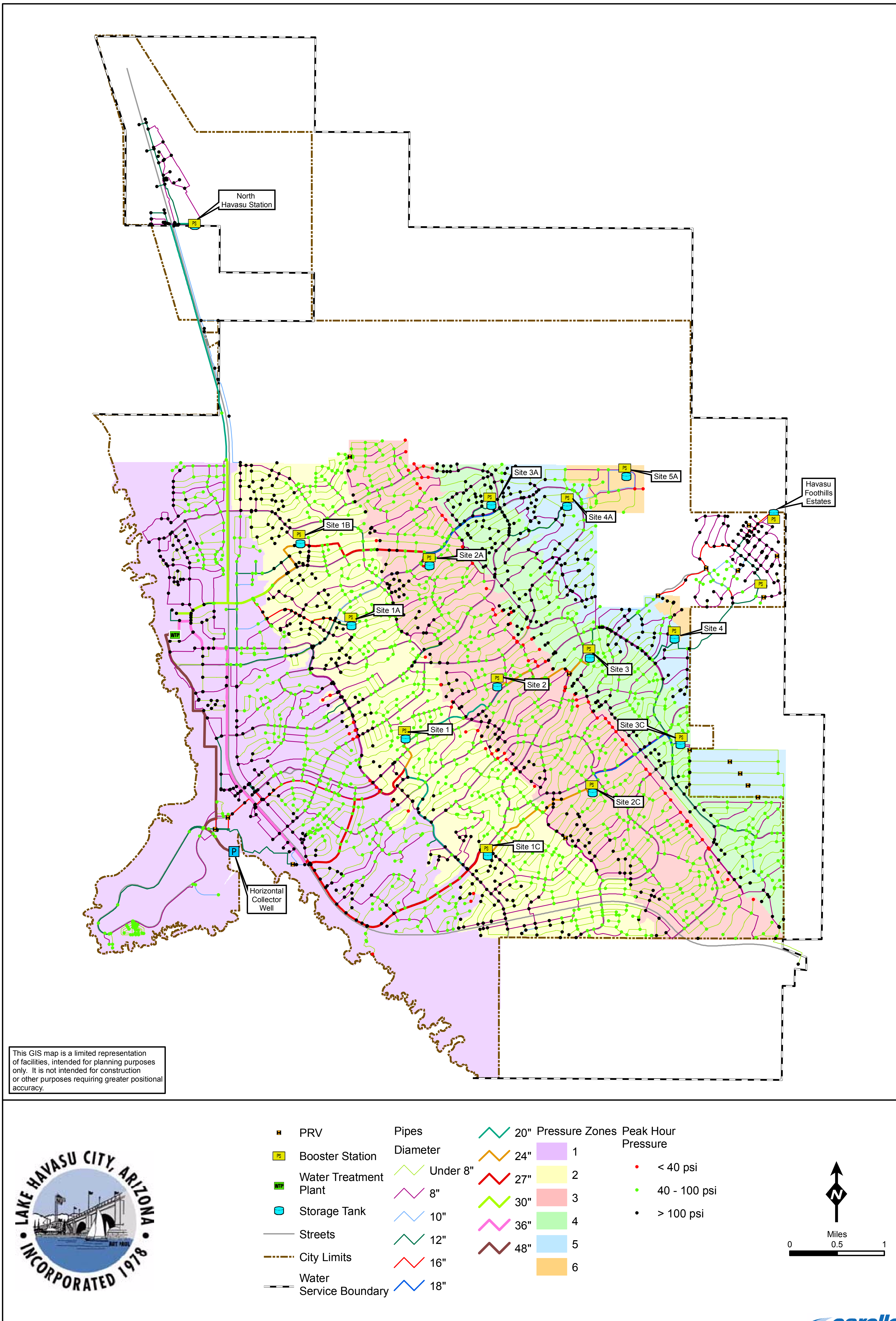


Figure 4.2

LAKE HAVASU CITY SYSTEM PRESSURES WITH 2006 PEAK HOUR DEMANDS

Lake Havasu City Water Master Plan Update

Final - October 2007

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 4_2 LHC System Pressures with 2006 Peak Hour Demands.mxd

Table 4.6 Water Distribution Mains Necessary to Strengthen Existing Pressure Zones
Lake Havasu City Water Master Plan Update

Project No.	Location	Description	Recommended Diameter	Approximated Length (ft)
1	Zone 1	Along AZ 95 from just east of Cabana Dr and Mandarin Dr to the Existing North Havasu Reservoir	20	15,528
2	Zone 1	Acoma Blvd N from Rainbow Ave N to Rainbow Ave S	12	1,712
3	Zone 1	Acoma Blvd S from Green Dr to Jamaica Blvd S	12	3,340
4	Zone 1	Jamaica Blvd S / Little Dr. / Viejo Dr.	12	5,226
5	Zone 1	McCulloch Blvd N / Beachcomber Blvd to Kickapoo Dr	12	8,666
6	Zone 1	Island Feed with PRV (4" set @ 95 psi)	12	2,730
7	Zone 1	South of AZ 95 / Jamaica Blvd S / Lake Havasu Ave S	8 12	2,390 15
8	Zones 1 and 2	Future secondary connection at Jamaica Blvd S and Acoma Blvd S	12	42
9	Zone 2	Site 1A Discharge to Zone 2 Improvements	8 12 16	493 1,436 866
10	Zone 2	Scout Dr / Southwind Ave / Acoma Blvd S / Alley 43 just north of AZ 95	8 12	2,919 11,863
11	Zone 2	Thunderbolt Ave from Rolling Hills Dr to Oro Grande Blvd	8 12	685 2,786
12	Zones 2 and 3	Reinforce existing connection at Kiowa Blvd and Avalon Ave	12	662
13	Zones 2 and 3	Reinforce existing connection at Jamaica Blvd S and Acoma Blvd S	12	88
14	Zone 3	Mohican Drive and Chesapeake Blvd Improvements	8 12 16	1,950 6,328 4,471
15	Zone 3	Oro Grande Blvd Improvements from Mohican Dr to Sweetwater Dr	12	1,259
16	Zone 3	Saratoga Ave / Oro Grande Blvd / Vaquero Dr / Lost Dutchman Dr / Kearsage Dr / Pecos Dr / Alley 44 just north of AZ 95	12	13,025

Table 4.6	Water Distribution Mains Necessary to Strengthen Existing Pressure Zones Lake Havasu City Water Master Plan Update			
Project No.	**Location**	**Description**	**Recommended Diameter**	**Approximated Length (ft)**
17	Zones 3 and 4	Reinforce existing connection at Chemehuevi Blvd and Mohican Dr	16	136
18	Zones 3 and 4	Future connection at Daytona Ave and Monte Carlo Ave	24	13
19	Zones 3 and 4	Transmission Main from Site 2A to 3A with a future connection at Desert View Dr and Kiowa Blvd N	12 16 24	2,977 32 3,824
20	Zones 3 and 4	Zone boundary change at Pioneer Dr, El Dorado Ave N and McCulloch Blvd N	6	751
21	Zone 4	Secondary Sara Park Feed	8	3,734
22	Zone 4	Site 3A Discharge and Improvements along Kiowa Blvd N / Palo Verde Blvd S to Sumac Dr	12 20 24	1,062 1,722 718
23	Zone 4	Transmission Main from Site 4A to Palo Verde Blvd S and Fiesta Dr	20	4,363
24	Zone 4	Transmission Main from Site 3 to Site 4 with a future connection at Swordfish Dr and McCulloch Blvd N	12 16	71 7,741
25	Zone 5	Transmission Main from Site 4A to Site 5A	20	4,431
26	Zone 5	From Geronimo Blvd and Hiawatha Dr south to McCulloch Blvd N, then east to the intersection with Mission Dr	8	3,085
27	Zone 6	Parallel Site 5A Discharge and Improvements	20 12	417 1,028
28	Zone 5	Zone 5 extension mains from Shlawassee Dr to Solar Dr	10	2,938

4.1.4.3 <u>Water System Improvements to Address Specific Deficiencies</u>

Carollo received feedback from the City on several areas where problems in the distribution system have been noted by the City in the past. Results of the evaluation to address these issues are provided below.

In an area south of Jamaica Boulevard and west of Acoma Boulevard, low pressures were observed in the Zone 1 distribution system. The major reason is that there are significant head losses in water mains at Little Drive and Jamaica Boulevard. Upsizing of these water mains can resolve the low pressures (see Table 4.7).

Table 4.7 summarizes the recommendations made to improve pressures.

Table 4.7 Recommendations for Existing Water System Deficiencies
Lake Havasu City Water Master Plan Update

Area	Problem	Reasons	Recommendations
Saratoga Avenue/Jamaica Boulevard (Zone 2)	Low Pressure	High elevations of the home sites	Move to Zone 3
Kiowa Boulevard South/El Dorado Avenue/McCulloch Boulevard (Zone 3)	Low Pressure	High elevations of the home sites	Modify Zone Boundary
South of Jamaica Boulevard and west of Acoma Boulevard	Low Pressure	Excessive head-losses through Zone 1 water-mains	Add new water mains parallel to existing water mains*
Mohican Drive	Low Pressure	Excessive head-losses through water-mains	Add new water mains parallel to existing water mains*
Zone 5 above McCulloch Boulevard	Single Feed	Reliability and redundancy deficiency	Add new water mains parallel to existing water mains*
Sara Park	Insufficient Fire Flow Supply and High Pressure	Park elevation is lower than Zone 4	Add new 8-inch Zone 3 Water Main
South of Jamaica Boulevard and west of Acoma Boulevard	High Pressure	Low elevations in Zone 2 area	Continue with City practice of requiring a service line PRV

Note:
* See Table 4.6 - Water Distribution Mains Necessary to Meet Performance Criteria

In the same area (south of Jamaica Boulevard and west of Acoma Boulevard), pressures higher than 120 psi were observed at the bottom of the Zone 2 distribution system. Modifying the zone boundary to include these homes in Zone 1 will drop the pressures in these homes to below 40 psi. Service line pressure reducing valves control the pressure to customers, so there are no infrastructure recommendations to resolve the high pressures.

The water pressure at 2972 Saratoga Avenue is too low. This house is located at a higher elevation in Zone 2. The elevations of these houses are around 900-920 feet. The reservoir elevation of Zone 2 is 1,020 feet. Therefore, the static pressure at this location cannot be greater than 43 psi. Under most demand conditions, pressures will be less than 40 psi. In addition, the water mains in the surrounding neighborhood are relatively small. Head losses through these water mains will drop the pressure further under higher demand conditions. We suggest paralleling these water mains to reduce the head losses (see Table 4.7.) Houses at Saratoga Avenue can be tied to Zone 2 water mains by opening and closing several valves.

There is a single feed that comes across the bottom of Zone No. 5 and crosses the El Dorado Wash. It feeds the area above McCulloch Boulevard and the area to the south. Parallel the existing 8-inch water main with another 8-inch water main will not only provide an additional feed across the bottleneck in the zone, but also reduce the excessive head-losses. Another connection from Hiawatha Drive to Comet Drive can be constructed in the future to provide additional looping as well.

A 4-inch line runs under Highway 95 to feed Sara Park. This water main is tied to Zone 4. It supplies the irrigation system along with bathrooms, concession areas, racetrack, gun range, etc. This park is at an elevation consistent with Zone 3. Also, the 4-inch line will not be sufficient to supply fire flow of 1,000 gpm in the case of fire. An 8-inch water main is to be added to supply water demands, including fire flow to Sara Park. This main is to be connected to Zone 3.

Figure 4.3 shows the pressures and main velocities under buildout peak hour conditions. This figure demonstrates that the zone boundary changes and improvements shown in Table 4.7 also address pressure deficiency issues. Appendix C contains a larger version of Figure 4.3.

4.1.4.4 Fire Flows

Figure 4.4 shows the fire hydrant locations that do not meet the City's fire flow criteria in 2006. Per the performance criteria, the fire flow analyses were performed using maximum day demands. Model node junctions that represent hydrants in residential areas were set to flow at 1,000 gpm. However, the fire flow requirement in Havasu Foothills Estates is set at 500 gpm with the stipulation that all homes in the development have sprinkler systems. Junctions in commercial areas were set to flow at 3,500 gpm. The model predicts the capability of the distribution system to deliver fire flows to the junction in the distribution system. Actual commercial fire flows would need to be delivered through more than one hydrant because a single hydrant cannot deliver 3,500 gpm under typical flow conditions. Most of the hydrants that failed are on cul-de-sacs where mains are small and looping does not exist. In these cases it is usually not practical to upsize mains to supply these fire flow demands. Figure 4.5 shows fire flow results at buildout with the improvements that have been recommended in this Master Plan. Appendix C contains a larger version of Figures 4.4 and 4.5.

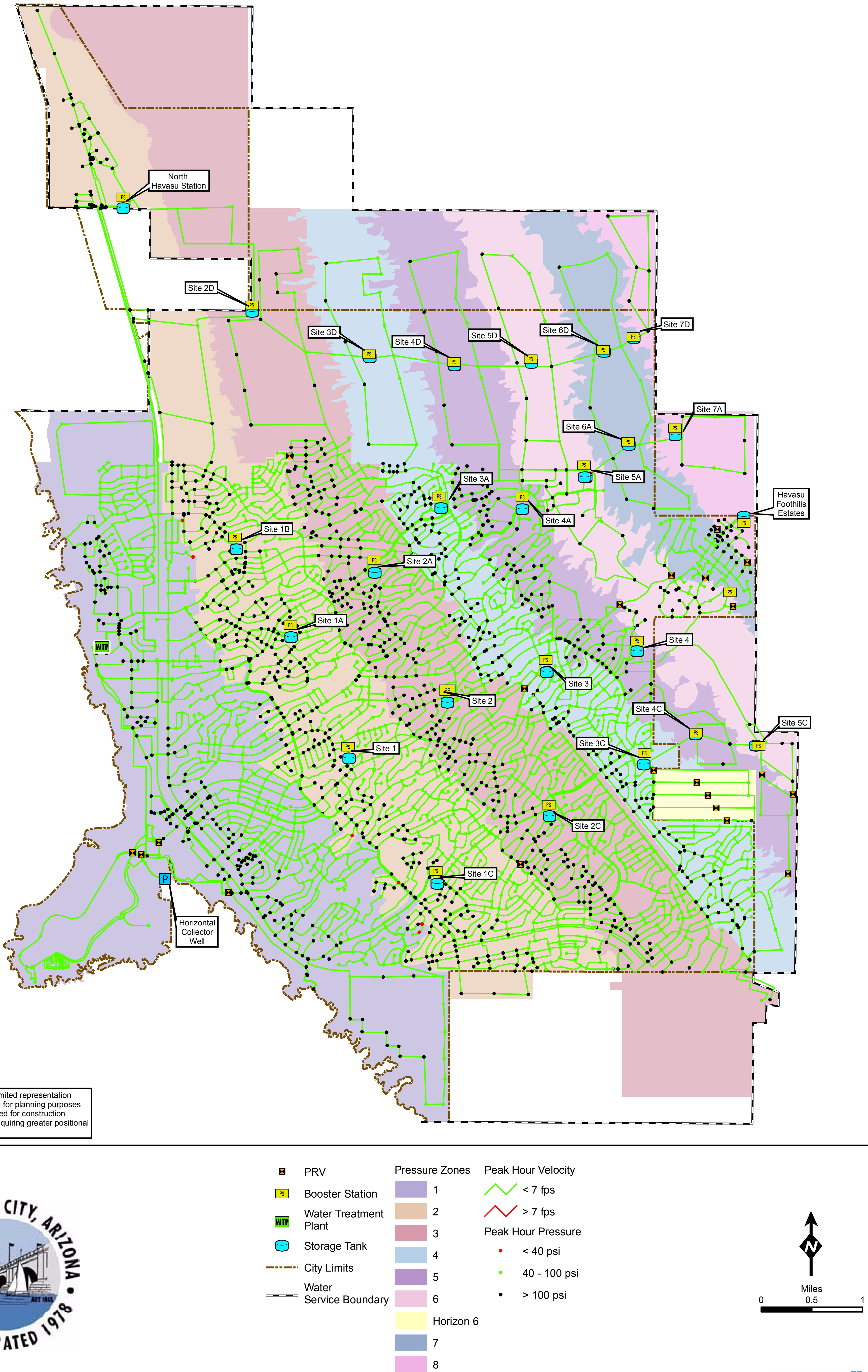


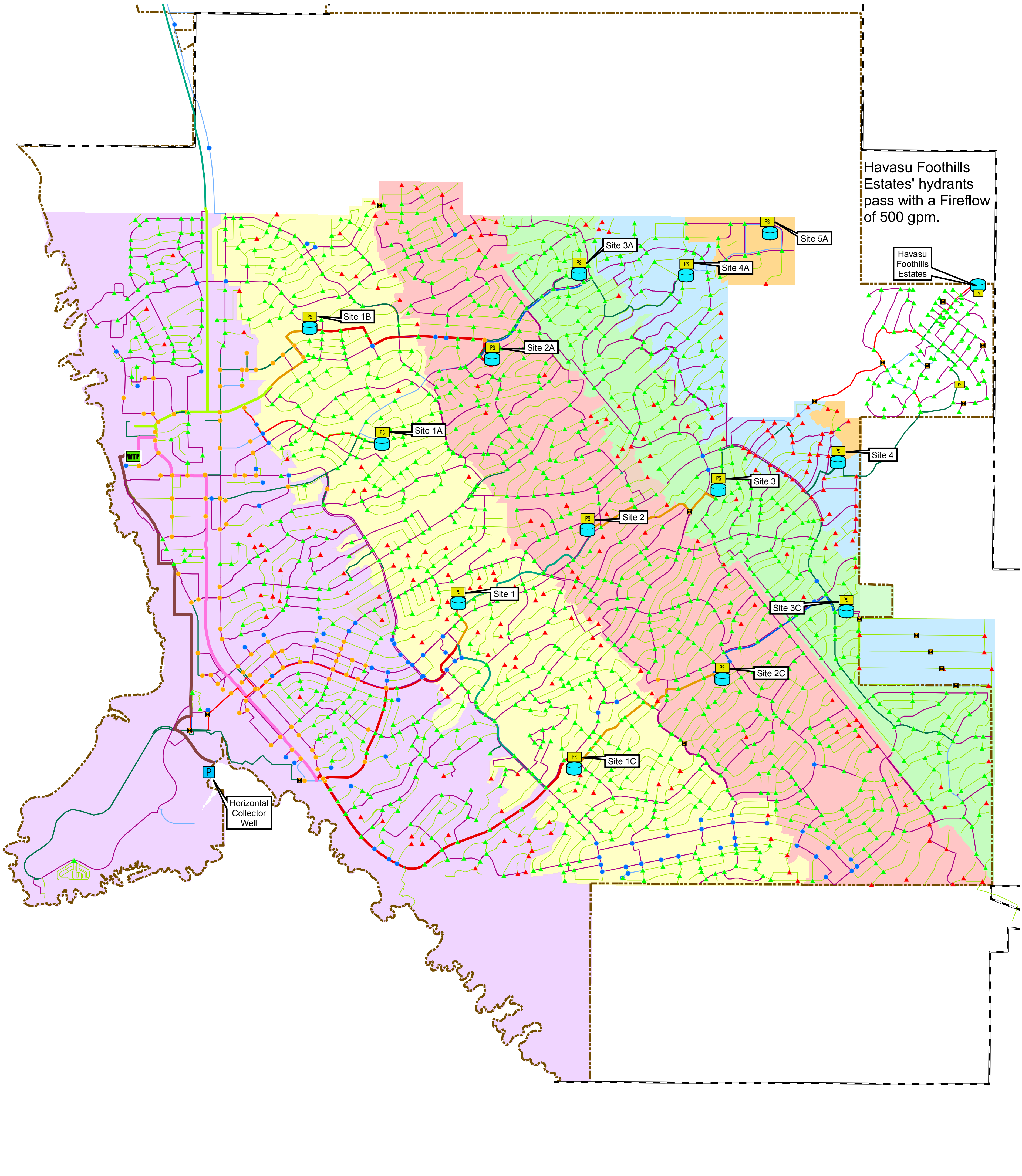
Figure 4.3

LAKE HAVASU CITY SYSTEM PRESSURES AT BUILDOUT PEAK HOUR DEMAND

Lake Havasu City Water Master Plan Update

Final - October 2007

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 4_3 LHC System Pressures with Buildout Peak Hour Demands.mxd



This GIS map is a limited representation of facilities, intended for planning purposes only. It is not intended for construction or other purposes requiring greater positional accuracy.

- PRV
- Booster Station
- Water Treatment Plant
- Storage Tank
- City Limits
- Water Service Boundary

Pressure Zones: 1, 2, 3, 4, 5, 6

Pipes Diameter: Under 8", 8", 10", 12", 16", 18", 20", 24", 27", 30", 36", 48"

Residential Fireflow Demands
- Cannot Supply 1000 gpm
- Can Supply 1000 gpm

Non - Residential Fireflow Demands
- Cannot Supply 3500 gpm
- Can Supply 3500 gpm

N

Miles: 0, 0.5, 1

Fireflow results are not calculated for every hydrant. These fireflow results indicate the capability of the distribution system to deliver fireflows to the locations indicated.

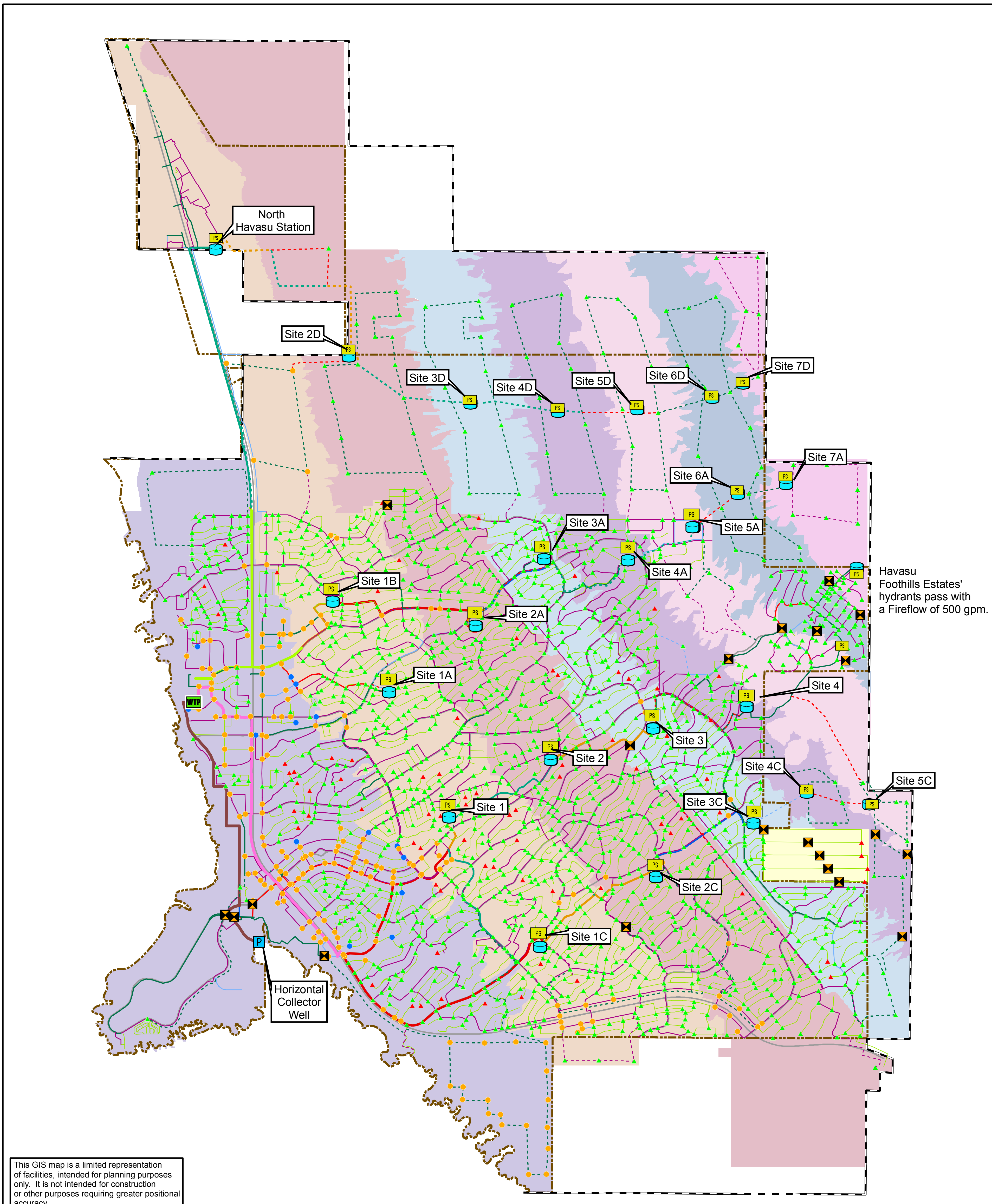
carollo

Figure 4.4

FIREFLOW RESULTS WITH RESIDENTIAL DEMANDS SET AT 1000 GPM, 2006 MAXIMUM DAY DEMANDS

Lake Havasu City Water Master Plan Update
Final - October 2007

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 4_4 FF Results with 2006 Maximum Day Demands.mxd



This GIS map is a limited representation of facilities, intended for planning purposes only. It is not intended for construction or other purposes requiring greater positional accuracy.

LAKE HAVASU CITY, ARIZONA • INCORPORATED 1978 •

- PRV
- Booster Station
- Water Treatment Plant
- Storage Tank
- Streets
- City Limits
- Water Service Boundary

Pressure Zones: 1, 2, 3, 4, 5, 6, Horizon 6, 7, 8

Existing Pipes Diameter: Under 8", 8", 10", 12", 16", 18", 20", 24", 27", 30", 36", 48"

Proposed Pipes Diameter: Under 8", 8", 10", 12", 16", 20", 24", 30"

Residential Fireflow Demands
- Cannot Supply 1000 gpm
- Can Supply 1000 gpm

Non - Residential Fireflow Demands
- Cannot Supply 3500 gpm
- Can Supply 3500 gpm

Miles: 0, 0.5, 1

Fireflow results are not calculated for every hydrant. These fireflow results indicate the capability of the distribution system to deliver fireflows to the locations indicated.

carollo

Figure 4.5

FIREFLOW RESULTS WITH RESIDENTIAL DEMANDS SET AT 1000 GPM, BUILDOUT MAXIMUM DAY DEMANDS

Lake Havasu City Water Master Plan Update

Final - October 2007

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Fig 4_5 FF Results with Buildout Maximum Day Demands.mxd

WATER MASTER PLAN DEVELOPMENT

5.1 OVERVIEW

The infrastructure recommendations that were identified in Chapter 4 are listed in this chapter along with opinions of cost for each of the capital improvements. The approximate timing of the capital improvements is also presented.

5.2 COST METHODOLOGY

5.2.1 Unit Costs

Table 5.1 shows the unit construction costs that have been estimated for this project. These costs were prepared in accordance with the guidelines of the AACE International, (the Association for the Advancement of Cost Engineering) for a Class 5 estimate. According to the definitions of AACE International, the Class 5 Estimate is defined as:

> "CLASS 5 ESTIMATE. Generally prepared based on very limited information, where little more than proposed plant type, its location, and the capacity are known. Strategic planning purposes, such as but not limited to, market studies, assessment of viability, evaluation of alternate schemes, project screening, location and evaluation of resource needs and budgeting, long-range capital planning, etc. Some examples of estimating methods used would be estimating methods such as cost/capacity curves and factors, scale-up factors, parametric and modeling techniques. Typically, very little time is expended in the development of this estimate. The typical expected accuracy range for this class estimate is –20 percent to –50 percent on the low side and +30 percent to +100 percent on the high side."

It is important to note that these unit costs are in 2007 dollars and must be escalated by the anticipated rate of inflation. The City should escalate costs in this report in the City's Capital Improvement Plan.

The unit construction cost for new water treatment capacity is based on the actual cost of water treatment plants that are being constructed in Arizona. The construction cost of these other plants varies between $2.25 and $3.83/gallon of treatment capacity. The actual water treatment costs that the City could incur depends on the treatment processes that are selected and the quality of the plant infrastructure. For planning purposes, a construction cost of $2.67 has been assumed, resulting in a project cost of $4/gallon.

Table 5.1 Estimated Unit Construction Costs for Capital Improvement Projects Lake Havasu City Water Master Plan Update		
	Measure	**Unit Cost**
Ductile Iron Pipe		
8" DIP	LF	$157
10" DIP	LF	$170
12" DIP	LF	$175
16" DIP	LF	$202
20" DIP	LF	$220
24" DIP	LF	$260
New Reservoir		
Aboveground Steel Reservoir	gallon of capacity	$1.00
New Booster Station (gpm)		
Capacity: 1,000	EA	$1,230,000
Capacity: 1,500	EA	$1,306,000
Capacity: 2,000	EA	$1,380,000
Capacity: 6,000	EA	$2,079,000
Capacity: 3,600	EA	$1,720,000
Capacity: 3,000	EA	$1,630,000
Capacity: 2,800	EA	$1,576,000
Well Sites		
Design Capacity: 800 gpm	EA	$963,000
Design Capacity: 1,300 gpm	EA	$1,214,000
Water Treatment		
Water Treatment	gallon of treatment capacity	$2.67
Notes: ENR CCI = 7856 (20 Cities Index, March, 2007) Costs are in 2007 dollars and must be escalated by the anticipated rate of inflation to be used in future years.		

Unit construction costs are multiplied by the factors listed below to obtain total project costs:

1. Engineering Design 10%
2. Inspection, City Project Management 10%
3. Contingency 30%

5.3 CAPITAL IMPROVEMENT PLAN

5.3.1 Capital Improvement Plan and Projects

The Capital Improvement Projects in Tables 5.2 and 5.3 are recommended to improve the ability of the Lake Havasu water system to deliver water, and to provide the capacity to serve the remaining undeveloped land within the City's water service areas. Projects have been phased in time according to the planning period that the capital improvements are anticipated. Table 5.2 lists the capital improvements that are recommended to replace worn pump stations, and to upgrade the water system to satisfy the performance criteria. These improvements are sized to serve any remaining new infill growth in the areas served by this infrastructure. This infrastructure is also sized to deliver water to new development to the east of the City. These projects have been phased so that the upgrades to existing facilities are completed by 2015, although projects can be accelerated if conditions at a pump station site require an earlier upgrade.

Table 5.3 lists those capital improvement items that are needed exclusively for projected growth. The timing of these capital improvements depends on the rate and location of new development that actually occurs within the City.

Table 5.4 summarizes project costs for the master planning period.

5.3.2 Timing of Projects

Capital improvements to strengthen the existing water system have generally been phased so that improvements to lower zones are constructed first. However, the City may decide to deviate from this strategy if the physical condition of a specific site requires major rehabilitation or replacement. This is the case with the current situation of Site 3 being rehabilitated prior to Site 1.

This type of project timing deviation does not affect the overall outcome of the improvements of the existing system compared to the City's buildout infrastructure. All of the improvements to the existing system are scheduled to be in place by 2020.

Table 5.2 Water System Capital Improvement Projects for the Existing System
Lake Havasu City Water Master Plan Update

Location	Project/Site Description	Existing Firm Capacity (gpm or MG)	Buildout Firm Capacity (gpm or MG)	Estimated Project Cost ($)	2007	2008	2009	2010	2015	2020
Existing Wells	Refurbish and Re-equip Existing Wells	N/A	20.3	$10,000,000						X
Site 1B	Replace Booster Station	3,000	6,000	$3,119,000			X			
Site 1A	Replace Booster Station	700	1,400	$2,085,000			X			
Site 1C	Replace Booster Station	2,800	5,600	$3,029,000		X				
Site 2A	Replace Booster Station	1,750	3,500	$2,557,000		X				
Site 2	Replace Booster Station	2,800	3,200	$2,490,000					X	
Site 2C	Replace Booster Station	1,800	3,600	$2,580,000					X	
Site 3A	Replace Booster Station	1,200	2,400	$2,310,000					X	
Site 3	Replace Booster Station	1,400	2,800	$2,400,000	X					
Site 3	Add Additional Storage	0.75	2.25	$750,000			X			
Site 4A	Replace Booster Station	1,150	2,400	$2,310,000					X	
Site 4	Add Additional Storage	1.25	2.25	$1,500,000			X			
Site 4	Replace Booster Station	500	1,000	$1,995,000				X		
Site 5A	Add Additional Storage	0.5	1.5	$1,500,000			X			
Site 5A	Replace Booster Station	500	2,000	$2,220,000				X		
Zone 1 Water Main Improvements	Main reinforcements in Table 4.6	N/A	N/A	$11,391,000			X			
Zone 2 Water Main Improvements	Main reinforcements in Table 4.6	N/A	N/A	$5,646,000				X		
Zone 3 Water Main Improvements	Main reinforcements in Table 4.6	N/A	N/A	$9,727,000				X		
Zone 4 Water Main Improvements	Main reinforcements in Table 4.6	N/A	N/A	$5,811,000					X	
Zone 5 Water Main Improvements	Main reinforcements in Table 4.6	N/A	N/A	$3,207,000					X	
Zone 6 Water Main Improvements	Main reinforcements in Table 4.6	N/A	N/A	$408,000						X
			Total	**$86,140,000**						

Notes:
ENR CCI = 7856 (20 Cities Index, March, 2007)
Costs are in 2007 dollars and must be escalated by the rate of inflation for future years.

Table 5.3 Water System Capital Improvement Projects to Supply Projected Growth
Lake Havasu City Water Master Plan Update

Location	Project/Site Description	Treatment Plant or Pumping Firm Capacity (gpm or mgd)	Buildout Reservoir Capacity (MG)	Estimated Project Cost ($)	2007	2008	2009	2010	2015	2020	2025	Buildout
WTP	Add 6 mgd of Water Treatment Plant Capacity	32		$24,000,000				X				
WTP	Add 6 mgd of Water Treatment Plant Capacity	38		$24,000,000							X	
WTP	Add 7 mgd of Water Treatment Plant Capacity	45		$28,000,000								X
New Well Sites	Additional Wells	N/A	7.7	$9,105,000			X					
Site 3C	New Booster Station and Add 0.5 mgd of Additional Storage	2,000	2.33	$3,570,000					X			
Site No. 4C	New Booster Station and New Storage	1,000	0.5	$2,595,000							X	
Site 5C	New Booster Station and New Storage	1,000	0.5	$2,595,000						X		
Site 6A	New Booster Station and New Storage	1,400	0.5	$3,630,000							X	
Site 7A	New Booster Station and New Storage	1,000	0.5	$2,595,000								X
Site 2D	New Booster Station and New Storage	3,200	2	$5,490,000						X		
Site 3D	New Booster Station and New Storage	2,800	2	$5,400,000							X	
Site 4D	New Booster Station and New Storage	2,400	1	$3,810,000							X	
Site 5D	New Booster Station and New Storage	2,000	1	$3,720,000								X
Site 6D	New Booster Station and New Storage	1,400	0.5	$2,835,000								X
Site 7D	New Booster Station and New Storage	1,000	0.5	$2,595,000								X
Zone 1	Future Water Mains	N/A	N/A	$10,733,000				X				
Zone 2	Future Water Mains	N/A	N/A	$13,363,000						X		
Zone 3	Future Water Mains	N/A	N/A	$10,435,000							X	
Zone 4	Future Water Mains	N/A	N/A	$12,373,000							X	
Zone 5	Future Water Mains	N/A	N/A	$13,406,000								X
Future Zone 6	Future Water Mains	N/A	N/A	$19,450,000								X
Future Zone 7	Future Water Mains	N/A	N/A	$9,954,000								X
Future Zone 8	Future Water Mains	N/A	N/A	$6,626,000								X
			Total	**$211,175,000**								

Notes:
ENR CCI = 7856 (20 Cities Index, March, 2007)
Costs are in 2007 dollars and must be escalated by the rate of inflation for future years.

Table 5.4 Water System Capital Improvement Project Cost Summary
Lake Havasu City Water Master Plan Update

Improvement Type	2007	2008	2009	2010	2011 - 2015	2016 - 2020	2021 - 2025	Buildout	Total
Water Supply (Wells)					$9,105,000	$10,000,000			$19,105,000
Water Treatment				$24,000,000			$24,000,000	$28,000,000	$76,000,000
Improvements to the Existing Water System	$2,400,000	$5,586,000	$20,345,000	$19,588,000	$18,708,000	$408,000			$66,016,000
Improvements to Serve Projected Growth				$10,733,000	$3,570,000	$21,448,000	$38,243,000	$61,181,000	$135,924,000
Total	**$2,400,000**	**$5,586,000**	**$20,345,000**	**$54,321,000**	**$30,383,000**	**$31,856,000**	**$62,243,000**	**$89,181,000**	**$297,045,000**

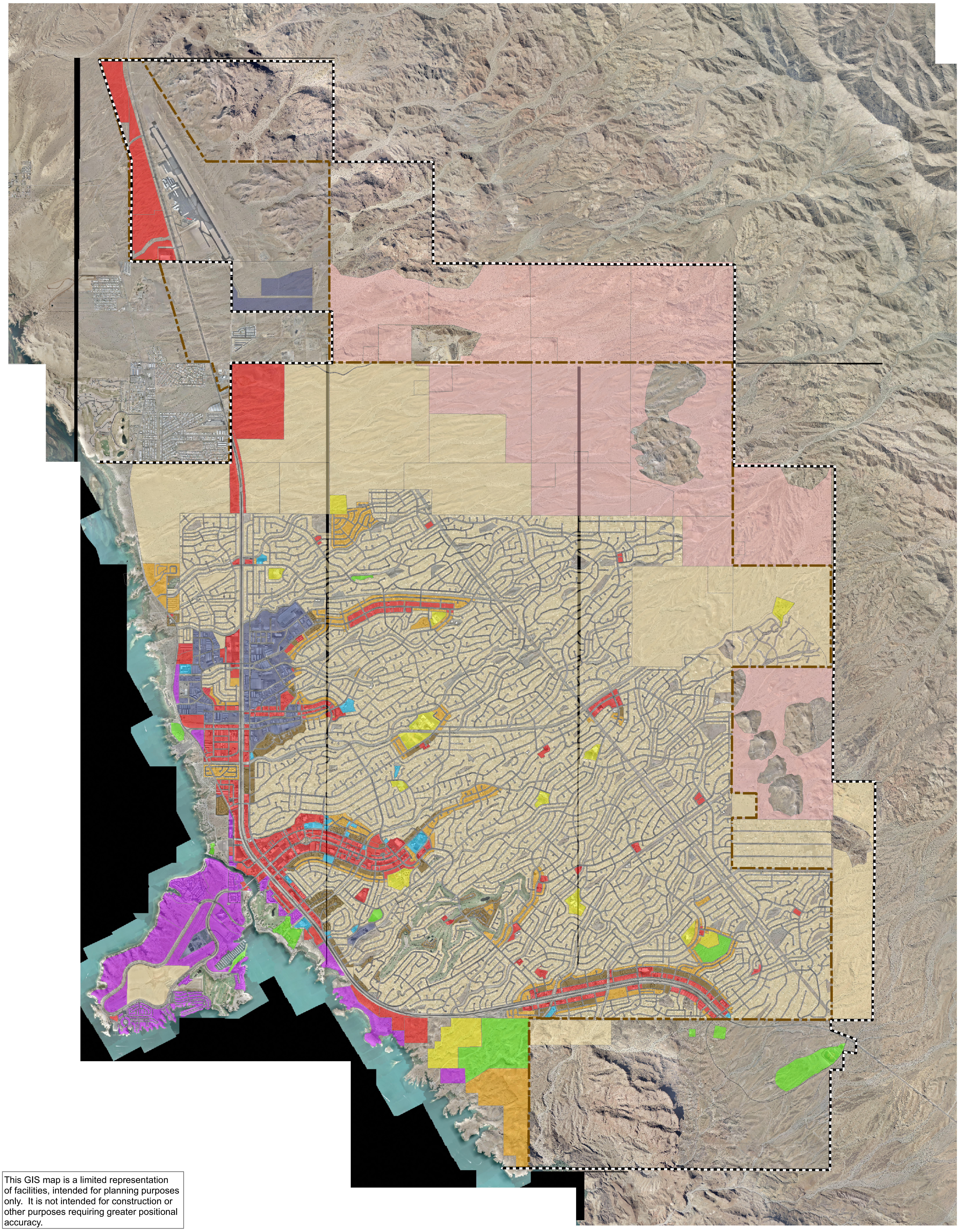
Notes:

ENR CCI = 7856 (20 Cities Index, March, 2007)

Costs are in 2007 dollars and must be escalated by the rate of inflation for future years.

Appendix A

LAND USE PLAN AND LARGE SCALE MAP OF EXISTING WATER SYSTEM



Water Service Boundary

Lake Havasu City Limits

Land Use Category

- Rural Residential (0 - 2 DU/AC)
- Low Density Residential (2 - 4 DU/AC)
- Medium Density Residential (4 - 10 DU/AC)
- High Density Residential (5 - 20 DU/AC)
- Resort
- Business / Government
- Commercial
- School
- Irrigation
- Industrial
- No Water Use Or Reclaimed Effluent Irrigation

N

Note: Sara Park and City Hall are currently irrigated by potable water but will be irrigated by effluent in the future.

LAKE HAVASU CITY LAND USE PLAN

Lake Havasu City Water Master Plan Update

Final - October 2007

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MAP A.1

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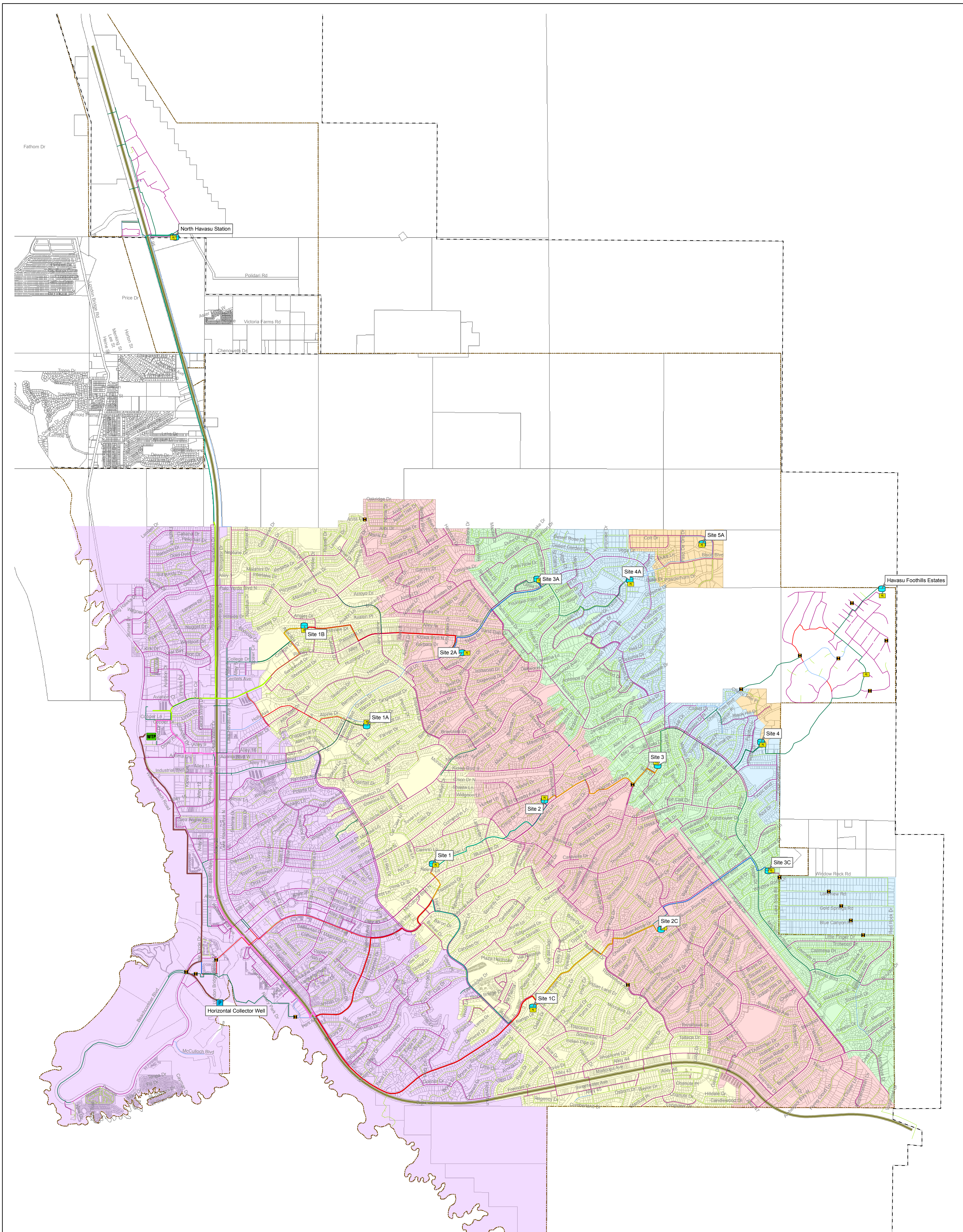

Existing Pipes Diameter

- Under 8"
- 8"
- 10"
- 12"
- 16"
- 18"
- 20"
- 24"
- 27"
- 30"
- 36"
- 48"

- PRV
- Booster Station
- Water Treatment Plant
- Storage Tank
- Water Service Boundary
- City Limits

Pressure Zones

- 1
- 2
- 3
- 4
- 5
- 6

0 0.5 1 Miles

EXISTING WATER DISTRIBUTION SYSTEM

Lake Havasu City Water Master Plan Update

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MAP A.2

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MODEL CALIBRATION INFORMATION

MODEL CALIBRATION

Hydraulic models are calibrated by comparing field data with model results to accomplish the following purposes:

- Assist in determining water demands and the distribution of those demands.
- Identify data errors or identify missing data parameters.
- Discover anomalies in the field.
- Establish a degree of confidence in the models.

To calibrate the model, a 6:30 am time was selected because that is the time when peak hour flows are assumed to occur. Peak flows will give the highest pressure drops in the distribution system. Field data was then compared with the model, and adjustments were made to the model to make the model match field data. Table B.1 shows the dates where data was taken for the calibration. The main adjustment made to the model was the friction factor for the pipes.

Table B.1 Calibration Days
Lake Havasu City Water Master Plan Update

Field Test Letter	Selected Date/Day
A	June 27, 2006 - Tuesday
B	July 5, 2006 - Wednesday
C	July 11, 2006 - Tuesday
D	July 18, 2006 - Tuesday
E	July 21, 2006 - Friday
F	July 25, 2006 - Tuesday

Table B.2 shows the friction factors by pipe material and pipe diameter that were necessary to calibrate the model.

Table B.2 Pipe Roughness Coefficients (C-values)*
Lake Havasu City Water Master Plan Update

Diameter	Asbestos Cement	Concrete	Ductile Iron	Plastic	Average for Unknown Material
4	80	80	80	110	90
6	90	90	80	110	95
8	90	90	90	110	95
10	100	100	90	120	100
12	115	100	110	130	115
16	115	100	110	130	115
18	115	100	110	130	115
20	120	100	110	130	120
24	120	100	120	130	120
30	120	100	120	130	120
48	140	120	130	140	130

* AWWA Manual M11, Steel Pipe - A Guide for Design and Installation (AWWA, 1989)

Pressures within +/- 10 percent are considered to be a reasonable calibration. Tables B.3 through B.8 show the model calibration results for Zones 1 through 6, respectively. In each pressure zone, the model results appear to be reasonable.

Table B.3 Model Calibration for Zone 1
Lake Havasu City Water Master Plan Update

Field Test Points

Test ID	Location	Area	Pressure (psi)		
			Model	Field	% Difference(1)
A11	1385 Piper Drive	North	113	110.6	2
A12	Park Terrace Ave and Palo Verde Blvd North	North	67	63.9	4
A14	1841 Cabana Drive	North	93	92	1
B11	Spawr Circle at College Ave	North	55	54.5	0
A10	Kiowa Blvd and San Juan Drive	Central	63	61.2	3
A5	Magnolia Drive and Saguaro Drive	Central	104	98.5	5
A6	2175 Senita Drive	Central	37	33.9	8
A8	360 Lake Havasu Avenue North	Central	106	102.3	4
A9	1940 Holly Drive	Central	60	59.8	1
B7	1734 Rainbow Avenue	Central	28	25	10
A1	Bryce and Fremont Drive	South	69	68.1	2
A2	Snead and Chip Drive	South	68	62.7	9
A3	Acoma Boulevard S and Swanson Avenue	South	39	35.8	8
B4	2510 Jamaica Boulevard	South	39	40.7	-4
B17	2525 Avocado Ln	South	34	30.5	10
A15	Beachcomber Boulevard	PRV to island	90	83.8	7

Reservoir

Name	Level (ft)
Site 1	15.0
Site 1B	17.5
Site 1C	16.0
Site 1A	15.8

Table B.3 Model Calibration for Zone 1
Lake Havasu City Water Master Plan Update

Pumps

Name	Flow (gpm)	Dynamic Head (ft)	Discharge Pressure (psi)
Pump 1	0	0	141
Pump 2	0	0	141
Pump 3	4,276	322	141
Pump 4	0	0	141
Pump 5	0	0	141
Pump 6	0	0	141
WTP North High Service Pumps	4,276		
Pump 7	0	0	141
Pump 8	0	0	141
Pump 9	4,261	324	141
Pump 10	0	0	141
Pump 11	0	0	141
Pump 12	0	0	141
WTP South High Service Pumps	4,261		

Notes: (1) % Difference = (Model Pressure - Field Pressure) / Field Pressure

Table B.4 Model Calibration Results for Zone 2
Lake Havasu City Water Master Plan Update

Field Test Points

Test ID	Location	Area	Pressure (psi) Model	Pressure (psi) Field	Pressure (psi) % Difference[(1)]
A13	Palo Verde Dr and Lake Havasu Ave	North	138	139.7	-1
B13	2525 Anita Ave	North	74	74.4	-1
B15	1610 Anita Ct	North	46	45	2
B8	1732 Rainbow Ave	North	129	126.3	2
C11	950 Huntington Dr at Huntington Pl	North	50	46	8
A7	Acoma Blvd and Smoketree Ave North	Central	126	121.1	4
B12	College Ave at Lampkin Dr	Central	128	126.3	1
B9	2695 Cisco Dr North	Central	54	49.6	9
B6	2635 Castaway Dr	South	90	84.2	7
B1	3240 Longview Dr	South	65	63.3	2
B3	881 Rolling Hills Dr	South	59	52.9	11
B5	2580 Talisman Dr	South	124	115.6	7

Reservoir

Name	Level (ft)
Site 2A	18.0
Site 2	17.8
Site 2C	16.5

Pumps

Pump Station	Flow (gpm)	Dynamic Head (ft)	Discharge Pressure (psi)
Site 1B Pump 1	2,893	239	111
Site 1B Pump 2	2,893	239	111
Site 1B Pump 3	0	0	111
Site 1B BPS	5,786		
Site 1A Pump 1	739	365	164
Site 1A BPS	739		
Site 1C Pump 1	2,803	296	135
Site 1C Pump 2	2,803	296	135
Site 1C BPS	5,606		
Site 1 Pump 1	1,105	282	128
Site 1 Pump 2	0	0	128
Site 1 Pump 3	1,105	282	128
Site 1 BPS	2,211		

Notes: (1) % Difference = (Model Pressure - Field Pressure) / Field Pressure

Table B.5 Model Calibration for Zone 3
Lake Havasu City Water Master Plan Update

Field Test Points

Test ID	Location	Area	Pressure (psi)		
			Model	Field	% Difference[1]
B14	2780 Alibi Dr at Anita Ave	North	119	112.9	5
C12	2743 Arcadia and Barbara Dr	North	124	123.3	1
C13	3117 Palo Verde Blvd North	North	56	57.6	-3
D11	1230 Crater Ct	North	40	40.3	0
C10	3141 Hidden Valley Dr at Valley Ln	North	66	64.8	1
B10	2836 Seville Ln	Central	120	124.4	-3
C7	3375 Monte Carlo Ave at El Toro Dr	Central	47	45	4
C5	3471 Chesapeake Blvd	Central	40	40.1	1
C8	2853 Wanderer Ln off Cisco Drive South	Central	120	117.1	3
D5	3313 Dolphin Dr	Central	41	40.6	1
C1	2209 Medeterranean Ln at Martinique Dr	South	82	76.5	7
C2	1332 Mohican Dr at Cholla Dr	South	39	35.4	10
C4	3641 Cactus Ridge Dr at Verga Dr	South	88	83.8	5

Reservoir

Name	Level (ft)
Site 3A	18.0
Site 3	16.8
Site 3C	18.0

Pumps

Name	Flow (gpm)	Dynamic Head (ft)	Discharge Pressure (psi)
Site 2A Pump 1	1,747	276	125
Site 2A Pump 2	1,747	276	125
Site 2A Pump 3	0	0	125
Site 2A BPS	3,493		
Site 2 Pump 1	1,336	207	96
Site 2 Pump 2	0	0	96
Site 2 Pump 3	0	0	96
Site 2 BPS	1,336		
Site 2C Pump 1	1,847	241	110
Site 2C Pump 2	1,847	241	110
Site 2C Pump 3	0	0	110
Site 2C BPS	3,695		

Notes: (1) % Difference = (Model Pressure - Field Pressure) / Field Pressure

Table B.6 Model Calibration for Zone 4
Lake Havasu City Water Master Plan Update

Field Test Points

Test ID	Location	Area	Pressure (psi) Model	Field	% Difference[1]
D10	3250 Palo Verde Blvd North and Crater Dr	North	120	124.2	-3
D6	310 Driftwood Dr and Buckboard Ln	North	68	71.5	-4
D8	620 Sand Dab Dr and Foothill Dr	North	115	124.4	-8
D9	3557 Fiesta Dr and Pocahontas Dr	North	62	60.6	2
E8	956 Joshua Tree Dr at Date Row Dr	North	76	78.8	-4
C6	3540 Chesapeake Blvd at Tarpon Dr	Central	116	112.8	3
D3	3793 Bluegrass Dr	Central	65	69.8	-7
D4	3365 El Dorado Ave North	Central	107	112.3	-5
C3	1496 Mohican Dr at Blackhawk Dr	South	125	121.1	3
D1	4116 Trimaran Dr and Trimaran Pl East	South	99	93.1	6

Reservoir

Name	Level (ft)
Site 4A	17.0
Site 4	15.5

Pumps

Name	Flow (gpm)	Dynamic Head (ft)	Discharge Pressure (psi)
Site 3A Pump 1	1,206	351	156
Site 3A Pump 2	0	0	156
Site 3A Pump 3	0	0	156
Site 3A BPS	1,206		
Site 3 Pump 1	1,420	249	115
Site 3 Pump 2	0	0	115
Site 3 BPS	1,420		
Site 3C Pump 1	91	347	158
Site 3C Pump 2	0	0	158
Site 3C BPS[2]	91		

Notes: (1) % Difference = (Model Pressure - Field Pressure) / Field Pressure
(2) There are two hydropneumatic tanks that serve Horizon Six and the Site 3C pumps are reflecting the calibration demand, not actual operation.

