Imagine the result

Pressure Zones Evaluation

FINAL Technical Memorandum

August 27, 2015

FINAL Technical Memorandum

Pressure Zones Evaluation

Prepared for:
City of Avondale

Prepared by:
ARCADIS U.S., Inc.
410 N 44th Street
Suite 1000
Phoenix
Arizona 85008
Tel 602 438 0883
Fax 602 438 0102

Our Ref.:
00864027.0003

Date:
August 27, 2015

Timothy Francis, P.E.
Principal Environmental Engineer

Venkat Radhakrishnan
Project Engineer, P.E.

Tables

Figures

Appendices

Acronyms and Abbreviations

AACE - Association for the Advancement of Cost Engineering

HGL – Hydraulic Grade Line

MG – Million Gallons

mgd – Million Gallons per Day

PIR – Phoenix International Raceway

PRV – Pressure Reducing Valve

psi – Pounds per Square Inch

SCADA – Supervisory Control and Data Acquisition

VFD – Variable Frequency Drive

EXECUTIVE SUMMARY

Introduction

The City of Avondale's water distribution system currently has one primary pressure zone. However, as future development continues to the south, the pressures generally south of Lower Buckeye Road will have to be stepped down due to the elevation differences. The City has installed a pressure reducing valve (PRV) along Avondale Boulevard to begin protecting these southern areas. In addition, the City has installed PRVs to protect other individual older areas in the south (e.g., the former Rigby Water Company service area). These older areas will be protected whether or not a new pressure zone is established in the north.

Areas in the northern portions of the water system currently exhibit minimum pressures of 40 to 50 psi during peak water demand conditions. Customers in these areas have complained of low pressures during peak demands. Although the existing system is conforming to the City's system performance criteria and providing at least 40 psi pressure during peak demands, these customers have experienced even lower pressures due to the head losses in their water meters and backflow preventers.

The work conducted in this Pressure Zones Evaluation project investigated various alternatives to address the low pressure concerns in the north. The alternatives were developed and evaluated to maintain the current pressures in the southern portions of the system, and also considered the City's policy that no part of the system should exceed a maximum pressure of 85 psi at any time, especially in the lowest elevation areas of the system near the riverbed in the north.

Preferred Pressure Increase Alternative

Three alternatives were identified and evaluated that would result in pressure increases in the northern areas by instituting operational changes such as simply increasing existing booster station set points, and by physical system changes such as creation of new pressures zones:

- Alternative 1: Increase booster pump station discharge pressure set-points to raise the hydraulic grade line and pressures throughout the system. These alternative would result in only very minor overall pressure increases (0.2 psi).

- Alternative 2: Split the City into two pressures zones with the boundary generally along Van Buren Street, and increase the booster pump station set points in the north zone. This alternative would require significant additional supply in the south as most existing wells are north of Van Buren Street.

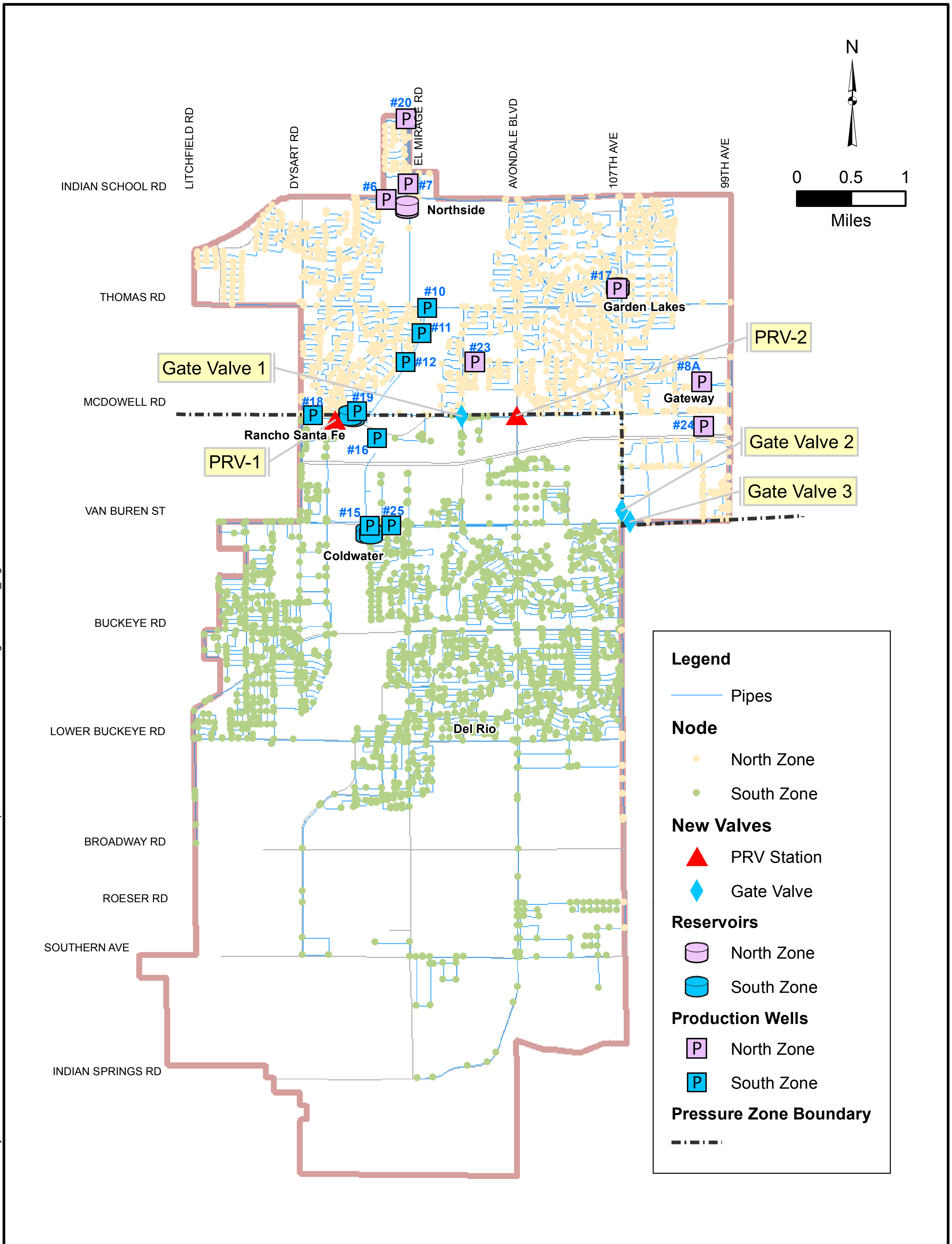
- Alternative 3: Split the City into two pressure zones with a new boundary along McDowell Road from Dysart Road to 107th Avenue, and then south along 107th Avenue to Van Buren Street, and increase the booster pump station set points in the north zone. This alternative achieves the pressure increase objectives with the least amount of additional supply and storage required and is, thus, the preferred pressure increase alternative.

The preferred pressure increase alternative (Alternative 3) is illustrated on Figure ES-1. The North Zone would be supplied by the Northside, Garden Lakes, Gateway and Well 23 facilities. The South Zone would be supplied by the Rancho Sante Fe and Coldwater facilities initially. The Del Rio facility would supply the South Zone once it is rehabilitated.

In order to achieve the pressure increase objective without exceeding maximum pressures of 85 psi, the recommended booster station set-points will be dictated by system demands. Table ES-1 shows the recommended booster station set-points in the North Zone for the preferred pressure increase alternative. If the booster stations can achieve the recommended set-points under maximum day demands, they will also be able to achieve the lower pressure set-points for the average day demand and minimum day demand conditions.

Table ES-1 Recommended Booster Station Set-points

Water Supply Facility	Existing Set-points	Recommended Set-points	
		Under Maximum Day Demands	Under Average Day Demands
Northside	54	73	72
Gateway	45	72	68
Garden Lakes	48	76	65
Well #23	58	80	80



CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Recommended Pressure Zones Configuration

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FIGURE ES-1

\\arcadis-us.com\OfficeData\Phoenix-AZ\Projects\08640027\0003 - Additional Pressure Zone Evals\R-1 Final Report\Pressure Zones Evaluation\Figures\FINAL_Figure ES-1 Recommended Pressure Zone.mxd

Table ES-2 shows the resulting average pressure increases in the North Zone under maximum day demand conditions.

Table ES-2 Pressure Increases under Maximum Day Demands and Recommended Set-points

Time Period	Parameter	Pressure (psi)		
		With Recommended Set-points	With Existing Set-points	Increase
Existing	Minimum Pressure	67.8	51.1	16.7
	Average Pressure	73.5	53.4	20.1
Build-Out	Minimum Pressure	62.6	51.1	11.5
	Average Pressure	71.9	53.4	18.5
Maximum Pressure (psi)				
Existing		84.5		
Build-Out		84.2		

System Modifications Required in the Near-Term

The two primary pressure zones will need to be isolated from each other with the installation of two PRV stations on transmission mains currently connecting the north and south areas, and closing of three smaller pipes (Figure ES-1). The PRV stations will be configured to allow water to be automatically transferred between the two pressure zones during emergencies, and the smaller pipe closures will be with valves that can also be manually opened, if needed, during emergencies.

The existing booster stations in the North can accommodate operations at the higher system pressures. Production from Well 23 is currently limited due to air entrainment problems and will need to be rehabilitated to operate at the higher pressures. The well rehabilitation can be achieved with either upgrades to the existing motor and well pump (i.e., addition of a 6^{th} stage), or replacement of the well pump with a new well pump. The evaluations assumed installation of a new well pump.

Incremental Annual O&M Impacts in the Near-Term

As compared to existing operations, implementing the preferred pressure zones alternative will result in the following additional water system annual O&M costs:

- Booster pumping power - $340,000 per year.
- Water treatment - $1,430,000 per year
- PRV station - $4,000 per year
- **Total additional O&M costs - $1,774,000**

Capital Costs to Implement the Preferred Pressure Zones Alternative

Implementing the preferred pressure zones alternative will require the following capital costs for designing and constructing the required system improvements:

- PRV Station 1: $155,000
- PRV Station 2: $155,000
- Three pipe closures: $123,000
- Well 23 rehabilitation: $26,000
- **Total Capital Costs: $459,0000**

Impacts to Water Master Plan

Implementing the preferred pressure zones alternative will modify the 2013 Water Master Plan Update recommendations. Although no new master plan capital improvements will be required, the necessary modifications will include reallocation of new water supply previously planned in the North Zone to the South Zone. Similarly, new water storage previously planned for the South Zone should be reallocated to the North Zone. These modifications are required because each pressure zone should be capable of individually providing its own water supply under normal operations. If the preferred alternative is implemented, it is recommended that the Water Master Plan be updated again to incorporate the new pressure zones and to update the water demand projections and the master plan recommendations.

Benefits of Implementing Preferred Pressure Zones Alternative

Implementing the preferred pressure zones alternative will provide the following water system benefits.

- The North Zone will experience overall higher pressures, with average increases in minimum pressures during peak demands of 16 psi immediately. The estimated increases in minimum pressures (during peak demands) for specific areas of concern immediately are as follows:
    - 103rd Avenue and McDowell Road – 22 psi
    - 99th Avenue and Indian School Road – 23 psi
    - 99th Avenue and Van Buren Street – 22 psi
    - Rio Crossings – 18 psi

- Booster stations in the North Zone and South Zone will be isolated from each other during normal operations, resulting in more flexible operations. The booster stations will stop fighting each other as they currently do.

- The pumps at the North Zone booster stations will operate closer to their design points than under existing conditions, making them operate more efficiently.

- Under emergency conditions, the recommended PRV stations and interconnects between the two pressure zones can be utilized to move water between zones.

- The majority of the City's system demand and future growth will be in the South Zone which will be served by the City's largest facilities – Rancho Santa Fe, Coldwater, and Del Rio after it is rehabilitated.

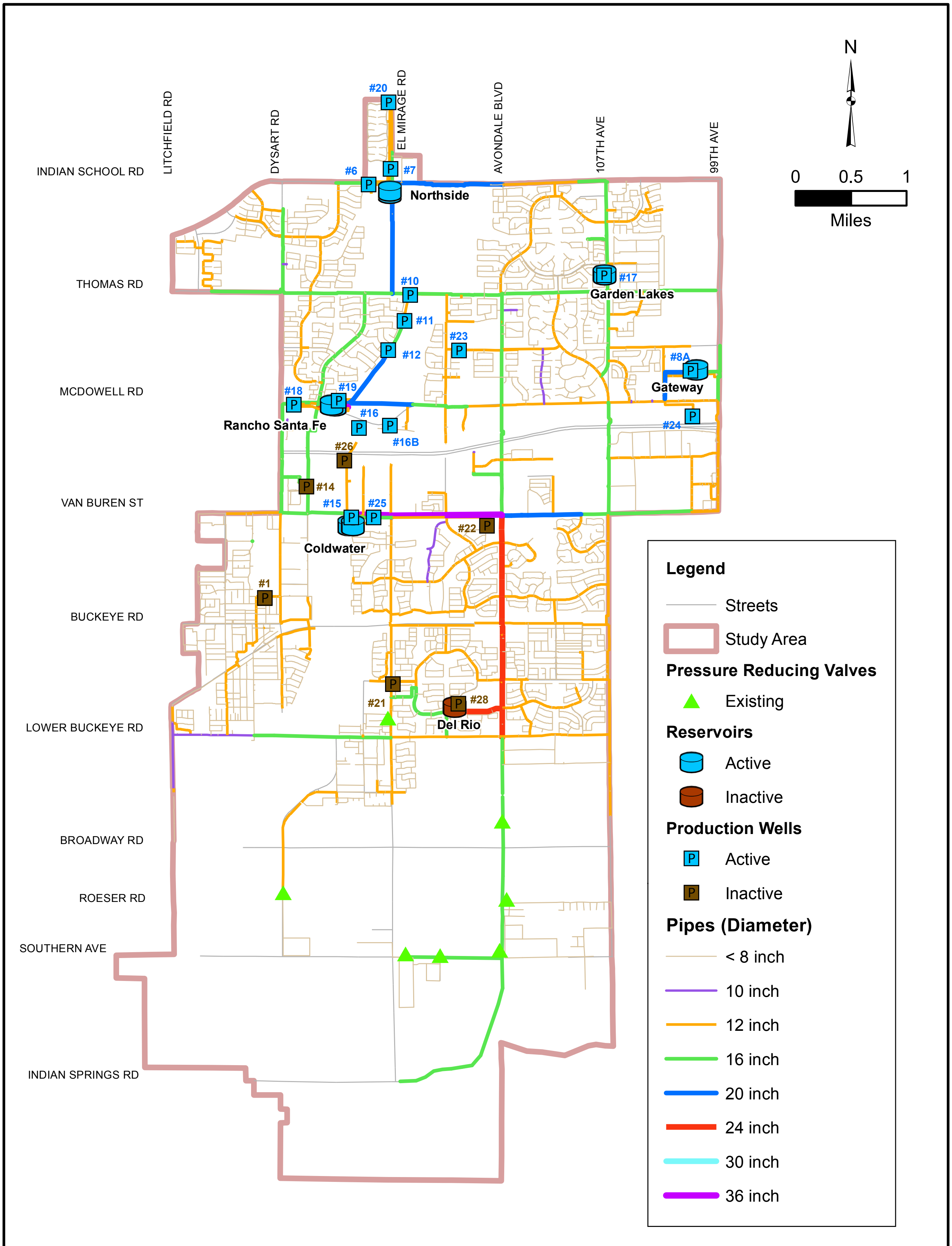
1. Introduction

The City of Avondale completed a water infrastructure master plan in 2005. At that time, a hydraulic model was created of the water distribution system. The water system model was last updated and calibrated in 2009. Since 2009, this model has been used to evaluate the impacts of new demands, system improvements, and changes to system operations. Most recently, the model was used in the 2013 Water Master Plan Update and in the development of design criteria for the Northside Water Supply Facility booster station rehabilitation project, also in 2013. The hydraulic water model serves as an important tool to support key decisions related to operational changes.

During the more recent modeling efforts, it had become apparent that the model may not be accurately simulating all portions of the water system, discrepancies between actual and modeled ground elevations and system pressures were suspected. As a result, the City retained ARCADIS in February, 2014 for the Water System Model Update and Pressure Zones Evaluation project. A final technical memorandum summarizing the Water System Model Update and Calibration was submitted to the City on March 31, 2015.

The City's water system currently has one primary pressure zone. However, as future development continues to the south, the pressures generally south of Lower Buckeye Road will have to be stepped down due to the elevation differences. The City has installed a pressure reducing valve (PRV) along Avondale Boulevard to begin protecting these southern areas. In addition, the City has installed PRVs to protect other individual older areas in the south (e.g., the former Rigby Water Company service area). These older areas will be protected whether or not a new pressure zone is established in the north. Figure 1-1 illustrates the existing water infrastructure.

As part of this phase of the project, the verified water system model was used to assess alternatives for increasing pressures in the northern portions of the service area where new commercial developments have experienced periodic episodes of low water pressures. This technical memorandum summarizes the findings, conclusions and recommendations of the Pressure Zones Evaluation portion of the project.



CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Existing Water Infrastructure

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FIGURE 1-1

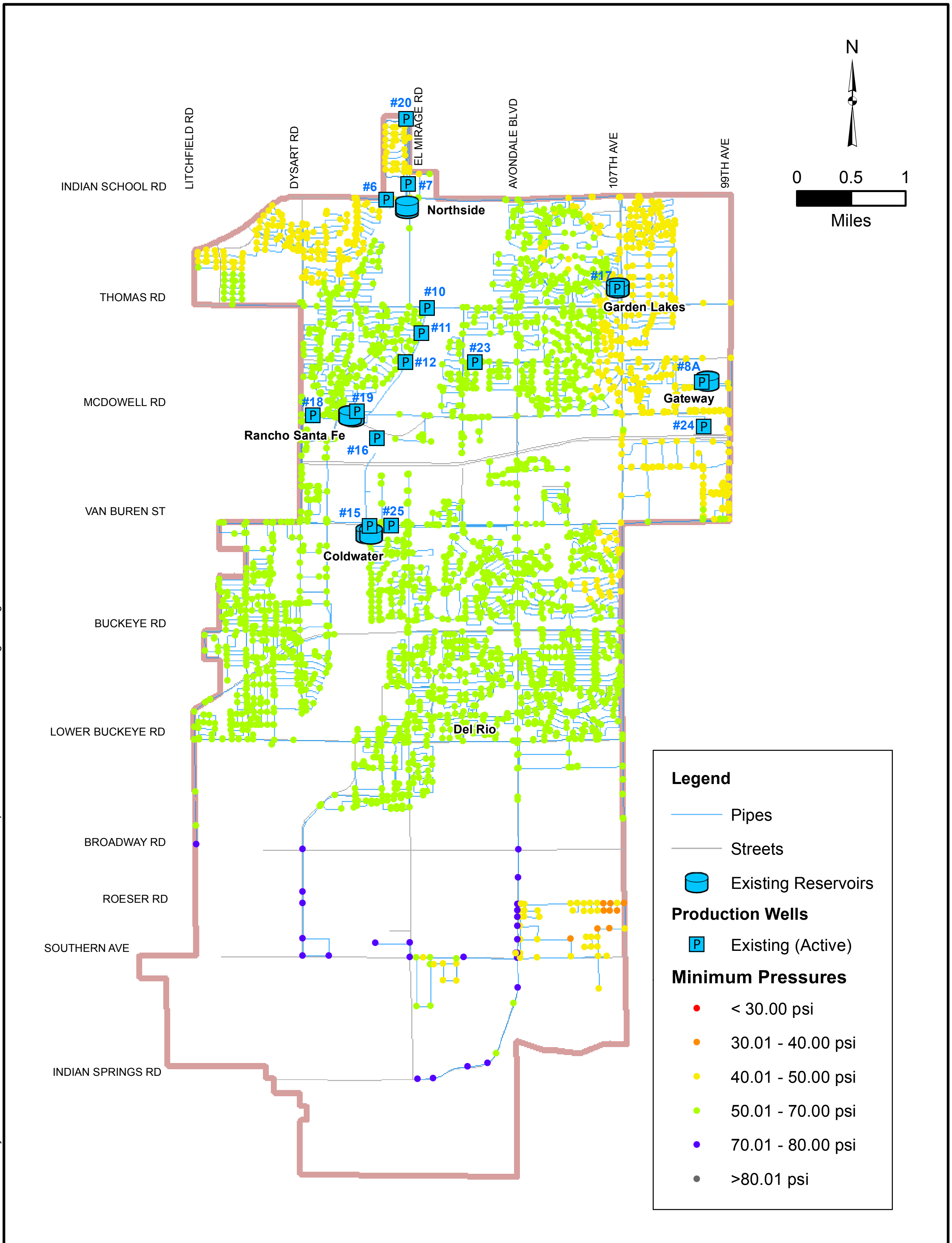
\\arcadis-us.com\OfficeData\Phoenix-AZ\Projects\086402710003 - Additional Pressure Zone Evals\R-1 Final Report\Pressure Zones Evaluation\Figures\Figure 1-1 Existing Water Infrastructure.mxd

2. Existing Pressure Zone Concerns

The 2013 Water Master Plan Update indicates that the City's distribution system satisfies its pressure design criteria, which states that system must be capable of providing at least 40 psi under peak hour conditions.

Figure 2-1 shows the minimum pressures within the system under existing maximum day demand conditions. Areas in the northeast part of the water system (Thomas Road between 99th Avenue and 107th Avenue) and in the northwest (near Dysart Road) exhibit minimum pressures between of 40 and 50 psi under peak hour conditions. Customers in these areas have complained of low pressures particularly some commercial customers in the northeast. Although the existing system is conforming to the City's system performance criteria and providing at least 40 pounds per square inch (psi) pressure during peak demand periods, these customers have experienced even lower pressures due to the head losses in their water meters and backflow preventers. Raising overall pressures during peak demand periods should alleviate the low pressure complaints.

The City's calibrated model was used to investigate various alternatives to address the low pressure concerns in the northern parts of the system. As there are no similar concerns in the south area, the alternatives were developed and evaluated to maintain the current pressures in the southern parts of the system. The City also has a policy that no part of the system should exceed a maximum pressure of 85 psi at any time. The policy is followed due to concerns of the impacts of high system pressures in the low areas near the riverbed and on the older portions of the service area. Thus, the preferred alternatives would have to comply with this policy.



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CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Minimum Pressures under Existing Maximum Day Demand Conditions

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FIGURE 2-1

\\arcadis-us.com\OfficeData\Phoenix-AZ\Projects\08640027\0003 - Additional Pressure Zone Evals\R-1 Final Report\Pressure Zones Evaluation\Figures\Figure 2-1 Minimum Pressures under Peak Hour Conditions.mxd

3. Pressure Zones Evaluation General Methodology

The identification and evaluation of alternatives to increase pressures in the northern portions of the water system was conducted in the following general steps:

- Several alternatives for increasing pressures were developed and the three most promising alternatives were selected for evaluation.
- Preliminary modeling and analysis of each of the pressure increase alternatives was completed in order to select a preferred alternative. The objective of the preliminary modeling and analyses was to arrive at a preferred alternative which will increase minimum pressures in the north area by an average of 10 psi.
- After agreement was reached on the preferred alternative, additional modeling and analysis was conducted to 1) identify increases in minimum pressures beyond 10 psi that can be achieved, 2) confirm that maximum pressures of 85 psi would not be exceeded, and 3) confirm the feasibility of implementing the pressure increase alternative.
- Final modeling of the preferred and refined pressure increase alternative was performed to refine the concepts, costs, and benefits of the preferred alternative.

Water demands contained in the City's most recent calibrated hydraulic model were used for the evaluations. The water demands typically used in water system evaluations include the following:

- The annual average demand is the total water use during the year averaged over the entire year. The annual average demand in the City water service system in 2014 was 12.7 mgd.
- The maximum day demand is the highest day of water use experienced in the water system during the year. The maximum day demand in the City water service area in 2014 was 20.9 mgd.
- The peak hour demand is highest hour of water use experienced in the water system during the year. This typically occurs on the day that maximum day demand occurs. Based on the updated diurnal water usage curve provided in the Water System Model Update and Calibration technical memorandum, the peak hour demand in 2014 was approximately 31 mgd.

4. Identification of Pressure Increase Alternatives

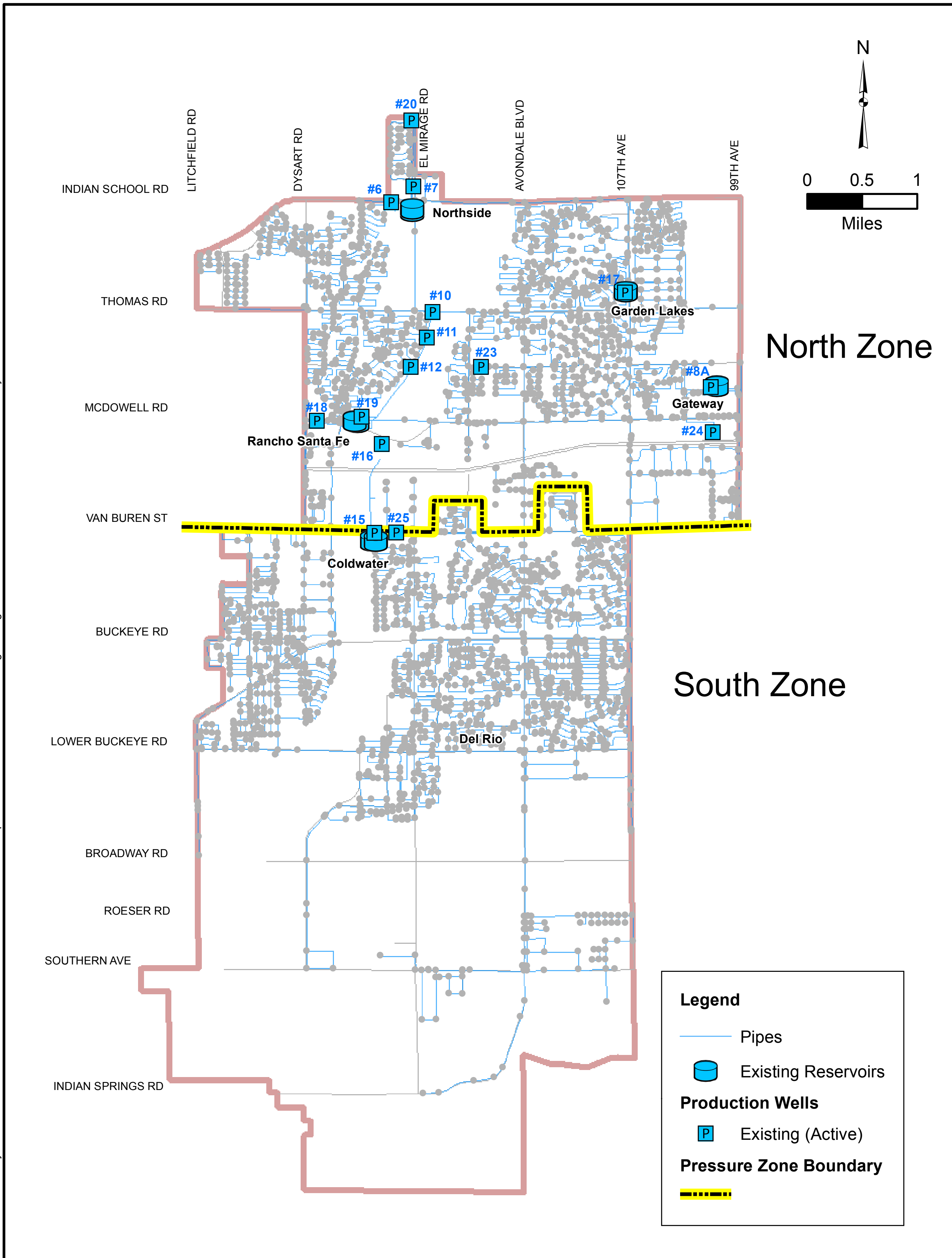
Several alternatives to increase pressures were identified by preliminary modeling of changes that could be made that would result in pressure increases in the northern portion of the water service area. These included operational changes such as increasing booster station set points and system changes such as creation of new pressures zones. The alternatives took into account the elevation contours across the City service area and considered minimizing major changes to the existing system.

The various alternatives were discussed with the City. Based on the discussions, three alternatives were identified for final modeling:

- Alternative 1: Increase booster pump station discharge pressure set points to raise the hydraulic grade line and pressures throughout the system
- Alternative 2: Split the City into two pressures zones with the boundary at Van Buren Street (Figure 4-1), and increase the booster pump station set points in the North Zone.
- Alternative 3: Split the City into two pressure zones with a new boundary along McDowell Road and 107th Avenue (Figure 4-2), and increase the booster pump station set points in the North Zone.

With all the above alternatives, the focus was to evaluate pressure increases in the northern parts of the system, in areas that were experiencing low pressures during peak demands. The system pressures in the areas generally south of Van Buren Street remained unchanged.

A water pressure zone is a geographic, isolated section of a water distribution network. Pressures within a pressure zone are established by pumping stations and/or reservoirs. Water does not flow between pressure zones unless it flows from a zone of higher pressure to a zone of lower pressure, through a pressure reducing valve (PRV). PRVs utilize pressure sustaining valves that are designed to allow flow in one direction. Two pressure sustaining valves are typically installed in parallel configuration, but in opposite orientations to allow flow to pass to and from each zone. The pressure differential between the two zones will provide the hydraulic pressure to modulate the valves. If the pressure in one zone drops, one of the valves will modulate to equalize pressure and flow by allowing flow from the zone of higher pressure to the zone of lower pressure.



\\arcadis-us.com\OfficeData\Phoenix-AZ\Projects\08640270\0003 - Additional Pressure Zone Evals\R-1 Final Report\Pressure Zones Evaluation\Figures\Figure 4-1 Alternative 2- Pressure Zone Boundary at Van Buren Street.mxd

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CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Alternative 2 - Pressure Zone Boundary at Van Buren Street

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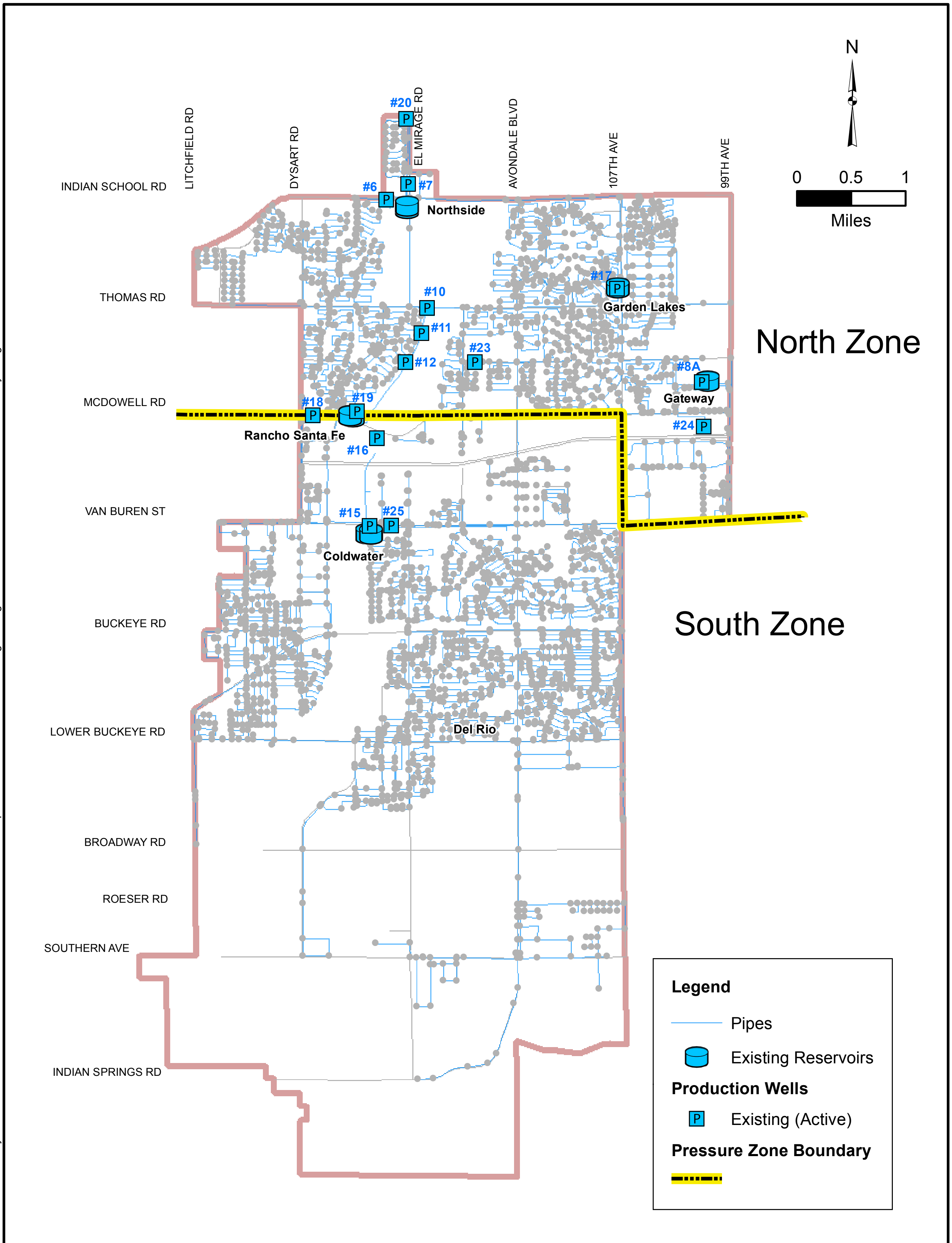
FIGURE 4-1



CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Alternative 3- Pressure Zone Boundary along McDowell Road and 107th Avenue

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FIGURE 4-2

\\arcadis-us.com\OfficeData\Phoenix-AZ\Projects\08640270\0003 - Additional Pressure Zone Evals\R-1 Final Report\Pressure Zones Evaluation\Figures\Figure 4-2 Alternative 3- Pressure Zone Boundary along McDowell Road and 107th Avenue.mxd

5. Preliminary Evaluation of Pressure Increase Alternatives

This chapter summarizes the results of the preliminary hydraulic analysis performed on the alternatives described in Chapter 4. The alternatives were evaluated on their ability to achieve a 10 psi increase in minimum pressures in the North zone, ease of implementation, and need for additional infrastructure.

5.1 Basis of Preliminary Pressure Increase Analyses

Figure 2-1 showed the minimum pressures in the existing system under maximum day demand conditions and showed that minimum pressures between 40 and 50 psi occurred in the northern parts of the system. The focus of the alternatives and the preliminary analysis of alternatives were to attempt to increase the minimum pressures in the northern parts of the system by an average of 10 psi.

The following assumptions were made during the preliminary analyses and comparison of the pressure increase alternatives:

- The new pump station at Northside (4 pumps) is assumed to be operational for this analysis, with a total capacity of 8.4 million gallons per day (mgd) and firm capacity of 6.3 mgd.
- An updated diurnal curve (week of March 21 through March 26, 2014) was used (refer to the Water System Model Update and Calibration technical memorandum).
- The system was analyzed under existing and build-out maximum day demand conditions.
- The water demands in the system (existing and build-out) were assumed to remain unchanged and are based on projections in the 2013 Water Master Plan Update. These demands are also loaded in the updated and recalibrated water system hydraulic model.
- The Del Rio facility and its associated wells are assumed to be operational at build-out, pursuant to the 2013 Water Master Plan Update assumptions.

In addition to the above assumptions, the existing and proposed PRVs in the 2013 Water Master Plan Update were included in the modeling (Figure 1-1 illustrated the existing PRVs):

- Avondale Boulevard PRV: Located on Avondale Boulevard, south of Lower Buckeye Road. This PRV is likely to be part of the lower pressure zone in the south, if necessary, and is required to cut pressures to Phoenix International Raceway (PIR). The PRV will be needed somewhere, but may be moved if the lower zone is not needed. The PRV includes an 8-inch with a set-point of 56 psi and a 6-inch with a set-point of 61 psi
- South Dysart PRV: Serves the areas south of the Charles M. Wolf Water Reclamation Facility (WRF), and is needed due to the existing high pressures, and the old infrastructure in the area. The PRV may need to be maintained depending on the low zone pressure set points. This is a 6-inch PRV set at 50 psi.

- Rio Vista PRV: This area is currently fed at one location only and the PRV is needed due to the existing supply lines located in yards throughout the subdivision. The lines are scheduled to be replaced in fiscal year 2015-2016 (FY 15-16), and may be removed at that time. This is a 6-inch PRV set at 55 psi.
- Rigby PRVs: These are required due to the poor infrastructure in the former Rigby Water Company system and will have to remain in the future. There are 4 PRVs connecting the City's system to the former Rigby Water Company system:
  - PRV1 on Roeser Road: 8-inch with set-point of 47 psi, and 4-inch with a set-point of 51 psi
  - PRV2 located near the Circle K: 4-inch with a set-point of 53 psi
  - PRV3 is located at 119th Avenue and Southern Avenue: 2-inch with a set-point of 51 psi
  - PRV4 is located at 121st Avenue and Southern Avenue: 2-inch with a set-point of 54 psi

Production, storage and pumping analyses were performed to verify that each of the alternatives meets the City's potable water system performance criteria. For purposes of the analyses, additional production, storage and pumping requirements, if any, were developed based on the recommendations of the 2013 Water Master Plan Update.