Table B.7 Model Calibration for Zone 5
Lake Havasu City Water Master Plan Update

Field Test Points

Test ID	Location	Area	Pressure (psi) Model	Pressure (psi) Field	Pressure (psi) % Difference[1]
D7	320 Opossum Dr and Texoma Dr	North	129	124.1	4
E6	3747 Vegas Dr	North	76	76.9	-2
E7	977 St. Claire Dr and Desert Garden Dr	North	140	134.6	4
E1	599 Azul Dr at Aloha Wy	Central	120	114.9	4
E2	3746 Cherry Tree Blvd and Mission Dr	Central	134	125.9	6
F7	4044 Cherry Tree Blvd at Cherry Tree Wy	Central	60	49.6	22[2]

Reservoir

Name	Level (ft)
Site 5A	19.0

Pumps

Name	Flow (gpm)	Dynamic Head (ft)	Discharge Pressure (psi)
Site 4A Pump 1	675	206	96
Site 4A Pump 2	0	0	96
Site 4A Pump 3	0	0	96
Site 4A BPS	675		

Notes: (1) % Difference = (Model Pressure - Field Pressure) / Field Pressure
(2) A closed valve or other restriction may exist in this area

Table B.8 Model Calibration for Zones 6 and 6A
Lake Havasu City Water Master Plan Update

Field Test Points

Test ID	Location	Area	Pressure (psi)		
			Model	Field	% Difference(1)
F3	3935 Duke Dr	North	125	121.3	3
F2	4181 Colt Dr at Bison Blvd	North	69	67.5	2
F9	4180 Blackhill Dr	South	116	108.9	7
F8	4093 Blackhill Bay	South	71	73	-2

Reservoir

Name	Level (ft)
Site 5A	19.0

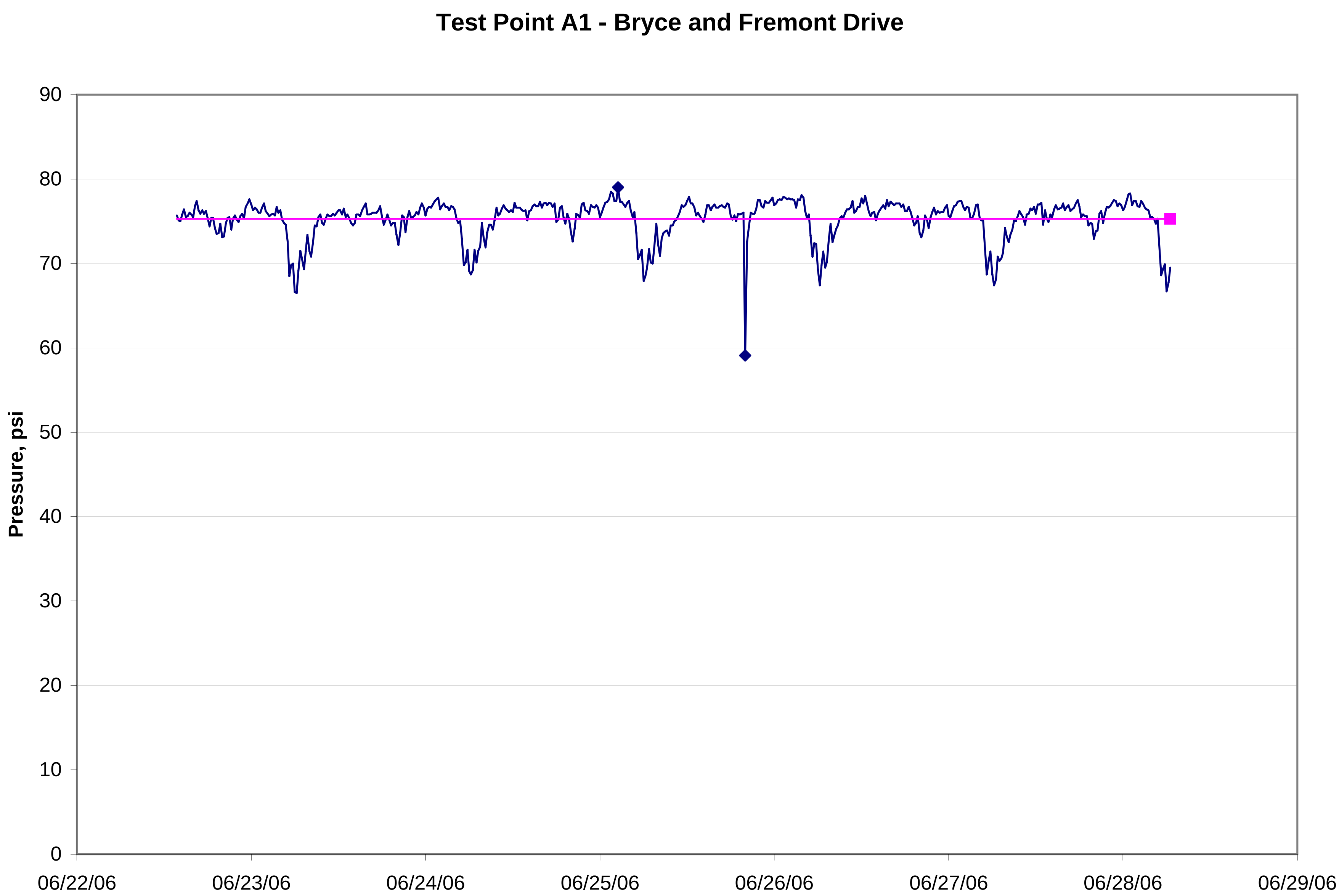
Pumps

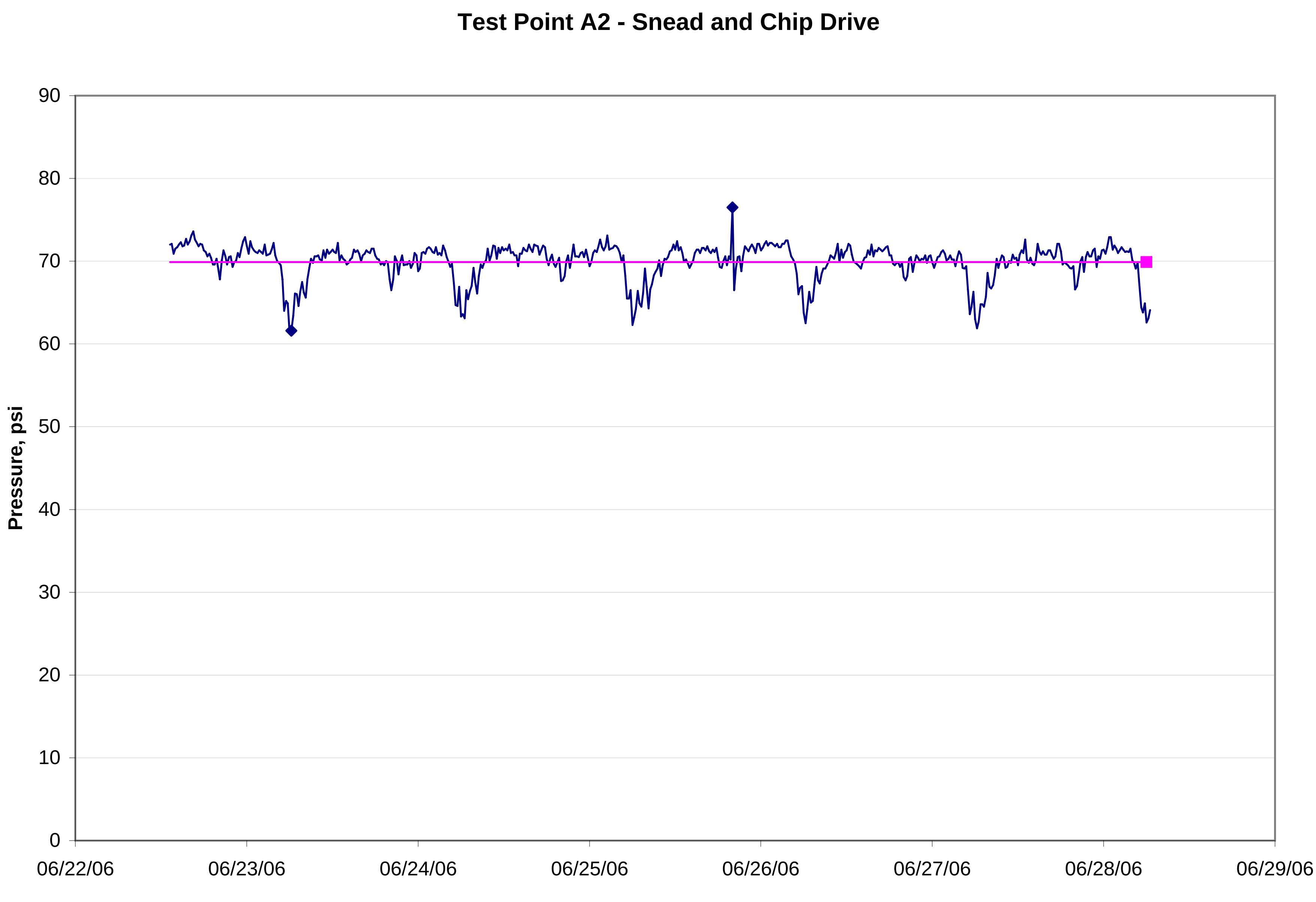
Name	Flow (gpm)	Dynamic Head (ft)	Discharge Pressure (psi)
Site 5A Pump 1	0	0	109
Site 5A Pump 2	86	238	109
Site 5A BPS(2)	86		
Site 4 Pump 1	0	0	182
Site 4 Pump 2	17	405	182
Site 4 BPS(3)	17		

Notes: (1) % Difference = (Model Pressure - Field Pressure) / Field Pressure

(2) There is a hydropneumatic tank that serves Zone 6A and the Site 5A pumps are reflecting the calibration demand, not actual operation.

(3) There is a hydropneumatic tank that serves Zone 6 and the Site 4 pumps are reflecting the calibration demand, not actual operation.


Test Point A1 - Bryce and Fremont Drive
Pressure, psi
90
80
70
60
50
40
30
20
10
0
06/22/06
06/23/06
06/24/06
06/25/06
06/26/06
06/27/06
06/28/06
06/29/06



Test Point A2 - Snead and Chip Drive
Pressure, psi
0
10
20
30
40
50
60
70
80
90
06/22/06
06/23/06
06/24/06
06/25/06
06/26/06
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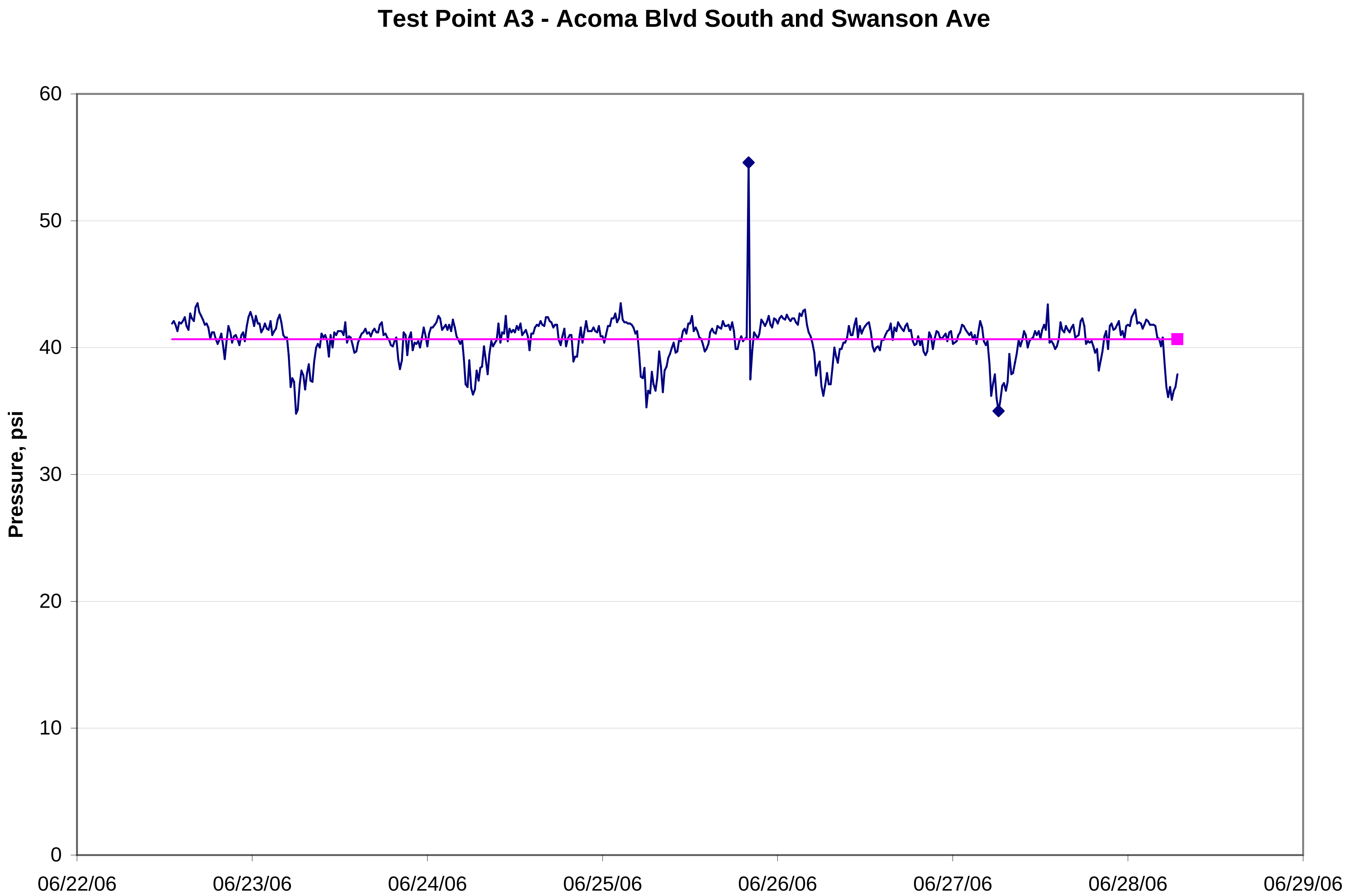
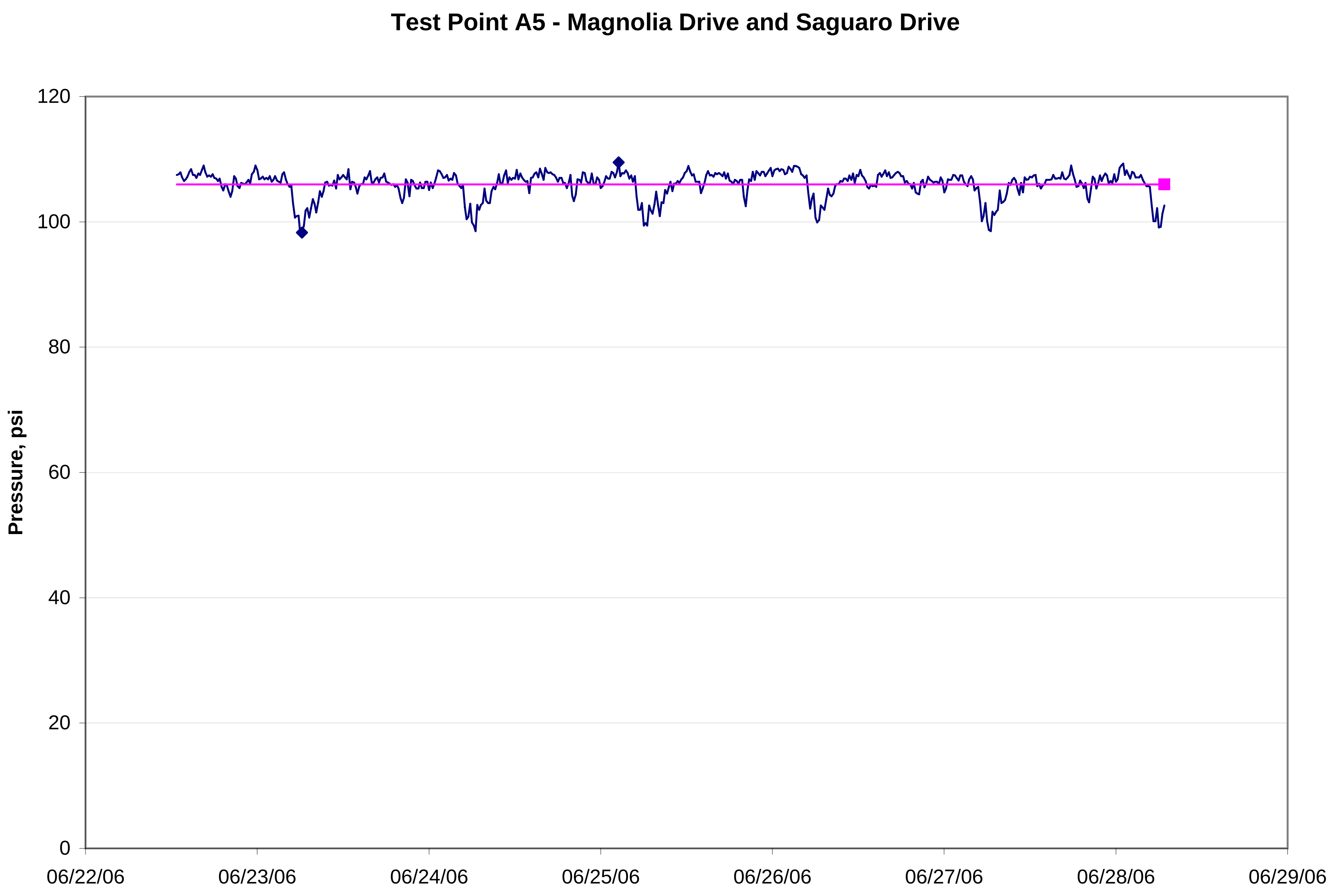
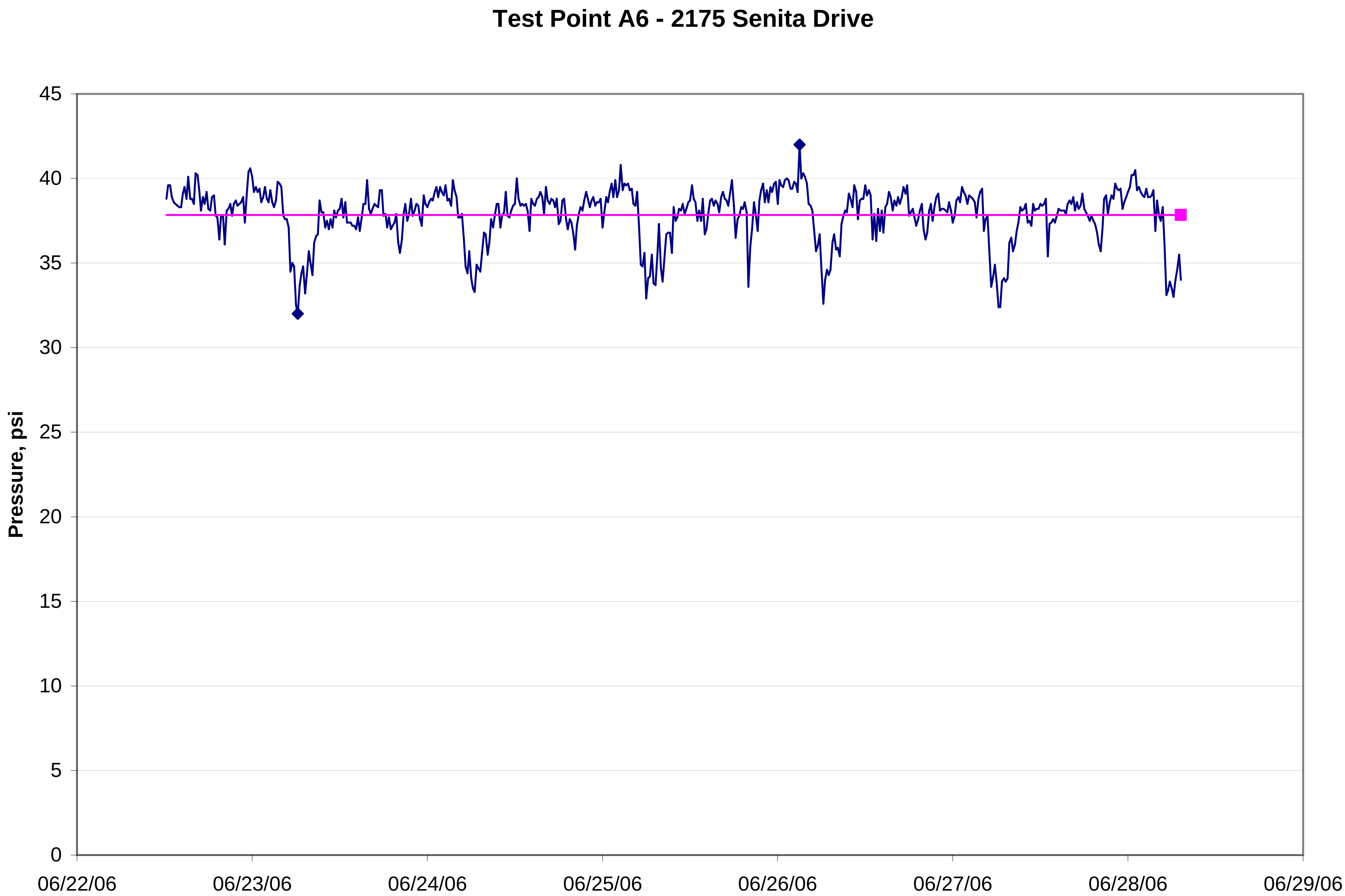
06/28/06
06/29/06



Test Point A3 - Acoma Blvd South and Swanson Ave
Pressure, psi
60
50
40
30
20
10
0
06/22/06
06/23/06
06/24/06
06/25/06
06/26/06
06/27/06
06/28/06
06/29/06


Test Point A5 - Magnolia Drive and Saguaro Drive
Pressure, psi
0
20
40
60
80
100
120
06/22/06
06/23/06
06/24/06
06/25/06
06/26/06
06/27/06
06/28/06
06/29/06



Test Point A6 - 2175 Senita Drive
Pressure, psi
45
40
35
30
25
20
15
10
5
0
06/22/06
06/23/06
06/24/06
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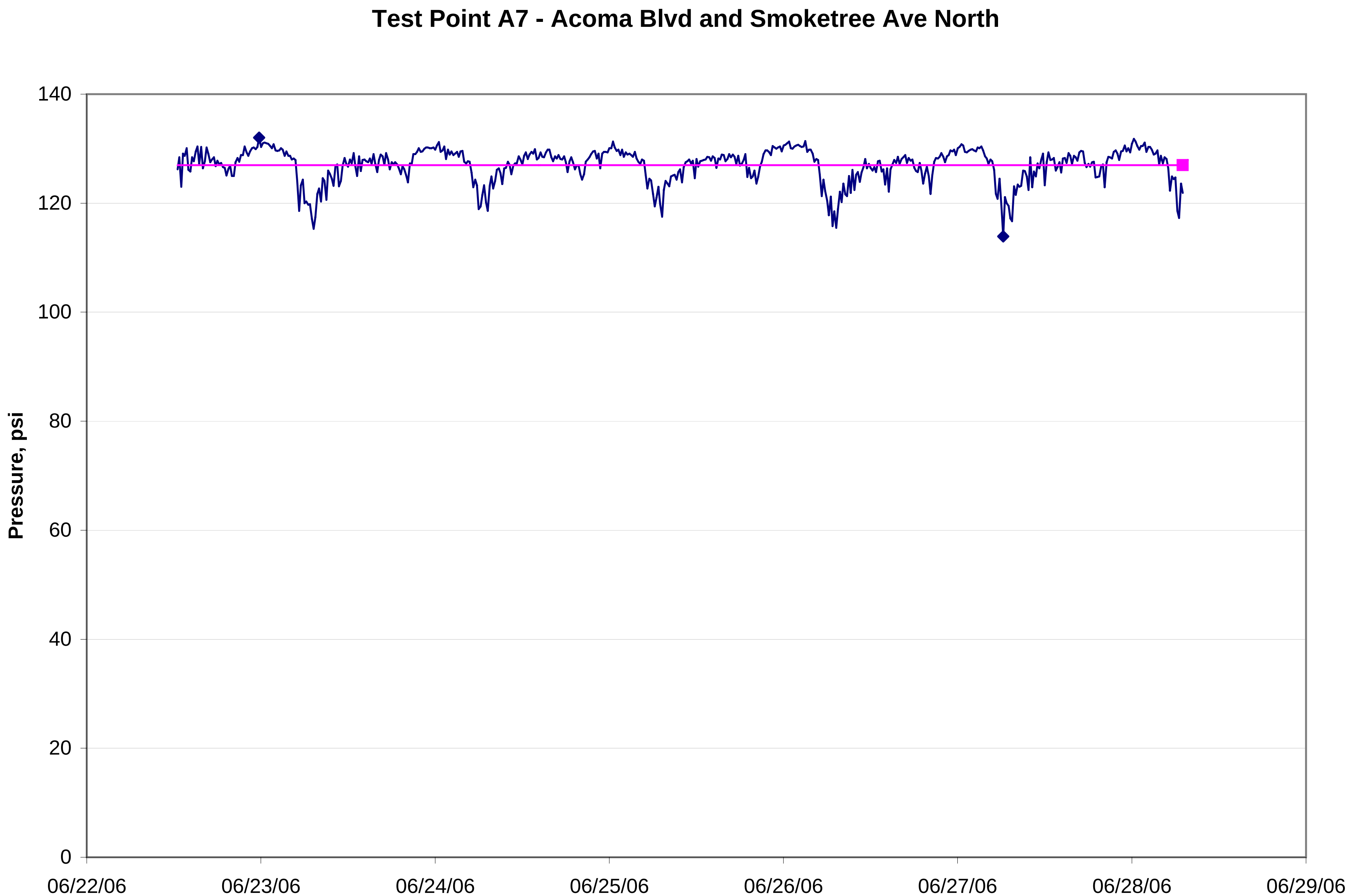
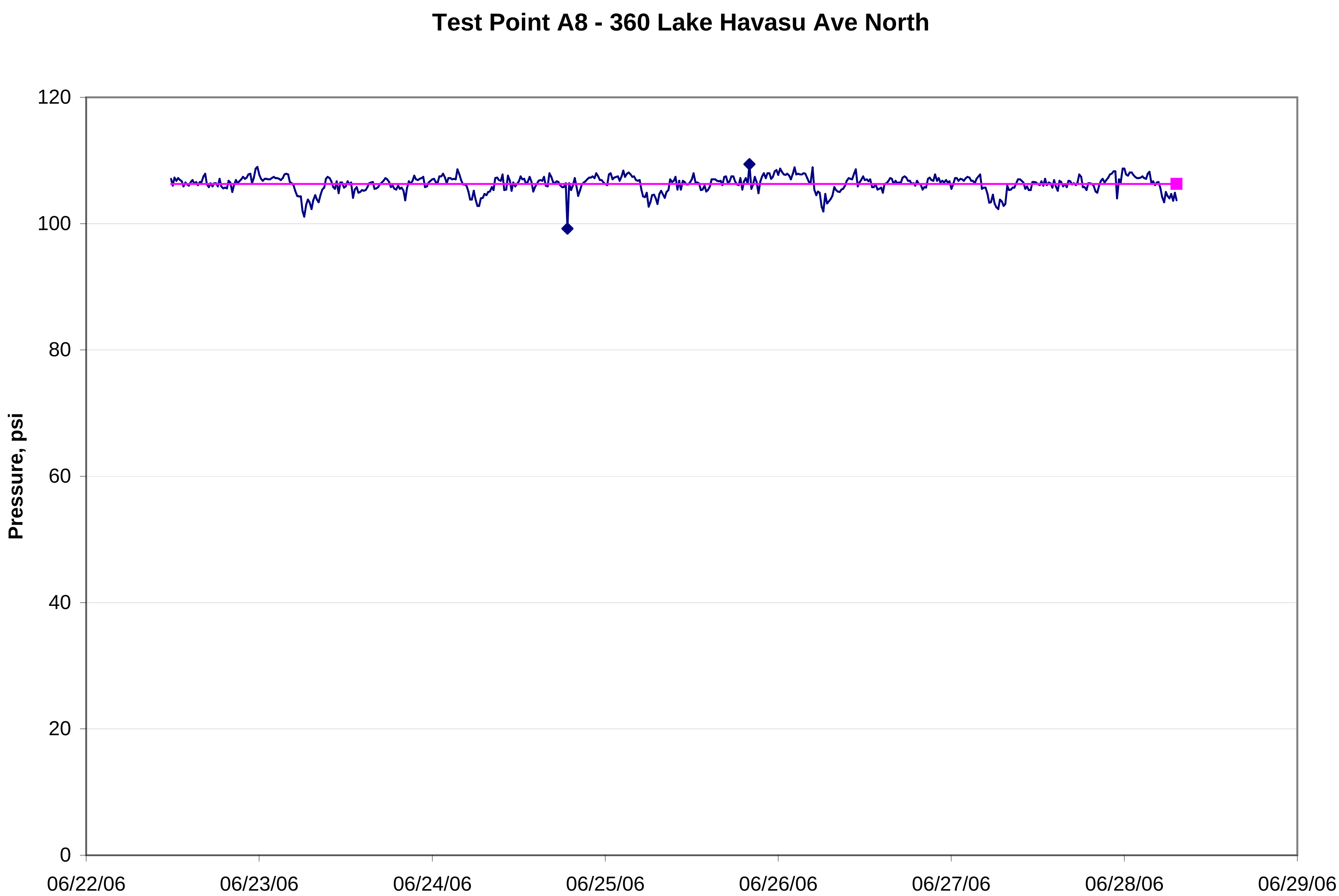
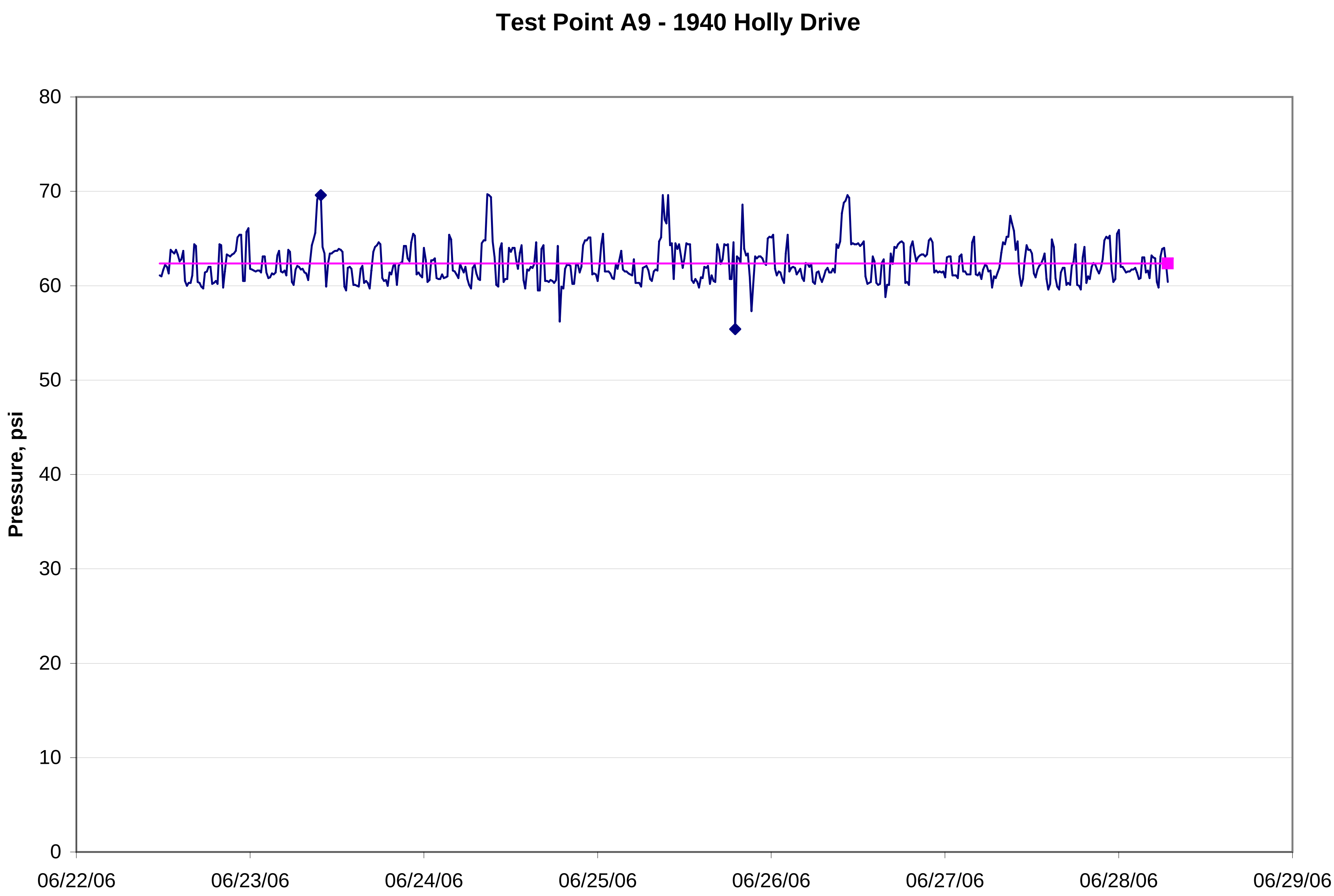
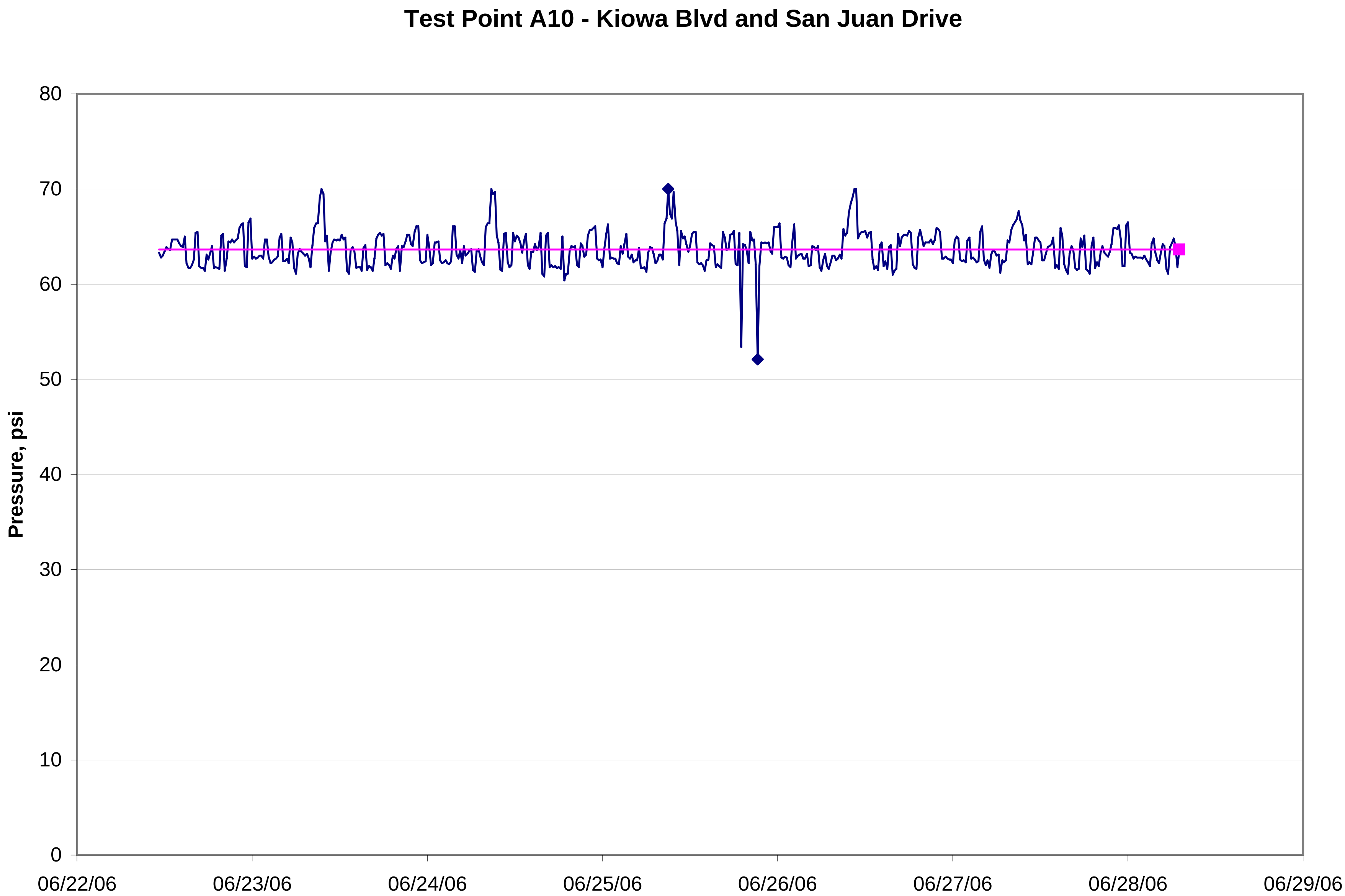
06/26/06
06/27/06
06/28/06
06/29/06


Test Point A7 - Acoma Blvd and Smoketree Ave North
Pressure, psi
0
20
40
60
80
100
120
140
06/22/06
06/23/06
06/24/06
06/25/06
06/26/06
06/27/06
06/28/06
06/29/06

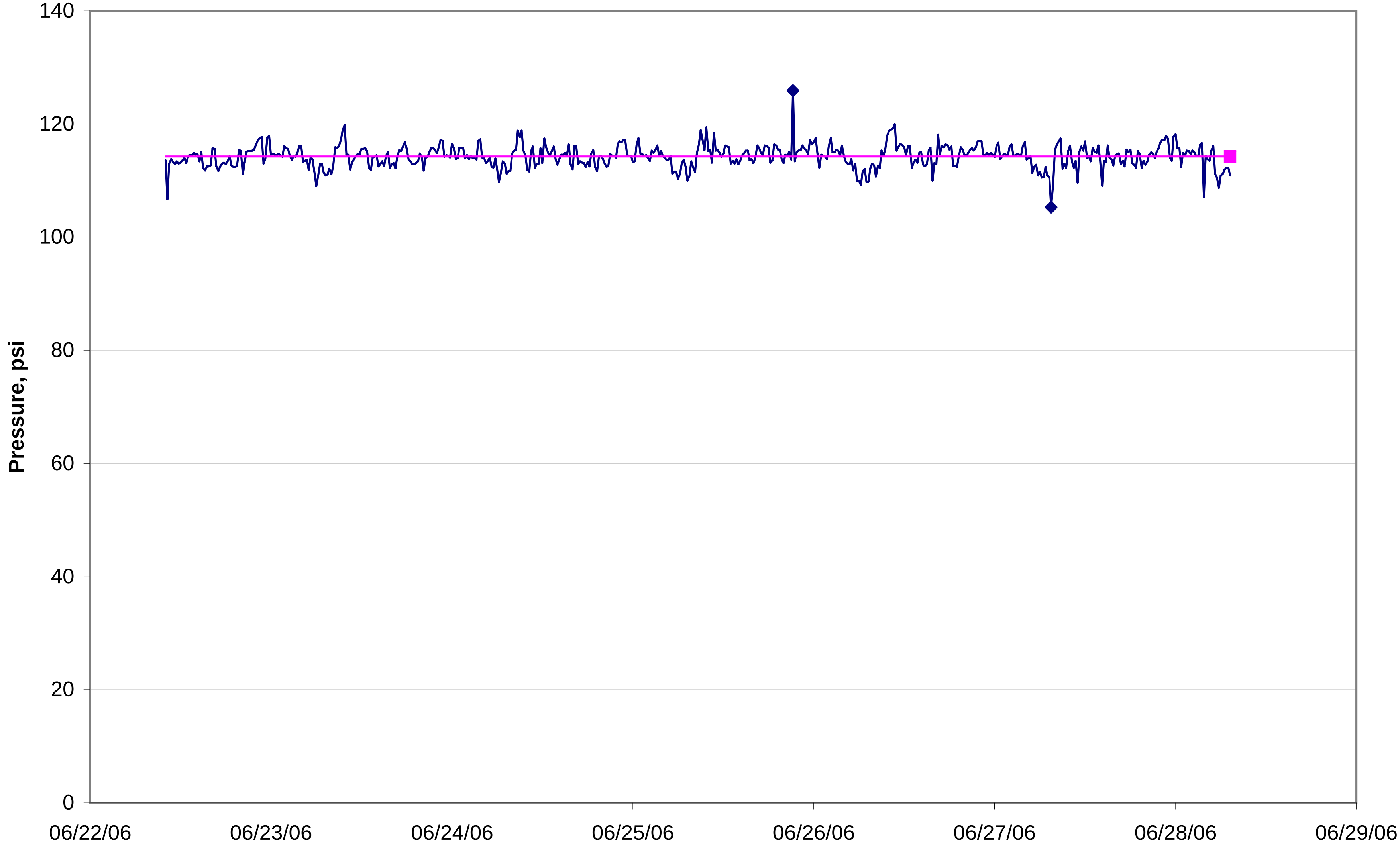

Test Point A8 - 360 Lake Havasu Ave North
Pressure, psi
0
20
40
60
80
100
120
06/22/06
06/23/06
06/24/06
06/25/06
06/26/06
06/27/06
06/28/06
06/29/06


Test Point A9 - 1940 Holly Drive
Pressure, psi
80
70
60
50
40
30
20
10
0
06/22/06
06/23/06
06/24/06
06/25/06
06/26/06
06/27/06
06/28/06
06/29/06

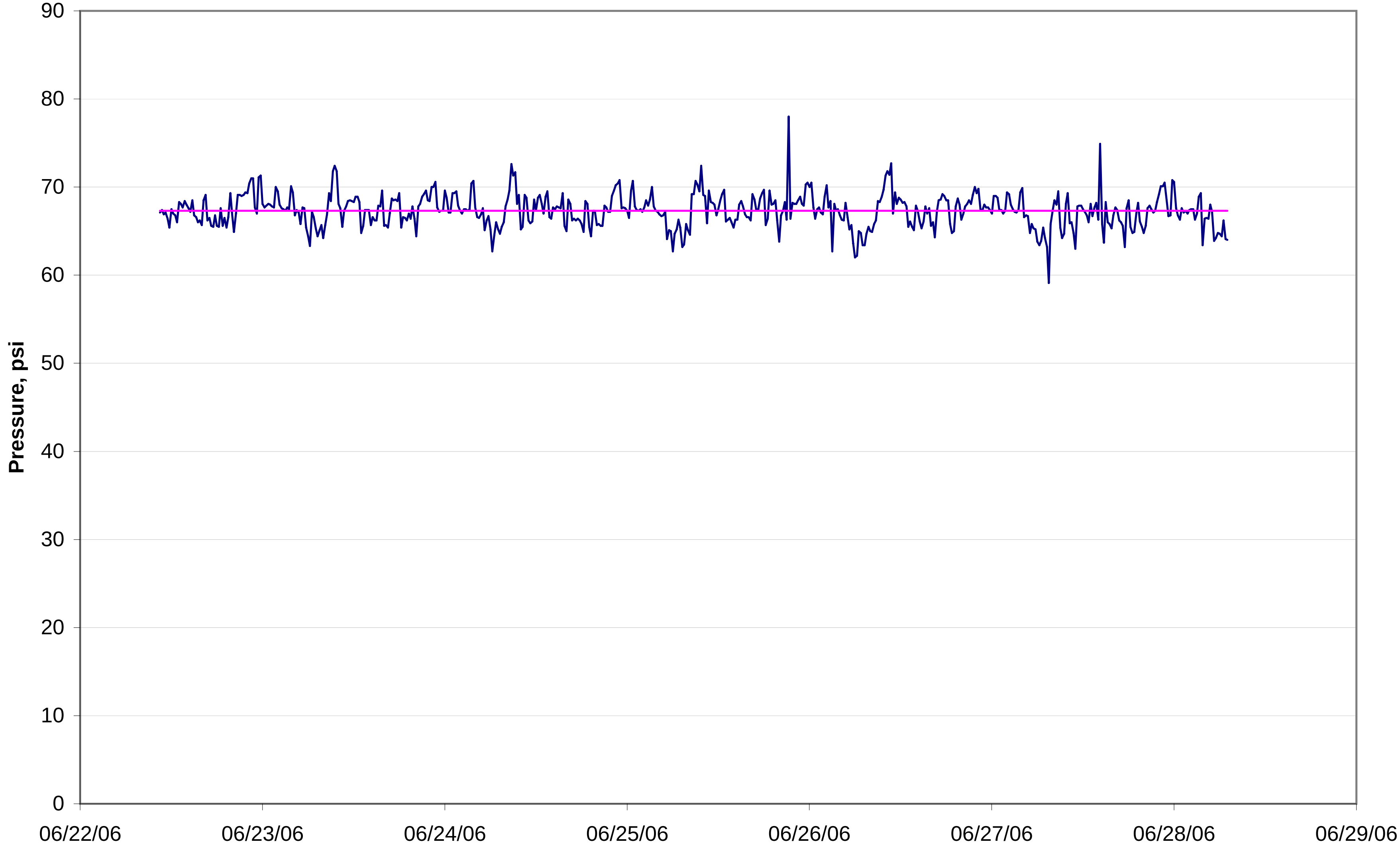


Test Point A10 - Kiowa Blvd and San Juan Drive
Pressure, psi
80
70
60
50
40
30
20
10
0
06/22/06
06/23/06
06/24/06
06/25/06
06/26/06
06/27/06
06/28/06
06/29/06

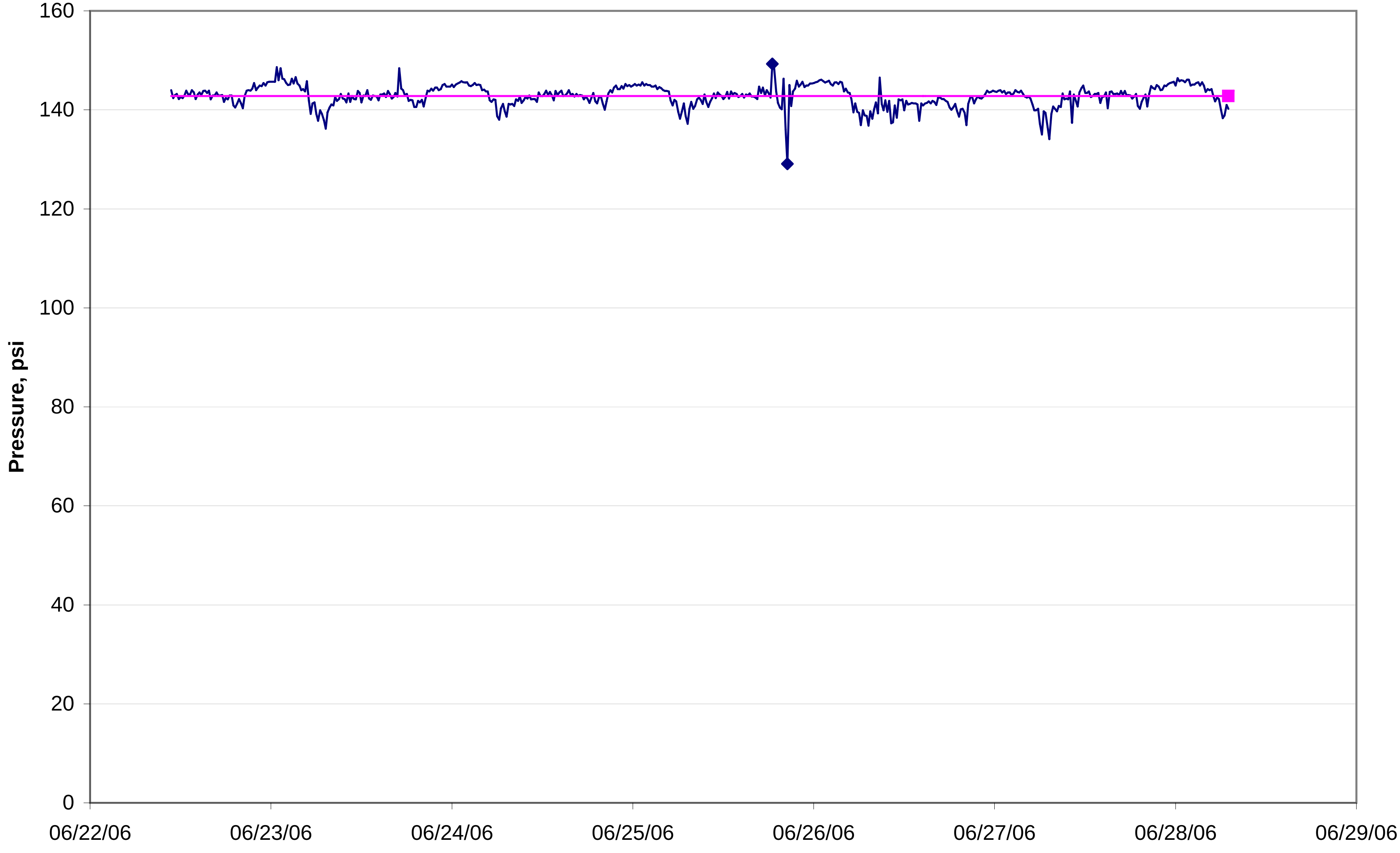
Test Point A11 - 1385 Piper Drive



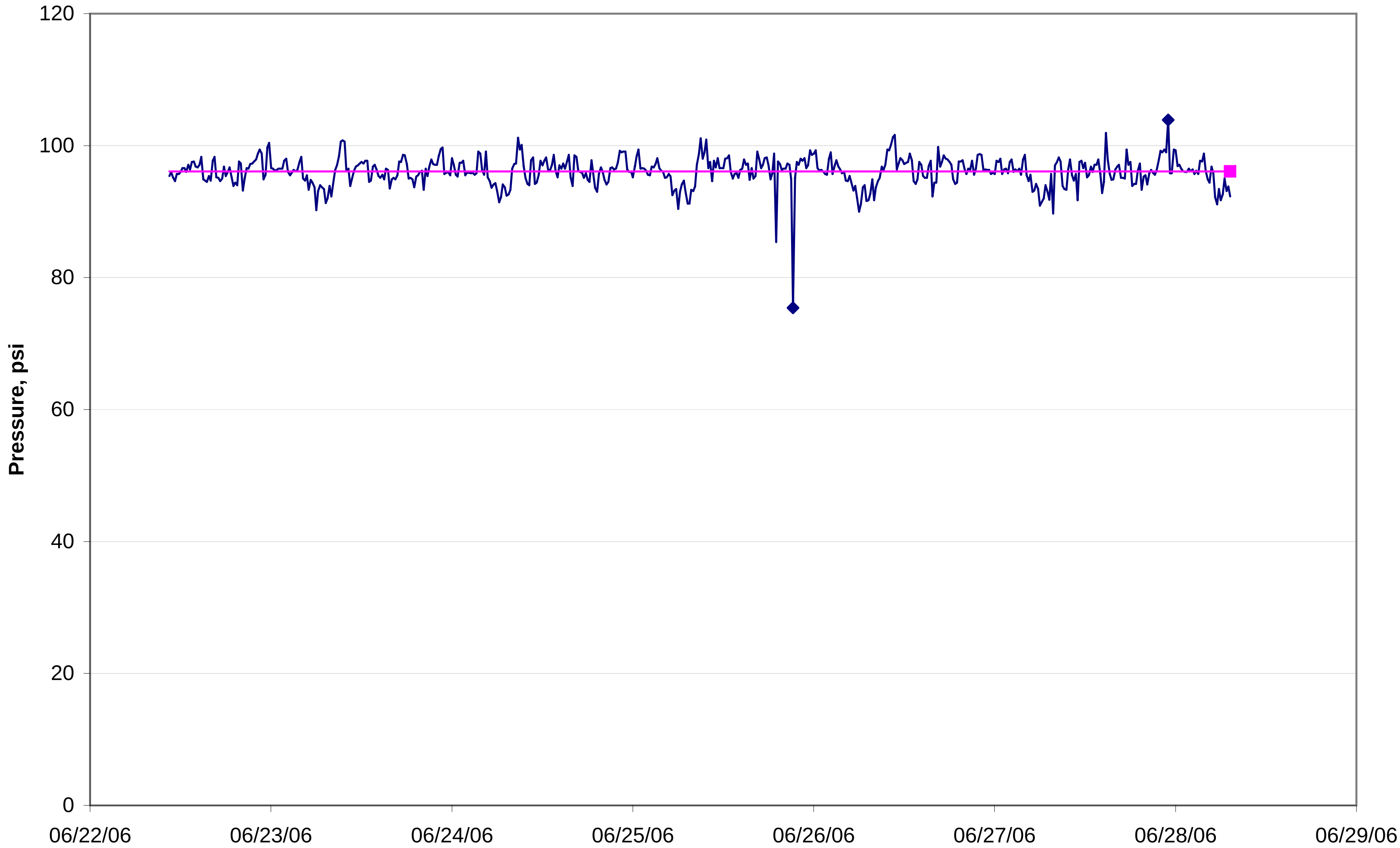
Test Point A12 - Park Terrace Ave and Palo Verde Blvd North

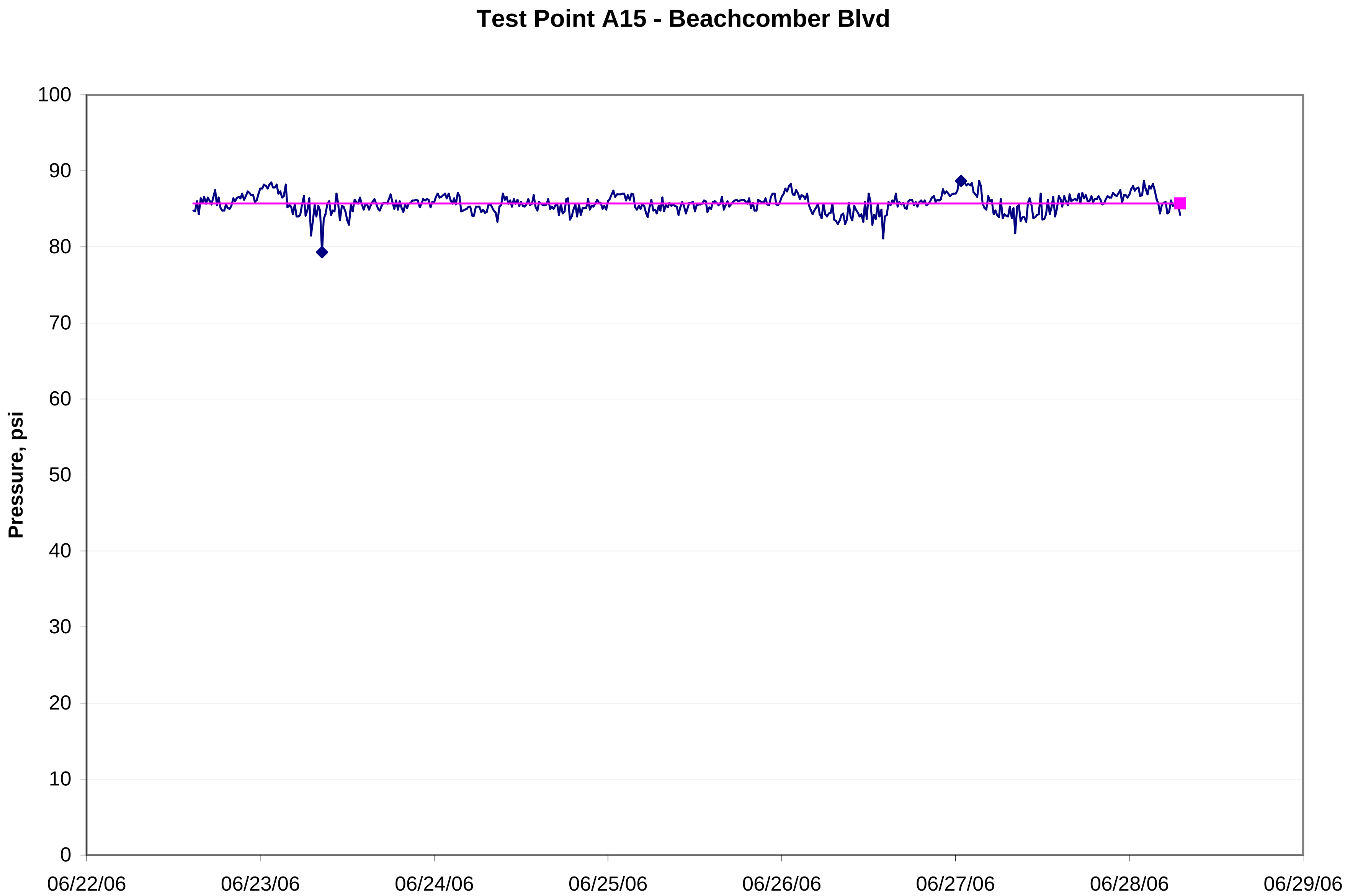


Test Point A13 - Palo Verde Dr and Lake Havasu Ave



Test Point A14 - 1841 Cabana Dr




Test Point A15 - Beachcomber Blvd
Pressure, psi
100
90
80
70
60
50
40
30
20
10
0
06/22/06
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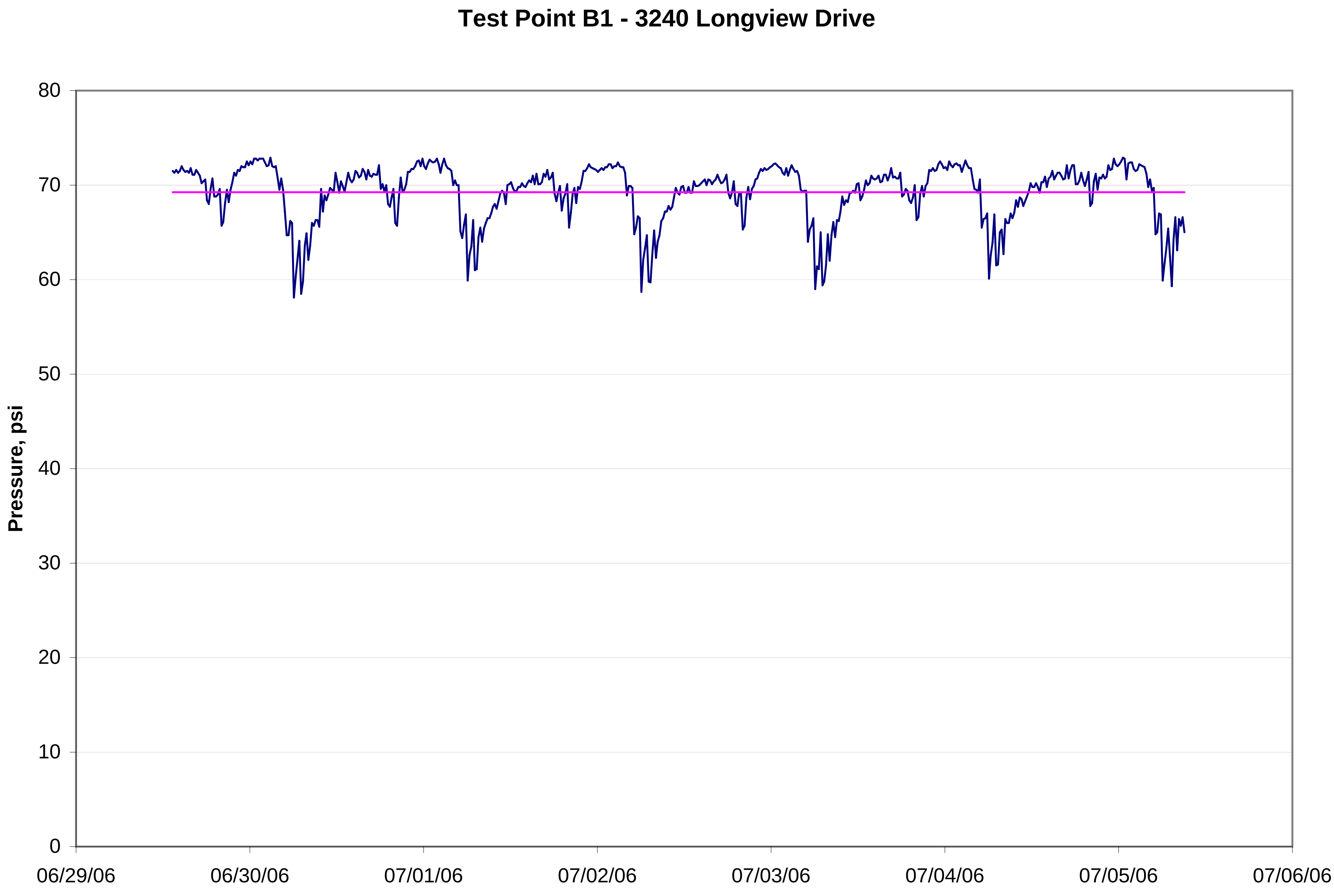
06/28/06
06/29/06



Test Point B1 - 3240 Longview Drive
Pressure, psi
0
10
20
30
40
50
60
70
80
06/29/06
06/30/06
07/01/06
07/02/06
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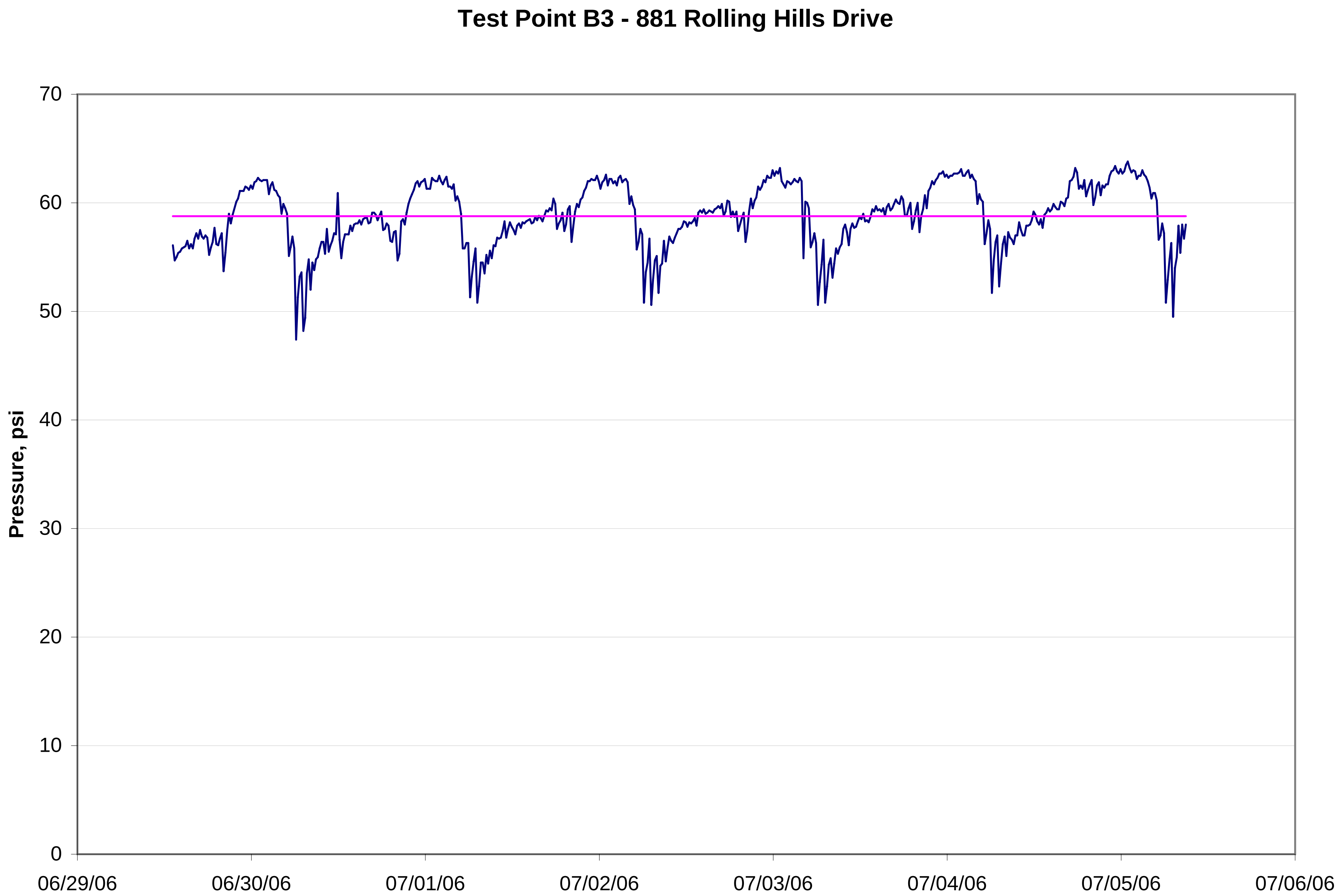
07/04/06
07/05/06
07/06/06



Test Point B3 - 881 Rolling Hills Drive
Pressure, psi
70
60
50
40
30
20
10
0
06/29/06
06/30/06
07/01/06
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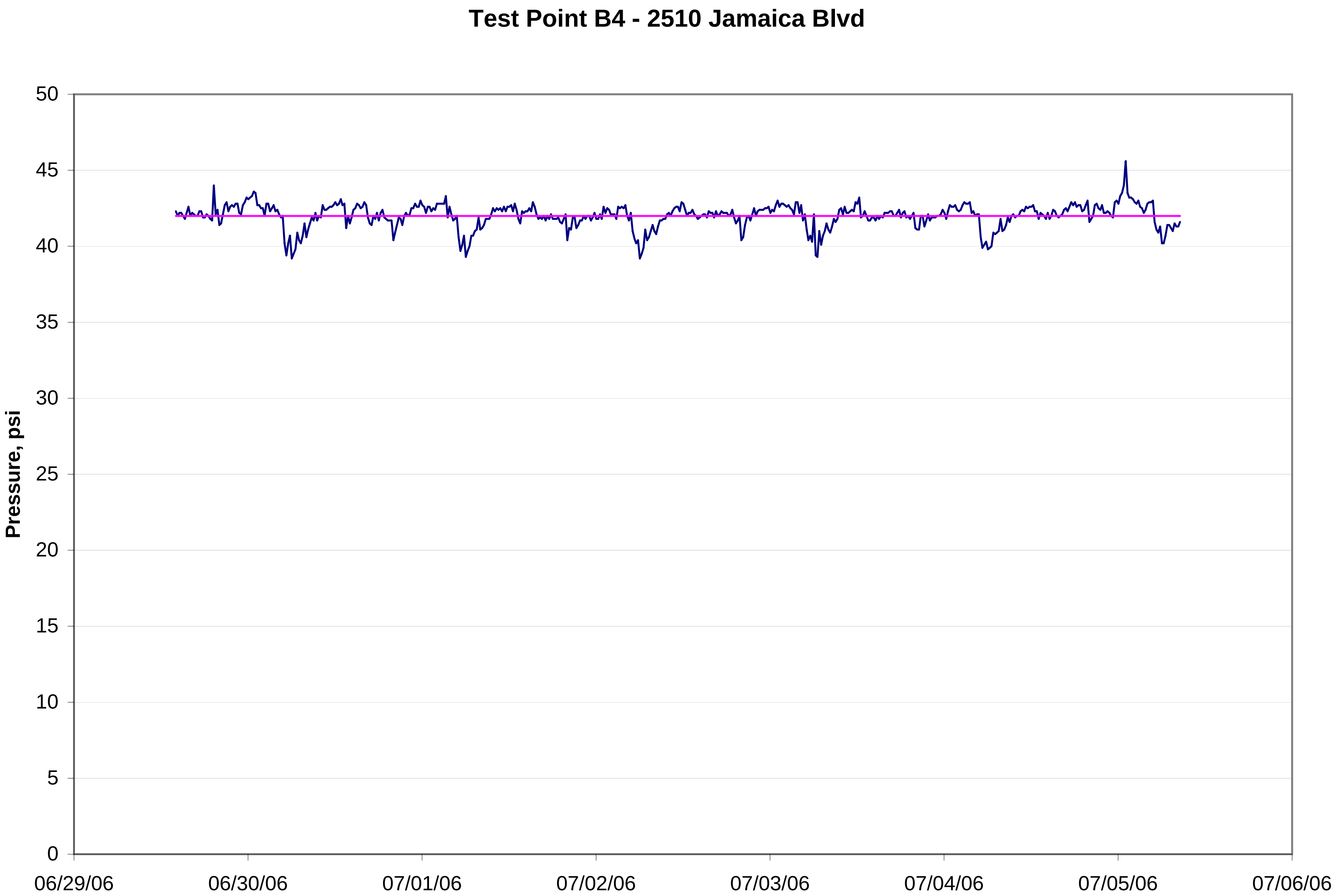
07/04/06
07/05/06
07/06/06



Test Point B4 - 2510 Jamaica Blvd
Pressure, psi
0
5
10
15
20
25
30
35
40
45
50
06/29/06
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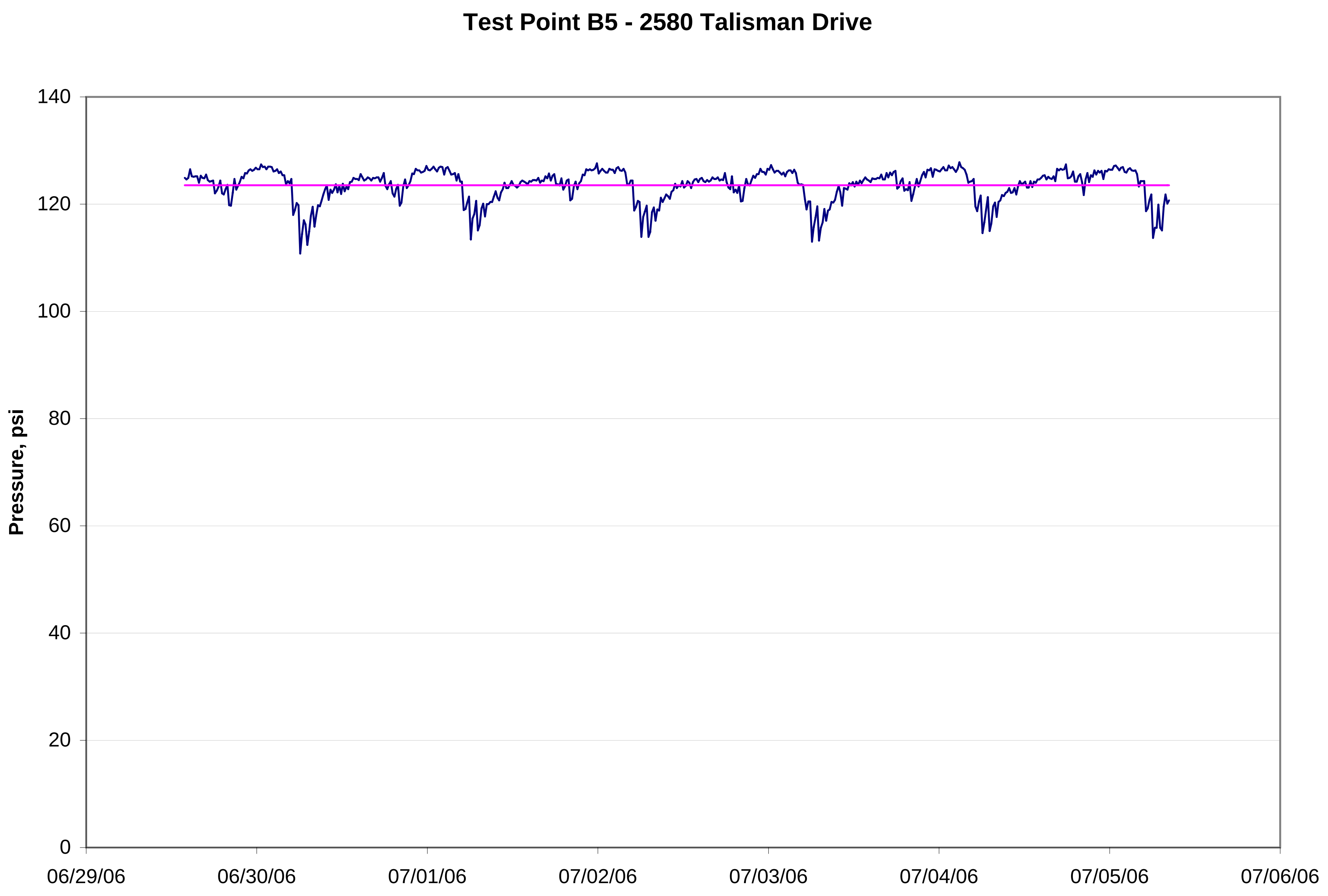
07/05/06
07/06/06



Test Point B5 - 2580 Talisman Drive
Pressure, psi
0
20
40
60
80
100
120
140
06/29/06
06/30/06
07/01/06
07/02/06
07/03/06
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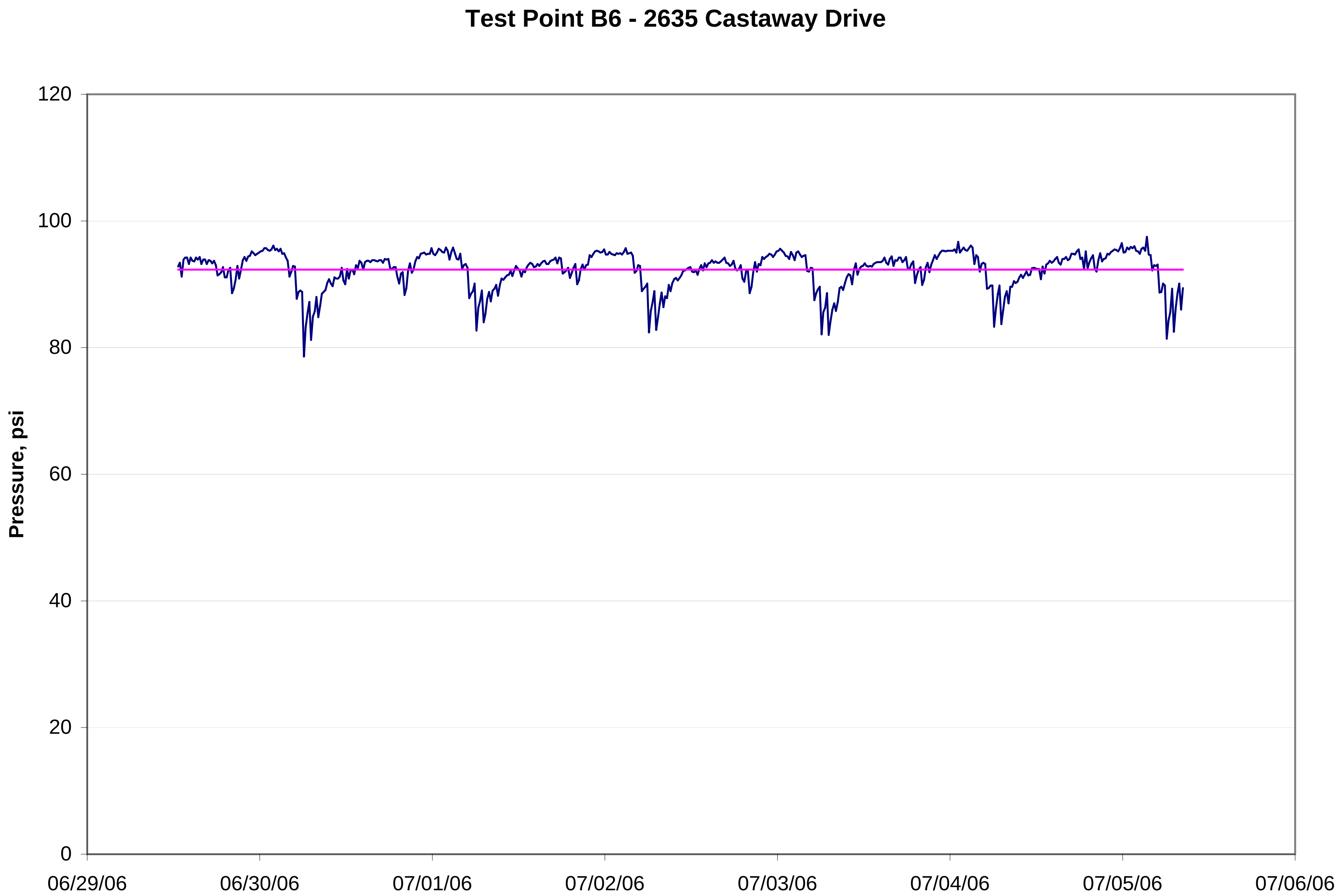
07/05/06
07/06/06


Test Point B6 - 2635 Castaway Drive
Pressure, psi
120
100
80
60
40
20
0
06/29/06
06/30/06
07/01/06
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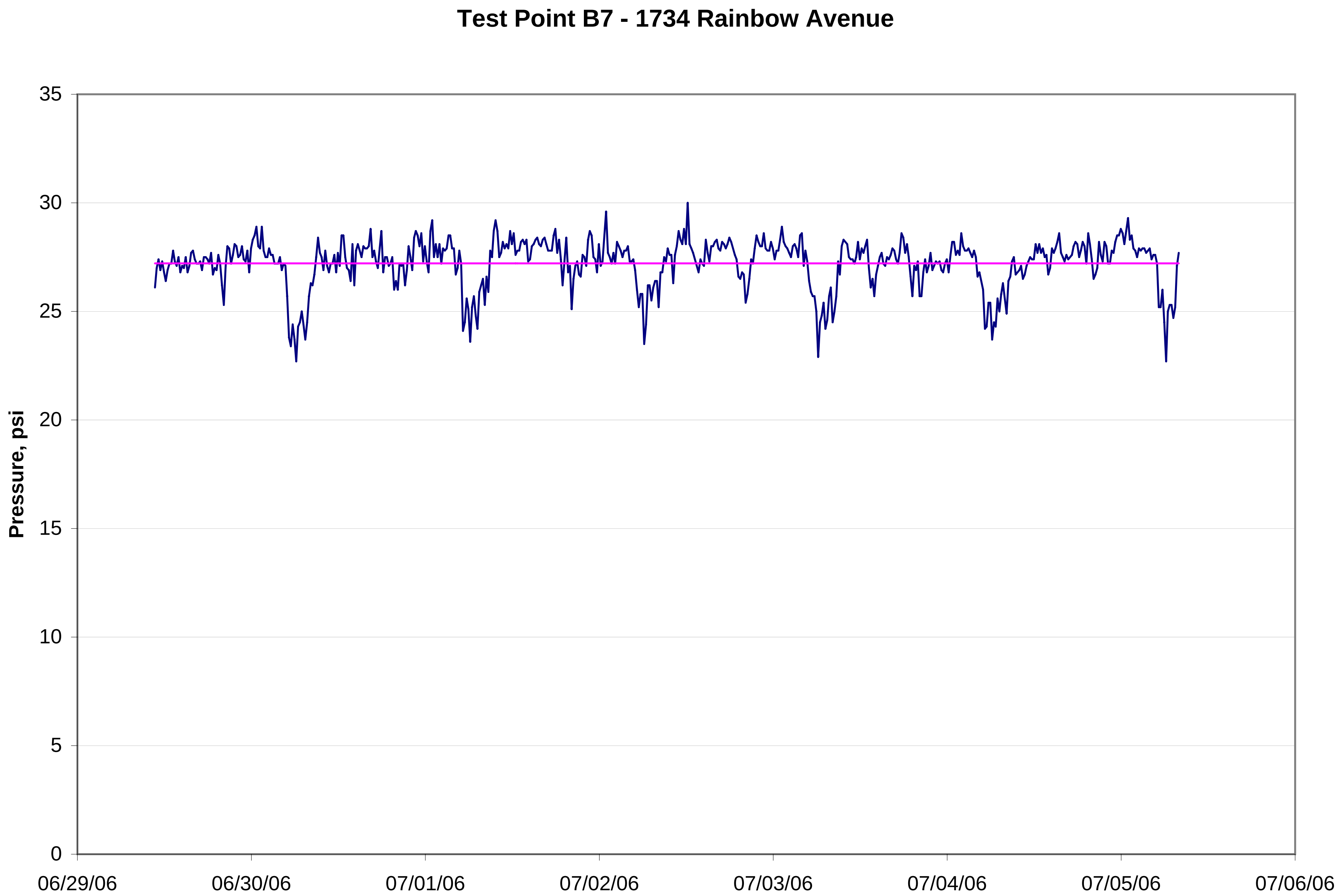
07/03/06
07/04/06
07/05/06
07/06/06



Test Point B7 - 1734 Rainbow Avenue
Pressure, psi
35
30
25
20
15
10
5
0
06/29/06
06/30/06
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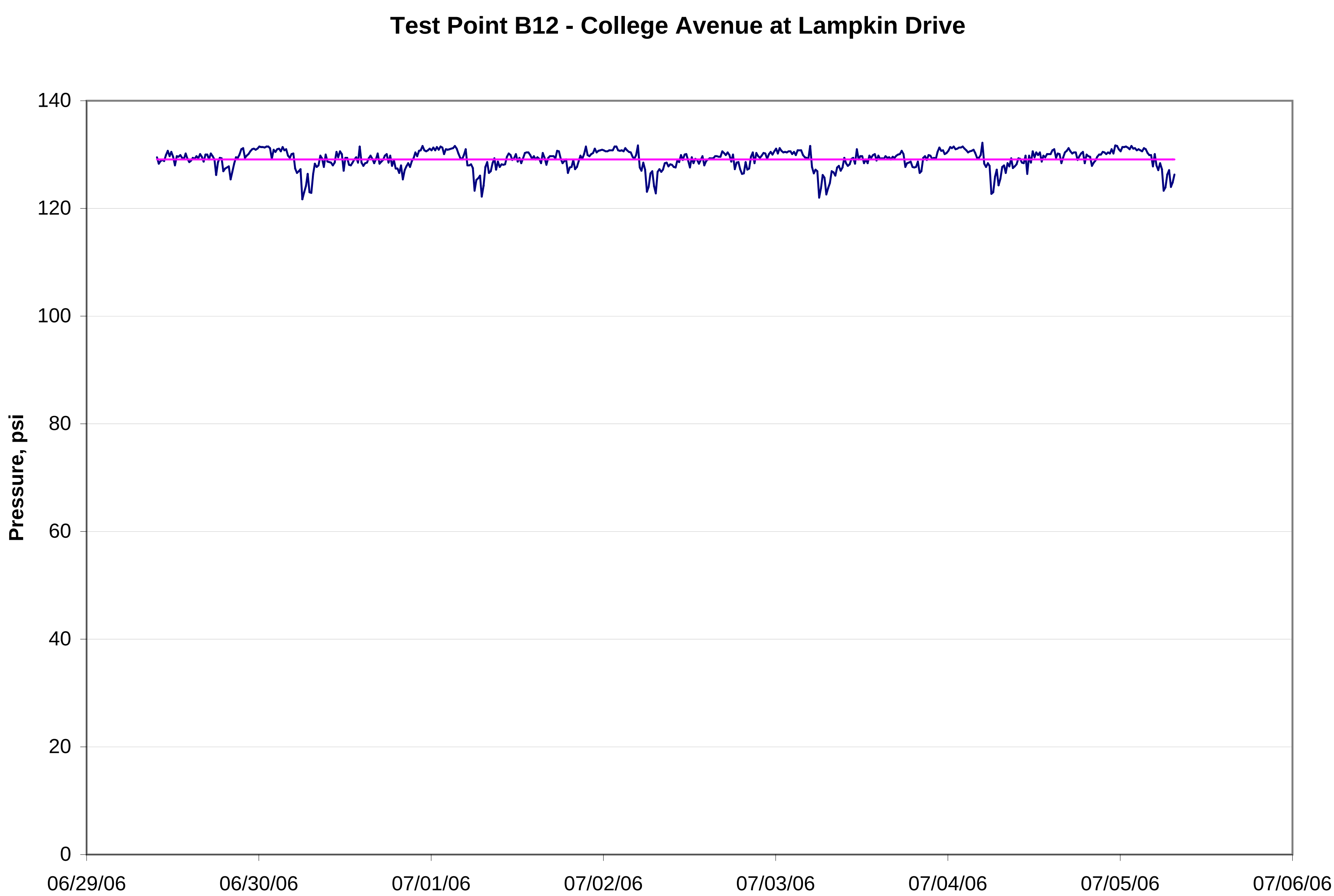
07/05/06
07/06/06



Test Point B12 - College Avenue at Lampkin Drive
Pressure, psi
0
20
40
60
80
100
120
140
06/29/06
06/30/06
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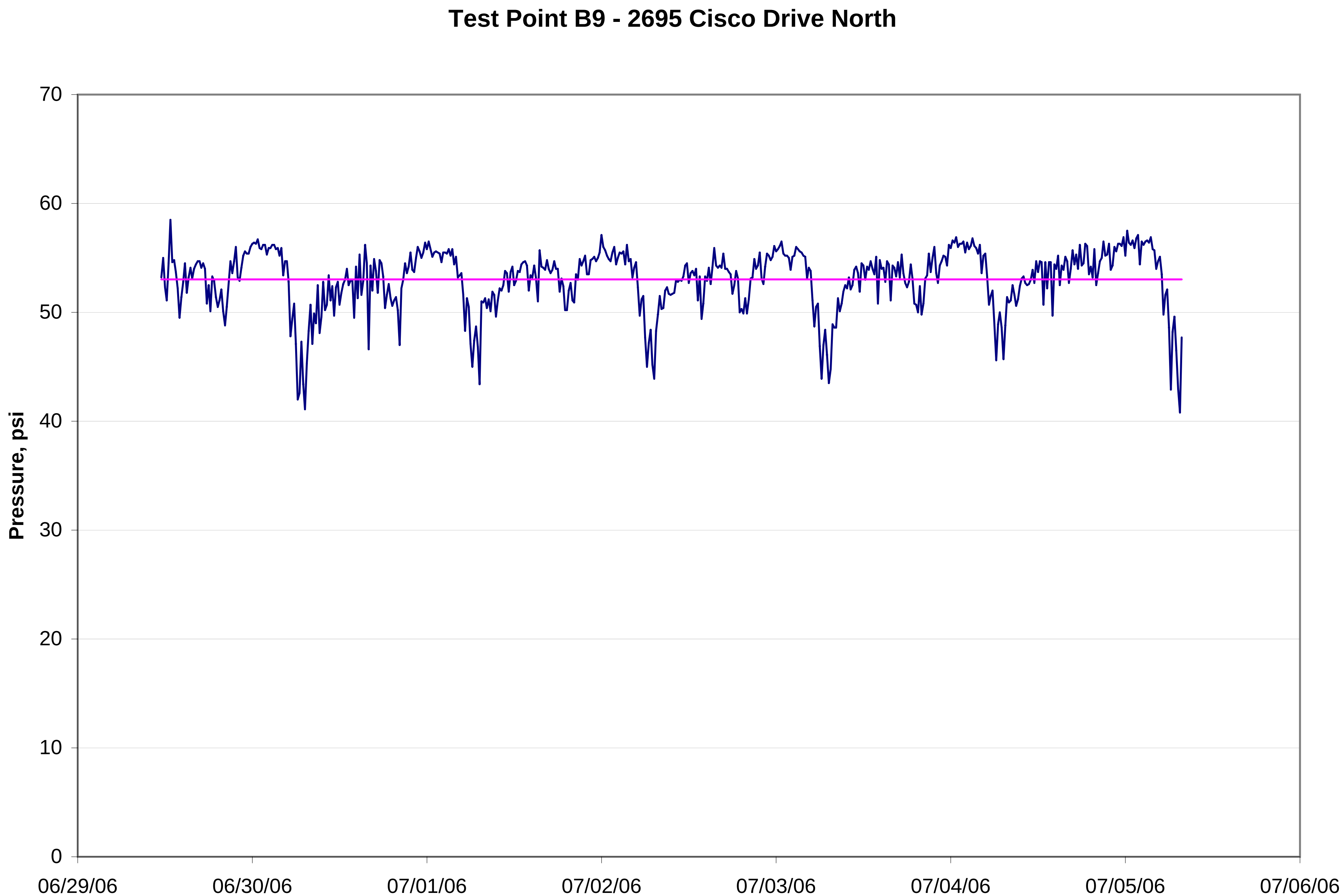
07/05/06
07/06/06


Test Point B9 - 2695 Cisco Drive North
Pressure, psi
0
10
20
30
40
50
60
70
06/29/06
06/30/06
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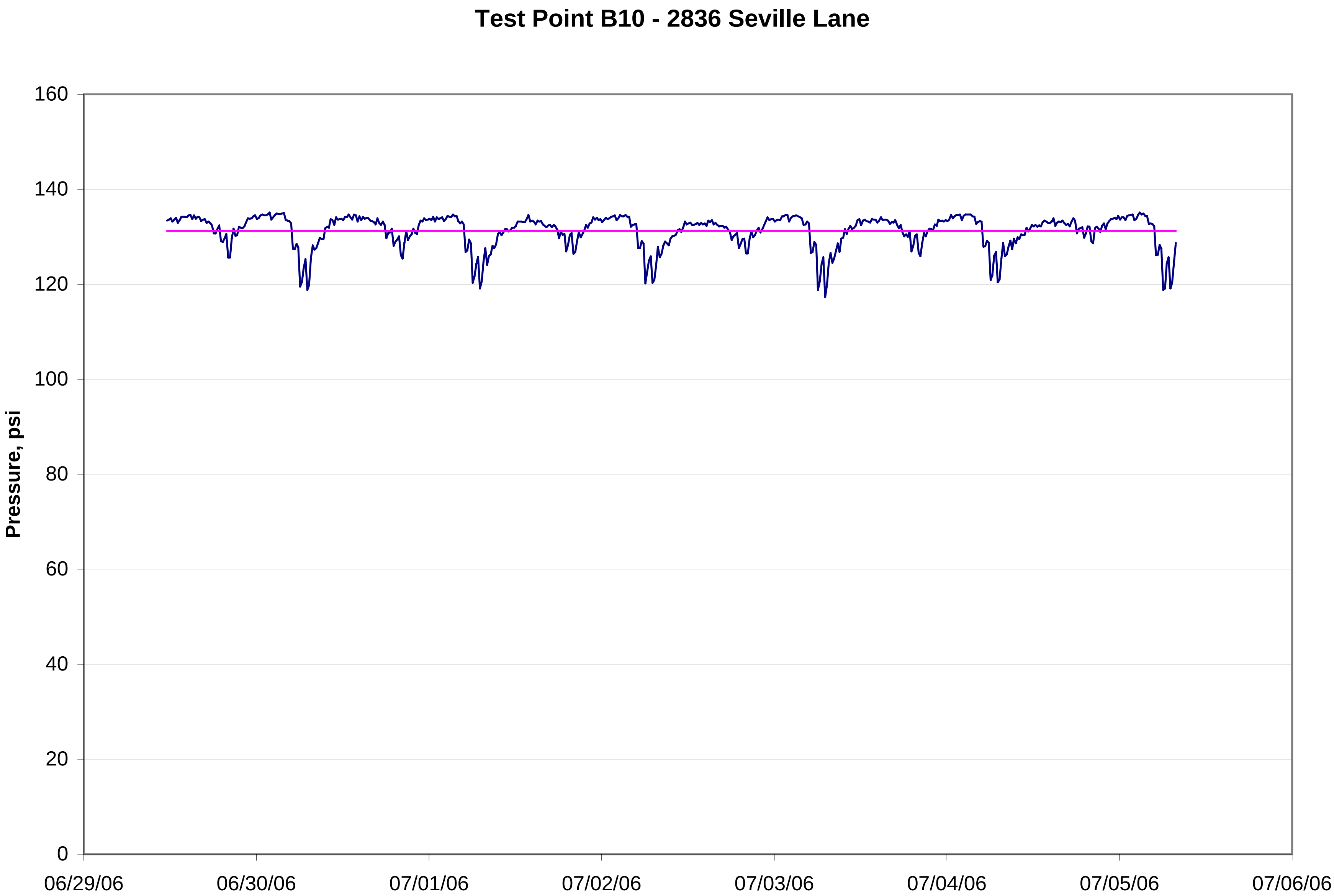
07/05/06
07/06/06



Test Point B10 - 2836 Seville Lane
Pressure, psi
160
140
120
100
80
60
40
20
0
06/29/06
06/30/06
07/01/06
07/02/06
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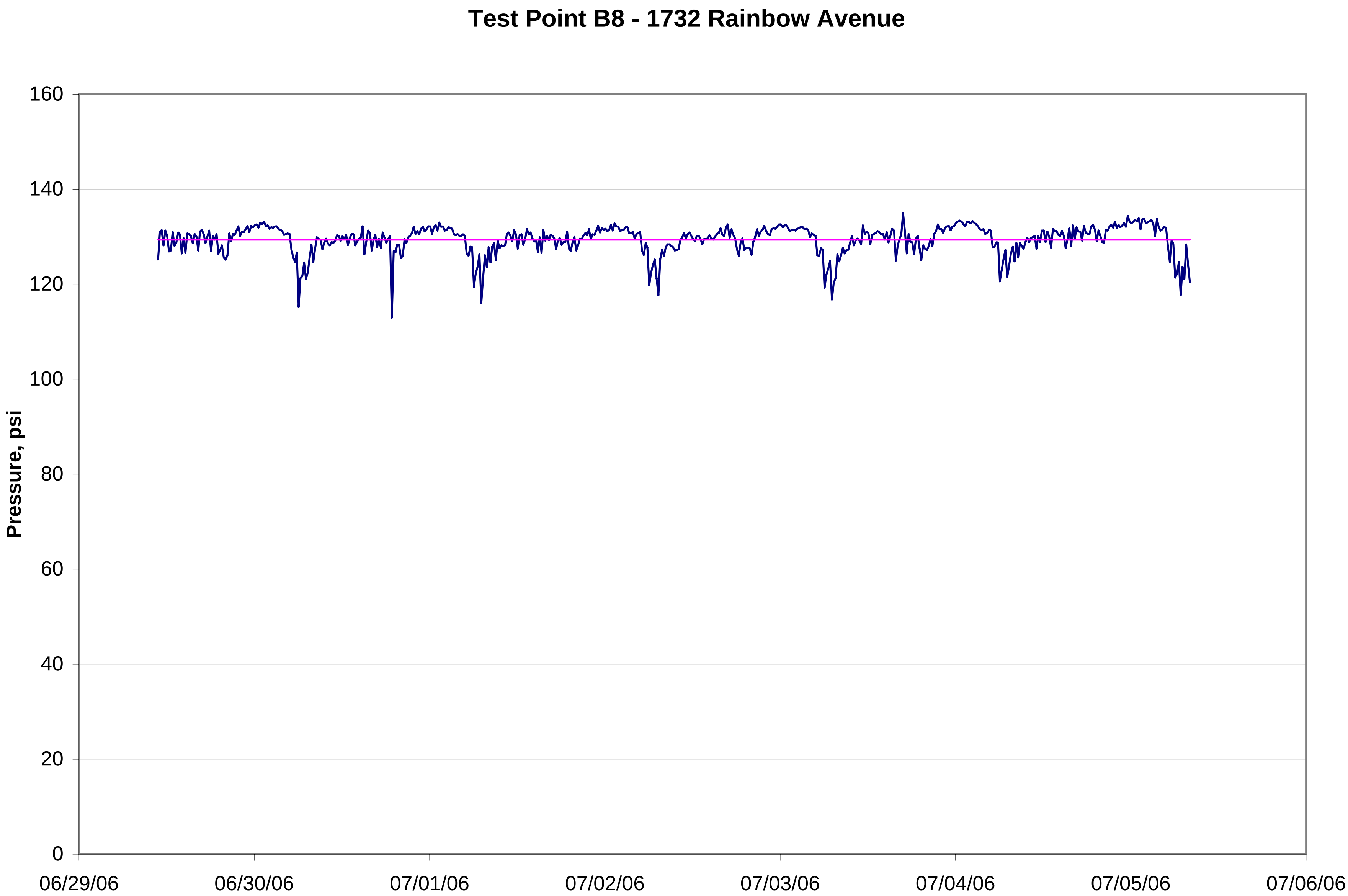
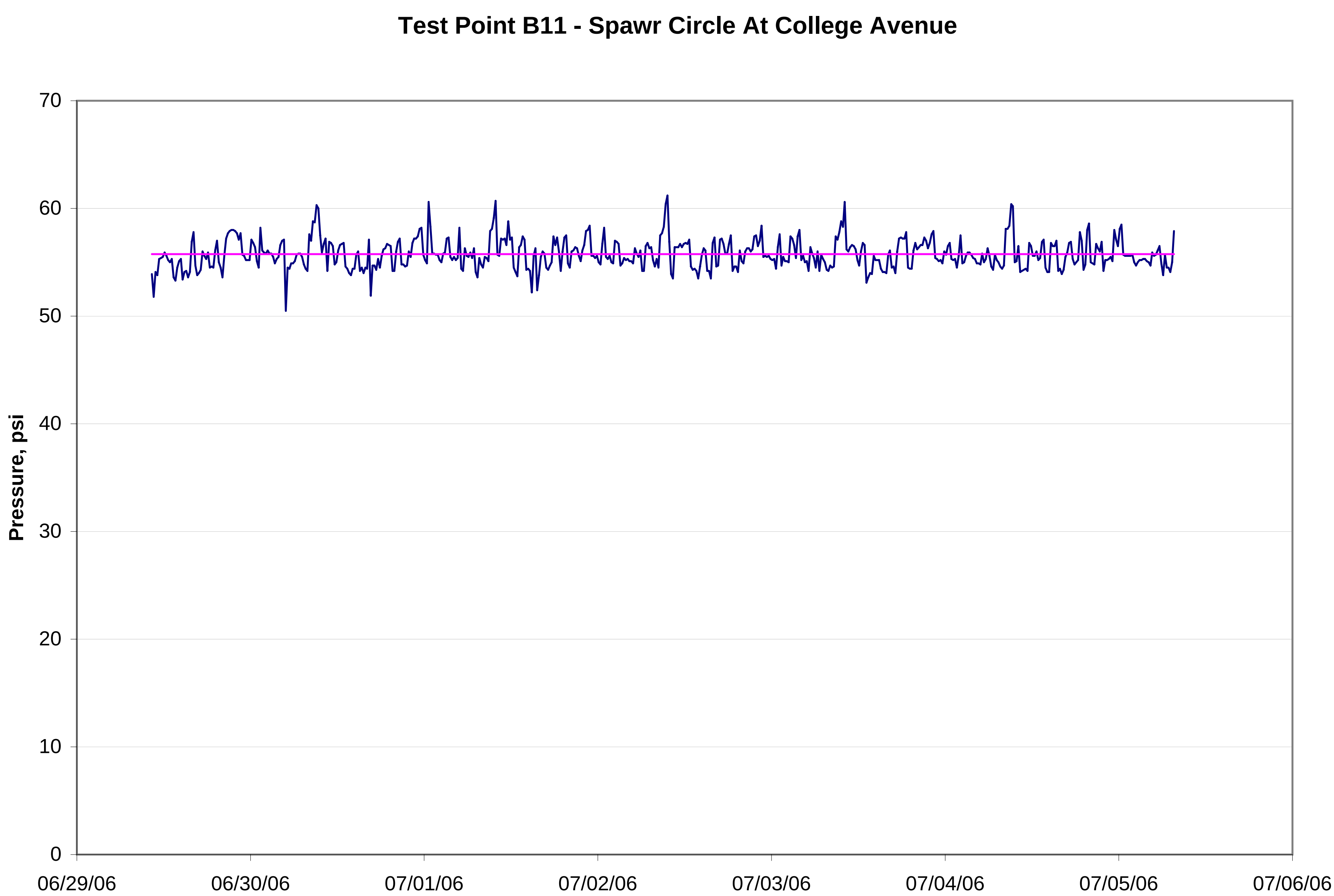
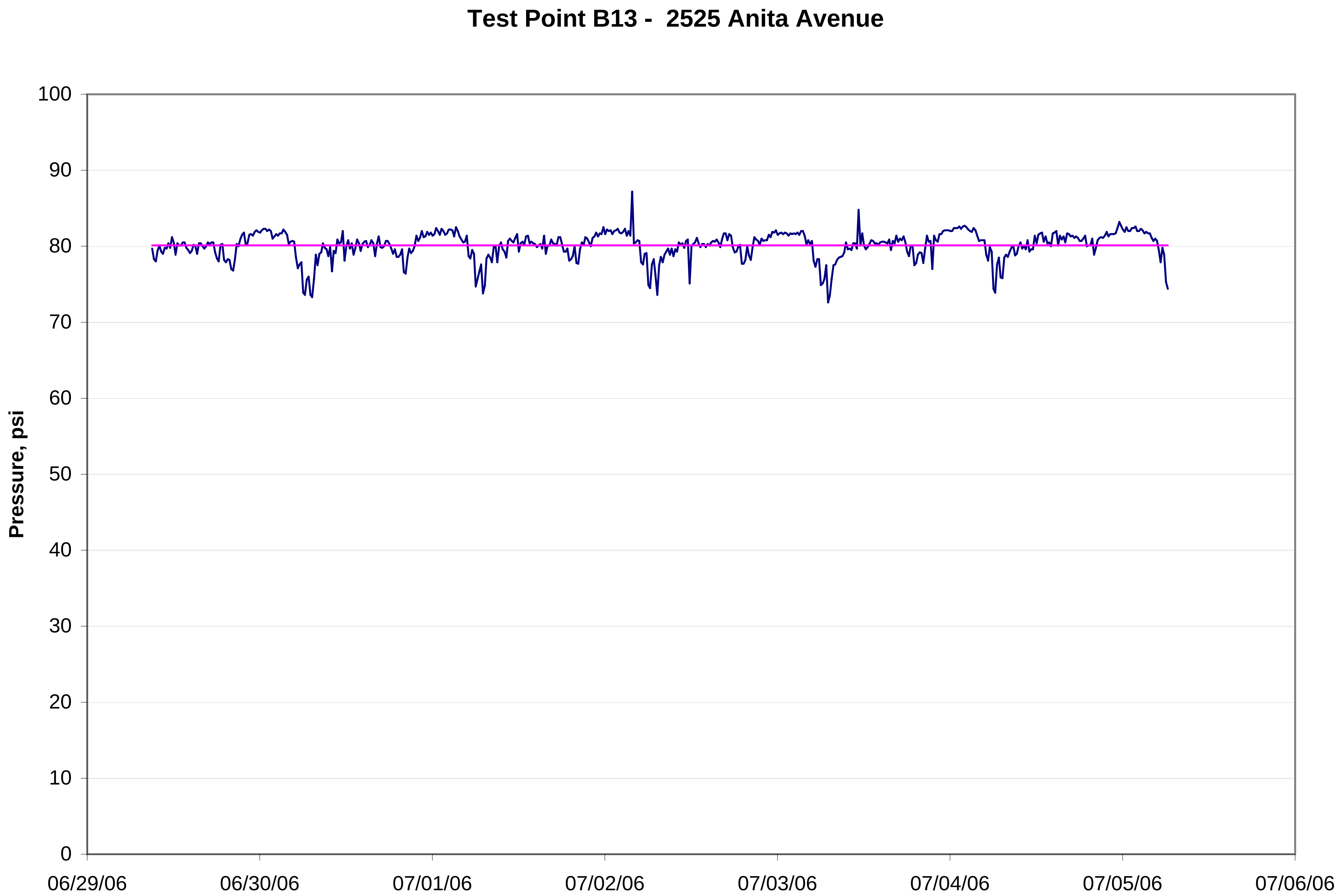
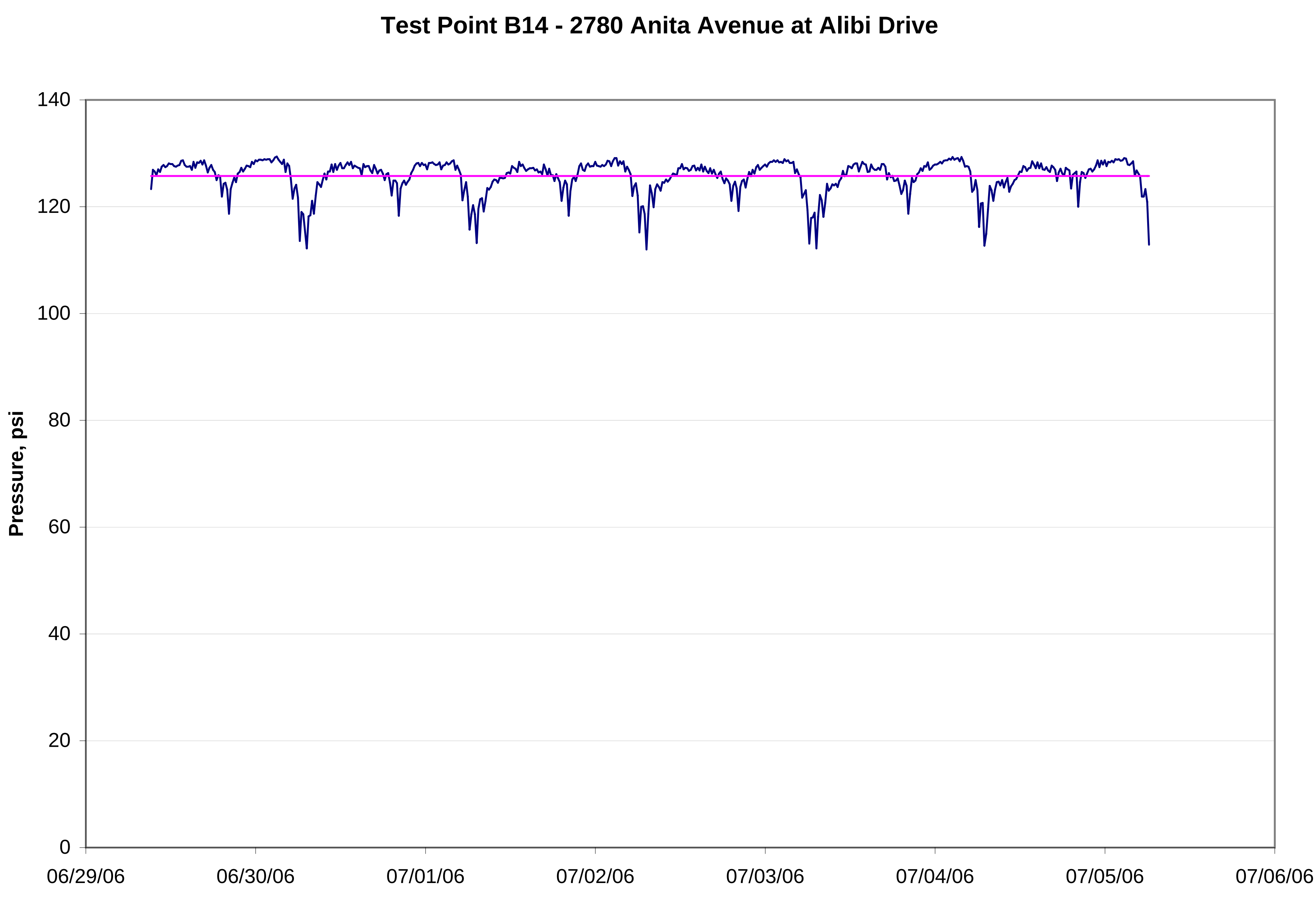
07/05/06
07/06/06