5.2 Evaluation of Alternatives

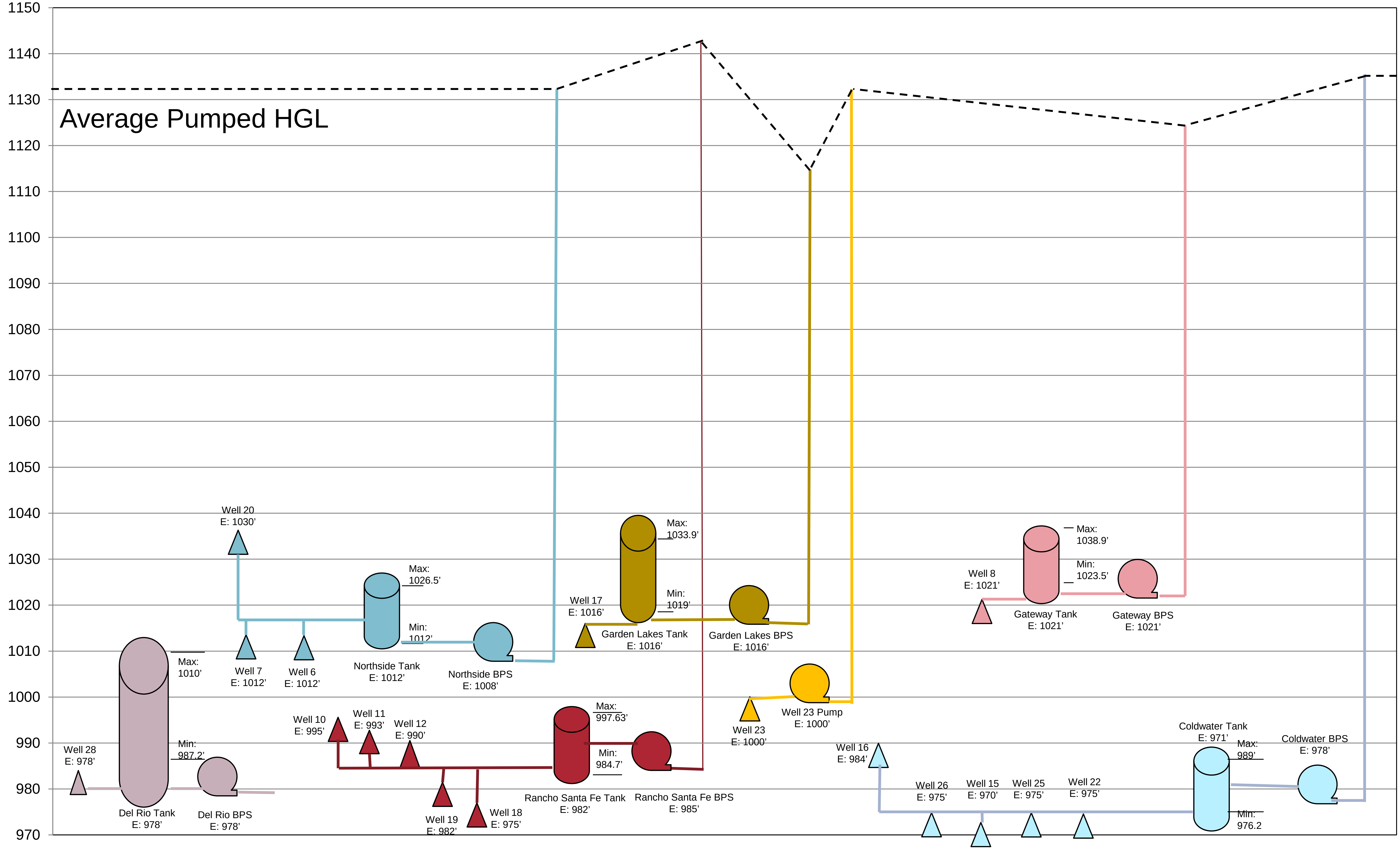
5.2.1 Alternative 1: Increase Booster Station Discharge Pressure Set Points

This alternative includes simple operational changes in the system in order to increase pressures system-wide. Table 5-1 shows the existing discharge pressure set points at each booster station across the system. These discharge pressures are achieved through the use of variable frequency drives (VFDs) associated with the pumps.

Table 5-1 Existing Booster Station Set Points

Facility	Pressure Set Points (psi)
Rancho Santa Fe	69
Coldwater	68
Northside	54
Gateway	45
Garden Lakes	48
Well #23	58

Figure 5-1 shows the hydraulic grade line (HGL) map for the existing system. All of the booster stations pump into the same pressure zone which supplies water to customers within a very narrow band of ground elevations (elevations of facilities and pump stations vary between 978 feet and 1021 feet).



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PRESSURE ZONES EVALUATION
Existing Hydraulic Grade Line Map

Figure 5-1

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Imagine the result

This results in each booster station trying to compete with one or more other booster stations to serve overlapping service areas. Small changes in the discharge pressure set points therefore cause the pumping network to become unstable and individual pumps to be shut down. The analysis of Alternative 1 indicated that small increases (2- 3 psi) in set points was possible at the booster stations, but these yielded only an average of 0.2 psi rise in minimum pressures under existing maximum day demands in the system**.** In some areas, resulting pressures were lower than under existing conditions. These are due to reduced discharge pressures from some booster stations (like Northside) in response to increased pressures from other stations (Rancho Santa Fe and Cold Water). Figure 5-2 shows the resulting pressures under existing maximum day demands and Figure 5-3 shows pressures under build-out maximum day demands. **As shown by the figures, this alternative does not provide significant increases in minimum pressures during maximum day demands under existing and build-out conditions**.

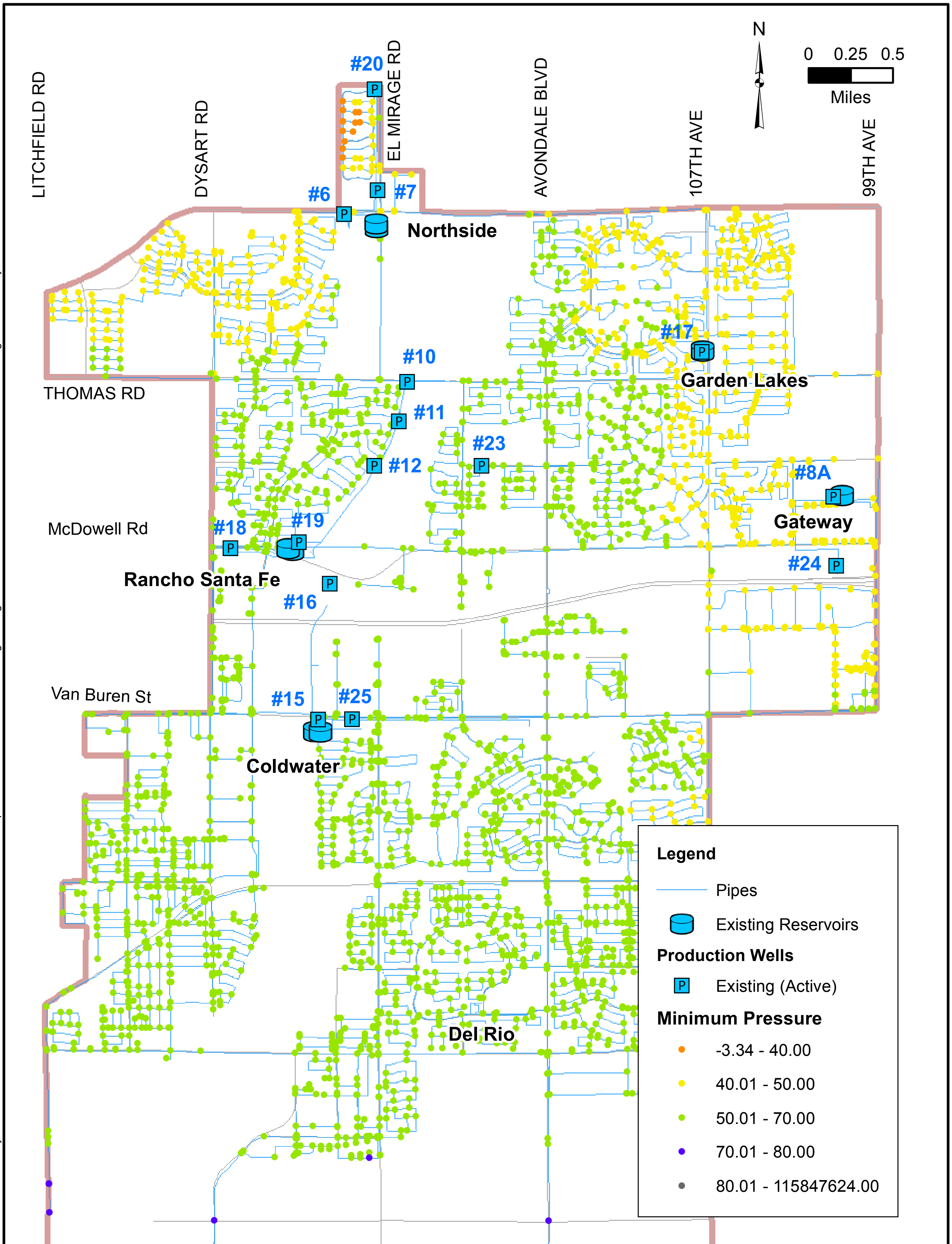
Production, storage and pumping requirements were not recalculated as no changes are made to the system. All the infrastructure requirements stay the same as outlined in the 2013 Water Master Plan Update.

5.2.2 Alternative 2: Pressures Zone Boundary at Van Buren Street

This alternative is based on splitting the existing distribution system into two pressure zones. This should reduce the interaction between the booster pump stations and allow them to pump at higher pressures, thus resulting in overall higher system pressures. Alternative 2 proposes to split the system along Van Buren Street into a North and a South pressure zone (refer to Figure 4-1). The North zone will be served by Rancho Santa Fe, Northside, Garden Lakes, Gateway, and Well 23 facilities; and, the South Zone will be served by Coldwater and Del Rio (at build-out only) facilities.

The analysis of this alternative under existing demands and increasing the North booster station set points resulted in the minimum pressures in the North zone increasing by an average of 10.3 psi (Figure 5-4); and by an average of 8.9 psi under build-out demand conditions (Figure 5-5).

A supply analysis (Table 5-2) for Alternative 2 revealed that the new South Zone would require additional well supply under existing and build-out conditions, compared to the recommendations of the 2013 Water Master Plan Update. According to the typical system performance and design criteria, each pressure zone should independently satisfy its supply requirements and PRVs separating the zones should only be used to supply the other pressure zones in emergencies. Since most of the proposed wells in the 2013 Water Master Plan Update are physically located in the proposed North zone, the South zone will need its own additional supply (or some of the proposed Master Plan wells may need to be moved to locations in the South zone).



\\arcadis-us.com\OfficeData\Phoenix-AZ\Projects\08640270\0003 - Additional Pressure Zone Evals\R-1 Final Report\Pressure Zones Evaluation\Figures\Figure 5-2 Alternative 1 – Minimum Pressures in Existing Maximum Day Demands.mxd

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CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION
Alternative 1 – Minimum Pressures under Existing Maximum Day Demands

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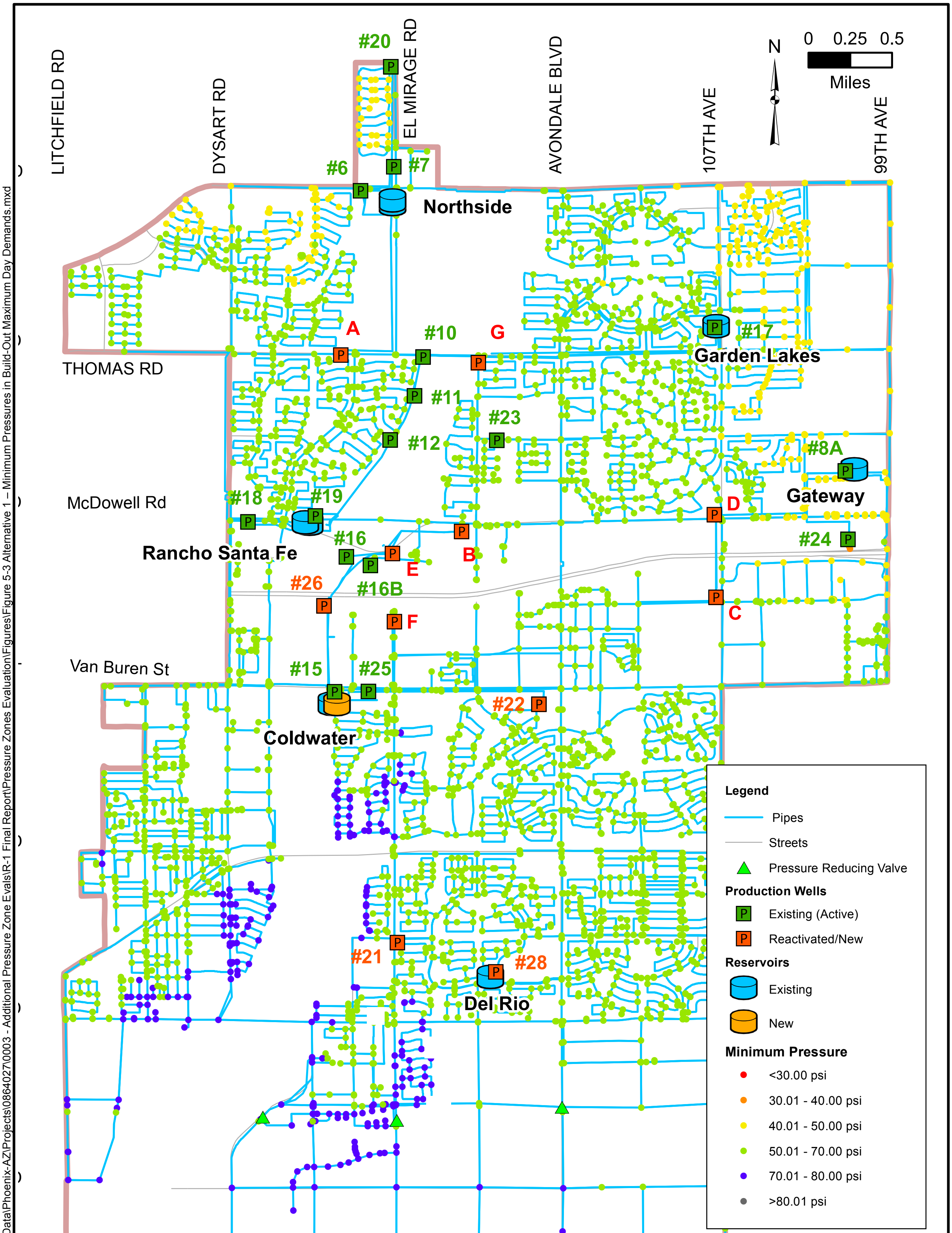
FIGURE 5-2



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CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Alternative 1 – Minimum Pressures under Build-Out Maximum Day Demands

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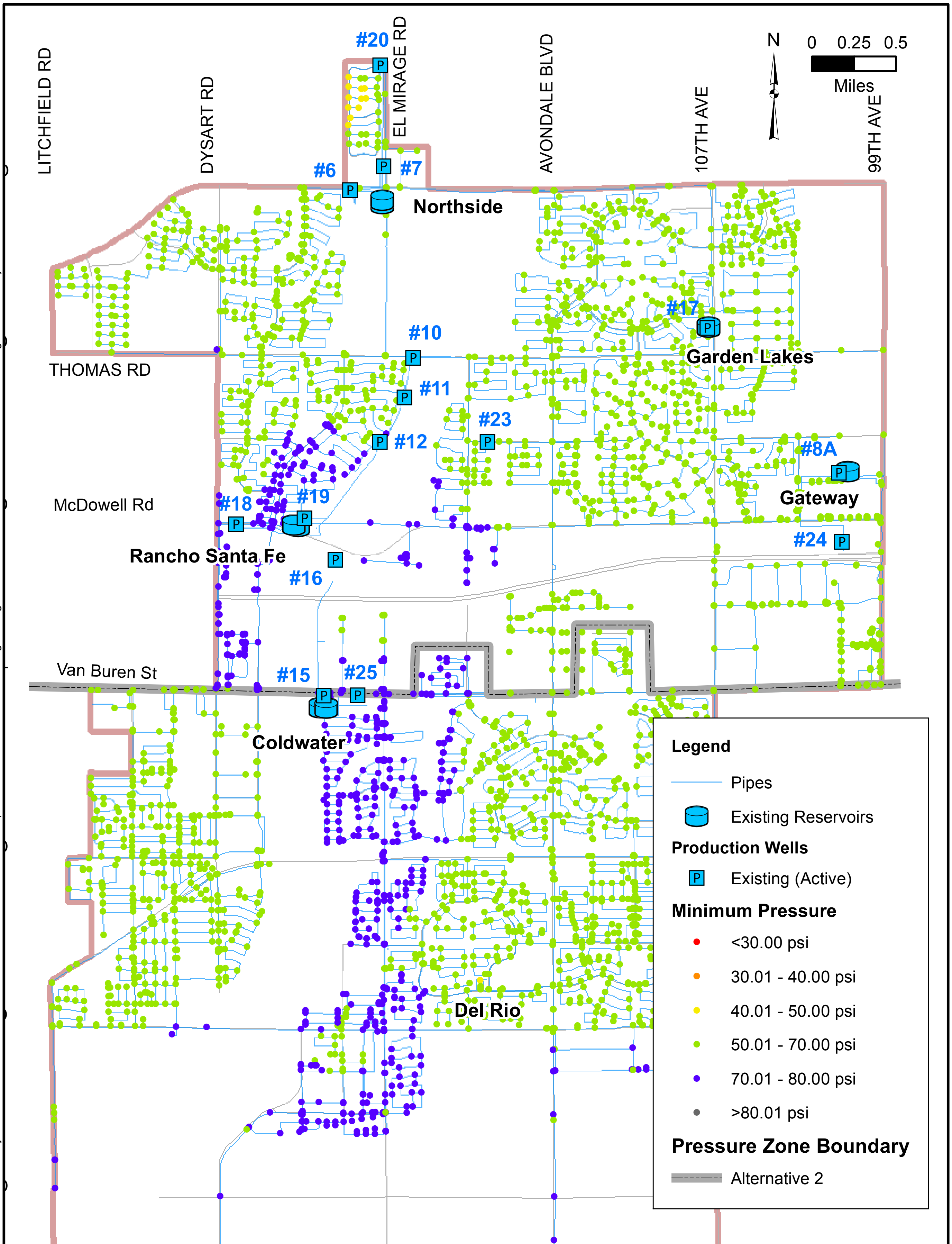
Figure 5-3