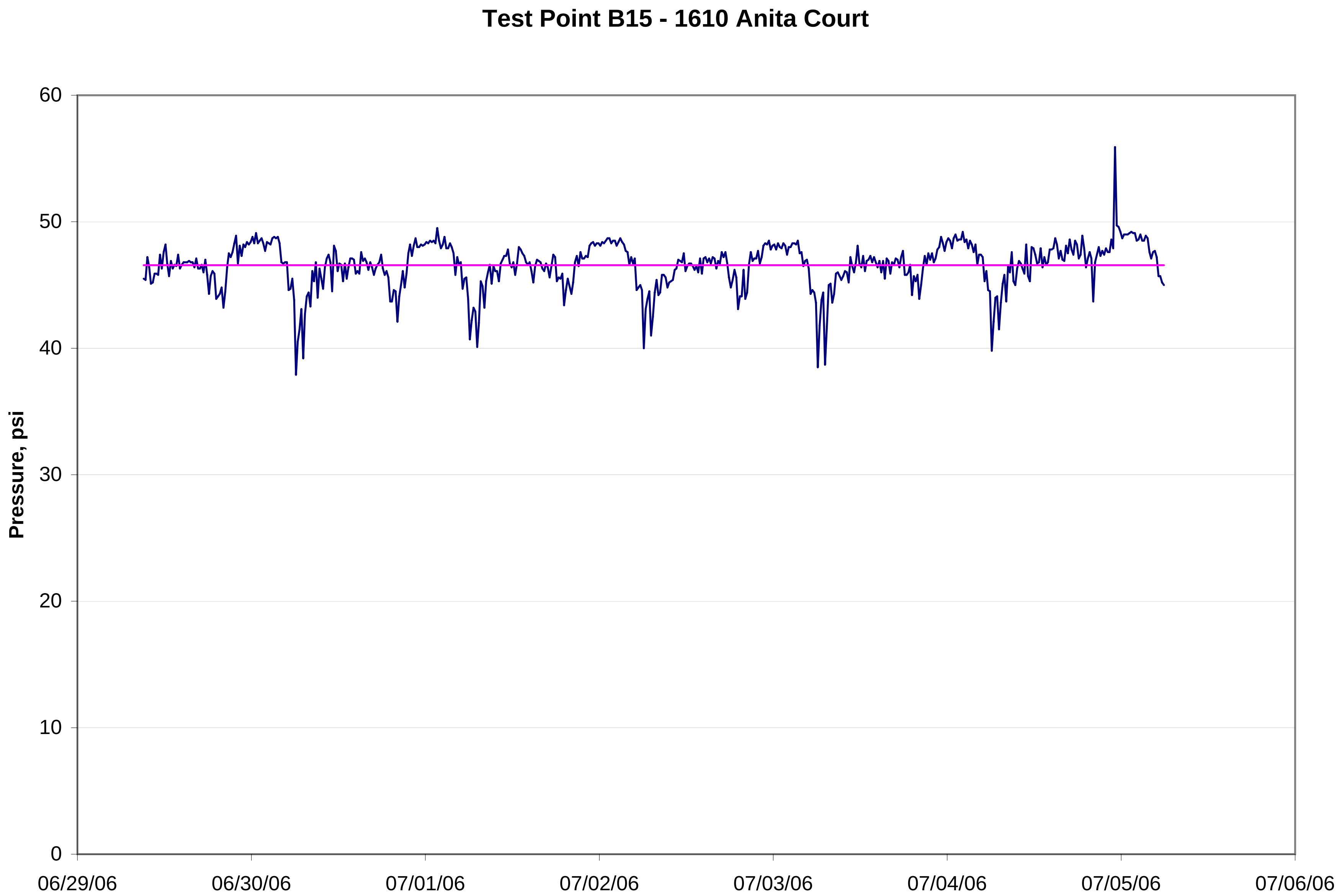


Test Point B8 - 1732 Rainbow Avenue
Pressure, psi
0
20
40
60
80
100
120
140
160
06/29/06
06/30/06
07/01/06
07/02/06
07/03/06
07/04/06
07/05/06
07/06/06

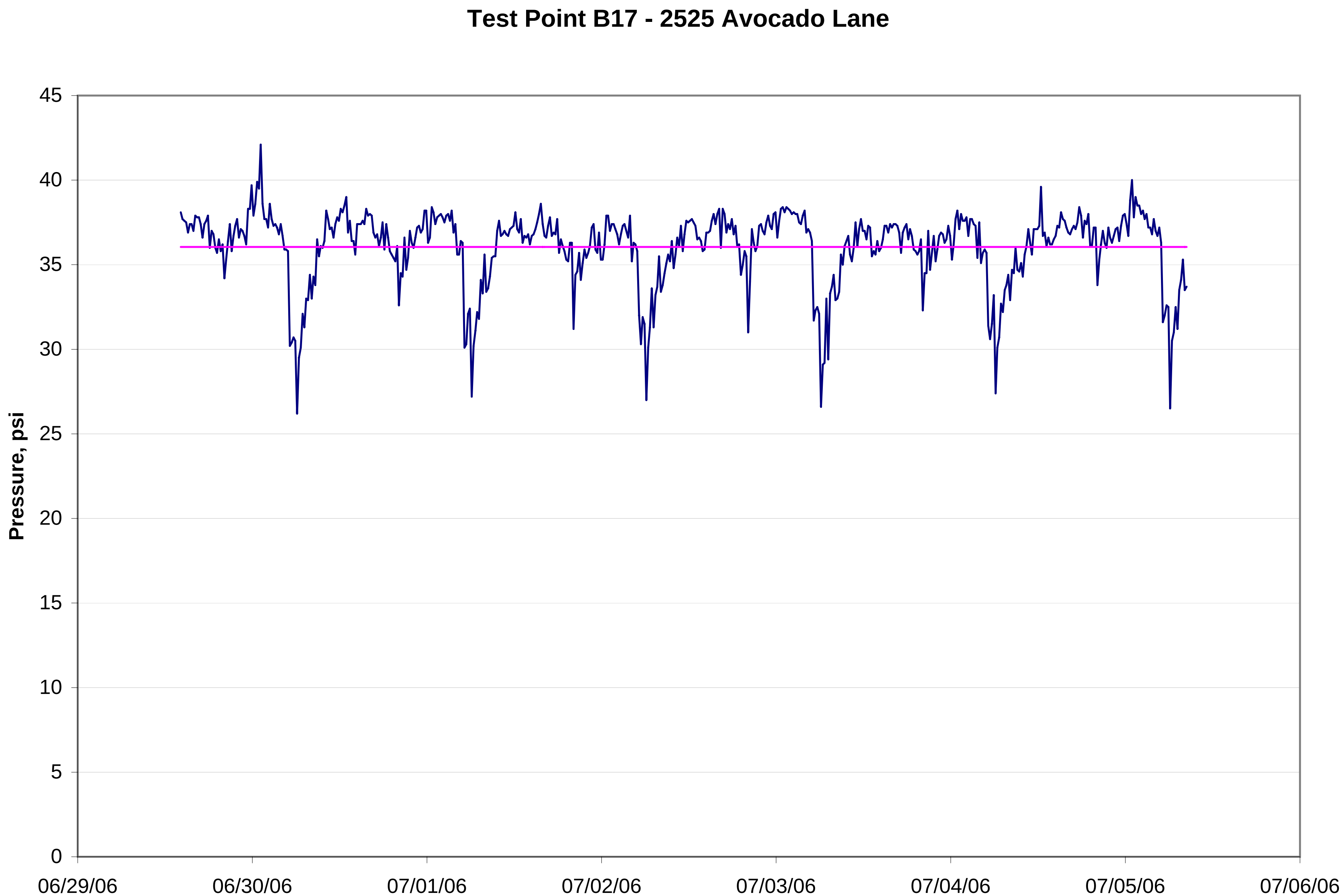

Test Point B11 - Spawr Circle At College Avenue
Pressure, psi
70
60
50
40
30
20
10
0
06/29/06
06/30/06
07/01/06
07/02/06
07/03/06
07/04/06
07/05/06
07/06/06

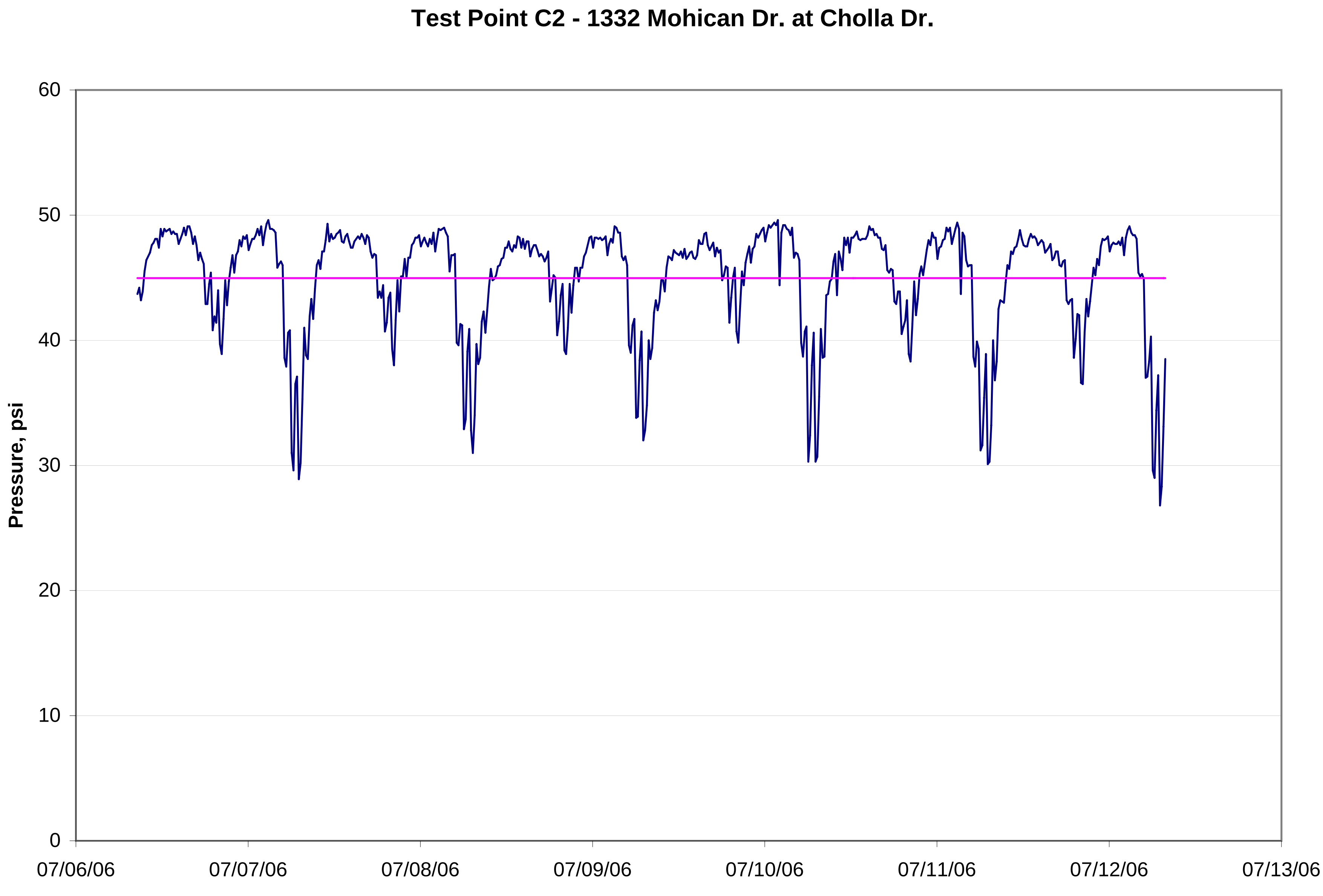

Test Point B13 - 2525 Anita Avenue
Pressure, psi
100
90
80
70
60
50
40
30
20
10
0
06/29/06
06/30/06
07/01/06
07/02/06
07/03/06
07/04/06
07/05/06
07/06/06

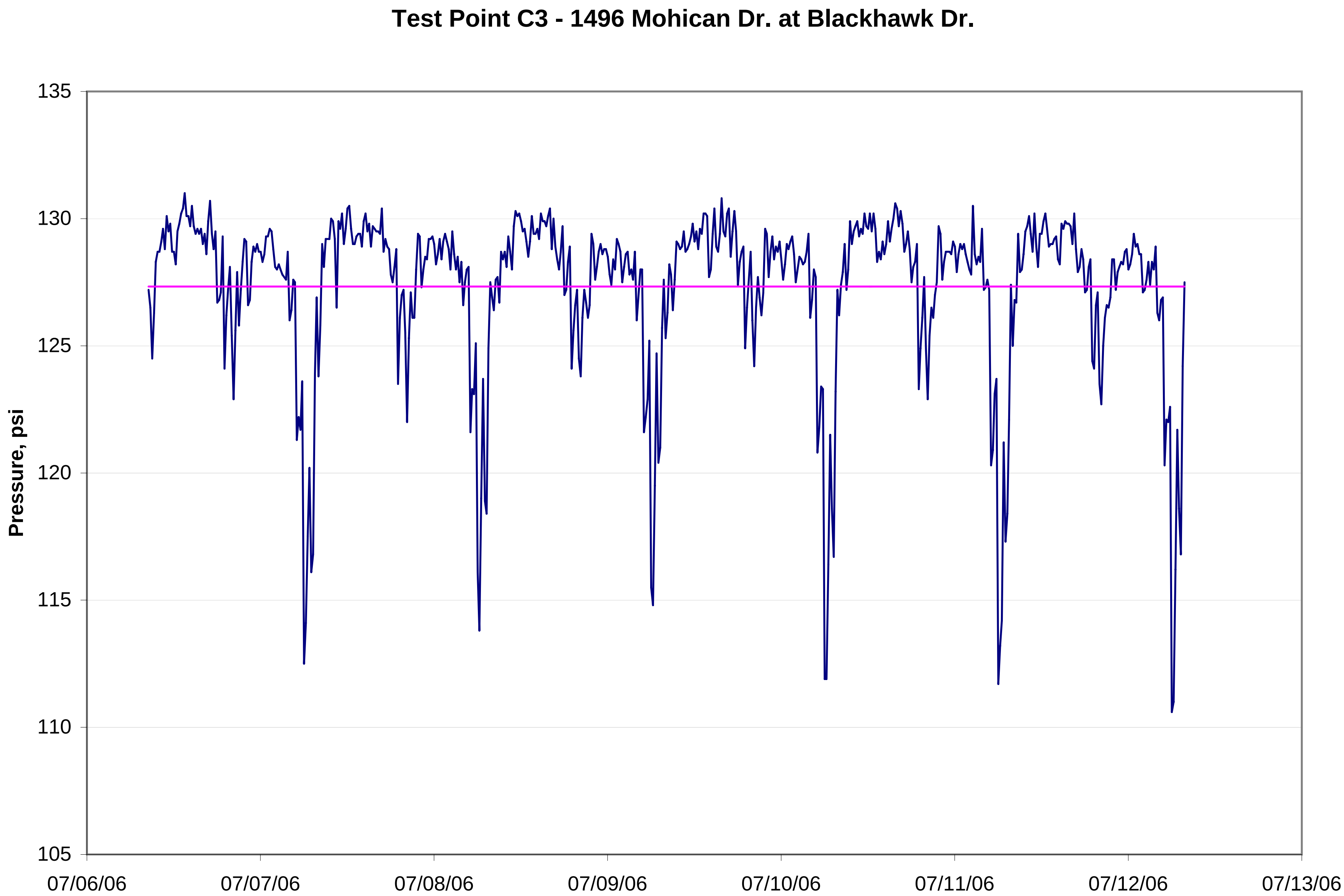

Test Point B14 - 2780 Anita Avenue at Alibi Drive
Pressure, psi
140
120
100
80
60
40
20
0
06/29/06
06/30/06
07/01/06
07/02/06
07/03/06
07/04/06
07/05/06
07/06/06

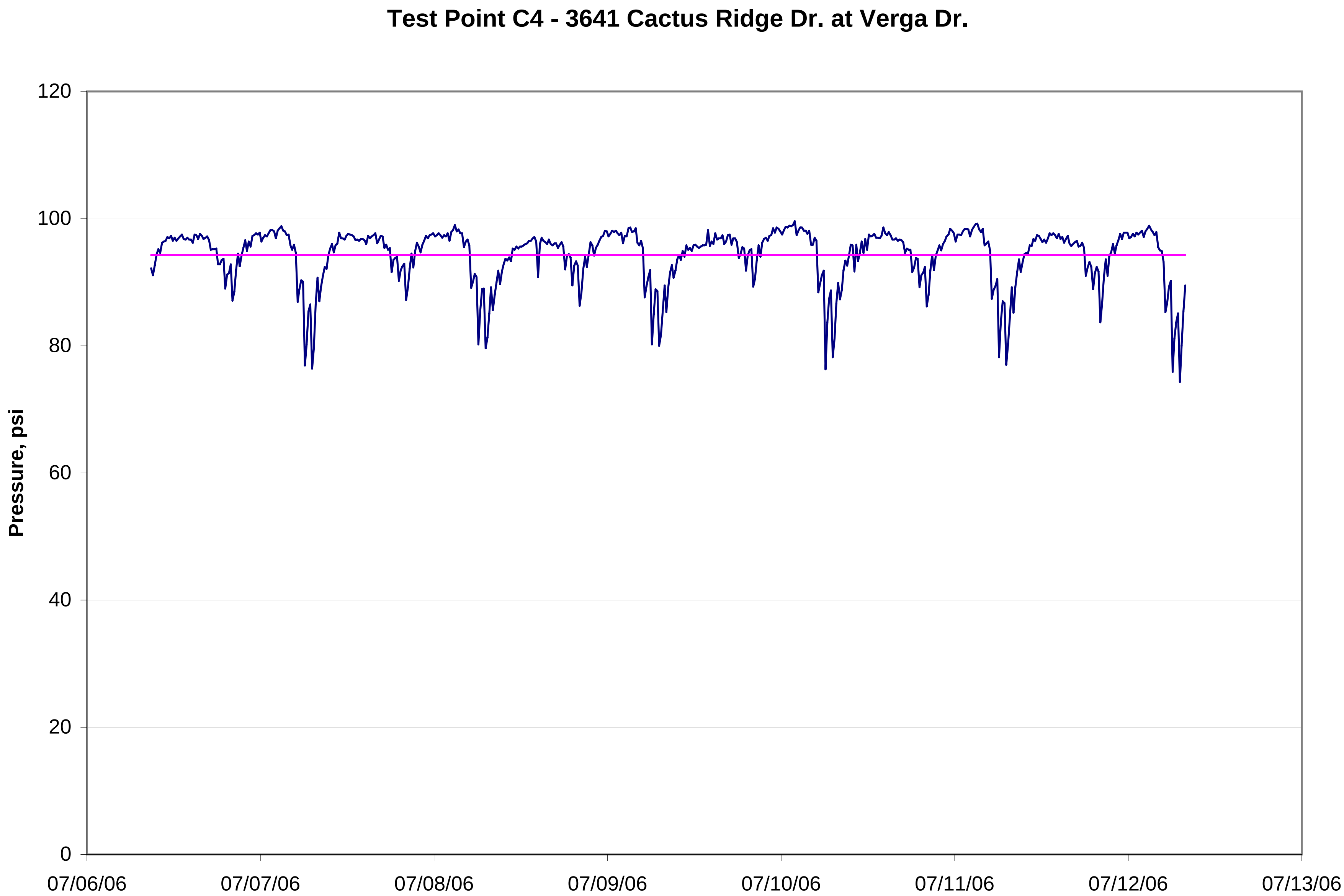


Test Point B15 - 1610 Anita Court
Pressure, psi
60
50
40
30
20
10
0
06/29/06
06/30/06
07/01/06
07/02/06
07/03/06
07/04/06
07/05/06
07/06/06


Test Point B17 - 2525 Avocado Lane
Pressure, psi
45
40
35
30
25
20
15
10
5
0
06/29/06
06/30/06
07/01/06
07/02/06
07/03/06
07/04/06
07/05/06
07/06/06

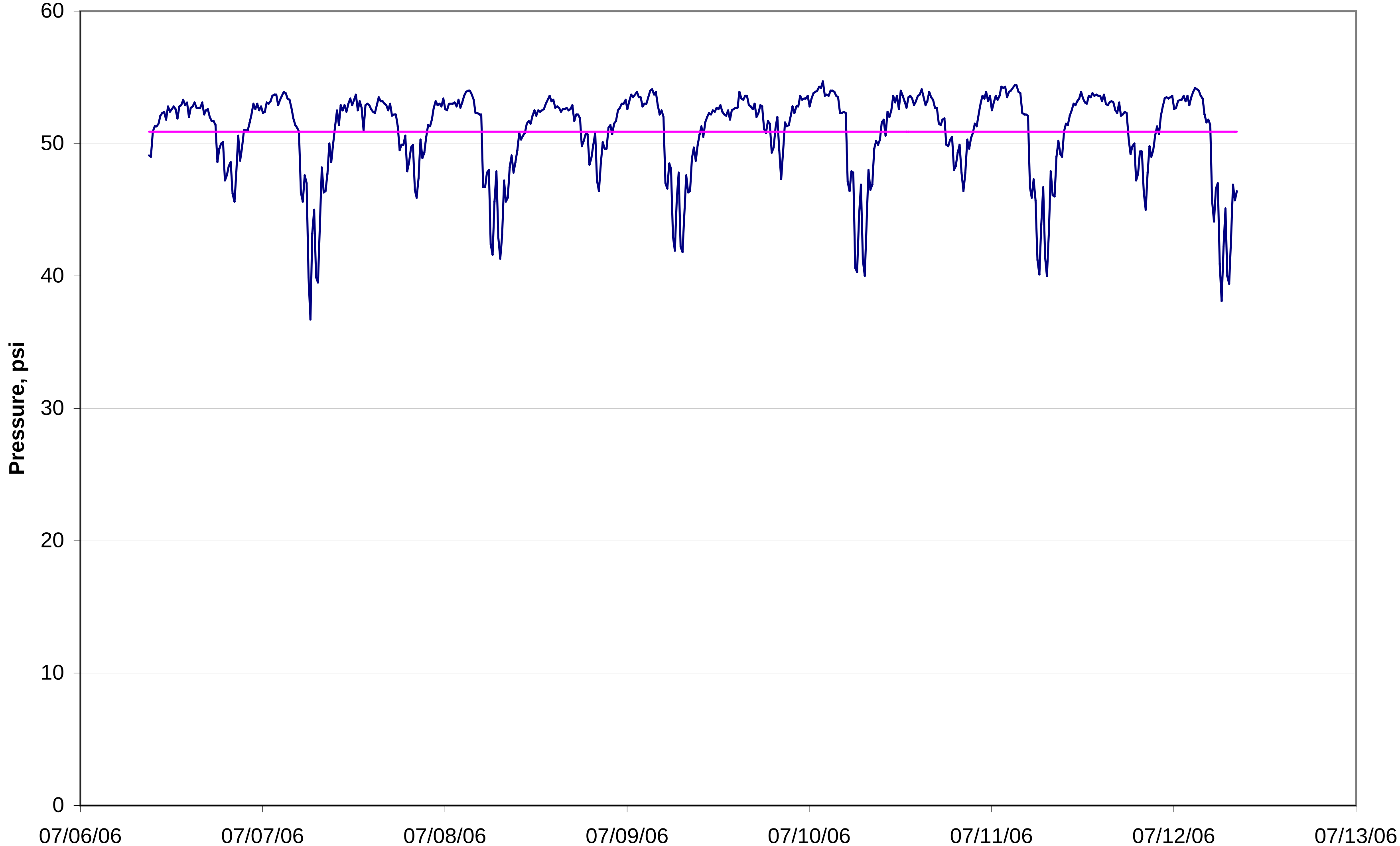

Test Point C2 - 1332 Mohican Dr. at Cholla Dr.
Pressure, psi
60
50
40
30
20
10
0
07/06/06
07/07/06
07/08/06
07/09/06
07/10/06
07/11/06
07/12/06
07/13/06

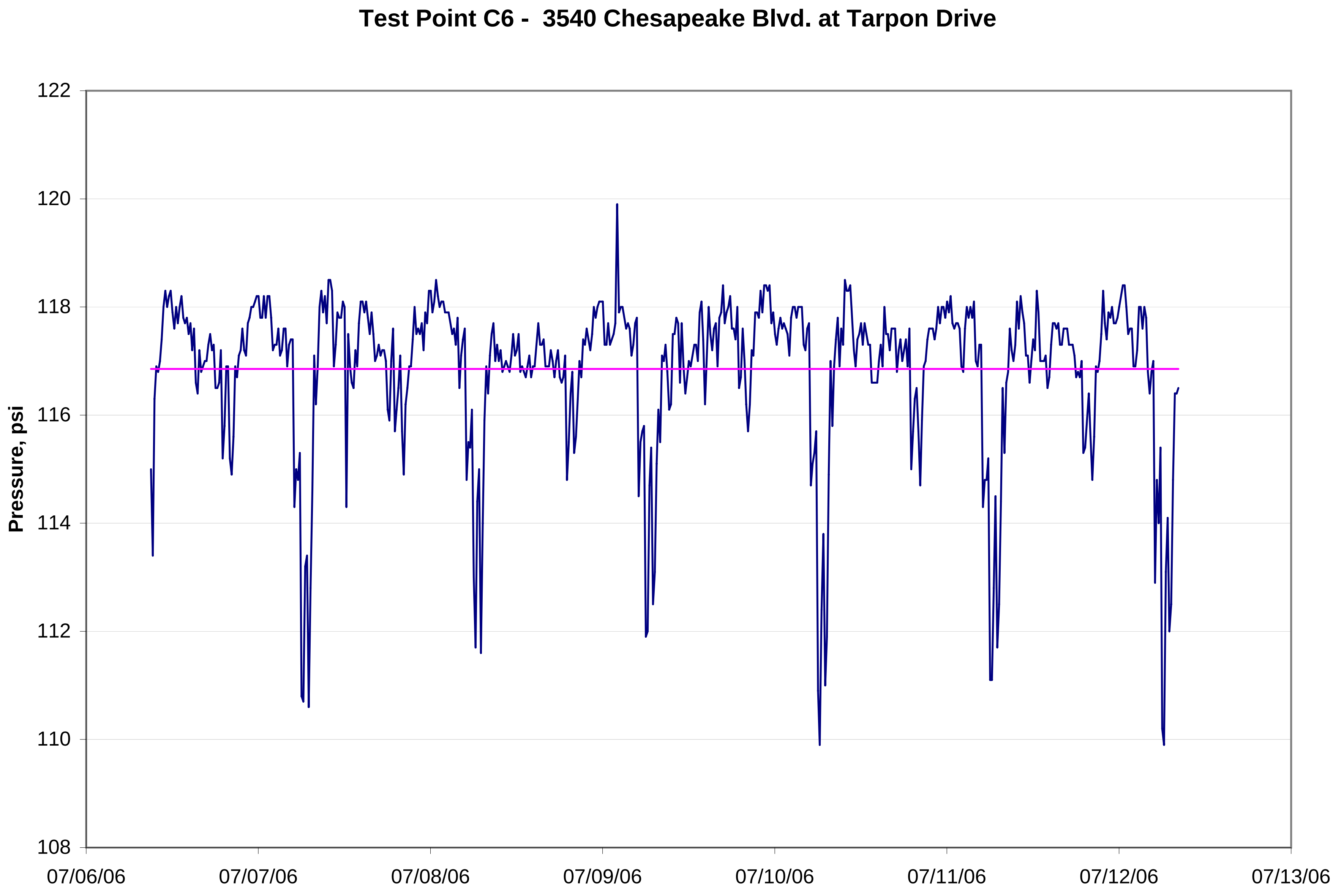

Test Point C3 - 1496 Mohican Dr. at Blackhawk Dr.
Pressure, psi
135
130
125
120
115
110
105
07/06/06
07/07/06
07/08/06
07/09/06
07/10/06
07/11/06
07/12/06
07/13/06



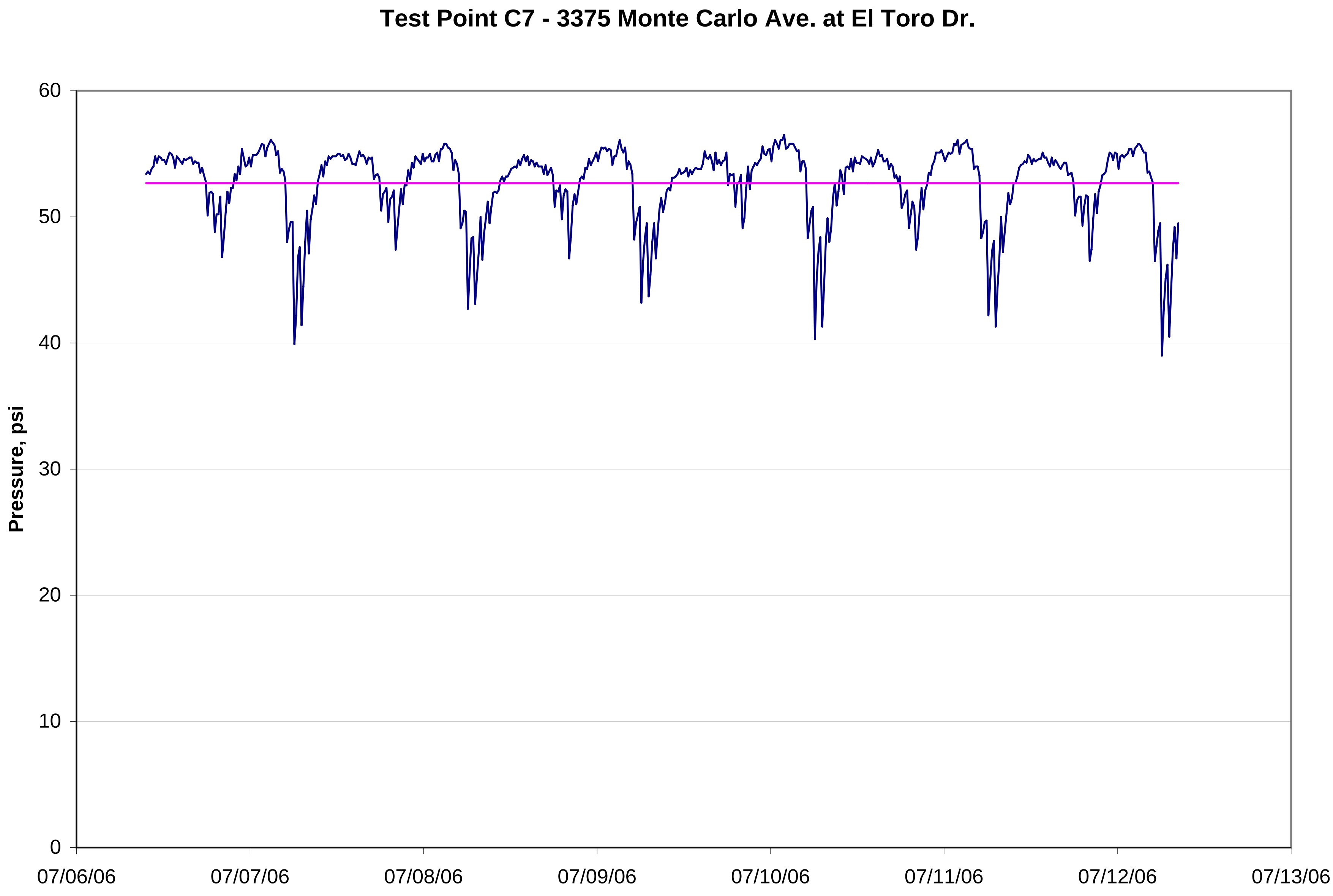
Test Point C4 - 3641 Cactus Ridge Dr. at Verga Dr.
Pressure, psi
120
100
80
60
40
20
0
07/06/06
07/07/06
07/08/06
07/09/06
07/10/06
07/11/06
07/12/06
07/13/06

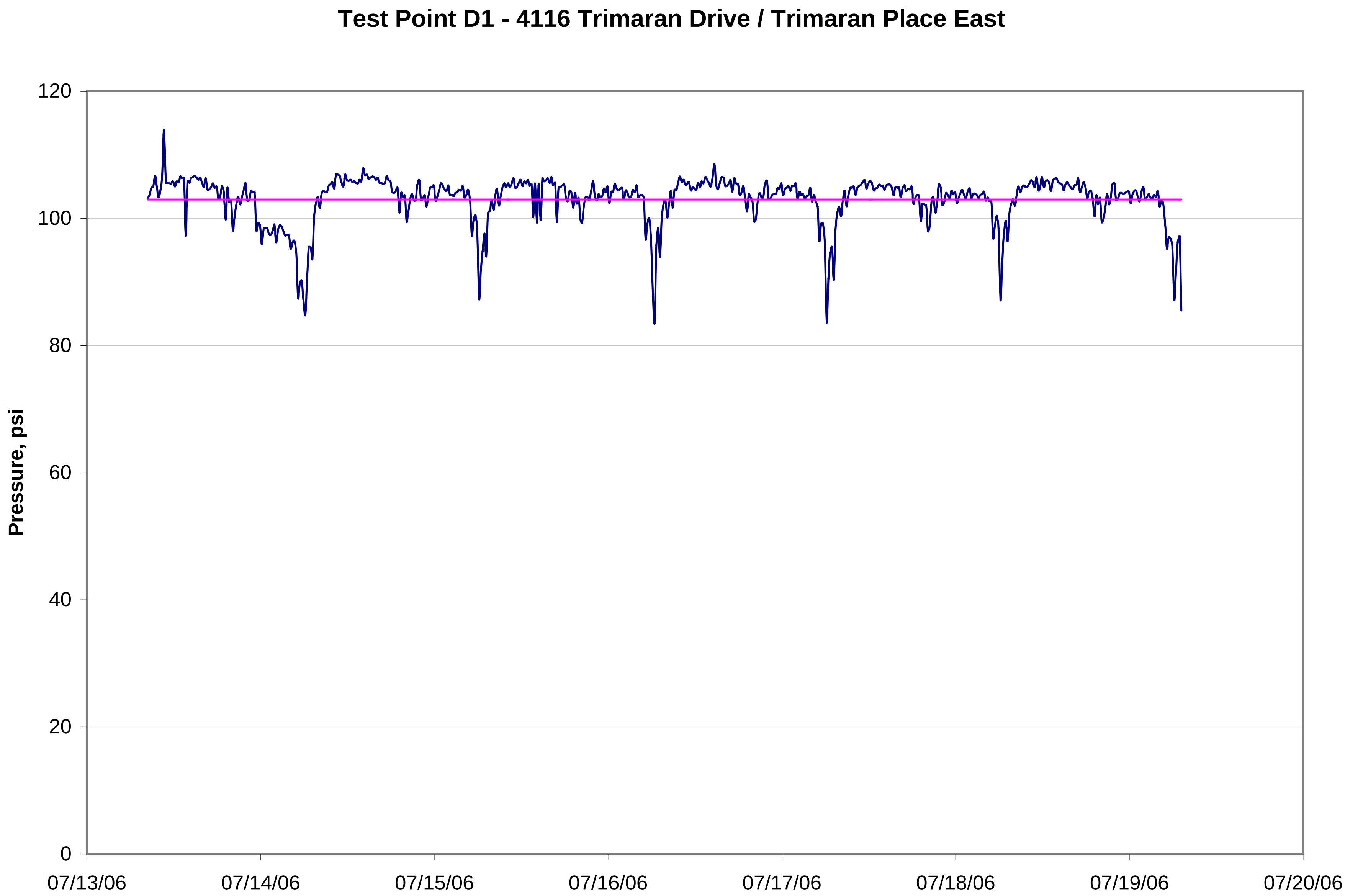
Test Point C5 - 3471 Chesapeake Blvd

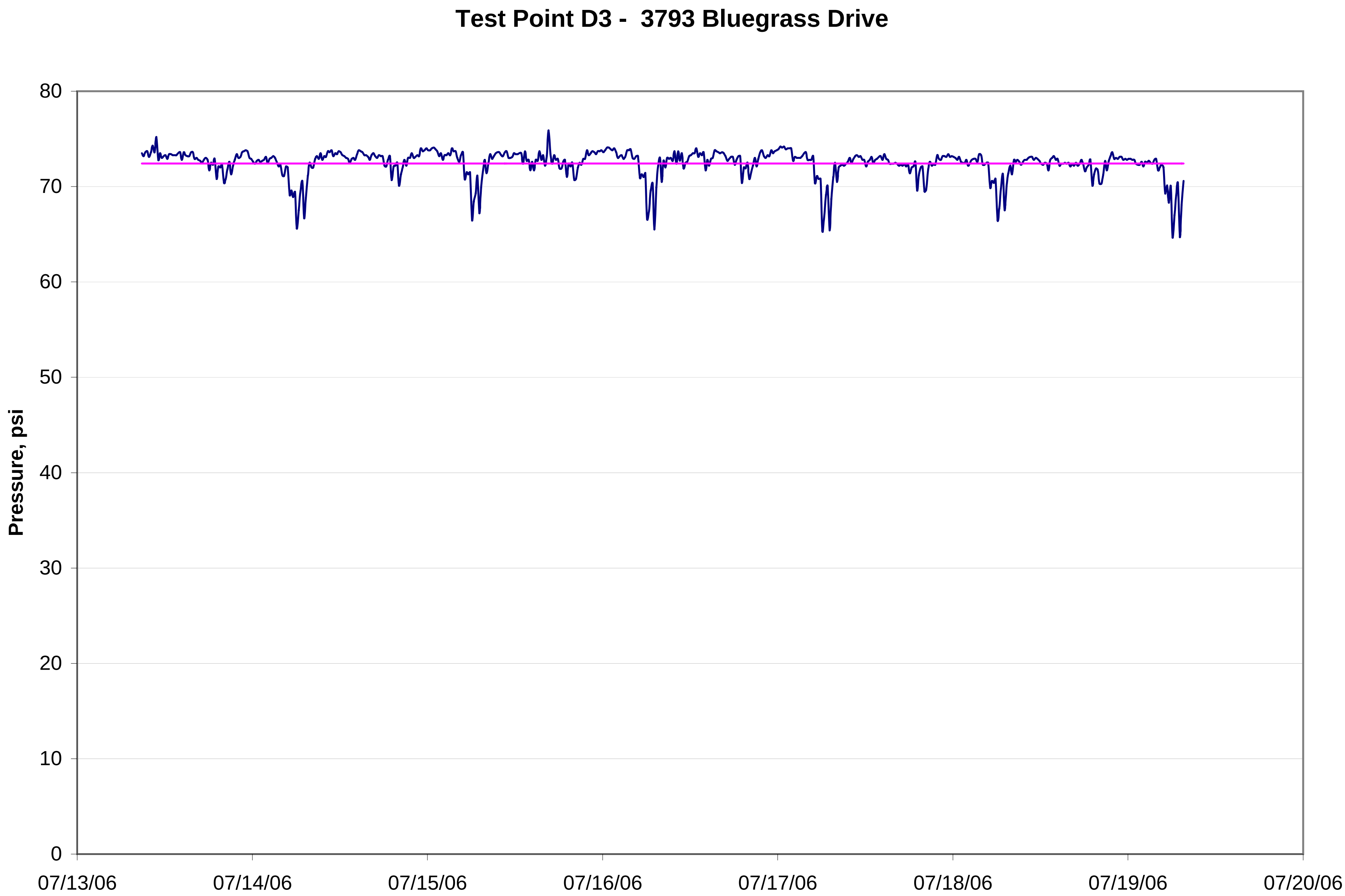


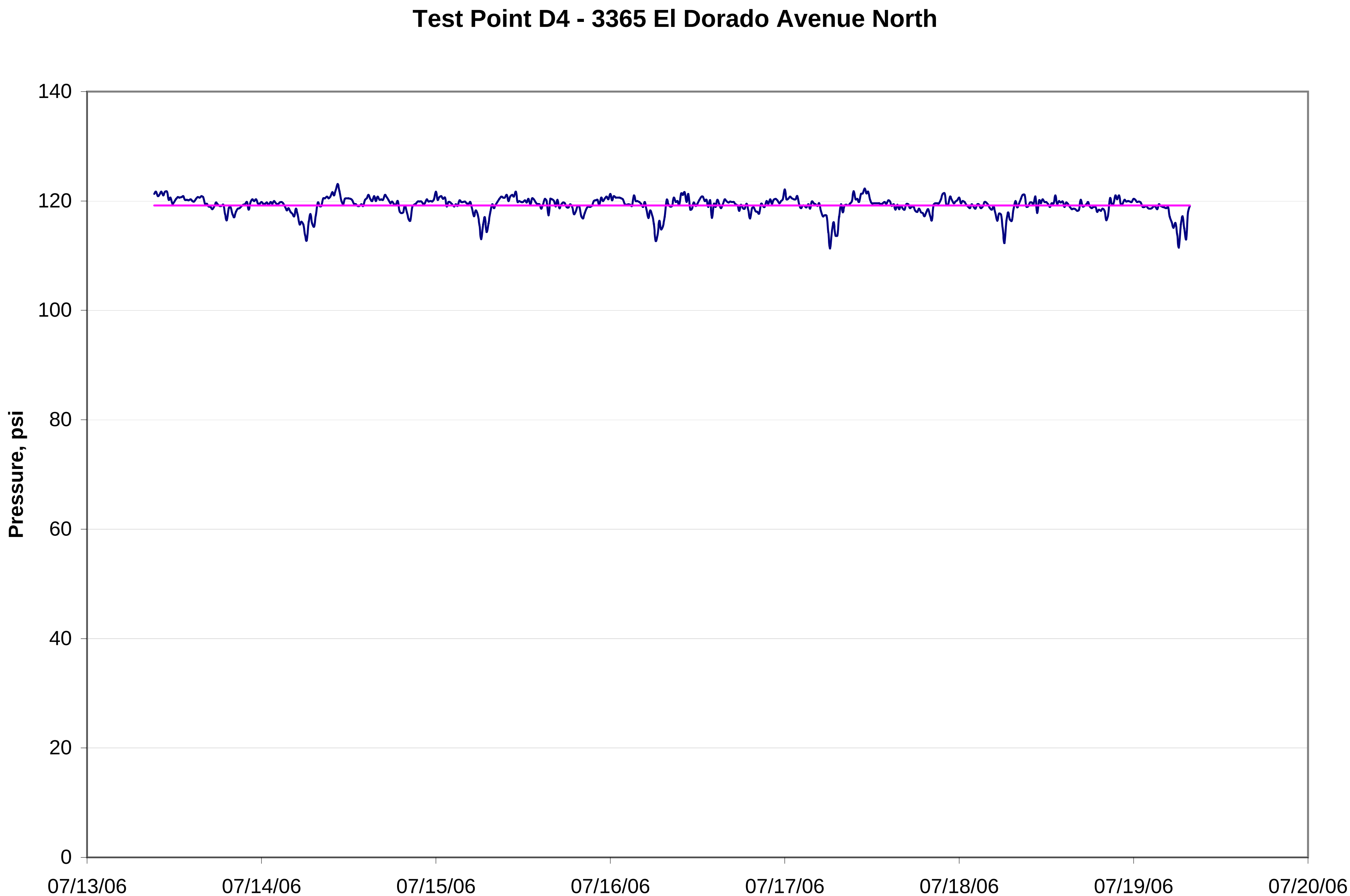


Test Point C6 - 3540 Chesapeake Blvd. at Tarpon Drive
Pressure, psi
122
120
118
116
114
112
110
108
07/06/06
07/07/06
07/08/06
07/09/06
07/10/06
07/11/06
07/12/06
07/13/06


Test Point C7 - 3375 Monte Carlo Ave. at El Toro Dr.
Pressure, psi
60
50
40
30
20
10
0
07/06/06
07/07/06
07/08/06
07/09/06
07/10/06
07/11/06
07/12/06
07/13/06

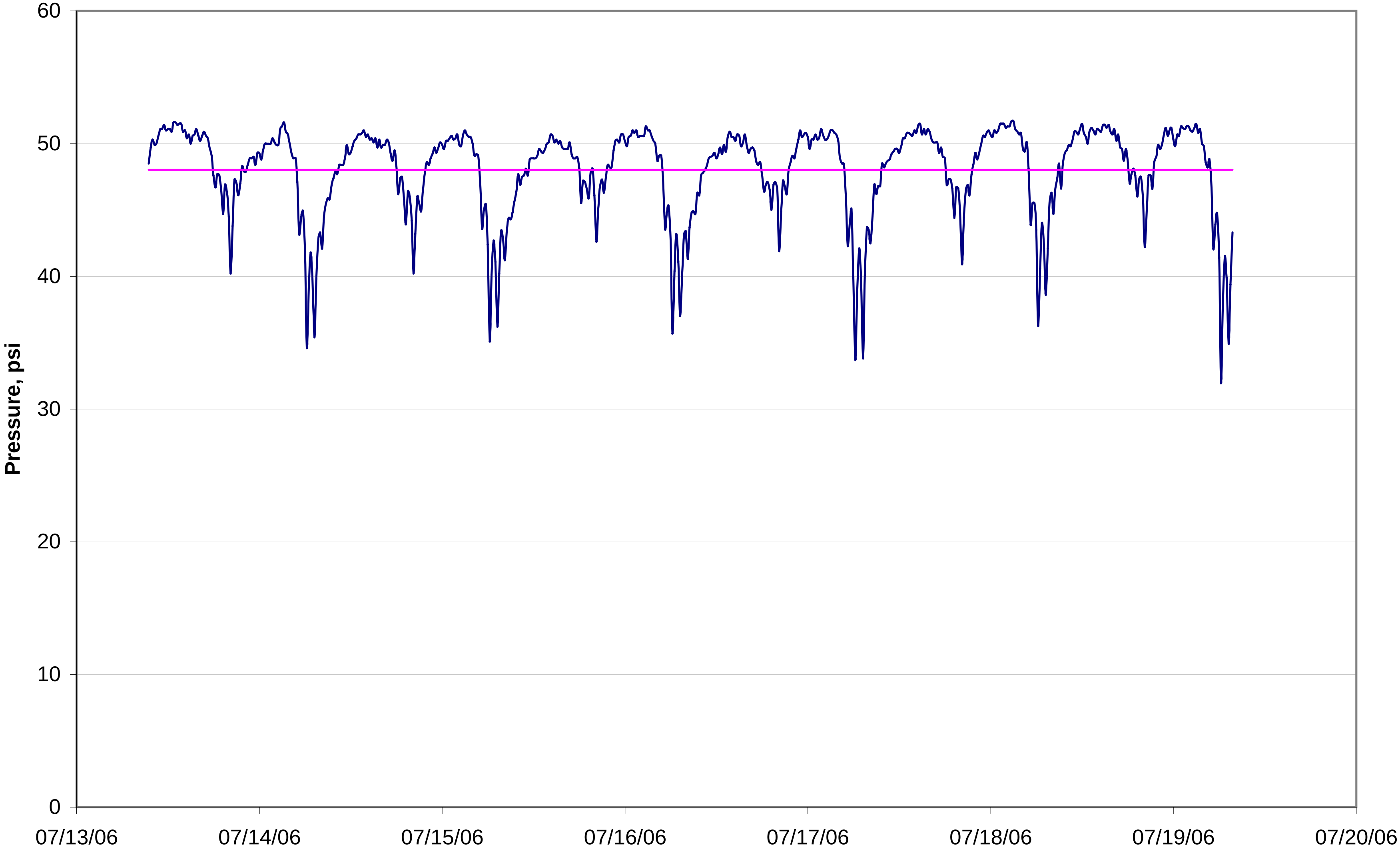

Test Point D1 - 4116 Trimaran Drive / Trimaran Place East
Pressure, psi
120
100
80
60
40
20
0
07/13/06
07/14/06
07/15/06
07/16/06
07/17/06
07/18/06
07/19/06
07/20/06

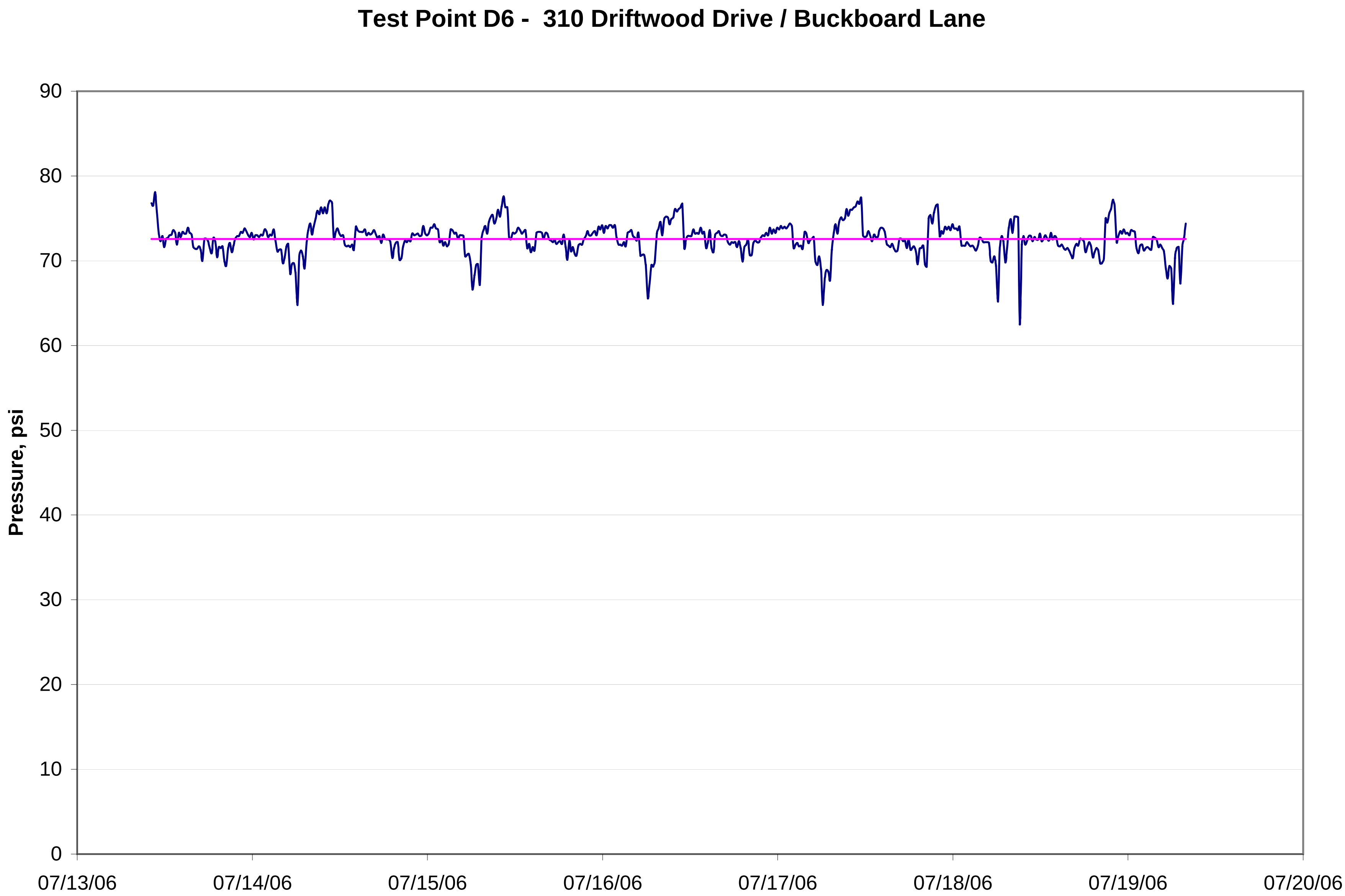

Test Point D3 - 3793 Bluegrass Drive
Pressure, psi
80
70
60
50
40
30
20
10
0
07/13/06
07/14/06
07/15/06
07/16/06
07/17/06
07/18/06
07/19/06
07/20/06