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CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Alternative 2 – Minimum Pressures under Existing Maximum Day Demands

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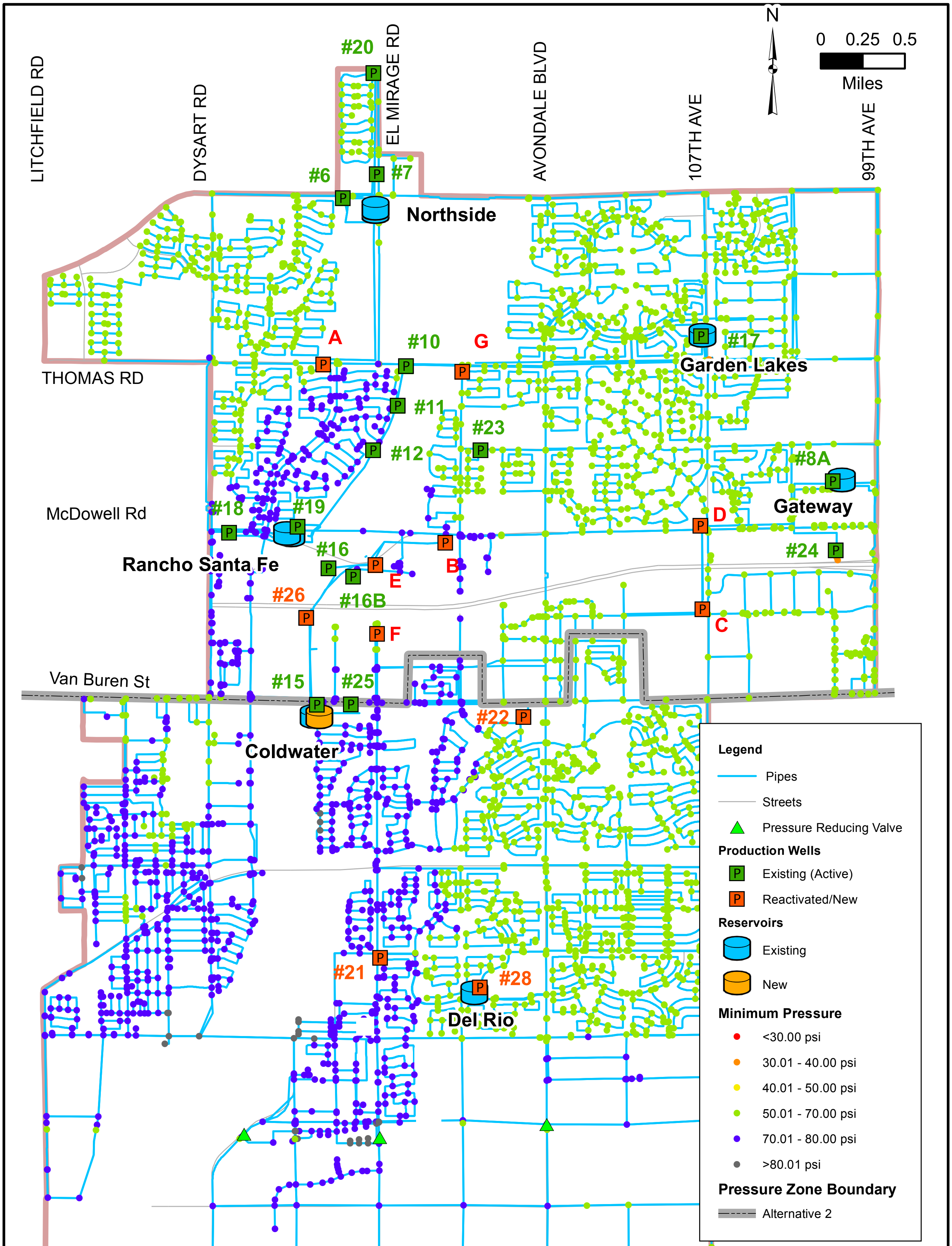
FIGURE 5-4



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CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Alternative 2 – Minimum Pressures under Build-Out Maximum Day Demands

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FIGURE 5-5

Table 5-2 Alternative 2 - Production Analysis

2014		
Parameters	**North Zone**	**South Zone**
Average Day Demand (mgd)	6.1	6.4
Maximum Day Demand (mgd)	10.1	10.5
Existing Well Supply (mgd)	27.0	5.8
Production Criteria		
Reliable Supply Needed (mgd)[1]	13.5	14.0
Additional Supply Required (mgd)	0	8.1
Additional Supply Available (mgd)	0	0
Meets Criteria?	Yes	**No**
Build-Out		
Parameters	**North Zone**	**South Zone**
Average Day Demand (mgd)	10.7	13.3
Maximum Day Demand (mgd)	17.7	21.9
Existing Well Supply (mgd)	27.0	5.8
Production Criteria		
Reliable Supply Needed (mgd)[1]	23.5	29.2
Additional Supply Required (mgd)	0.0	23.4
Additional Supply Available (mgd)[2]	8.4	12.5
Meets Criteria?	Yes	**No**

Notes - [1]Governing criteria: system supply needed to fulfill the maximum day demand with all wells operating for 18 hours or less.
[2]Based on the 2013 Water Master Plan Update recommendations.

If the 2013 Water Master Plan Update recommendations are to remain unchanged (in terms of proposed well locations), an additional supply of 8.1 mgd is required in the South Zone under existing conditions and an additional 10.9 mgd in well supply would be needed (both beyond the recommendations in the 2013 Water Master Plan Update) at build-out under Alternative 2. This is due to fact that most of City's existing and proposed wells are all located north of Van Buren Street.

A storage analysis for Alternative 2 (Table 5-3) shows that there will be enough storage capacity in each of the zones and that the City's storage criteria would be met under both existing and build-out demands.

Table 5-3 Alternative 2 - Storage Analysis

2014		
Parameters	**North Zone**	**South Zone**
Average Day Demand (mgd)	6.1	6.4
Maximum Day Demand (mgd)	10.1	10.5
Peak Hour Demand (mgd)	15.2	15.7
Fire Flow (MG) - 3500 gpm for 4 hours	0.8	0.8
Total Production Capacity (mgd)	13.5	14.0
Existing Storage Capacity (MG)	5.3	3.2
Storage Criteria		
Peak Hour Storage Needed (MG)[1]	2.8	2.9
Additional Storage Required (MG)	0	0
Additional Storage Available (MG)	0	0
Meets Criteria?	Yes	Yes
Build-Out		
Parameters	**North Zone**	**South Zone**
Average Day Demand (mgd)	10.7	13.3
Maximum Day Demand (mgd)	17.7	21.9
Peak Hour Demand (mgd)	26.5	32.9
Fire Flow (MG) - 3500 gpm for 4 hours	0.8	0.8
Total Production Capacity (mgd)	23.5	29.2
Existing Storage Capacity (MG)	5.3	3.2
Storage Criteria		
Peak Hour Storage Needed (MG)[1]	4.9	6.1
Additional Storage Required (MG)	0.0	2.8
Additional Storage Available (MG)[2]	0	2.8
Meets Criteria?	Yes	Yes

Note - [1]Governing criteria: Satisfy peak hour demand for four hours with 50% source capacity and 50% storage capacity.
[2]Based on the 2013 Water Master Plan Update recommendations.

A review of the booster pumping analysis for Alternative 2 (Table 5-4) shows that under existing conditions, the South zone would not satisfy the City's performance criteria. The firm capacity of the Coldwater pump station cannot satisfy the peak hour demand in the South Zone. Under existing conditions, however, use of all the pumps at the Coldwater facility can satisfy the peak hour demands. The City's pumping performance criteria would be satisfied at build-out in both zones.

Table 5-4 Alternative 2 - Pumping Analysis

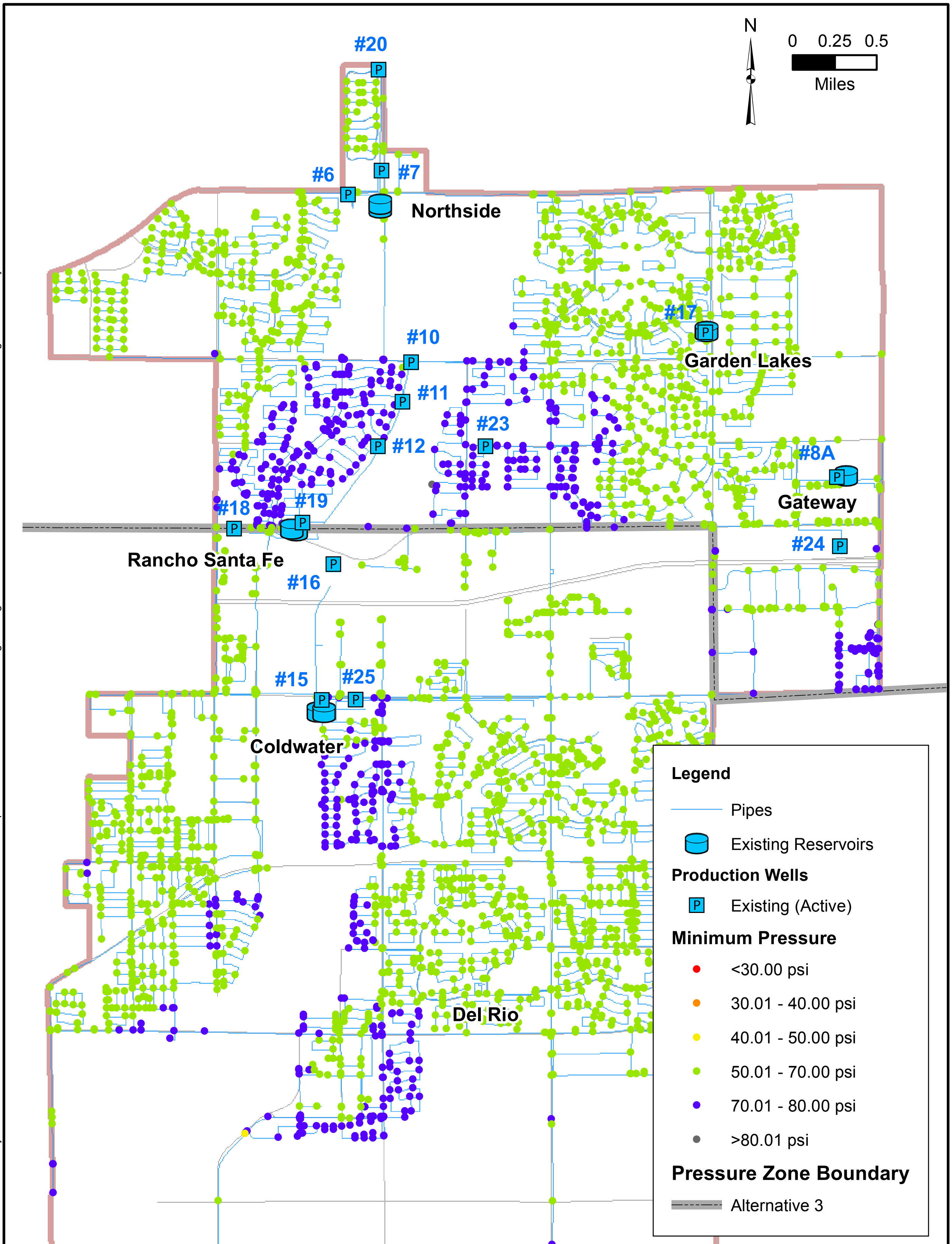
2014		
Zone	**North**	**South**
Average Demand (mgd)	6.1	6.4
Existing Booster Pumping Firm Capacity (mgd)	30.4	14.4
Pumping Criteria		
Maximum Day + Fire Flow (mgd)	15.1	15.6
Peak Hour Demand (mgd)	15.1	15.9
Additional Pumping Required (mgd)	0	1.5
Additional Pumping Available (mgd)	0	0
Meets Criteria?	Yes	**No**
Build-Out		
Zone	**North**	**South**
Average Demand (mgd)	13.3	10.7
Existing Booster Pumping Firm Capacity (mgd)	30.4	14.4
Pumping Criteria		
Maximum Day + Fire Flow (mgd)	26.9	22.7
Peak Hour Demand (mgd)	32.9	26.5
Additional Pumping Required (mgd)	2.6	12.1
Additional Pumping Available (mgd)[1]	8.5	14
Meets Criteria?	Yes	Yes

Note - [1]Based on the 2013 Water Master Plan Update recommendations.

5.2.3 Alternative 3: Pressures Zone Boundary along McDowell Road and 107th Avenue

Similar to Alternative 2, Alternative 3 focuses on splitting the system into two pressure zones. Figure 4-2 showed the pressure zone boundary which divides the system into a North and a South pressure zone. The North zone is supplied by Northside, Garden Lakes, Gateway, and Well 23 facilities. The demands in the South Zone are supplied by the Rancho Santa Fe, Coldwater and Del Rio (at build-out only) facilities.

The analysis of this pressure zone alternative and increasing the North booster station set points results in a 10 psi increase in minimum pressures under maximum day demands in the North Zone under existing and build-out demand conditions (Figure 5-6 and Figure 5-7).



CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Alternative 3 – Minimum Pressures under Existing Maximum Day Demands

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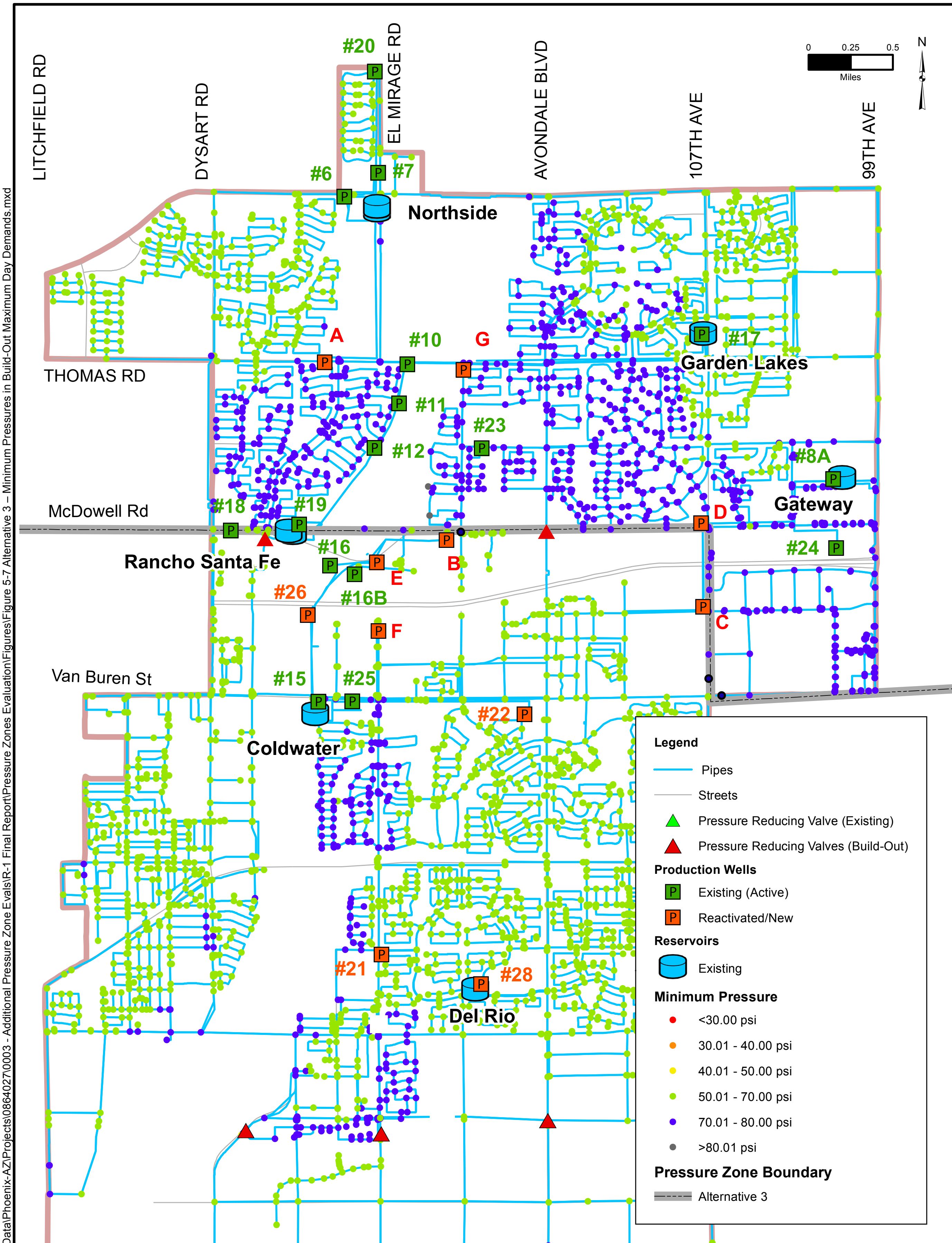
FIGURE 5-6

\\arcadis-us.com\OfficeData\Phoenix-AZ\Projects\08640027\0003 - Additional Pressure Zone Evals\R-1 Final Report\Pressure Zones Evaluation\Figures\Figure 5-6 Alternative 3 – Minimum Pressures in Existing Maximum Day Demands.mxd



City of Avondale

CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Alternative 3 – Minimum Pressures under Build-Out Maximum Day Demands

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FIGURE 5-7

A production analysis of Alternative 3 indicates that the South Zone will need an additional supply of 2.2 mgd at build-out (Table 5-5). A storage analysis of Alternative 3 indicates that additional storage of 0.7 million gallons (MG) will be needed in the North Zone at build-out (Table 5-6).

Table 5-5 Alternative 3 - Production Analysis

2014		
Parameters	**North Zone**	**South Zone**
Average Day Demand (mgd)	5.5	7.0
Maximum Day Demand (mgd)	9.0	11.5
Existing Well Supply	13.7	19.2
Production Criteria		
Reliable Supply Needed (mgd)[1]	12.0	15.3
Additional Supply Required (mgd)	0.0	0.0
Additional Supply Available (mgd)	0.0	0.0
Meets Criteria?	Yes	Yes
Build-Out		
Parameters	**North Zone**	**South Zone**
Average Day Demand (mgd)	8.6	15.4
Maximum Day Demand (mgd)	14.2	25.4
Existing Well Supply	13.7	19.2
Production Criteria		
Reliable Supply Needed (mgd)[1]	18.9	33.8
Additional Supply Required (mgd)	5.2	14.7
Additional Supply Available (mgd)[2]	8.4	12.5
Meets Criteria?	Yes	**No**

Note - [1]Governing criteria: system supply needed to fulfill the maximum day demand with all wells operating for 18 hours or less.
[2]Based on the 2013 Water Master Plan Update recommendations.