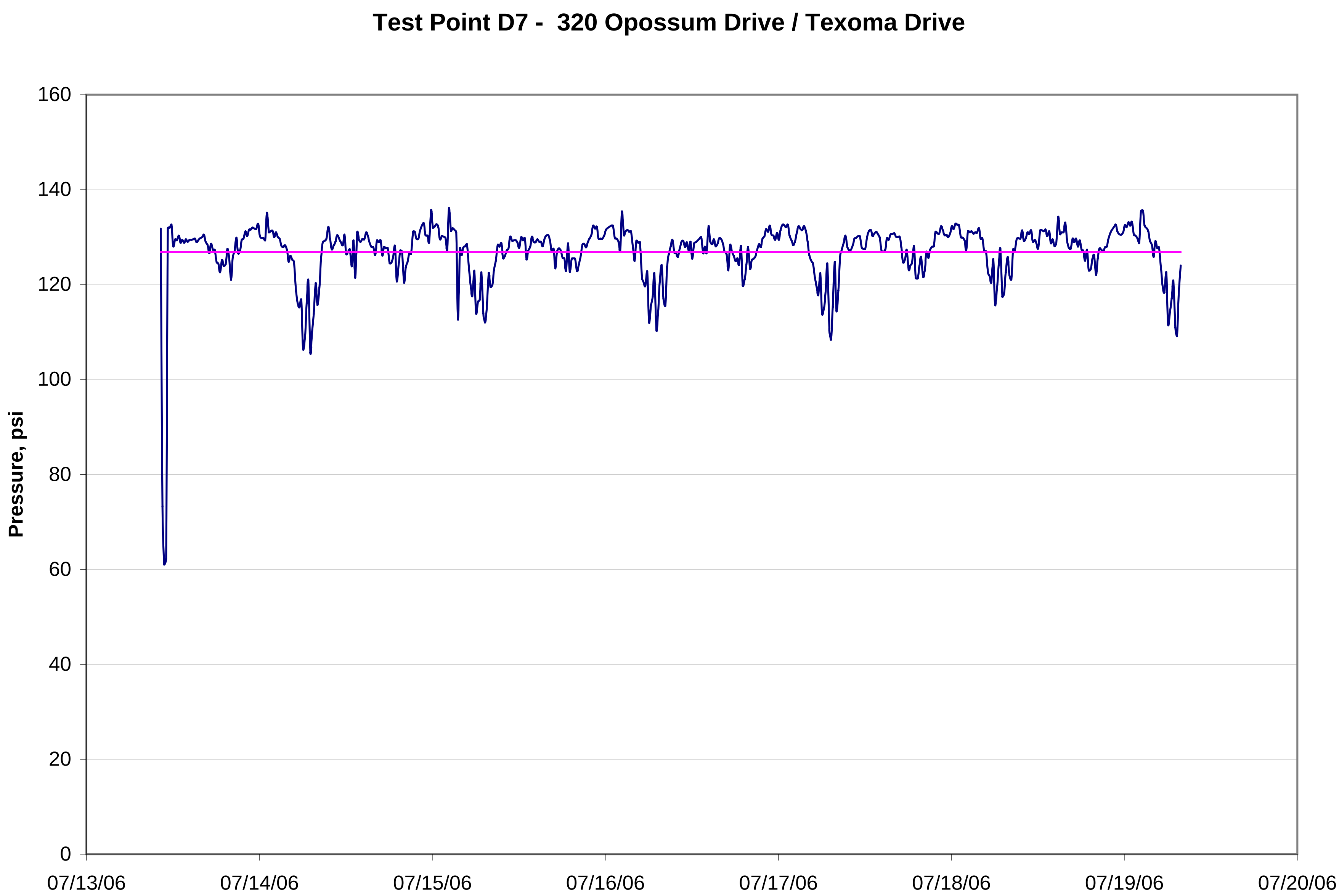


Test Point D4 - 3365 El Dorado Avenue North
Pressure, psi
140
120
100
80
60
40
20
0
07/13/06
07/14/06
07/15/06
07/16/06
07/17/06
07/18/06
07/19/06
07/20/06

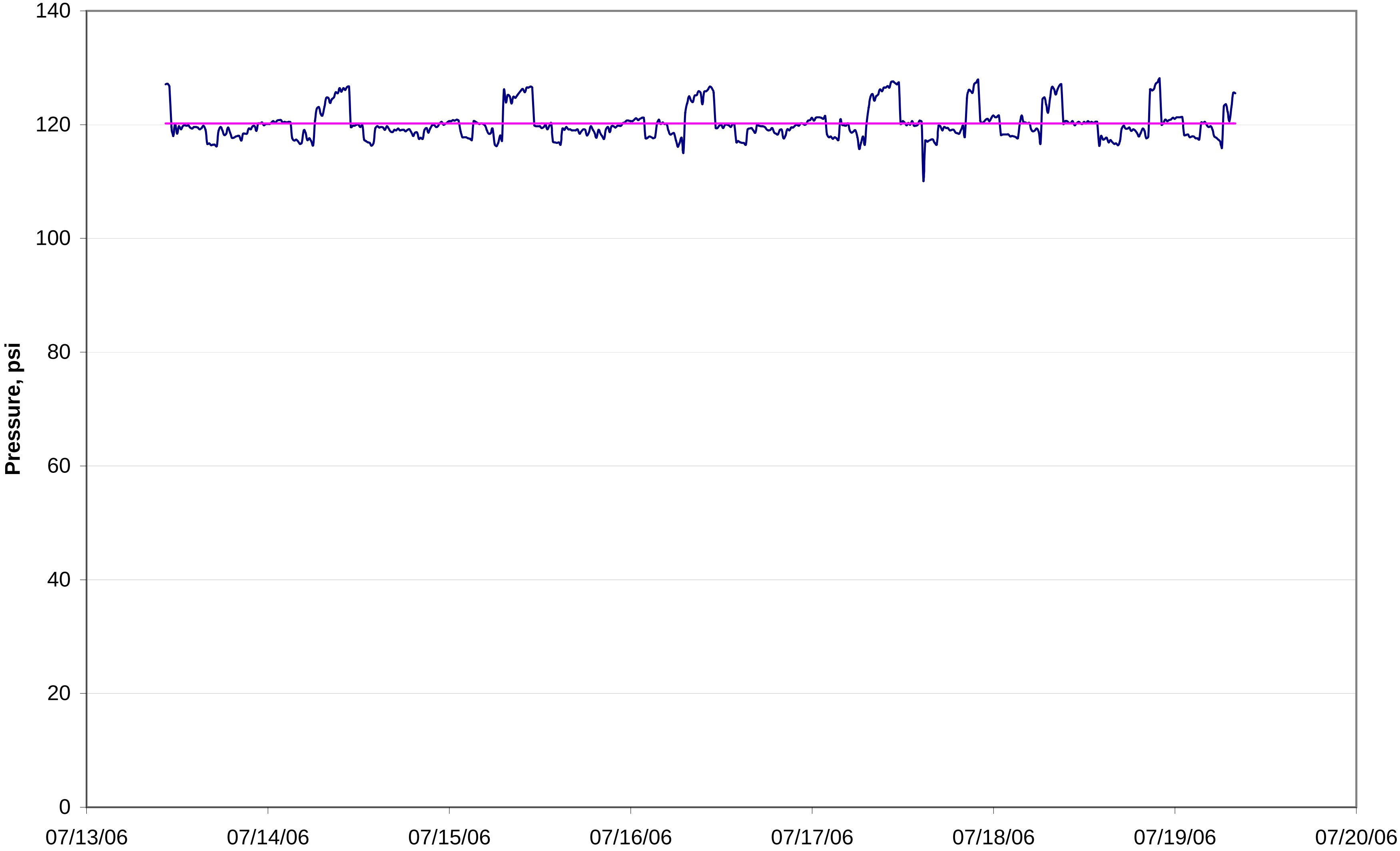
Test Point D5 - 3313 Dolphin Drive (Dolphin Drive and Lark Lane)



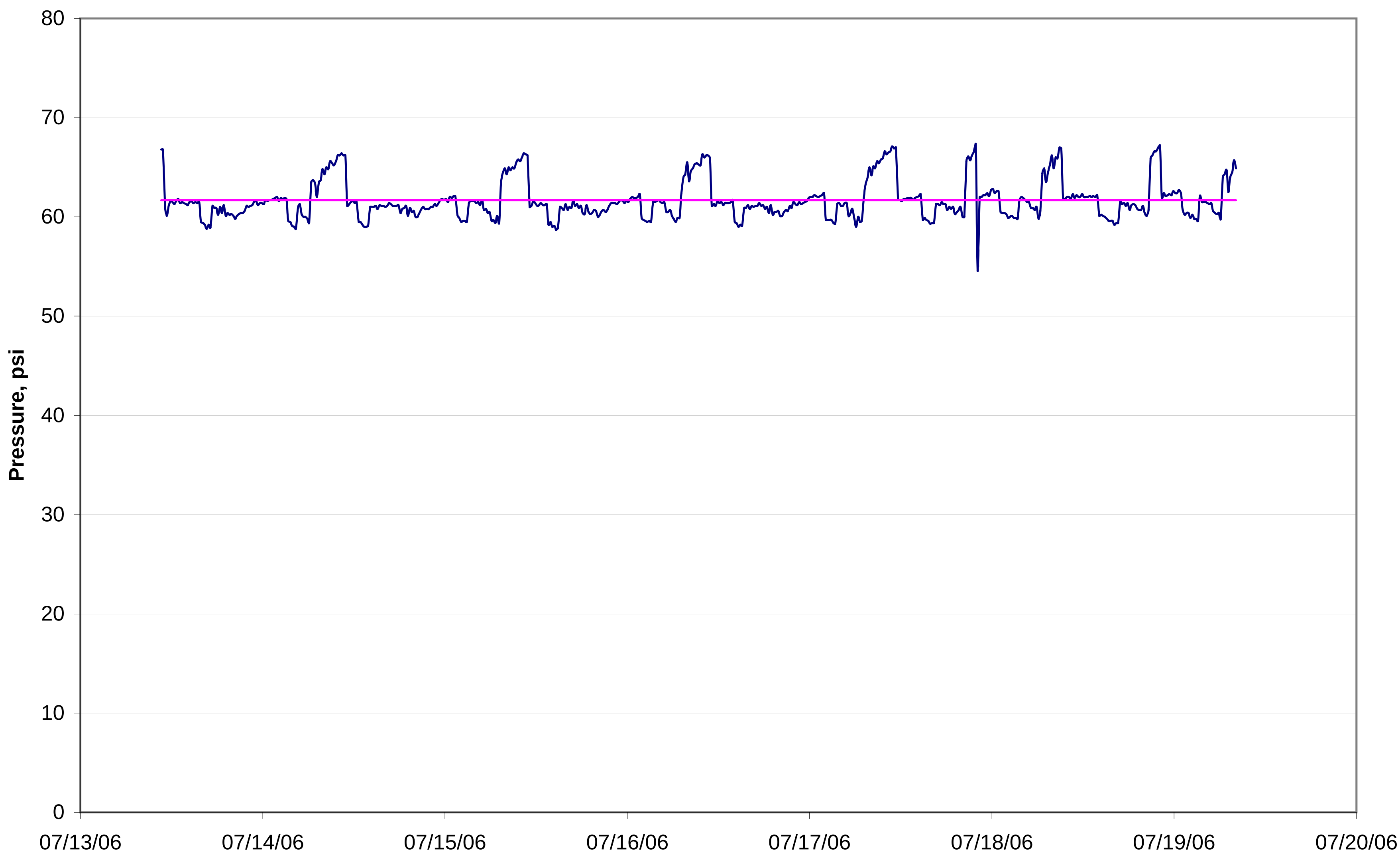

Test Point D6 - 310 Driftwood Drive / Buckboard Lane
Pressure, psi
0
10
20
30
40
50
60
70
80
90
07/13/06
07/14/06
07/15/06
07/16/06
07/17/06
07/18/06
07/19/06
07/20/06


Test Point D7 - 320 Opossum Drive / Texoma Drive
Pressure, psi
160
140
120
100
80
60
40
20
0
07/13/06
07/14/06
07/15/06
07/16/06
07/17/06
07/18/06
07/19/06
07/20/06

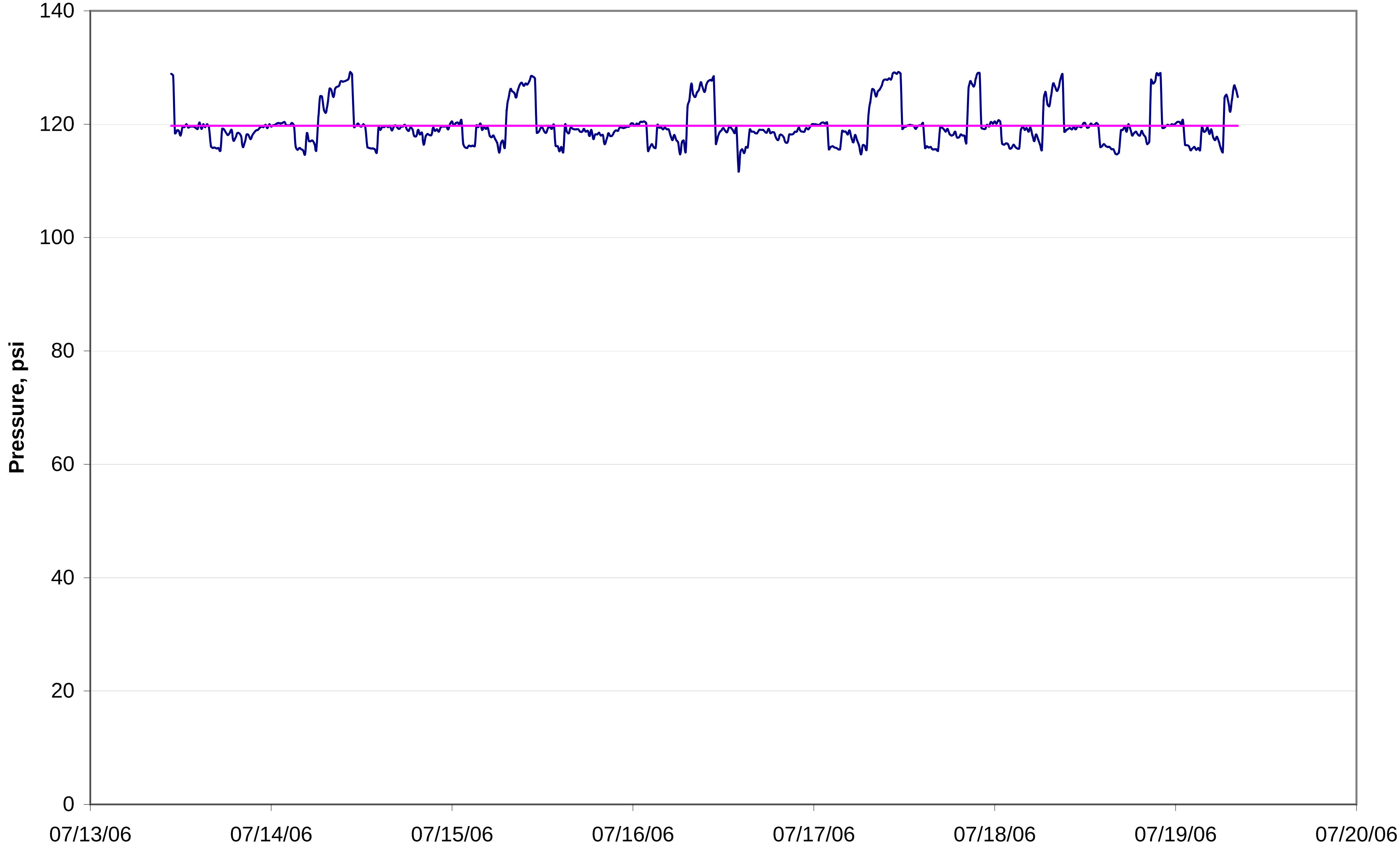
Test Point D8 - 620 Sand Dab Drive / Foothill Drive



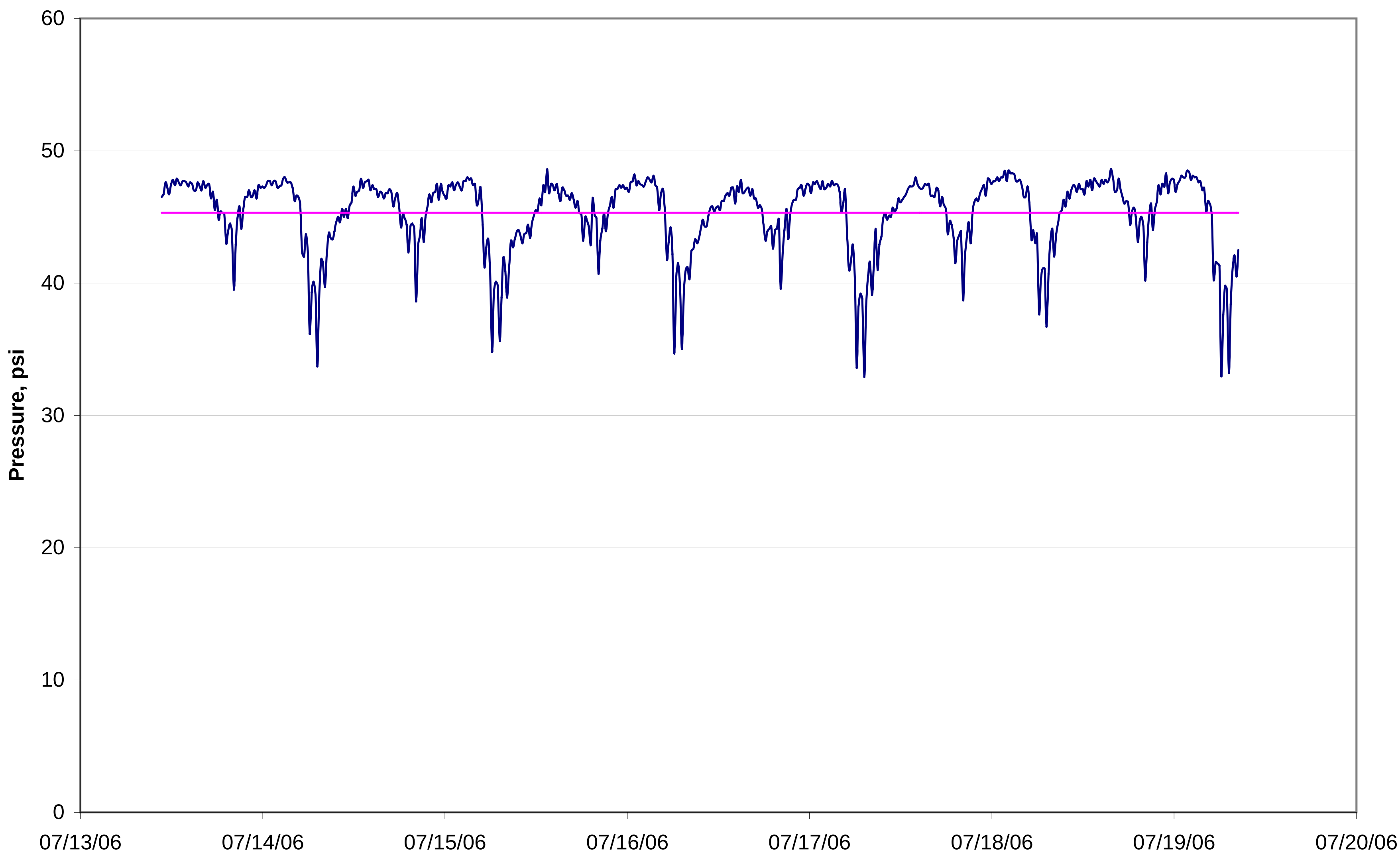
Test Point D9 - 3557 Fiesta Drive / Pocahontas Dr.

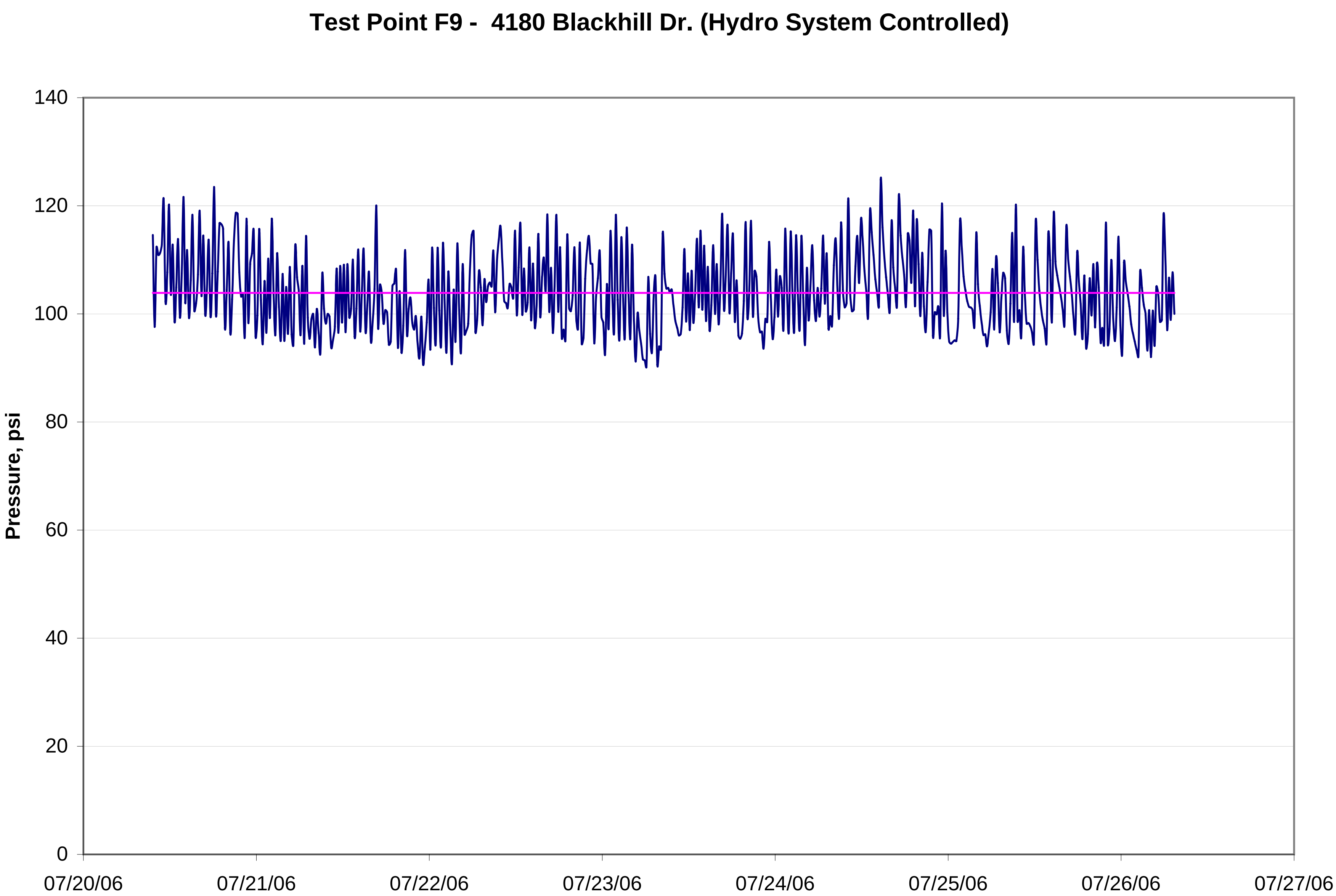


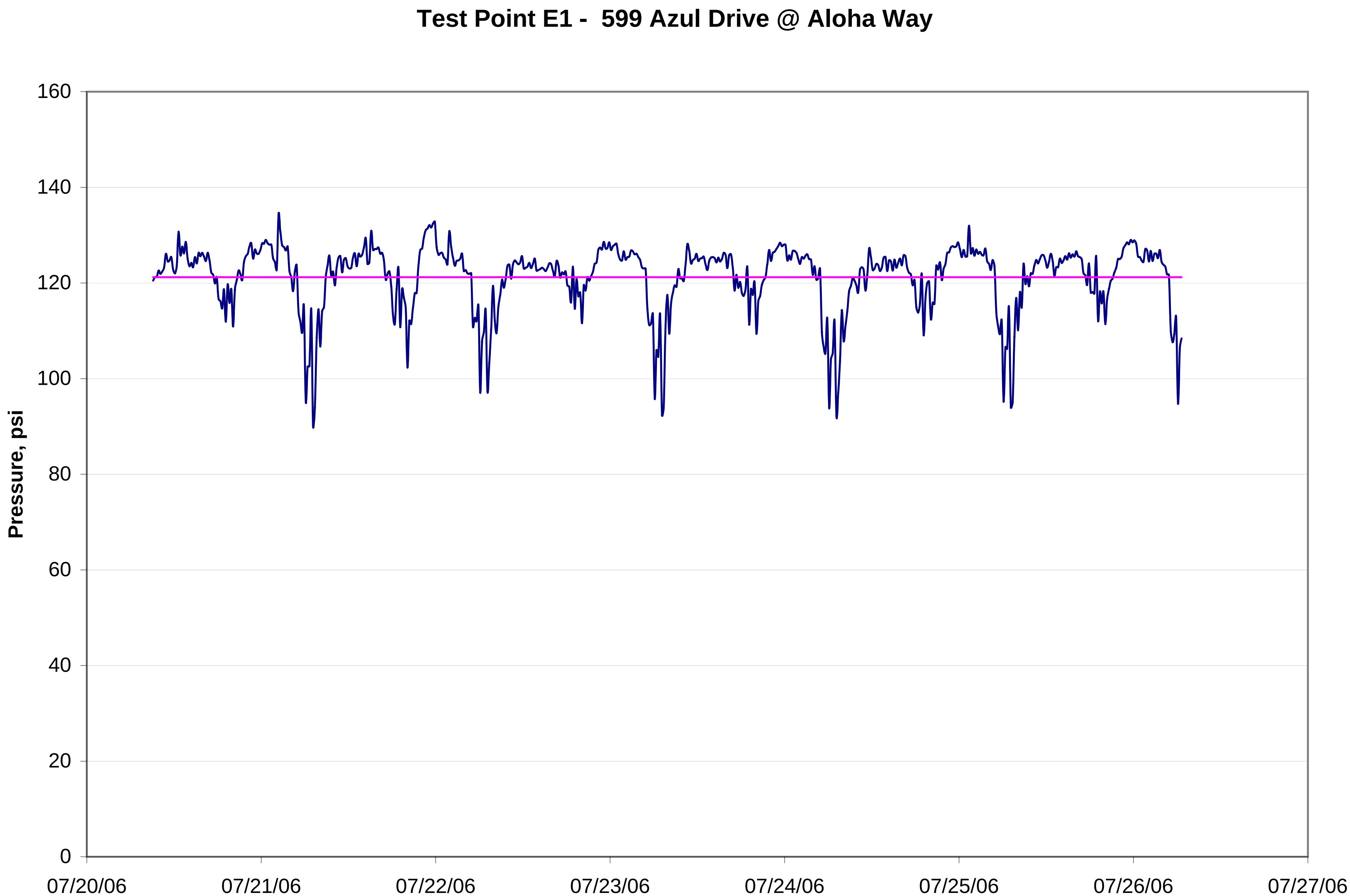
Test Point D10 - 3250 Palo Verde Blvd. North / Crater Drive



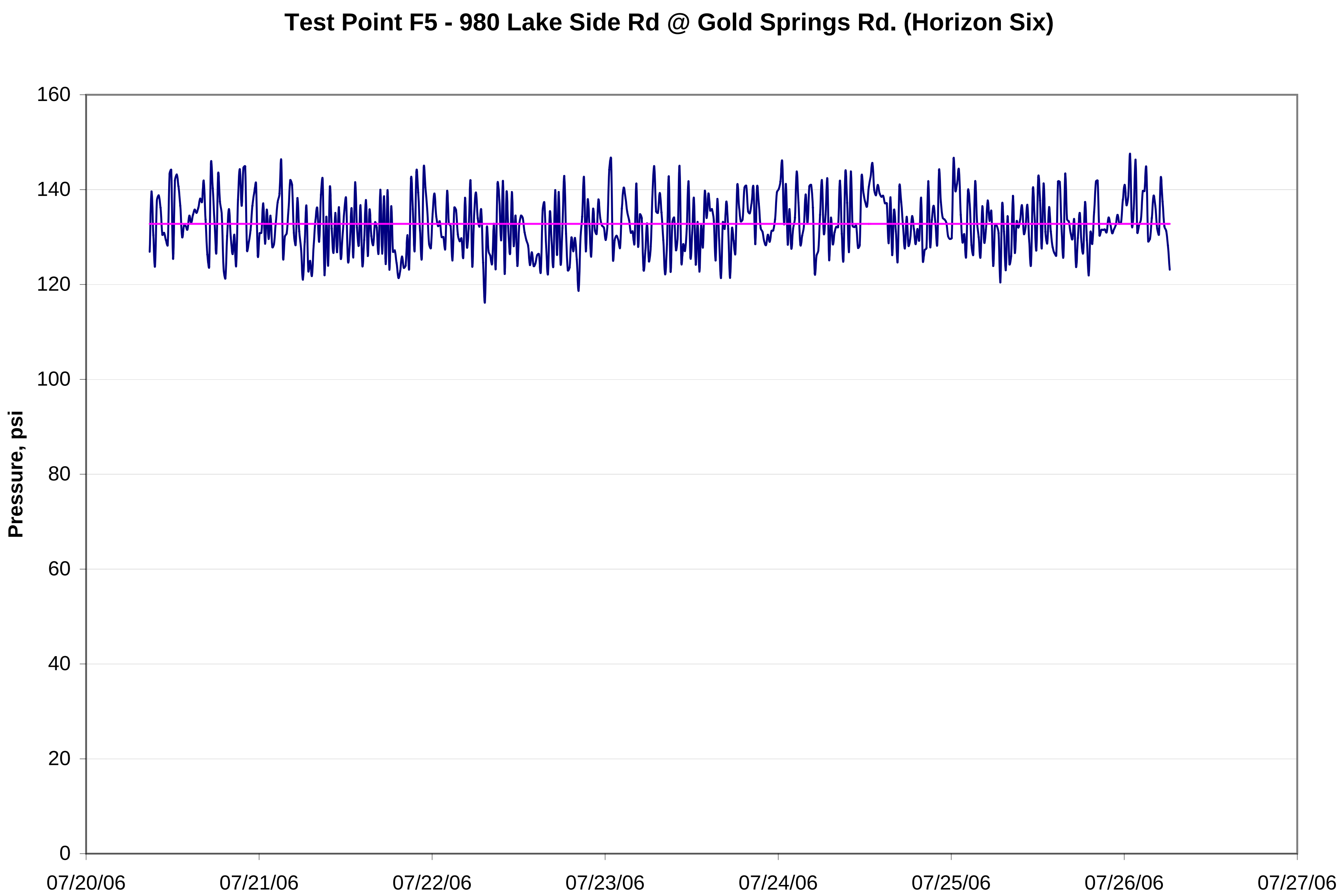
Test Point D11 - 1230 Crater Court

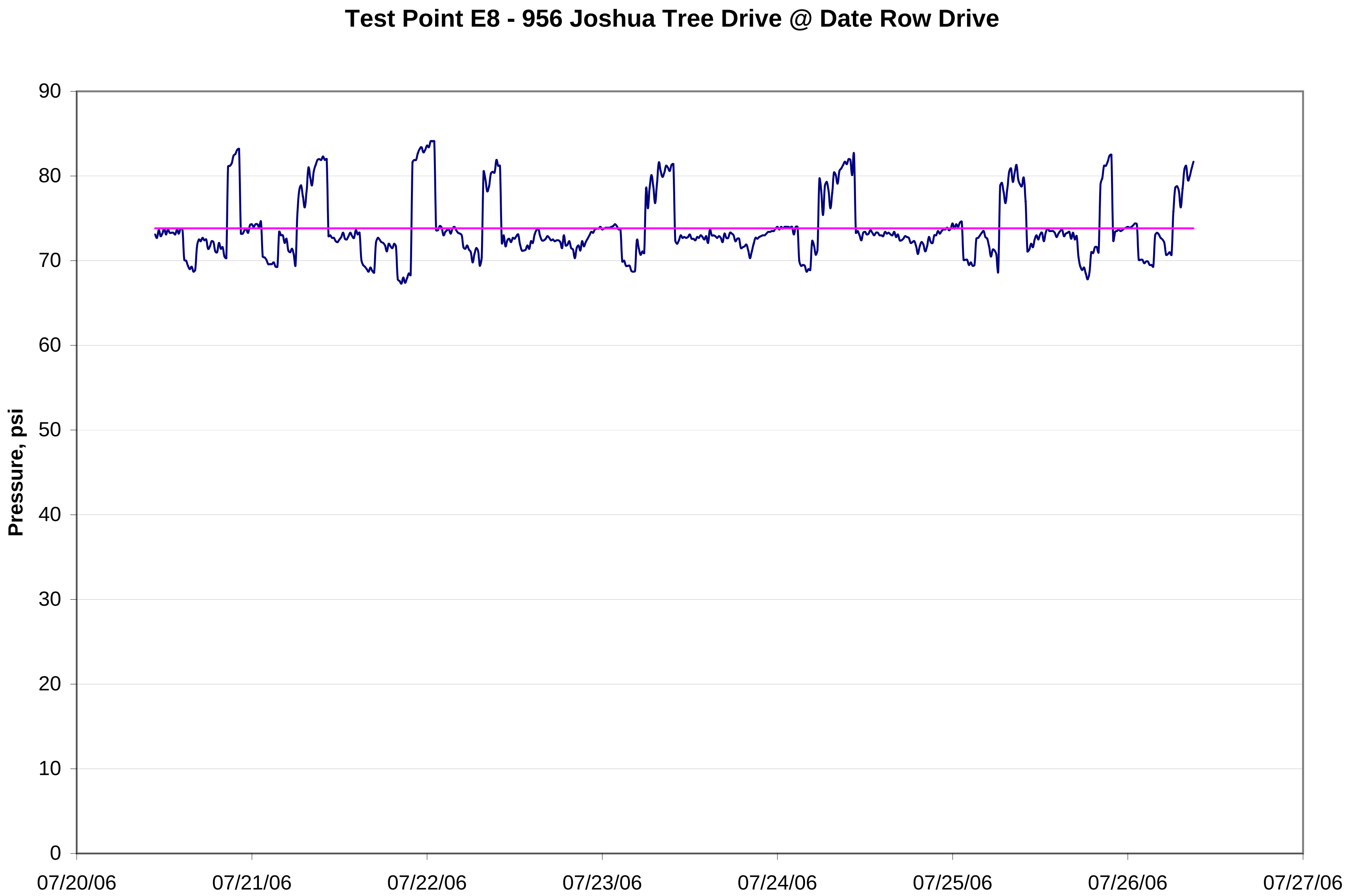



Test Point F9 - 4180 Blackhill Dr. (Hydro System Controlled)
Pressure, psi
0
20
40
60
80
100
120
140
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06

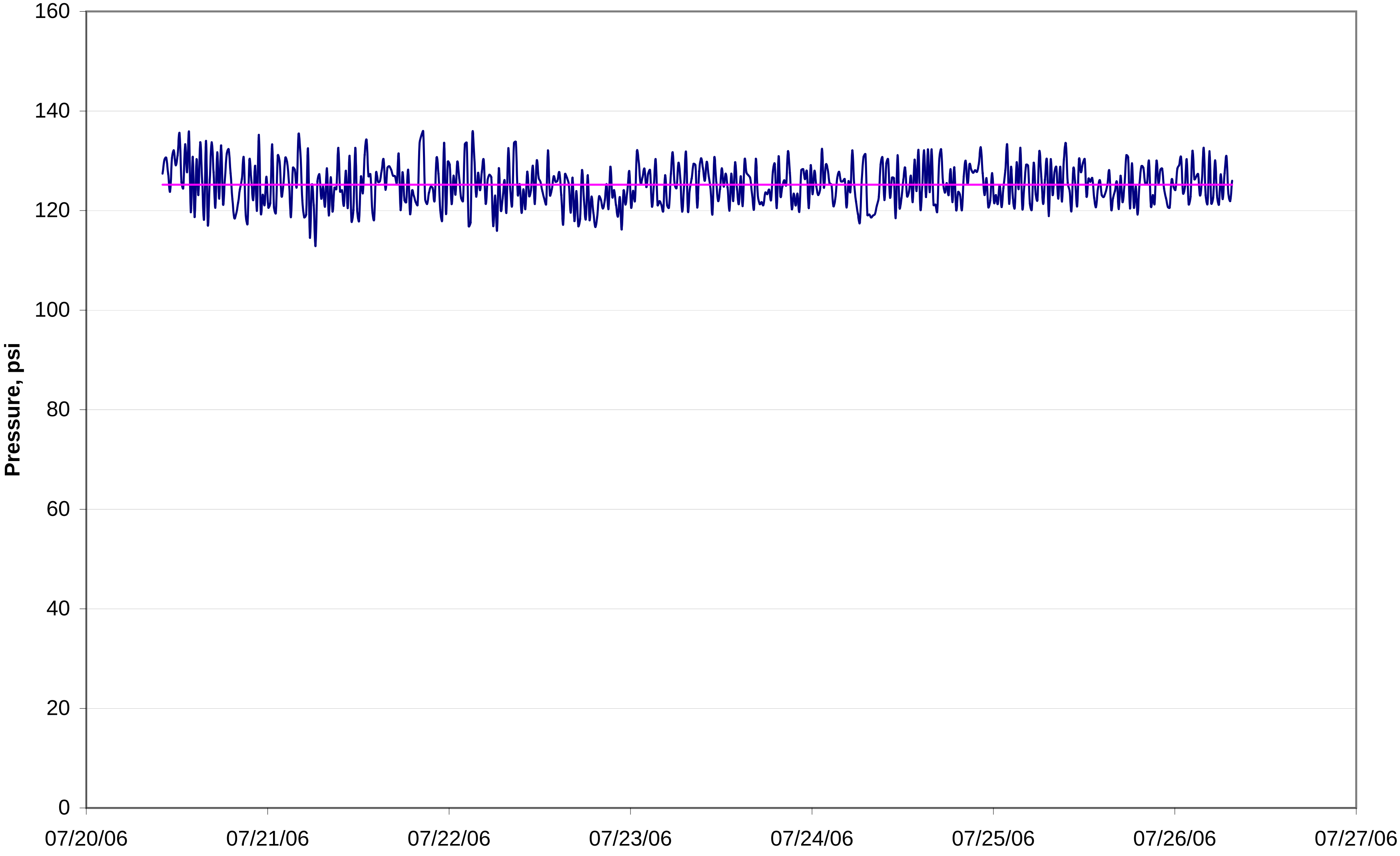


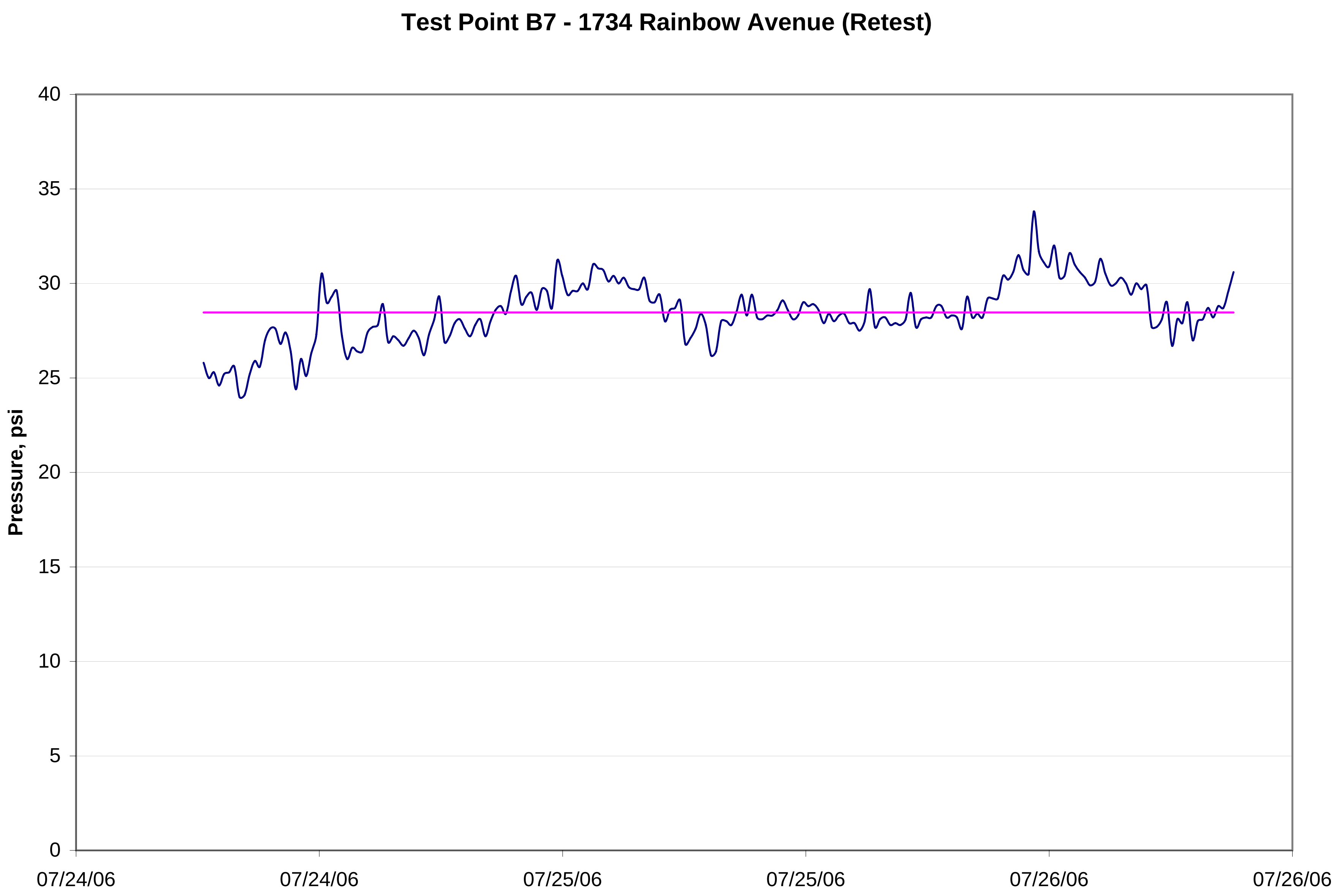
Test Point E1 - 599 Azul Drive @ Aloha Way
Pressure, psi
160
140
120
100
80
60
40
20
0
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06

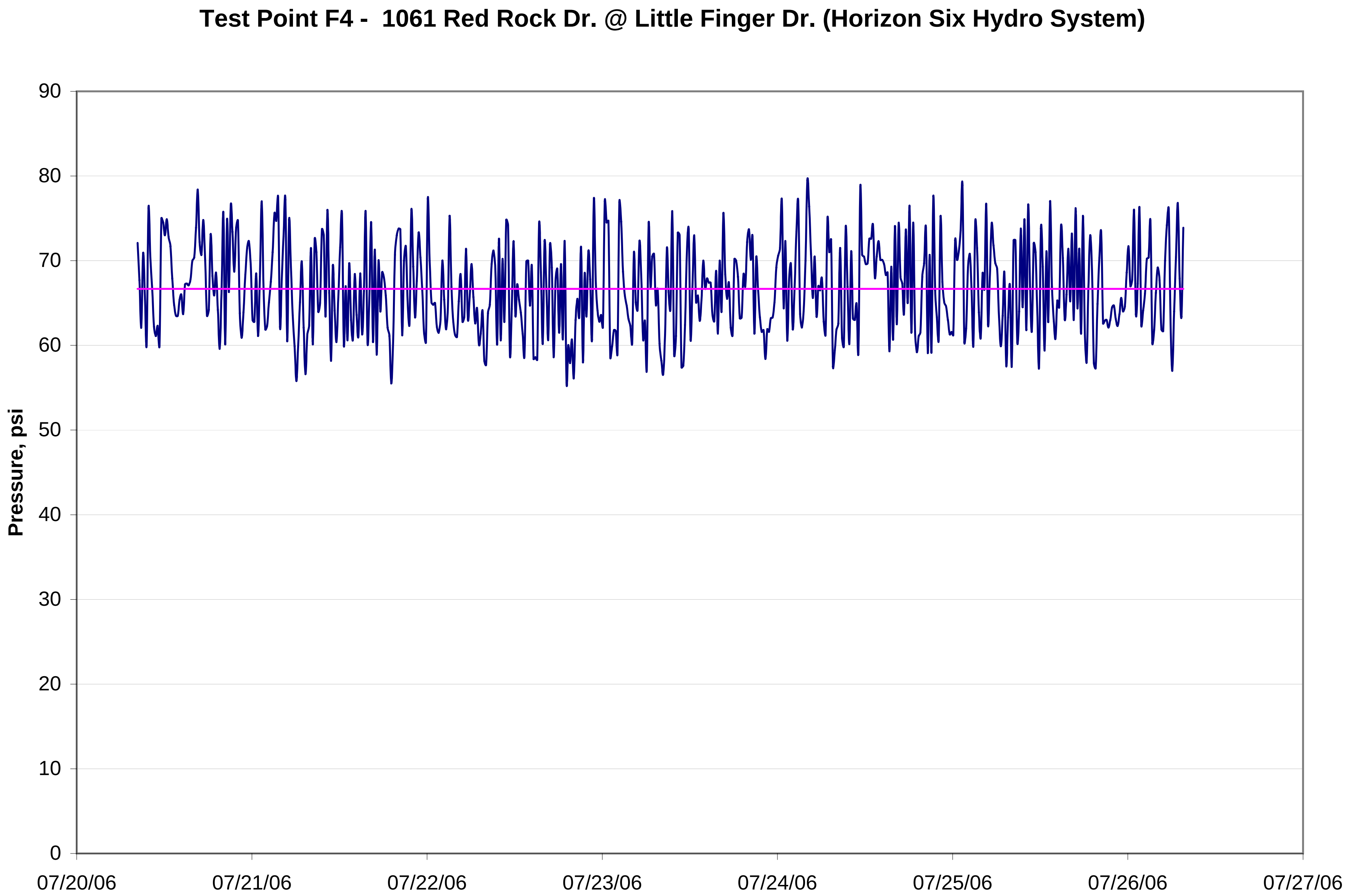

Test Point F5 - 980 Lake Side Rd @ Gold Springs Rd. (Horizon Six)
Pressure, psi
0
20
40
60
80
100
120
140
160
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06


Test Point E8 - 956 Joshua Tree Drive @ Date Row Drive
Pressure, psi
0
10
20
30
40
50
60
70
80
90
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06

Test Point F3 - 3935 Duke Drive

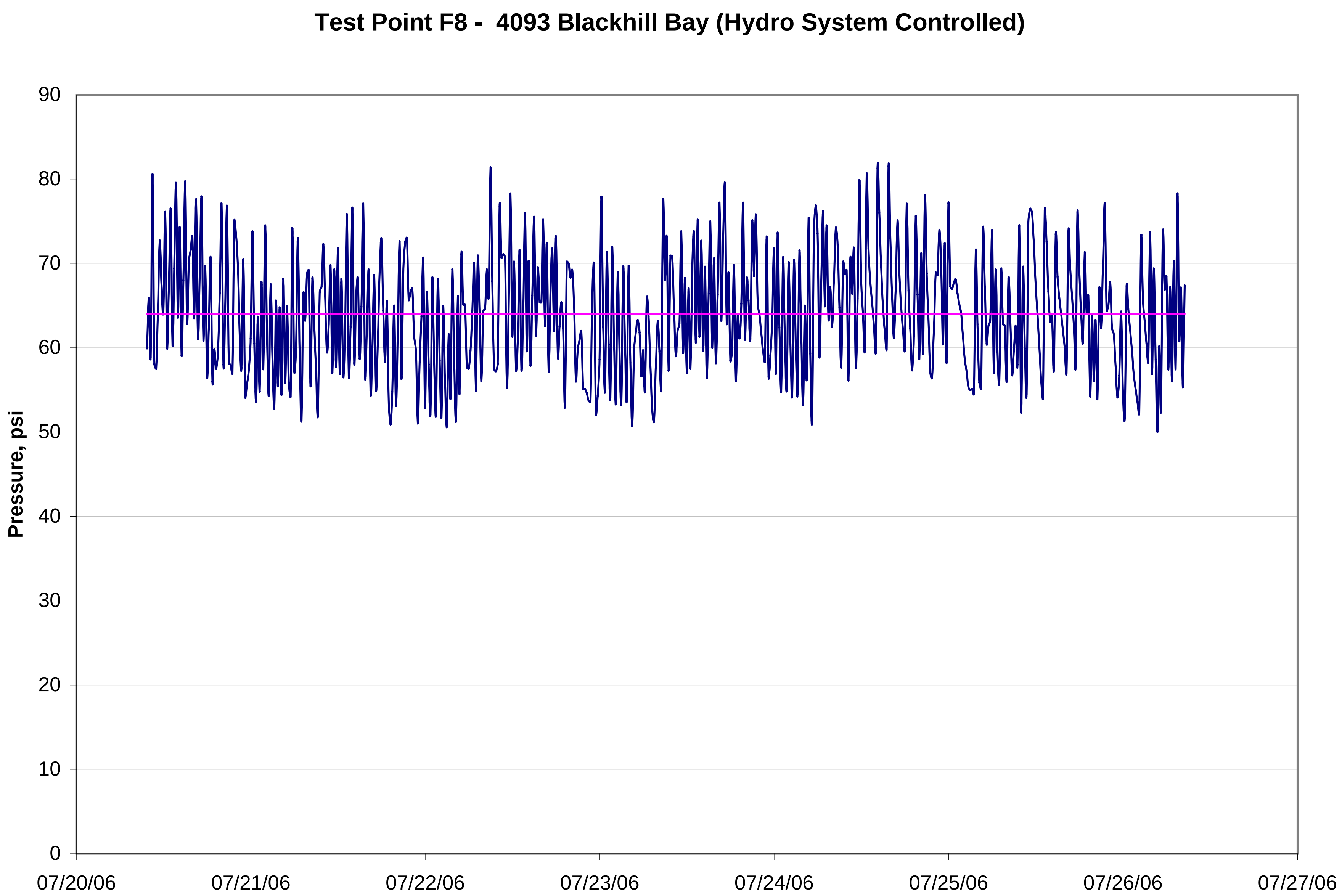



Test Point B7 - 1734 Rainbow Avenue (Retest)
Pressure, psi
40
35
30
25
20
15
10
5
0
07/24/06
07/24/06
07/25/06
07/25/06
07/26/06
07/26/06