Table 5-6 Alternative 3 – Storage Analysis

2014		
Parameters	**North Zone**	**South Zone**
Average Day Demand (mgd)	5.5	7.0
Maximum Day Demand (mgd)	9.0	11.5
Peak Hour Demand (mgd)	13.5	17.3
Fire Flow (MG) - 3500 gpm for 4 hours	0.8	0.8
Total Production Capacity (mgd)	12.0	15.3
Existing Storage Capacity (MG)	3.2	5.3
Storage Criteria		
Peak Hour Storage Needed (MG)[1]	2.5	3.2
Additional Storage Required (MG)	0	0
Additional Storage Available (MG)	0	0
Meets Criteria?	Yes	Yes
Build-Out		
Parameters	**North Zone**	**South Zone**
Average Day Demand (mgd)	8.6	15.4
Maximum Day Demand (mgd)	14.2	25.4
Peak Hour Demand (mgd)	21.3	38.0
Fire Flow (MG) - 3500 gpm for 4 hours	0.8	0.8
Total Production Capacity (mgd)	18.9	33.8
Existing Storage Capacity (MG)	3.2	5.3
Storage Criteria		
Peak Hour Storage Needed (MG)[1]	3.9	7.0
Additional Storage Required (MG)	0.7	1.8
Additional Storage Available (MG)[2]	0	2.8
Meets Criteria?	**No**	Yes

Note - [1]Governing criteria: Satisfy peak hour demand for four hours with 50% source capacity and 50% storage capacity.
[2]Based on the 2013 Water Master Plan Update recommendations.

A pumping analysis of Alternative 3 indicates that there is enough pumping in both zones under existing conditions (Table 5-7). Under build-out conditions, an additional 14.8 mgd of pumping is required. The 2013 Water Master Plan Update recommends 21.6 mgd of additional pumping, which will cover the above requirement.

Table 5-7 Alternative 3 - Pumping Analysis

2014		
Zone	**North**	**South**
Average Demand (mgd)	5.5	7.0
Existing Booster Firm Capacity (mgd)	21.4	23.3
Pumping Criteria		
Max. Day + Fire Flow (mgd)	14.0	16.5
Peak Hour Demand (mgd)	13.5	17.3
Additional Pumping Required (mgd)	0	0
Additional Pumping Available (mgd)	0	0
Meets Criteria?	Yes	Yes
Build-Out		
Zone	**North**	**South**
Average Demand (mgd)	8.6	15.4
Existing Booster Firm Capacity (mgd)	21.4	23.3
Pumping Criteria		
Max. Day + Fire Flow (mgd)	19.2	30.4
Peak Hour Demand (mgd)	21.3	38.1
Additional Pumping Required (mgd)	0	14.8
Additional Pumping Available (mgd)[1]	0	21.6
Meets Criteria?	Yes	Yes

Note - [1]Based on the 2013 Water Master Plan Update recommendations.

5.3 Preferred Pressure Increase Alternative

Based on the findings from the preliminary analysis of alternatives, Table 5-8 summarizes a comparison of the pressure increase alternatives.

Table 5-8 Results of Preliminary Pressure Increase Alternatives Analysis

Alternative	10 psi Increase in Minimum Pressure?		Additional Production Requirements[1]		Additional Storage Requirements[1]		Additional Pumping Requirements[1]	
	Existing	Build-Out	Existing	Build-Out	Existing	Build-Out	Existing	Build-Out
1	No	No	0	0	0	0	0	0
2	Yes	No	8.1 mgd in South	12.5 mgd in South	0	0	1.5 mgd in South	0
3	Yes	Yes	0	2.2 mgd in South	0	0.7 MG in North	0	0

Note – [1]Compared to recommendations of the 2013 Water Master Plan Update.

Table 5-8 shows that Alternative 3 is the best choice to augment the pressures in the north areas of the system. The need for additional well capacity and storage capacity for Alternative 3 is estimated to occur close to build-out conditions. As further discussed in Chapter 7, the additional production and storage requirements could be eliminated by updating the 2013 Water Master Plan Update recommendations to adjust future well and storage tank locations.

The results of the preliminary evaluation of pressure increase alternatives were discussed with the City and it was agreed that Alternative 3 would be carried forward and be subjected to additional modeling and analyses.

6. Additional Evaluation of Preferred Pressure Increase Alternative

This chapter summarizes additional evaluations of the preferred pressure increase alternative (Alternative 3) on its viability to meet the City's water system operational requirements. The evaluations included:

- Additional hydraulic modeling to:
  - Identify the maximum increase in average minimum pressures that can be achieved in the North Zone without exceeding maximum pressures of 85 psi at any time, particularly near the Aqua Fria River (lowest parts of the system in the North Zone).
  - Finalize the booster pump and Well 23 set points for the North Zone facilities that will achieve the maximum increase in average minimum pressures.
- Fire flow analyses with the finalized booster pump and Well 23 set points to identify any significant changes in fire flow protection as compared to existing conditions. The analyses are also needed to assess the impacts of multiple valve closures, needed to create the recommended pressure zones, on available fire flows near these valve closures.
- Assessment of the North Zone booster pump stations and Well 23 to verify that they are capable of operating at the increased pressure settings

No changes were made to the South Zone and its booster stations – Rancho Santa Fe and Coldwater.

6.1 Additional Pressure Increase Modeling

The preferred pressure zones alternative was further evaluated for increases in maximum pressures in the North Zone. The area surrounding the riverbed was a particular area of concern due to its lower elevations, so special attention was given to maximum pressures in this area. As part of the evaluation, the maximum pressures in these areas were assessed to verify that they do not exceed 85 psi.

To finalize the booster station pressure settings in the North Zone and to identify maximum pressure increases that can be achieved, various combinations of increased booster station set-points were analyzed under maximum day demand conditions as the system experiences the lowest pressures during this stressed condition.

6.1.1 Pressure Set-points – 10 psi Increase

In the analysis of alternatives described in Chapter 5, the pressure set-points were developed to provide an average increase in minimum pressures of approximately 10 psi in the North Zone. Table 6-1 shows the booster station pressure set points that were used compared to the existing set-points, and Table 6-2 shows the resulting pressure increases for certain parameters in the North Zone.

Table 6-1 Booster Station Set-points for 10 psi Increase in Minimum Pressures

Booster Station	Existing Set-point (psi)	Increased Set-point (psi)
Northside	54	66
Gateway	45	64
Garden Lakes	48	70
Well #23	58	72

Table 6-2 Pressure Increases under Existing and Build-Out Maximum Day Demands

Time Period	Parameter	Pressure (psi)		
		With Increased Set-points	With Existing Set-points	Increase
Existing	Minimum Pressure	61.2	51.1	10.1
	Average Pressure	71.6	53.4	18.2
Build-Out	Minimum Pressure	60.9	51.1	9.8
	Average Pressure	71.4	53.4	18.0
Maximum Pressure (psi)				
Existing		78.3		
Build-Out		75.1		

Table 6-2 shows an increase in minimum pressures in the North Zone of approximately 10 psi. To achieve this increase, the set-points are increased by more than 10 psi to account for the system headlosses. This increase will be seen at the service connections to the customer before any backflow prevention devices. With around 5 to 10 psi headloss through the backflow preventer, the minimum pressure at the points-of-use will be very close to or below the system performance criteria of 40 psi. Thus, the next step was to estimate what additional pressure increases can be achieved in the North Zone with the preferred pressure zones alternative.

Additional modeling was conducted to achieve higher pressure increases in the North Zone with the existing and planned infrastructure. Using the same methodology as described above, a set of higher booster station set-points was evaluated that resulted in an average increase in minimum pressures of approximately 19 psi under existing demand conditions and 14 psi under build-out conditions.

However, after evaluation of the pressures surrounding the riverbed, it was found that the low areas near the riverbed would be very close to the maximum pressure limit of 85 psi, these areas would be in danger of exceeding the limit if any pressure surges occur (these surges are known to happen). Thus, another lower set of booster station set-points was evaluated to arrive at the final recommended set-points.

6.1.2 Final Recommended Set-points

Table 6-3 shows recommended booster station set-points under maximum day demands such that pressures near the river do not approach 85 psi and Table 6-4 shows the resulting average pressure increases in the North zone under the same conditions.

Table 6-3 Recommended Set-points for Existing and Build-Out Maximum Day Demands

Pump Station	Existing Set-points (psi)	Recommended Set-points (psi)
Northside	54	73
Gateway	45	72
Garden Lakes	48	76
Well #23	58	80

Table 6-4 Pressure Increases under Maximum Day Demands and Recommended Set-points

<table>
<tr><th rowspan="2">Time Period</th><th rowspan="2">Parameter</th><th colspan="3">Pressure (psi)</th></tr>
<tr><th>With Recommended Set-points</th><th>With Existing Set-points</th><th>Increase</th></tr>
<tr><td rowspan="2">Existing</td><td>Minimum Pressure</td><td>67.8</td><td>51.1</td><td>16.7</td></tr>
<tr><td>Average Pressure</td><td>73.5</td><td>53.4</td><td>20.1</td></tr>
<tr><td rowspan="2">Build-Out</td><td>Minimum Pressure</td><td>62.6</td><td>51.1</td><td>11.5</td></tr>
<tr><td>Average Pressure</td><td>71.9</td><td>53.4</td><td>18.5</td></tr>
<tr><td colspan="5">Maximum Pressure (psi)</td></tr>
<tr><td colspan="2">Existing</td><td colspan="3">84.5</td></tr>
<tr><td colspan="2">Build-Out</td><td colspan="3">84.2</td></tr>
</table>

The set-points in Table 6-3 yielded considerable pressure increases throughout the North Zone under maximum day demand conditions. Additionally, maximum pressures in the area surrounding the riverbed were below 85 psi. The average maximum pressure in the nodes surrounding the riverbeds is 81.4 psi.

The recommended set-points in Table 6-3 were developed under the stressed condition of maximum day demands. These settings were then applied to existing average day demand conditions (~12.7 MGD) to verify the system performance under this condition. It was found that using the recommended set-points under average day demand resulted in pressures near the riverbed exceeding 85 psi. Therefore, the set-points are recommended to be reduced under the average day demand conditions. The recommended set-points for average day demand conditions are summarized in Table 6-5.

Table 6-5 Recommended Set-points for Existing Average Day Demand Conditions

Pump Station	Existing Set-points (psi)	Recommended Set-points (psi)
Northside	54	72
Gateway	45	68
Garden Lakes	48	65
Well #23	58	80

It is important to note that the set-points for all possible demand conditions were not been determined in this pressure zones evaluation. If the booster stations can achieve the recommended set-points under maximum day demands, they will also be able to achieve the lower pressure set-points for the average day demand and minimum day demand conditions. This indicates the system demand will dictate the set-points that the pump stations should be operated at in order to limit the maximum pressures near the riverbed.

The City was particularly interested in pressure increases in certain parts of the system. The recommended set-points were used to assess the pressure increases at specific locations (Table 6-6) under existing maximum day demand conditions.

Table 6-6 Pressure Increases at Specific Locations under Existing Maximum Day Conditions

Location	Increase in Minimum Pressures under Existing Maximum Day Demands
103rd and McDowell	22.2
99th and Indian School	22.7
99th and Van Buren	22.3
Rio Crossings	18.2

Table 6-6 shows significant pressure increases can be anticipated in areas of concern in the North Zone with the recommended booster set-point settings in Tables 6-3 and 6-5.

6.2 Fire Flow Analysis

The ability of a water system to provide adequate fire flow under all conditions is extremely critical. Any changes to the system will affect the system's ability to provide fire flow. For example, multiple valves will be closed along McDowell Road and Avondale Boulevard to create the preferred pressure zones. The available fire flow in the system was evaluated to ensure that implementing the new pressure zones with new pressure settings and the closing of valves will not hinder the system from providing adequate fire flow. Two fire flow scenarios were evaluated for the recommended pressure zones alternative (with all PRVs and valves installed and closed): residential fire flow and commercial fire flow. The results of the fire flow analyses are provided in Appendix A.

The residential fire flow criteria stipulate that the system be able to provide 1,000 gpm to the system. This was evaluated by examining the available flow across the system under maximum day demand conditions with the proposed pressure zones and recommended booster station settings (Table 6-3). Appendix A shows that available flow throughout the system exceeded 1,000 gpm indicating adequate fire flow across the system after implementation of the pressure zones. Furthermore, there were no significant decreases in residential fire flow protection in any areas if the pressure zones are implemented.

The commercial fire flow criteria stipulate that the system be able to provide 3,500 gpm of flow to specific commercial locations for four hours. This was evaluated at several specific commercial locations within the City by applying a 3,500 gpm flow at the location and running the model to simulate a 4-hour runtime and verifying that the City's system performance criteria (velocities, headlosses, and pressures) were not violated. The commercial fire flows were tested at various locations in the system with commercial or industrial customers. The results are summarized in the Table 6-7.

Table 6-7 Commercial Fire Flow Results

Location	Commercial Fire Flow Met?
107th Avenue and Van Buren	Yes
107th Avenue and McDowell	Yes
Avondale Blvd and McDowell	Yes
Dysart Road and Coldwater Plaza Lane	Yes
Commercial Area South of I10	Yes

6.3 Capability of North Zone Facilities to Accommodate Higher Pressures

To confirm the viability of the existing booster stations to achieve the final recommended set-points, additional evaluations were performed on the equipment at the booster stations in the proposed North

Zone. A site visit was conducted at each of the North Zone facilities to evaluate controls and configuration of the facilities and to assess the capability of the stations to operate efficiently at the higher system pressures. The capability of the booster stations to accommodate higher pressures was further evaluated by comparing pump manufacturer data to the recommended pressure set-points and historical operational data.

6.3.1 Site Visit

ARCADIS staff, accompanied by City officials, visited the Coldwater, Rancho Santa Fe, Gateway, Garden Lakes, and Well 23 facilities during the first week of April 2015. At each location, detailed evaluation was conducted of the control systems, its configurations, and mechanical elements to assess the capability to operate at the higher recommended set-points.

During and after the visit, ARCADIS staff were able to verify that most pumps and booster stations were stable and configured to operate efficiently. The pressure control and pump selection logic were configurable to allow improvements in the future. Some of these may even be possible via operator accessible set-points. This will allow implementation of the recommended set-points. Changes (pressure set-points) to accommodate the new pressure zones can be made with minimal changes in controls and configurations.

6.3.2 Current Operation *and* Recommended Pressure Set-Points Evaluation

Next, the current operation of the booster stations was evaluated by relating historical pressure and flow data to pump curves to determine where the pumps are currently operating on their respective pump curves. The pump curves for the Gateway and Garden Lakes were obtained from the pump manufacturers. The manufacturer's pump curves are the theoretical operation of each pump and are not necessarily representative of current pump operation; therefore, the results of this evaluation are inherently theoretical as well.

The current operation was evaluated for Gateway, Garden Lakes, and Well 23. New boosters have been recently installed at Northside, thus their historical operational data was not available. The basic process for evaluating current pump operation is described below:

- Plot flow verses pressure data for each booster station throughout the year
- Develop trend line for data
- Compare trend line to manufacturer's pump curve

The comparison between the historical operating data and the manufacturer's pump curve is representative of where each booster station is operating on its pump curve and its efficiency. The comparisons for

Gateway, Garden Lakes, and Well 23 are shown on Figures 6-1, 6-2, and 6-3, respectively. The figures show that at their current operational set-points (full lines), Gateway, Garden Lakes, and Well 23 are all operating well below their capacities and design points. The recommend set-points were also plotted on Figures 6-1, 6-2 and 6-3 to evaluate performance on the pump curves (dashed lines).The figures indicate that at the increased set-points, the North Zone facilities will operate more efficiently and closer to their respective design points.

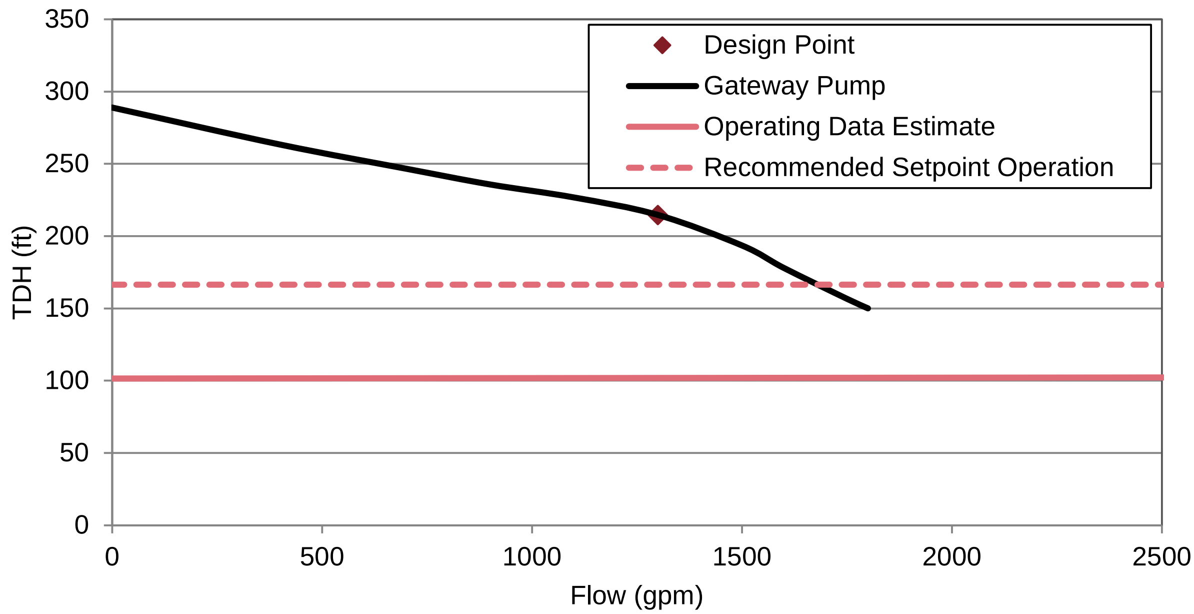


Figure 6-1 Gateway Pump Operation Evaluation

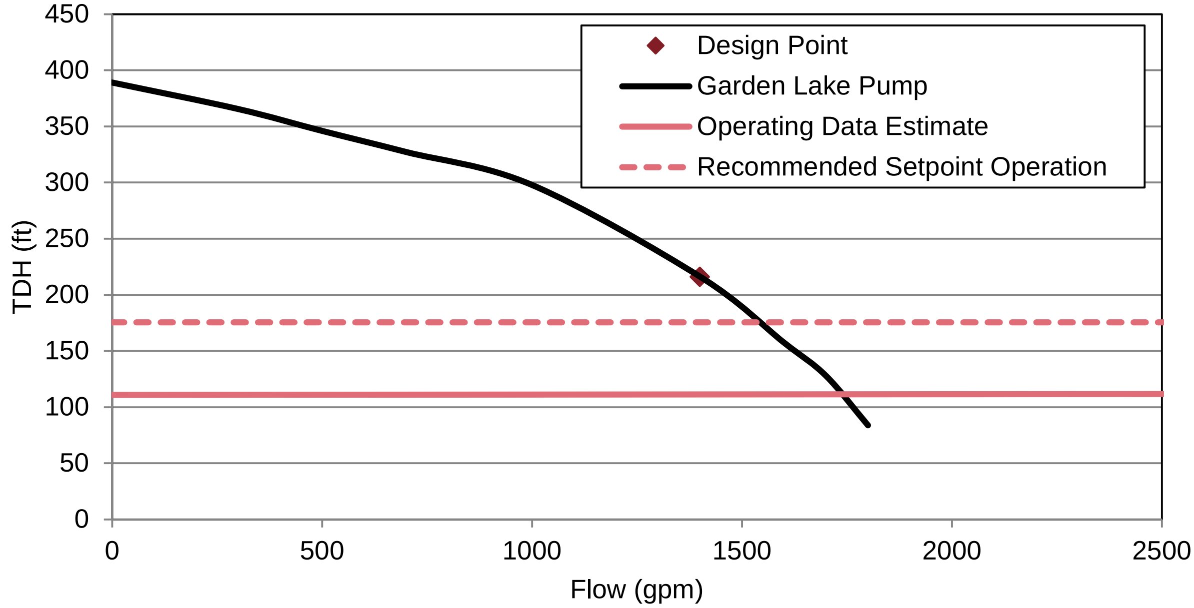


Figure 6-2 Garden Lakes Pump Operation Evaluation

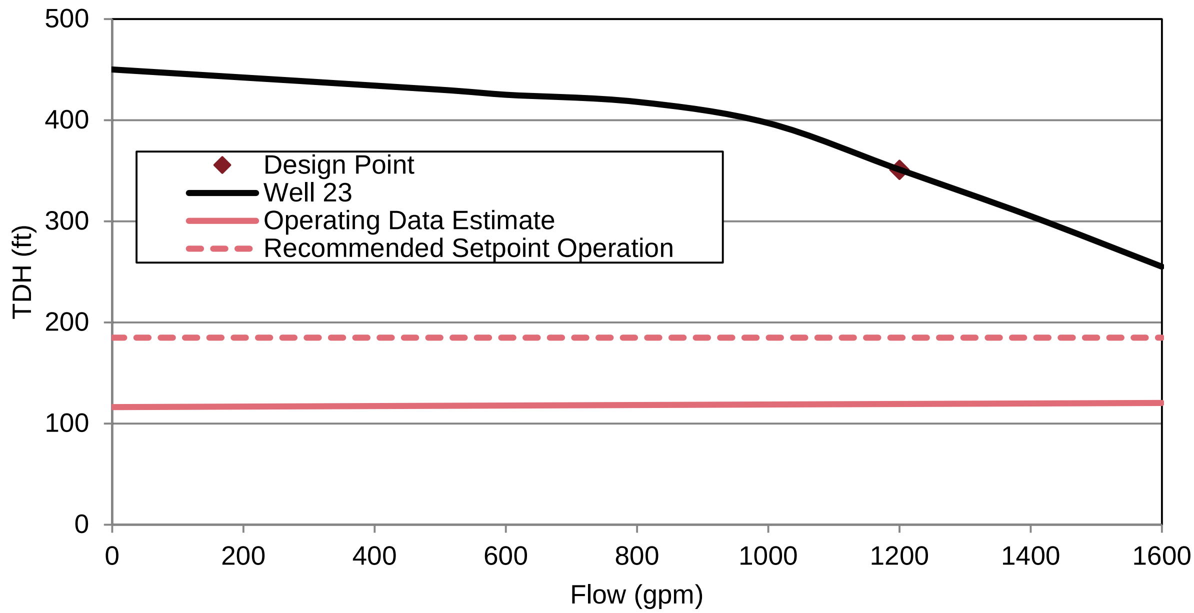


Figure 6-3 Well 23 Pump Operation Evaluation

The evaluation was also performed for the new Northside booster station using their design pump curves. The results for Northside are shown on Figure 6-4.

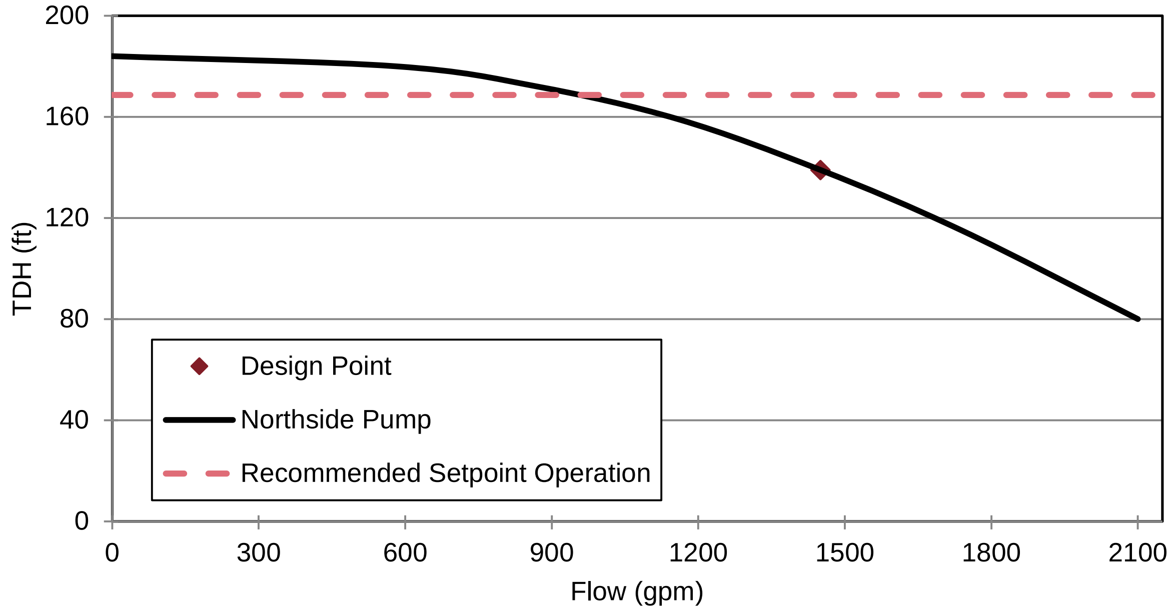


Figure 6-4 Northside Pump Operation Evaluation

The evaluation indicated that the pumps at the North Zone booster stations and Well 23 can operate at the recommended set-points and still stay within the limits of the pump curve. With higher pressure set-points at the booster stations, the flow rate from each pump will decrease as opposed to existing lower set-points; however, by using multiple pumps together, the City can compensate for the lowering of flow from a single pump.

The City indicated that Well 23 is hindered by air entrainment issues, and also would require modifications to operate at the higher recommended set-points. These potential well modifications and costs are described in Chapter 7.

Use of the manufacturer's pump curves in this type of evaluation gives the City a good indication of the viability of the recommended set-points, but it may not accurately represent current pump operations. The pumps should be evaluated in the field to confirm operation at higher set-points before any significant changes are made to the system.

7. Opinion of Cost Impacts for Implementing the Recommended Alternative

This chapter summarizes the cost impacts associated with implementation of the preferred pressure zones and the recommended booster station settings. The cost opinions include capital costs to build the necessary infrastructure and operational costs required to run and maintain the modified system.

7.1 Pressure Zone Configurations

Figure 7-1 shows the recommended pressure zones configuration along with the associated system modifications required. The exact alignment of the pressure zones boundary is as follows:

- Along McDowell Road, from Dysart Road to 107th Avenue
- Along 107th Avenue, from McDowell Road to Van Buren Street

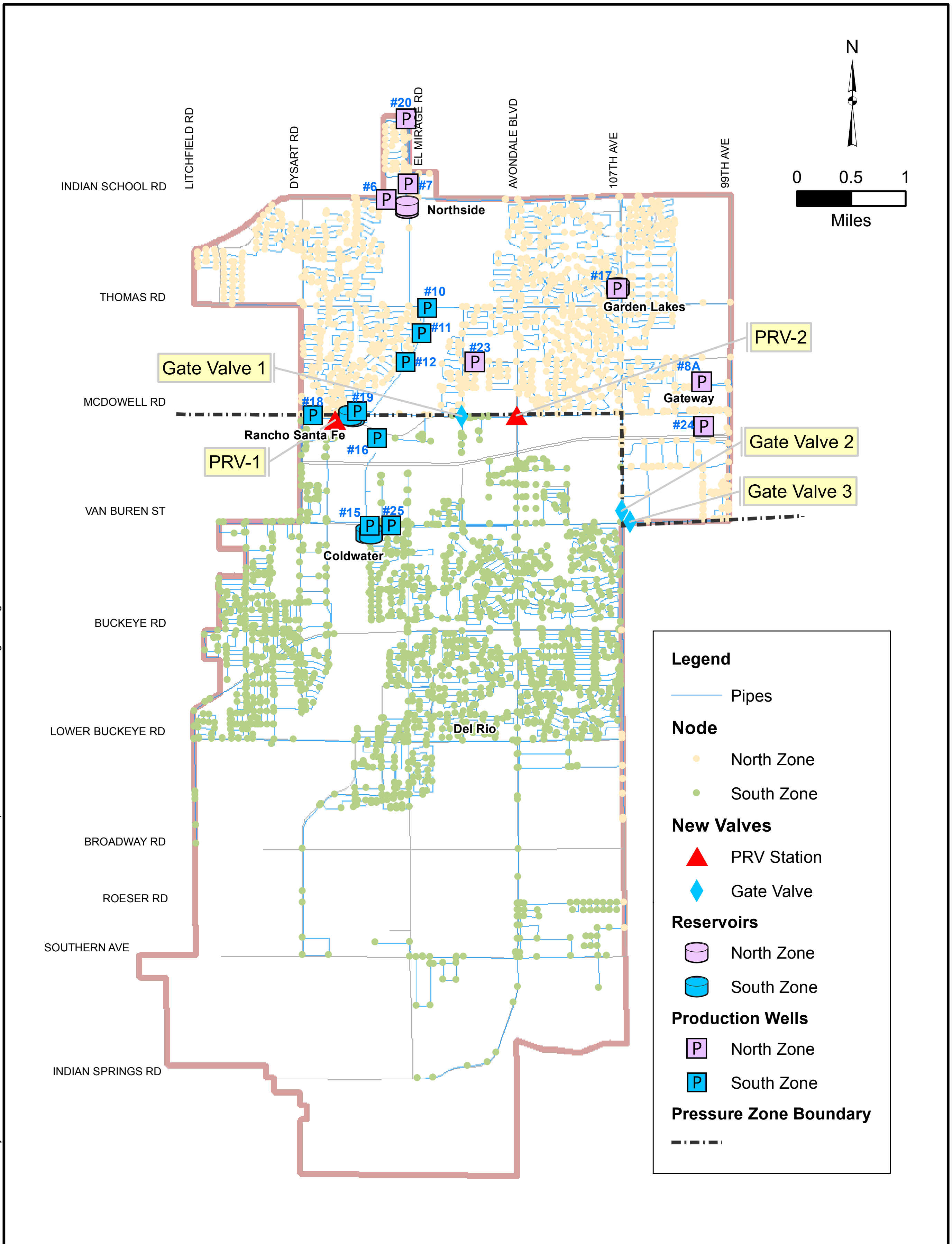
The recommended pressure zones boundary will divide the system into a North Zone and a South Zone. The North Zone will be the smaller zone and will be supplied by Northside, Gateway, Garden Lakes, and Well 23. The South Zone will be the larger zone, will have the most future development, and will be served by Rancho Santa Fe, Coldwater, and Del Rio (when rehabilitated) facilities. Table 7-2 summarizes the system demands for each pressure zone.

Table 7-1 System Demands by Pressure Zones

Parameters	North Zone	South Zone	Total
2014			
Average Day Demand (mgd)	5.5	7.0	12.5
Maximum Day Demand (mgd)	9.1	11.6	20.7
Build-Out			
Average Day Demand (mgd)	8.6	15.3	23.9
Maximum Day Demand (mgd)	14.2	25.2	39.4

Note: Demands are based on 2013 Water Master Plan Update.

The available storage in the North Zone is 3.2 MG and in the South Zone is 5.3 MG. Additionally, 2.8 MG of additional storage would be available in the South Zone after rehabilitation of the Del Rio reservoir. The North Zone will have 21.4 mgd of existing booster pumping capacity and the South Zone will have 23.3 mgd of existing boosting pumping capacity. The boosters at the Del Rio facility will be available to the South Zone after the Del Rio tank is rehabilitated.



City of Avondale

CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Recommended Pressure Zones Configuration

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FIGURE 7-1

7.2 Opinion of Incremental Annual O&M Cost Increases

Implementing the new pressure zones will result in operational changes that will increase O&M costs. This is largely driven by increased usage of the pumping stations where water treatment is provided to produce drinking water meeting applicable state and federal regulations. Currently these stations are only used to supplement supplies during peak demands. If the pressure zones are implemented, these treatment facilities in the North Zone will have to operate more to supplement some of the average demands as well. The additional pumping will also require additional power. Finally, the new PRV stations and interconnect valves will require annual maintenance.

7.2.1 Additional Water Treatment Costs

The City has water treatment facilities at three pumping stations:

- Northside treats arsenic through coagulation with ferric chloride, and filtration via conventional filtration. Periodic backwashes are mechanically thickened; supernatant is sent back to the head of the plant, and the thickened sludge is hauled by truck to a landfill.
- Gateway treats nitrate with regenerable strong base anion exchange (SBA-IX), and dibromochloropropane (DBCP) with granular activated carbon (GAC). Spent regenerant (brine) is then held before being hauled by truck to a landfill.
- Garden Lakes treats nitrate with SBA-IX. Residuals are managed in the same fashion as the Gateway facility.

Actual treatment cost information was provided by the City for the Northside and Gateway treatment facilities:

- Ion exchange (IX) treatment costs for Garden Lakes were assumed to be the same as Gateway after noting that the primary constituents affecting treatment costs were similar for both locations:
- Nitrate was approximately 10-15 mg/L – N at both locations.
- Sulfate was approximately 80-100 mg/L at both locations.
- GAC costs at Gateway were provided as a replacement cost over a period of time (approximately 2-3 years).

The assumed unit treatment costs for each facility, based on the City's information, are summarized in Table 7-2.

Table 7-2 Assumed Unit Treatment Costs

Treatment Facility	Contaminant	Cost/MG	Costs included
Northside	Arsenic (C/F)	$300	labor, coagulant, pH depressant, electricity, thickened backwash hauling
Gateway	Nitrate (IX)	$2,000	labor, salt, electricity, spent brine hauling
	DBCP (GAC)	$300	GAC replacement
Garden Lakes	Nitrate (IX)	$2,000	labor, salt, electricity, spent brine hauling

Note: C/F- Coagulation/Filtration
IX- Ion Exchange
GAC- Granular Activated Carbon

The City's distribution system model was used to estimate the treatment usage for each facility based on four different scenarios to aid the treatment evaluation:

1. Single pressure zone (current operation):
    a. Average day demand
    b. Maximum day demand
2. Dual pressure zones (proposed operation):
    a. Average day demand
    b. Maximum day demand

Typically, costs would be estimated based purely on the average day demand; however, the majority of average day demand is accommodated by flow from Northside and Well 23. As a result, activity at Gateway and Garden Lakes—primarily used to accommodate higher demand conditions—was not being accurately represented. In order to better estimate the increased treatment costs for the North Zone, a composite day was created by using the average and maximum day demand in conjunction to account for increased treatment at Garden Lakes and Gateway. These composite costs were estimated over a year of operation by assuming the maximum day demand represented the three summer months and the average day demand represented the remaining nine months. The single pressure zone demands were calibrated with 2013 production values from each facility.

It was assumed that the facilities were appropriately sized to handle the increased usage, and thus no additional capital costs would be incurred.

The estimated water demands based on the methodology discussed above are shown in Table 7-3, and the results of the treatment evaluation are presented in Table 7-4. Current annual operation of all three treatment facilities is estimated at $970,000. The estimated annual cost of current operation is expected to increase approximately 2.5 fold to $2,400,000 with dual zone operation due to significantly increased usage of the higher O&M cost treatment facilities at Gateway and Garden Lakes.

Table 7-3 Estimated Water Produced from Treatment Facilities for Single and Dual Zone Operation

Treatment Facility	Single Zone (mgd)			Dual Zone (mgd)		
	Average Day	Maximum Day	Annual Composite	Average Day	Maximum Day	Annual Composite
Northside	1.2	1.5	**1.3**	3.2	2.3	**3.0**
Gateway	0	4.0	**1**	1.7	2.5	**1.9**
Garden Lakes	0	0	**0**	0	2.4	**0.6**

Table 7-4 Estimated Treatment Costs for Single and Dual Zone Operation

Treatment Facility	Monthly		Annual	
	Single Zone	Dual Zone	Single Zone	Dual Zone
Northside	$12,000	$27,000	$140,000	$320,000
Gateway	$69,000	$130,000	$830,000	$1,600,000
Garden Lakes	$0	$37,000	$0	$440,000
Total	**$81,000**	**$200,000**	**$970,000**	**$2,400,000**

The high cost of this increased utilization could potentially be mitigated by a number of different measures. The City could evaluate the following options to help reduce costs and operational burden at the North Zone treatment systems:

- *Evaluate sizing of spent brine and thickened backwash (residuals) holding facilities*. During high usage periods, waste hauling is sometimes taking place as frequently as once a day. Larger holding facilities will reduce hauling frequency to make operations more manageable.

- *Evaluate alternate residuals disposal options*. Waste hauling is a significant portion of current treatment costs. Evaluate applicable regulations for sewer disposal, as this would likely be the most economical disposal method if small or no changes to residuals handling processes can be made to accommodate sewer restrictions. The City has a limit of 0.41 mg/L for arsenic in sewer discharges, but has no explicit restrictions for sulfate, nitrate, or total dissolved solids (TDS), which may merit further consideration for IX brine disposal.

- *Evaluate alternate resins.* Nitrate-selective resins will likely provide much longer run times between regenerations resulting in savings through reduced salt and residuals handling costs for the ion exchange systems at Gateway and Garden Lakes. A side-by-side case test performed by Purolite found the nitrate selective resin to require 16 percent fewer regenerations, which would result in a similar reduction in salt and residuals handling costs. The resin will also accumulate chromium less effectively, which could help to minimize the risk of exceeding hazardous waste criteria during brine disposal. Pilot testing will be required to verify performance at the existing facilities.

- *Evaluate brine reduction capabilities*. Reusing spent brine multiple times before disposal has been effective in certain situations. Reduced brine usage will lower brine costs and hauling frequency and costs - reusing brine once would reduce salt and hauling costs by approximately 50 percent. Pilot testing to ensure effectiveness is recommended, as capital expenditures will be required to reconfigure the system to allow reuse.