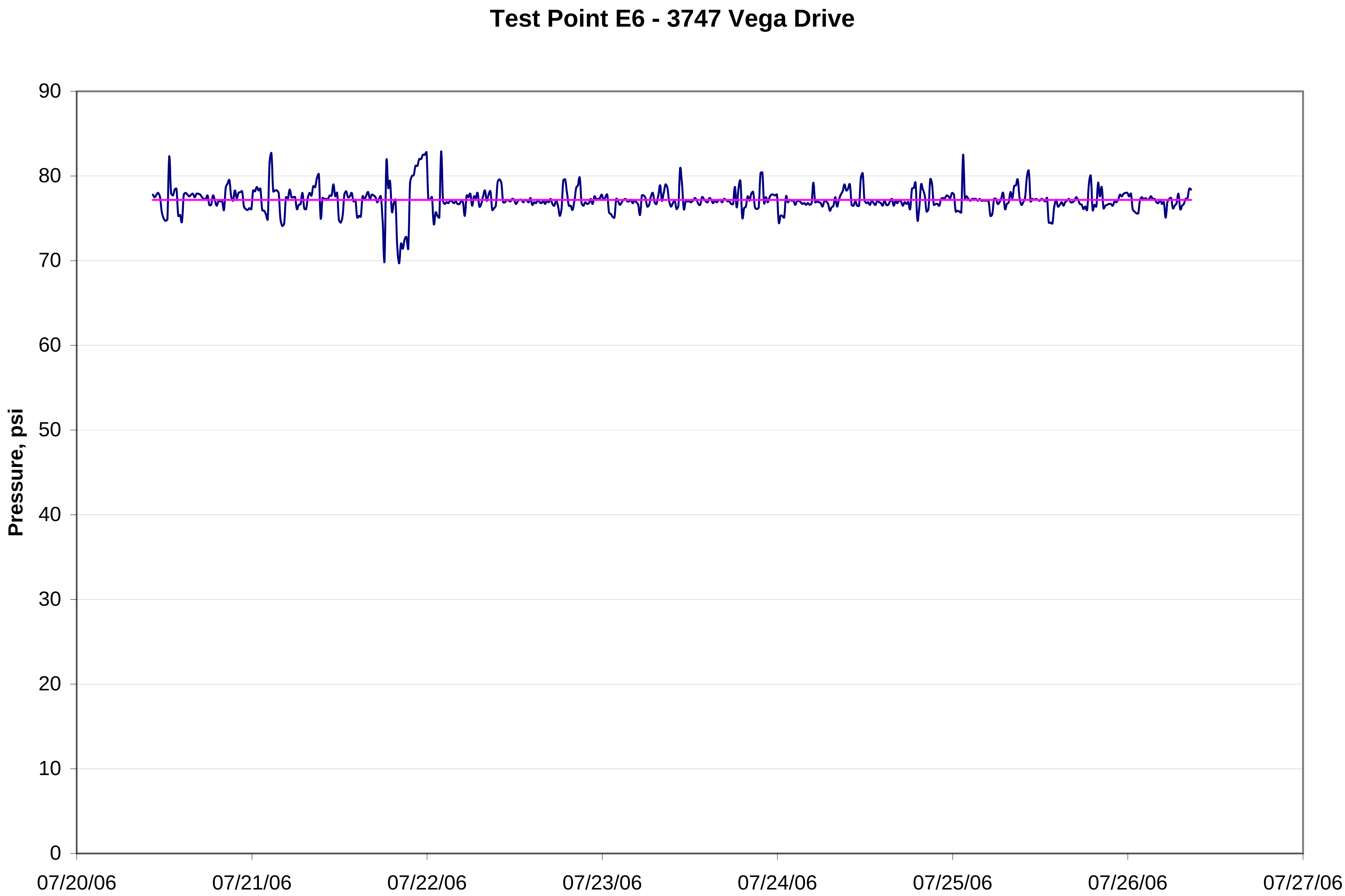


Test Point F4 - 1061 Red Rock Dr. @ Little Finger Dr. (Horizon Six Hydro System)
Pressure, psi
0
10
20
30
40
50
60
70
80
90
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06

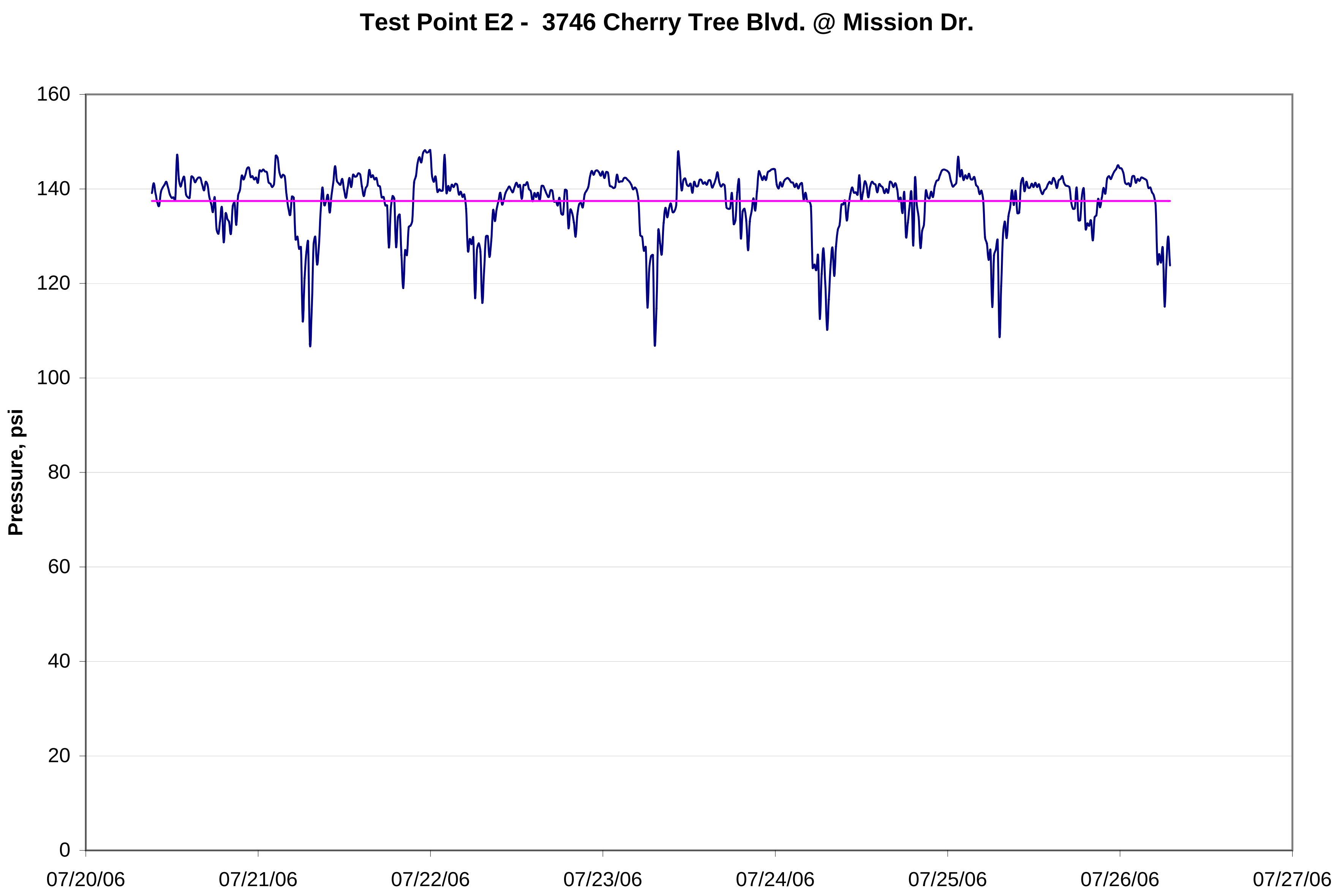
Test Point E7 - 977 St. Claire Drive @ Desert Garden Drive

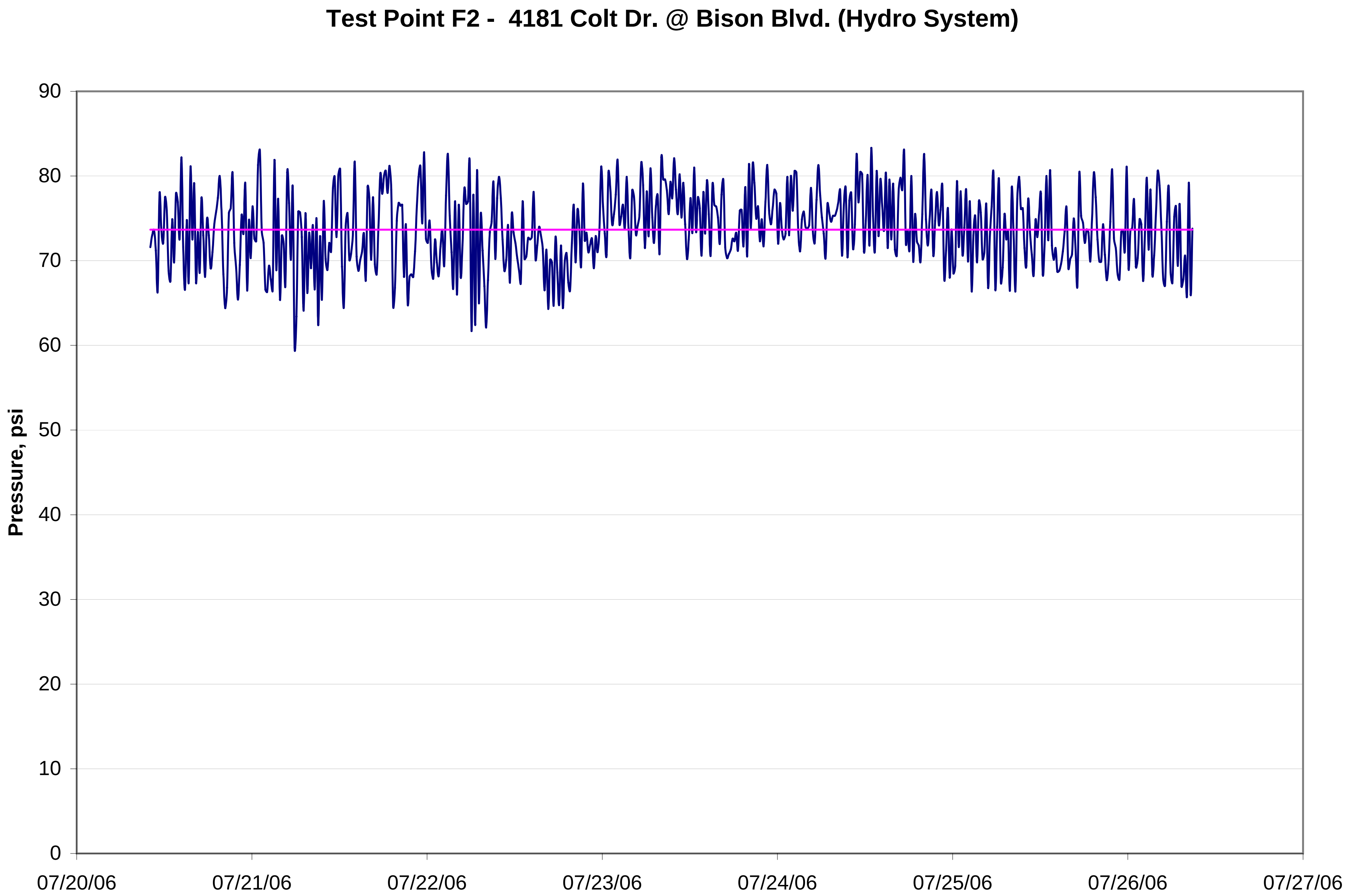


Test Point F8 - 4093 Blackhill Bay (Hydro System Controlled)
Pressure, psi
0
10
20
30
40
50
60
70
80
90
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06

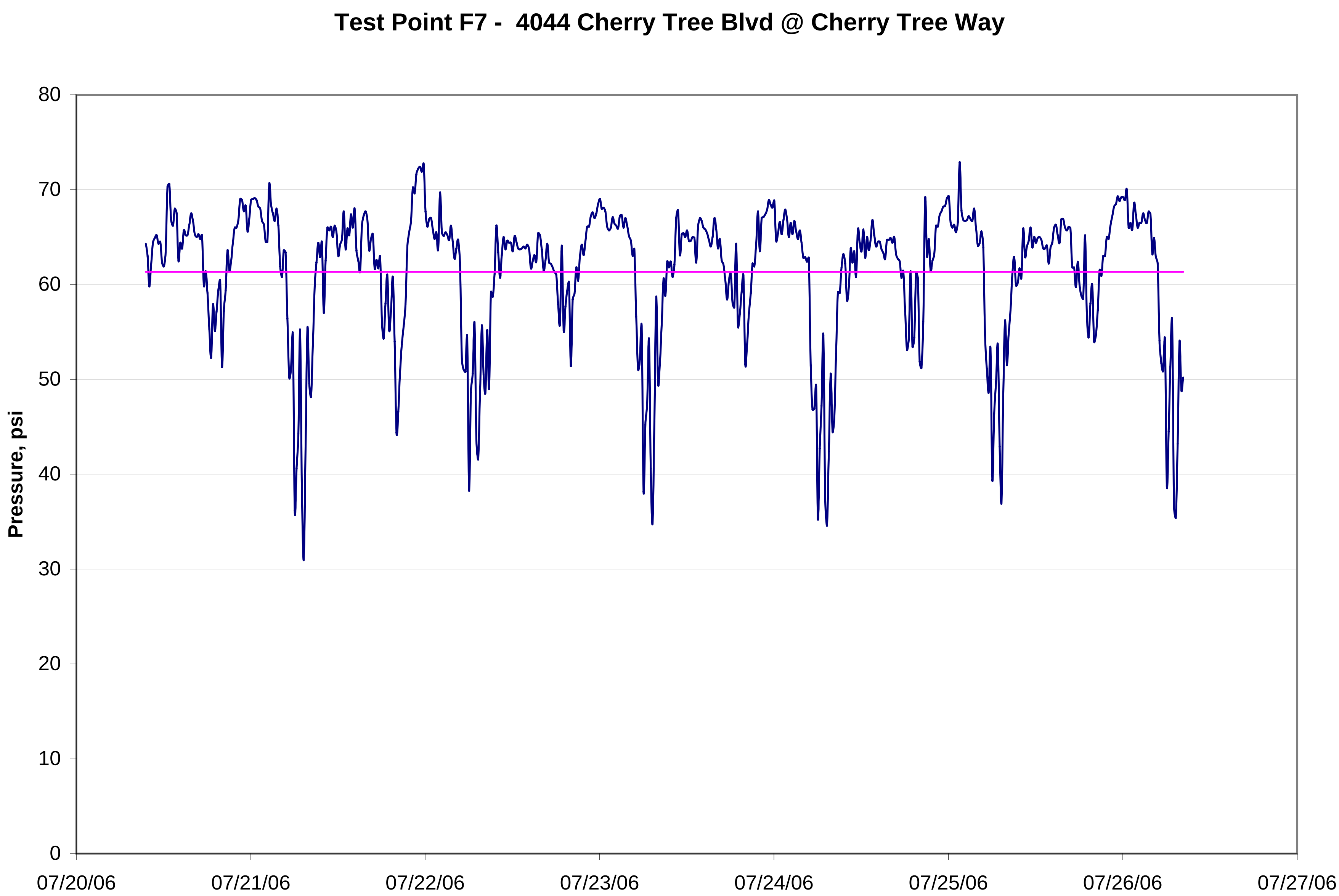


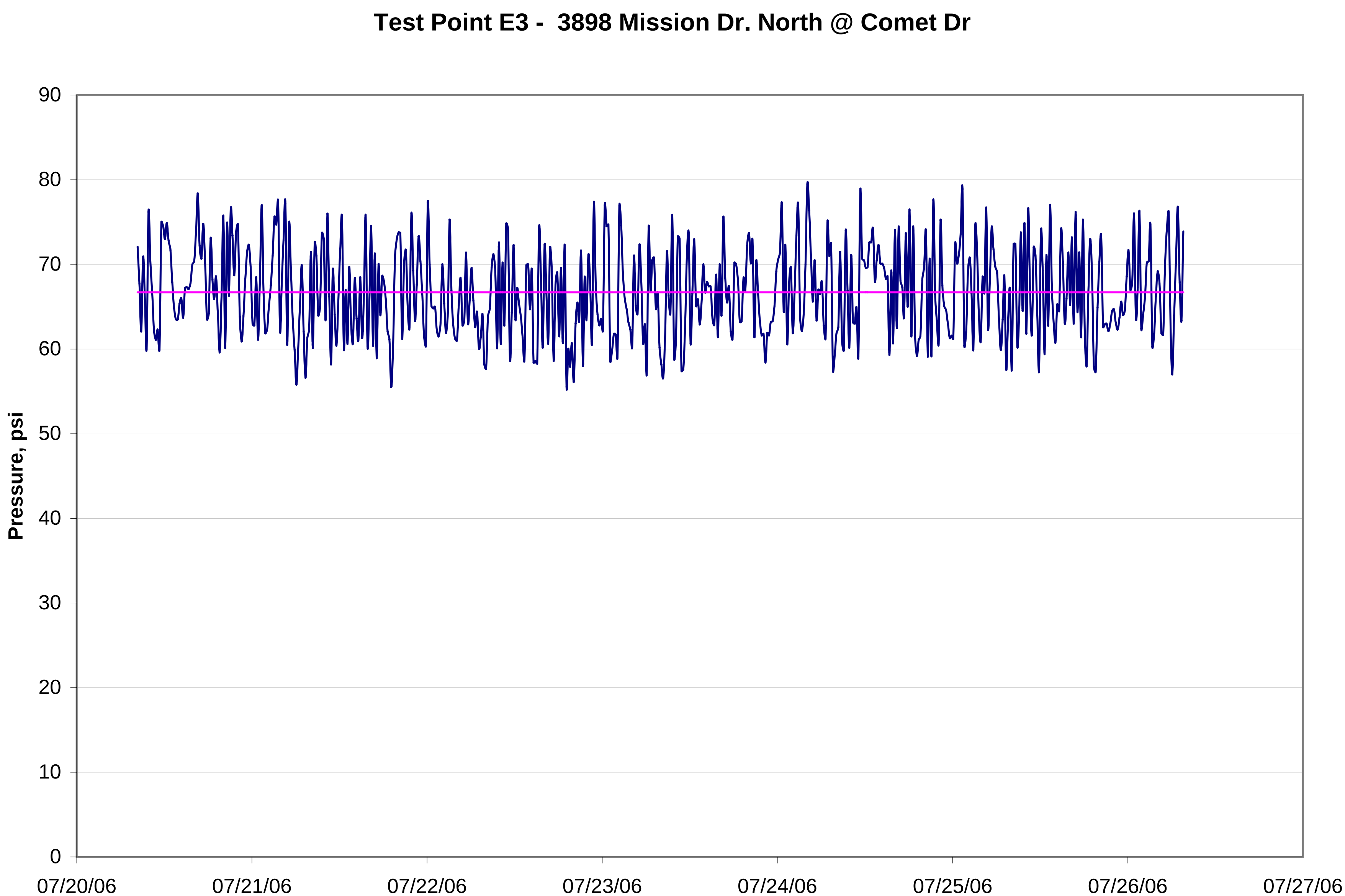
Test Point E6 - 3747 Vega Drive
Pressure, psi
90
80
70
60
50
40
30
20
10
0
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06


Test Point E2 - 3746 Cherry Tree Blvd. @ Mission Dr.
Pressure, psi
160
140
120
100
80
60
40
20
0
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06



Test Point F2 - 4181 Colt Dr. @ Bison Blvd. (Hydro System)
Pressure, psi
90
80
70
60
50
40
30
20
10
0
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06


Test Point F7 - 4044 Cherry Tree Blvd @ Cherry Tree Way
Pressure, psi
0
10
20
30
40
50
60
70
80
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06


Test Point E3 - 3898 Mission Dr. North @ Comet Dr
Pressure, psi
0
10
20
30
40
50
60
70
80
90
07/20/06
07/21/06
07/22/06
07/23/06
07/24/06
07/25/06
07/26/06
07/27/06

Appendix C

WATER SYSTEM EVALUATION RESULTS

Table C.1 Evaluation of Zone 2 Sites with 2006 Demands
Lake Havasu City Water Master Plan Update

	Zone 2			Zone 2 - if 1A is Out of Service			Zone 2 - if 1B is Out of Service			Zone 2 - if 1 is Out of Service			Zone 2 - if 1C is Out of Service		
	Site	**Pump**	**Flow Rate(1) (gpm)**	**Site**	**Pump**	**Flow Rate(1) (gpm)**	**Site**	**Pump**	**Flow Rate(1) (gpm)**	**Site**	**Pump**	**Flow Rate(1) (gpm)**	**Site**	**Pump**	**Flow Rate(1) (gpm)**
	1A	1(2)	700	1A	1(2)	0	1A	1(2)	700	1A	1(2)	700	1A	1(2)	700
	1B	1	3,000	1B	1	3,000	1B	1	0	1B	1	3,000	1B	1	3,000
		2	3,000		2	3,000		2	0		2	3,000		2	3,000
		3(2)	750		3(2)	750		3(2)	0		3(2)	750		3(2)	750
	1	1	1,100	1	1	1,100	1	1	1,100	1	1	0	1	1	1,100
		2	1,100		2	1,100		2	1,100		2	0		2	1,100
		3	1,100		3	1,100		3	1,100		3	0		3	1,100
	1C	1	2,800	1C	1	2,800	1C	1	2,800	1C	1	2,800	1C	1	0
		2	2,800		2	2,800		2	2,800		2	2,800		2	0
		3(2)	1,000		3(2)	1,000		3(2)	1,000		3(2)	1,000		3(2)	0
Total Pumping Capacity			17,350			16,650			10,600			14,050			10,750
Firm Pumping Capacity(3)			9,750			9,750			6,000			7,550			5,950
Firm Electric Pumping Capacity(4)			7,300			8,000			4,300			5,100			4,500
2006 Average Demand (Zones 2 and higher)			6,597			6,597			6,597			6,597			6,597
Unused Firm Electric Capacity			703			1,403			**-2,297**			**-1,497**			**-2,097**
2006 Maximum Day Demand (Zones 2 and higher)			10,554												
Unused Firm Electric Capacity			**-3,254**												

Notes:
(1) Flow rates are actual values from the City staff.
(2) Gas engine pump.
(3) Firm capacity is the total capacity with the largest pump per station out of service. Currently, demands are supplied using the total pumping capacity, not the firm pumping capacity.
(4) Firm electric capacity is the sum of the electric pump flow rates minus the largest electric pump in each station.

Table C.2 Evaluation of Zone 3 Sites with 2006 Demands
Lake Havasu City Water Master Plan Update

	Zone 3			**Zone 3 - if 2A is Out of Service**			**Zone 3 - if 2 is Out of Service**			**Zone 3 - if 2C is Out of Service**		
	Site	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**
	2A	1[2]	1,750	2A	1	0	2A	1	1,750	2A	1	1,750
		2	1,750		2	0		2	1,750		2	1,750
		3	1,000		3[2]	0		3[2]	1,000		3[2]	1,000
	2	1	1,400	2	1	1,400	2	1	0	2	1	1,400
		2	1,400		2	1,400		2	0		2	1,400
		3	1,400		3	1,400		3	0		3	1,400
		4[2]	700		4[2]	700		4[2]	0		4[2]	700
	2C	1	1,800	2C	1	1,800	2C	1	1,800	2C	1	0
		2	1,800		2	1,800		2	1,800		2	0
		3[2]	750		3[2]	750		3[2]	750		3[2]	0
Total Pumping Capacity			13,750			9,250			8,850			9,400
Firm Pumping Capacity[3]			8,800			6,050			5,300			6,250
Firm Electric Pumping Capacity[4]			6,350			4,600			3,550			4,550
2006 Average Demand (Zones 3 and higher)			3,758			3,758			3,758			3,758
Unused Firm Electric Capacity			2,592			842			**-208**			792
2006 Maximum Day Demand (Zones 3 and higher)			6,013									
Unused Firm Electric Capacity			337									

Notes:
(1) Flow rates are actual values from the City staff.
(2) Gas engine pump.
(3) Firm capacity is the total capacity with the largest pump per station out of service.
(4) Firm electric capacity is the sum of the electric pump flow rates minus the largest electric pump in each station.

Table C.3 Evaluation of Zone 4 Sites with 2006 Demands
Lake Havasu City Water Master Plan Update

	Zone 4		
	Site	**Pump**	**Flow Rate[1] (gpm)**
	3A	1	1,200
		2	1,200
		3	1,200
	3	1	1,400
		2	1,400
Total Pumping Capacity			6,400
Firm Pumping Capacity			4,000
2006 Max Day + Fire Flow Demand[2]			2,521
Unused Firm Capacity			1,479

Notes:
(1) Flow rates are actual values from City staff.
(2) Residential fire flow demand is set at 1,000 gpm.

Table C.4 Evaluation of Zone 5 Sites with 2006 Demands
Lake Havasu City Water Master Plan Update

	Zone 5		
	Site	**Pump**	**Flow Rate[1] (gpm)**
	4A	1	650
		2	650
		3[2]	500
Total Pumping Capacity			1,800
2006 Max Day + Fire Flow Demand[3]			1,535
Unused Firm Capacity			265

Notes:
(1) Flow rates are actual values from City staff.
(2) Gas engine pump.
(3) Residential fire flow demand is set at 1,000 gpm.

Table C.5 Evaluation of Terminal Zones with 2006 Demands
Lake Havasu City Water Master Plan Update

	Zone 6			Zone 6A			Horizon Six		
	Site	Pump	Flow Rate(1) (gpm)	Site	Pump	Flow Rate(1) (gpm)	Site	Pump	Flow Rate(1) (gpm)
	5A	1	500	4	1	500	3C	1	290
		2	500		2	500		2	290
Total Pumping Capacity			1,000			1,000			580
Max Day + Fire Flow Demand(2)			1,053			1,013			1,103
Unused Firm Capacity			**-53**			**-13**			**-523**

Notes:

(1) Flow rates are actual values from City staff.

(2) The residential fire flow demand is set at 1,000 gpm.

Table C.6 Evaluation of Zone 2 Sites with Buildout Demands
Lake Havasu City Water Master Plan Update

	Zone 2			Zone 2 - if 1A is Out of Service			Zone 2 - if 1B is Out of Service			Zone 2 - if 1 is Out of Service			Zone 2 - if 1C is Out of Service			Zone 2 - if NH is Out of Service		
	Site	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**
	1A	1	700	1A	1	0	1A	1	700	1A	1	700	1A	1	700	1A	1	700
		2	700		2	0		2	700		2	700		2	700		2	700
		3	700		3	0		3	700		3	700		3	700		3	700
	1B	1	3,000	1B	1	3,000	1B	1	0	1B	1	3,000	1B	1	3,000	1B	1	3,000
		2	3,000		2	3,000		2	0		2	3,000		2	3,000		2	3,000
		3	3,000		3	3,000		3	0		3	3,000		3	3,000		3	3,000
	1	1	1,800	1	1	1,800	1	1	1,800	1	1	0	1	1	1,800	1	1	1,800
		2	1,800		2	1,800		2	1,800		2	0		2	1,800		2	1,800
		3	1,800		3	1,800		3	1,800		3	0		3	1,800		3	1,800
	1C	1	2,800	1C	1	2,800	1C	1	2,800	1C	1	2,800	1C	1	0	1C	1	2,800
		2	2,800		2	2,800		2	2,800		2	2,800		2	0		2	2,800
		3	2,800		3	2,800		3	2,800		3	2,800		3	0		3	2,800
	NH	1	175	NH	1	175	NH	1	175	NH	1	175	NH	1	175	NH	1	0
		2	1,500		2	1,500		2	1,500		2	1,500		2	1,500		2	0
		3	1,500		3	1,500		3	1,500		3	1,500		3	1,500		3	0
		4	2,000		4	2,000		4	2,000		4	2,000		4	2,000		4	0
		5	2,000		5	2,000		5	2,000		5	2,000		5	2,000		5	0
		6	2,000		6	2,000		6	2,000		6	2,000		6	2,000		6	0
Total Pumping Capacity			34,075			31,975			25,075			28,675			25,675			24,900
Firm Pumping Capacity[2]			23,775			22,375			17,775			20,175			18,175			16,600
Buildout Average Demand (Zones 2 and higher)			12,752			0			0			0			0			0
Unused Firm Capacity			11,023			22,375			17,775			20,175			18,175			16,600
Buildout Maximum Day Demand (Zones 2 and higher)			20,403															
Unused Firm Capacity			3,372															

Notes:

(1) Pump flow rates are planned design flow rates of future and rebuilt pump stations.

(2) Firm capacity is the total capacity with the largest pump per station out of service.

Table C.7 Evaluation of Zone 3 Sites with Buildout Demands
Lake Havasu City Water Master Plan Update

	Zone 3			Zone 3 - if 2A is Out of Service			Zone 3 - if 2 is Out of Service			Zone 3 - if 2C is Out of Service			Zone 3 - if 2D is Out of Service		
	Site	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**
	2A	1	1,750	2A	1	0	2A	1	1,750	2A	1	1,750	2A	1	1,750
		2	1,750		2	0		2	1,750		2	1,750		2	1,750
		3	1,750		3	0		3	1,750		3	1,750		3	1,750
	2	1	1,600	2	1	1,600	2	1	0	2	1	1,600	2	1	1,600
		2	1,600		2	1,600		2	0		2	1,600		2	1,600
		3	1,600		3	1,600		3	0		3	1,600		3	1,600
	2C	1	1,800	2C	1	1,800	2C	1	1,800	2C	1	0	2C	1	1,800
		2	1,800		2	1,800		2	1,800		2	0		2	1,800
		3	1,800		3	1,800		3	1,800		3	0		3	1,800
	2D[2]	1	1,600	2D[2]	1	1,600	2D[2]	1	1,600	2D[2]	1	1,600	2D[2]	1	0
		2	1,600		2	1,600		2	1,600		2	1,600		2	0
		3	1,600		3	1,600		3	1,600		3	1,600		3	0
Total Pumping Capacity			20,250			15,000			15,450			14,850			15,450
Firm Pumping Capacity[3]			13,500			10,000			10,300			9,900			10,300
Buildout Average Demand (Zones 3 and higher)			7,605			7,605			7,605			7,605			7,605
Unused Firm Capacity			5,895			2,395			2,695			2,295			2,695
Buildout Maximum Day Demand (Zones 3 and higher)			12,168												
Unused Firm Capacity			1,332												

Notes:
(1) Pump flow rates are planned design flow rates of future and rebuilt pump stations.
(2) This site is planned for the future.
(3) Firm capacity is the total capacity with the largest pump per station out of service.

Table C.8 Evaluation of Zone 4 Sites with Buildout Demands
Lake Havasu City Water Master Plan Update

	Zone 4			Zone 4 - if 3A is Out of Service			Zone 4 - if 3 is Out of Service			Zone 4 - if 3C is Out of Service			Zone 4 - if 3D is Out of Service		
	Site	Pump	Flow Rate[1] (gpm)	Site	Pump	Flow Rate[1] (gpm)	Site	Pump	Flow Rate[1] (gpm)	Site	Pump	Flow Rate[1] (gpm)	Site	Pump	Flow Rate[1] (gpm)
	3A	1	1,200	3A	1	0	3A	1	1,200	3A	1	1,200	3A	1	1,200
		2	1,200		2	0		2	1,200		2	1,200		2	1,200
		3	1,200		3	0		3	1,200		3	1,200		3	1,200
	3	1	1,000	3	1	1,000	3	1	0	3	1	1,000	3	1	1,000
		2	1,000		2	1,000		2	0		2	1,000		2	1,000
		3	1,000		3	1,000		3	0		3	1,000		3	1,000
		4	1,000		4	1,000		4	0		4	1,000		4	1,000
	3C[2]	1	1,000	3C[2]	1	1,000	3C[2]	1	1,000	3C[2]	1	0	3C[2]	1	1,000
		2	1,000		2	1,000		2	1,000		2	0		2	1,000
		3	1,000		3	1,000		3	1,000		3	0		3	1,000
	3D[3]	1	1,400	3D[3]	1	1,400	3D[3]	1	1,400	3D[3]	1	1,400	3D[3]	1	0
		2	1,400		2	1,400		2	1,400		2	1,400		2	0
		3	1,400		3	1,400		3	1,400		3	1,400		3	0
Total Pumping Capacity			14,800			11,200			10,800			11,800			10,600
Firm Pumping Capacity[4]			10,200			7,800			7,200			8,200			7,400
Buildout Average Demand (Zones 4 and higher)			3,941			3,941			3,941			3,941			3,941
Unused Firm Capacity			6,259			3,859			3,259			4,259			3,459
Buildout Maximum Day Demand (Zones 4 and higher)			6,306												
Unused Firm Capacity			3,894												

Notes:
(1) Pump flow rates are planned design flow rates of future and rebuilt pump stations.
(2) Site 3C has two different pump stations serving Zone 4 and Horizon Six, respectively. The pumps in this table serve Zone 4.
(3) This site is planned for the future.
(4) Firm capacity is the total capacity with the largest pump per station out of service.

Table C.9 Evaluation of Zone 5 Sites with Buildout Demands
Lake Havasu City Water Master Plan Update

	Zone 5			Zone 5 - if 4A was Out of Service			Zone 5 - if 4 was Out of Service			Zone 5 - if 4C was Out of Service			Zone 5 - if 4D was Out of Service		
	Site	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**	**Site**	**Pump**	**Flow Rate[1] (gpm)**
	4A	1	1,200	4A	1	0	4A	1	1,200	4A	1	1,200	4A	1	1,200
		2	1,200		2	0		2	1,200		2	1,200		2	1,200
		3	1,200		3	0		3	1,200		3	1,200		3	1,200
	4[2]	1	500	4[2]	1	500	4[2]	1	0	4[2]	1	500	4[2]	1	500
		2	500		2	500		2	0		2	500		2	500
		3	500		3	500		3	0		3	500		3	500
	4C[3]	1	500	4C[3]	1	500	4C[3]	1	500	4C[3]	1	0	4C[3]	1	500
		2	500		2	500		2	500		2	0		2	500
		3	500		3	500		3	500		3	0		3	500
	4D[3]	1	1,200	4D[3]	1	1,200	4D[3]	1	1,200	4D[3]	1	1,200	4D[3]	1	0
		2	1,200		2	1,200		2	1,200		2	1,200		2	0
		3	1,200		3	1,200		3	1,200		3	1,200		3	0
Total Pumping Capacity			10,200			6,600			8,700			8,700			6,600
Firm Pumping Capacity[4]			6,800			4,400			5,800			5,800			4,400
Buildout Average Demand (Zones 5 and higher)			2,028			2,028			2,028			2,028			2,028
Unused Firm Capacity			4,772			2,372			3,772			3,772			2,372
Buildout Maximum Day Demand (Zones 5 and higher)			3,245												
Unused Firm Capacity			3,555												

Notes:

(1) Pump flow rates are planned design flow rates of future and rebuilt pump stations.
(2) Site 4 has two different pump stations serving Zone 5 and Zone 6A, respectively. The pumps in this table are the pumps to Zone 5.
(3) These sites are planned for the future.
(4) Firm capacity is the total capacity with the largest pump per station out of service.

Table C.10 Evaluation of Zone 6 Sites with Buildout Demands
Lake Havasu City Water Master Plan Update

	Zone 6			Zone 6-If 5A is Out of Service			Zone 6-If 4 is Out of Service			Zone 6-If 5D is Out of Service		
	Site	Pump	Flow Rate(1) (gpm)	Site	Pump	Flow Rate(1) (gpm)	Site	Pump	Flow Rate(1) (gpm)	Site	Pump	Flow Rate(1) (gpm)
	5A	1	1,000	5A	1	0	5A	1	500	5A	1	500
		2	1,000		2	0		2	500		2	500
		3	1,000		3	0		3	500		3	500
	4(2)	1	500	4(2)	1	500	4(2)	1	0	4(2)	1	500
		2	500		2	500		2	0		2	500
		3	500		3	500		3	0		3	500
	5D(3)	1	1,000	5D(3)	1	500	5D(3)	1	500	5D(3)	1	0
		2	1,000		2	500		2	500		2	0
		3	1,000		3	500		3	500		3	0
Total Pumping Capacity			7,500			3,000			3,000			3,000
Firm Pumping Capacity			5,000			2,000			2,000			2,000
Buildout Average Demand (Zones 6 and higher)(4)			1,137			1,137			1,137			1,137
Unused Firm Capacity			3,863			863			863			863
Buildout Maximum Day Demand (Zones 6 and higher) (4)			1,820									
Unused Firm Capacity			3,180									

Notes:
(1) Pump flow rates are planned design flow rates of future pump stations.
(2) Site 4 has two different pump stations serving Zone 5 and Zone 6, respectively. The pumps in this table are for Zone 6.
(3) These zones and sites are planned for the future.
(4) Zones 6 and 6A as configured in 2006 will be interconnected to the entire Zone 6 at buildout.

Table C.11 Evaluation of Zone 7 Sites with Buildout Demands
Lake Havasu City Water Master Plan Update

	Zone 7		
	Site	**Pump**	**Flow Rate[1] (gpm)**
	6A[2]	1	700
		2	700
		3	700
	6D[2]	1	700
		2	700
		3	700
Total Pumping Capacity			4,200
Firm Pumping Capacity			2,800
Buildout Average Demand (Zones 7 and higher)			228
Unused Firm Capacity			2,572
Buildout Maximum Day Demand (Zones 7 and higher)			365
Unused Firm Capacity			2,435

Notes:
(1) Pump flow rates are planned design flow rates of future pump stations.
(2) These zones and sites are planned for the future.

Table C.12 Evaluation of Terminal Zones with Buildout Demands
Lake Havasu City Water Master Plan Update

	Horizon Six			Zone 7A			Zone 7D		
	Site	**Pump**	**Flow Rate(1) (gpm)**	**Site**	**Pump**	**Flow Rate(1) (gpm)**	**Site**	**Pump**	**Flow Rate(1) (gpm)**
	3C(2)	1	290	7A(3)	1	500	7D(3)	1	500
		2	290		2	500		2	500
		3	1,000		3	500		3	500
Total Pumping Capacity			1,580			1,500			1,500
Max Day + Fire Flow Demand(4)			1,119			1,058			1,058
Unused Firm Capacity			461			442			442

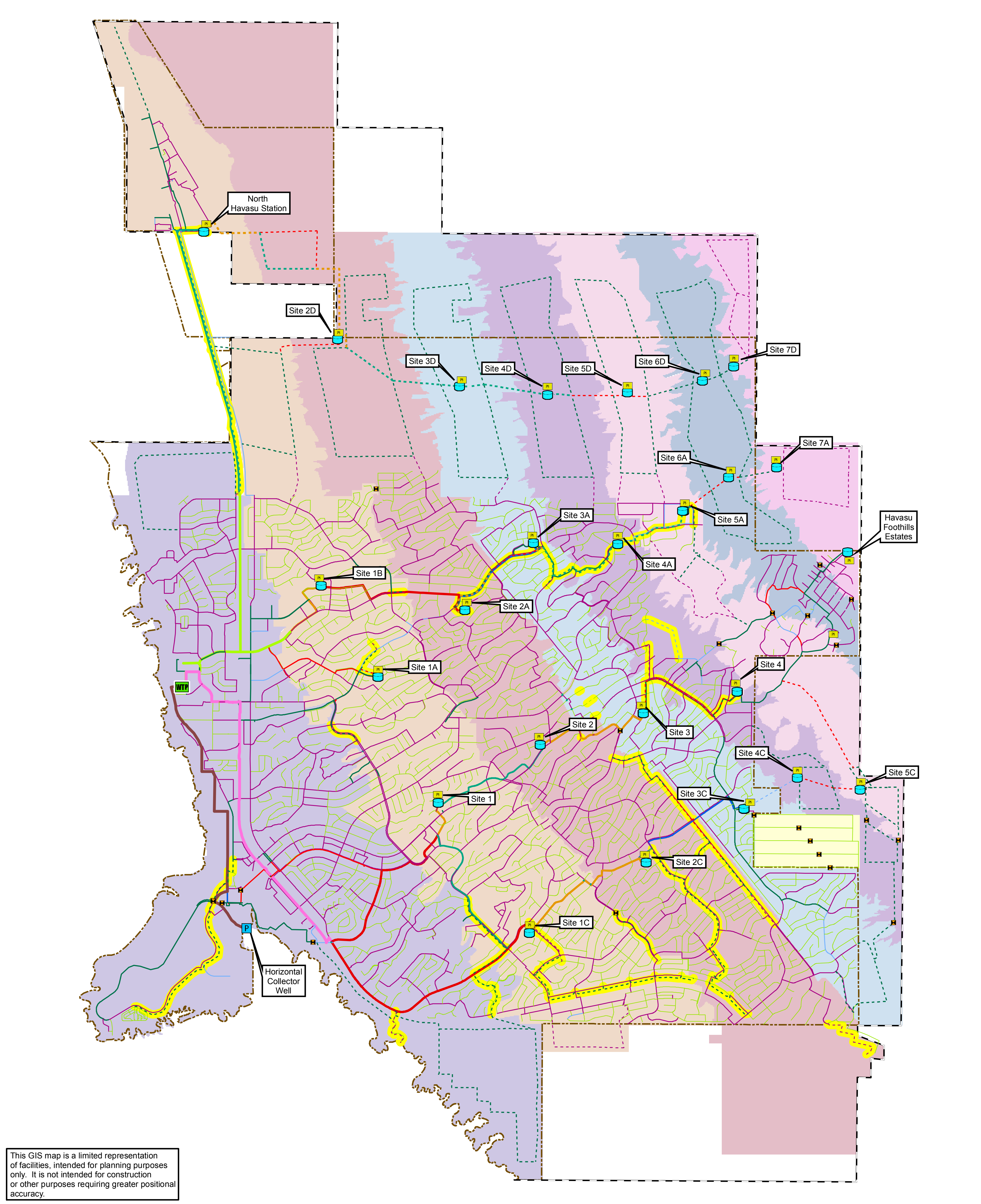
Notes:

(1) Pump flow rates are planned design flow rates of future pump stations.

(2) Site 3C has two different pump stations serving Zone 4 and Horizon Six, respectively. The pumps in this table serve Horizon 6.

(3) These zones and sites are planned for the future.

(4) Residential fire flow demand is set at 1,000 gpm.



This GIS map is a limited representation of facilities, intended for planning purposes only. It is not intended for construction or other purposes requiring greater positional accuracy.

PRV
Booster Station
Water Treatment Plant
Storage Tank
City Limits
Water Service Boundary

Pressure Zones
1
2
3
4
5
6
Horizon 6
7
8

Existing Pipes Diameter
Under 8"
8"
10"
12"
16"
18"
20"
24"
27"
30"
36"
48"

Proposed Pipes Diameter
Under 8"
8"
10"
12"
16"
20"
24"
30"

Capital Project Pipes

N

Miles
0 0.5 1

carollo

Figure C.1

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS OVERVIEW

Lake Havasu City Water Master Plan Update

Final - October 2007

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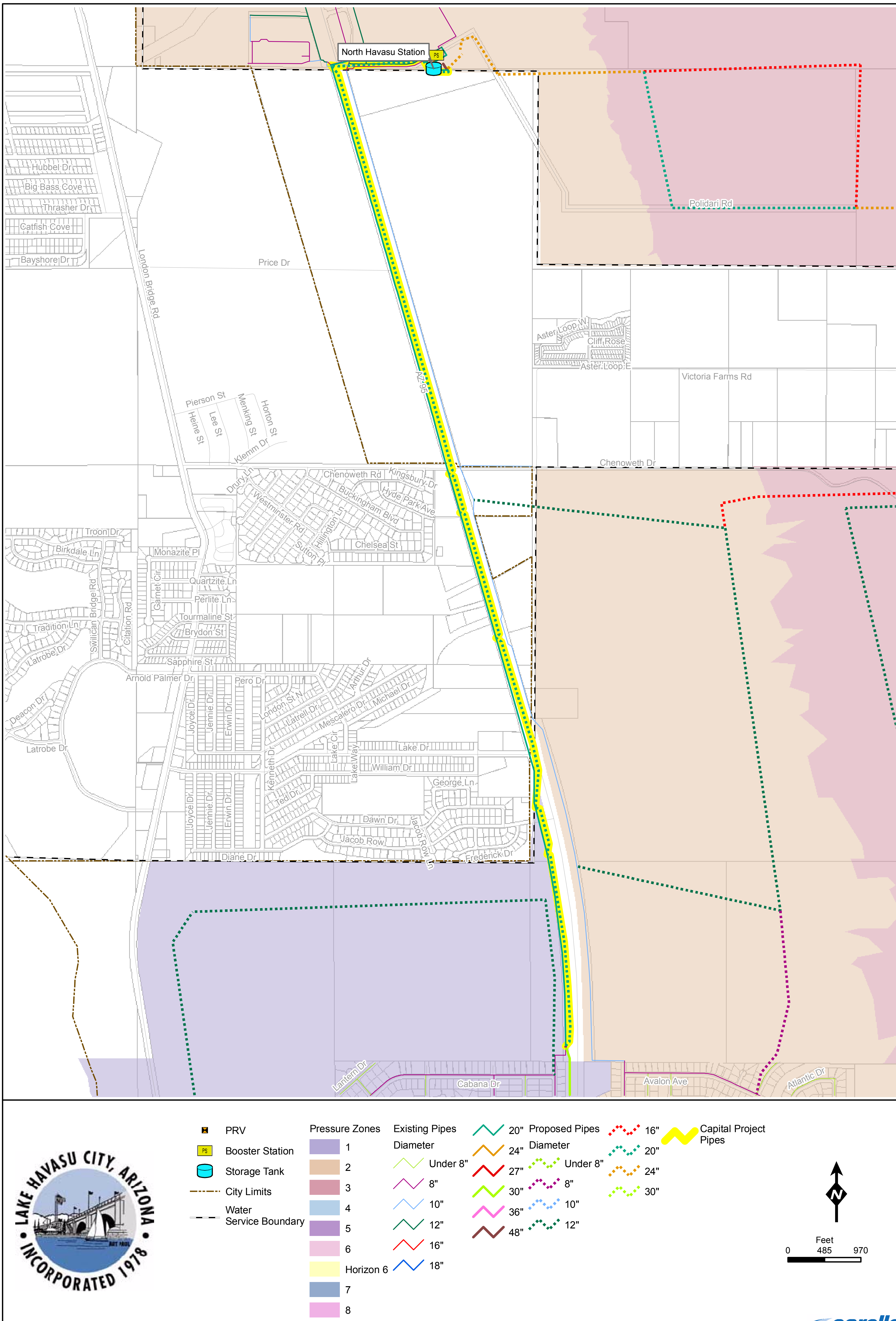

Figure C.2

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 1

Lake Havasu City Water Master Plan Update
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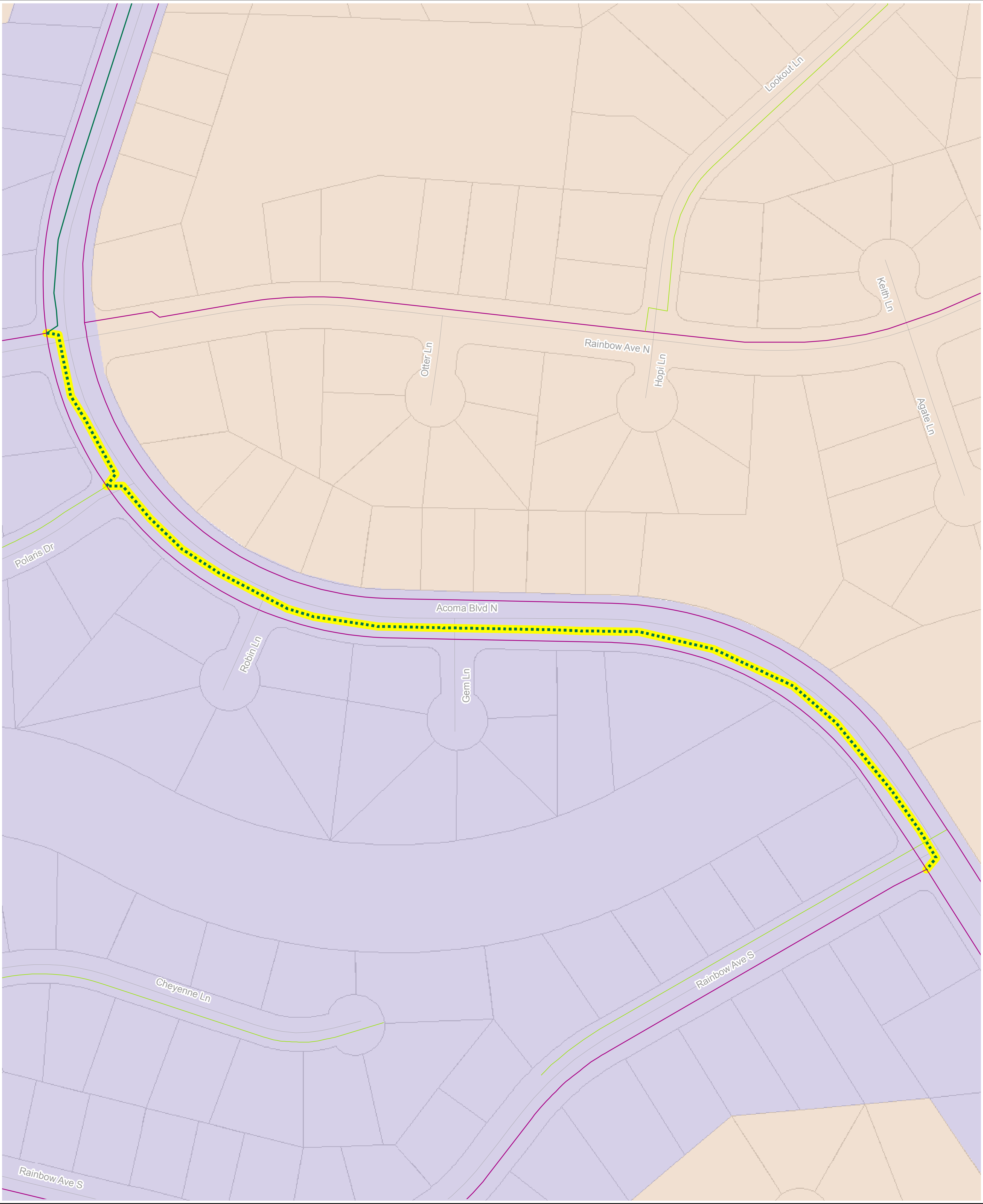

PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones: 1, 2, 3, 4, 5, 6, Horizon 6, 7, 8

Existing Pipes Diameter: Under 8", 8", 10", 12", 16", 18", 20", 24", 27", 30", 36", 48"

Proposed Pipes Diameter: Under 8", 8", 10", 12", 16", 20", 24", 30"

Capital Project Pipes

N

Feet
0 60 120

carollo

Figure C.3

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 2

Lake Havasu City Water Master Plan Update
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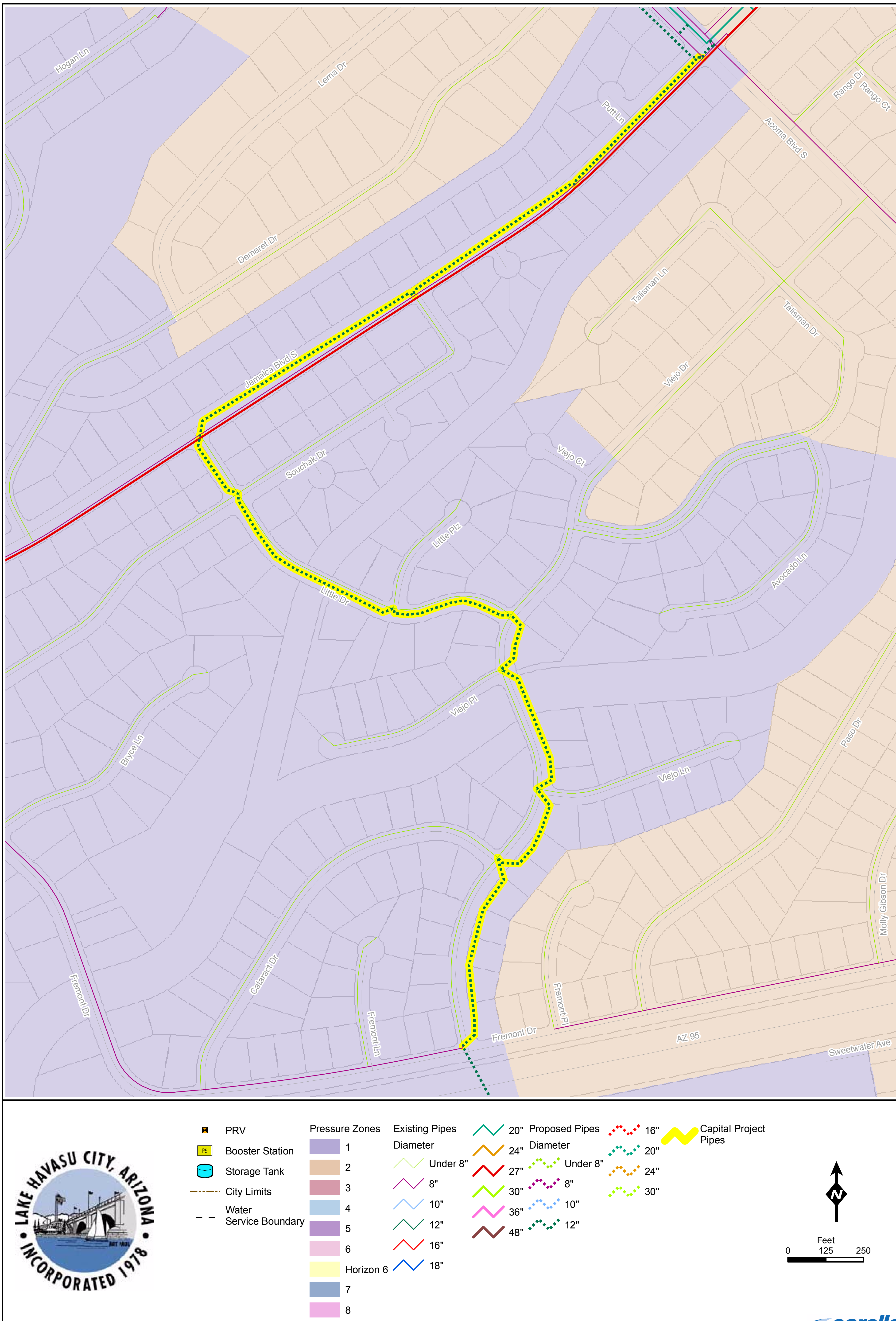