Three of above four options were evaluated in the City's 2013 Wellhead Treatment Study within the context of minimizing spent brine chromium levels; however, these options may warrant further consideration either alone or in combinations in the context of lowering overall operations cost.

7.2.2 Additional Power Costs

Typically, the majority of power costs in distribution systems are related to pumping. Pumping costs are attributed to pumping water from a well to a tank, and booster pumping from the tanks to the distribution system. The unit treatment costs for each treatment facility (Table 7-2) provided by the City included the power costs for pumping from the wells to the tanks. This section focuses only on the power costs associated with booster pumping.

Power costs will vary with the North Zone booster pumps running longer than before and the South Zone booster pumps running less. Power costs were compared for present operating conditions and after implementing the proposed pressure zones. The comparison was developed by estimating the run time for the pumps at each booster station based on the model runs. The composite method described in Section 7.2.1 was also used for calculating the power costs. Additional assumptions are summarized below:

- Pumps were assumed to be either running at full power or off, i.e., the pumps running at lower frequency is not accounted for in the analysis.

- Pumps were assumed to be the same size. The pump motor size was assumed to be 100 horsepower (hp) based on motors at Gateway and Garden Lakes.

- Pumps were assumed to be 85 percent efficient in transferring power from the motor to the water.

- Based on the electric bill provided by the City for Northside Well #6 (December 2014), the electric rate was estimated at $0.16 per kilowatt-hour (kWh).

The results of the power analysis are shown in Table 7-5 and Table 7-6. The total pumping hours increased from 151 to 228 with annual electric costs rising from $760,000 to $1,100,000 for the single zone and dual zone operation, respectively.

Table 7-5 Summary of Pumping Costs for Single Zone

Pump Station	Pump Hours	Monthly Cost	Annual Cost
Northside	48	$20,000	$240,000
Gateway	0.75	$300	$3,800
Garden Lakes	0	$0	$0
Rancho Santa Fe	54	$23,000	$270,000
Coldwater	48	$20,000	$240,000
Total	**150.75**	**$63,000**	**$760,000**

Table 7-6 Summary of Pumping Costs for Dual Zone

Pump Station	Pump Hours	Monthly Cost	Annual Cost
Northside	72	$30,000	$360,000
Gateway	48	$20,000	$240,000
GardenLakes	6	$2,500	$30,000
Rancho Santa Fe	54	$23,000	$270,000
Coldwater	48	$20,000	$240,000
Total	**228**	**$96,000**	**$1,100,000**

7.2.3 PRV Stations and Interconnects Annual O&M Costs

PRV stations with proposed pressure sustaining valves do not require much maintenance after they are installed. This additional O&M cost is estimated to be 1 percent annually of the total capital costs or approximately $4,000 per year. This includes yearly valve inspection and rotation, periodic rebuilding of valves, replacement of seals, etc.

7.2.4 Summary of Incremental Annual O&M Costs

Table 7-7 summarizes the incremental annual O&M costs described above. In general, annual O&M costs are estimated to increase by $1.8 million annually if the pressure zones are implemented. These costs increases can be refined by collecting more operational data such as pump frequencies, or reduced by considering the recommendations described in the Section 7.2.1.

Table 7-7 Summary of Annual O&M costs

Item	Single Zone	Dual Zone	Difference
Water Treatment	$970,000	$2,400,000	$1,430,000
Booster Pumping Power	$760,000	$1,100,000	$340,000
PRV Maintenance	$0	$4000	$4,000
Total	**$1,730,000**	**$3,504,000**	**$1,774,000**

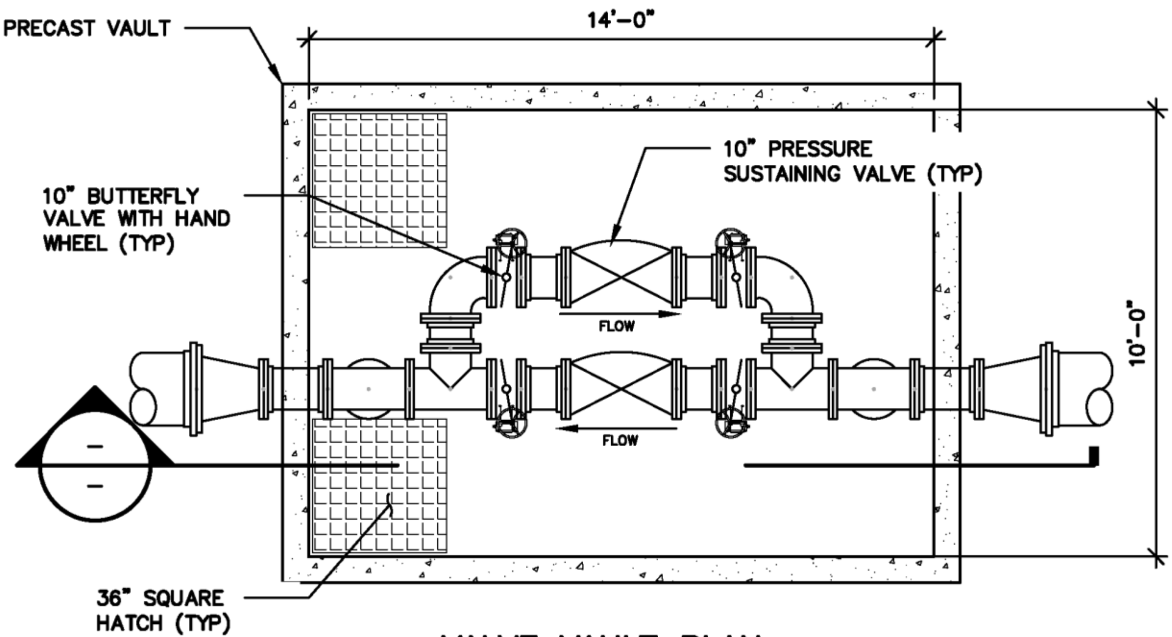
7.3 Opinion of Conceptual Construction Costs

In addition to increased O&M costs, the recommended pressure zones will require system modifications. The modifications include the installation of new PRV stations (valves and vaults) to separate the pressure zones and rehabilitation of Well 23 so that it can operate at the higher system pressures. This section summarizes the estimated capital costs of implementing the pressure zones alternative.

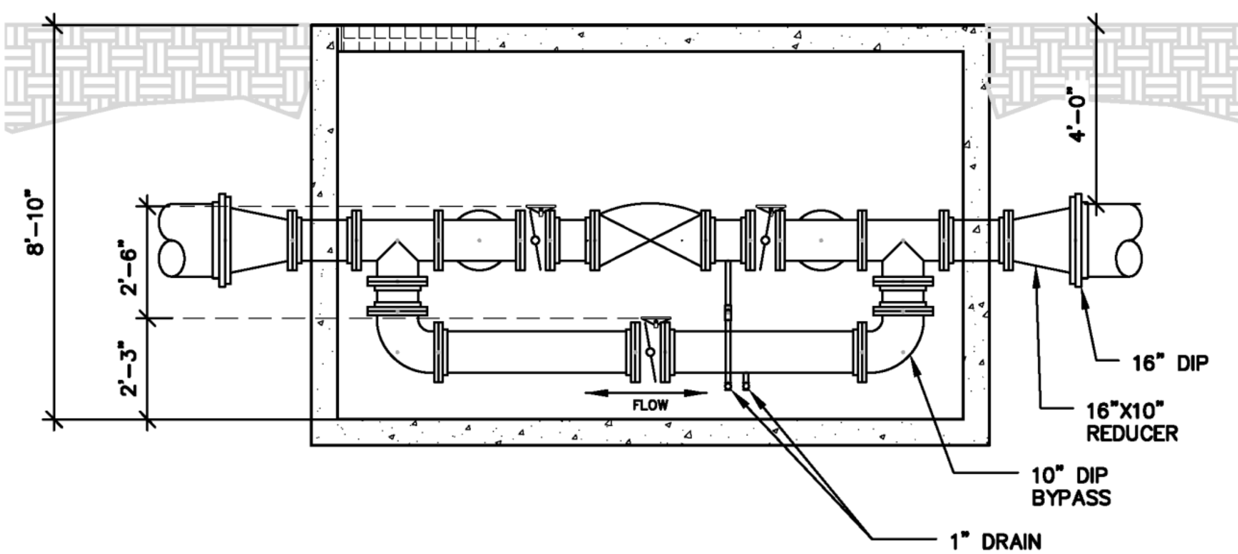
7.3.1 PRV Stations

The recommended pressure zones configuration consists of two valve and vault installations (shown on Figure 7-2) along the pressure zone boundary. Each PRV station will be comprised of two parallel pressure sustaining valves (PSVs) oriented opposite of each other, and will include a check feature. Furthermore, a 10-inch bypass line and butterfly valve are proposed to allow for maintenance without system shutdown.

This configuration will allow water to flow between the two separate zones, if necessary, at each location. During typical operation, the PSVs will be closed and thus not allow flow between the two pressure zones creating two independent zones. However, if operating conditions of the system require flow from one zone to the other, the dual valve layout allows the flexibility to do so. The pressure differential between the two zones will provide the hydraulic pressure to modulate the valves. If one zone requires flows to meet demand or decrease pressures, the necessary valve will modulate to equalize pressure and flow between the zones. The detailed cost estimate for this PRV station arrangement is provided in Appendix C. It is recommended that the City consider connecting these PRV sites to its SCADA system.



VALVE VAULT PLAN



VALVE VAULT SECTION

CITY OF AVONDALE, ARIZONA

PRESSURE ZONES EVALUATION

Schematic of PRV Vault

August 2015

Figure 7-2

7.3.2 Modification and Upgrades to Well 23

Several alternatives were considered to increase the discharge pressure produced by Well 23 to meet the desired system requirements. The pump currently installed in the well has a capacity of 1,200 gpm, and the flow rate is controlled with a VFD. The well is currently operated at a flow rate of approximately 900 gpm because of problems with air entrainment at higher flow rates. It appears likely that the air entrainment is caused by pumping water levels that are below the top of the well screen when the well is operated. Records show that pumping water levels are in the range of 170 feet below ground surface (bgs), whereas the top of the well screen is at 148 feet bgs. Operating at the lower flow rates appears to reduce air entrainment through the upper portions of the screen.

Although the discharge pressure and corresponding flow rate from the well could be increased by increasing the speed of the pump with the VFD, this is not recommended because of the limitations of the well. It may be possible to reduce air entrainment by blanking off the upper portions of the well screen; however, cleaning records show that the lower portions of the screen are severely plugged, and blanking the upper portions could severely limit the flow of water through the screen. Cleaning the well could potentially improve the flow through the screen and reduce drawdowns (thereby reducing air entrainment), but the well has been cleaned within the last two years and is on a regular maintenance cycle, suggesting that additional cleaning may not substantially improve the condition of the well.

Two potential alternatives were considered for increasing the pressure from the well without increasing the flow rate:

- Add an additional stages of impellers
- Replace the pump.

Each of these alternatives increases the pressure by changing the operating point relative to the system curve. Based on correspondence with the pump manufacturer, it will likely be possible to achieve the desired pressure setting by adding additional stages of impellers. The estimated cost for upgrading the bowl and shaft of the pump and adding a sixth stage is $8,000. The addition of an impeller could also necessitate an upgrade to the existing motor. The upgrade to the motor is estimated to cost $15,000. Additional analysis should be conducted of the well construction to confirm if the existing can accommodate an additional impeller and if the motor needs to be upgraded as well to achieve the desired pressures.

If the desired pressure cannot be achieved by adding additional impeller stages, it would be necessary to install a new well pump meeting the flow and pressure requirements. The estimated cost for a new well pump is $26,000. For purposes of further cost comparisons and discussion, the higher cost alternative (a new well pump) will be utilized.

7.3.3 Summary of Conceptual Cost Opinions to Implement Recommended Pressure Zones

The opinions of conceptual capital costs presented herein were based on available existing studies, recent projects with similar components, standard construction cost estimating manuals, and engineering judgment. The level of accuracy for the cost estimates corresponds to the Class 4 estimate as defined by the Association for the Advancement of Cost Engineering (AACE) International. This level of engineering cost estimating is approximate and is generally made without detailed engineering data and site layouts, but is appropriate for preliminary budget-level estimating. The accuracy of a Class 4 estimate is minus 15 to plus 20 percent in the best case, and minus 30 percent to plus 50 percent in the worst case.

The unit costs include materials of construction, installation, contractor costs (overhead, profit, bonding, mobilization), and engineering. All costs include a 30 percent factor for engineering and construction administration, and a 20 percent factor for project consistencies. All costs were in June, 2015 dollars referenced to an Engineering News Record Construction Cost Index (ENR CCI) of 10,036.

Table 7-8 summarizes the opinion of probable construction costs for the system modifications for implementing the preferred pressure zones alternative.

Table 7-8 Conceptual Capital Cost Opinions to Implement Preferred Pressure Zones Alternative

Project No.	Description		Location	Cost ($)[1,2,3]
PRV Vaults				
PRV-1	10 inch	2	Near McDowell Rd and Rancho Santa Blvd	$155,000
PRV-2	10 inch	2	Near McDowell Rd and Avondale Blvd	$155,000
Well 23 Alternatives				
Well 23	1200 gpm	185 feet	Add a new well pump at Well 23	$26,000
Gate Valves				
Gate Valve 1	16 inch	1	Near McDowell Rd and N 119th Ave	$41,000
Gate Valve 2	16 inch	1	Near Van Buren St and N 107th Ave	$41,000
Gate Valve 3	16 inch	1	Near Van Buren St and N 107th Ave	$41,000
Total				**$459,000**

[1] June 2015 Costs (ENR CCI = 10036).
[2] Unit capital costs include engineering/design, materials of construction, installation, contractor overhead & profit, engineering & construction administration (30%) and contingency (20%).

7.3.4 Impacts to Water Master Plan

Implementation of the preferred pressure zones alternative will change the recommendations of the 2013 Water Master Plan Update in terms of production and storage capacity. As described in Section 5.2.3, implementing the preferred pressure zones alternative (Alternative 3) will require the following additional supply and storage if the Master Plan recommendations are not updated:

- Supply - Additional supply of 2.2 mgd will be required in the South Zone when the system average demand reached 22.8 mgd.

- Storage – Additional storage will be required in the North Zone in the future. When the system average demand increases to 22.5 mgd, an additional storage of 1 MG will be required. There is existing land available and booster pumping capacity at Garden Lakes for this additional storage. Also, based on 2013 Water Master Plan update, additional supply will be provided at Garden Lakes in the future.

The 2013 Water Master Plan Update provided the following recommendations:

- Four new wells (A, C, D, and G) located in the North Zone and seven new wells (21, 22, 26, 28, B, E and F) located in the South Zone.

- Rehabilitation of the Del Rio reservoir (2.8 MG usable) and one new 1 MG reservoir (0.7 MG usable) at the Coldwater facility, both located in the South Zone.

The Master Plan can be updated to move two of four new wells from the North Zone to the South Zone and to move the 1 MG reservoir planned at Coldwater to Garden Lakes to satisfy the need for future supply and storage as described above. This will result in no additional capital costs due to implementation of the preferred pressure zones alternative. Identifying the exact wells to be moved and new well locations will require additional analysis. Thus, if the preferred alternative is implemented, it is recommended that the Water Master Plan be updated again to incorporate the new pressure zones and to update the water demand projections and the master plan recommendations

8. Summary of Costs and Benefits of Implementing the Preferred Alternative

This pressure zones evaluation was conducted to identify a preferred alternative for to alleviate low system pressure concerns in the northern parts of the City. The evaluations resulted in the following conclusions and recommendations:

Preferred Alternative

- The preferred alternative consists of splitting the water system into two primary pressure zones. The pressure zone split should be located along McDowell Road from Dysart Road to 107th Avenue, and then south along 107th Avenue to Van Buren Street (refer to Figure 7-1).

- The North Zone would be supplied by the Northside, Garden Lakes, Gateway and Well 23 facilities. The South Zone would be supplied by the Rancho Sante Fe and Coldwater facilities initially. The Del Rio facility would supply the South Zone once it is rehabilitated.

System Modifications Required in the Near-Term

- The two primary pressure zones will need to be isolated from each other with the installation of two PRV stations on transmission mains currently connecting the north and south areas, and closing of three smaller pipes. The PRV stations will be configured to allow water to be automatically transferred between the two pressure zones during emergencies, and the smaller pipe closures will be accomplished with valves that can also be manually opened, if needed, during emergencies.

- The existing booster stations in the North can accommodate operations at the higher system pressures. Production from Well 23 is currently limited due to air entrainment problems and will need to be rehabilitated to operate at the higher pressures, the recommended rehabilitation includes either upgrades to the existing motor and well pump (addition of the 6th stage), or replacement of the well pump to meet the desired pressure setting. For purposes of additional discussions, installation of a new well pump is assumed.

Incremental Annual O&M Impacts in the Near-Term

- As compared to existing operations, implementing the preferred alternative would result in additional annual O&M costs for power, water treatment, and maintenance of new infrastructure. The estimated additional annual O&M costs include the following:
  - Booster Pumping Power - $340,000 per year.
  - Water treatment - $1,430,000 per year
  - PRV station - $4,000 per year
  - **Total additional O&M costs - $1,774,000**

Capital Costs to Implement the Preferred Alternative

- Implementing the preferred alternative will require capital costs for designing and constructing the required system improvements. The estimated capital costs include the following:
  - PRV Station 1: $155,000
  - PRV Station 2: $155,000
  - Three pipe closures: $123,000
  - Well 23 rehabilitation: $26,000
  - **Total: $459,0000**

Water Master Plan Impacts

Implementing the preferred pressure zones alternative will modify the 2013 Water Master Plan Update recommendations, including reallocation of new water supply previously planned in the North Zone to the South Zone. Similarly, new water storage previously planned for the South Zone should be reallocated to the North Zone. These modifications are required because each pressure zone should be capable of individually providing its own water supply under normal operations. If the preferred alternative is implemented, it is recommended that the Water Master Plan be updated again to incorporate the new pressure zones and to update the water demand projections and the master plan recommendations.

Benefits of Implementing the Preferred Alternative

- The North Zone will experience overall higher pressures, with average increases in minimum pressures of 16 psi during peak demands immediately. The estimated increases in minimum pressures during peak demands for specific areas of concern immediately are as follows:
  - 103rd Avenue and McDowell Road – 22 psi
  - 99th Avenue and Indian School Road – 23 psi
  - 99th Avenue and Van Buren Street – 22 psi
  - Rio Crossings – 18 psi
- Booster stations in the North Zone and South Zone will be isolated from each other during normal operations, resulting in more flexible operations. The booster stations will stop fighting each other.
- The pumps at the North Zone booster stations will operate closer to their design points than under existing conditions, making them operate more efficiently.
- Under emergency conditions, the recommended PRV stations and interconnects between the two pressure zones can be utilized to move water between zones.
- The majority of the City's system demand and future growth will be in the South Zone which will be served by the City's largest facilities – Rancho Santa Fe, Coldwater, and Del Rio after it is rehabilitated.

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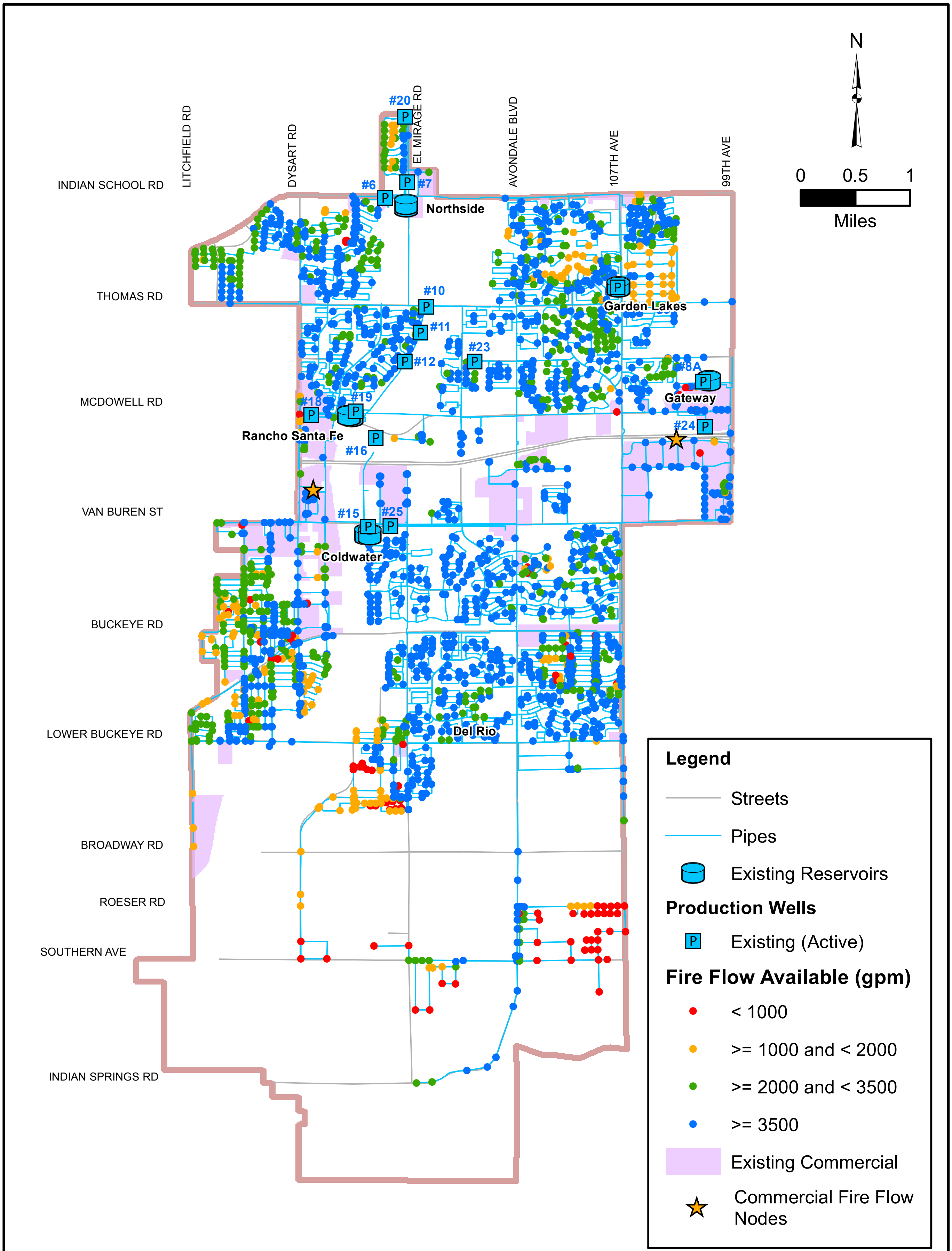
Appendix A

Fire Flow Maps



City of Avondale

CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Existing System Available Fire Flow

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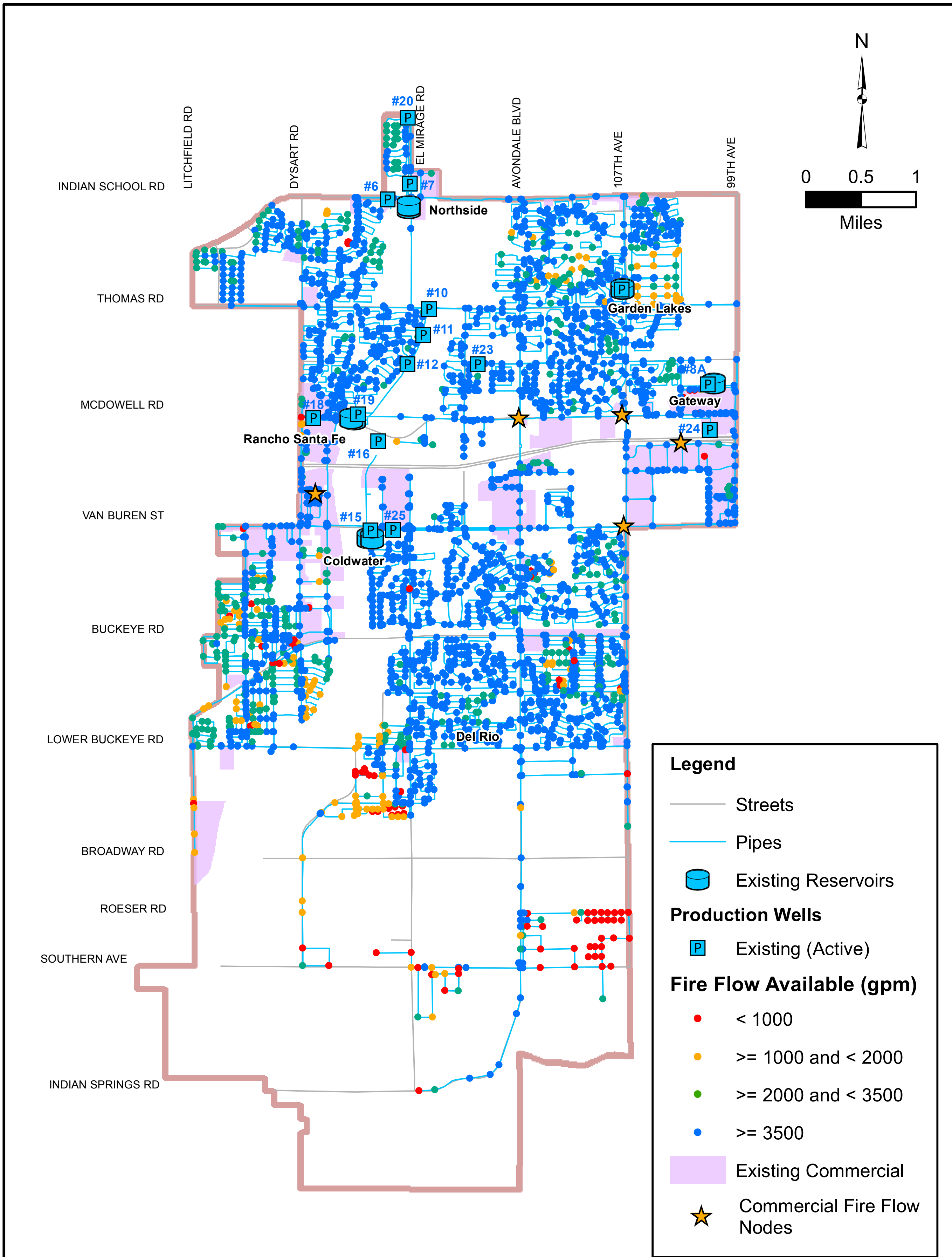
FIGURE A-1

\\arcadis-us.com\OfficeData\Phoenix-AZ\Projects\086402710003 - Additional Pressure Zone Evals\R-1 Final Report\Pressure Zones Evaluation\Figures\Figure A-1 Existing System Available Fire Flow.mxd



CITY OF AVONDALE, ARIZONA
PRESSURE ZONES EVALUATION

Pressure Zone Alternative 3: Available Fire Flow

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FIGURE A-2

\\arcadis-us.com\OfficeData\Phoenix-AZ\Projects\086402710003 - Additional Pressure Zone Evals\R-1 Final Report\Pressure Zones Evaluation\Figures\Figure A-2 Pressure Zone Alternative 3 - Available Fire Flow.mxd

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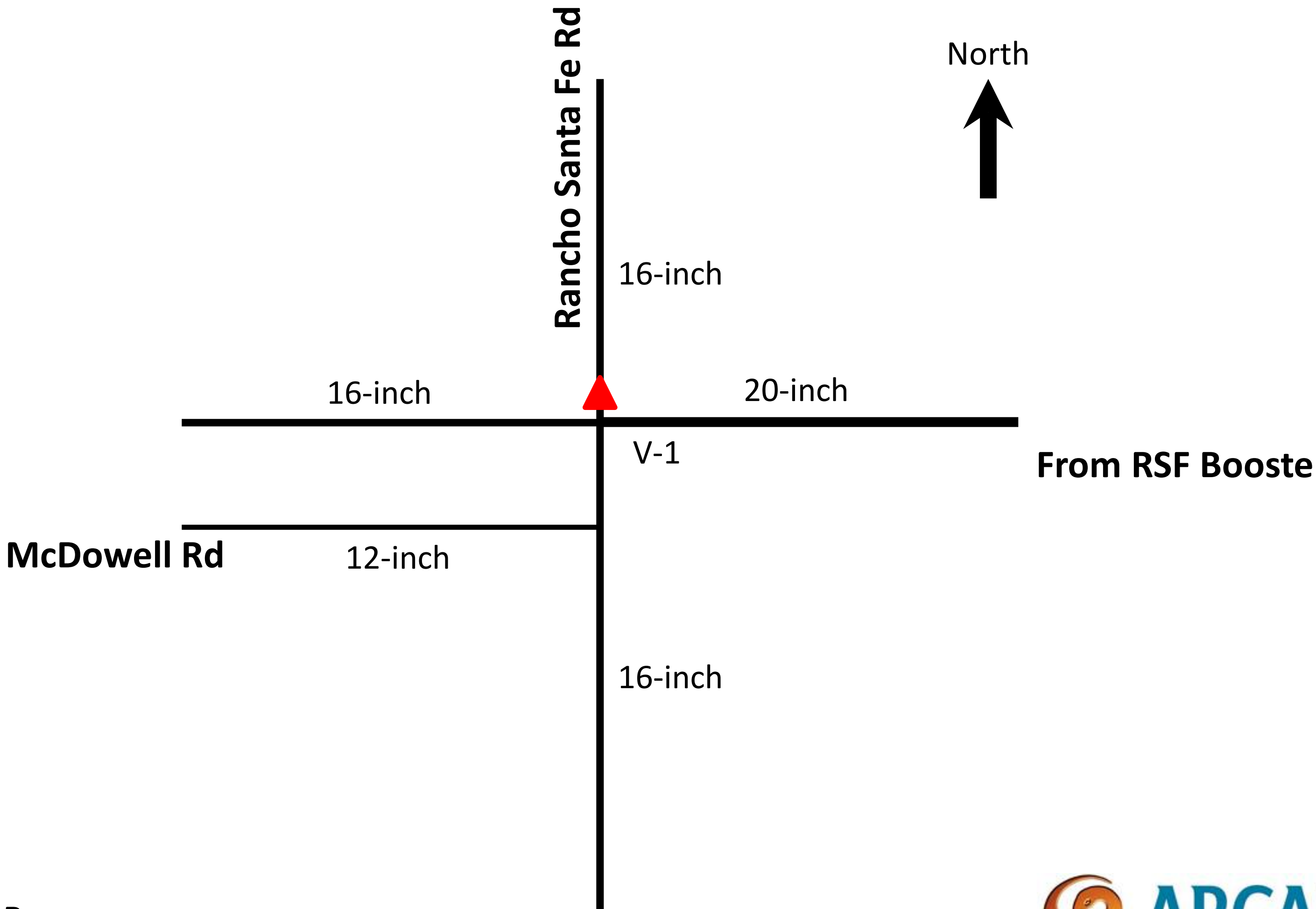
Appendix B

PRV Location Details

Valve Location Details - PSV (V-1) at Rancho Santa Fe Drive and McDowell Road



Appendix B

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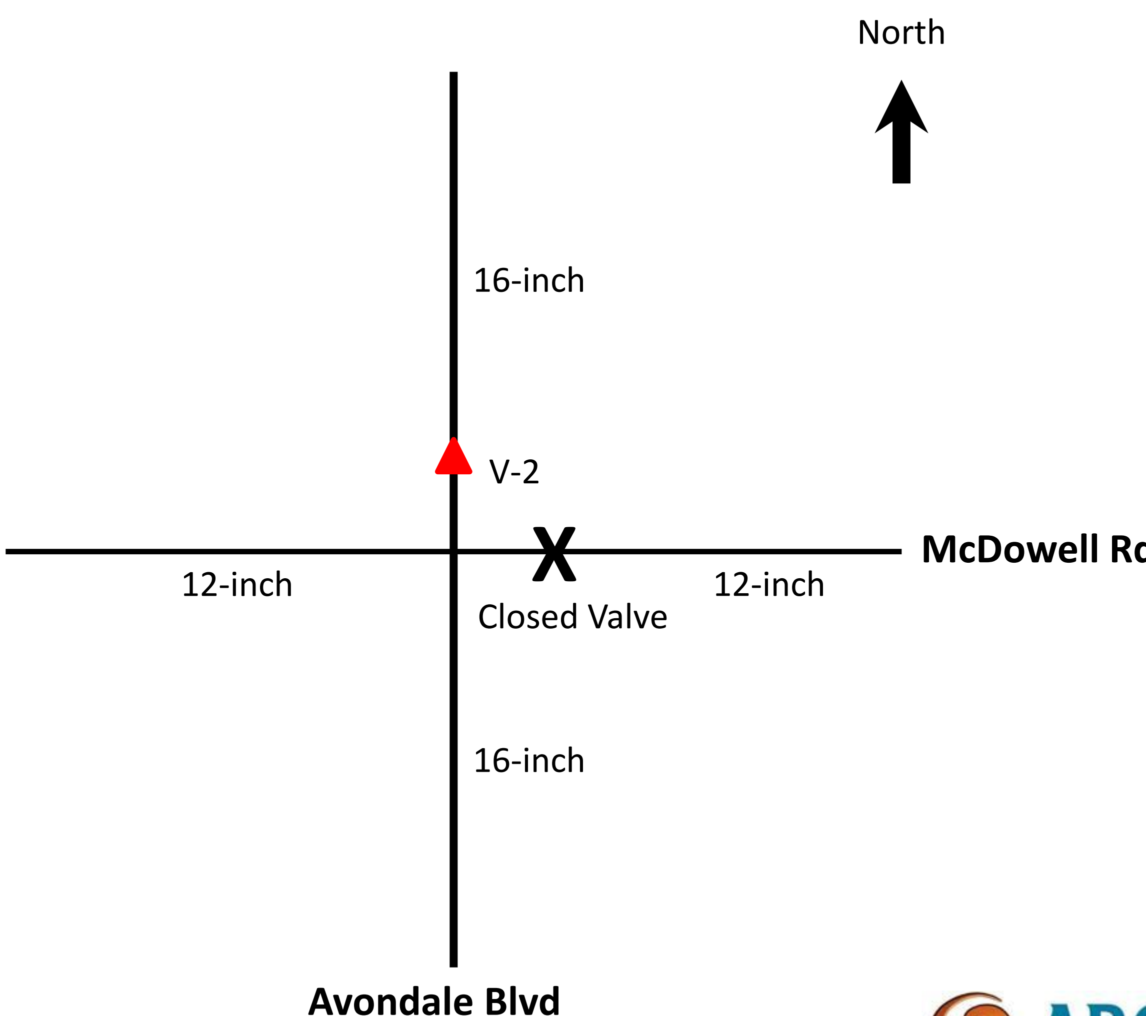
Valve Location Details - PSV (V-2) at Avondale Bouleward and McDowell Road



Appendix B

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Appendix C

Capital and Unit Costs

Engineer's Opinion of Probable Construction Cost for Valve and Vault						
Capital Costs	**Units**	**Unit Cost**	**# of Units**	**Subtotal**	**Installation**	**Total**
Division 3 - Concrete						
Vault	CY	$ 600	16	$ 9,800	Incl.	$ 9,800
Subtotal						**$ 9,800**
Division 33 - Utilities						
Buried Piping and Valves						
10" BFV w/ Manual Handwheel	EA	$ 2,000	5	$ 10,000	$2,000	$ 12,000
10" Pressure Sustaining Valve w/ check	EA	$12,200	2	$ 12,200	$2,440	$ 29,280
10" Tee	each	$ 5,040	4	$ 20,200	Incl.	$ 20,200
10" 90 deg Bend	each	$ 3,227	4	$ 13,000	Incl.	$ 13,000
18"x10" Reducer	each	$ 7,646	2	$ 15,300	$3,060	$ 18,360
						$ 78,200
				Subtotal		$ **92,840**
Subtotal						$ **102,640**
Land Acquisition	SF	$0.46	24	$ 11	N/A	$ 11
TOTAL CAPITAL COST						**103,000**
Engineering and Administration (30%)						**$ 30,900**
Contingency (20%)						**$ 20,600**
GRAND TOTAL						**$ 154,500**

Summary of Capital Unit Costs[1,2]							
ITEM	COST	UNITS	COST (June. 2015)	COST with E&CA[3] (June. 2015)	COST with E&CA and Cont.[4] (June. 2015)	**Included in Unit Cost**	**Source**
Reservoirs							
0.0 to < 2.5 MG	$1,426,741	$/MG	$1,560,459	$1,872,550	$2,434,316		Tucson Water and City of Avondale 2010 Water Resource Master Plan
Booster Pump Stations							
0 to < 7 mgd	$378,270	$/MGD	$413,722	$496,467	$645,407	Includes fencing and access gates, site paving, landscaping, earth and concrete work, electrical, mechanical, instrumentation and SCADA	Tucson Water and City of Avondale 2010 Water Resource Master Plan
New Production Wells	$2,209,440	$/well	$2,560,501			Includes contingency and engineering & construction administration	City of Avondale 2010 Water Resources Master Plan

NOTES:

(1) June 2015 Costs (ENR CCI = 10,064).

(2) Unit capital costs include engineering/design, materials of construction, installation and contractor overhead and profit.

(3) Engineering & Construction Administration (30 percent)

(4) Contingency (20 percent)