Figure C.5

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 4

Lake Havasu City Water Master Plan Update
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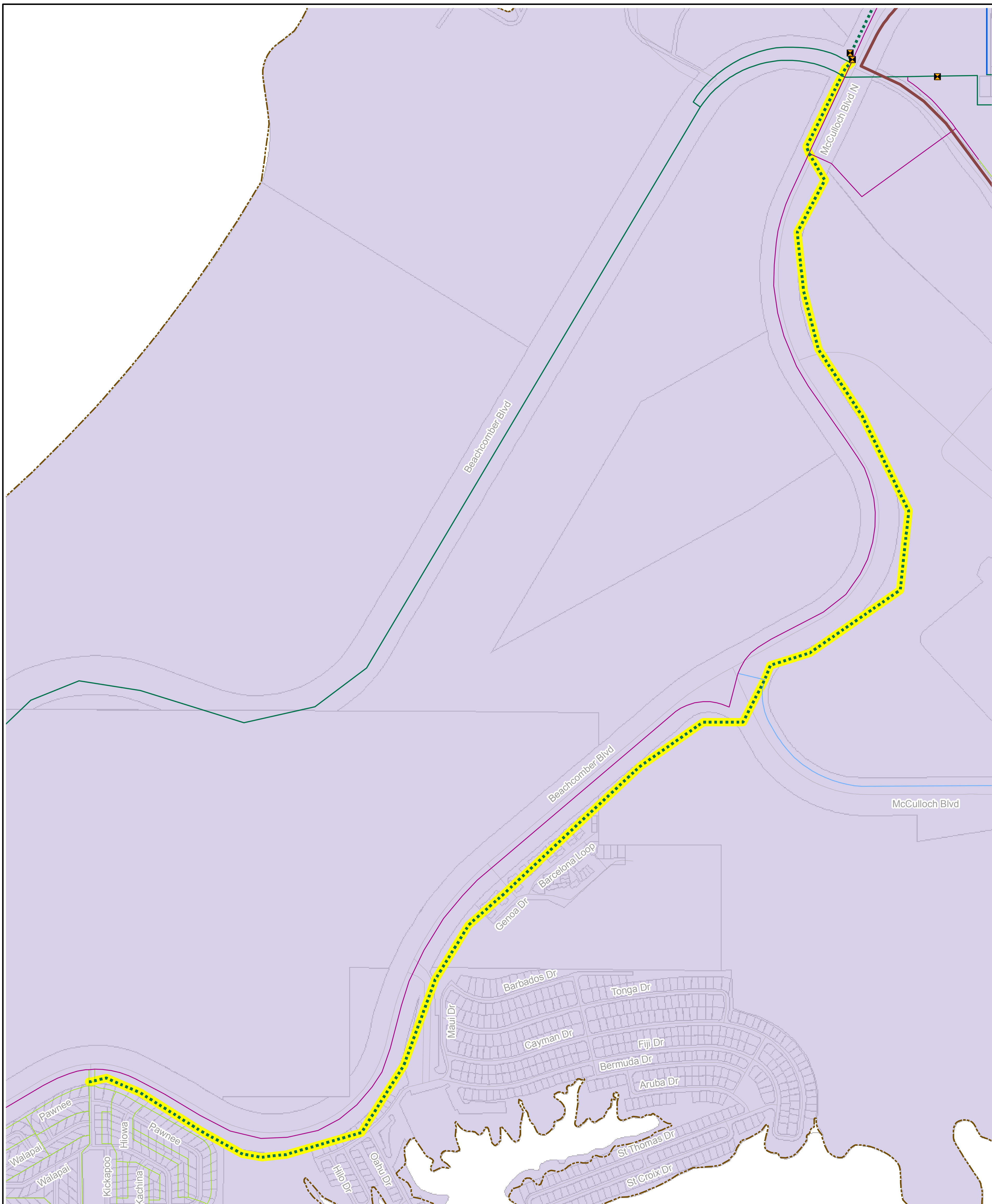


PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones: 1, 2, 3, 4, 5, 6, Horizon 6, 7, 8

Existing Pipes Diameter: Under 8", 8", 10", 12", 16", 18", 20", 24", 27", 30", 36", 48"

Proposed Pipes Diameter: Under 8", 8", 10", 12", 16", 20", 24", 30"

Capital Project Pipes

N

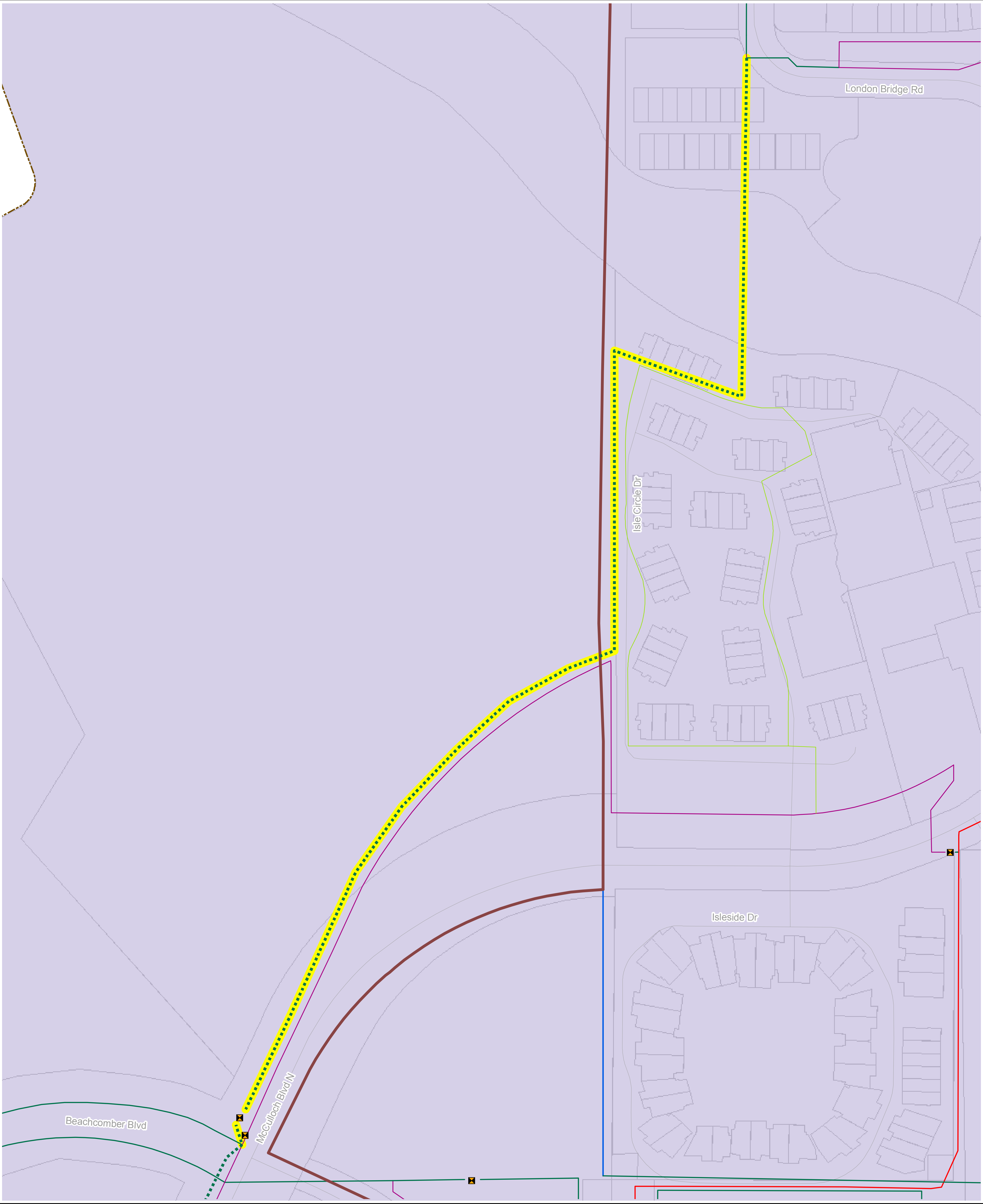
Feet
0 210 420

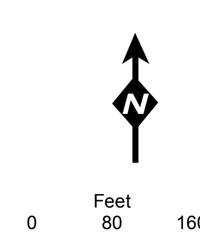
carollo

Figure C.6

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 5

Lake Havasu City Water Master Plan Update
Final - October 2007





PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones
1
2
3
4
5
6
Horizon 6
7
8

Existing Pipes Diameter
Under 8"
8"
10"
12"
16"
18"
20"
24"
27"
30"
36"
48"

Proposed Pipes Diameter
Under 8"
8"
10"
12"
16"
20"
24"
30"

Capital Project Pipes

Feet
0 80 160

Figure C.7

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 6

Lake Havasu City Water Master Plan Update
Final - October 2007

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Figure C.8

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 7

Lake Havasu City Water Master Plan Update
Final - October 2007

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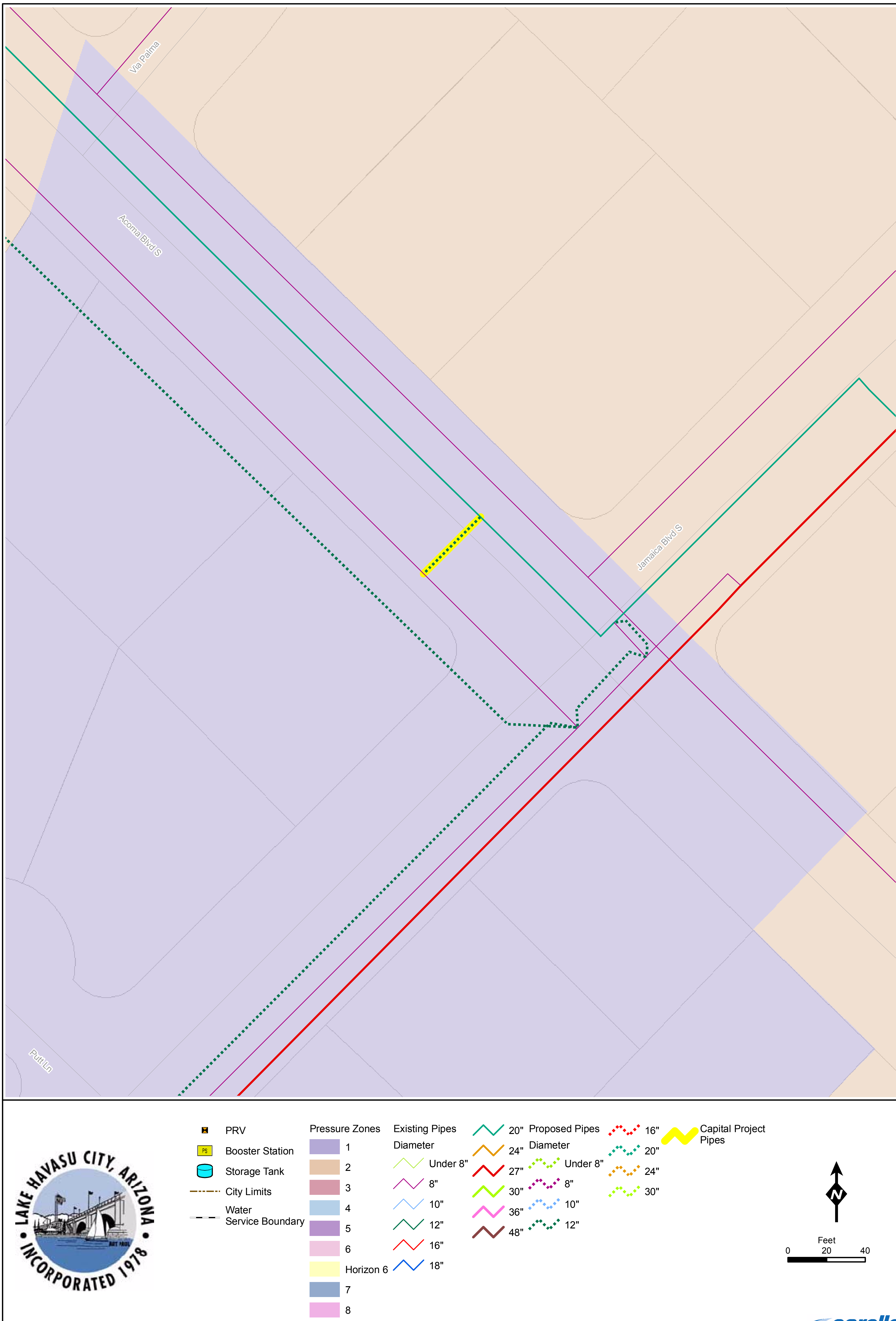

Figure C.9

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 8

Lake Havasu City Water Master Plan Update
Final - October 2007

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PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones
1
2
3
4
5
6
Horizon 6
7
8

Existing Pipes Diameter
Under 8"
8"
10"
12"
16"
18"
20"
24"
27"
30"
36"
48"

Proposed Pipes Diameter
Under 8"
8"
10"
12"
16"
20"
24"
30"

Capital Project Pipes

Feet
0 62.5 125

Figure C.10

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 9

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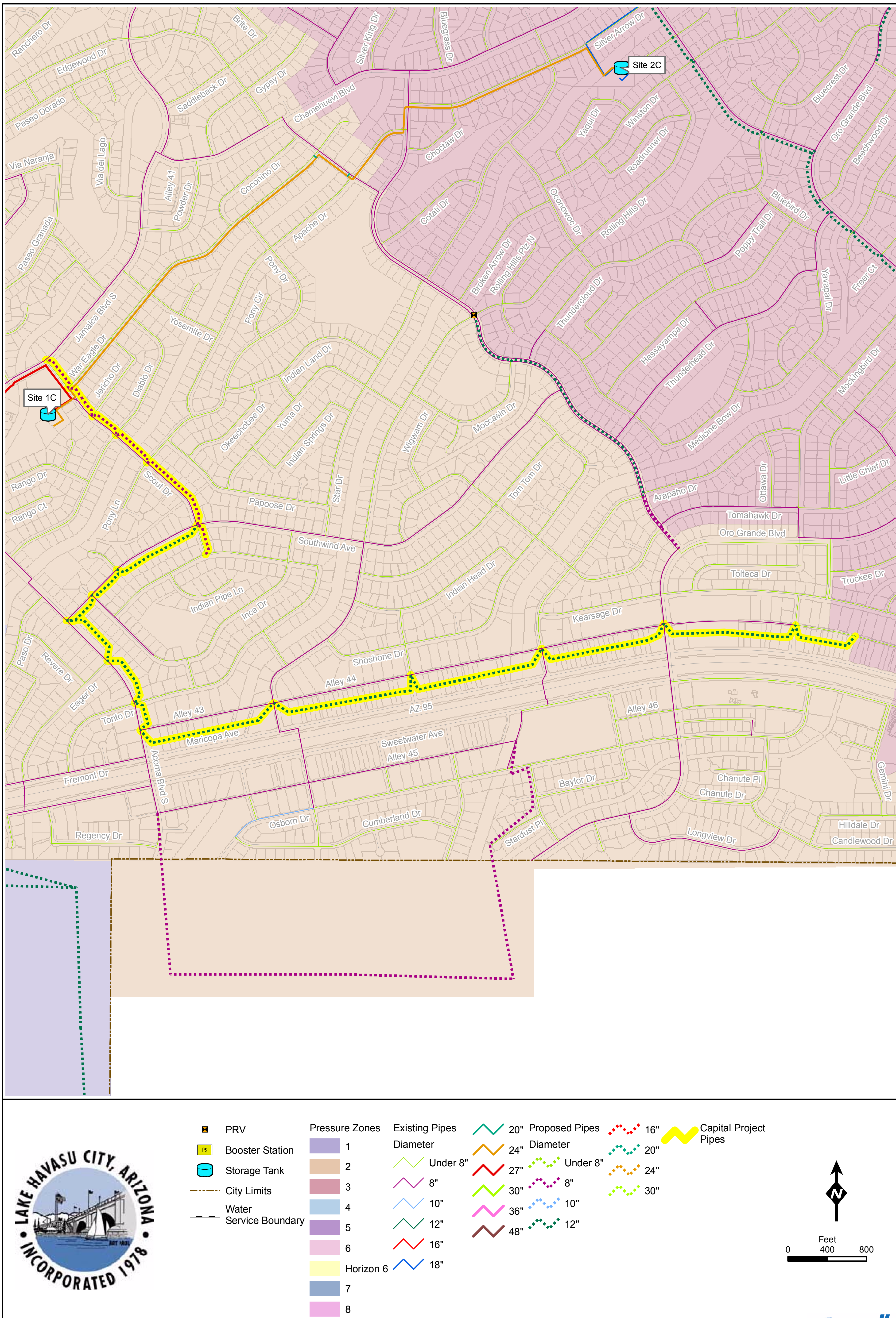

Figure C.11

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 10

Lake Havasu City Water Master Plan Update
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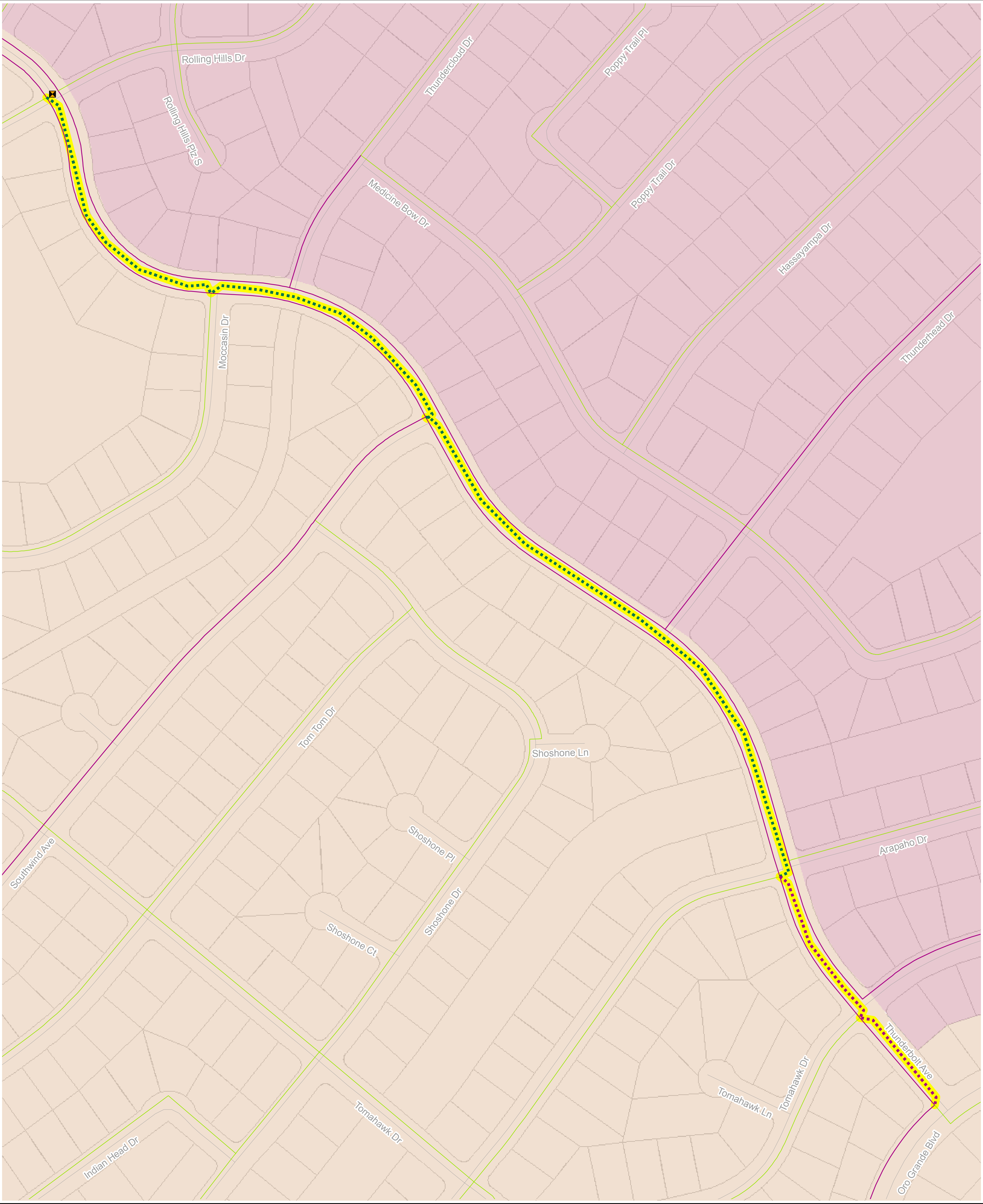

PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones: 1, 2, 3, 4, 5, 6, Horizon 6, 7, 8

Existing Pipes Diameter: Under 8", 8", 10", 12", 16", 18", 20", 24", 27", 30", 36", 48"

Proposed Pipes Diameter: Under 8", 8", 10", 12", 16", 20", 24", 30"

Capital Project Pipes

Feet: 0, 100, 200

carollo

Figure C.12

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 11

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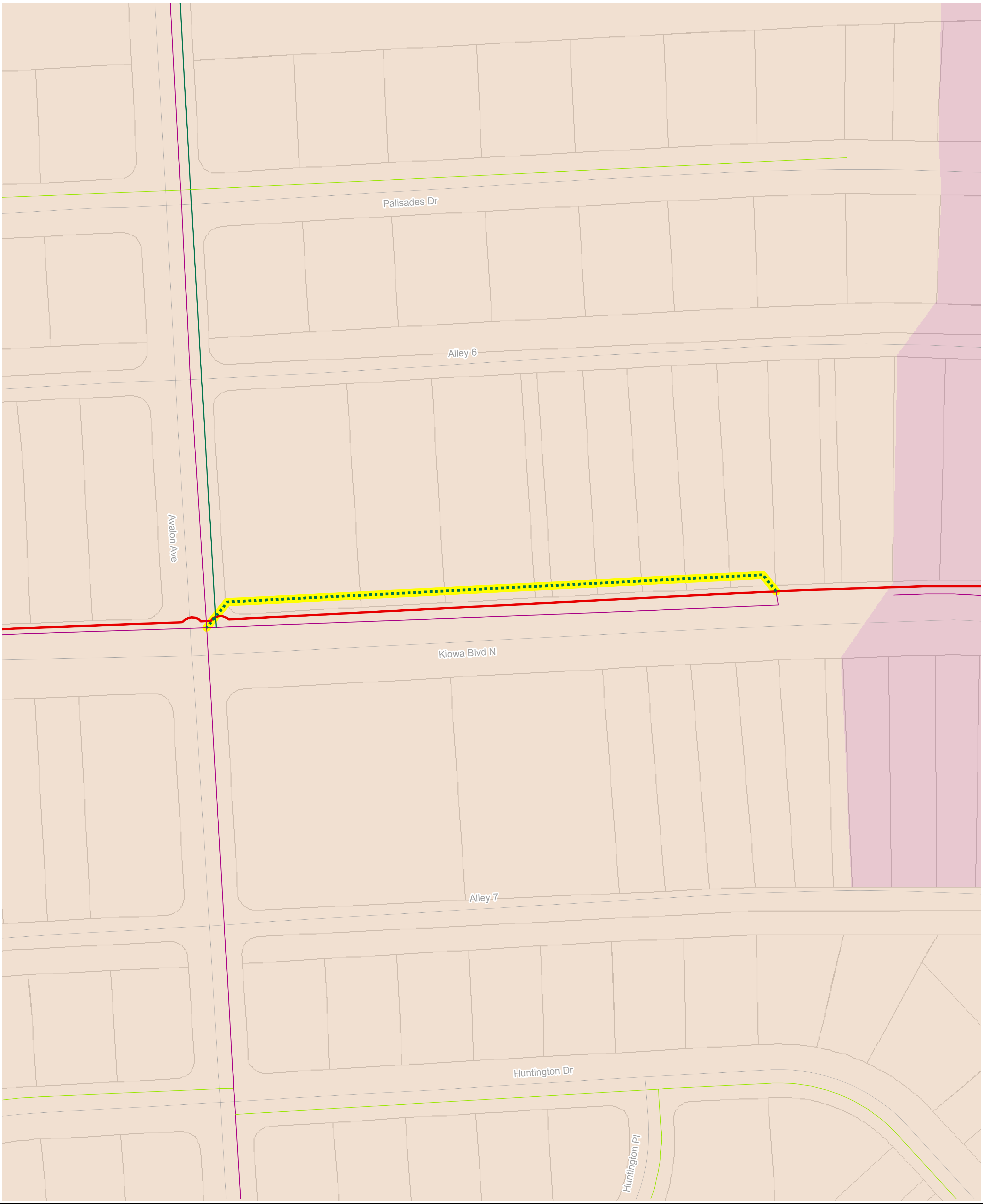

PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones: 1, 2, 3, 4, 5, 6, Horizon 6, 7, 8

Existing Pipes Diameter: Under 8", 8", 10", 12", 16", 18", 20", 24", 27", 30", 36", 48"

Proposed Pipes Diameter: Under 8", 8", 10", 12", 16", 20", 24", 30"

Capital Project Pipes

Feet
0 45 90

carollo

Figure C.13

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 12

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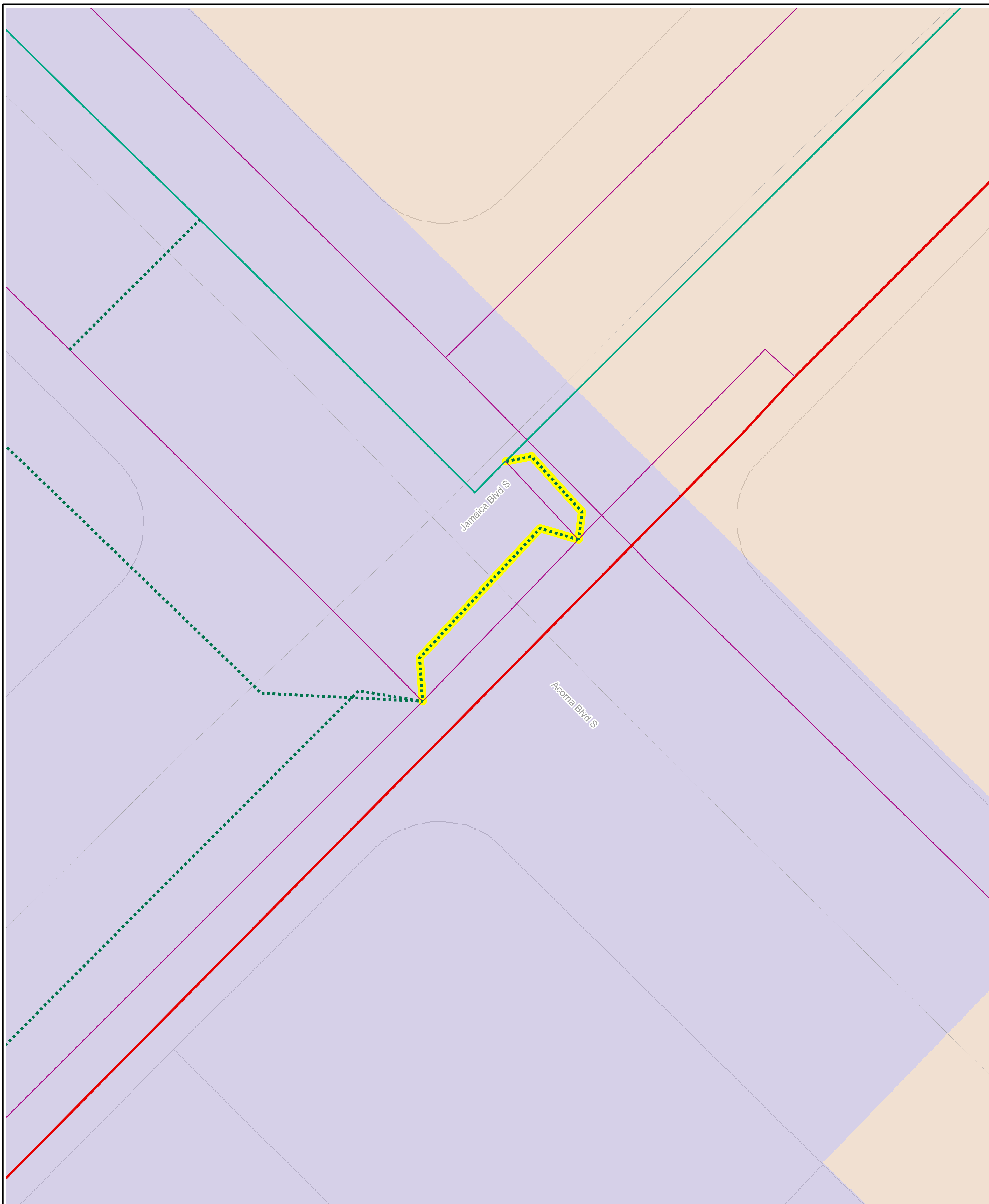

PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones
1
2
3
4
5
6
Horizon 6
7
8

Existing Pipes Diameter
Under 8"
8"
10"
12"
16"
18"
20"
24"
27"
30"
36"
48"

Proposed Pipes Diameter
Under 8"
8"
10"
12"
16"
20"
24"
30"

Capital Project Pipes

N

Feet
0 10 20

carollo

Figure C.14

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 13

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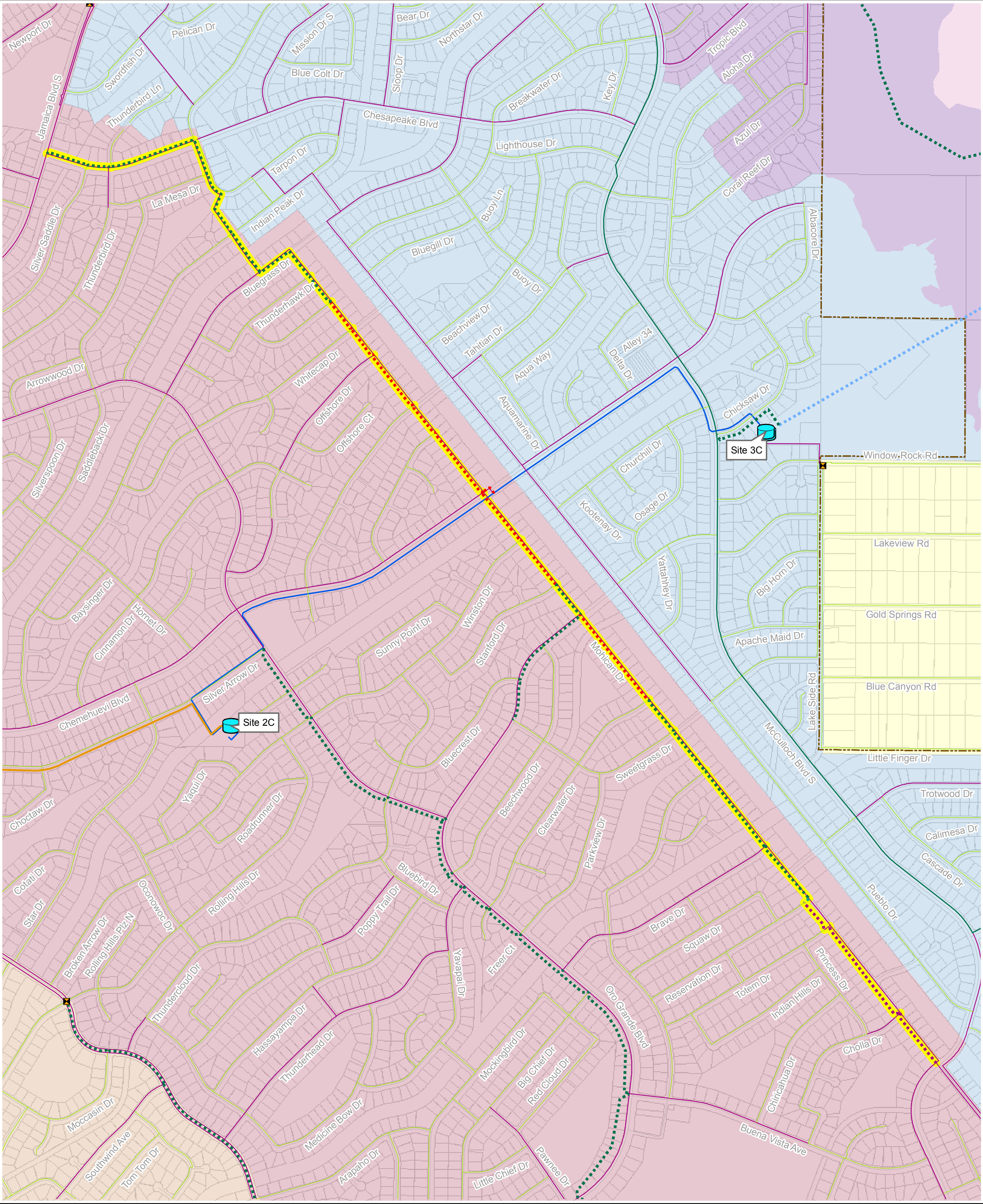

PRV	
PS	Booster Station
	Storage Tank
	City Limits
	Water Service Boundary

Pressure Zones

- 1
- 2
- 3
- 4
- 5
- 6
- Horizon 6
- 7
- 8

Existing Pipes Diameter

- Under 8"
- 8"
- 10"
- 12"
- 16"
- 18"
- 20"
- 24"
- 27"
- 30"
- 36"
- 48"

Proposed Pipes Diameter

- Under 8"
- 8"
- 10"
- 12"
- 16"
- 20"
- 24"
- 30"

Capital Project Pipes

carollo

Figure C.15

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 14

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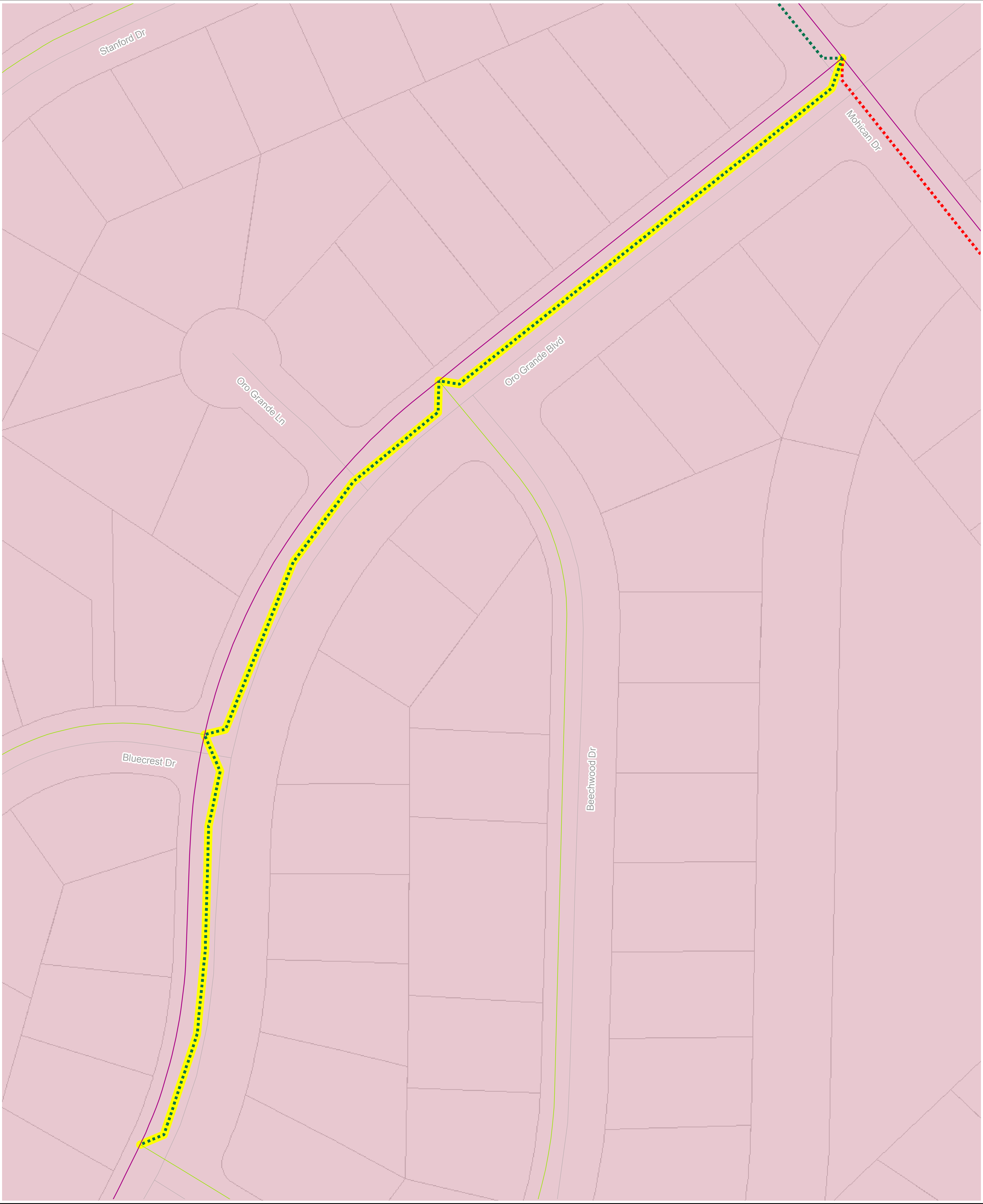

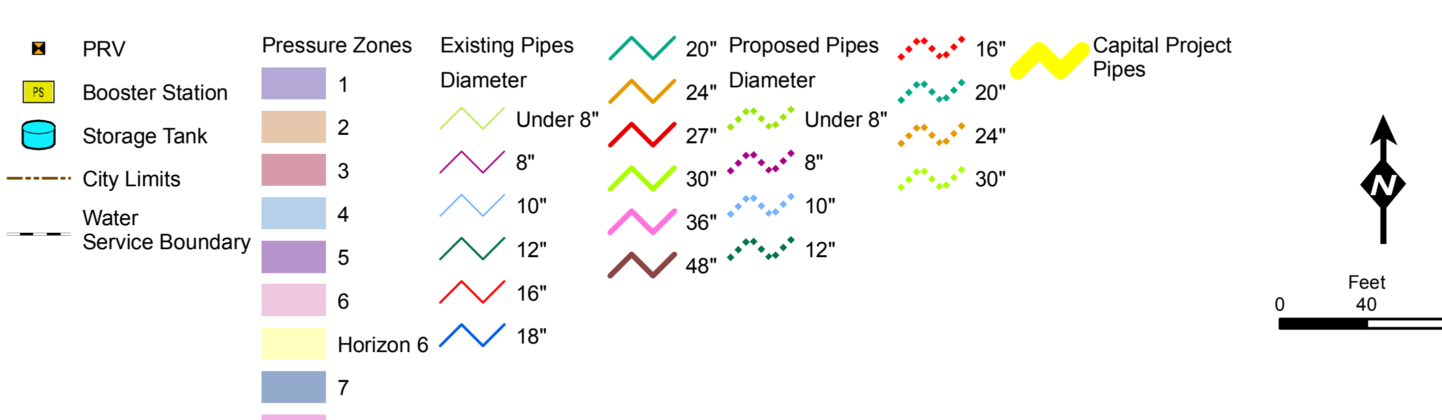

Figure C.16

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 15

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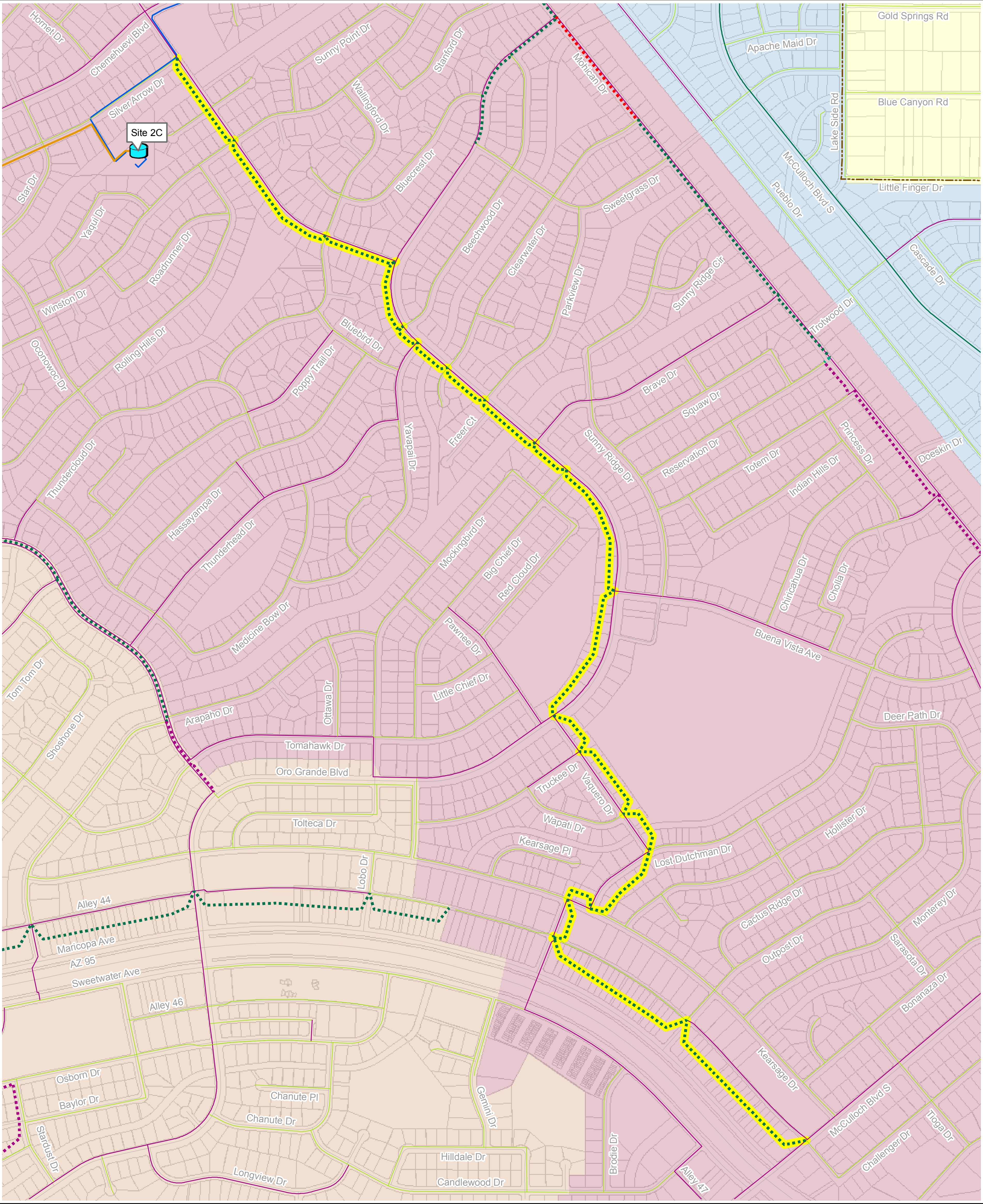

PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones	
	1
	2
	3
	4
	5
	6
	Horizon 6
	7
	8

Existing Pipes Diameter: Under 8", 8", 10", 12", 16", 18", 20", 24", 27", 30", 36", 48"

Proposed Pipes Diameter: Under 8", 8", 10", 12", 16", 20", 24", 30"

Capital Project Pipes

N

Feet
0 337.5 675

carollo

Figure C.17

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 16

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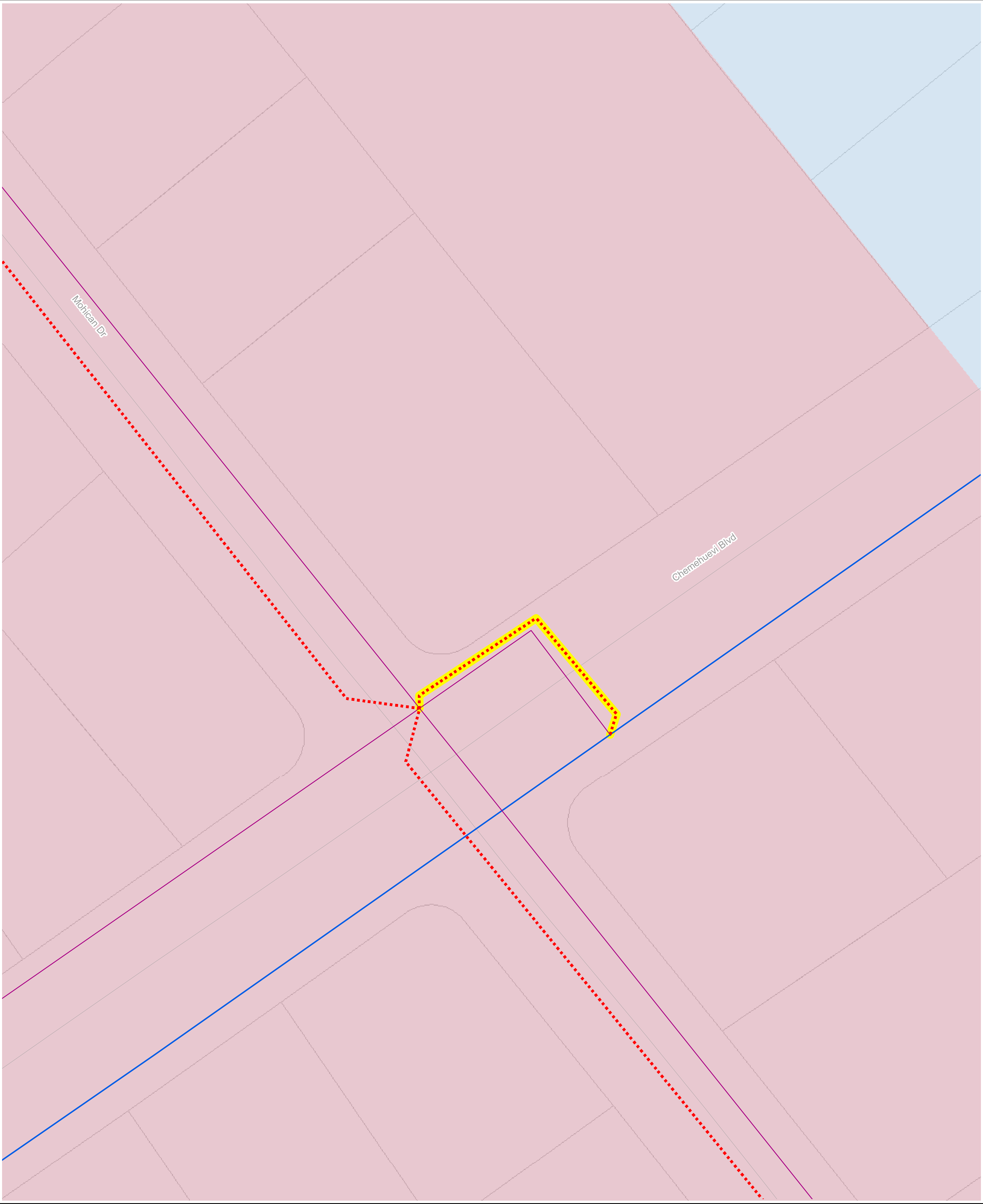

PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones
1
2
3
4
5
6
Horizon 6
7
8

Existing Pipes Diameter
Under 8"
8"
10"
12"
16"
18"
20"
24"
27"
30"
36"
48"

Proposed Pipes Diameter
Under 8"
8"
10"
12"
16"
20"
24"
30"

Capital Project Pipes

N

Feet
0 20 40

carollo

Figure C.18

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 17

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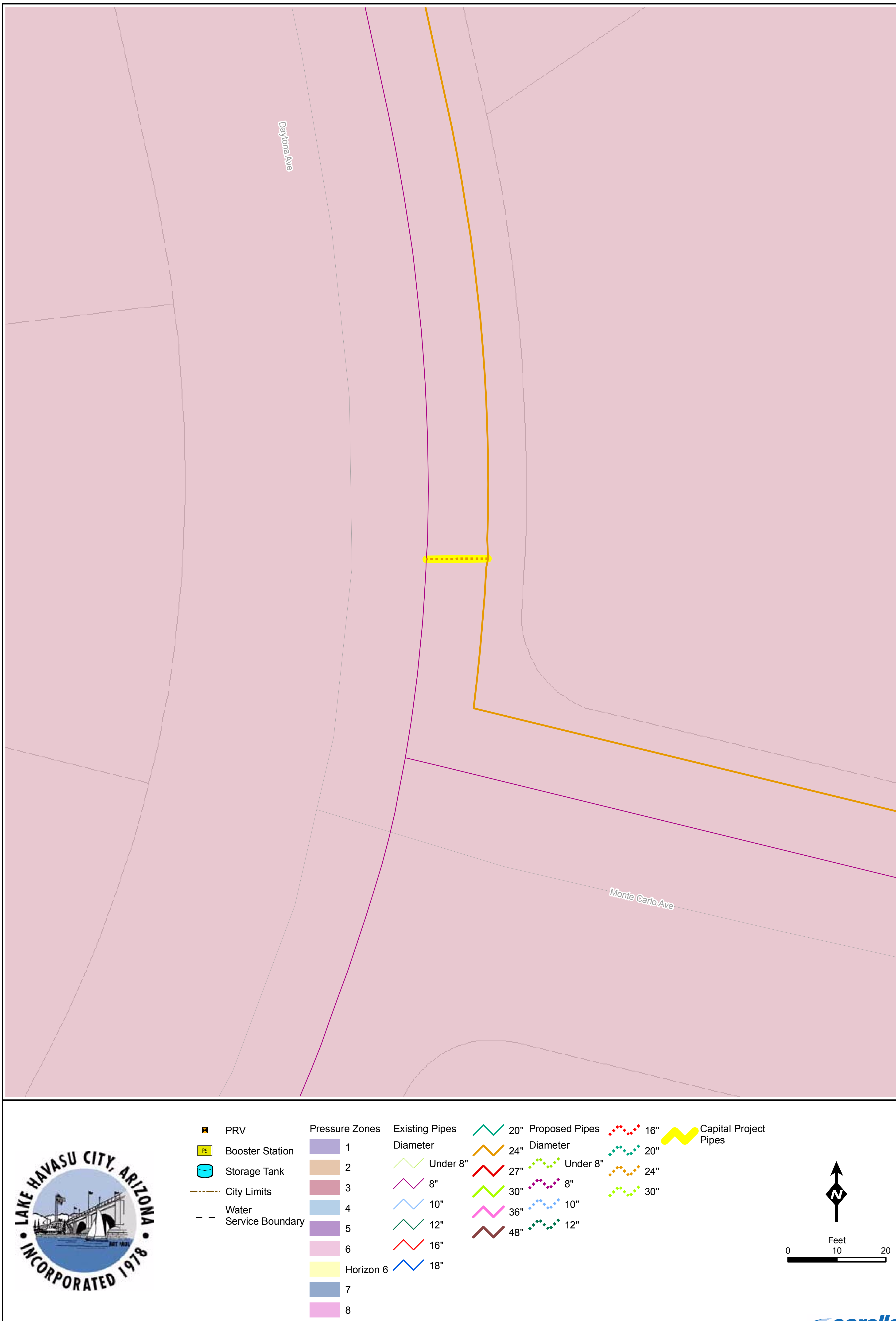

Figure C.19

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 18

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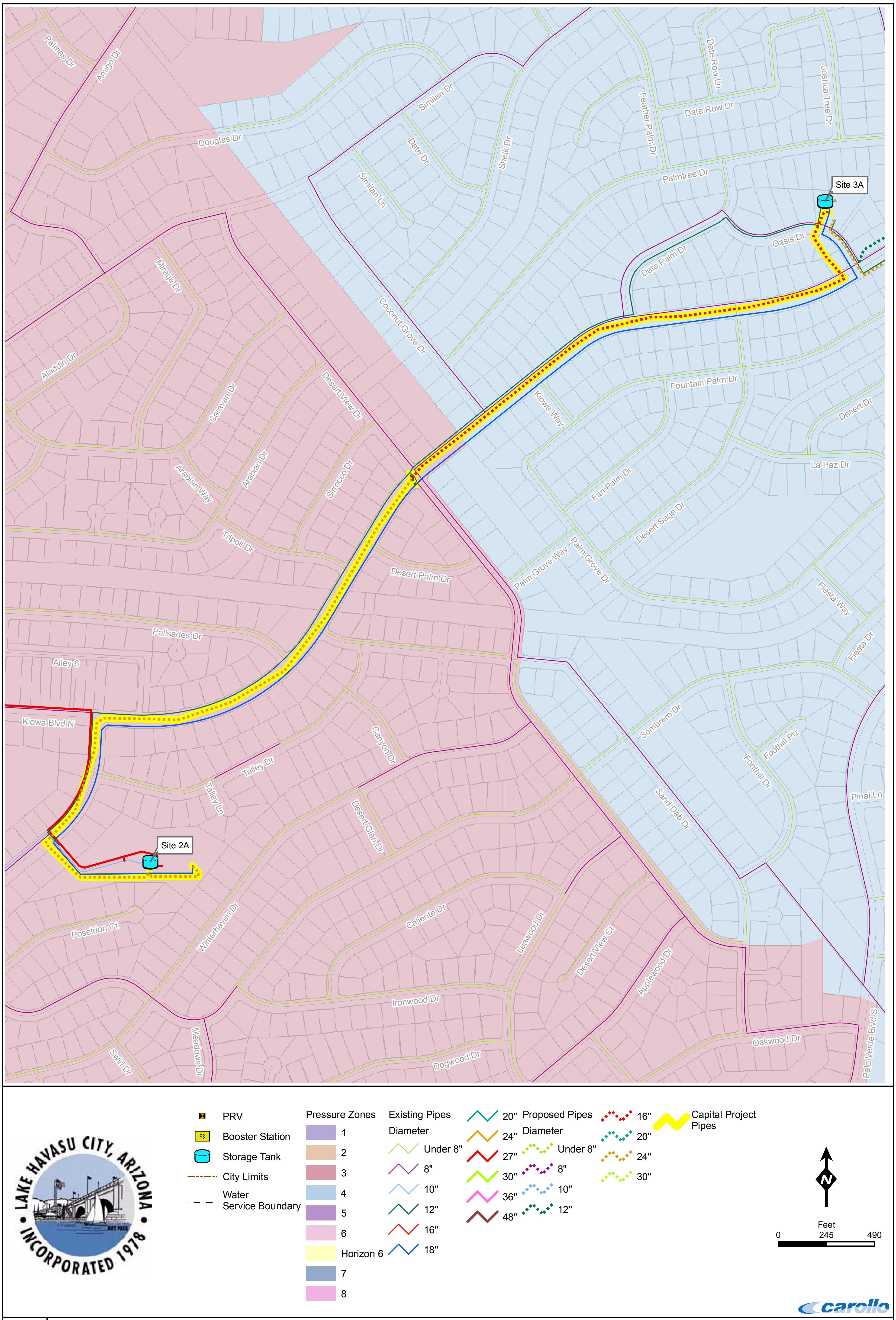

Figure C.20

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 19

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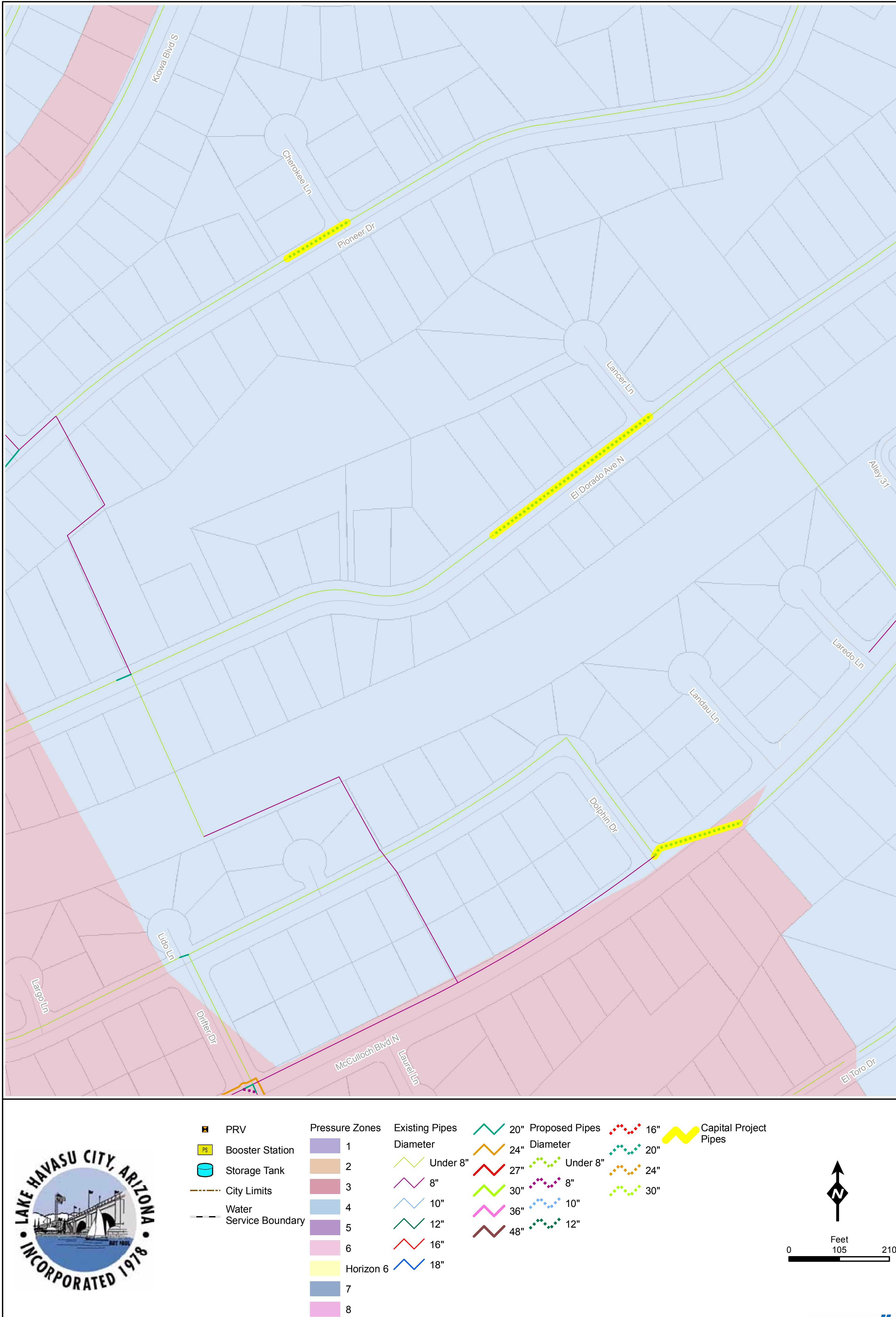

Figure C.21

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 20

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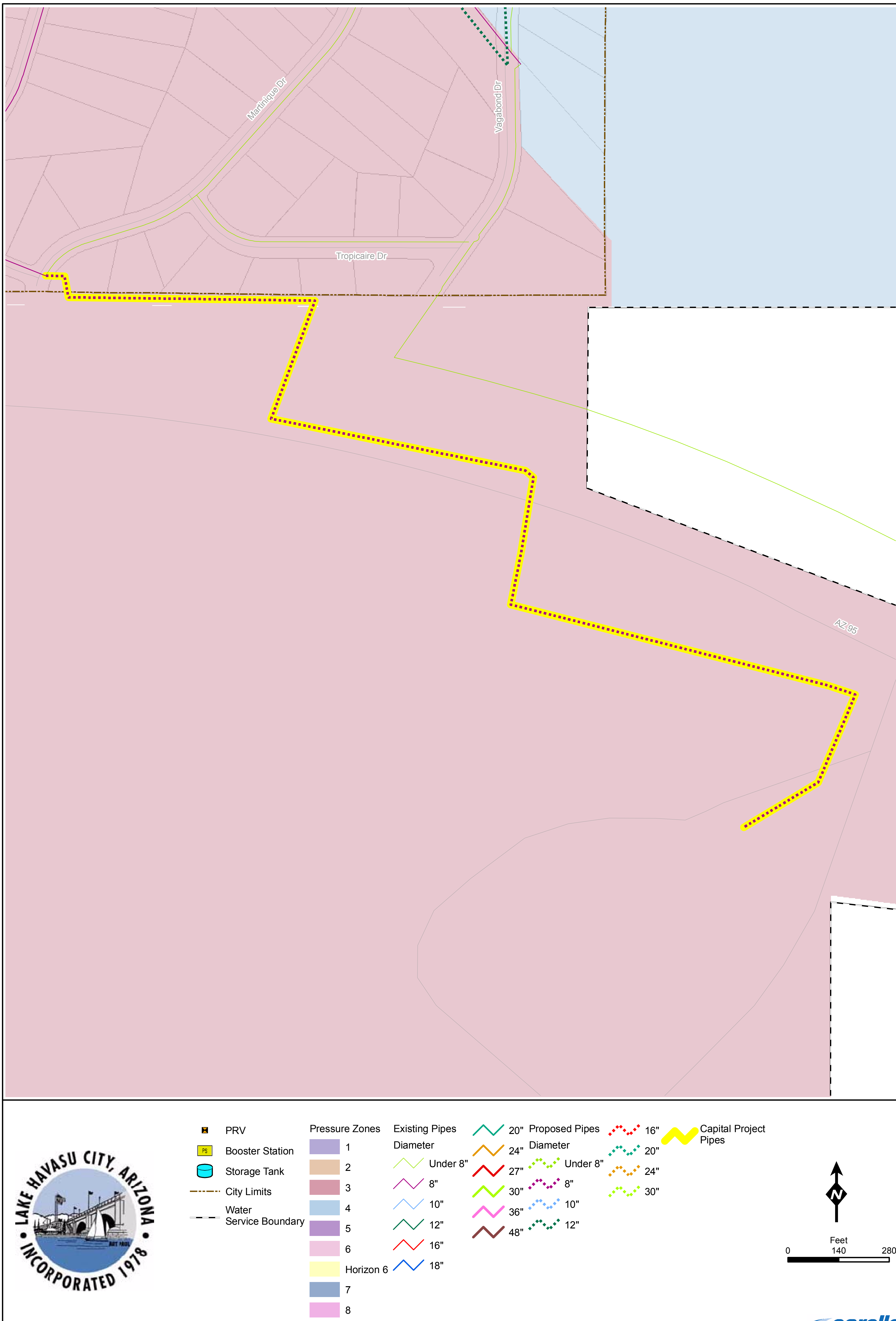

Figure C.22

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 21

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M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\August maps\LHC Wtr Dist Sys CIP work file.mxd

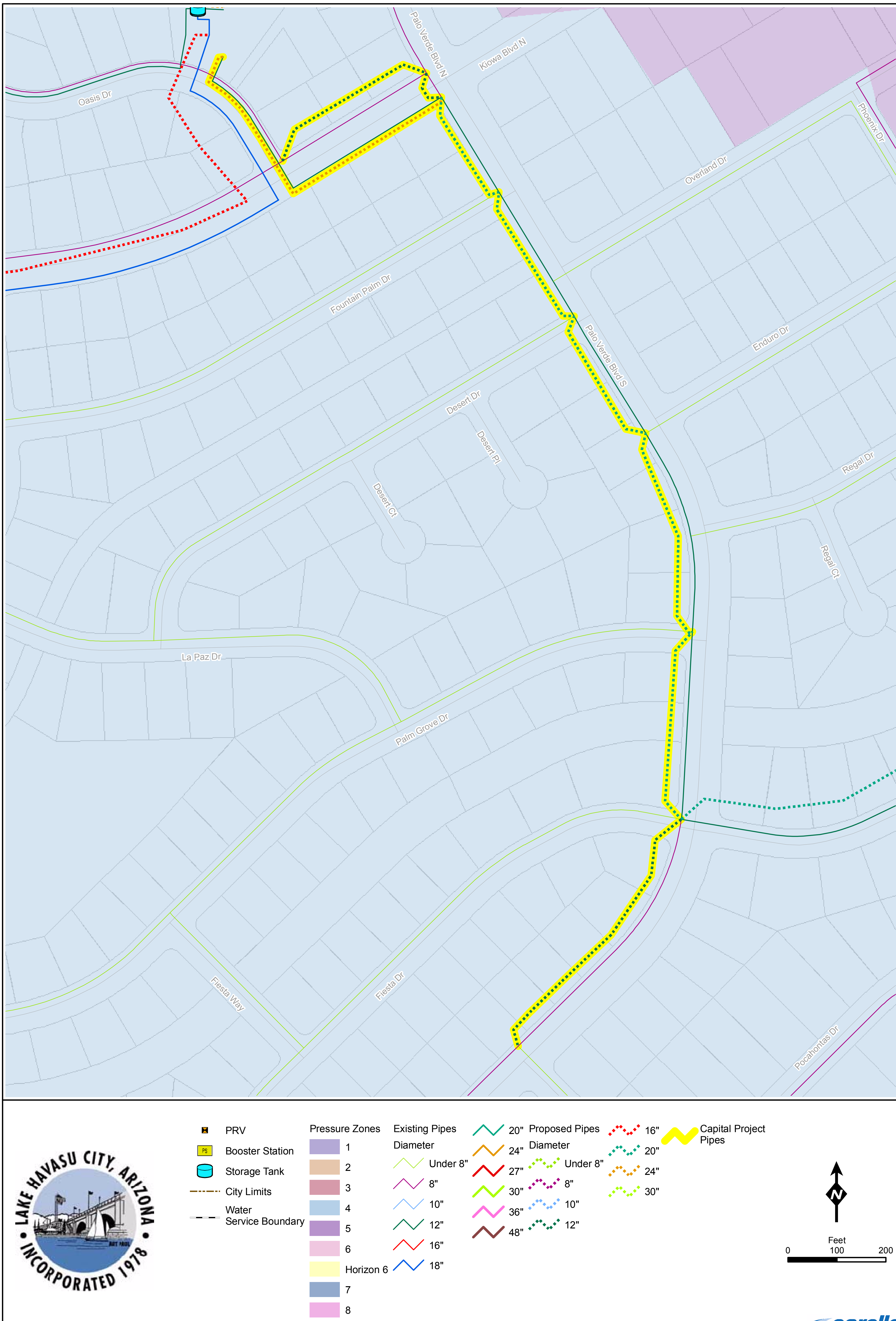

Figure C.23

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 22

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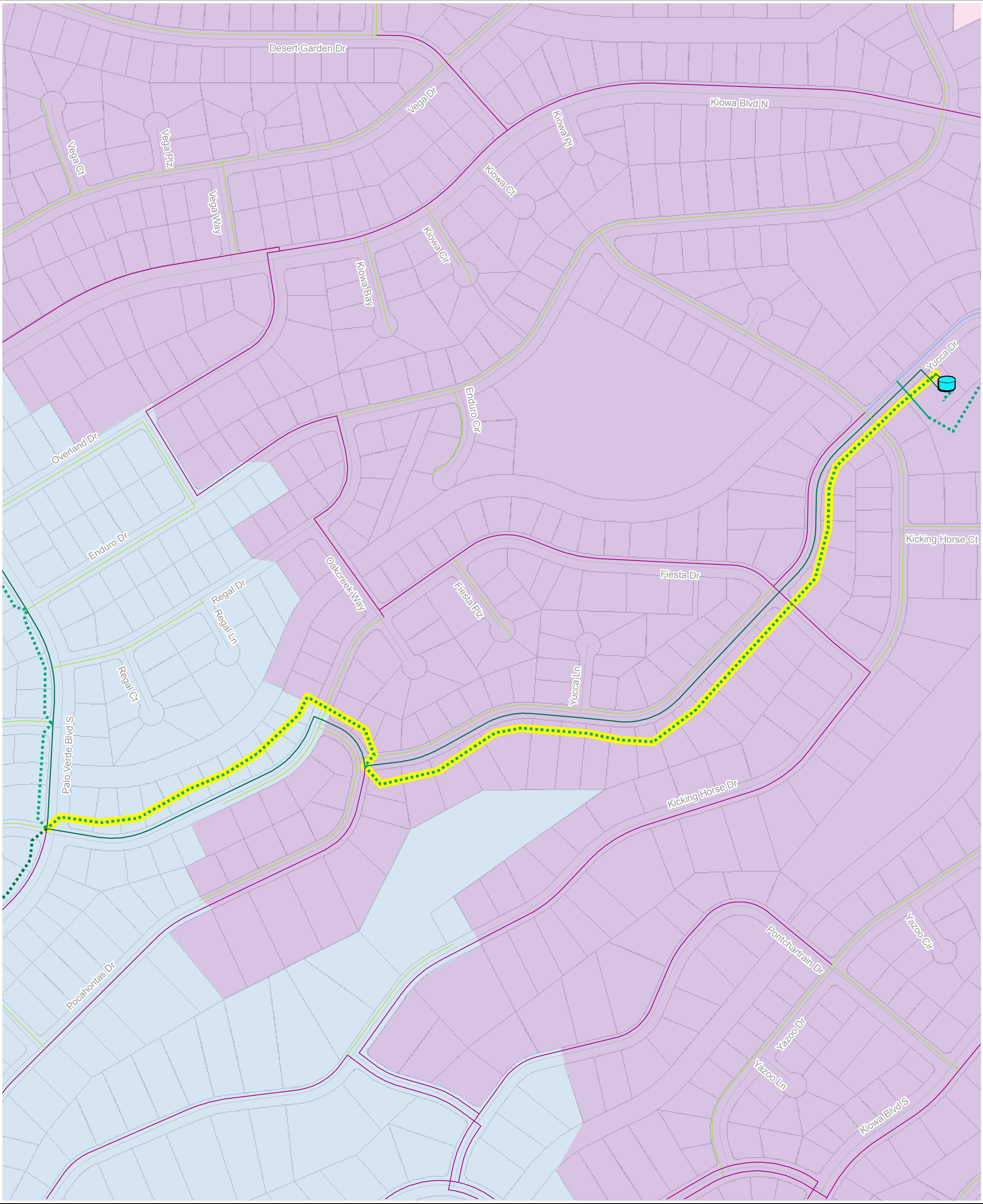

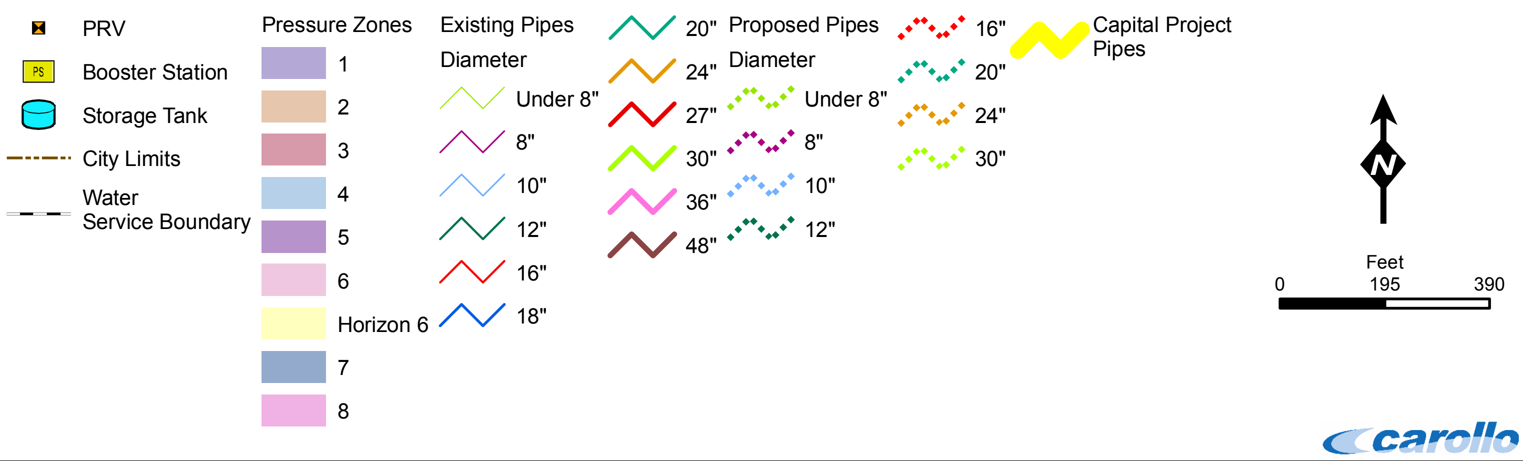

Figure C.24

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 23

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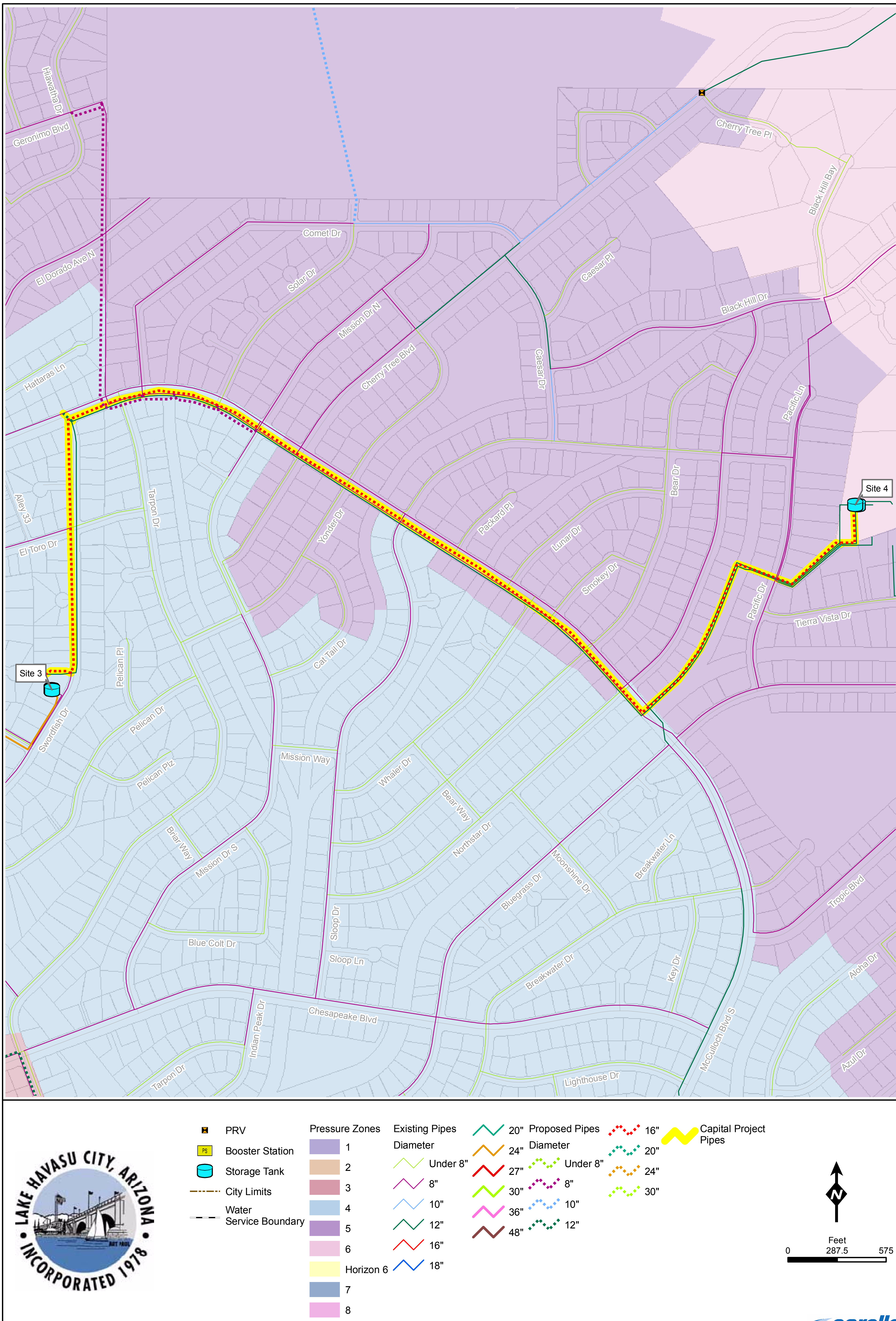

Figure C.25

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 24

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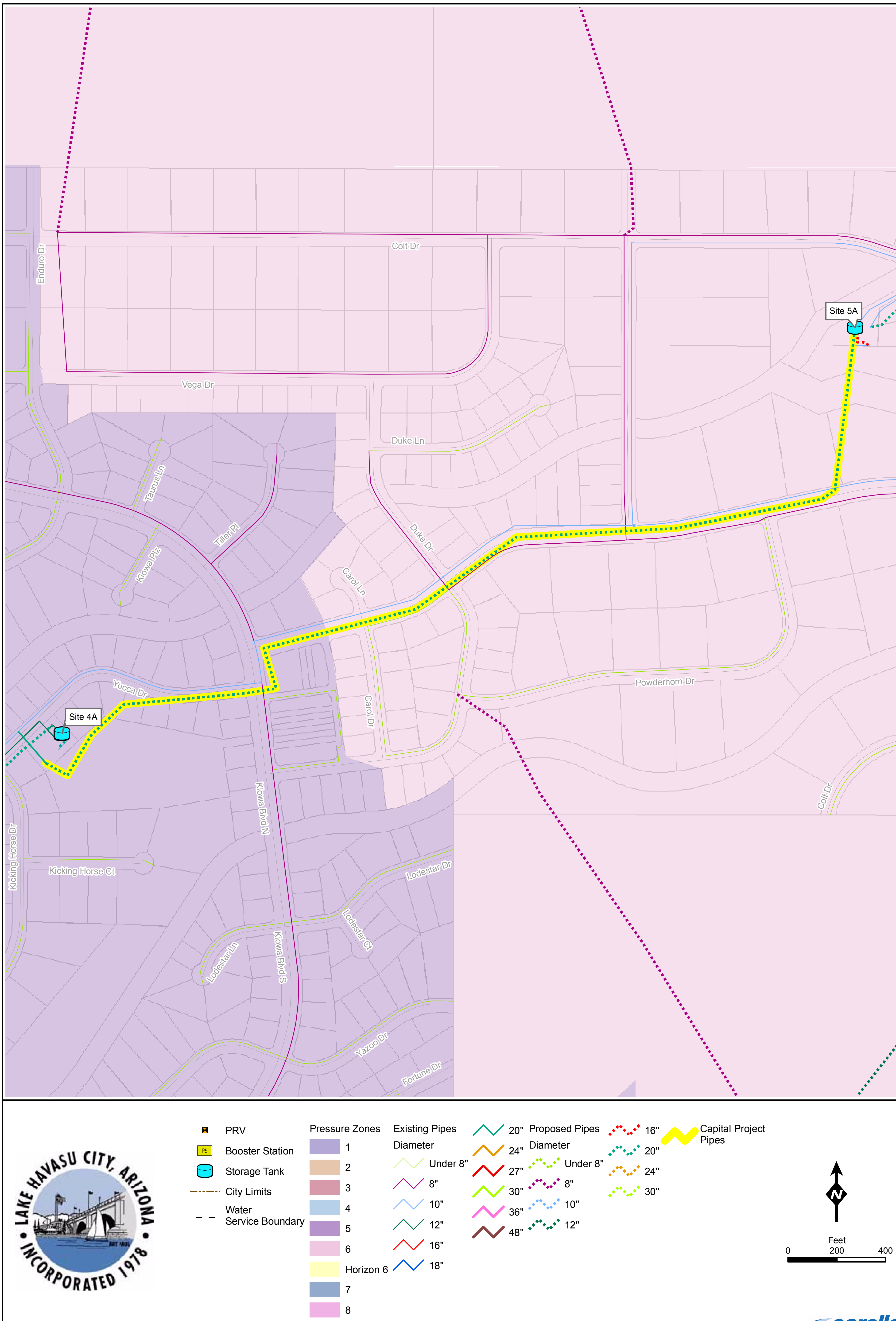

Figure C.26

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 25

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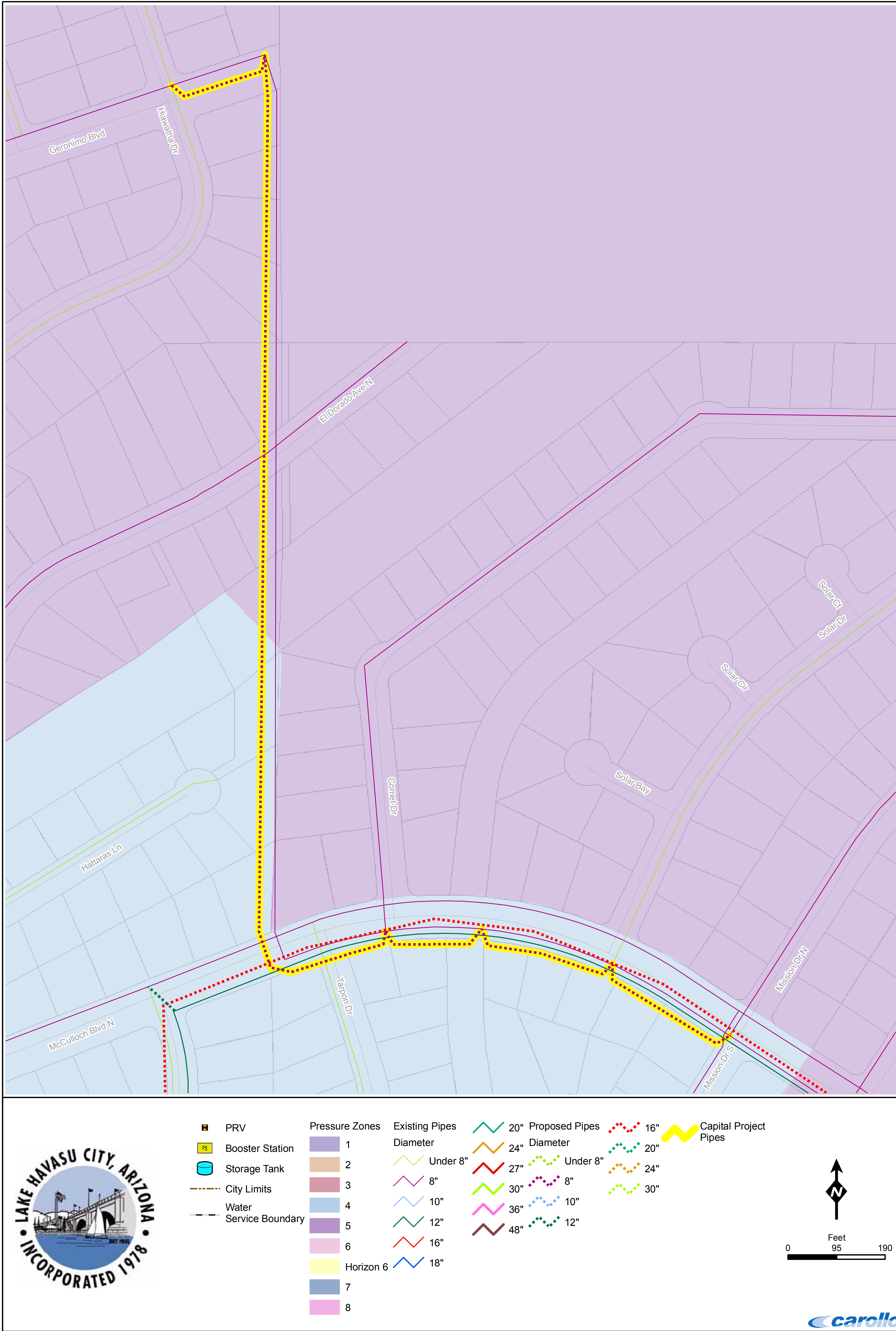

Figure C.27

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 26

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PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones
1
2
3
4
5
6
Horizon 6
7
8

Existing Pipes Diameter
Under 8"
8"
10"
12"
16"
18"
20"
24"
27"
30"
36"
48"

Proposed Pipes Diameter
Under 8"
8"
10"
12"
16"
20"
24"
30"

Capital Project Pipes

Feet
0 45 90

carollo

Figure C.28

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 27

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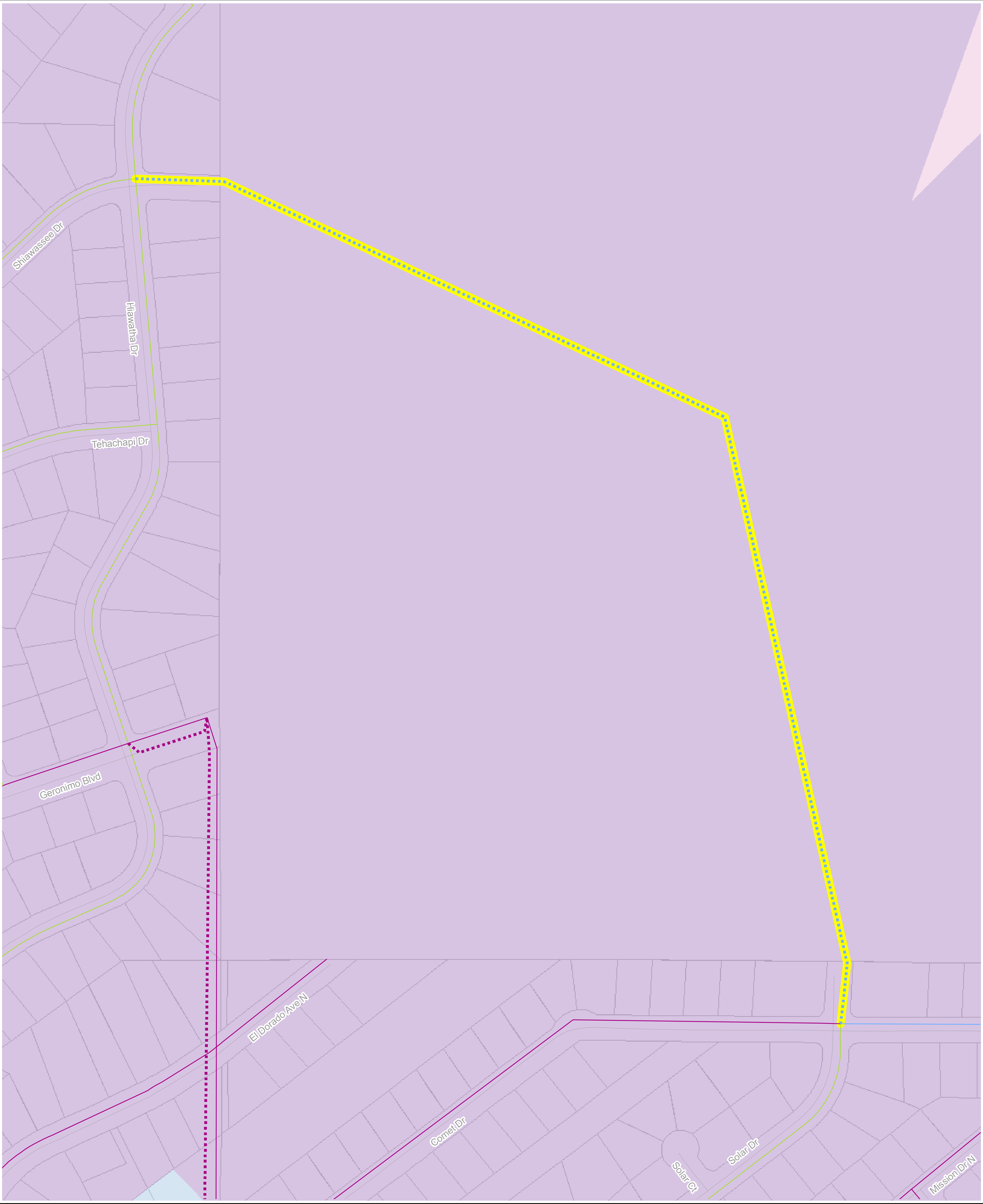
M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\August maps\LHC Wtr Dist Sys CIP work file.mxd



PRV
Booster Station
Storage Tank
City Limits
Water Service Boundary

Pressure Zones: 1, 2, 3, 4, 5, 6, Horizon 6, 7, 8

Existing Pipes Diameter: Under 8", 8", 10", 12", 16", 18", 20", 24", 27", 30", 36", 48"

Proposed Pipes Diameter: Under 8", 8", 10", 12", 16", 20", 24", 30"

Capital Project Pipes

Feet: 0, 120, 240

Figure C.29

WATER DISTRIBUTION SYSTEM - CAPITAL IMPROVEMENT PROJECTS
PROJECT NO. 28

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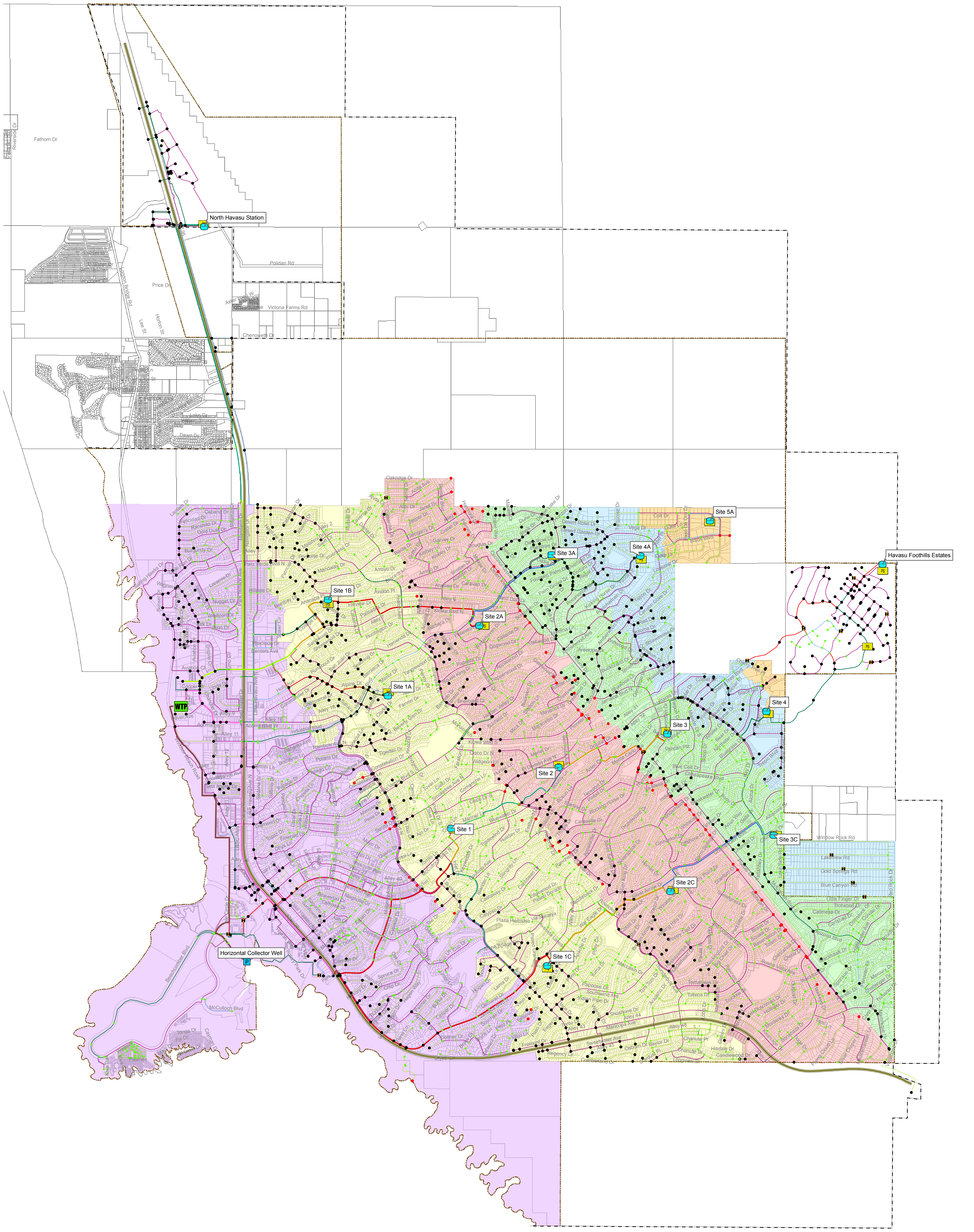

PRV
Booster Station
Water Treatment Plant
Storage Tank
City Limits
Water Service Boundary

Pipes Diameter
Under 8"
8"
10"
12"
16"
18"
20"
24"
27"
30"
36"
48"

Pressure Zones
1
2
3
4
5
6

Peak Hour Pressure
< 40 psi
40 - 100 psi
> 100 psi

0 0.5 1 Miles

LAKE HAVASU CITY SYSTEM PRESSURES WITH 2006 PEAK HOUR DEMANDS

Lake Havasu City Water Master Plan Update
Final - October 2007

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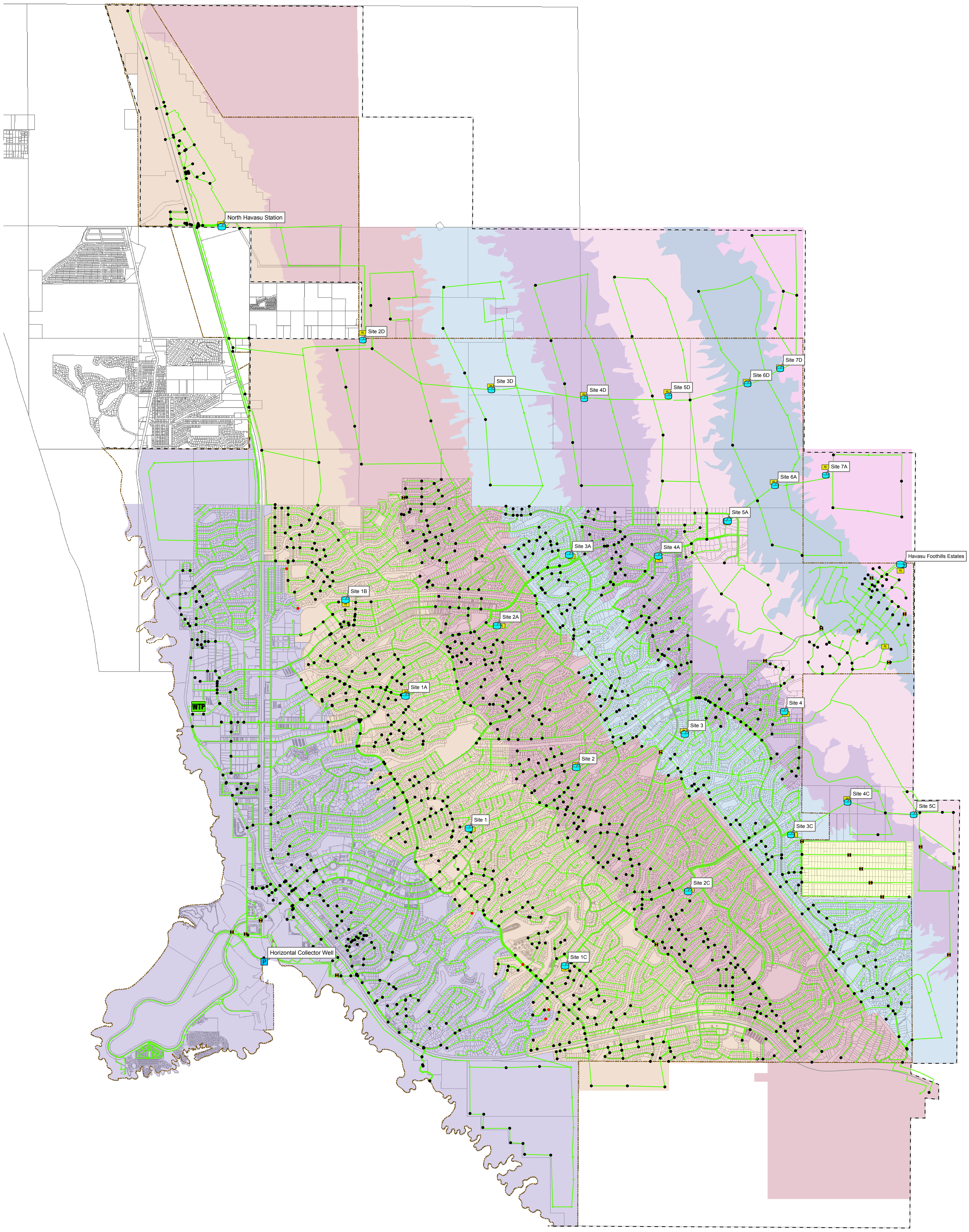
MAP C.1

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Map C1_2006 Peak Hour Pressures.mxd



LAKE HAVASU CITY, ARIZONA
INCORPORATED 1978

Legend	
PRV	
Booster Station	
Water Treatment Plant	
Storage Tank	
Pump Station	
City Limits	
Water Service Boundary	

Peak Hour Pressure
- < 40 psi
- 40 - 100 psi
- > 100 psi

Peak Hour Velocity
- < 7 fps
- > 7 fps

Pressure Zones
- 1
- 2
- 3
- 4
- 5
- 6
- Horizon 6
- 7
- 8

N

0 0.5 1 Miles

LAKE HAVASU CITY SYSTEM PRESSURES WITH BUILDOUT PEAK HOUR DEMANDS

Lake Havasu City Water Master Plan Update
Final - October 2007

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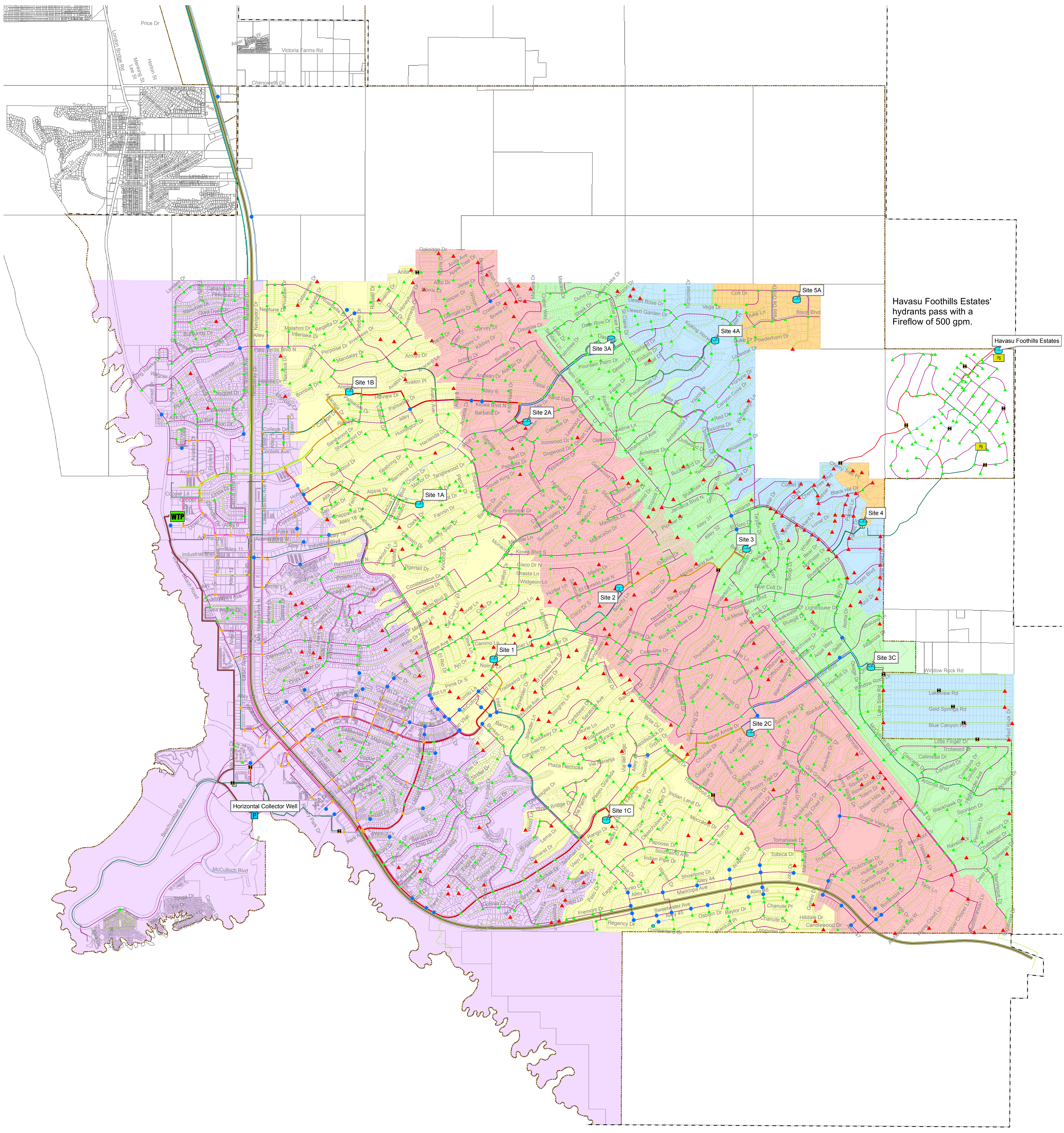
MAP C.2

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Map C2_Buildout Peak Hour Pressures.mxd



PRV

Booster Station

Water Treatment Plant

Storage Tank

City Limits

Water Service Boundary

Pressure Zones	
1	
2	
3	
4	
5	
6	

Pipes

Diameter

- Under 8"
- 8"
- 10"
- 12"
- 16"
- 18"
- 20"
- 24"
- 27"
- 30"
- 36"
- 48"

Residential Fireflow Demands

- Cannot Supply 1000 gpm
- Can Supply 1000 gpm

Non - Residential Fireflow Demands

- Cannot Supply 3500 gpm
- Can Supply 3500 gpm

Fireflow results are not calculated for every hydrant. These fireflow results indicate the capability of the distribution system to deliver fireflows to the locations indicated.

0 0.5 1 Miles

FIREFLOW RESULTS WITH RESIDENTIAL DEMANDS SET AT 1000 GPM, 2006 MAXIMUM DAY DEMANDS

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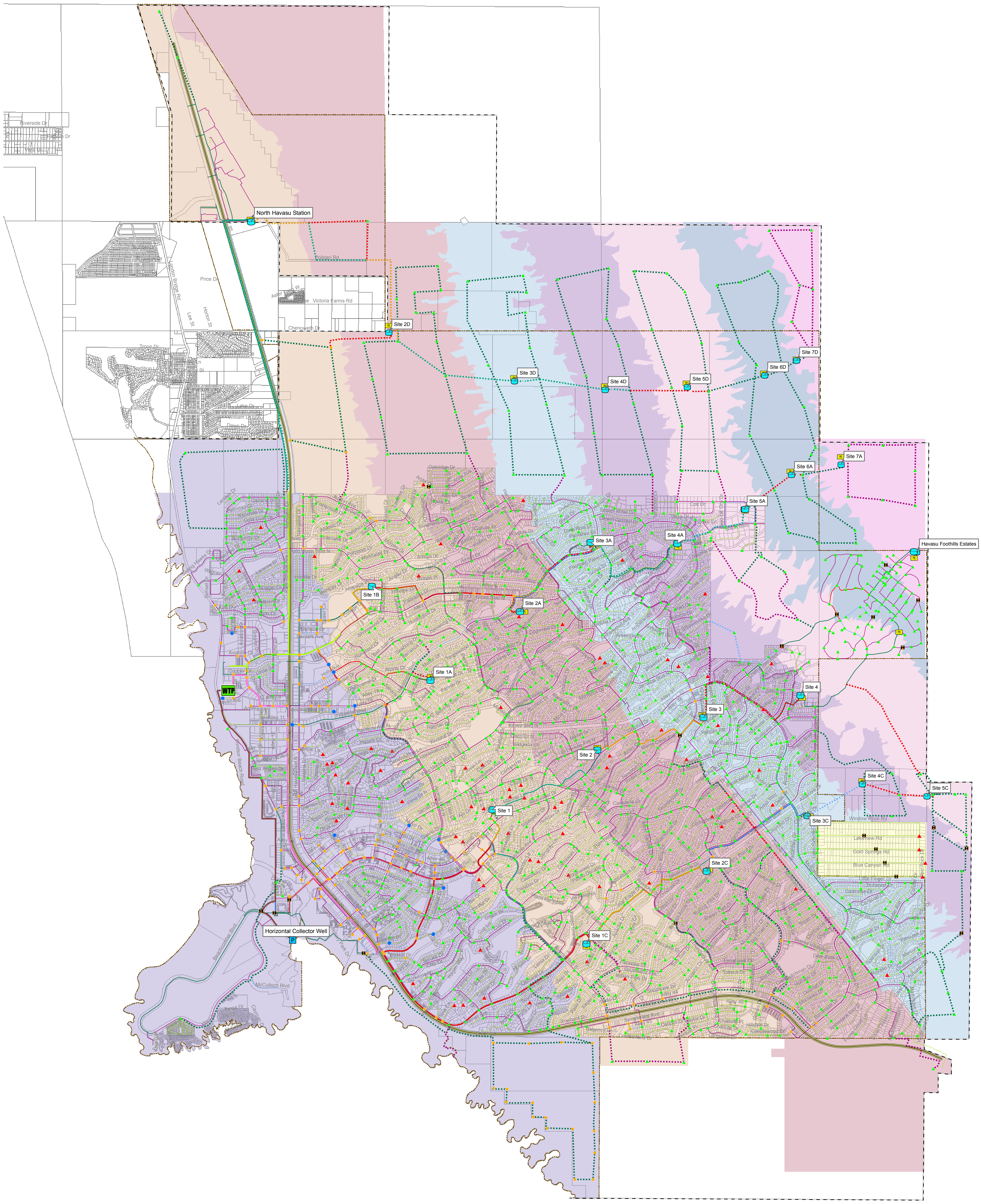
MAP C.3

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Map C3_2006 Fireflow.mxd



PRV

Booster Station

Water Treatment Plant

Storage Tank

City Limits

Water Service Boundary

Pressure Zones

1

2

3

4

5

6

Horizon 6

7

8

Existing Pipes Diameter

Under 8"

8"

10"

12"

16"

18"

20"

24"

27"

30"

36"

48"

Proposed Pipes Diameter

Under 8"

8"

10"

12"

16"

20"

24"

30"

Residential Fireflow Demands

Cannot Supply 1000 gpm

Can Supply 1000 gpm

Non - Residential Fireflow Demands

Cannot Supply 3500 gpm

Can Supply 3500 gpm

Fireflow results are not calculated for every hydrant. These fireflow results indicate the capability of the distribution system to deliver fireflows to the locations indicated.

0 0.5 1 Miles

FIREFLOW RESULTS WITH RESIDENTIAL DEMANDS SET AT 1000 GPM, BUILDOUT MAXIMUM DAY DEMANDS

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MAP C.4

M:\Client\Lake Havasu_PHXMP\7391a.00 water master plan\analysis\GIS analysis\Maps\Final Report Maps\Map C4_Buildout Fireflow.mxd